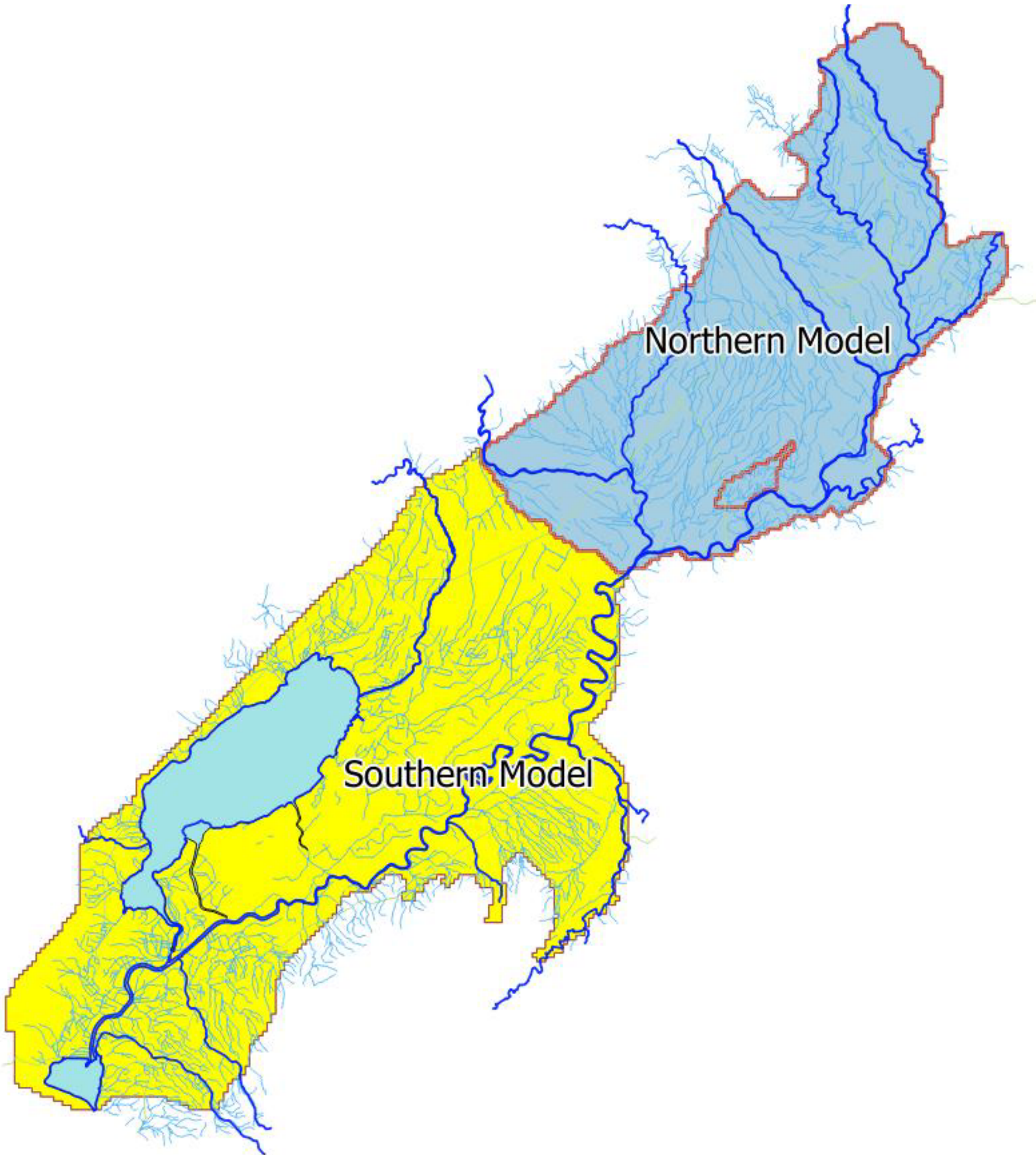
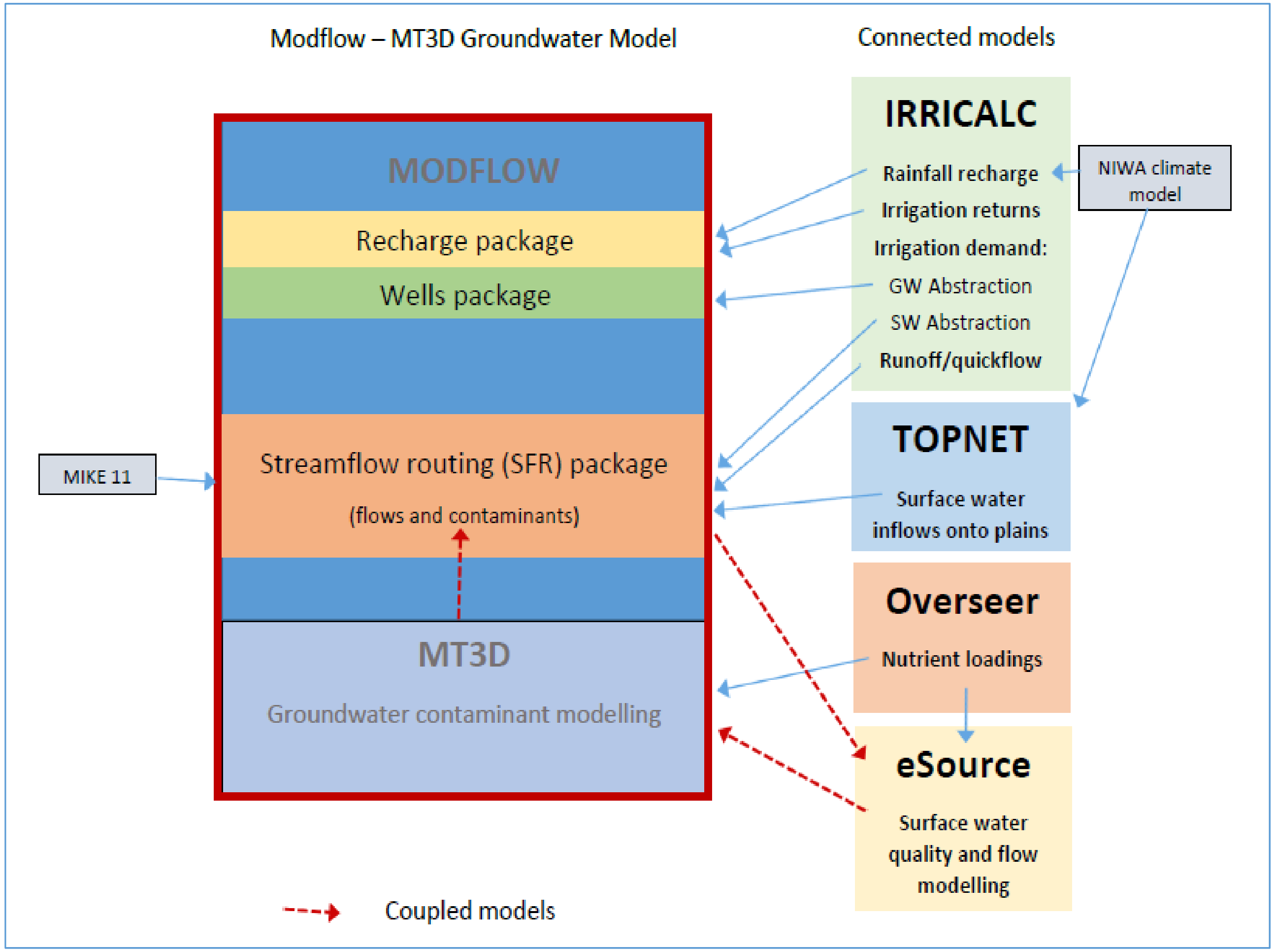
Groundwater modelling of the Ruamahanga Valley: USGS **MODFLOW-MT3D**



Previous three FEFLOW GW flow models (Upper/Middle/Lower valley) converted to two MODFLOW/MT3D models:

- Integration with other models
- Simulation of surface water and groundwater concurrently
- Improved rainfall recharge and abstraction simulation
- Contaminant transport
- More calibration options



Modflow – MT3D Groundwater Model
Connected models
MODFLOW
Recharge package
Wells package
Streamflow routing (SFR) package
(flows and contaminants)
MT3D
Groundwater contaminant modelling
MIKE 11
IRRICALC
Rainfall recharge
Irrigation returns
Irrigation demand:
GW Abstraction
SW Abstraction
Runoff/quickflow
NIWA climate model
TOPNET
Surface water inflows onto plains
Overseer
Nutrient loadings
eSource
Surface water quality and flow modelling
Coupled models

Groundwater Model Inputs & Assumptions

- Input 1: Physical structure: geology, layers, faults etc (FEFLOW)
- Input 2: Rivers/streams/springs (TOPNET / Mike11)
- Input 3: Rainfall recharge (IRRICALC)
- Input 4: Groundwater and surface water abstraction (IRRICALC)
- Input 5: Aquifer properties
- Input 6: Nutrient loadings (Overseer - MPI / Jacobs)

Input 1: Geology and structure – physical model set up

- Complex geology. Conceptualisations developed for the Feflow models – robust work based upon best current levels of understanding using best expertise available.

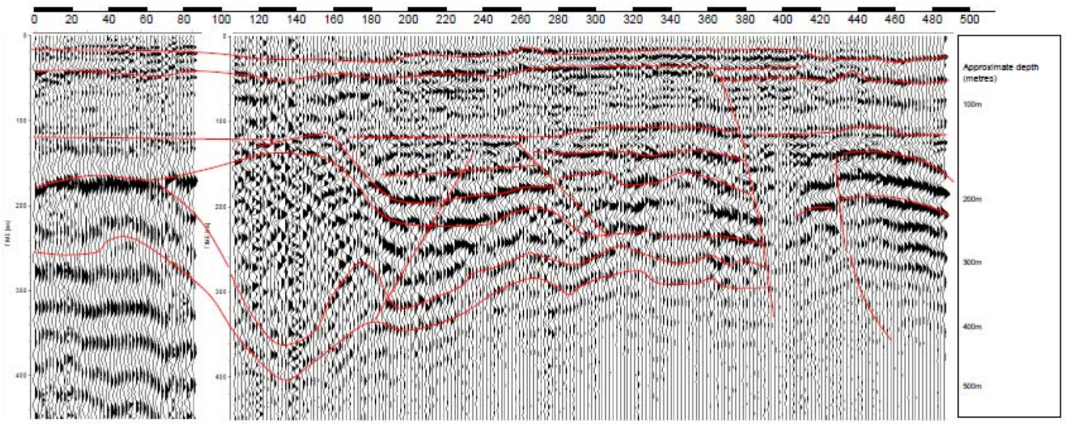
- Assumptions – there are numerous assumptions and simplifications in the geological conceptualisations due to the highly complex and heterogeneous geological environment. This is unavoidable.

- Assumptions tested during the Feflow calibrations – the groundwater system behaves as a single leaky system. The groundwater model probably least sensitive to assumptions made for Input 1.

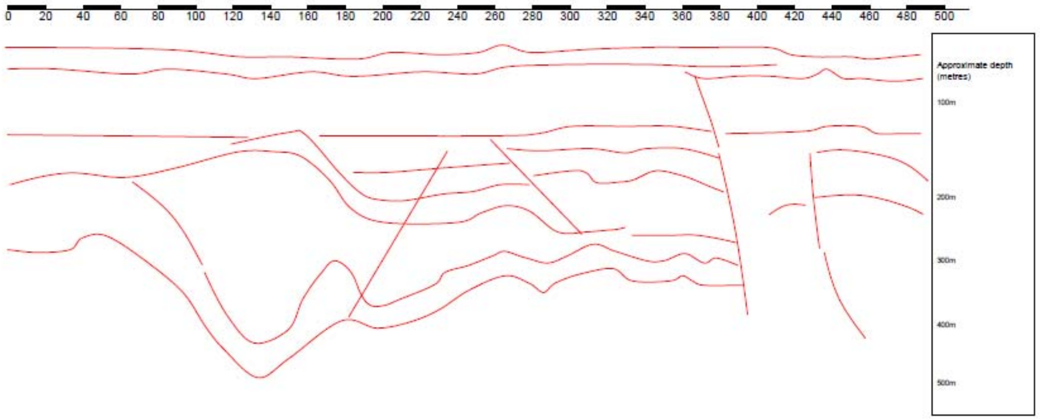
- A highly interconnected groundwater system – which has strong connectivity to surface water = basis for conjunctive sw/gw allocation management approach

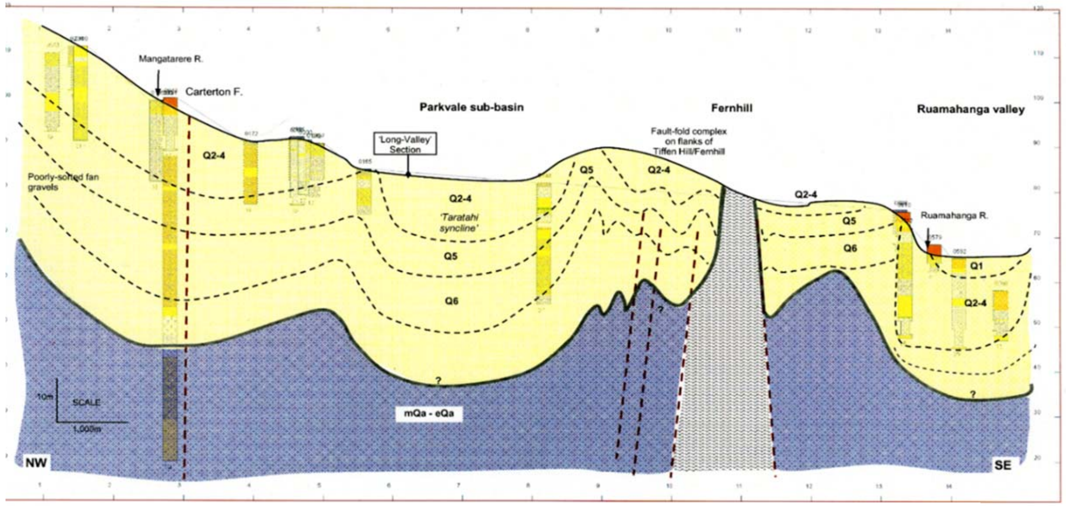
Input 1: Geology/physical system structure

LINE 1
PART 4



LINE 1
PART 4





Geophone on land streamer

Geometrics GEODE seismograph and computer control equipment in back of vehicle

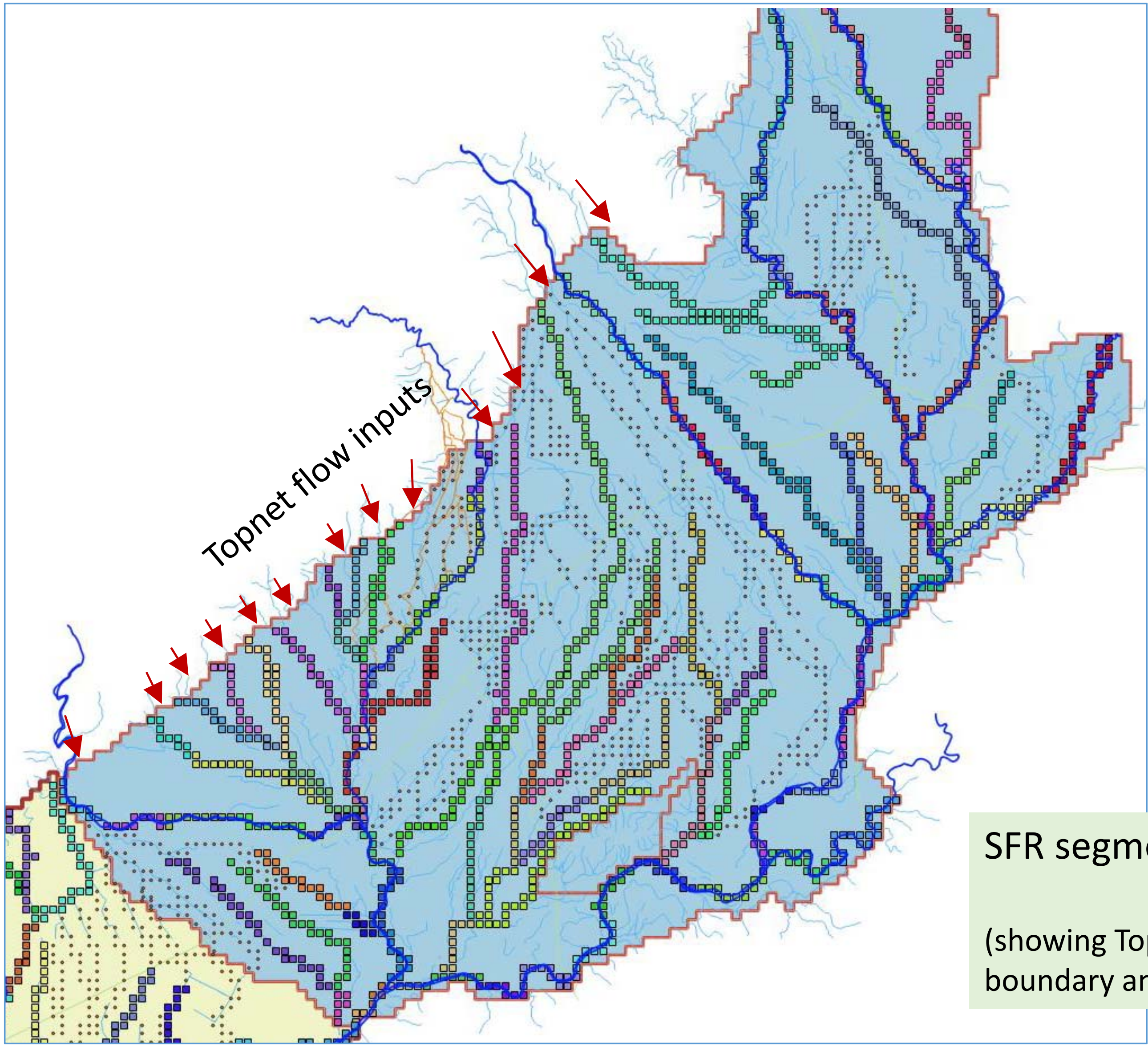
Seismic Line 1, SE end.

Seismic shot (sledge hammer) in action. Typically 3 shots (stacked) at each location.

Geophone cable in road verge

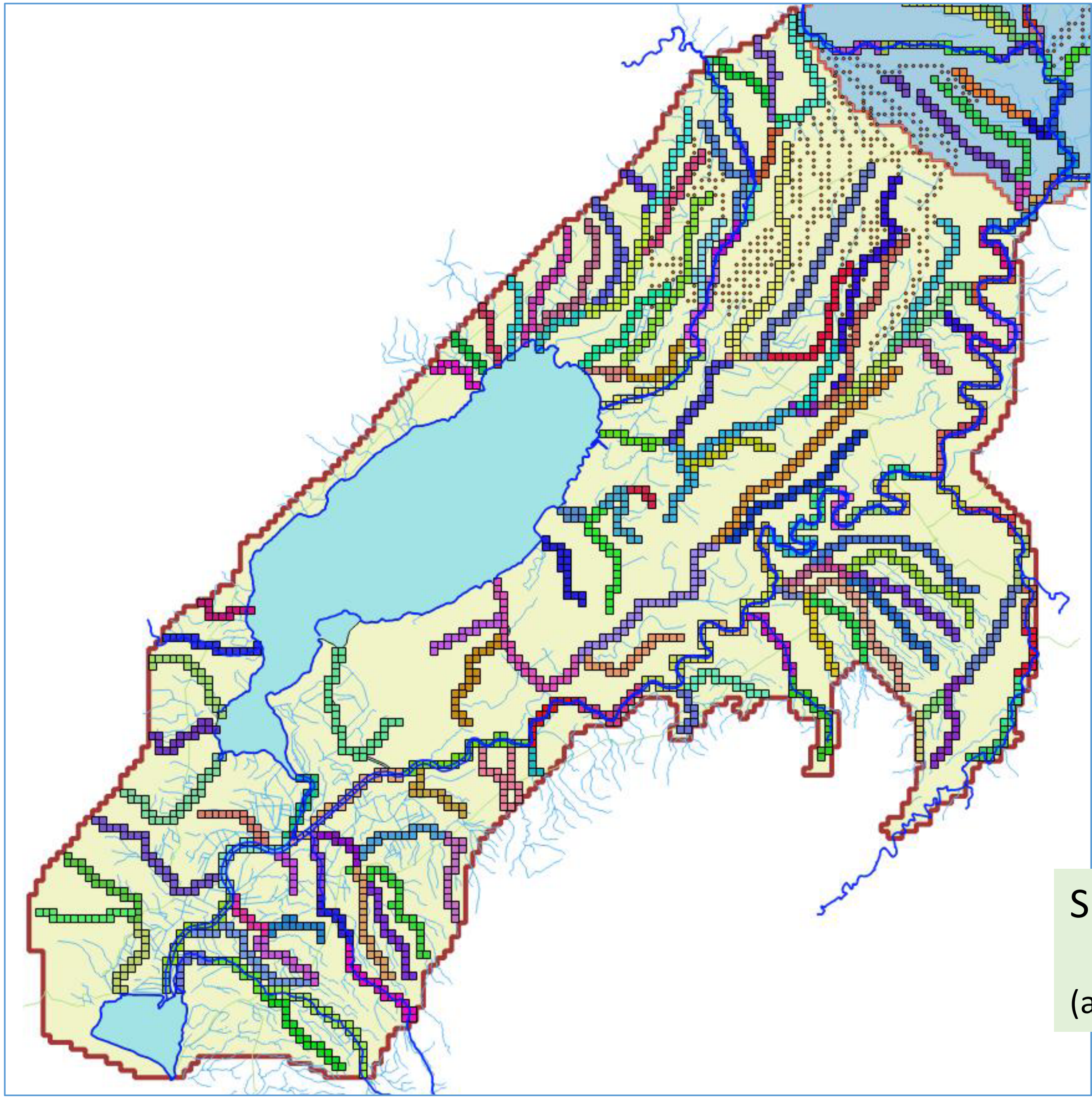
Input 2: Rivers/streams/springs – physical model set up

- Modflow's SFR module (Stream Flow Routing) is a fundamental modelling component which simulates channel flow and the interaction between surface water and groundwater.
- TOPNET feeds water into the SFR segments where rivers/streams enter the plains
- Surface water courses set up using GWRC bed survey and river cross-section data (MIKE 11).
- SFR also simulates contaminant transport between groundwater and surface water.
- A big improvement over Feflow with regards its flexibility to integrate with other models.
- SFR handles inputs from overland flow/runoff, surface water abstractions (provided by Irricalc), diversions to water races.
- *Assumptions:* Few flow monitoring sites on the plains for calibration; quite a few synthetic flow sites based upon calculated relationships. Spatial resolution - SFR set up using segments of about 2km length for major rivers – water balances therefore lumped for each segment.



SFR segments – Northern Model

(showing Topnet inputs at model boundary and water race injection nodes)



SFR segments – Southern Model

(also showing water race injection nodes)

Inputs 3 and 4: Rainfall recharge and irrigation demand (IRRICALC)

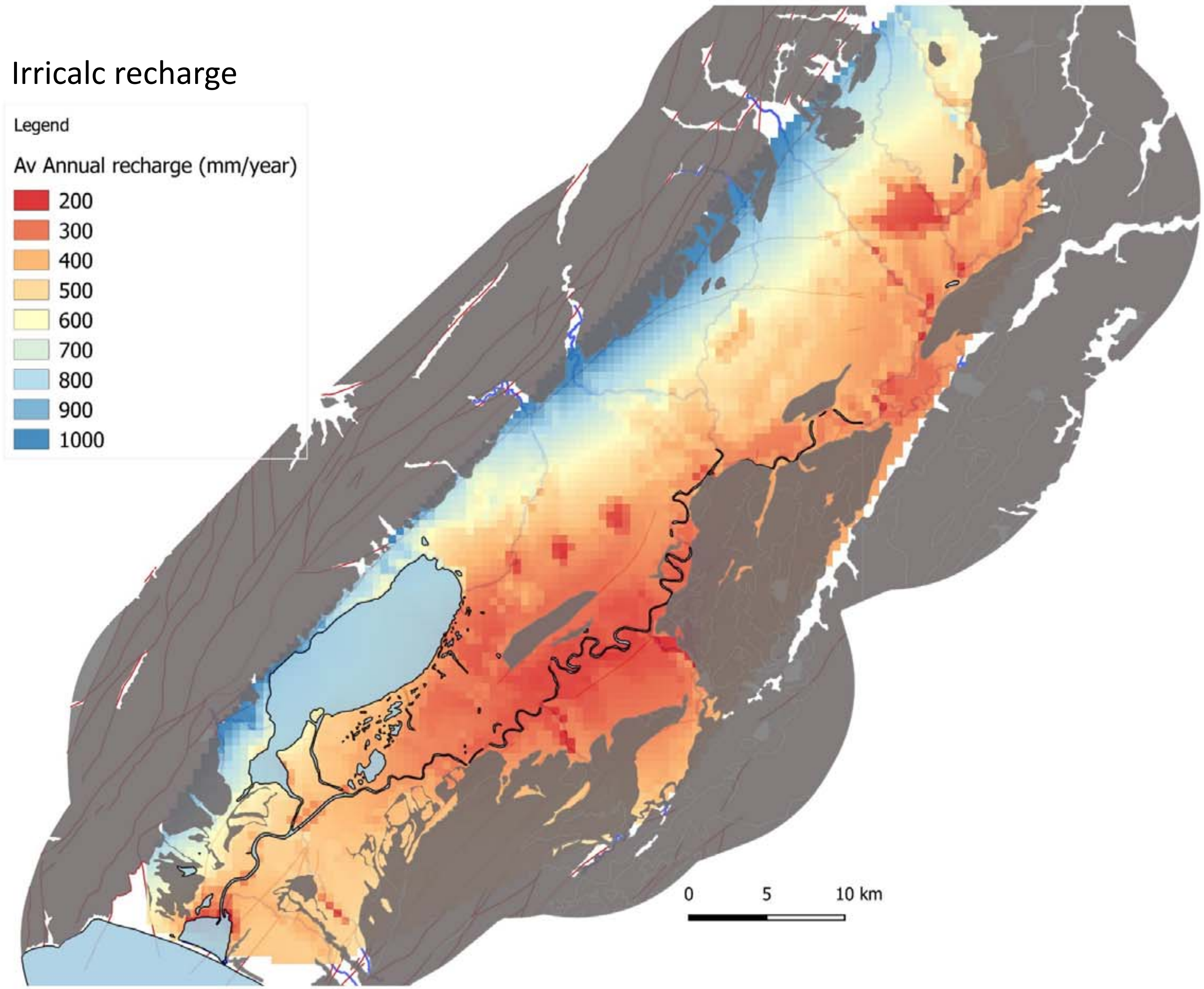
- Rainfall recharge externally calculated using a soil moisture balance model (IRRICALC). Similar methodology to the previous feflow models although Irricalc is a more integrated soil water balance model which incorporates irrigation water demand and runoff.

- Irricalc requires input data: climate (rainfall and potential evapotranspiration), crop (crop factors, rooting depths) and soil (soil water holding capacity) data. Provided by NIWA and Landcare Research.

- Recharge has been calculated using the same 500m grid and distributed input daily data rainfall and PET series as used in the previous Feflow models (1992 to present).

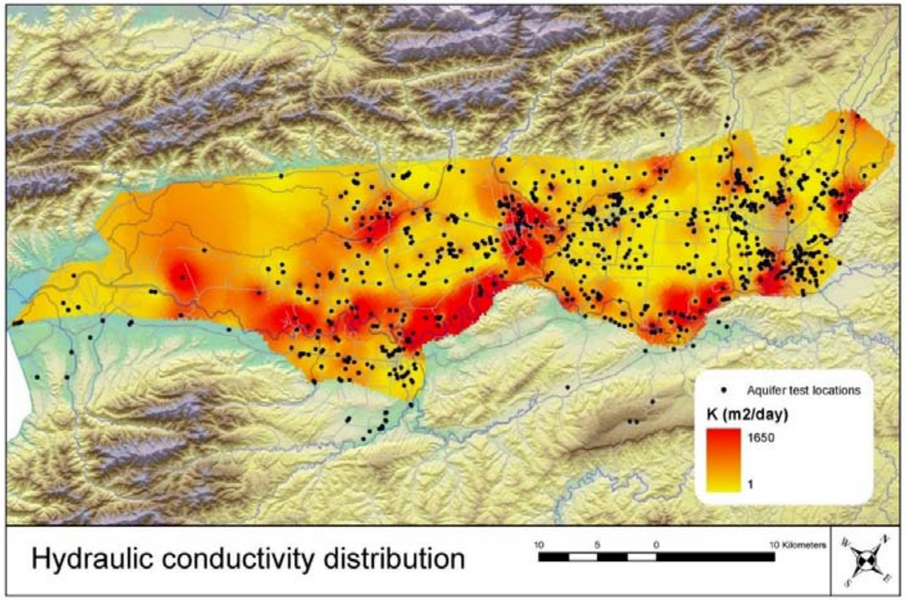
- Irricalc has been used to model historic irrigation abstraction rates based upon crop water demand. These demands have been incorporated into the model calibration (either as surface water or groundwater abstractions)

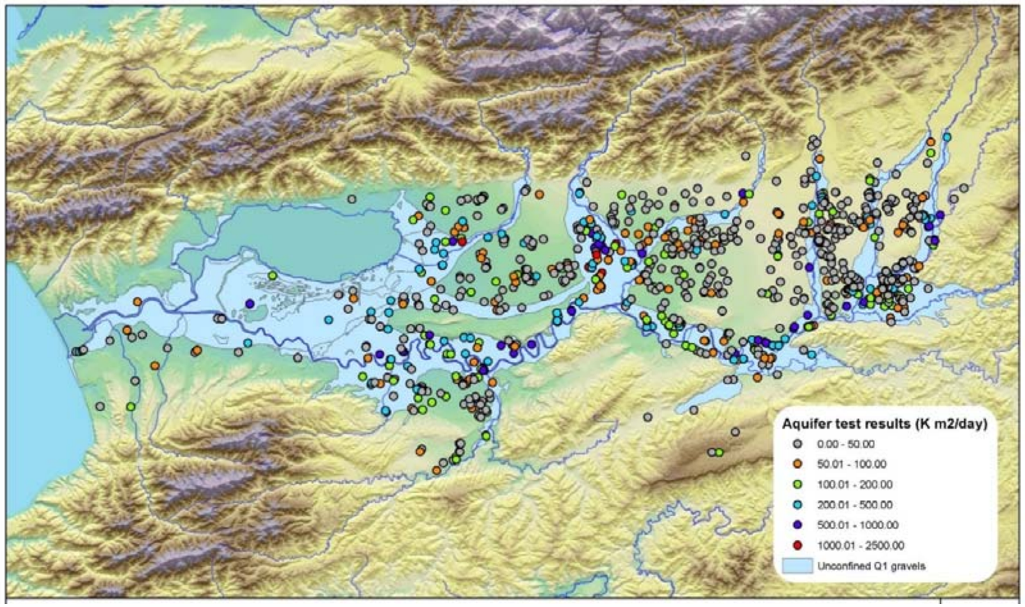
- Assumptions: Recharge calculated using soil moisture balance models assumes a free-draining soil; recharge is applied directly to the water table/aquifer and does not take into account unsaturated zone properties/lags or short-circuits; irrigation demands assume certain irrigation practices/rules and land use; water is always available for irrigation at the rate required; assumptions concerning irrigation returns; assumptions concerning partitioning of runoff/interflow and groundwater recharge.


Irricalc recharge
Legend
Av Annual recharge (mm/year)
200
300
400
500
600
700
800
900
1000
0
5
10 km

Input 5: Aquifer properties (hydraulic conductivity and storage)

- Aquifer properties are based upon the previous Feflow models – which relied upon field-measured transmissivity/storage data (starting values in MODFLOW – will be refined during calibration).
- Model values are restricted to field-measured ranges (pumping tests).
- Model calibration allows for a more distributed/heterogeneous distribution of parameters – derived through the calibration process.
- Assumptions – areas where no data exist – but nature of geology provides a good guide. Natural system is highly heterogeneous so simplifications need to be made: model parameter estimation and uncertainty analysis will interrogate assumptions in terms of their effect on model predictive reliability.





Groundwater Model Outputs & Assumptions

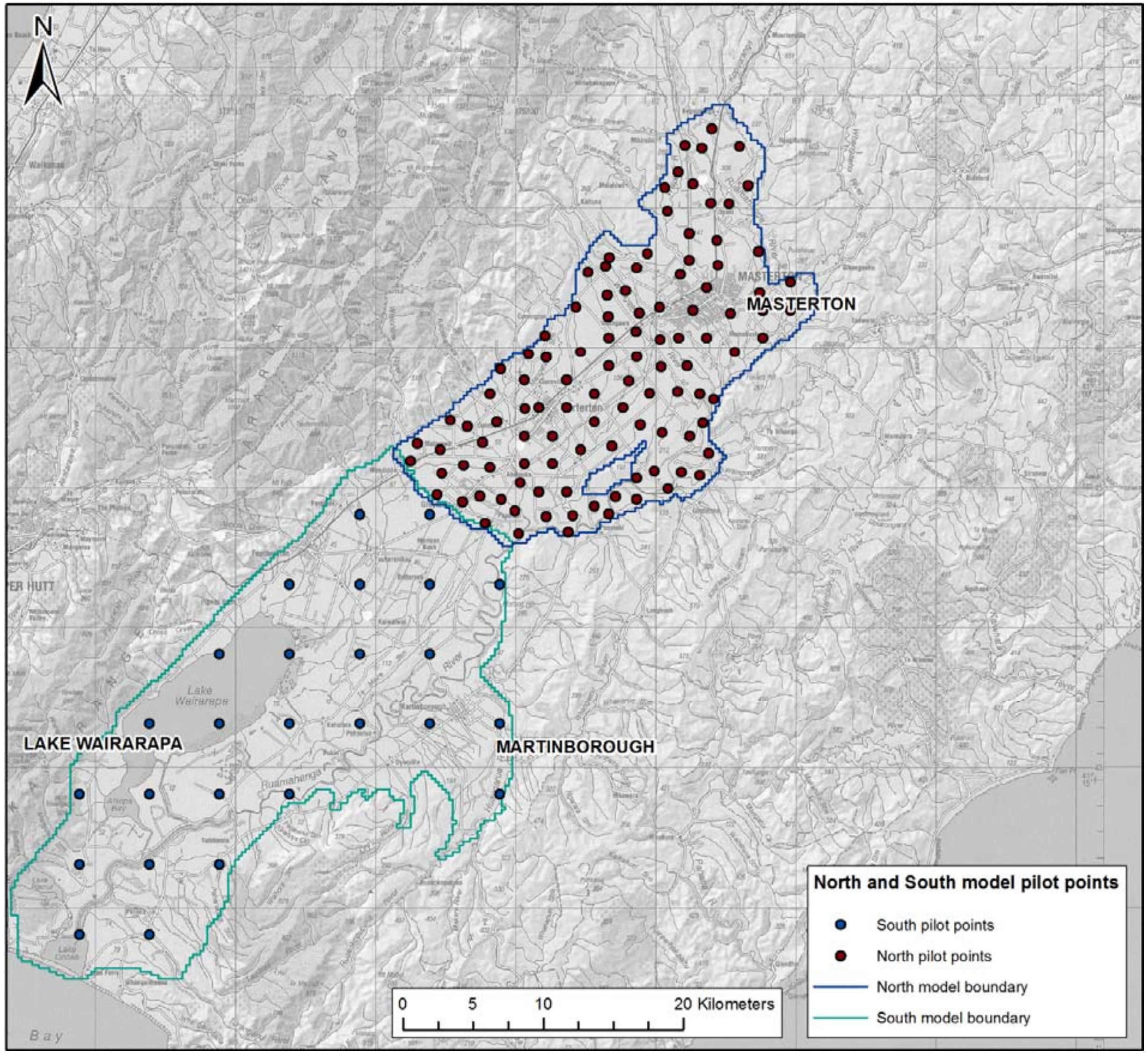
- Output 1: Groundwater levels
- Output 2: Stream flows
- Output 3: Stream – groundwater fluxes
- Output 4: Nitrate concentrations

Model calibration is currently being revised due to new TOPNET and Nitrate model input files supplied.

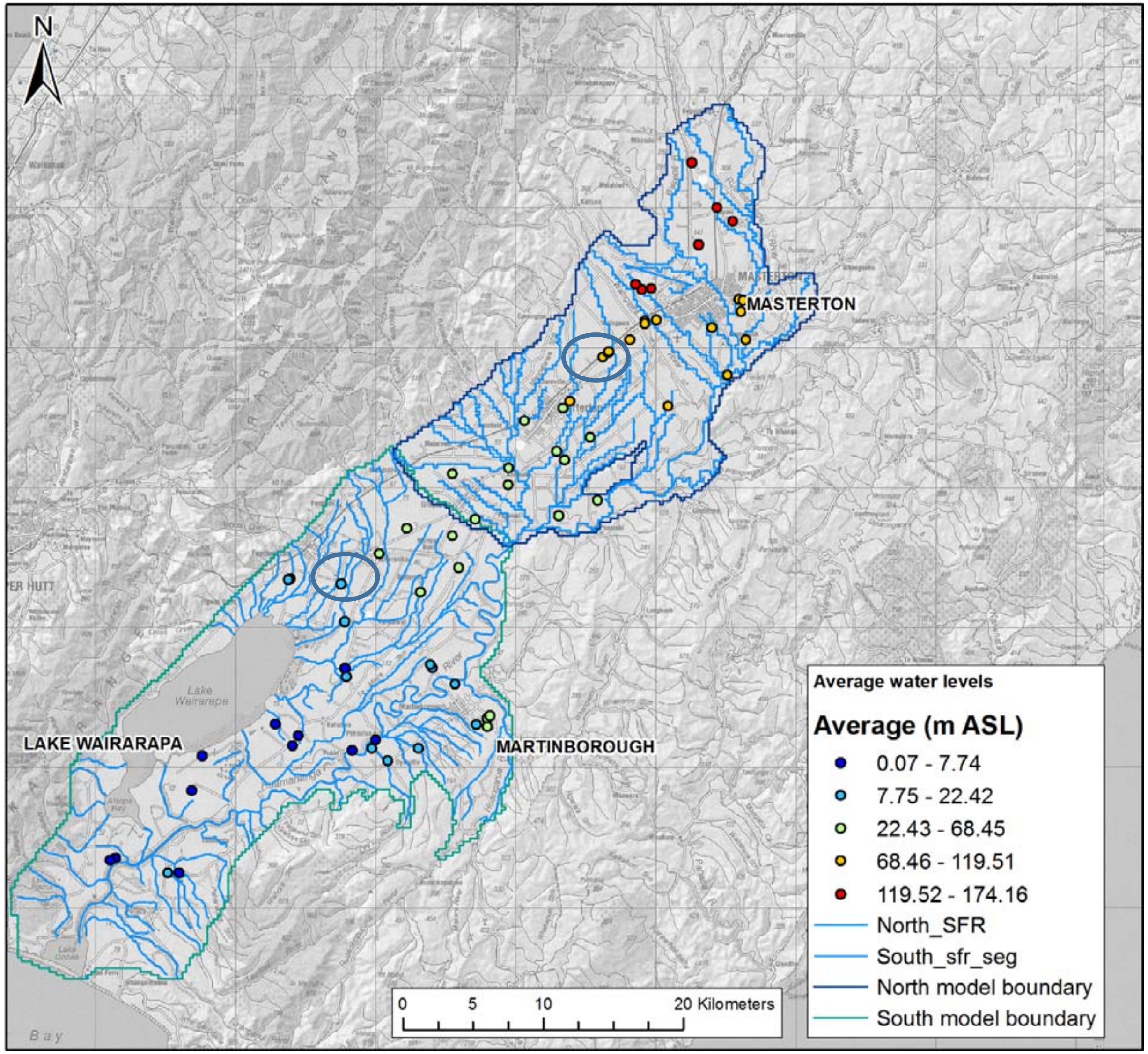
Assumptions:

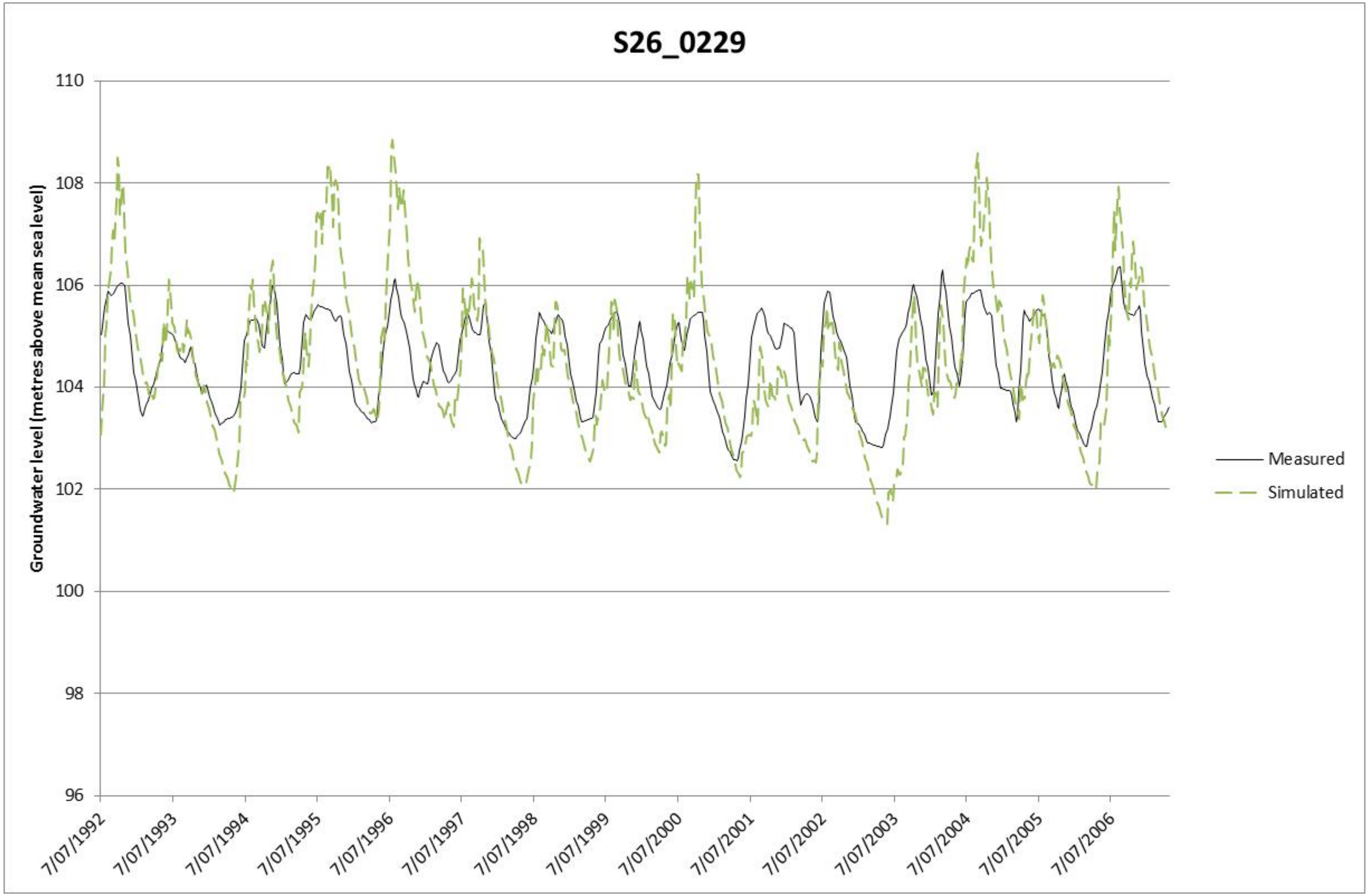
<u>Groundwater levels</u>

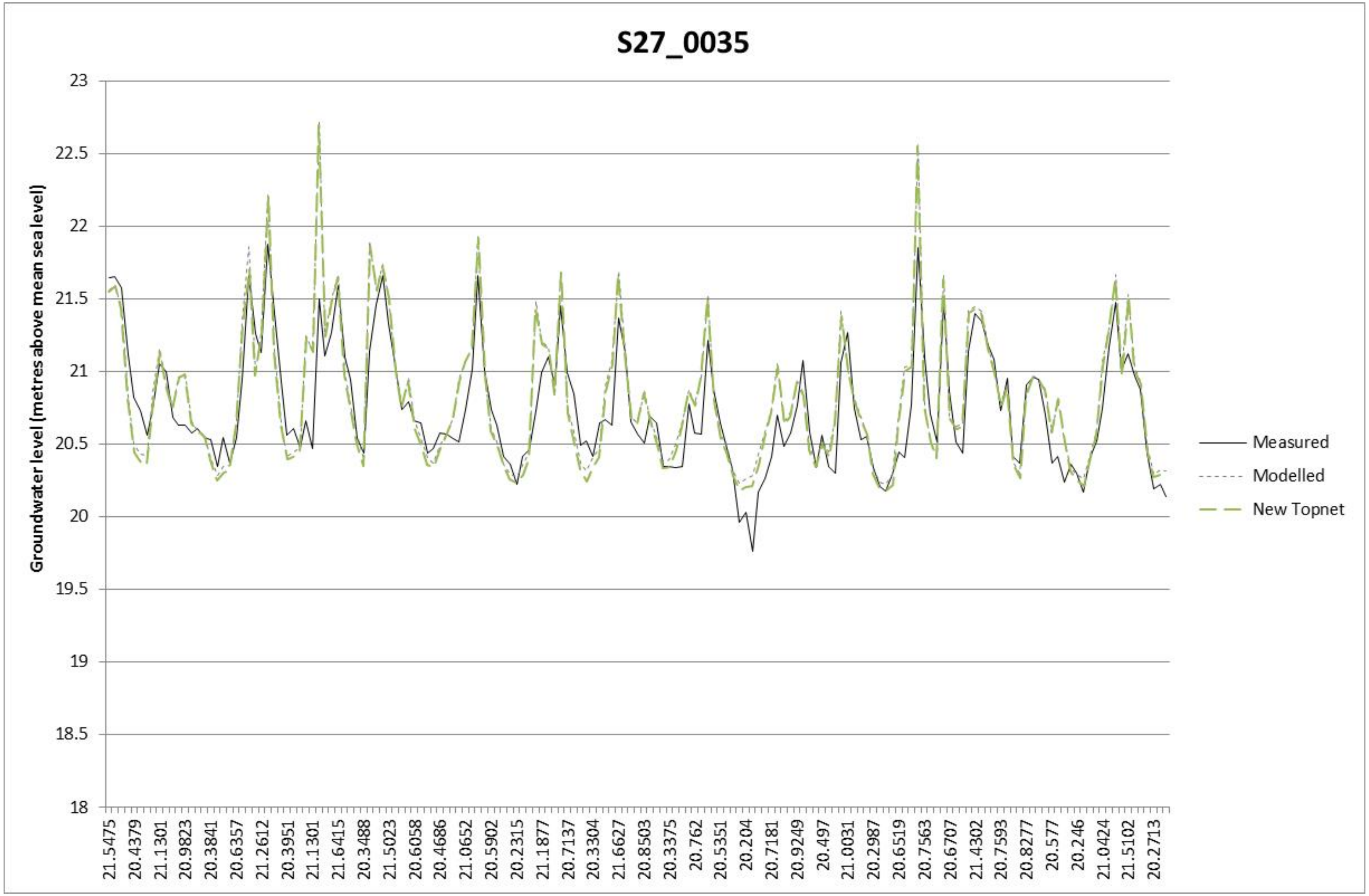
- Weekly stress periods
- 5 model layers in the north
- 8 model layers in the south
- Pilot point parameters x original Feflow parameter zones
- Irricalc estimated recharge, abstraction, and quickflow
- Topnet estimated inflows to model



Output 1: Groundwater levels




S26_0229
Groundwater level (metres above mean sea level)
110
108
106
104
102
100
98
96
7/07/1992
7/07/1993
7/07/1994
7/07/1995
7/07/1996
7/07/1997
7/07/1998
7/07/1999
7/07/2000
7/07/2001
7/07/2002
7/07/2003
7/07/2004
7/07/2005
7/07/2006
Measured
Simulated



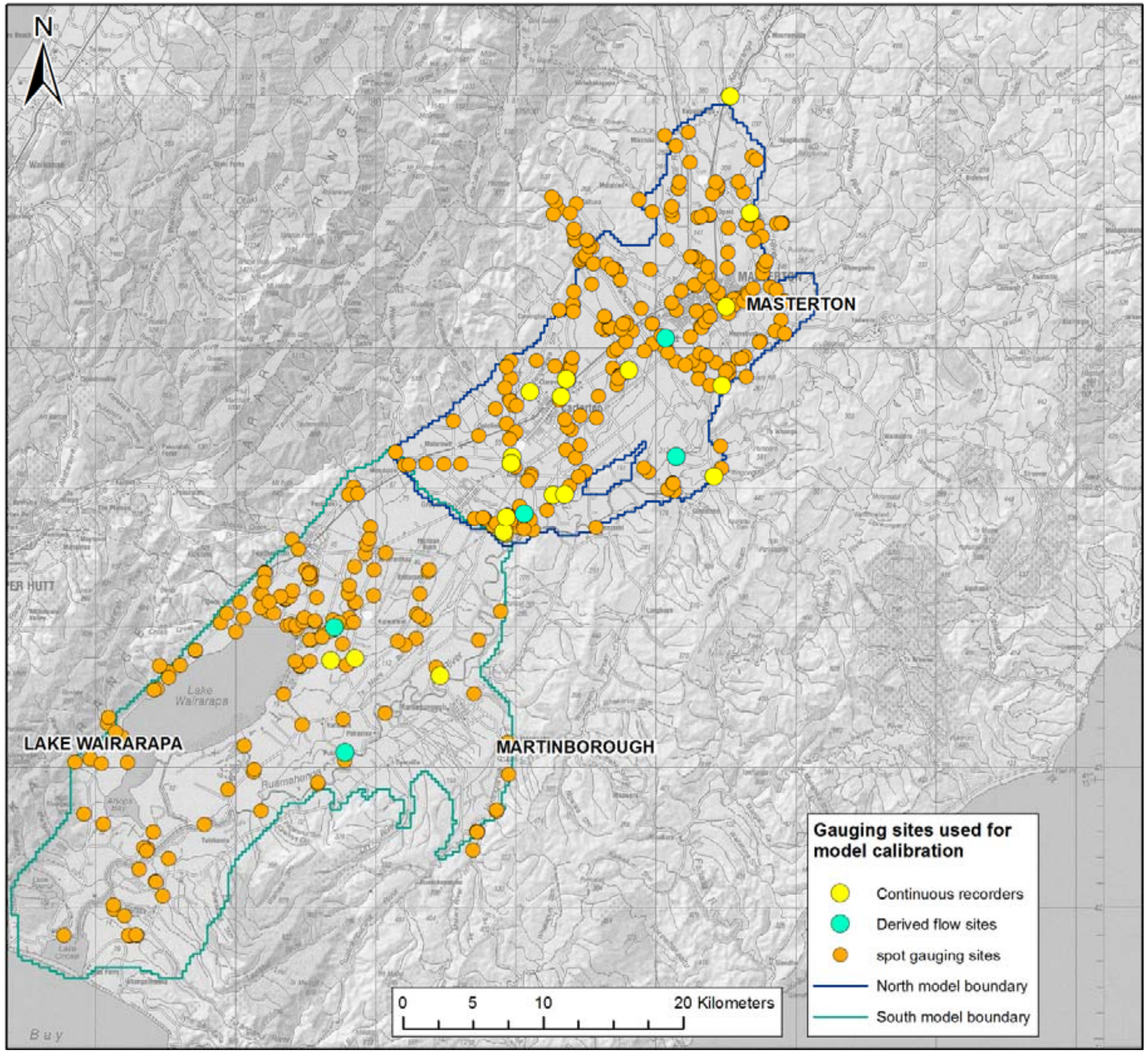
S27_0035
Groundwater level (metres above mean sea level)
23
22.5
22
21.5
21
20.5
20
19.5
19
18.5
18
Measured
Modelled
New Topnet

Output 2: Stream flows

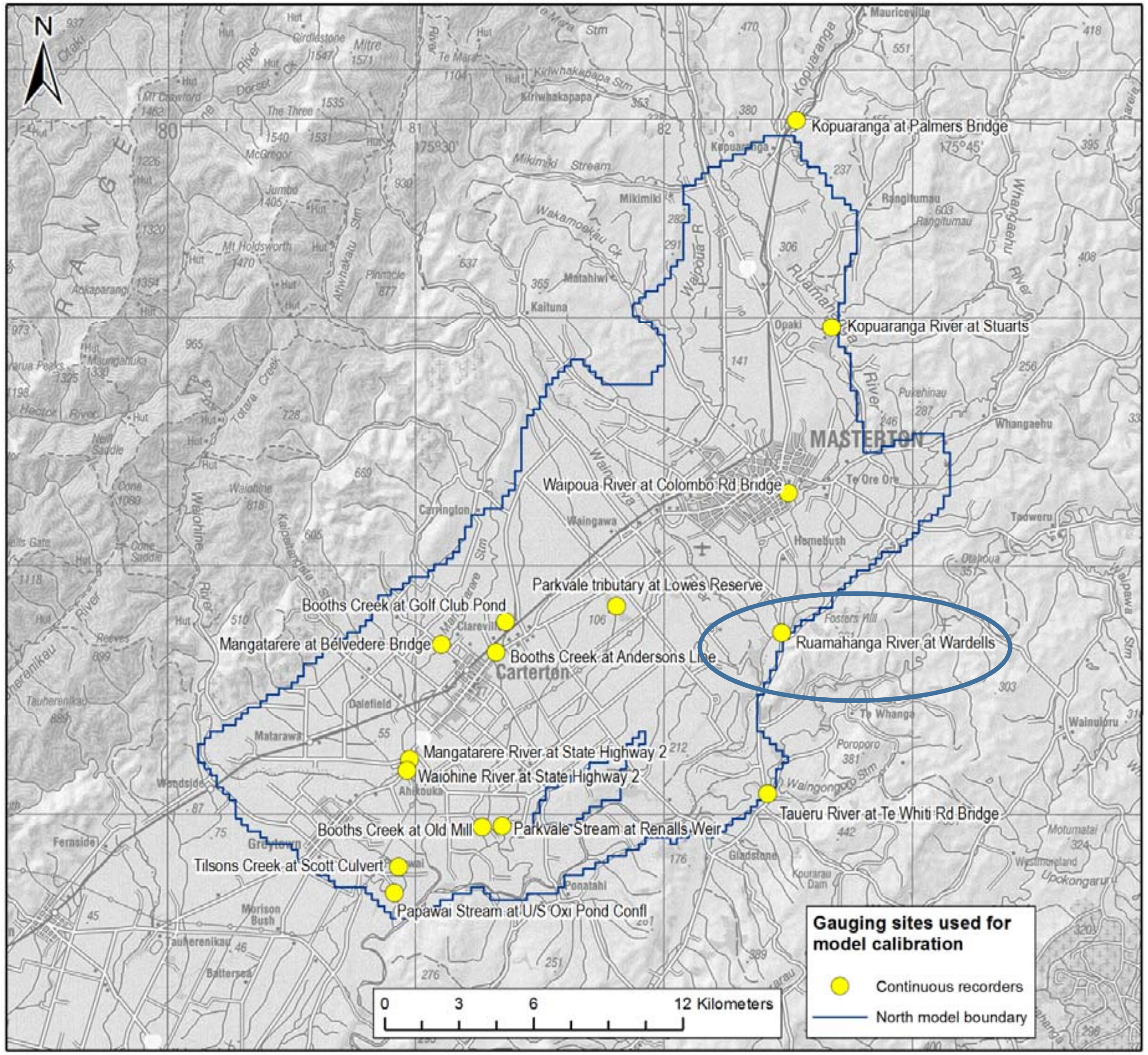
Assumptions:

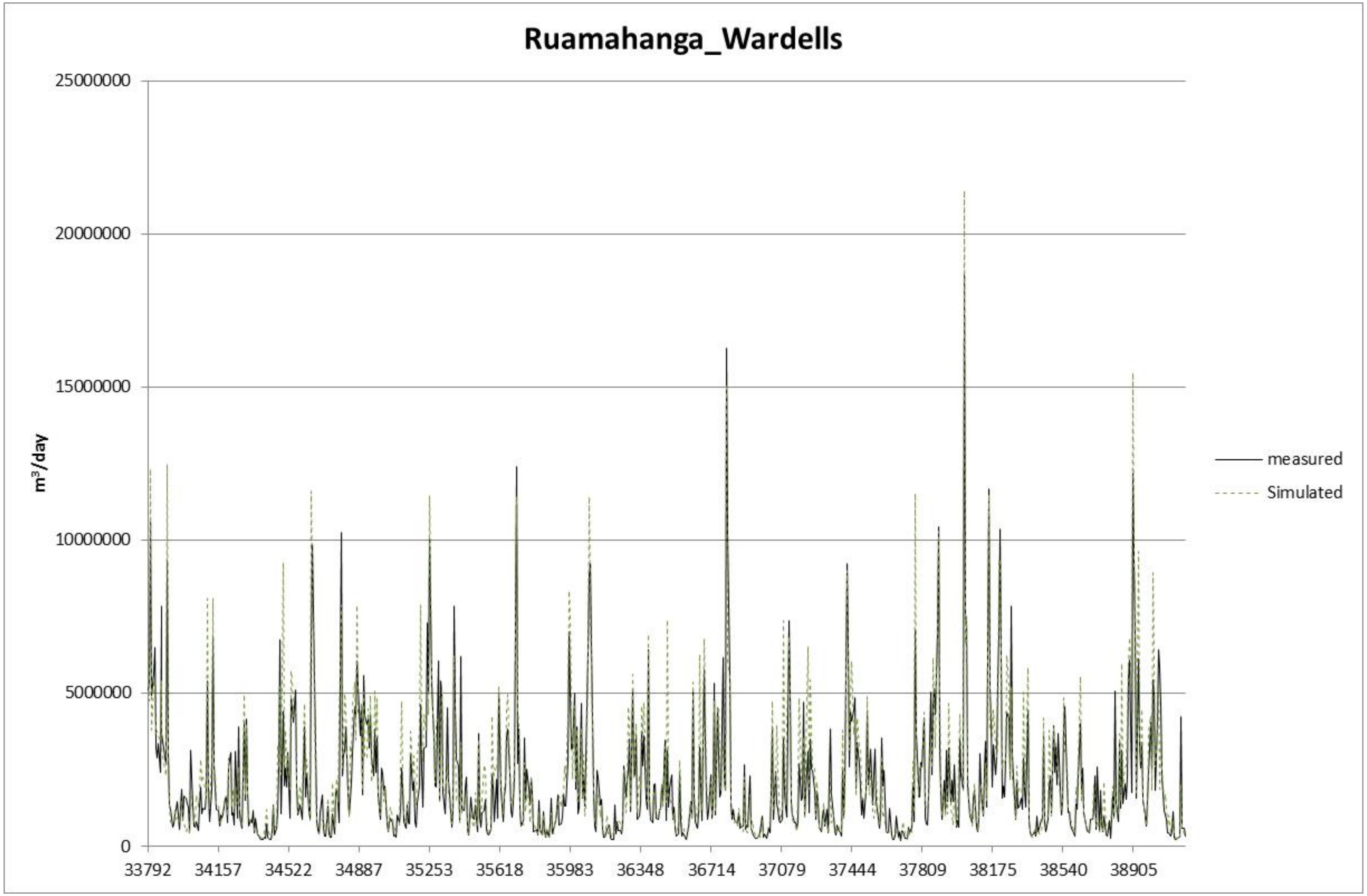
<u>Stream flows</u>

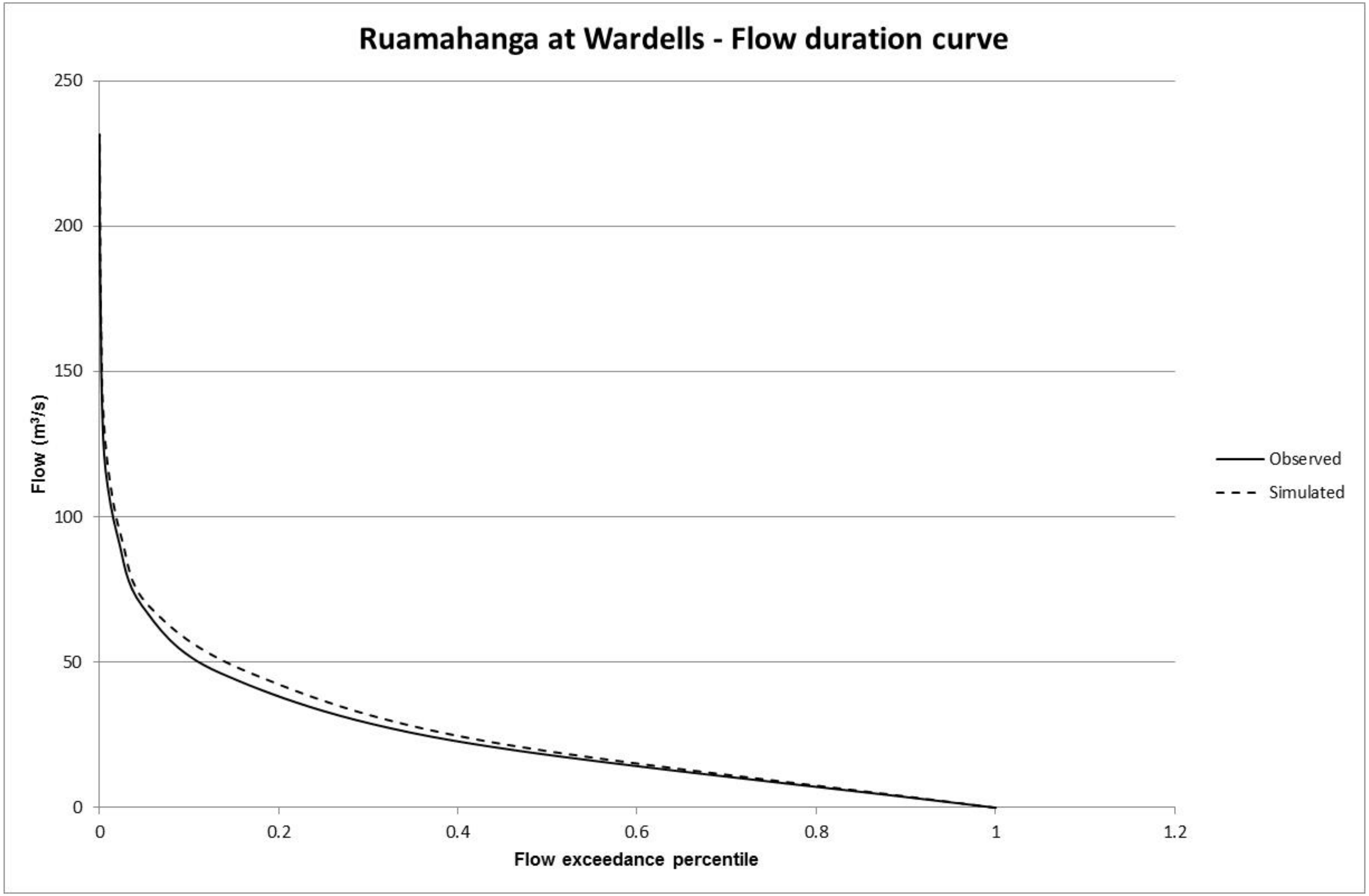
- Weekly stream flows used as calibration targets
- Irricalc estimated recharge, abstraction, and quickflow
- Topnet estimated inflows to model



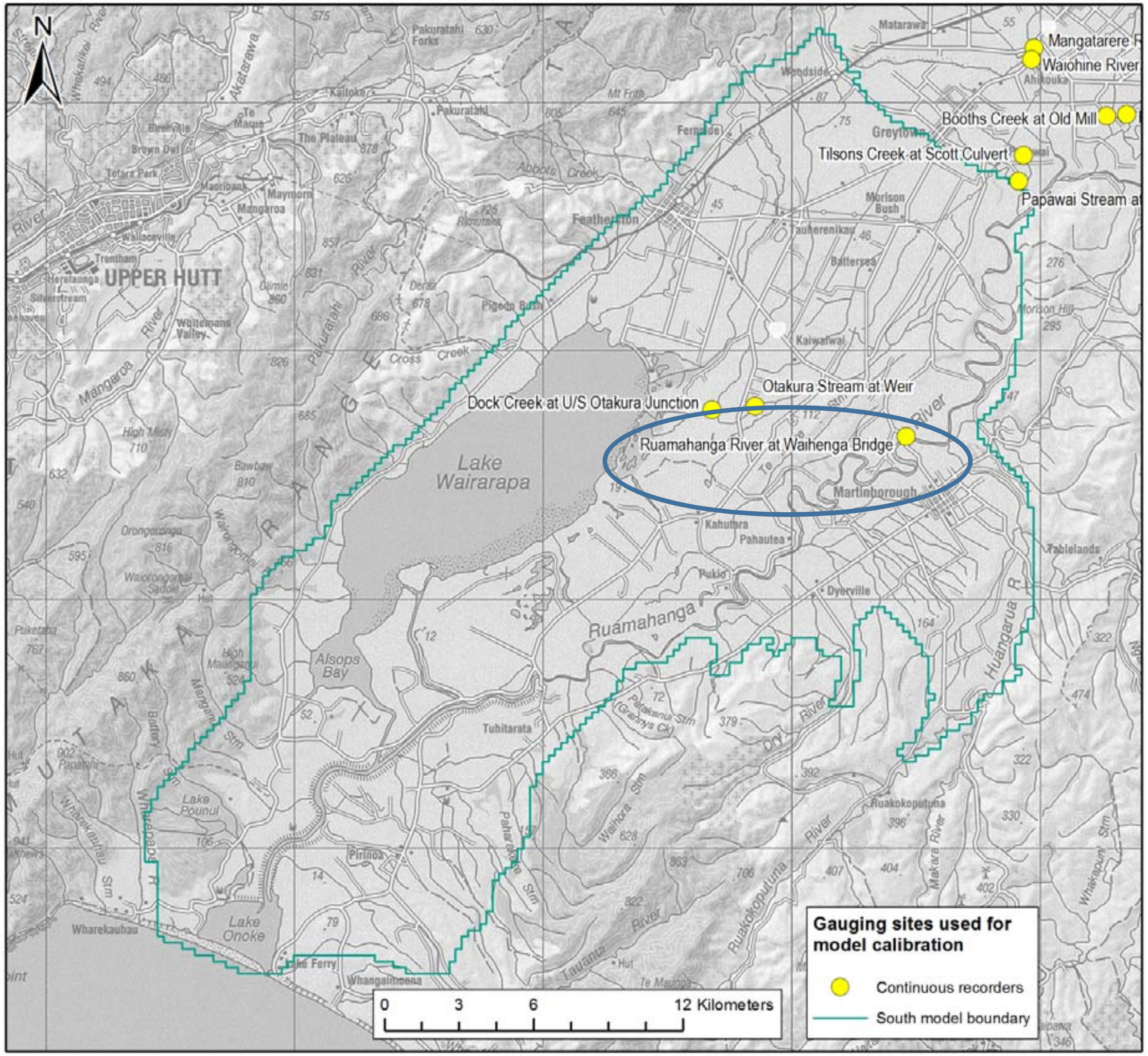
Output 2: Stream flows

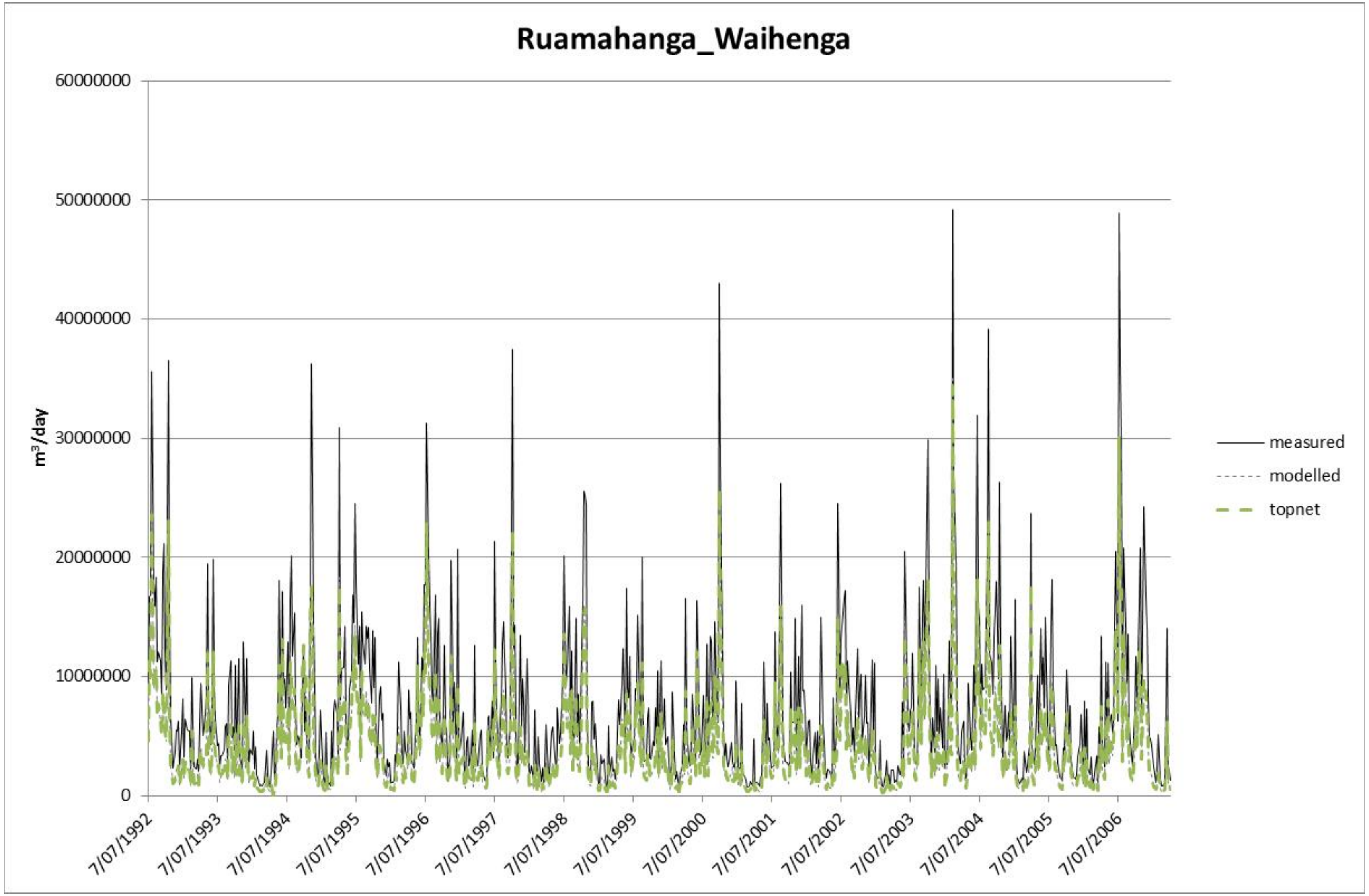



Ruamahanga_Wardells
25000000
20000000
15000000
10000000
5000000
0
m³/day
33792
34157
34522
34887
35253
35618
35983
36348
36714
37079
37444
37809
38175
38540
38905
measured
Simulated

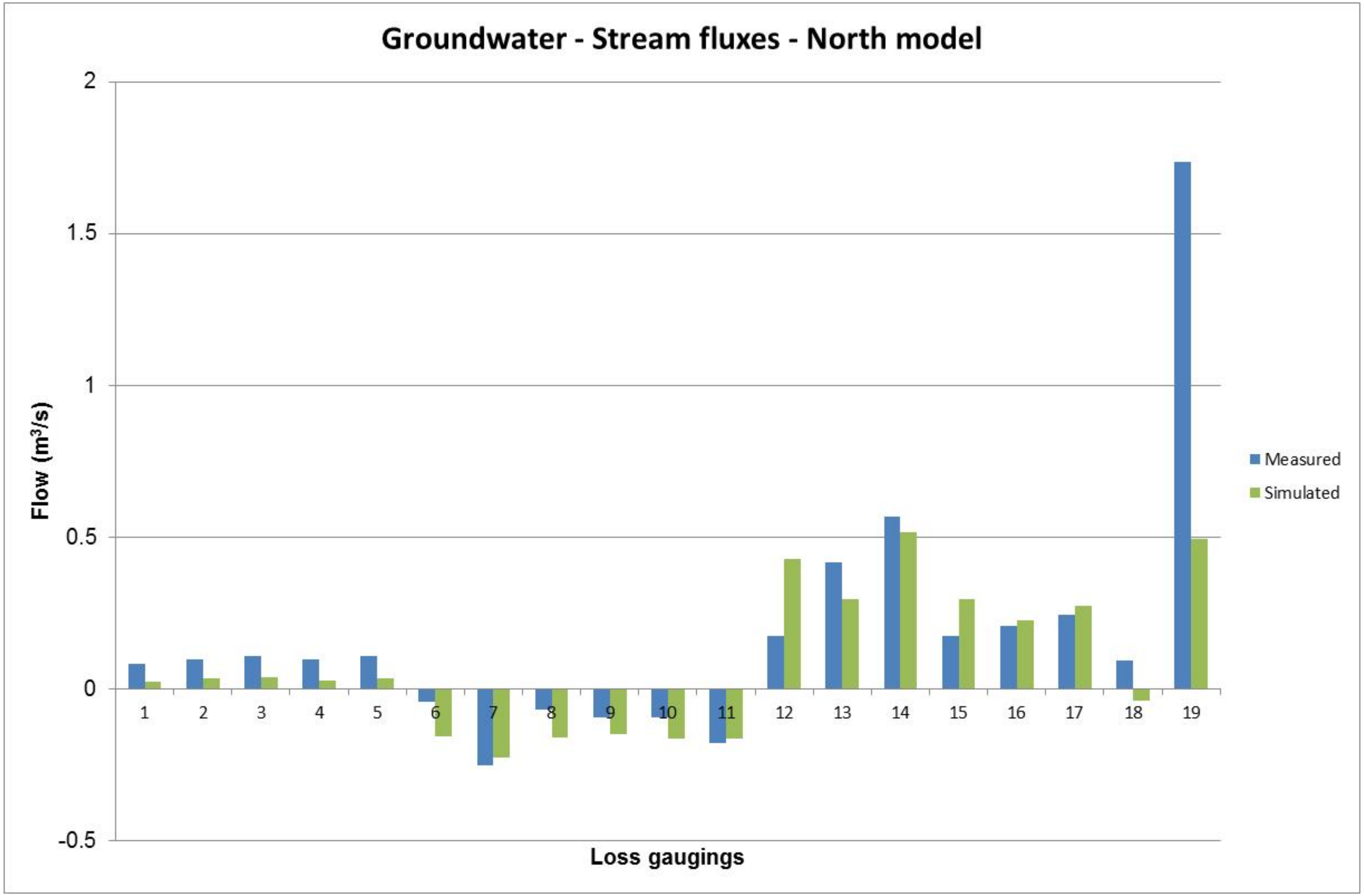

Ruamahanga at Wardells - Flow duration curve
250
200
150
100
50
0
Flow (m³/s)
0
0.2
0.4
0.6
0.8
1
1.2
Flow exceedance percentile
Observed
Simulated

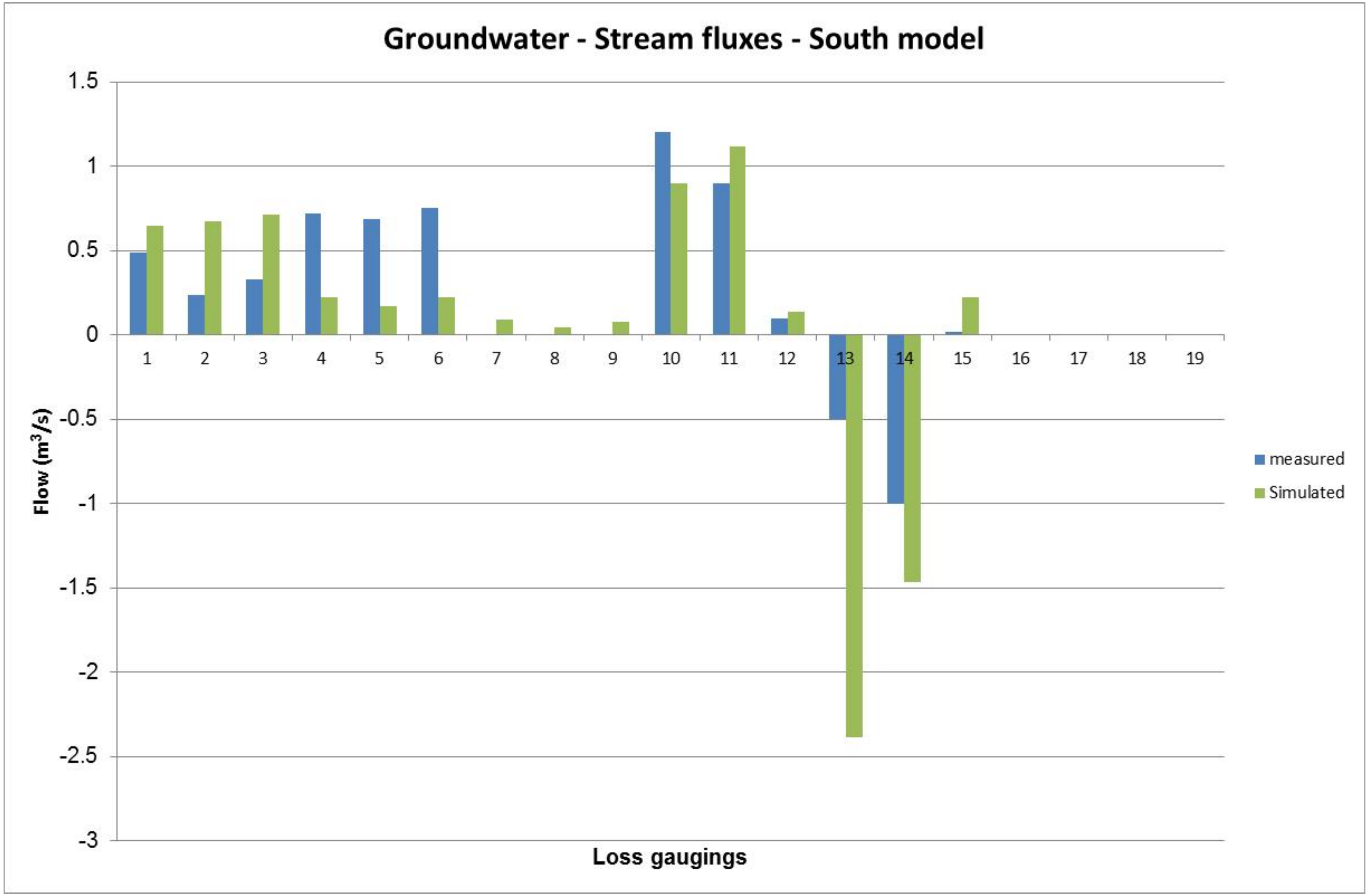
Output 2: Stream flows




Ruamahanga_Waihenga
60000000
50000000
40000000
30000000
20000000
10000000
0
m³/day
7/07/1992
7/07/1993
7/07/1994
7/07/1995
7/07/1996
7/07/1997
7/07/1998
7/07/1999
7/07/2000
7/07/2001
7/07/2002
7/07/2003
7/07/2004
7/07/2005
7/07/2006
measured
modelled
topnet

Output 3: Stream – groundwater fluxes





Groundwater - Stream fluxes - South model
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
Flow (m3/s)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Loss gaugings
measured
Simulated

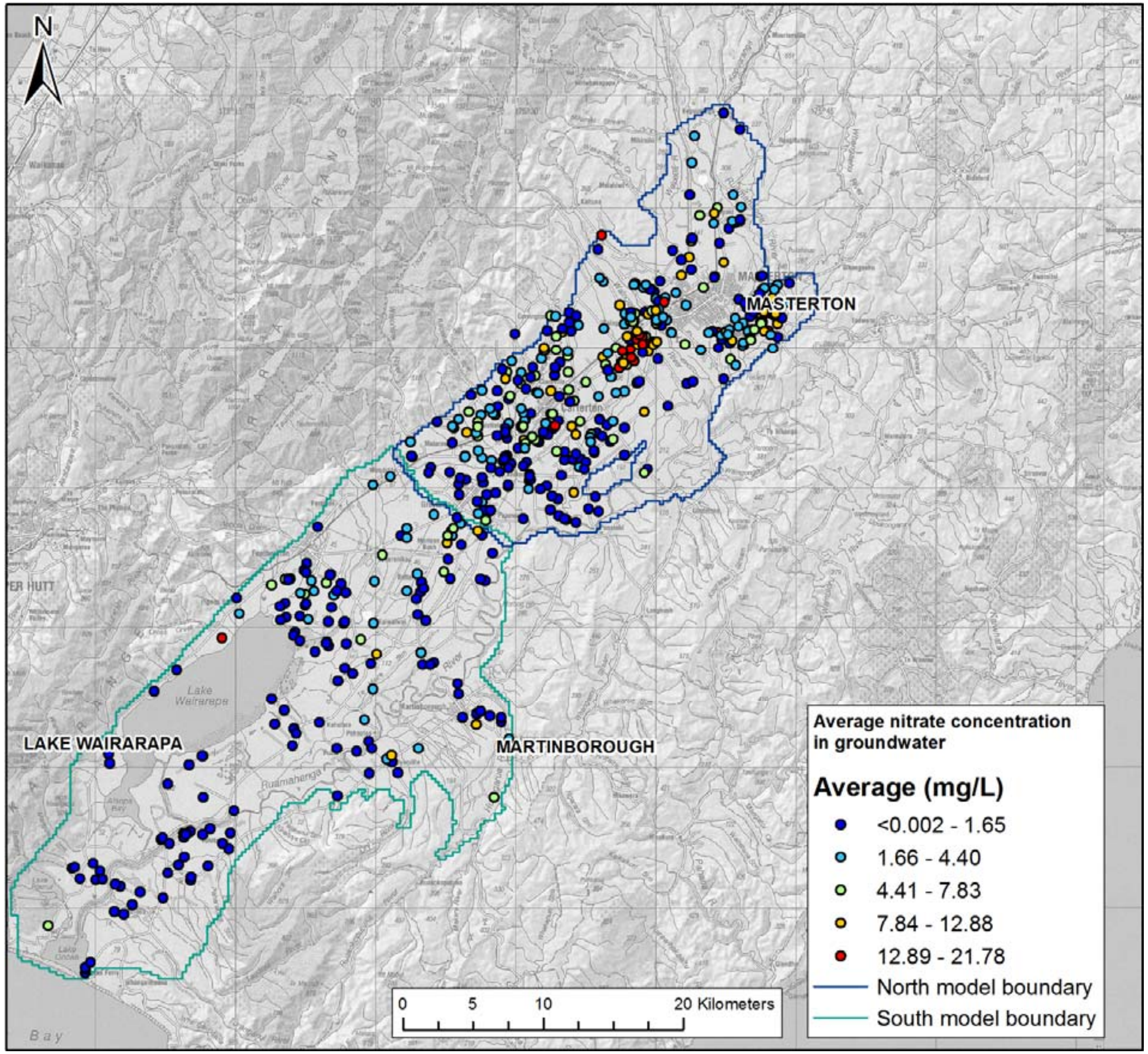
Output 4: Nitrate concentrations

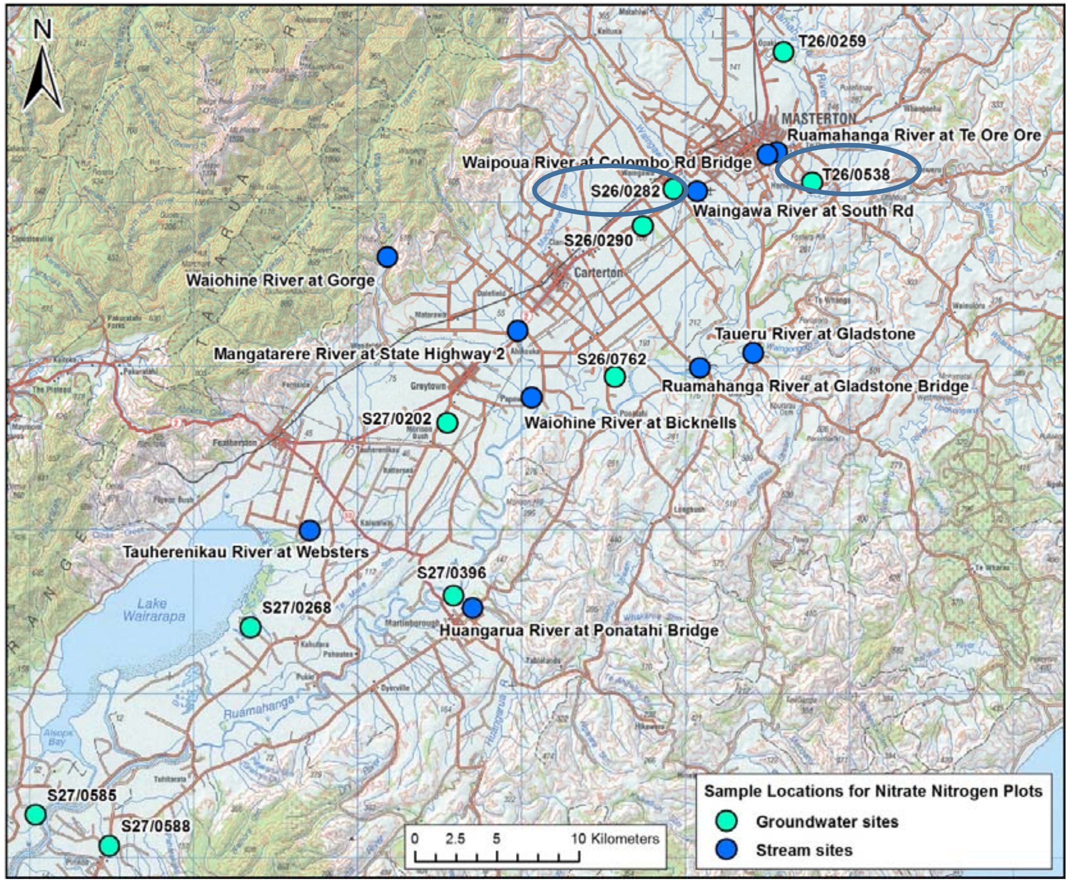
Assumptions:

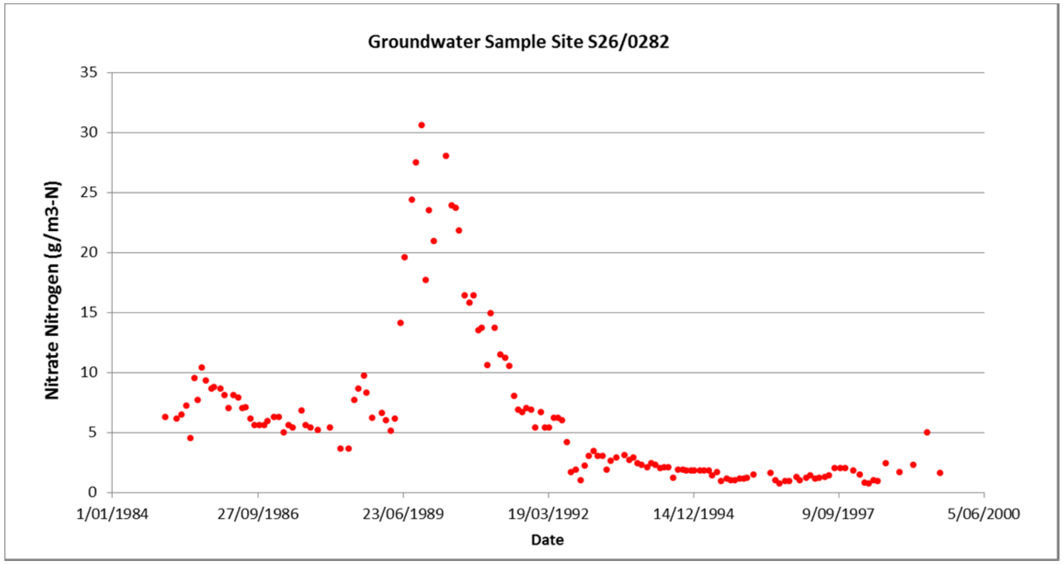
Groundwater concentrations

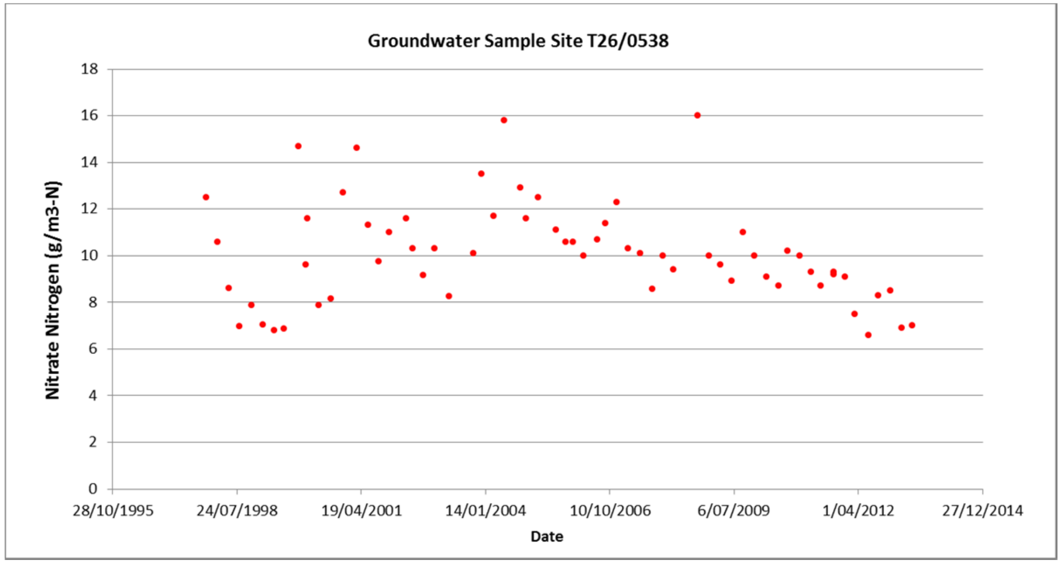
- Annual average nitrate input into model from Overseer
- Average nitrate concentration in surface water ways as input into model (will iterate with Esource for final model version)
- 5 model layers in the north
- 8 model layers in the south
- Calibrated to average nitrate concentrations in groundwater (monitoring period dependant)

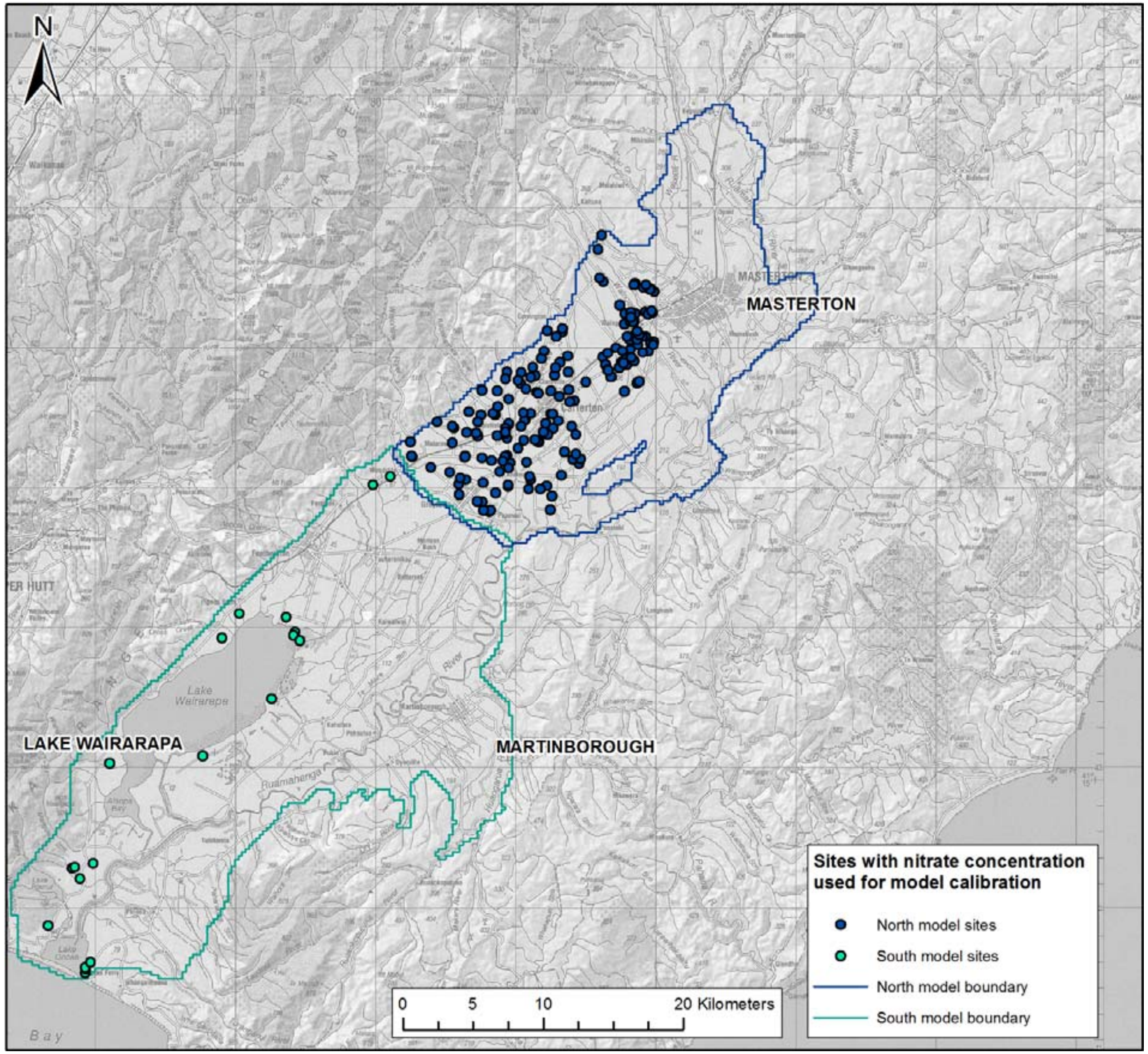
Pending new nitrate inputs…

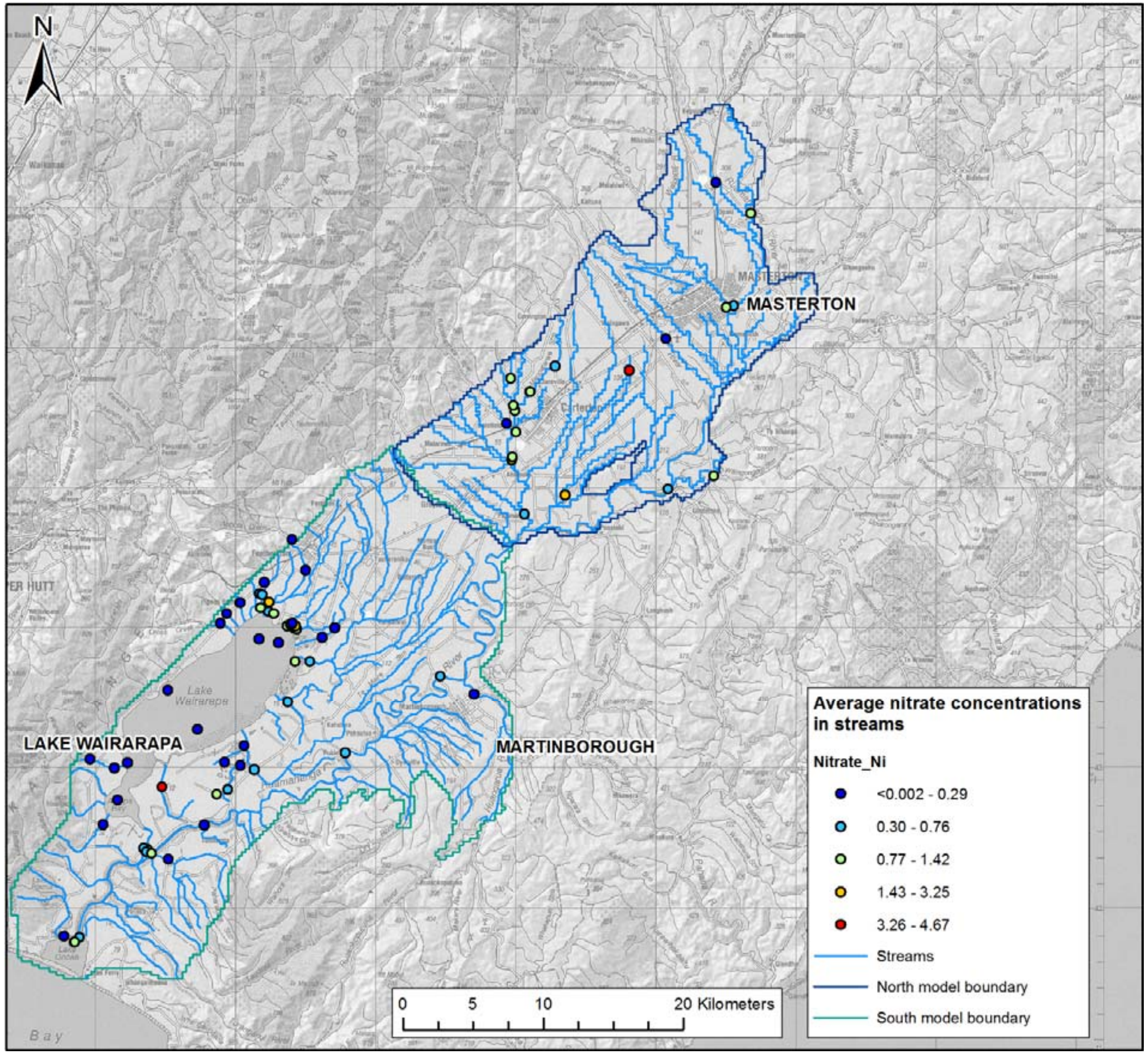


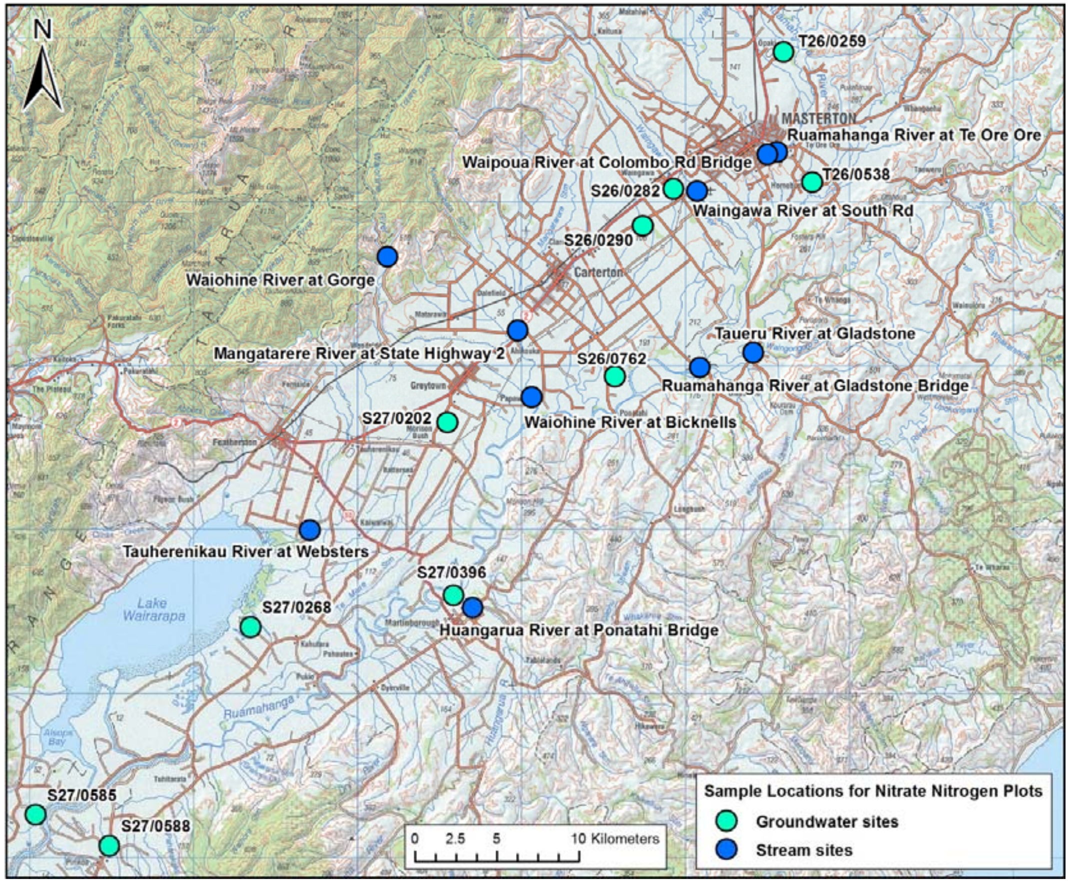

N
T26/0259
MASTERTON
Ruamahanga River at Te Ore Ore
Waipoua River at Colombo Rd Bridge
T26/0538
S26/0282
Waingawa River at South Rd
S26/0290
Carterton
Waiohine River at Gorge
Taueru River at Gladstone
Mangatarere River at State Highway 2
S26/0762
Ruamahanga River at Gladstone Bridge
S27/0202
Waiohine River at Bicknells
Tauherenikau River at Websters
S27/0396
S27/0268
Lake Wairarapa
Huangarua River at Ponatahi Bridge
Ruamahanga
S27/0585
S27/0588
0 2.5 5 10 Kilometers
Sample Locations for Nitrate Nitrogen Plots
Groundwater sites
Stream sites

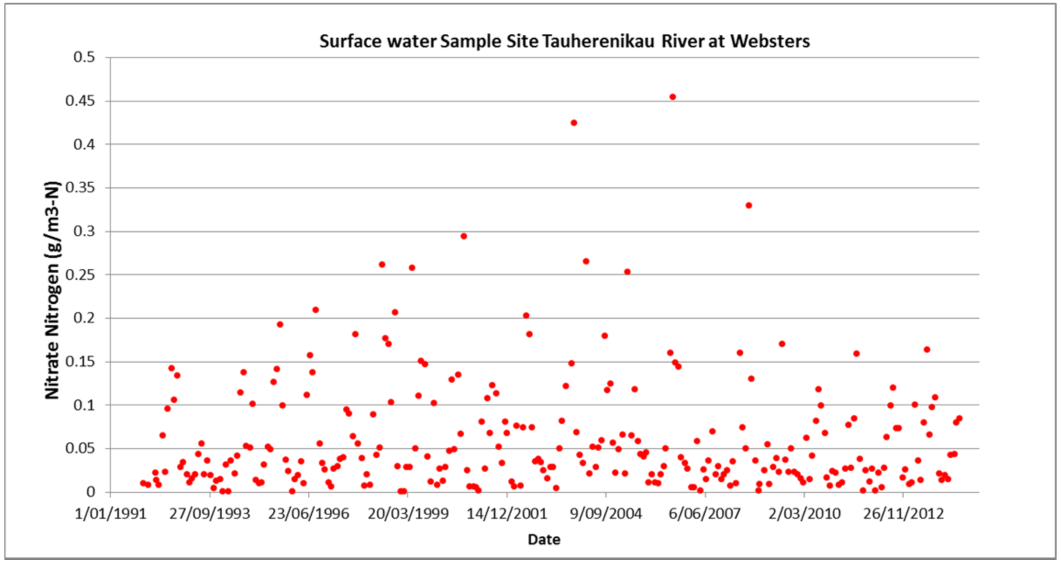

Groundwater Sample Site S26/0282
Nitrate Nitrogen (g/m3-N)
35
30
25
20
15
10
5
0
1/01/1984
27/09/1986
23/06/1989
19/03/1992
14/12/1994
9/09/1997
5/06/2000
Date

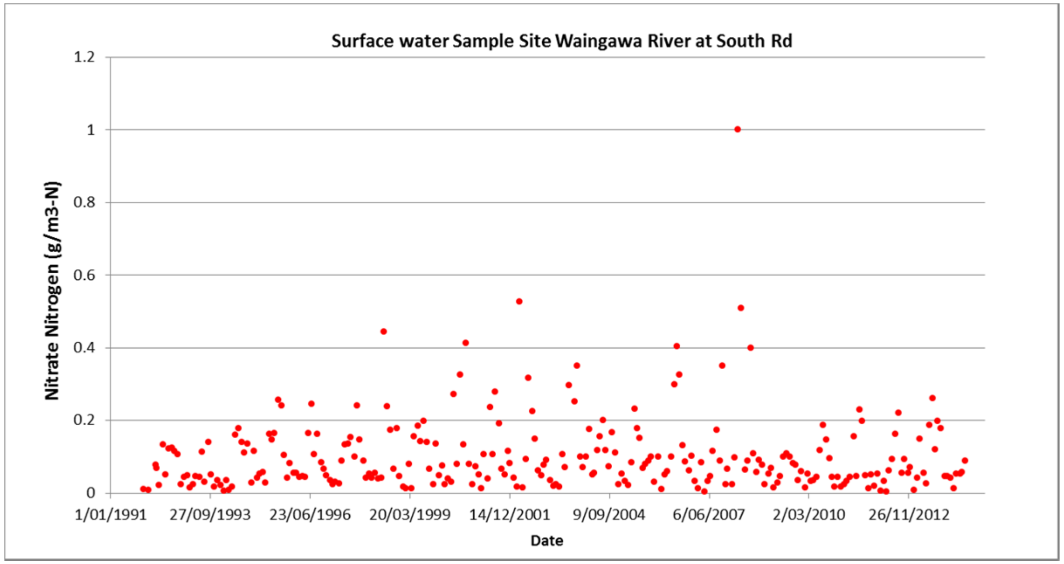

Groundwater Sample Site T26/0538
Nitrate Nitrogen (g/m3-N)
18
16
14
12
10
8
6
4
2
0
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Date


N
MASTERTON
LAKE WAIRARAPA
MARTINBOROUGH
0 5 10 20 Kilometers
Sites with nitrate concentration used for model calibration
North model sites
South model sites
North model boundary
South model boundary


N
MASTERTON
LAKE WAIRARAPA
MARTINBOROUGH
Average nitrate concentrations in streams
Nitrate_Ni
<0.002 - 0.29
0.30 - 0.76
0.77 - 1.42
1.43 - 3.25
3.26 - 4.67
Streams
North model boundary
South model boundary
0 5 10 20 Kilometers







Used 0.5 for initial condition