TECHNICAL NOTE 2008/22

Department of Water, Land and Biodiversity Conservation

PADTHAWAY GROUNDWATER FLOW AND SOLUTE TRANSPORT MODEL (PADMOD2)

NEW ABSTRACTION SCENARIOS REQUESTED BY THE SENRM BOARD

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INTRODUCTION

Previous groundwater management for the Padthaway Prescribed Wells Area (PWA) operated under the Irrigation Equivalent (IE) area-based water allocation system. Brown *et al* (2006) undertook a comprehensive review of the groundwater resource condition and management framework for the Tertiary Limestone Aquifer, which developed sustainable abstraction rates for all South East unconfined groundwater management areas. Latcham *et al* (2007) combined the results of Brown *et al* (2006) and the Volumetric Conversion Project to determine new water balance calculations to facilitate future water allocation planning. Utilising this information, Aquaterra Consulting Pty Ltd (Aquaterra), under contract by the Department of Water, Land and Biodiversity Conservation (DWLBC), produced a groundwater flow and solute transport model (PADMOD1) for the Padthaway PWA (Aquaterra, 2007). The PADMOD1 calibration and prediction model simulations were run over the time periods 1950-2006 and 2006-2120, respectively. PADMOD1 supported a 40% reduction in allocations over the Padthaway PWA.

The South East Natural Resources Management (SENRM) Board requested that the DWLBC undertake a new modelling exercise to test potential allocation and abstraction scenarios, based on the expected lifting of the “Notice of Restriction”, at the adoption of the new Water Allocation Plan (WAP). The 2001 WAP recognised that a significant portion of the Padthaway PWA was over-allocated, therefore the then Minister for Environment and Conservation placed a Notice of Restriction on abstraction levels while a sustainable management plan for groundwater was developed. The SENRM Board also stipulated that the new scenarios be modelled over the identical time frame as PADMOD1 therefore allowing direct comparison between the outputs of the respective models. Modelling new allocation and abstraction scenarios improves confidence in the science behind water allocation planning, thereby giving defensibility to the soon to be adopted WAP.

MODEL UPGRADE

Following on from the work of Wohling *et al* (2005), updated groundwater recharge and salt flux prediction mapping has been carried out (Osei-Bonsu and Barnett, in prep) on the Naracoorte Ranges portion of the Padthaway PWA, which improved scientific rigour by assessing a greater number of soil types. The original soil cores (Wohling *et al*, 2005) were drilled along two comparatively sandy transects. Additional drilling in the Naracoorte Ranges in 2006 provided soil cores to the water table, which when analysed for soil physical properties indicated a heavier soil (higher clay content) and reduced recharge rates.

The original Naracoorte Ranges groundwater recharge and salt flux prediction modelling (developed with CSIRO Land and Water) was a single layer model; whereas the current groundwater recharge and salt flux prediction model (again developed with CSIRO Land and Water) is a two-layer model. The additional soil physical property data allowed for adjustment of the drainage vs. % clay (0-2 m) and soil water salinity vs. % clay (0-2 m) relationships, and better minimum and maximum water content (θ) values for the ‘sand’ and ‘clay’ layers. These revised parameters allowed for improved groundwater recharge and salt flux predictions to be modelled for the Naracoorte Ranges.

PADMOD1 capped groundwater recharge at 50 mm/y and salt flux at 10 000 mg/L within the Naracoorte Ranges for calibration purposes. Improved groundwater recharge rate and salt flux predictions in the Naracoorte Ranges presents a maximum recharge rate of 57 mm/y, marginally higher than the capped maximum groundwater recharge rate, and a maximum salt flux of 3 700 mg/L, which is lower than the capped maximum salt flux reported by Aquaterra (2007).

This new version of the Padthaway groundwater flow and solute transport model is termed PADMOD2 to draw attention to the model upgrades and new scenarios undertaken.

Further development of PADMOD2 utilised the PMWIN Pro package to include the improved time-varying recharge and solute concentration grids from the Naracoorte Ranges at the time steps of 1970, 1980, 2005, 2010, 2025, 2055 and 2120.

Evapotranspiration (ET) is applied in PADMOD2 using Modflow's ET package in the same way it was applied to the final processing of PADMOD1. A maximum ET rate of 500 mm/y is applied in the model where the water table is at the surface and decreases to zero at an extinction depth of three metres (Aquaterra, 2007).

MODEL CALIBRATION

A calibration model run was undertaken for both hydraulic head and solute concentration using the improved groundwater recharge and salt flux grids. All other time-varying inputs (including historical abstraction, drainage and recharge rates and salinity fluxes on the flats including below irrigation) to the model remained as per the original PADMOD1. Appendix A presents the calibration results of both the 'Ranges' and 'Flats' against 'measured' water level and salinity observation well data. In general, the calibrated water levels and salinity for both the Ranges and Flats achieve a very good history match against measured observation data, giving confidence that the model resembles actual conditions as shown by Figure 1 for observation well GLE 99.

As a 'base case' for comparison against the new scenarios, the final results of the calibration model were used as the initial conditions for the prediction model. Again, the base case prediction model used the improved Naracoorte Ranges groundwater recharge and salt flux grids at appropriate time steps. Abstraction rates coincide with the original PADMOD1 capped base case prediction model run, being 110% of the 2004-05 abstraction rate, while the groundwater recharge on the Flats (both below irrigation and outside irrigation) again match the original PADMOD1 parameters. The hydraulic head and solute concentration model was run. Appendix B presents water level and salinity results of the base case model run. It should be noted that the base case reflects groundwater abstraction rates at current development, which for this model, is 110% of 2004-05.

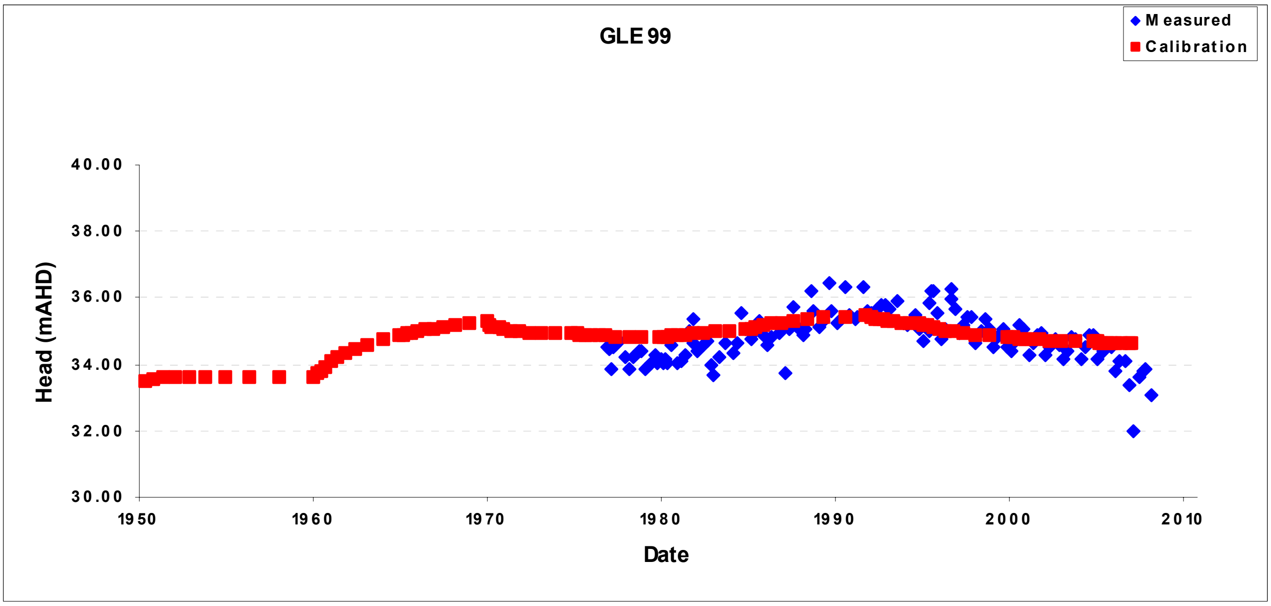
MODEL SCENARIOS

The new scenarios being requested by the SENRM Board are summarised below.

1. 55 096 ML/y abstracted at current locations (i.e. 100% of proposed allocation, including previously categorised "Notice of Restriction" allocation)

2. "Notice of Restriction" groundwater not abstracted at its current location, but rather transferred evenly across all flood irrigators. Remaining allocations abstracted from current locations.

3. "Notice of Restriction" groundwater not abstracted at its current location, but rather transferred evenly across all drip irrigators. Remaining allocations abstracted from current locations.



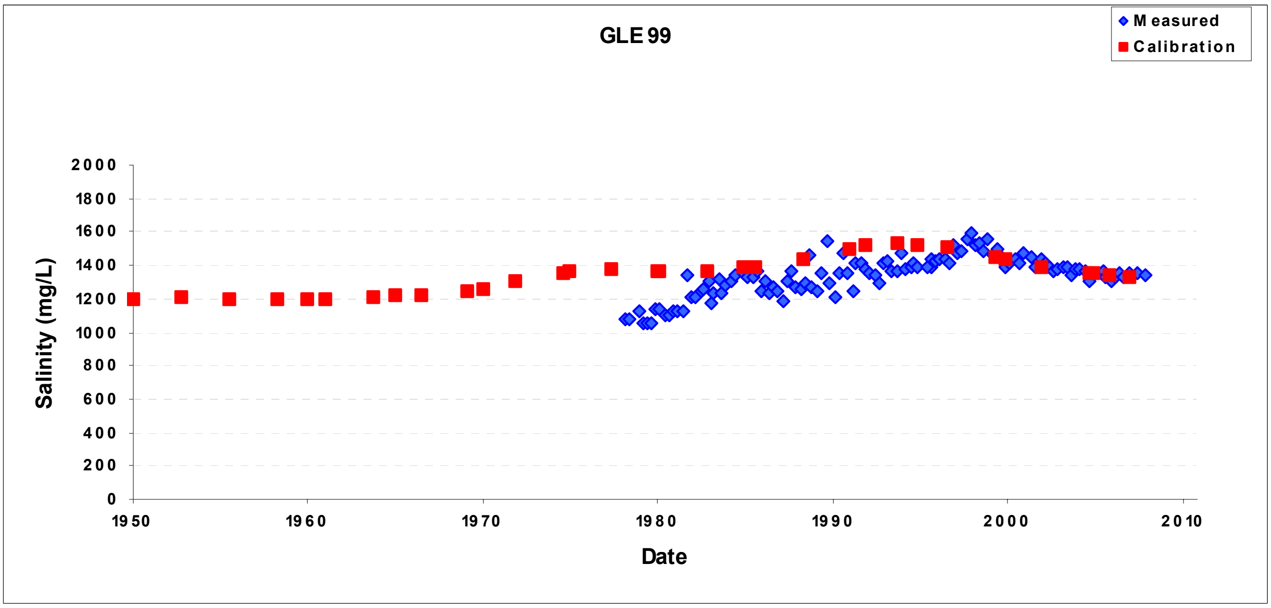


Figure 1. GLE 99 - Calibration History Match

For each of the new scenarios the abstraction rate is the only variable (100% of the proposed allocation, distributed in a different way for each scenario). The abstraction rate in ML/y has been averaged out over the year to a daily rate in m^3/day for the entire period. This does not generally represent irrigation practice, however it is consistent with the original model runs by Aquaterra.

The original model area does not entirely cover the Padthaway PWA, with the area between 2 km and 2.5 km south of the northern boundary being left out of the model domain. Five licensed irrigation wells are located in the omitted area; therefore slightly changing the total volume abstracted for each scenario. However this does not significantly influence the performance of the model. Although the total volume abstracted within the Padthaway PWA is 55 096 ML/y, the actual volumes abstracted within the model domain for each scenario are: Scenario 1 = 51 870 ML/y, Scenario 2 = 52 026 ML/y and Scenario 3 = 52 126 ML/y, which for all scenarios relates to less than a 6% variance.

MODEL RESULTS

Appendix C presents predicted water levels for each of the three scenario runs against the base case and measured data in both the Ranges and Flats.

In the Ranges, there was little difference between the base case prediction and the predicted water levels from each of the three scenarios over the next 10 years. Several observation sites (including PAR 28) do however show that over time, water levels have the potential to decline by up to 2 m under all scenarios compared to the base case. Predicted water levels along the Flats from all three scenarios collectively illustrate a decline in water levels compared to the base case. A number of observation sites (including MAR 25) predict that under Scenario 2, water levels will be lower than those predicted under Scenario 1 and 3. Conversely, observation sites (including GLE 101) predict that under Scenario 3, water levels will be lower than those predicted under Scenario 1 and 2. This difference relates to the location of flood and drip irrigation sites and the distribution of allocations for those scenarios. In general, the variation between all scenarios is minimal.

In some areas, the abstraction rate has been increased leading to a decrease in evaporative enrichment where the water table has been lowered below the ET extinction depth (3 m). Appendix C presents salinity results of the three scenario runs against the base case and measured data for both the Ranges and Flats.

Differences in predicted salinities between each scenario and the base case are not discernable within the Ranges, including observation site PAR 44. For many of the observation sites within the Flats (including GLE 100) there is minimal change in predicted salinity between each scenario and the base case. While at other observation points (including GLE 99) predicted salinities for each scenario are less than under base case conditions. Contrast between the predicted salinities for each scenario is related to evaporative enrichment. In this case (GLE 99), the lowest predicted salinity (Scenario 3) matches those areas with greater abstraction rates due to the transferring of allocations across drip irrigation. Alternatively at observation site MAR 27, predicted salinity across all scenarios is forecast to rise above the predicted base case salinity after a period of between 15 – 25 years. In this case, Scenarios 1 and 2 show the greatest predicted salinity increase.

Over the next 10 years, the potential difference in groundwater levels between current conditions (current development refers to 110% of the 2004-05 abstraction rate and water levels calibrated to the end of 2004 for this model) and Scenarios 1, 2, 3 and the base case is determined by taking away the 2004 calibration hydraulic head grid from each 2018 hydraulic head grid. Under base case conditions (Appendix D), water levels in the Ranges are predicted to increase predominately by 0.5 m to 2 m by 2018 (being the area shaded green). However in the Flats, there is no discernable change under base case conditions.

Scenarios 1, 2 and 3 (Appendix D), suggest that the predicted water levels for 2018 compared to 2004 calibrated water levels are of generally the same pattern. Increasing water levels in the Ranges (but not to the extent shown under base case conditions) and decreasing water levels in the flats (being the area shaded red). There are however a few points to note. Decreasing water levels are predicted by all three scenarios in the Ranges, particularly along the boundary between the Flats and Ranges north of the Padthaway township and to a lesser extent south of the Padthaway township, again along the boundary between the Flats and Ranges. As a general comment, the greatest predicted decline in water levels (-2.5 m to -3 m) occurs for all three scenarios in two 'hot spots' north of the Padthaway township within the Flats along the boundary of the Ranges. The spatial distribution of the predicted water level decline varies slightly between scenarios. The most obvious change is a less significant water level decline (-2.5 m contour) within the hot spot in Scenario 3 (where allocations are transferred away from this area) compared to a -3 m decline in Scenario 1 and 2. Coinciding with this transfer of allocations to drip in Scenario 3 is a broader water level decline (-0.5 m contour) along the southern boundary between the Flats and Ranges.

Designed for the comparison of groundwater salinity conditions predicted over the next 10 years by each scenario run, a salinity difference plot (TDS, mg/L) is created by subtracting the salinity grid for each scenario at 2018 from the base case salinity grid at 2018. This gives an indication of what could be expected if the allocation (abstraction) regime were to change from current practices (base case) to either Scenario 1, 2, or 3. Positive numbers in the blue colour spectrum represent a given scenario will be of better quality compared to the base case conditions. Conversely, negative values in the red colour spectrum indicate that the predicted salinity values under a scenario will be of poorer quality compared to the base case conditions. As depicted in Appendix E, there is little change predicted in salinity conditions under any scenario in the Ranges. However, throughout the Flats, the predicted salinity difference plots (Appendix E) spatially illustrate how salinity levels are predicted to vary both positively (better quality under the respective scenario model run) and negatively (poorer quality under the respective scenario model run). The predicted salinity difference between Scenarios 1, 2 and 3, and the base case at 2018 is marginal.

CONCLUSIONS

There is a very good match between measured and predicted water levels until the end of 2006. Continued monitoring of observation wells (measured data) in the Padthaway PWA, particularly within the Flats, since 2006 shows an overall 'dip' in water levels until early 2008. There is a possible need to re-run the calibration model with additional pumping data for 2005-06, 2006-07 and 2007-08. Note; the PADMOD2 calibration model used 2004-05 pumping data (110% of the abstraction rate).

In general, modelled water levels and salinity in all three scenarios (using an abstraction rate of 55 096 ML/y) matched measured water levels and salinity extremely well for the period between December 2006 and March 2008. Further investigation of metered and calculated abstraction for 2005-06 (~37 000 ML) and 2006-07 (~58 000 ML) against water level response highlights that the three new scenario runs are indicative of current irrigation practices.

PADMOD2 can be used as a tool to support water allocation planning for the Padthaway PWA due to the close agreement between measured, calibrated and predicted modelling results, which have significantly improved confidence in the science behind the model.

The accuracy of the surface elevation is a limitation of PADMOD2 as ET has the possibility of being enhanced or reduced depending on the accuracy of the surface topography. An accurate Digital Elevation Model (DEM) would decrease the uncertainty due to the effect of the ET extinction depth.

RECOMMENDATIONS

Recommendations for future modelling include the following:

- Acquisition of the PMWIN Pro modelling package.
- Extend the model domain north to include the entire Padthaway PWA and re-run the model accordingly.
- Include metered abstraction data from 2005/06 to 2007/08 to improve the calibration and base case models.
- Include improved recharge data beneath drip irrigation when available.

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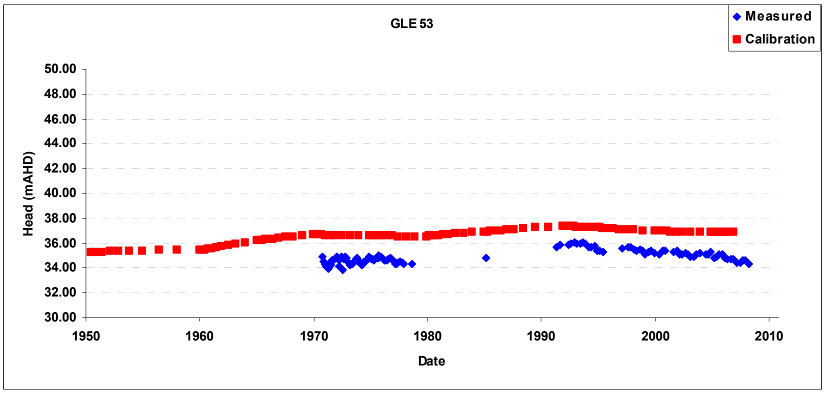
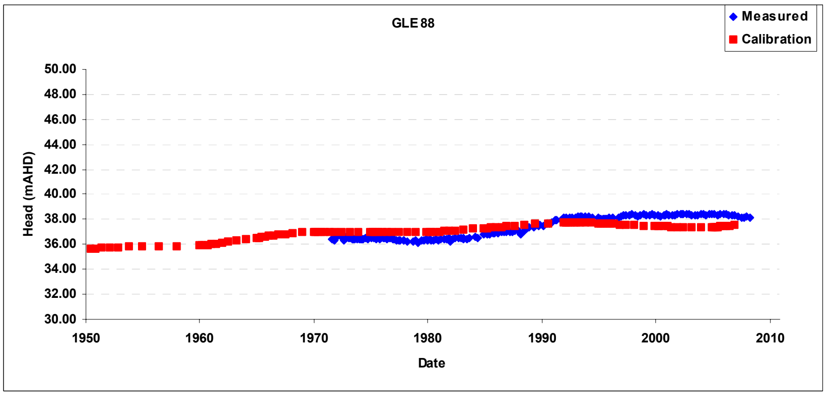
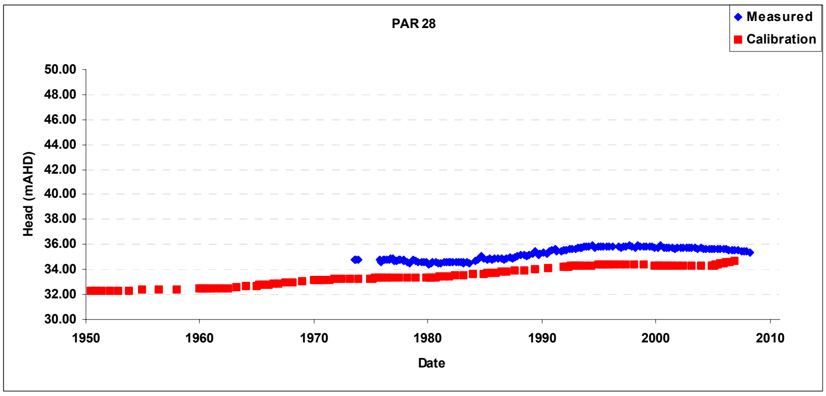
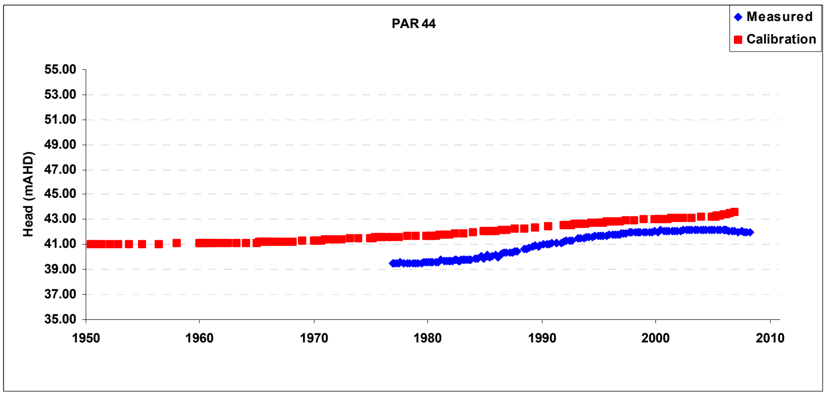
APPENDIX A

Measured and Calibration Water Levels – Ranges









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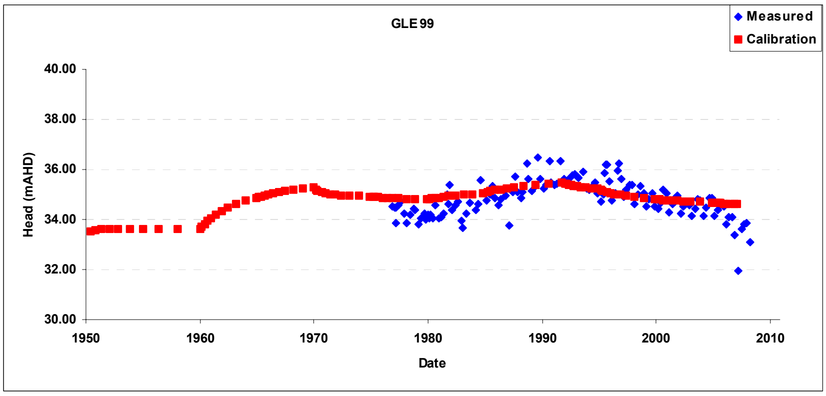
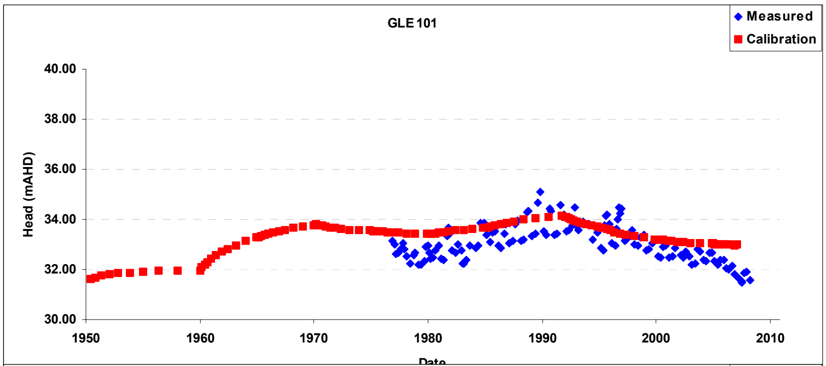
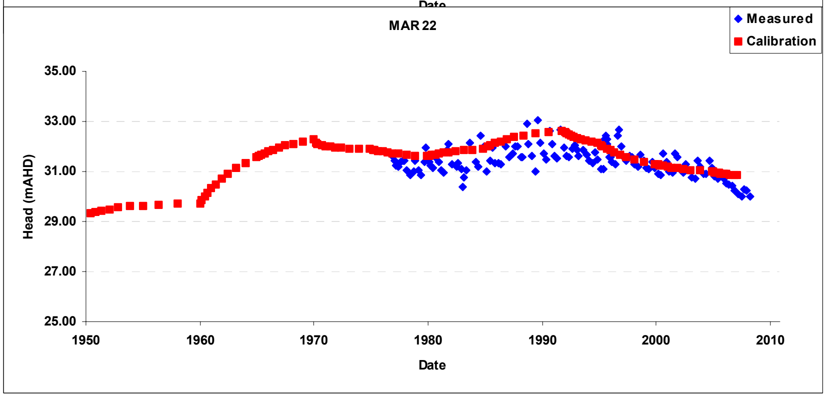
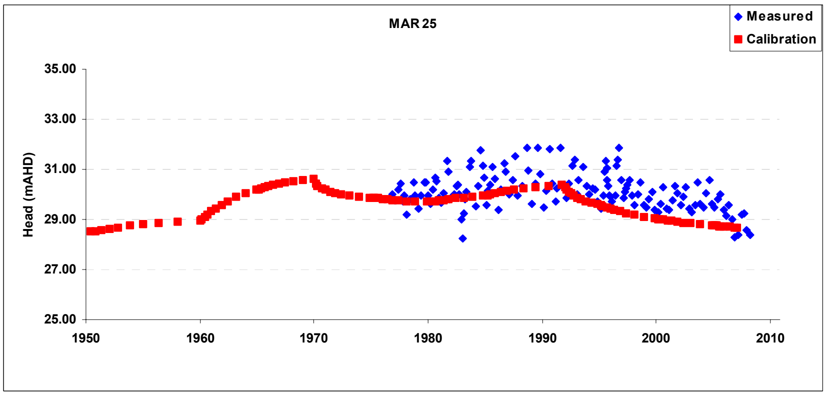
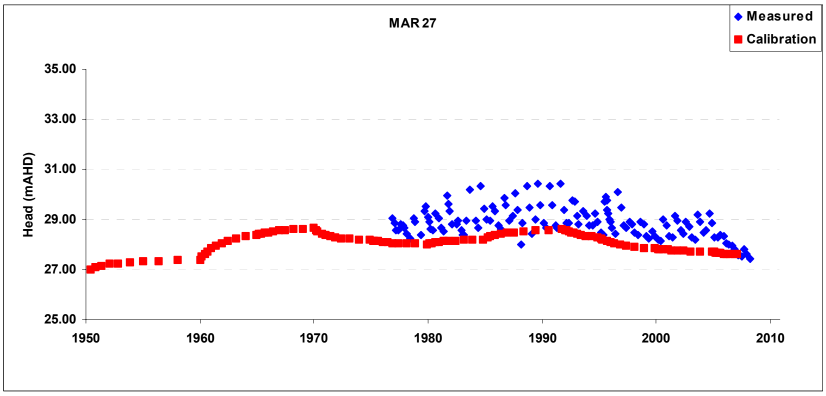


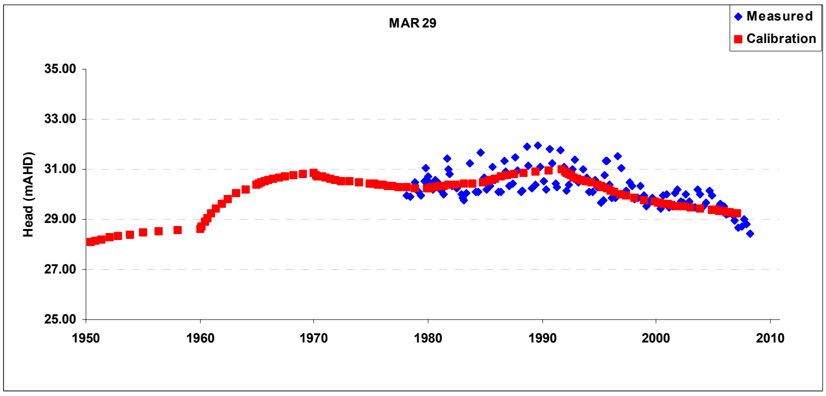


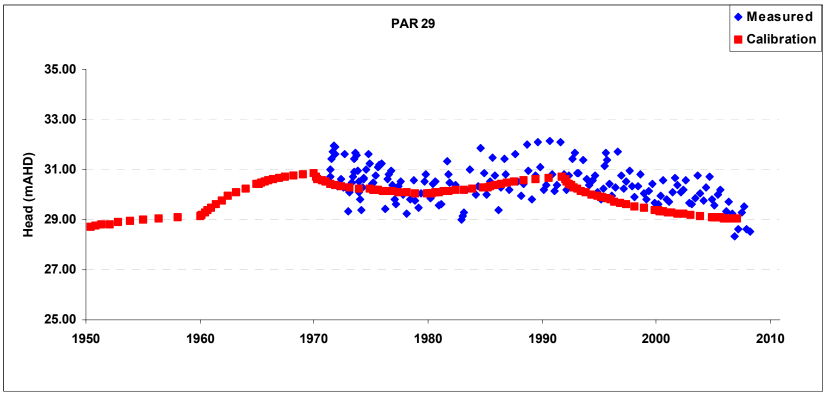


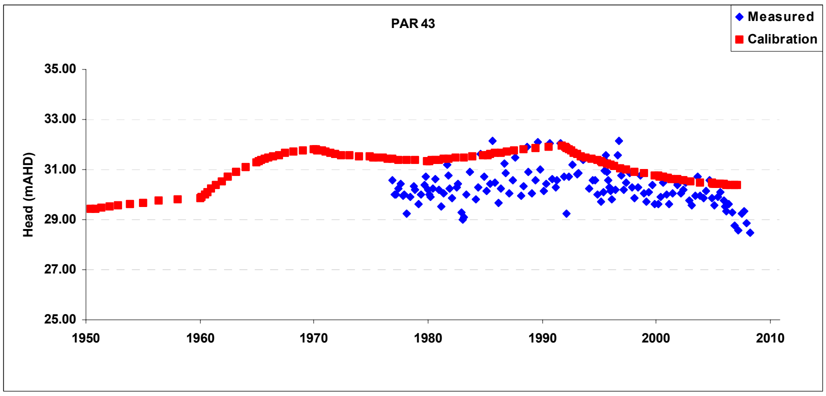


Measured and Calibration Water Levels – Flats

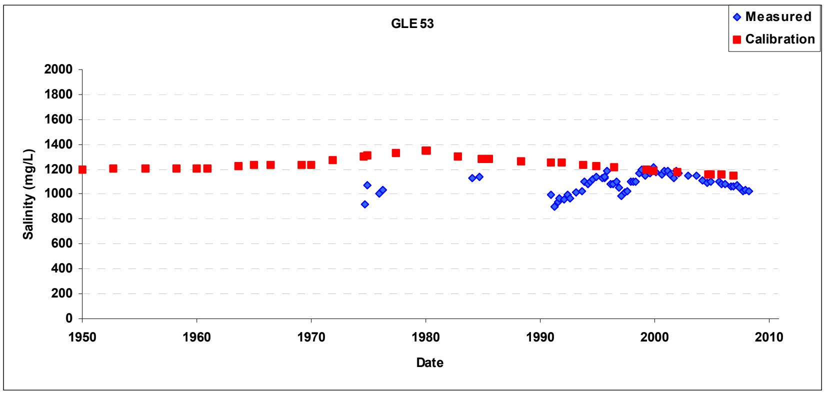


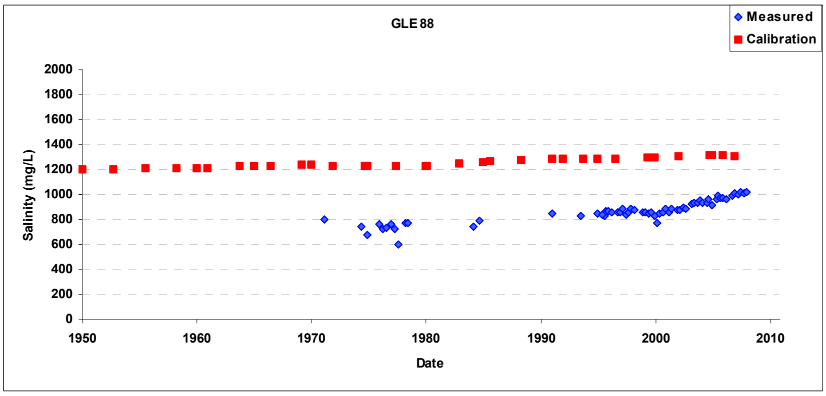


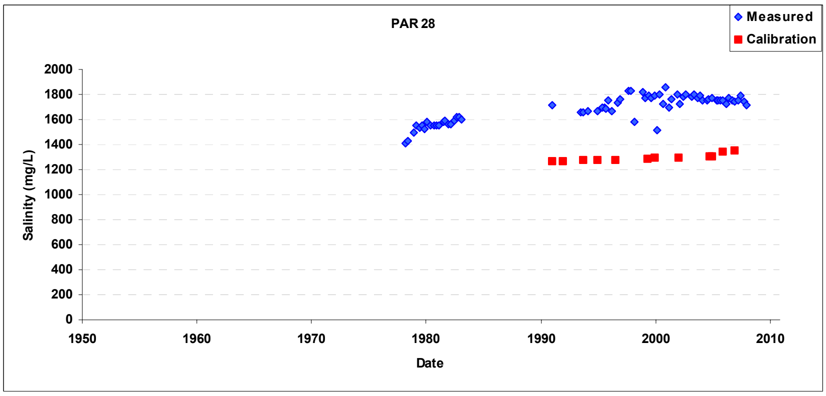


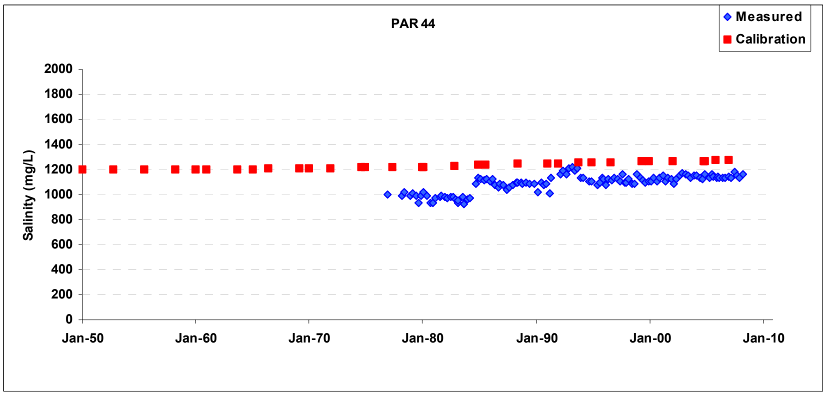


Measured and Calibration Salinity – Ranges









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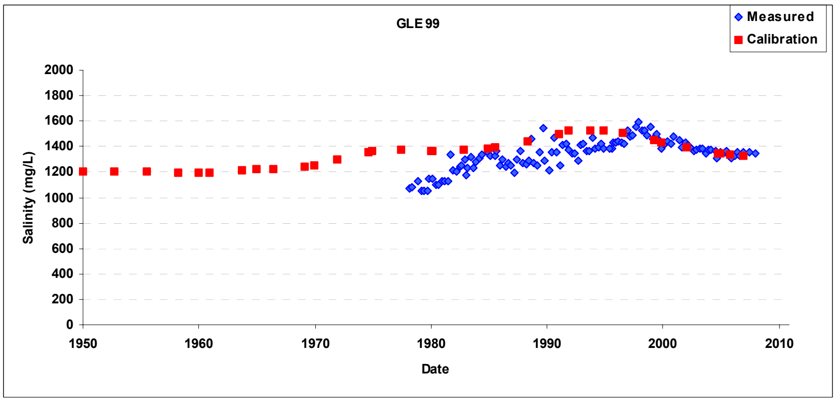

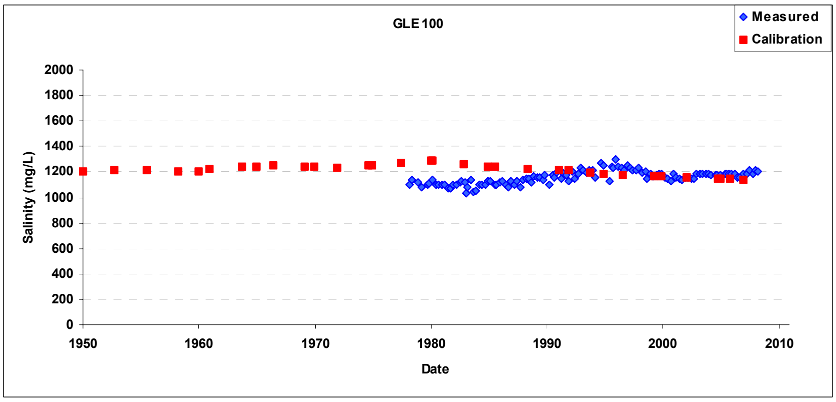

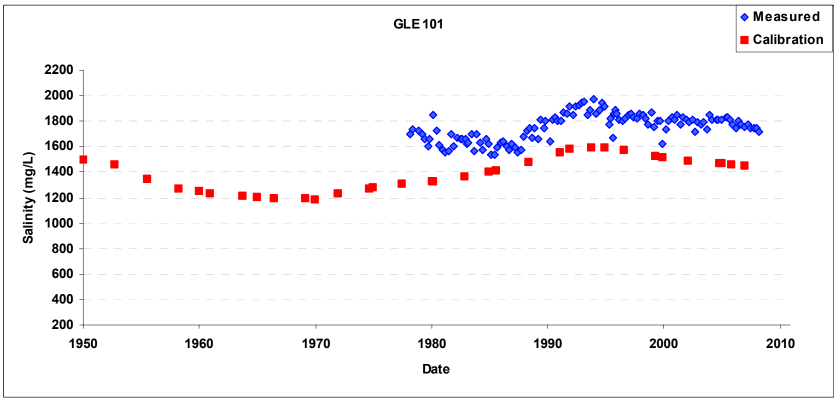

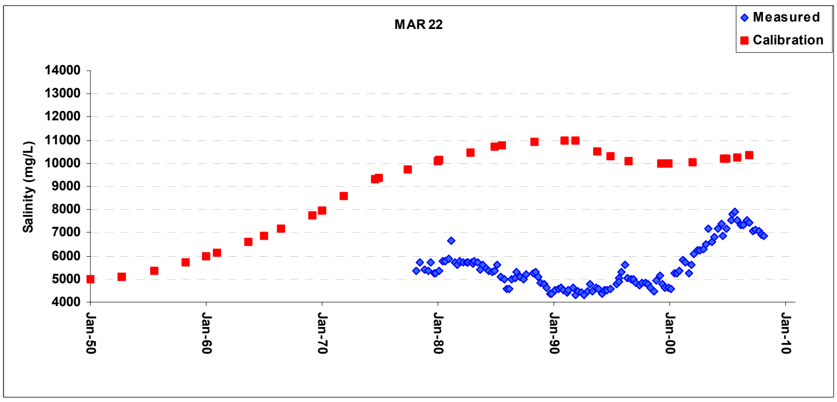

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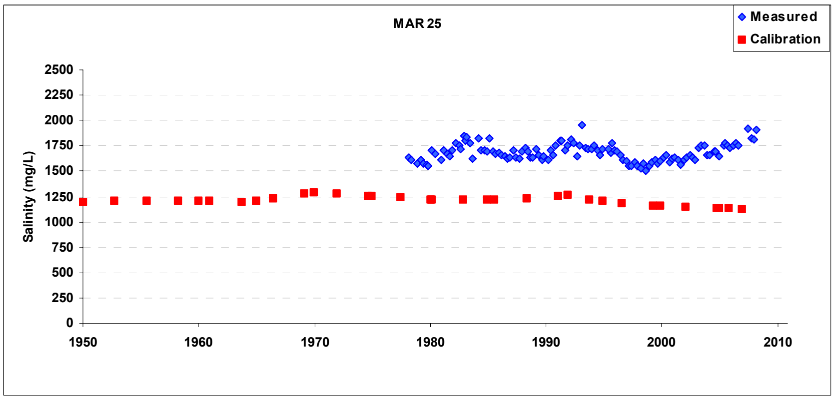
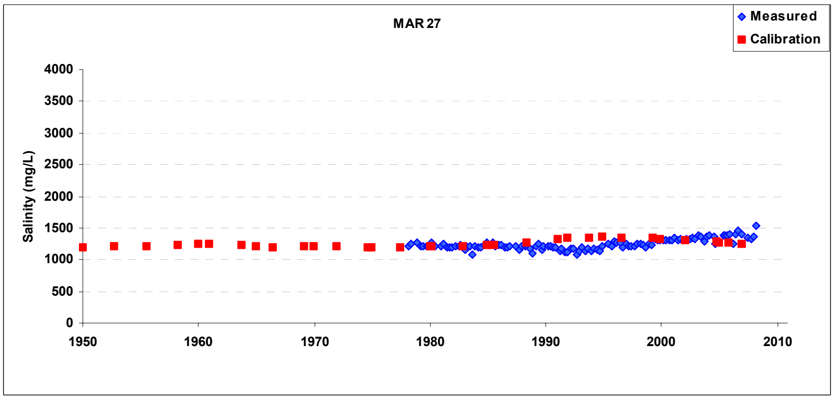
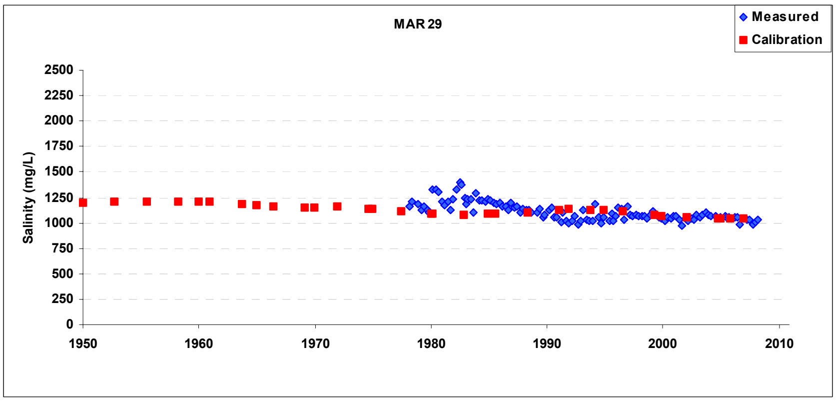
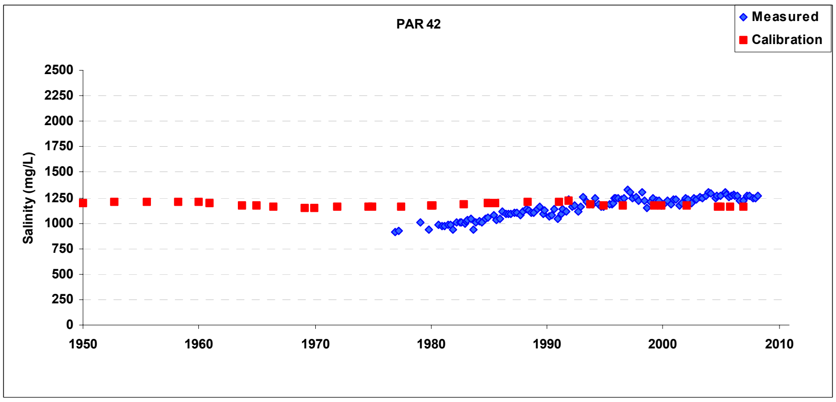


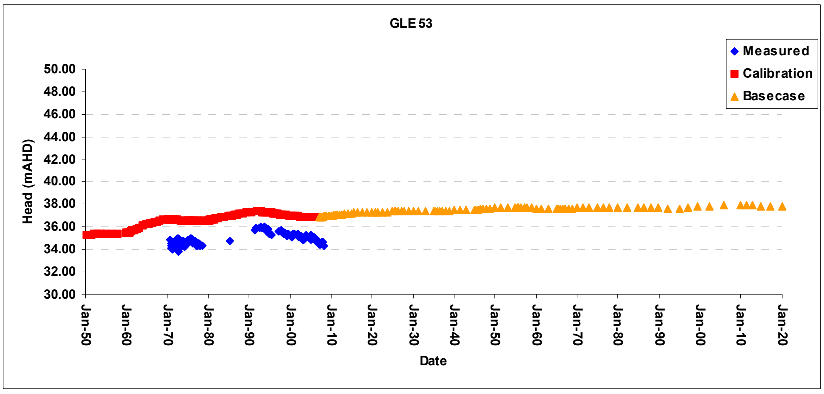


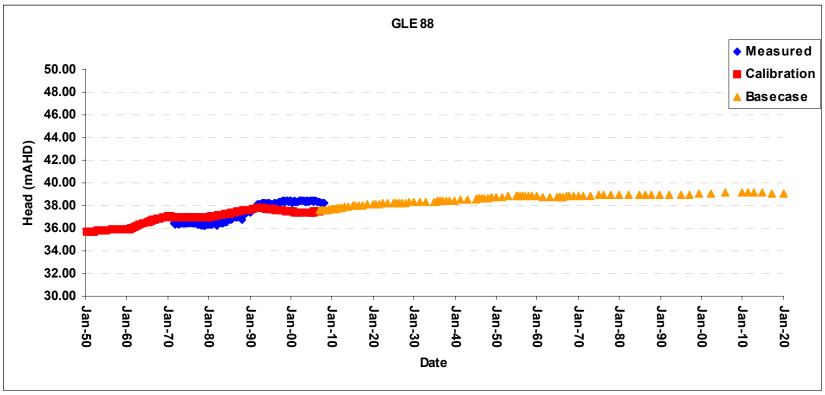


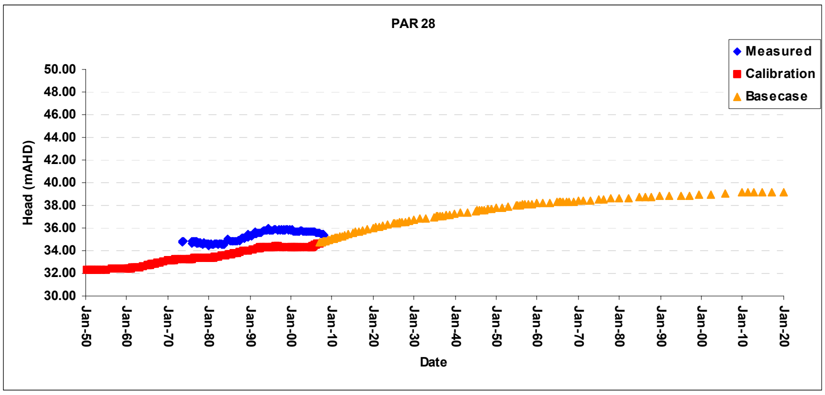


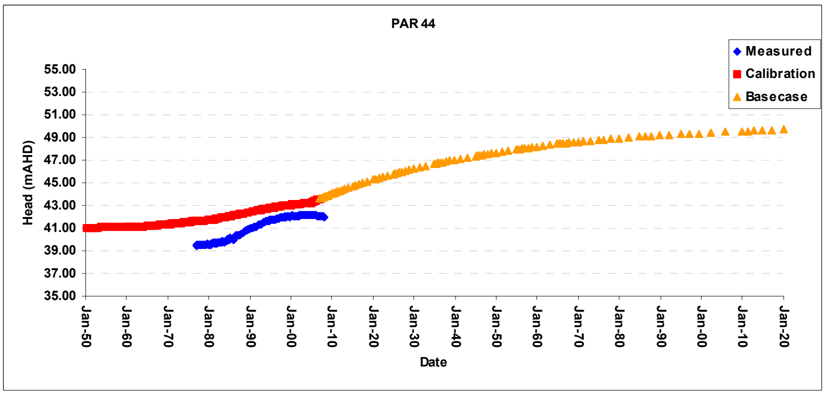
APPENDIX B

Measured, Calibration and Base case Water Levels – Ranges

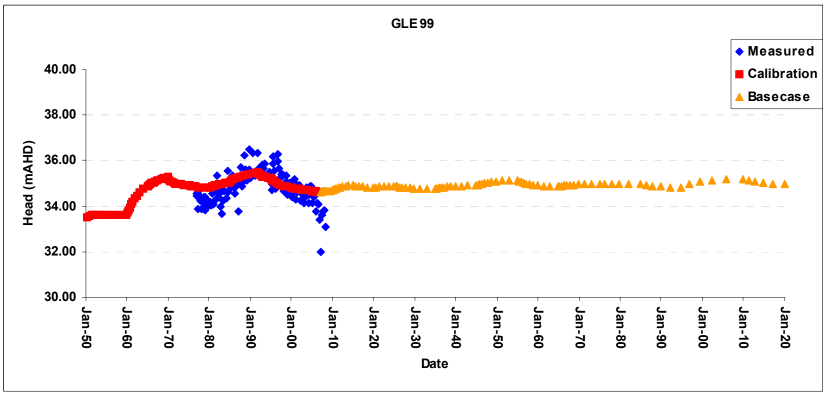


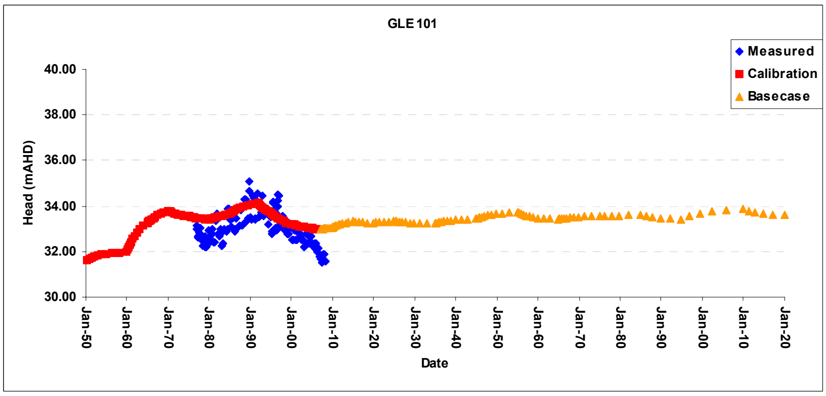


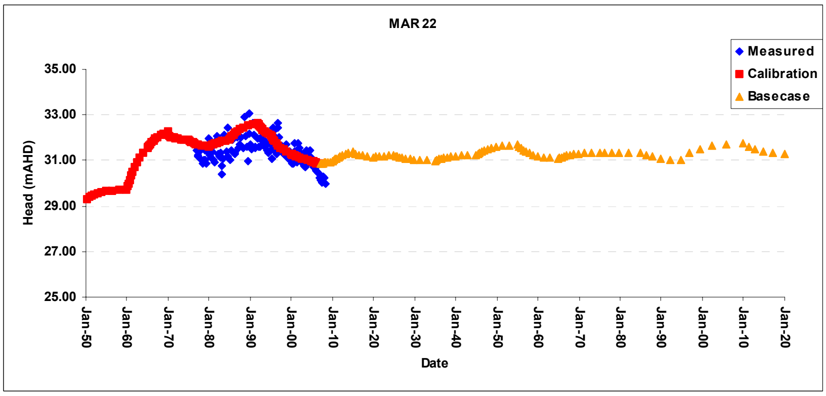


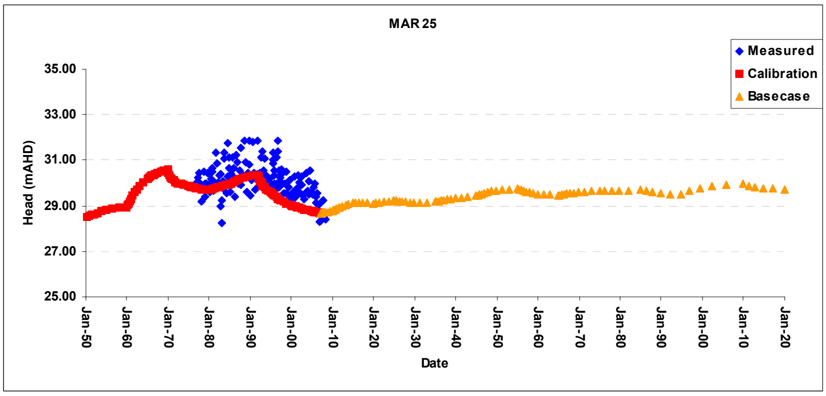


Measured, Calibration and Base case Water Levels - Flats

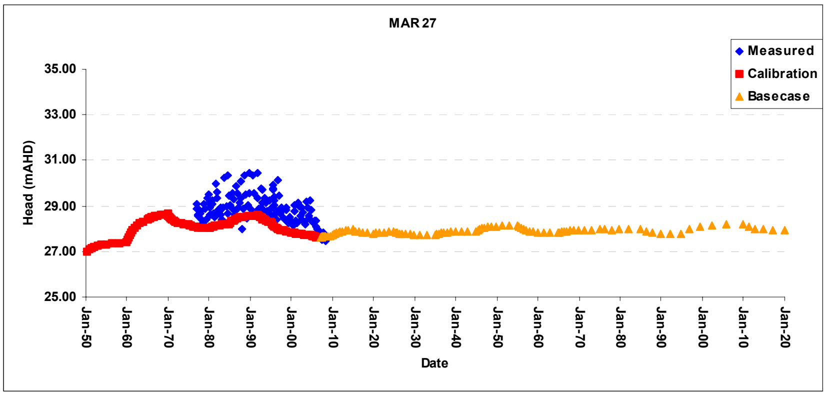


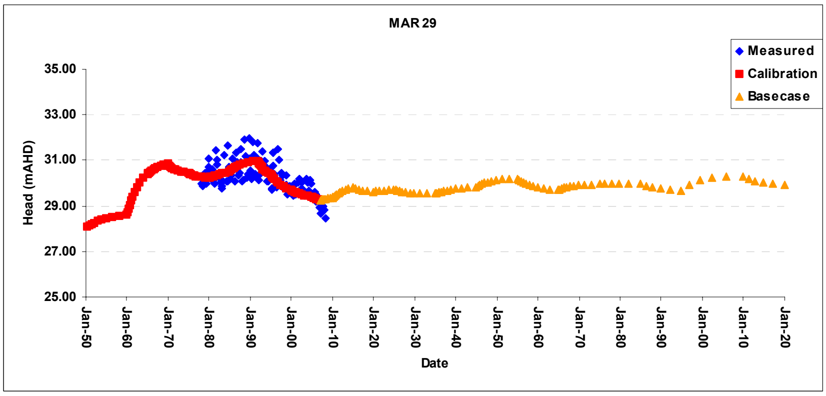


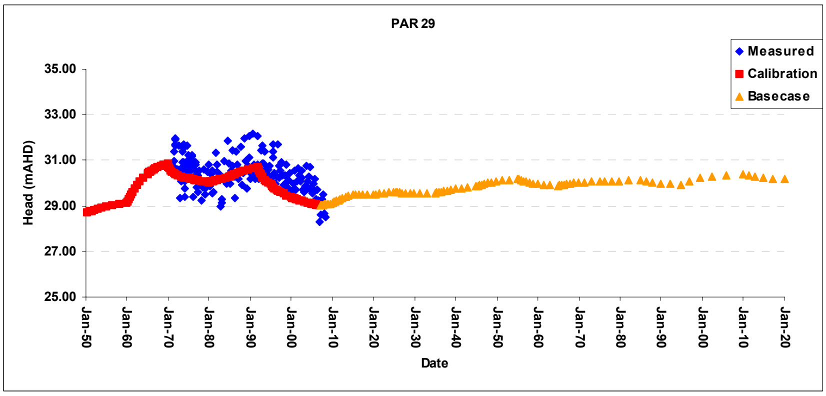


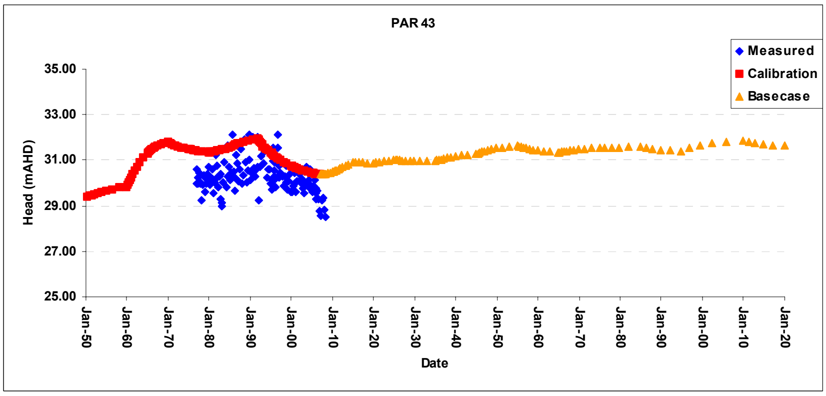


Measured, Calibration and Base case Water Levels - Flats

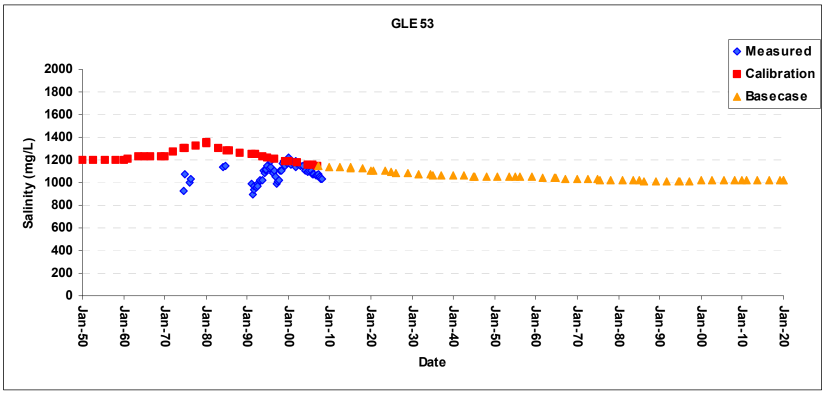


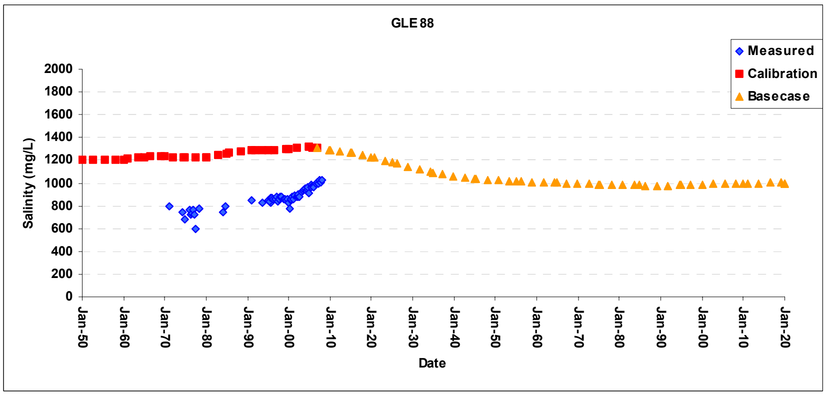


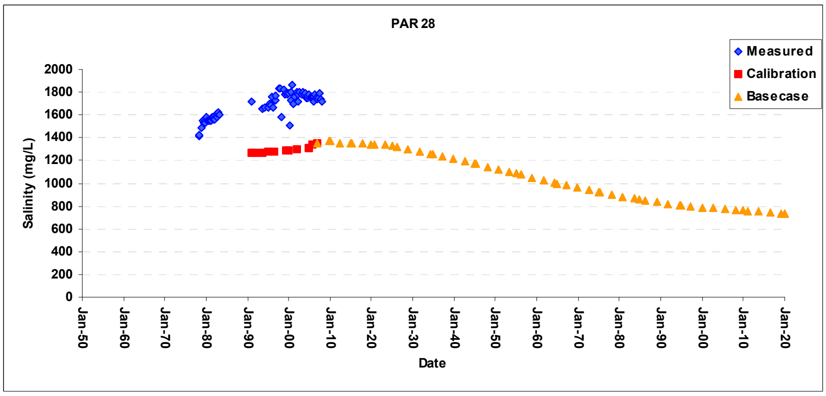


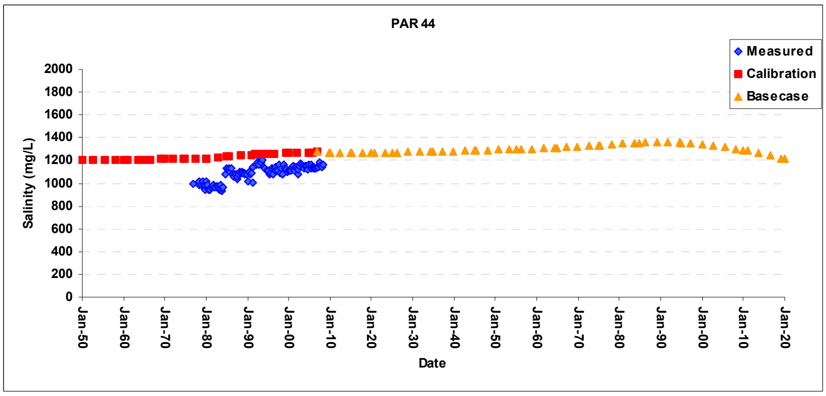


Measured, Calibration and Base case Salinity – Ranges

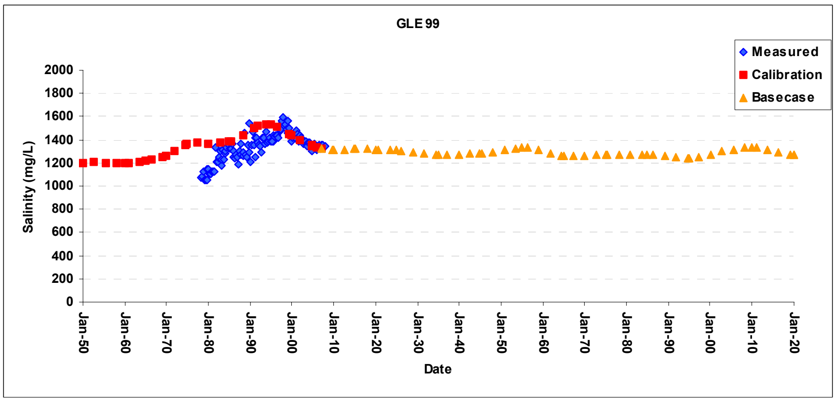


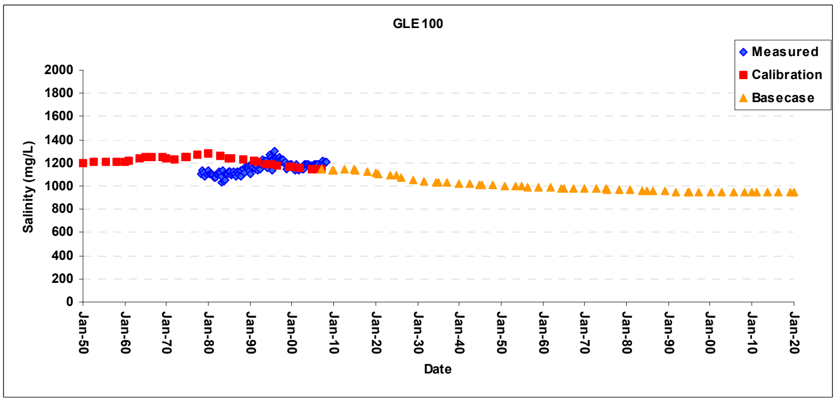


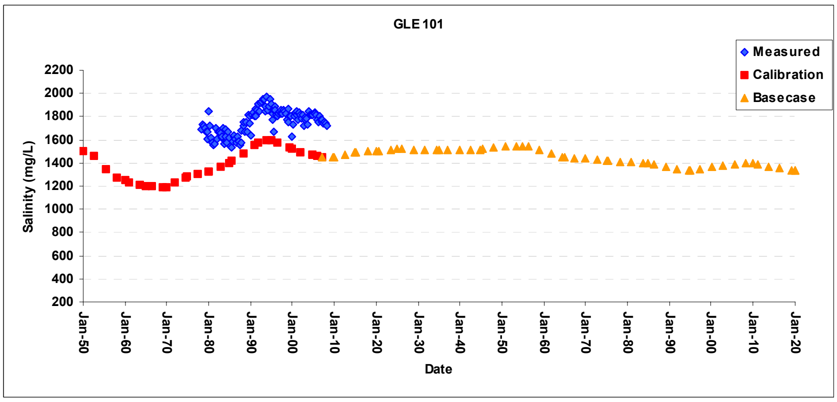


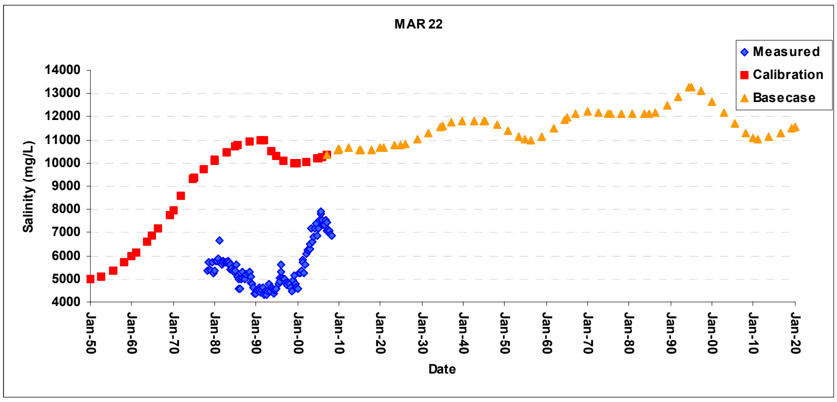


Measured, Calibration and Base case Salinity – Flats

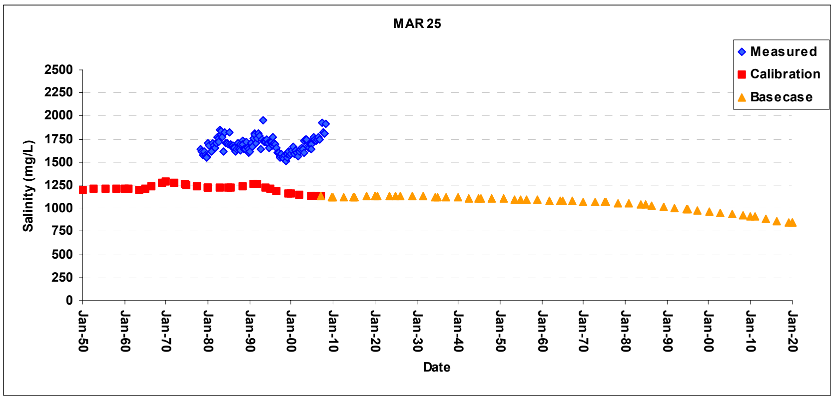


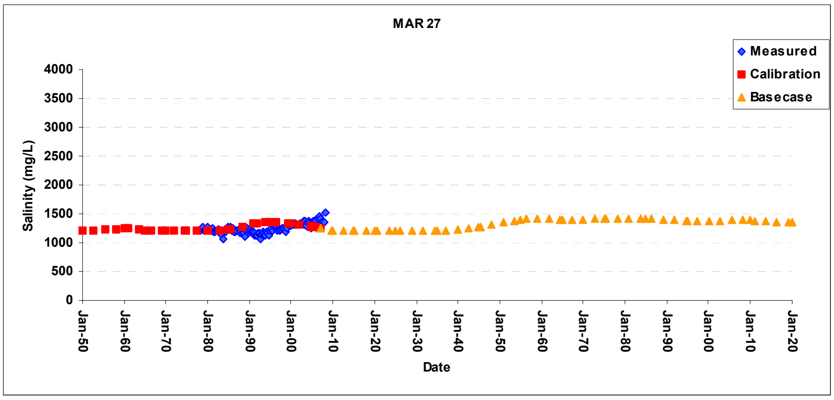


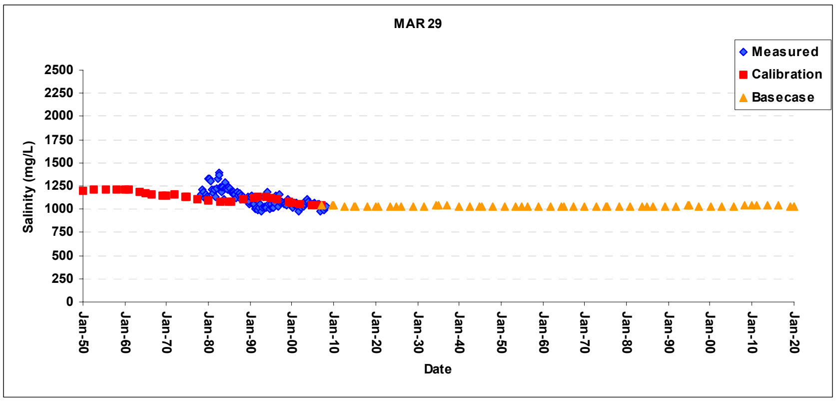


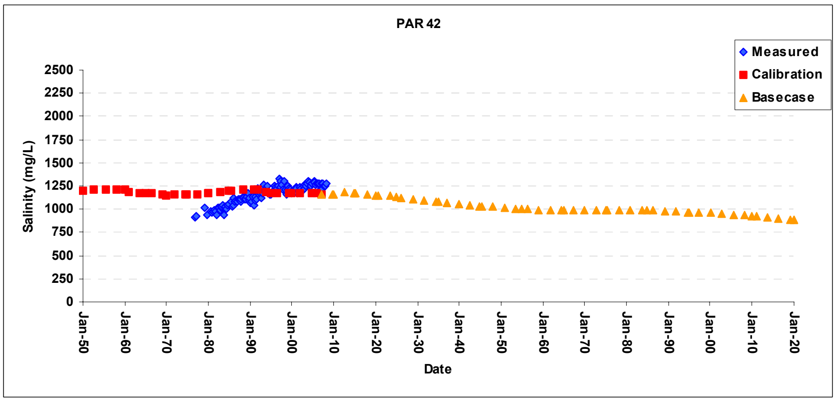


Measured, Calibration and Base case Salinity – Flats



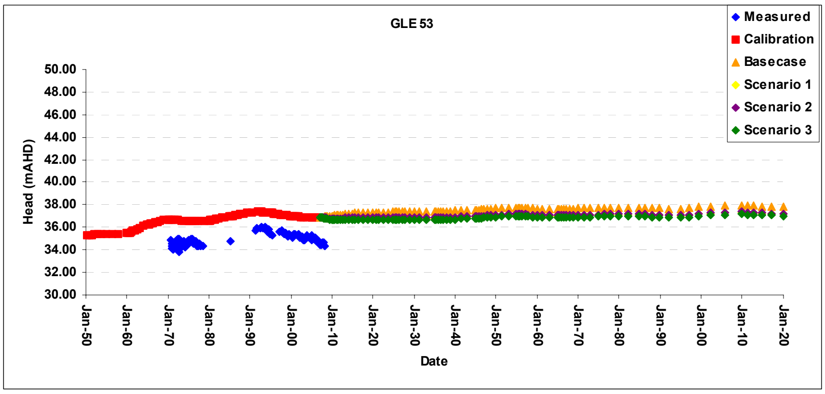


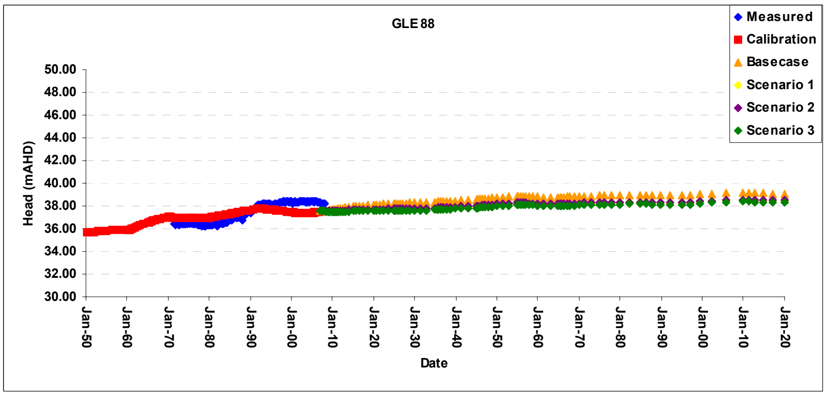


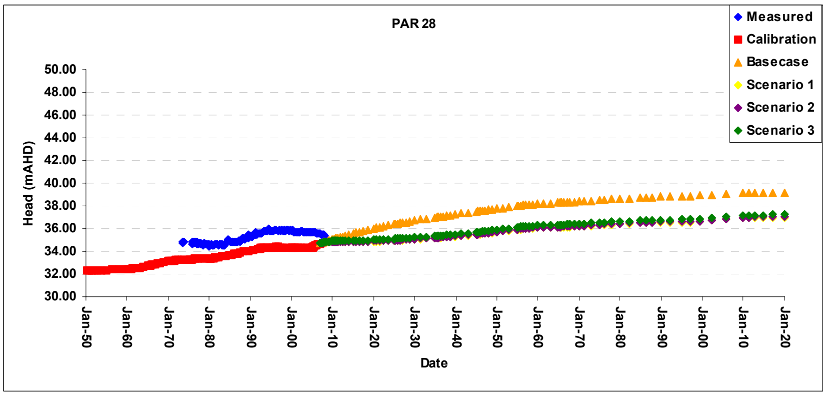


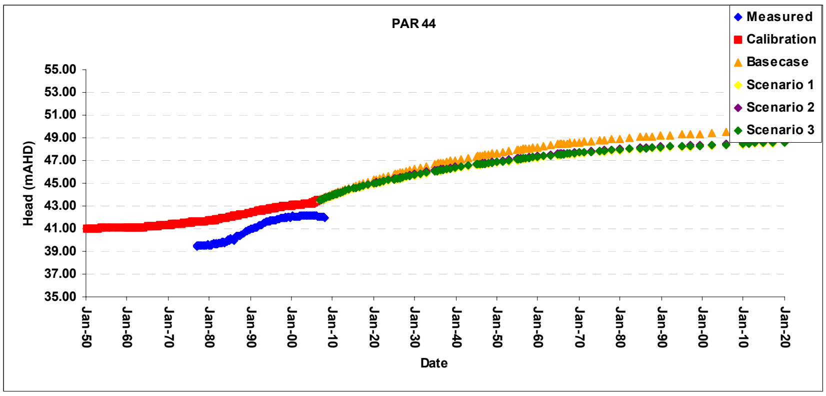
APPENDIX C

Measured, Calibration, Base case and Scenario 1, 2 & 3 Water Levels – Ranges

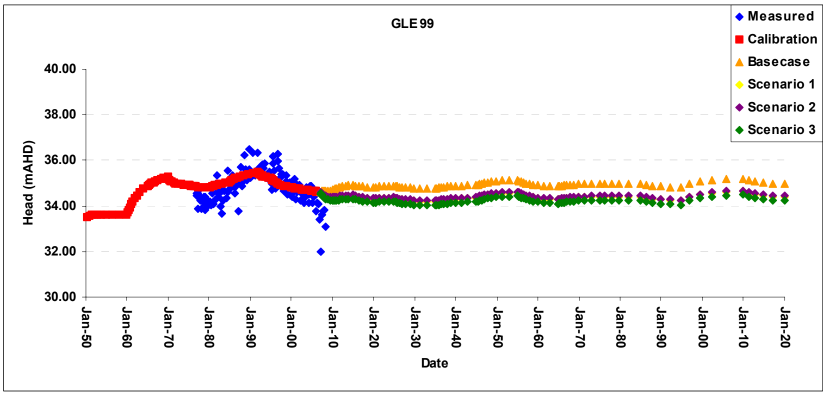


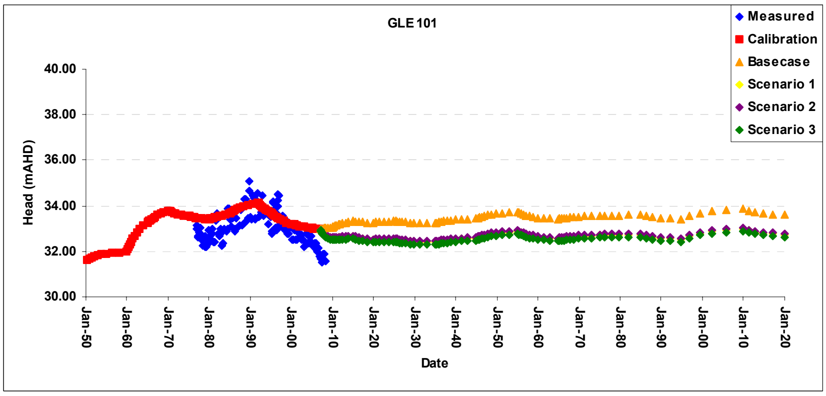


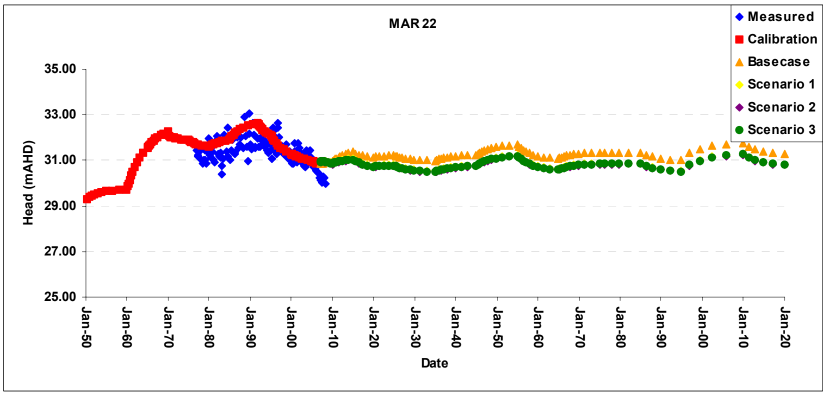


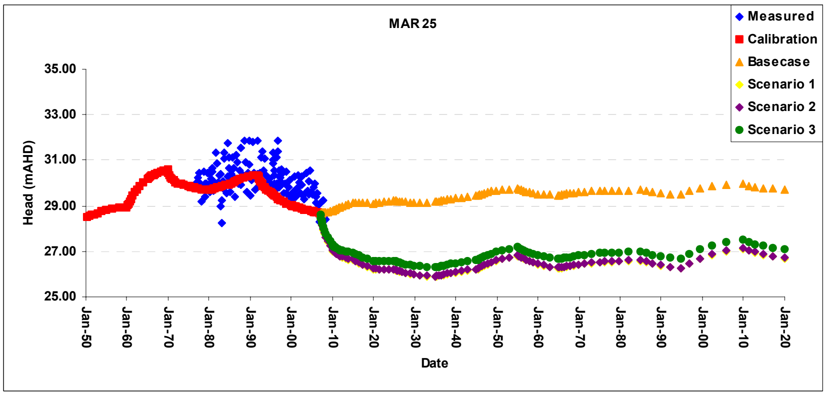


Measured, Calibration, Base case and Scenario 1, 2 & 3 Water Levels – Flats

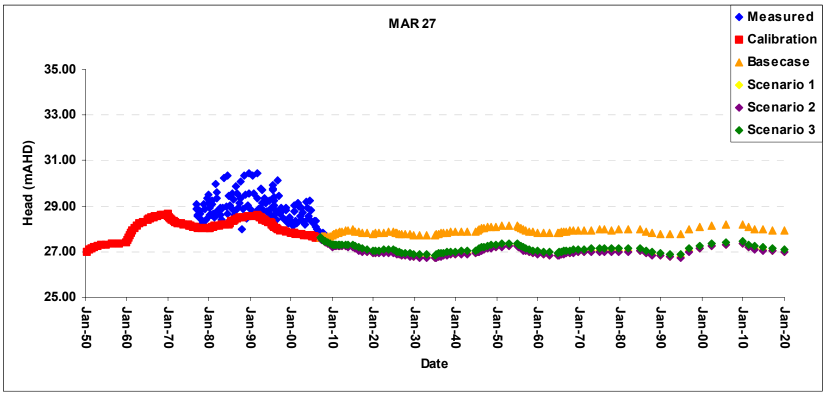


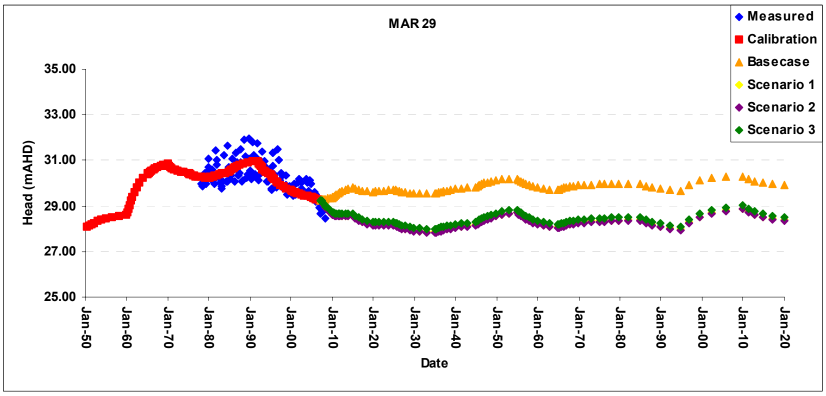


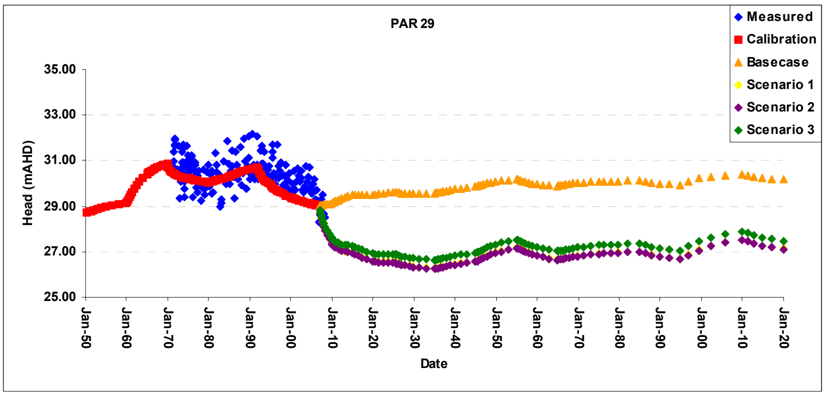


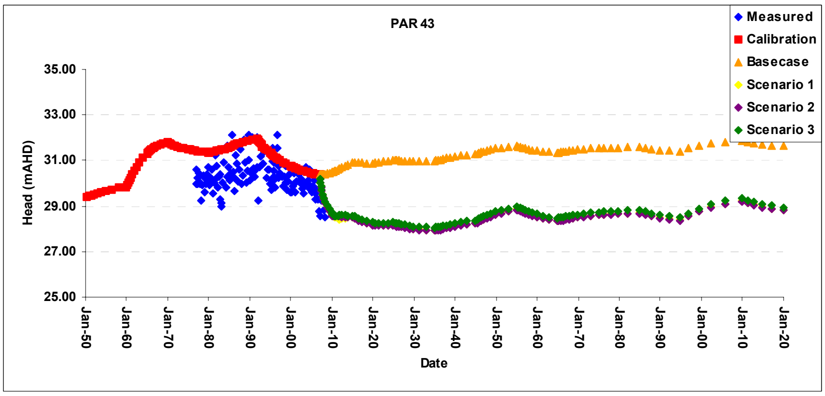


Measured, Calibration, Base case and Scenario 1, 2 & 3 Water Levels – Flats

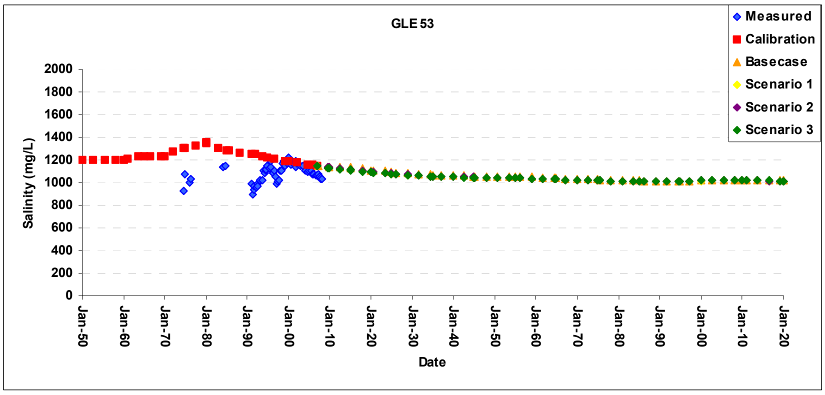


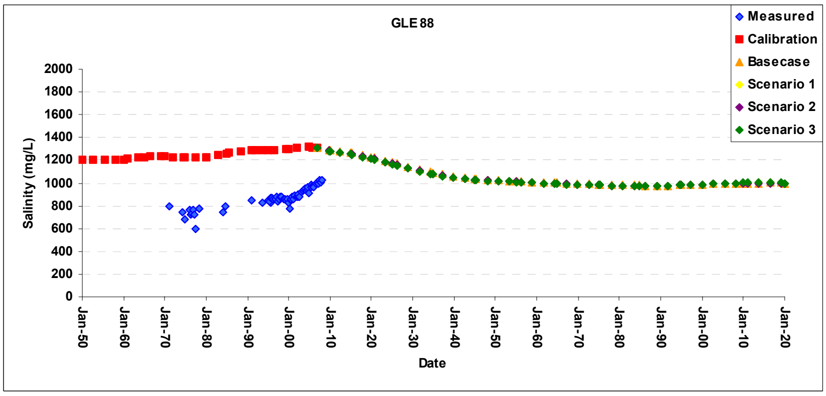


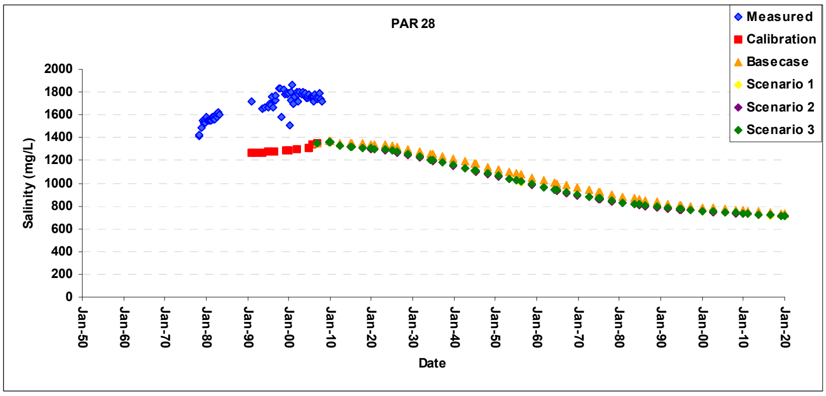


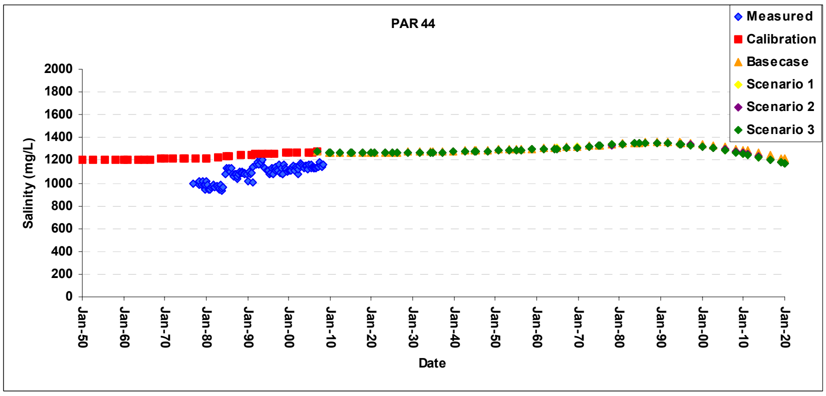


Measured, Calibration, Base case and Scenario 1, 2 & 3 Salinity – Ranges

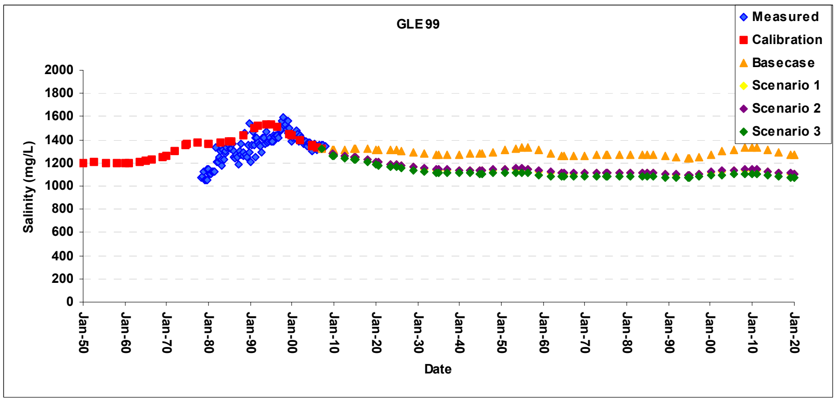


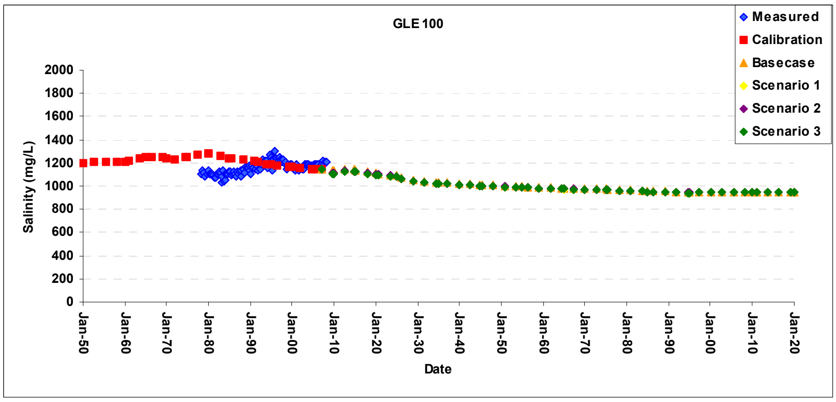


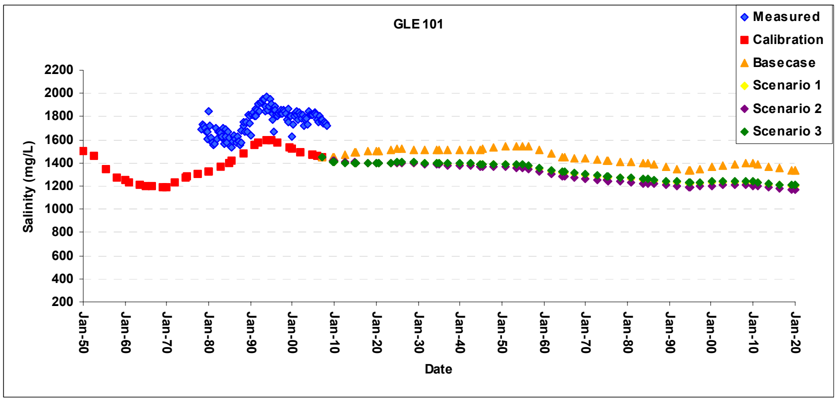


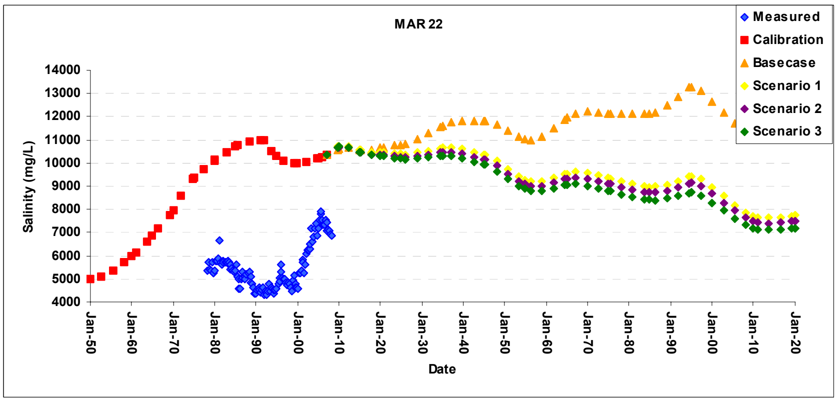


Measured, Calibration, Base case and Scenario 1, 2 & 3 Salinity – Flats

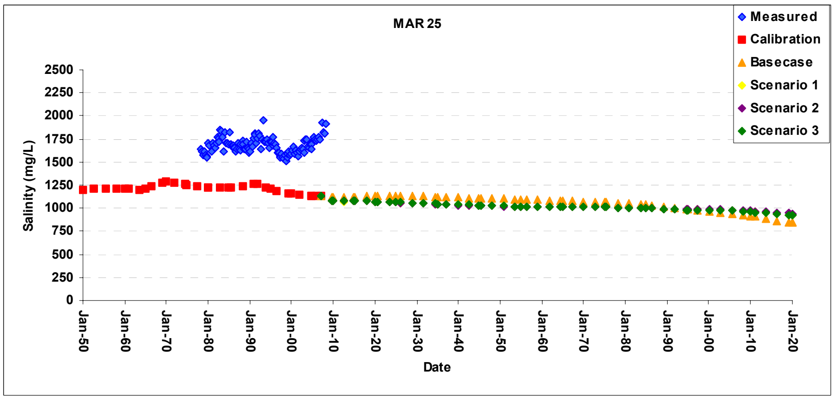


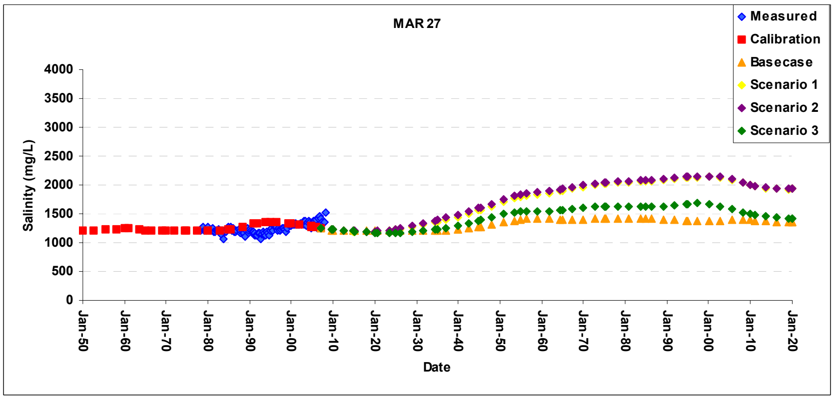


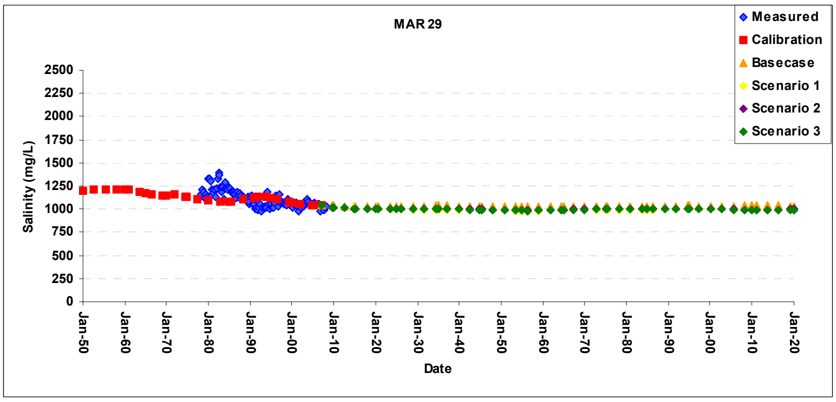


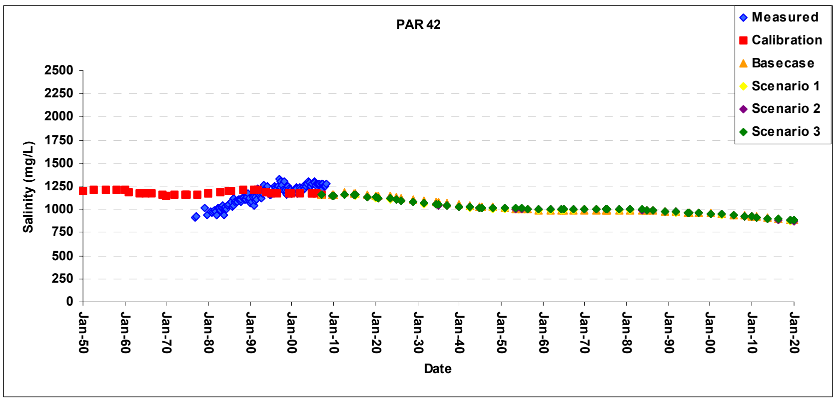


Measured, Calibration, Base case and Scenario 1, 2 & 3 Salinity – Flats



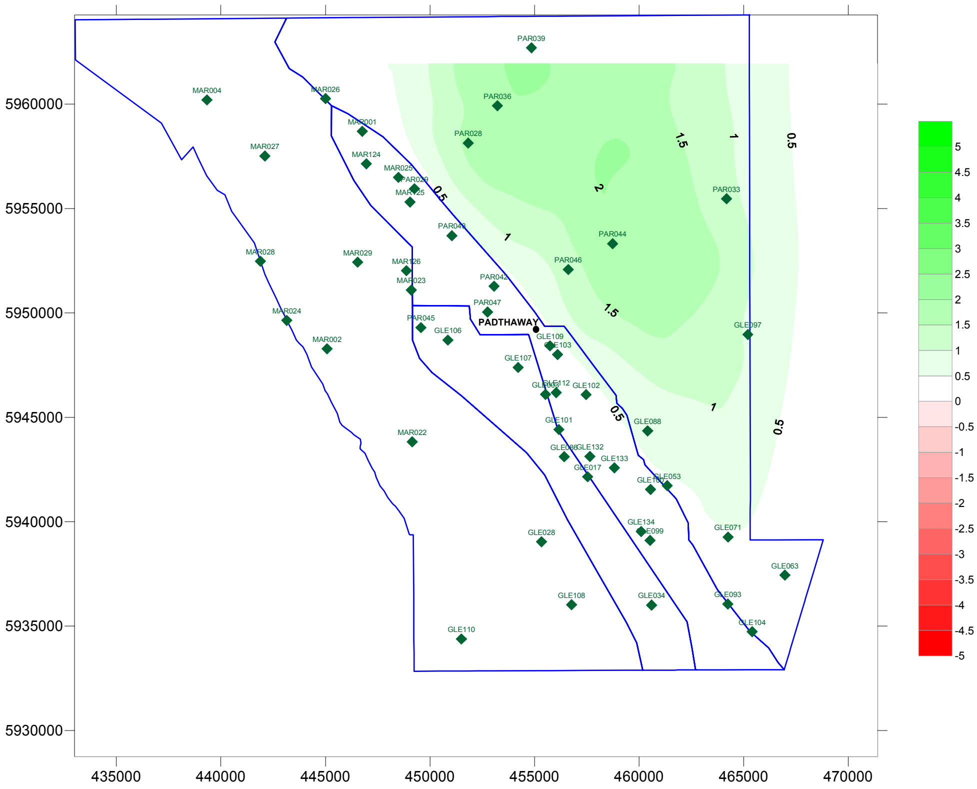




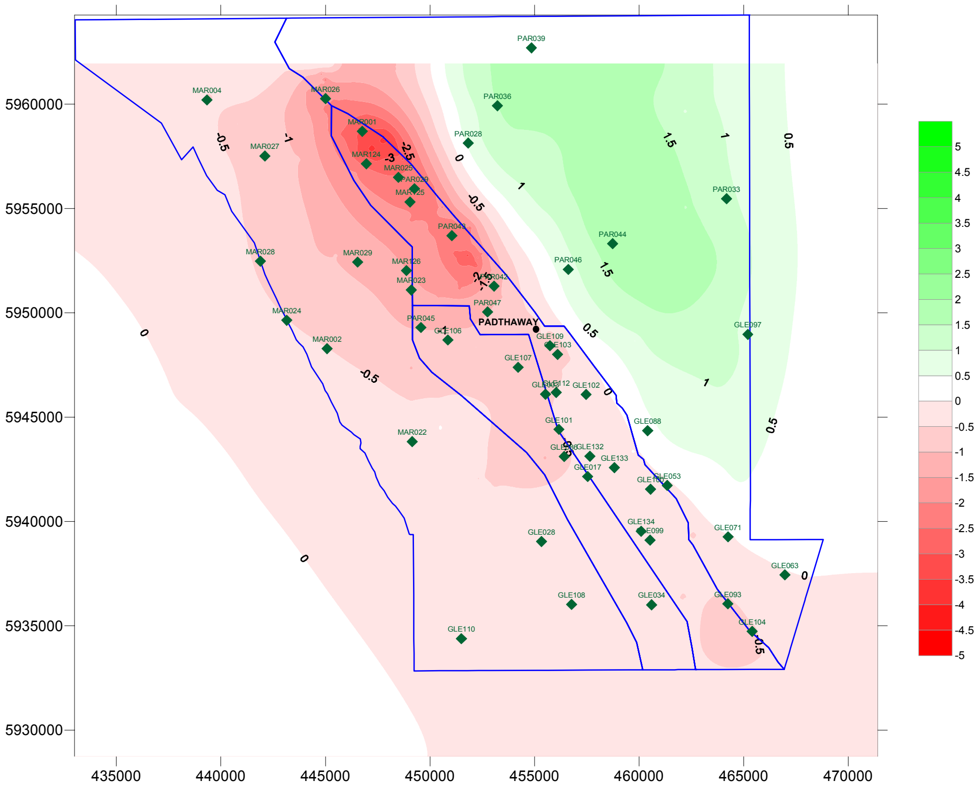


APPENDIX D

Water Level Difference Plots

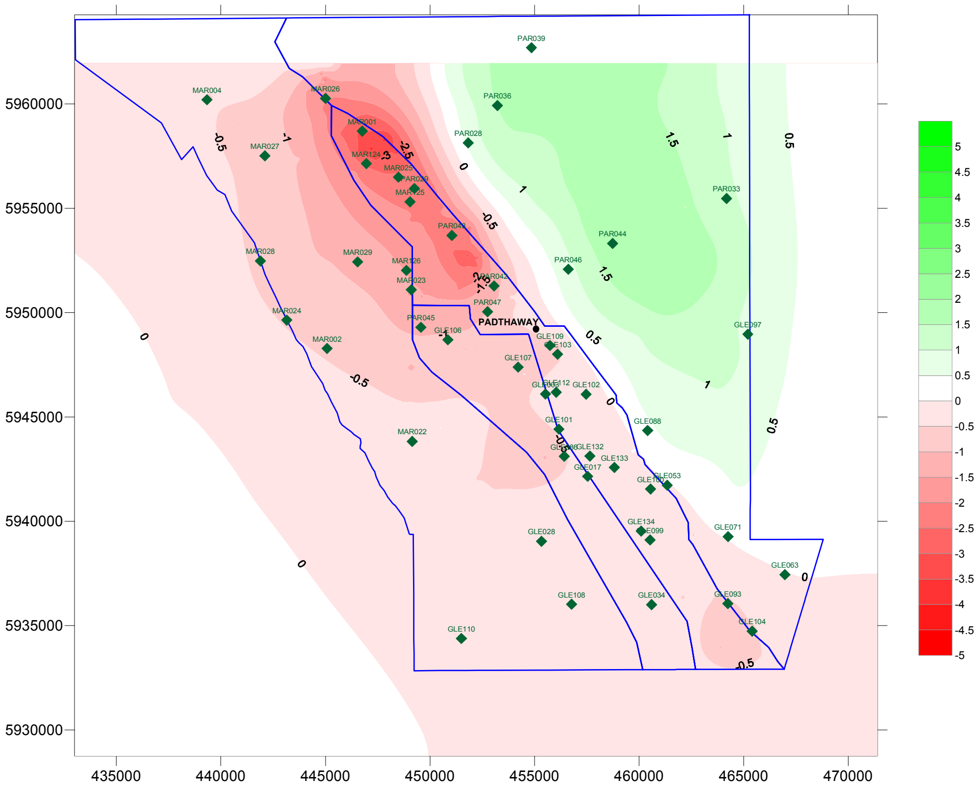


2018 Basecase less 2004 Calibration - Head Difference (m)

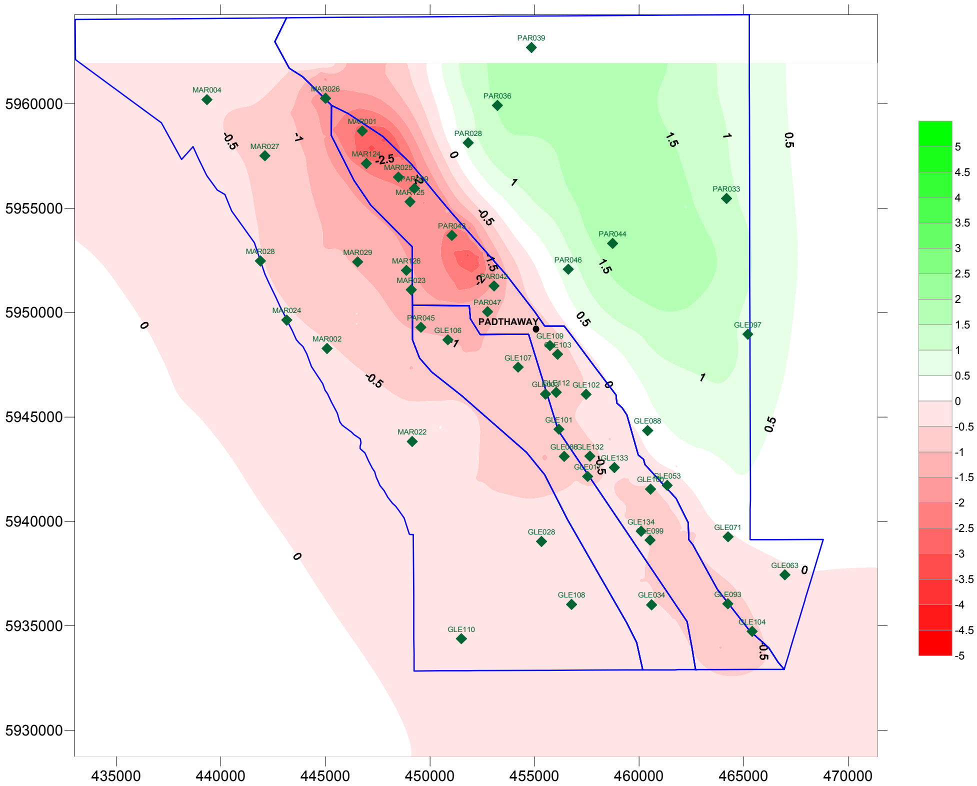


2018 Scenario 1 less 2004 Calibration - Head Difference (m)

Water Level Difference Plots



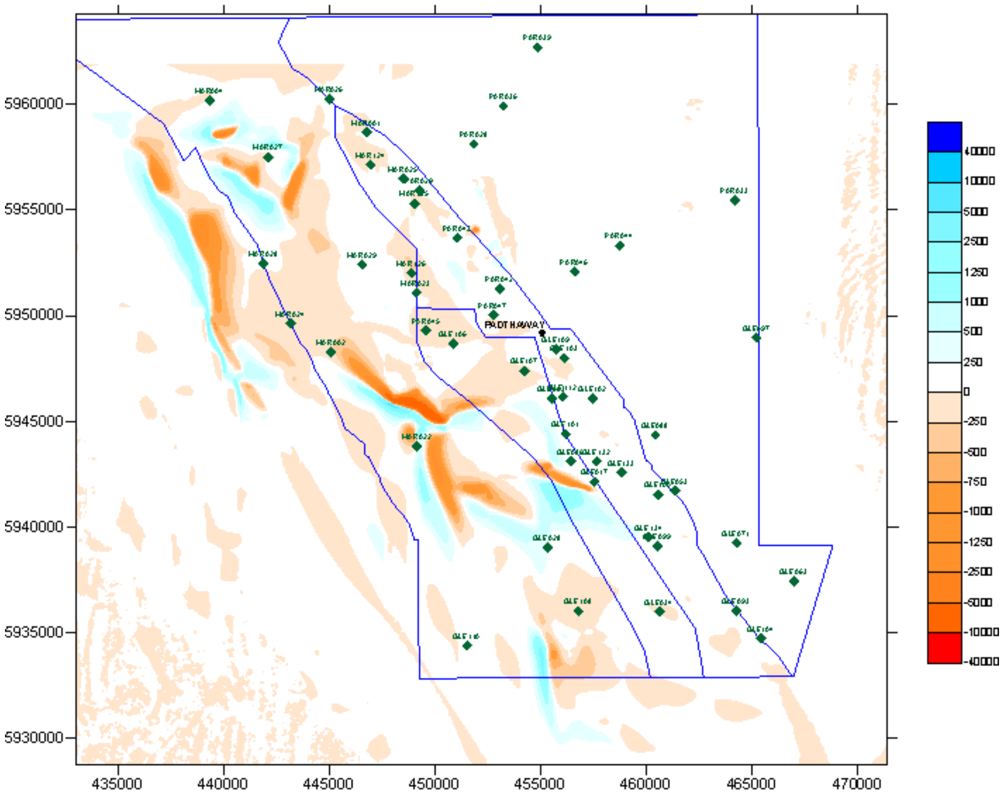
2018 Scenario 2 less 2004 Calibration - Head Difference (m)



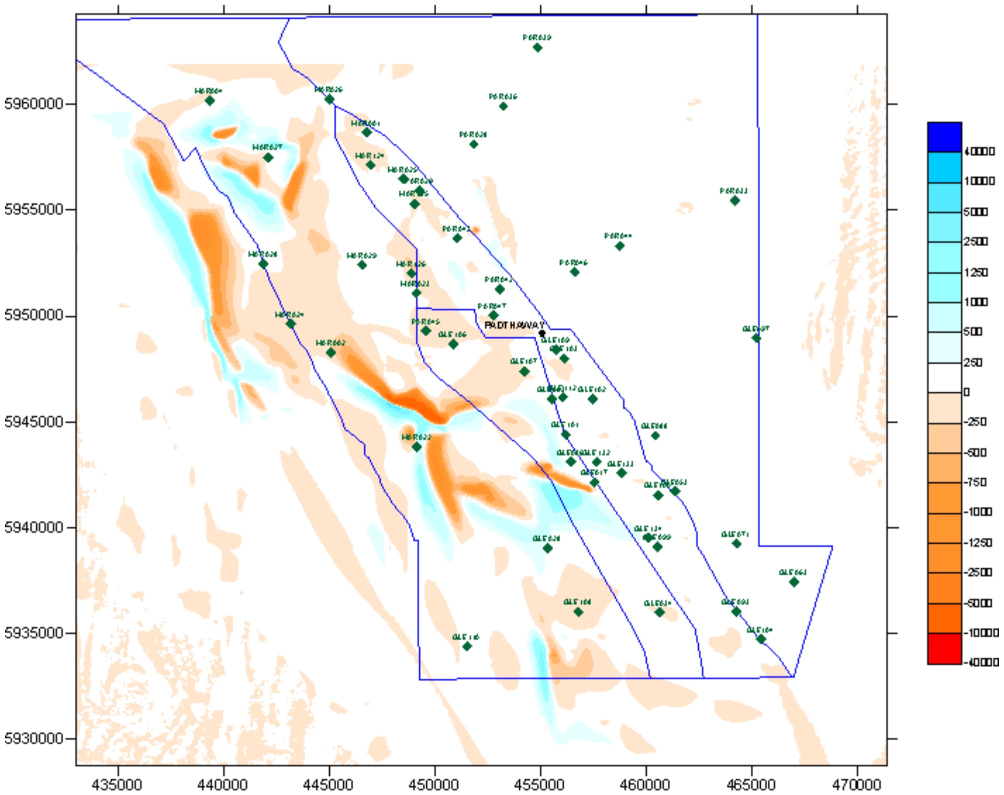
2018 Scenario 3 less 2004 Calibration - Head Difference (m)

APPENDIX E

Salinity Difference Plots

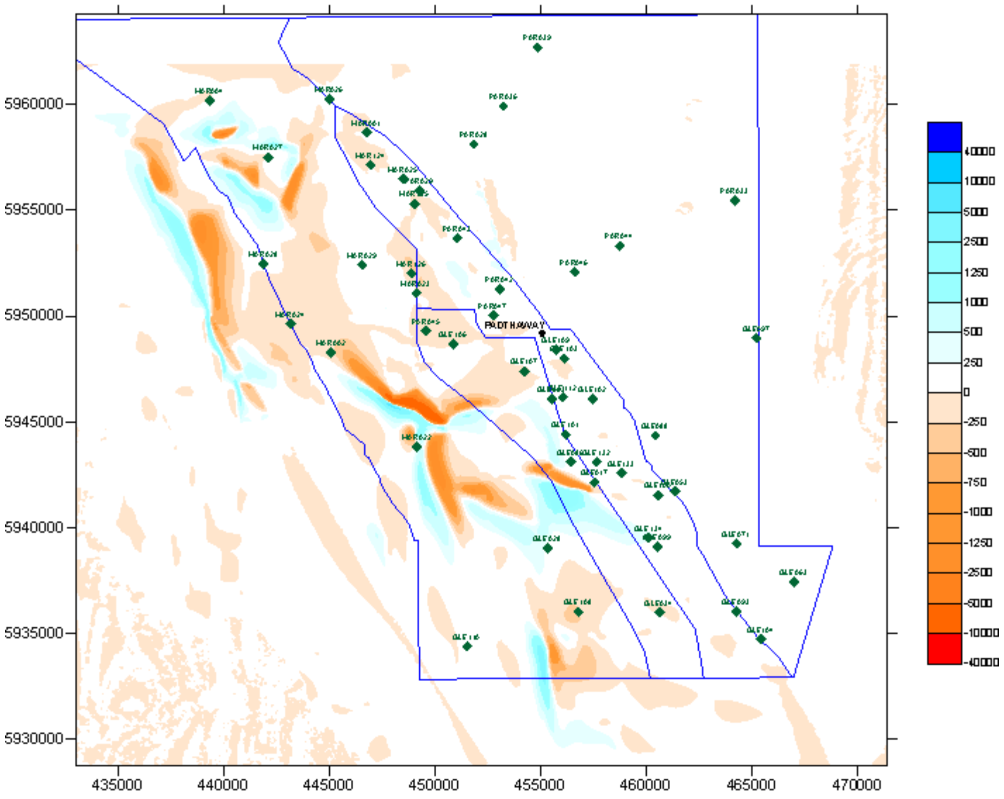


2018 Basecase less Scenario 1 - TDS Difference (mg/L)



2018 Basecase less Scenario 2 - TDS Difference (mg/L)

Salinity Difference Plots



2018 Basecase less Scenario 3 - TDS Difference (mg/L)