9.7.4 Grinder Pump System (GPS)

The GPS consist of macerating pumps capable of grinding normal constituents of domestic wastewater into small pieces and then pumping the wastewater to a small diameter (usually 30 - 50 mm for small communities) pressure sewer system similar to the STEP system. A septic tank for pre-treatment is therefore not required. Instead, a small wet well complete with the pump isolating and non-return valves and control equipment is installed. The wet well has one day's extra storage capacity to cater for pump failures. A single grinder pump can be used within a cluster arrangement for several homes to offset the installation costs.

A general summary of the major advantages and disadvantages of the GPS are outlined in Table 28.

Table 28: Summary of operation and maintenance advantages and disadvantages of GPS.

Advantages	Disadvantages
• Lower construction costs due to smaller piping and shallow narrow trenches. Also, piping can be redirected around obstacles. • Septic tanks are not required. • Infiltration is eliminated. • Pressure sewers follow natural ground profiles. • All sewage is removed off site.	• Septage treatment facility required. • Higher operation and maintenance costs. • Relies on power supply to individual systems. • Grinder pumps are relatively expensive (up to $2000). • Possible exfiltration from pressure sewer.

9.7.5 Vacuum Sewer System (VSS)

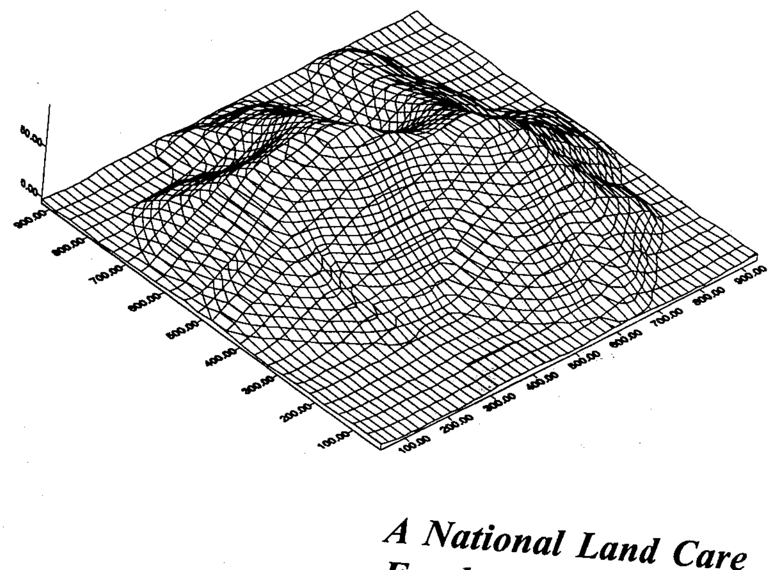
The VSS option comprises of a centrally located vacuum source which draws sewage through a sewer network to a collection tank from where it is conveyed to a treatment facility. Each allotment, or group of allotments, has a holding tank (gravity fed) and an interface valve. When the level in the holding tank reaches an upper limit, the valve is activated and the tank contents are drawn as a slug of liquid into a small bore sewer. A volume of atmospheric air follows the liquid slug. The slug soon disintegrates and gravitates to a low point (transportation pocket) in the sewer where it re-establishes. Subsequent flows of atmospheric air then push the slug further downstream and this action continues until the slug eventually reaches a collection tank at the vacuum pump station.

A general summary of the major advantages and disadvantages of the VSS are outlined in Table 29.

Environment
Engineering
Software

WATER AND SEWAGE OPTIONS STUDY: Scotland Island, Sydney, NSW

STAGE 2: Report 96/019B



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Martens & Associates Pty Ltd
Locked Bag 12
Newtown, NSW 2042, Australia
ANC 070 240 890

Phone (02) 9519 5970
Fax (02) 9519 1535
Email mail@martens.com.au

WATER AND SEWAGE OPTIONS STUDY: Scotland Island, Sydney, NSW

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MARTENS & ASSOCIATES PTY LTD

A.C.N. 070 240 890
Locked Bag 12
Newtown NSW 2042, Australia

Telephone: (02) 9519 5970 Facsimile: (02) 9519 1535
International Telephone: +61-2-9519-5970
International Facsimile: +61-2-9519-1535
Email: ma@mpx.com.au

1. Executive Summary

This report represents the second report of a two stage study funded by a Landcare Grant awarded to the Scotland Island Landcare Group (SILG) and administered by the Scotland Island Residents Association (SIRA). The initial study investigated the environmental and public health impacts of current on-site wastewater disposal on Scotland Island, which primarily consists of septic tank treatment and soil absorption disposal systems. The current study represents the findings of an investigation into future water and wastewater options for the Island in the light of findings of the initial (Stage 1) impact assessment study conducted by Martens & Associates Pty Ltd (1997).

Wastewater Treatment and Management Options

Both on- and off-Island wastewater treatment and management options were considered by this study. These included a variety of reticulated (wastewater collected and transported by a centralised sewer mains pipeline) and non-reticulated (on-site management) treatment methods listed below:

Non-reticulated On-Island Wastewater Treatment

- Septic Tank Pump-out Systems
- Enhanced Septic Tanks (EST)
- Sand Filter Systems
- Separate Grey- and Black-water Treatment / Disposal Systems
- Aerated Wastewater Treatment Systems (AWTS)
- Composting Toilet and Grey-water Treatment / Disposal

Reticulated On-Island Treatment / Disposal Options

- On-Island Packaged Treatment Plant (PTPs)

Reticulated Off-Island Treatment / Disposal

- Conventional Mains Sewer (GMS)
- Common Effluent Systems (CES)
- Variable Grade Sewer (VGS)
- Grinder Pump System (GPS)
- Vacuum Sewer System (VSS)

The study examined the main advantages and disadvantages of each system, together with the associated environmental impacts and economic costs of implementing and maintaining each type of system. These are broadly summarised below.

Type	Advantage	Disadvantage	Costs
On-site Options			
Septic Tank Pump-out System	No wastewater applied on-site. Low up-front cost.	Costs are very high to have system 'pumped-out'.	$2000-$3000 up-front. $200-$400/pump-out.
Enhanced Septic Tank (EST)	Low operational costs and maintenance. No power required. Increased trench life.	Costs are moderate to have system 'pumped-out' and filters maintained.	$2500-$3500 up-front. $200-$400 pump-out/3 years.
Sand Filter System	High effluent quality	Power, servicing and sand filter replacement required. Large dedicated area required.	$5000-$6000 up-front $445 maintenance/yr
Separate Grey- and Black-water Treatment / Disposal System	No power required. Grey-water re-use option. Improved effluent absorption and treatment.	Requires two treatment systems. Limited wastewater treatment prior to soil application.	$3000-$4000 up-front $100 maintenance/yr
Aerated Wastewater Treatment System (AWTS)	High effluent quality. Effluent re-use option over gardens.	Power and regular 3 monthly service required. Health risks if system fails.	$4000-$5000 up-front $300 maintenance/yr
Composting Toilet and Grey-water System	30 % hydraulic load reduction. Compost recycling. Reduced wastewater flow.	Servicing required. Compost disposal required. Potential for system failure.	$3500-$4500 up-front $300 maintenance/yr
Reticulated Options			
On-Island Packaged Treatment Plant (PTPs)	No septic tanks. High quality effluent. Tertiary treatment available.	Space and power required. Operator and servicing required.	$4800-$8200 per lot $450/lot/yr maintenance
Conventional Mains Sewer (GMS) and Vacuum Sewer System (VSS) with smaller diameter pipes.	Effluent removed from Island. Low on-going environmental impacts on Island.	High cost. Major earthworks required. Infiltration & surcharge impacts with ageing system	$10000-$20000 per lot $maintenance unknown
Common Effluent System (CES)	Small pipes laid at shallow depths. Low power requirements.	On-going maintenance. Septic tanks still used and require 'pumping-out'.	$10000-$20000 per lot $maintenance unknown but $200-$400/3 years.
Variable Grade Sewer (VGS)	Small pipes laid at shallow depths. Low power requirements.	High maintenance costs. Septic tanks still used and require pumping-out.	$10000-$20000 per lot $maintenance unknown but likely to be high.
Grinder Pump System (GPS)	Small pipes laid at shallow depths. Septic tanks not required.	Power required. Servicing of electro-mechanical equipment.	$10000-$20000 per lot $maintenance unknown but may to be high.

Current Water Supply and Future Options

Observations made of the emergency pipe line during the Stage 1 investigation indicated that the pipe leaks and is at risk of wastewater infiltration at several locations around the Island. Limited water sampling of both the rainwater tanks and the emergency water line indicated that Faecal Coliforms were found in both water supplies, although levels were higher in the rainwater tanks. Low levels found in the emergency supply were within an expected margin of error.

Relatively high Faecal Coliform counts in three of the eight rainwater tank samples are most likely to be associated with animal (possum and bird) faeces, and have to date not been regarded as a threat to public health. Importantly, it is generally accepted that Faecal Coliforms die off if stored for some 30 days. First flush diversion is therefore recommended to minimise contamination.

The options for water-supply considered included:

1. continued use of the current rainwater collection and storage system;
2. upgrading the existing reticulated supply to ensure that infiltration of contaminated water does not occur; and
3. implementation of a fully reticulated water mains supply.

Recommendations
This study makes recommendations for water and wastewater management on the Island. These have been separated into immediate, short-term (next two years), and long-term actions and are based on protecting and improving on the current state of environmental amenity on the Island.

Immediate Actions

1. An Island-wide survey of existing on-site wastewater treatment systems is recommended. The survey should focus on health aspects and show particular care in identifying lots where there is evidence of effluent surcharging and leakage downslope of the effluent application area, and / or, those lots where the wastewater treatment system is damaged or not performing to the original design specifications. Wastewater systems should be 'upgraded' to the levels required by Australian Standard 1547 (1994 or later) where the site inspection deems failure. This should be to the satisfaction of Pittwater Council.

2. A data-base of the Island's wastewater treatment systems should be established which covers each of the elements of the Island-wide survey (still to be determined). The data-base should be updated once every two years through repeated surveys of on-site wastewater treatment systems.

3. New installations and other building activities where additional wastewater is to be produced should comply with Australian Standard 1547 (1994 or later) for the disposal of domestic wastewater on-site.

Short-term Recommendations

1. Options for on-site disposal should principally include those options which produce high quality effluent. These therefore include AWTS's, sand filters, enhanced septic tanks and other similar systems / technologies producing a high grade effluent (including new technologies which have not been covered in this review).

2. Composting toilets, together with grey-water treatment/disposal systems, may provide a suitable wastewater management alternative for some sites on the Island. However, a three monthly service contract between the home owner and the manufacturer, similar to that required for AWTS's, is

recommended for such systems. In the light of the low nutrient content and high erosion potential of Island soils, deep burial of composted toilet wastes (> 50 cm) on the Island or removal from the Island are recommended.

3. The method of on-site effluent disposal may be by surface spray irrigation where effluent is sufficiently disinfected to meet appropriate public health standards. Where disinfection does not occur or does not meet public health standards/requirements or insufficient area is available for spray irrigation, then effluent should be distributed directly to sub-surface layers. This can be achieved either by disposal into standard absorption trenches or by application to a pressurised sub-surface irrigation area.
4. Effluent disposal buffer zones of 20 m to the ephemeral streams are recommended. This applies in particular to Catherine Park, and the wetter gullies on the southern side of the Island.
5. That the reticulated off-site disposal of sewage be investigated in further detail, providing considerations to the cost of such an installation and the environmental impacts with installation and ageing of proposed systems.
6. A community education programme is recommended to ensure that Island residents are aware of the current wastewater management problems on the Island and suitable future practices for wastewater management.
7. The surface water quality monitoring programme initiated on the Island during the stage 1 report should be continued on a 3 monthly basis for an initial period of 2 years so that changes to surface water quality conditions can continue to be monitored.

Long-term Recommendations

1. If a full reticulated town water mains supply is brought to the Island then many of the current effluent disposal areas are likely to become hydraulically overloaded and fail. It is critical that disposal areas would then either need to be completely upgraded to meet the requirements of Australian Standard 1547 (1994 or newer) or, in the event that this is not possible, one of the reticulated options should be implemented.

2. The Island's environmental (particularly surface water quality and native tree populations) and public health status should be reviewed every two years. Data for this review should come from the two year wastewater treatment system inspections and the continuing surface water quality monitoring programme established for the Island. Where environmental degradation continues and risks to public health increase from the present situation, the reticulated effluent management options are recommended subject to a full Environmental Impact Assessment.

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5. Introduction

5.1 Background

This water and wastewater options study for Scotland Island represents the second stage in a four stage project for the Island. Stage 1 of the project was concerned with an Island-wide assessment of the impacts and implications of currently installed wastewater management systems. These are predominantly septic tank and absorption trench units, although a small proportion of the existing building allotments maintain and operate aerobic wastewater treatment units (AWTSs) and surface irrigation systems. The Scotland Island Residents Association (SIRA) contracted Martens & Associates Pty Ltd to undertake Stage 1.

The findings of Stage 1 are contained in the report entitled:

Martens & Associates Pty Ltd (1996) *Scotland Island Wastewater Impact Study: Impact Assessment of Water and Wastewater on Environmental Quality and Public Health*, Scotland Island, Sydney

The report on Stage 1 of the project provides information on the Island-wide soil survey, the monitoring of surface runoff during wet weather in local creeks, monitoring of soil water quality in septic tank absorption trenches, and an assessment of both the suitability and impact of current on-site wastewater management systems, and the capability of land to accept domestic effluents. The recommendations of the Stage 1 report are as follows:

1. Current septic tank and trench absorption systems (including combined and separate systems) are not suitable and are likely to further degrade the Island environment.
2. Given the poor quality of surface runoff in the Island's ephemeral streams, effluent disposal buffer zones of a minimum of 20 m are recommended.
3. Contact with surface water should be avoided due to the potential health hazard.
4. Soil erosion control measures and urban runoff retention facilities are required to reduce Island soil loss and the deterioration of water quality in Pittwater
5. Community education on proper wastewater management practices is required.
6. The reticulated water supply should not be increased unless current wastewater treatment and disposal systems are improved.

This report is based on the findings of the initial Island investigation and examines the possible options for water and wastewater management on Scotland Island. Stages 3 and 4 of the project are concerned with public education and implementation of the findings of Stages 1 and 2.

5.2 About This Study

This study is primarily a desk top based study which examines the options for water and wastewater management available to the residents of Scotland Island. The study is based on the findings of Stage 1 of the project and refers specifically to management options which would lead to an improvement to the existing Island situation.

6. Review of Social and Environmental Factors

6.1 Location

Scotland Island is a small island of approximately 55 ha located in Pittwater, the southern arm of Broken Bay, some 25 km north of Sydney's central business district. The Island is bounded on all sides by 500 -1000 m of sea water with access restricted to private boat or ferry. Five wharves are available for public access: Tennis Court; Eastern; Carols; Bell; and Cargo.

6.2 Geology and Geomorphology

The Island is a steep sided bedrock outcrop situated within Pittwater on the boundary of two physiographic units of the Sydney region, the Hornsby Plateau and the Erina Hills. To the west of the island an escarpment of Triassic aged Hawkesbury Sandstone marks the edge of the Hornsby Plateau. To the east the Erina Hills, comprised of the Triassic aged Narrabeen Group outcrop to form the present bedrock configuration at the coast. Scotland Island possesses a Hawkesbury Sandstone cap underlain by the more lithologically diverse units of the Narrabeen Group comprised of interbedded sandstone, shale and claystone characteristic of the Erina Hills district.

Pittwater forms part of the Broken Bay drowned river valley estuary that evolved during the Postglacial Marine Transgression (PMT) at the mouth of the Hawkesbury river. Stream incision and valley widening processes formed deep and steep sided valleys that were progressively drowned by the rising sea level and infilled by fluvial sands overlain by estuarine basin sediments. Marine sand composed mainly of quartz with variable shell content derived from the continental shelf has been transported in an onshore direction with the rising sea level and form the flood and ebb tide deltas at the mouth of Broken Bay.

6.3 Topography

Topography on the island is largely the result of underlying geology and has been addessed in detail in the Stage 1 report where a digital terrain model was constructed for the Island using 4m contour interval orthophoto maps provided by the NSW Department of Land and Water Conservation. In general, local relief is approximately 30-90m and slopes are frequently moderate to steep (> 20 %). The Island rises to a central ridge and saddle unit composed of Hawkesbury Sandstone at an elevation of 80-90 mAHD. The western ridge top represents the highest point on the Island reaching approximately 92 mAHD. The distribution of Island slope categories is provided in Table 1.

Table 1: Scotland Island slope categories and aerial coverages.

Category	Slope (%)	Aerial coverage (ha)	Aerial coverage (%)
Low	< 5	4.3425	7.93
Moderate	5 - 10	4.7550	8.72
Steep	10 - 20	29.3925	53.71
Very steep	> 20	16.2225	29.64
TOTAL	**na**	**54.7125**	**100.00**

6.4 Vegetation

Native vegetation of Scotland Island varies both between ridges and gullies, and between northern and southern sides of the Island. Several vegetation communities have been identified including: Closed Forest (Rainforest), Open Forest (Wet Sclerophyll, WScl, or Dry Sclerophyll, DScl); degraded bushland near urban areas; coastal fringe vegetation (eg. *Allocasuarina littoralis*); and intertidal Mangrove forest. Open forests occur predominantly on the drier and more exposed slopes and crests. Closed forest occurs in small pockets on the sheltered slopes on the southern side of the Island.

6.5 Soils

Soils of Scotland Island approximate those described in the Watagan Soil Landscape that occur on rolling hills to very steep small hills atop the rocks of the Narrabeen Group (Charman and Murphy, 1989). These are generally described as shallow to moderate depth podzols with brown to brownish-black sandy loam A horizons and yellowish brown sandy clay loam to clay B horizons (sub-soils). General morphological characteristics of Island soils are summarised in Table 2 below.

Table 2: General morphological character of soils on Scotland Island (Charman and Murphy, 1989; Martens & Associates Pty Ltd, 1996).

Soil Horizons	General Morphological Character
A1	Loose, stony, brownish-black sandy loam
A2	Hardsetting, brown sandy clay loam
B1	Strongly pedal, yellowish brown fine sandy clay (atop sandstone bedrock)
B2	Strongly pedal clay (atop shale or siltstone bedrock)

As a part of the initial wastewater impact investigation, an Island-wide soil survey was undertaken to provide increased detail about local soil chemistry and morphology. The results of this soil survey are provided in Table 3.

In summary, soils on the Island are generally highly permeable in the upper A horizons and highly impermeable in the lower B horizons. Both horizons are extremely acidic, providing conditions which are conducive to nutrient and contaminant leaching away from effluent disposal areas. Electrical Conductivity (EC), sodicity (Exchangeable Sodium Percentage, ESP%) and phosphorus sorption capacity (P-sorption) increase with depth. Nutrient content, including cation exchange capacity (CEC), oxidised-nitrogen, total-nitrogen, and Bray-phosphorus (Bray-P) each are low and consistently decrease with depth.

Table 3: Summary of Island-wide soil survey results (Martens & Associates Pty Ltd, 1996).

Parameter	A Horizon	B horizon	Comment
Depth (m)	0.46 ± 0.24	0.54 ± 0.24	Moderate depth
Texture	LS-SL	SCL-C	Clay increasing with depth
K_{sat} (mm/day)	952 ± 608	< 20	Impermeable sub-soil
pH (1:5 suspension)	4.10 ± 0.24	4.00 ± 0.34	Extremely acidic
EC (dS/m, 1:5 suspension)	0.05 ± 0.02	0.09 ± 0.05	Non-saline
CEC (cm(+)/kg)	3.69 ± 1.62	4.77 ± 1.41	Very low
Sodicity (ESP%)	6.7 ± 3.4	12.6 ± 5.9	Marginal to highly sodic
Oxidised nitrogen (mg/kg)	3.8 ± 3.0	2.5 ± 0.0	Deficient, lower with depth
Total nitrogen (%)	0.14 ± 0.07	0.07 ± 0.02	Low
Bray-P (mg/kg)	4.3 ± 4.3	3.8 ± 1.8	Very low
P-sorption (mg/kg)	163.2 ± 58.5	237.1 ± 13.7	Medium, higher with depth

6.6 Climate

A rain gauge established on the Island by Mr Steven Crosby some 16 years ago provides some recent data on Island rainfall. However, Newport data (some 1-2 km from the Island) are utilised as a surrogate to indicate monthly rainfall variations. Mean annual rainfall at Newport is 1242 mm based on records obtained from the National Climate Centre via the Bureau of Meteorology for the years spanning 1931 to 1993 (62 years). Table 4 indicates variations in monthly rainfall for 1 %, 2 %, 10 %, 20 % and 50 % exceedence probabilities.

Table 4: Monthly rainfall totals over a range of probabilities (calculated using n=62 years or 100% of Newport monthly rainfall records).

Month	1%prob	2%prob	10%prob	20%prob	50%prob
JAN	531	454	273	195	92
FEB	538	476	284	202	93
MAR	579	496	302	218	108
APR	576	489	285	197	81
MAY	615	519	295	199	72
JUN	611	519	308	216	96
JUL	383	324	188	129	51
AUG	397	337	198	139	60
SEP	342	289	167	115	45
OCT	343	294	178	128	63
NOV	405	345	206	147	68
DEC	311	266	165	122	64
Total	5631	4808	2849	2007	893

Observations made from Observatory hill (39 m ASL, National Climate Centre) near the southern approaches to the Harbour Bridge indicate temperature ranges from a low of 2.1 degrees Celsius to a maximum of 45.3 degrees Celsius. The daily maximum may exceed 30 degrees from September to April and may fail to reach 15 degrees between April and October. Fogs are rare in the eastern coastal suburbs. The broad scale wind pattern is easterly in the summer and westerly in the winter. However during the summer months the coastal wind regime, in which Scotland Island is situated, is dominated by local sea breezes.

6.7 Population and Growth

At present there are some 350 development allotments on the island. A recent residents survey (1993) of 40% of the islands households indicated that on average 3.1 people lived in each house. Therefore, there are presently approximately 1000 residents on the island. Some fluctuation in this figure is expected due to the presence of holiday homes. Despite a heavily treed semi-urbanised visual quality that the island possesses when viewed from surrounding areas, the density of dwellings and people on the island represent a mature urban environment [at just below 2.5 houses per acre] that has developed without the usual urban drainage and sewage infrastructure. In the urban areas of the Island, houses frequently exist at a density of > 4 houses per acre.

Presently, some 50 building allotments are not developed. Therefore, some moderate increase in the Island's population is expected over the next 10-50 years culminating in a population of more than 1000 people based on average current occupancy numbers.

7. Current Water Supply and Wastewater Management

7.1 Water Supply and Usage

7.1.1 Supply

The Island's resident's water supply is currently comprised of rainwater tanks supplemented by purchases of water from an emergency supply that circles the island in the form of an exposed polythene pipe. A detailed residents survey was conducted by the Scotland Island Residents Association in December, 1993 to collect information and opinions relevant to the issues of water supply and wastewater disposal. 160 out of 300 surveys were returned which provided the only available information on tank capacity, estimated water usage and types of wastewater treatment systems.

Results from the SIRA water survey (December, 1993) indicate an average water tank capacity of 25,000 L, well below the 45,000 L recommended by Pittwater Council of which 10,000 L are required for fire fighting. Only 35% of residents have sufficient water supply to last more than 16 weeks without rain. Slightly less than 27% of residents were found to have sufficient water storage capacity to never use the emergency water supply. Clearly the water collection and storage capacity of most residences is insufficient to satisfy normal water use.

The emergency water supply line from which residents supplement tank water is in poor condition. In March 1992 Warringah Council notified the Residents Association that the line was sub-standard and should be repaired or removed. The pipe is exposed in many locations throughout the island and is susceptible to puncture, burning and melting. Observations made of the pipe line during the Stage 1 investigation indicated that if leaks occurred, then there would be a risk of wastewater infiltration at several locations around the Island. This is particularly the case where the emergency water supply line rests in drainage depressions or in roadside puddles. In response to these problems S.I.R.A. has now imposed a maintenance levy on the purchase of water in order to employ a person to maintain the line.

Warringah Pittwater Bush Fire Service's are currently addressing water storage and strategic operational plans.

7.1.2 Usage

Currently there is very little water usage information available for Scotland Island. This situation is attributed to the use of tank water supplies and the consequent lack of mains water meters. Water usage [and therefore wastewater flows] on the Island were estimated using the data supplied by the SIRA water use survey (1993) in the Stage 1 report (Tables 5). The low usage figure of approximately 110 L/person/day estimated from the water use survey reflects restrictions on water use imposed on residents by their dependence on tank water and supplements from the emergency water supply.

Table 5: Water use statistics based on SIRA water use survey (1993), taken from Martens & Associates Pty Ltd (1996).

SIRA water use survey, results summary	**Amount**
Mean tank water use (weighted mean based on mean tank size and distributed water usage)	298 L/day/house
Mean amount of water purchased (weighted mean)	6700 L
Mean number of times water is purchased per year	1.69
Mean amount of water purchased per day	31 L/day
Total weighted mean water usage per household	329.1 l/day
Daily water use per person based on 3 people per house (including holiday houses)	109.7 l/day
Daily water use per person based on AS1547 (1994)	***180 L/day***

Table 6: Household and Island wide water use estimates per month.

Month	**Lot Water Use (survey data)** l/hm/mth	**Island Water use (survey data)** l/mth	**Lot Water Use (AS1547 data)** l/hm/mth	**Island Water Use (AS1547 data)** l/mth
January	10202	3060630	16740	5022000
February	9215	2764440	15120	4536000
March	10202	3060630	16740	5022000
April	9873	2961900	16200	4860000
May	10202	3060630	16740	5022000
June	9873	2961900	16200	4860000
July	10202	3060630	16740	5022000
August	10202	3060630	16740	5022000
September	9873	2961900	16200	4860000
October	10202	3060630	16740	5022000
November	9873	2961900	16200	4860000
December	10202	3060630	16740	5022000
Total litres	120121	36036450	197100	59130000
Total Megalitres	**0.12**	**36.04**	**0.2**	**59.13**

7.2 Wastewater Management

7.2.1 Review of Wastewater Management Practices

Effluent disposal information is based on the 1993 SIRA survey of on-site wastewater systems. Of 160 surveys completed, septic systems accounted for 91% of effluent disposal. Of these systems, 21% received only black wastewater while 79% received both grey and black wastewater. An additional 8% have aerobic wastewater treatment systems (AWTS) and 1% have composting toilets. The septic systems are of various ages, 23% are over 15 years old and 16% had no record of ever being pumped out. A community organised effort resulted in a pump-out of approximately 100 houses following the SIRA water survey.

The majority of the Island utilises soil absorption trenches for the disposal of domestic wastewater from septic tank systems. Typically, 20 % of sites utilise separate grey and black water systems and 80 % utilise combined grey/black water treatment and disposal. Those few sites utilising AWTSs treat combined wastes and irrigate the effluent over varying sizes of land up to 50 m^2. The percentage of AWTSs would have increased since 1993 as many Building Applications have been processed since then and Council has usually required AWTS.

8. Water Supply Options

8.1 Background to Issues

Scotland Island residents are currently faced with the option of either utilising rainwater tanks as their primary water supply facility or using the existing emergency supply line which encircles the Island. There are several options available to the Island residents for water supply. These are discussed below in Sections 8.3, 8.4 and 8.5.

8.2 Quality of Existing Supply

As a part of this options study, the quality of existing water supplies was assessed through limited [,due to budgetary constraints,] sampling of both rainwater tanks and the existing reticulated emergency water supply. The emergency water supply was sampled on the 19/3/96 at three locations, two on the eastern side of the Island and one on the western side.

Eight tank water samples were collected at a later date by Island residents, five of these coming from Galvanised Iron tanks, and three coming from concrete tanks. All water samples were analysed for both bacterial contaminants as well as heavy metal composition. Field measurements of electrical conductivity, temperature and chlorine (free and total) were determined for the emergency water supply line but not for the rainwater tanks. The results of both field and laboratory analyses are provided in Table 7:

Table 7: Quality of existing water supplies including an average of the emergency water supply line samples (3 in total) and each of the tank water samples

Parameter Type	Line (3 samples)	Tank (Gal. Iron)	Tank (Concrete)	Tank (All samples)
EC (mS/cm)	0.21 ± 0.03	na	na	na
Temp (°C)	23.9 ± 1.76	na	na	na
Free Chlorine (mg/L)	0.01 ± 0.01	na	na	na
Total Chlorine (mg/L)	0.02 ± 0.01	na	na	na
Faecal Coliform	2 ± 0	391 ± 788	50 ± 69	263 ± 623
Total Coliform	2 ± 0	19801 ± 41499	110 ± 96	12417 ± 32984
Enterococci	24 ± 38	324 ± 713	101 ± 98	241 ± 554
Total Barium	16 ± 3	3 ± 2	6 ± 1	4 ± 2
Total Silver	1 ± 0	1 ± 0	1 ± 0	1 ± 0
Hexavalent Chromium	0.4 ± 0	0.4 ± 0	0.4 ± 0	0.4 ± 0
Total Arsenic	1 ± 0	1 ± 0	1 ± 0	1 ± 0
Total Cadmuim	1 ± 0	1 ± 0	1 ± 0	1 ± 0
Total Chromium	2 ± 0	2 ± 0	2 ± 0	2 ± 0
Total Copper	142 ± 21	37 ± 58	4 ± 2	25 ± 47
Total Lead	1 ± 1	16 ± 17	2 ± 1	11 ± 14
Total Selenium	3 ± 0	3 ± 0	3 ± 0	3 ± 0
Total Zinc	15 ± 9	3495 ± 2413	262 ± 113	2282 ± 2476
Total Calcium	9370 ± 1164	3167 ± 5218	10823 ± 5086	6038 ± 6217
Total Magnesium	5087 ± 516	1336 ± 213	1197 ± 133	1284 ± 190
Total Potassium	1750 ± 190	2084 ± 688	2343 ± 342	2181 ± 567
Total Sodium	23500 ± 8697	14614 ± 6471	30767 ± 7801	20671 ± 10545
Total Mercury	0.1 ± 0.0	0.2 ± 0.0	0.1 ± 0.0	0.1 ± 0.0
Sodium Absorption Ratio	4.3 ± 1.7	4.9 ± 3.0	6.7 ± 3.0	5.6 ± 3.0

Note: Heavy metal samples in µg/L. Faecal Coliform, Total Coliform and Enterococci samples in CFU/100ml. na = not analysed.

Data for the emergency water supply line indicates that Faecal Coliform and Enterococci bacteria where found in the samples. Although sampling was limited to three water samples, this may indicate that some contamination of the emergency water supply line has occurred. Alternatively, it may also indicate that the samples have become contaminated during collection or transport to the laboratory. Additional sampling of the emergency supply line would resolve this issue.

Results of the tank water sample analyses indicated relatively high bacterial counts (eg. Faecal Coliforms 263 ± 623 CFU/100 mls) suggesting that rainwater is possibly becoming contaminated with possum droppings. This was more apparent for the second set of rainwater samples collected within 24 hours of rainfall. However, the Northern Region Health Office indicated that this is typical of rainwater tanks and advised that holding rainwater for approximately 30 days will result in effective sterilisation of water due to the lack of growth media (Pers. Comm. Dr Kris Hort, 1996).

Some important findings of the analyses of Island water supplies are given below.

1. The emergency water supply line contained only low levels of free and total chlorine.
2. The emergency water supply line contained Faecal bacteria.
3. Faecal bacterial levels were high in three of the eight rainwater tank samples and exceeded ANZECC (1992) recommendations for potable water.
4. Heavy metal concentrations in both the emergency water supply line and the rainwater tanks were below ANZECC (1992) guidelines for potable water.
5. The emergency water supply line contained slightly higher copper concentrations than the rainwater tanks.
6. The rainwater tanks, notably the galvenised iron tanks, contained higher lead concentrations than the emergency water supply line although still below ANZECC (1992) guidelines of 50 μg/L.
7. Sodium levels are each below the recommended (ANZECC, 1992) drinking water guidelines of 300 mg/L.

From these findings, there are three principal options for the Island's water supply. These are outlined below in sections 8.3 - 8.5. The costs for these options are not part of the scope of this report. The advantages and disadvantages of each option are discussed later in relation to wastewater management options.

8.3 Option 1: Maintain use of Rainwater Tanks

This option ensures that rainwater tanks continue to be used on the Island and that further increases in the use of reticulated water supplies from the mainland are prevented. Permissible rainwater tanks can be constructed in a range of prefabricated shapes and sizes from materials including concrete, galvanised iron, plastic and fibreglass. Minimum rainwater tank sizes of 45,000L as specified by Pittwater Council would be required for new installations.

There are no real costs associated with this option except to residents wishing to install a new rainwater collection and storage system. Residents would be allowed to continue utilising their existing rainwater collection and storage systems.

Data on water quality of the rainwater tanks indicate that they provide high quality potable water, although they are susceptible to occasionally high bacterial levels associated with animal droppings.

8.4 Option 2: Upgrade Emergency Water Supply

Water quality analyses of the emergency water supply line indicate that there is a possibility that the supply line can become contaminated. If this situation were confirmed, then the emergency supply would required upgrading [provided that its use be continued]. Currently the emergency water supply line circles the Island in two primary rings. These sit on the ground surface and are at risk of damage by traffic and pedestrians in many areas around the

Island. Upgrading may require the pipes to be buried to reduce the risk of damage and subsequent infiltration of contaminated water.

8.5 Option 3: Full Reticulated Water Supply

This option would involves the installation of a full reticulated water supply system to each residence on the Island. This would be provided by a submarine pipeline from the mainland. Discontinuing the use of existing rainwater collection and storage facilities would not be required.

Under this options, residents would be charged additional water rates by Sydney Water.

9. Wastewater Treatment / Disposal Options Assessment

9.1 Option 1: Septic Tank Pumpout Systems (STPS)

Septic tank Pumpout Systems (STPS) are facilities where all the household wastewater is temporarily stored on-site in a storage vessel. No domestic wastewater is discharged to any portion of the allotment at any time. All wastewater is collected from the storage vessel at regular periods [governed by the volumetric holding capacity of the storage facility] and transported off-site to a centralised treatment facility.

The major advantages and disadvantages of STPS are outlined in Table 8.

Table 8: Summary of operation and maintenance advantages and disadvantages of septic tank pumpout systems.

Advantages	Disadvantages
• No discharge of effluent to allotment • Low initial cost • Does not normally require any power • Can operate without any artificial chemicals • Accommodates both grey- and black-water	• Very high on-going costs. • Site requires excavation for large holding well • Site requires simple access. • User is responsible for the maintenance • Illegal discharges • Road damage through heavy vehicular traffic.

9.1.1 Land Capability

Theoretically, there are very few land capability issues associated with the STPS wastewater management option as all domestic household waste-streams are stored in the receiving vessel and transported off-site to receive further treatment.

Direct restrictions to the applicability of this options relate to slope, land area available, and suitable substrate on which to site the storage vessel. The location of a large storage tank, would be limited by the following factors

1. steep slopes;
2. sites with land-slip potential; and
3. small area of land available for suitable location of the vessel

9.1.2 Maintenance and Management Requirements

Probably the single most important factor for the long-term success of the STPS is that the storage vessel is regularly emptied by a reputable septic tank cleaning / desludging contractor, thereby ensuring the system does not overflow and subsequently discharge directly to nearby environments. The frequency of tank evacuation is related to both the domestic wastewater load and the size of the storage tank. Table 9 indicates estimates of the required frequencies of evacuation according to both of these parameters.

Table 9 indicates that for a domestic household which receives reticulated town water supply situation where up to 900 litres of wastewater can be produced each day, a typical 2.0 m diameter tanks (and 2.0 m depth,or 6.3 m^3) would only serve to retain effluent for approximately 1 week. Such a system would therefore need to be evacuated weekly.

In the case of Scotland Island, the water survey indicated that water usage on the Island was particularly low, averaging approximately 110 L per person per day. Table 9 indicates that under such water usage conditions, a 2.0 m diameter tank for a design 5 person family would required evacuation somewhere between every 2 to 3 weeks. This would represent a maximum 26 evacuations each year. Should a larger 3.0 m [diameter tank again with 2 m depth] be used for storage, a similar 5 person family would require evacuation at a frequency of approximately 8-10 times per year.

Table 9: Septic tank evacuation period requirements, varied according to wastewater volume, tank volume and method of domestic water supply.

	Flow/day	D=1.0m	D=2.0m	D=3.0m	D=4.0m
	Town Water Supply (300L/bedrm/day)				
1 Bedroom	300	5	21	47	84
2 Bedroom	600	3	10	24	42
3 Bedroom	900	2	7	16	28
	Tank Water Supply (240L/bedrm/day)				
1 Bedroom	240	7	26	59	105
2 Bedroom	480	3	13	29	52
3 Bedroom	720	2	9	20	35
	Scotland Island Tank Water (110 L/pers/day)				
1 Person	110	14	57	129	228
3 Person	220	7	29	64	114
5 Person	330	5	19	43	76

Note: D = Tank Diameter. Tank storage depth of 2.0 m assumed for all calculations.

Council would need to regularly inspect the storage facility to ensure that the tank construction materials were not damaged or corroding, thereby allow raw wastewater to leach from the facility.

9.1.3 Environmental and Public Health Implications

In theory, all domestic wastewater is contained on-site, until it is evacuated from the storage facility by the liquid waste service provider. However, in practice this is not always the case and there is usually some risk associated effluent leaving the facility. This may occur when systems are not properly maintained, or, when homeowner deliberately allow tanks to overflow and discharge to nearby environments in an effort to reduce the on-going costs of the effluent pump-out service provider.

Table 10: Environmental and public health implications of septic tank pumpout systems.

Short-term Environmental Effects	Long-Term Environmental Effects	Public health implications
• Immediately relieves wastewater loads to land application areas. • Liquid waste pumping service provider requires site access, resulting in greater road usage.	• High risk of illegal effluent release to environment. • Risk of storage facility failure through cracks or overflows.	• Illegal effluent releases are a significant risk to local and downstream environments.

9.2 Option 2: Enhanced Septic Tanks (ESTs)

Septic tanks are the most commonly used method of domestic wastewater treatment for single households. They typically consist of a single or double compartment, rectangular or cylindrical, 3000 to 3200 L, concrete or fibreglass tank. Each state has its own guidelines for design of tanks, but all provide the same basic functions of sedimentation and digestion of settleable solids, flotation of oils and fats, and storage of the solids. Gases are exhausted to the atmosphere by back-flow through the inlet pipe and through the household. Presently, there are approximately 2 million people in Australia using on-site sewage facilities with the majority of these consisting of septic tanks.

Enhanced septic tanks (ESTs) are septic tanks with several enhancements which lead to higher grade effluent quality prior to discharge to the absorption trenches (see Section 9.2.1.1). The advantages and disadvantages of ESTs are outlined in Table 11.

Table 11: Summary of operation and maintenance advantages and disadvantages of enhanced septic tank systems.

Advantages	Disadvantages
• Produce higher quality effluent than conventional septic tank • Low cost • Does not normally require any power • Can operate without any artificial chemicals • Accommodates both grey- and black-water	• Requires a dedicated land area. • System requires desludging every 2 years • Filters need desludging every 2 years • Site requires excavation . • User is responsible for the maintenance.

9.2.1.1 Enhancements

There are several avenues through which an already installed septic tank treatment system may be 'improved' to produce higher quality effluent prior to discharge to the absorption trench. These include: add-on filters; flow baffles; and gas baffles (sections 9.2.1.1.1 - 9.2.1.1.3). Following the improvement of the septic tank, the absorption area can also be 'improved' or upgraded to promote long-term effective disposal of household effluent on-site.

9.2.1.1.1 Filters

Several types of filters are available for traditional septic tanks which are reported to provide significant improvements to final effluent quality. Brand names of these filters include Orenco and Zabel products.

In both cases, the filter is attached within the septic tank to the outlet of the final septic tank compartment and is used for the reduction of BOD_5 and suspended solids. Filters operate as surge controllers for high hydraulic flows and filtration for oil, grease and other fibrous products. Manufacturers report that the life of the absorption trenches can be extended by up to 2-3 times.

Filters consist of a series of plastic circular disks which are stacked within the filter. These may improve septic tank effluent to provide an average reduction in BOD_5 of 26 ± 10 % and suspended solids of 30 ± 23 % (Treanor, 1994). Results of effluent quality testing, although variable, consistently show improved effluent quality.

9.2.1.1.2 Flow baffles

Flow baffles have the effect of compartmentalising the septic tank into a number of smaller constituent sedimentation / flotation units. As raw wastewater passes through the septic tank, each compartment acts to progressively remove the majority of influent solids, by preventing effluent 'bypassing' from inlet to outlet.

Each baffle is constructed in such a way that accumulated scum and sludge are prevented from passing into the proceeding chamber (see Figure 1). Where baffles are not installed in a tank, the tank would require upgrading by either the installation of a baffle(s) or the replacement of the entire existing septic tank with an improved model. An alternative is to install a second septic tank downstream of the existing system. The existing system would therefore act as a pre-treatment unit for the new system.

There are limited data available regarding the precise influence of the flow baffles. However, provided that proper construction measures are ensured, the inclusion of flow baffles to septic tanks is most likely to improve BOD_5 and suspended solids concentrations in the final effluent.

9.2.1.1.3 Gas baffles

Gas baffles are simple, cost effective devices which are attached to the tank wall and act to deflect rising solids coupled with gaseous bubbles produced during the anaerobic digestion process. The can be utilised in conjunction with the filter (Orenco or Zabel) to reduce suspended solids throughput to the land application area as well as prolonging the ultimate life of the installed filter. As with flow baffling, it is assumed that the installation of gas baffles would result in improved effluent quality (BOD_5 and suspended solids). However, data on the influence of gas baffles on septic tank effluent quality is currently unavailable.

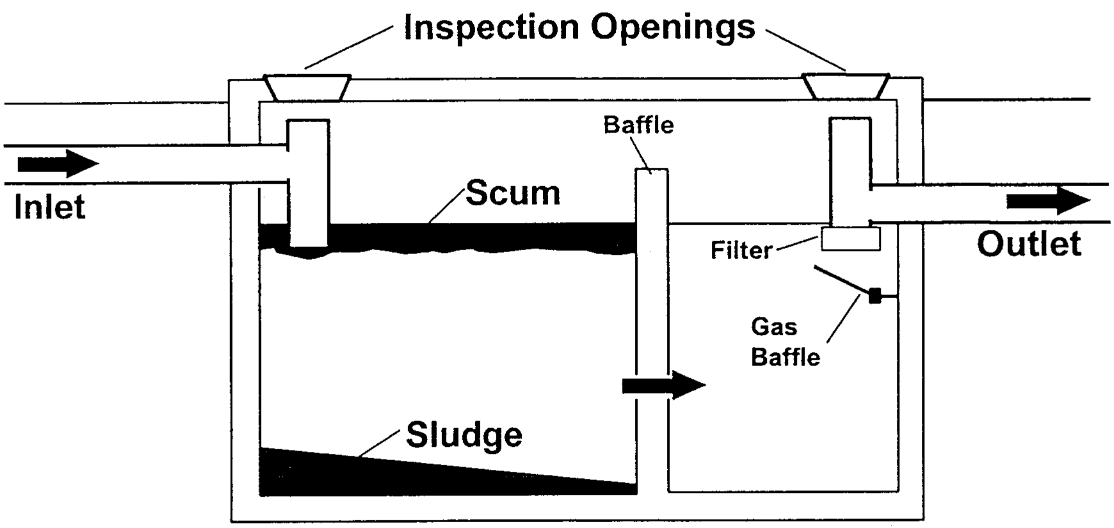

Figure 1: Enhanced septic tank configuration.

9.2.2 Land Capability

The factors that affect the capability of Scotland Island to accommodate effluent from ESTs are similar to those for other on-site effluent land application systems and include: suitable slope (< 20%); sufficient land area; impact on native and introduced vegetation; and soil assimilative capacity. The importance of each of these factors is controlled by the likely volume of wastewater produced and the quality of effluent from the EST.

It is not possible to determine the precise quality of effluent that would emanate from the EST. However, it is unlikely that significant nutrient removal would take place.

However, in these circumstances, recommendations currently provided in Australian Standard 1547 (1994) would provide a general 'rule of thumb' specifying absorption trench requirements.

For a standard septic tank on the Island catering for effluent from a 5 person household, the following absorption trench and evapotranspiration bed design requirements would apply:

Given: **A** horizon: Sandy loam, permeability approx. 1m/day, depth 40 cm
B horizon: Clayey loam, permeability approx. 0.02 m/day depth 45 cm

Hydraulic flow:550 (5 persons @ 110 L/person/day)

Design LTAR: 30 mm/day (AS1547, 1994)

Trench design:18.3 m^2 wetted surface area of trench
15.28 m trench length (600 mm wide, 600 mm deep)

Evapotranspiration bed design:

OPTIONS	
A: Lined, LTAR = 0	1670 m^2 of surface area Storage depth of 1127 mm Trench length 235 m (where disposed into trench)
B: Not lined, low LTAR	106 m^2 of surface area (LTAR = 5 $L/m^2/day$) Storage depth of 734 mm
C: Not lined, high LTAR	18 m^2 of surface area (LTAR = 30 $L/m^2/day$) Storage depth of 881 mm

Note: LTAR = Long Term Acceptance Rate

From these calculations, it is evident that only the standard absorption trench or the unlined evapotranspiration (ET) beds offer feasible alternatives to effluent disposal. Totally lined [and therefore sealed] evapotranspiration beds which rely only on ET processes would require surface disposal areas frequently exceeding the average allotment size and storage depths which exceed typical total soil depths on the Island.

The unlined evapotranspiration bed utilising a high LTAR of 30 $L/m^2/day$, is an appropriate alternative to the standard absorption trench, combining characteristics of on-site storage, evapotranspiration and percolation.

9.2.3 Maintenance and Management Requirements

Filters act to trap solids prior to discharge to the absorption trenches. Manufacturers report that the continued action of anaerobic organisms on the filter discs causes lodged particles to disintegrate and fall to the bottom of the tank. Filters would therefore require cleaning, at least at during regular inspections and pumping intervals. These are a function of how many solids enter the system as well as the hydraulic flow. Advice from manufacturers suggests that filters would require servicing and cleaning approximately every 1-2 years, approximately the same frequency as would be required for tank desludging.

The gas baffles would require cleaning upon each inspection to ensure that material has not substantially accumulated in the lee of the baffle where it is fixed to the wall of the septic tank.

9.2.4 Environmental and Public Health Implications

The primary advantage of this option is the reduction of organic and suspended solids loads leaving the septic tank and entering the absorption trench, thereby extending the life of the land application area. However, septic tank effluent is still high in nutrient and bacterial content as the enhancements do not provide any mechanism for their reduction.

It is therefore important that trench disposal areas would still comply with design parameters as provided in AS1547 (1994).

Table 12: Environmental and public health implications of enhanced septic tanks.

Short-term Environmental Effects	Long-Term Environmental Effects	Public health implications
• Produces higher quality effluent than conventional septic tank. • Little construction works involved with implementation.	• Produces higher quality effluent than conventional septic tank. • High nutrient loads to land application areas	• Continued risk of effluent leaching from drain-fields to downstream areas. • Effluent is not disinfected prior to discharge.

9.3 Option 3: Sand Filter System (SFS)

A sand filter is a bed of fine sand over which septic tank effluent is distributed and under which treated effluent is collected for subsequent disposal. The system is generally passive, requiring only a minimum of mechanical equipment. Under current requirements [in Queensland and Victoria], the bed area required for an average household is approximately 20 m^2 based on a loading rate [or Long-term Acceptance Rate, LTAR] of 50 L/m^2/day. The sand bed provides a medium for aerobic bacteria to grow and treat the septic effluent and further purify it. A system of two sand filters with intermittent dosing may be used for situations where heavy loading is expected. SFS are not at present an approved on-site treatment system in NSW.

Effluent from sand filters, followed by effluent disinfection can be used for surface irrigation (Australian Water Resources Council, 1988). Where site land area available for disposal is limited, they can be used to upgrade septic tank and AWTS effluent prior to sub-surface disposal in either an absorption trench, or a sub-surface irrigation area. The advantages and disadvantages of SFSs are outlined in Table 13.

Table 13: Summary of operation and maintenance advantages and disadvantages of sand filter type systems.

Advantages	Disadvantages
• Produces high quality effluent • No odours • Does not normally require any power • Can operate without any artificial chemicals • Accommodates both grey- and black-water	• High installation costs • May have a limited life and need periodic replacement (10-15 years). Alternatively, larger beds could be used. • Requires a dedicated land area. • User is responsible for the maintenance. • Transport of sand on/off Island.

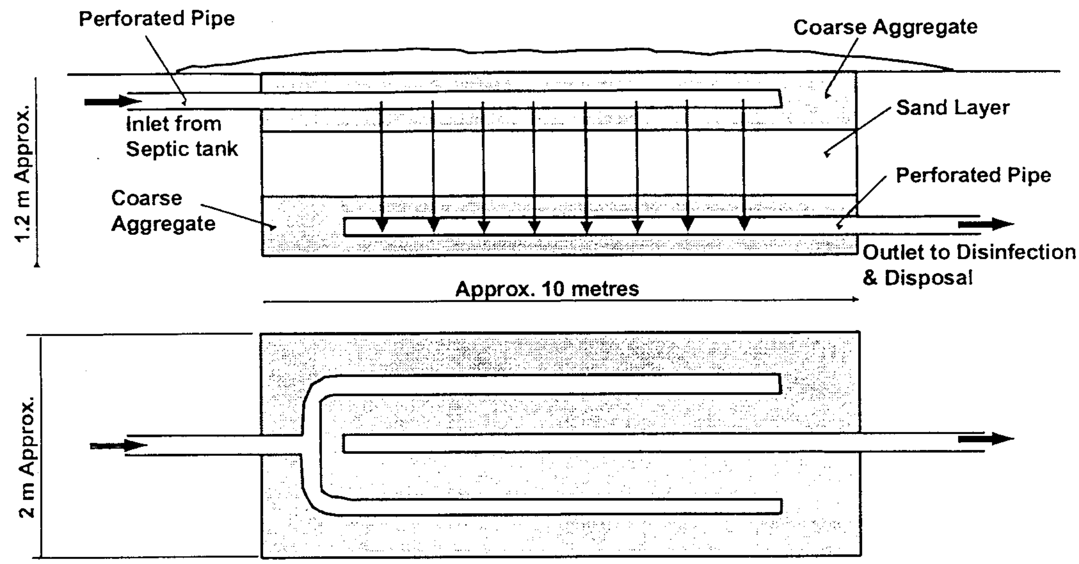

Figure 2: Configuration and size of a typical sand filter system.

9.3.1.1 Mound Systems

Mound systems are a variant of the sand filter, being installed above ground rather than below ground level. The Wisconsin mound on-site disposal system is typically utilised on relatively flat slopes which have a shallow layer of 300 to 600 mm of unsaturated topsoil and sub-soil overlying a limiting layer such as rock, hardpan or high water-table. The mound is constructed directly onto the natural ground surface which is ploughed or cultivated beforehand.

Wastewater renovation takes place within the sand fill of the mound, enabling the unit to be placed on freely permeable sub-soils. It can even be used on fill areas. Where the land slopes, the system can be extended along the contour to ensure that the loading limits are reduced. The effective basal area taken for disposal in the sloped system is increased over that for flat land. Design sizing is based on the following:

- 50 mm/day - Distribution area
- 35 mm/day - basal area over free draining soils
- 12 mm/day - basal area over slowly draining soils
- 75 L/m^2/day - downslope edge (parallel to contour) leading, maximum value.

Excess effluent can be collected from the base of the mound and disposed of by similar means as for the standard sand-filter system (Section 9.3).

9.3.2 Land Capability

Sand filters, together with mound style systems, require a relatively flat area for the filter system to be installed. In areas where steep slopes exist, sites can be made more suitable through the addition of fill material to effectively 'terrace' the site. Alternatively, mound systems can be built so that they run parallel with slope contours.

The quality of effluent from sand filters can be very high and approach that from an average secondary treatment plant. Manufacturers report that effluent from sand filters can maintain the following quality criteria:

BOD_5	< 5 mg/L
Suspended solids	< 5 mg/L
Faecal Coliform	< 200 organisms/100mls (without disinfection)

These levels indicate that the standard of effluent quality is potentially high. Envirotech Pty Ltd, a Queensland manufacturer of aerobic sand filter systems indicates that the systems frequently produce Faecal Coliform counts of zero and have the capacity to significantly reduce influent nutrient concentrations.

Nitrogen is removed primarily through aeration and nitrification/denitrification processes, whilst phosphorus is primarily removed through adsorption processes. Although little data are available on the rates of nutrient removal, nitrogen removal may be as high as 50 %, whilst phosphorus removal would depend largely on the phosphorus sorption capacity of the filter medium. Ecomax Waste Management Systems Pt Ltd, a Western Australian company, manufactures a filtering system which contains a Bauxite-based red-mud residual. This has a high affinity for phosphorus and provides removal efficiencies of greater than 90 % of the influent phosphorus for the duration of the filter life.

9.3.3 Maintenance and Management Requirements

There are both short-term and long-term maintenance requirements for filter based systems. These primarily depend on the size of the sand filter and long-term hydraulic and organic loading factors. The three primary maintenance requirements are listed below:

1. septic tank desludging (every 1-2 years);
2. service and maintenance visit (annual); and
3. sand filter replacement (every 10 years).

All sand filter systems rely on 'front-end' septic tanks to remove the primary portions of suspended solids and larger organic material. Because tanks are generally smaller than traditional septic tanks, these would require desludging every 1-2 years.

Sand filter systems also require regular service and maintenance. This is primarily to ensure that effluent pumps and distribution lines are fully functional and unclogged. Usually, the service is provided on an annual basis.

In the long-term, filters are likely to accumulate solids and organic materials. Towards the end of a filter's life, the rate of accumulation is likely to increase as the filtering system becomes progressively less efficient. Nutrients, particularly phosphorus, are also likely to accumulate in the filter. However, provided that the filters are regularly cleaned or upgraded [say every 10 years] then there is a high capacity for the system to maintain a long operational life.

9.3.4 Environmental and Public Health Implications

The environmental and public health implications of sand filter systems are discussed in the light of the method of land application method utilised. Land application methods include: (i) sub-surface disposal; and (ii) surface irrigation.

9.3.4.1 Sub-surface Disposal

Sand-filter filtrate is, under normal operating conditions, low in solids and organic material, but potentially contains unacceptable levels of bacteria. Sand-filter filtrate is therefore disposed of below ground surfaces where effluent is not disinfected so as to prevent the possibility of human contact with treated wastewater. The environmental and public health implications of sand-filter systems are summarised in Table 14.

Table 14: Environmental and public health implications of sand-filter type systems utilising sub-surface disposal methods.

Short-term Environmental Effects	Long-Term Environmental Effects	Public health implications
• Produces higher [secondary] quality effluent than conventional septic tank. • In-ground filters require substantial excavation and construction works to implement.	• Produces higher [secondary] quality effluent than conventional septic tank. • Unknown nutrient loads to land application areas • Some terracing required to install the filter bed • Removal of sand when replacement required.	• Continued risk of effluent leaching from drain-fields to downstream areas. • Effluent is not disinfected prior to discharge.

9.3.4.2 Above-ground Disposal

The above ground disposal of sand filter filtrate is by pressurised irrigation, similar to that utilised in the AWTS. However, where treated wastewater is surface irrigated, it must first be disinfected, usually by means of chlorination. This add would effectively increase the frequency of systems servicing as chlorine tablets would need to be replaced and/or replenished on a 3 monthly basis. The environmental and public health implications of sand filter systems are summarised in Table 15.

Table 15: Environmental and public health implications of sand filter systems utilising above ground spray irrigation methods.

Short-term Environmental Effects	Long-Term Environmental Effects	Public health implications
• Produces higher [secondary] quality effluent than conventional septic tank. • In-ground filters require substantial excavation and construction works to implement.	• Produces higher [secondary] quality effluent than conventional septic tank. • Unknown nutrient loads to land application areas • Possible build-up of chlorine compounds. • Removal of sand when replacement required	• Risk of system failure and poorly disinfected effluent being surface irrigated. • Effluent is not disinfected prior to discharge.

9.4 Option 4: Separate (segregated) Grey- and Black water treatment

This option involves the separation of domestic wastewater into constituent grey- and black-water components, followed by the respective treatment and disposal of each. Grey-water, including all wastewaters from the kitchen, showers and washing activities, is gravity fed into a septic tank holding well, prior to re-use over the garden area. Black-water wastes include all waste streams produced from the toilet system only. This is also fed into a separate septic tank, and then discharged into an absorption bed. The quality of grey- and black-water are summarised in Table 16. This indicates that grey-water is some 50-75 % lower in solids, 85 % lower in total nitrogen, but usually higher in total phosphorus, primarily due to washing products. It still contains Faecal Coliforms and must therefore be treated with care.

Table 16: Quality characteristics of black-, grey-, and combined- wastewater. All concentrations in mg/L except for conductivity (μS/cm), Faecal Coliforms (cfu/100mL) and pH (Petrozzi and Martens, 1995).

Parameter	Black Water #	Grey Water *	Combined ***
pH	-	7.4	7.0
BOD_5	208-556	175-417	250
COD	944-1929	481-694	500
TOC	111	222	250
Suspended Solids	556	120-231	220
Conductivity	-	580	-
Organic-N	55.6	6.5-16.6**	25
Ammonia	13.9	1.9-5.5	25
TKN	69.4	12.0-18.5	50
Oxidised Nitrogen	0.42	0.31-0.50	0
Total-N	70-167	9.3-12.3**	50
Total-P	7.63	27.8-37.0	12
Faecal Coliforms (cfu/100 mL)	5.3×10^7	2.3×10^7	-
Sodium	-	70	-

Adapted from Laak (1986) and Canter & Knox (1988) based on per capita blackwater flow of 72 $l.day^{-1}$
* Data from Brisbane City Council (1992) and Canter & Knox (1988).
** Date not provided in source - estimated by subtraction or addition of mean concentrations.
*** Gray (1989) - United States data.

Grey-water 'sullage' tanks are usually some 1.5 m in diameter and 1.2 - 1.5 m in height. Grey-water is fed from the household to the grey-water treatment system where solids are separated either by sedimentation or flotation. Grey-water is then fed to a series of shallow trenches designed in accordance with AS1547 (1994). It is generally not recommended that grey-water is surface irrigated without further disinfection due to the potential for sullage to contain high bacterial levels.

The principal advantages and disadvantages of segregated wastewater treatment / disposal systems are summarised in Table 17..

Table 17: Summary of operation and maintenance advantages and disadvantages of segregated wastewater treatment and disposal systems.

Advantages	Disadvantages
• Less stress on land application areas. • Increased longevity of land application areas. • Do not normally require any power • Can operate without any artificial chemicals	• Higher installation costs • Two treatment and disposal systems are required. • Septic tanks require desludging. • Requires a dedicated land area. • User is responsible for the maintenance. • Separate plumbing required.

9.4.1 Land Capability

Factors affecting the capability of Scotland Island to accommodate segregated wastewaters are similar to those for ESTs and include: suitable slope (< 20%); sufficient land area; impact on native and introduced vegetation; and soil assimilative capacity. The importance of each of these factors is controlled by the likely volume of wastewater produced and the quality of effluent from the segregated system. Using AS1547 (1994) as a general guide, the following requirements would be necessary for each component of the wastewater management facility.

For a segregated wastewater treatment / disposal facility on the Island catering for effluent from a 5 person household, the following absorption trench and design requirements would apply:

Given: A horizon: Sandy loam, permeability approx. 1m/day, depth 40 cm
B horizon: Clayey loam, permeability approx. 0.02 m/day depth 45 cm

Note: LTAR = Long Term Acceptance Rate
DIR = Design Irrigation Rate

Hydraulic flow:550 (5 persons @ 110 L/person/day)

Considerations
A: Flow to Grey-water tank (@ 70% total) = 385
B: Flow to Black-water tank (@ 30 % total) = 165

Design LTAR: 30 mm/day (AS1547, 1994)

Trench design:

OPTIONS
A: Grey-water system
12.8 m^2 wetted surface area of trench
10.7 m trench length (600 mm wide, 600 mm deep)

B: Black-water system
5.5 m^2 wetted surface area of trench
4.6 m trench length (600 mm wide, 600 mm deep)

Evapotranspiration bed design for grey-water disposal:
OPTIONS

A: Lined, LTAR = 0	469 m^2 of surface area Storage depth of 1025 mm Trench length 177 m (where disposed into trench)
B: Not lined, low LTAR	72 m^2 of surface area (LTAR = 5 $L/m^2/day$) Storage depth of 705 mm
C: Not lined, high LTAR	13 m^2 of surface area (LTAR = 30 $L/m^2/day$) Storage depth of 434 mm

From these calculations, it is evident that only the standard absorption trench or the unlined evapotranspiration (ET) beds offer feasible alternatives to effluent disposal. Totally lined [and therefore sealed] evapotranspiration beds which rely only on ET processes would require surface disposal areas which approach the average allotment size and storage depths which exceed typical total soil depths (often < 0.75 m) on the Island. This would make it difficult to install the ET system on individual allotments without importing additional soil material to the site.

The unlined 70 m^2 evapotranspiration bed utilising a low LTAR of 5 $L/m^2/day$ for grey-water disposal and a second trench approximately 5 m in length, would therefore appear to be the most suitable options for segregated wastewater management. These options would remove the majority of daily effluent through evapotranspiration, with the black-water being disposed of into the second absorption trench.

9.4.2 Maintenance and Management Requirements

Both the grey- and black-water systems utilise separate septic tanks for the primary treatment of effluent, prior to discharging to separate land application areas. Therefore, both systems would require desludging at regular intervals. Few data are available regarding the frequency of desludging grey-water systems. However, under the assumption that these systems receive 50 % of the total solids load, yet are responsible for 70 % of the total flow, desludging would be required at 4-5 year intervals, twice the interval expected for a septic tank receiving combined wastes. The black-water septic tank would also require desludging at similar periods.

9.4.3 Environmental and Public Health Implications

The primary advantage of this option is that large proportions of the wastewater solid and organic materials are separated from the majority of flow, resulting in the grey-water trenches having substantially reduced contaminant loads and increased longevity. However, absorption trenches receiving black-water will still be subject to both high solids and nutrient loads. These are, in the case of nitrogen, higher than those expected from a septic tank receiving combined household wastewater, with black-water nitrogen concentrations several times higher than those expected in grey-water.

It is therefore important that trench disposal areas would still comply with design parameters as provided in AS1547 (1994). Particular care should be taken to ensure that: (i) trenches receiving black-water are not hydraulically overloaded; and (ii) excessive sodium concentrations are not reached in the grey-water application area.

General short- and long-term environmental implications of segregated wastewater treatment are summarised in Table 18.

Table 18: Environmental and public health implications of separate grey- and black-water treatment and disposal systems.

Short-term Environmental Effects	Long-Term Environmental Effects	Public health implications
• Additional construction works involved with implementation.	• Nutrient build-up and leaching from trenches receiving black-water. • Higher rate of sodium build-up in grey-water application areas.	• Continued risk of effluent leaching from drain-fields to downstream areas. • Effluent is not disinfected prior to discharge.

9.5 Option 5: Aerobic Wastewater Treatment Systems (AWTS)

This option involves the treatment of all domestic wastewater by an AWTS, followed by land application, either by surface or sub-surface irrigation. AWTSs are small scale secondary treatment plants capable of producing high grade effluent quality.

The first AWTS was approved by the NSW Health Department in 1983 (Martens and Warner, 1991) and there are now approximately 15 approved manufacturers (NSW Health Department, 1994) each with a number of models. Clause 75 of the Local Government Act stipulates that local authorities may only allow the use of Health Department approved systems.

By mid-1988 over 2000 AWTSs were installed in NSW (van Lien, 1988). Health Department approval for AWTSs follows satisfactory performance during a test period of 6 months wherein weekly effluent samples are analysed for BOD_5, suspended solids, free chlorine and Faecal Coliforms. Every sample must satisfy effluent-quality criteria (Table 19).

Table 19: NSW Health Department effluent quality criteria for AWTSs.

Parameter	Maximum Permissible Value (mg/L)
BOD_5	20
Suspended Solids	30
Faecal Coliforms	30 cfu/100mL
Free Chlorine (Range)	0.5 - 2.0

There exist significant generic differences in the design and operation of available AWTSs but all include the following treatment stages (van Lien, 1988):

- primary treatment involving settling and flotation in a septic tank;
- an aeration phase to produce bio-chemical oxidation and consumption of organic matter;
- a clarification and chlorination stage; and
- effluent irrigation.

These phases may occur in a series of separate tanks or all the treatment may occur in one internally divided tank. Configuration is largely dependant upon system capacity. Effluent is treated by sedimentation, flotation, contact aeration and activated sludge (Martens and Warner, 1991). All AWTSs use septic tank systems for primary treatment of sewage.

Effluent is gravity-fed from the septic tank to the aeration chambers. Aeration occurs through submerged diffusers, submerged air pumps, rotating agitators, rotating discs or through trickle-filter mechanisms. These are briefly discussed below.

1. **Continuous and Intermittent Aeration AWTSs**
   In continuous aeration systems, air is delivered to effluent through a number of basal air blowers, or diffusers, connected to an electric pump. These systems generally contain a media for biofilm growth as well as microbial growth on suspended particles.

   Air is also supplied to the effluent through a series of basal blowers in most intermittent systems. Rather than running continuously, these systems alternate between periods of contact aeration and quiescent conditions of approximately 15 minutes of aeration and 30 minutes of quiescence.

2. **Disk Rotor**
   These systems also utilise continuous aeration. However, aeration is carried out through the rotation of a stainless-steel shaft with protuberances. This shaft is rotated continuously by an electric motor to produce a stirring action in the effluent.

3. **Rotating Biological Filters**
   In these systems, a biofilm develops on a series of flat discs. These are slowly rotated so that half of the disc is submerged in the effluent while half is in contact with air inside the chamber. Aeration occurs through contact with this air and as effluent trickles down the discs.

4. **Trickle Filters**
   These systems provide aeration by continuously passing effluent through a coarse filter media. The typically consist of 40mm x 38mm segments of pool hose. Aeration is provided by a trickle action and biological treatment is provided by biofilm growth on filter media. The large voids in trickle filters are not intended to trap or strain effluent.

Submerged biological growth media, usually consisting of corrugated plastic, are placed in the aeration chambers of several AWTSs. The media are used to provide a surface area which will entrap air, impede effluent flow and thus allow wastewater to uptake air. Bacterial growth in the effluent remains suspended during aeration. Contact aeration takes place on submerged media on which a biofilm or zoogleal film consisting of bacteria and algae (when lit) is formed (van Lien, 1988). Systems containing media are termed "fixed film reactors" (Gray, 1989). Biofilms consist of an aerobic outer layer, an anoxic middle layer and an anaerobic inner layer. Biofilms consume organic matter, thicken and periodically slough off from the media resulting in the gradual accumulation of sludge in the aeration tank (Martens and Warner, 1991).

Sludge, suspended particles and scum in the treated effluent are removed by sedimentation in the clarification chamber. Accumulated sludge and scum are returned by pump or an airlift Venturi system to the first aeration chamber or the septic tank (ie. activated sludge). It is argued by van Lien (1988) that sludge return to the septic tank is preferable in order to reduce the accumulation of sludge in the AWTS.

Clarified effluent is chlorinated to give free or residual chlorine concentrations of 0.5 to 2.0 mg/L in the disinfection or chlorination chamber. Research by Martens and Correy (1992) indicates that free chlorine concentrations in excess of 2.0 mg/L are necessary for effective disinfection. This is particularly the case when detention time is reduced by peak effluent production. Contact chlorination is the most widely used method of disinfection. Calcium hypochlorite or sodium hypochlorite ($Ca(OCl)^2$; NaOCl) tablets are stored in a vertical PVC tube through which effluent passes. Contact time of 30 minutes is required for effective disinfection (Martens and Warner, 1991).

Table 20 provides a summary of the advantages and disadvantages associated with the use of AWTSs on Scotland Island.

Table 20: Summary of operation and maintenance advantages and disadvantages of AWTSs.

Advantages	Disadvantages
• High quality of effluent • Low odours • Less stress on land application areas. • Increased longevity of land application areas. • Several options available for land application.	• Higher installation costs • High energy costs are required for most systems. • On-going maintenance costs. • Septic tanks require desludging. • Requires a dedicated land area. • User is responsible for the maintenance. • Susceptible to shock loads and irregular usage. • Susceptible to failure.

9.5.1 Effluent Quality

General characteristics of AWTS effluent provided by Martens (1996) are summarised in Table 21. These data indicate that treated effluent is highly variable and may contain nutrients, chloride and Faecal Coliforms.

Table 21: Effluent quality from AWTSs in the Sydney Area (Martens, 1996).

Parameter	Data Ranges*
BOD_5	1 - 40
Suspended solids	10 - 60
Total-N	10 - 40
Total-P	10 - 20
Faecal Coliforms (CFU/100mL)	0 - 3000
Chloride	60 - 80

* All concentrations in mg/L except for Faecal Coliforms.

Standard AWTSs are not designed specifically to remove nutrients from effluent. This is reflected by nutrient concentrations and removal rates. Total nitrogen (TN) reduction is generally between 10% and 80% and total phosphorus (TP) removal is in the order of 0 - 30% relative to influent concentrations (Martens and Correy, 1993; Martens and Warner, 1995). Typically, a 50 % reduction in influent total nitrogen can be expected where AWTSs are properly installed and maintained. The *Durrant and Waite*

BioMAX systems with '*Nutri Safe P'* installed may achieve phosphorus removal rates of 99.2 %. These systems are to date not available in NSW.

9.5.2 Disposal Options

Where AWTSs are properly installed and maintained, several options are available for land application of effluent. These include the following:

A. Surface Irrigation
Treated wastewater may be surface irrigated to a fixed (passive) or movable area of the allotment. The designated area should be sign-posted to indicate that treated wastewater is being re-used.

B. Sub-terranean Application
This mode of application involves the discharge of treated wastewater by trickle irrigation below a thin layer of mulch. This prevents the formation of effluent aerosols and therefore reduces the risk of human contact with effluent.

C. Sub-surface Irrigation
Sub-surface irrigation involves the application of effluent to a series of shallow laid trickle irrigation pipes which are buried between 100 and 200 mm below the surface. The lateral distribution pipe network should be spaced no more than 2000 mm. This mode of application prevents any effluent reaching the surface, therefore reducing the risks of human contact with effluent and removing the need to chlorinate effluent prior to discharge.

D. Trench Disposal
This mode of application is similar to the sub-surface irrigation method, only that effluent is discharged into a standard absorption trench. This would be generally substantially deeper than the sub-surface irrigation field and would occupy a smaller surface area.

E. Sand-filter Bed
The sand-filter bed application option involves AWTS effluent being passed through a small sand-filter bed prior to being discharged to the soil [to trenches or sub-surface irrigation fields]. It has the advantage of further enhancing the quality of effluent prior to release to the environment.

9.5.3 Land Capability

AS1547 (1994) outlines procedures for the calculation of appropriate irrigation areas for AWTSs. Currently, minimum blanket irrigation areas for the Blue Mountains, Hawkesbury and Wollondilly Local Government Areas (LGA) have been set at 200, 200 and 300 m^2 respectively. Importantly, these blanket sizes compare poorly with those estimated from AS1547 (1994) using soil type and associated permeability. Council regulations often stipulate a minimum block-size for the use of AWTS's. For example, installation is not permitted on blocks smaller than 4000 m^2 (one acre) in the Blue Mountains LGA (Blue Mountains City Council, 1993).

Using AS1547 (1994) as a guide for determining the design irrigation rates (DIRs), the following recommendations are made for irrigation area size, including surface and sub-surface application methods.

Given: A horizon: Sandy loam, permeability approx. 1m/day, depth 40 cm
B horizon: Clayey loam, permeability approx. 0.02 m/day depth 45 cm

Hydraulic flow:550 (5 persons @ 110 L/person/day)

Design DIR: 50 mm/week (AS1547, 1994: conservative estimate for 0.5 m/day perm.)
7 mm/day (AS1547)

Irrigation area::

BEDROOMS	FLOW (L/day)	AREA (m^2)*	ADJUSTED**
1 bedroom	183	26	41
2 bedroom	366	52	81
3 bedroom	549	78	122
4 bedroom	732	104	163
5 bedroom	915	130	203

* Generally suitable for sub-surface irrigation areas.
** These areas are modified to correspond with generally required minimum areas of 200 m^2 for a 3 bedroom household producing 900 L/day (300 L/bedroom) on well drained soils. The adjustment would be required where surface disposal was utilised.

9.5.4 Maintenance and Management Requirements

It is mandatory that owners of AWTSs engage a service provider that services the wastewater treatment unit on a 3 monthly basis. Servicing and maintenance are required to ensure that the system is operating correctly [including for example pumps and blowers] and that there is sufficient chlorine available to disinfect the treated effluent. The service provider normally completes a limited service report which is held by the service provider, the customer, and the local Council. The septic compartment may also require periodic desludging although limited data are available on the typical frequencies involved with such activities.

A list of common maintenance requirements include the following:

1. sludge accumulation and the burial of blowers in the aeration chambers placing additional back-pressure on air blowers;
2. air blower failure and solids carryover to subsequent chambers;
3. clogging of in-line irrigation filters; and
4. chlorination hindered by the swelling of chlorine tablets.

It should be noted that several Councils in NSW have expressed concerns about the effectiveness of servicing contractors. In particular, concerns have been expressed regarding inefficient or late servicing resulting in poor system performance.

9.5.5 Environmental and Public Health Implications

Environmental and public health concerns are greatest when AWTS effluent is surface irrigated. Under this application method, there is both the potential for treated wastewater to leave the site as surface runoff, and the greatest risk of direct human contact with effluent.

Surface runoff would be facilitated on Scotland Island by locally steep slopes, particularly at times when soil moisture is high. In areas where effluent is irrigated over exposed sub-soil clays, the risk of surface runoff would be increased.

Chlorine used for disinfection purposes, although rapidly volatilised, may be toxic to local soil micro-flora. However, little research data are available which address the impact of chlorine on soil micro-fauna.

Variable chlorine contact times in systems without flow regulation, may also result in occasionally high pathogen levels in treated effluent. High bacterial levels may persist in the presence of higher free chlorine concentrations (Martens and Correy, 1992). The degree to which viruses and parasitic eggs (eg. Giardia) are eliminated by chlorination is less known.

A recent report by Camden Council (1995) on the performance of 100 AWTSs was aimed at examining AWTS compliance with NSW Department Guidelines. Results were compiled between brands, between service providers (system 3 monthly maintenance contract), and as brand/servicer. Only 15 % of all tanks surveyed registered Faecal Coliform levels of < 30 cfu/100mL. A similar pilot study of 51 AWTSs conducted by the NSW Department of Health (Langhorne *et al*, 1995) indicated that 68 % of effluent samples failed to comply with NSW Department Guidelines, with failure primarily associated with either insufficient chlorine levels or high Faecal Coliform counts (> 30 cfu/100mL). Both these studies suggest that current modes of disinfection produce variable results which do not consistently meet NSW Department of Health Requirements for surface irrigation.

Table 22: Environmental and public health implications of AWTSs.

Short-term Environmental Effects	Long-Term Environmental Effects	Public health implications
• Additional construction works involved with implementation. • Preparation of designated land application areas. • Chlorine released into local environment (surface disposal only)	• Nutrient (notably phosphorus) build-up in application areas.	• Surface irrigation of treated effluent from failing systems may come in contact with humans • Runoff to downstream areas.

9.6 Option 6: Composting Toilets and Grey-water Disposal Systems

The use of a composting toilet requires the additional use of a grey-water disposal system, similar to that described in section 9.4. This section will only discuss the actual composting toilet set-up.

Composting toilets are water-less units designed to treat black-water and putrescible household garbage. There are two broad classes of composting toilets available: continuous (eg. *Clivus Multrum; Dowmus; Envirolet; Biolet*) and batch (eg. *Rota-Loo*) systems. Currently, there are no set standards for composting toilets in Australia. However, a Standards Committee has begun to draft a joint Australian and New Zealand Standard which should be completed toward the end of 1996.

Composting toilets operate by allowing aerobic micro-organisms and any introduced compost worms to consume organic matter and release carbon dioxide gas and water vapour. The compost is generally applied to gardens on the immediate house block. Government authorities, including the Queensland Health Department, often stipulate that compost be buried [usually to a depth of 30 cm]. This measure is taken for health reasons associated with potentially poor quality compost. The amount of compost produced varies considerably between households.

Figure 3 indicates the general configuration of a composting toilet installed below a slab house. This would vary somewhat in situations where houses were built on slopes utilising pier support structures.

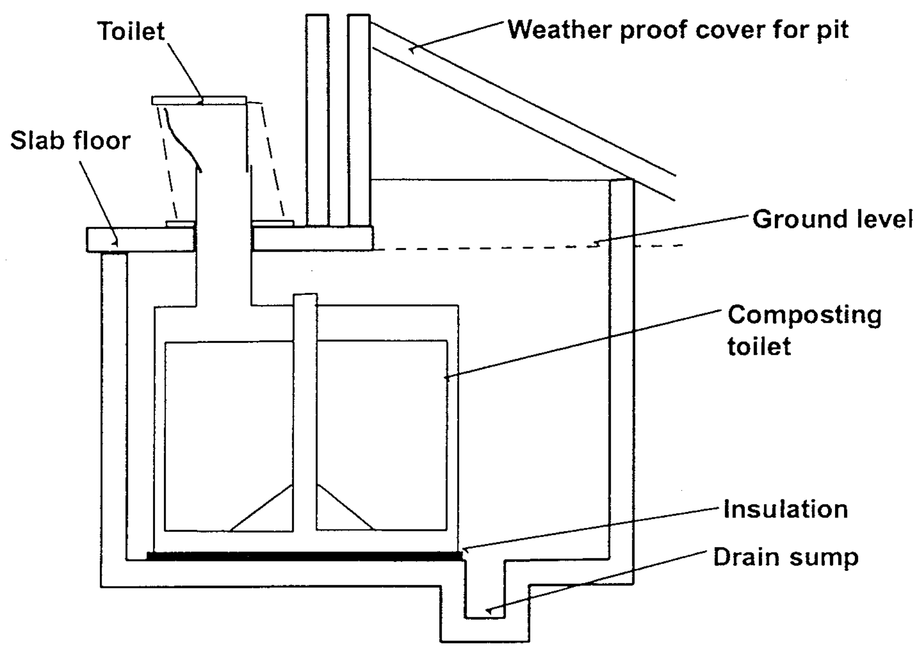

Figure 3: General installation set-up of a composting toilet below slab house. Variations occur for houses on piers. Note that venting has not been indicated.

The general differences between continuous and batch composting system are explained below:

Continuous Systems
With the exception of generic-brand differences, continuous compost systems consist of a large polyethylene tank situated below the toilet pedestal or pedestals. Tanks are installed below floor level (Figure 3). *Clivus Multrum* tanks are internally divided into a waste chamber and finished compost

chamber. *Dowmus* systems consist of a single, undivided tank. Toilet and urinal wastes are amended with carbon-rich material such as lawn clippings, kitchen wastes and wood chips for bulk. These materials also aerate the waste mound and provide voids. Aerobic conditions are also maintained by aeration baffles and air channels built into the tank. A small electric or solar powered fan is installed to draw odours from the chamber and toilet room. Ventilation through the toilet pedestal also reduces odours. Ultimately, completed compost is removed by the home owner [by rake or compost auger] and distributed over the yard. Liquid drains are typically included to draw off accumulated fluids. Vents are screened with mesh to keep flies and rodents from entering compost chambers.

Large systems require time for the establishment and stabilisation of micro-organisms. Seeding with mature compost or worms may be necessary.

Envirolet and *Biolet* systems are smaller in size than *Clivus Multrum* and *Dowmus* and are more suited to use in holiday home settings and as a convenience in isolated locations with infrequent visitors. Sub-floor installation is not required as the units are typically totally self contained. Compost is mixed and aerated by two horizontal blades which are operated by electric or manual action after each use. A small electric fan is used to recirculate warm air produced by a heating element and to expel odours through an external vent. Liquids are evaporated by the heating element. A "humus tray" is installed at the bottom of units in order to remove completed compost. As liquids are not readily evaporated in these systems, an external liquid drain and disposal system are required. These small systems are not recommended for year round use.

Batch Systems

Rota-Loo composting toilets come in a variety of sizes for domestic and commercial, or institutional use. Tanks are installed under floors. A circular receptacle is divided into a number of chambers, one of which is used at any one time. Once a chamber is filled, the tank is rotated to bring the next chamber into service. Once the entire tank is full, chambers are emptied individually. This usually occurs after the bin has held compost for a single year. *Rota-Loo* systems are also equipped with a fan, liquid collection tray and heating element, thus necessitating a power supply. Theoretically, there are no liquid discharges from these systems as the majority of liquids are evaporated by the heating fan.

9.6.1 Compost and Effluent Quality

Evaluation and testing carried out on *Clivus Multrum* compost end-product by the National Sanitary Foundation (1982) revealed low Faecal Coliform (FC) concentrations. Values for large *Clivus Multrum* systems ranged from 0 to 7 FC/100g of compost. Septic-tank sludge generally contains numbers in the order of 100,000 FC/100g dry sludge. Data are not available for other systems.

Compost is very high in nutrients. Data supplied by *Clivus Multrum* indicate that nitrogen, phosphorous (P_2O_5) and potassium (K_2O) concentrations are in the order of 24, 36 and 39 g/kg (dry-weight basis) respectively for compost (Clivus Multrum, 1994). It was reported that calcium, magnesium and sulphur are also present in significant amounts, however no data were available.

Although limited data exist, the United States research (National Sanitary Foundation, 1982) suggests that where liquid is discharged from the composting toilet, the following concentrations in large *Clivus Multrum* systems can be expected.

Faecal Coliforms	< 200 cfu/100 mL
Total Nitrogen	5700 mg/L

Data on the amount of liquid produced is not available. Table 23 provides a summary of the advantages and disadvantages associated with the use of composting toilets on Scotland Island.

Table 23: Summary of operation and maintenance advantages and disadvantages of composting toilet systems.

Advantages	Disadvantages
• Reduced wastewater volume (up to 30 %) • Less stress on land application areas. • Increased longevity of land application areas. • Several options available for land application. • Low energy costs	• Installation is below house and therefore difficult to 'retro-fit' systems. • High installation costs. • On-going maintenance costs. • Compost must be periodically removed. • Compost is high in nutrients. • Two wastewater systems are required. • Requires a dedicated land area for the grey-water system. • User is responsible for the maintenance and this may be unacceptable for some people. • Susceptible to shock loads of water and chemicals.

9.6.2 Land Capability

In terms of land capability, CTS require space for both the composting toilet to be installed, as well as a dedicated land application area for the grey-water treatment and disposal system. On sloping propreties, composting toilets may be readily installed below the toilet prior to the construction of the house. This requires substantially more excavation effort where the allotment is flat and the house is constructed on a concrete slab. Installation after the house has been erected is logistically more difficult, requiring excavation below an exiting premises.

Land capability requirements for the grey-water treatment and disposal system have already been discussed in section 9.4 above.

9.6.3 Maintenance and Management Requirements

Composting toilets require substantial amounts of householder maintenance in terms of cleaning the pedestal, maintaining, removing and disposing of compost. The risk of problems increases if maintenance is not carried out. Some of these problems are briefly discussed below.

Vinegar, scuttle and compost flies may be present in large numbers in the initial stages of *Clivus Multrum* and *Dowmus* systems until an ecological balance is achieved between organisms in the tank. Fly problems may also be caused by the introduction of eggs with food and vegetable scraps. Flies and rodents may enter compost chambers if mesh/plastic coverings become damaged or if access ports are not secured.

Damage of fans or covering of vents may result in the accumulation of odours in the toilet room. In addition, moisture may accumulate within the compost chamber resulting in increased liquid discharges. Under these conditions, discharges would increase with decrease in temperature and hence evaporation. This may be influenced by the volume of dry compost in the chamber and incoming fluid volumes.

Toxic loads of cleaning agents and insecticides may kill organisms responsible for composting and result in the accumulation of wastes in the chamber. Odours may become problematic at such times.

Composting in smaller systems (*Rota-Loo*) is more susceptible to disturbance as a result of extreme conditions. Such conditions include changes in moisture levels, temperature and pH. These conditions, combined with the failure of mixing mechanisms in *Envirolet* systems may significantly disrupt composting.

The above points indicate that regular servicing of the composting toilet system is required to ensure that long-term performance is maintained. This is currently not required by either Council or the Department of Health.

9.6.4 Environmental and Public Health Implications

Compost contains large amounts of nutrients which occur primarily in organic-bound forms. These may place stress on compost application areas and cause tree dieback. Nutrients would probably be made available at a slower rate than dissolved or colloid-associated nutrients in effluent from AWTSs and septic systems. Liquid discharges also contain high nutrient concentrations, the impact of which is dependant upon fluid volumes. Impact on the immediate disposal area may be significant. Fluid volumes are greatly increased by any accidental or deliberate influxes of water into the compost pile. Where there is no facility for the removal of excess water, this may build-up in the compost pile.

Water-less toilet systems require that the pedestal and surrounding areas be cleaned by hand with limited use of water and disinfectants. Unattended children may come into contact with any pathogens that persist in these areas. When toilet pedestals are installed one or more storeys above composting tanks, it is probable that faeces become smeared along the connecting pipe resulting in odours and pathogen accumulation.

Compost technology effectively reduces concentrations of indicator Faecal bacteria in the final product. However, the impact of composting on viruses and other pathogens is less clear. Helminths (worms) and protozoan cysts are not eliminated by this process. Therefore, contact with compost is potentially hazardous and problems would be exacerbated by failure to bury the final product. Liquid discharges may also contain high levels of pathogens, particularly when composting processes are not functioning optimally, and must be disposed of cautiously.

Where an open chute exists between the toilet seat and the compost, small children may fall down the toilet and fall into the compost/effluent pile. Potential for injury is minimal because of cushioning provided by compost. Contact with un-treated effluent both in the chute and in the compost chamber may pose a significant health risk, particularly if the facility has been recently used by sick individuals.

Potential health problems are also associated with insects and rodents entering compost chambers through broken, or poorly secured, ventilation and access apertures and screens.

Table 24: Environmental and public health implications of composting toilets.

Short-term Environmental Effects	Long-Term Environmental Effects	Public health implications
• Additional construction works involved with implementation. • Preparation of designated land application areas for grey-water trenches.	• Nutrient (notably phosphorus) build-up in compost application areas. • Nutrient build-up in grey-water absorption trenches (notably phosphorus)	• Human contact with septic compost. • Continued risk of effluent leaching from drain-fields to downstream areas. • Effluent is not disinfected prior to discharge.

9.7 Option 7: Reticulated Sewerage: On- and Off-site Disposal

Several options for off-site disposal are available. However, each involves the reticulation of domestic wastewater off the Island to a central wastewater treatment facility.

The off-site options principally vary according to the methods of wastewater collection and transport to the off-site wastewater treatment facility. Each of these options are discussed in greater detail in sections 9.7.1 through to 9.7.5.

9.7.1 Conventional Gravity Mains Sewer (GMS)

The GMS option consists of the collection and transport of all domestic wastewater off-site to an off-Island centralised treatment facility such as the Warriewood sewage treatment plant. The option would make redundant all the exiting on-site wastewater management facilities currently utilised on the Island.

The primary advantages and disadvantages of this option are summarised in Table 25.

Table 25: Summary of operation and maintenance advantages and disadvantages of conventional GMS.

Advantages	Disadvantages
• All wastewater is removed on-site. • No on-site wastewater treatment or storage facility is required. • Reduces pollution and health risks from backyards. • Low energy costs.	• Installation of sewer pipes may require substantial excavation works. • High capital costs on an allotment by allotment basis compared to other on-site options. • Requires that each household has full access to reticulated potable water supply.

9.7.2 Common Effluent Systems (CES)

The common effluent system involves preliminary wastewater treatment on-site, followed by wastewater collection and transport, typically through small diameter pipes (due to the decreased solids load), to a centralised wastewater management facility for additional treatment prior to disposal or utilisation.

Two types of collection and transport systems are typically employed.

1. Common Effluent Drain (CED);
2. Septic Tank Effuent Pumping sytems (STEP).

In the case of the CED option, this is a similar disposal scheme to a conventional full gravity reticulation system except that wastes are firstly treated in a septic tank prior to discharge. The lack of settleable solids enables smaller diameter sewers to be utilised. These may be laid at flatter grades and with lower self cleansing velocities.

The STEP system allows effluent from septic tanks to flow to storage tanks equipped with a pump (submersible or externally mounted and equipped with isolating and non-return valves) which discharges the wastewater into a small bore reticulated pressure sewer system. The storage tank has sufficient volume to typically cater for pump failures of up to 24 hours. The pressure sewer can serve several hundred homes. Wastewater is discharged to a centralised treatment plant. STEP systems can be used for individual dwelling or in a cluster of dwellings. In both the CED and STEP alternatives, septic tanks require periodic desludging.

The CES system offers several advantages including:

1. a single, centralised point for effluent treatment and disposal;
2. greater potential for a higher level of management and environment performance than individual on-site systems; and

3. greater potential for a higher degree of monitoring and scrutiny by the appointment of a suitably qualified plant manager or service contractor.

The main advantages and disadvantages of common effluent systems are described in Table 26.

Table 26: Summary of operation and maintenance advantages and disadvantages of CES.

Advantages	Disadvantages
• Reduced frequency of blockages resulting in reduced sewer maintenance. • Reduced capital costs due to smaller pipes, shallower installation, flatter grades, and fewer manholes. • Organic and hydraulic peak loads reduced in the septic tank. • Reduced treatment requirements at the centralised treatment plant. • Reduced infiltration because of smaller pipes and fewer manholes.	• Septage treatment facility required. • Odours from the septic tank are not removed. • Periodic pump-outs of septic tanks (once every 2 years).

9.7.3 Variable Grade Sewer (VGS)

The variable grade sewer (VGS) is a variation of the CES, but it permits even more economical construction because collecting sewers can be laid at inflective grades (ie. with a series of low points). The complete system comprises a series of sink traps stretched out over a distance with net fall from inlet to outlet. The system can thus be laid at constant depth irrespective of grade. The system outlet must be located lower than the inlet of any house served by the sewer system. Overall, the majority of houses discharge by gravity. However, premises in a valley section of the sewer which are below the sewer high-point require pumps and valves similar to the STEP system. Some sections of the reticulation system will always be full and excessive slime growth on pipe walls may occur, leading to possible maintenance problems.

Table 27: Summary of operation and maintenance advantages and disadvantages of VGS.

Advantages	Disadvantages
• Reduced frequency of blockages resulting in reduced sewer maintenance. • Reduced capital costs due to smaller pipes, flatter grades, fewer manholes. • Organic and hydraulic peak loads reduced in the septic tank. • Reduced treatment requirements at the centralised treatment plant. • Reduced energy requirements in the collection system. • Reduced infiltration because of smaller pipes and fewer manholes. • Sewer can be laid at constant depth irrespective of slope.	• Septage treatment facility required. • Odours from the septic tank are not removed. • Periodic pumpouts of septic tanks (once every 2 years) to remove scum and sludge, ensuring that blockages in the sewer do not occur. • Low points remain full of wastewater. • Pumps and valves may be required at some premises.

Table 29: Summary of operation and maintenance advantages and disadvantages of VSS

Advantages	Disadvantages
• Sewer can be shallow, can follow terrain and can be redirected around obstacles. • Aerobic effluent is achieved. • No exfiltration from the transport system. • Centralised power utilisation. • Takes all domestic wastewater flows. • Doesn't require a septic tank for pre-treatment.	• Regular maintenance of vacuum valves is required. • Needs standby electrical power. • Need for precise construction. • Potential for high infiltration due to negative pressure. • Limit on lift due to vacuum limitation. • Less tolerance to flows exceeding design values.

9.7.6 Land Capability

The capability of Scotland Island to accommodate the reticulated sewerage options is principally associated with the ability to lay the required reticulation pipes for transporting domestic wastewater to the centralised treatment facility. Where septic tanks or grinder pumps are utilised for either pre-treatment or temporary storage of domestic wastewater, sufficient space is also required for these installations. Construction issues associated with the reticulated options are discussed in Section 11.4.

9.7.7 Maintenance and Management Requirements

Each of the reticulated sewage management options have maintenance requirements which are primarily associated with the upkeep of the wastewater transport pipes and operation of the centralised treatment facility.

These vary according to whether on-site treatment is utilised, and secondly, the way in which effluent is collected and transported off site (ie. whether septic tanks are utilised for holding purposes).

In all reticulated cases, the laying of pipes will represent the largest environmental intrusions.

Those options which include septic tank pre-treatment include:

CED (acts as pre-treatment unit allowing smaller diameter reticulation pipes)
STEP (acts as pre-treatment unit allowing smaller diameter reticulation pipes)
VSS (primarily acts as temporary storage facility although not always required)

Those options which require pumps or macerating pumps

STEP (many pumps required)
VGS (pumps required on low points)
GPS (macerating pumps for single or group households).
VSS (centralised vacuum source required)

Each of the reticulated options would be managed by Sydney Water. Where septic tanks are required for pre-treatment or effluent storage, the homeowner would be responsible for the upkeep of the septic tank and ensuring that it was regularly desludged.

9.7.8 Environmental and Public Health Implications

Environmental and public health concerns associated with the reticulated sewage option varies with each of the sub-options primarily as a function of the continuing use of on-site septic tanks for preliminary treatment and / or temporary storage of domestic effluent prior to removal off-site. Septic tanks are susceptible to leakage particularly when old tanks are used. Under these circumstances, there is the possibility of relatively untreated effluent leaving the tank.

Environmental and public health risks associated with the reticulation system are low as all wastewater is theoretically transported off-site. This reduces the chance of human contact with effluent and prevents soils and vegetation being exposed to wastewater. Failure, by means of exfiltration from the transport line, is the primary risk associated with the reticulation system.

Tables 30 and 31 outline the primary environmental and public health implications of reticulated sewage options both with (Table 30) and without (Table 31) septic tank pre-treatment.

Table 30: Environmental and public health implications of reticulated options with septic tank pre-treatment.

Short-term Environmental Effects	Long-Term Environmental Effects	Public health implications
• Additional construction works involved with implementation of the reticulation system.	• Risk of septic tank failure and possible effluent leakage to surrounding environment. • Possible exfiltration of partly treated effluent to surrounding local environment	• Possible human contact with septic tank effluent. • Effluent in septic tank is not disinfected.

Table 31: Environmental and public health implications of full sewer reticulation and off-site treatment.

Short-term Environmental Effects	Long-Term Environmental Effects	Public health implications
• Additional construction works involved with implementation of the reticulation system.	• Possible exfiltration of untreated effluent to surrounding local environment.	• Improvement in water quality of ephemeral streams is likely..

9.8 Option 8: On-Island Packaged Treatment Plant(s) (PTP)

On-site packaged treatment plants offer an alternative to an off-site treatment facility. Effluent from individual households is reticulated to a centralised Island packaged treatment plant(s) (PTP), providing secondary biological treatment. Such a system may require between 1 to 5 individual secondary biological treatment plants on the Island. The exact number would depend on the capacity of each system and the availability of land on the Island.

Further to the secondary treatment, each PTP may be reticulated to a centralised Memtech filtration plant / unit. This would provide further tertiary polishing of the secondary treated effluent, placing it into a form suitable for either direct discharge to Pittwater or, alternatively, for subsequent reticulation and re-use on the Island (subject to licencing to Sydney Water and the NSW Environment Protection Authority). The final effluent quality would contain very low Coliform (< 10 CFU/100 ml), suspended solids (< 5 mg/L) and BOD_5 (< 5 mg/L) levels. Septic tanks would not be required for pretreatment of effluent prior to discharge to the sewer. Table 32 lists the primary advantages and disadvantages of on-Island PTPs.

Table 32: Summary of advantages and disadvantages of on-Island PTPs.

Advantages	Disadvantages
• Effluent is treated to a high standard. • Effluent may be discharged directly to Pittwater. • Effluent may be re-used. • Less stress on land effluent land application areas if effluent is re-used. • Increased longevity of land application areas. • Several options available for land application. • Low energy costs per user. • Treatment plant can accommodate shock loads	• Requires regular maintenance by a trained sewage treatment plant operator (part-time or full-time basis). • High installation costs. • On-going maintenance costs. • Requires a dedicated land area for the re-used wastewater.

9.8.1 Land Capability

The capability of Scotland Island to accommodate on-Island PTPs is principally associated with two aspects; land area available for the PTPs and the reticulation system (similar to the off-Island reticulated sewerage options), and the land area available to support the re-use of effluent on the Island. The size of the site required for each treatment plant may be in the order of 200 - 300 m^2. This would be subject to further design specifications from treatment plant manufacturers. Construction issues associated with the reticulated options are discussed in Section 11.4.

9.8.2 Maintenance and Management Requirements

Maintenance and management requirements of the PTP option are primarily associated with the upkeep of the wastewater transport pipes and operation of the centralised treatment plant(s). It is most likely that the wastewater collection, treatment and disposal system would be managed by either Council or the local water authority, presumably Sydney Water. A part-time or full-time sewage treatment plant operator would be required to provide adequate servicing of the Island wastewater management facility.

9.8.3 Environmental and Public Health Implications

The environmental and public health implications of the PTPs option depend primarily on the level of construction involved with the installation of the reticulated pipes to transport domestic wastewater to the central treatment plant(s) and the final elflfuent quality. The implications of construction of the pipe works are similar to those described for the other reticulated options.

The suitability of discharging effluent to Pittwater and / or re-use of effluent on the Island is dependant on effluent quality from the Memtec plant. High quality effluent with zero [or close to] Coliform counts would probably be suitable for discharge to Pittwater [depending on the requirements of governing regulatory authorities such as the Environmental Protection Authority], otherwise, land application of treated wastewater through re-use would be the more viable method of disposal.

Table 33: Environmental and public health implications of on-Island PTPs.

Short-term Environmental Effects	Long-Term Environmental Effects	Public health implications
• Additional construction works involved with implementation of the reticulation system.	• Risk of polluting Pittwater if effluent quality deteriorates. • Possible nutrient accumulation in Island soils if re-use option is preferred. • Possible exfiltration of partly treated effluent to surrounding local environment	• Improvement in water quality of ephemeral streams is likely.

10. Evaluation of Wastewater Options Costs

10.1 General

This section outlines the various costs, including both up-front and ongoing, of each of the disposal systems. These are given in $Australian for 1996 and are subject to change without notice. Particular attention is given to each of the on-site options, as these represent wastewater management options which are immediately available to Island residents. The economic analyses may also vary with scale, although this is not within the scope of this report.

10.2 Septic Tank Pump-out Systems

There are several costs involved with the septic tank pump-out option, although the majority of these are associated with on-going service requirements. Following is an approximate outline of the costs for a single household to dispose of domestic wastewater from the Island.

Upfront costs	
3 m diameter tank and installation (14,000 L)	$2000 - $3000
Ongoing costs	
Cost of Tank pump-out	$300
Barge costs ($125/hr, min. 4 hours)	$500
Total cost per individual allotment per service	$800
Service requirements for 5 person household	8-10 services/year
Average yearly cost per allotment for pump-out	$6,400 - $8,000

This assessment is based on service requirements at approximately 40 - 45 day intervals, or a frequency of some 8 - 10 services per year.

Some discounts are normally applied where volume rates can be given. Abel Liquid Waste Services Pty Ltd (Hornsby), a regular tanker service provider for the Island, indicated that where more than 3 households could be serviced a the single day, the cost per tank could be reduced by some 20 %, and that the cost of hiring the barge could be shared between each of the customers. Under this price sharing scheme, the minimum cost per allotment would be as follows:

Upfront costs	
3 m diameter tank and installation	$2000 - $3000
Ongoing costs	
Cost of Tank pump-out	$240
Barge costs ($125/hr, min. 4 hours, shared between 4)	$125
Total cost per individual allotment per service	$365
Service requirements for 5 person household	8-10 services/year
Average yearly cost per allotment for pump-out	$2,920 - $3,650

These price estimates are not fixed, but are likely to vary according to the amount of wastewater produced and the size of the wastewater storage facility.

10.3 Enhanced Septic Tanks (EST)

Fewer upfront and ongoing costs are associated with the EST option than with the STPS option. This is primarily due to the reduced frequency with which each of the septic tanks would require desludging. For a single allotment with an average of 5 persons, the costs for an EST are as follows:

Upfront costs	
Cost of upgrading the trenches to AS1547 (1994)	up to $1,500
Cost of Zabel / Orenco filter	$380
Ongoing Costs	
Costs of desludging	$300
Barge costs ($125/hr, min. 4 hours)	$500
Costs of cleaning tank filter (Zabel)	$40
Total cost per individual allotment per service	$840
Service requirements for 5 person household (every 2 years)	0.5 services/year
Average yearly cost per allotment for pump-out	$420

The on-going costs of the EST option may also be reduced where volume discount rates can be applied. In situations where > 3 allotments opt to have their septic tank desludged, the following costs apply:

Upfront costs	
Cost of upgrading the trenches to Australian Standards	up to $1,500
Cost of Zabel filter	$350
Ongoing Costs	
Costs of desludging	$240
Barge costs ($125/hr, min. 4 hours, shared between 4)	$125
Costs of cleaning tank filter (Zabel)	$40
Total cost per individual allotment per service	$405
Service requirements for 5 person household (every 2 years)	0.5 services/year
Average yearly cost per allotment for pump-out	$202.50

10.4 Sand Filters

Sand filter systems can be purchased as a complete wastewater management facility for approximately $5,500. Some price negotiations can possibly be made and the cost may be brought down to $2,800-$3,600 if installed with an AWTS. Costs, including upfront and on-going costs (based on reduced barge costs where 4 or more households are serviced), are outlined below:

Upfront costs	
Cost of sand filter system and irrigation system	$5,500
Cost of reduced sand-filter system	$3,200
Ongoing Costs	
Costs of desludging (once per 2 years)	$240
Barge costs ($125/hr, min. 4 hours, shared between 4)	$125
Annual inspection and service cost	$200
Average yearly cost per allotment maintenance	$445.00

10.5 Separate Grey- and Black-water Treatment / Disposal

Grey-water treatment systems are relatively inexpensive and can be purchased for $750 for the tank and $80 for the effluent distribution box and fittings. Additional costs would include system delivery, installation and preparation of the disposal trenches or evapotranspiration bed. The black-water system would be costed in a similar fashion to a standard septic tank installation. On-going costs would primarily consist of tank desludging at a frequency of approximately 4 years.

The costs, including both upfront and on-going, for the separate grey- and black-water treatment facility are outlined below:

Upfront costs	
Cost of grey-water treatment tank system (no delivery)	$750
Effluent distribution box and fittings	$80
Grey-water trench application system	$200
Cost of black-water septic tank and installation	$2000-$3000
Ongoing Costs	
Costs of desludging (once per 4 years)	$240
Barge costs ($125/hr, min. 4 hours, shared between 4)	$125
Average yearly maintenance cost per allotment	$91.25

10.6 AWTS

The AWTS facility requires that all household wastewater be connected directly to the system. Treatment units can be purchased for $4,000 - $5,000, with additional upfront fees primarily consisting of the costs of transport and installation. On-going costs are primarily associated with the mandatory 3 monthly service contract required on all AWTSs. The costs, both upfront and on-going, for AWTSs are outlined below. Note that although desludging of the septic compartments is infrequent, a small component for this has been included in the cost analyses.

Upfront costs	
Cost of AWTS system	$4,000-$5000
Ongoing Costs	
Costs of desludging (once per 10 years)	$240
Barge costs ($125/hr, min. 4 hours, shared between 4)	$125
3 monthly service contract	$265
Average yearly maintenance cost per allotment	$301.50

10.7 Composting Toilet and Grey-water Treatment / Disposal

The composting toilet facility requires that a grey-water treatment / disposal system are also installed on the allotment. Composting toilet units vary in price depending on the size of the unit installed. For domestic purposes, this may vary from $2,000 for 1 person households to $3,000 for 3 bedroom homes.

Upfront costs	
Cost of composting toilet	$2,000-$3,000
Transport and installation (estimate)	$400
Cost of grey-water treatment system (no delivery)	$750
Effluent distribution box and fittings	$80
Grey-water trench application system	$200
Total upfront costs	$3,430-$4,430
Ongoing Costs	
Costs of desludging grey-water system (once per 4 years)	$240
Barge costs ($125/hr, min. 4 hours, shared between 4)	$125
Annual service contract (cost estimated)	$200 (estimate)
Average yearly maintenance cost per allotment	$291.25

10.8 Reticulated Systems

There are several major costs associated with each of the reticulated sewerage options. These entail:

1. the cost installation of the reticulation pipes used to collect and transport domestic wastewater;
2. the cost of possible pumping stations to transport sewage off the Island;
3. the cost of on-site constructions such as vacuum sources and storage facilities; and
4. the cost to transport sewage from Scotland Island to the mains connection point at Church Point.

Broad cost estimates for each of these items have been provided by Sydney Water (pers. comm. Bob Nimmo, 1996) and AirVac (pers. Comm David Saunders) and are given below:

Upfront costs	
Cost of sewage reticulation	3.5 - 4.5 million $
Pumping stations (3 in total)	$675,000
Estimate of cost per allotment*	$14,000-$17,000
Ongoing Costs	
Costs of desludging septic tanks (once per 2 years)**	$240
Barge costs ($125/hr, min. 4 hours, shared between 4)**	$125
Operating costs of sewerage system	$400 (estimate only)
Average yearly maintenance cost per allotment	$765

Note: * State government subsidies for the installation of reticulated systems may exist.
** These only apply to systems requiring septic tank pre-treatment.

It is important to note that with the above cost estimates, each of the pretreatment systems have a maintenance cost of having the septic pumped out (eg. CED, STEP, VGS, GPS, VSS [optional]). These need to be considered in addition to the other charges associated with maintenance and service fees with the reticulation system.

Considerable savings in construction costs can be made by pumping the septic tank effluents into small diameter (< 100 mm) PVC or polyethylene pipes laid in narrow trenches at relatively shallow depths following terrain contours. This would most likely be the case for the reticulated options utilising septic tanks for pretreatment (eg. CED, STEP, CGS, GPS, and VSS). However, under the scope of this report, it is not possible to examine all of these cost alternatives.

10.9 On-Island Packaged Treatment Plant (PTPs)

The on-Island treatment plants consist of two principal costs; the cost of reticulation; and the cost of the treatment plant(s). Approximate cost estimates are broken down as follows:

Upfront costs	
Cost of sewage reticulation system	1-2 million $
5 treatment plants (@ $40,000 each, 20,000-25,000L capacity)	$200,000
Memtech filtration plant	$250,000
Estimate of cost per allotment	$4,800-$8,200
Ongoing Costs	
Operating costs	$450 (estimate only)
Average yearly maintenance cost per allotment	$450

On-going operation costs are unknown but likely to involve a levy similar in charge to that of those areas in the Council area which are connected to mainline sewer.

11. Additional Considerations and Requirements

11.1 Water Balance Considerations

The monthly balance of water on the Island reveals the times of year when effluent is most likely to be assimilated or removed by evapotranspiration processes on-site, and when it is most likely to be lost from the application area to ground-water either by shallow sub-surface through-flow or through deeper percolation.

Water balances for both grass and shrub/tree covers are given in Table 34. Calculations are provided for mean annual rainfall, median rainfall (1:2 or 50 % rainfall), and extreme rainfall (1 in 5 year or 20 %, 1 in 10 year or 10 %, and 1 in 50 year or 2 %).

In both sets of calculations, June is consistently the month where evapotranspiration (ET) less precipitation (P), or effluent capacity (EFC) is at its lowest. The water balance using median rainfall data (Newport Bowling Club) indicate that effluent accumulation in land application areas is most likely during May and June. However, the analyses using more extreme monthly rainfall totals indicates that EFC can be negative at most times of the year. The annual EFC totals using mean and median rainfall are positive indicating that sufficient net evapotranspiration occurs to throughout the year to remove much effluent on-site provided that application areas are of sufficiently large size.

Table 34: Monthly water balance assessments of Scotland Island, including balances for mean, median (1:2), and extreme events (1:5 or 20 %, 1:10 or 10 %, and 1:50 or 2 %). Rainfall data come from Newport Bowling Club. Evaporation data come from Sydney Airport. The first set of calculations are based on crop factors of 0.80 (grass) in the effluent application area. The second set of calculations are based on crop factors of 1.20 (shrubs and trees) in the effluent application area.

Water Balance on Crop Factors of 0.80 (grass)

Month	Mean P (mm)	50% (mm)	20% (mm)	10% (mm)	2% (mm)	E (mm)	ET (mm)	ET-P mean (mm)	ET-P 50% (mm)	ET-P 20% (mm)	ET-P 10% (mm)	ET-P 2% (mm)
Jan	120	92	195	273	454	217	173.6	53.6	81.6	-21.4	-99.4	-280.4
Feb	125	93	202	284	476	176	140.8	15.8	47.8	-61.2	-143.2	-335.2
Mar	141	108	218	302	496	164	131.2	-9.8	23.2	-86.8	-170.8	-364.8
Apr	116	81	197	285	489	123	98.4	-17.6	17.4	-98.6	-186.6	-390.6
May	110	72	199	295	519	87	69.6	-40.4	-2.4	-129.4	-225.4	-449.4
Jun	132	96	216	308	519	78	62.4	-69.6	-33.6	-153.6	-245.6	-456.6
Jul	75	51	129	188	324	84	67.2	-7.8	16.2	-61.8	-120.8	-256.8
Aug	84	60	139	198	337	115	92	8	32	-47	-106	-245
Sep	66	45	115	167	289	141	112.8	46.8	67.8	-2.2	-54.2	-176.2
Oct	82	63	128	178	294	177	141.6	59.6	78.6	13.6	-36.4	-152.4
Nov	92	68	147	206	345	195	156	64	88	9	-50	-189
Dec	82	64	122	165	266	233	186.4	104.4	122.4	64.4	21.4	-79.6
Annual Total	1225	893	2007	2849	4808	1790	1432	207	539	-575	-1417	-3376

Water Balance on Crop Factors of 1.20 (shrubs and trees)

Month	Mean P (mm)	50% (mm)	20% (mm)	10% (mm)	2% (mm)	E (mm)	ET (mm)	ET-P mean (mm)	ET-P 50% (mm)	ET-P 20% (mm)	ET-P 10% (mm)	ET-P 2% (mm)
Jan	120	92	195	273	454	217	260.4	140.4	168.4	65.4	-12.6	-193.6
Feb	125	93	202	284	476	176	211.2	86.2	118.2	9.2	-72.8	-264.8
Mar	141	108	218	302	496	164	196.8	55.8	88.8	-21.2	-105.2	-299.2
Apr	116	81	197	285	489	123	147.6	31.6	66.6	-49.4	-137.4	-341.4
May	110	72	199	295	519	87	104.4	-5.6	32.4	-94.6	-190.6	-414.6
Jun	132	96	216	308	519	78	93.6	-38.4	-2.4	-122.4	-214.4	-425.4
Jul	75	51	129	188	324	84	100.8	25.8	49.8	-28.2	-87.2	-223.2
Aug	84	60	139	198	337	115	138	54	78	-1	-60	-199
Sep	66	45	115	167	289	141	169.2	103.2	124.2	54.2	2.2	-119.8
Oct	82	63	128	178	294	177	212.4	130.4	149.4	84.4	34.4	-81.6
Nov	92	68	147	206	345	195	234	142	166	87	28	-111
Dec	82	64	122	165	266	233	279.6	197.6	215.6	157.6	114.6	13.6
Annual Total	1225	893	2007	2849	4808	1790	2148	923	1255	141	-701	-2660

11.2 Vegetation Impacts

Vegetation plays a significant role in determining water and nutrient budgets. Inappropriate, or no, vegetation cover combined with permeable soils further increases the risk of surface- and ground-water contamination because of greater nutrient and pathogen losses by percolation.

Australian heathland and sclerophyllous vegetation occur primarily on phosphorus deficient soils. Some field studies have indicated that phosphorus application rates of 20 $kg.ha^{-1}$ (Specht, 1981) are sufficient to cause phosphorous toxicity in some native species. Charman and Murphy (1991) quote a phosphorus "toxicity symptom limit" of 200 $mg.kg^{-1}$. Toxicity is dependant upon the phosphate buffering, or adsorption capacity of soils. In addition to causing the death of seedlings and mature vegetation, increased nutrient status increases survival rates of exotic species resulting in a reduction in ecosystem quality.

High concentrations of aluminium occur in natural soils in the form of alumino-silicates and layered clay minerals (Moore, 1990; Yong *et al*, 1992). Manganese also occurs widely. Aluminium and manganese toxicity are a potential hazard when soil pH is lowered by the irrigation of acidic effluent for long periods. Manganese toxicity is of particular concern in frequently water-logged soils (Woolhouse, 1981). Effluent pH is generally neutral, however, these toxicities may be significant when low pH effluent is irrigated. This is particularly the case on Scotland Island where background soil acidity is already very low (< 5.5, Martens & Associates Pty Ltd, 1996). Boron toxicity is also a concern to many native species.

Waterlogging of soils because of high effluent application rates relative to soil permeability and evapo-transpiration can kill plants through fungal diseases such as "root rot" and fungal infections such as *Phytophthora cinnamonii* and *Armillaria sp.*. Irrigation of effluent with high BOD_5 combines with waterlogging to produce anoxic or anaerobic atmospheric conditions in soils. Vegetation death may result from these conditions because of the anaerobic conditions causing the death of beneficial mycorhizal fungi, important in mineralisation, and because the roots of terrestrial plants can no longer uptake and deliver oxygen. In the initial stages of waterlogging, soil pH may decrease as a result of respiration and the dissolution of carbon dioxide end products to form carbonic acid, as reported in landfill waste degradation (Petrozzi, 1994). Localised aluminium and manganese toxicity may then become significant as these contaminants are mobilised under acidic conditions.

11.3 Nutrient Balance Considerations

Nutrient balances are considered as they provide a useful means of determining the necessary size of on-site domestic wastewater disposal areas to achieve zero nutrient export.

Nutrient balances have been conducted for both nitrogen and phosphorus, with the phosphorus balance including soil sorption as a factor allowing site longevity to be determined. In the case of nitrogen, two balances are determined based on effluent quality. These balances are approximate only and assume local plant nutrient uptake rates of 140 kg/ha/year for Nitrogen and 50 kg/ha/year for Phosphorus. These values are likely vary for Island specific vegetation. However, more specific data were not available at the time of report preparation. Assumptions are as follows:

Nutrient balance effluent quality assumptions	
Septic tank (or primary effluent)	TN = 50 mg/L
Septic tank (or primary effluent)	TP = 15 mg/L
AWTS (or secondary effluent, eg. sand filter)	TN = 25 mg/L
AWTS (or secondary effluent, eg. sand filter)	TP = 15 mg/L

Nutrient balances were conducted for both the current rainwater tank water supply situation, and also for the situation where the Island would receive full connection to reticulated town water. The following water usage and soil characteristics assumptions were made prior to the nutrient balance determination.

Nutrient balance water and soil assumptions

OPTION A: Continued tank water usage		***OPTION B: Connection to town water***	
Persons/house	5	Persons per house	5
Hydraulic flow (L/day)	550	Hydraulic flow (L/day)	900
P-sorption (mg P/kg soil)	165	P-sorption (mg P/kg soil)	165
Soil depth (m)	0.3	Soil depth (m)	0.3

The results of each of the nutrient balances (nitrogen and phosphorus) are given in Tables 35 and 36 and Figures 4 and 5 below. Both tables indicate that significantly large effluent application areas are required to achieve approximately zero nutrient export from the disposal site where septic tanks or AWTSs are utilised. Nitrogen balance assessments are calculated to include vegetative uptake.

For the current rainwater tank water supply, areas of approximately 400 (AWTS) to 800 (septic tank) m^2 are required to completely assimilate nitrogen within the land application areas. Generally lower nitrogen concentrations in AWTS effluent result in smaller application areas being required for the assimilation of nitrogen. Should reticulated town water be supplied to the Island, then the areas required would increase to approximately 600 (AWTS) to 1200 (septic tank) m^2 respectively.

The phosphorus balance assessment included both soil sorption and vegetative uptake of phosphorus (Table 36). This indicated that due to the relatively low sorptive capacity of many of the Island soils, large application areas are required to provide complete assimilation of phosphorus on-site and unlimited storage capacity. Under the current rainwater tank supply, areas of greater than 600 m^2 would be required where as areas of greater than 900 m^2 would be required should full reticulated town water be supplied to the Island. These results therefore also suggest that nutrient loads in current effluent disposal systems are in excess and may be/lead to vegetation dieback. The use of low phosphorus detergents may alleviate this situation somewhat.

Both nitrogen and phosphorus balances therefore indicate that connection to full reticulated town water supply would result in unsustainably larger areas (approximately greater than 800 m2) being required for complete nutrient assimilation on-site.

Table 35: Nitrogen balance assessment with vegetative uptake.

Disposal area (m^2)	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**	**1100**	**1200**	**1300**
Septic: tank (kg/ha/year)	1004	502	335	251	201	167	143	125	112	100	91	84	77
Septic: town (kg/ha/year)	1643	821	548	411	329	274	235	205	183	164	149	137	126
AWTS: tank (kg/ha/year)	502	251	167	125	100	84	72	63	56	50	46	42	39
AWTS: town (kg/ha/year)	821	411	274	205	164	137	117	103	91	82	75	68	63
Veg. Uptake (kg/ha/year)	140	140	140	140	140	140	140	140	140	140	140	140	140
Septic balance: tank (kg/ha/year)	864	362	195	111	61	27	3	-15	-28	-40	-49	-56	-63
Septic balance: town (kg/ha/year)	1503	681	408	271	189	134	95	65	43	24	9	-3	-14
AWTS balance: tank (kg/ha/year)	362	111	27	-15	-40	-56	-68	-77	-84	-90	-94	-98	-101
AWTS balance: town (kg/ha/year)	681	271	134	65	24	-3	-23	-37	-49	-58	-65	-72	-77

Note: Negative balances indicate that plant nitrogen uptake is likely to exceed application rate.
Septic and AWTS refer respectively to nitrogen concentrations from septic tanks and AWTSs.
Tank and Town refer respectively to tank water and reticulated town water supplies.

Table 36: Phosphorus balance assessment with soil sorption and vegetative uptake.

Disposal area (m^2)	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**	**1100**	**1200**	**1300**
TP: tank (kg/ha/year)	301	151	100	75	60	50	43	38	33	30	27	25	23
TP: town (kg/ha/year)	493	246	164	123	99	82	70	62	55	49	45	41	38
Veg. Uptake (kg/ha/year)	50	50	50	50	50	50	50	50	50	50	50	50	50
P-sorption (kg)	8.17	16.34	24.50	32.67	40.84	49.01	57.18	65.34	73.51	81.68	89.84	98.01	106.18
Balance: tank (kg/ha/year)	251	101	50	25	10	0	-7	-12	-17	-20	-23	-25	-27
Balance: tank (kg/ha/year)	443	196	114	73	49	32	20	12	5	-1	-5	-9	-12
Longevity: tank (years)	3.3	8.1	16.2	32.3	79.9	4356.0	U	U	U	U	U	U	U
Longevity: town (years)	1.8	4.2	7.1	11.2	16.8	25.4	40.1	70.4	171.9	U	U	U	U

Note: U = Unlimited storage capacity based on design loading and vegetation uptake rates.
Negative balances indicate that plant phosphorus uptake is likely to exceed application rate.
Tank and Town refer respectively to tank water and reticulated town water supplies.

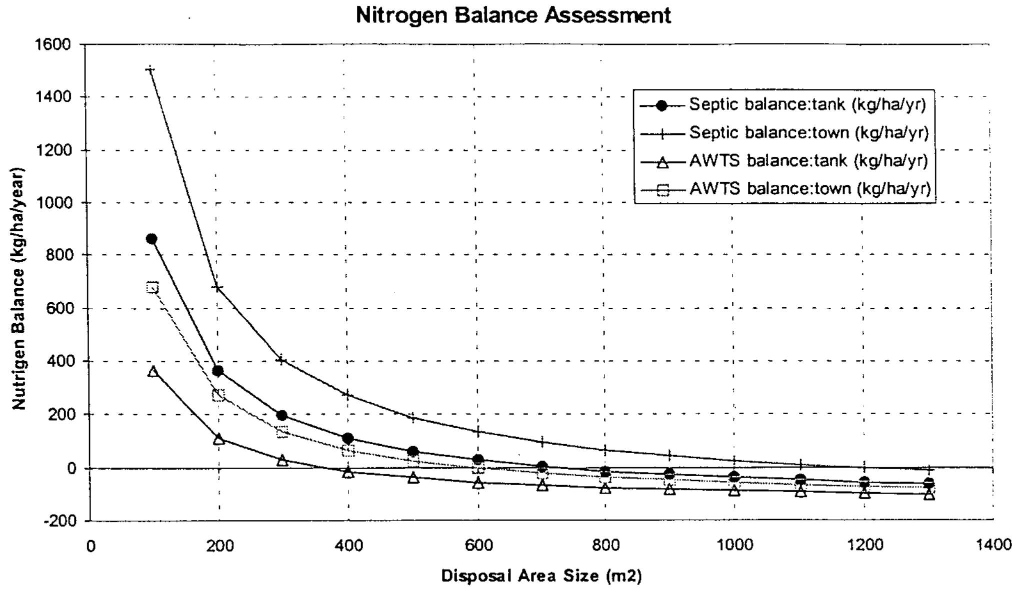

Figure 4: Nitrogen balance assessment for variable disposal area sizes receiving septic tank and AWTS effluents.

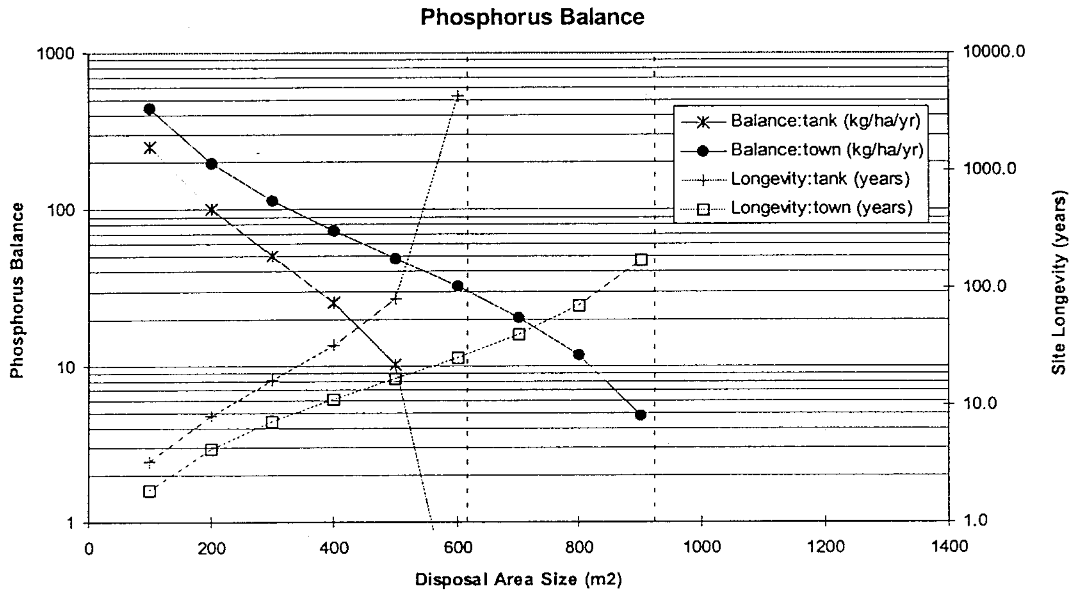

Figure 5: Phosphorus balance assessments and site longevity for variable disposal area sizes receiving septic tank and AWTS effluents. Dashed lines indicate where longevity becomes unlimited under both rainwater tank supplies and town water.

11.4 Construction Requirements

A report prepared by Terrene Research outlines the general environmental management implications for the construction of both on-site and off-site wastewater management options (Appendix A). The findings of this study are summarised below.

1. To reduce present erosion and minimise erosion the road network requires upgrading.
2. Implementation of one of the reticulated sewage options is a large scale disturbance of relatively short duration (pluse disturbance, 0.5 - 2 years). In contrast on-site options necessitate small scale disturbances over a relatively long period (press disburbance, 10-15 years). Although a pulse can have significant environmental impact, it is usually a press that has the greater ecological effects.
3. Environmental management of construction of one or more of the reticulated sewerage treatment and disposal options available has four phases. The tender, pre-construction, construction and post-construction phases. Guidelines to these phases of project management are provided in section 2 of the report (Appendix A).
4. Implementation of a reticulated option will require that the full Environmental Impact Assessment (EIA) process be undertaken and an Environmental Impact Statement (EIS) be prepared. The process of approval can take significant periods of time, especially when time is required to research and prepare the EIA documentation such as an EIS.
5. The environmental impact of on-site options should be assessed during the normal building and development application process. Disposal system characteristics are directed by Australian Standard 1547 (1994).
6. Remedial measures on roads and access tracks should concentrate on erosion control as fine grain sediment, transported in suspension by the Island's ephemeral streams, is ineffectively trapped by common control devices.
7. Sediment [and erosion] control measures are required on all construction sites.

12. Summary of Wastewater Management Options

Each of the wastewater management options are summarised in Table 37 below. This outlines the major advantages and disadvantages of each option, together with descriptions of the situations where each are either more or less suitable. An approximate order of cost is given [where information is available], and some additional specific comments are also provided.

Table 37: Summary of main advantages and disadvantages, suitability and approximate costs of each wastewater management option for Scotland Island.

OPTION	MAIN ADVANTAGES	MAIN DIS-ADVANTAGES	MORE SUITABLE FOR	LESS SUITABLE FOR	ORDER OF COST PER LOT	COMMENTS
GRAVITY MAINS SEWER (GMS) & VACUUM SEWER SYSTEM (VSS)	• Effluent removed	• Cost • Large scale excavation work required.	• Flat or constant sloped terrain • Solid ground material	• Rocky ground • High ground-water table • Very hilly terrain	• $10,000 - $20,000	• If well maintained, no effluent is disposed of onto the Island. • Highest level of local environmental service
SEPTIC TANK EFFLUENT PUMPING (STEP)	• Small bore pipes laid at shallow depths. • Infiltration / inflow is limited • Low organic and solids loads to treatment plant • Peaking factors reduced	• Odour occurs • Corrosion may occur • Power supply required for each system • Septic tanks require desludging • Equipment requires servicing • High operation / maintenance costs • Possible exfiltration from pressure sewer	• Unstable soils • High groundwater • Rocky terrain • Flat and undulating terrain	• Very hill terrain	• Maintenance costs are high • $10,000 - $20,000 assuming existing septic tanks	• Attractive option as the majority of the Island is already served by septic tanks. • Limited use where seasonal loadings exist.
COMMON EFFLUENT DRAINAGE (CED)	• Reduced blockage. • No power generally req. • Reduce peaking factors. • Reduced organic loading at treatment plant.	• Pump-out required. • Septic effluent • septage facility required.	• flat terrain or constant slope	• Rocky ground • High ground water • Hilly terrain	• Maintenance costs are high • $10,000 - $20,000 assuming existing septic tanks	• Attractive option as the majority of the Island is already served by septic tanks.
VARIABLE GRADE SEWER (VGS)	• Reduced blockage frequency • Small diameter pipes • No power generally required • reduced peaking	• Pump outs required • septage facility required	• Flat to undulating terrain	• Rocky ground • High groundwater • Hilly terrain	• Maintenance costs are high • $10,000 - $20,000 assuming existing septic tanks	• Attractive option if majority of Island serviced by septic tanks

	factors • reduced organic load at treatment plant					
GRINDER PUMP SYSTEM (GPS)	• Small pipes folllowing terrain • Septic tanks not required • All sewage removed	• Power required • Servicing of electromechanical equipment	• Unstable soil • High groundwater • Rocky terrain • Flat and undulating terrain		• $10,000 - $20,000 • Ongoing depends on whether septic tanks are used.	• Attractive option where septic tanks exist • Limited use where seasonal loadings exist
PACKAGED TREATMENT PLANTS (PTP)	• No septic tanks required • High quality effluent • Low cost • Tertiary treatment option available (UV, Memtec) • Accepts grey and black water	• Space requirements • Power required • Servicing required • Operator required	• Larger populations • Unsuitable locations • Sensitive environments	• Large allotments • Individual households	• $200,000 for five treatment plants. • $250,000 for Memtec filtration • 1-2 $million reticulation lines • $1500-$2500 per lot + $450/lot/yr mainten.	• Attractive option if high quality effluent is achieved and discharge to Pittwater is possible.
SEPTIC TANK PUMPOUT SYSTEM	• No effluent disposal on-site. • Low up-front cost. • Easy installation.	• Expensive to pump out. • Illegal effluent disposal risk. • Risk of tank failure.	• low land capability	• high land capabilty • Portablity	• $2,000-3,000 + $3,000 - $4,000 per year	• Not attractive due ongoing costs.
ENHANCED SEPTIC TANK	• Improved septic tank effluent . • Low cost. • Enhance disposal area longevity.	• high nutrient content in effluent • High maintenance	• More suitable for limited disposal areas	• Environmentally sensitive areas.	• $2,500 - $3,500 for septic unit. • $420 per year for pump outs	• Attractive initial option for upgrading failing systems
SAND FILTER SYSTEM	• High quality effluent	• Power required • Servicing required • sand bed replacement required every 10-15 years	• More suitable for limited disposal areas. • Low land capability	• Hilly terrain • Rocky ground	• $5,500 • $2,800-$3,600 add-on system • $445 / year mainte.	• Attractive option where high quality effluent is required and land is available.
SEPARATE GREY-BLACK WATER	• Grey water reuse option. • No power	• Poor quality effluent. • Requires two treatment systems & two disposal areas.	• Large allotments	• Small allotments • Environmentally sensitive areas.	• $3,000-$4,000 • $100 / year mainten.	
AWTS	• High quality effluent. • Effluent reuse option. • Regularly maintained.	• Servicing required. • Servicing costs. • Health risk if system fails.	• Hilly terrain • environmentally sensitive areas. • Low land capability	• Steep terrain • Wet/cold climates	• $4,000-$5,000 + installation • $300 / year mainten.	• Attractive option due to high quality effl. ,larger disposal areas.
COMPOSTING TOILETS AND GREYWATER TREATMENT PLUS TRENCHES	• Compost recycling. • Reduced wastewater volume.	• High cost. • Householder to service. • Dual system required. • Disposal of compost.	• Remote areas	• Urban / semi-urban areas.	• $3,500 - $4,500 • $300 / year mainten.	• Generally not an attractive option due to large demands on householder to service.

Following on from this table, some additional summarising comments can be made about the available wastewater options:

1. Under the current situation, nutrients are likely to be accumulating in designated effluent application areas, and in some instances this may be leading to local tree die-back. This would also be the situation for each of the current on-site treatment/disposal options. On-site domestic effluent treatment and disposal options which permit for nutrient removal should therefore be encouraged. This is particularly important in the light of the many small allotments which exist on the Island.
2. It is important to recognise that the on-site wastewater treatment and disposal technology is rapidly changing. These options are therefore likely to expand in the coming years. As new technologies become available, these should be reviewed for their suitability for the Island.
3. Each of the reticulated options are considerably costly on a lot by lot basis when compared to the on-site treatment/disposal options. It would be therefore more difficult for home owners to afford these wastewater management options without some form of government assistance.
4. The implementation of each of the reticulated options, including the on-island packaged treatment plants, may incur considerable impact on the Island's road system and lead to increased soil loss. This should be an important consideration in the planning process for any reticulated water and wastewater schemes proposed for the Island.

13. Recommendations

13.1 Water Management

Separate recommendations are made for each of the water supply options presented. These are given in Sections 13.1.1., 13.1.2. and 13.1.3. below.

13.1.1 Future Use of Rainwater Tanks

The continued use of the current rainwater collection and storage system is recommended and is regarded as suitable for the existing wastewater management facilities. The water samples collected from three (of five) water tanks indicated elevated Faecal Coliform and Enterococci levels. However, these are most likely attributed to animal (possum) droppings and are not likely to present a significant risk to public health.

13.1.2 Upgrade of Existing Reticulated Supply

This study has indicated that there is a potential for the emergency water supply line to be contaminated with effluent [as indicated by the presence of faecal bacteria]. The following recommendations are made for the emergency water supply line:

1. Further testing of the quality of water in the emergency supply line should be carried out. This should establish whether the line is indeed contaminated by infiltration of effluent and other contaminated water.
2. If it can be shown that the emergency water supply line is contaminated with infiltrated effluent, then the line should be immediately upgraded, provided that it continues to be utilised on the Island. If it is upgraded, then the entire pipe works should be buried so that the risk of damage and subsequent infiltration of contaminated water are prevented.
3. There should be no further increase in the usage of the emergency water supply. Council should closely monitor water usage on the Island and annually review average rates of use. Should the total water consumption rates for the Island increase towards 180 L/person/day, then the on-site wastewater treatment options would need to be reviewed as increased hydraulic loads may result in an increased absorption trench failure rate.
4. Subject to current Council policy, cost restrictions can be placed by Council on the emergency water supply to ensure that usage remains at a minimum. Differential pricing or price structuring may be useful to distinguish between drought and non-drought times.

13.1.3 Full Reticulated Supply

A full reticulated water supply to each residence on the Island should not be implemented unless the Island is to be serviced by a reticulated sewerage system. The reason for this is that many of the existing on-site wastewater disposal areas may become hydraulically overloaded and subsequently fail.

13.2 Wastewater Management

Recommendations for wastewater management are given as three distinct management stages. These include:

1. immediate requirements;
2. short-term recommendations; and
3. long-term recommendations.

These are provided in further detail in Sections 13.2.1, 13.2.2 and 13.2.3.

13.2.1 Immediate Requirements

The initial water and wastewater impact assessment report prepared by Martens & Associates Pty Ltd (1997) for the Island identified that current wastewater treatment and disposal practices on the Island are inadequate and have lead to substantial degradation in surface water quality (particularly during wet-weather) and elevated risks to public health incurred through possible contact with surface runoff and ponded water in pools on the Island dirt roads. This may be contributed to by failing septic tank and absorption field installations on the Island, and introduced and native animals.

In the light of these conclusions and the discussions provided on each of the wastewater management options, the following recommendations are made as immediate requirements for Scotland Island.

1. An Island-wide survey of existing on-site wastewater treatment systems is recommended. This should be used to identify those systems which do not currently comply with Australian Standard 1547 (1994), including septic tanks, AWTS, grey-water treatments systems and composting toilets. The survey should focus on identifying lots where there is evidence of effluent surcharging and leakage downslope of the effluent application area, and / or, those lots where the wastewater treatment system is damaged or not performing to the original design specifications. Wastewater systems should be upgraded where the site inspection deems failure. This would be to the satisfaction of Pittwater Council and include such measures as the installation of a new treatment system, installation of new trenches or irrigation areas, and the repair of damaged equipment. The survey should preferably be conducted following wet-weather when the risk of effluent surcharging from absorption trenches is greatest.

2. A data-base of the Island's wastewater treatment systems should be established which covers each of the elements of the Island-wide survey outlined above. The data-base should be updated once 2 years through repeated surveys of on-site wastewater treatment systems, to ensure that compliance is maintained.

3. New on-site wastewater treatment system installations and other building activities where additional wastewater is to be produced should establish the ability to comply with Australian Standard 1547 (1994) for the disposal of domestic wastewater on-site. This would require an on-site wastewater assessment report to prepared by a suitably qualified consultant to establish the sites capability to accept wastewater and the requirements for adequate treatment and disposal. In the event that Australian Standard 1547 (1994) is superseded, compliance with the most recent edition is recommended. Compliance with Australian Standard 1547 (1994) will ensure that future on-site treatment/disposal facilities are suitably designed, preventing trench and irrigation field failure and subsequent effluent loss from the land application area. In the event that the guidelines in AS1547 (1994, or most recent version) cannot be followed, then a septic tank pump-out system is recommended.

13.2.2 Short-term Recommendations

Short-term recommendations represent those actions which should be implemented during the next two years. These include restrictions on the usage of particular treatment and disposal method and the provision for alternative methods based on the discussions provided in Section 9. Short-term recommendations are outlined below:

1. Due to the generally poor soil conditions for on-site disposal encountered on the Island, the options for on-site disposal should principally include those options which produce higher quality effluent. These therefore

include AWTSs, sand filters and other similar systems / technologies producing a high grade effluent which may be constructed and become available in the future but are not covered in this review. With the recent development of ESTs, these also represent an alternative method of effluent treatment.

2. Composting toilets, together with grey-water treatment/disposal systems, may provide a suitable wastewater management alternative for some sites on the Island. However, such systems have typically high maintenance requirements and Council would need to ensure that adequate servicing of the facility occurs. In the light of the low nutrient content and high erosion potential of Island soils, deep burial of composted toilet wastes (> 50 cm) on the Island or removal from the Island are recommended. A three monthly service contract between the home owner and the manufacturer, similar to that required for AWTSs, is therefore recommended for such systems. Servicing should include an examination of the compost and details of how the compost has been disposed.

3. The method of on-site effluent disposal may be by surface spray irrigation where effluent is sufficiently disinfected to meet public health standards. Where disinfection does not occur / does not meet public health standards/requirements or insufficient area is available for spray irrigation, then effluent should be distributed directly to sub-surface soil horizons. This can be achieved either by disposal into standard absorption trenches or by application to a sub-surface irrigation area. Approximate appropriate sizes of application areas for varying hydraulic loads based on Australian Standard 1547 (1994) have been outlined in Sections 9. The role of vegetation in the renovation of effluent is important and should be considered in the design of on-site effluent application systems.

4. Individual site assessment for future developments producing wastewater is recommended based on soil type, aspect and slope predominantly. The land capability map (Figure 6) provided in the stage one report can provide some guidance for areas which would require further investigation or are likely to be unsuitable for effluent disposal.

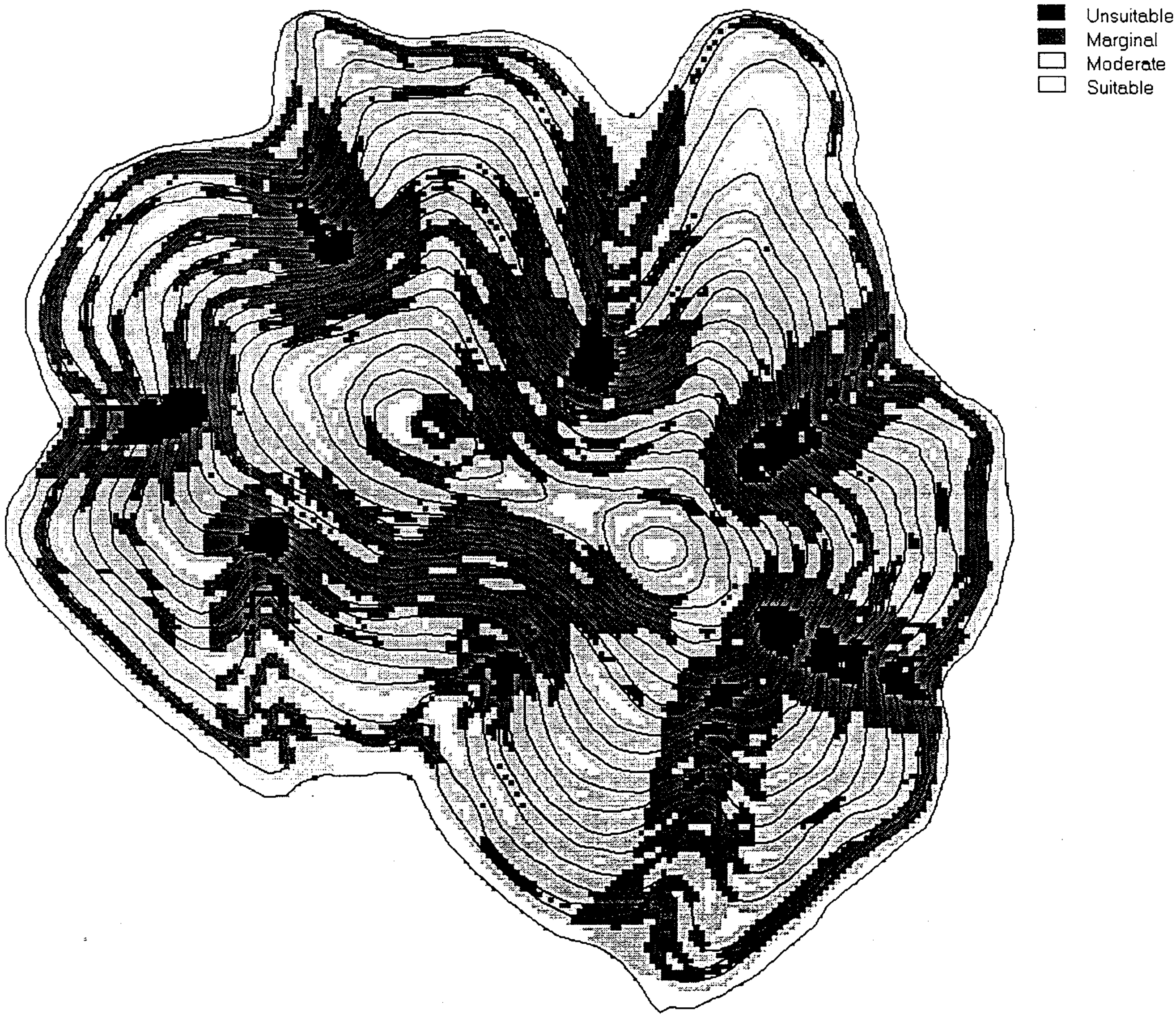

Figure 6: Land capability map of Scotland Island (reproduced from Martens & Associates Pty Ltd, 1996).

5. Effluent disposal buffer zones of 20 m to the ephemeral streams are recommended. This applies in particular to Catherine Park, and the gullies on the southern side of the Island where evapotranspiration is locally reduced due to shading. Advice received from the Department of Land and Water Conservation (2/7/96) indicates this should be extended to 40 m. However, due to the ephemeral nature of flow in these gullies (storm related only), 20 m is seen as suitable by Martens & Associates.

6. It has not been the purpose of this report to provide a detailed investigation of each of the reticulated sewerage options, but only to provide general guidance for which systems are more suitable for the Island. Therefore, it is recommended that the reticulated off-site disposal of sewage be investigated in further detail, providing considerations to the cost of such an installation and the environmental impacts.

7. A community education programme is recommended to ensure that Island residents are aware of the current wastewater management problems on the Island and suitable practices for water and wastewater management. This should include information on low sodium, boron and phosphorus content detergents, the implications of using garbage grinders on organic loads to on-site treatment plants, managing effluent disposal areas, the importance of suitable servicing and maintenance of treatment plants, and the current of current wastewater management practices on the Island to name but a few.

8. The surface water quality monitoring programme initiated on the Island during the stage 1 report provided valuable data on the quality of background surface runoff on the Island. It is recommended that this monitoring programme be continued on a 3 monthly basis for a period of 2 years so that changes to surface water quality conditions can be monitored and that seasonal variations in surface water quality can be identified.

13.2.3 Long-term Recommendations

The long-term management of wastewater on the Island is dependent on the water supply system in operation. The following recommendations for long-term Island management are made:

1. If a full reticulated town water supply is brought to the Island then the current disposal areas would become hydraulically overloaded. Nutrient loads to current disposal areas would also increase substantially. It is critical that disposal areas would then either need to be completely upgraded to meet the requirements of Australian Standard 1547 (1994 or newer) or one of the reticulated options should be considered. Reticulated options are preferred due to limited space on the Island.

2. The Island's environmental (particularly water quality and tree die-back) and public health status should be reviewed every two years. Data for this review should come from the two year wastewater treatment system inspections and the continuing surface water quality monitoring programme established on the Island. As a result of the upgrading of existing systems and improved new treatment plant installations, there may be a measurable improvement in surface-water quality. Where environmental degradation continues and risks to public health increase from the present situation, the reticulated effluent management options are recommended for the Island. These may consist of either of the following two options discussed previously in Section 9.

   a. on-Island packaged treatment plants; and
   b. reticulated sewer and off-Island treatment

   Importantly, the implementation of one of the reticulated options may result in substantial soil erosion and will require significant preliminary investigation of the impacts of construction on road surfaces on the Island.

Should reticulated sewerage proceed, very strict environmental controls would be required during all phases of construction.

13.3 Special Areas

There are several areas on the Island which contain closed forest ecosystems. These are primarily located in some of the gullies on the eastern and southern sides of the Island. These should be maintained and effluent disposal should not occur within such areas. It is not in the scope of this report to address these areas in detail.

13.4 Soil Conservation Measures

Several parts of the Island show significant levels of soil erosion. This is particularly the case along many of the Island's dirt roads. Soil erosion control measures currently utilised on the Island are not adequately maintained and are not performing to their intended function. This has been identified by the report prepared by Terrene Research (Appendix A). Erosion control works should be required for all construction of future on-site wastewater management facilities. Remedial works to the roads would be required should any of the reticulated options be implemented.

13.5 Recommended Plan of Action for Council

A plan of action is recommended for Council. This is outlined in Figure 7 below.

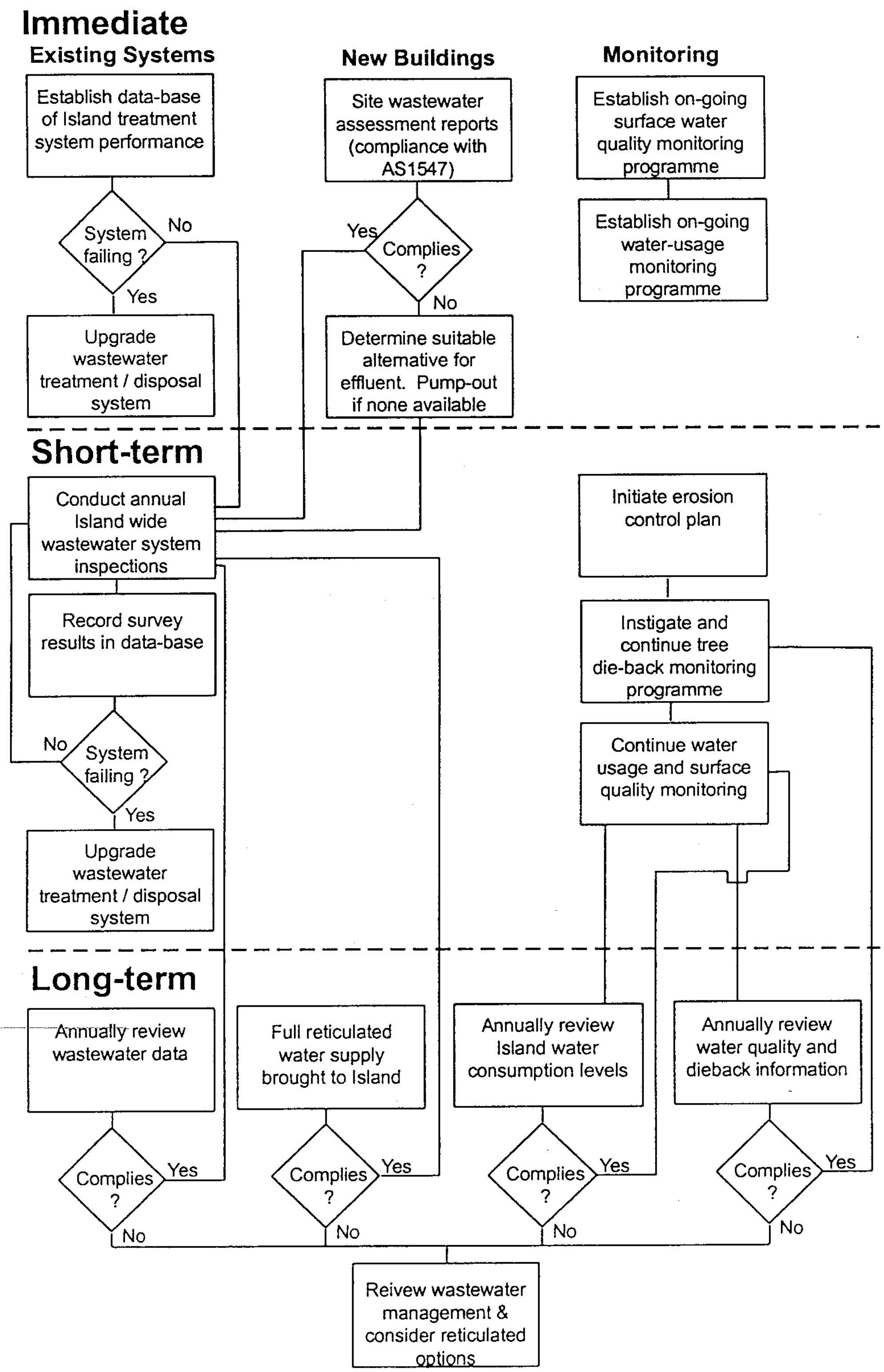

Figure 7: Recommended plan of action for Council.

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15. Appendix A: Terrene Research Construction Issues Report

Terrene Research Report on construction related issues for each of the wastewater management options.

Environmental Management Implications for Construction of Wastewater Treatment Options, Scotland Island, Pittwater, NSW.

by

Martin A. Bergs M.Sc.
Geomorphgologist

January, 1997

Report prepared by *Terrene Research* for Martens and Associates Pty Ltd for inclusion in the Scotland Island Water and Sewage Options Study.

Terrene Research
1/1 Gray St Kogarah NSW 2217
Ph: 02 588 4682
Fax: 02 553 7579
Email: On request

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1. Executive Summary

This report address the principal environmental management implications of construction related issues of each of the proposed wastewater management options for Scotland Island. In particular, the report focuses on highlighting differences between reticulated and non-reticulated management options. In section 2 the principal tasks prerequisite to the environmental management of construction projects are outlined. In section 3 the environmental factors relevant to the construction of water and wastewater treatment options are described in the context of Scotland Island. Section 4 discusses erosion and sediment control measures required on Scotland Island to minimise the environmental impact of the implementing one of the proposed wastewater treatment options. The main issues contained in this document are summarised below.

- Implementation of one of the reticulated sewage options will be a large scale disturbance of relatively short duration (0.5 - 2 years). In contrast, on-site options necessitate small scale disturbances over a relatively long period (10-15 years)
- Environmental management of construction of one or more of the reticulated sewerage treatment and disposal options available has four phases: the tender; pre-construction; construction; and post-construction phases. Guidelines to these phases of project management are provided in section 2.
- Implementation of a reticulated option will require that the full Environmental Impact Assessment (EIA) process be undertaken and an Environmental Impact Statement (EIS) be prepared. The process of approval can take significant a period of time, especially when time is required to research and prepare the EIA documentation such as an EIS.
- The environmental impact of on-site options is assessed during the normal building and development application process. Disposal systems characteristics are directed by AS1547 (1994 or newer).
- To reduce present erosion and minimise erosion, the road network requires upgrading.
- Remedial measures on roads and access tracks should concentrate on erosion control as fine grain sediment, transported in suspension by the Island's ephemeral streams, is ineffectively trapped by common control devices.
- Sediment [and erosion] control measures are required on all construction sites.

2. Introduction

This document has been included in the Scotland Island Wastewater Project Stage 2 report to outline the implications for environmental management of construction activity associated with the water and wastewater options contained in the enclosing document. Construction issues are particularly important to include in the options study because access roads that would be utilised on the Island are unsealed, generally narrow and generally degraded. Other concerns include limited storage areas, the impact of excavation and noise.

3. Environmental Management of Construction Projects

3.1 Responsibility

The successful environmental management of construction projects requires consideration of environmental factors be integrated into the project from the start. The SIRA possess a comprehensive GIS describing the Islands environment. This, together with other data bases can be provided to tenderers for use in development of their environmental management plans. The management of the environment should not be considered separate from the total project management of the proposal. A preliminary review of environmental factors may highlight and therefore off-set the potential environmental problems associated with particular activities. In Table 1 common environmental risks are listed adjacent to some of the potential impacts.

Four stages of a construction project must be considered if all environmental aspects of the project are to be considered. These are the;

1. tendering stage;
2. planning stage;
3. construction stage; and
4. post construction stage.

The consideration of all risks associated with construction projects is the legal responsibility of all participants involved in the undertaking of the work.

Table 1: Common environmental factors and associated environmental risks incurred when planning construction projects.

Environmental Factor	Potential Impact
Proximity to Residents	Restricted work hours location of stockpiles / waste. Dust and noise levels
Land Zoning & Planning Laws	Submission of development and other applications and development may delay proposed commencement dates.
Proximity to Waterways	Access restriction, planning for erosion and sediment controls, hazard management.
Access	Proposed access routes to be travelled by trucks may be restricted due to proximity to private residences, power poles, narrowness, steepness.
Flora and Fauna	Surveys for rare or endangered species, clearing required, vegetation affected by storage of equipment.
Heritage Items	Restrict demolition, alteration or reconstruction of an item, changes to materials and colour schemes.

3.2 Tendering Stage

During the tendering stage it is important that the tenderers identify the environmental limitations and determine the time and money required to fulfil the statutory environmental obligations. In Table 2 six tasks are described. These should be considered in terms of the entire water and sewage treatment improvement project, they are not intended to be a checklist for individual lot owners, rather, starting points from which implications and actions may be identified.

Table 2: Main project management tasks required in tendering stage of construction of proposed wastewater treatment options.

Main Tasks*	Description
1	Delegate responsibility to undertake environmental management during project. Or employ project manager.
2	Determine ownership of work areas.
3	Determine statutory planning requirements.
4	Determine licensing or approval requirements.
5	Determine heritage issues.
6	Community liaison

3.3 Pre-construction Stage

Prior to the constuction of the reticulated wastewater management options, significant planning is required. The main project management tasks required in this pre-construction stage are outlined in Table 3. Effective planning requires that tasks be completed about 6 weeks before the commencement of work to allow sufficient time to gain the appropriate approvals.

Table 3: Main project management tasks required in pre-construction phase of proposed wastewater treatment options.

Main Tasks*	Description
1	Prepare Environmental Impact Assessment documentation for approval determination.
2	Preparation of environmental management plan.
3	Submit applications for relevant approvals.
4	Staff training or briefing.
5	Community liaison.

3.4 Construction Stage

To be effective, environmental safeguards need to be implemented at all stages of construction activity. Monitoring of this procedure throughout the various phases of work in conjunction with other tasks listed in Table 4 will assist in minimising environmental impacts of construction.

Table 4: Main project management tasks required in construction of proposed wastewater treatment options.

Main Tasks*	Description
1	Implement environmental management plan
2	Implement monitoring and reporting plan
3	Address any/all reported problems and update management plan and procedures.
4	Site clean up.
5	Implement rehabilitation / revegetation plan
6	Continue monitoring until site reparation complete

3.5 Post Construction Stage

Following completion of construction, environmental monitoring and maintenance is required to ensure minimal ongoing environmental impacts. This includes regular water quality assessment, inspection and maintenance of erosion control measures and the satisfactory completion of site rehabilitation works such as revegetation. Maintenance of erosion control measures includes excavation and re-distribution of trapped sediment in addition to general maintenance of fences and other structural items.

Terrene Research
1/1 Gray St Kogarah NSW 2217
Ph: 02 588 4682
Fax: 02 553 7579
Email: On request

Table 5: Main project management tasks required post construction of proposed wastewater treatment options.

Main Tasks*	Description
1	Implement environmental monitoring procedures where applicable.
2	Maintain any remaining sediment/ erosion control measures.
3	Maintain revegetated areas until established

* - modified from Working Guide to the Environmental Management of Construction Projects, Benkroarto Pty Ltd (1995).

4. Construction Operations Environmental Factors

Thirteen construction and operation sub-factors are described in sections 3.1 to 3.15 as they pertain to on-site and reticulated effluent treatment and disposal options. These factors need to be addressed in environmental impact assessment and environmental management plans. Additional factors may become apparent when a decision is made as to which option is most appropriate for the Island. Erosion control is discussed in section 4.

Table 6: List of construction and operation sub-factors considered during assessment of wastewater management options.

Construction and Operations Environmental Factors
Access requirements
Construction infrastructure
Duration of work
Dust and vehicle emissions
Erosion and sediment control
Impact of imported materials
Labour force requirements
Maintenance
Noise control measures
Site availability & Population displaced
Surface area requirements
Vehicular disturbance
Waste Disposal

4.1 Access Requirements

Road access is required for all wastewater management options. Erosion control measures are most important around the Island's access roads to prevent further degradation. Sediment control measures are also required around actual construction sites.

Terrene Research
1/1 Gray St Kogarah NSW 2217
Ph: 02 588 4682
Fax: 02 553 7579
Email: On request

Access around the Island is by one, and in some areas, two largely unsealed roads that are narrow and in degraded condition. While the present access roads provide adequate pedestrian access their capacity for vehicular traffic is limited. High traffic volumes are considered to have the potential to exacerbate the erosion rate if erosion control measures are not installed prior to the commencement of the work and maintained throughout and following completion of the work.

The progressive implementation of each of the on-site wastewater treatment options will also require suitable access to be maintained years into the future as systems are either upgraded or new systems (such as aerated wastewater treatment sytems and composting toilets) are brought to the Island. It is estimated that a period of up to 10 years may be required before all the systems on the Island are in good operating condition. In contrast the implementation of one of the reticulated sewerage treatment options would require greater pressures on access for a shorter period of time.

The present erosion hazard from roads around the Island is severe under intense rainfall conditions. At this stage there has been no formal approval for implementation of an erosion and sediment control plan on Scotland Island. Tender applications should include details of access routes, frequency of use, environmental safeguards and maintenance procedures.

4.2 Construction Infrastructure

The basic construction infrastructure and equipment required to carry out the water and wastewater options are listed in Table 7.

Table 7: List of construction infrastructure and equipment requirements.

Construction Infrastructure and Equipment
power
water
stockpile and waste handling areas
generators and compressors to run power tools
bobcats
loaders
backhoe
grader
dumper bins
deployment and recovery vehicles.

Electric power supply is presently on the Island. The existing emergency water supply line is considered adequate to supply construction needs.

Earthen stockpile and materials handling areas would be required on the Island during the implementation of any of the reticulated options. Many of these areas require sediment and erosion control measures and require Council approval of site location.

Damage to unsealed road surfaces by tracked vehicles can be significant, especially in wet conditions and where they have to negotiate sharp bends and inclines such as those on Scotland Island. Lateral movement of one track relative to the stationary track may churn road surfaces.

Powerlines are low in several locations around the Island and may require relocation (temporary or permanent) to facilitate equipment deployment.

4.3 Duration of Work

The duration of work required for implementation of the reticulated options is potentially less than the time required to replace or upgrade the majority of on-site disposal systems on the Island. While on-site options can be installed within a few working days reticulation of the Island will require continuous construction work for a period of between 6 months and 2 years.

4.4 Dust and Vehicle Emissions

Vehicle emissions on the island are low due as there are few cars. During construction activity vehicle emissions will rise but are not considered to be a significant pollution factor provided all machinery used is in good working order.

Dust and vehicle emissions can also be minimised by use of a water cart or other watering equipment to reduce dust from access routes to stockpile sites for example. This measure would only be necessary where frequent vehicle use is anticipated such as would occur during phases of construction of one of the reticulated options.

4.5 Erosion and Sediment Control

During Stage 1 of the water and wastewater study, Martens and Associates P/L (MA) reported results of stream sampling that indicate significant volumes of sediment are removed from the Island in suspension. The Island's streams are ephemeral and respond rapidly to rainfall due to the relatively steep terrain. The combination of rapid run-off and fine sediment travelling in suspension drastically reduces the sediment trapping efficiency of common control devices such as silt stop fences and retention basins. Therefore, it is recommended that the erosion and sediment control plans prepared focus on erosion control. The abundance of fine silt and clay sized particles in the soil is inherent in the lithological character of the Island's bedrock.

Soil erosion on Scotland Island is the subject of a report prepared by the former Department of Land and Water Conservation (DLWC, formerly the department of Conservation and Land Management, CaLM). This report also concluded that the roads were the principal source of sediment loss on the Island and that remedial measures were required to stabilise the degraded surfaces in the long term.

The road and access network is required to implement the wastewater treatment options. Therefore, to both reduce present erosion and minimise potential damage due to implementation of one or more of the treatment and disposal options erosion control measures initially need to be focused on access routes.

Climatic factors play a major role in the initiation of erosion. However, rainfall intensity and frequency are essentially non-predictable elements. Therefore, to minimise risk, erosion and sediment control measures need to be implemented prior to the start of construction work and be designed to address local climatic and geomorphologic conditions.

Reticulated options have the potential to create a relatively large scale disturbance due to clearing, trenching and general construction activity that may be exposed to worst climatic conditions. In contrast, the potential erosion risk due to implementation of on-site options is considered to be less than that from an extensive trenching and pipe laying operation required by reticulated options.

In the case of reticulated wastewater options, trench dimensions, and therefore the volumes of material excavated or imported to the Island are specific to each of the available options except the no change option. This is due to the differing engineering requirements for laying various types of pipes. Trenching frequently requires disturbance to a minimum of 1m either side of the trench. Therefore, it is considered reasonable to estimate the surface area of disturbance as being the length of trench proposed multiplied by 2.0m width. The depth of trenching may also vary from 0.5m for small connecting pipes to greater than 2m for the mains pipeline. Where mains sewerage lines are constructed inspection ports are also required and these may require larger localised excavations.

Implementation of on-site options may still cause significant environmental impact over the medium term if appropriate environmental guidelines are not followed and may continue if not managed properly.

Implementation of any of the reticulated options will involve significant construction activity on the Island. Sediment trapping devices need to be implemented around construction sites to controlling soil from transport away from construction sites into adjacent waterways. Guidelines for the construction of these sediment trapping devices are available from the Local Council or Department of Land and Water Conservation.

Terrene Research
1/1 Gray St Kogarah NSW 2217
Ph: 02 588 4682
Fax: 02 553 7579
Email: On request

4.6 Impact of Imported Materials

The volume and type of material brought onto the island varies greatly with the option chosen. Reticulated options require trench excavation and pipe laying operations. Where excavation occurs backfill material will be specified by engineers to ensure stability and drainage. The volume of material imported to replace excavated waste material can be significant. For example, manhole construction can require over $20m^3$ of excavations each.

Waste material may have a long-term impact if stored on the Island for the long term. Flat ground is preferred for stockpile areas to minimise the risk of down-slope migration of run-off transported sediment and other pollutants such as fuel.

Oil and fuel stored should always be bunded to prevent discharge of this materials to the local waterways. Fuel storage is a potential fire hazard on the Island which is poorly equipped to deal with such an emergency. Therefore, adequate fire suppression equipment must accompany any fuel storage.

It is not possible to detail exactly the materials to be imported to the Island until a decision has been made as to which option will be adopted.

4.7 Labour Force Requirements

On-site options require less labour than does the construction of any of the reticulated options. Usually and on-site system may be installed and commissioned within a few days. Clearly the reticulated options will require a much larger work-force with a wide variety of trade and other skills. The increased labour force will require more construction infrastructure be temporarily established on the island to accommodate, materials and tools storage, site sheds, portable toilets, potable water supply, general waste disposal.

4.8 Maintenance

Formal monitoring of treatment system performance and maintenance schedules for on-site systems would require Council to implement an ongoing monitoring program. Public education as to the environmental implications of poor or non-existent maintenance of on-site effluent disposal systems may improve standards. However, over time this may need to be repeated to educate newly arrived residents and remind others of their responsibility to the local environment.

Implementation of a reticulated option removes the onus of maintenance from the Island population. The system would require employees to maintain and monitor the operation.

4.9 Noise Control Measures

Noise limits are set by the EPA. Noise assessment often requires that on-site measurements be made by consultants. Results are submitted to the EPA and / or Council for approval. The approvals cost increases with increasing dollar value of the proposed project.

4.10 Site Availability and Population Displaced

On-site options are unlikely to require the displacement of any of the Island residents. Construction of some of the reticulated options are also unlikely to require any acquisition of residential land (except those requiring a septage treatment plant or Memtec) provided that the majority of the common pipes are located within the bounds of existing service and access corridors.

4.11 Surface Area Requirements

New developments on the Island are required to make available an adequate area of land to satisfy AS1547 (1994 or newer) in regards to wastewater disposal. Where insufficient land is available to upgrade trench dimensions other solutions have been recommended to improve the quality of the effluent that is the disposed of in the trench or irrigation areas. These are primarily placement of additional filters to improve effluent quality prior to discharge to the disposal area and other methods of disinfection (eg. UV light). See the main report for further details.

4.12 Vehicular Disturbance

All the wastewater management options will lead to an increase in traffic on the island. The frequency and of disturbance and the type of vehicle both contribute to the potential for further degradation of the Islands already degraded unsealed roads. Reticulated options require heavy equipment be deployed on the Island, probably for months at a time as various stages of construction are completed. Though rubber tyred vehicles do less damage to the road surface some equipment will likely be tracked. Tracked vehicles have the most potential to degrade the road surface further. The frequency of disturbance during the implementation of the reticulated options will be far greater than that experienced by progressive upgrading of present systems accompanied by installation of AWTSs in new developments over the next decade or so.

4.13 Waste Disposal

Waste disposal during the implementation of reticulated options will require significant resources be concentrated on collection and removal from the Island of waste materials. It will be necessary to estimate the volume of waste materials exported from the Island during the environmental impact assessment process. Details of transport and disposal methods are also required.

On-site upgrades or new installations will create small volumes of waste material. It should be within the capability of contracted personnel to remove and dispose of waste material in a environmentally responsible manner. For example, recyclable materials should be delivered to the appropriate collection and re-distribution centre.

5. Conclusions

Implementation of one of the reticulated sewage options will be a large scale disturbance of relatively short duration (0.5 - 2 years). In contrast on-site options necessitate small scale disturbances over a relatively long period (10-15 years). Implementation of a reticulated option will require that the full EIA process be undertaken and an EIS be prepared.

The environmental impact of on-site options is assessed during the normal building and development application process. Disposal systems characteristics are directed by AS1547 (1994 or newer).

To reduce present erosion and minimise future erosion, the road network around Scotland Island requires remedial works.

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