WATER MANAGEMENT AND SUSTAINABILITY AT QUEENSLAND TOURIST RESORTS

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EXECUTIVE SUMMARY

Water management at tourist locations that are not connected to mains water and/or the sewer system (remote resorts) should be sustainable and effect both economical and ecological benefits. Sustainability with respect to the water cycle requires that there is no decline in the stock of fresh water, persistent pollutants do not accumulate and the natural cycle of other materials is not disrupted in the water environment.

Sustainable water/ wastewater management at remote tourist resorts should incorporate the following measures.

- Rainwater should be collected where possible and used as a water source prior to any other source.
- Extracted water should be returned to source with no loss in quality.
- All treated wastewater should be reused.
- Reuse is recommended for all non-potable purposes.
- Water saving devices should be used where possible.
- Cleaner practice should be implemented where possible.
- Dry composting toilets should be used.
- Xeriscape (low water) gardens should be employed.
- If possible greywater should be kept separate from blackwater.
- Wastewater treatment should use a minimum of chemicals and energy.
- All wastewater should be treated to such a standard to allow reuse.

A survey, concerning water and waste management practice, of 80 resorts in Queensland and New South Wales not connected to sewer and/or to mains water was recently undertaken. No standard for wastewater treatment exists and the potential for combining treatment with reuse was utilised at fewer than 50% of the resorts surveyed. The current focus is efficient and effective wastewater treatment with no thought for sustainable practices.

It is argued that to be truly sustainable, resorts should not require connection to either mains water supply or to the sewer. It is further postulated that the systems for wastewater treatment should not be energy nor chemical hungry and that it is possible to treat wastewater using natural systems. Wetlands and aquatic plant systems are becoming common in the polishing of wastewater prior to reuse. This technology has been taken a step further in the Northern Hemisphere with the introduction of engineered ecosystems that utilise a variety of flora and fauna to treat wastewater. The aesthetic and educational aspects of such sustainable systems may be instrumental in changing the image of wastewater into that of a valuable resource.
1 INTRODUCTION

1.1 Ecotourism and Sustainability

1.1.1 Ecotourism

The 1997 Queensland ecotourism plan (Department of Small Business and Industry Queensland, 1997) defines ecotourism as 'nature-based tourism that involves education and interpretation of the natural environment and is managed to be ecologically sustainable'. It recognises cultural, community and conservation components and sets 36 discrete tasks for implementation in the next 5 years to achieve four objectives:

1. environmental protection and management,
2. ecotourism industry development,
3. infrastructure development, and
4. community development.

The fact that a plan has been formulated and is currently being implemented is indicative of how important ecotourism and its associated principles have become. This is observed to be an international trend that mirrors the growing interest in, and implementation of, ecological philosophies.

This report is concerned mainly with the third point but the remaining three objectives are considered in all the report findings and recommendations.

1.1.2 Sustainability

Much has been written recently with respect to sustainability and its achievability coinciding with a change in attitude towards the environment. In 1987, the World Commission on Environment and Development identified five basic principles of sustainability (The Brundtland report):

- the idea of holistic planning and strategy making,
- the importance of preserving essential ecological processes,
- the need to protect both human heritage and biodiversity,
- the need to develop in such a way that productivity can be sustained over the long term for future generations, and
- the achievement of a better balance of fairness and opportunity between nations.

These principles can be applied generally such that they encompass every facet of modern life or specifically, as in the case of this report, to infrastructure development associated with tourism. Ecologically sustainable development will meet the needs of the present without compromising the ability of future generations to meet their needs; it will 'leave no trace'. This statement contains the implicit philosophy of environmental protection.

To achieve sustainability, the following philosophies (Otterpohl et al., 1997) must be adopted:
• energy and material usage must be minimised,
• there must be no transfer of problems in space or time to other persons,
• there must be no reduction or degradation of natural resources, and
• human activities must be integrated into natural cycles.

To account for the environmental impact of developing countries, it has been postulated (Linz, 1998) that material and energy flows must be reduced by a factor of 10 over the next two decades. This will require significant changes in every aspect of our lives.

The seeds of the requirement for sustainable development can be seen in Australian documents. In 1992, Australian federal governments adopted the National Strategy for Ecologically Sustainable Development. It (Commonwealth Government of Australia, 1991) defines ecologically sustainable development as:

using, conserving and enhancing the community's resources so that the ecological processes on which life depends are maintained and the total quality of life, now and in the future, can be increased.

The strategy recommends the management of the tourism industry to promote conservation and minimise impacts.

Further, The Royal Australian Institute of Architects (1995) defined ecologically sustainable design as the:

use of design principles and strategies which help reduce the ecological impact of buildings by reducing the consumption of energy and resources, or by minimising disturbances to existing vegetation

and incorporated this definition in their environmental policy.

Sustainable philosophies are incorporated into all levels of this report as they are seen to be integral to both ecotourism and any future development of infrastructure.

1.1.3 Sustainability and the water cycle

Water is one of the major requirements for life and is a precious natural resource. Australia is the driest continent with unpredictable rainfall patterns and hence it would be logical to assume that sustainable water use practices would be a necessity and widespread practice. However, until implementation of a 'user-pays' principle, there is little incentive to move towards water conservation as witnessed by events in Brisbane over the past 3 years. It is only now that a gradual swing towards the use of water saving devices and the reuse of treated wastewater is being seen. The sight of people washing down concrete and leaves has become far less commonplace.

This trend is another example of the move towards sustainability.

Although true sustainability may not be achievable as this violates the thermodynamic law of entropy (Harremoës, 1997), it should be within our grasp to approach the ideal with respect to the water cycle. Water is utilised and managed to fulfil a number of criteria (Larsen and Gujer, 1997):

• to maintain hygiene standards (supply and collection),
• to provide drinking water and water for personal hygiene,
• to prevent flooding or draining of an area,
• to promote agriculture via irrigation, and
• to provide water for pleasure and recreational aspects.

It is submitted that water management processes currently used to implement the above, have been established on the basis of 19th century requirements and need to be rethought with respect to sustainability. Prohibitive costs (Varis and Somlyody, 1997) may limit what can be done with existing systems but there is no reason why new developments should not incorporate all the principles of sustainability.

1.2 Contents of Report

This report summarises the work done in the first year of a PhD degree course at The University of Queensland. It includes:

• a review of pertinent literature concerning:
  o sustainable guidelines for water management,
  o relevant ecotourism case studies, and
  o conventional and sustainable methods of wastewater treatment; and

• a summary of the results of the questionnaire which was distributed to tourist destinations in Queensland and New South Wales in 1998.

It is structured such that general water management principles are discussed before analysis of wastewater treatment methods. The report concludes with an outline of a sustainable water management plan and objectives for future research into sustainable wastewater treatment.
2 GUIDELINES FOR ECORESORTS

This chapter gives a general overview of the criteria for ecoresorts and includes a list of relevant legislation.

2.1 Literature Recommendations

A number of recent publications have proposed guidelines for ecotourism resorts. These are summarised below and can be seen to address both the environment and the community.

Standards

• Ecological design does not have to, and should not, compromise the high standards of hotel service, cuisine, and amenities that a large majority of international ecotourists expect. (Ayala, 1995)

Costs

• The tourist must recognise the investment in providing ecological measures. (Ayala, 1995) The tourist demand for eco-sensitive systems and accommodation must match their willingness to pay. (Wight, 1997)

Impacts

• [There is a need] to identify, quantify and assess the impacts associated with every stage including: raw materials extraction and processing, manufacture or construction, use and operation, transport and distribution, disposal, recycling and/or demolition. (Gertsakis, 1995)

Commitment

• Executive level commitment needs to be guaranteed with an individual in charge of each primary aspect of the environmental program. (Iwanowski, 1995)

Criteria

• The key characteristics of ecologically sustainable accommodation (Moscardo et al., 1996) are that it is:
  i small scale,
  ii locally owned,
  iii staffed by local community,
  iv providing other economic opportunities for local community,
  v spread throughout a region rather than clustered near major attractions,
  vi characteristic of the region,
  vii encouraging protection of the heritage of a region,
  viii not adversely impacting on other industries or activities,
  ix providing a quality experience for guests,
  x a successful business.
• Accommodation (Wight, 1997) must become:
  i  part of the experience,
  ii  an extension of the conservation site,
  iii  integrated with the surrounding environment, and
  iv  environmentally sensitive in terms of planning, design and operation.

  Design Criteria

• [The resort] must be designed in harmony with the local natural and cultural environment, using principles of sustainable design; they should minimise the use of non-renewable energy resources and avoid the use of non-renewable materials for construction; they should use recycled materials where possible; they should work in harmony with the local community offering jobs with a wide range of responsibilities and employment via contracts with locally owned vendors; they should work to provide benefits to local conservation and research initiatives both public and private; and they should offer excellent interpretive programs to educate the visitor about the local environment and culture. (Hawkins et al., 1995)

• The industry must address 10 priorities (World Travel and Tourism Council, 1995):
  i  waste minimisation, reuse and recycling,
  ii  energy efficiency, conservation and management,
  iii  management of freshwater resources,
  iv  wastewater management,
  v  reduction of hazardous substances,
  vi  transport,
  vii  land-use planning and management,
  viii  involving staff, customers and communities in environmental matters,
  ix  design for sustainability, and
  x  partnerships for sustainable development.

As an example of accommodation that satisfies the above, a patented ecologe, the Geo-Lite ™, which claims to be a self-sufficient dwelling system requiring no connection to utility services, is being marketed (Galbreath, 1995). The system can house up to 10 people, generates its own electricity through solar and wind power, utilises composting toilets, separates greywater for irrigation and stores/ pumps rainwater.
2.2 Legislation

There is a multitude of legislative requirements for resorts (Australian Tourism Industry Association, 1990) both in terms of the Commonwealth and Queensland government. The major acts are:

- **Commonwealth legislation**
  - Environment Protection Act (1994),
  - Australian Heritage Commission Act (1975),
  - World Heritage Properties Conservation Act (1983),
  - National Parks and Wildlife Conservation Act (1975), and

- **Queensland government**
  - For environmental planning and assessment:
    - Environmental Protection Regulation (1998)
  - For pollution control:
    - Environmental Protection (Water) Policy (1997)
    - Environmental Protection (Noise) Policy (1997)
    - Environmental Protection (Air) Policy (1997)
  - For conservation issues:

Local council and planning authority regulations will also need to be observed and will be a function of both the nature of the resort and the site.
3 SUSTAINABLE WATER MANAGEMENT

This chapter discusses the recent trends towards sustainability in water management. These trends include that of cleaner production, water reuse and decentralised treatment. Each is discussed in terms of guidelines for implementation, case studies and potential limitations.

3.1 Cleaner Production

3.1.1 Overview

Cleaner production techniques, which are at the front line in terms of sustainability (Figure 1.1), aim to:

- reduce the contamination of wastewaters, and
- minimise the quantity of wastewaters.

Whilst cleaner production is a separate issue to that covered in this report, the basic principles must be adopted if sustainable water usage is to be achieved. Therefore the philosophies are summarised here for completeness.

3.1.2 Volume reduction

There are three important factors driving wastewater minimisation in the ecotourism industry (Toplis, 1995):

- the industry’s inherent dependence on sensitive ecosystems,
- the remoteness of most operations, and
- client expectations.

Many guides to the reduction of water usage and wastewater production have been produced (Office of National Tourism, 1997), (Tourism Council Australia, 1998), (Hodges, 1998), (South Australian Tourist Commission, 1994). A summary of recommendations from these references is listed below.

- Reduce water demand by changing habits and work practices to avoid or reduce water use. For example, wash vehicles such that runoff is to the garden and reduce evaporation from swimming pools by covering them when they are not in use.
- Educate staff and guests to be wise with water.
  The aim of any ecocamp in the driest state, in the driest continent on earth would be to make visitors aware of the precious nature of water at every possible opportunity. (South Australian Tourist Commission, 1994)
- Restrict access for example by having fewer taps.
- Install water efficient devices (water pressure balancing devices, low flow shower roses, dual flush toilets, aerated taps, flow restrictors, manual urinals, hand pumps to sinks and baths) and appliances.
- Undertake regular maintenance and check for water leaks.
• Separate greywater.
• Use composting toilets.
• Reuse water wherever possible for non-potable uses (eg. firefighting, gardens, vehicle washing).
• Collect uncontaminated rainwater (eg. from roofs) and store.
• Reduce garden requirements by utilising:
  o xeriscape (low water) gardens;
  o sprinklers with efficient watering patterns and droplet sizes which encourage soil penetration;
  o timers and moisture meters to avoid overwatering;
  o drip irrigation or sub-surface hoses which eliminate runoff and evaporation; and
  o soil conditioners that encourage water infiltration and plant absorption.

The successful implementation and practical usage of the above recommendations will be site specific. In some cases, as with the installation of composting toilets, success will depend on tourist expectation and education. In other cases, such as with the separation of greywater, feasibility will depend on whether the site is established or design is just beginning.

A clever Japanese invention for minimising water usage is the toilet hand basin. This device has a hand basin situated above the cistern; when the toilet is flushed the cistern fills up via the hand basin spigot. Innovations such as this should be welcomed in the quest for sustainability.

3.1.3 Pollution reduction

The philosophy with respect to chemical usage and sustainability is presented in Figure 3.1 (Harremoës, 1997); all possible options are represented in decreasing order of sustainability.

![Figure 3.1 Philosophy of chemical usage](image)

Cleaner production requires that chemicals are not used or are replaced by natural substances. As an example of this, there are four non-toxic, biodegradable ingredients
that can be used as alternatives to chemical cleaners (Queensland Department of Environment and Heritage, 1996): baking soda, pure soap, washing soda and white vinegar. These ingredients can be used for everything from disinfection to grease removal to water softening.

Prevention of contamination can usually be achieved by good practices. For example, implementation of a solids separation system for use with food preparation prevents putrescible solids and fats/grease contaminating wastewater and hence reduces the pollutant load. The solids separation system should be coupled with catering practices that minimise food wastage through portion control, self service, appropriate food storage, post-mixing of drinks and pre-ordering of meals (Office of National Tourism, 1998) for maximum effect.

3.1.4 Tourism case studies

Tourism accommodation is second only to hospitals in the potential for adverse environmental impact. (Office of National Tourism, 1998) This is due to restaurants, laundries and recreational facilities that require large amounts of resources and produce equivalent amounts of waste.

A cleaner production site (Commonwealth Government, 1995) has been set up on the Internet detailing some case studies of successful cleaner production implementation in the Australian tourism industry. The examples include:

- the use of water saving devices at the Park Royal (St Kilda Rd),
- the use of water saving devices and laundry rinse recycler at the Hotel Inter Continental (Sydney), and
- the use of water saving devices, alternative chemicals and kitchen waste separation at the Hotel Kurrajong and the Regent (Sydney).

In all cases, substantial cost benefits have been realised. It is submitted that this benefit in itself should persuade all tourist accommodation to implement such practices without taking into account ecotourism incentives.

Dry toilets (Section 4.3.6) are also being utilised as a method of reducing water usage through cleaner production. There are successful systems installed at Cradle Mountain National Park (Office of National Tourism, 1996), Fitzroy Falls Visitor Centre (Office of National Tourism, 1997) and Jemby Rinjah Lodge (Office of National Tourism, 1997) amongst others.

The water reduction technique of cleaner production can also be seen at sites such as J's Bay YHA hostel in Byron Bay (Tourism Council Australia, 1998) where rainwater is collected to supplement mains water. Maho Bay resort (Selengut, 1995) provides guests with refillable water dispensers for potable use, utilises low water use toilets and limits shower usage. The resort collects rainwater and treats wastewater for reuse in both toilet flushing and irrigation.

Further examples of cleaner production in the tourism industry (Stanley, 1995) not previously mentioned are summarised below:
• bottled (refillable) drinking water (Bloomfield Lodge and Kingfisher Park),
• natural toiletries (Coconut Beach, Daintree Eco-lodge, Lady Elliot Island),
• raw water to rooms (Bloomfield Lodge and Ayers Rock Resort),
• solid wastes separated at source (Crystal Creek Rainforest Retreat),
• seawater used for toilet flushing (Heron Island and Lady Elliot Island),
• separate greywater system (Broken River Mountain Retreat and Jemby Rinjah),
• rainwater harvesting (Bloomfield Lodge and Gipsy Point Lodge), and
• laundry off-site (Cradle Mountain Lodge and Lady Elliot Island).

The Grand Bwa Lodge in Dominica puts the 'emphasis on sewage as a recyclable resource rather than a disposal problem' (White, 1995). River water is gravity fed through the resort, treated to tertiary standards and then returned to the river via a hydro generator. Wetlands are used in the treatment of the wastewater.

3.2 Water Reuse

3.2.1 Overview and limitations

Water must be reused wherever possible to achieve sustainability. However, this philosophy is tempered by the absolute requirement to safeguard human health and therefore it is recognised that the ultimate objective of providing treated water for potable use involves inappropriately complex technology. In addition, a long-term and large-scale public education program would be required to ensure acceptance. In terms of tourism, there must be no doubt as to the safety and quality of the water supply.

The reuse of water for potable requirements (drinking, personal hygiene and cooking) is therefore not considered in this report. As potable water requirements are only a small percentage of total water requirements this is acceptable although less than sustainable. The proposed reuse of water is therefore for irrigation, water features, vehicle washing, firefighting and road spraying.

The water for reuse will need to be free from bacterial and viral contamination unless it is to be reused in a manner that precludes human contact. Consideration of the type of reuse will determine the level of treatment and disinfection.

Both greywater and the effluent from on-site wastewater treatment plants will be considered for reuse purposes. 'Greywater is untreated household sewage that has not come into contact with toilet waste. It includes wastewater from bathtubs, bathroom washbasins, clothes-washing machines and laundry tubs.' (Jeppesen, 1996) Greywater does not typically include kitchen wastewater due to contamination from additional materials, such as fats, oils and readily putrescible material, not present in wastewater arising from hygienic purposes. These contaminants require additional treatment stages and hence kitchen wastewater is usually only included in greywater where stringent controls, such as waste separation practices, are in place.
3.2.2 Current situation in Australia and overseas

There is no national unified approach to water reuse in Australia; each state has a different legislation with respect to greywater, roofwater and stormwater. This is no different to America where the USEPA has different guidelines for different states (Crites and Tchobanoglous, 1988) or Spain where regional health authorities developed their own guidelines to combat a period of drought (Salgot and Pascual, 1996). However, it has been recognised (Anderson, 1994) that the development of a national framework addressing health, reclaimed water quality, environmental aspects of discharge and site sustainability is required. Indeed, the Urban Water Research Association of Australia has produced a report postulating guidelines for greywater reuse (Jeppesen, 1996).

In addition Draft Guidelines for Sewerage Systems - Use of Reclaimed Water have been prepared (National Health and Medical Research Council of Australia, 1996). The guidelines set down water quality requirements with respect to intended application and are intended to be used in conjunction with local government legislation.

At present legislation requires that those sites connected to sewer utilise the service and this precludes domestic reuse of greywater. This situation has forced some to take the law into their own hands (Berry, 1998) and contravene Health, Local Government and Water, Supply and Sewage legislation by installing home-made composting toilets and greywater irrigation systems. These systems are reported by users as being successful in terms of economics, sustainability and treatment objectives.

On the positive side, legal direct beneficial reuse of urban water in Australia is already in the order of 100,000 ML/y (6% of urban wastewater flow). Reuse applications include (Eden, 1996):

- irrigation of golf courses, racetracks, sports ovals, turf farms, pasture crops and vineyards,
- restricted growing of vegetables,
- hydroponics,
- silviculture,
- flower and ornamental tree growing,
- wetland nature reserves,
- firefighting (industrial), and
- cooling towers (industrial).

Notable mention must be made of Rouse Hill in NSW, which is the first area in which recycled water is available on a large scale for domestic non-potable use in Australia. Treated wastewater is recycled through dual reticulation, to each individual household for watering the garden/ lawns, flushing the toilet, washing the car and similar outdoors use. Although the scheme has failed to achieve economic goals, this can be seen to be a fault of planning (the resident population did not reach expected levels) and not design of the reuse system.
International types of water reuse are similar to those bulleted above, with the following important additions (Asano et al., 1996; Shelef and Azov, 1996):

- water recharge (aquifers and wells),
- environmental water and flow augmentation, and
- passenger train washing.

3.2.3 Greywater usage

The separate collection, treatment and reuse of greywater are integral parts of the philosophy of sustainable water usage. As such, they should be incorporated into ecoresort development wherever possible.

Although faeces and urine are not present, the quality of greywater is highly variable and contains chemicals and microorganisms that can be harmful to public health and the environment (Table 3.1).

Therefore safe reuse of greywater requires the implementation of cleaner production techniques and also either treatment facilities or prevention of human contact. To simplify requirements for greywater reuse the following recommendations have been made:

- kitchen greywater should not be included as it is highly polluted, putrescible and contains many undesirable compounds (Christova Boal et al., 1996),
- greywater should not include wastewater from kitchen sinks, dishwashers, garbage disposal units, laundry water from soiled nappies or wash water from the bathing of domestic animals (Jeppesen, 1996),
- removal of hair, lint etc. via strainer or filter is necessary to ensure systems do not clog (Christova Boal et al., 1996),
- blockages and build up of slime may be avoided by using pressurised systems (Jeppesen, 1996),
- storage of greywater is undesirable due to the potential for the growth of pathogenic microorganisms, mosquito breeding and odour generation (Christova Boal et al., 1996; Jeppesen, 1996),
- sub-surface reuse is the preferred method of irrigation as surface irrigation is prone to ponding, runoff and aerosols (Jeppesen, 1996), and
- reuse for toilet flushing should not be considered as it requires a high degree of treatment to ensure no health risks, toilet staining or biodegradation in cistern (Christova Boal et al., 1996; Jeppesen, 1996).

It is recommended that the above philosophies be adopted within tourism development projects to remove any risk to human health that may arise through the reuse of greywater.
Table 3.1 Greywater quality

<table>
<thead>
<tr>
<th>Parameters (mg/L except as stated)</th>
<th>(Christova Boal et al., 1996; Lechte et al., 1995)</th>
<th>(Jeppesen, 1994)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bathroom Water</td>
<td>Laundry Water</td>
</tr>
<tr>
<td>pH, units</td>
<td>6.4 - 8.1</td>
<td>9.3 - 10</td>
</tr>
<tr>
<td>Conductivity 25°C, µS/cm</td>
<td>82 - 250</td>
<td>190 - 1400</td>
</tr>
<tr>
<td>Colour, Pt/Co</td>
<td>60 - 100</td>
<td>50 - 70</td>
</tr>
<tr>
<td>Turbidity, NTU</td>
<td>60 - 240</td>
<td>50 - 210</td>
</tr>
<tr>
<td>SS</td>
<td>48 - 120</td>
<td>88 - 250</td>
</tr>
<tr>
<td>Nitrate, Nitrate-N</td>
<td>&lt;0.05 - 0.20</td>
<td>0.10 - 0.31</td>
</tr>
<tr>
<td>Ammonia-N</td>
<td>&lt;0.1 - 15</td>
<td>&lt;0.1 - 1.9</td>
</tr>
<tr>
<td>TKN</td>
<td>4.6 - 20</td>
<td>1.0 - 40</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>0.11 - 1.8</td>
<td>0.062 - 42</td>
</tr>
<tr>
<td>BOD</td>
<td>76 - 200</td>
<td>48 - 290</td>
</tr>
<tr>
<td>Oil and Grease</td>
<td>37 - 78</td>
<td>8.0 - 35</td>
</tr>
<tr>
<td>Alkalinity - CaCO₃</td>
<td>24 - 43</td>
<td>83 - 200</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>3.5 - 7.9</td>
<td>3.9 - 12</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>1.4 - 2.3</td>
<td>1.1 - 2.9</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>7.4 - 18</td>
<td>49 - 480</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>1.5 - 5.2</td>
<td>1.1 - 17</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>0.34 - 1.1</td>
<td>0.29 - 1.0</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>0.2 - 6.3</td>
<td>0.09 - 0.35</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>0.06 - 0.12</td>
<td>&lt;0.05 - 0.27</td>
</tr>
<tr>
<td>Aluminium (Al)</td>
<td>&lt;1.0</td>
<td>&lt;1.0 - 2.1</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>&lt;0.1</td>
<td>&lt;0.1 - 0.5</td>
</tr>
<tr>
<td>Sulphur (S)</td>
<td>1.2 - 3.3</td>
<td>9.5 - 40</td>
</tr>
<tr>
<td>Silicon (Si)</td>
<td>3.2 - 4.1</td>
<td>3.8 - 49</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Arsenic (As)</td>
<td>0.001</td>
<td>0.001 - 0.007</td>
</tr>
<tr>
<td>Selenium (Se)</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Chloride (Cl)</td>
<td>9.0 - 18</td>
<td>9.0 - 88</td>
</tr>
<tr>
<td>Total coliforms/ 100 mL (MPN)</td>
<td>500 - 2.4x10⁷</td>
<td>2.3x10³-3.3x10⁷</td>
</tr>
<tr>
<td>Faecal coliforms/ 100 mL (MPN)</td>
<td>170 - 3.3x10⁵</td>
<td>110 - 1.09x10⁵</td>
</tr>
<tr>
<td>Faecal streptococci/ 100 mL (MPN)</td>
<td>79 - &gt;2.4x10³</td>
<td>23 - &gt;2.4x10³</td>
</tr>
</tbody>
</table>
An innovative American system utilises the roots of ‘clean air’ plants to treat greywater (Gillette, 1996). This system is located inside the building (house, school etc.) and thus allows a healthy atmosphere to be generated as well as water for reuse. Plants chosen for these systems include: areca palm, syngonium, golden pothos, philodendron, bird of paradise, schefflera, umbrella plant, peace lily, Chinese evergreen and ficus ali.

3.2.4 Stormwater and integrated catchment management

With the implementation of integrated catchment management (ICM) strategies, stormwater has the potential to be a major sustainable water source.

Stormwater runoff from Australian cities is about equal to the amount of drinking water that is supplied. More than half of all domestic water is used for lower water quality purposes including garden watering and toilet flushing. There is therefore potential to store and reuse stormwater for non-drinking purposes and to markedly reduce the demand for drinking water. (National Capital Planning Authority, 1993)

Treatment of collected stormwaters would be required prior to reuse. It has been suggested (National Capital Planning Authority, 1993) (MacCormick, 1995) that three phases of treatment may be necessary:

1. trash racks and sediment traps (trash and coarse sediment interception),
2. sedimentation and detention basins (reduce flood peaks and trap finer sediment), and
3. wetlands (physical and biological treatment).

Collected stormwaters can be recirculated over a cascade system in order to keep them aerobic (Anonymous, 1997b).

Systems such as ICM, stormwater collection and stormwater treatment must be considered in ecoresort developments. Rainwater must be collected for use where legislation allows. (Legislation prevents rainwater from being collected in National Park areas.) As long as contamination is prevented, this pure source of water is considered to be acceptable for potable purposes.

3.3 Centralised vs. Decentralised Treatment

The centralised water management system, wherein sewage is transported away from the source to a large, often complex treatment plant, tends to be inherited from a time when public health and not sustainability was the issue. The end-of-pipe system tends to be inflexible and an expensive investment, designed for long life.

It is submitted that to achieve the goal of sustainable water management, we must move away from the end-of-pipe philosophy and move towards decentralised systems. There is presently a great deal of debate on the advantages of decentralised systems. Some of the arguments are presented in Table 3.2.
Table 3.2 Comments regarding decentralised wastewater treatment

<table>
<thead>
<tr>
<th>FOR DECENTRALISATION</th>
<th>AGAINST DECENTRALISATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centralised sewage treatment system has succeeded in terms of hygiene but has failed in terms of environmental performance. (Harremoës, 1997)</td>
<td>Centralised sewerage systems are usually the best method of sewage management in urban areas and in rural residential areas where a council water supply is available. This is because there is generally insufficient land to sustainably manage all the wastewater in these areas. (Department of Local Government, 1998)</td>
</tr>
<tr>
<td>Receiving waters associated with end-of-pipe technology cannot sustain organic and nutrient loads. (Newman and Mouritz, 1994)</td>
<td>Centralised systems are also the most suitable in regions with site constraints such as high rainfall, restrictive topography, or poor or shallow soils. (Department of Local Government, 1998)</td>
</tr>
<tr>
<td>Necessity of end-of-pipe treatment, described as a last option, is a sign of our failure in organising society in a non-polluting way. (Niemczynowicz, 1994)</td>
<td>Ownership is unclear and hence the units often do not receive sufficient maintenance. Unskilled personnel often undertake operation. (Keller, 1999)</td>
</tr>
<tr>
<td>Large flows are not concentrated in one pipe or plant and therefore bypasses, leaks and overflows are less likely. The collection system infrastructure is eliminated. (Venhuizen, 1997)</td>
<td>The successful performance of existing decentralised systems has not been proven. (Keller, 1999)</td>
</tr>
<tr>
<td>The treatment and reuse systems can be tailored to the waste stream. (Venhuizen, 1997)</td>
<td></td>
</tr>
<tr>
<td>The environmental and health principles underpinning the management of on-site systems include: ecologically sustainable development, water cycle management, total catchment management, protection of public health and the prevention of public health risk. (Department of Local Government, 1998)</td>
<td></td>
</tr>
</tbody>
</table>

It is generally agreed that decentralised wastewater treatment systems are useful for: individual residences, clusters of homes, public facilities, commercial establishments, industrial parks and small communities. However these systems must mirror the level of service currently provided if they are to be successful in terms of acceptance and achieving sustainability.

Ecoresort developments fall easily into the category of sites where decentralised wastewater treatment systems are most beneficial.
4 CONVENTIONAL ON-SITE WASTEWATER TREATMENT

This chapter gives an overview of the common methods of conventional on-site wastewater treatment. Management, collection and treatment options are discussed. The treatment section covers legislative requirements in addition to methods for producing secondary and tertiary effluent quality. The recent innovations of dry composting toilets and urine/faeces separation are also discussed.

4.1 Management and Planning

As with any system, management and planning are an integral part of successful operation. Many poorly designed, constructed or maintained on-site systems have been responsible for creating a negative image for such systems.

New South Wales recently produced guidelines for on-site sewage management (Department of Local Government, 1998). These outline planning and management processes for single households as summarised below.

- **Planning process**
  i. Rural residential release strategy,
  ii. Local environmental plan,
  iii. Development control plan,
  iv. Development application (subdivision then dwelling).

- **Management process (Council driven)**
  i. Survey and maintain database of all systems,
  ii. Map and maintain details of soil and site conditions,
  iii. Provide a training program,
  iv. Ensure land application areas comply with management requirements,
  v. Ensure regular inspection and maintenance of systems.

It is not difficult to see these principles being applied to remote tourist destinations employing on-site treatment. Management programs employed by such resorts will need to address (Anonymous, 1996c):

- planning for the future,
- supervision of siting, design, construction and installation of new systems,
- regular system monitoring and maintenance,
- educating operators, and
- record keeping.
4.2 Waste Collection and Transport

Section 2.3 summarised the current argument away from end-of-pipe systems and towards decentralisation. One of the benefits of decentralisation is the comparative lack of infrastructure; wastewater transport is no longer a priority issue. Indeed, systems such as dry toilets negate the need for collection and transport of blackwater, and greywater separation imposes new design criteria.

This section recognises that there are alternatives to the conventional gravity sewers and rising mains such as vacuum or pressure systems that are more applicable to on-site treatment (Anonymous, 1996a). These would need to be addressed on a site basis.

4.3 Wastewater Treatment (Conventional)

4.3.1 Overview

There are observed to be four methods for wastewater treatment (Ma and Yan, 1989):

1. control of pollution sources (cleaner production) such that treatment requirements are negated or reduced,
2. artificial chemo-mechanical systems (conventional treatment),
3. natural self-purification (observed with polluted systems that have been left for long periods of time without intervention),
4. ecologically engineered systems.

This section deals with conventional treatment wherein chemicals and energy are utilised to treat wastewater. These are the traditional on-site systems that do not incorporate principles of sustainability and have arisen through an historical need to protect human health. The fourth method is discussed in Section 5.

4.3.2 Requirements

In Australia, two million people depend on on-site system technologies to manage their sewage treatment and disposal. (Australian Water and Wastewater Association, 1998) Regulations in New South Wales (Department of Local Government, 1998) detail the level of treatment required for land application of final effluent; the Queensland government has not yet produced such a document and requirements depend on the local council regulations. Table 4.1 summarises the requirements.
Table 4.1 NSW treatment requirements for land application
(Department of Local Government, 1998)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Device Type</th>
<th>Land Application System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>Septic tank&lt;br&gt;Greywater tank&lt;br&gt;Waterless composting toilet&lt;br&gt;Wet composting toilet&lt;br&gt;Combustion toilet</td>
<td>Soil adsorption systems&lt;br&gt;Burial (compost)</td>
</tr>
<tr>
<td>Secondary</td>
<td>Septic tank + sand filter&lt;br&gt;Aerated treatment unit (ATU)&lt;br&gt;Greywater treatment</td>
<td>Subsurface irrigation</td>
</tr>
<tr>
<td>Tertiary</td>
<td>Secondary + disinfection</td>
<td>Subsurface irrigation&lt;br&gt;Surface irrigation (non-aerosol)</td>
</tr>
<tr>
<td>Tertiary (Greywater)</td>
<td>Greywater treatment + disinfection</td>
<td>Subsurface irrigation&lt;br&gt;Surface irrigation (non-aerosol)&lt;br&gt;Toilet flushing</td>
</tr>
</tbody>
</table>

The regulations also indicate the following restrictions:

- the hydraulic loading rate must be such that surface ponding, run-off and excessive percolation do not occur, and
- irrigation areas should be determined based on nitrogen, phosphorus, organic matter and sodium levels to ensure that build-up and groundwater contamination does not occur.

Discharges to receiving waters will be regulated depending on the sensitivity of the receiving water and local government legislation. The requirement for nutrient removal will exist if there is potential for eutrophication of the receiving waters.

On-site systems have gained a bad reputation and recent technological advances do not seem to have changed the trend for system failure.

Recent surveys in NSW have indicated failure rates of 50 to 90% of on-site systems. Reasons for failure may include unsuitable location of treatment units, poor design of systems and ineffective operation and maintenance. (Australian Water and Wastewater Association, 1998)

These factors are not specific to conventional on-site wastewater treatment but are applied more often due to the relatively small size of the systems and the fact that operation and maintenance are carried out by unskilled people.

4.3.3 Septic systems

In general, septic systems effect minimal treatment of raw sewage. They are inappropriate for sites with sandy soils or high water tables. Design needs to incorporate both the septic tank (tank size and pumping frequencies) and the associated drainfield (soil loading rates). Site features such as climate, slope, drainage and geology and soil features such as depth to watertable, permeability and density.
(Department of Local Government, 1998), require evaluation in the design stage to ensure successful operation.

Failure of septic systems is common and mainly due to inappropriate design, poor management or inadequate planning controls. Slow drainage, gurgling, odours and mushy ground are indicators of failure (Anonymous, 1995a). Poor system performance may require soil modification, fill or mounded systems, alternating systems, aquaculture or wetlands (Geary, 1988).

There are numerous articles on the design, operation and maintenance of septic systems. Table 4.2 summarises some of the more salient points.

<table>
<thead>
<tr>
<th>Table 4.2 Septic system design, operation and maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design</strong></td>
</tr>
<tr>
<td>Both septic tank and drainfield need to be addressed.</td>
</tr>
<tr>
<td>Design life should be over 20 years.</td>
</tr>
<tr>
<td>Design site features include: climate, slope, exposure,</td>
</tr>
<tr>
<td>drainage, and geology. (Department of Local Government, 1998)</td>
</tr>
<tr>
<td>Design soil features include: depth, depth to watertable,</td>
</tr>
<tr>
<td>permeability, density, pH, and conductivity. (Department of Local Government, 1998)</td>
</tr>
<tr>
<td>System inappropriate for sandy soils with high watertable. (Middle, 1994)</td>
</tr>
</tbody>
</table>

Table 4.3 shows literature values for the quality of effluent from properly designed septic systems at various points in the system.

Clearly, the level of faecal coliforms (F.C.) is unacceptable, even with polishing, for reuse within a tourist resort and disinfection would be required. Requirements for nutrient removal will depend on the type of reuse and local restrictions but in general, the use of a polishing step appears to effect both N and P removal to below standard requirements.
Table 4.3 Septic tank effluent quality

<table>
<thead>
<tr>
<th>Parameter</th>
<th>After septic system</th>
<th>After polishing step</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD (mg/L)</td>
<td>120 - 150</td>
<td>150</td>
</tr>
<tr>
<td>SS (mg/L)</td>
<td>50 - 70</td>
<td>50</td>
</tr>
<tr>
<td>N (mg/L)</td>
<td>20 - 30 a</td>
<td>50 - 60 c</td>
</tr>
<tr>
<td></td>
<td>&lt;1 b</td>
<td></td>
</tr>
<tr>
<td>P (mg/L)</td>
<td>7 - 20</td>
<td>10 - 15</td>
</tr>
<tr>
<td>F.C (No./100 mL)</td>
<td>$10^3$</td>
<td>$10^5$ - $10^7$</td>
</tr>
<tr>
<td>Polishing Step</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

NOTES
a Ammonium-N
b Nitrate-N
c Total-N

4.3.4 Aerated treatment units (ATU’s)

Aerated treatment units (ATU's) may utilise suspended or attached growth, but, by definition, allow aerobic decomposition of wastewater through active aeration.

Aerobic wastewater treatment may be a good option when: the soil quality is not appropriate for a septic system, there is high groundwater or shallow bedrock, a higher level of wastewater treatment is required, a septic system has failed and/or there is not enough land available for a septic system. (Anonymous, 1996b)

A further claim of the ATU is that the effluent is more stable than that from septic tanks. (Ivery, 1996) Table 4.4 shows the quality of final effluent from ATU's as reported in the literature. This treatment is significantly better than that provided by a septic tank. However, the disadvantages of ATU's with respect to septic systems include:

- the need for energy input,
- the need for regular maintenance,
- the potential for higher nitrate release, and
- the sensitivity to shock loads.

Systems will still require tertiary treatment and disinfection prior to reuse at a tourist resort.
Table 4.4 ATU effluent quality

<table>
<thead>
<tr>
<th>Parameter</th>
<th>(Gunn, 1994)</th>
<th>(Department of Local Government, 1998)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD (mg/L)</td>
<td>25 - 35</td>
<td>&lt;20</td>
</tr>
<tr>
<td>SS (mg/L)</td>
<td>40 - 50</td>
<td>&lt;30</td>
</tr>
<tr>
<td>N (mg/L)</td>
<td>&lt;1 a</td>
<td>25 - 50 c</td>
</tr>
<tr>
<td></td>
<td>35 b</td>
<td></td>
</tr>
<tr>
<td>P (mg/L)</td>
<td>-</td>
<td>10 - 15</td>
</tr>
<tr>
<td>F.C (No./100 mL)</td>
<td>3 x 10^3</td>
<td>10^4</td>
</tr>
</tbody>
</table>

NOTES
a Ammonium-N
b Nitrate-N
c Total-N

4.3.5 Biofilters

Much research has been undertaken with respect to on-site biofiltration. Some of the work is summarised in Table 4.5.

Table 4.5 Summary of on-site biofilter research

<table>
<thead>
<tr>
<th>Researcher/ Experimental Scale/ Influent</th>
<th>System</th>
<th>Effluent (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Imura et al., 1995) /Full scale trial /Household water (cooking, bathing and washing)</td>
<td>Flow equalisation, gross solids removal, anaerobic filter, anoxic-oxic recirculation biofilm, sedimentation</td>
<td>7.8 (BOD), 5.9 (SS), 6.4 (TN), 1.2 (TP)</td>
</tr>
<tr>
<td>(Jowett and McMaster-Michaye, 1995) /Pilot scale trial /Domestic sewage</td>
<td>Aerobic plastic-foam biofilter, forced aeration</td>
<td>97.8% (BOD removal), 96.1% (SS removal), 99.5% (Faecal coliform removal)</td>
</tr>
<tr>
<td>(Lens et al., 1994) /Laboratory scale trial /Domestic sewage</td>
<td>Matured bark/ peat packed column</td>
<td>97% (BOD removal), 72% (SS removal), 35% (TN removal), 93% (Amm.N removal)</td>
</tr>
<tr>
<td>(McKee and Brooks, 1994) /Operational system /Domestic sewage</td>
<td>Peat filter used after septic system</td>
<td>90% (BOD removal), 82% (TN removal), &gt;87% (TP removal), 99.9% (bacterial indicator removal)</td>
</tr>
<tr>
<td>(White et al., 1995) /Operational system? /Septic tank effluent</td>
<td>Peat filter used after septic system</td>
<td>85% (BOD removal), 96% (Amm.N removal), 98% (faecal coliform removal)</td>
</tr>
</tbody>
</table>

In general, there are a number of factors that tend to preclude biofilters for on-site use. Biofilters are land intensive in comparison to ATU’s or septic systems and this can make them unsuitable where land is at a premium. In addition, as the majority of biofilters are naturally aerated they are required to be exposed and this brings problems
of fly nuisance, odours and potential health risks. However, good distribution of wastewater and no blockages is hard to achieve and hence biofilters are not commonly used for on-site treatment.

4.3.6 Dry toilets

Dry toilets are a sustainable method of treating blackwater (faeces and urine). They do not require water for carriage as the systems are designed to utilise gravity. There are many different systems currently being marketed as summarised in Table 4.6.

<table>
<thead>
<tr>
<th>Type</th>
<th>Common System</th>
<th>Description</th>
<th>Additional Materials</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inclined Base</td>
<td>Clivus Multrum</td>
<td>Air drawn through baffles, compost falls to base where it is shovelled out, maintenance required to ensure good compost</td>
<td>Household organics, garden trimmings, old paper</td>
<td>High</td>
</tr>
<tr>
<td>Carousel Batch</td>
<td>Rotaloo</td>
<td>Rotating bins, air circulated but not through bins, heating element to cause evaporation/ increase digestion</td>
<td>Minimal organic waste</td>
<td>Medium to high</td>
</tr>
<tr>
<td>Bin Batch</td>
<td>Naturelooo</td>
<td>Full bins removed and kept in storage area, air circulated</td>
<td>Household organics, some paper</td>
<td>Low to medium</td>
</tr>
<tr>
<td>Continual Batch</td>
<td>Dowmus</td>
<td>Air introduction, internal liquid treatment, compost to separate chamber</td>
<td>Household organics</td>
<td>Medium to high</td>
</tr>
<tr>
<td>Compact</td>
<td>Biolet</td>
<td>Urine separation, ventilation and heating, small composting chamber, mixing tines, compost extraction tray</td>
<td>Peat moss</td>
<td>Low to medium</td>
</tr>
</tbody>
</table>

One of the most common problems with dry toilets against their common acceptance and usage is that of odours. A study in Sweden of 37 houses utilising 3 different types of composting toilets (Fittschen and Niemczynowicz, 1997) concluded:

Composting toilets were implemented without sufficient knowledge and usage directions, resulting in partly disastrous operational results. In consequence, the majority of the ecovillage’s composting toilets are now replaced with water toilets.

The study also found that access to the compost was poor and ventilation was poor but that these design flaws could be overcome. One household that did not experience problems with the composting toilet was found to be adding bark shavings on a regular basis.

Research by numerous others has also shown that proper design and maintenance can alleviate problems associated with dry toilets. Design and operation guidelines include (Office of National Tourism, 1997):

- incorporate fans or black vent pipe to ventilate system,
• incorporate vermiculture (worms) to speed up the decomposition (adding sawdust as a bulking agent and to ensure system remains aerobic by absorbing liquids),
• do not site near water sources, depressions or runoff areas,
• add kitchen scraps,
• monitor moisture levels to ensure system does not become too wet or too dry,
• locate in sunny spot out of the wind, and
• insulate and where possible draw air in from a heated room (especially pertinent where temperatures can drop below 8°C).

The use of dry toilets at Australian ecoresorts (Section 3.1.4) has been reported as being successful. However, tourist acceptance remains low; this also applies to the non-flush drop toilet used in conjunction with a septic system also accepting greywater.

4.3.7 Polishing systems

4.3.7.1 Requirement

The conventional systems discussed above provide, at best, secondary treatment. Polishing systems, used in conjunction with the above systems, generally reduce solids concentrations producing an effluent with a lower turbidity for reuse. Some systems such as membrane filtration can also be instrumental in removing nutrients. In most cases additional energy is needed to operate these systems.

The systems discussed in this section would require to be used in conjunction with disinfection prior to effluent reuse.

4.3.7.2 Sand filters

Sand filters are used as a second step in wastewater treatment and are usually placed after septic systems or solids separation. Final effluent is usually colourless and odourless with BOD and SS concentrations less than 10 mg/L (Anonymous, 1997a). Sand filters do not remove nutrients but do remove many pathogens. However, disinfection would still be required as pathogen reduction is not to a level acceptable for reuse at a tourist destination.

4.3.7.3 Membrane filtration

The types of membrane filtration commercially available are classified as per Table 4.7. The process has prohibitively high associated capital and operating costs. Energy requirements are also high.

Membrane filtration has been used in conjunction with sewer mining (Day, 1996) to produce the following effluent characteristics:

- microscreening \(\rightarrow\) 230 mg/L BOD, 50 mg/L TKN, 11 mg/L TP,
- microfiltration \(\rightarrow\) 94 mg/L BOD, 44 mg/L TKN, 9 mg/L TP,
- reverse osmosis \(\rightarrow\) 1 mg/L BOD, 2.8 mg/L TKN, 0.05 mg/L TP,
<table>
<thead>
<tr>
<th>Type</th>
<th>Pressure (Bar)</th>
<th>Pollutant Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microfiltration</td>
<td>&lt;5</td>
<td>Emulsified oils and salts</td>
</tr>
<tr>
<td>Ultrafiltration</td>
<td>2 - 10</td>
<td>Biological matter (bacteria, viruses, starches, dyes, paints)</td>
</tr>
<tr>
<td>Nanofiltration</td>
<td>10 - 40</td>
<td>Smaller particles (dyes, sugars)</td>
</tr>
<tr>
<td>Reverse Osmosis</td>
<td>10 - 60</td>
<td>All dissolved material (salts, sugars, metal ions)</td>
</tr>
</tbody>
</table>

4.3.7.4 Algal turf scrubbers

Algal turf scrubbers (ATS) are used as a polishing stage following secondary treatment of wastewater. Although not a common system, nor conventional, they are included here for completeness. They can be used as a polishing stage for the conventional systems described in this section or for the ecosystems in Section 5.

The system uses attached periphyton, microalgae and bacteria to remove nutrients and sediment. Reductions from 3.1 to 1.7 mg/L of total phosphorus and from 5.0 to 3.9 mg/L of total Kjeldahl nitrogen have been achieved (Craggs et al., 1996).

The benefits of ATS also include reoxygenation of the water as well as production of a saleable commodity. Algae are harvested to remove nutrients, stimulate production and control invertebrate populations; harvested algae can be used as a soil amendment.

4.3.7.5 Disinfection

Current methods of disinfection either require high energy inputs (e.g. UV and ozone) or high chemical inputs (e.g. chlorine, peracetic acid etc.). Membranes have been used to disinfect but have both high capital and operating costs.

Sustainable treatment using the sun as an energy source and receiving waters for dilution may pose a health risk at tourist resorts due to unreliable performance.

4.4 Wastewater Separation

Current research in Northern Europe (Fittschen and Hahn, 1998) (Fittschen and Niemczynowicz, 1997) (Hanæus et al., 1997) (Hoglund et al., 1998) has been concerned with separation of urine and faeces in order to tailor treatment requirements. Assuming the use of phosphorus-free detergents, urine contains approximately 90% of the nitrogen and 70% of the phosphorus found in domestic sewage and hence, if separated, can be reused to allow nutrient recycle. The system proposed incorporates:

- a specially designed separation toilet,
- collection and storage (6 months to reduce pathogenic bacteria) of urine prior to direct use in agriculture,
- treatment of faeces by dry composting system.
Currently 2000 separating toilets have been installed and are being monitored in Sweden, mostly in eco-villages.

This technology requires the user to be educated in the use of the toilet and it has been found to be difficult for children to use. Therefore, the present incarnation of this technology is perhaps not suited to use at tourist destinations where the population is transient by definition. Developments are eagerly awaited.
5 SUSTAINABLE WASTEWATER TREATMENT

Ecosystem principles are discussed and examples of their use to treat wastewater are given. These examples comprise wetlands, engineered ecosystems and aquaculture.

5.1 Ecosystem Principles

An ecosystem is described as the various plants and animals living in a particular environment (e.g. a lake or rainforest) and the resources and energy required by this biota. Ecosystems are sensitive to external inputs and have multiple feedback systems such that an event in one part of the system may affect a seemingly remote part of the ecosystem (Straskraba, 1993). Ecosystems are known for their ability to adapt to changes such as those that may occur in wastewater composition and quantity. Passive ecosystems have been known to develop and thrive around polluted sites.

A set of criteria for the design of ecosystems has been proposed (Todd and Josephson, 1996).

1. Provide mineral diversity (igneous, sedimentary and metamorphic rocks) to encourage nutrient diversity.
2. Provide nutrient reservoirs for immediate requirements.
3. Provide abrupt or rapid changes, as measured in time or space, in the basic underlying properties of the subsystem (DO, redox, pH, T etc) to increase biochemical reactions.
4. Maximise surface area of living material to which a waste stream is exposed to get high exchange rates.
5. Provide periodic and random pulsed exchanges (light, flow, O2) to make the system more robust to external changes.
6. Design as multiple rows of cells differing in internal design and function as per design in nature to allow for growth.
7. Utilise at least 4 subecosystems coupled by flow, for a viable, self-designing and organising system capable of sustaining itself.
8. Utilise microbial communities; bacteria, algae, molds, protozoa, and fungi are all necessary.
9. Employ plant diversity (e.g. algae, root zones, crops).
10. Employ animal diversity (e.g. snails, bivalves, algivorous fish, zooplankton, protists, rotifers, insect larvae filter, vertebrates).
11. Allow for biological exchanges beyond the mesocosm on gaseous, nutrient, mineral and biological levels.
12. Base microcosm, mesocosms, macrocosm relationships on the world.

It is thought that the concept of ecosystems and their design principles will form an important part of the development of sustainable wastewater treatment systems of ecotourism resorts.
5.2 Ecosystem Examples

5.2.1 Wetlands

Wetlands have become an established method of polishing wastewater to a tertiary level. Designs of the various systems (free water surface, subsurface flow and floating aquatic plant) are well documented with new textbooks appearing every year (Crites and Tchobanoglous, 1988), (Tchobanoglous, 1997).

Lessons that have been learned from the use of wetlands over the last decade, and which have a bearing on this particular project, include the following:

- Aquatic plants are typically adapted to smaller concentrations (fine) of nutrients than are wetland plants, and therefore come at the end of the treatment process. Upland plants typically have higher nutrient requirements (coarse). This follows the natural mode of water moving from land to marsh to open water. (Anonymous, 1998c)
- Duckweed, pennywort and water hyacinth are particularly suited to taking up nutrients with root systems and storing in leaves. (Anonymous, 1998c)
- Nutrient enrichment changes the composition of the biota naturally occurring in wetlands and hence there is need for intervention to achieve treatment requirements. (Greenway, 1994)
- Australian natives have shown favourable results with respect to nutrient uptake. (Greenway, 1996)
- Wetlands follow seasonal patterns of nutrient uptake and release. (Mitsch et al., 1989)

The value of wetlands can be seen in three different fields (Greenway, 1994):

- hydrological (water quality, flood mitigation, clean groundwater recharge),
- ecological (habitats, refuges, diversity), and
- social (educational, amenity).

Novel uses of wetlands include an installation on the side of a building in Berlin (Thomas and Zeisel, 1997). The 'vertical swamp' is used in the treatment of greywater that is recycled to toilets and urinals.

Wetlands are land intensive and to date have only been successful in treating secondary effluent. The high biological oxygen demand of raw sewage quickly creates anaerobic conditions in the wetlands leading to a low survival rate of macrophytes. This effect is added to the build up of sediment on the roots which has also been shown to inhibit plant growth and eventually cause death. The freestanding water above the substrate is more likely to create odour nuisance, produce insect pests and promote unwanted algae growth if the influent has not received secondary treatment.

5.2.2 Engineered Ecosystems

Engineered ecosystems used for the treatment of wastewater are mostly based in the Northern Hemisphere where there are over 20 in operation (Wilhelmus, 1998). Flora
and fauna are utilised in a hierarchical fashion to treat wastewater to standards applicable for reuse or discharge. The processes usually begin with settlement and anaerobic digestion. This is then followed by a number of stages incorporating various biota, each successively improving the wastewater quality. Less sensitive biota is used at the beginning of the system.

The processes are claimed to be cost effective, robust, reliable and aesthetically pleasing. In addition, it is claimed that the sludge volumes are minimal to non-existent.

Tables 5.1 and 5.2 summarise details of actual systems utilising this philosophy. The former contains qualitative information whereas the latter contains sizes and effluent qualities.

These systems approach sustainability with their zero requirements for chemicals or power other than sunlight, slight aeration and pumping for transport. The installation at Bear River, Nova Scotia is a tourist attraction and that at South Burlington is used as an educational resource for school and college students.

**Table 5.1 Engineered ecosystems for the treatment of domestic wastewater**

<table>
<thead>
<tr>
<th>Location</th>
<th>Reference</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bear River, Nova Scotia</td>
<td>(Farrell, 1996), (Redwood, 1996)</td>
<td>Screens, grit removal, fine bubble aeration, flow equalisation, floating and racked plants (protozoa, algae, worms, frogs, fish and snails), marshland, UV disinfection, discharge to river. Sludge to reed/ worm beds.</td>
</tr>
<tr>
<td>Indiana, USA</td>
<td>(Logsdon, 1992)</td>
<td>Flow equalisation, aeration, snail and algae tanks, bluegill and snail tanks, aerated lagoon (water hyacinth, arrowhead, duckweed, tree seedlings, bluegill, Japanese koi, tropical sucker fish, mosquito fish), wetland marsh (elephant ear, reed canary grass, bulrushes, papyrus, wild aster, monkey flowers, variegated orchard grass, Japanese blood grass, wild iris, calladium, smartweed, angel trumpet), UV disinfection, discharge to creek.</td>
</tr>
<tr>
<td>Kolding, Denmark</td>
<td>(Anonymous, 1997b)</td>
<td>Sedimentation, anaerobic reactor, UV/ ozone disinfection, series of 'Bioworks' tanks (algae, plankton, plants, aquatic species and fish in natural food chain), market garden, root zone marsh, sub-surface filtration system.</td>
</tr>
<tr>
<td>Nacka, Sweden</td>
<td>(Bokalders, 1997)</td>
<td>Engineered marsh (zooplankton, fish, water hyacinths, plant beds, aeration), polishing marsh/ soil bed, discharge to groundwater/ lake.</td>
</tr>
<tr>
<td>Location</td>
<td>Reference</td>
<td>Size (m³/d)</td>
</tr>
<tr>
<td>------------------------</td>
<td>----------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Body Shop, USA</td>
<td>(Anonymous, 1998a)</td>
<td>15</td>
</tr>
<tr>
<td>Earth Centre, UK</td>
<td>(Anonymous, 1998a)</td>
<td>150</td>
</tr>
<tr>
<td>Findhorn, Scotland</td>
<td>(Anonymous, 1998a)</td>
<td>65</td>
</tr>
<tr>
<td>Harwich, USA</td>
<td>(Peterson and Teal, 1996)</td>
<td>34 avg 61 max</td>
</tr>
<tr>
<td>National Audubon Soc., USA</td>
<td>(Anonymous, 1998a)</td>
<td>38</td>
</tr>
<tr>
<td>Rhode Island, USA</td>
<td>(Todd and Josephson, 1996)</td>
<td>34 avg 61 max</td>
</tr>
<tr>
<td>South Burlington, USA</td>
<td>(Anonymous, 1998a)</td>
<td>300</td>
</tr>
<tr>
<td>Stensund, Norway</td>
<td>(Guterstam, 1996)</td>
<td>6 avg 20 max</td>
</tr>
<tr>
<td>Vermont Welcome Centre, USA</td>
<td>(Anonymous, 1998a)</td>
<td>25</td>
</tr>
</tbody>
</table>
5.2.3 Aquaculture

Fish are used in engineered ecosystems as part of the wastewater treatment process; this section deals with processes that concentrate on the use of fish.

5.2.3.1 Contamination

In some areas of the world, aquaculture processes utilise wastewater to produce fish. However, legislation in developed countries prevents this process due to the associated health risk and hence the fish produced through wastewater treatment are used for bait, animal feed or fertiliser. It is not foreign to us to feed fish, Hinchinbrook Island feeds organic waste to fish (Stanley, 1995), but perhaps engineering the systems to treat a waste and produce a commodity is.

Contamination of fish gut and muscle as well as skin has been shown (Hejkal et al., 1983) when fish are reared in settled sewage. However, it has been presented (Pearson, 1996) that the use of upstream stabilisation ponds can remove the risk of pathogen contamination as is possible in raw sewage fed fishponds. This has been demonstrated by Shereif et al (Shereif et al., 1995) and also a study undertaken in Egypt (Easa et al., 1995) where bacterial contaminants were found to be present only of the surface of fish raised in the effluent from a stabilisation pond system. However, levels of heavy metal in the fish did increase by 25% to 100% of the initial values over a period of 4 months.

5.2.3.2 Requirements

Fish require a pH between 6.5 and 9, a dissolved oxygen greater than 2 mg/L and an ammonia concentration less than 1 mg/L (Crites and Tchobanoglous, 1988). Dissolved oxygen should be above 5 mg/L as between 2 and 5 mg/L, only slow growth is observed (Reed et al., 1988). Fish activity is also highly dependant on temperature, most preferring warmer waters.

It must not be forgotten that fish produce their own waste and hence a downstream polishing process is usually required to achieve good quality effluent. Daphnia can be used for this purpose (Metcalfe, 1995) or algal turf scrubbers (Section 4.3.7.3) but care must be taken as daphnia is subject to seasonal variations and die off.

'Eco-techniques' required for successful aquaculture can be summarised as follows (Yan and Honglu, 1989).

- Choose different species fish and also different sizes of fingerlings when stocking.
- Ensure fish densities (number and body mass) are at correct level.
- Harvest larger fish and replace with fingerling.
- Apply feed/ fertiliser (green fodder, animal feed etc.) as necessary.
- Maintain adequate water supply and good water quality protection (oxygen and temperature).
5.2.3.3 Examples

A number of aquaculture systems, quoted in recent literature, are summarised in Table 5.3.

As can be seen from Table 5.3, polyculture is an important technique for aquaculture. 'In general, one to three species of fishes are reared as the dominant species of fish stock in a polyculture, and the others are secondary or companion species.' (Yan and Honglu, 1989) Each species of fish have their own particular niche on the food chain and thus fully utilise the wastewater.

<table>
<thead>
<tr>
<th>Location</th>
<th>Reference</th>
<th>Size (m³/d)</th>
<th>System Details</th>
<th>Effluent Quality (mg/L, CFU/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cairo, Egypt</td>
<td>(El Gohary et al., 1995)</td>
<td>Pilot scale</td>
<td>Facultative pond, algal pond, fishpond (Silver carp, Nile Tilapia). Silver carp died due to toxic Amm.N levels.</td>
<td>26 BOD 7 Amm.N 3 P</td>
</tr>
<tr>
<td>Calcutta, India</td>
<td>(Ghosh, 1997)</td>
<td>&gt; 3000 ha</td>
<td>Multiple species polyculture (Carp, Tilapia, Chanda, Mourala, Punti) most successful. Air breathing fish (Ophiocephalidae, Channidae) in 1st pond. Algae/ plankton important for food chain.</td>
<td>15 BOD 73 SS 31 N 0.04 P</td>
</tr>
<tr>
<td>Arkansas, USA</td>
<td>(Hejkal et al., 1983)</td>
<td>1700</td>
<td>Screen, clarifier, stabilisation pond, fishpond series (Silver carp, Bighead carp, Channel fish, Buffalofish, Grass carp).</td>
<td>Meets standards for secondary effluent.</td>
</tr>
<tr>
<td>Hungary</td>
<td>(Olah and Pekar, 1997)</td>
<td>50 - 150</td>
<td>Polyculture most efficient.</td>
<td>9 - 10 BOD 150 - 200 SS 0.3 - 0.5 Amm.N 2 - 3 N 0.7 - 1.0 P</td>
</tr>
<tr>
<td>Suez, Egypt</td>
<td>(Shereif et al., 1995)</td>
<td></td>
<td>Anaerobic pond, facultative pond, maturation pond, plankton pond, fish pond (Oreochromis niloticus, Mugil sehli), irrigation.</td>
<td>24 BOD 10 N 2.9 P 0 F Coliform</td>
</tr>
</tbody>
</table>

Table 5.3 Examples of aquaculture systems treating domestic wastewater
6 QUEENSLAND/NSW PRACTICE

This chapter details water management practices in Queensland and NSW at remote tourist destinations. The data was gathered through distribution of a questionnaire in 1998.

6.1 Questionnaire Overview

A questionnaire was developed to ascertain the water and wastewater practices currently employed at remote\(^1\) tourist destinations in Queensland and New South Wales (NSW). Remote resorts were selected as being those sites most likely to employ sustainable water and wastewater practices for economic reasons. It is also true that resorts are required by legislation to utilise council facilities if they exist. A copy of the questionnaire is attached as Appendix A; although the copy is in A4 format, those distributed were presented as an A5 booklet.

A total of 255 questionnaires were sent out to tourism operators in Queensland and NSW. These operators were sourced as follows:

- RACQ Handbook 89
- TCA - NSW 60
- TCA - Queensland 29
- Tourism NSW 26
- Tourism Tropical North Queensland 23
- Gulf Savannah Tourist Organisation 16
- Queensland Tourist and Travel Corp 11
- Travel Australia 1

Where known, questionnaires were not sent to those tourist operations which were not remote (ie. connected to both mains water and to sewer).

Follow-up cards were sent to operators who failed to reply to the first mail drop and a further questionnaire was mailed out to all those who failed to reply to both the initial letter and the follow-up card.

A total of 108 replies were received; 84 of these were from remote sites.

The questionnaire was constructed such that it could be completed anonymously, it also asked whether the operator would be interested in further participation. Responses to this section showed a large amount of interest in the project.

- 16 respondents decided to return the questionnaire anonymously,
- 2 respondents indicated that they did not want to have any further involvement,
- 4 respondents did not indicate whether or not they wanted any further involvement, and
- 62 respondents indicated that they would like to be involved further.

\(^1\) Remote is defined as being not connected to a sewer system and/or not connected to mains water.
The geographical locations of the 108 responses are as summarised in Table 6.1. Southern Queensland encompasses all sites south of Rockhampton and tropical Queensland accounts for the rest of the state.

Table 6.1 Summary of questionnaire responses (Sample size: 108)

<table>
<thead>
<tr>
<th>Location</th>
<th>Type</th>
<th>Coastal</th>
<th>Inland</th>
<th>Island</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical Qld</td>
<td>Remote</td>
<td>12</td>
<td>15</td>
<td>11</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Not remote</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Southern Qld</td>
<td>Remote</td>
<td>7</td>
<td>19</td>
<td>3</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Not remote</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>NSW</td>
<td>Remote</td>
<td>10</td>
<td>7</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Not remote</td>
<td>7</td>
<td>6</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>Remote</td>
<td>29</td>
<td>41</td>
<td>14</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>Not remote</td>
<td>16</td>
<td>8</td>
<td>0</td>
<td>24</td>
</tr>
</tbody>
</table>

6.2 Water Source

Table 6.2 indicates the source of water by geographical location.

Table 6.2 Water source vs. resort location (Sample size: 84)

<table>
<thead>
<tr>
<th>Location</th>
<th>Mains/ Tanker / Barge</th>
<th>Rain water</th>
<th>Rain water+ (Note 1)</th>
<th>Bore water</th>
<th>Bore water+ (Note 2)</th>
<th>Stream</th>
<th>Seawater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal</td>
<td>Tropical Qld</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Southern Qld</td>
<td>3</td>
<td>-</td>
<td>3</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>NSW</td>
<td>5</td>
<td>-</td>
<td>1</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>10</strong></td>
<td><strong>7</strong></td>
<td><strong>7</strong></td>
<td><strong>2</strong></td>
<td><strong>2</strong></td>
<td><strong>-</strong></td>
</tr>
<tr>
<td>Inland</td>
<td>Tropical Qld</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Southern Qld</td>
<td>1</td>
<td>2</td>
<td>7</td>
<td>3</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>NSW</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>4</strong></td>
<td><strong>3</strong></td>
<td><strong>11</strong></td>
<td><strong>8</strong></td>
<td><strong>2</strong></td>
<td><strong>12</strong></td>
</tr>
<tr>
<td>Island</td>
<td>Tropical Qld</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Southern Qld</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>NSW</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>2</strong></td>
<td><strong>1</strong></td>
<td><strong>3</strong></td>
<td><strong>5</strong></td>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>16</strong></td>
<td><strong>6</strong></td>
<td><strong>21</strong></td>
<td><strong>20</strong></td>
<td><strong>5</strong></td>
<td><strong>15</strong></td>
</tr>
</tbody>
</table>

NOTES

1. Rainwater is the primary source of water and is supplemented by bore water (10 sites), stream (4 sites), tanker (3 sites), mains water (2 sites), bore water/ stream (1 site) and bore water/ seawater (1 site).

2. Bore water is the primary source of water and is supplemented by mains water (2 sites), stream (2 sites) and dam water (1 site).
A number of points can be made about the above data:

- in the majority of cases, rainwater cannot be relied on to provide all of the resort water requirements,
- mains water is used more extensively along the coast most probably due to availability and relatively cheap costs,
- at geographically remote resorts, an alternative water source (rainwater, bore water or stream) is more likely to be used, and
- desalination is employed only on the islands due to necessity; high capital and operating costs preclude its use elsewhere.

The methods of water treatment are summarised in Table 6.3 below along with the water source.

Table 6.3 shows no apparent trends in the requirements for water treatment other than the fact that the majority of sites treat water prior to use and that conventional systems are used.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Additional Treatment</th>
<th>Total Sites</th>
<th>Major Water Source (No. of sites)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bore</td>
</tr>
<tr>
<td>Nothing</td>
<td>Nothing</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Settlement</td>
<td>Nothing</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Chemical addition</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Filtration</td>
<td>Nothing</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Chemical addition</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>UV disinfection</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Chlorine disinfection</td>
<td>Nothing</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Chemical addition</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>UV disinfection</td>
<td>Nothing</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Reverse osmosis</td>
<td>Nothing</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

NOTES

1. Chemicals are added to the water for a variety of reasons: solids removal, pH adjustment disinfection and iron/ manganese removal.

2. Reverse osmosis is used at one other site to supplement water from other sources. This site has been catalogued with respect to the treatment used for the main water supply.

Costs for water treatment varied depending on the water source; results are summarised in Table 6.4.
Table 6.4 Water treatment costs (Sample size: 84 No comment: 51 sites)

<table>
<thead>
<tr>
<th>Water Source</th>
<th>Number of Respondents</th>
<th>Costs (c/kL)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average</td>
<td>Range</td>
</tr>
<tr>
<td>Rain</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Stream</td>
<td>7</td>
<td>15</td>
<td>0 - 42</td>
</tr>
<tr>
<td>Bore</td>
<td>8</td>
<td>25</td>
<td>0 - 110</td>
</tr>
<tr>
<td>Mains</td>
<td>7</td>
<td>129</td>
<td>30 - 356</td>
</tr>
<tr>
<td>Desalination</td>
<td>3</td>
<td>300 - 1299</td>
<td>Note 1</td>
</tr>
<tr>
<td>Tanker/ Barge</td>
<td>4</td>
<td>752</td>
<td>50 - 2000</td>
</tr>
</tbody>
</table>

NOTE

1. Seawater desalination is the only source of water at one site; the cost of this operation is $12.99/kL. Two other sites use desalination to supplement rainwater as the water source; one site desalinates seawater and the other desalinates bore water. The overall cost of both these operations is $3/kL.

Table 6.4 supports the previous supposition that the driving force behind the choice of a source of water is that of economics. Those sources classified as the most sustainable (rainwater, stream water and bore water) are also usually the cheapest.

Water usage figures were examined with respect to population to determine if there were any correlations. These correlations may be useful in determining design flows for new tourism developments. Table 6.5 shows those correlations that were determined.

Table 6.5 Correlations of water usage vs. population

<table>
<thead>
<tr>
<th>X parameter</th>
<th>Y parameter</th>
<th>No. data points</th>
<th>Correlation coefficient ($r^2$)</th>
<th>Slope</th>
<th>Intercept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average water usage (kL/d)</td>
<td>Average o/night population</td>
<td>27</td>
<td>0.85</td>
<td>1.56</td>
<td>38.7</td>
</tr>
<tr>
<td>Average water usage (kL/d)</td>
<td>Average o/night population</td>
<td>27</td>
<td>0.83</td>
<td>1.70</td>
<td>0 Constrained</td>
</tr>
<tr>
<td>Peak water usage (kL/d)</td>
<td>Average water usage (kL/d)</td>
<td>23</td>
<td>0.994</td>
<td>0.71</td>
<td>-1.99</td>
</tr>
</tbody>
</table>

There was not enough data to support a correlation between the maximum water usage and the maximum overnight population.

6.3 Reuse

Table 6.6 shows the location of those sites that reuse water. Overall only 40% of the sites reuse their water.

It is no surprise that less than a fifth of coastal resorts reuse water whilst almost three-quarters of the island-based resorts practice reuse. This is probably a direct relation to the cost of water.
Table 6.6 Water reuse (Sample size: 84)

<table>
<thead>
<tr>
<th>Location</th>
<th>Reuse</th>
<th></th>
<th>No Reuse</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. Sites</td>
<td>Percentage</td>
<td>No. Sites</td>
<td>Percentage</td>
</tr>
<tr>
<td>Coastal</td>
<td>4</td>
<td>14%</td>
<td>25</td>
<td>86%</td>
</tr>
<tr>
<td>Inland</td>
<td>20</td>
<td>49%</td>
<td>21</td>
<td>51%</td>
</tr>
<tr>
<td>Island</td>
<td>10</td>
<td>71%</td>
<td>4</td>
<td>29%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>34</td>
<td>40%</td>
<td>50</td>
<td>60%</td>
</tr>
</tbody>
</table>

Of the 34 sites that reuse water:

- 24 sites reuse all water (final effluent and greywater),
- 6 sites reuse greywater only, and
- 4 sites reuse laundry water only.

Water is almost exclusively reused for irrigation (29 sites) with only 3 sites using it for vehicle washing as well as irrigation and one site using it for toilet flushing, fire fighting and irrigation. One of the respondents failed to specify what water was reused for.

With the exception of 5 sites, treatment prior to reuse involved disinfection (chemical or UV) in addition to:

- tertiary wastewater treatment processes (10 sites),
- nothing (9 sites),
- sand filtration (8 sites), and
- solids removal (2 sites).

Eight respondents quoted a cost for treatment prior to water reuse; these ranged from 0 to 870 c/kL with an average of 148 c/kL.

6.4 Waste Generation

Cleaner production and water conservation practices are summarised in Tables 6.7 and 6.8.

Table 6.7 Cleaner Production Systems (Sample size: 84 No comment: 19 sites)

<table>
<thead>
<tr>
<th>System</th>
<th>+ Nothing</th>
<th>+ Garbage disposal unit</th>
<th>+ Grease trap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nothing</td>
<td>1</td>
<td>5 (including grease trap)</td>
<td>41</td>
</tr>
<tr>
<td>Separate green waste</td>
<td>5</td>
<td>1</td>
<td>12</td>
</tr>
</tbody>
</table>
A survey (Buckley and Araujo, 1997) of Gold Coast accommodation providers (31 hotels, 38 motels and 125 apartment complexes) showed high interest in environmental issues but low saturation of energy and water saving measures. Table 6.8 shows that only 15 sites are utilising all available technology; the uptake of water saving measures appears to be not as universal as would be hoped given the reported cost benefit and sustainable advantages.

Waste discharge points are as summarised in Table 6.9.

### Table 6.9 Discharge Points (Sample size: 84, No comment as specified)

<table>
<thead>
<tr>
<th>Waste</th>
<th>No comment</th>
<th>Greywater /Reuse</th>
<th>On-site</th>
<th>Sewer</th>
<th>Septic</th>
<th>Off-site</th>
<th>Other (Notes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitchen</td>
<td>5</td>
<td>24</td>
<td>41</td>
<td>2</td>
<td>6</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>Grease</td>
<td>15</td>
<td>-</td>
<td>19</td>
<td>-</td>
<td>-</td>
<td>41</td>
<td>9</td>
</tr>
<tr>
<td>Laundry</td>
<td>7</td>
<td>27</td>
<td>38</td>
<td>3</td>
<td>3</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>Sewage</td>
<td>1</td>
<td></td>
<td>34</td>
<td>6</td>
<td>41</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Stormwater</td>
<td>2</td>
<td>41</td>
<td>11</td>
<td>10</td>
<td>20</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

NOTES
1. *Other* kitchen wastewater discharged to grease traps (4 sites), wetland (1 site) and unspecified (1 site).
2. *Other* grease discharged to garden (2 sites), driveway (1 site), soakage (1 site), garbage disposal (1 site), pondage (1 site), sink (1 site), buried (1 site) and unspecified (1 site).
3. *Other* laundry wastewater discharged to tank (3 sites), land (2 sites) and wetland (1 site).
4. *Other* sewage wastewater discharged to ground (1 site) and buried (1 site).

### 6.5 Waste Treatment

Table 6.10 shows the methods of wastewater treatment employed at the remote sites.

A recent survey (Toplis, 1995), showed that of 110 national nature-based operators, 34% used on-site systems, 54% had septic systems, 3% used the sewer system and 9% used dry toilets. The relative significance of these figures agrees with those detailed in Table 6.6.
Table 6.10 Wastewater Treatment Methods (Sample size: 84)

<table>
<thead>
<tr>
<th>Location</th>
<th>On-site</th>
<th>Septic</th>
<th>Sewer</th>
<th>Dry Toilets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal</td>
<td>3 (10%)</td>
<td>21 (72%)</td>
<td>5 (17%)</td>
<td>-</td>
</tr>
<tr>
<td>Inland</td>
<td>16 (39%)</td>
<td>22 (54%)</td>
<td>1 (2%)</td>
<td>2 (5%)</td>
</tr>
<tr>
<td>Island</td>
<td>13 (13%)</td>
<td>1 (7%)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>32 (38%)</td>
<td>44 (52%)</td>
<td>6 (7%)</td>
<td>2 (3%)</td>
</tr>
</tbody>
</table>

The on-site treatment methods are summarised in Table 6.11.

Table 6.11 On-site Treatment Methods (Sample size: 32 No comment: 2 sites)

<table>
<thead>
<tr>
<th>Treatment Method</th>
<th>No. Sites</th>
<th>Specific Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not a package plant</td>
<td>13</td>
<td>Oxidation ditch (1), Oxidation pond (3), Activated sludge (8), Sedimentation (1)</td>
</tr>
<tr>
<td>Aerobic sand filter</td>
<td>2</td>
<td>Envirotech</td>
</tr>
<tr>
<td>Anaerobic system + biological film</td>
<td>7</td>
<td>Aquatec-Maxcon (2), Enviroflow (4), Sewpadisc (1)</td>
</tr>
<tr>
<td>Biophase</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>Biotreat (1), Epcor (1), Dowmus (1), Clearwater 90 (1)</td>
</tr>
</tbody>
</table>

There appears to be no discernible trend for implementation of an on-site sewage treatment system.

Generally the operators of on-site systems were happy with the performance of the systems (23 said 'yes', 5 said 'no' and 4 did not comment). Tables 6.12 and 6.13 indicate the relative frequency of failure to meet the discharge requirements and other problems noted with respect to on-site systems. These tables that approximately one third of sites have no problems with the operation of their systems.

Table 6.12 On-site System Discharge Problems (Sample size: 32 No comment: 8 sites)

<table>
<thead>
<tr>
<th>Frequency</th>
<th>No. Sites</th>
<th>Specifics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Rarely/occasionally</td>
<td>10</td>
<td>BOD, SS, Amm.N and P</td>
</tr>
<tr>
<td>Yearly</td>
<td>1</td>
<td>Amm.N</td>
</tr>
<tr>
<td>Monthly</td>
<td>1</td>
<td>BOD, COD</td>
</tr>
<tr>
<td>Daily</td>
<td>2</td>
<td>BOD, SS, Amm.N and P</td>
</tr>
</tbody>
</table>
Table 6.13 On-site System Problems (Sample size: 32 No comment: 8 sites)

<table>
<thead>
<tr>
<th>Problem</th>
<th>No. Sites</th>
<th>Specifics</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>14</td>
<td>-</td>
</tr>
<tr>
<td>Overload</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Odours</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>5</td>
<td>Cold weather, Mechanical failures, Peak use, Low flows, Inability to meet requirements</td>
</tr>
</tbody>
</table>

The operators and the weekly hours required to maintain the on-site systems are summarised in Table 6.14.

Table 6.14 a). System Operator (Sample size: 32 No comment: 3 sites)

Table 6.14 b). Time Input (Sample size: 32 No comment: 4 sites)

<table>
<thead>
<tr>
<th>Operator</th>
<th>No. Sites</th>
<th>Time (h/week)</th>
<th>No. Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance staff</td>
<td>7</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Dedicated Operator</td>
<td>7</td>
<td>0 - 0.5</td>
<td>5</td>
</tr>
<tr>
<td>Contractor</td>
<td>5</td>
<td>1 - 5</td>
<td>5</td>
</tr>
<tr>
<td>Management</td>
<td>5</td>
<td>5 - 10</td>
<td>2</td>
</tr>
<tr>
<td>Engineering staff</td>
<td>3</td>
<td>10 - 20</td>
<td>3</td>
</tr>
<tr>
<td>Water officer</td>
<td>2</td>
<td>20 - 30</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30 - 70</td>
<td>4</td>
</tr>
</tbody>
</table>

One of the problems with operation of an on-site wastewater treatment system can be the transient nature of the staff. Correct operation requires not only knowledge of the principles of the system but also experience. Less than a quarter of the resorts employ a dedicated operator with most relying on staff whose duties may incorporate the grounds (maintenance and engineering staff) and resort operation (management). It can also be seen that 13 of the 28 sites that responded (46%) spend less than 1 hour per day maintaining the system.

6.6 Solids

Wastewater sludge treatment was undertaken by at least 24 of the 84 remote sites; 26 sites indicated that no sludge was produced and 34 sites did not indicate if any sludge treatment was necessary. Treatment methods employed by the resorts were:

- Anaerobic digestion (7 sites, one of which coupled this with composting and one with aerobic digestion),
- Lime addition (4 sites, one of which coupled this with composting),
- Aerobic digestion (3 sites, one of which coupled this with composting),
- Composting (5 sites),
• Dewatering (2 sites),
• Off-site (2 sites), and
• Enzyme addition (1 site).

As with wastewater treatment systems, there is no discernible trend for the treatment of wastewater sludge. It is postulated that the systems have been selected on the basis of site and disposal requirements. It is encouraging to see that the sustainable option of composting is used at one third of those sites that reported a requirement to treat sludge.

The methods of disposal of solid wastes are indicated in Table 6.15.

<table>
<thead>
<tr>
<th>Disposal Method</th>
<th>Water Sludge</th>
<th>Wastewater Sludge</th>
<th>Green Wastes</th>
</tr>
</thead>
<tbody>
<tr>
<td>No comment</td>
<td>11</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>None generated</td>
<td>39</td>
<td>10 (11 -not as yet)</td>
<td>-</td>
</tr>
<tr>
<td>Animal feed</td>
<td>-</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>Buried</td>
<td>3</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Composted (Note 1)</td>
<td>1</td>
<td>3</td>
<td>28</td>
</tr>
<tr>
<td>Drying Beds</td>
<td>-</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Mixed with wastewater sludge</td>
<td>14</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>-</td>
<td>2 (Tip) 1 (Garbage)</td>
</tr>
<tr>
<td>Truck/ tanker</td>
<td>15</td>
<td>37</td>
<td>21</td>
</tr>
<tr>
<td>Vermiculture</td>
<td>-</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

NOTE
1. The majority (22 sites) of the 32 sites that employ composting utilise the compost in their gardens; 2 sites leave the compost at site and 8 resorts did not comment on the final compost use.

A recent survey undertaken by the Office of National Tourism (1997) wherein 110 operators were canvassed as to methods of solid waste management, showed the following:

• recycle: on-site (15 sites), municipal (15 sites),
• on-site: composted (23 sites), burnt (4 sites), buried (3 sites), vermiculture (1 site), and
• off-site: contractor (19), municipal (14).

There is a high percentage of sites using the non-sustainable option of disposal as evidenced by both surveys.
6.7  Problems
The questionnaire asked if the resorts had any particular problems that needed to be addressed with respect to water and wastewater management. In particular they were asked about odours, corrosion, infiltration and costs. The findings of the questionnaire are detailed in Tables 6.16, 6.17, 6.18 and 6.19.

Table 6.16 Odour, Corrosion and Infiltration Problems (Sample size: 84 No comment as specified)

<table>
<thead>
<tr>
<th>Odour Problems</th>
<th>Corrosion Problems</th>
<th>Infiltration Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 No comment</td>
<td>27 No comment</td>
<td>24 No comment</td>
</tr>
<tr>
<td>45 None</td>
<td>51 None</td>
<td>51 None</td>
</tr>
<tr>
<td>4 Daily</td>
<td>3 Treatment plant</td>
<td>8 Rainwater</td>
</tr>
<tr>
<td>6 Weekly</td>
<td>1 Collection system</td>
<td>1 Seawater</td>
</tr>
<tr>
<td>5 Monthly</td>
<td>1 Accretion</td>
<td></td>
</tr>
<tr>
<td>2 Quarterly</td>
<td>1 Buildings</td>
<td></td>
</tr>
<tr>
<td>13 Rarely</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Peak times</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Other</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.17 Odour Sources (Sample size: 36 No comment: 2)

<table>
<thead>
<tr>
<th>Source</th>
<th>No. Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sewage collection and treatment</td>
<td>22</td>
</tr>
<tr>
<td>Sludge collection and treatment</td>
<td>7</td>
</tr>
<tr>
<td>Other:</td>
<td></td>
</tr>
<tr>
<td>Grease trap/ Kitchen waste</td>
<td>2</td>
</tr>
<tr>
<td>Septic breather</td>
<td>2</td>
</tr>
<tr>
<td>Composting toilet</td>
<td>1</td>
</tr>
<tr>
<td>Wineries</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTE
1. Some sites nominated more than one source and hence figures do not sum to 34.
Only 5 of odour problems were due to hydrogen sulphide as indicated by the presence of rotten egg gas.
Table 6.18 Excessive Costs (Sample size: 84 No comment 25 sites)

<table>
<thead>
<tr>
<th>Source</th>
<th>No. Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sludge disposal</td>
<td>8</td>
</tr>
<tr>
<td>Water supply</td>
<td>7</td>
</tr>
<tr>
<td>Sewage treatment</td>
<td>6</td>
</tr>
<tr>
<td>Water treatment</td>
<td>4</td>
</tr>
<tr>
<td>Sewage disposal</td>
<td>3</td>
</tr>
<tr>
<td>Sludge treatment</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTE
1. Some sites nominated more than one source of excessive costs and hence figures do not sum to 59.

Table 6.19 Other Areas Requiring Attention (Sample size: 84 No comment 59)

<table>
<thead>
<tr>
<th>Area/ Problem</th>
<th>No. Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disparity between legislative bodies, Legislation confusing, Policing inadequate</td>
<td>3</td>
</tr>
<tr>
<td>Water reuse practices</td>
<td>3</td>
</tr>
<tr>
<td>Excessive barge costs, Excessive trade waste costs</td>
<td>2</td>
</tr>
<tr>
<td>Neighbours practices causing damage</td>
<td>2</td>
</tr>
<tr>
<td>Alternate power source</td>
<td>1</td>
</tr>
<tr>
<td>Better information source</td>
<td>1</td>
</tr>
<tr>
<td>Compost and greywater system evaluation</td>
<td>1</td>
</tr>
<tr>
<td>Methane utilisation evaluation</td>
<td>1</td>
</tr>
<tr>
<td>Trenching system evaluation</td>
<td>1</td>
</tr>
</tbody>
</table>

A recent survey of Tourism Council Australia members (Huybers and Bennett, 1996) indicated that operator's permits were the most common type of environmental regulation and that there were a number of problems with them:

- complexity of regulations,
- delays in decision making by authorities, and
- uncertainty as to future regulations.

There appears to be no particular problem that is suffered by the resorts, indeed 70% of the resorts indicated that wasn't any area requiring attention.
6.8 Summary

As quoted in recent literature (Toplis, 1995):

Specifically, most organisations/individuals realise that waste and energy are both financially and environmentally costly and are therefore keen to make progress in these areas. Although there are elements of best practice and innovation within the industry, with most of these operators interested to share their experiences, much of the ecotourism industry is still unaware of new practices and technologies in waste and energy minimisation. This, combined with other barriers such as lack of reliable infrastructure, currently inhibit operator's ability to reduce waste and energy.

The results of the questionnaire support this view; there are elements of best practice implemented within the industry but on the whole, the level of sustainability is low. Increasing costs will drive the industry closer to sustainable practice but there is an element of lack of enthusiasm to change systems that have always served well.

Education may be the key to inducing further change and this is already being implemented through publications from the Office of National Tourism, Queensland Tourist and Travel Corporation, Tourism Council Australia and CRC for Sustainable Tourism.
7 CONCLUSIONS

This chapter concludes the previous chapters by proposing a system for sustainable water management. The system takes into account resort requirements and matches them with the principles of sustainability.

Figures 7.1 and 7.2 indicate water and wastewater management options for combined and separate blackwater/ greywater systems respectively. The options for treatment and reuse are classified as either non-sustainable or sustainable.

In summary, for sustainable water/ wastewater management at remote tourist accommodation, the following must be implemented.

- Water Source
  - Rainwater should be collected where possible and used as a water source prior to any other source. Rainwater collection and supply requires the least energy and chemical input and has the smallest environmental impact.
  - Bore water, spring water and river/ stream water can be used to supplement rainwater where the extraction does not cause an environmental impact. Water should be returned to source with no loss in quality. Treatment requirements should not be excessive; chemical and energy input should be minimal.
  - Mains water usage is less sustainable than other sources due to the energy and chemical requirements of transport and treatment. This is reflected in the generally higher cost.

- Water Reuse
  - All treated wastewater should be reused.
  - Reuse is recommended for all non-potable purposes (eg. irrigation, vehicle washing, firefighting, and water features).

- Water Use
  - Water saving devices should be used where possible.
  - Cleaner practice should be implemented where possible.
  - Dry composting toilets should be used.
  - 'No irrigation is undertaken other than for immediate plant establishment unless effluent is reused.' (Office of National Tourism, 1996) Xeriscape gardens that conserve water through creative landscaping, appropriate plant selection, and efficient irrigation should be employed.
• Wastewater Treatment
  o 'All cleaning chemicals are selected to be compatible with wastewater and effluent treatment and disposal (ie. biodegradable).' (Office of National Tourism, 1996)
  o If possible greywater should be kept separate from blackwater in order to minimise contamination and also to simplify treatment requirements.
  o Wastewater should be treated in such a manner as to minimise the input of both chemicals and energy.
  o All wastewater should be treated to such a standard as to allow reuse; at least secondary treatment will be required and in all probability tertiary treatment as well.
  o The wastewater system employs a failsafe process.
8 RECOMMENDATIONS

This report proposes a set of guidelines for water management at remote tourist destinations. It is submitted that there are sustainable systems currently in place and being developed/implemented in the following fields of water management:

- rainwater collection and use,
- greywater separation,
- dry composting toilets,
- cleaner practice (water usage reduction and minimisation of contamination), and
- water reuse.

Although the majority of these systems have also been shown to have a significant cost benefit attached to their implementation, adoption by the tourism industry has been slow and levels of usage are still minimal. This situation is being remedied through dissemination of information and by the successful demonstration of systems as outlined above.

However, it is obvious that there is a need for the development of sustainable wastewater treatment practices. The questionnaire showed that the tourism industry currently employs a myriad of wastewater treatment systems including septic systems, package treatment plants, conventional treatment plants and discharge to sewer. With the exception of the single resort that utilises only dry composting toilets, the industry does not employ systems that embrace sustainable philosophies.

All new resort developments should incorporate sustainable practices as a matter of principle. As traditional and sustainable systems are not dissimilar in terms of capital cost, there should be no 'up-front cost penalty' for the developer. The potential for future operational savings should be one of the incentives for implementation. However, the lack of experience of the industry with such systems is proving to be a major barrier. Ironically, until such systems are implemented, experience will not be gained.

At existing resorts, adoption of sustainable philosophies does represent a capital outlay that, in many cases, will not be quickly returned through operational savings. The driving forces of tourist expectation and legislative requirements will need to outweigh this cost before sustainable systems will be implemented. At present the ecotourist is in the minority and legislation is only just beginning to incorporate requirements for sustainability, hence the driving force is minimal.

Dry composting toilets combined with greywater treatment and reuse are seen as the ultimate in sustainable practice. Treatment requirements are minimised and water, nutrients and biodegradable materials are reused. It could be argued that this combination negates the need for development of sustainable wastewater treatment, however, there is presently low usage and adoption of this combination.
Consideration therefore needs to be given to sustainable treatment of combined blackwater and greywater. The aims of such a treatment system are outlined below and are based on the sustainable philosophies detailed in Section 1.1.2.

- Energy and material usage must be minimised.
  
  The proposed system will require no chemical input.
  
  Sunlight will be the main source of energy used for wastewater treatment. Gravity-fed systems will be used where possible however there may be some requirement for pumping in the transport of wastewater.

- There must be no transfer of problems in space or time to other persons.
  
  By-products of the treatment process will be of a form requiring no further treatment and able to be used for a specified purpose (ie. considered to be a resource and not a waste product).
  
  Wastewater will be treated immediately; there will be no storage.

- There must be no reduction or degradation of natural resources.
  
  Wastewater will be treated to a standard to allow reuse. Nutrients will be recycled through harvesting and composting.
  
  The final effluent will be of a standard comparable to the water supplied.

- Human activities must be integrated into natural cycles.
  
  Wastewater will be treated using the natural properties of a constructed ecosystem.

In addition, the final treatment process should:

- be cost effective,

- comply with all relevant legislation,

- provide an added attraction at the resort and/ or provide habitat for local flora and fauna and/ or produce a resource.

An engineered ecosystem, utilising Australian biota and climatic conditions, as discussed in Section 5.2.2, would appear to satisfy these criteria.
REFERENCES


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APPENDIX A

The Questionnaire