SUSTAINABLE ON-SITE SYSTEM DESIGN FOR AN ECOTOURISM SITE

Ben Kele[1], David J. Midmore[1], Keith Harrower[1], Barry Hood[1], Brendan McKennariey[2], Graham Doyle[2], David G. Saunders[3], Peter Macey[4]

1. Central Queensland University (CQU); 2. GBG Project Management P/L;
3. Building Services Hydraulic Design P/L; 4. AustralAsian Resource Consultants P/L

Abstract

The water usage and wastewater treatment and effluent reuse of an ecotourist development needs to be ecologically sustainable and meet the environmental goals of the project. Ecotrans (Qld) Ltd is proposing a large ecotourism development in the Gold Coast Hinterland. The site has access to reticulated water but not to municipal sewerage treatment. A best-practice holistic approach has been taken by CQU and GBG in regards to the projected water management plan. The design uses water-efficient techniques and chemical input controls so that the minimum volume of wastewater is generated with the smallest possible inorganic pollutant load. A combination of non-chemical treatment, relatively low maintenance, and biological treatment systems has been selected to treat the wastewater at the site. More than 40 separate on-site wastewater treatment systems will be used. Effluent reuse will be contained so that the risk of environmental pollution, especially that of natural waterways, is minimised. Treated effluent will be reused to irrigate re-vegetation programs.

Keywords

Best-practice, chemical control, evapotranspiration, peat filter, reed bed filter, sand filter, septic

1 Introduction

This paper outlines the water management, wastewater treatment, and effluent reuse designs proposed by CQU and GBG P/L for the Ecotrans (Qld) Ltd ecotourism development. The site is located on the Darlington range, near Coomera, in the Gold Coast Hinterland (AustralAsian 2003). Sub-tropical rainforests are the dominant vegetation type, although past grazing activities has resulted in parts of the site having been cleared. The proposed development will cost at least $110 million to construct and will incorporate day visitor facilities, conference centres, restaurants, holiday units, research centres, and staff quarters. Facilities will be positioned at various locations over the 1250 ha freehold site and the planned development will be accessed by a cableway. It is expected that over the period of a year an average of 2000 people will visit Ecotrans each day. The water management plan, including the treatment and reuse of the wastewater generated from the 550 construction workers, will be implemented as soon as building starts. Each building will have an on-site treatment system specifically designed and installed, as the topography of the area makes a central wastewater treatment system impractical.

2 Water management

Different types and grades of water will be used for domestic and non-domestic purposes at the Ecotrans site (see Table 1). Potable water will be supplied from Gold Coast Water with a 150 KL storage capacity at the site fed by a 65 mm main. Roof runoff from the buildings will be captured and stored in rainwater tanks. First flow flush devices will be fitted to all down-pipes to improve the quality of the water captured. The storage volume of this water will depend on the final number of buildings. The roof runoff will be calculated as:

$$Q = \max\{0, C(P-L)\} \quad \text{(Equation 1)}$$

Where the symbols Q and P are runoff, and rainfall depths respectively, C is a proportional loss due to infrastructure design, and L is the loss from the first flush device. Evaporation is assumed to be 0 (VanDerWal 2001).

All stormwater from developed areas at the site will be captured. Best practice stormwater capture, treatment, and storage mechanisms such as water sensitive urban design and storm water quality improvement devices will be used (McAlister et al. 2000). Stormwater flowing through non-developed areas will not be captured or stored.

Table 1. Water Types with Domestic and Non-Domestic Usage

Water Source	Domestic Use	Non-Domestic Use
Potable Water	Drinking and Food Preparation	Emergency Fire Fighting
Roof Runoff (Rainwater)	Showers, Hand-basins, Laundry	Emergency Fire Fighting Backup Toilet Flushing
Treated Greywater (Shower only)	Toilet Flushing	Emergency Fire Fighting and Sub-surface Irrigation
Ground Runoff (Stormwater)	None	Fire Fighting and Sub-surface Irrigation
Groundwater	None	Fire Fighting and Sub-surface Irrigation
Treated All-waste Effluent	None	Sub-surface Irrigation

The fire management plan requires the availability of large quantities of water. The storage tanks and areas for the ground runoff and groundwater will all be equipped with large fire-fighting pumps. The potable water, roof runoff, and treated shower greywater tanks, will all be fitted with outlets to which fire fighting pumps can be attached. The risk management plan calls for the potable water supply to be used first, roof runoff second, and treated greywater last.

3 Water use efficiency and chemical control

The water infrastructure at the site will follow best-practice principles and be AAA rated water-efficient (water-wise). Taps will be installed with flow regulators, and automatic shut-off in public areas. A leak detection and maintenance program will be implemented to retain the efficiency of the water infrastructure. All showers will be AAA rated with an expected water usage of 7 L/min. Waterless urinals and AAA dual flush toilets will be used to reduce the amount of blackwater generation. Kitchens will use AAA rated dishwashers (commercial standard) and laundries will have AAA rated front-loading washing machines. These washing machines have the additional benefit of a 50% reduction in detergent requirement.

Household chemicals, such as detergents, will be regulated at the site. Many domestic chemicals contain pollutants, such as sodium (Na), that degrade on-site treatment systems and reduce the sustainability of effluent reuse techniques (Patterson 1998). Products such as shampoos, conditioners, soaps, cleaners, and detergents will be selectively supplied so that only the most ecologically sustainable chemicals enter the waste-stream. It is acknowledged that this is only a partial control as visitors and staff will continue to use their own toiletries that may contain inappropriate chemicals. An education program will encourage people to use the soaps, shampoos, and conditioners provided. The use of non-chlorinated water for all domestic purposes, excluding potable use and food preparation tasks, will also significantly reduce the chemical load in the water.

The water-efficient technologies will reduce the overall volume of wastewater generated at the site, and as a consequence the wastewater produced will be more concentrated. The chemical input control will reduce the amount of inorganic pollutants in the wastewater. The overall effect should be a relatively small volume of wastewater with a low inorganic pollutant load.

4 Greywater treatment, storage and reuse

The greywater from the showers will enter the waste-stream separately and undergo a series of treatment and disinfection techniques so that it can be reused for the flushing of toilets. The reuse of the shower greywater reduces the total average water use per person by 20 L per day. This results in a substantial reduction in the amount of wastewater generated at the site.

Shower greywater was selected for reuse in toilet flushing as it has a relatively low faecal contaminant load. The chemical control measures should minimise the inorganic pollutants in the greywater. The first stage of treatment will be deep 4500 L vertical greasetraps. Unlike shallow interceptor greasetraps, a vertical design prevents hot-water surges from lifting fats and grease and transporting them through the primary treatment stage and into the secondary (Kele et al. 2001). The vertical greasetraps will also have in-line filters to further aid in the removal of solids. The main two types of organic solids that are of concern are human hair and fats from soaps. Hair and fats take a relatively long time to degrade and can clog filters and damage pumps. Regularly maintained in-line filters should dramatically decrease the amount of fats and hair that enter the next treatment stage. The primary treated shower greywater will be aerated and pumped through a recirculating sand and zeolite filter. This should help eliminate any suspended solids, both organic and inorganic, from the effluent and reduce the microbial levels. The main disinfection system will be ultra-violet (UV) light. The effluent will flow along a shallow trough that incorporates the UV lights. The UV lights will be self-cleaning to reduce the sludge accumulation on the bulbs. The in-line filters and the sand-filters should remove the solids that can impact negatively upon the disinfection performance of UV lights (Darby et al. 1993). The storage tanks that hold the treated greywater will need to be aerated. An aeration system that incorporates ozone, as well as O_2, is under consideration. Ozone will assist in the maintenance of the disinfection of the treated effluent (Collivignarelli et al. 2000). The storage tanks for the treated effluent will be equipped with outlets that fire-fighting pumps can be connected to in an emergency when the other supplies of water have been exhausted. The water will only be stored for a short time, any excess treated shower greywater will be diverted into the normal waste-stream and enter at the beginning of the biological filter stage. A risk management plan has been constructed for the reuse of the treated shower greywater for toilet flushing. Pipes that contain treated effluent will be colour coded, clearly labeled and only connected to the toilet cistern. Roof runoff will be used as the backup water supply in the event of a breakdown in the shower greywater treatment and reuse cycle. The appropriate backflow prevention devices will be installed (Ganoulis and Papalopoulou 1996).

5 Wastewater generation

The combination of the AAA rated water-efficient infrastructure, the drips maintenance program, and the reuse of treated shower greywater to flush toilets should all reduce the volume of wastewater generated. After consultation with the relevant authorities in the Gold Coast area the wastewater treatment system will be designed using the following wastewater generation figures, 120 L/per-person/day overnight-visitor and staff, 20 L/per-person/day normal day-visitor, and 40 L/per-person/day conference centre day-attendees. Visitor numbers are expected to fluctuate from day-to-day. During peak-periods the visitor numbers are expected to reach 4000 per day. The number of tourists visiting Ecotrans is not expected to fall below 1000 people per day during non-peak times. The total volume of wastewater generated at the site per day will depend on the percentage of day visitors, conference attendees, overnight guests, and staff. The wastewater treatment system is designed to cope with the hydraulic surges caused by variations in wastewater generation.

6 Wastewater treatment

There will be over 40 separate wastewater treatment systems ranging in size from 10 equivalent people (EP) to 500 EP installed at the Ecotrans site. The size of each system will depend on its location and purpose within the tourist areas. Day-visitor facilities where large fluctuations in wastewater generation volumes are expected will have the biggest systems installed so that treatment quality is not adversely affected by hydraulic surges.

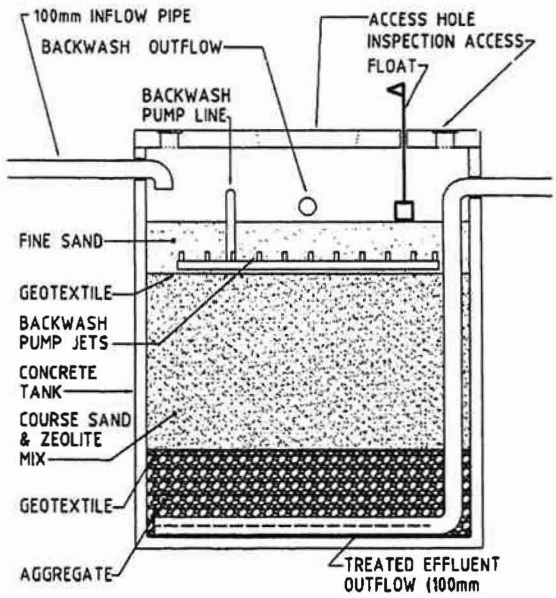

Figure 1. Small Sand and Zeolite Filter

All wastewater will undergo primary treatment in all-waste septic tanks fitted with in-line filters. In most instances a dual septic tank system will be installed, for example, two 4500 L all-waste septic tanks in sequence. This technique is preferred to a single large baffled tank as it has better solid retention, especially when in-line filters are used, thus resulting in a better quality of effluent (Gray 1995; Kele et al. 2001). The primary treated effluent will then pass into a holding tank, where it will be aerated and then pumped intermittently through a series of biological filters. The intermittent dosing of the filters allows for better aeration of the filter media and control of the water-flow through the system (Schudel and Boller 1990). Three types of biological filters will be used; sand and zeolite, peat bed, and sub-surface reed beds. All of the effluent will pass through at least two types of filters. Filters will range in size from tank-based systems, such as in Figure 1, to large in-ground 75 KL capacity filters that are fed primary treated effluent from a number of all-waste septic systems. The role of the filters is to concentrate the various pollutants inherent in the effluent within the filter-media itself. As the treated effluent will be reused in the re-vegetated degraded areas of the Ecotrans site, it is not desirable for the pollutants to concentrate in the soil surrounding the irrigation systems. The filter-media can be replaced when it has become polluted; it is not feasible to replace the soil in the re-vegetation sites. Sand and zeolite, peat bed, and sub-surface reed beds have been selected because of the various advantages that each system offers (Craven and Davison 2001; Geary et al. 2001; Patterson et al. 2001). All of the selected filter types can be designed to keep the effluent sub-surface and isolated from the external environment. This reduces the risk of environmental pollution and inadvertent human contact.

Sand and zeolite filters and subsurface reed beds can easily be designed to recirculate, thus improving detention times and treatment quality (Craven and Davison 2001). It may be possible to make peat beds recirculate, but the advantages of this need to be further investigated. Sand and zeolite filters are used to remove solids, heavy metals, faecal coliforms, and ammonia (Geary et al. 2001; Krebs et al. 1999). Sub-surface reed beds also remove faecal coliforms, begin to lower the nitrate and nitrite levels; but can add solids to the effluent (Craven and Davison 2001; Headley et al. 2001). Peat bed filters can lower total phosphorus (TP) levels, reduce the electrical conductivity (EC), and produce better than 90% faecal coliform reduction (Patterson et al. 2001). When used in sequence the filters can reduce total solids, faecal coliforms, heavy metals, total nitrogen (TN), TP, and EC. Until the final decision is made on the number and sizes of buildings, the exact number of all-waste septic tanks and biological filters cannot be determined. It is expected that the combined wastewater treatment systems will have a detention capacity well in excess of 1 ML. The biological filters will all need to be maintained to ensure treatment performance. The effluent, after it has passed through the biological filters, will then enter the first of the sub-surface irrigation reuse schemes.

7 Wastewater treatment system maintenance

All wastewater treatment systems require maintenance so that performance standards can be sustained (Goonetilleke et al. 1999). The Ecotrans development will employ a full-time worker who has the minimum qualification of the Yeronga TAFE domestic wastewater treatment plant maintenance course or equivalent (Harms 2002). In-line filters will be regularly cleaned and maintained. Sludge accumulation in the primary treatment tanks will be monitored, and pumped out when required. Wherever possible the biological filters will have a backwash capability (see Figure 1) that will send sludge back to the primary treatment tank. This will increase the sustainability of the filter media. Geotextile between the different layers of the filter media (see Figure 1) will allow each specific substrate layer to be removed and replaced separately when required. The bio-solids from the treatment systems will be disposed of at the nearest suitable sewage treatment plant (STP). Electrical equipment will have a 3-month inspection cycle. The shower greywater treatment system and treated effluent storage tanks will be inspected daily. A maintenance budget, with appropriate monies for testing requirements, has been written into the business plan to ensure the sustained performance of the treatment systems.

8 Effluent reuse

It is important that the cleared areas at the Ecotrans are re-vegetated. As an environmental tourist park the areas that have been cleared for grazing lower the value of the property. Wildlife corridors need to be established between remnant stands of native vegetation. The plants need to grow as quickly as possible, and one way to help ensure this is with irrigation. As irrigation water will be relatively scarce at the site the treated effluent will be used for this purpose.

Three different types of planting schemes are planned. Firstly, in the most degraded areas in the southwest corner of the site, high transpiration rate plants will be grown. Existing development outside the Ecotrans property boundaries surrounding this area have made wildlife corridors impractical. Secondly, cleared areas that are close to remnant vegetation stands will be planted with local native species. The large tree species will mainly be Eucalypts suitable for Koalas habitats. The shrubs and small trees will include those local species that are endangered or vulnerable such as, *Randia moorei, Macadamia tetraphylla, Zieria collina, Baloghia marmorata, Hicksbeachia pinnatifolia*, and *Corchorus cunninghami* (AustralAsian 2003). The selection of these species will aid in maintaining the flora biodiversity of the region as well as provide wildlife corridors. The third planting scheme irrigated with effluent will be the landscape plants surrounding some of the buildings.

Irrigation will only be sub-surface using two distinct methods, a contained evapotranspiration channel developed by CQU and sub-surface drip irrigation. All the treated effluent will pass through the CQU system at least once before it is diverted to the sub-surface drip irrigation installations. The two systems may be used side-by-side (see Figure 2) or independently.

Figure 2. Cross sections of the 2 sub-surface irrigation techniques used at the Ecotrans site

In the CQU system treated effluent is kept aerated in a holding tank. It is intermittently pumped through a 100 mm slotted pipe that runs through an aggregate layer in the bottom of a concrete channel (see Figure 2). The normal pump cycle is 15 minutes every 3 hours. The design of the channel is such that no effluent can escape into the outside environment. The concrete lip of the channel is kept aboveground level to prevent the intrusion of stormwater runoff. Sandy loam soil fills and is mounded over the channel. The selected plant species are then planted along the length of the channel, forming a contained evapotranspiration trench. The CQU channel will be supplied in 3 m sections. Just over 2 km of the channel will be installed. Each 3 m section allows the detention of 0.75 KL of treated effluent; thus resulting in approximately 525 KL of storage under normal operating conditions. Every 24 sections of channel will have a 4500 L holding tank attached allowing for an additional 130 KL of contained storage. Each section will be installed level, but with a 25 mm cascade to the next section in sequence. Irrigation runs will have 6 sections of channel, with 4 runs attached to each holding tank. The effluent is pumped to the highest channel section. Each channel section fills with effluent with any excess flowing to the next section. The design keeps the effluent 400 mm underground. Unused effluent does not accumulate within the channels but is returned to the holding tank attached to the irrigation run. Unused effluent can be recirculated through the CQU system or diverted to the other sub-surface irrigation system.

The unused effluent from the CQU evapotranspiration channels will be put through a single pass sand and zeolite filter to remove accumulated bio-solids. It will then be pumped through trickle irrigation tape attached to the top internal surface of a 100 mm half pipe and laid along a 400 mm deep trench (see Figure 2). This helps prevent root intrusion, and dripper head clogging, while increasing the filtration and aeration of the effluent. The majority of the plants irrigated with this method will be large trees with substantial taproots. This type of vegetation is unsuitable for CQU evapotranspiration channels but is required for the biodiversity in the re-vegetation process. It is planned for over 5 km of trickle tape irrigation to be installed at the site. This irrigation system is over-engineered, which allows it to act as an emergency overflow. Stormwater and groundwater will be used as irrigation water in both effluent irrigation techniques. The irrigation schemes will be split into areas, and in rotation, each area will be irrigated for a period of approximately a month with a non-effluent source of water (groundwater or stormwater). This should improve the quality of the soil surrounding the effluent irrigation.

9 Effluent reuse system maintenance

The wastewater treatment system employees will maintain the effluent irrigation infrastructure. Qualified horticulturists will care for the plants grown with the treated effluent. The rare and vulnerable plants may need specialist care. Plants grown with treated effluent are susceptible to disease and insect damage and management plans must be in place to counter these attacks (Kele et al. 2001). Plants that suffer infestations can have lower transpiration rates thus lowering the amount of treated effluent the reuse schemes can utilize.

10 Conclusion

Through the use of best-practice techniques, environmentally friendly technologies, and a holistic approach to the urban water cycle at the Ecotrans site, CQU and GBG have attempted to design an ecologically sustainable treatment and reuse system. The system will be examined fully and refined through a rigorous testing regime that will use the wastewater from the development's construction.

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