Modelling Group
WATER NEW ZEALAND

# Modelling Symposium

# Modelling the ground(water) beneath our feet

## Supporting a resilient water supply for Wellington

Presented by
Dr Jeremy Bennett, Tonkin & Taylor Ltd

Tonkin+Taylor

water NEW ZEALAND
The New Zealand Water & Wastes Association Wainga Aotearoa

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- Modelling objectives
- Modelling framework
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- Model implementation
- History-matching + results
- Next steps

HAM5

# Modelling objectives

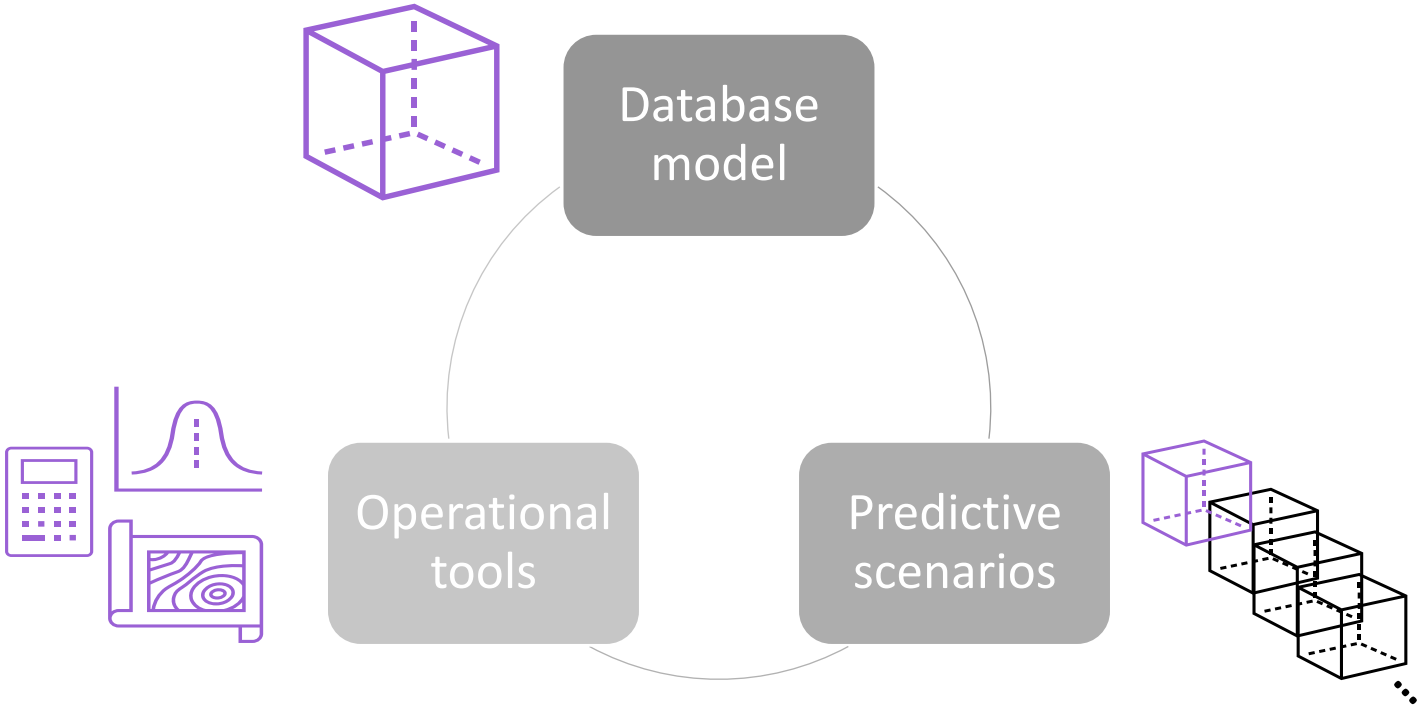
## Planning

- Waterloo and Gear Island wellfield replacement strategy
- Source water risk management
- Water resource management and decision making
- Monitoring system design

## Operations

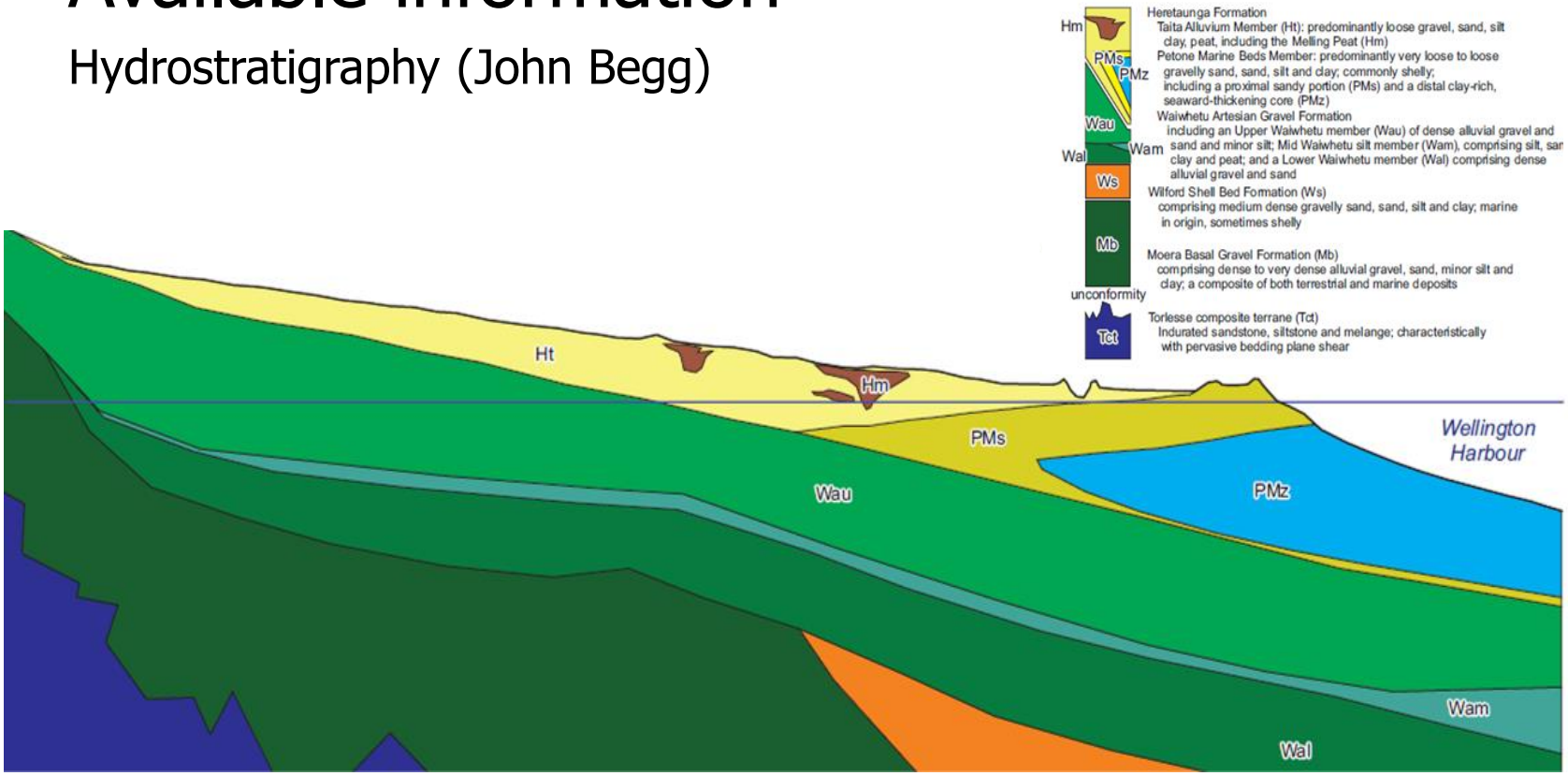
- Yield forecasting and optimisation
- Contamination event response
- Aquifer management effect assessment tools

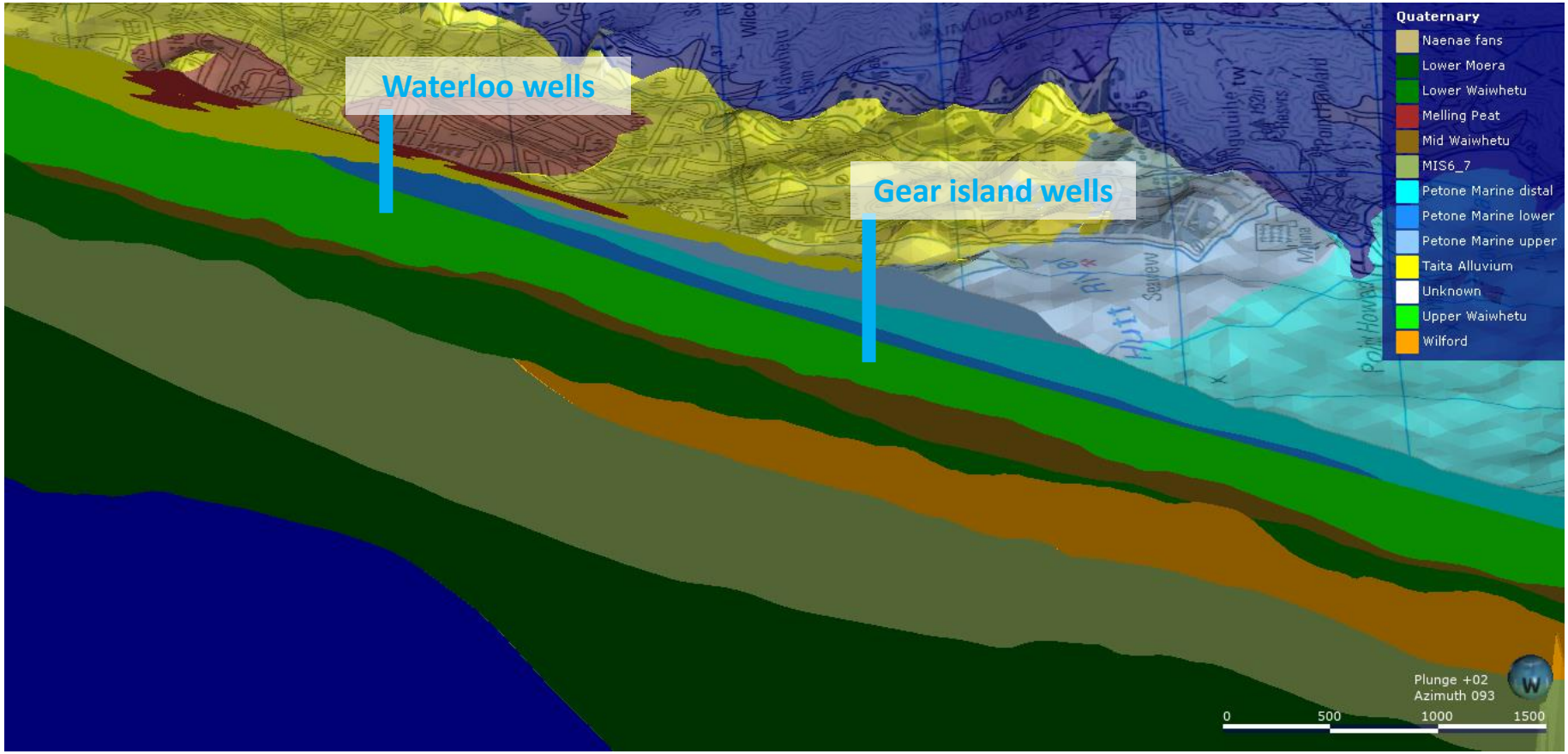
# Modelling framework

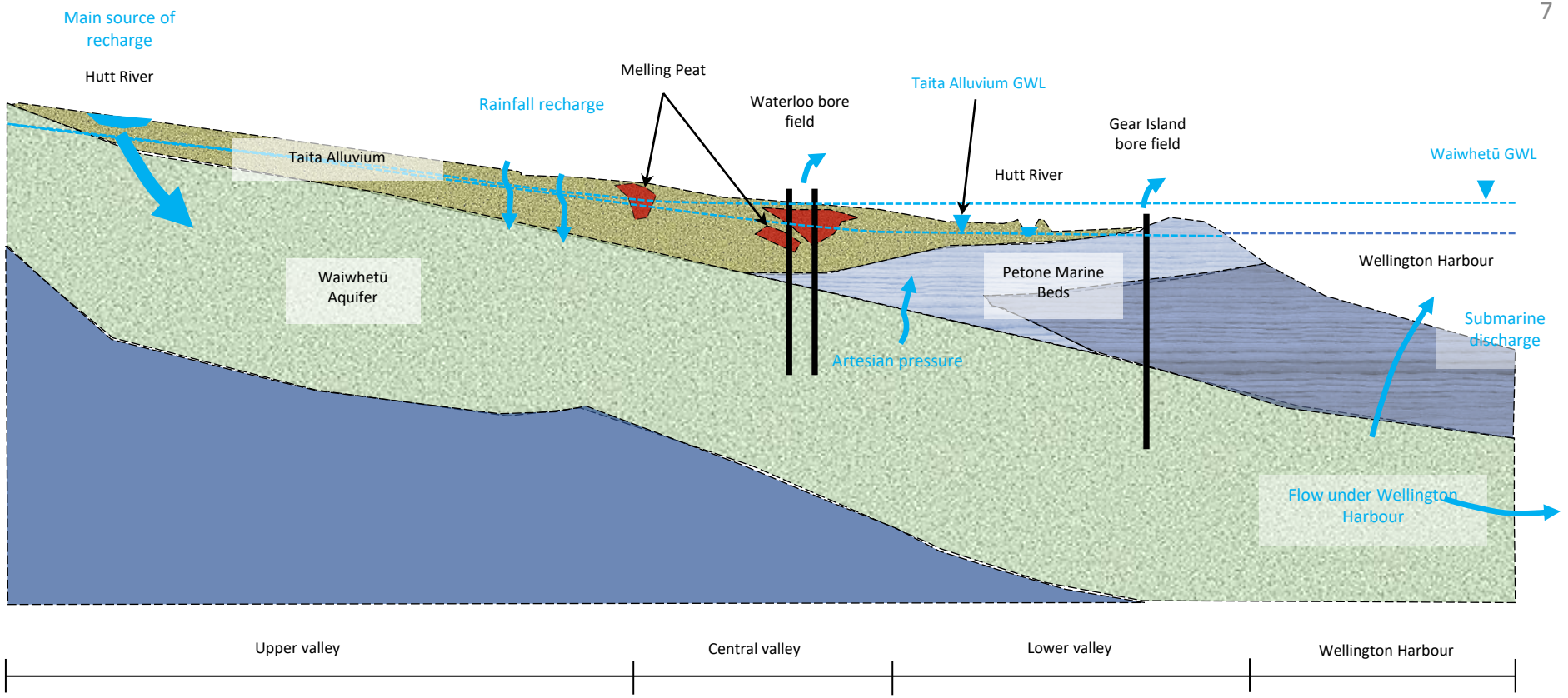


# Available information

## Hydrostratigraphy (John Begg)



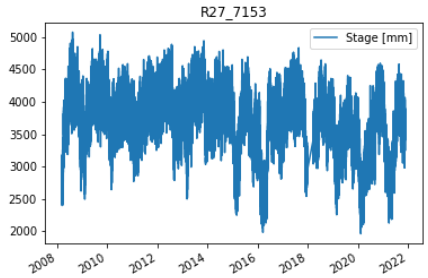

Waterloo wells
Gear island wells
Quaternary
Naenae fans
Lower Moera
Lower Waiwhetu
Melling Peat
Mid Waiwhetu
MIS6_7
Petone Marine distal
Petone Marine lower
Petone Marine upper
Taita Alluvium
Unknown
Upper Waiwhetu
Wilford
Plunge +02
Azimuth 093
0
500
1000
1500

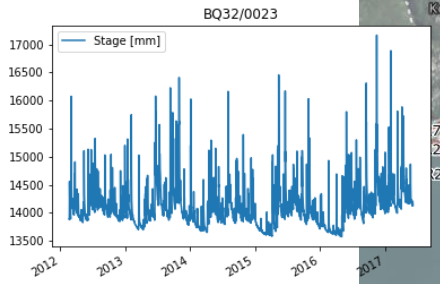

Main source of recharge
Hutt River
Melling Peat
Rainfall recharge
Waterloo bore field
Taita Alluvium GWL
Gear Island bore field
Waiwhetū GWL
Taita Alluvium
Hutt River
Waiwhetū Aquifer
Petone Marine Beds
Wellington Harbour
Submarine discharge
Artesian pressure
Flow under Wellington Harbour
Upper valley
Central valley
Lower valley
Wellington Harbour

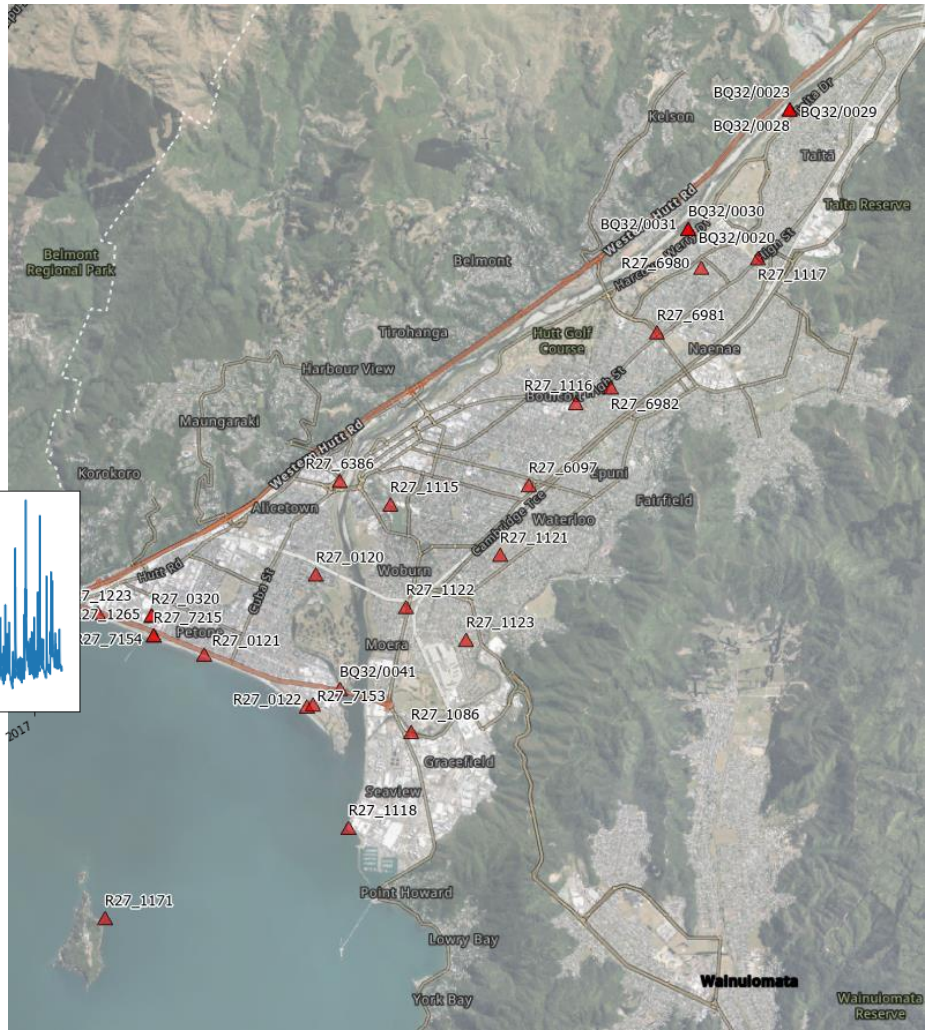
# Available information

## Groundwater level monitoring

- GWRC groundwater monitoring network
- Continuous monitoring
- Recent multi-level piezometers installed



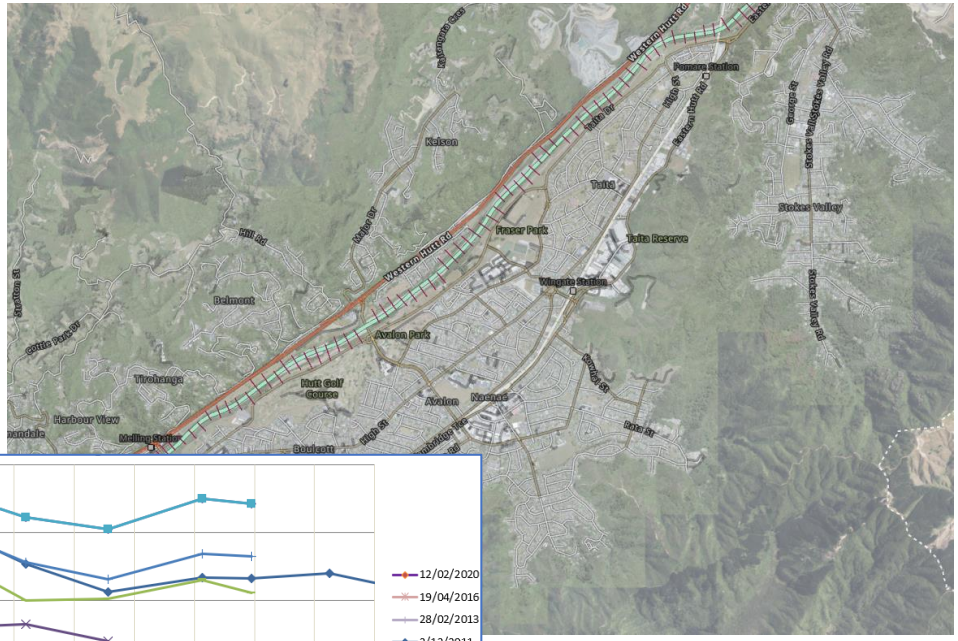



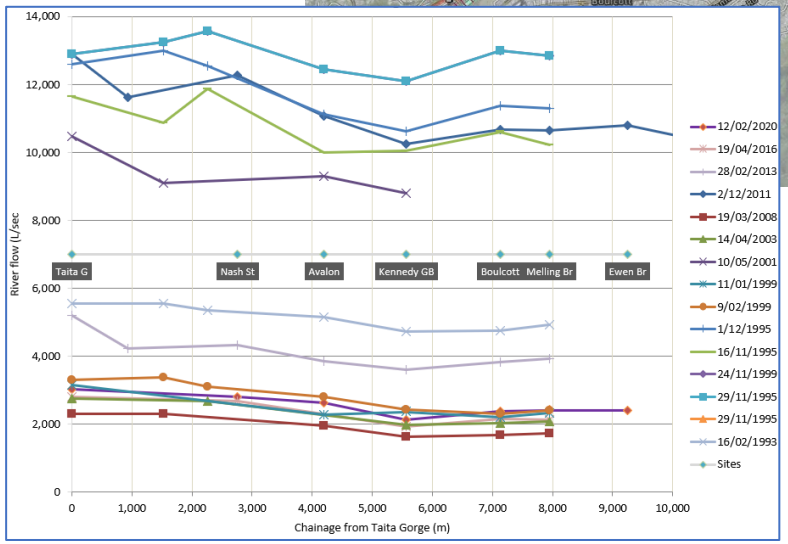



# Available information

## River information

- Continuous gauging at Taita Gorge
- Concurrent gauging
- Hydraulic flood models

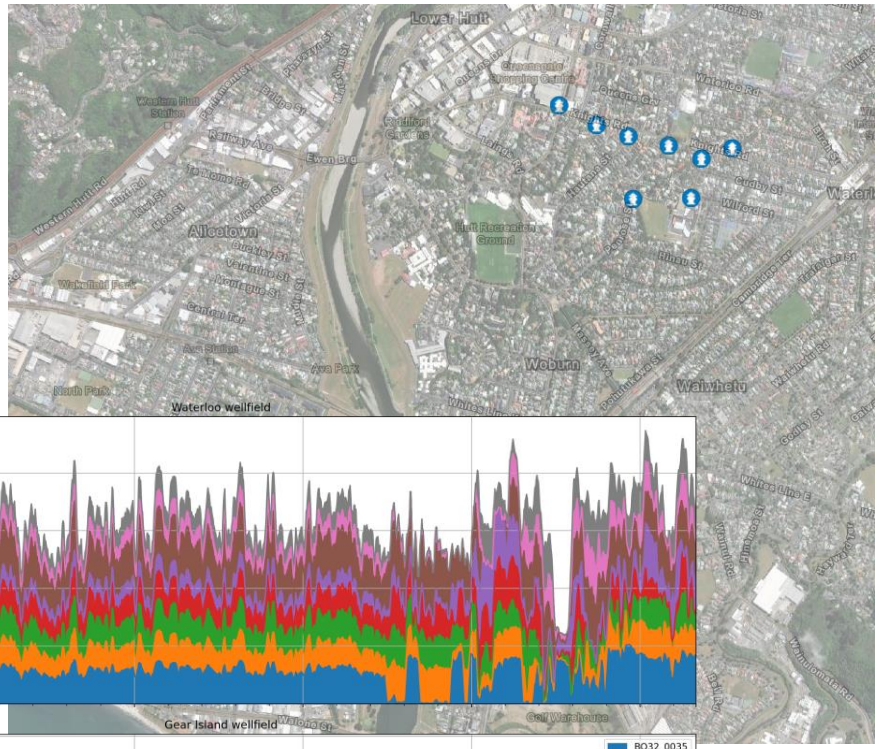


# Available information

## Groundwater abstraction

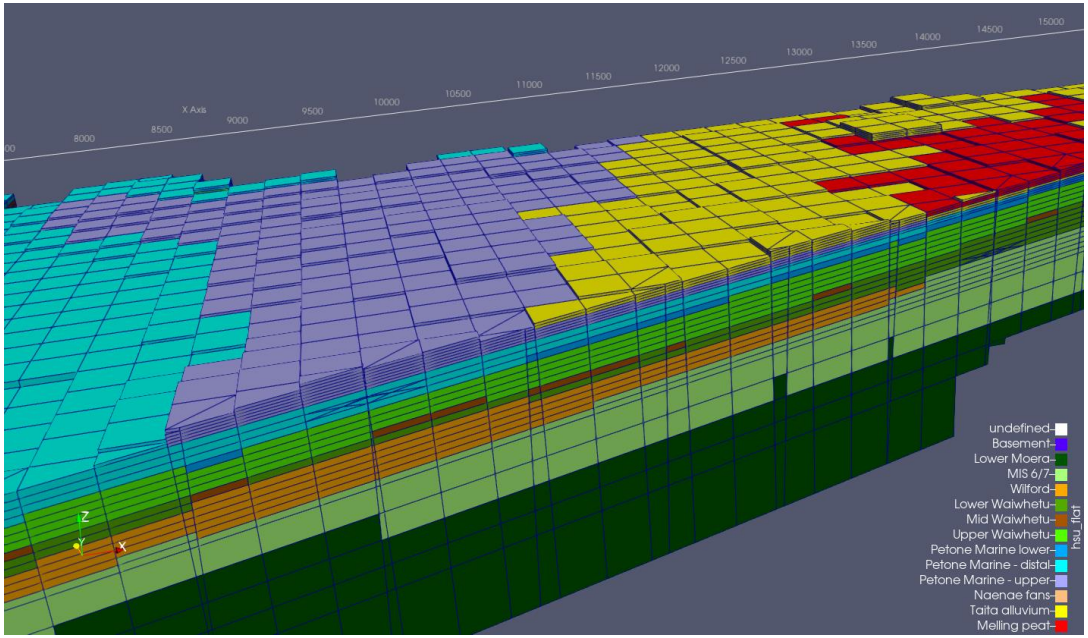
- Daily abstraction volumes
- Continuous SCADA monitoring
- Approximation of pumping rates based on pump operation



# Model implementation

## Overview

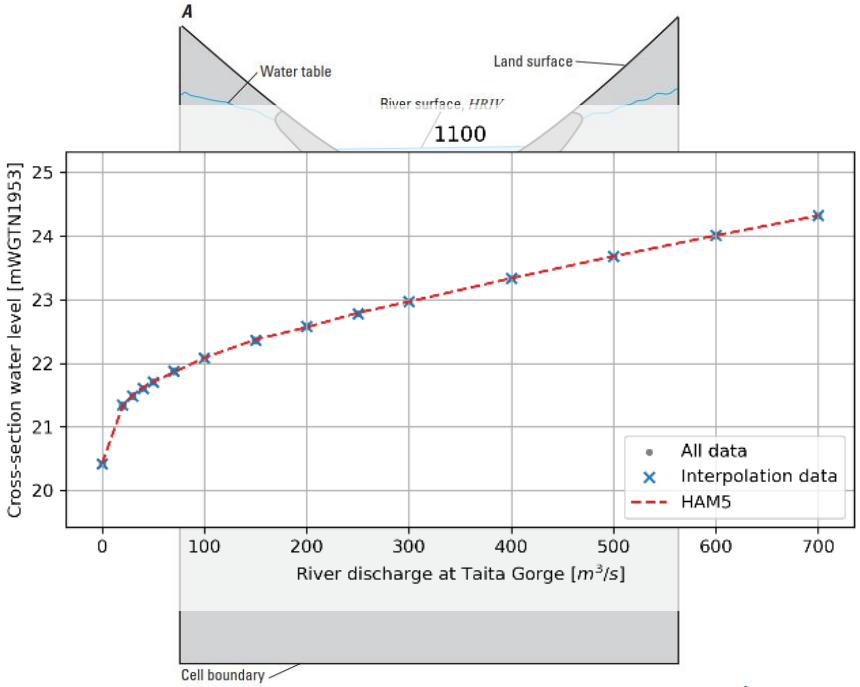
- Numerical groundwater flow model using MODFLOW 6 from USGS
- 'GUI-less' scripting approach to model development in python
- 'Cut once, model twice' – model build framework allows flexibility in model gridding, stress periods and model boundary conditions



# Model implementation

## Boundary conditions – Hutt River

- Main driver of recharge into the aquifer system
- MODFLOW *RIV* package used
  - Flow driven by head differences between the river and groundwater domain
- River stage in each model cell based on relationship between Taita Gorge discharge and modelled water levels
- Hydraulic model developed by DamWatch as part of RiverLink design and will include pre- and post-construction bed morphologies.

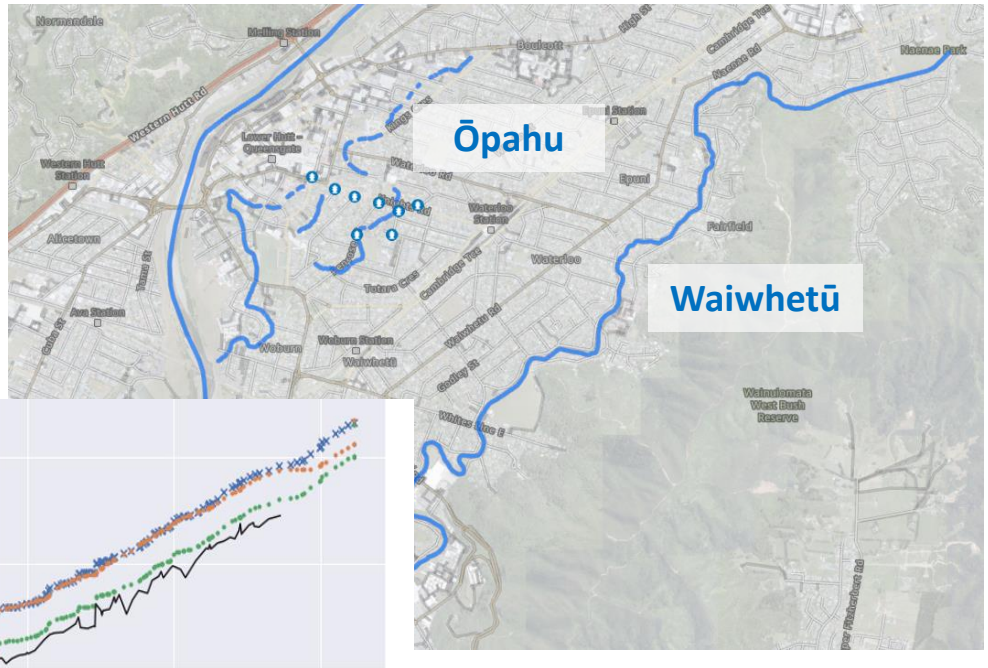


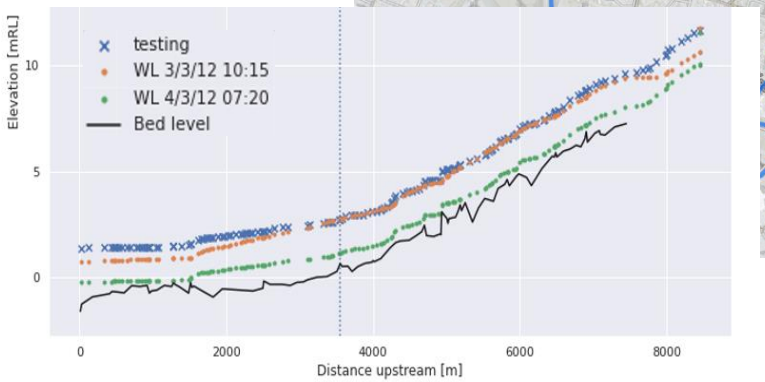

Langevin et al., 2017 DOI: 10.3133/tm6A55

# Model implementation

## Boundary conditions – Waiwhetū / Ōpahu Streams

- Eastern Hutt Hydraulic Model (Stantec, 2022) used to understand stage-discharge relationships
- Relationship inferred between rainfall and river stage for each stream

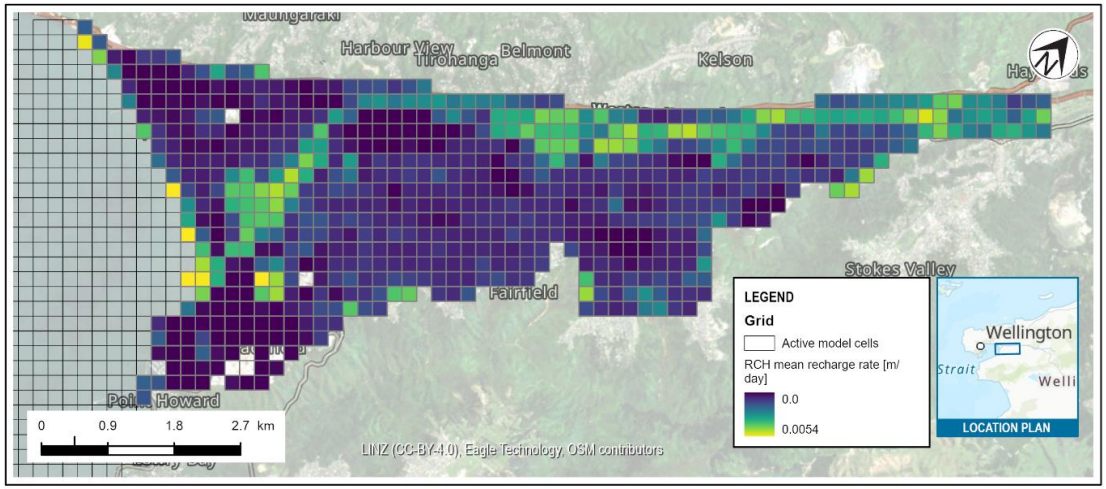


# Model implementation

## Boundary conditions – Rainfall recharge

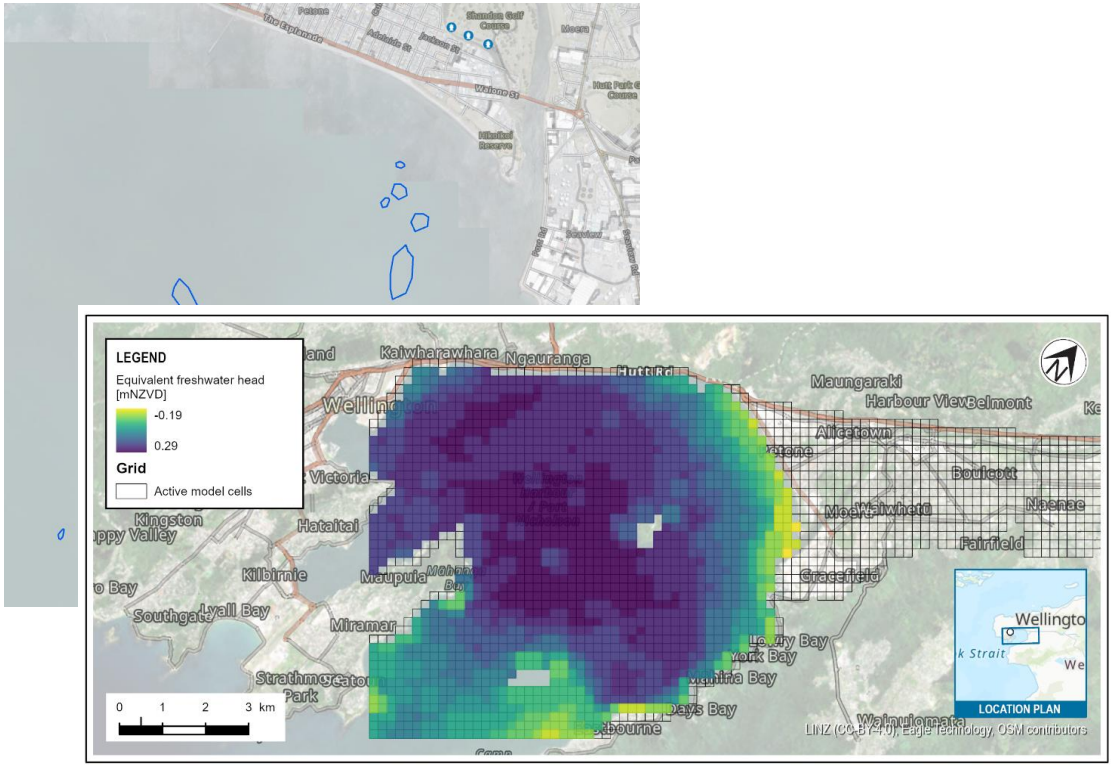
- Spatially variable recharge using Rushton method for soil moisture balance
- Climate data from GWRC climate observations
- Weighted curve numbers based on proportion of model grid cell covered by soil type (Wellington Water/Cardno, 2019)
- Recharge value multiplied by pervious proportion of model grid cell



# Model implementation

## Boundary conditions – Wellington Harbour

- Harbour springs
- Constant head boundary
- Equivalent freshwater head



# History-matching

## The PEST of groundwater modelling

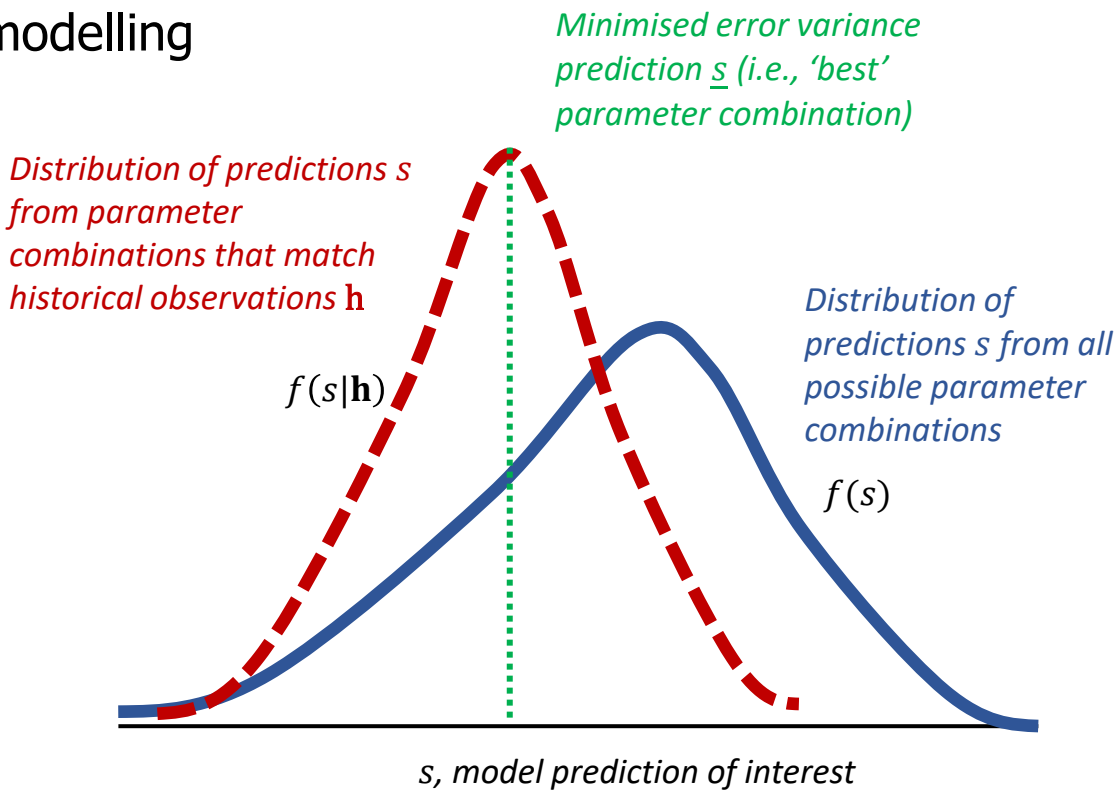
https://pesthomepage.org/

- Model-Independent Parameter Estimation and Uncertainty Analysis
- Introduced from Australia
- Spread widely across the groundwater modelling ecosystem

# History-matching

## The PEST of groundwater modelling

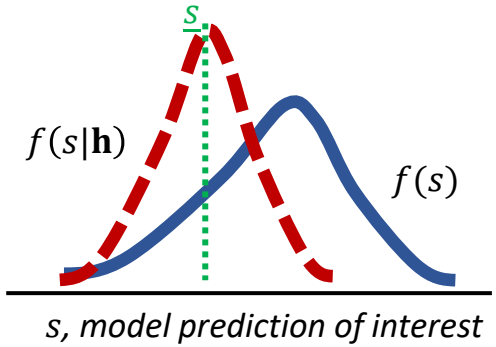
- Calibration implies:
  - Predictive certainty
  - Parameter uniqueness
- History-matching:
  - Prior parameter distribution
  - Posterior parameter distributions
  - Minimised error variance parameters $\underline{s}$




Doherty, 2015

# History-matching

## HAM5 approach




**PEST_HP**

- S***load of model runs
- Minimised error variance parameters
- Single deterministic 'calibrated model'

**PESTPP-IES (Database)**

- Fewer model runs (with some cheats) = more parameters
- Uncertainty analysis baked in
- Prior and posterior parameter ensemble
- Don't even need to 'calibrate'

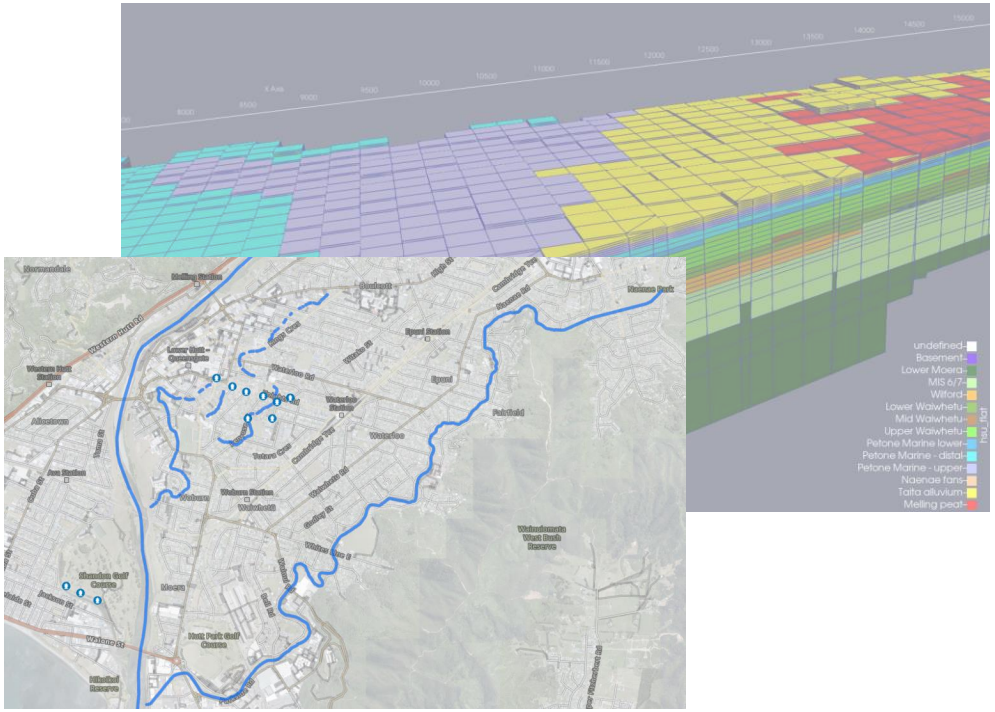
**PESTPP-IES (Predictive scenarios)**

- Posterior/prior paramete ensemble
- Predictive uncertainty
- Prediction-specific child models

# History-matching

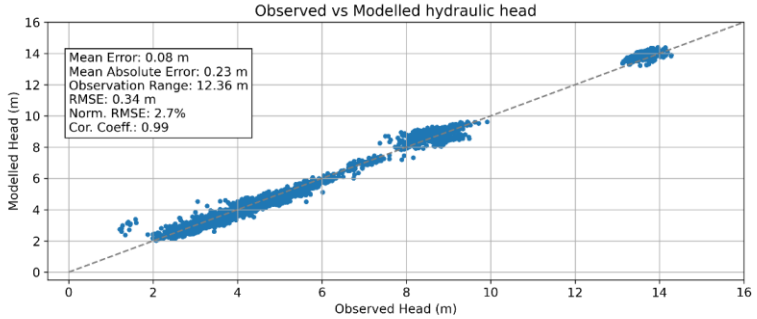
## Model parameters

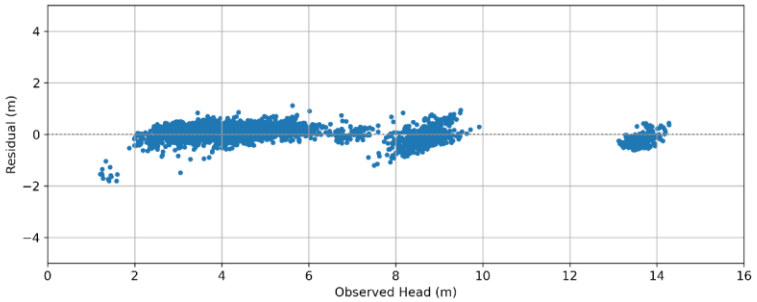
- Aquifer properties for each hydrostratigraphic unit
  - Kx, Kz, Ss, Sy
- Spatial pilot points along waterways
- Global multipliers on constant head boundary and well abstraction
- **"If it's uncertain – let it wiggle"**

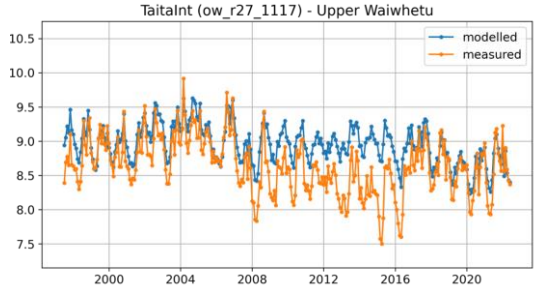


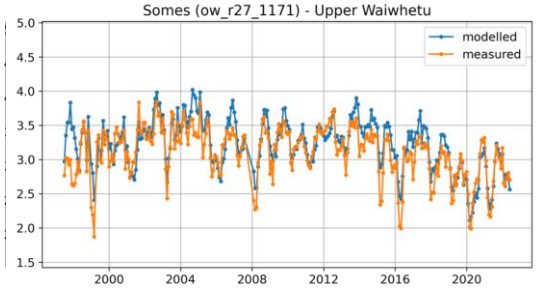
# History-matching

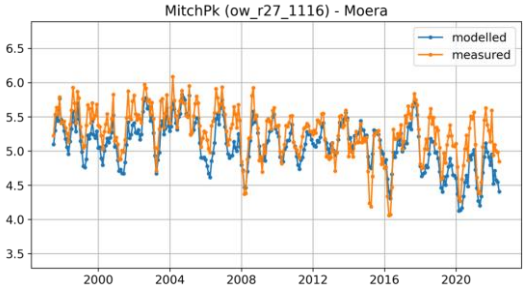
## Calibration results to date – hydraulic head

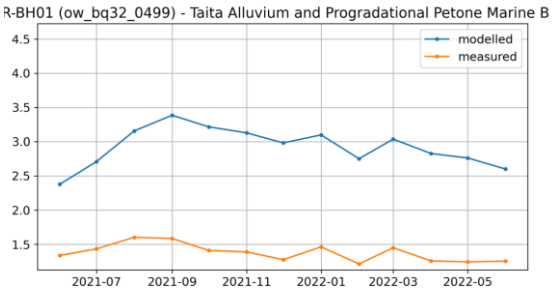


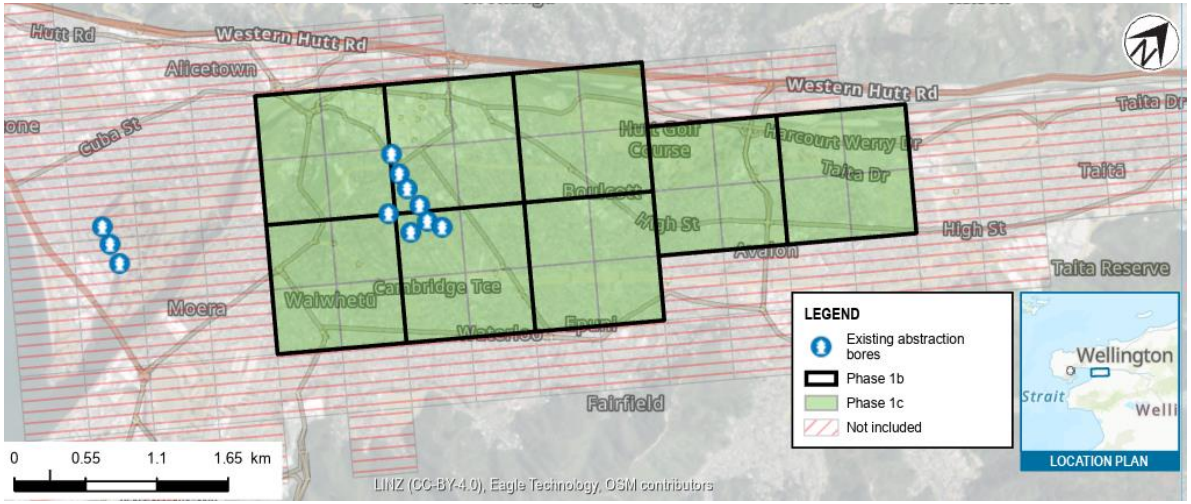



# Predictive scenarios

## Wellfield redevelopment

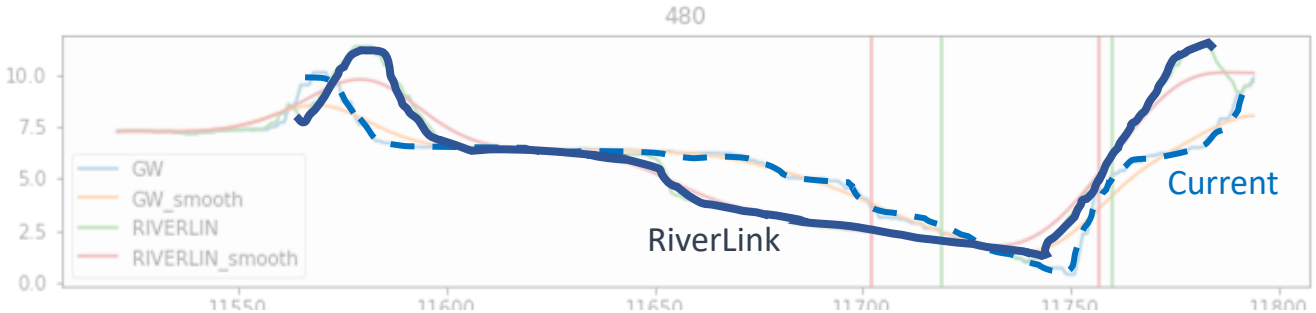
- Grid-based approach
- Aquifer yield optimisation
- Within environmental limits for:
  - Saline intrusion
  - Hutt river depletion



# Predictive scenarios

## River morphology

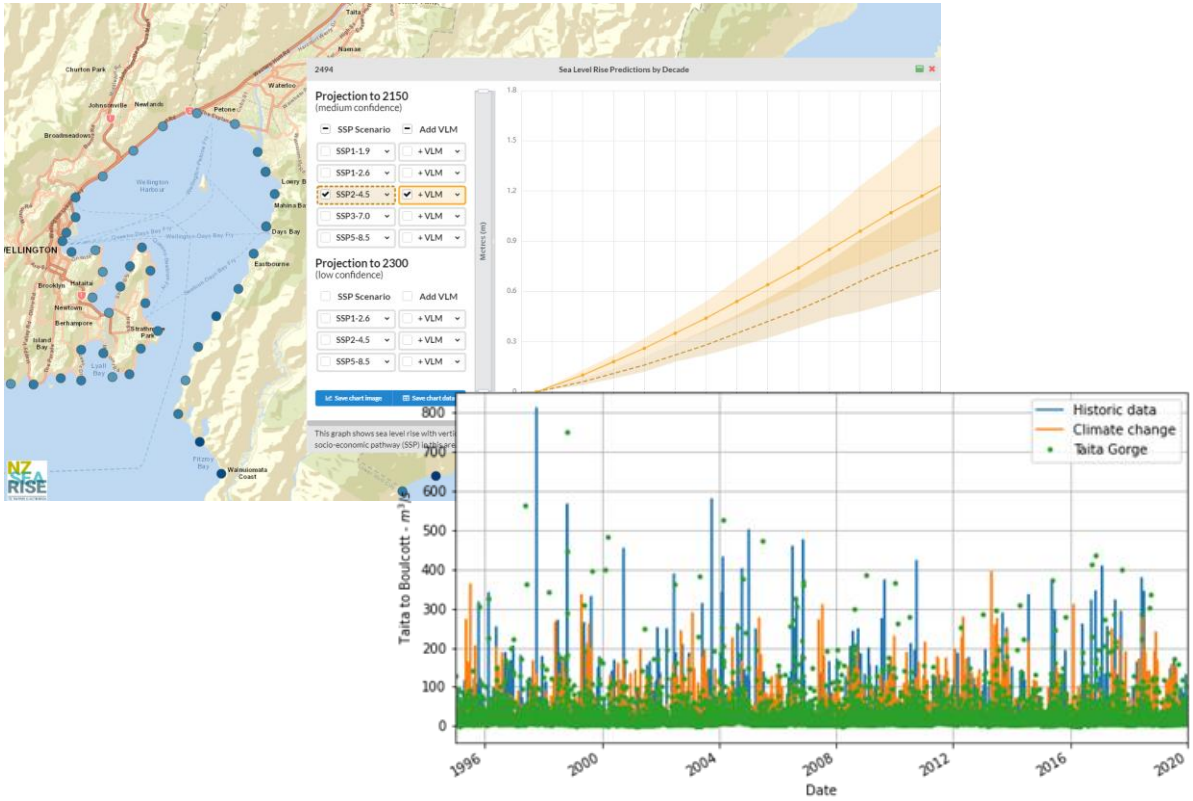
- Pre- and post-construction RiverLink design floods from DamWatch
- Will history-match Database model to pre-construction bathymetry



# Predictive scenarios

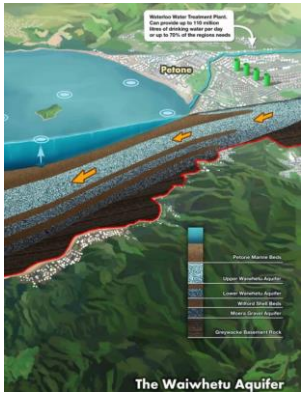
## Climate change

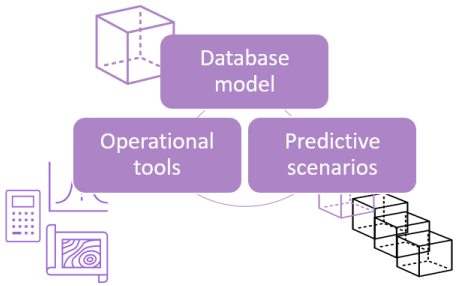
- Sea-level rise
- River flows (volume/timing)
- Rainfall (volume/timing)
- Evapotranspiration

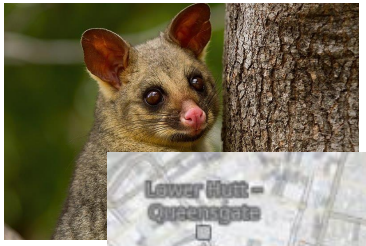


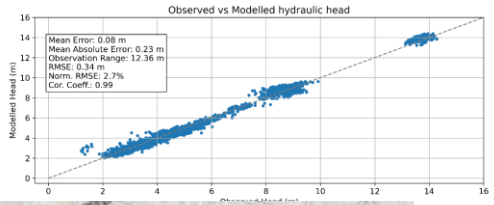
# Summary

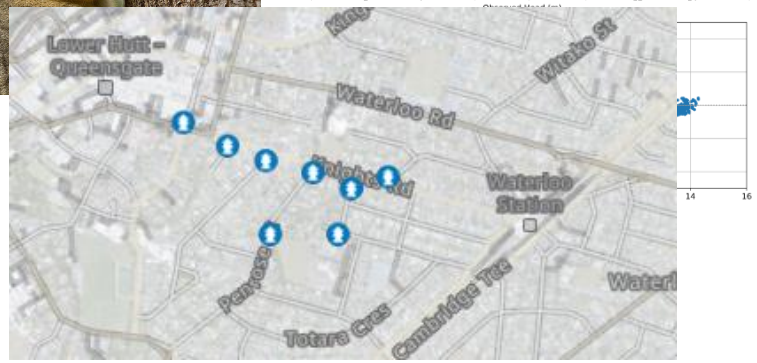
- Waiwhetū Aquifer is an important water resource for Wellington
- HAM5 model development incorporates recent investigations within rapid model-build framework
- Automated parameter estimation using PEST tools in groundwater modelling achieving good fits to observations
- History-matched model will be used for predictive scenario analysis, including wellfield redevelopment





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# Modelling Symposium

# Thank you!
# Questions? Patai?

Modelling the ground(water) beneath our feet:
Supporting a resilient water supply for Wellington

Dr Jeremy Bennett, Tonkin & Taylor Ltd
Dr Mark Gyopari, Earth in Mind
Dr Cath Moore, GNS

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The New Zealand Water & Wastes Association Wainga Aotearoa