

# Informing the Decision Process to Improve the Sustainability of an Urban Greenfield Development Water System

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**Abstract:** The provision of water supply, sanitation and drainage services is an essential part of an urban greenfield development. The Brazil Development Study is a joint project initiated by CSIRO Urban Water, Brisbane City Council, Pike Mirils McKnoulty Pty Ltd and Brazil Enterprises, with the objective of providing water services to the Heathwood residential and industrial development site that is more sustainable than conventional practice. A series of water system scenarios were developed and analysed to quantify their benefits and drawbacks. The analysis comprised of detailed water and contaminant balance modelling, preliminary design and costing of infrastructure, assessment of social perspectives and embodied energy analysis. This paper discusses the approach used in this study and the role that modelling and conceptual design played within the broader urban greenfield development decision process.

**Keywords:** Water supply; stormwater; wastewater; urban development; sustainability

## 1. INTRODUCTION

Cities around the world face the challenge of managing their impact on the natural environment and the stress on aging infrastructure. As a result, the sustainable cities concept is an international movement, with the major objective of making cities greener and healthier places for their inhabitants [Gardener, 2000]. Sustainability involves economic viability, social stability and wise use of resources while protecting and nourishing the natural environment [Lowe, 2000]. A city that is genuinely sustainable would be significantly different from the cities of today [Lowe, 2000]. An important component of any urban area is the water system, providing water supply, sanitation and drainage services. But, in many cases, the conventional approach to the provision of these services does not comply with the goals of sustainability.

In order to reorientate urban areas towards sustainability, it is recognised that the different aspects of urban water systems have to be viewed in relation to each other, requiring the adoption of an integrated approach to urban water system development and management [Geldof, 1997; Mouritz and Newman, 1997]. Consideration should

be given to the collective impact of all possible water-related urban processes on issues such as human health, environmental protection, quality of receiving waters, urban water demand, affordability, land- and water-based recreation, and stakeholder satisfaction. Individual processes should be planned and managed in a way that the collective impact be minimised as much as possible [Odendaal, 1999].

The most important benefit of an integrated approach to urban water systems is the potential to increase the range of opportunities available in order to be able to develop more sustainable systems. In as much as the robustness of ecological systems is increased through diversity, so too will the sustainability of urban water systems be improved if an increased range of options are made available, enabling solutions to be tailored to local circumstances [Speers and Mitchell, 2000]. However, in trying to apply the concept of integrated urban water management, at least three obstacles will be met [Geldof, 1997]: (i) the number of component parts is large and their interactions are complex; (ii) the information required to make sense of the complex system will be, in part, subjective; and (iii) there will be uncertainty due to incomplete information.

So, there is great interest in approaches to providing water systems that lower the impact on the natural environment and control expenses. However, there are several questions yet to be answered: what will these future water systems look like? how do we get from the present system to these alternate systems? The purpose of this paper is to explain the process used in the Brazil Development Study to inform the decision making process associated with the selection of a water system for an urban greenfield development.

## 2. THE BRAZIL DEVELOPMENT STUDY

The Brazil Development Study is a collaborative project, with the objective of creating an integrated water system in the Heathwood site that is more sustainable than current practice. Four groups have coalesced around the Heathwood site, each with its own objectives, but with many other goals in common. For *Brisbane City Council* (BCC), the project is a practical component of Council's Sustainable City initiative. For the developer, *Brazil Enterprises*, an opportunity to develop an 'eco-friendly' development that minimises cost and environmental impact. For the developer's consultants, *Pike Miris McKnoulty* (PMM), the chance to further the philosophy of the group – that sustainability needs to become part of the ethos of the development and design industries – and to provide critical input to the study. For *CSIRO Urban Water* (CUW), the project is an opportunity to put recent research into practice in the form of a tangible demonstration, and further explore the science underlying new techniques for urban water services.

The specific objectives of the Brazil Development Study are to minimise wastewater flow leaving the site and potable water imported to the site, and to reduce post-development stormwater flows to mimic those that currently exist on the site in terms of quality, quantity and flow pattern.

The scope of the study is confined to the water supply, stormwater and wastewater systems that are required for the greenfield development of the Heathwood site. Other infrastructure components of a greenfield development, such as transport and energy and management arrangements, are not within the scope of this study, although they play important roles in ecological sustainable development.

### 2.1. Description of Study Site

The Heathwood site lies within a major growth corridor of the south-east Queensland region, which is one of the fastest growing regions in Australia. The Heathwood site is located some 20 km south of the Brisbane central business district in the southern most area of BCC's jurisdiction. The site is divided by a motorway into a residential development known as Heathwood North and an industrial development known as Heathwood South. About 200 m from the eastern boundary is Oxley Creek. Brisbane has a subtropical climate; with an annual rainfall of 1,146 mm/y and pan evaporation of 1,500 mm/y. Rainfall is seasonal, with the highest rainfall in the months of December to March.

The initial development concept plan, land use, street layout and lot sizes were determined by the developer, town planners and engineering consultants involved in the development, and were provided to the CSIRO study team during Stage 1 and early Stage 2. They were worked up largely for the purpose of providing development characteristics (Table 1) that were required for the water and contaminant balance modelling, the conceptual design and costing of infrastructure, and the assessment of innovative technologies. Heathwood North was divided into 711 allotments grouped into five house types (townhouse, small, medium, large and eco-urban), while the industrial site was divided into allotments that varied in size from 4300 m<sup>2</sup> to 4.38 ha. An average occupancy of 3 people per residential allotment was assumed, while for the industrial development an equivalent population of 30 people/ha.

**Table 1.** Heathwood development statistics

	Heathwood North	Heathwood South
Land use	Residential	Industrial
Total site area (ha)	93.2	132.9
Road widening (ha)	2.9	1.6
Developable area (ha)	63.2	78.8
Open space (ha)	27.1	52.5
Number of lots	711	74

## 3. THE STUDY PROCESS

The technique of scenario analysis was used to explore the benefits and drawbacks of the many different water service approaches that could be applied to such a site. A scenario represented a 'theme' or 'philosophy' about the way in which water supply, sanitation and drainage could function

within the site and its interaction with the surrounding water infrastructure and waterways. There are many ways in which the water supply, stormwater and wastewater infrastructure could be configured within a given theme, that is, there are many ways to skin a cat. So, by necessity, any set of scenarios represents only a sample of the myriad of options available. A base case scenario was also defined, representing the development of the site according to current standard practice. The base case is used as the benchmark against which the scenarios can be compared, highlighting the degree of change that would occur due to the implementation of a scenario.

A set of guiding principles was drawn up by the developer, the town planners and the city council, and defined the space within which the CSIRO team could operate to seek water system scenario alternatives. The majority of guiding principles were articulated verbally during Stage 1, but they were formalised and documented during Stage 2 [Mitchell et al., 2001a].

The study was divided into four stages: Stage 1 – initial scenario identification; Stage 2 – conceptual analysis of selected scenarios; Stage 3 – preliminary design of a single scenario; and Stage 4 – final design. (Figure 1)

### **3.1. Stage 1: Initial Scenario Identification**

The first step in the creation of an initial set of scenarios, referred to collectively as Stage 1 scenarios, was a brainstorming session amongst the CSIRO study team. In this session, a comprehensive list of conventional and non-conventional structural and non-structural water supply, sanitation and drainage components was generated. Then, 20 or so scenario themes were drafted and discussed with the BCC and PMM. Six of these scenarios were selected on the basis that they represented the spectrum of divergence from the current approach to urban water service provision for greenfield development, were considered to be of interest to the parties involved in the study, took account of the studies guiding principles and would partially or fully meet the specific objectives of the study. The scenario themes were: (i) non-structural measures; (ii) optimise existing water service approach; (iii) utilise locally generated stormwater and groundwater; (iv) utilise locally generated and treated wastewater; (v) utilise a combination of

locally generated stormwater, groundwater and wastewater; and (vi) no water impact development.

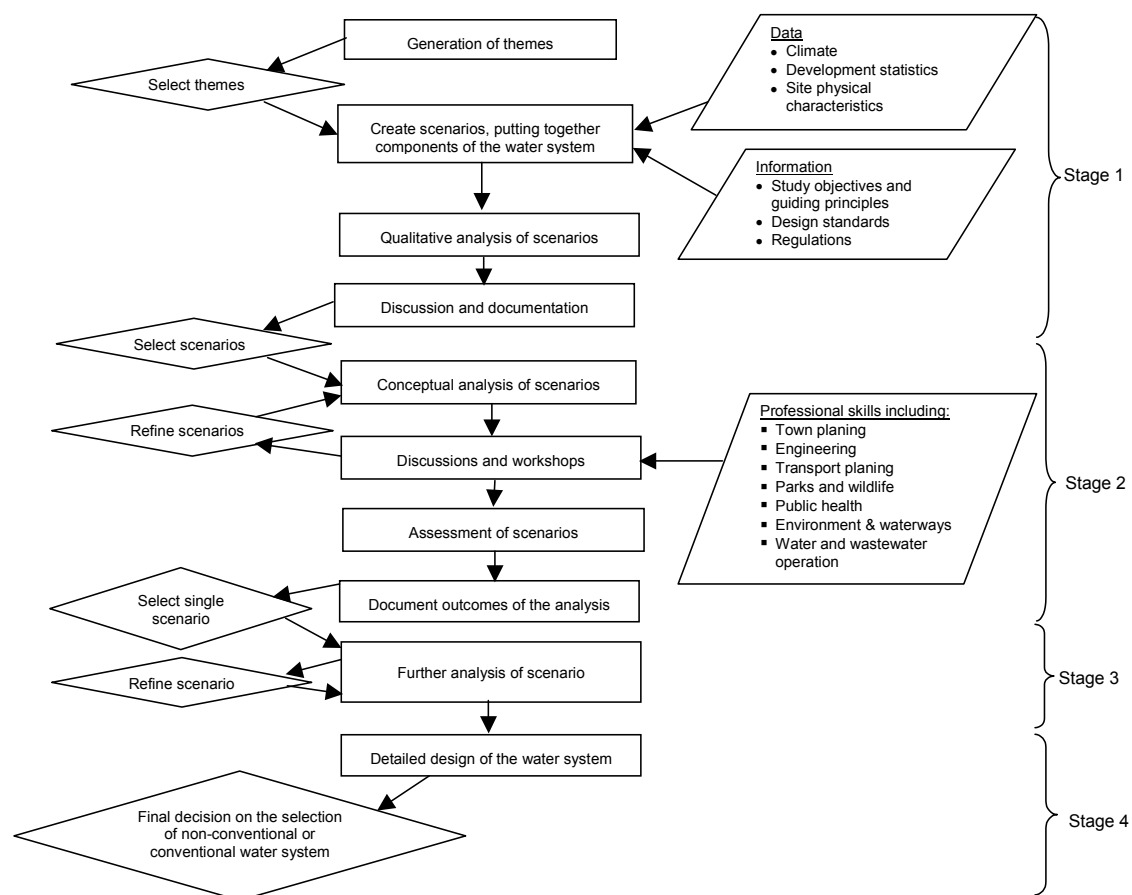
This initial set of six scenarios, along with the base case, was portrayed through a narrative description and accompanying table listing its components and a schematic diagram. The aim was to give the BCC, PMM and the developer a mental picture of the style of residential and industrial development that would result from adopting the scenario, and a qualitative assessment of the extent to which each met the project objectives. In addition, a brief commentary on maintenance, reliability, public health and social acceptance was given. They were presented to BCC, PMM and the developer in the form of round table discussions and a written report.

At the end of Stage 1 of the study, there was a high level of optimism that the urban development process could be influenced by the knowledge gained from the next stages of the study, and this would result in the adoption of a more sustainable water system at the Heathwood site. However, it was clear that any alternative to conventional practice should not impact on the financial viability and marketability of the development.

At this point in the study, the CSIRO research team was acting as ‘technical experts’ and was on a learning curve about the process of urban land development beyond the technical realm and the different viewpoints and concerns of the many stakeholders involved.

### **3.2. Stage 2: Conceptual Analysis of Scenarios**

From the six alternative scenarios developed in Stage 1 of the study, three were selected by the developer, PMM and BCC to be analysed in Stage 2, viz.: (i) utilise locally generated stormwater and groundwater; (ii) utilise a combination of locally generated stormwater, groundwater and wastewater; and (iii) no water impact development. A process of refining the scenarios was also undertaken by all parties involved in the study in order to produce a set of Stage 2 scenarios that were of most interest, either for adoption at the site or for exploring how far the envelope can be pushed within the city of Brisbane. The Stage 2 scenarios were further refined as more information became available and the results of analysis indicated certain components of a scenario required alteration.



**Figure 1.** The framework used to select a water system for the Heathwood site

The purpose of this stage of the study was to determine the feasibility of the Stage 2 scenarios and assess them against the criteria of meeting the project objectives and guiding principles. To meet the information needs of the developer, PMM and BCC, a set of outputs from the conceptual analysis of base case and alternative scenarios were specified, viz.:

- (i) Water and contaminant balance modelling to determine relative impacts on water cycle.
- (ii) Modelling, design and costing of water supply, stormwater and wastewater infrastructure to determine relative costs on a life cycle cost basis.
- (iii) Social assessment in the form of expert opinion to predict acceptability to potential homebuyers and industrial operators.
- (iv) Assessment of site suitability of a range of innovative water service technologies.
- (v) Assessment of the potential for groundwater utilisation and aquifer storage and recovery.
- (vi) Assessment of the externalities associated with the base case and alternative scenarios.

All but the final item, the assessment of externalities, was completed during Stage 2 of the study. The results of item (i) is given in Mitchell et al. [2001b], item (ii) in Shipton et al. [2001], and items (iii) to (v) in Ambrose et al. [2001]. The assessment of externalities was delayed until Stage 3 due to the difficulty of engaging a suitably experienced resource economist. During Stage 2, a comparative embodied energy analysis of the base case and alternative scenarios was also conducted [Ambrose et al., 2001]. A Stage 2 summary report was also written to provide an overview of the outcomes of the study thus far [Mitchell et al., 2001a].

During this stage of the study, the primary focus of the research team was to conduct the large amount of modelling, design and costing and document the results. Stage 2 of the study was an iterative process, with a significant amount of discussion with and incorporating feedback from stakeholders in the Heathwood development. This was essential to ensuring that the scenarios analysed and the

results produced were pertinent to all parties involved.

The research team put considerable effort into ensuring the accuracy of the modelling and design, and into producing comprehensive written reports, which ensure that the many technical details and results are available to all who are interested. However, on its own, this written material was not sufficient to convey the complex nature of the Stage 2 outcomes, particularly to non-technical professionals. Therefore, meetings and workshops proved valuable in transferring information between the research team and the other parties involved and discussing their implications. In particular, the Design Workshop and Social Assessment Workshop proved valuable, with participants that had a wide range of skills and viewpoints, who were either directly involved in the study or key to the decision-making process associated approving such a greenfield urban development.

A multi-criteria analysis approach was used to compare the various Stage 2 scenarios, comprising of an environmental rating, infrastructure cost rating and acceptability (to key stakeholders) rating, loosely related to the environmental, social and economic performance of each scenario. The base case scenario was used as the datum, against which the performance of the other scenarios is compared. This scenario comparison method distilled the results of a large body of work into a few pages of text, tables and graphs, and was sufficiently concise to clearly convey a number of key findings to BCC and PMM.

To illustrate the scenario comparison approach, the results of the environmental rating are presented. The environmental impact rating is calculated as the weighted sum of a series of scaled goal variables, based on the project objectives (Table 2). The goal

variables are scaled between 0 and 1, relative to their target and maximum values, and are assigned weightings to represent their relative importance, with the aim of minimising the value of each goal variable.

At the end of Stage 2, all parties involved had a greater appreciation of the complexity of achieving a major step forward in adapting more sustainable water systems in urban greenfield developments. One key lesson for the research team was the identification of the particular concerns of the various stakeholders and how these, at times, can be at odds. Also, adopting a non-conventional water system involved more uncertainty than the conventional approach, which leads to an increase in real and perceived technical, financial and political risk. What was unclear was if the incentives for change would sufficiently counteract these risks.

### 3.3. Stage 3: Preliminary Design

At the time of writing this paper Stage 3 is drawing to completion. At the beginning of this stage in the study, a new scenario was drafted by the CSIRO team, which took into account the outcomes of Stage 2 and the views of all parties involved. This new scenario represented a blend of the various Stage 2 scenarios and new components put forward during the Stage 2.

The CSIRO research team's main activities during this stage of the study are the assessment of externalities, a sensitivity analysis to investigate the robustness of the Stage 3 scenario and the impact of key modelling and design assumptions, and a review of methodologies to 'measure' the sustainability of conventional and alternative water systems.

**Table 2.** Environmental rating assessment of the Stage 2 scenarios

Goal variable	Unit	Weighting	Target value	Base case	Scenario 1-100%	Scenario 1-50%	Scenario 2A	Scenario 2B	Scenario 3	Scenario 3(WC)
G <sub>E1</sub> Minimise imported potable water	ML/y	0.3333	0	475	110	136	102	65	0	0
G <sub>E2</sub> Minimise export of wastewater - volume	ML/y	0.1667	0	385	286	285	279	241	1	1
G <sub>E3</sub> Minimise export of wastewater - contaminant TN	kg/y	0.0833	0	1,927	1,430	1,422	1,388	1,184	5	5
G <sub>E4</sub> Minimise export of wastewater - contaminant TP	kg/y	0.0417	0	193	143	142	139	139	0	0
G <sub>E5</sub> Minimise export of wastewater - contaminant Na	kg/y	0.0417	0	78,043	71,371	71,522	70,000	63,000	600	600
G <sub>E6</sub> Pre-development stormwater - Q2 flood peak - Heathwood North	L/s	0.0370	13.1	16.5	13.2	13.2	13.2	13.2	13.2	13.2
G <sub>E7</sub> Pre-development stormwater - Q2 flood peak - Heathwood South	L/s	0.0370	31.2	37.0	31.0	31.0	31.0	31.0	31.0	31.0
G <sub>E8</sub> Pre-development stormwater - Q50 flood peak - Heathwood North	m <sup>3</sup> /s	0.0185	25.9	31.4	24.0	24.0	24.0	24.0	24.0	24.0
G <sub>E9</sub> Pre-development stormwater - Q50 flood peak - Heathwood South	m <sup>3</sup> /s	0.0185	72.2	81.7	69.2	69.2	69.2	69.2	69.2	69.2
G <sub>E10</sub> Pre-development stormwater - volume	ML/y	0.1111	368	936	687	715	687	687	864	864
G <sub>E11</sub> Pre-development stormwater - contaminant TN	kg/y	0.0370	305	4,257	2,891	2,997	2,891	2,891	3,984	3,991
G <sub>E12</sub> Pre-development stormwater - contaminant TP	kg/y	0.0185	26	236	217	221	217	217	226	227
G <sub>E13</sub> Pre-development stormwater - contaminant TSS	kg/y	0.0556	29440	170,901	146,916	148,079	146,916	146,916	167,800	167,815
<b>Environmental rating</b>				<b>0.00</b>	<b>0.52</b>	<b>0.49</b>	<b>0.53</b>	<b>0.58</b>	<b>0.79</b>	<b>0.79</b>

The engineering section of Brisbane Water and several engineering consultancy companies are conducting the majority of the preliminary water system design. CSIRO has the role of collating the designs and ensuring coherence between the elements of the water supply, sewage and stormwater systems.

#### 4. CONCLUSION

In the introduction to this paper, three obstacles to the adoption of integrated urban water management were given. All three of these obstacles have been encountered in this study. There are many structural and non-structural components of each scenario, as there are in all urban water systems. The analysis of these components was time consuming and required many assumptions to be made, which, inherently, were subjective. The state of understanding about the performance of various components of the proposed water systems and the interaction of the system as a whole is incomplete. These gaps in knowledge increased the uncertainty about the outcome of the adoption of a particular scenario and, therefore, increase the risk involved.

Modelling, design and qualitative analysis were very useful for the research team to gain a deeper understanding of the performance of non-conventional urban water systems and their benefits and drawbacks. The modelling tools used in this study enabled many more scenarios to be analysed than would otherwise be possible. This removed a significant portion of the technical uncertainty associated with the adoption of more sustainable urban water systems. However, the technical dimension is only one of many requiring consideration and balancing. As the study progressed, modelling and design proved to be a smaller part of the decision-making process than was originally anticipated.

Due to the subjective nature of aspects of the urban development process and the many professional disciplines involved, round table discussions and workshops played an integral role in the transfer of technical and non-technical information between the parties involved in the study and the formation of decisions. The process used to generate, progressively refine and evaluate, in terms of technical, financial, social and organisational perspectives, a range of non-conventional urban water systems that could be implemented at the Heathwood site, provided all parties with a greater

understanding of what a more sustainable urban water system might look like, both at this site and throughout Australia.

#### 5. ACKNOWLEDGEMENTS

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