Enabling the Use of the Lockyer Valley Groundwater System as a Buffer in the South East Queensland Regional Water Grid – An Assessment Framework

Leif Wolf
PRW in the Lockyer

Science Forum, 19-20 June 2012
ACKNOWLEDGEMENTS

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• Queensland Water Commission
• SEQ Water Grid Manager: Barry Dennien, Dan Spiller, Brett Salisbury
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• Cia Musgrove (DERM)
• P. Shoecraft, M. Schmidt, C. Witte, B. Powell (DERM)
WHAT IS NEW THIS YEAR IN THE LOCKYER PROJECT?

• Assessment framework proposed for research adoption, ready to transfer to other areas
• One-off sampling for trace chemical contaminants to establish a baseline
• Salt flux modeling suggests future salinisation risk upcoming without PRW
• Climate change assessment suggests future need for PRW
• Infrastructure for 232 GL/a PRW already constructed
• Majority of PRW only needed in drought conditions (if Wivenhoe reservoir levels < 40%)
• Large potential to augment rural water supplies
• Up to 37 GL/a specified in the SEQ Water Strategy for irrigation in the Lockyer
Indirect Potable Reuse cycle of a coastal city with an upstream agricultural user

1. Upstream Catchment
2. Agriculture
3. Connecting River system
4. Drinking water treatment plant
5. Urban water user
6. Natural environment
7. DWTP

- Groundwater reservoir
- Surface water reservoir
### BUFFER and STORAGE

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Soil, loam, silt</td>
<td>946</td>
<td>5</td>
<td>47</td>
</tr>
<tr>
<td>Clay, silty clay, silty sand, sand</td>
<td>3027</td>
<td>7</td>
<td>212</td>
</tr>
<tr>
<td>Coarse sand, gravel</td>
<td>690</td>
<td>17</td>
<td>117</td>
</tr>
<tr>
<td><strong>Total Lockyer Alluvium</strong></td>
<td><strong>4,663</strong></td>
<td><strong>376 (+/- 30%)</strong></td>
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</tr>
</tbody>
</table>

Comparison: Wivenhoe reservoir (maximum design, **acquired area 33,750 ha**) 1165
Buffer & Storage from water table fluctuation methods

>Ca. 40 GL storage fluctuation in the Central Lockyer
## TIERED ASSESSMENT FRAMEWORK

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## Tier 1: Initial risk screening

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Sampling for pharmaceutical residues and persistent organics

- One-off sampling for 4 artificial sweeteners, 5 pharmaceuticals, 4 perfluorated compounds and 10 pesticides to establish baseline
- Proves relevant existing loading of the Lockyer Creek with wastewater components
- PRW import would likely reduce concentrations in surface water

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site Type</th>
<th>Carbamazepin</th>
<th>DEET</th>
<th>Caffeine</th>
<th>Atrazine</th>
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</thead>
<tbody>
<tr>
<td>14320787</td>
<td>Groundwater</td>
<td>4</td>
<td>&lt;5</td>
<td>&lt;10</td>
<td>&lt;5</td>
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<tr>
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<td>Groundwater</td>
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<td>&lt;5</td>
<td>&lt;10</td>
<td>&lt;5</td>
</tr>
<tr>
<td>14320782</td>
<td>Groundwater</td>
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<td>&lt;10</td>
<td>&lt;5</td>
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<tr>
<td>Gatton WWTP</td>
<td>WWTP</td>
<td>1348</td>
<td>179</td>
<td>319</td>
<td>19</td>
</tr>
<tr>
<td>Gatton Weir</td>
<td>Surface water</td>
<td>14</td>
<td>9</td>
<td>trace</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Lake Clarendon</td>
<td>Surface water</td>
<td>3</td>
<td>trace</td>
<td>77</td>
<td>10</td>
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<tr>
<td>Atkinson Dam</td>
<td>Surface water</td>
<td>&lt;1</td>
<td>21</td>
<td>78</td>
<td>&lt;5</td>
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<tr>
<td>Glenore Grove Weir</td>
<td>Surface water</td>
<td>4</td>
<td>trace</td>
<td>trace</td>
<td>7</td>
</tr>
<tr>
<td>Lake Dyer</td>
<td>Surface water</td>
<td>&lt;1</td>
<td>25</td>
<td>58</td>
<td>&lt;5</td>
</tr>
<tr>
<td>O'Reilly’s Weir</td>
<td>Surface water</td>
<td>&lt;1</td>
<td>8</td>
<td>40</td>
<td>37</td>
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## Tier 2: System understanding

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REMOTE SENSING METHODOLOGY FOR ANALYSING HISTORIC LANDSAT DATA
HISTORICAL LANDUSE CHANGES – INDICATIVE

- Bare area could vary by a factor of two
- No clear correlation to rainfall apparent
- Methodology for historic images requires more validation
Deep drainage and irrigation demand time series maps based on remote sensing landuse mapping

- Approach to predict future irrigation demand and deep drainage using HOWLEAKY/HYDRUS based on remote sensing landuse data
- Forward modelling was constrained with:
  - known sw and gw water use in Central Lockyer
  - Known gw-level evolution during 1990-2010
- Additional Outcome: Method to estimate water use in unmetered areas based on landuse data
Salt washed out  Accumulation  +/- stable  Salt washed out  +/- stable

Forest Hill
Soil Chloride (mg/kg)

Tent Hill
Soil Chloride (mg/kg)

Mulgowie
Soil Chloride (mg/kg)

Glenore Grove
Soil Chloride (mg/kg)

Gatton DPI
Soil Chloride (mg/kg)

Chloride levels in irrigation water
97 mg/L  260 mg/L  430 mg/L  29 mg/L  410

Estimate of deep drainage from SODIC’s method (Rose et al.) for non steady state solute movement
For Forest Hill profile: ~ 45 t/ha lost from top 18.3 m
Modelling mobilisation of salt from the unsaturated zone

- Numerical modeling suggests that under typical climate and irrigation conditions, salt peaks may take more than 60 years to reach the groundwater.
- If some of the measured salt peaks in the soil migrate downwards, groundwater quality is expected to deteriorate significantly (HYDRUS modeling suggests salt fluxes up to 1.1 t/h/yr).

HYDRUS unsaturated zone modeling at Forest Hill assuming a shallow rooted crop with a deep drainage rate of 68 mm/a.
Modelling mobilisation of salt from the unsaturated zone

- PRW will reduce salt fluxes if applied at similar rates: eg for the Tent Hill soil (profile B on slide 17), the salt flux reduces from 0.65 t/ha/yr (normal irrigation, 166 ppm) to 0.24 t/ha/yr (PRW), a decline of 61% during last 30 years of a 100-yr run of normal irrigation (shallow root crops).

- The thickness of the unsaturated zone varies widely in the Lockyer (typically 2-40 m), as does the salt distribution over depth. This results in a large variety of travel times.
Modelling concept

- Scenarios
  - Piping to farm gates for agriculture
  - Release and discharge only to existing reservoirs and creeks
  - Direct aquifer injection
  - Climate change

APSIM / HOWLEAKY: Simulation of Irrigation Requirements & Topsoil

HYDRUS: Simulation of water and solute transport through the entire unsaturated zone profile (20 m)

MODFLOW / MT3DMS: Simulation of water and solute transport in groundwater

IQQM: Simulation of water and solute transport in surface water systems
**Tier 3: Demand and Tradeoffs**

**Objective**
- Determine import volumes required for environmental and supply security targets
- Provide costs for delivery and substitution scenarios
- Agree on target groundwater levels / environmental goals

**Methods**
- Inverse numerical groundwater modelling with optimisation targets
- Draft design plans/ infrastructure costs, assume likely water price and multiply with volumes
- Stakeholder consultation, Multi-Criteria Analysis, Mediation
Comparing modelled demand with measured water use to generate transferable methodology

- Developed and tested two approaches for modelling of water demand and deep drainage (crop rotation vs. static crop)
- Validation with metered water use data in the Central Lockyer
- Uncovered large uncertainties in soil water balance models
- Provided time series of deep drainage maps for the entire valley as input for the groundwater model
SUPPLY SCENARIOS

- Delivery to three main reservoirs
- Delivery to farm gates
- Society decision on target groundwater levels determines amount of PRW required or conversely to determine how much is too much in terms of water logging
- Models required to calculate how much PRW is required in each month to keep water levels within a desired range
**SUPPLY SCENARIO 1**

**Delivery to farm gate**

- Farmer uses all available natural water resources
- Groundwater well dries up or allocation limit exceeded
- PRW supplied to farm gates is used (and paid for)
- Increased supply security for irrigators enables higher value crops and extended agriculture

This trigger determines:

- a) amount of PRW required
- b) environmental benefits from PRW scheme

Options to set the trigger:

- a) Well falling dry: Economic optimum for the irrigator, low requirement for PRW
- b) Definition of allocation limit: environmental optimum could be achieved, higher requirement for PRW
Improved numerical groundwater model for the Lockyer Valley

- MODFLOW-NWT to simulate the de-rating effect on pumping as the GW level falls below a certain level
- Calibration with state-of-the-art PEST SVDA-ASSIST which combines the advantages of regularisation with SVDA
- Extended calibration time period (1991 – 2011)
- 834 calibration parameters as against 276 in KBR model
- Metered water use from Central Lockyer included
- Diffuse recharge parameters (crop coefficient and lag) considered as calibration parameters
- River conductance included as parameters for calibration
Proof of concept: Calculating the demand for water import required to maintain June 1992 GW-levels...

**Comparison of rate change of PWR demand**

- Total 37.8 GL/a
- Predictive error SD = 20%

1) Setting environmental targets
2) Using custom made numerical GW-Models to calculate transient RO-water demand in each cell
3) Quantify uncertainty
4) Determine injection and substitution strategies

Moore and Wolf (2011)
HYPOTHETICAL COSTS TO MEET DIFFERENT ENVIRONMENTAL TARGETS

Proof of concept – Numbers not validated – Research ongoing!
## Tier 4: Robustness and Rules

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EIGENMODEL ANALYSIS

• The Eigenmodel Method is a two-dimensional simplification of a numerical model in which the differential equations are transformed into a mathematically similar construct of Eigenvalues and Eigenvectors.
• Was calibrated and tested for 12 bores in the Lockyer Valley, including the 2011 flood event.
• Method performed satisfactory in selected wells.

[Graph showing water level measurements with blue dots and black line, indicating blue=measured, black=modeled]
CLIMATE CHANGE

• CSIRO downscaled climate data, processed by DERM in IQQM, subsequently used by CSIRO to estimate groundwater impact using an Eigenmodel
• First Draft results, not for quotation, internal verification ongoing
• Model suggests that the 25th percentile of low groundwater levels in the historic case will be reached during 52% of the time in the medium ECHAM5 scenario for a representative bore.
The future need: Hydro-economic modelling

Accessible integration of agriculture, groundwater, and economic models using the Open Modeling Interface (OpenMI): methodology and initial results

T. Bulatewicz¹, X. Yang², J. M. Peterson¹, S. Staggenborg³, S. M. Welch¹, and D. R. Steward²
KEY MESSAGES

• Environmental risks appear as manageable.
• Water use in the Lockyer appears to have declined.
• PRW demand relies on definition of environmental goals.
• PRW demand will be highly variable in time.
• A holistic framework is required which recognizes both environmental and the economic benefit to the local community from the new high value water resource.
• Climate change may have a significant impact on the need for PRW.
• The build up of a long term drought buffer is possible.
• Groundwater modelling to quantify trade-offs was introduced as proof of concept.
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#### Tier 1: Risk screening

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- Analyse water use changes
- Quantify groundwater recharge mechanisms
- Assess risk of salt & contaminant mobilisation

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#### Tier 3: Demand & Tradeoffs

- Assess impacts of changed water pricing & water availability on future landuse
- Reassess & assess robustness and uncertainty of projections
- Devise adaptive management strategy

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#### Tier 4: Robustness & Rules
RESEARCH ADOPTION

Provision of revised groundwater model to DERM for future assessment of sustainable yield and allocation planning.

We strongly suggest a continuation of the research with a hydro-economic model and a more robust prediction of agricultural change, corresponding to Tier 3 and Tier 4 of the assessment framework, to be taken forward by QUU, Seqwater or DERM.

Use of the provided transient PRW demand profiles by Seqwater to assess impact on the supply grid.

3D Groundwater Visualisation System by QUT is already being continued and applied also to the Condamine.

Verification of the initial findings on climate change impacts.
THANK YOU!

www.urbanwateralliance.org.au