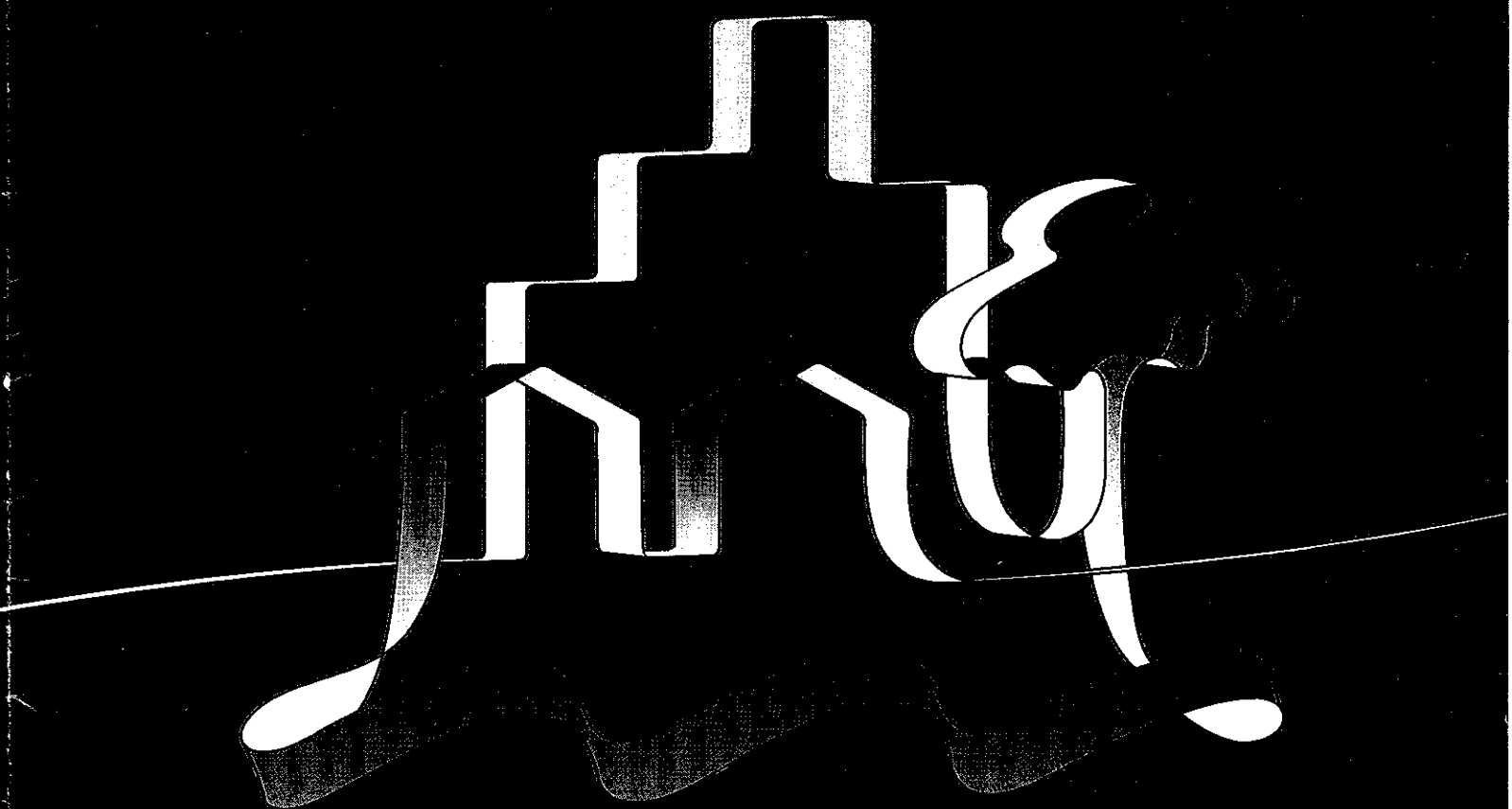
Urban Water Research Association of Australia

Model Guidelines for Planning Stormwater Drainage in Australia



Report No. 61

URBAN WATER RESEARCH ASSOCIATION OF AUSTRALIA (UWRAA)

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Urban Water Research Association of Australia

Model Guidelines for Domestic Greywater Reuse for Australia

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Brisbane City Council

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FOREWORD

This report is based on UWRAA Research Project WS-66 which was undertaken over the period June 1994 to December 1994. Organisational responsibility for the project was as follows:

Sponsoring Authority	:	Brisbane City Council
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The project was funded by the Urban Water Research Association of Australia.

These guidelines propose technical and administrative procedures for domestic greywater re-use in sewered areas. While the technical component of these guidelines apply in general in Australia, the administrative guidelines may vary between States and Territories, due to differing organisational structures.

Between the time of publishing of the second report, "Domestic Greywater Re-use: Overseas Practice and its Applicability to Australia", and this report, the review panel and the author have had further opportunity to refine this research, and address new issues not previously discussed. Appendix 6 discusses in brief these new issues.

SYNOPSIS

This report is the third in a three part research project. Its purpose is to achieve the projects final goal of formulating model guidelines for the regulation of greywater re-use systems in Australia; that is, those systems which re-use domestic greywater from sewered premises. Domestic greywater is defined as that which is derived from a non-industrial source.

The first part, *"Domestic Greywater Re-use: The Preliminary Evaluation (UWRAA Research Report No 60, 1993)"*, was completed in 1993. It included:

- overseas correspondence
- a literature search
- chemical and microbial analysis of some sullage systems

The report concluded that:

- the western states of the USA and Japan are the world leaders in this type of onsite re-use

- greywater re-use poses environmental and health concerns but, with adequate guidelines, could achieve substantial water savings.

The second part, *"Domestic Greywater Re-use: Overseas Practice and its Applicability to Australia (UWRAA Research Report No 73, March 1994)"*, was completed in 1994. This report investigated overseas practices in greywater re-use and how this could be applied to Australia.

It is intended that this report, "Domestic Greywater Re-use: Model Guidelines", will assist Australian water and regulating authorities in meeting the challenge to fully utilise this valuable resource without:

- Compromising public health,

- causing detrimental impact to the environment or

- down grading the livability of our residential areas.

Background

The segregation of domestic wastewater at the source into two separate streams gives:

- ***Blackwater*** - water closet, bidet and bidette waste; has gross faecal contamination
- ***Greywater*** (also referred to as sullage) - all remaining household wastewater; for example, bath, laundry; and by definition is not faecal contaminated.

The preliminary evaluation undertaken as part of this project found that the above definition is not a reliable one. Greywater contains human faecal indicator bacteria in concentrations high enough to indicate a health risk from the potential presence of pathogenic micro organisms. A level of caution should be exercised with greywater re-use due to associated health risks. Overseas authorities have confirmed this conclusion.

Treatment vs Separation of the Risk

For safe re-use, either of the following must occur:

- greywater must be treated to remove or destroy these micro organisms
- human contact with greywater must be prevented.

Treatment of greywater to make it safe for human contact is expensive to achieve on an individual household basis. It is also difficult to ensure that treatment systems are maintained. Surveys in the USA and Australia have found that 60% to 80% of "onsite domestic wastewater treatment plants" are not maintained adequately, nor do they consistently produce an acceptable quality effluent.

The safest method of greywater re-use is one that excludes human contact with greywater (UWRAA Research Report No 73). The 22 western states of the USA have firmly adopted this principle in allowing domestic greywater re-use as part of their uniform plumbing code.

For lawn and garden watering, separation of greywater from human contact may be achieved by the following:

- sub-surface irrigation (greywater does not reach the ground surface)
- surface irrigation confined to non habitable dedicated areas (greywater does not form aerosols or surface runoff).

Surface re-use

Surface disposal methods and poor irrigation practices promote ponding which can provide an ideal habitat for breeding of mosquitos. Surface disposal methods promote runoff after heavy rain or from excessive irrigation. This does pose concerns for public health and the environmental impact that nutrients, other chemicals and pathogens could have if washed into waterways.

The surface spraying of greywater has the risk of transmitting disease directly by either inhalation of aerosols, indirectly by contact with spray residues and or by surface runoff.

Aerosols are defined as particles ranging from 0.01 to 50 um in diameter that are suspended in air. Viruses and most pathogenic bacteria are of respirable size. Studies have shown that under optimum conditions high concentrations of coliform bacteria travelled 90 - 130 metres with a wind velocity of 1.5 m/s (Crook, 1985).

As previously discussed, greywater has the potential to contain significant levels of pathogenic contamination. Over 120 possible distinct pathogenic viruses may be found in wastewater because of human secretions. These same diseases may be found in greywater. Those of greater concern cause gastrointestinal illness and are known as enteric viruses.

There can be many potential causes of a particular illness and it can be difficult, if not impossible, to be certain of the cause. The fact that no health incidents have been directly attributed to existing sullage systems does not indicate that these systems have not caused illness. This may only indicate poor recording practice or lack of any such practice at all.

Sub surface Re-use

Sub surface drip irrigation of greywater is arguably the safest, most efficient method of lawn and garden watering when applied in a zone 200 mm to 300 mm below the surface.

Studies by the University of California into irrigation methods, conclude that sub surface drip irrigation can be up to 60% more efficient than conventional surface spray. This is partly because 70% of a plants water and nutrition uptake occurs in the upper 50% of the root zone. For most plants this is in the top 300 to 600 mm of soil. A drip system can apply the nutrient rich greywater directly to this root zone.

If greywater is applied in the top 300 mm of soil, pathogens are less likely to survive than with surface application. This upper level of the soil is the most aerobic and has the highest level of natural microbial activity. Pathogens would be subject to the predatory activities of the micro flora, a hostile environment and filtration through the soil structure.

Storage

Storage of greywater promotes the generation of offensive odours, and the growth of micro-organisms, including faecal coliforms. Direct re-use without storage minimises the micro-organism growth, offensive odours, and the health risk with contact.

Allowing storage may in fact promote over watering of the landscape and the associated problems with this poor practice. Short term storage may be necessary when filtration systems (eg. sand, membrane etc) are used. And then only if odours are controlled.

Chemical Content

Greywater contains chemical pollutants that primarily come from household detergents and cleansers. These can be a source of sodium, boron, phosphate, chlorine and other chemicals.

Greywater can be both nutrient rich, and alkaline, and garden application may not suit all plants. Some Australian natives in particular do not tolerate these conditions (refer Appendix 6).

Greywater can have a high sodium content and when applied excessively to clay soils will damage the soil structure resulting in reduced drainage capabilities. Sodium also alters the osmotic concentration relationship between the plant and the soil, reducing the plant's ability to take up water.

Sewered premises will generally have insufficient landscape area available to daily re-use all of the greywater produced. Where this occurs the bathroom/ensuite should be the preferred re-use source as the wastewater has a lower chemical loading than laundry wastewater. The potentially higher micro biological loading of the bathroom/ensuite can be managed by re-use through sub surface irrigation practices.

Hand Basin Toilets

Based on the extent of use of hand basin toilets in Japan, it is expected that Hand Basin Toilets do not pose the same microbial health concerns as greywater flushed toilets. It is assumed that pollutants transferred to a cistern after hand washing would be minimal, and any health risks would be of no greater level than those of existing toilet levels. Further research is required to confirm this assumption.

Toilet Flushing

The preliminary evaluation wrongly concluded that greywater re-use for toilet flushing did not require treatment other than disinfection and coarse screening. Toilet and urinal flushing water cannot be totally separated from human contact. Health risks do exist with the potential for splashing of flush water onto the genitals and from aerosols formed during flushing. These concerns are accentuated by the inadequacies of poorly maintained onsite domestic treatment systems, and the potential for growth of micro organisms with storage in the supply reservoir, the toilet cistern, and the pan water seal. A higher degree of treatment than simple screening and contact disinfection is necessary to achieve pathogen free greywater for this application. Findings from the trials by the Northern Territory Power and Water Authority, using this type of system, have reinforced all of these concerns (Guy,1995).
Further research is required, but simple solutions appear unlikely.

For these reasons, greywater used as a toilet flushing medium was specifically not included in the USA Uniform Plumbing Code guidelines.

Current Legal Aspect

The disposal of domestic wastewater in all Australian States is governed by Acts; for example, Health, Building, Environmental Protection, Clean Waters and Plumbing and Drainage. In non sewered areas the regulatory authority determines the requirements for the disposal of domestic sullage. Generally this is in accordance with Australian Standard AS 1547-94 Disposal systems for effluent from domestic premises. In sewered areas all states have similar legislation that requires discharge of all wastewater to the sewer, with allowance for exemption to the satisfaction of the regulatory authority.

For the legal application of on-site domestic greywater re-use for lawn and garden watering to occur in sewered areas, state legislation must first be amended.

Conclusion

This report proposes model guidelines should the re-use of domestic greywater become legal.

However, caution must be exercised when introducing greywater re-use because of the undefined increase in risk to public health and the environment.

We live in a society that has a relatively healthy population with little natural resistance to most water, mosquito and vermin borne diseases. The sanitary sewer has been one of the fundamental measures which has improved health in the developed world and any change from the current status must be such as to not compromise the gains in population health which have been achieved.

Infectious disease epidemics can occur once disease is introduced to the non resistant population and has a mode of transmission. Any decision to change the present sanitary practices needs to be seriously considered.

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1 INTRODUCTION

1.1 Scope

These guidelines set out the requirements for the design and installation of Domestic Greywater Re-use Systems for sewered premises and apply to new installations as well as alterations, additions and repairs to existing installations. Except as otherwise provided for in these guidelines the provisions of the National Plumbing and Drainage Code AS 3500-1990 apply.

The following systems of re-use are covered in these guidelines:

(a) Hand Basin toilets - these incorporate a hand basin in the top of the cistern with a spout for hand washing which operates automatically when the toilet flushes, simultaneously refilling the cistern while allowing for hand washing.

(b) Primary Greywater Systems.(PGS) - these directly re-use untreated domestic greywater from a single family home for sub-surface lawn and ornamental garden watering. These systems do not allow storage or treatment, apart from a coarse screen filter which removes lint, hair and coarse particles. To prevent human contact with untreated greywater, the following sub-surface watering techniques are specified as the only recommended method of re-use:

- sub-surface drip irrigation
- sub-surface trickle irrigation.

(c) Secondary Greywater Systems (SGS) - these are any system that re-use domestic greywater that can not be caterogised as either Hand Basin Toilets or Primary Greywater Systems (PGS). Secondary greywater systems may be used for multiple occupancy dwellings. Short term storage to facilitate filtration prior to drip irrigation is acceptable were the stored greywater does not present a health risk or cause nuisance. The method of re-use is for the purposes of lawn and ornamental garden watering using sub-surface watering techniques as specified for primary greywater re-use systems.

1.2 Purpose

This document provides model guidelines for the use of domestic greywater in sewered areas. The focus of the document is the facilitating of on-site wastewater re-use without the compromising of public health, and the environment, both now and in the future.

1.3 Application

These guidelines apply to domestic sewered sites only and should be read in conjunction with the By-Laws and Regulations of the relevant Regulatory and/or Administrative Authority.

1.4 Definition

Domestic Greywater is untreated household sewage which has not come into contact with toilet waste. It includes wastewater from bathtubs, showers, bathroom wash basins, clothes washing machines and laundry tubs. For the purposes of these guidelines, greywater does not include wastewater from kitchen sinks, dishwashers, garbage disposal units, laundry water from soiled nappies or wash water from the bathing of domestic animals.

1.5 Objectives

The objectives of these guidelines is to:

- safeguard the population from diseases that could be attributed to the operation of greywater re-use installations,
- ensure that installations do not harm the environment or cause public nuisance, are appropriate to the site and are maintained to a specified standard,
- apply greywater in a cost and water efficient manner for specific sites.

1.6 Functional Requirements

The functional requirements of these guidelines for domestic greywater re-use systems is to:

- ensure that greywater re-use practices do not create a mode of transmission for disease, both now and in the future. Systems must be designed and operated in a manner that excludes human contact with domestic greywater,
- be designed to minimise the potential for the growth of micro organisms in stored greywater by using only direct re-use methods,
- avoid the likelihood of blockages in irrigation pipework caused by the accumulation of oils, grease, bacterial slime etc by using pressurised systems,
- encourage the application of greywater to the landscape to occur on a needs basis only, by ensuring that the re-use can only occur through active daily participation of the owner/operator,
- have operation and routine service requirements that are user friendly,
- be designed in such a manner that inadequately serviced systems will not compromise public health or the environment,
- be designed and operated such that the system as a whole does not provide a breeding habitat for mosquitoes, other vectors, or be a transmission point for disease,
- re-use domestic greywater for lawn and ornamental garden watering purposes only,

- apply greywater directly into the aerobic zone of the soil where the uptake of water by plants is at its most efficient,

- ensure that by-products of greywater systems be disposed of in hygienic manner which is not detrimental to the environment or the sewer system,

- ensure that the re-use of greywater is maintained within the boundary of the property from which it is produced.

1.7 Performance Requirements

A Domestic greywater Re-use System is to be constructed, operated, and maintained to:

- convey greywater from the building to the appropriate re-use point,

- prevent the likelihood of blockage, leakage, or overflow,

- be provided with access points for maintenance and clearing of any blockages,

- be ventilated to avoid the likelihood of foul air and gases accumulating in the sanitary drainage and greywater installation,

- prevent the likelihood of such greywater, air and gases entering buildings or causing nuisance,

- prevent the likelihood of continuous application of greywater to the landscape regardless of vegetation needs or ambient climatic conditions,

- prevent the likelihood of any contamination of potable water supplies or storages,

- prevent detrimental impacts on the environment,

- prevent the likelihood of the discharged greywater in an irrigation area causing offensive odours and nuisance,

- prevent the surfacing of greywater after it has been applied to the lawn and/or garden, through inappropriate soil loading or the affects of wet weather,

- prevent it being a means for stormwater entering the sewer system.

1.8 Health and Safety Requirements

Domestic greywater can contain pathogenic micro organisms. It may represent a health risk if these organisms are transmitted to susceptible hosts. To minimise this risk the following requirements apply:

- All gross faecally contaminated waste must be connected to the Authority's Sanitary Sewer System,
- installation of anti backflow devices on the potable water service to the property at the boundary and on all external potable water taps and hose points within the property as per AS 3500 National Plumbing and Drainage Code,
- where potable water is used as a supplement into greywater vessels, air gaps should be provided (as per AS 3500 - "National Plumbing and Drainage Code"). An overflow to sewer must be incorporated into greywater vessels to ensure the integrity of the air gap,
- colour coding and labelling of pipe work, valves and fittings to identify the contents (as per AS 1345 - "Identification of the Contents of Piping, Conduits and Ducts"),
- maintain the operating pressure of the greywater irrigation system at pressures less than that of the potable water service to the property,
- greywater should not be contacted by humans, except as required to maintain the greywater system,
- greywater should not include laundry water that has likely gross faecal contamination (eg soiled nappies),
- greywater should not include any wastewater resulting from the bathing of animals (eg family pets),
- greywater should not be applied above the land surface or allowed to reach the land surface, and should not be discharged directly into or reach any stormwater drainage system, waterway or contaminate any domestic water supply,
- greywater should not be re-used for watering edible plants and vegetables gardens. Fruit crops that do not make contact with the ground are suitable for watering with greywater,
- within or adjacent to each sub surface irrigation area there shall be a sign advising that reclaimed effluent or greywater is being used for irrigation. The sign shall be on a white background with red lettering at least 20mm high (in accordance with AS 1319, Safety Signs for the Occupational Environment).

The sign shall state:

RECYCLED WATER OR GREYWATER
IRRIGATION AREA
DO NOT DRINK, AVOID CONTACT

The warning sign must be completed prior to the commencement of use of the system.

1.9 Restrictions

The following restrictions apply in the application of greywater:

1.9.1 Re-use of greywater for the purposes of toilet flushing is not permitted as part of these guidelines because of the risk of human contact (from splashing and aerosols) and the unreliability of household treatment. Hand basin toilets are not included as part of this restriction (refer Section 2).

1.9.2 Re-use methods that apply greywater above the ground surface are not permitted as part of these guidelines because of the risk of human contact, and the likelihood of creation of aerosols, ponding and surface runoff.

1.9.3 Sub surface systems where absorption trenches are the primary end use are precluded. Absorption is a waste water "disposal" method that does not meet the "re-use" objectives of these guidelines.

1.9.4 Evapotranspiration trench methods have not been included as the minimum re-use area required (as per AS 1547) is beyond the capacity of most sewered sites.

1.9.5 The use of stored rainwater and swimming pool/spa overflow and filter backwash water as supplementary sources to greywater re-use systems is precluded unless the following can be demonstrated to the Administrative Authority:

(a) There is no potential for cross contamination of stored rainwater supplies, swimming pool or spa waters from the greywater re-use system,

(b) there is no potential for cross connection of stormwater, pool and spa water or like, to overflow into the sanitary sewer system,

(c) the re-use area is suitably designed to receive any additional loadings,

(d) alternate water supplements to the greywater re-use system do not occur in wet weather,

(e) contaminates from these sources do not have a detrimental impact on the function, operation, and performance of the greywater system.

2. HAND BASIN TOILETS

2.1 General

Hand basin toilets incorporate a hand basin in the top of the cistern with a spout for hand washing which operates automatically with the toilet flushing to simultaneously refill the cistern while allowing for hand washing.

Hand basin toilets pose no increased microbial health concerns from the direct re-use of wastewater for toilet flushing above that of existing standard cistern (refer Appendix 3).

2.2 Design and Installation requirements

The cistern design must comply with AS3500 - 1992 National Plumbing and Drainage Code and the Cisterns and Pans Standard. Installation requirements must comply with AS3500.

2.3 System Management, Responsibilities and Monitoring

Hand basin toilets do not require installation permits. As a new plumbing product, without an Australian Standard, the manufacture does require authorisation for use of their product from the relative Regulatory Authority at level 4, or through a specification in SAA MP52-1993, (Manual of Authorisation of Procedures for Plumbing and Drainage Products).

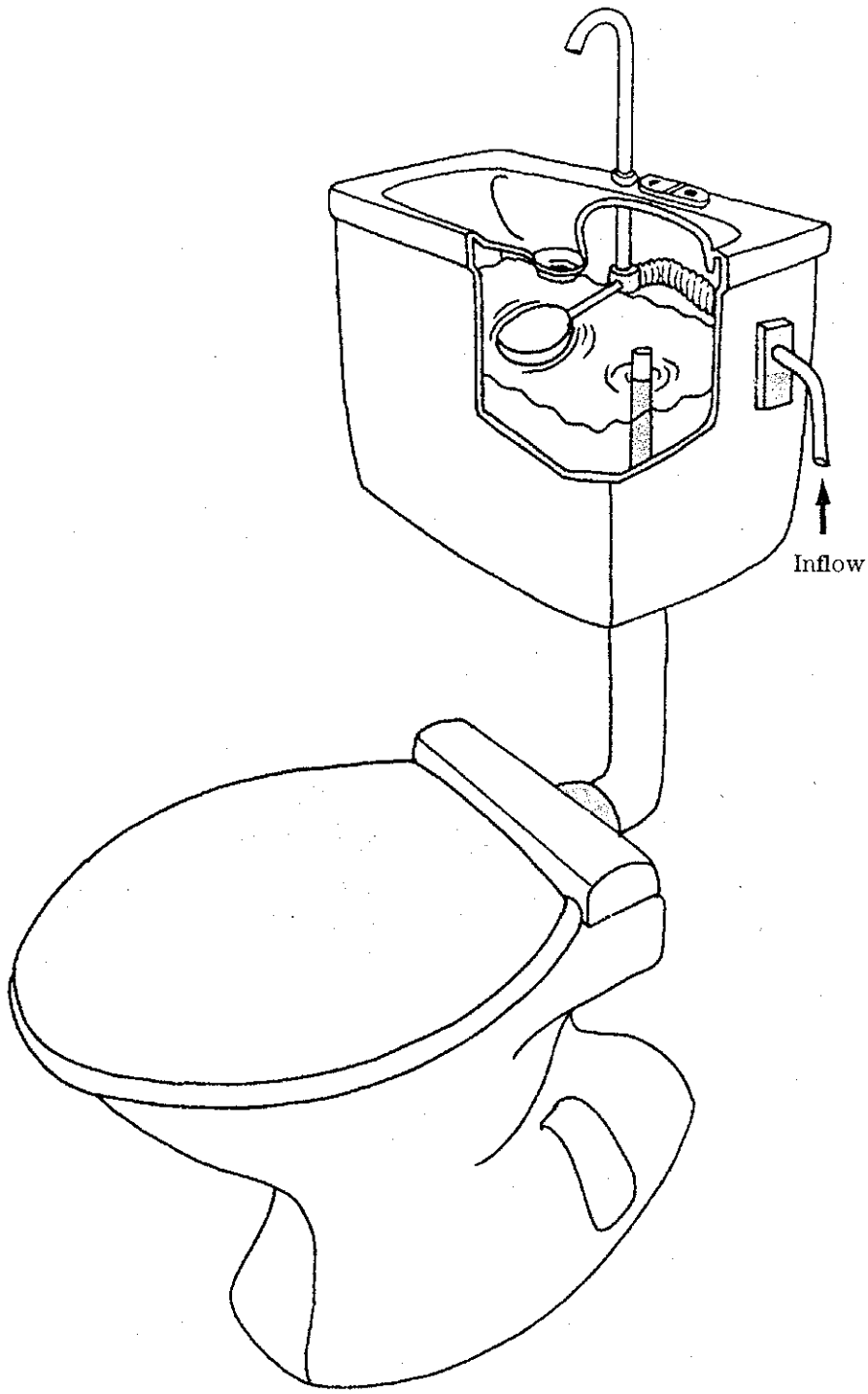


Figure 2.1 - Cross-section of a Hand Basin Toilet

3. GUIDELINES FOR PRIMARY GREYWATER RE-USE SYSTEMS - by permit

3.1 General

Primary Greywater Re-use System installations, including the effluent re-use areas, must comply with the Regulatory Authorities guidelines before final approval will be given.

3.2 Definition

Primary Greywater Systems (PGS) directly re-use untreated domestic greywater (sourced from the bathroom and/or laundry fixtures only) from the single family home for sub-surface lawn and ornamental garden watering. These systems do not allow storage or treatment, apart from the use of coarse screen filters to remove lint, hair and coarse particles.

3.3 Methods of re-use

The following sub-surface watering techniques are specified as the only permissible methods of re-use:

- sub-surface drip irrigation
- sub-surface trickle irrigation.

These watering techniques can be applied to habitable lawn and garden areas. Where there is insufficient irrigation area to utilise the design total daily greywater flow produced from a dwelling, the bathroom/ensuite is the preferred greywater source for re-use (refer 3.6.2).

3.4 Responsibilities

3.4.1 The owner shall be responsible to ensure that the installation complies with the following:

- All relevant Acts and by laws of the local Administrative Authority,
- Administrative Authority permit conditions,
- these guidelines.

3.4.2 The design configuration of the system shall be determined on the basis of location, soil type, impact on sub surface potable water supplies and ground water level, and shall be designed to accept all greywater connected to the system from the residential building. The system shall discharge into sub surface irrigation fields and may include surge tank(s) and appurtenances, as required by the Administrative Authority. Relevant Standards (such as the Australian Standard AS 1547-1994, Disposal of Sullage and Septic Tank Effluent from Domestic Premises) should be used for this assessment.

3.4.3 A greywater system, or part thereof, shall not be located on any parcel of land other than that on which is located the building or structure which discharges the greywater; nor shall any greywater system or part thereof be located at any point having less than the minimum distances indicated in Table 3.2.

3.4.4 No permit for any greywater system shall be issued until a site plan with appropriate information satisfactory to the Administrative Authority has been submitted and approved. When there is insufficient property area, or inappropriate soil conditions for adequate absorption of the greywater, as determined by the Administrative Authority, no greywater system shall be permitted.

3.4.5 No permit shall be issued for greywater system which would adversely impact on environmentally sensitive areas as determined by the Administrative Authority.

3.4.6 The owner/operator of a greywater re-use system must ensure that any by-products are disposed of in accordance with the guidelines approved by the Authority.

3.4.7 The irrigation system shall be constructed and operated in such a manner that ensures that greywater does not surface or pond in dry or weather periods.

3.4.8 Greywater re-use areas are to be completely prepared or landscaped and the irrigation system fully installed to the satisfaction of the Administrative Authority prior to commissioning of the system.

3.4.9 The Greywater Re-use area/system shall be sited so, as to be unaffected by surface and rain water run-off.

3.4.10 Installers of greywater systems shall provide an operation and maintenance manual, acceptable to the Administrative Authority, to the owner of each system.

3.4.11 The Administrative Authority shall provide the applicant with a copy of appropriate guidelines as part of the permit,

3.4.12 Certain installations or portions of installations that are unusual, due to particular circumstances or construction methods, may not be covered in detail, or be permitted by these guidelines. Details of such proposed installations shall be submitted to the relevant authority, which, having regard to the circumstances, may authorise the installation.

3.5 Management and Monitoring

3.5.1 New Installations

An application for a permit to install an onsite domestic greywater re-use system shall include:

- complete installation, design and system layout (plan position and levels), including house drainage,
- calculations showing the site can support the installation proposed,
- copies of site plans, to scale, shall be provided with the application. The plans shall indicate:
  - soil classification and depth,
  - existing structures.
  - any retaining and filling,
  - site slopes,
  - location of domestic water sources (underground, surface or piped),
  - position of irrigation lines,
  - depth to water table at location of disposal unit or area,
  - irrigation equipment details,
  - methods to prevent rainfall run-off entering the disposal area,
  - dimensions from boundaries, buildings, water sources and gullies and domestic water sources in adjoining properties,
  - any other relevant information required by the Authority.

3.5.2 Permit

Following approval of the application, installation may proceed when the final inspection is complete. A compliance permit will then be issued to the property owner.

The renewal of the permit shall be subject to a performance inspection by the regulatory authority. Failure to operate and maintain the greywater system in a manner deemed acceptable by the Administrative Authority could result in either rectification of the problem by the Authority at the owners expense, or

in the revoking or non renewal of the permit to operate.

No permit shall be issued where there is:-

(a) insufficient property area

(b) inappropriate soil conditions

(c) the property is in a geologically, or environmentally sensitive area as determined by the Authority

As knowledge of the performance of different systems improves, conditions of the permit may be revised. These new conditions will be advised at the time of the annual permit review.

3.5.3 Change of ownership

The existence of the greywater re-use system will be noted on the Administrative Authority's records and this information together with any special permit conditions will be provided during any subsequent conveyance property search.

When a property changes title the permit will not automatically be transferred to the new property owners. The new owners are required to apply for a permit and when doing so demonstrate to the Authority the following:

- they are conversant with their responsibilities as a greywater system owner,
- they are familiar with the function, operation and maintenance requirements of their greywater system,
- that greywater is raw sewage and good hygiene practice must be applied after any contact.

3.5.4 Installation

Installation of greywater systems may be performed by unskilled persons up to, but not including, the connection of the system with the house drain. The connection to the drain can only be performed by an authorised or licensed person after said person has certified to the Authority that the system has been inspected, tested and complies with the relevant requirements of the Authority, AS 3500, AS 1547, and these guidelines.

3.5.5 Inspection

(a) All applicable provisions of these Guidelines, AS 3500 and AS 1547 shall be complied with.

(b) The manufacture shall be clearly identified on all system components.

(c) Surge tanks shall be installed on dry, level, well-compacted soil, or on a level, 75 mm thick concrete slab or equivalent, if above ground.

(d) Above ground surge tanks shall be anchored against overturning.

(e) If the irrigation design is based on soil tests, the irrigation fields shall be installed at the same location and depth as the tested area.

(f) Installation shall conform with the equipment and installation methods identified in the approved plans.

3.5.6 Testing

(a) Surge tanks shall be filled with water to the overflow line prior to and during inspection. All seams and joints shall be left exposed and the tank shall remain watertight.

(b) A flow test shall be performed through the system to the point of greywater irrigation. All lines and components shall be watertight.

3.6 System Design

3.6.1 Procedure for Estimating Greywater Discharge

The Authority may utilise the greywater discharge procedure listed below in table 3.1, water use records, or calculations of local daily per person interior water use as follows:-

(a) Number of occupants

The number of occupants for each dwelling shall be calculated as follows:

- First Bedroom 2 Person
- Each additional bedroom 1 Person

The minimum design occupancy per dwelling is 5 persons.

(b) Design Flows

The minimum design greywater flow for each person shall be calculated as follows:

- Bathroom 100 Litres/person/day
- Laundry 60 Litres/person/day
- Total 160 Litres/person/day

The design flow is calculated by multiplying the total number of occupants by the applicable estimated greywater flow of fixtures connected to the greywater system.

Alternately Table 3.1 shows design flows calculated for various home design configurations. In this table, design flows for ensuites have been calculated with only the master bedroom connected. Where multiple bedrooms are connected the flow design should be amended accordingly.

TABLE 3.1
MINIMUM DESIGN FLOWS
FOR
GREYWATER RE-USE SYSTEMS

Total No Bedrooms in Dwelling	One Bathroom Only L/day	Each Laundry L/day	Ensuite only L/day	Each Additional Bathroom L/day	Total Flow L/day
1 to 4	500	300	200	300	800
5	600	360	200	400	960
6	700	420	200	400	1120

3.6.2 Location

Greywater re-use areas shall be located in a position such that the following occurs:

(a) where practical , they are exposed to the prevailing wind and not shaded from the sunlight;

(b) they comply with the requirement of the relevant authority with respect to the following:

- areas subject to inundation, flooding or high watertable; and
- distance from any canal, dam, watercourse or potable underground water.

(c) they maintain not less than the minimum horizontal clearances as specified in table 3.2.

(d) the slope of the irrigation zone is not greater than 5 degrees from horizontal. Where this does occur terracing of the incline is required.

TABLE 3.2
SITE CLEARANCES FOR GREYWATER SYSTEMS

Minimum Horizontal Clearances (metres)	Surge Tank	Re-use Area
Any buildings or structures.	2	2
Property Alignment when located higher than re-use system. Submersible distribution pump only.	2	2
Property Alignment when located lower than re-use system. Submersible distribution pump only.	2	4
Property alignment when non submersible distribution pump is used	4	as above
Adjoining re-use areas and concreted or paved areas.	1	1.5
Edge of swimming pool, spas and like	3	6
Potable water lines (both private services and public reticulation lines).	3	6

3.6.3 Permeability of Soil

The soil permeability is to be determined in accordance with the requirements of AS 1547 - 1994, Disposal of Sullage and Septic Tank Effluent from Domestic Premises, by either of the following methods:

(a) Percolation test

(b) Texture classification of soil

3.6.4 Site Evaluation

Approval of a site for suitability to install and operate a domestic greywater re-use system must be determined by the Administrative Authority. Local knowledge of site conditions, and environmental considerations are necessary in evaluating each site for the greywater system proposed. Australian Standard AS 1547 "Disposal Systems for Effluent from Domestic Premises" provides suitable guidelines for assessing each site. These include:

- depth and permeability of the soil,
- the risk of prejudicing adjoining property, underground water supplies and or swimming and wading pools and the like, by seepage or run-off from the site.
- any seasonal changes in ground water level and absorptive capacity of the site,
- the general climate and its effect on the evaporation or transpiration from the site; for example seasonal distribution of rainfall, hours of sunshine, prevalence of wind,
- the effect of seepage and surface water from surrounding areas at higher levels than the proposed disposal area.

3.6.5 Procedure for Sizing of Re-use area

Where there is insufficient irrigation area to utilise the design total daily greywater flow produced from a dwelling the bathroom and or ensuite are the preferred single sources of re-use (refer 3.6.2).

Each irrigation area shall have a minimum effective irrigation area for the type of soil and infiltration rate to distribute the daily volume of greywater produced.

The irrigation area is to be calculated in accordance with Australian Standard AS 1547-1994 Disposal Systems for Effluent from Domestic Premises, Section 3.6 (c), Sizing of a disposal area, Irrigation area. Table 3.4 of these guidelines is based on this standard with no allowance for kitchen wastewater.

The required irrigation area shall be based on the estimated greywater volumes, as detailed in section 3.3.2 of these guidelines.

TABLE 3.4
SIZING OF DRIP IRRIGATION DISPOSAL AREA

SOIL TYPE	MINIMUM AREA M2 FOR DRIP/TRICKLE IRRIGATION METHODS PER ZONE						
	DESIGN AREA per PERSON (m2)	ALL FIXTURES CONNECTED		MULTIPLE BATHROOMS		SINGLE BATHROOM (minimum of 5 persons. Add 20% for each additional person.)	LAUNDRY ONLY (minimum of 5 persons. Add 20% for each additional person.)
		2-4 BEDROOM (5 person minimum)	For Each Additional Room Add	ENSUITE (maximum of 2 persons)	Each additional Bathroom (minimum of 3 persons. Add 33% for each additional person.)		
Silty Clay	62	310	62	78	117	195	115
Clay	45	225	45	56	84	140	85
Clay Loam	36	180	36	45	68	113	67
Loam	28	140	28	35	53	88	52
Sandy Loam	20	100	20	25	38	63	37
Sand	15	75	15	19	29	48	27

Source: AS 1547-1994; UWRAA report no 73/ 1994.

3.6.6 Classification of soils

Soils shall be classified in accordance with AS 1726 Geotechnical Site Investigations.

3.6.7 Surge Tank Construction

A surge tank is required to be installed between the plumbing fixtures sourcing the greywater and the re-use area on all greywater re-use systems. The surge tank must incorporate the following:

(a) Design Capacity.

The capacity of the Surge tank shall not contain a surge volume greater than 80 litres.

(b) Overflow drain to sewer.

An overflow drain shall be provided at top water level of the surge tank, connecting to the private drain. The overflow and private drain shall have a permanent connection to the sanitary sewer.

The invert level of the overflow where it connects to the surge tank, must be constructed at an operating level below that of the overflow relief gully that services the upstream private drains connected to the surge tank. The invert level of the overflow must also be positioned so that the surge tank has a maximum operating capacity of 80 litres.

The overflow shall be of a diameter not less than the inlet pipe diameter, and be laid at not less than minimum grade falling directly to the house drain. The overflow shall not be fitted with any isolating device other than a reflux valve to prevent backflow from the private drain.

(c) Scour.

A scour line shall be provided from the invert of the surge tank to the house drain. The scour shall be of a diameter not less than the inlet pipe diameter. The scour drain shall be laid at not less than minimum grade falling to the house drain. The scour line shall be fitted with an authorised isolating valve.

(d) Venting

The surge tank and associated drainage pipe work shall be vented. Vents shall be constructed as per AS 3500 National Plumbing and Drainage Code.

(e) Pumped discharge systems

The surge tank shall be provided with an electrically driven pump or equivalent, approved by the regulatory authority. The pump shall be fitted with an automatic on/off function eg. float switch or electrodes. The pump shall automatically operate when flow enters the surge tank.

There is to be no retained greywater in the surge tank between operations other than what is deemed impractical to be removed. The pump outlet shall be fitted with an authorised non-return valve.

(g) Hopper floor

The floor of the collection well shall be graded in a hopper-like arrangement to direct all settleable solids to the scour outlet.

(h) Construction

The materials used and the construction of the surge tank shall be in accordance with the relevant requirements for small septic tanks in AS 1546 Small Septic Tanks or as approved by the authority.

(i) Access Openings

All surge tanks shall be provided with access openings fitted with a locking gasket cover, or approved equivalent, to allow for inspection and cleaning, and to prevent entry by of mosquitoes, flies and vermin. Access opening covers must be child proof.

Covers should be designed in accordance with AS 1546 (Small septic tanks). Where the capacity of the surge tank is smaller than the minimum size as specified under AS 1546 , access opening requirements are to be determined by the authority.

(j) Warning Signs

"GREYWATER IRRIGATION SYSTEM, DANGER - UNSAFE WATER" shall be permanently marked on the surge tank in a visible location. The warning sign shall meet the minimum size and colour requirements as specified by AS 1319, Safety Signs for the Occupational Environment. In addition the symbolic (pictorial) safety sign for "not drinking water" shall be clearly marked as per the requirements of AS 1319.

(k) Screens

A coarse screen for the removal of lint and hair is to be fitted to the inlet of the surge tank supply pipe. Minimum 140 mesh size (115 micron), is to be fitted . The screen is to be installed in a chamber that fully drains to the house drain. Storage or ponding of greywater is not to occur. Should blockage of the coarse screen occur flow is to automatically divert to the house drain. The screen is to be readily accessible and removable for cleaning purposes.

(l) Active/Passive Valve

An Active/Passive valve of not less than 50 mm diameter is to be fitted to the inlet of the greywater supply pipe to the surge tank. The active/passive valve is a solenoid operated ball or gate valve that is to be directly wired to a timer operated on/off switch which in turn is directly wired into the power supply. No power points are to be used and there is to be no capacity to by-pass the timer operated on/off switch to allow operation of the active/passive valve. The timer shall not have greater than a 12 hour operating span before it returns the valve to the passive position. After which manual resetting of the timer is necessary.

The valve in the passive (normally closed) position shall direct all greywater flow to the sanitary sewer, by-passing the greywater re-use system.

When the switch is manually activated the valve will open into the active mode diverting greywater to the surge tank. After the expiring of the set time span the timer operated switch automatically returns the valve to the passive mode.

3.6.8 Plumbing and Drainage

(a) Overflow Relief Gullies

Private drains discharging into the surge tank of a greywater re-use system must be served by an overflow relief gully constructed in accordance with AS 3500. The operating level of the relief gully should be not less than 100 mm higher than operating level for the surge tank's overflow to sewer.

(b) Vent Cowls

Vent cowls shall be suitably screened to prevent entry by mosquitoes, flies and vermin.

(c) Pipe and valve markings

All pipe work shall be suitably identifiable as per AS 1345 Identification of Piping Conducts and Ducts. Plumbing shall be marked or shall have a continuous tape marked with the words "DANGER - UNSAFE WATER".

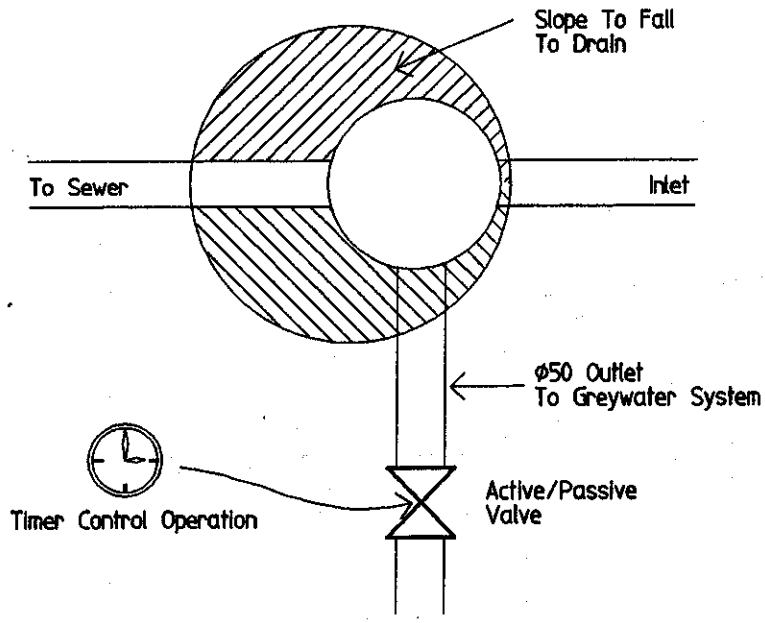
(d) Valves

All valves shall be readily accessible and shall be approved by the Authorising Authority.

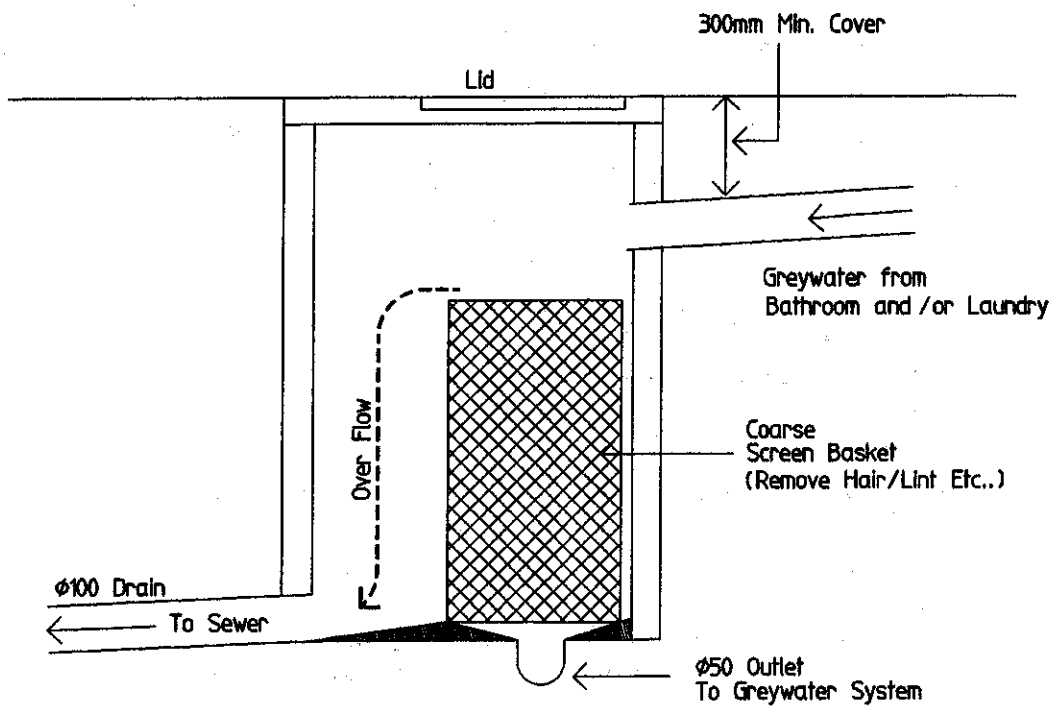
(e) Materials and Products

Materials and products used in the installation of greywater re-use system shall comply with the relevant statutory requirements for authorisation and with AS 3500, AS 1546 and SAA MP 52

SCREEN CHAMBER
(Approx. 6 Litres Capacity)
With Active/Passive Valve



PLAN



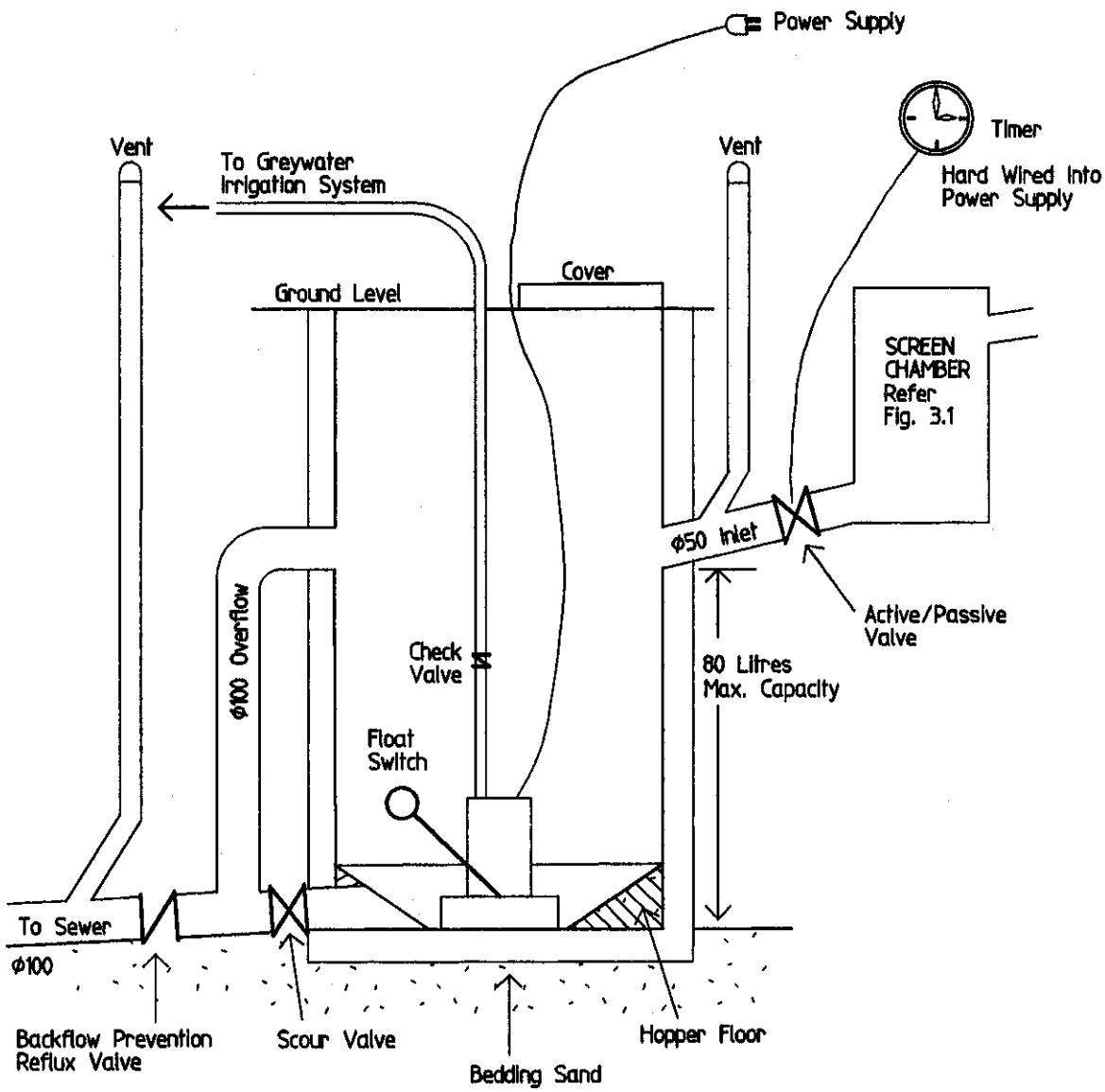
ELEVATION

FIGURE 3.1

Scale : NTS

../hmn/chamber

GREYWATER INGROUND SURGE TANK
(CAPACITY 80 LITRES)



NB : The use of electrodes to operated the pump in preference to a float switch can reduce the operating depth of the surge tank.

FIGURE 3.2

Scale : NTS

../hmn/tank1

ABOVE GROUND SURGE TANK
INCORPORATING APV & SCREEN CHAMBER

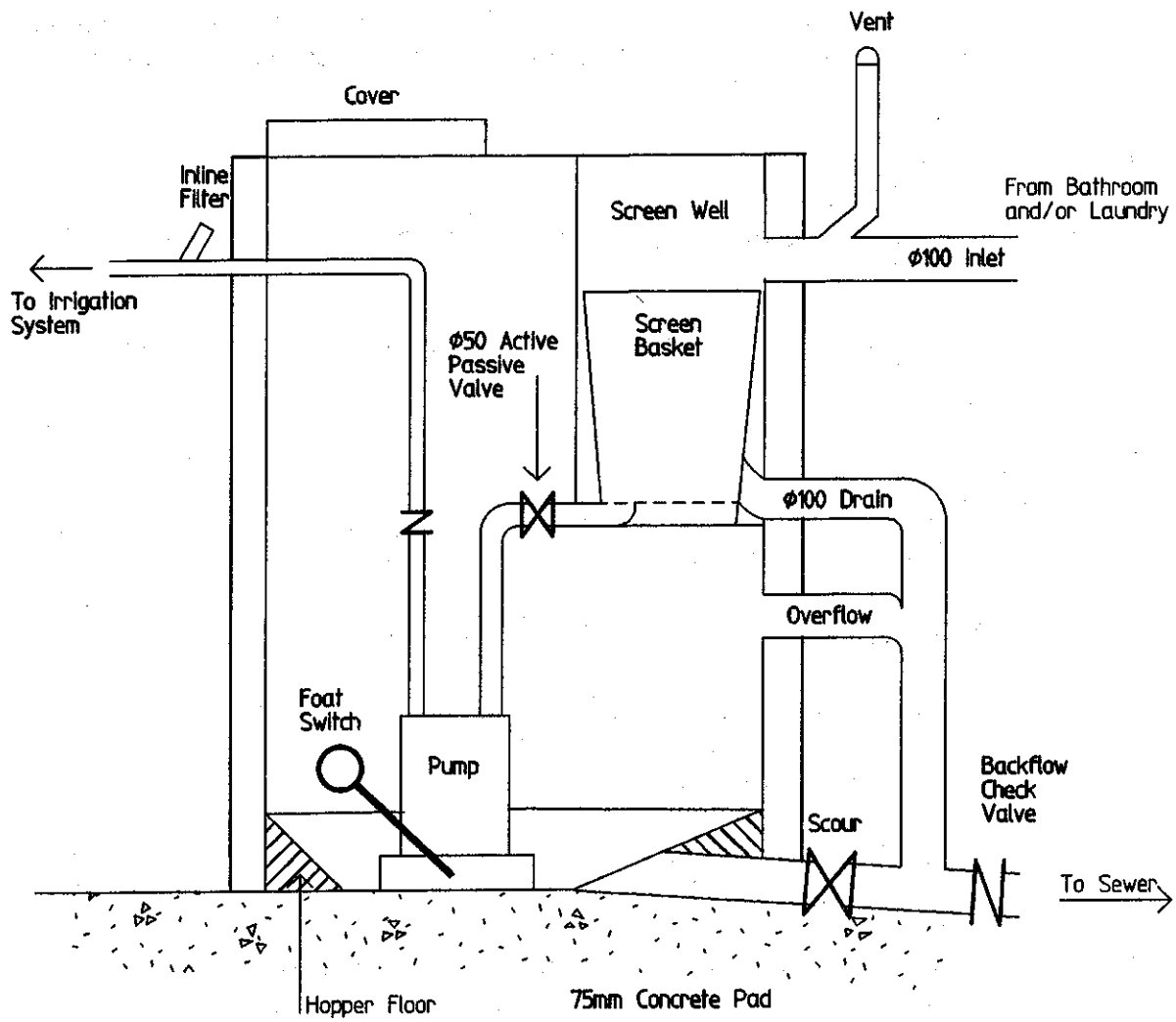


FIGURE 3.3

Scale : NTS

../hmn/tank2

3.7 Re-use Area Construction

3.7.1 General

The Authority may permit sub surface drip irrigation, sub surface trickle irrigation or other equivalent irrigation methods which discharge greywater in a manner which ensures that the greywater does not surface and is re-used for the purpose of watering vegetation. Design standards for sub surface drip irrigation systems and sub surface trickle irrigation areas are as follow:

3.7.2 Preparation of irrigation area

The irrigation area is to be prepared in accordance with AS 1547, appendix E. For sub surface drip irrigation systems with low permeability soils the top 400 mm of soil is to be scarified.

3.7.3 Materials

All drip irrigation pipework and fittings shall comply with AS 1477 or AS 2698.2.

Porous soakage hose is not acceptable for distribution of greywater due to the likelihood of clogging.

3.7.4 Sizing of pipes

The hydraulic design of the distribution network should be done by a qualified person. The irrigation pipes for -

(a) manifolds should not be less than 40 mm in diameter; and

(b) laterals should be not less than 25 mm in diameter.

3.7.5 Depth of cover of pipes

Supply pipes shall have a minimum natural cover of 200 mm below the ground surface.

Distribution or lateral pipes shall have a maximum depth of 300 mm and maintain a minimum depth of 200 mm below the natural ground level. The depth of garden mulch layer is to be measured as additional on this cover.

For elevated gardens which have been built on top of the natural ground, the finished surface shall be deemed to be the natural ground level.

3.7.6 Mulch layer in gardens

A mulch layer of not less than 50 mm depth is to be maintained on the surface of gardens irrigated with greywater. It is recommended that the mulch be made of decomposing organic matter that will decompose and contribute to the humus content of the soil. Regular replenishing of this layer will be necessary. Bark and non decomposing materials will be a lesser but acceptable alternative. The purpose of the mulch layer is as follows:

- minimises plant stress by reducing temperature variations in the soil,
- minimise moisture loss through evaporation,
- prevent crusting of the soil surface so that rainwater leaching can occur,
- increase the humus content of the soil,
- help sustain the micro flora in the soil thus promoting the predatory activity against any pathogens that may be present,
- encourage healthy soil and thus healthier plant growth through more efficient wastewater and chemical uptake.

3.7.7 Clearances

Irrigation areas shall maintain the clearances as specified in Table 3.2. Distribution or lateral pipes shall also maintain a minimum horizontal clearance of 1 metre from the defined irrigation area boundary. For elevated gardens the edge of the irrigation area is the edge of the garden.

3.7.8 Sloped land

Irrigation areas shall not be constructed where the ground surface has a slope that is greater than 5 degrees. Terracing of the site is an acceptable method of complying with this requirement. Diversion spoon drains or mounds are required on the uphill sides of terraced irrigation areas to prevent rainwater surface runoff entering.

3.7.9 Maximum supply pressure

Where pressure at the discharge side of the pump exceeds 140 kPa, a pressure reducing valve able to maintain downstream pressure no greater than 140 kPa shall be installed downstream from the pump and before any emission device.

3.7.10 Distribution of flow

The system design shall provide user controls, such as valves, switches, timers, and other controllers as appropriate, to rotate and or evenly distribute the greywater between irrigation areas and at the inlets to the laterals within those areas.

The variation in pressure heads at the inlets to the lateral pipes shall be not more than 10%.

Table 3.5
DRIP EMITTER DESIGN

Soil Texture Classification	Permeability. Representative Values "p" M/day	Design Irrigation Rate. (DIR) mm/week	Maximum Emitter Discharge. (Lts/day)	Minimum Number of Emitters per Kl of average daily flow
Sand	1.2	75	6.8	160
Sandy Loam	0.6	57	5.3	180
Loam	0.3	40	4.5	240
Clay-Loam	0.18	31	3.4	290
Clay	0.06	25	2.3	420
Silty Clay	0.012	18	1.9	530

Notes:
1 Soil permeability from Table 3.1 AS 1547-1994
2 DIR from Figure 3.2 AS 1547-1994

3.7.11 Drip irrigation systems

(a) For drip irrigation systems a minimum of 140 mesh (115 micron) 25 mm filter with a capacity of 100 litres per minute, or equivalent filtration, shall be used between the supply pump and the distribution network. Filtered material shall be disposed of to the sanitary sewer system. Sanitary procedures shall be followed when handling filtered material.

(b) Emitters shall have a minimum flow path of 1200 microns and shall have a coefficient of manufacturing variation (Cv) of no more than seven percent. Irrigation system design shall be such that emitter flow variation shall not exceed plus or minus ten percent. Emitters shall be recommended by the manufacturer for sub surface use and greywater use, and shall have demonstrated resistance to root intrusion. Flow rates for each emitter should be in the order of 2-4 litres per hour. For emitter ratings refer to the manufacturers specification.

(c) Each irrigation zone shall be designed to include no less than the number of emitters specified in Table 3.3, or through a procedure designated by the Administrative Authority. Minimum spacing between emitters is 350 mm in any direction.

3.7.12 Trickle irrigation areas

(a) Emitter outlets

The distribution or lateral lines shall have either of the following types of emitter outlets:

- 3 mm diameter punched (not drilled) emitter holes spaced to give uniform distribution of the greywater into the trench area. Flow rates for each emitter should be in the order of 2-4 litres per hour. Where this method is used an in-line filter as specified in 3.7.10 (a) is to be used; or

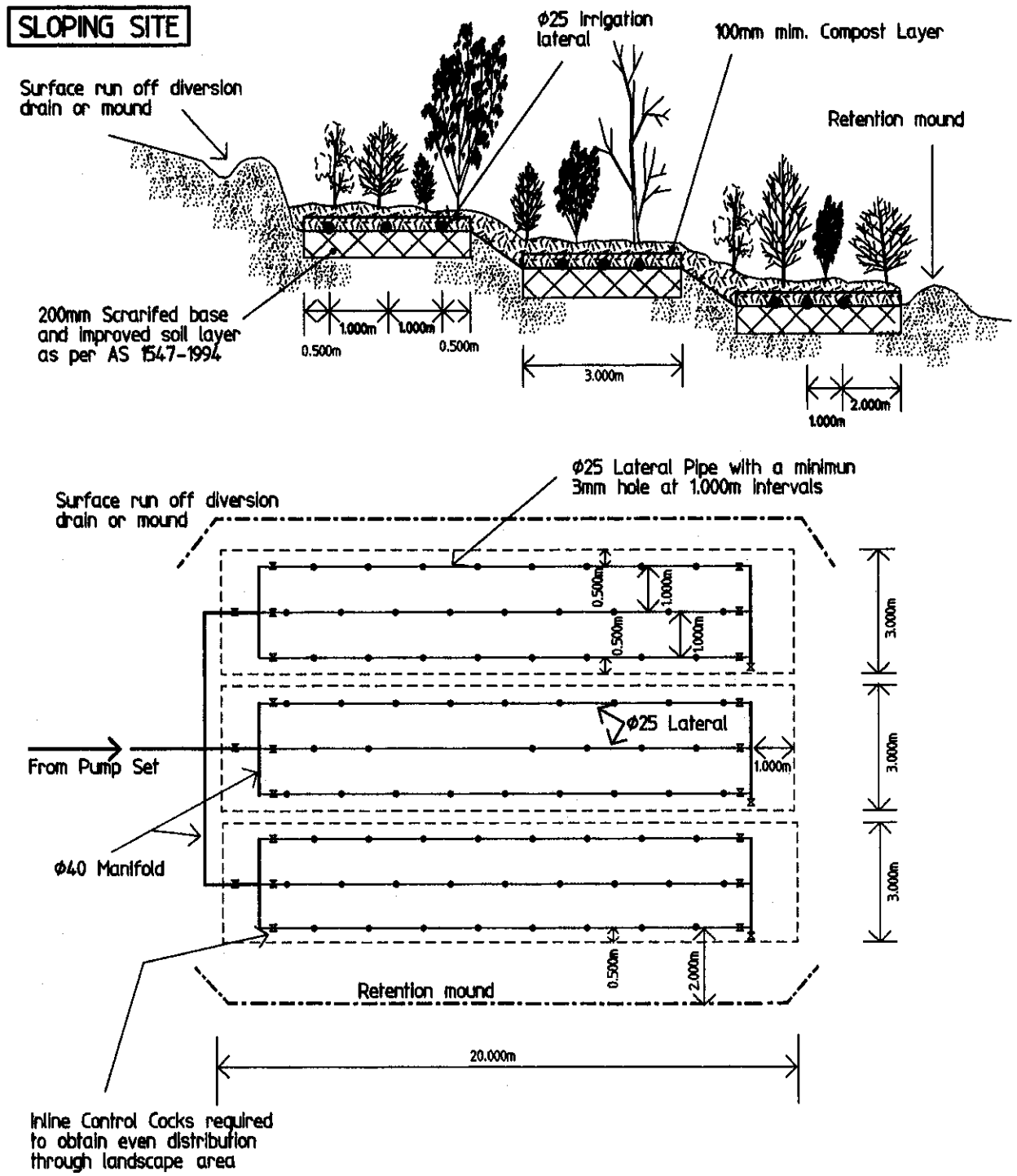
- 12 mm diameter outlet "T" fittings spaced in-line to give even distribution of the greywater into the trench area. In-line filters are not required.

(b) Effluent distribution trenches

The effluent distribution trenches shall be constructed in the order of 150 mm wide by 150 mm deep. The distribution or lateral line shall be centrally placed within this trench and run the length of the trench. The trench is to be filled with durable aggregate with the grading requirements as specified in AS 2758.1 for single-size course aggregate for nominal sizes from 20 mm to 40 mm.

Effluent distribution trenches are to be covered with a minimum of 200 mm of scarified soil or sandy loam.

SUGGESTED SUB-SURFACE TRICKLE IRRIGATION AREA FOR SLOPING SITE



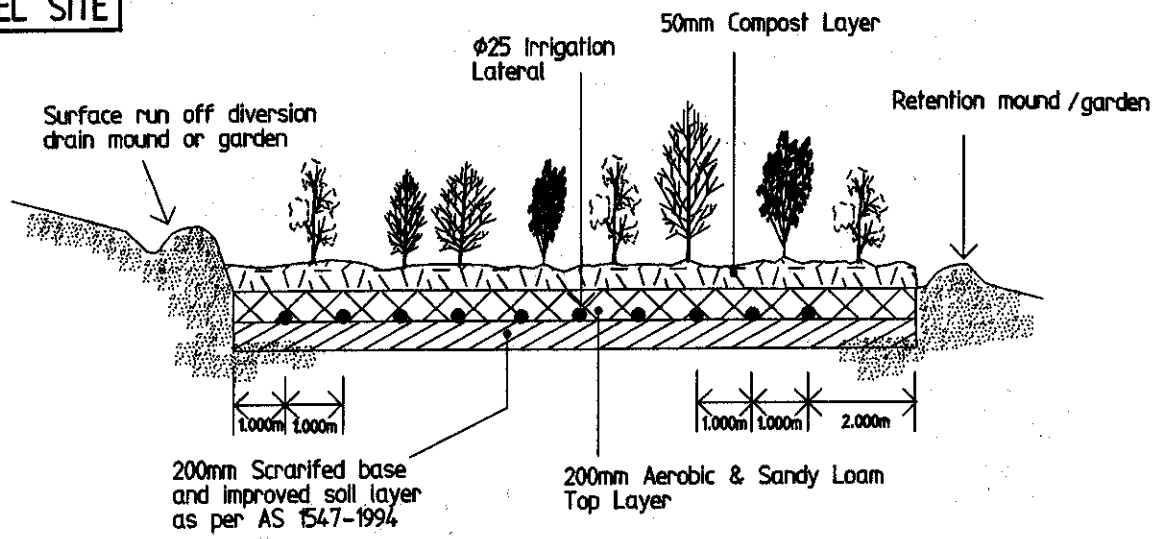
TYPICAL PLAN LAYOUT & LATERALS FOR AN IRRIGATION AREA 200m^2

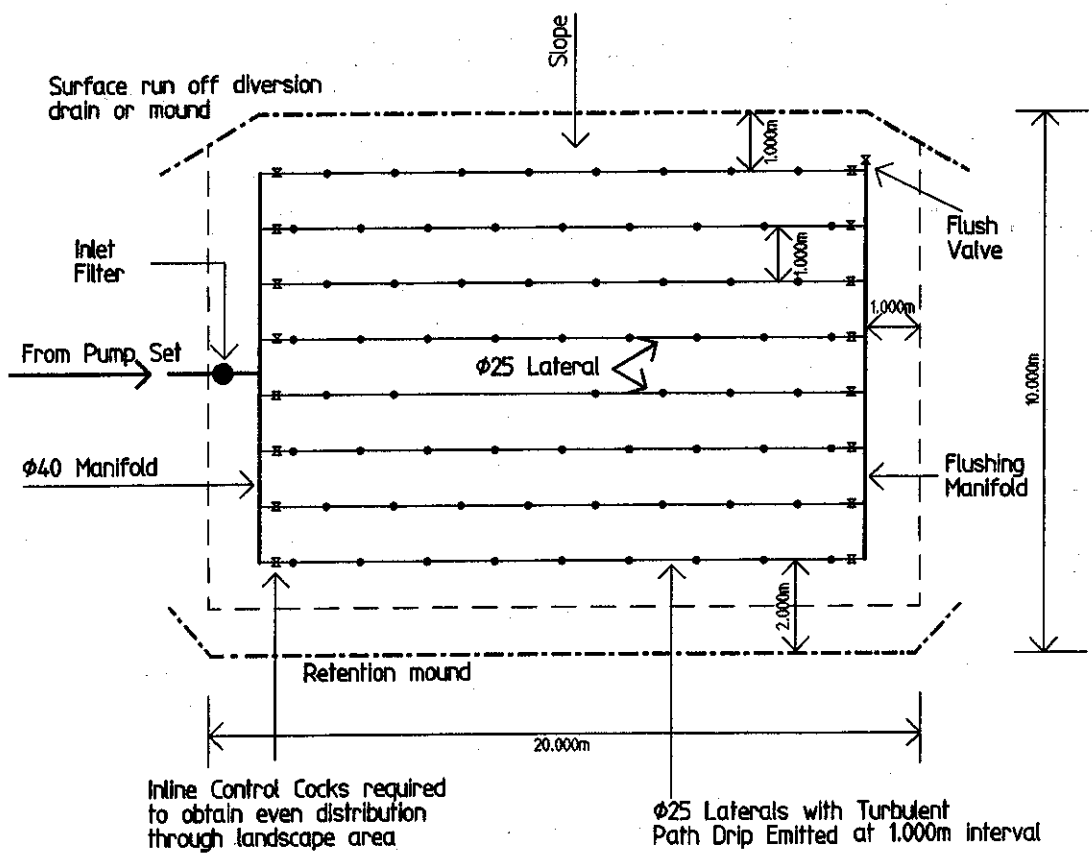
FIGURE 3.7

Scale : N.T.S.

SUGGESTED SUB-SURFACE DRIP IRRIGATION AREA

LEVEL SITE





TYPICAL PLAN LAYOUT & LATERALS FOR AN IRRIGATION AREA 200m^2

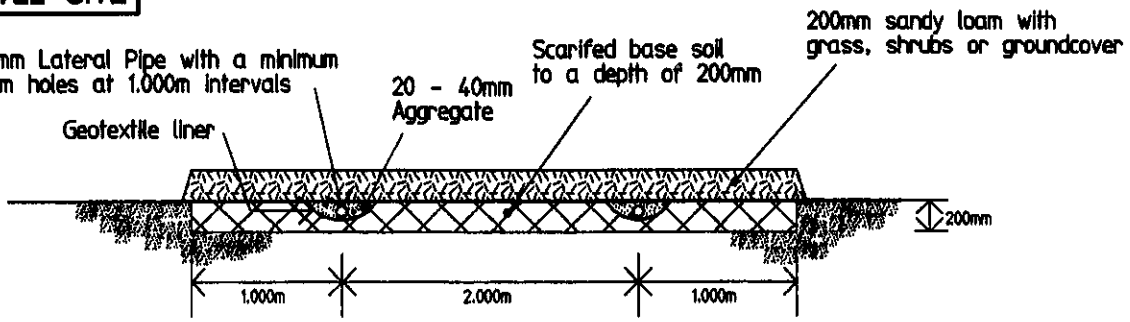
FIGURE 3.4

Scale : N.T.S.

...wsshcn1/hmn/s3

SUGGESTED SUB-SURFACE TRICKLE IRRIGATION AREA
METHOD 1

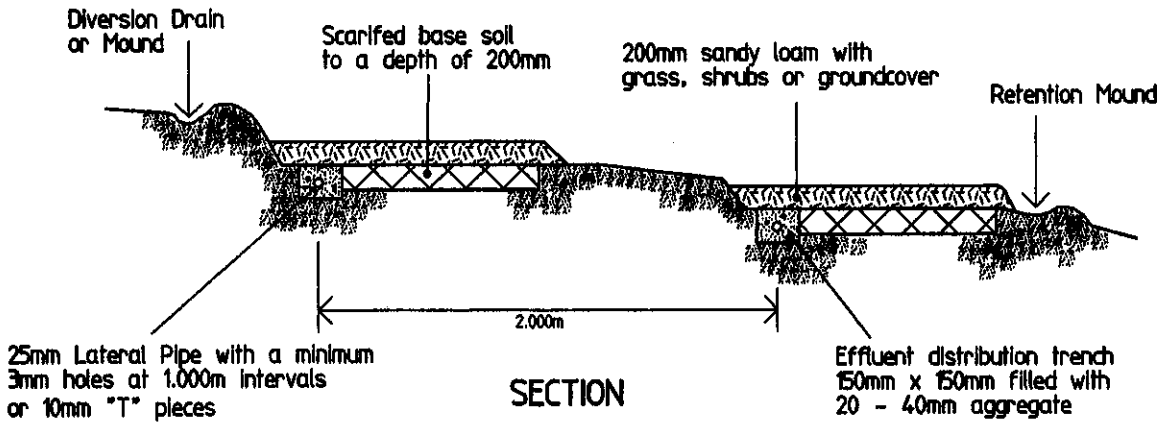
LEVEL SITE



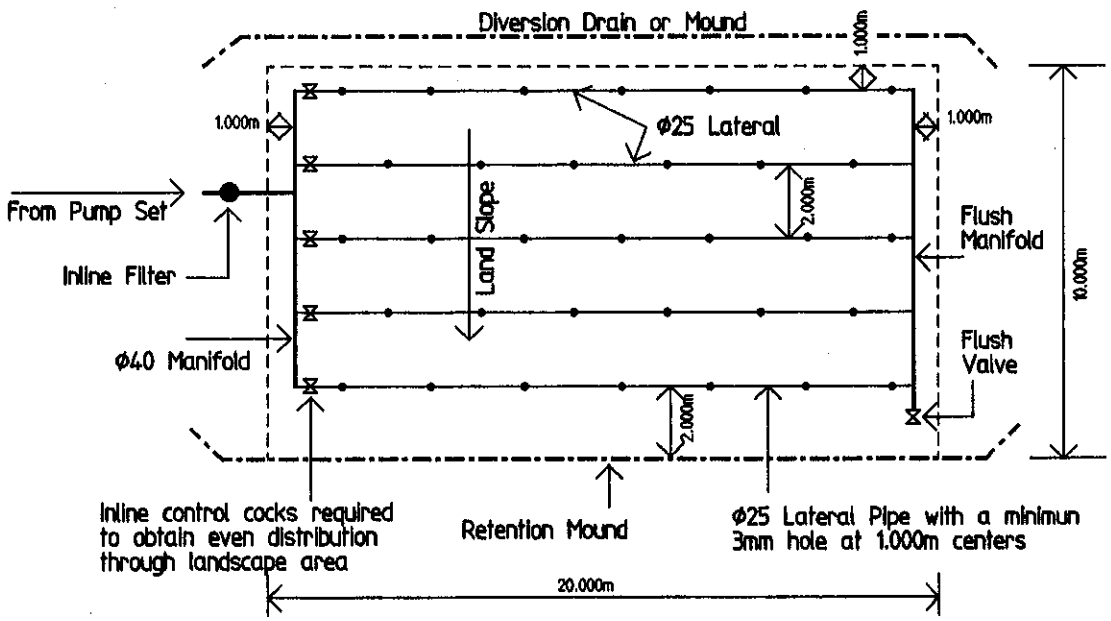
NOTE : A form of stormwater diversion and effluent retention is required

SECTION

SLOPING SITE



SECTION

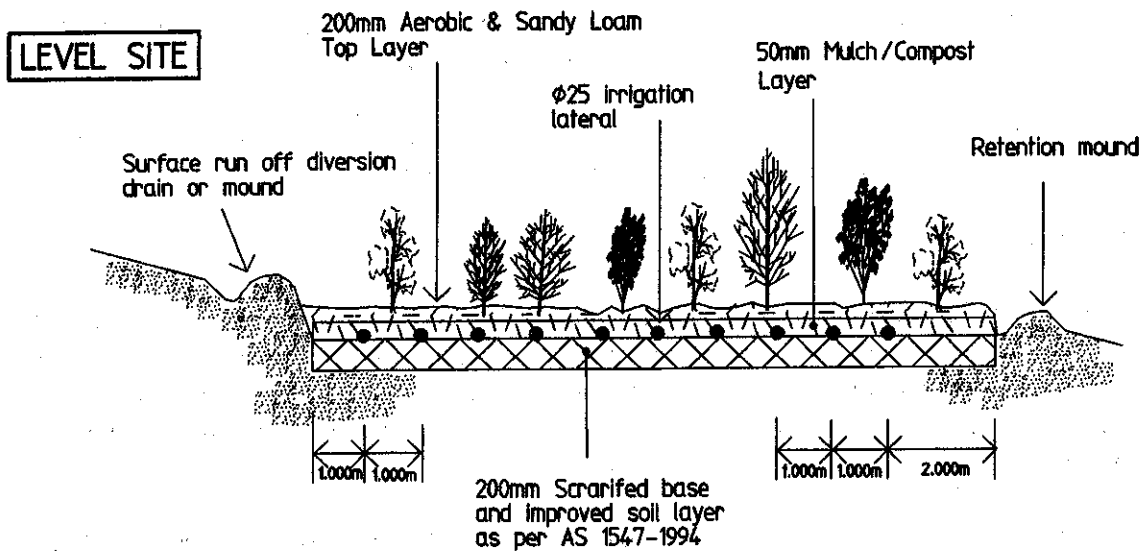


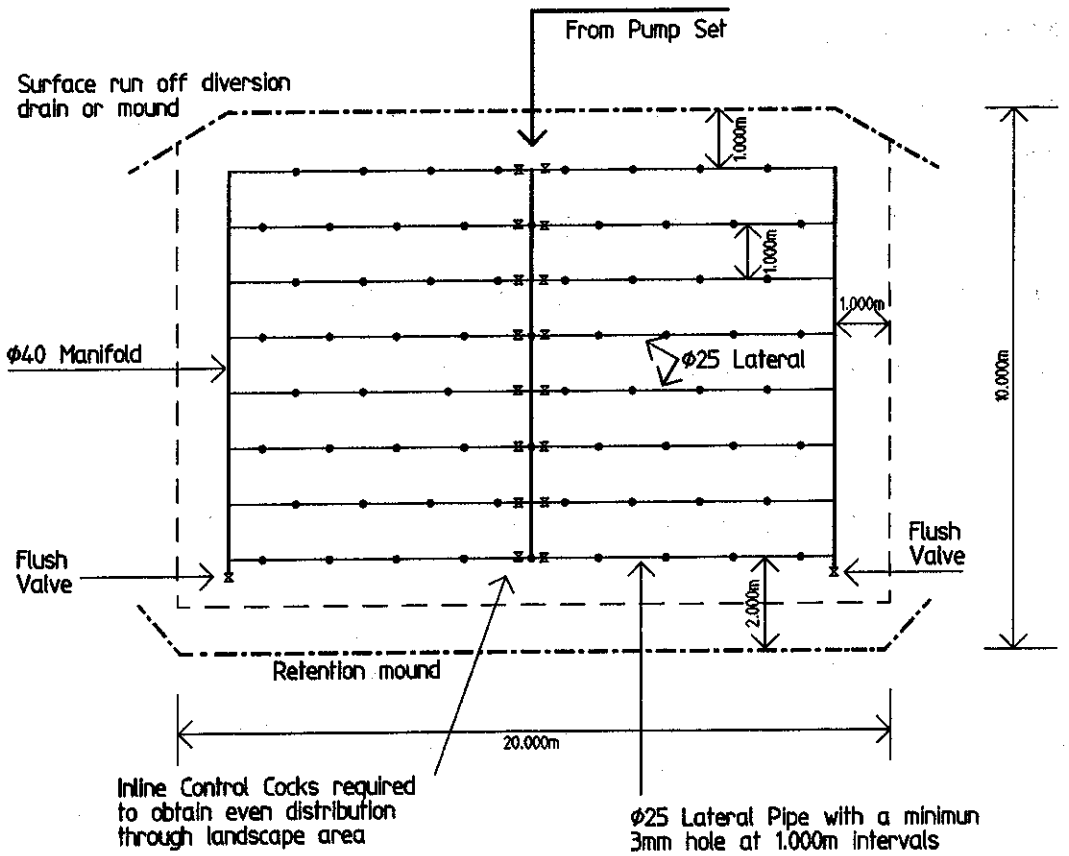
TYPICAL PLAN LAYOUT & LATERALS FOR AN IRRIGATION AREA 200m²

FIGURE 3.5

Scale : N.T.S.

SUGGESTED SUB-SURFACE TRICKLE IRRIGATION AREA
METHOD 2





TYPICAL PLAN LAYOUT & LATERALS FOR AN IRRIGATION AREA 200m^2

FIGURE 3.6

Scale : N.T.S.

...wsshcn1/hmn/s2

4. GUIDELINES FOR SECONDARY GREYWATER REUSE SYSTEMS - by licence

4.1 General

Secondary Greywater Re-use System Treatment Processes require Licensing by the relevant State Health and or Water Regulatory Authority.

Secondary Greywater Re-use System installations, including effluent re-use areas, must comply with the Authority's guidelines before final approval is granted.

4.2 Definition

Secondary Greywater Systems (SGS) - these are any system which can not be caterogised as either hand basin toilets or primary greywater systems. Secondary greywater systems may be used for multiple occupancy domestic dwellings. Short term storage to facilitate filtration is acceptable were the stored greywater does not present a health risk or cause nuisance.

The method of re-use is for the purposes of lawn and ornamental garden watering using sub-surface watering techniques as specified for primary greywater re-use systems.

4.3 Methods of Re-use

The following sub-surface watering technique is specified as the only permissible methods of re-use:

- sub-surface drip or trickle irrigation

These watering techniques can be applied to non dedicated areas.

4.4 Reclaimed Water Quality & Permissible Uses

4.4.1 Storage of Greywater

For storage of greywater the requirement is that for the duration of storage the greywater will satisfy the following:

- Biochemical Oxygen Demand (5 day) (BOD_5) of not greater than 20 mg/L for the greywater both during storage and at the outlet,
- Suspended Solids (S.S.) not greater than 30 mg/L.
- Emit no offensive odours or cause public nuisance.

4.4.2 Maximum Storage Period

The maximum acceptance storage period is dependant on the criteria as specified in 4.1.

4.4.3 Maximum Storage Capacity

The maximum storage capacity should not be greater than the maximum daily design irrigation capacity of the system.

4.5 Greywater Treatment Processes

4.5.1 Automatic Filtration Systems

Minimum 140 mesh (115 micron) 25 mm filter with a capacity of 100 litres per minute, or equivalent, filtration shall be used. Filter back-wash and flush discharge shall be caught, contained, and disposed of to the sanitary sewer system. There shall be no loss of filter media to the sanitary sewer. Sanitary procedures shall be followed when handling filter back-wash, flush discharge and greywater.

4.5.2 Filtration Processes

Short term storage may be deemed to be a viable option if it is for the purpose of facilitating the following filtration methods:

- Membrane filtration,
- Sand filtration.

Storage systems must be accompanied with processes to maintain the Biological Oxygen Demands, Suspended Solids and nuisance odours as specified in 4.4.1.

4.6 System Management, Control, and Monitoring

4.6.1 The owner of a Greywater treatment plant shall enter into a maintenance contract with the supplier of the system, or other agent, to ensure the proper operation of the unit.

4.6.2 Inspections and maintenance by the maintenance contractor shall be carried out in accordance with the equipment State license or Authority.

4.6.3 Copies of all the contractor's normal service reports for the year shall be submitted to the Administrative Authority at the time of paying the annual permit.

4.6.4 As a result of the reports received, audit procedures will be developed by the Administrative Authority for each facility type and inspection frequency will depend on the facility type and the record of performance of each individual installation.

4.6.5 The owner shall ensure that by-products of greywater systems be disposed of in an hygienic manner which is not detrimental to the sewer system or environment.

5. USER GUIDELINES

5.1 Greywater as a Plant Fertiliser

Greywater does contain contaminates that can be beneficial to most plants. The following is a summary of these criteria.

Most plants require three principal nutrients for healthy growth: nitrogen, phosphorus and potassium.

- ***Nitrate Nitrogen*** regulates a plant's ability to make proteins, controlling the rate and quantity of growth. Nitrogen is only taken up by plants as a nitrate compound and is easily leached from the soil.

  Nitrogen deficient plants may have stunted growth and pale, sickly looking leaves, which they drop prematurely. Excessive nitrogen will give a soft and succulent growth that is prone to disease.

  Greywater is low in nitrogen content.

- ***Phosphorus*** is needed for the production of sugars and energy in plants. It also plays a vital role in seed production, root development and flower formation. Phosphorus does not occur in its pure form in the soil, but in various insoluble salts. Micro-organisms in the soil convert these insoluble salts into plant food. Very little phosphorous is lost by leaching.

  Phosphorous deficiency in plants will appear in stunted growth with leaves showing odd reddish brown tones. Australian soils generally can be phosphorus poor.

  Washing detergents used in the laundry are the primary source of phosphates found in greywater.

- ***Potassium*** is only available to plants through the compound potassium oxide (K_20) and is also referred to as potash. Potassium contributes to the manufacture of sugars, starches and cellulose. Clay soils and heavy loams generally contain sufficient quantities where as sandy soils and high organic soils may be deficient.

  Potassium deficiency in plants appears first in the yellowing of the tips and edges of older leaves, which eventually die.

The percentage by weight of these elements contained in artificial fertilisers is shown on the packaging as N:P:K. The proportioning of the elements in an artificial fertiliser is designed to suit specific plant needs. For example:

- Lawn grasses require a high nitrogen content and a suitable fertiliser may have an N.P.K of 9:4:6.

- Native plants require a low phosphorus content and a suitable fertiliser may have an N:P:K of 8:0:6.

- Trees & shrubs generally require a more balanced content and may have an N:P:K of 8:8:8. During the formation of fruits or flowers an N:P:K of 15.3:10 may be more appropriate.

The N:P:K of greywater is site specific due to the variable habits and products used in the home. Supplementing of the essential nutrients to balance may be necessary after consideration of the existing soil conditions, and the types of plants being watered with greywater (refer Appendix 4).
Secondary nutrients essential to plants are calcium, magnesium and sulphur. These are required by plants in smaller quantities than the three principal nutrients.

- ***Calcium*** aids in the manufacture and growth of the root system and plant cells. Calcium is relatively abundant in most soils.

- ***Magnesium*** is an important component of chlorophyll, necessary in photosynthesis. However high levels of magnesium may affect soil structure causing clay to disperse on wetting and to set hard on drying. This may require the application of gypsum.

- ***Sulphur*** like nitrogen contributes to the formation of proteins.

Other essential nutrients required by plants are boron, chloride, copper, iron, manganese, molybdenum and zinc. Plant growth naturally depletes these major nutrients from the soil. To sustain healthy growth, replenishment eventually is needed. Greywater can contain all of these nutrients.

Laundry detergents and other household cleaners can contain high levels of sodium. Through watering with greywater, sodium applied excessively to clay soils will damage the soil structure by reducing the air space, giving it a greasy texture and poor drainage capability. Ponding on the surface is an undesirable symptom of excessive sodium. Because of the health concerns (refer to UWRAA Report 73, 1994), this condition can be repaired by the application of gypsum, repeated leaching, and time. Excessive application of sodium can be harmful to plants. A preferable option is to use detergents with low sodium content.

Aerobic micro organisms in the soil play an integral part in plant growth, in treating greywater by decomposing organic matter, and in the conversion of mineralised nutrients into a soluble form that is available for plants to absorb. These micro organisms are best promoted in moist soils that have a compost layer and a high humus content. Dry or over watered soil (to the point of saturation), inhibits their survival and thus plant growth (Kourik, 1992).

pH Greywater is generally alkaline in pH. The optimum range for most plants is a pH between 5 and 8. Outside these limits certain elements become deficient, for example, iron and manganese in alkaline soils, and magnesium in acid soils. With long term application of greywater the periodic addition of lime to the soil may be necessary to maintain the soil pH in this range.

5.2 Vegetation Suitable for Watering with Greywater

Trees	Nyssa sylvatica	Leptospermum laevigatum	
	Casuarina glauca	Leptospermum petersonii	
	Casuarina stricta	Tristaniopsis laurina	
	Photinea x fraseri "Robusta"	Banksia integrifolia	
	Callistemon viminalis	Callistemon salignus	
	Angophora costa	Eucalyptus robusta	
	Melaleuca quinquenervia - Sandy Soil	Eucalyptus botryoides	
	Melaleuca styphelioides - Clay Soil		
	Melaleuca armillaris - Sandy Soil		
	Melaleuca linariifolia - Clay Soil		
Ground Cover	Grevillea poorinda "Royal Mantle"	**Grasses**	Kikuyu
	Coprosma x kirkii		Buffalo
	Acanthus mollis		
	Liriope muscari		
	Ophiopogon		
Shrubs	Nerium oleander	Jasminum mesnyi	
	Abelia x grandiflora	Acacia longifolia	
	Cassia bicapsularis	Cotoneaster pannosus	
	Hebe speciosa	Cotoneaster lacteus	
	Lantana camera (cultivars only)	Cotoneaster glaucophyllus	
	Lantana montevidensis	Euphorbia pulcherrima	
	Pyrachantha fortuneana	Leptospermum flavescens	
	Jasminum officinale "Grandiflorum"	Correa alba	
	Jasminum polyanthum	Plumbago auriculata	
	Callistemon citrinus	Westringia fruticosa	
	Thunbergia alata	Ceratostigma	
	Chaenomeles lagenaria	Cuphea ignea	
	Euonymum japonicus	Euphorbia millii	
Climbers	Bougainvillea	**Perennials**	Agapanthus preaecos
	Hibbertia scandens		Aster novi-belgii
	Kennedia		Canna x generalis
	Lonicera japonica		Chrysanthemum maximum
	Panorea jasminoides		Salvia x superba
	Hardenbergia		Stokesia laevis
			Viola hederacea
			Gazania x hybrida

N.B. The main plants to avoid are those from the Proteaceae family, as they like many native plants, evolved in low phosphorus soils and are susceptible to excess phosphates. This family includes Grevillea, Hakea, Banksia and Silky Oak.

5.3 Owner Maintenance Guidelines

A permit for the operation of a greywater system is issued to the property owner subject to compliance with the following conditions and should be subject to yearly inspection and renewal:

5.3.1 All installations shall comply with the provisions of the "Greywater Reuse" guidelines and the Water Supply and Sewerage Authority requirements.

5.3.2 On site, modifications and repairs shall only be done by a licensed person as per the relevant State Water Supply and Sewerage Acts.

5.3.3 It is the responsibility of the property owner to ensure that the "greywater system" is maintained in good working order at all times. Any defect shall be rectified as soon as it becomes apparent.

5.3.4 It is the responsibility of the owner to maintain any required warning signs in good order.

5.3.5 Greywater shall not be used for any of the following purposes :

- Drinking, cooking or kitchen purposes,
- Surface Irrigation,
- Baths or showers,
- Clothes washing,
- Swimming pools,
- Water contact recreation,
- Irrigation of vegetable and root crops for human consumption.

5.3.6 The owner shall ensure the following materials do not enter the greywater system:

- Cooking fats and oils
- Faecal matter from the washing of nappies
- Paints, automotive oils and greases etc.
- Any matter designated as " Trade Waste" by the Authority

5.3.7 The owner shall control the rate of watering to avoid over-irrigation and resulting in soil degradation and/or surface run off.

5.3.8 Failure to comply with any or all of the above conditions, may result in the revoking of the operation permit.

5.3.9 The owner shall ensure that the greywater re-use system is only operated in periods of dry weather and is not operated immediately after rain or if rain is likely within the next 12 hours.

5.3.10 The owner shall ensure that good hygiene practice is maintained at all times when contact with the greywater occurs. Good hygiene practice includes the following:

- Avoid direct contact with the skin through the use of rubber gloves and protective clothing
- Avoid the splashing of greywater into the mouth and respiratory tract by wearing a face mask
- Ensure that any cuts, sores, open wounds etc are adequately covered and protected from any contact with greywater
- Ensure that exposed body areas that come into contact with greywater are immediately washed with a biocidal soap or disinfectant. Exposed areas are to be washed clean with particular attention given to beneath finger nails.
- Do not make contact with the mouth or face either directly (eg fingers, hands) or indirectly (eg smoking cigarettes etc), until after washing
- Do not eat food until after washing
- Disinfect spillage areas

APPENDIX 1 - LIST OF REFERENCES

ACT Electricity and Water, (1994), Wastewater Reuse Study Phase 1: Opportunities Threats and Further Actions - October 1994, ACTEW Engineering Department, Sewerage Planning Section.

Brisbane City Council, Department of Water Supply and Sewerage, (1993), Domestic Greywater Re-use: Preliminary Evaluation, Urban Water Research Association of Australia, Report No 60.

Brisbane City Council, Department of Water Supply and Sewerage, (1994), Domestic Greywater Re-use: Overseas Research and its Application to Australia, Urban Water Research Association of Australia, Report No. 73.

Campbell, C., (1995), private communications, Collin Campbell Horticulture Pty Ltd.

Christova - Boal, D., (1995), Installation and Evaluation of Domestic Greywater Reuse Systems, Victoria University of Technology.

Crook, J, (1985), Water Re-use in California, Journal of American Water Works Association, Vol.77, No. 7, pp 60-71.

Department of Water Resources, State of California, (1994), California Plumbing Code, Appendix J - Graywater Systems for Single Family Dwellings.

Guy, R, (1995), private communications, Northern Territory Power and Water Authority.

Kourik, R., (1993), Drip Irrigation for every landscape and all climates., Metamorphic Press, Santa Rosa, California.

Lechte, P., (1995), Installation and Evaluation of Domestic Greywater Reuse Systems in Melbourne, AWWA 16th Federal Convention, Victoria University of Technology.

National Health and Medical Research Council, (1988), The National guidelines for the Management of Clinical and related Wastes. Australian Government Printing Service, Canberra.

National Health and Medical Research Council, National Water Quality Management Strategy, (1995), Guidelines for the use of Reclaimed Water, Draft - January, 1995.

Northern Territory Power and Water Authority, (1994), Greywater Reuse, (Interim Report - October 1994).

NSW Recycled Water Coordination Committee, (1993), NSW Guidelines for Urban and Residential Use of Reclaimed Water, 1st edition - May 1993. Public Works Department, Sydney.

Okun, D.A., (1994), private communication, Kenan Professor of Environmental Engineering, University of Carolina, USA

Parliament of NSW, (1994), Joint Select Committee upon the Sydney Water Board - Report, April 1994.

Queensland Department of Primary Industries, (1986), Water Quality for Agriculture in Queensland.

SAA MP 52, (1993), Manual of Authorisation Procedures for Plumbing and Drainage Products

Standards Australia, (1983), AS 1319 - 1983, Safety signs for the occupational environment.

Standards Australia, (1982), AS 1345 - 1982, Identification of piping, conduits and ducts.

Standards Australia, (1993), AS 1546 - 1993, Small Septic Tanks

Standards Australia, (1994), AS 1547 - 1994, Disposal of Sullage and Septic Tank Effluent from Domestic Premises.

Standards Australia, (1994), AS 1726 - 1992, Geotechnical Site Investigations

Standards Australia, (1984), AS 2698 - 1984, Plastic pipes and fittings for irrigation and rural applications.

Standards Australia, (1991), AS 2845 - 1991, Water Supply - Mechanical Backflow Prevention Devices.

Standards Australia, (1992), AS 3500 - 1992, National plumbing and drainage code.

APPENDIX 2 - DEFINITIONS

ACTIVE/PASSIVE VALVE The active/passive valve is an electric solenoid operated ball or gate valve that is timer operated. The valve in the passive (normally closed) position directs all greywater flow to the sanitary sewer, by-passing the greywater re-use system.

When the timer is manually activated the valve opens into the active mode diverting greywater to the surge tank. After the expiring of the set time span, the valve returns to the passive mode.

ADMINISTRATIVE AUTHORITY. The authority defined under the relevant legislation as responsible for applying and managing the the act in respect to greywater re-use.

AEROBIC LAYER The upper levels of the soil are the most aerobic and the natural antagonistic microbial activity more prominent.

AUTHORISED Applies to materials, products, fixtures, appliances and apparatus which are sanctioned for use in the area of jurisdiction of the authorising authority.

BLACKWATER Domestic wastewater from the water closet, bidet and bidette; has gross faecal contamination. Kitchen wastewater has been included as blackwater as part of these model guidelines.

COMPOST Organic matter that has partially broken down into a friable consistency.

CROSS-CONNECTION Cross linking of the potable water supply with wastewater, risking contamination.

DRAIN A line of pipes above or below ground level within the property boundary, including all fittings and equipment, intended to convey under gravity, sewage or trade waste.

FITTING Anything placed in a pipeline for jointing, connecting or changing the direction or internal diameter of the pipeline.

FIXTURE A receptacle with necessary appurtenances designed for a specific purpose, the use or operation of which results in a discharge into the sanitary plumbing or sanitary drainage installation.

FULLY VENTED SYSTEM A system of sanitary plumbing with provision for the separate ventilation of every fixture trap connected (other than fixtures discharging to a floor waste gully) and of the trap of every floor-waste gully.

GREYWATER (also referred to as sullage). Domestic wastewater from bath, basins, shower, laundry, and including floor wastes from these sources etc. It does not include water closet, bidet and bidette waste or wastewater from the kitchen or dishwasher.

GREYWATER SYSTEM Shall mean any appliance, fitting or device that re-uses/recycles greywater from any single greywater source or a combination of sources.

GREYWATER TOILET FLUSHING SYSTEM Toilet systems that re-use bathroom and or laundry wastewater as the flushing medium.

HAND BASIN TOILET A toilet suite that incorporates a hand basin in the top of the cistern with a water spout for hand washing. The water spout operates automatically when the toilet flushes, simultaneously refilling the cistern and allowing hand washing.

HUMUS is the final residue of composted organic matter in the soil.

HOPPER FLOOR The angled floor of greywater vessels. Directs settleable solids towards the scour outlet and or dewatering point (pump etc).

IRRIGATION The distribution of water for such purposes as growth, leaching, cooling, treating, humidifying, frost protection and water replenishment of the soil for plants, turf, lawns, gardens, nurseries, agriculture, crops, flowers and horticulture.

IRRIGATION AREA The area of landscape dedicated for watering with greywater.

INSPECTION OPENING An access opening in a pipe or pipe fitting arranged to facilitate inspection testing or the clearing of obstructions and fitted with a threaded cap or plug or an access cover.

OVERFLOW

(a) Flow from an overfilled vessel, sanitary appliance, or chamber.

(b) That part of a sanitary drain vessel, sanitary appliance, or chamber through which overflow is intended to take place.

(c) The level of the rim of a fixture or the invert level of an overflow pipe.

PATHOGEN A human disease producing organism.

PIPE A single length of tube usually of circular cross-section used for the conveyance of fluids.

POTABLE WATER Water which is suitable for human consumption.

PRIMARY GREYWATER SYSTEM (PGS) These are any greywater system that directly re-use untreated domestic greywater, sourced from the bathroom and laundry only, from a single family home for sub-surface lawn and ornamental garden watering. These systems do not allow storage or treatment, apart from a coarse screen filter which removes lint, hair and coarse particles.

PUMP A mechanical device generally driven by a prime mover, and used for raising fluids from a lower to a higher level or for circulating fluid in a pipe work system.

REGULATORY AUTHORITY The authority responsible for developing and maintain the legislation, rules and regulations under which greywater re-use would be permitted.

SCARIFIED LAYER Scarifing or ploughing the upper natural soil layer in the irrigation area, loosens and aerates the soil, for the purpose of improved water absorption properties and plant root growth.

SECONDARY GREYWATER SYSTEMS (SGS) These are any greywater system which are not hand basin toilets or primary greywater systems. Secondary greywater systems may be used for multiple occupancy dwellings. They can also store greywater for treatment purposes only for re-use in sub surface lawn and garden watering.

SEWERED SITE Premises served by and connected to a sanitary sewerage system

SCOUR VALVE Fitted to storage vessels for the purpose of dewatering and or removal of settleable solids.

SCREEN (Coarse) A device generally made from wire or nylon mesh or spaced bars to separate solid matter from a liquid (eg lint and hair).

SCUM A floating mass of sewage or sullage solids buoyed up by entrained gas, grease or other substances.

SEWAGE The wastewater from the community including all faecal matter, urine, household and commercial wastewater that contains human waste.

SLUDGE Semi-liquid solids settled from sewage in septic tanks, sedimentation tanks, and grease arresters.

SUB SURFACE IRRIGATION Application of wastewater to the landscape by sub surface methods eg drip or trickle.

SULLAGE For the purposes of this paper the definition will be as per Australian Standard AS3500-1990, part 0 glossary of terms. Domestic wastes from bath, basins, showers, laundries, and kitchens, including floor wastes from these sources. Sullage will differ from the definition for Greywater in that there is an intent to re-use\recycle greywater and greywater does not include kitchen or dishwasher wastewater.

SURGE TANK A vessel designed to capture the high volume greywater flows for the purpose of direct reuse. Not used for storage.

SURCHARGE Overflow from a sewer, combined sewer, stormwater channel, or stormwater drain caused by overloading, or blockage. Usually used in reference to wet weather infiltration or inflow.

SURFACE FLOOD IRRIGATION An irrigation method where the irrigation water is applied by flowing over the ground surface. This practice is precluded in these model guidelines

SURFACE IRRIGATION Application of wastewater to the landscape by traditional surface methods eg; spray, trickle, drip and flood.

SURFACE RUN OFF Irrigated wastewater that has not been absorbed into, and retained by the soil and as a result has drained from the irrigation area.

TREATED GREYWATER Greywater that has incurred some treatment process apart from simple coarse screening.

TURBULENT PATH EMITTER A drip irrigation component. Contains a complex (or torturous) path of right angled channels for the water to follow. This maintains the fine particles in suspension until they are passed from the emitter.

VENT A pipe provided to limit the pressure fluctuations within the discharge pipe system or to encourage the passage of gases.

UNTREATED GREYWATER Greywater that has had no form of treatment apart from simple coarse screening.

APPENDIX 3 - COMPONENT COSTS

The following is a list of basic components for constructing a primary greywater system as specified in these guidelines:

• Screen chamber	$120	Everhard Industries QLD (Not currently available)
• 80 Litre Surge Tank	$120	Everhard Industries QLD (not currently available)
• Active/passive valve		
50 mm Solenoid valve Richdel 217pr or similar	$110	Aqua-field McCracken
240 volt transformer	$20	" "
timer	$ -	
• Sullage pump		
Grundfos KP 150 includes float switch	$289	" "
• 25mm Polyethylene irrigation tubing	$2 /Metre	

NB There are currently two Australian suppliers of turbulent path inline drip irrigation tubing. These products are superior to tubing with punched holes as they give controlled flow rates and are less likely to clog.

- "Drip-In" available from James Hardie Irrigation Distributors.
- "Geoflow with Rootguard" available from Triangle Filtration, Braeside, Victoria.

APPENDIX 4 - CHEMICAL AND PHYSICAL QUALITY OF GREYWATER

TABLE 1
SUMMARY OF ANALYTICAL DATA
FOR SULLAGE SYSTEMS IN THE BRISBANE AREA

Parameter	Range	Mean	Standard Deviation	Relative Std % Deviation	Suitability Criteria for watering plants		
					minimum	ideal	maximum
BOD (mg/L)	90-290	159	69	43	NA	NA	NA
pH	6.6 - 8.7	7.3	0.6	8	5	6-7.5	8
Suspended solids(mg/L)	45-330	113	91	81	NA	NA	NA
Turbidity (NTU)	22 - >200	100	55	55	NA	NA	NA
Conductivity (uS/cm)	325-1140	601	233	39	0	0-650	650 - 5000 (a)
Nitrite (mg/L N)	All <0.1	NA	NA	NA		<10	(b)
Nitrite (mg/L N)	<0.1- 0.8	0.3	0.2	67			
Pottassium (mg/L K)						0-15	
Sulphate (mg/L)	7.9 -110	35	43	123		0-100	(c)
Total phosphorus (mg/L)	0.6-27.3	8.1	10.0	123		0-0.2	
Ammonia(mg/L)	<1.0-25.4	5.3	7.9	149			
Total Kjeldahl Nitrogen (mg/L)	2.1-31.5	11.6	10.2	88			
Aluminium (ug/L)	100-3550	603	996	165		<5000	(c)

Parameter	Range	Mean	Standard Deviation	Relative Std % Deviation	Suitability Criteria for watering plants		
					minimum	ideal	maximum
Barium (ug/L)	16-120	41	29	71			
Calcium(mg/L)	11-35	27	9	33		<100	
Magnesium (mg/L)	5-19	14	6	43		<100	(b)
Sodium(mg/L)	29-230	73	57	78		<70	(b)
Cadmium (ug/L)	All <10	NA	NA	NA			
Chromium (ug/L)	<10.26	NA	NA	NA			
Copper	18-390	130	117	90		<200	
Iron (ug/L)	94-4370	700	1240	177		<100	
Manganese (ug/L)	14-75	31	20	65		<200	
Nickel (ug/L)	<15-27	NA	NA	NA			
Lead (ug/L)	<50-150	NA	NA	NA		0	
Zinc (ug/L)	<10-440	100	128	128		<200	
Mercury (ug/L)	All<1	NA	NA	NA			

(a) Conductivities greater than this range are suitable for salt tolerant plants only.

(b) For values greater than this range, apply gypsum, cease greywater re-use, and allow natural leaching to occur.

(c) For values greater than this range apply lime and high phosphorus fertiliser to the soil.

APPENDIX 5 - FURTHER DISCUSSION

5.1 Health risks from Cytotoxic waste

People suffering from some forms of disease, including cancer, are treated with Cytotoxic therapy. Their body secretions can be a source for this type of drug in sewage. The principal source in greywater would be from patients urinating in the shower or bath.

There are two broad types of cytotoxic drugs:

- Radioactive drugs/materials,
- Chemotherapeutic drugs.

In the case of radioactive materials the isotopes used have a short half life (ie they quite rapidly become non reactive). In this circumstance, the combination of a very small amount of material being involved in the first place combined with a short half life and very significant dilution factors, the health risk in greywater can only be assumed to be inconsequential.

Similar arguments apply to chemotherapeutic agents. There is a vast range of chemicals involved in this group, all with somewhat different properties. Many are significantly metabolised within the body before excretion to much less toxic and non-toxic materials. Again the dilution factors, relatively small initial amounts and pre-excretory metabolization would suggest a negligible risk in greywater (Niven, 1995)

The National guidelines for the Management of Clinical and related Wastes, 1988 states the following:

> Waste with low concentrations of cytotoxic drugs, such as urine, faeces and vomitus, may be disposed of safely into the normal sewerage system. Appropriate precautions must therefore be taken when handling these materials, and they must be suitably diluted. The relevant State and Territory authorities should be consulted.

5.2 Onsite Disposal in the Future

The current environmental awareness of the community, has given greater emphasis to the onsite treatment and re-use of wastewater. The re-use option has considerable appeal over the sanitary sewer as a conservation measure. There are already numerous low density residential developments in all areas of Australia, that only have onsite disposal or re-use systems for their waste water.

However, an alternate view is that greywater re-use or onsite treatment should not be used to down size or replace the sanitary sewer system. Caution should be exercised by water authorities as the towns and cities in Australia will follow the trends of the rest of the world. That is, they will ever increase in population, growing both up and out. The present city fringe residential developments will in the not too distant future become heavily populated. There will then be limited green space to re-use the waste produced. Onsite treatment and re-use will no longer be possible and retrofitting the area with sanitary sewers will be far more expensive than if they where constructed in the beginning (Okun, 1994)

5.3 Greywater to stabilise building foundations

Reactive soils when used for building foundations are subject to movement through variations in moisture content. This movement can cause cracking and failure of footings and walls, and in extreme cases the structure its self. Reactive soils typically have a high clay content, but also include black soils. These soils will swell or shrink as the moisture content increases or decreases respectively. This problem generally becomes most evident during extreme dry periods. Trees seeking water, upset the fine moisture balance beneath the foundations causing excessive shrinkage of the soil. In the less extreme cases, cracks generally close when the moisture content again stabilises eg: after rain.

Greywater used to stabilise foundation soils may be a suitable option. Before this measure is taken further research is required to evaluate the following:

- Application rates for different soil types,
- the impact of anaerobic waste water accumulating around the foundations,
- the potential to encourage tree root growth beneath the footings.

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