Investigation of decentralised wastewater recycling for irrigation of public open space in urban villages:

Development of a model for reliable management systems and improved protection of public health and the environment within the Perth Metropolitan Region

Technical Report #2/3
Premiers Water Foundation Project #034/04G
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Investigation of decentralised wastewater recycling for irrigation of public open space in urban villages:

Development of a model for reliable management systems and improved protection of public health and the environment within the Perth Metropolitan Region

Technical Report #2/3

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The views expressed are not necessarily the views of the Government of Western Australia, nor the Premier’s Water Foundation.
Preface

This technical report is the second of 3 to emerge from a project entitled “Demonstration of Decentralised Wastewater Recycling in Urban Villages” that is funded by the Premier’s Water Foundation and industry partners including National Lifestyle Villages Pty Ltd, Peel Waters Pty Ltd and Moltoni Infratech Pty Ltd.

The Premier’s Water Foundation was created in response to the State Water Strategy released in February 2003 by the Western Australian Government. The Foundation’s programs will support research and development projects that challenge boundaries and investigate innovative new ways of conserving water and maximising reuse of wastewater. For further information refer to the following website:

The PWF project 034 04G “Demonstration of Decentralised Wastewater Recycling in Urban Villages” will monitor and evaluate decentralised wastewater recycling and irrigation demonstration projects operating in Perth urban villages. The project will complete a wastewater recycling trial to demonstrate the performance and reliability to meet regulatory standards, effects on soil and vegetation, pathogen disinfection, nutrients prevented from infiltration to groundwater, maintenance issues of the systems and the effective amount of scheme and bore water saved in the long term. The research will occur in collaboration with National Lifestyle Villages Pty Ltd, Peel Waters Pty Ltd, Moltoni Infratech Pty Ltd and other developers with support from Department of Health (DoH), Department of Water (DoW), local government and Water Corporation. The project is focussed on the Perth metropolitan area and Peel Region over the period 2005-08. The demonstration projects are as follows:

- **Year 1**: Bridgewater Lifestyle Village (by National Lifestyle Villages Pty Ltd) at Erskine, City of Mandurah, with 389 onsite household greywater recycling systems for yard irrigation;
- **Year 2**: Timbers Edge Residential Village (by Peel Waters Pty Ltd) at Dawesville, City of Mandurah with common greywater collection from 260 houses to a central on-site treatment system for irrigation of POS;
- **Year 3**: Banksia Village at Midvale, City of Swan where all wastewater from the existing 162 park homes, caravans and ablutions facilities in a village setting are being collected to one new on-site MBBR treatment plant which has capacity to also receive effluent from a future proposed 143 park homes.

Five (originally 3) research studies will be completed over the duration of the project:

- Deliverable 1: Honours project #1 (by Beth Strang 2005): Decentralised Wastewater Treatment and Recycling Systems (DeWaTARS) in WA Urban Villages: Development of a Legislative Framework. COMPLETE
- Deliverable 2: Honours project #2 (by Shaun Jamieson 2006): Decentralised wastewater recycling: performance requirements for use in village scale urban environments under current planning, public health and environmental regulatory requirements for irrigation of POS in urban villages. COMPLETE
- Deliverable 19: Monitoring the operational and environmental performance of an urban village-scale wastewater recycling system. A “zero emissions development” (ZED) model will be developed for appropriate technology in urban villages.
This Technical report is the first of three to be prepared during the project:


There will also be at least 2 papers published in scientific journals. So far the following articles have been published:


The following papers have been presented at conferences and publication of the reviewed proceedings is sought:


Dr Martin Anda  
Murdoch University  
February 2007
Executive Summary

The Premiers Water Foundation provided funding for the “Demonstration of Decentralised Wastewater Recycling in Urban Villages”. This technical report is the second from this project. It meets the requirements of Deliverable 13: Technical requirements for reliable management systems and improved protection of groundwater resources.

It is specifically focussed on decentralised wastewater recycling via irrigation in Western Australia and presents the following findings:

- A review of the current public health requirements;
- A review of the current environmental requirements;
- A review of the management system requirements;
- A review of the available treatment technologies and appropriate technology choice criteria;
- An outline of a new Technical Elements Model.

The first Technical Report identified the main deterrents to Decentralised Wastewater Treatment and Recycling System (DeWaTARS) projects as:

- Pricing – The initial start up costs as well as ongoing maintenance and monitoring costs;
- Public Confidence – The ability to meet public health and environmental concerns as well as confidence in the final product reliability;
- Technology – The ability to meet public health and environmental concerns, whilst being economically and easily maintained; and
- Legislation – The long turn around times for approval and the various requirements across many governing bodies.

This study attempts to address these deterrents by identifying the current technical requirements and technologies for wastewater recycling via irrigation and incorporate these elements into a model.

A Technical Element Model (TEM) was developed that identifies each technical element component, how they interconnect, and where they apply within the various implementation process steps. The TEM can potentially assist with the development of reliable management systems and improved protection of public health and the environment within the Perth Metropolitan Region.
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1.0 Introduction

Perth, Western Australia’s largest city is under increasing pressure to implement a more sustainable means of water supply and use. The coastal city is expanding rapidly in both population and geographical size (EPA, 2005), while annual rainfall is variable and gradually decreasing (WC, 2005). On top of the supply issues Perth is continuing to implement a centralised approach to wastewater sanitation, which combines many wastewater streams before treatment and disposal to ocean outfall (EPA, 2005). This creates an open cycle system that has many sustainability issues including inefficient use of potable water supplies, loss of freshwater resources and nutrients, pollution of the receiving water bodies, as well as the need for high energy infrastructure (Ho and Anda, 2004).

In response to Perth’s water supply concerns the Western Australian Government implemented a State Water Strategy in February 2003. Part of this strategy was to create a Premiers Water Foundation to support research and development projects that investigate water conservation and reuse. A project titled “Demonstration of Decentralised Wastewater Recycling in Urban Villages” was funded by the foundation and aims to achieve a number of demonstration projects and research studies. This technical report is the second of three reports within Premiers Water Foundation project and is focused on technical requirements associated with decentralised wastewater recycling.

The aim of the research study is to investigate the technical requirements and technologies (technical elements) associated with the successful implementation of an urban village wastewater recycling system within the PMR, for which a model can be formulated to create reliable management systems and improved protection of public health and the environment.
2.0 Objectives and Methods

The specified research topic is: "Investigate decentralised wastewater recycling for irrigation of Public Open Space (POS) in urban villages and determine technical requirements for reliable management systems and improved protection of public health and groundwater resources".

The core purpose of this research project was to investigate the associated technical requirements/obligations to ensure that public health and the environment are not jeopardised and a comprehensive management systems can be developed. The requirements are specific to decentralised wastewater recycling onto public open space within urban villages of the PMR and can be summarised as:

- Public health requirements;
- Environmental requirements; and
- Management system requirements.

Meeting these technical requirements in the best possible manner also includes an requirement to select the most appropriate wastewater treatment technology. This was determined as being the fourth element required to achieve reliable management systems and improved protection of public health and the environment.

The research for this technical report was conducted as follows:

- Literature research of current technical requirements and guidelines;
- Literature research of scientific journals and papers;
- Review of existing decentralised wastewater recycling technologies; and
- Review of existing models and tools.

The findings from the research were used to develop a model that will assist the implementation of suitable decentralised wastewater recycling systems. The model will aim to determine the associated technical requirements and appropriate technologies, referred to as the technical elements, to meet those requirements based on specified characteristics of the situation. The developed model will therefore be titled the Decentralised Wastewater Recycling for Public Open Space of Urban Villages Technical Elements Model or ‘Technical Elements Model’ for short.
3.0 Technical Elements Model

The ‘technical elements’ include the technical requirements/obligations to ensure reliable management systems and improved protection of public health and the environment. This can be summarised as four key technical elements:

- Public health requirements;
- Environmental requirements;
- Management system requirements; and
- Appropriate technology selection.

The successful employment of a decentralised wastewater recycling system requires an integrated consideration of many components. These components have been grouped within two core employment phases, (1) preliminary investigation and (2) implementation process (Figure 1, below). Figure 1 also illustrates how the PWF Technical Reports 1 and 2 fit within the successful employment phases.

Figure 1 The phases and components associated with successful employment of a decentralised wastewater recycling system.

This technical report is focused towards the system design and technical requirements, which are required within the implementation process to achieve best management practices and gain government approval.
Figure 2 The five steps of the implementation process and the interconnection with the technical elements
According to ASNZS 1547:2000 there are five key steps within the implementation process of a decentralised wastewater recycling system:

1. Feasibility study;
2. Subdivision design;
3. System design;
4. System installation; and
5. System use.

Figure 2 illustrates how the technical elements can be used within the first three steps in order to successfully progress to steps 4 and 5. This interconnection of technical elements forms the core framework of the TEM.

---

**Public Health Requirements**

- **End (irrigation) use**
  - Controlled or uncontrolled public access

- **Type of wastewater**
  - Sewage or greywater

- **Water quality class**
  - Section 4.3

- **Appropriate technology selection**

- **Management system**
  - Section 7.1

---

Figure 3 The public health requirements component of the model
Figure 4 The environmental requirements component of the model

The TEM further expands the interrelation between the specific components of each technical element. This is demonstrated for environmental and public health requirements in Figures 3 and 4.

Note that the ‘General System Configuration’ and ‘Scale of Collection’ components in Figure 2 form part of the Appropriate Technology Selection technical element. Each technical element and its components are discussed further in the relevant sections below.
4.0 Public Health Requirements

There are three main components of the public health requirements technical element.

- Type of wastewater (greywater or sewerage);
- End use (type of irrigation)
- Water quality class (as per the DoH Fit for Purpose Guidelines)

4.1 Type of wastewater

‘Type of wastewater’ is used to determine the expected quality of the wastewater. As the technical elements model is restricted to domestic wastewater with irrigation as the end use, only two wastewater types have been considered – greywater and sewage (sewage = combined blackwater and greywater). Other types of wastewater that are not considered may include yellow water (separated urine), stormwater or specific industrial effluents (i.e. paper mill, brewery, etc.).

The ‘type of wastewater’ determines the level of treatment to achieve the desired water quality (explained further for greywater and sewage in section 4.3 below).

4.2 End use

The desired end use of the effluent is used to determine the likelihood of exposure to the public. The TEM is restricted to irrigation as the end use, however there are different types of irrigation that must be considered:

- Spray irrigation;
- Sub-strata irrigation (underneath mulch); and
- Sub-surface irrigation (underneath soil).

The irrigation system can also be deemed as controlled or uncontrolled public access. Subsurface irrigation is generally classified as controlled public access, while spray irrigation is generally uncontrolled. Spray irrigation in a fully contained area with drift control and sufficient buffer zones can also be classified as controlled public access (Refer to Table 2).

The end use ultimately indicates the risk of exposure to the treated effluent and therefore determines the desired water quality. The type of wastewater and end use combined can be used to obtain the water quality class (Refer to section 4.3 below).

4.3 Water quality class

Determining the water quality class will indicate the recycled water quality objectives and the treatment processes required. The specified water quality classes for the two wastewater types (sewage and greywater) and how they were derived are discussed below.

4.3.1 Sewage

According to the Draft National Guidelines for Water Recycling (DNGWR) there are many constituents within sewage (combined blackwater and greywater) that pose a risk to human health, including chemicals and pathogenic micro-organisms (EPHC 2005). In order to reduce the associated risks to tolerable levels, health based targets are required that are consistent with a level of risk that is acceptable (EPHC 2005). Using a risk assessment process the draft guideline has determined a range of health based targets for the recycling of wastewater.

The health based targets specified in the DNGWR are consistent with the guidelines adopted by Western Australia, which have been titled the ‘Fit for Purpose Guidelines for Recycled Water’ (EPA, 2005) (Appendix A). It lists five different classes of water (A+, A, B, C and D) along with their associated water quality objectives, the treatment processes required to obtain the class and the appropriate uses (EPA, 2005). The water quality objectives are largely
focused on microbiological parameters (The ‘Fit for Purpose Guidelines for Recycled Water’ is provided in Appendix A). Chemical contaminants are not specified in these guidelines.

The DGNWR has identified a range of chemicals that may pose a risk to public health, including heavy metals, organic chemicals, pesticides and disinfection by-products. A review of three separate wastewater recycling case studies found that most of the problematic chemicals had a high rate of compliance with drinking water guideline values and many were below limits of detection. Some of the more specific chemicals analysed included polychlorinated biphenyls (PCB’s), polycyclic aromatic hydrocarbons (PAH’s), phenol, toluene, benzene, and endocrine disrupters.

Following this chemical hazards investigation, the DGNWR states “In properly designed and managed recycled water schemes, health impacts from these chemicals should be minimal, because of the relatively low exposure.” Therefore, the main health risk associated with recycled wastewater for irrigation is associated with the microbial pathogens. According to the DGNWR, the microorganisms of concern include Bacteria, Viruses, Protozoa and Helminths. The Fit for Purpose Guidelines for Water Recycling (FPGWR) considers all four pathogen types in the Class A+ and A recycled water quality objectives and only E.coli in Classes B, C and D (Appendix A), which is a bacteria species commonly used as a pathogen indicator.

Table 1 Summary of the two classes within the Fit for Purpose Guidelines for Water Recycling that are applicable for wastewater recycling via POS irrigation

<table>
<thead>
<tr>
<th>Class</th>
<th>Recycled Water Quality Objectives</th>
<th>Treatment Process</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 E.coli org/100 mL</td>
<td>Secondary, Filtration, Disinfection</td>
<td>Urban (non-potable): with uncontrolled public access</td>
</tr>
<tr>
<td>A</td>
<td>Turbidity &lt; 2 NTU&lt;sup&gt;6&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 10 / 5 mg/L BOD / SS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pH 6 – 9 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 mg/L Cl&lt;sub&gt;2&lt;/sub&gt; residual</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(or equivalent disinfection)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;10 E.coli per 100 mL;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;1 helminth per litre;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 1 protozoa per 50 litres;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 1 virus per 50 litres</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| C     | <1000 E.coli org/100 mL          | Secondary + pathogen reduction | Urban (non-potable): with controlled public access |
|       | pH 6 – 9 7                      |                   |      |
|       | < 20 / 30 mg/L BOD / SS         |                   |      |

Application of the FPGWR for public open space irrigation is summarised in Table 1, which does not include Class B as it is not specified as being applicable for Urban (non-potable) uses (Appendix A). However, the DNGWR study indicates that Class B should be preferred over Class C, as it poses less public health risk. Also, it is likely that secondary treatment combined with conventional disinfection, (e.g. chlorination, UV, etc.) will produce Class B water, and Class C largely represents pathogen reduction by die-off achieved by long detention times in lagoons or wetlands (i.e. >30days for secondary treated water or >60days for primary treated effluent).

The applicable parts of the FPGWR can be combined with the additional information provided in the DNGWR to produce a more informative description of the available water
quality classes (Table 5, below). This can act as a more informative framework to be used in the overall model, while also complying with the Department of Health specified guidelines.

Table 2 Revised version of the Fit for Purpose Guidelines including information from the Draft National Guidelines for Water Recycling and to be used in the Technical Elements Model.

<table>
<thead>
<tr>
<th>Class</th>
<th>Irrigation Use</th>
<th>Treatment Process</th>
<th>Disinfection Objectives</th>
<th>Likely Disinfection Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Urban (non-potable): with uncontrolled public access</td>
<td>Secondary + Advanced filtr’ n + Disinfection</td>
<td>&lt; 10 E.coli org/100 mL</td>
<td>Chlorine residual ~ &gt;60mg.min/L; UV light ~ 100mJ/cm²; Or equivalent</td>
</tr>
<tr>
<td></td>
<td>- Uncontrolled Spray Irrigation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B/C</td>
<td>Urban (non-potable): with controlled public access</td>
<td>Secondary + Disinfection</td>
<td>&lt;1000 E.coli per 100 mL acceptable</td>
<td>Chlorine residual ~ &gt;15mg.min/L; Or equivalent</td>
</tr>
<tr>
<td></td>
<td>- Drip irrigation; or Controlled spray irrigation*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Includes a combination of the following:
- No public access during irrigation
- Exclusion periods (e.g. no use until 1-4 hours after irrigation)
- 25-30m buffer zones to nearest point of public access
- Spray drift control

4.3.2 Greywater

DNGWR has identified that the total number of thermotolerant coliforms in greywater can be as low as $10^1$ and as high as $10^7$ per 100mL, largely due to the variable nature of greywater. While these figures are largely determined based on the presence of E.coli, in general there is little data on the levels of specific pathogens in greywater (EPHC, 2005). However, an assumption can be made that there will be less pathogens associated with greywater than general sewerage due to the exclusion of blackwater.

Analysis studies of greywater to obtain typical water quality values are often carried out on single dwellings causing a high degree of variability. Variability is likely to be much lower for village scale collection of greywater, however, even with a low variability a study by Fane et al (2002), concluded that the health risks from public exposure to greywater that has undergone secondary treatment but not disinfection is unacceptably high. Therefore, disinfection objectives still have to be considered for this domestic wastewater type.

Table 3 Revised version of the Fit for Purpose Guidelines for Water Recycling for greywater to be used in the Technical Elements Model.

<table>
<thead>
<tr>
<th>Equivalent Class</th>
<th>Irrigation Use</th>
<th>Treatment Process</th>
<th>Disinfection Objectives</th>
<th>Likely Disinfection Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Urban (non-potable): Unrestricted access</td>
<td>Secondary + Disinfection</td>
<td>&lt; 10 E.coli org/100 mL</td>
<td>Chlorine residual ~ &gt;15mg.min/L; Or equivalent</td>
</tr>
<tr>
<td></td>
<td>- Spray irrigation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Sub strata irrigation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B/C</td>
<td>Urban (non-potable): Restricted access</td>
<td>Primary (or secondary)</td>
<td>&lt;1000 E.coli per 100 mL acceptable</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>- Sub surface irrigation.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The DoH has released a Code of Practice for the Reuse of Greywater in Western Australia (CPRGWA) (DoH, 2005). Within this document it specifies the level of treatment required based on the greywater reuse application, which closely correlates with the ‘Fit for Purpose’ guidelines outlined in Table 1. The CPRGWA specifications have been adapted into a format similar to Table 2 to provide a simple representation (Table 3). Note that secondary treatment combined with disinfection is enough to achieve Class A equivalent effluent, while Class B can be achieved using no disinfection, however it is required to have restricted access by using sub-surface (bellow ground) drip irrigation.
5.0 Environmental Requirements

Environmental requirements are associated with assessing the risk of chemical hazards to the receiving environment and determining the target criteria. The receiving environment includes four major considerations:

- Design hydraulic loading;
- Soil and groundwater analysis;
- Downstream surface waters and buffer zones; and
- Other receiving environments (i.e. biota).

The chemical hazard of most concern often involves the macronutrients nitrogen and phosphorous. The water quality class information (i.e. the type of wastewater, the type of treatment and the end application) can be used to help determine the level of environmental risk (Refer to Figure 3).

Setting environmental protection guidelines is often linked to the key objectives of the Australia’s National Strategy for Ecological Sustainable Development, which are to (EPHC, 2005):

- Enhance individual and community well-being and welfare by following a path of economic development that safeguards the welfare of future generations;
- Provide for equity within and between generations; and
- Protect biological diversity and maintain essential ecological processes and life-support systems.

Environmental guidelines are designed to minimise the adverse consequences of water recycling to end points or receptors within the environment (EPHC, 2005). For the recycling of domestic wastewater onto POS of urban villages of Perth, the receptors of most concern are native vegetation, soil, groundwater and surface water bodies.

5.1 Design hydraulic loading

The Australian and New Zealand Standard 1547:2000 is typically designed for flows up to a maximum of 14000L/week (lot scale systems – see section 6.2, below). However the soil classification and recommended hydraulic loadings for recycled water irrigation can be applied to all size systems. The ASNZS 1547 also details how to carry out a Site-and-soil evaluation to determine the soil classifications and characteristics.

<table>
<thead>
<tr>
<th>Soil texture</th>
<th>Indicative permeability (m/day)</th>
<th>Design irrigation rate (mm/week)</th>
<th>Indicative drainage class</th>
<th>New drainage class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels and sands</td>
<td>&gt;3.0</td>
<td>35</td>
<td>Rapidly drained</td>
<td>Well drained</td>
</tr>
<tr>
<td>Sandy loams</td>
<td>1.4 – 3.0</td>
<td>35</td>
<td>Well drained</td>
<td></td>
</tr>
<tr>
<td>Loams</td>
<td>0.5 – 1.5</td>
<td>28</td>
<td>Moderately well drained</td>
<td>Moderately drained</td>
</tr>
<tr>
<td>Clay loams</td>
<td>0.06 – 0.12</td>
<td>25</td>
<td>Imperfectly drained</td>
<td>Poorly drained</td>
</tr>
<tr>
<td>Light clays</td>
<td>0.01 – 0.12</td>
<td>20</td>
<td>Poorly drained</td>
<td></td>
</tr>
<tr>
<td>Medium to heavy clays</td>
<td>0.01 -0.06</td>
<td>15</td>
<td>Very poorly drained</td>
<td></td>
</tr>
</tbody>
</table>

Six soil categories with a different indicative drainage class are provided in the standard. These have been summarised into three basic groups including well drained, moderately drained and poorly drained for the purpose of the TEM (Table 4). While most of the soils within the PMR are likely to be sandy and in the well drained class, Perth is spreading east
into the darling scarp where deeply weathered profiles exist (Newsome, 1998). Therefore, it is important to include considerations for all soil types.

The three new drainage classes correlate with the design irrigation rates (DIR), which can also be roughly correlated with the three basic soil types of sands, loams and clays. It should be noted that the DIR provided are conservative figures that do not consider the effluent quality and the climatic characteristics of Perth.

The Department of Health (2005) has specified a figure of 10mm/day for drip or spray irrigation in sandy and sandy loam soils (well drained). Therefore, it has been assumed that the conservative figures listed in the ASNZS 1547 can be doubled to obtain the maximum daily DIR for wastewater that has been treated to a level consistent with that specified for greywater and sewage in Chapter 4 above (E.g. Class A and B/C).

Table 5  The new maximum design irrigation rates for the Technical Elements Model.

<table>
<thead>
<tr>
<th>Drainage class</th>
<th>ASNZS 1547 Design irrigation rate (mm/week)</th>
<th>New Max. Design irrigation rate (mm/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well drained</td>
<td>35</td>
<td>10</td>
</tr>
<tr>
<td>Moderately drained</td>
<td>28</td>
<td>8</td>
</tr>
<tr>
<td>Poorly drained</td>
<td>&lt;25</td>
<td>&lt;7</td>
</tr>
</tbody>
</table>

The estimated maximum design irrigation rates are provided in Table 5, however more accurate design irrigation rates should be determined based on a consideration of chemical hazards such as nutrients in the wastewater and the receiving environment, which is disused further below. These figures should be used as guidance for initial design purposes and reduced if required during a more accurate environmental analysis.

5.2 Soil and groundwater analysis (nutrient requirements)

The soil and groundwater analysis can be largely associated with the other three environmental considerations. However within the TEM this section has been specifically dedicated to nutrient management requirements.

In order to obtain the target criteria concentrations for nitrogen and phosphorus the Water Quality Protection Notes – Irrigation with Nutrient Rich Wastewater released by the Department of Environment were reviewed (DoE, 2004). The recommendations of the document are summarised in Table 6 and 7 below.

Table 6  Vulnerability to eutrophication of downstream surface water bodies and vulnerability classes as specified by Department of Environment Water Quality Protection Notes

<table>
<thead>
<tr>
<th>Characteristics of the irrigated soil</th>
<th>Vulnerability to eutrophication of downstream surface waters (within 1 kilometre)</th>
<th>Vulnerability Category e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse grained soils a e.g. sands, or gravels.</td>
<td>Significant b</td>
<td>A</td>
</tr>
<tr>
<td>Fine grained soils (PRI d above 10) e.g. loam, clays, peat-rich sediment</td>
<td>Significant b</td>
<td>C</td>
</tr>
<tr>
<td>Low c</td>
<td>B</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
a. Specific restrictions may apply where near-surface soil conditions are likely to lead to rapid water movement without achieving significant immobilisation of entrained contaminants (e.g. in karstic limestone, coarse gravels or fractured rock).
b. Significant eutrophication risk applies to translucent inland waters, with nutrient leaching pressures from catchment land use resulting in occasional algal blooms; or where warm season dissolved inorganic nitrogen concentrations exceed 1 mg/L and filterable reactive phosphorus (ortho-phosphate) concentrations exceed 0.1 mg/L in the water body.
c. Low eutrophication risk applies to highly coloured waters, those with rarely observed algal blooms (less than 5000 cells/mL), having low nutrient pressure from land use and those with warm season inorganic nitrogen concentrations of less than 0.5 mg/L and filterable reactive phosphorus less than 0.05 mg/L.

d. PRI means Phosphorus Retention Index, a scientifically determined measure of the phosphorus holding capacity of soils between the ground surface and base of the vegetation root zone

e. These vulnerability categories are applied to nutrient application rate recommendations in Table 13.

**Table 7 The maximum inorganic nitrogen and phosphorus for the vulnerability categories as specified by Department of Environment Water Quality Protection Notes**

<table>
<thead>
<tr>
<th>Vulnerability Category</th>
<th>Maximum inorganic nitrogen (TN)</th>
<th>Maximum inorganic phosphorus (TP)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Application rate (kilograms / hectare / year)</td>
<td>Equivalent water concentration (mg/ litre) a</td>
</tr>
<tr>
<td>A</td>
<td>140</td>
<td>9</td>
</tr>
<tr>
<td>B</td>
<td>180</td>
<td>11</td>
</tr>
<tr>
<td>C</td>
<td>300</td>
<td>19</td>
</tr>
<tr>
<td>D</td>
<td>480</td>
<td>30</td>
</tr>
</tbody>
</table>

Notes:

- The N and P concentrations are based on an average of 50 mm (500 kilolitres/ ha) of water applied per week for 32 weeks/year, and no additional nutrient addition to the land (including animal manure). For other irrigation regimes, equivalent water concentration rates should be calculated on a pro-rata basis.

b. Application rates are based on quantities of plant-available N and P (as N as ammonia & nitrate, and P as orthophosphate) to promote healthy vegetation growth that are matched to the growth cycle of the irrigated plant species. For materials that require micro-biological decomposition to release plant-available nutrients (e.g. decay of green-waste), the local conditions will need to be factored into calculations (i.e. time, moisture, warmth, available oxygen and absence of toxins).

It should be noted that the figures provided in Table 7 are recommended nutrient (nitrogen and phosphorus) application criteria in irrigated waters, based on no additional measures being taken to minimise contaminant leaching. The figures are based on 50mm per week application rate for 32 weeks of the year. Many large scale wastewater irrigation systems will require irrigation for 52 weeks of the year, unless an alternative system is devised such as lagoon storage or deep sewerage disposal during wet periods.

Within the sandy coastal plain of Perth it is likely that any groundwater receiving water body within 1 kilometre will be classified as a category A, or at best category B. Therefore, in these situations high nutrient removal should be achieved followed by a detailed assessment to identify the risks and determine if any additional preventative measures are required. Such measures may include:

- Buffer plantings to strip nutrients from groundwater before receiving water body
- Location of irrigation system to maximise distance to groundwater (vertically) and water body (horizontally)
- Shandying (mixing with other source) the water to reduce nutrient concentrations
- Minimising the application rate
- Reducing major nutrient sources from influent such as urine separation and low nutrient detergents.

Other important specifications included in the Water Quality Protection Note are:

- Any irrigation sites proposed within 500 metres of a sensitive environmental feature should be referred with supporting information addressing the environmental risks
- For loamy soils irrigation rates 3 to 5 mm/ hour are reasonable, while sandy sites may accept up to 15 mm/ hour without run-off. Irrigated water should always be applied evenly. The irrigated area should be allowed to dry out for 24 hours between applications during hot, dry weather; and for 3 to 7 days during cool weather.
- Irrigated areas should have a land slope of between 1 in 20 and 1 in 200 to avoid either soil erosion or formation of boggy ground.
5.3 Downstream surface waters and buffer zones

Downstream surface waters are considered for nutrients in section 5.2. This section deals more specifically with required setback distances or ‘buffer zones’.

The area to be irrigated with treated wastewater should be setback from various items to ensure environmental performance, which can also be termed buffering distance or buffer zones. The Code of Practice for the Reuse of Greywater in Western Australia stipulates a range of guideline distances for greywater irrigation. As the distances are for greywater that has been treated to an equivalent class B/C or better (Table 6), it can be assumed that these figures can also be applied to blackwater treated to a class B/C or better. The distances set by the Code of Practice are summarised in Table 8 (below).

Table 8 Minimum setback distances or ‘buffer zones’ to be applied in the Technical Elements Model.

<table>
<thead>
<tr>
<th>Item</th>
<th>Drip irrigation (m)</th>
<th>Spray irrigation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed fence boundaries</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Open boundaries (e.g. open fence or no fence)</td>
<td>0.5</td>
<td>1.2</td>
</tr>
<tr>
<td>Buildings</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Paths, drives, carports, etc.</td>
<td>0.3</td>
<td>1.8</td>
</tr>
<tr>
<td>Sub-soil drains</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Bores (private)</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Public drinking water source *</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Wetlands and water dependant ecosystems where the PRI is &lt; 5</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

* Includes Drinking Water Source Protection Areas

5.4 Other receiving environments

This section provides an overview of all possible receiving environments and the chemical constituents that present a potential hazard.

There are many potential constituents within recycled water that may cause adverse effects to the receiving environment. However, it is the substances within recycled wastewater that are consistently in damaging concentrations that are of major concern. According to the EPHC (2005), there are seven chemicals that can cause key environmental hazards, which are summarised in Table 9 (below). Additional to chemical contaminants, hydraulic loading and salinity is also considered as a chemical hazard.
<table>
<thead>
<tr>
<th>Chemical of hazard</th>
<th>Environmental End Point</th>
<th>Effect of Impact on the Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boron</td>
<td>Accumulation in soil</td>
<td>Plant toxicity</td>
</tr>
<tr>
<td>Chlorine disinfection residuals</td>
<td>Plants, Surface waters</td>
<td>Directly toxic to plants, Toxic to aquatic biota</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>Soils</td>
<td>Nutrient imbalance and pest and disease in plants, Eutrophication of soils and effects on terrestrial biota, Eutrophication, Contamination</td>
</tr>
<tr>
<td></td>
<td>Soils</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surface water, Groundwater</td>
<td></td>
</tr>
<tr>
<td>Phosphorous</td>
<td>Soils</td>
<td>Eutrophication of soils and toxic effects on phosphorus sensitive terrestrial biota (Native plants), Eutrophication</td>
</tr>
<tr>
<td></td>
<td>Surface waters</td>
<td></td>
</tr>
<tr>
<td>Salinity</td>
<td>Infrastructure</td>
<td>Rising damp, corrosion, secondary salinity</td>
</tr>
<tr>
<td></td>
<td>Soils</td>
<td>Plant stress due to osmotic affects of soil salinity</td>
</tr>
<tr>
<td></td>
<td>Soils</td>
<td>May increase release of cadmium from soil</td>
</tr>
<tr>
<td></td>
<td>Groundwater</td>
<td>Increase salinity</td>
</tr>
<tr>
<td></td>
<td>Surface water</td>
<td>Increase salinity</td>
</tr>
<tr>
<td>Chloride</td>
<td>Plants</td>
<td>Toxicity to plants when sprayed on leaves</td>
</tr>
<tr>
<td></td>
<td>Soils</td>
<td>Plant toxicity via root uptake</td>
</tr>
<tr>
<td></td>
<td>Surface water</td>
<td>Toxicity to aquatic biota</td>
</tr>
<tr>
<td>Sodium</td>
<td>Plants</td>
<td>Toxicity to plants when sprayed on leaves</td>
</tr>
<tr>
<td></td>
<td>Soils</td>
<td>Plant toxicity via root uptake</td>
</tr>
<tr>
<td></td>
<td>Surface water</td>
<td>Toxicity to aquatic biota</td>
</tr>
<tr>
<td>Hydraulic loading</td>
<td>Soil</td>
<td>Water logging of plants</td>
</tr>
<tr>
<td></td>
<td>Groundwater</td>
<td>Soil salinity</td>
</tr>
</tbody>
</table>
Table 10  Environmental factors, hazards and effects that need to be considered when determining environmental risk.

<table>
<thead>
<tr>
<th>Water sources</th>
<th>Uses</th>
<th>Receiving environments and major end points</th>
<th>Key hazards</th>
<th>Major Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Sewer mining</td>
<td>Irrigation</td>
<td>Plants</td>
<td>Boron</td>
<td>Concentration</td>
</tr>
<tr>
<td>- Village scale system (sewerage)</td>
<td></td>
<td>Soil</td>
<td>Chloride residuals</td>
<td>Contamination</td>
</tr>
<tr>
<td>- Village scale system (greywater)</td>
<td></td>
<td>Water body - surface / groundwater</td>
<td>Nitrogen</td>
<td>Eutrophication</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Biota (aquatic and terrestrial)</td>
<td>Phosphorous</td>
<td>Loss of Biodiversity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Salinity</td>
<td>Nutrient imbalance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Chloride</td>
<td>Salinity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sodium</td>
<td>Sodicity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hydraulic loading</td>
<td>Toxicity</td>
</tr>
</tbody>
</table>
| In order to determine the environmental risks associated with the recycling system a range of factors need to be considered such as water sources, uses, receiving environments, key hazards and major effects (Table 10). A summary of the potential environmental risks and target criteria are provided for the major chemical hazards in Appendix B.
6.0 Appropriate Technology Selection

“Environmentally sound practices in wastewater and stormwater management are practices that ensure that public health and environmental quality are protected. A range of technologies exist that can achieve this objective” (IETC, 2002 p65).

Technology choice can be viewed as the most fundamental component of implementing a sustainable wastewater management system. Selecting the most appropriate sanitation system in the design stages will help to ensure the best possible economic, social and environmental solution (IETC, 2002).

While appropriate choice is vital, there are a wide range of variable factors and site conditions to be considered. On top of this there are many different technology types with countless variations of which to choose from (Hellstrom and Jonsson, 2005), all of which can make the process of technology choice difficult and time consuming.

Before selection of the most suitable technologies, the characteristics of the wastewater recycling system and the receiving environment must be established. One of the most important environmental issues surrounding wastewater recycling is contamination through excess nutrients. The characteristics of the wastewater recycling system that need to be considered are:

- General configuration;
- Scale of collection; and
- Recycling system components (appropriate technologies).

6.1 General configuration

There are three possible wastewater type configurations for village scale wastewater recycling, including:

- Sewage recycling (independent of deep sewerage network)
- Greywater recycling (with blackwater to deep sewerage)
- Sewer mining (deep sewerage connection still required)

Selection of these wastewater types can sometimes be governed by legislation. For example the Perth Metropolitan Sewerage Policy may specify that deep sewerage connection is required if the infrastructure is available at the site, in which case an investigation of sewer mining or greywater recycling can be considered.

The general configuration of the wastewater recycling system should be considered in the ‘feasibility study’ step of the implementation process (Refer to Table 1)

6.2 Scale of collection

The scale of collection is a major consideration for decentralised wastewater recycling systems. Different wastewater treatment systems are suited to different wastewater flows, therefore making it an important part of appropriate technology choice. Also, the scale will alter the values of certain characteristics, for example capital or management cost per connection. Three different scales of collection have been identified as:

- Lot (individual house);
- Cluster (medium cluster of houses); and
- Village (large residential developments).
Table 11 The three available scales of decentralised wastewater recycling

<table>
<thead>
<tr>
<th>Scale of collection</th>
<th>Acceptable size</th>
<th>Typical size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(kL/day)</td>
<td>No. homes (connections)</td>
</tr>
<tr>
<td>Lot</td>
<td>1.8</td>
<td>1</td>
</tr>
<tr>
<td>Cluster</td>
<td>3.6-50</td>
<td>2-100</td>
</tr>
<tr>
<td>Village</td>
<td>50-1000</td>
<td>100-2000</td>
</tr>
</tbody>
</table>

Table 11 identifies the progression used to define the three different scales. The acceptable size figures are very broad and represent what is acceptable within each scale. The typical size figures were estimated based on a range of case studies and available treatment technology information. The typical figures were used to calculate the capital and management cost variations between different scales of collection.

Table 12 The general concept behind the scale of collection selection model

<table>
<thead>
<tr>
<th>Indicated wastewater collection size</th>
<th>Wastewater treatment scales</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 home</td>
<td>Lot</td>
</tr>
<tr>
<td>Less than 50kl/day</td>
<td>Cluster scale</td>
</tr>
<tr>
<td>More than 50kl/day</td>
<td>Village scale</td>
</tr>
</tbody>
</table>

The scale of collection model is not as clear cut as Table 12 indicates. A residential development may have a total wastewater flow of 100kL/day, however due to design layout or geographic features it may be preferable to implement two or more cluster systems rather than one village system. As lot scale collection of the wastewater is not suitable for public open space irrigation it is not included in the TEM.

6.3 Recycling system components

The three recycling system components include:

- Core treatment – the initial treatment system that will typically provide the primary and secondary treatment;
- Additional treatment components – any additional systems and processes that provides extra quality enhancement of the wastewater such as tertiary filters and additives;
- End application – which refers to the public open space irrigation method

Choosing the ‘core treatment’ process can often be difficult as there are many technology types (Table 13 below) and considerations to assess.
Table 13 Technology types available for the core treatment of wastewater in a recycling system.

<table>
<thead>
<tr>
<th>Group</th>
<th>Category</th>
<th>Subcategory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Aerobic Treatment Units</td>
<td>1.1 Suspended growth 1.1a Activated sludge (continuous aeration) 1.1b Activated sludge (intermittent aeration) 1.1c Membrane bioreactor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.2 Attached growth (forced aeration) 1.2a Submerged (continuous aeration) 1.2b Submerged (intermittent aeration) 1.2c Fluidised bed 1.2d Moving bed bioreactor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.3 Attached growth (passive aeration) 1.3a Percolating (Primary – septic) 1.3b Percolating (Primary – humus) 1.3c Rotating biological contactor</td>
</tr>
<tr>
<td>2.0</td>
<td>Soil and peat filters</td>
<td>2.1 Amended soil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.2 Peat bed filter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.3 Infiltration trenches</td>
</tr>
<tr>
<td>3.0</td>
<td>Composting systems</td>
<td>3.1 Wet composting 3.1a High influent (liquid separation) 3.1b Low influent (heater)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.2 Dry composting 3.2a Remote (no heater) 3.2b Remote (heater) 3.2c Self contained (heater)</td>
</tr>
<tr>
<td>4.0</td>
<td>Ponds and wetlands</td>
<td>4.1 Constructed wetlands 4.1a Free water surface 4.1b Subsurface water flow</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.2 Ponds 4.2a Aerobic 4.2b Facultative</td>
</tr>
<tr>
<td>5.0</td>
<td>Anaerobic systems</td>
<td>5.1 Open digesters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.2 Closed digesters</td>
</tr>
<tr>
<td>6.0</td>
<td>Physico-chemical</td>
<td>6.1 Electro chemical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.2 Dissolved air flotation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.3 Screening and membrane</td>
</tr>
<tr>
<td>7.0</td>
<td>Greywater treatment systems</td>
<td>7.1 Primary filters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.2 Secondary units</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.3 Constructed wetlands</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.4 Advanced systems</td>
</tr>
</tbody>
</table>
An Evaluation System was devised to help determine which core treatment ‘end group’ (i.e. category or subcategory – Table 13) is the most appropriate, which can be employed within the TEM. The Evaluation System incorporates a range of measures or criteria that are commonly required in the establishment of a wastewater recycling system. These were determined by assessing a number of case studies for the most commonly considered treatment system characteristics and explained in Table 14 (below).

Table 14 A brief description and associated measurement values used in the evaluation system

<table>
<thead>
<tr>
<th>Evaluation criteria</th>
<th>Description</th>
<th>Measurement value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic</td>
<td>Biological oxygen demand and suspended solids (mg/L) in the treatment system effluent.</td>
<td>BODmg/L / SSmg/L</td>
</tr>
<tr>
<td>Nutrient</td>
<td>Percentage ammonia removal by the treatment system</td>
<td>NH₄ (% removal)</td>
</tr>
<tr>
<td></td>
<td>Percentage total nitrogen removal by the treatment system</td>
<td>TN (% removal)</td>
</tr>
<tr>
<td></td>
<td>Percentage total phosphorus removal by the treatment system</td>
<td>TP (% removal)</td>
</tr>
<tr>
<td>Energy use</td>
<td>Kilowatt hours used per kilolitre of water treated</td>
<td>kWh/kL</td>
</tr>
<tr>
<td>Capital cost</td>
<td>Capital cost (SAU.) per kilolitre per day rated treatment capacity</td>
<td>$/kL/day</td>
</tr>
<tr>
<td>Management cost</td>
<td>Yearly management cost (SAU.) per inhabitant</td>
<td>$/inhab/year</td>
</tr>
<tr>
<td>Footprint</td>
<td>Footprint (land area required) in m² per inhabitant</td>
<td>m²/inhab</td>
</tr>
<tr>
<td>Sludge</td>
<td>Liquid sludge required to be treated/disposed of per year in litres per inhabitant</td>
<td>L/inhab.year</td>
</tr>
</tbody>
</table>

The evaluation system comprises of a numbering matrix that provides a score between zero and ten for a range of evaluation criteria (Table 15, below). Low scores are better than high scores (i.e. the poorest score is 10). The scores are linked with estimated real values for that criterion, illustrated in Table 15 (below).

Table 15 An example of the scoring sheet used for the treatment type: Activated Sludge (continuous aeration) on a cluster scale

<table>
<thead>
<tr>
<th>Evaluation criteria</th>
<th>Description</th>
<th>Value</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic impact</td>
<td>BODmg/L / SSmg/L</td>
<td>20/20</td>
<td>5</td>
</tr>
<tr>
<td>Nutrient impact</td>
<td>Ammonia (% removal)</td>
<td>&gt;80</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Nitrogen (% removal)</td>
<td>&lt;60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Phosphorus (% removal)</td>
<td>&lt;35</td>
<td></td>
</tr>
<tr>
<td>Energy use</td>
<td>kWh/kL</td>
<td>1.5</td>
<td>8</td>
</tr>
<tr>
<td>Capital cost</td>
<td>$/kL.day</td>
<td>7,000</td>
<td>7</td>
</tr>
<tr>
<td>Management cost</td>
<td>$/inhab/year</td>
<td>40-60</td>
<td>6</td>
</tr>
<tr>
<td>Footprint</td>
<td>m²/inhab</td>
<td>0.12-0.25</td>
<td>4</td>
</tr>
<tr>
<td>Sludge</td>
<td>Liquid sludge to be treated (L/inhab/year)</td>
<td>2000</td>
<td>6</td>
</tr>
</tbody>
</table>
The two criteria that relate to cost (management cost and capital cost) are general estimations based on a range of figures obtained from product companies, case studies and sourced literature. The cost values used in the evaluation system have limited accuracy because they can vary from individual suppliers and the exact number of connections.

The cost values used for cluster and village applications are largely based on the typical flows for that scale (Table 11). The general finding was that a 100kL/day (approximately 500 inhabitants) aerobic treatment unit system (village scale) would cost approximately $500,000 installed (not including the piping network for collection or irrigation) and roughly $10-15,000/year in management costs. A 30kL/day (approximately 150 inhabitants) system would cost approximately $200,000 (not including the piping network for collection or irrigation) and roughly $7,000-9,000/year in management costs.

The cost related scores are based on very general figures to provide a comparison that indicates economies of scale. Obviously, as the flows decrease from the typical values used to calculate scores the cost figures are likely to increase slightly. The same is also true for the reverse.
7.0 Management system

The management system includes all the reports or plans to ensure the design and ongoing technical requirements are met. The plans are usually documented and used to obtain government approval.

The information within the TEM is likely to aid with the management system development and approval, as it can be used to meet specific requirements (e.g. Water quality classes and nutrient calculations) and illustrate the consideration of other public health, environment and system design requirements.

7.1 Department of Health

Currently in WA the Department of Health (DoH) requires an Operation and Maintenance Plan with an application of approval. However, it is likely that more detail is required for large scale systems within the PMR or to obtain water service provider status for the scheme.

Information that may be required by the DoH includes:

- Site and soil report;
- System design report;
- Operation and maintenance plans;
- Monitoring plans; and
- Contingency plans.

7.2 Department of Water

The Department of Water will require a Nutrient Irrigation Management Plan (NIMP) if the irrigation land area exceeds 5,000 square metres, and may be required for lesser areas where the surrounding environment is sensitive to nutrient contamination.

The information required to fulfil a NIMP is very extensive. Some of the details required include:

- A pre-development and post-development nutrient irrigation and management program;
- Contingency plans;
- Detailed site and soil analysis;
- Nutrient inputs and outputs from the site; and
- Expected seasonal nutrient uptake by the plant species being irrigated.
8.0 Technical Elements Model Summary

The process of implementing the Technical Element Model can be summarised by the following progression.

1. General System Configuration (feasibility study step)
   a. Sewage recycling; or
   b. Greywater recycling; or
   c. Sewer mining.

2. Scale of Collection (subdivision design step)
   a. Lot (not included); or
   b. Cluster; or
   c. Village.

3. Public Health Requirements (system design step)
   a. Type of wastewater
      i. Greywater; or
      ii. Sewage.
   b. End use
      i. Spray irrigation; or
      ii. Sub-strata irrigation; or
      iii. Sub-surface irrigation.
   c. Water quality class
      i. Class A; or
      ii. Class B/C.

4. Environmental requirements (system design step)
   a. Design hydraulic loading
      i. Well drained; or
      ii. Moderately drained; or
      iii. Poorly drained.
   b. Soil and Groundwater analysis (nutrient management)
      i. A, B, C or D
   c. Downstream surface waters and buffer zones
   d. Other receiving environments

5. Appropriate technology selection
   a. Recycling system components
      i. Core treatment
         - Evaluation system
      ii. Additional treatment
      iii. End use

6. Management system requirements
   a. DoH
      i. Site and soil report
      ii. System design report
      iii. Operation and maintenance plans
      iv. Monitoring plans
      v. Contingency plans
   b. DoW
      i. Nutrient irrigation and management program;
      ii. Contingency plans;
      iii. Detailed site and soil analysis;
      iv. Nutrient inputs and outputs from the site; and
      v. Expected seasonal nutrient uptake by the plant species being irrigated.
9.0 Conclusion

Achieving wastewater recycling within urban villages requires much planning, innovative design and ongoing operation and management. Within the implementation process there are many technical elements which need to be considered to achieve the most sustainable option and gain government approval, which are related to public health and environmental protection criteria, management plan development and appropriate technology selection.

By identifying each technical element, how they interconnect, and where they apply within the various implementation process steps, improved protection of public health and the environment and more reliable management systems will result. As well, making the implementation process easier will encourage the employment of this water saving and potentially more sustainable approach. It is likely that the Technical Elements Model will help to achieve this, however, further development and trials are required before any definite conclusions can be made about the real life performance of such model.
References


## Appendices

### Appendix A – Fit for Purpose Guidelines for Recycled Water

<table>
<thead>
<tr>
<th>Class</th>
<th>Recycled Water Quality Objectives</th>
<th>Treatment Process</th>
<th>Range of Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>A+</td>
<td>Turbidity &lt; 2 NTU6</td>
<td>Secondary</td>
<td>Indirect Potable Reuse Aquifer Recharge</td>
</tr>
<tr>
<td></td>
<td>&lt; 10 / 5 mg/L BOD / SS</td>
<td>Filtration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>pH 6 – 9</td>
<td>Disinfection</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 mg/L Cl2 residual (or equivalent disinfection)</td>
<td>Advanced treatment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 1 E.coli per 100 mL;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 1 helminth per litre;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 1 protozoa per 50 litres;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 1 virus per 50 litres.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 2-10mg/L nitrogen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>&lt; 10 E.coli org/100 mL</td>
<td>Secondary</td>
<td>Urban (non-potable): with uncontrolled public access</td>
</tr>
<tr>
<td></td>
<td>Turbidity &lt; 2 NTU6</td>
<td>Filtration</td>
<td>Agricultural: eg human food crops consumed raw</td>
</tr>
<tr>
<td></td>
<td>&lt; 10 / 5 mg/L BOD / SS</td>
<td>Disinfection</td>
<td>Industrial: open systems with worker exposure potential</td>
</tr>
<tr>
<td></td>
<td>pH 6 – 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 mg/L Cl2 residual (or equivalent disinfection)</td>
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<td>&lt; 10 E.coli per 100 mL;</td>
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<td>&lt; 1 protozoa per 50 litres;</td>
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<tr>
<td></td>
<td>&lt; 1 virus per 50 litres.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>&lt; 100 E.coli org/100 mL</td>
<td>Secondary +</td>
<td>Agricultural: eg dairy cattle grazing</td>
</tr>
<tr>
<td></td>
<td>pH 6 – 97</td>
<td>pathogen reduction</td>
<td>Industrial: eg washdown water</td>
</tr>
<tr>
<td></td>
<td>&lt; 20 / 30 mg/L BOD / SS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>&lt; 1000 E.coli org/100 mL</td>
<td>Secondary +</td>
<td>Urban (non-potable): with controlled public access</td>
</tr>
<tr>
<td></td>
<td>pH 6 – 97</td>
<td>pathogen reduction</td>
<td>Agricultural: eg human food crops cooked/processed, grazing/fodder for livestock</td>
</tr>
<tr>
<td></td>
<td>&lt; 20 / 30 mg/L BOD / SS</td>
<td></td>
<td>Industrial: systems with no potential worker exposure</td>
</tr>
<tr>
<td>D</td>
<td>&lt; 10000 E.coli org/100 mL</td>
<td>Secondary</td>
<td>Agricultural: non-food crops including instant turf, woodlots, flowers</td>
</tr>
<tr>
<td></td>
<td>pH 6 – 97</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 20 / 30 mg/L BOD / SS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
* Table adapted from Victorian EPA guidelines

1. Unless otherwise noted, recommended quality limits apply to the recycled water at the point of discharge from the WWTP.

2. Secondary Treatment processes include activated sludge processes, trickling filters, rotating biological contractors, and may include stabilization ponds.

3. Filtration means the passing of wastewater through natural undisturbed soils or filter media such as sand and/or anthracite, filter cloth, or the passing of wastewater through micro-filters or other membrane processes.

4. Disinfection means the destruction, inactivation, or removal or pathogenic microorganisms by chemical, physical, or biological means.

5. Advanced wastewater treatment processes include chemical clarification, carbon adsorption, reverse osmosis and other membrane processes, air stripping, ultrafiltration, and ion exchange.

6. Turbidity limit is a 24-hour median value measured pre-disinfection. The maximum value is five NTU.

7. pH range is 90th percentile. A higher upper pH limit for lagoon-based systems with algal growth may be appropriate, provided it will not be detrimental to receiving soils and disinfection efficacy is maintained.

8. Chlorine residual limit of greater than one milligram per litre after 30 minutes (or equivalent pathogen reduction level) is suggested where there is a significant risk of human contact or where recycled water will be within distribution systems for prolonged periods.

9. Helminth reduction is either detention in a pondage system for greater than or equal to 30 days, or by a DOH approved disinfection system (for example, sand or membrane filtration).

10. Where Class C or D is via treatment lagoons, although design limits of 20 milligrams per litre BOD and 30 milligrams per litre SS apply, only BOD is used for ongoing confirmation of plant performance. A correlation between process performance and BOD / filtered BOD should be established and in the event of an algal bloom, the filtered BOD should be less than 20 milligrams per litre.
Appendix B – Risk analysis of the chemical hazards

The following analysis uses sourced information from the DNWRG (EHPC, 2005) or others where indicated.

**Boron**
The source of boron in wastewater typically comes from water softeners, cleaners and detergents, largely in the form of sodium perborate. Concentrations of boron in recycled water are unlikely to be high enough to cause direct toxicity to plants, although an accumulation in the soil may cause health problems in the plant species. Provided that the soil is well to moderately drained (i.e. not clay) this is unlikely present a major threat. Boron is found naturally in most soils and as result concentrations in marine ecosystems are well above the expected levels in treated wastewater.

**Environmental risk:** Low risk to plants in well to moderate drained soils and moderate risk in poorly drained soils such as clays. Contamination risk to ground and surface water from irrigation is low.
**Target criteria:** 0.5mg/L

**Chlorine residual**
Chlorine is often added to the wastewater for pathogen disinfection purposes during the treatment process. A residual level of chlorine is often required to reduce the health risks associated with recycled water. For Class A water the guideline specifies 1mg/L to be sufficient.

**Environmental risk:** Studies suggest that <1mg/L chloramine or free chlorine should present a low risk to plants. Concentrations above 1mg/L should also pose a low risk unless crop species were highly sensitive. Concentrations approaching 5mg present a moderate risk and detailed assessment of the plant species should be carried out.
Provided that the chlorine residual contained water is not directly discharged to a surface water body toxicity risk is low.
**Target criteria:** 1mg/L

**Hydraulic loading**
Environmental hazards can be caused by excess hydraulic loading to the soil, which can cause water logging, surface pooling, runoff and secondary salinity. The main considerations to determine the risk and appropriate controls are soil type and application rate.

**Environmental risk:** Low risk for well to moderately drained soils and moderate to high risk for poorly drained soils. Site selection of the irrigation system can be used to choose the most suitable locations. The application rates should be determined accordingly, based on soil type, evapotranspiration rates and rainfall events. Conservative DIR are provided in ASNZS 1457 and summarised in Table 7, and estimated maximum DIR figures are provided in Table 8.  
**Target criteria:** Delivery of correct water volumes and groundwater >2m in poorly drained sites.

**Nitrogen**
Nitrogen is a nutrient required by most plants in a greater quantity than any other soil nutrient. Nitrogen can be found in high concentrations in both sewage and greywater, although higher levels are expected in sewage because of the inclusion of human urine which contributes to a large percentage of nitrogen in domestic wastewater (see Table 2).
Nitrogen within recycled irrigation water acts as a plant fertiliser, similar to a fertigation system, although it is important to ensure that excess nitrogen is not applied to the environment due to potential hazards. Some nitrogen will be removed by the wastewater treatment system and biological processes (i.e. aerobic treatment units) can be designed to increase the level of biological nitrogen removal. Currently there are no chemical additives or non-biological processes that can viably remove inorganic nitrogen from a wastewater stream. Urine separation can be employed to significantly lower nitrogen levels of the incoming wastewater stream.

**Environmental risks:** The largest risk associated with excess nitrogen application to the environment is contamination of groundwater through leaching, and eutrophication of surface water bodies through groundwater and surface water inflows. On top of plant uptake, nitrogen can also be removed within the soil and groundwater via denitrifying bacteria. Therefore site characteristics such as ability of the soil to prevent leaching, depth to groundwater, and distance to receiving surface water body can all influence the associated environmental risk. Moderate to high risks include nutrient imbalances and increased susceptibility to pests and disease in plants. Direct plant toxicity presents a low risk.

**Target criteria:** Excess nitrogen following plant demand does not exceed the assimilative capacity of the receiving environment. This is discussed further in sections 4.2.3 and 4.2.4 below.

**Phosphorus**

Similar to nitrogen, phosphorus is an important nutrient required for plant growth, although the levels required are somewhat lower. The concentrations of phosphorus in domestic wastewater will often be lower than the nitrogen concentrations (10mg/L phosphorus compared with 50mg/L nitrogen). Phosphorus is less susceptible to leaching than nitrogen due to the availably to react with soil constituents to form a precipitate. The ability of a soil to remove phosphorous in this way is referred to as phosphorus retention index (PRI), and generally soils with higher clay content have a higher PRI.

Due its properties phosphorus will often be in low supplies in native sandy soils and similarly be the limiting nutrient to algal growth within natural wetlands of similar geology. Native plants have adapted to the low levels of phosphorus and may suffer a toxic affect when exposed to high concentration. According to Donnelly et al (1997), an increase in nutrient concentrations does not immediately increase algal growth as many other factors are involved, however it is evident that it will increase the risk of an algal bloom.

Some phosphorus is removed from a wastewater stream during the treatment process through biological uptake and suspended solid removal. Biological treatment processes can be modified to increase biological phosphorus removal, or alternatively a precipitant can be added to the process to reduce levels to less than 1mg/L. A combination of the two could see concentrations as low as 0.1mg/L or less.

**Environmental risk:** The most significant environmental risk associated with phosphorus in recycled irrigation water is eutrophication of receiving surface water bodies. Similar to nitrogen, the more permeable a soil and the closer the groundwater and receiving surface water body, the higher the risk. Toxicity presents a high to moderate risk to sensitive native plants and a low risk to non-sensitive plants.

**Target criteria:** Concentrations should be minimised in landscapes that do not typically contain high levels of the phosphorus and have a low PRI.

**Salinity**

Total dissolved salts (TDS) within water can include a range of soluble compounds, although sodium and chloride are the most important from an environmental point of view. High concentrations of salt within the soil can cause toxic effects to plants and release cadmium by
displacement with chloride. Irrigation with water containing high salt concentrations can cause a build up of salt within the soil due to evaporation and evapotranspiration processes, which effectively removes the water and leaves the salt. Salt levels can also build up in surface water bodies to the point where it becomes toxic to the biota.

The concentration of TDS in wastewater is largely dependant on the salinity of the original water supply. Some of the wastes entering the feed water will contribute to the TDS of the treated effluent, such as detergents and urine. According to study detailed in the DNGWR, treated effluent from 40 wastewater treatment plants had an average TDS of 675mg/L, and a maximum value of 1224mg/L. As a guide, water for drinking is generally considered acceptable with a TDS between 100 to 800 mg/L, and less than 500mg/L is preferable (DNGWR, 2005).

Therefore, if the supply water has a TDS of less than 500mg/L (which is preferable for scheme water) then it is likely that the TDS of the treated wastewater will be less than 1000mg/L. However, if feed water has a high TDS (i.e. greater than 500mg/L) than the reclaimed effluent may have TDS concentration greater than 1000mg/L, which is likely to cause a higher risk.

**Environmental risks**: Recycled water with a TDS less than 1000mg/L is likely to cause a low risk in well to moderately drained sites, provided that the irrigation water is not applied in areas of shallow groundwater expression. Poorly drained soils will have a moderate to high risk. Recycled water with a TDS greater than 1000mg/L is likely to cause a moderate to high risk to plants, soil, and groundwater in all soil types. The risk of cadmium release by the soil is significantly increased with concentrations above 1000mg/L.

**Target criteria**: TDS <1000mg/L with well to moderately drained soils and groundwater >2m.

**Chloride and sodium**

Chloride and sodium are the main constituents of TDS (salinity). In addition to their salinity impacts they can cause toxic effects and nutrient imbalances in plants, toxicity to aquatic biota and other soil related impacts. High concentrations of sodium can cause soil sodicity in which the clay particles absorb the sodium ion, which causes the soil to swell when wet and prevents further movement of water through the soil.

**Environmental risk**: The DNGWR study found that concentrations of chloride and sodium in recycled water is typically 135 and 180 mg/L respectively, which mostly come from household products such as detergents. Such concentrations have a high to moderate risk of causing toxicity to the foliage of some plants when sprayed directly onto the leaves. In poorly drained soils the risk of sodium and chloride toxicity to plants, and the risk of soil sodicity is moderate to high.

**Target criteria**: Encourage low sodium and chloride containing household products, use tolerant plants species and irrigate in well drained soils were possible.