Estimating the water performance of medium density development at Knutsford

Land use / development type	Scale
Residential – medium density infill	Precinct
Water source/supply	**Scale**
Rainwater tanks	POS irrigation/Non-potable
Sewer mining	POS irrigation/Non-potable
Site conditions	
Soils	Shallow soil on a limestone ridge
Groundwater level	High
Groundwater availability	Contaminated/ unavailable
Local government	**Location**
City of Fremantle	Knutsford development

In order to combat urban sprawl, many cities are promoting infill development as a means to revitalise areas and optimise investment in infrastructure and services. Recent research has shown; however, that without significant intervention, 'business as usual' redevelopment will have a considerable negative influence on urban hydrology, resource efficiency, urban heat, liveability and amenity (London, et al, 2020a). Research for the Department of Planning, Lands and Heritage has indicated that for every new dwelling there is an additional $1,460 per year of additional costs to the wider community for medium density infill developments with sub-optimal outcomes (SGS Economics and Planning, 2020).

Changing ‘business as usual practices’ is often challenging, but it can be assisted by tools that are able to quantify and compare the impact of new practices.

The Cooperative Research Centre for Water Sensitive Cities (CRCWSC) has developed an Infill Performance Evaluation Framework that quantifies the performance of water sensitive infill development using three groups of performance criteria: (i) water performance (includes hydrology, water storage, water demand and supply, greening), (ii) urban heat, and (iii) architectural and urban spaces quality. This case study outlines the results of the assessment of the water performance (criteria 1) and architectural and urban space quality (criteria 3). The results of the urban heat assessment (criteria 2) are outlined in a supplementary case study.

What does water sensitive infill look like?

While large building footprints and low-rise developments are the most common form of suburban infill, this form of development often results in unusable open spaces, with inadequate tree canopy and poor cross-ventilation and solar access. Water sensitive infill development can yield more outdoor space, reduce overall water and energy demand per dwelling and per person, and provide valuable stormwater infiltration and deep root zones that support tree canopy.

Key principles of water sensitive infill development are improved water performance (hydrological flows, stormwater management and water use efficiency), access to quality outdoor public, private and communal space, and quality design amenity and function.

The CRCWSC’s Infill typologies catalogue (London, 2020a) provides ideas for architects to help design water sensitive infill development. It contains a range of housing typologies, at densities and configurations relevant to Australian cities and applicable to different contemporary infill development scenarios. The scenarios have also been evaluated for their water sensitive performance and compared against business-as-usual approaches to provide an evidence base for better design.

How do we measure performance?

The CRCWS’s Infill Performance Evaluation Framework (the Framework) helps to assess the performance of a range of outcomes, defined in the Framework by performance principles, criteria and indicators.

The performance criteria of water sensitive infill are:

Aspect	Performance criteria
Hydrology	**Restored natural water flows:** infiltration (groundwater recharge) is restored towards a desired state, by the presence of pervious surfaces; evapotranspiration volume is restored towards a desired state, by the presence of vegetated surfaces, vegetation selection, and irrigation of vegetation; and stormwater runoff volume is restored towards a desired state, by the harvesting, storage and use of rainwater and stormwater
	Waterway and wetland ecology and water quality: peak daily stormwater discharges are restored towards a desired state.
	Flood resilience (overland flow): peak daily stormwater discharges are restored towards a desired state.
Water storage capacity	**Storage:** water storage capacity (tanks, basins, etc) within the development is optimised; and soil moisture storage is maximised through permeability.

Aspect	Performance criteria
Water demand and supply	Water demand is minimised by water-efficient appliances, water-efficient behaviours and higher dwelling occupancy (where possible); and water supply self-sufficiency is maximised by harvesting, storing and using supplementary water sourced from the urban system.
Greening	**Water and space for vegetation**: reliability of supplementary water supply is sufficient to enable irrigation, even in dry periods, to maintain soil moisture and dense tree canopies; and the amount of space for vegetation is optimised.
Urban heat	**Outdoor thermal comfort** can be maintained within a tolerable range (relevant to the climate).
Architectural and urban space quality	**Amenity and useability (private and public):** the following qualitative performance criteria are met for dwelling interiors, and outdoor private, communal and public spaces: a. Availability and diversity b. Size and proportion c. Accessibility and connectivity d. Privacy and noise management though balanced transition between spaces e. Multifunctionality, adaptability, flexibility f. Solar access, cross-ventilation g. Outlook to gardens, vegetation, canopy trees

The Framework also outlines the performance indicators that can be used to measure achievement of the performance criteria and recommends a range of models and methods of assessment for each of the three groups of criteria.

In order to guide better designs for water sensitive infill, it was also necessary to understand which elements of the urban form (design variables) were directly related to the performance criteria. These linkages are critical to inform improvements in performance through changes in design and also allows the choice of indicators and variables that is most applicable to the climate and landscape qualities of the site. This "cause and effect" framework is presented in Figure 1.

Applying the framework

Case study site

The proposed development known as Knutsford, is approximately 4 ha in area and located 1.5 km from the Fremantle city centre. The redevelopment site is proposed to accommodate a range of medium-density dwellings and demonstrate best practice design and sustainability.

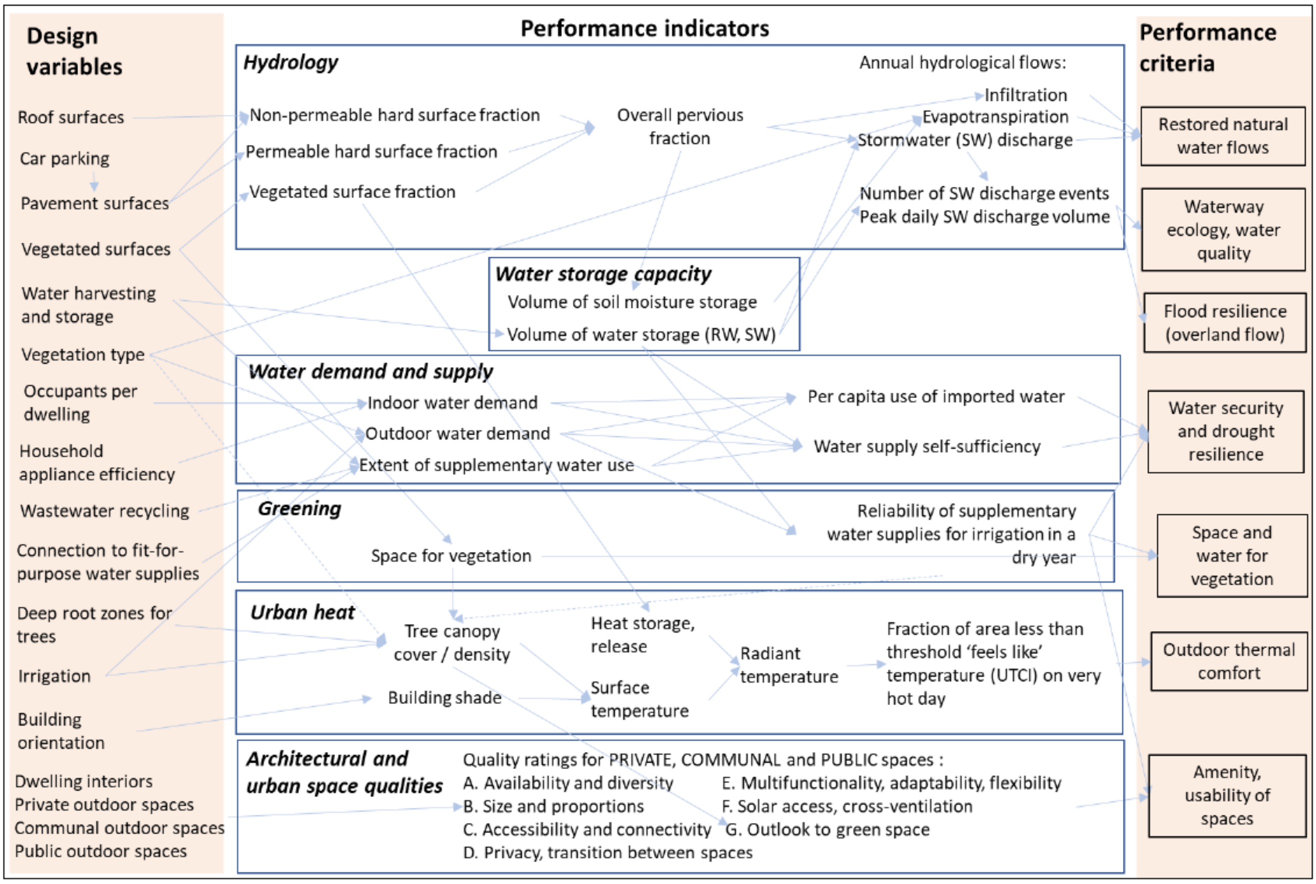

Figure 1: Cause and effect framework linking urban design parameters to water sensitive performance criteria.

Comparing development types

To compare the performance of different forms of development, the CRCWSC defined three development scenarios as (i) existing low density development, (ii) business as usual, and (iii) water sensitive (London *et al*, 2020b).

The existing development scenario (EX) provides a baseline for measurement and is reflective of the typical pre-development state, providing 43 single storey detached houses on large (approximately 600 m²) lots with a net density of 16 dwellings per hectare.

The business-as-usual scenario (BAU) comprises single storey, affordable dwellings and is reflective of the type of infill likely to be constructed in the 2019 housing market. This scenario assumes 107 dwellings on the site, with a net dwelling density of 45 dwellings per hectare.

The Water Sensitive development scenario (WS) includes three dwelling typologies from the Infill typologies catalogue - apartment units, townhouses, and warehouse units. It also incorporates more green space and communal and public space areas, as well as rainwater tanks (RW)and/or a sewer mining scheme (WW) to supply water for irrigation.

The WS scenario provides two design variants (WS-Conservative) and (WS-Maximised). The conservative case provides 154 dwellings on the site, whereas the maximised case has a greater number of stories and provides 200 dwellings. The respective net dwelling densities (not including communal spaces) are 81 and 105 dwellings per hectare. There is no difference in the water sensitive strategies included.

Figure 2: Site plan of water sensitive development scenario

Key inputs

Assessing performance of the three scenarios using the Framework requires a number of key inputs as follows:

- Defining the water servicing arrangements for each scenario including demands and source availability.
- Definition of relevant indicators for each of the performance criteria and context-specific targets to measure against. This step is often influenced by the choice of variables that can be measured and modelled by the Framework.
- Application of the Aquacyle tool (Mitchell, 2005) to develop a precinct-scale water balance which addresses the performance criteria and provides values for the indicators (and assessment) relating to water performance (hydrology, water storage capacity, water demand and supply, and greening).
- Evaluation of the architectural and urban space qualities of each development against the agreed criteria and targets.

It is noted that application of the Framework also includes an assessment of urban heat. This is provided in an accompanying case study.

Results

Results from the water balance assessment as documented in *Knutsford case study final report: water sensitive outcomes for infill development* (London et al, 2020b) show that the WS scenarios should all maintain current levels of infiltration (29-30% of rainfall), whereas infiltration will decrease to 11% of rainfall in the BAU scenario due to the significant decrease in pervious surfaces. The WS scenarios also perform better for stormwater runoff, which increases significantly from 25% in the existing scenario to 62% in the BAU scenario. With harvesting, storage, and use of rainwater, stormwater runoff can be reduced to around 4%.

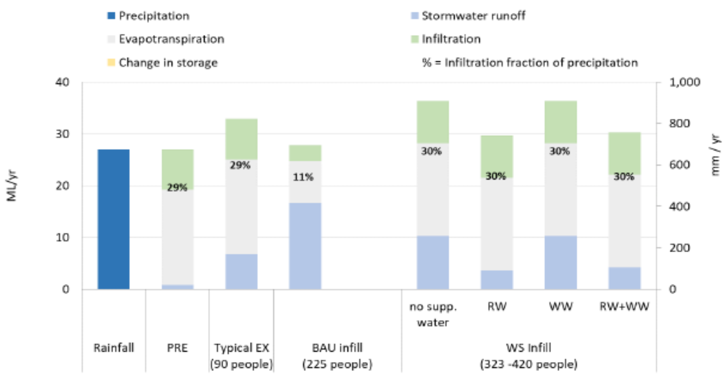

Figure 3: Water balance results for Hydrology

The increased population for both the BAU and WS scenarios will increase water demands. However, supplementary supplies of rainwater and/or recycled wastewater reduces the use of imported water by various degrees. The harvesting and indoor use of rainwater (RW) alone provides 25% water self-sufficiency. This concurs with other estimates that suggest 'an appropriately sized rainwater tank could supply up to 20% of a household's total water needs' in Perth (WA Government, 2020). The outdoor use of recycled wastewater alone provides an overall 40% water self-sufficiency, meeting all of the outdoor water demand. The combined use of both provides 63% self-sufficiency, which brings the demand for imported water to be less than the BAU case, with the added benefits of a higher population yield and greening supported by irrigation (London et al, 2020b).

The WS scenarios are also expected to perform better than the BAU scenario for architectural and urban space qualities. This is due to the increased access to all forms of open space (private, public and communal) including canopy trees, and increased amenity and functionality through diversity.

Outcome

The results of the Knutsford assessment suggests that water sensitive options incorporating alternative water sources such as rainwater harvesting can more closely mimic natural flows. This has additional benefits of significantly reducing reliance on imported mains water supplies, improving reliability of water supply for greening and consequently positively influencing water security and liveability, which is also enhanced through greater access to open space.

Key strategies to ensure optimal performance are:

- Purposeful design of built form to include as much permeable and vegetated surfaces as possible to promote infiltration and evapotranspiration.
- Incorporation of retention devices (raingardens and infiltration cells) that capture and hold surface runoff from impervious surfaces to make water available in the soil profile for trees and facilitate infiltration.
- Rainwater harvesting and use, which provides supplementary water supply and reduces runoff.

Principles of water sensitive infill design

1. Infill design does not adversely alter the natural hydrology (infiltration, evapotranspiration and stormwater discharge) of the development area, and aims to mimic the hydrological water balance of a desired state. This will help to maintain or improve water quality and help protect the ecological condition of waterways and wetlands.
2. Infill designs facilitate soil moisture storage (where beneficial) through permeable surfaces that promote infiltration consistent with principle 1.
3. Infill designs incorporate water storages to facilitate the availability of supplementary water supply and slow/retain/detain runoff to reduce flooding.
4. Infill designs enable reduced reliance on imported water by facilitating the use of supplementary water supplies (harvested rainwater and stormwater, recycled greywaters and wastewaters), by making space for water storage and/or connections to supplementary supplies.
5. Infill designs include space and deep root zones for vegetation and large trees, to provide greening for cooling, biodiversity and amenity.
6. Infill designs enable irrigation of vegetated areas with supplementary water supplies, to support greening for cooling and amenity.
7. Infill designs enable passive mitigation of outdoor urban heat through building orientation and tree canopy shading.
8. Dwellings and urban spaces are efficiently designed and equipped to enable improved amenity, usability and flexibility.

References and resources

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