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Aupouri Aquifer Groundwater Model Update Based on LIDAR Survey

1. Introduction

In 2019 Williamson Water & Land Advisory (WWLA) completed the calibration of the Aupouri Aquifer Groundwater Model (AAGWM), a groundwater flow model developed in MODFLOW, for the purpose of evaluating groundwater use on the Aupouri Peninsula.

A 1m digital elevation model (DEM) derived from a LIDAR survey over the model area became available in December 2019. Previously, the land surface elevations in the model were based on the LINZ 8 m DEM.

Comparison of the improved resolution land elevation contours from LIDAR relative to the original DEM identified widespread discrepancies, which in some cases were over 20 m. These discrepancies impacted the model in the following ways:

- Geological layer elevations; and
- Groundwater levels.

1.1 Geological Layer Elevations

The model was developed using bore logs to characterise geologic layers over the area where the shellbed aquifer is present. Layer thickness interpolated from borelog information, was used to determine the elevation of the interfaces of the geologic layers in the model. Surface elevation, based on the 8m was the original basis for calculating the interface elevations at the bore locations, which were in turn used to determine layer elevations in the model.

1.2 Groundwater Levels

The change in surface elevations resulted in adjustments to calculated water table elevation in monitoring bores where groundwater elevation was originally estimated by NRC or in the case of farm bores, calculated from the 8m DEM due to lack of previous surveys. In the case of the NRC Waterfront monitoring bore the previous survey data was found to be 2.5 m higher than the LIDAR data.

1.3 Modifications to the Model

The surface elevation of the model area necessitated a re-calculation of the model layer elevations, particularly for the base layer of the model that defines the lower boundary. The model was then re-calibrated to accommodate the revised, and improved, strata and groundwater elevation information that had been incorporated into the model.

This document is intended to highlight the major changes to the AAGWM, including:

- Land surface elevation.
- Base of aquifer elevation.
- Hydraulic parameters.
- Summary statistics for model performance.
- Observed versus simulated water level hydrographs.

2. Surface and Base Elevation

Surface elevation contours based on the 2019 LIDAR survey are shown in **Figure 1** while the contours from the 8m DEM are shown in **Figure 2**. **Figure 3** shows the difference between the two data sets. It is apparent that the LIDAR elevation is lower than the 8m DEM over most of the model area.

Contours of the model base elevation interpolated from bore log depth and land surfaces derived from the LIDAR survey are shown in **Figure 4**, while **Figure 5** shows contours of the model base elevation derived from the 8m DEM. Elevation contours for intermediate model layers are not shown as layer thickness were maintained the same as the original and updated model, so the elevation changes are only relative to the base elevation.

A survey of five monitoring piezometer locations (Waterfront, Burnage, Browne, Hukatere, and Forest) was commissioned by NRC in January 2019. The survey was undertaken using a Fast Static GNSS methods. Survey results were checked against the LIDAR derived elevation values at the monitoring location and found to be very close with survey results ranging from 0.0 to 0.5 m higher than the LIDAR results. The higher elevations are likely due to the survey points being at the top of the piezometer pipes rather than ground levels.

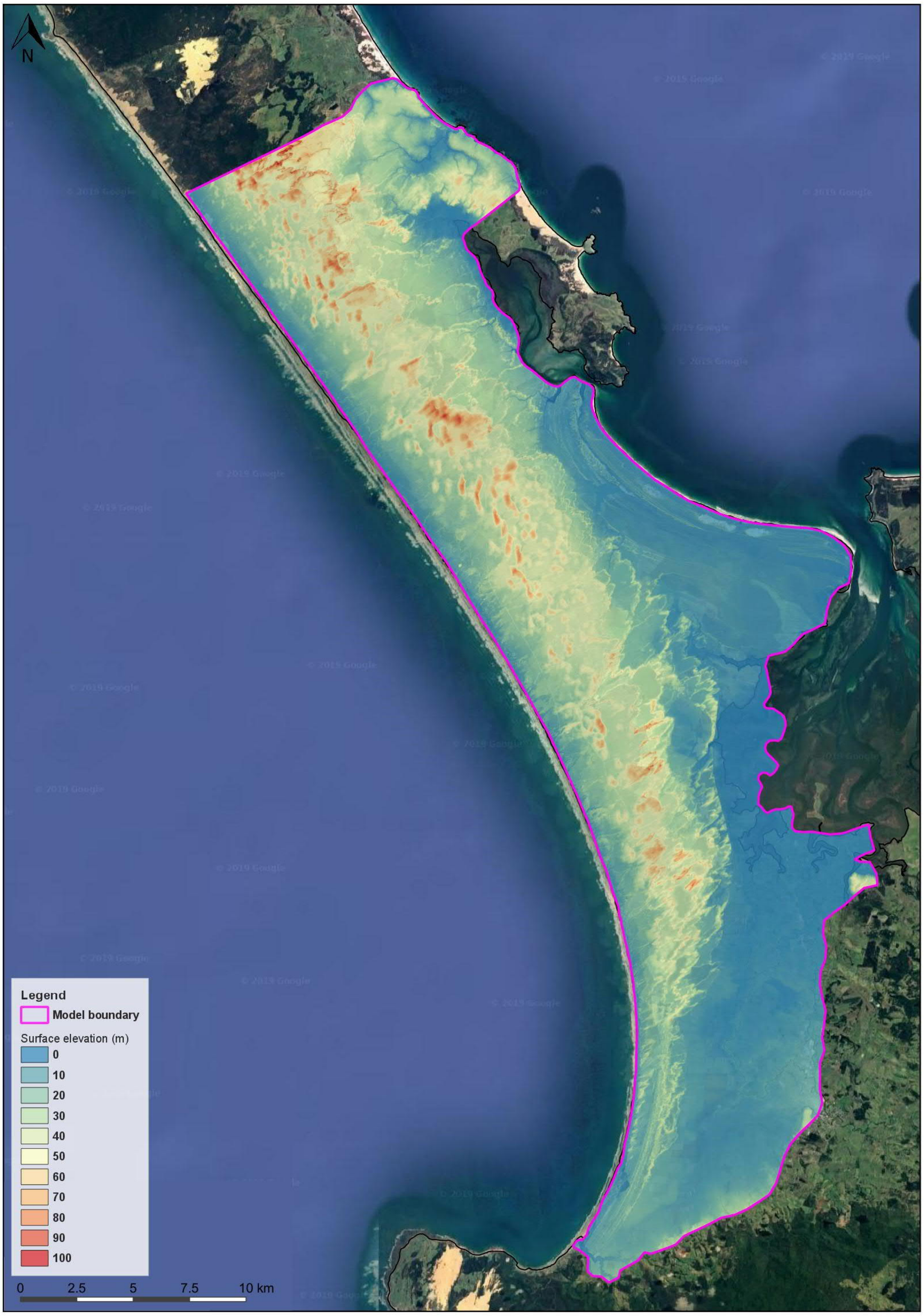


Figure 1. Surface elevation over AAGWM model area based on LIDAR survey.

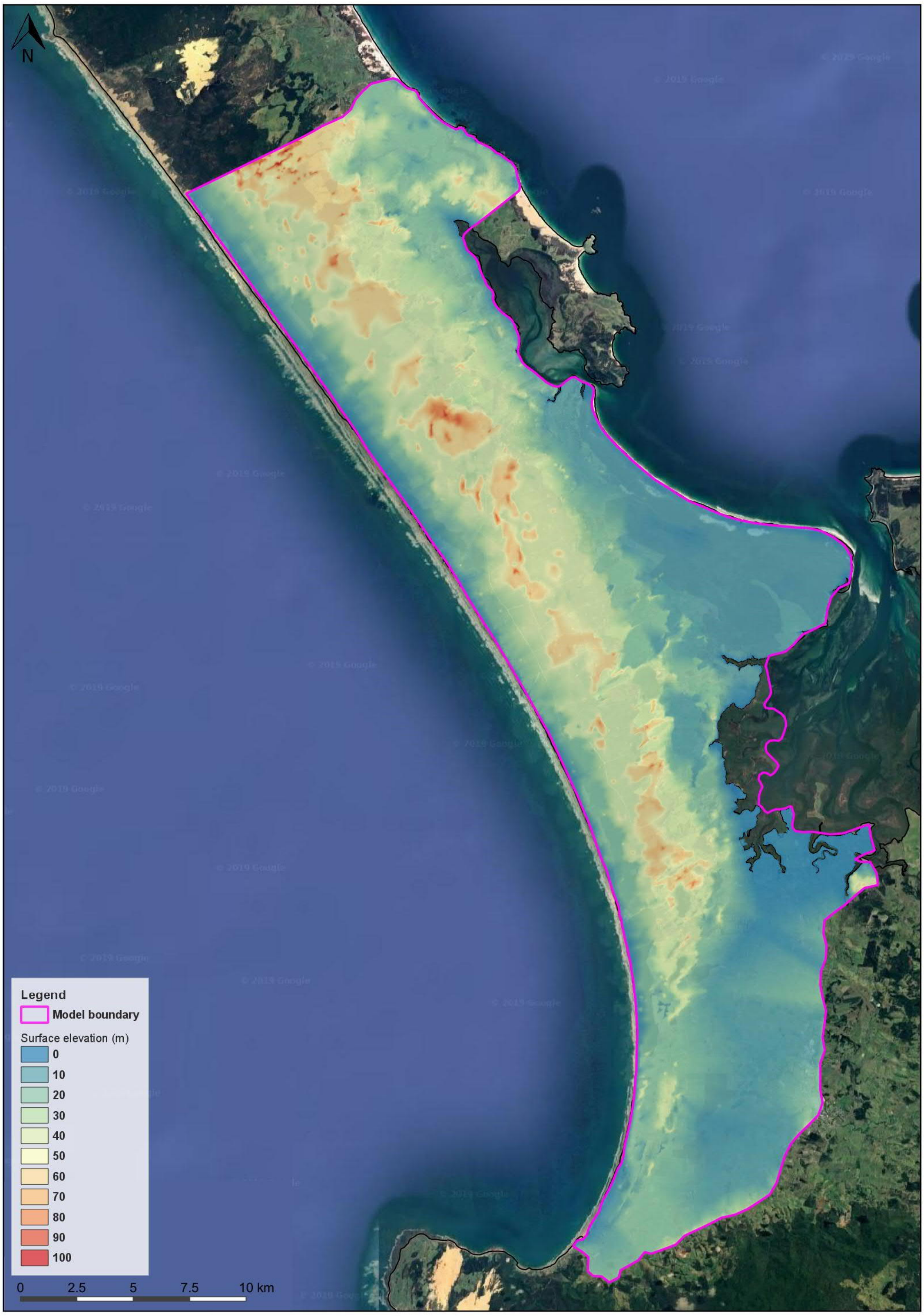


Figure 2. Surface elevation over AAGWM model area based on 8m DEM.

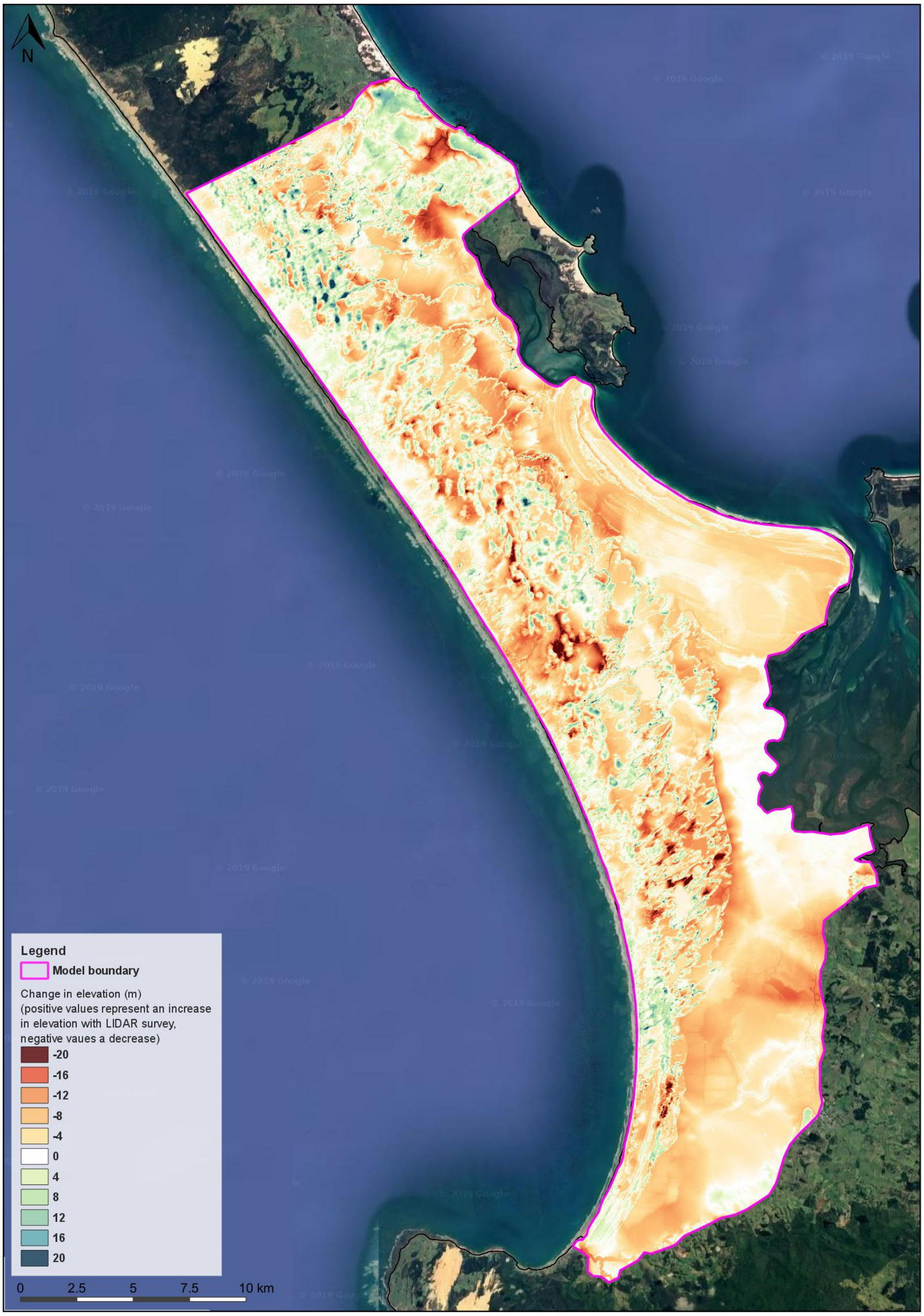


Figure 3. Difference in surface elevation (LIDAR – 8m DEM).

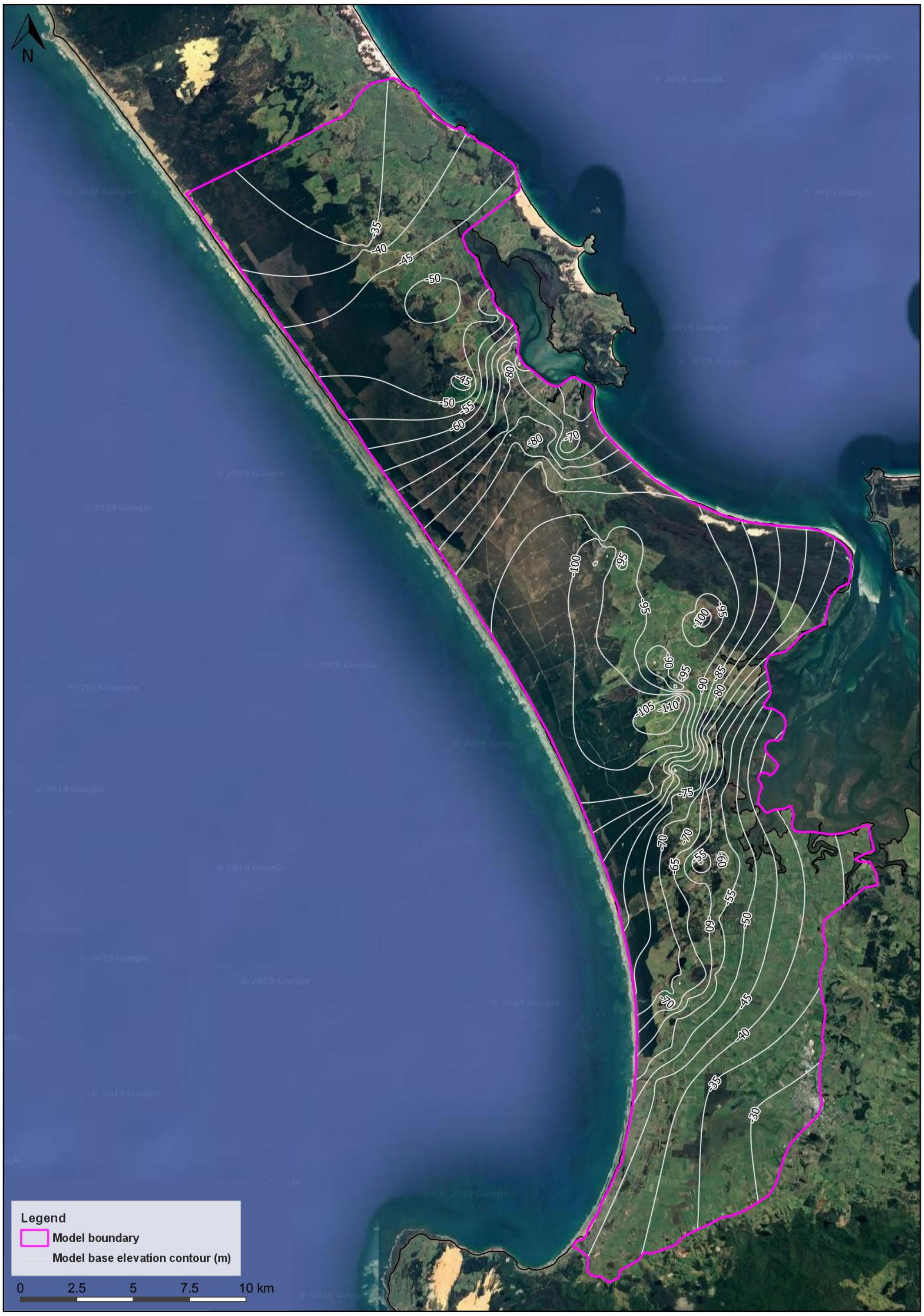


Figure 4. Model base elevation contours derived from bore log interpolation and LIDAR DEM data.

Figure 5. Model base elevation contours derived from bore log interpolation and 8m DEM data.

3. Hydraulic Parameters

Calibrated hydraulic parameters were adjusted to optimise calibration for the new model configuration and observation water levels. Minor adjustments were made using the hydraulic conductivity parameter while vertical anisotropy, specific yield, and specific storage were not adjusted. **Table 1** shows hydraulic conductivity in the 2019 (original) and 2020 (updated) versions of the model for comparative purposes. Rows are highlighted where conductivity was altered for the new calibration, and as can be seen the changes are small.

Table 1. Hydraulic Parameters from 2019 original and 2020 updated AAGWM versions.

Model Layer	Model Geological Units	Hydraulic Conductivity-				Comments
		2019 (original)		2020 (updated)		
		(m/d)	(m/s)	(m/d)	(m/s)	
Layer 1: Interbedded sand, peat, and iron pans	Coastal sand-North	4.20	4.9E-05	4.20	4.9E-05	-
	Coastal sand-Motutangi	4.85	5.6E-05	4.85	5.6E-05	-
	Coastal sand-Waiharara-Paparore	2.75	3.2E-05	2.75	3.2E-05	-
	Coastal sand-South	6.69	7.7E-05	7.50	8.7E-05	Slight increase to conductivity in coast area targeting calibration of Waipapakauri and Lake Heather monitoring bores.
	Inland sand-North	2.40	2.8E-05	2.40	2.8E-05	-
	Inland sand-Motutangi	2.93	3.4E-05	3.00	3.5E-05	Slight increase in conductivity to improve calibration in shallow piezometers on Hukatere transect.
	Inland sand-Waiharara-Paparore	1.65	1.9E-05	1.00	1.2E-05	Slight decrease in conductivity to improve calibration in Valic-4 and Ogle drive piezometers.
	Inland sand-South	0.90	3.5E-06	0.60	6.9E-06	-
	Peat wetland-Motutangi	0.12	1.4E-06	0.12	1.4E-06	-
	Peat-Waiharara-Paparore	0.6	6.9E-06	1.00	1.2E-05	Slight increase to conductivity intended to decrease hydraulic gradient around Paparore to reduce simulated water level.

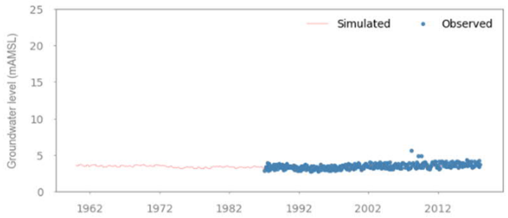
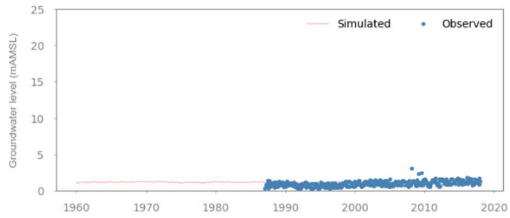
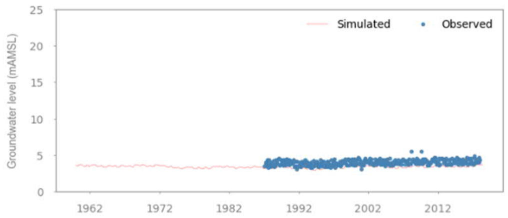
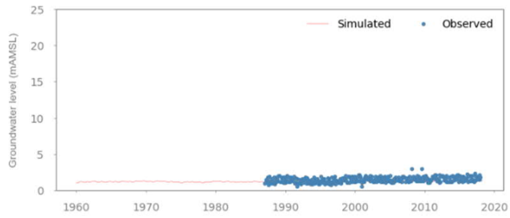
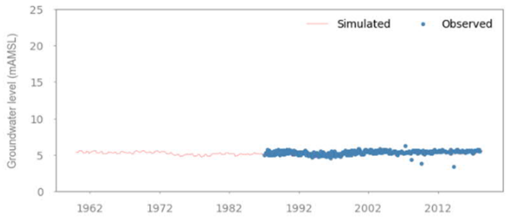
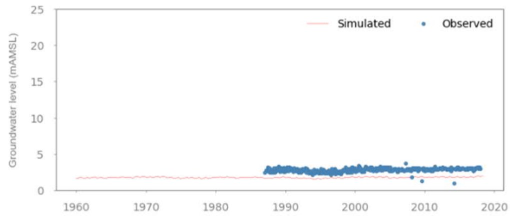
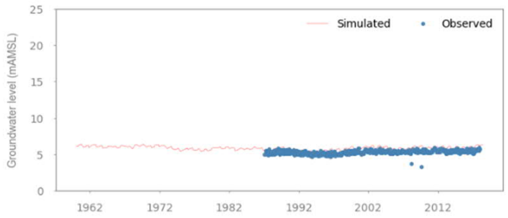
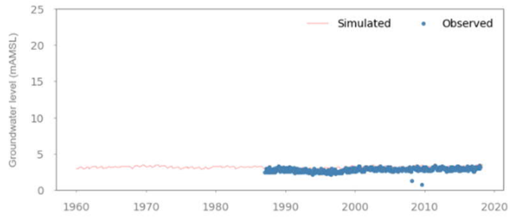
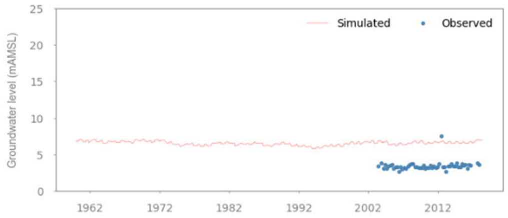
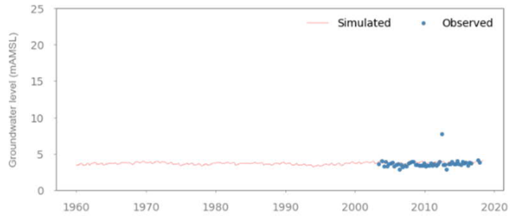
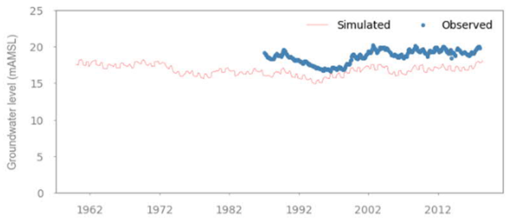
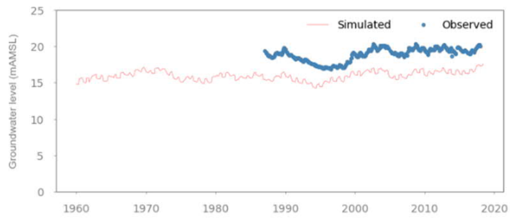
Model Layer	Model Geological Units	Hydraulic Conductivity-				Comments
		2019 (original)		2020 (updated)		
		(m/d)	(m/s)	(m/d)	(m/s)	
	Estuary-Waiharara-Paparore	1.00	1.2E-05	1.00	1.2E-05	-
	Plains-South	5.00	5.8E-05	8.00	9.3E-05	Increase in conductivity along eastern plains in southern part of model to improve calibration at Sweetwater 2A, Welch, Vinac, Shanks, and Matich.
Layers 2 & 3: Interbedded sand, peat, and iron pans	Coastal sand-North	4.20	4.9E-05	4.20	4.9E-05	-
	Coastal sand-Motutangi	4.80	5.6E-05	4.80	5.6E-05	-
	Coastal sand-Waiharara-Paparore	2.55	3.0E-05	2.55	3.0E-05	-
	Coastal sand-South	12.00	1.4E-04	12.00	1.4E-04	-
	Inland sand-North	4.20	4.9E-05	4.20	4.9E-05	-
	Inland sand-Motutangi	3.36	3.9E-05	2.00	2.3E-05	Decreased conductivity to raise simulated water level for shallow layers at Browne, Forest, and Hukatere piezometers.
	Inland sand-Waiharara-Paparore	2.25	2.6E-05	2.50	2.9E-05	-
	Inland sand-South	1.20	1.7E-05	0.80	9.3E-06	Decrease conductivity to increase simulated water level at Lake Heather-shallow bores and Sweetwater 1-shallow
Layer 4: Upper Shellbed	Upper Shellbed-North	36.00	4.2E-04	36.00	4.2E-04	-
	Upper Shellbed-Motutangi	42.00	4.9E-04	32.00	3.7E-04	Decrease conductivity to raise simulated water level to improve calibration in piezometers on the Hukatere transect.
	Upper Shellbed-Waiharara-Paparore	19.20	2.2E-04	15.00	1.7E-04	Decrease conductivity to raise simulated water level to improve calibration at Valic-deep

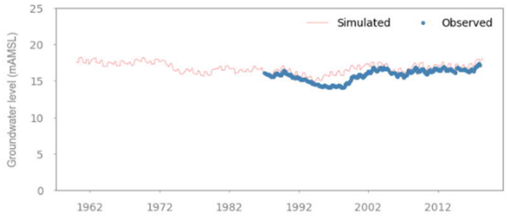
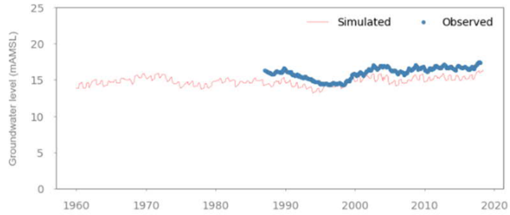
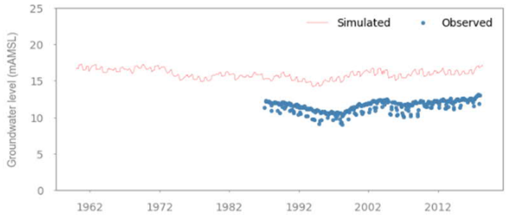
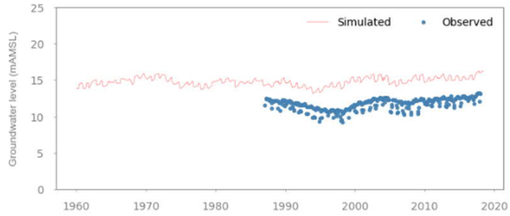
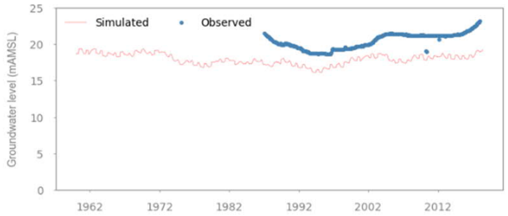
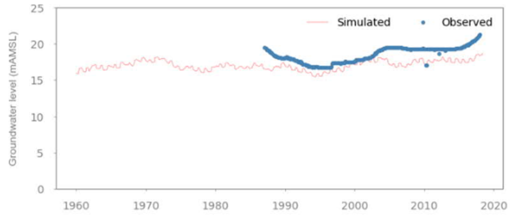
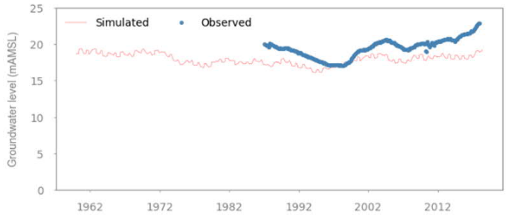
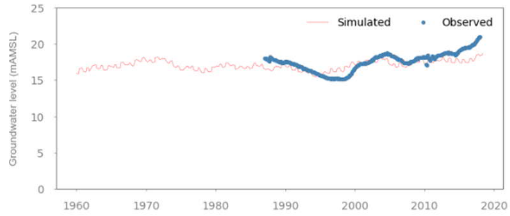
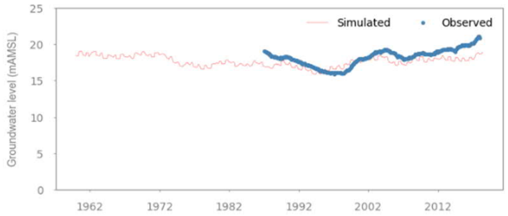
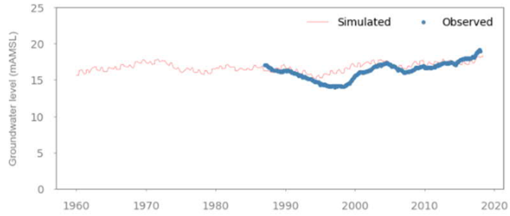
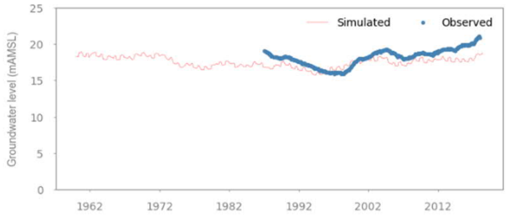
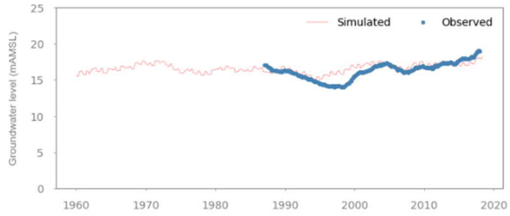
Model Layer	Model Geological Units	Hydraulic Conductivity-				Comments
		2019 (original)		2020 (updated)		
		(m/d)	(m/s)	(m/d)	(m/s)	
						and Paparore deep monitoring piezometers.
	Upper Shellbed-South	30.00	3.5E-04	20.00	2.3E-04	Decrease conductivity to raise simulated water level to improve calibration at Sweetwater-deep monitoring piezometers.
Layer 5: Compact Sand	Compact sand-North	1.20	1.4E-05	1.20	1.4E-05	-
	Compact sand-Motutangi	7.20	8.3E-05	7.20	8.3E-05	-
	Compact sand-Waiharara-Paparore	0.60	6.9E-06	0.60	6.9E-06	-
	Compact sand-South	1.50	1.7E-05	1.00	1.2E-05	Decrease conductivity to raise simulated water level to improve calibration at Sweetwater-deep monitoring piezometers.
Layer 6: Lower Shellbed	Lower Shellbed-North	36.00	4.2E-04	36.00	4.2E-04	-
	Lower Shellbed-Motutangi	26.40	3.1E-04	26.40	3.1E-04	-
	Lower Shellbed-Waiharara-Paparore	42.00	4.9E-04	25.00	2.9E-04	Decrease conductivity to raise simulated water level to improve calibration at Valic-deep and Paparore deep monitoring piezometers.
	Lower Shellbed-South	50.00	5.8E-04	25.00	2.9E-04	Decrease conductivity to raise simulated water level to improve calibration at Sweetwater-deep monitoring piezometers.

4. Calibration Hydrographs

Table 2 includes groundwater hydrographs showing observed and simulated data for all monitoring bores in the model domain. Results from the updated and original model versions can be compared directly.

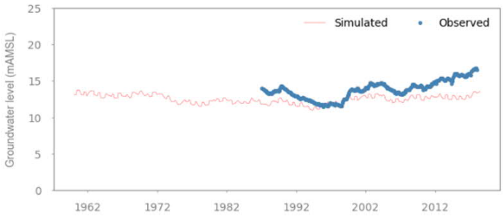
Table 2. Hydrographs showing observed and simulated groundwater levels for all monitoring bores in the model domain for both the 2019 and 2020 versions of the AAGWM.

2019 AAGWM results	2020 AAGWM results
Waterfront (19 m)	Waterfront (19 m)
	
Waterfront (37 m)	Waterfront (37 m)
	
Waterfront (57 m)	Waterfront (57 m)
	
Waterfront (74 m)	Waterfront (74 m)
	
Fishing Club (78 m)	Fishing Club (78 m)
	
Browne (16 m)	Browne (16 m)
	

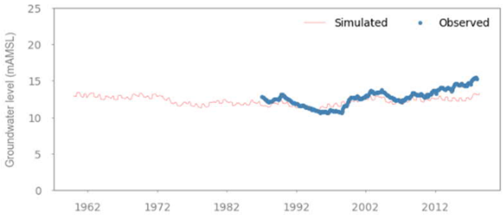
2019 AAGWM results	2020 AAGWM results
Browne (29 m) 	Browne (29 m) 
Browne (59 m) 	Browne (59 m) 
Forest (16 m) 	Forest (16 m) 
Forest (36 m) 	Forest (36 m) 
Forest (64 m) 	Forest (64 m) 
Forest (79 m) 	Forest (79 m) 

2019 AAGWM results

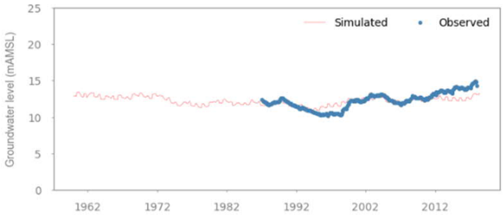
Hukatere (19 m)



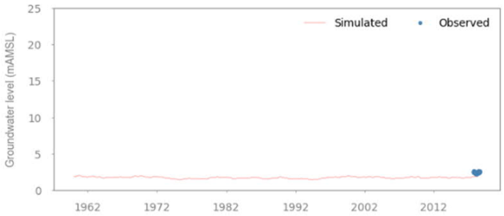
Hukatere (36 m)



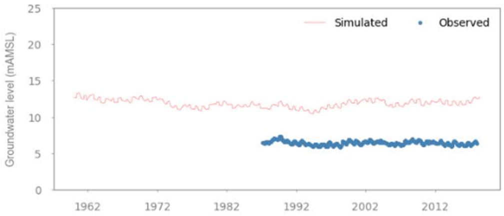
Hukatere (58 m)



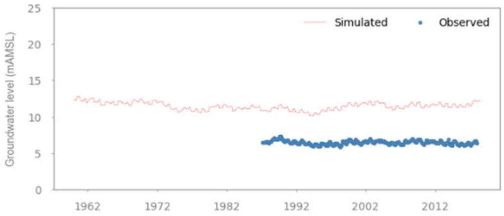
Kaimaumau Deep (72 m)



Paparore (18 m)

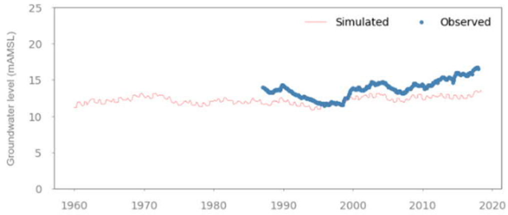


Paparore (35 m)

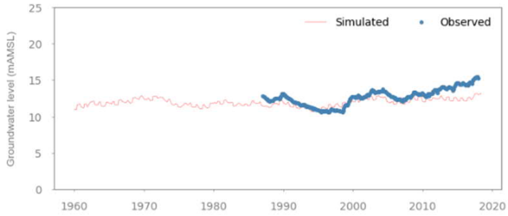


2020 AAGWM results

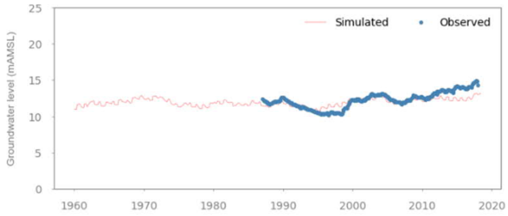
Hukatere (19 m)



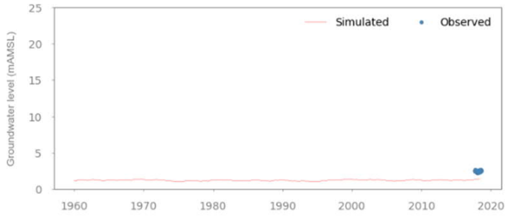
Hukatere (36 m)



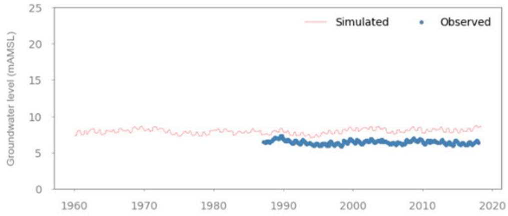
Hukatere (58 m)



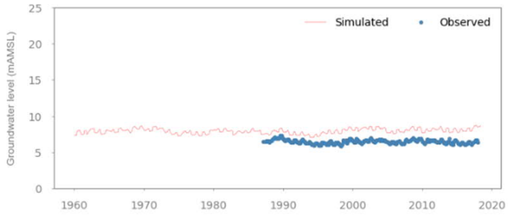
Kaimaumau Deep (72 m)



Paparore (18 m)

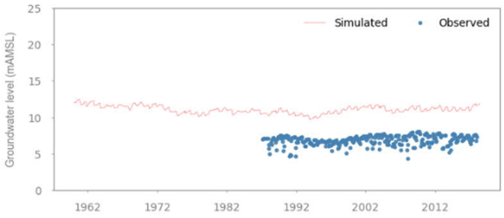


Paparore (35 m)

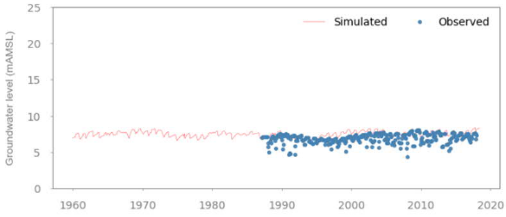


2019 AAGWM results	**2020 AAGWM results**

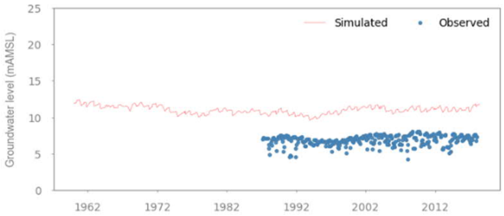
Paparore (65 m)



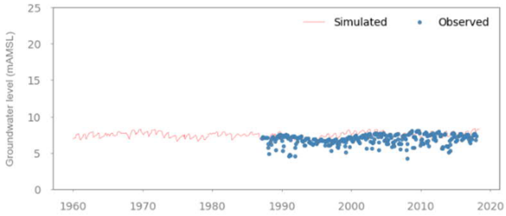
Paparore (65 m)



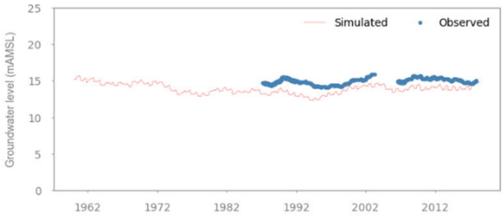
Paparore (75 m)



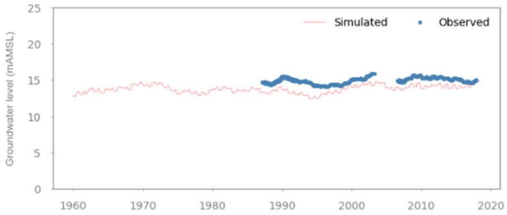
Paparore (75 m)



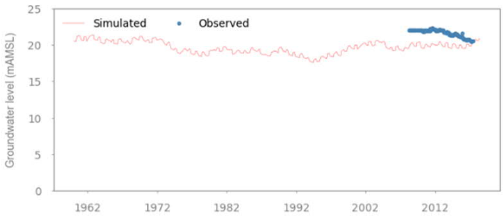
Ogle Drive (68 m)



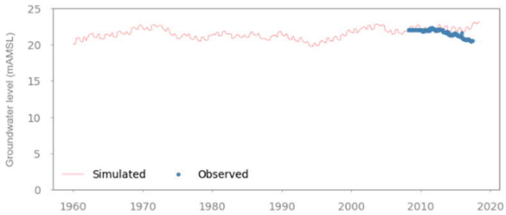
Ogle Drive (68 m)



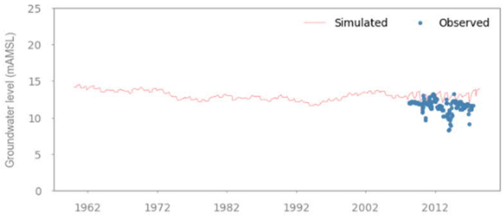
Valic-1 (Shallow Monitoring-17 m)



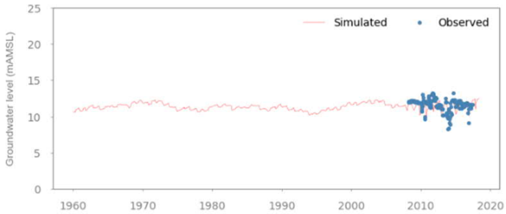
Valic-1 (Shallow Monitoring-17 m)



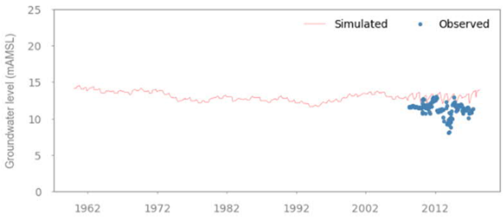
Valic-1 (Deep Monitoring-103 m)



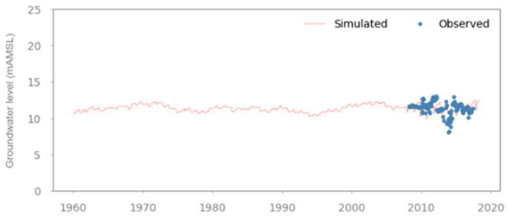
Valic-1 (Deep Monitoring-103 m)



Valic-1 (Production Bore-103 m)

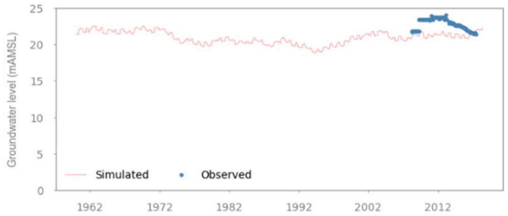


Valic-1 (Production Bore-103 m)

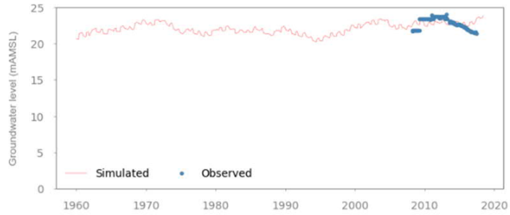


2019 AAGWM results	2020 AAGWM results

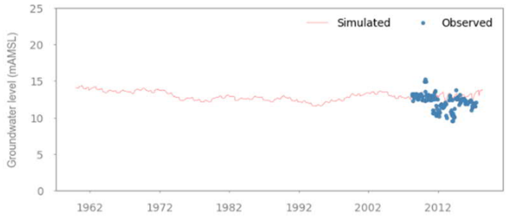
Valic-2 (Shallow Monitoring-55 m)



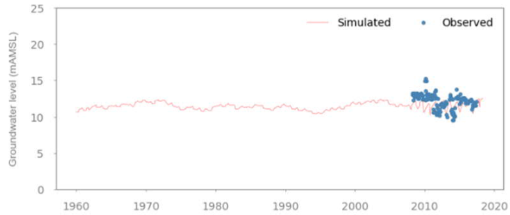
Valic-2 (Shallow Monitoring-55 m)



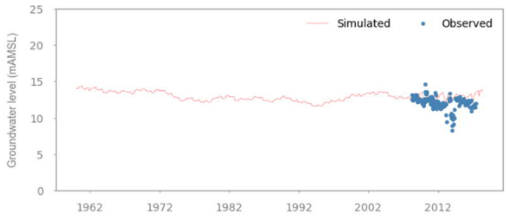
Valic-2 (Deep Monitoring-121 m)



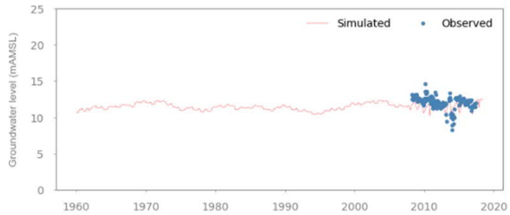
Valic-2 (Deep Monitoring-121 m)



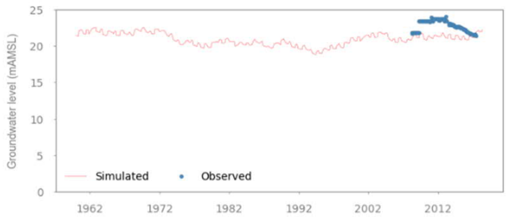
Valic-2 (Deep Production-121 m)



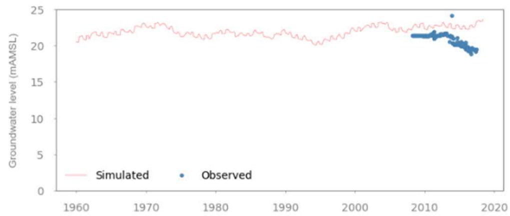
Valic-2 (Deep Production-121 m)



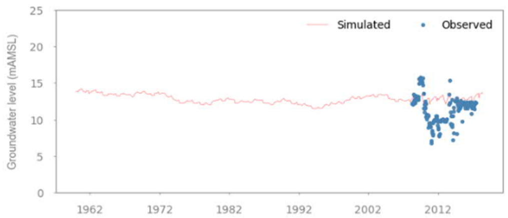
Valic-3 (Shallow Monitoring-45 m)



Valic-3 (Shallow Monitoring-45 m)



Valic-3 (Deep Monitoring-124 m)



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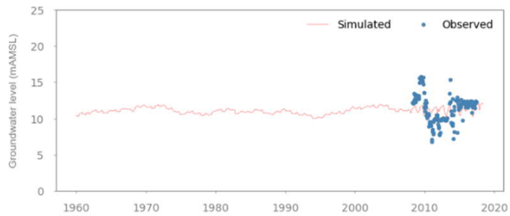
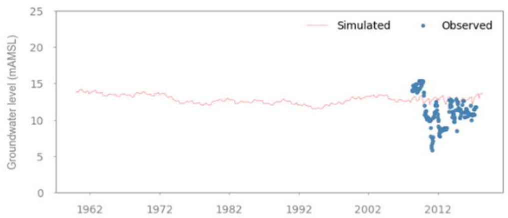
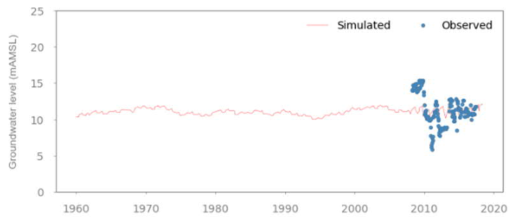


Valic-3 (Deep Production-124 m)

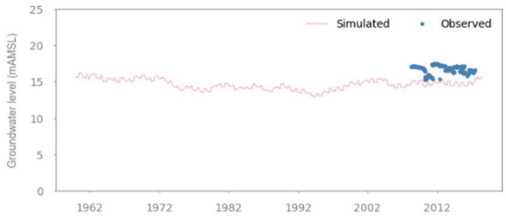


Valic-3 (Deep Production-124 m)

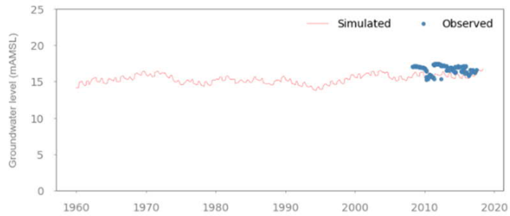


2019 AAGWM results	2020 AAGWM results

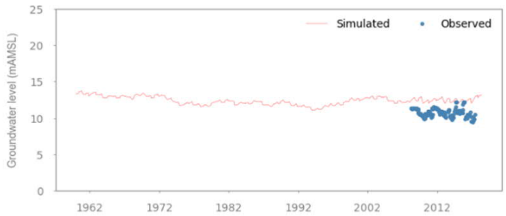
Valic-4 (Shallow Monitoring-13 m)



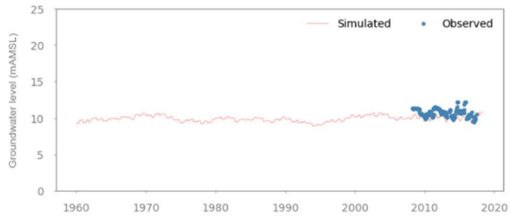
Valic-4 (Shallow Monitoring-13 m)



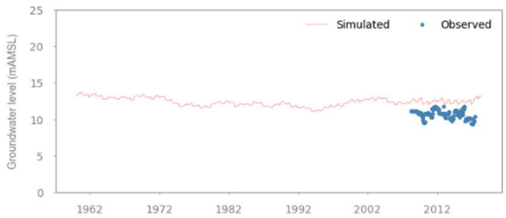
Valic-4 (Deep Monitoring-93 m)



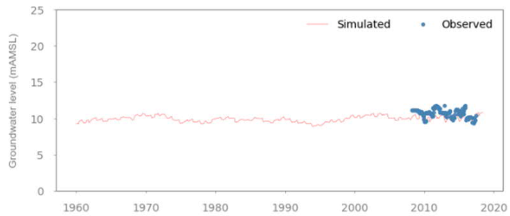
Valic-4 (Deep Monitoring-93 m)



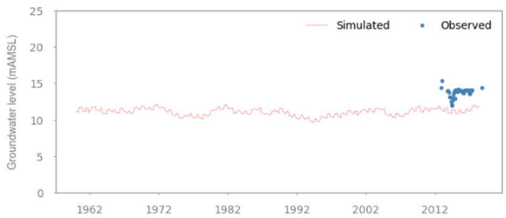
Valic-4 (Deep Production-93 m)



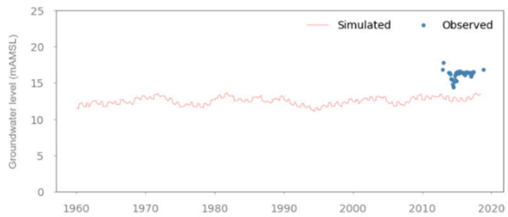
Valic-4 (Deep Production-93 m)



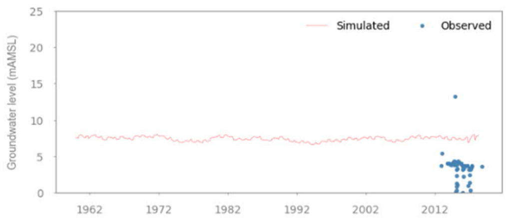
Sweetwater MW1 (13 m)



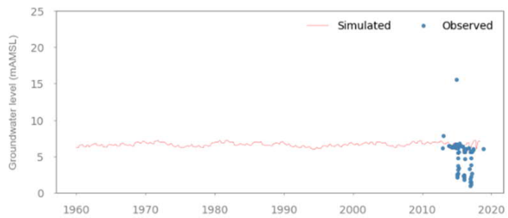
Sweetwater MW1 (13 m)



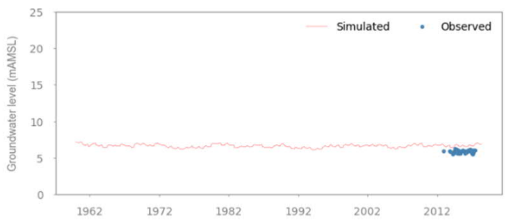
Sweetwater MW1 (94 m)



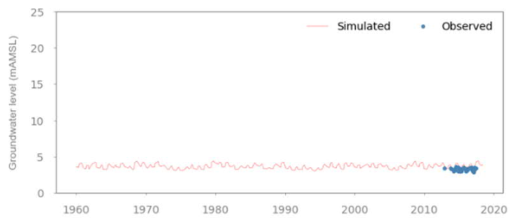
Sweetwater MW1 (94 m)

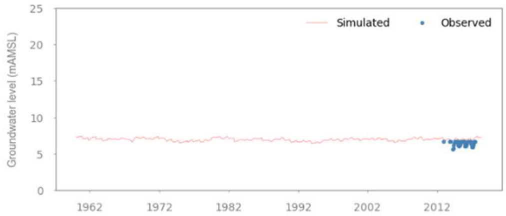
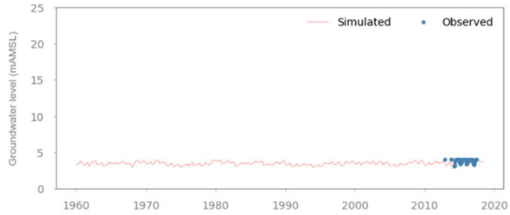
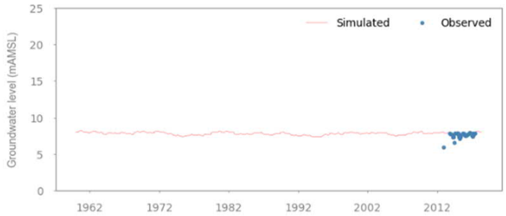
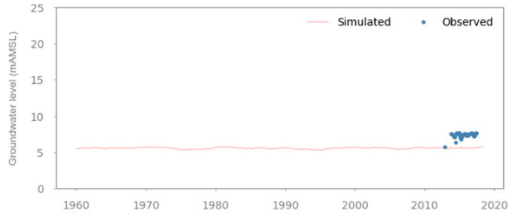
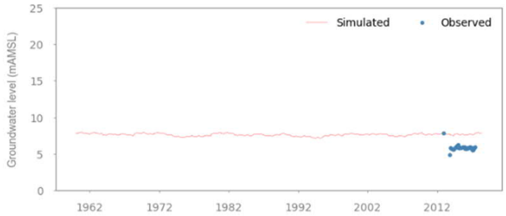
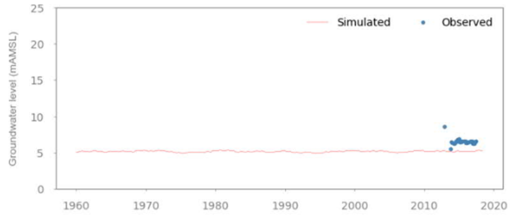
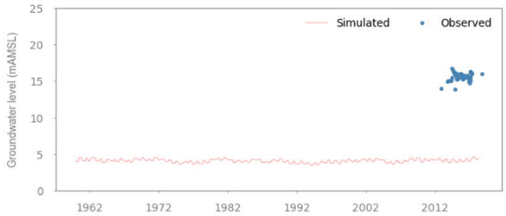
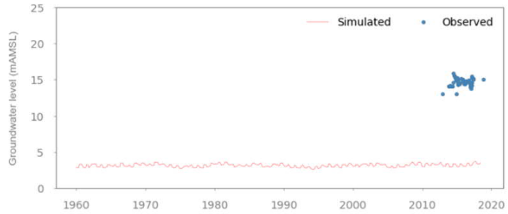
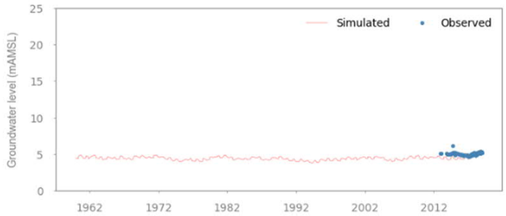
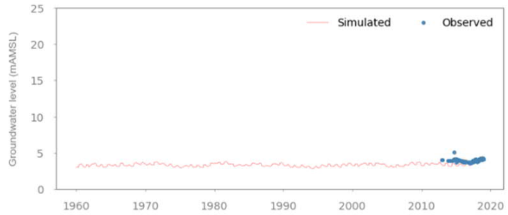
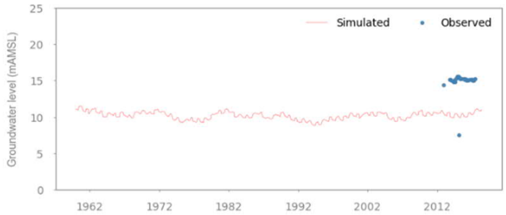
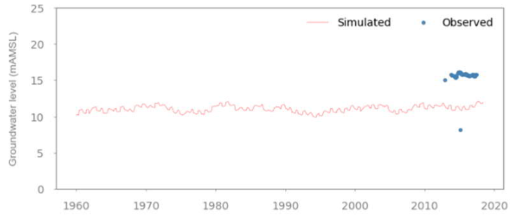


Sweetwater MW2 (15 m)



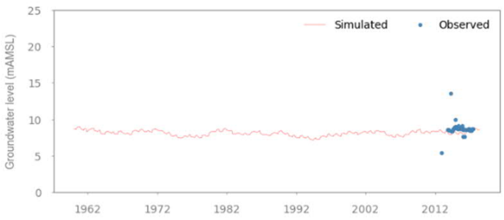
Sweetwater MW2 (15 m)



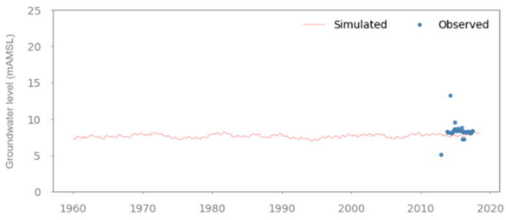
2019 AAGWM results	2020 AAGWM results
Sweetwater MW2 (59 m)  	Sweetwater MW2 (59 m) 
Sweetwater MW3 (5 m)  	Sweetwater MW3 (5 m) 
Sweetwater MW3 (47 m)  	Sweetwater MW3 (47 m) 
Sweetwater MW4 (25 m)  	Sweetwater MW4 (25 m) 
Sweetwater MW4 (92 m)  	Sweetwater MW4 (92 m) 
Sweetwater MW5 (6 m)  	Sweetwater MW5 (6 m) 

2019 AAGWM results	2020 AAGWM results

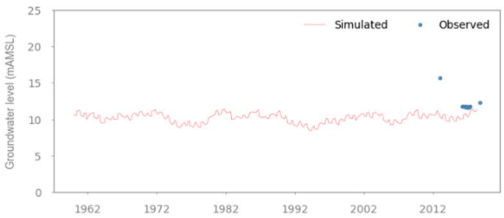
2019 AAGWM results – Sweetwater MW5 (61 m)



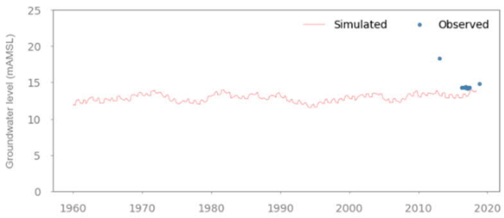
2020 AAGWM results – Sweetwater MW5 (61 m)



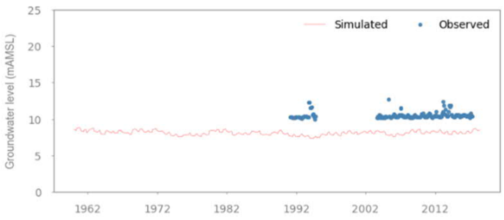
2019 AAGWM results – Sweetwater MW6 (15 m)



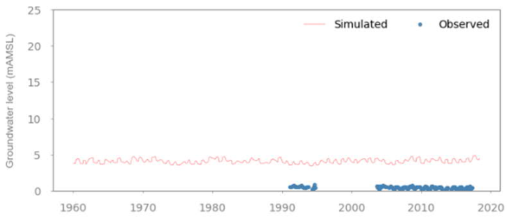
2020 AAGWM results – Sweetwater MW6 (15 m)



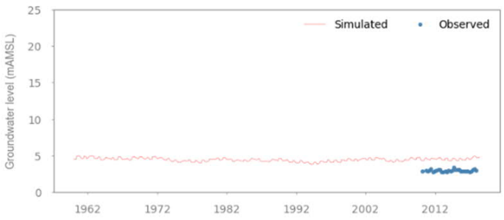
2019 AAGWM results – Sweetwater Nursery (34 m)



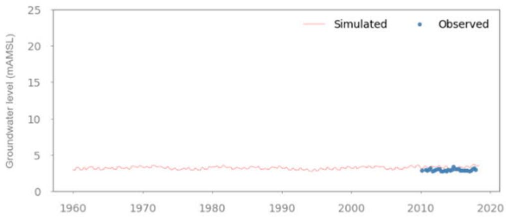
2020 AAGWM results – Sweetwater Nursery (34 m)



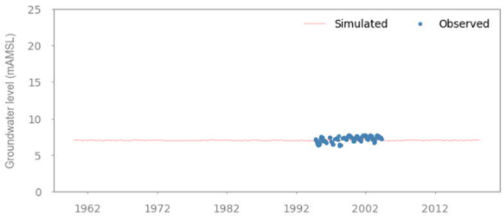
2019 AAGWM results – Waipapa (56 m)



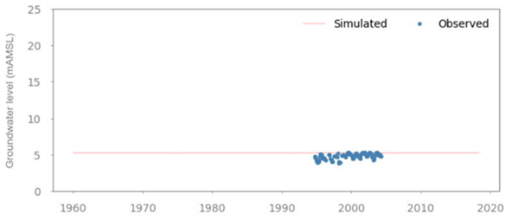
2020 AAGWM results – Waipapa (56 m)



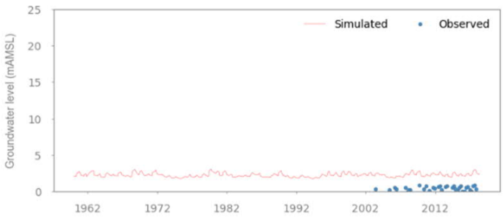
2019 AAGWM results – Shanks (Unknown depth)



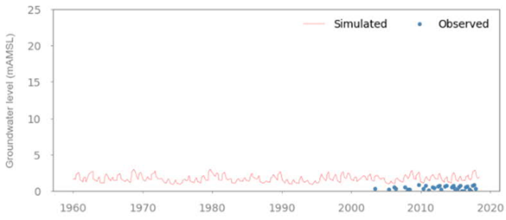
2020 AAGWM results – Shanks (Unknown depth)



2019 AAGWM results – Vinac (33 m)

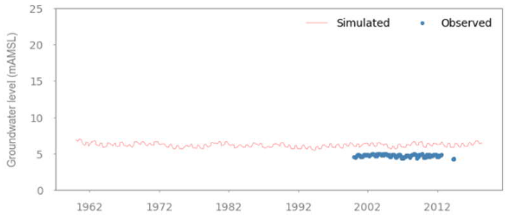


2020 AAGWM results – Vinac (33 m)

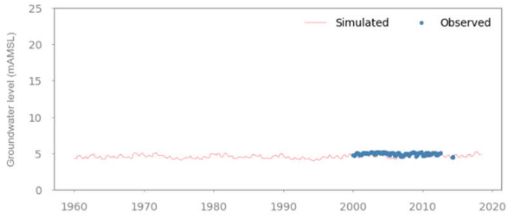


2019 AAGWM results	2020 AAGWM results

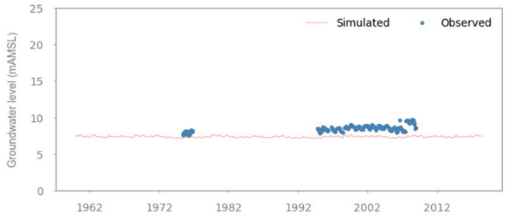
Matich (Unknown depth)



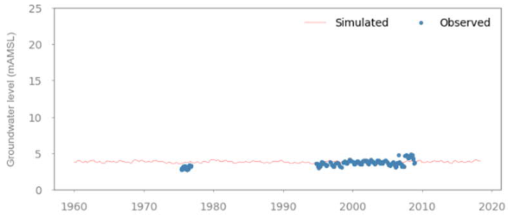
Matich (Unknown depth)



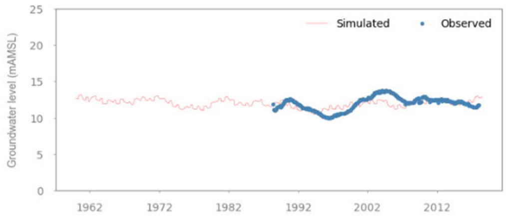
Welch (32 m)



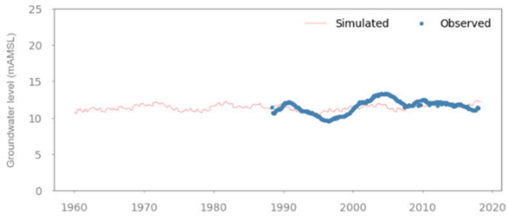
Welch (32 m)



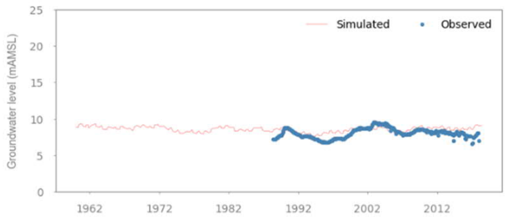
Lake Heather 1 (26 m)



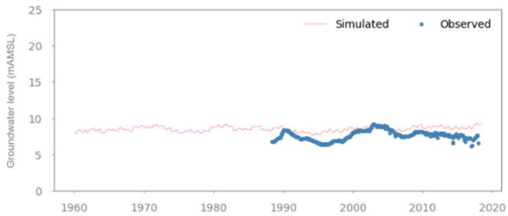
Lake Heather 1 (26 m)



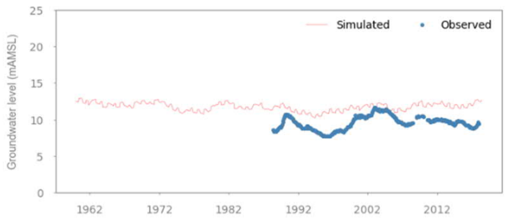
Lake Heather 1 (105 m)



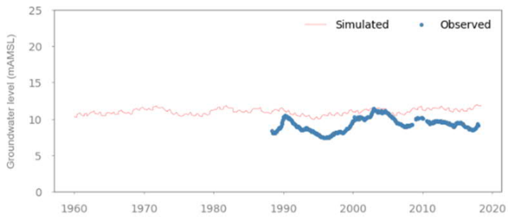
Lake Heather 1 (105 m)



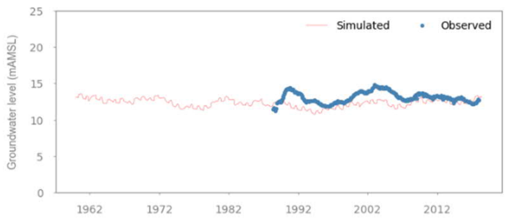
Lake Heather 2 (29 m)



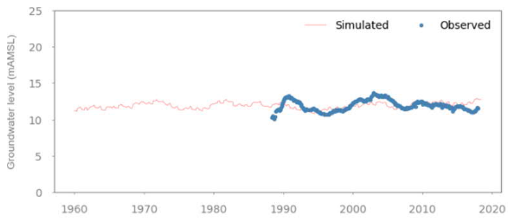
Lake Heather 2 (29 m)



Lake Heather 3 (29 m)



Lake Heather 3 (29 m)



5. Summary Statistics

Table 3 shows summary statistics from the original (2019) and updated (2020) versions of the AAGWM. The mean of the RMSE in the updated model for all bores is 1.55 m, which is 5.9% of the observed range in groundwater head (26.5 m), while the RMSE for all observations in the model is 1.77 m, or 6.7 % of the range of observations. The latter number reflects a bias for gauges where more data is available whereas the former metric gives equal weight to a gauge with limited data. A simulated RMSE of less than 10% of the measured range is considered a good calibration so both analysis criteria meet this standard.

Both RMSE values for the updated model represent an improvement relative to the 2019 model calibration.

Table 3 also shows model calibration statistics separately for the upper aquifer (model layers one through three) and the shellbed aquifer (model layers four through six). In the 2019 model the model calibration is slightly better in the upper aquifer whereas in the 2020 version of the model the calibration is better in the shellbed aquifer. It is notable that model calibration improved in both the upper and lower aquifer in the updated version of the model and mean error in the lower aquifer was halved.

Simulated and observed hydrographs for all monitoring wells used for model calibration are provided in **Section 5.**

Table 3. Summary statistics from original and updated AAGWM.

Analysis Metric		AAGWM Model Version	
		2019	2020
Full Model RMSE (m)	All gauges	1.89	1.31
	All observations	2.10	1.47
Upper aquifer RMSE (m)	All gauges	1.78	1.51
	All observations	2.08	1.61
Shellbed RMSE (m)	All gauges	2.01	1.02
	All observations	2.15	1.05

6. Additional Monitoring Locations

In response to an email request (Brydon Hughes; Stuart Savill 14/02/2020) for model outputs at select locations, WWLA has prepared a series of plots showing simulated water levels under naturalised conditions and with consented and proposed pumping (Scenario 2) at the specified locations. These locations are shown in **Figure 6**.

Seven of the ten locations that were specified have associated monitoring bores, several of which are included in the model calibration data sets that are presented in **Table 2**. The other monitoring sites were established in 2019, after the model calibration period.

Table 4 shows average water levels at the analysis locations, where available, based on the available data set. The average water levels for the analysis locations can be compared to the simulated water levels presented in **Table 5**.

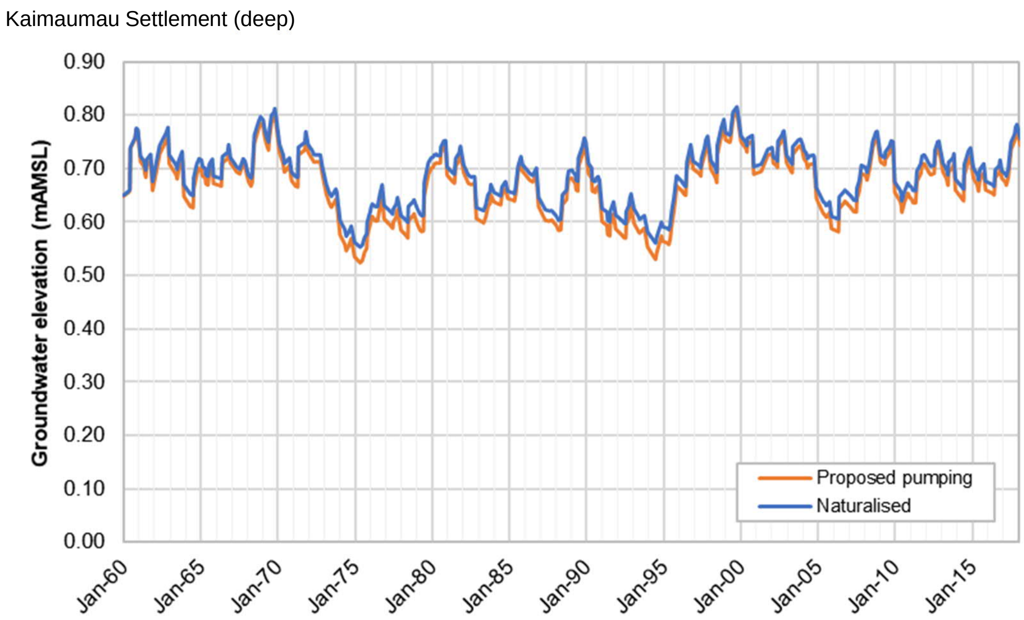
It is evident in the plots in **Table 5** that locations proximal to pumping bores show effects from seasonal pumping whereas other locations show differences in overall water level but the seasonal impact of pumping is muted or not apparent.

Figure 6. Locations of additional analysis point requested by NRC.

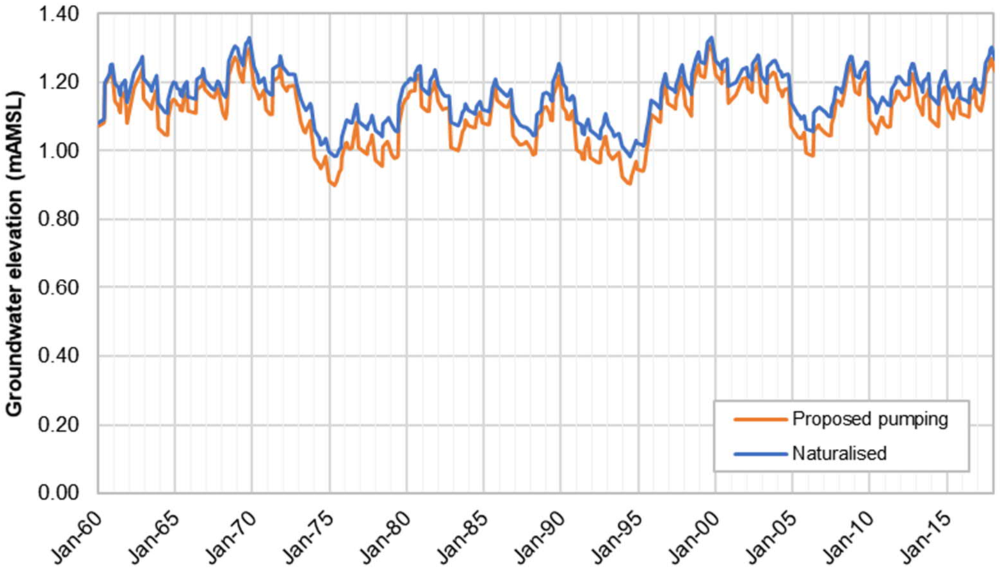
Table 4. Mean observed water level for analysis locations.

Location	WL (mAMSL)	Measurement period
Norton Rd	4.49	26/6/2019-19/9/2019
Motutangi-Deep	5.18	27/6/2019-18/9/2019
Waterfront-deep	2.78	28/1/1987-19/9/2019
Sweetwater MW4	3.99	13/12/2012-5/12/2018
Paparore-deep	6.88	25/2/1987-8/1/2018
Kaimaumau-NRC	2.43	19/09/2019
Kaimaumau Settlement-deep	0.63	19/09/2019

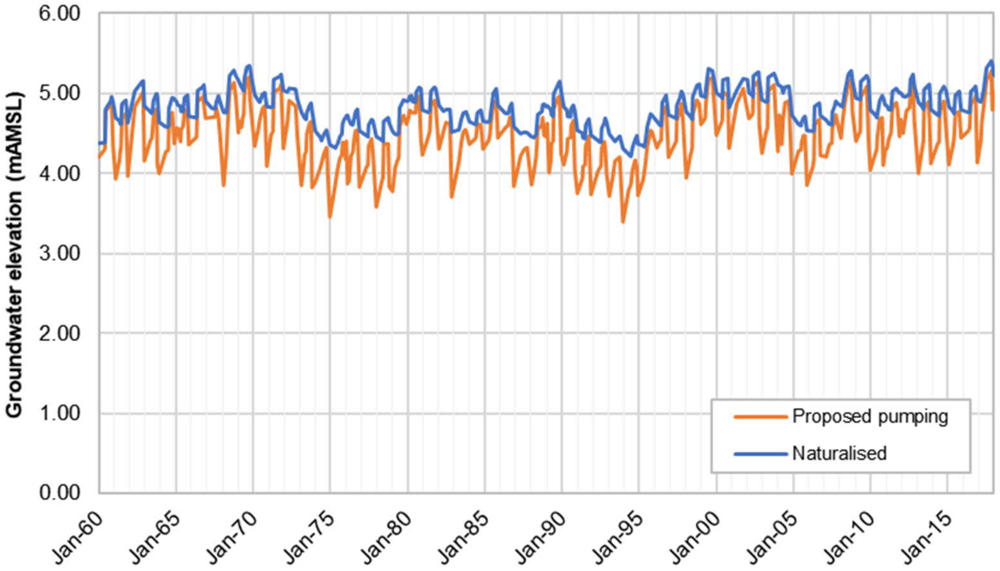
Table 5. 2020 AAGWM results for analysis locations requested by NRC.



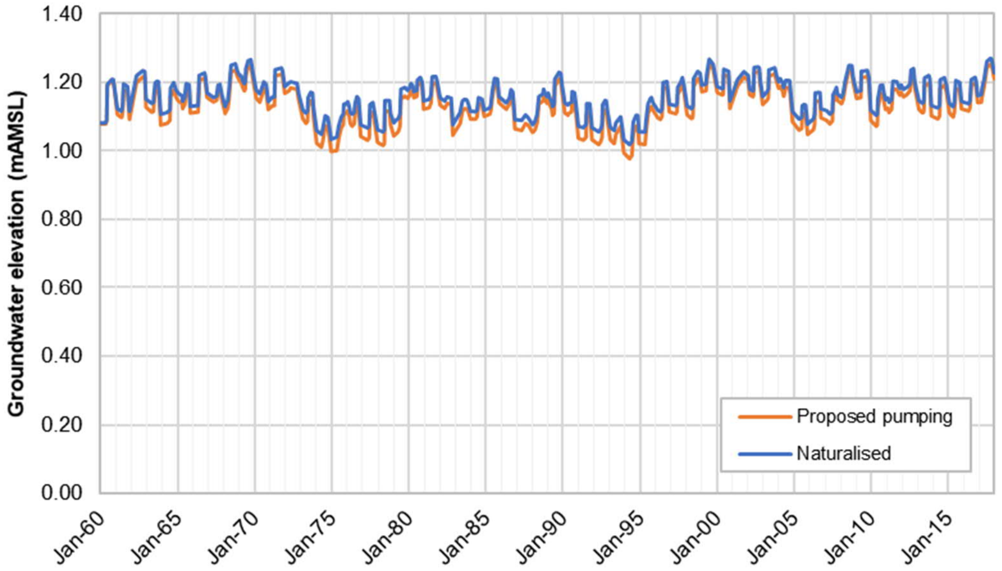
Kaimaumau NRC (deep)



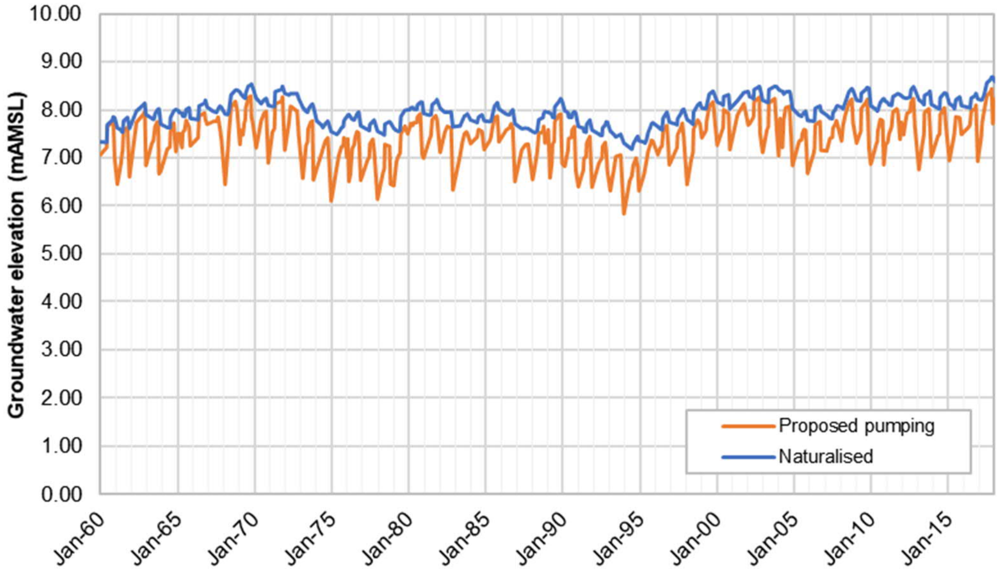
Kaimaumau at Norton Road



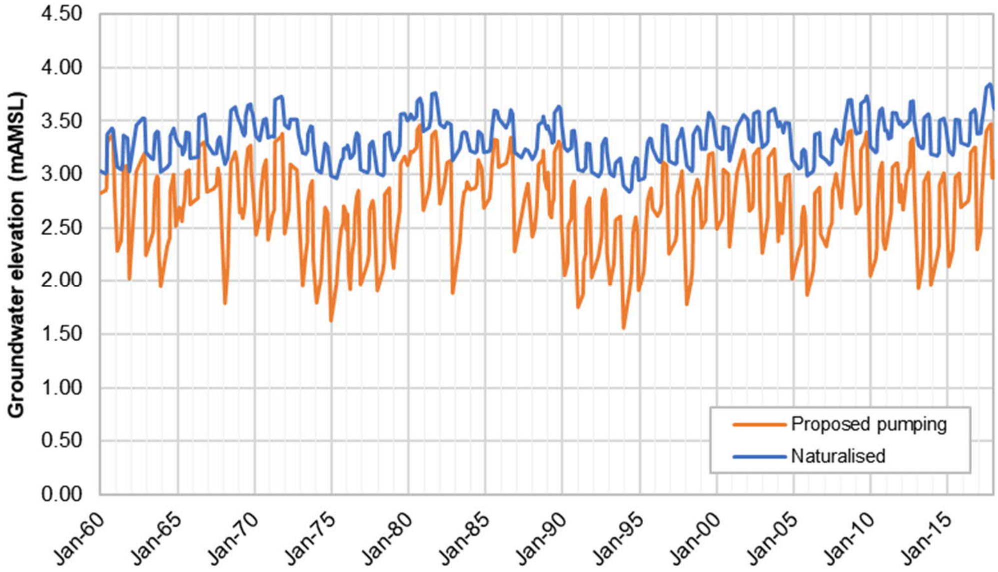
East Beach



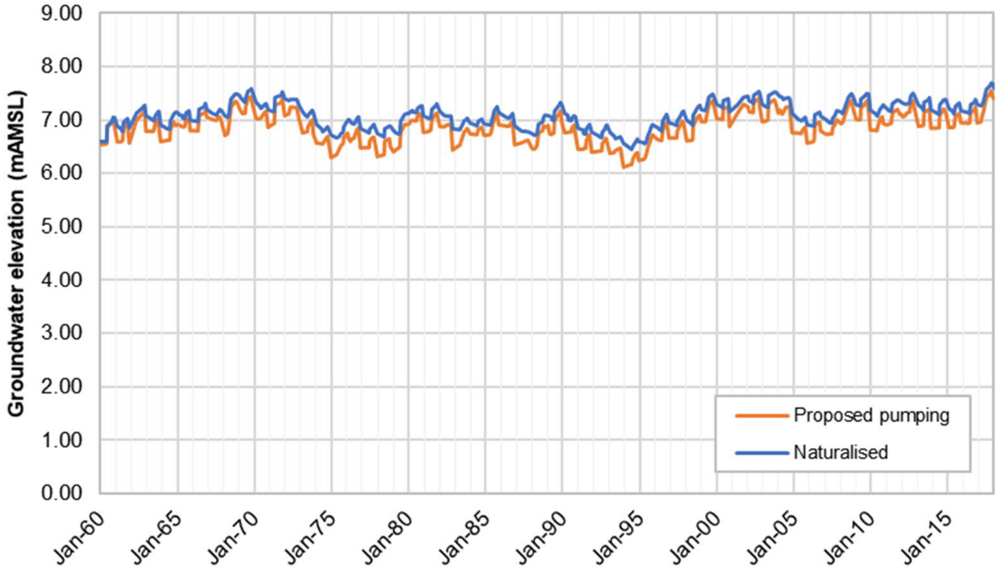
Paparore-NRC monitoring bore (deep)



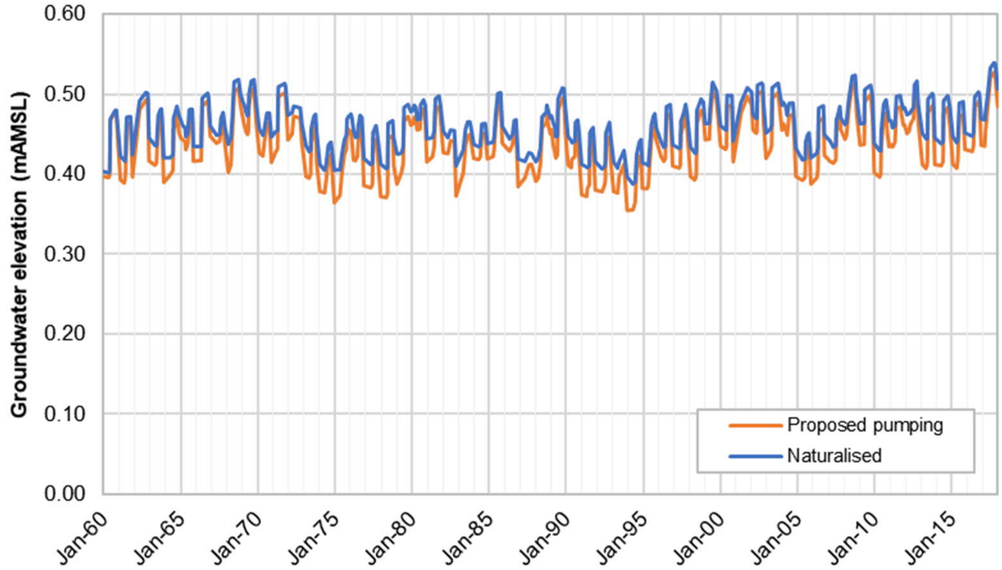
Sweetwater MW4 (deep)



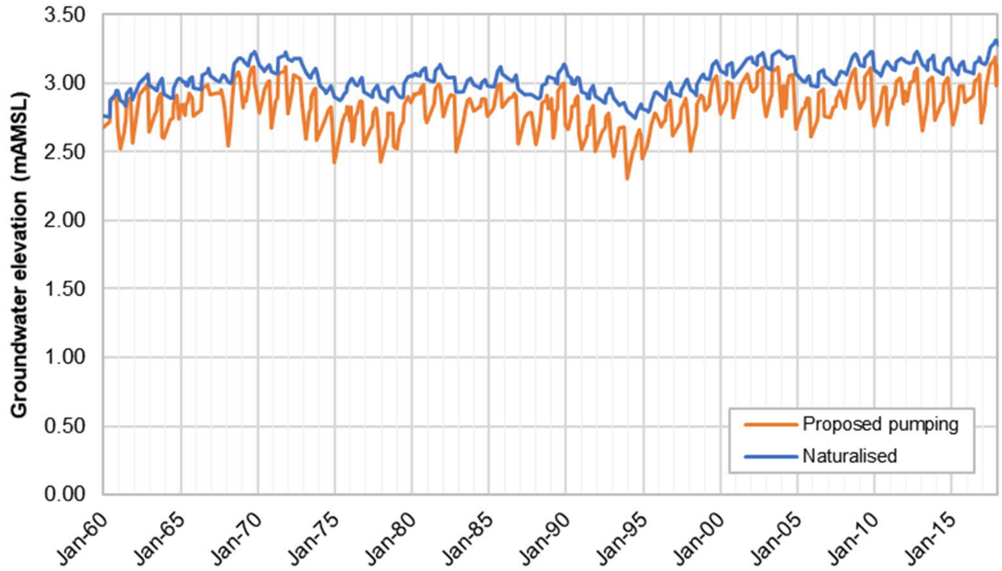
Motutangi (deep)



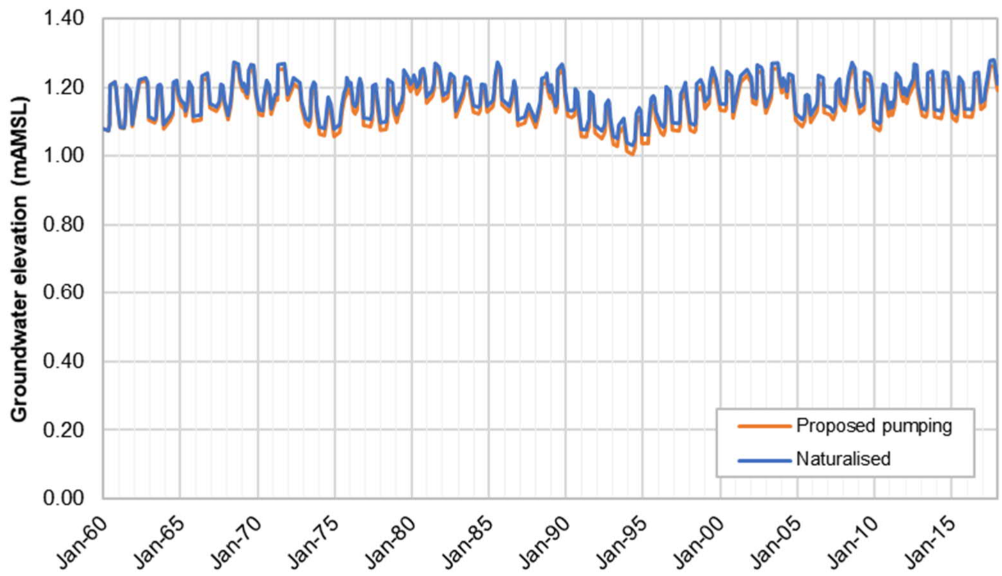
Houhora Campground



Waterfront-NRC (deep)



Subritzky Road



7. Closure

A LIDAR based elevation survey of the Aupouri peninsula commissioned by NRC has provided a new and improved surface elevation data set, improving on the 8 m DEM that was previously available. With this information WWLA has undertaken an update to the AAGWM. This entailed revising the model structure in terms of surface elevation and base elevation, as the latter was based on depth to basement rock as determined from borelogs. Model parameters were revised as needed to account for changes in observed and simulated water levels based on the new information.

Model results improved relative to the previous version of the AAGWM. Model wide RMSE for all observations was reduced from 2.10 m to 1.47 m. The accuracy of the model also improved when averaging RMSE for each gauge, reducing from 1.89 m to 1.31 m. The improved accuracy of information available for model development has enabled a corresponding improvement in the overall simulation of groundwater on the Aupouri Peninsula.

Yours sincerely,

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