Our Ref: L0702617

11 June 2009

Environment Canterbury
PO Box 345
CHRISTCHURCH

Attention: Donald Fraser

Dear Donald

**VALETTA AND ASHBURTON RIVER GROUNDWATER ZONE HEARING**
***- RESPONSE TO COMMISSIONERS' RFI***

Further to the Commissioners' two requests for further information dated 12 February 2009 and 14 April 2009, we provide the attached information in reply. Would you please circulate this to the Commissioners and any other parties required.

Yours sincerely

Julian Weir
Senior Engineer

Encl

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## 1 Summary

The Valetta and Ashburton River Hearing Commissioners requested additional model runs that considered varying the original model parameters. From this work, it has been concluded that the original model parameters were the best representation of the groundwater and surface water system in the Valetta and Ashburton River zones. Any changes made to the model parameters strengthened the appropriateness of the original parameters to clearly model these zones.

## 2 Introduction

On 12th February 2009, the Commissioners for the Valetta and Ashburton River consents hearing issued a Request for Further Information (RFI). This RFI related to the groundwater modelling presented by Aqualinc Research Ltd (Aqualinc), on behalf of the Applicants, as part of hearing evidence. In the RFI, the Commissioners requested additional modelling scenarios be completed and reported along with the results from a zone budget package recently added to the FEMWATER modelling software. The additional model scenarios requested by the Commissioners primarily focus on varying the vertical hydraulic conductivity (Kz) of the model's aquitards. One set of scenarios also considers alterations to the specific yield (Sy) values for aquifer 1.

On 25th February 2009, Aqualinc wrote to the Commissioners requesting clarification of some aspects of the RFI. On 14th April 2009, a reply from the Commissioners was issued in the form of a second RFI relating to the first.

The information presented below is Aqualinc's reply to the Commissioners RFI on behalf of the Applicants. The order of information presented is similar to that of the Commissioners' RFI; results of various steady state model scenarios are presented first, followed by results from the equivalent transient model scenarios. Key points have been **highlighted in bold**.

## 3 Location of Calibration Wells

Paragraph 6.4 of the Commissioners' February RFI listed several wells for which they would like model results presented, plus other unspecified wells in the Valetta and Ashburton River zones. In the results that follow, information for all wells within the Valetta and Ashburton River zones used for model calibration are presented for each scenario completed, plus some additional wells located near to the lateral boundaries of these zones. The locations of the wells chosen for presentation herein are shown on the map in Appendix A. There are 25 wells for which specific modelling results are presented. This, in our opinion, is a reasonable number of wells to consider model results for the Valetta and Ashburton River areas.

In addition, to demonstrate the appropriateness of the model parameters for suitability of calibration, model calibration statistics are presented that combine all model calibration wells. However, results from *all* calibration wells will not be individually presented, as this has not been requested.

## 4 Model Budget Zones

For the zone budget analyses, specific model sub-zones have been chosen from which zone budget results are reported. In paragraph 6.2 of the February RFI, the Commissioners requested that zones budgets be calculated for the Valetta zone and the Ashburton River zone individually, including flows into and out of these zones from adjacent zones. Therefore, the model has been divided horizontally into four budget zones: the Valetta zone, the Ashburton zone, the remaining model north of the Ashburton zone, and the remaining model south of the Valetta zone.

In addition, each horizontal zone has been further subdivided vertically into three aquifer layers: aquifer 1, aquifer 2 and aquifers 3-5 (all combined). Aquitard 1 has been grouped with aquifer 1, aquitard 2 with aquifer 2, and aquitards 3-4 with aquifers 3-5. In all, the model has been divided into 12 budget zones (four horizontal multiplied by three vertical). These zones are presented in Appendix B.

Zone budget boundaries have been aligned as close as possible to the boundary of Environment Canterbury's (ECan's) Valetta and Ashburton River allocation zones. It is necessary for budget analysis to align the zones with model element boundaries. Therefore the boundaries of the budget zones are not precisely the same as ECan's allocation zone boundaries. However, they are similar; the Valetta model budget zone is 5% smaller than ECan's zone (53,200 ha versus ECan's 56,100 ha) and the Ashburton River zone is 6% larger (55,100 ha versus ECan's 51,700 ha). Nevertheless, the length of the boundaries between all adjacent zones are equivalent and therefore the zone budget information relating to inter-zone water movement is representative.

The southern boundary of the 'Ashburton River' zone comprises both the 'Valetta' zone and a portion of the northern boundary of the zone 'South' (Appendix B); this is the short boundary between the 'South' and 'Ashburton River' zones located inland from the top of the Valetta zone. Consequently, flows out of the 'Ashburton River' zone to the south are not the same as the flows into the 'Valetta' zone from the north, and vice versa. This inland area is where the Ashburton River first flows onto the plains and therefore there is substantial interaction between this river and the underlying aquifer system. Because of this, there is a reasonable amount of water flowing across this common boundary, even though the boundary is relatively short.

The zone budget results presented do not include any provision for the future Barhill-Chertsey Irrigation (BCI) scheme. The operation of the BCI scheme will introduce additional water into the aquifer system which will augment groundwater levels and lowland stream flows.

## 5 Model Scenarios

Paragraph 9 of the Commissioners' April RFI describes four development scenarios to be modelled. These are:

- ‘Calibration’: actual land use varying over time;
- ‘No Abstraction’: the ‘natural’ scenario – large surface water supplied schemes (e.g. RDR) have been included in this scenario;
- ‘Status Quo’: simulating the level of irrigation development as at 2006 as though it had been in place since 1967; and
- ‘Valetta and Ashburton River Consents’: the status quo scenario plus the additional takes proposed in this hearing.

Paragraph 6.1 of the Commissioners’ February RFI and paragraph 10 of their April RFI list the model runs required by varying the model parameters, as follows:

- Calibrated model parameters;
- Calibrated parameters but with aquitard vertical conductivities (Kz) increased by two orders of magnitude (i.e. 100 times larger);
- Calibrated parameters but with aquitard vertical conductivities (Kz) increased by four orders of magnitude (i.e. 10,000 times larger); and
- Calibrated parameters but with the specific yield of aquifer 1 set at 0.1 (under the calibrated scenarios, this is set at 0.01). This parameter only affects the transient model; Sy is not used by a steady state model.

Combining the above required the running of **12 steady state models and 16 transient models**. The results from each are presented below.

Further to Aqualinc’s letter of clarification dated 25 February 2009, the Commissioners agreed that sufficient information would be gained from the first 14 years of each model simulation. However, to provide 14 years of model runs, each scenario was run for the first 17 years of the simulation (1967 through to 1984) to allow for the usual 1-3 year ‘warm up’ period at the start of each simulation.

For water balance reporting purposes, the Commissioners have requested that the ‘Status Quo’ and the ‘Valetta and Ashburton River Consents’ scenarios be run for their full 40 year period, which has been done. For completeness, the ‘Calibration’ scenario has also been run for the full 40 year period.

## 6 Results from the Steady State Model Scenarios

Results from the steady state model scenarios are presented in Appendices C-F.

Appendix C summarises key results from the various steady state models under the ‘Calibration’ land use scenario. Results are presented from the three model parameter sets concurrently (that is, calibration, Kz x 100, and Kz x 10,000). Comparisons of overall model fit to long-term average measured groundwater levels (and associated calibration statistics) are presented first, followed by groundwater level comparisons for the specific wells in the Valetta and Ashburton River zones (plus nearby wells) shown in Appendix A. Lastly, zone budget information as listed in Tables 1 and 2 of the Commissioners’ February RFI is tabulated for each model parameter set, and for the Valetta and Ashburton River zones separately.

Appendix D presents the equivalent information from the 'No Abstraction' scenario set. Likewise Appendices E and F present equivalent results from the 'Status Quo' and 'Valetta and Ashburton River Consents' scenario sets respectively.

The steady state models assume that the given land use has not changed over time. However, the measured groundwater levels reflect the effects of varying recharge and discharge (including pumping) and hence are influenced by changing land use over time. In addition, the time length over which groundwater levels are measured varies from well to well (some have relatively short periods of records compared to others). Therefore, a true comparison of 'apples with apples' is not possible. The comparison between average measured groundwater levels and steady state modelled groundwater levels should be considered only as indicative, particularly for the 'Status Quo' and 'Valetta & Ashburton River Consents' scenarios. The comparisons have been specifically requested by the Commissioners.

### *6.1 Comments on the Results of Increasing Kz*

The Commissioners requested several model scenarios be completed that consider increasing the vertical conductivity (Kz) of the model aquitards. This provides an assessment of the sensitivity of these parameters to model calibration and to the prediction of effects from the proposed additional takes, particularly on lowland stream flows.

The appropriateness of higher Kz values is demonstrated by the comparison of measured and modelled groundwater levels. Under the model scenarios where Kz is 100 x larger, the model calibration is significantly jeopardised. Maximum residuals (Appendix C) increase from approximately 7 m to 89 m. The additional residual under the scenario where Kz is 10,000 x larger is only a little more (91.5 m maximum residual). This is because much of the change has occurred in the Kz x 100 scenario, suggesting that model calibration is relatively sensitive to Kz. Once model calibration is lost by increasing Kz, then further adjustments to Kz makes very little difference. **This supports the results from the original PEST sensitivity analysis** described Paragraph 103 of Julian Weir's main evidence.

As Kz increases, much more water is able to pass vertically between layers; that is, higher Kz allows a significant amount of extra water to move into the deeper layers. This results in much higher groundwater levels in the deeper (gaining) layers and lower groundwater levels in the shallower (losing) layers. **The use of Kz values that are higher than the calibrated parameters is not a realistic representation of the regional aquifer system. However, the original calibrated model Kz parameters *are* a realistic and accurate representation of the regional aquifer system.**

Comparing scenarios of increasing Kz, the smallest differences in water levels occur in wells that are located closest to the coast, or to rivers and streams. Wells located near to these features remain relatively stable due to the recharge or discharge nature of these features (hence why the minimum residuals stay relatively unchanged in all scenarios). However, further away (deeper wells and wells located more central on the plains), the regulating properties of the rivers and the coast are not as strong and groundwater levels are able to move much further due to changes in Kz.

The zone budget information presented in Appendices C-F indicate that as Kz increases, the effects of the additional pumping on lowland stream flows increases. For example, given the calibrated parameters, the 'Status Quo' (Appendix E) net discharge to streams in the Valetta zone is 0.4 $m^3$/s (3.3-2.9 $m^3$/s) and under the Valetta and Ashburton River consent scenario (Appendix F) it is the same (3.3-2.9 $m^3$/s) (i.e. there is no predicted depletion in stream flows due to the additional pumping from the Valetta zone). Under the equivalent scenarios where Kz is 100 x larger, the net status quo discharge to streams is 3.1 $m^3$/s (7.4-4.3 $m^3$/s), reducing to 3.0 $m^3$/s (7.3-4.3) with the additional takes (i.e. an overall depletion of 0.1 $m^3$/s). Similarly, under the equivalent scenarios where Kz is 10,000 x larger, the net status quo discharge to streams is 4.0 $m^3$/s (8.5-4.5 $m^3$/s), reducing to 3.8 $m^3$/s (8.3-4.5) with the additional takes (i.e. an overall depletion of 0.2 $m^3$/s).

A similar comparison of zone budget outputs for the Ashburton River zone results in a similar pattern of increasing stream depletion, these being -0.1 (i.e. a gain in stream flow), 0.1 and 0.2 $m^3$/s under the model parameter sets of calibration, Kz x 100 and Kz x 10,000 respectively.

Though stream depletion increases with increasing Kz, the overall stream depletion in the Valetta and Ashburton River zones remains relatively small in all cases, not varying significantly compared to the overall discharge to these features.

### *6.2 Observations from Zone Budget Results*

The groundwater model generally took longer to converge to a final solution (that is, to reach a new equilibrium) under the scenarios with increased Kz compared to the model with calibration parameters. This is because the groundwater gradient away from the major rivers is much steeper than in reality, which makes it harder for the model to find a solution. The overall model mass balance differences reflect this, with differences between inflows and outflows generally greater for the models with increasing Kz. Differences range from 0.7-3.5% for all scenarios, which is considered small for a regional scale model such as this.

As a general observation, increasing Kz induces more movement of groundwater both vertically between aquifers, and horizontally to adjacent zones, and an increase of discharge to the coast. This is expected.

## 7 Results from the Transient Model Scenarios

Results from the transient model scenarios are presented in Appendices G-N.

Appendix G presents time series plots of measured groundwater levels and simulated groundwater levels for each of the 'Calibration' development scenario under all four parameter sets. One plot for each of the 25 observation wells in Appendix A are presented in this appendix. These plots show how the transient model calibration varies at the locations of each observation well as a result of changing model parameters (increasing Kz and changing Sy).

Appendix H presents similar transient groundwater level plots comparing all four development scenarios modelled with calibration parameters. Appendix I, J and K compare all development scenarios with scenarios of Kz x 100, Kz x 10,000 and Sy = 0.1, respectively. When comparing these plots, care should be taken to consider the vertical axes as the scale has been changed for some wells.

Paragraph 16 of the Commissioners' April RFI requests times series plots of the water balance components indicated in Table 1 and 2 of their February RFI. These plots are provide in Appendix L for the full 40-year model simulation period. To minimise visual clutter, plots for inputs and outputs are provide for each of the Valetta and Ashburton River zones separately. The plots have been derived from model runs utilising the 'Calibration' set of model parameters only.

There is a lot of information presented in the time series zone budget plots in Appendix L. To simplify the interpretation of this information, the individual components of the water balance have been averaged over the full 40 year simulation period and tabulated, similar to the results from the steady state scenarios. These long-term average water balance components are tabulated in Appendix M. **These balances are consistent with the equivalent zone budget information presented in Figure 15 of the main evidence by Julian Weir.** There are differences, and these differences are primarily derived from differing zone budget areas and assumptions made with regard to river recharge (paragraph 166 of Julian Weir's Main evidence). Particularly, the length of coastline along which the coastal discharge is calculated by the model is shorter in the results presented in the original evidence compared to the results presented herein. Hence, the off shore discharge presented herein is larger compared to model results presented in evidence.

Paragraph 8.3 of the Commissioners' February RFI requests that updated tables for the predicted change in simulated stream flow statistics between the 'Status Quo' and the 'Valetta & Ashburton River Consents' scenarios be provided (as per Table 5 of Julian Weir's main evidence). These are provided in Appendix N for scenarios modelled using the calibrated model parameters, Kz x 100, Kz x 10,000 and Sy = 0.1. The reported statistics are all based on model runs spanning the period from 1967 through to 1984 and therefore vary from the equivalent data presented in Julian Weir's main evidence (which spans the full 40 year period). In addition, minor changes were made to the stream package (during the addition of the zone budget package to FEMWATER) to assist model run times. This will also result in slightly different stream flow statistics when compared with earlier model results, but dos not alter the validity of the model results.

### *7.1 Comments on the Results of Increasing Kz*

Regional changes in predicted transient groundwater levels as a result of changing Kz values are consistent with results from the steady state models. The predicted groundwater levels from the transient model runs that incorporate increased Kz values are significantly different in some wells than measured groundwater levels (Appendices I and J). Here, the year to year variations are similar, but the entire time series are translated vertically by several metres (or tens of metres) in deeper wells away from rivers, streams and the coast (such as K36/0436, K37/0264, K37/1457 and K37/1819). **Model calibration is severely compromised.**

Overall, the groundwater level differences between development scenarios (i.e. as a result of additional pumping) lessen with increasing Kz (Appendices H, I and J). This is because as Kz increases, the aquifer system acts more and more like a single block model (as referred to in paragraph 6 of the Commissioners' April RFI), or 'bathtub'. The effects of pumping are propagated vertically more quickly through the aquifer system and the effects of additional pumping are dispersed over a much larger column of water. Given the large differences in measured and modelled groundwater levels with increasing Kz, **the single block model theory is not valid**.

Similar to the steady state model results, the transient model results predict that lowland streams are more affected by the additional pumping as Kz increases. Again, this is expected as the effects of deeper pumping can propagate more freely to the surface. For example, the 7-day MALF for the Ashburton River (at the mouth) is predicted to change by 90 l/s between the 'Status Quo' and 'Valetta & Ashburton River Consents' scenarios given the calibration parameters (Appendix N). Under the Kz x 100 scenarios, it is predicted to changed by 257 l/s, and under the Kz x 10,000 scenarios by 231 l/s.

### *7.2 Comments on the Results of Increasing Aquifer 1 Sy*

Overall, increasing Sy in aquifer 1 reduces the variation in groundwater levels (i.e. comparing Appendix H and Appendix K). As a result, the effects from groundwater pumping are reduced, but so too are the positive effects from the net transfer of water from deeper to shallow layers. Consequently, the transient model results predict that lowland streams are more greatly affected by the additional pumping as aquifer 1 Sy increases. For example, the 7-day MALF for the Ashburton River (at the mouth) is predicted to change by 90 l/s between the 'Status Quo' and 'Valetta & Ashburton River Consents' scenarios given the calibration parameters (Appendix N). Under the Sy = 0.1 scenarios, it is predicted to changed by 162 l/s.

### *7.3 Comments on the No Abstraction Scenario*

In all scenarios modelled, predicted groundwater levels recovered to, or close to, the no abstraction level most years. This suggests that **the existing (status quo) pumping and the additional (proposed) pumping are not causing, or will not cause, a continual decline in groundwater levels.** Under increased development, groundwater levels lower further each season, but typically return to, or close to, their less developed state each year. Groundwater is not being mined.

In some shallow wells, groundwater levels are predicted to be higher than their less developed state. This is due to a net movement and recharge of water from deeper layers to shallow via irrigation.

### *7.4 Observations from Zone Budget Results*

Overall mass balance differences are small (0.3-2.6%) for the scenarios presented in Appendix M); the other transient scenarios completed have a similar range of mass balance differences. The zone budgets averaged from the transient scenario are very similar to the equivalent steady state results, with only small differences present.

Similar to the steady state models, the transient zone budget results (Appendix M) suggest that the additional proposed pumping will be rebalanced primarily by an increase in land surface recharge, and to a lesser extent by a reduction of flow offshore and to streams, and a rebalancing with adjacent aquifers and zones. This is expected. On a long-term scale, there is very little change in aquifer storage due to additional pumping, though this varies on an irrigation season basis.

### *7.5 Comments on Changes in Simulated Stream Flow Statistics*

As was concluded in the original evidence of Julian Weir, the proposed additional takes alter river and lowland stream flows slightly. However, the predicted effects are relatively small. For example, given the calibrated model parameters (Appendix N), the groundwater model predicts a reduction of 60 l/s in the Ashburton River at SH1 due to the proposed takes. This reduction equates to approximately 1.4% of the 7-Day MALF of 4.2 $m^3$/s.

Under the scenarios of Kz x 100 and Kz x 10,000, the reduction in 7-Day MALF for the Ashburton River equates to approximately 6% for both. Under the scenarios of Sy = 0.1, the reduction equates to approximately 4%.

## 8 Summary of Key Results

The following key conclusions are drawn from the additional modelling work completed in response to the Commissioners RFIs:

- The results from the modelling scenarios presented herein support the opinions and conclusions reached from the original modelling work as presented in the original evidence and Right of Reply of Julian Weir. These original opinions and conclusions have not been changed by the new modelling work. The overall scale of effects are similar and zone budget results compare well where direct comparisons can be made.

- Increasing Kz by two and four orders of magnitude significantly weakens the model calibration. The higher Kz values tend towards a single ‘bathtub’ system and do not support a realistic representation of the regional aquifer system; the original calibrated model parameters do. This, combined with accurate zone budget results, supports the conclusion that the original model calibrated parameters are realistic and the model is well calibrated.

- The modelling work and zone budget results conclude that the additional proposed pumping will be rebalanced primarily by increased land surface recharge, and to a lesser extent a reduction in stream flows, off shore discharge and interactions with adjacent zones and aquifers. On a long term scale, there is very little change in aquifer storage as a result of additional pumping.

- The modelling work predicts small changes to stream flows. For example, the proposed additional abstractions are predicted to reduced the 7-Day MALF of the Ashburton River (at SH1) by approximately 1.4%.

- Groundwater abstraction is not predicted to cause a continual long term decline in groundwater levels. At the end of each irrigation season, groundwater levels return to, or close to, the ‘No Abstraction’ state.

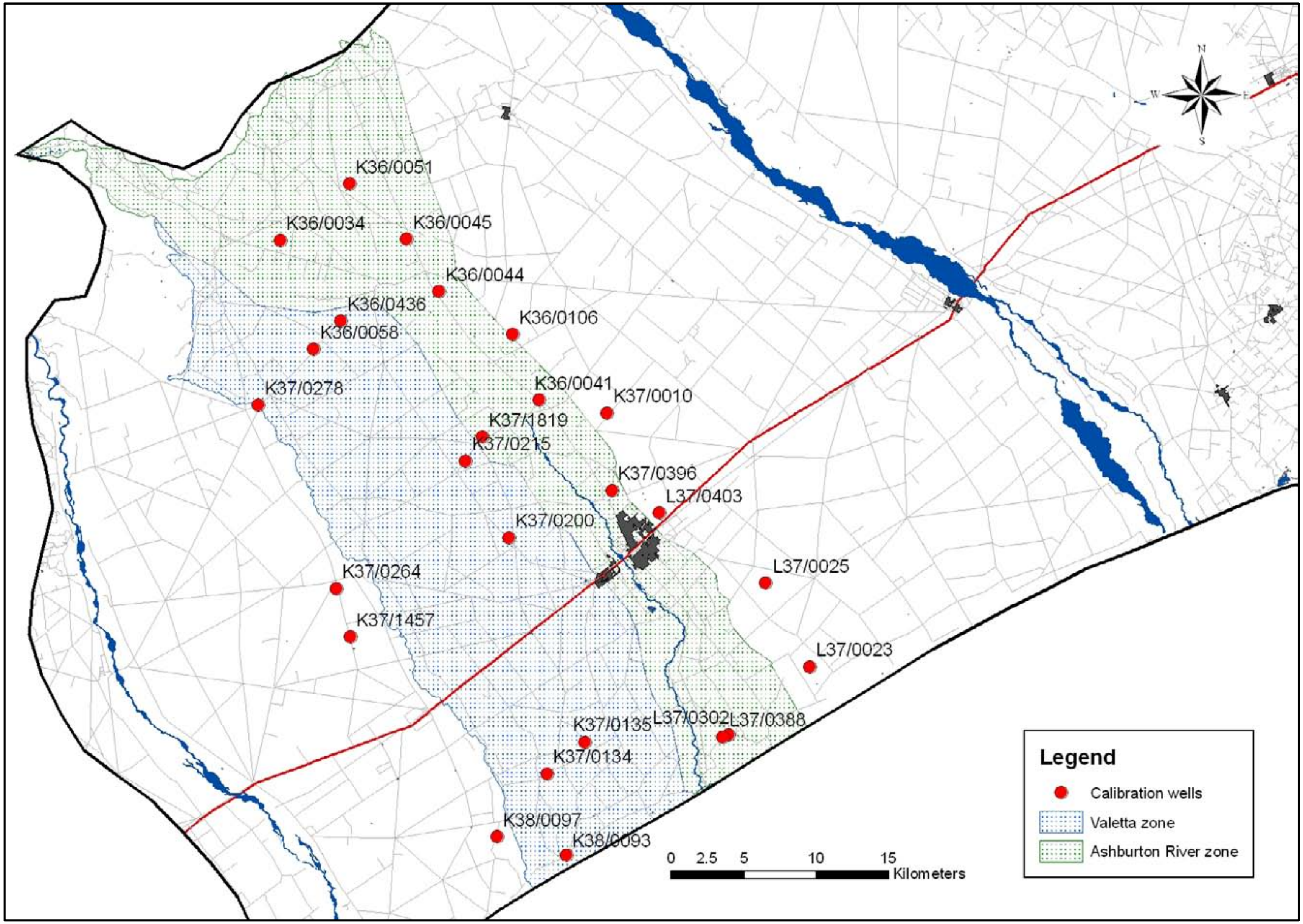
- The modelling work and zone budget information do not include any provision for the future BCI scheme. This scheme will further augment aquifer and lowland stream flows.

- Increasing Kz results in a greater effect on streams as a result of the additional proposed pumping, though the overall depletion still remains small compared to the total discharge to these features and the total flow through the aquifer system.

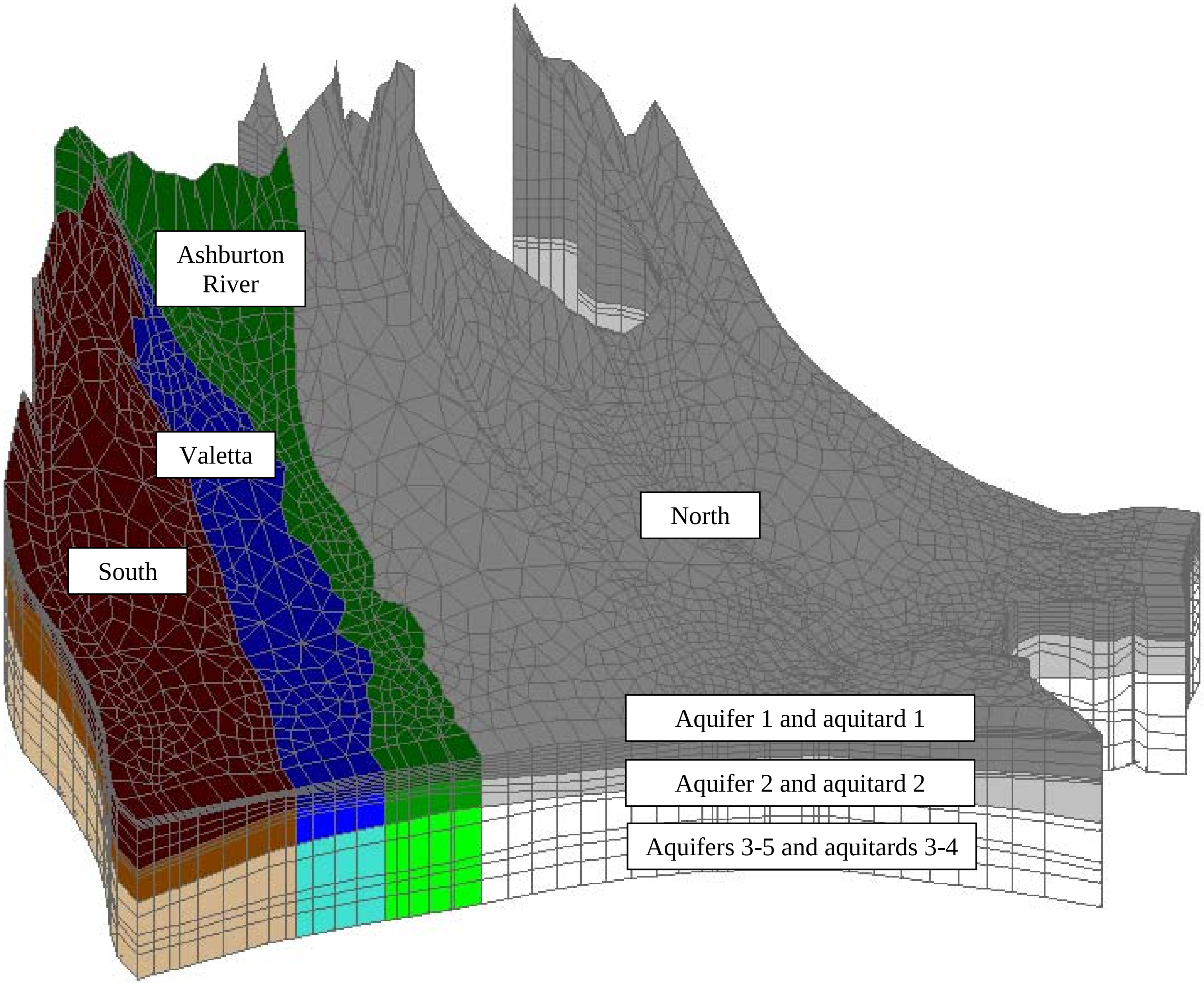
- Increasing Kz results in a reduction in seasonal groundwater level variation.

- Increasing Sy also results in a lesser variation in groundwater levels. It also causes an increase in effects on streams due to the mitigation of net recharge to shallower layers (i.e. a reduction of this positive effect).

# Appendix A: Location of Calibration Wells in the Valetta and Ashburton Rive zones

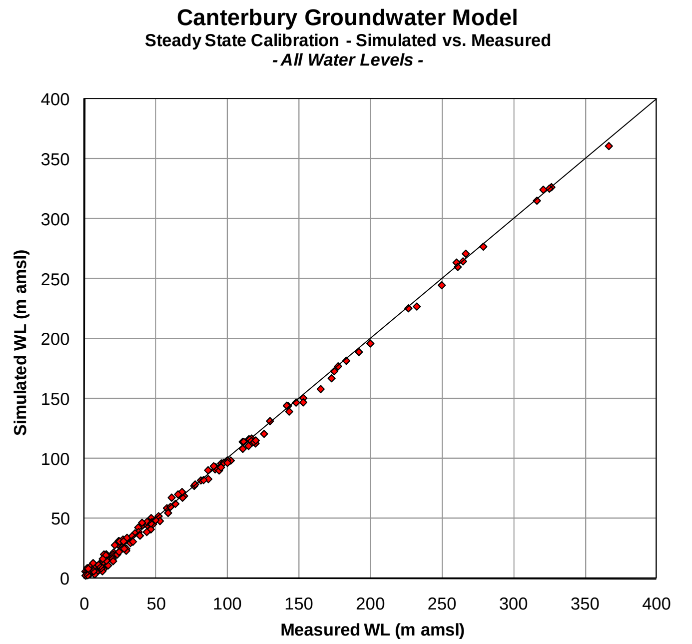

K36/0051
K36/0034
K36/0045
K36/0044
K36/0436
K36/0106
K36/0058
K37/0278
K36/0041
K37/0010
K37/1819
K37/0215
K37/0396
L37/0403
K37/0200
L37/0025
K37/0264
K37/1457
L37/0023
K37/0135
L37/0302
L37/0388
K37/0134
K38/0097
K38/0093
0 2.5 5 10 15
Kilometers
Legend
Calibration wells
Valetta zone
Ashburton River zone

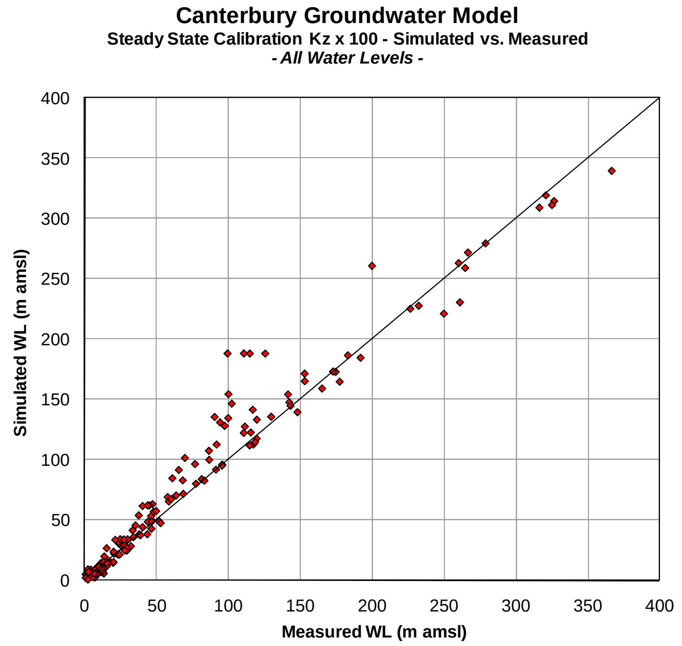
# Appendix B: Model Zones for Zone Budget Analyses

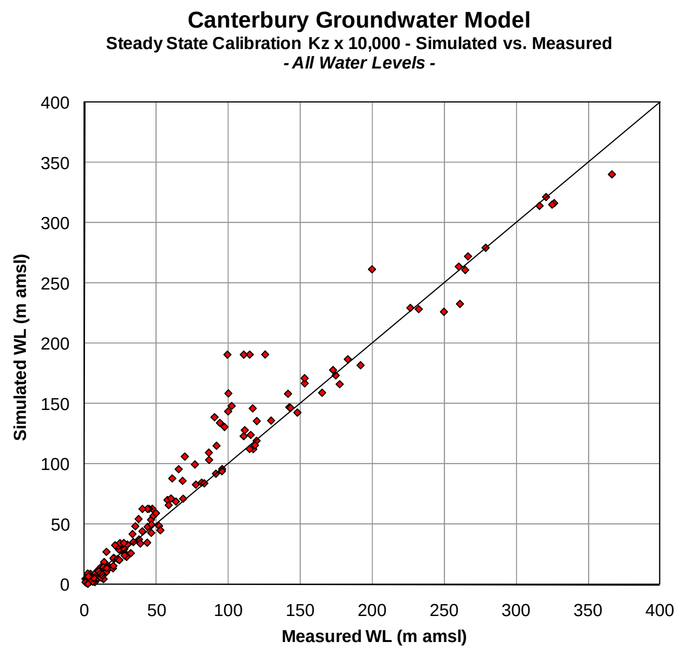

Ashburton River
Valetta
North
South
Aquifer 1 and aquitard 1
Aquifer 2 and aquitard 2
Aquifers 3-5 and aquitards 3-4

# Appendix C: Results from the Steady State Model Calibration Scenarios

# <u>*Comparison of Measured and Modelled Groundwater Levels for All Calibration Wells*</u>




| Objective function or statistic for all calibration wells | Calibration | Calibration Kz x 100 | Calibration Kz x 10,000 |
|---|---|---|---|
| Maximum residual (m) | 7.3 | 89.0 | 91.5 |
| Minimum residual (m) | 0 | 0.1 | 0 |
| Mean error (m) | -0.28 | 6.4 | 6.9 |
| Root mean square error (m) | 3.5 | 18.1 | 19.0 |
| Normalised RMS (%) | 1.0 | 4.9 | 5.2 |
| $R^2$ | 0.998 | 0.958 | 0.954 |
| Overall model mass balance difference | 0.7% | 2.0% | 2.2% |

# ***Comparison of Measured and Modelled Groundwater Levels for Specific Calibration Wells***

| Well | Aquifer / Aquitard | Avg. measured GW level (m amsl) | Calibration | | Calibration Kz x 100 | | Calibration Kz x 10,000 | |
|---|---|---|---|---|---|---|---|---|
| | | | Modelled (m) | Diff. to measured (m) | Modelled (m) | Diff. to measured (m) | Modelled (m) | Diff. to measured (m) |
| K36/0034 | Aquitard 1 | 321.0 | 324.2 | 3.2 | 319.5 | -1.5 | 321.4 | 0.4 |
| K36/0041 | Aquifer 1 | 165.2 | 157.9 | -7.3 | 159.3 | -5.8 | 159.3 | -5.9 |
| K36/0044 | Aquifer 1 | 232.4 | 226.7 | -5.7 | 227.9 | -4.5 | 228.5 | -3.9 |
| K36/0045 | Aquitard 1 | 266.7 | 270.8 | 4.1 | 272.1 | 5.4 | 272.2 | 5.5 |
| K36/0051 | Aquifer 1 | 326.6 | 326.3 | -0.3 | 314.7 | -11.9 | 316.3 | -10.3 |
| K36/0058 | Aquifer 1 | 264.7 | 264.4 | -0.3 | 259.3 | -5.5 | 260.9 | -3.8 |
| K36/0106 | Aquitard 1 | 183.1 | 181.5 | -1.6 | 186.8 | 3.7 | 187.0 | 3.9 |
| K36/0436 | Aquifer 3 | 199.9 | 195.9 | -4.0 | 261.0 | 61.1 | 261.5 | 61.6 |
| K37/0010 | Aquitard 1 | 129.7 | 131.1 | 1.4 | 135.9 | 6.2 | 136.2 | 6.5 |
| K37/0134 | Aquifer 1 | 40.1 | 44.0 | 3.9 | 44.5 | 4.3 | 44.5 | 4.4 |
| K37/0135 | Aquifer 1 | 46.6 | 50.2 | 3.6 | 50.0 | 3.4 | 49.8 | 3.2 |
| K37/0200 | Aquitard 1 | 110.6 | 113.9 | 3.2 | 122.5 | 11.9 | 123.3 | 12.7 |
| K37/0215 | Aquitard 1 | 153.1 | 150.3 | -2.7 | 165.4 | 12.3 | 167.1 | 14.0 |
| K37/0264 | Aquifer 1 | 141.5 | 144.0 | 2.5 | 154.4 | 12.9 | 158.4 | 16.9 |
| K37/0278 | Aquitard 1 | 260.3 | 263.4 | 3.2 | 263.3 | 3.1 | 263.8 | 3.5 |
| K37/0396 | Aquifer 1 | 117.3 | 113.3 | -4.0 | 112.9 | -4.4 | 112.6 | -4.7 |
| K37/1457 | Aquitard 4 | 102.3 | 98.2 | -4.1 | 146.8 | 44.5 | 148.3 | 46.1 |
| K37/1819 | Aquifer 3 | 153.0 | 146.8 | -6.2 | 171.7 | 18.7 | 171.3 | 18.3 |
| K38/0093 | Aquitard 2 | 11.2 | 13.0 | 1.8 | 14.6 | 3.4 | 14.8 | 3.6 |
| K38/0097 | Aquifer 2 | 26.1 | 27.2 | 1.2 | 28.3 | 2.3 | 28.7 | 2.7 |
| L37/0023 | Aquitard 1 | 20.3 | 21.5 | 1.1 | 23.6 | 3.2 | 22.5 | 2.2 |
| L37/0025 | Aquitard 1 | 46.4 | 40.8 | -5.6 | 43.1 | -3.2 | 43.2 | -3.1 |
| L37/0302 | Aquifer 1 | 20.4 | 19.3 | -1.1 | 22.4 | 2.1 | 21.6 | 1.2 |
| L37/0388 | Aquifer 2 | 20.0 | 19.6 | -0.4 | 24.0 | 4.0 | 22.3 | 2.2 |
| L37/0403 | Aquitard 1 | 95.5 | 92.5 | -3.0 | 95.4 | -0.1 | 94.4 | -1.1 |
| **Objective function or statistic for above calibration wells only** | | | | | | | | |
| Max. residual (m) | | | 7.3 | | 61.1 | | 61.6 | |
| Min. residual (m) | | | 0.3 | | 0.1 | | 0.4 | |
| Mean error (m) | | | -0.68 | | 6.63 | | 7.04 | |
| Rt. mean sq. er. (m) | | | 3.5 | | 16.7 | | 17.0 | |
| Normalised RMS (%) | | | 1.1 | | 5.3 | | 5.4 | |
| $R^2$ | | | 0.999 | | 0.975 | | 0.975 | |

# ***Zone Budgets for Specific Management Zones***

## *Calibration Scenario*

### Valetta Zone

***Inflows ($m^3/s$)***

| Aquifer | LSR | Rivers & streams | From coast | From aquifer above | From aquifer below | From aquifer to the north | From aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 6.3 | 3.2 | 0 | - | 7.6 | 3.6 | 6.5 | 27.2 | 860 |
| **2** | - | - | - | 8.3 | 4.6 | 2.3 | 1.5 | 16.7 | 530 |
| **3-5** | - | - | - | 4.8 | - | 1.8 | 1.8 | 8.4 | 260 |
| | | | | | | | **Total** | **52.3** | **1,650** |

***Outflows ($m^3/s$)***

| Aquifer | Abstraction | Rivers & streams | To coast | To aquifer above | To aquifer below | To aquifer to the north | To aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 0.2 | 4.1 | 7.5 | - | 8.3 | 5.4 | 1.8 | 27.3 | 860 |
| **2** | 0.2 | - | - | 7.6 | 4.8 | 2.9 | 0.7 | 16.2 | 510 |
| **3-5** | 0.1 | - | - | 4.6 | - | 2.9 | 0.9 | 8.5 | 270 |
| | | | | | | | **Total** | **52.0** | **1,640** |

Difference between inflows and outflows = 0.3 $m^3/s$ (0.6%)

### Ashburton River Zone

**Inflows ($m^3/s$)**

| Aquifer | LSR | Rivers & streams | From coast | From aquifer above | From aquifer below | From aquifer to the north | From aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 4.8 | 16.1 | 0 | - | 6.5 | 2.3 | 5.5 | 35.2 | 1,110 |
| **2** | - | - | - | 7.4 | 4.3 | 1.8 | 2.9 | 16.4 | 520 |
| **3-5** | - | - | - | 4.8 | - | 1.4 | 2.9 | 9.1 | 290 |
| | | | | | | | **Total** | **60.7** | **1,910** |

**Outflows ($m^3/s$)**

| Aquifer | Abstraction | Rivers & streams | To coast | To aquifer above | To aquifer below | To aquifer to the north | To aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 0.1 | 12.7 | 6.4 | - | 7.4 | 2.7 | 5.6 | 34.9 | 1,100 |
| **2** | 0.2 | - | - | 6.5 | 4.8 | 2.0 | 2.4 | 15.9 | 500 |
| **3-5** | 0.1 | - | - | 4.3 | - | 3.2 | 1.9 | 9.5 | 300 |
| | | | | | | | **Total** | **60.3** | **1,900** |

Difference between inflows and outflows = 0.4 $m^3/s$ (0.7%)

## *Calibration Kz x 100 Scenario*

### Valetta Zone

*Inflows ($m^3/s$)*

| Aquifer | LSR | Rivers & streams | From coast | From aquifer above | From aquifer below | From aquifer to the north | From aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 6.3 | 4.4 | 0 | - | 15.6 | 4.1 | 7.2 | 37.6 | 1,190 |
| **2** | - | - | - | 13.2 | 10 | 3.5 | 2.6 | 29.3 | 920 |
| **3-5** | - | - | - | 7.5 | - | 5.2 | 5.7 | 18.4 | 580 |
| | | | | | | | **Total** | **85.3** | **2,690** |

*Outflows ($m^3/s$)*

| Aquifer | Abstraction | Rivers & streams | To coast | To aquifer above | To aquifer below | To aquifer to the north | To aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 0.2 | 8.0 | 9.2 | - | 13.2 | 7.1 | 1.9 | 39.6 | 1,250 |
| **2** | 0.2 | - | - | 15.6 | 7.5 | 4.5 | 1 | 28.8 | 910 |
| **3-5** | 0.1 | - | - | 10 | - | 5.8 | 2.3 | 18.2 | 570 |
| | | | | | | | **Total** | **86.6** | **2,730** |

Difference between inflows and outflows = -1.3 $m^3/s$ (-1.5%)

### Ashburton River Zone

**Inflows ($m^3/s$)**

| Aquifer | LSR | Rivers & streams | From coast | From aquifer above | From aquifer below | From aquifer to the north | From aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 4.8 | 27.7 | 0 | - | 16 | 1.4 | 7.1 | 57 | 1,800 |
| **2** | - | - | - | 21.3 | 8.7 | 1.8 | 4.5 | 36.3 | 1,140 |
| **3-5** | - | - | - | 12 | - | 2.1 | 5.8 | 19.9 | 630 |
| | | | | | | | **Total** | **113.2** | **3,570** |

**Outflows ($m^3/s$)**

| Aquifer | Abstraction | Rivers & streams | To coast | To aquifer above | To aquifer below | To aquifer to the north | To aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 0.1 | 18.0 | 7.9 | - | 21.3 | 3.5 | 6.2 | 57 | 1,800 |
| **2** | 0.2 | - | - | 16 | 12 | 3.3 | 4.1 | 35.6 | 1,120 |
| **3-5** | 0.1 | - | - | 8.7 | - | 4.1 | 6.2 | 19.1 | 600 |
| | | | | | | | **Total** | **111.7** | **3,520** |

Difference between inflows and outflows = 1.5 $m^3/s$ (1.3%)

## *Calibration Kz x 10,000 Scenario*

### Valetta Zone

*Inflows ($m^3/s$)*

| Aquifer | LSR | Rivers & streams | From coast | From aquifer above | From aquifer below | From aquifer to the north | From aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 6.3 | 4.6 | 0 | - | 18.5 | 3.4 | 8.3 | 41.1 | 1,300 |
| **2** | - | - | - | 15.2 | 12.7 | 3.9 | 2.9 | 34.7 | 1,090 |
| **3-5** | - | - | - | 10.2 | - | 5.1 | 6.2 | 21.5 | 680 |
| | | | | | | | **Total** | **97.3** | **3,070** |

*Outflows ($m^3/s$)*

| Aquifer | Abstraction | Rivers & streams | To coast | To aquifer above | To aquifer below | To aquifer to the north | To aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 0.2 | 9.2 | 9.3 | - | 15.2 | 7.5 | 1.6 | 43 | 1,360 |
| **2** | 0.2 | - | - | 18.5 | 10.2 | 4.5 | 1.1 | 34.5 | 1,090 |
| **3-5** | 0.1 | - | - | 12.7 | - | 6.1 | 2.4 | 21.3 | 670 |
| | | | | | | | **Total** | **98.8** | **3,120** |

Difference between inflows and outflows = -1.5 $m^3/s$ (-1.5%)

### Ashburton River Zone

**Inflows ($m^3/s$)**

| Aquifer | LSR | Rivers & streams | From coast | From aquifer above | From aquifer below | From aquifer to the north | From aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 4.8 | 30.5 | 0 | - | 22.2 | 1.3 | 7.5 | 66.3 | 2,090 |
| **2** | - | - | - | 27.9 | 13.4 | 2.1 | 4.5 | 47.9 | 1,510 |
| **3-5** | - | - | - | 17 | - | 2.4 | 6.1 | 25.5 | 800 |
| | | | | | | | **Total** | **139.7** | **4,410** |

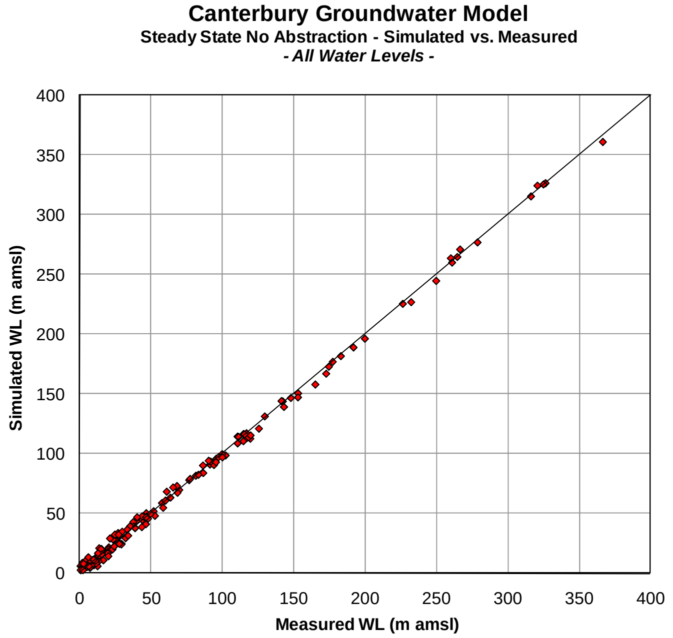
**Outflows ($m^3/s$)**

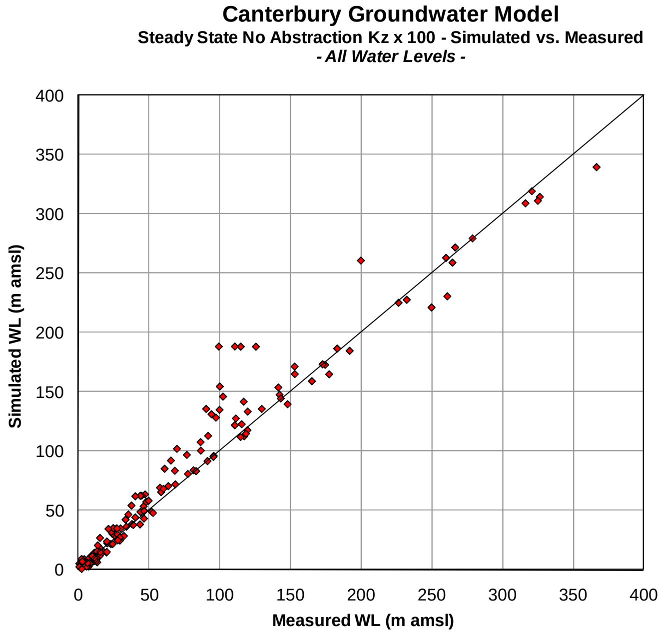
| Aquifer | Abstraction | Rivers & streams | To coast | To aquifer above | To aquifer below | To aquifer to the north | To aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 0.1 | 23.4 | 7.9 | - | 27.9 | 2.7 | 4.9 | 66.9 | 2,110 |
| **2** | 0.2 | - | - | 22.2 | 17 | 3.2 | 4.7 | 47.3 | 1,490 |
| **3-5** | 0.1 | - | - | 13.4 | - | 4.6 | 6.6 | 24.7 | 780 |
| | | | | | | | **Total** | **138.9** | **4,380** |

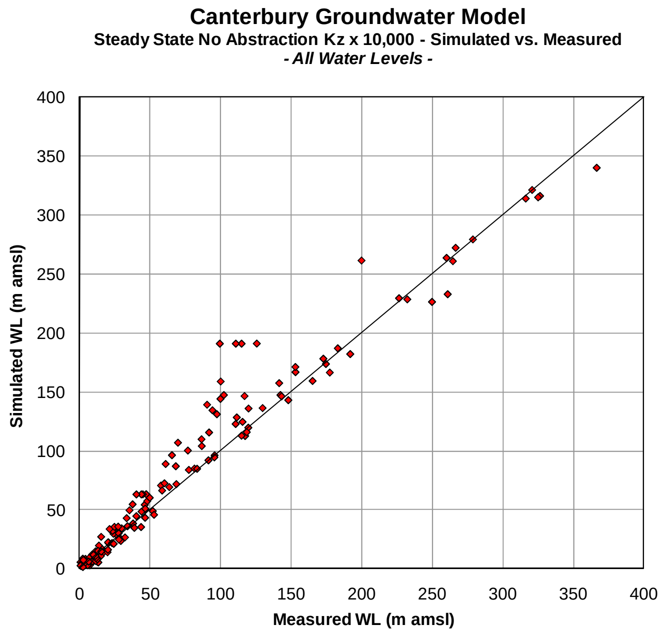
Difference between inflows and outflows = 0.8 $m^3/s$ (0.6%)

# Appendix D: Results from the Steady State Model No Abstraction Scenarios

# ***Comparison of Measured and Modelled Groundwater Levels for All Calibration Wells***




| Objective function or statistic for all calibration wells | No Abstraction | No Abstraction Kz x 100 | No Abstraction Kz x 10,000 |
|---|---|---|---|
| Maximum residual (m) | 8.0 | 89.2 | 91.5 |
| Minimum residual (m) | 0 | 0.1 | 0 |
| Mean error (m) | 0.29 | 6.63 | 7.03 |
| Root mean square error (m) | 3.6 | 18.2 | 19.1 |
| Normalised RMS (%) | 1.0 | 5.0 | 5.2 |
| $R^2$ | 0.998 | 0.957 | 0.954 |
| Overall model mass balance difference | 1.9% | 3.0% | 3.5% |

# ***Comparison of Measured and Modelled Groundwater Levels for Specific Calibration Wells***

| Well | Aquifer / Aquitard | Avg. measured GW level (m amsl) | No Abstraction | | No Abstraction Kz x 100 | | No Abstraction Kz x 10,000 | |
|---|---|---|---|---|---|---|---|---|
| | | | Modelled (m) | Diff. to measured (m) | Modelled (m) | Diff. to measured (m) | Modelled (m) | Diff. to measured (m) |
| K36/0034 | Aquitard 1 | 321.0 | 324.1 | 3.1 | 319.5 | -1.5 | 321.4 | 0.4 |
| K36/0041 | Aquifer 1 | 165.2 | 157.9 | -7.3 | 159.3 | -5.8 | 159.3 | -5.9 |
| K36/0044 | Aquifer 1 | 232.4 | 226.7 | -5.7 | 227.9 | -4.5 | 228.5 | -3.9 |
| K36/0045 | Aquitard 1 | 266.7 | 270.8 | 4.1 | 272.1 | 5.4 | 272.2 | 5.5 |
| K36/0051 | Aquifer 1 | 326.6 | 326.1 | -0.5 | 314.7 | -11.9 | 316.3 | -10.3 |
| K36/0058 | Aquifer 1 | 264.7 | 264.4 | -0.3 | 259.3 | -5.5 | 260.9 | -3.8 |
| K36/0106 | Aquitard 1 | 183.1 | 181.5 | -1.5 | 186.8 | 3.8 | 187.0 | 3.9 |
| K36/0436 | Aquifer 3 | 199.9 | 196.1 | -3.8 | 261.0 | 61.1 | 261.5 | 61.6 |
| K37/0010 | Aquitard 1 | 129.7 | 131.2 | 1.5 | 136.0 | 6.3 | 136.2 | 6.5 |
| K37/0134 | Aquifer 1 | 40.1 | 44.0 | 3.9 | 44.5 | 4.3 | 44.5 | 4.4 |
| K37/0135 | Aquifer 1 | 46.6 | 50.3 | 3.7 | 50.0 | 3.4 | 49.8 | 3.2 |
| K37/0200 | Aquitard 1 | 110.6 | 114.3 | 3.7 | 122.2 | 11.6 | 122.7 | 12.1 |
| K37/0215 | Aquitard 1 | 153.1 | 150.5 | -2.6 | 165.3 | 12.2 | 166.8 | 13.7 |
| K37/0264 | Aquifer 1 | 141.5 | 144.1 | 2.6 | 154.0 | 12.5 | 157.4 | 15.9 |
| K37/0278 | Aquitard 1 | 260.3 | 263.4 | 3.2 | 263.3 | 3.1 | 263.7 | 3.4 |
| K37/0396 | Aquifer 1 | 117.3 | 113.3 | -4.0 | 113.0 | -4.3 | 112.5 | -4.7 |
| K37/1457 | Aquitard 4 | 102.3 | 98.6 | -3.7 | 146.4 | 44.1 | 147.4 | 45.1 |
| K37/1819 | Aquifer 3 | 153.0 | 147.1 | -5.9 | 171.7 | 18.7 | 171.1 | 18.1 |
| K38/0093 | Aquitard 2 | 11.2 | 13.1 | 1.9 | 14.6 | 3.4 | 14.6 | 3.4 |
| K38/0097 | Aquifer 2 | 26.1 | 27.3 | 1.2 | 28.3 | 2.3 | 28.7 | 2.6 |
| L37/0023 | Aquitard 1 | 20.3 | 21.8 | 1.5 | 23.8 | 3.5 | 22.3 | 2.0 |
| L37/0025 | Aquitard 1 | 46.4 | 41.1 | -5.2 | 43.5 | -2.8 | 43.2 | -3.2 |
| L37/0302 | Aquifer 1 | 20.4 | 19.4 | -0.9 | 22.6 | 2.2 | 21.6 | 1.3 |
| L37/0388 | Aquifer 2 | 20.0 | 20.2 | 0.1 | 24.2 | 4.2 | 22.3 | 2.3 |
| L37/0403 | Aquitard 1 | 95.5 | 92.9 | -2.6 | 95.5 | 0.1 | 94.4 | -1.1 |

| Objective function or statistic for above calibration wells only | | | |
|---|---|---|---|
| Max. residual (m) | 7.3 | 61.1 | 61.6 |
| Min. residual (m) | 0.1 | 0.1 | 0.4 |
| Mean error (m) | -0.54 | 6.63 | 6.90 |
| Rt. mean sq. er. (m) | 3.5 | 16.6 | 16.9 |
| Normalised RMS (%) | 1.1 | 5.3 | 5.3 |
| $R^2$ | 0.999 | 0.975 | 0.975 |

# ***Zone Budgets for Specific Management Zones***

| No Abstraction Scenario | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Valetta Zone** | | | | | | | | | |
| ***Inflows ($m^3/s$)*** | | | | | | | | | |
| **Aquifer** | **LSR** | **Rivers & streams** | **From coast** | **From aquifer above** | **From aquifer below** | **From aquifer to the north** | **From aquifer to the south** | **Total ($m^3/s$)** | **Total (MCM/year)** |
| **1** | 6.1 | 3.2 | 0 | - | 7.7 | 3.6 | 6.4 | 27 | 850 |
| **2** | - | - | - | 8.2 | 4.7 | 2.3 | 1.5 | 16.7 | 530 |
| **3-5** | - | - | - | 4.8 | - | 1.8 | 1.8 | 8.4 | 260 |
| | | | | | | | **Total** | **52.1** | **1,640** |
| ***Outflows ($m^3/s$)*** | | | | | | | | | |
| **Aquifer** | **Abstraction** | **Rivers & streams** | **To coast** | **To aquifer above** | **To aquifer below** | **To aquifer to the north** | **To aquifer to the south** | **Total ($m^3/s$)** | **Total (MCM/year)** |
| **1** | 0 | 4.2 | 7.6 | - | 8.2 | 5.5 | 1.9 | 27.4 | 860 |
| **2** | 0 | - | - | 7.7 | 4.8 | 2.9 | 0.8 | 16.2 | 510 |
| **3-5** | 0 | - | - | 4.7 | - | 2.9 | 0.9 | 8.5 | 270 |
| | | | | | | | **Total** | **52.1** | **1,640** |
| Difference between inflows and outflows = 0 $m^3/s$ (0%) | | | | | | | | | |
| **Ashburton River Zone** | | | | | | | | | |
| **Inflows ($m^3/s$)** | | | | | | | | | |
| **Aquifer** | **LSR** | **Rivers & streams** | **From coast** | **From aquifer above** | **From aquifer below** | **From aquifer to the north** | **From aquifer to the south** | **Total ($m^3/s$)** | **Total (MCM/year)** |
| **1** | 4.6 | 16.1 | 0 | - | 6.6 | 2.3 | 5.6 | 35.2 | 1,110 |
| **2** | - | - | - | 7.3 | 4.4 | 1.8 | 2.9 | 16.4 | 520 |
| **3-5** | - | - | - | 4.8 | - | 1.4 | 2.9 | 9.1 | 290 |
| | | | | | | | **Total** | **60.7** | **1,910** |
| **Outflows ($m^3/s$)** | | | | | | | | | |
| **Aquifer** | **Abstraction** | **Rivers & streams** | **To coast** | **To aquifer above** | **To aquifer below** | **To aquifer to the north** | **To aquifer to the south** | **Total ($m^3/s$)** | **Total (MCM/year)** |
| **1** | 0 | 12.8 | 6.6 | - | 7.3 | 2.7 | 5.6 | 35 | 1,100 |
| **2** | 0 | - | - | 6.6 | 4.8 | 2.0 | 2.4 | 15.8 | 500 |
| **3-5** | 0 | - | - | 4.4 | - | 3.2 | 1.9 | 9.5 | 300 |
| | | | | | | | **Total** | **60.3** | **1,900** |
| Difference between inflows and outflows = 0.4 $m^3/s$ (0.7%) | | | | | | | | | |

## *No Abstraction Kz x 100 Scenario*

### Valetta Zone

***Inflows ($m^3/s$)***

| Aquifer | LSR | Rivers & streams | From coast | From aquifer above | From aquifer below | From aquifer to the north | From aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 6.1 | 4.4 | 0 | - | 15.8 | 4.1 | 7.2 | 37.6 | 1,190 |
| **2** | - | - | - | 13 | 10 | 3.5 | 2.6 | 29.1 | 920 |
| **3-5** | - | - | - | 7.4 | - | 5.2 | 5.7 | 18.3 | 580 |
| | | | | | | | **Total** | **85** | **2,680** |

***Outflows ($m^3/s$)***

| Aquifer | Abstraction | Rivers & streams | To coast | To aquifer above | To aquifer below | To aquifer to the north | To aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 0 | 7.9 | 9.2 | - | 13 | 7 | 1.9 | 39 | 1,230 |
| **2** | 0 | - | - | 15.8 | 7.4 | 4.5 | 1 | 28.7 | 910 |
| **3-5** | 0 | - | - | 10 | - | 5.8 | 2.3 | 18.1 | 570 |
| | | | | | | | **Total** | **85.8** | **2,710** |

Difference between inflows and outflows = -0.8 $m^3/s$ (-0.9%)

### Ashburton River Zone

**Inflows ($m^3/s$)**

| Aquifer | LSR | Rivers & streams | From coast | From aquifer above | From aquifer below | From aquifer to the north | From aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 4.6 | 27.6 | 0 | - | 16.2 | 1.4 | 7 | 56.8 | 1,790 |
| **2** | - | - | - | 21.1 | 8.7 | 1.9 | 4.5 | 36.2 | 1,140 |
| **3-5** | - | - | - | 12 | - | 2.1 | 5.8 | 19.9 | 630 |
| | | | | | | | **Total** | **112.9** | **3,560** |

**Outflows ($m^3/s$)**

| Aquifer | Abstraction | Rivers & streams | To coast | To aquifer above | To aquifer below | To aquifer to the north | To aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 0 | 18.1 | 7.9 | - | 21.1 | 3.5 | 6.2 | 56.8 | 1,790 |
| **2** | 0 | - | - | 16.2 | 12 | 3.3 | 4.1 | 35.6 | 1,120 |
| **3-5** | 0 | - | - | 8.7 | - | 4.1 | 6.2 | 19 | 600 |
| | | | | | | | **Total** | **111.4** | **3,510** |

Difference between inflows and outflows = 1.5 $m^3/s$ (1.3%)

## *No Abstraction Kz x 10,000 Scenario*

### Valetta Zone

*Inflows ($m^3/s$)*

| Aquifer | LSR | Rivers & streams | From coast | From aquifer above | From aquifer below | From aquifer to the north | From aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 6.1 | 4.5 | 0 | - | 18.5 | 3.4 | 8.2 | 40.7 | 1,280 |
| **2** | - | - | - | 15 | 12.7 | 3.9 | 2.9 | 34.5 | 1,090 |
| **3-5** | - | - | - | 10.2 | - | 5.2 | 6.3 | 21.7 | 680 |
| | | | | | | | **Total** | **96.9** | **3,060** |

*Outflows ($m^3/s$)*

| Aquifer | Abstraction | Rivers & streams | To coast | To aquifer above | To aquifer below | To aquifer to the north | To aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 0 | 8.9 | 9.2 | - | 15 | 7.4 | 1.6 | 42.1 | 1,330 |
| **2** | 0 | - | - | 18.5 | 10.2 | 4.4 | 1.1 | 34.2 | 1,080 |
| **3-5** | 0 | - | - | 12.7 | - | 6.1 | 2.4 | 21.2 | 670 |
| | | | | | | | **Total** | **97.5** | **3,070** |

Difference between inflows and outflows = 0.6 $m^3/s$ (0.6%)

### Ashburton River Zone

**Inflows ($m^3/s$)**

| Aquifer | LSR | Rivers & streams | From coast | From aquifer above | From aquifer below | From aquifer to the north | From aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 4.6 | 30.5 | 0 | - | 22.1 | 1.3 | 7.4 | 65.9 | 2,080 |
| **2** | - | - | - | 27.7 | 13.2 | 2 | 4.4 | 47.3 | 1,490 |
| **3-5** | - | - | - | 16.9 | - | 2.3 | 6.1 | 25.3 | 800 |
| | | | | | | | **Total** | **138.5** | **4,370** |

**Outflows ($m^3/s$)**

| Aquifer | Abstraction | Rivers & streams | To coast | To aquifer above | To aquifer below | To aquifer to the north | To aquifer to the south | Total ($m^3/s$) | Total (MCM/year) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 0 | 23.2 | 7.6 | - | 27.7 | 2.7 | 4.9 | 66.1 | 2,080 |
| **2** | 0 | - | - | 22.1 | 16.9 | 3.3 | 4.7 | 47 | 1,480 |
| **3-5** | 0 | - | - | 13.2 | - | 4.6 | 6.7 | 24.5 | 770 |
| | | | | | | | **Total** | **137.6** | **4,340** |

Difference between inflows and outflows = 0.9 $m^3/s$ (0.7%)