Water Sensitive Outcomes for infill developments (IRP4)
Overview of project
8 March 2018, Perth

Steven Kenway, Nigel Bertram, Geoffrey London, Marguerite Renouf and Project Team
Infill

- Significant infill expected (up to 94% of development).
- More runoff and adverse impacts on flooding, evapotranspiration, and livability.
- Hotter, less shade, more air-conditioning and energy
- Inadequate performance basis to current processes.
- Limited new design options and limitations to current governance arrangements.

R50  2675m²  11 dwellings

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Photo Source: Geoffrey London Presentation
(1) Develop a performance framework to understand infill impacts.

How can performance be defined, measured and assessed? What is the impact on hydrology, heat/energy, and liveability of new design options? What are key risks? How can “best” or “optimal” solutions be found and “move the needle”?

(2) Inform design tools, processes and typologies through engagement with real projects (case studies)

What housing/development typologies enable best outcomes? What information is critical for solutions? What technologies (eg traditional and new water sources) are best suited for different typologies and scales?

(3) Identify improved governance options / arrangements.

What governance arrangements work (or fail) and how can greater success be achieved through new measures?
Some background….Tranche 1

• What is urban water “mass balance” and “metabolism”?

• Outputs and outcomes of T1:
  1. Evaluation framework.
  2. Clarity of the ‘entity’ – the system boundary.

• Stakeholder feedback.

• Implications for integrating into WSC values and planning.
Research outputs

1. Justification for our conceptual framework (urban metabolism) and method (water mass balance)

   Problem: Lack of clarity about the role of various evaluation approaches for understanding urban water issues

   Question: How can evaluation approaches advance urban water management goals at the macro scale?

2. Concept for an urban metabolism evaluation framework

   Problem: Lack of frameworks and methods for evaluating urban water performance at macro urban scales (city-region)

   Question: Is it possible to construct an evaluation framework that quantifies the water metabolism of a city-region to support planning?
3. Pilot application of the concept to a case study urban development (Ripley Valley)

Problem: Not clear if alternative water servicing options can deliver desired outcomes for the ‘whole urban area’, considering both the managed and natural water cycles, as well as energy.

Question: What new insights about water servicing options does urban water metabolism evaluation provide?

4. Indicators of urban water metabolism

Problem: Lack of indicators that adequately quantify how well urban areas are progressing towards the urban water management visions.

Questions:

What is an ideal set of water metabolism indicators?
How can they be quantified from an urban water mass balance?
5. City-region application

*Problem:* The need to create a holistic picture of urban water management at the city-region scale to help identify water management and urban planning innovation.

‘We lose sight of the forest when we focus on the trees’

*Question:*

How can we characterize the water metabolism of city-regions?

What can it tell us about future opportunities for urban water management in Australian city-regions?
6. Metabolism for connecting land-use and water planning

**Problem:** There is disconnection between urban planning and water planning, which is a barrier to how we can plan city-regions for better water outcomes

**Question:** How can the concept of urban metabolism evaluation can help with integrated water and urban planning?

7. Metabolism knowledge needs of planners

**Problem:** Planners don’t have urban water performance information available to them in a way that can inform policy formulation and decision making

**Question:** What knowledge (information and metrics) should urban water metabolism evaluation generate to inform water sensitive urban and regional planning?
8. Communication of the urban metabolism

Problem: Metabolism information is not presented in meaningful ways, which is a barrier to its communication

Question: How has urban metabolism been interpreted and communicated?

9. Water-related energy

Problem: Heat recovery potential of grey water has not been adequately evaluated

Questions:

Will consideration of the heat recoverable from greywater reuse improve its viability?
<table>
<thead>
<tr>
<th>No.</th>
<th>Milestone/deliverable description</th>
<th>Lead</th>
<th>Due date</th>
<th>Work package</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water mass balance screening tool, used for case study (Beta)</td>
<td>SK</td>
<td>June 2018</td>
<td>WP5</td>
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<tr>
<td>2</td>
<td>Design typologies (catalogue/options)</td>
<td>NB/GL</td>
<td>Sept 2018</td>
<td>WP2</td>
</tr>
<tr>
<td>3</td>
<td>Infill performance evaluation framework (draft)</td>
<td>MR/SK</td>
<td>Dec 2018</td>
<td>WP3</td>
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<tr>
<td>4</td>
<td>Final Landscape design options for modelling case study 1</td>
<td>NB/GL</td>
<td>Sept 2018</td>
<td>WP4</td>
</tr>
<tr>
<td>5</td>
<td>Evaluation of infill projects in accordance with end-user agreed framework have commenced.</td>
<td>MR/SK</td>
<td>Sept 2018</td>
<td>WP5</td>
</tr>
<tr>
<td>6</td>
<td>Evaluation framework for infill projects is agreed by end-users.</td>
<td>MR/SK</td>
<td>Mar 2019</td>
<td>WP3</td>
</tr>
<tr>
<td>7</td>
<td>Evaluation of infill projects with end-user agreed framework is completed.</td>
<td>MR/SK</td>
<td>Sept 2019</td>
<td>WP5</td>
</tr>
<tr>
<td>8</td>
<td>Report on infill projects publically released</td>
<td>MR/SK/Team</td>
<td>Mar 2020</td>
<td>All</td>
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<tr>
<td>9</td>
<td>Final project report</td>
<td>MR/SK/Team</td>
<td>Sep 2020</td>
<td>WP1</td>
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</table>
Research Team

University of Queensland

- **Project leader**
  - Jurg Keller

- **Deputy project leader**
  - Marguerite Renouf

  - Marie-Laure Pype (Postdoc)

  - Ka Leung Lam (RA)

  - Beata Sochacka (RA/PM)

  - Xuli Meng (master student)

  - Bosco Chow (master student)

  - Owen Hoar (master student)

Monash University

- **Lead design researcher**
  - Nigel Bertram

  - Oscar Sainsbury

- **Lead microclimate researcher**
  - Nigel Tapper

  - Stephanie Jacobs

  - Linkage to TAP project
    - Christian Ulrich

  - Linkages to other projects nationally
    - Peter Newton (Swinburne University)

University of Western Australia

- **Lead design and governance researcher**
  - Geoffrey London

  - Daniel Martin

PhD Students – Mojitaba Moravej (UQ (IRP4))/Monash (TAP)
# Steering Committee

<table>
<thead>
<tr>
<th>Person</th>
<th>Organisation</th>
<th>Contribution/role*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mellissa Bradley</td>
<td>Water Sensitive SA</td>
<td>Chair of Steering/Participating Committee. Local case study/ies, garner local support.</td>
</tr>
<tr>
<td>Geoffrey London</td>
<td>The University of Western Australia</td>
<td>Project Researcher (Lead Design, Options Governance aspects, case studies).</td>
</tr>
<tr>
<td>Nigel Bertram</td>
<td>Monash University</td>
<td>Project Researcher (Lead Design, Options, Governance aspects, case studies).</td>
</tr>
<tr>
<td>Peter Newton</td>
<td>Swinburne University, Victoria</td>
<td>Connect to other work nationally. (Infill specialist research advice).</td>
</tr>
<tr>
<td>Phil Young</td>
<td>Brisbane City Council, Qld</td>
<td>Local case study/ies, garner local support.</td>
</tr>
<tr>
<td>Sadeq Zaman</td>
<td>Inner West Council, NSW</td>
<td>Local case study/ies, garner local support.</td>
</tr>
<tr>
<td>Nigel Corby</td>
<td>City West Water, Vic</td>
<td>Local case study/ies, garner local support.</td>
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<tr>
<td>Greg Ryan</td>
<td>LandCorp, WA</td>
<td>Local case study/ies, garner local support.</td>
</tr>
<tr>
<td>Nigel Tapper</td>
<td>Monash University</td>
<td>Local case study/ies, garner local support.</td>
</tr>
<tr>
<td>Pam Kerry</td>
<td>South East Water, Vic</td>
<td>Local case study/ies, garner local support.</td>
</tr>
<tr>
<td>Steven Kenway</td>
<td>The University of Queensland</td>
<td>Project Leader. Framework development, options analysis and performance quantification, case studies.</td>
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<tr>
<td>Lisa McLean</td>
<td>Flow Systems, NSW</td>
<td>Local case study/ies, garner local support.</td>
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<tr>
<td>Cintia Dotto</td>
<td>Water Technology, Vic</td>
<td>Local case study/ies, garner local support.</td>
</tr>
<tr>
<td>Nicholas Temov</td>
<td>Department of Planning, WA</td>
<td>Local case study/ies, garner local support.</td>
</tr>
<tr>
<td>Matt Stack</td>
<td>Department of Planning, WA</td>
<td>Local case study/ies, garner local support.</td>
</tr>
<tr>
<td>Marguerite Renouf</td>
<td>The University of Queensland, Qld</td>
<td>Deputy Project Leader, Project Researcher (performance framework, modelling analysis), engagement.</td>
</tr>
<tr>
<td>Andrew Allen</td>
<td>City of Manningham</td>
<td>Local case study/ies, local support</td>
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</table>
Urban metabolism and infill development

Next-generation performance-based criteria and guidelines.
Water Balance and Water Sensitive Urban Design
(Water by design)
The water mass balance

\[ Qi = Qo + \Delta S \]

(For a given boundary and specified time period)

Urban water metabolism evaluation framework

.. water mass balance example

- Quantifies managed and natural water flows (performance)
- Requires a defined boundary of the “city-entity”
- Includes a city water balance and a city water budget

\[ C + D + P = W + R_s + G + ET + \Delta S \]

Storages outside the urban entity

How can we evaluate urban water metabolism?

**Mass balances of water-related resource flows**

- **Precipitation (unharvested)** (P)
- **Evaporation (ET)**
- **Decentralised supply - harvested precipitation (Dp) and stormwater (Ds)**
- **Centralised supply (C)**
- **Groundwater infiltration (G, N_d)**
- **Recycled wastewater and stormwater - internal (Ri, N_ci)**
- **Recycled wastewater and stormwater - external (Re, N_Re)**
- **Surface water stores outside the urban boundary**
- **Stormwater runoff (SW)**
- **Wastewater (WW, N_ww)**

**Performance indicators**

- Restoration of natural hydrological flows
- Water supply internalization / decentralization.
- Functionality of water
- Resource efficiency
  - Water use efficiency

**Water Mass Balance**

\[
\text{Sum of water inflows} = \text{Sum of water outflows} + \text{change in storage} = (P + C + D + Ri) = (ET + SW + WW + G + Ri + Re) + \Delta S
\]

Want to know more?
How can we evaluate urban water metabolism?

Mass balances of water-related resource flows

Water Mass Balance
\[
\text{Sum of water inflows} = \text{Sum of water outflows} + \text{change in storage} \\
(P + C + D + Ri) = (ET + SW + WW + G + Ri + Re) + \Delta S
\]

Water-related Energy
\[
\text{Total energy use} = E_C + E_D + E_{WW} + E_{SW} + E_{Re} + E_{Re}
\]

Water-related Nutrient Balance
\[
\text{Sum of nutrient inflow} = \text{Sum of nutrient outflow} \\
(N_{Wi} + N_{ri}) = (N_{WW} + N_{Re} + N_{Re})
\]

Want to know more?
Urban water metabolism evaluation framework (UMEF) for water

Want to know more?


# Metabolism performance indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Description</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban water efficiency</td>
<td>Total external water use per capita per year (kL/capita/yr)</td>
<td>( \frac{C}{Population} )</td>
</tr>
<tr>
<td>Water supply internalisation</td>
<td>Proportion of total urban water demand met by internally harvested / recycled water</td>
<td>( \frac{D + Re}{D + Re + C} )</td>
</tr>
<tr>
<td>Hydrological performance</td>
<td>Ratio of post- (i) to pre-urbanised (o) annual flows of stormwater runoff (SW), evapotranspiration (ET), and groundwater infiltration (G)</td>
<td>( \frac{SWi}{SWo} ), ( \frac{Gi}{Go} ), ( \frac{ETi}{ETO} )</td>
</tr>
</tbody>
</table>
What is the ‘urban entity’ we are evaluating?
System boundaries - SEQ

- Assess mass balance in context of region.
- Delineate urban area and supporting region.
- Urban = residential, commercial, manufacturing, industrial, public services, utilities.
- Peri-urban = Rural residential.
Screening of Water Sensitive Opportunities applied to city-regions
## Water metabolism indicators aligned to urban water management objectives

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Indicator</th>
<th>Can Do?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Resource efficiency</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Overall urban water efficiencies</strong></td>
<td>total residential use of ‘environmental’ water per person per year</td>
</tr>
<tr>
<td></td>
<td><strong>Energy for urban water</strong></td>
<td>Energy input to urban water system</td>
</tr>
<tr>
<td></td>
<td><strong>Nutrient recovery from urban water</strong></td>
<td>proportion of the nutrient load in wastewater that is beneficially utilised</td>
</tr>
<tr>
<td></td>
<td><strong>Water supply internalisation</strong></td>
<td>proportion of water demand met by harvested / recycled water</td>
</tr>
<tr>
<td></td>
<td><strong>Hydrological performance</strong></td>
<td>post-urbanised hydrological flows/fluxes relative to pre-urbanised flows/fluxes</td>
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<tr>
<td></td>
<td><strong>Regional pollutant stress index</strong></td>
<td>point-source and diffuse nutrient loads discharged to waters relative to sustainable discharge rates</td>
</tr>
<tr>
<td></td>
<td><strong>Functionality of water</strong></td>
<td>water needed to maintain desired functions relative to water budgeted for the functions</td>
</tr>
</tbody>
</table>

## Visions for urban water management
- IWA’s Water Wise City
- Water Sensitive Cities
- ABD’s Asian water development outlook
- UK Water Partnership
- Singapore’s ABC program
- China’s Sponge City program

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New Report
Urban metabolism application

https://watersensitivecities.org.au/content/urban-metabolism-for-planning-water-sensitive-city-regions/

Potential to meet centralised demand from Current use of available resource

<table>
<thead>
<tr>
<th></th>
<th>Rainfall</th>
<th>Wastewater</th>
<th>Stormwater</th>
<th>Rainfall (D/P)</th>
<th>Wastewater (Re/W)</th>
<th>Stormwater (Re(s)/Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melbourne</td>
<td>384%</td>
<td>81%</td>
<td>127%</td>
<td>0.5%</td>
<td>7%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Water use: Res 67%, Non-res 23%, Unacc 10%
Feedback.…

• “Good for bringing multiple water sector stakeholders together. Particularly stormwater and centralized water.” (I.C.C.).

• “Helps identify points of waste and is good for options screening. Good for big picture, strategic assessment, and setting city targets.” (B.C.C. – City Design).

• “Helps give meaning to myriad current indicators.” (B.O.M.).

• “We need to measure the impact of stormwater harvesting programs against the whole system in order to appreciate how effective they will be.”

• “Critical for identifying where the water cycle impacts on energy and nutrient by creating a foundation balance.”
Implications for integrating into WSC values for urban planning, and operationalising

- Embedding in regional/local planning processes, national reporting and data systems, creates a driver for WSC.
- Gives evidence for integrated planning and system/city management, and fills a current gap of lack of performance quantification of “the city”.
- Can be used to shape long-term city and/or precinct / suburb, or catchment goals.
- Boosting local and national capacity for analysis (government, utilities, B.O.M.,) will be needed.
- Build on to create multi-faceted outcomes including energy and nutrient management in the city.
CRC-funded Urban Climate Research Program: key research questions and approach Tranche 1

- How effective are storm water harvesting technologies, tree cover, green infrastructure and water sensitive urban design (WSUD) in improving urban climates at a range of scales?
- What are the key configurations required to reduce temperatures, save lives under heat wave conditions and enhance human thermal comfort and liveability?

What learnings/tools from Tranche 1 might be applied to Tranche 2 IRP4?
Role of water and green infrastructure

Reduce local-scale air temperature

Reduce micro-scale air temperature and radiant temperature

Improve human thermal comfort

Scale of approach

Limit heat-health impacts

Coutts, Tapper, Beringer, Loughnan, Demuzere (2013)
Development Typologies

A. Suburban lot subdivision
   Building as usual backyard redevelopment model

B. Small infill combination
   Small co-op’s of neighbours and ‘like’ minded combinations of residents and occupants on small to medium scale lots (possibly amalgamated)

C. Block infill site + courtyard model
   Medium scale developments (with additional public value)

D. Suburban precinct
   Dispersed precinct in suburban residential setting

E. Mixed-use precinct
   Larger scale mixed use development or redevelopment within a structure plan

F. Employment cluster
   Large dispersed cluster of amenities and employment opportunities within a state government framework (often too big to be in structure plan)

G. Major urban renewal
   Large high density urban development sites designated for large population and employment opportunities, (often scrape and rebuild)

Typologies and design....illustrative

How do we “shift” knock-down rebuild to more sustainable precincts

Base Source figure: Nigel Bertram
Case studies

Illustrative success – **criteria** for water-sensitive infill:

- Hydrological performance etc (including heat)
- Increase in density (economic aspect)
- Increase in diversity (social aspect)
- Space for water and big trees (environmental aspect)
- Upgrade in technology (technological aspect)

• How does the site contribute to the precinct to make it sustainable? And vice versa? What is it that is being contributed and how?

Three well positioned and endorsed by Committee to progress to next level:

• Adelaide – City of Salisbury
• Perth – Knutsford/Hamilton Hill
• Brisbane – Norman Creek/Coorparoo (Site visit Nov 2017).

Co-investment/co-contribution discussions occurring.

Site visit and workshops 6-8 March 2018
Focus of various researchers in IRP4...

(illustrative/w.i.p.)

Stephanie Jacobs (climate), Oscar Sainsbury (Design), Bosco Chow (Wastewater technologies) .....
Publications / Further reading

Research outputs – conference papers, presentations, podcasts, tools.

• Three high quality Masters Students final projects and reports (Communication of metabolism, Implications of scale for grey water analysis).
• Plenary presentation: An integrated urban water cycle as the key to minimising the energy footprint? Possibilities, incentives and bottlenecks. Session T2.2.1 Daegu, Korea, 12 April 2015.
• Master of Integrated Water Management (International Water Centre) ~ 60 professionals trained in urban water mass balance and metabolism analysis 2014-2016.
• ABC Science Show, Ockham’s Razor podcast. December 2014 Urban Metabolism will help us manage the water needs of future Australian cities.
• Detailed city analysis, scenario analysis, analytical tool/model (ZUMBA).