Urban-rural water exchange with Purified Recycled Water as an adjunct to groundwater resources for irrigation in the Lockyer Valley

Leif Wolf

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1) Why is augmentation of rural aquifers with PRW attractive?
2) What is a heterogenous alluvial aquifer system?
3) What are the challenges?
4) What are possible solutions?
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 catchment
HOW OFTEN AND HOW LONG IS PRW REQUIRED FOR INDIRECT POTABLE REUSE?

- Very infrequent use, drought cases not expected to exceed 4 years

SEQ Water Strategy (2010)

Figure 5.5 Simulated SEQ Water Grid levels based on historic inflows and operation at LOS system yield
Facts about the Lockyer Valley

• supplies 35% of Qld irrigated vegetables (Cox et al. 2005)
• over 40,000 hectares of the most productive horticultural soil in Qld
• estimated annual groundwater withdrawal of 46,500 ML/a (DPI 1994)
• estimated safe yields were only 27,000 ML/a (DPI 1994)
• Recent surveys indicate that current production operates at only 20 to 30% of total potential due to the poor reliability of the water supply (SEQ Water Strategy Document 2010)
• Price of 1 ML water in Australia: $1 – 20,000. In the Lockyer $30 in proclaimed areas, willingness to pay up to $200-500 (van Opstal 2010)
### BUFFER & STORAGE

<table>
<thead>
<tr>
<th></th>
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<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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Comparison: Wivenhoe reservoir (maximum design, **acquired area 33,750 ha**)

1165
WHAT IS AN HETEROGENEOUS ALLUVIAL AQUIFER SYSTEM?
PRE-DEVELOPMENT STATUS (e.g. 1930)

- No, or only very limited abstractions
- Groundwater levels are high
- Some creeks are flowing all year round because they are supported by groundwater baseflow
MODERN DROUGHT CONDITIONS

- Widespread farming
- Only limited water volumes left in the aquifer system
- Many wells fall dry or tap water with high salinity
MAJOR RAINFALL EVENT

- Creeks fill with water & recharge locally to groundwater
- Farms close to the creeks benefit most
- Recharge to remote areas is occurring only on a very small scale and with large temporal delay
Introducing purified recycled water
CONVENTIONAL PRW SUPPLY SCENARIO

Delivery of PRW to farmers gate

Use for Irrigation

Reduced demand for groundwater
Reduced demand for surface water
Increased deep drainage

Restoration of groundwater levels

Increased water availability to all farmers sited on affected aquifers

HIGH CONSTRUCTION COST!
PREFERRED SUPPLY SCENARIO

- Delivery to three main reservoirs in first stage
- Low construction costs
PREFERRED SUPPLY SCENARIO

Release of PRW to Reservoirs and Creeks
Shandying with natural water resources
Increased groundwater recharge via creeks

Direct supply to farmers connected to existing surface water network
Reduced demand for surface water
Increased deep drainage
Restoration of groundwater levels

Increased water availability to all farmers sited on affected aquifers downstream of surface water releases

e.g. Lake Clarendon, at 17% on 26/9/2010
- Increased creek recharge
- Increased irrigation & increased recharge from irrigated areas
- Asymmetric benefit distribution
AUGMENTATION IN HETEROGENEOUS SYSTEMS

• Benefits are spatially different
• Fair billing for cost recovery of common pool resource augmentation requires modelling of individual benefit
• Prediction of benefits associated with uncertainty => research of implications on decision making process
PRW CREEK RELEASE + DIRECT INJECTION

- Direct injection of PRW in areas remote from recharging creek sections
- Creating water buffers in areas where most needed
- Equal benefit distribution, manageable system
PRW TOP UP – LATE STAGE

- Agriculture to full extent
- Sufficient water availability to all farmers in the region
- Creeks receive baseflow again
- Risk for Brisbane River from the infiltration of poor quality groundwater (elevated salinity & nitrate)
MANAGEMENT CHALLENGES

• COMMON POOL RESOURCE: How to quantify?
• SOIL IMPACTS: what are the impacts of applying different quality water on the Lockyer soils, to creeks and on aquifer materials
• SALT: is mobilisation of salts in the unsaturated and saturated zones expected?
• MANAGED AQUIFER RECHARGE: is there potential for direct aquifer recharge using injection wells?
• **TIME:** Water in the Lockyer may require between 10 and 100 years to reach from the surface to the groundwater.

• **INTENSE FARMING:** Crops in the Lockyer change very fast (down to just 12 weeks per crop)

• **GEOMETRY:** The Lockyer Valley alluvial aquifer is very heterogeneous

• **DATA:** Only limited information on groundwater use available outside the proclaimed areas
NUMERICAL GROUNDWATER MODELS

USE OF GW MODELS: EXAMPLE KBR 2002

- Salt mobilisation from ongoing irrigation, but ceased pumping
- Model predicted migration of salt out from Sandy Creek tributary

Scenario 4 - no Sandy Creek groundwater pumping
Observed rise in electrical conductivity confirmed by modelling

- Bore 14320542 (500m south of Forest Hill)
Valley wide numerical groundwater flow & transport model, now updated to 2010

Pros:
- Covers entire area
- Includes solute/salt transport
- Time series up to 2010

Cons:
- Uncertainty of pumping rates and gw recharge
- Requires new calibration

Sensitivity to 20% error in abstraction rate
VALIDATION

- Groundwater model was updated, but not calibrated (e.g. no fitting to data)
- Good assessment opportunity of performance
- Model performed well in some cases, but significantly over-predicted water levels in many cases
- Major cause: insufficient implementation of metered pumping data + differences in groundwater recharge
Need for updated modelling of groundwater recharge processes
UNSATURATED ZONE MODELLING

3 Crop types + Rotation

2 Sites; different soil types (root zone)

3 different soil types (below root zone)

15 – 25 m

Evapotranspiration

Rainfall

Irrigation

Root zone

Deep drainage

Time lag

Recharge

Groundwater

APSIM/HOWLEAKY

HYDRUS
TRAVEL TIMES & PULSES

- Time lag between rain events and groundwater recharge is **6 months – 16 years**.
- Salt travel times across the 20 m unsaturated zone were modelled between **7 years and 371 years**.
EFFECT OF CROP TYPE ON RECHARGE

- 3 different crops on a sandy loam
- Recharge rates modelled between 23 mm/a and 400 mm/a
- Crop type has **overriding influence on deep drainage** volumes compared with soil type or unsaturated zone thickness
Need to know crop patterns and landuse for the last decades
Landuse mapping based on satellite imagery

Step 1: Ground truthing sites on raw Landsat Thematic Mapper image (30m pixel resolution)
Landuse mapping based on satellite imagery

Step 2: Classification

Can we turn that into a time series for the last twenty years?

Use: Irrigation water requirements in unmetered areas & Deep drainage estimates

Classification algorithm trained with 130 image samples across 51 field sites
FIELD WORK

- Geoprobe coring
- Water sampling
- Soil dispersion tests
- Soil column tests
- Ground truthing for remote sensing
- Geophysical profile lines
FIELD WORK

- Soil column / Dispersion sample sites
- Ellis drilling sites
- Geoprobe sites 2010
- Water sample sites

Map showing locations related to the field work around Lake Clarendon, Lake Dyer, Gatton, Forest Hill, Laidley, and other towns and regional features.
Geoprobe cores taken at Forest Hill on Blenheim and Lockyer soils
Every plot has history and remembers salt for a long time:
50 years of cropping reconstructed for a site in Forest Hill
Forest Hill
Ellis sites revisited
-12 year change in soil EC and Cl
-Irrigation water change
(from bore to surface water application)

Ideal data set for validation of long term models!
RISKS OF REVERSE OSMOSIS WATER TO SOIL

- Documented problems with application of desalinated wastewater to soils in Israel and Australia
- Significant amounts of swelling clay minerals in the Lockyer present
- High Na⁺ adsorption by the soil and low electrolyte concentration in the soil solution may lead to significant swelling, dispersion and soil crust formation
- No SAR (Sodium Adsoption Ratios)-Values of PRW were published
SOIL DISPERSION TESTS

PRW  GW  GW  SW  De-ion

Water samples for soil dispersion tests.
SOIL COLUMNS & DISPERSION TESTS

- Undertaking soil column tests with PRW (5 columns running)
- So far no violation of drinking water guideline values for PRW operated soil columns with regard to heavy metals
- 5 soil types tested with 4 different water qualities
- Contrasting results from different test methods. Waiting for results from X-ray diffractometry
- No spontaneous dispersion of major soil types upon addition of PRW, most likely low risk, **but test series ongoing**
SUMMARY (after nine months)

- Groundwater Visualisation System developed with documentation
- Existing groundwater models assessed for fit-for-purpose. Valley wide groundwater model for risk assessment updated to 2010
- Deep coring and analysis of soil and salt profiles performed. Excellent opportunity to compare with 1998 campaign
- Unsaturated zone models used for sensitivity studies of deep drainage and salt transport
- Cropping pattern information acquired
- Remote sensing methodology tested
- Soil dispersion from PRW assessments started
Q: How to manage benefits for individual users from the augmentation of a natural common pool resource?

A:
- Provide sound definition of spatially varying sustainable yield in the base case
- Extend the current metering program
- Extend the monitoring program
- Update the available groundwater modelling
- Investigate the impact of model uncertainty on real world water management: Is it necessary to know with high precision?
FUTURE WORK

- Joint effort with DERM and QWC is planned to upgrade the available models for **sustainable yields estimation**
- Quantify **impacts of uncertainty** on management methodologies for the common pool resource augmentation
- Extend the **deep soil coring** activities to document changes in soil salinity over the last 12 years
- Validate **models for salt transport** triggered by additional irrigation with PRW
- Using the numerical groundwater models, **positions and injection rates for direct injection wells** need to be evaluated
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Urban Water Security Research Alliance

THANK YOU

www.urbanwateralliance.org.au