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SKM

KAPITI COAST DISTRICT COUNCIL

Greywater Reuse Risk Assessment

- Revision 1
- 19 May 2008

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Summary

The water resource issues facing the Kapiti Coast District are unique in New Zealand. In a push to improve water conservation in new homes, Kapiti Coast District Council (KCDC) and SKM undertook joint research to assess the potential benefits of rainwater tanks. Modelling by SKM suggested that a small rainwater tank and a greywater reuse system would optimise water conservation.

KCDC proposed plan change 75, to mandate the installation of either a 10,000 Litre Rainwater Tank for toilet flushing and outdoor use *or* a 4,500 litre Rainwater Tank for toilet flushing and outdoor use **and** a greywater dispersal system for outdoor subsoil irrigation.

The proposed revision to the building act in July 2007 raised concerns about greywater reuse, however. As a result SKM was engaged to prepare a risk assessment focussing on environmental aspects of greywater reuse, Ormiston and Associates were engaged to prepare a separate report focussing on greywater characteristics and public health risks.

KCDC raised seven distinct areas of concern for SKM to investigate, they were:

- What Impact will greywater have on the different Kapiti Soils? Is greywater reuse suitable in all soils and terrain?
- What processes can the Council implement to ensure the greywater discharge will not cause damage to the soil or cause surface ponding?
- What Impact will greywater have on the water use and disposal over time?
- Are the provisions in the Greater Wellington Regional Council "Discharge to land" provisions adequate to protect the water cycles?
- What source control measures can people do to reduce impact of greywater on natural systems?
- Is the NSW Health document suitable in avoiding, mitigating or remedying the risks greywater poses to the wider environment?

After a review of domestic and foreign greywater reuse literature, SKM identified areas unique to New Zealand and specifically the Kapiti Coast where further work is required. The following recommendations are made:

- KCDC must prepare their own regulations and a code of practice tailored to the Kapiti Coast focusing on one technology (sub surface irrigation, with soil moisture probe and automatic diversion).
- Installation of greywater systems must be part of the building consent process and be inspected by trained council staff.

- Sources of Greywater should not include any water from the Kitchen, Toilet or the Laundry sink.
- Public education will be vital to the sustainability of greywater reuse.
- A study to establishing the true concentrations of various constituents in greywater would make greywater reuse management more effective.
- Preliminary and ongoing soil and drinking water source testing, must be implemented
- The preparation of GIS plans can be used to identify areas that are or are not suitable for greywater reuse from the range of criteria identified in this report and of ongoing testing.

Once these recommendations have been followed up SKM believes a properly installed and maintained subsurface greywater irrigation system can successfully isolate or minimise the risks highlighted in this and the Ormiston and Associates report, in areas where greywater reuse is deemed appropriate.

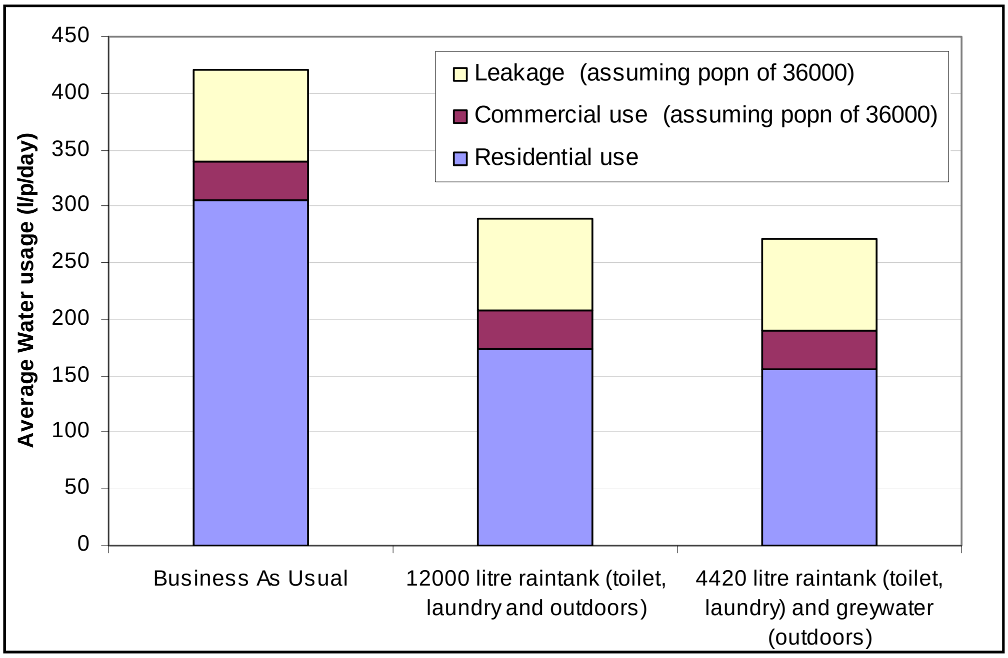
Introduction

Background to Plan Change 75

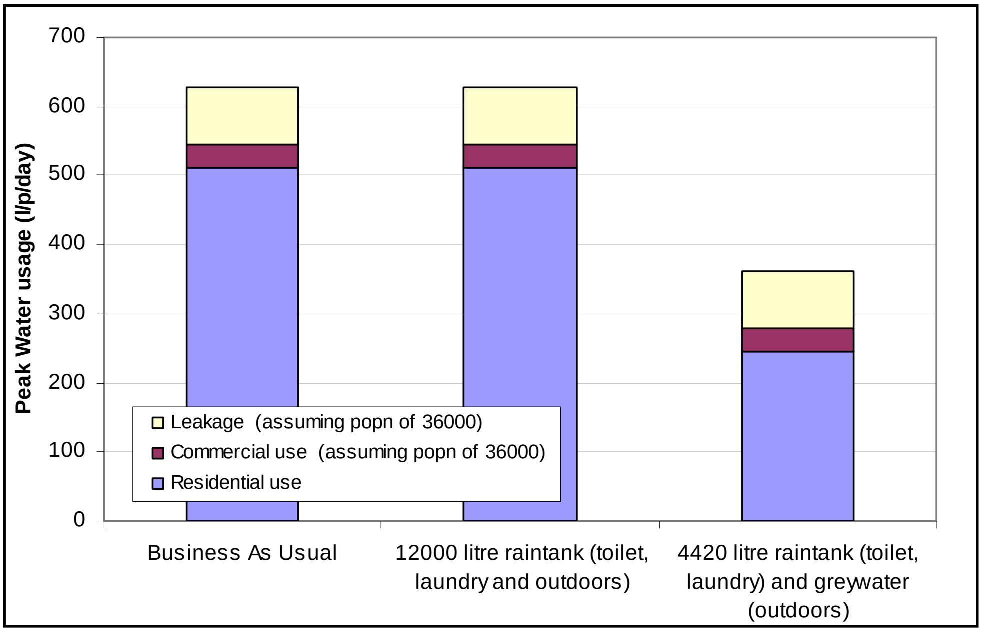
In July 2007 Kapiti Coast District Council (KCDC) proposed plan change 75, which would mandate that rainwater collection tanks be installed with all new dwellings as a method of water conservation. The draft plan change suggested a typical raintank of 10,000 litres would be appropriate but there was little science to back up the benefits associated with raintanks of this size. In order to quantify the benefit of the proposed raintanks, and optimise their size for the Kapiti rainfall profile, KCDC and SKM partnered to undertake some joint research to assess the potential benefits of rainwater tanks.

SKM carried out the modelling using the University of Newcastle's Probabilistic Urban Rainwater and Wastewater Reuse Simulator (PURRS) modelling package.

From the PURRS modelling in SKM 2008 (see Figure 1, below) the addition of a rain tank was estimated to reduce total average consumption by 33% from 420l/person/day to 280l/person/day. However during the modelling it became apparent that while a rainwater tank is an efficient way of reducing average water consumption, it achieves very little in terms of reducing peak summer demand (Figure 2).



- **Figure 1 Average Watermain Usage (SKM 2008)**



- **Figure 2 Peak Watermain Usage (SKM 2008)**

After discussions and further research, SKM introduced greywater recycling as an option for peak demand management. Figure 2 shows the benefit of incorporating greywater systems, with a reduction of peak water demand from mains network of 43%. The incorporation of greywater recycling also allowed homeowners to select a much smaller raintank as it was no longer required to service the majority of outdoor water use.

In response to these findings KCDC prepared a revised plan change 75, which will mandate the installation of either a 10,000 litre rainwater tank for toilet flushing and outdoor use *or* a 4,500 litre rainwater tank for toilet flushing and outdoor use **and** a greywater dispersal system for outdoor subsoil irrigation.

The Building Act

In July 2007 a draft revision of the building code was circulated for comment. The draft of the code stated that: "*We do not envisage greywater recycling for domestic use being economic, nor necessary in New Zealand for water conservation.*"

The revision of the building code went on to state that "*The level of pathogens in greywater for re-use as measured by microbial indicators shall be less than 1 E.coli/100 ml*" Which is the same as the level of *E.coli* in the drinking water standards.

When compared to the findings in the PURRS analysis (SKM, 2008) the codes statement is inaccurate for the KCDC situation as greywater has been shown to have the potential to significantly reduce peak potable water use at times when Kapiti's finite water supply resource is under stress.

In response to the concerns raised in the review of the building code, and due to the clear benefits of incorporating greywater into future urban development, KCDC commissioned SKM to carry out a risk assessment on the proposed greywater irrigation system from an engineering perspective. Ormiston and Associates were also engaged to carry out a risk assessments from a public health perspective.

SKM Literature Review / Risk Assessment

This literature review is part of the proposed change to the district plan, (Plan Change 75), to introduce water conservation methods in new subdivisions and in areas where zone changes occur. To investigate the risks that may be introduced by greywater reuse, the literature review / risk assessment was commissioned. The proposed research would enable council to make an informed decision about the proposed plan change, offsetting risks and benefits, and provide them with some direction for further research on the effects of greywater for Kapiti.

Issues Raised

Council raised seven key issues that may arise from widespread greywater reuse which they wished to form the risk assessment, they are:

1) What Impact will greywater have on the different Kapiti Soils?
2) Is greywater reuse suitable in all soils and terrain?
3) What processes can the Council implement to ensure the greywater discharge will not cause damage to the soil or cause surface ponding?
4) What Impact will greywater have on the water use and disposal over time?
5) Are the provisions in the Greater Wellington Regional Council "Discharge to land" provisions adequate to protect the water cycles?
6) What source control measures can people do to reduce impact of greywater on natural systems?
7) Is the NSW Health document suitable in avoiding, mitigating or remedying the risks greywater poses to the wider environment?

SKM used experience in hydrology, municipal engineering, groundwater engineering, geotechnical engineering and planning to complete this review.

Geology and Topography

Geology and Permeability

Permeability is the ability of soils and rock to transmit a fluid. It is dependant on the size of the pore spaces between soil and rock particles and their connectedness. It is essential when assessing the suitability of greywater use to take into account the permeability of the local soils. If the soils are highly permeable this could increase the risk of contamination of the underlying groundwater. If the soils are impermeable, there is a risk of surface waterlogging.

Kapiti Coast Geological setting

The Kapiti coastal plain flanks the Tararua Range to the east. The landforms and depositional sequence have been formed by climatic fluctuations during the Quaternary period. Deposition on the coastal plain occurred during glacial periods as a result of erosion of the Tararua Range. Thick sequences of poorly sorted alluvial gravels were deposited as a result of subsidence of the greywacke basement by tectonic deformation.

Marine sediments were deposited on the coastal plain due to the transgression of the ocean during interglacial periods. Aeolian dune deposits have accumulated due to progradation of the coastline during the last 6500 years.

Greywacke basement rocks are indicated to be outcropping to the south and east of the area, consisting highly deformed and metamorphosed sedimentary rocks of Mid Permian to Mid Cretaceous age 9265-100 Ma.

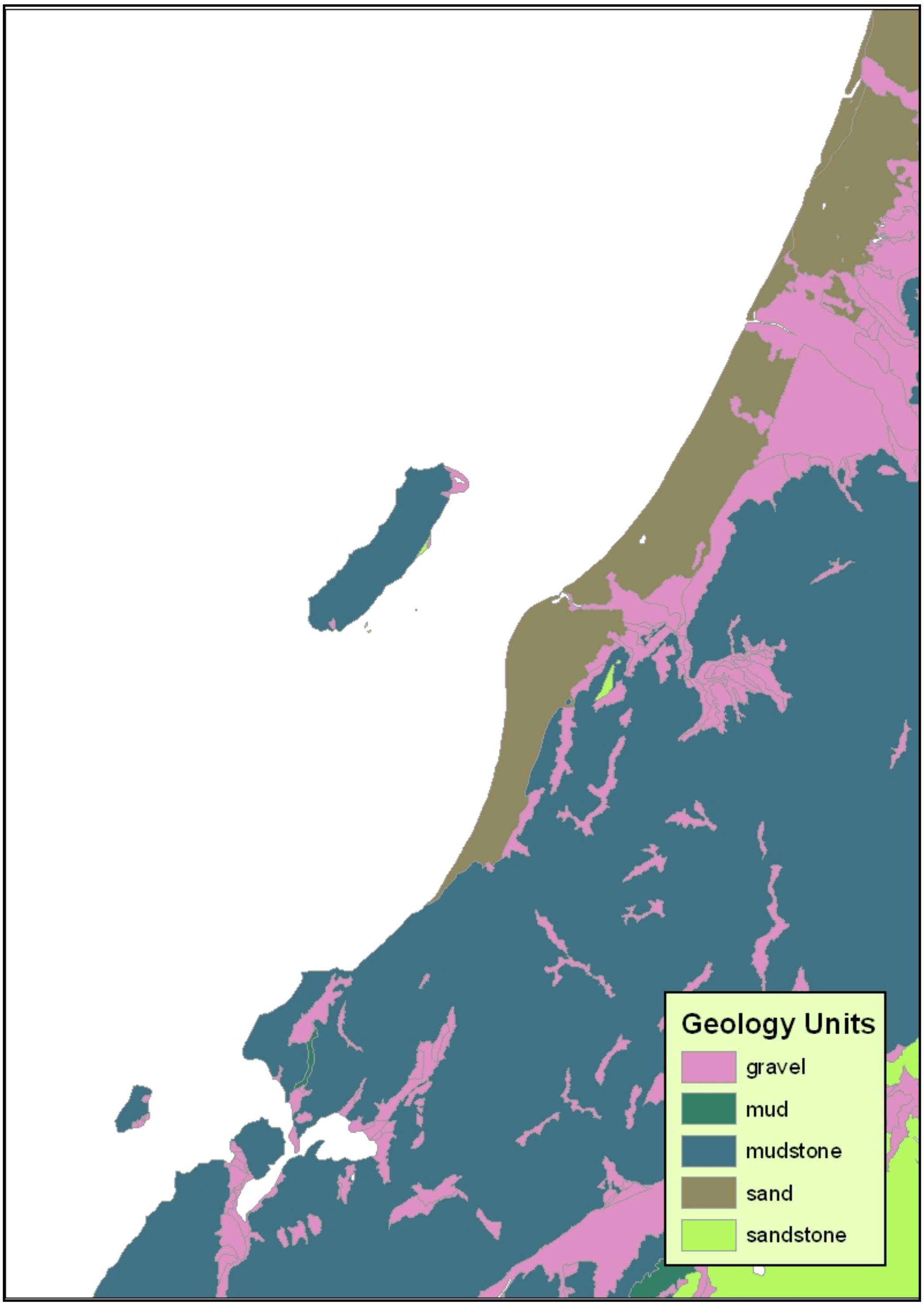
The following table indicates the main geology of the Kapiti district as detailed on the geological map.

Geological Code	Formation Characteristics	General Geographical Area
Q1a	Well sorted floodplain gravels Poorly sorted alluvial fan, scree and colluvium gravels	River Floodplains
Q2a/Q3a	Poorly/moderately sorted gravels with minor sand/silt underlying terraces Poorly sorted fan gravels	Te Horo, Southern Levin

Q6a/Q8a	Poorly/moderately sorted gravels, underlying loess (wind blown silt) covered aggradational (depositional) surfaces	Otaki River area
Q1d	Aeolian dunes (wind blown dune sand)	Along coastline
Q5b	Beach deposits – marine gravel and sand underlying loess & fan deposits	Northern Levin
uQ1	Landslide deposits (angular rock fragments in fine-grained matrix)	Small area to the east of Paekakariki
Tt	Greywacke (poorly bedded sandstone)	Inland areas in southeast

Soils in the Kapiti Coast District Council area consist of sand, grading inland to sand and gravel or gravel. To the east and southeast, Greywacke bedrock is indicated with no overlying superficial deposits. Faults in the Greywacke, especially around Paraparaumu and Waikanae, as well as intermittent belts of broken formation, are indicated throughout the Kapiti area. The greywacke in these areas are likely to be fractured.

In summary, the soils of the Kapiti district are generally sands and gravels which are likely to be highly permeable. Inland areas to the east are indicated to be rock at or near the surface. The bedrock is likely to be permeable in fractured areas and impermeable in unfractured areas.



- **Figure 1: Geology of the Kapiti Area**

Sub Surface Irrigation.

On-Site Disposal

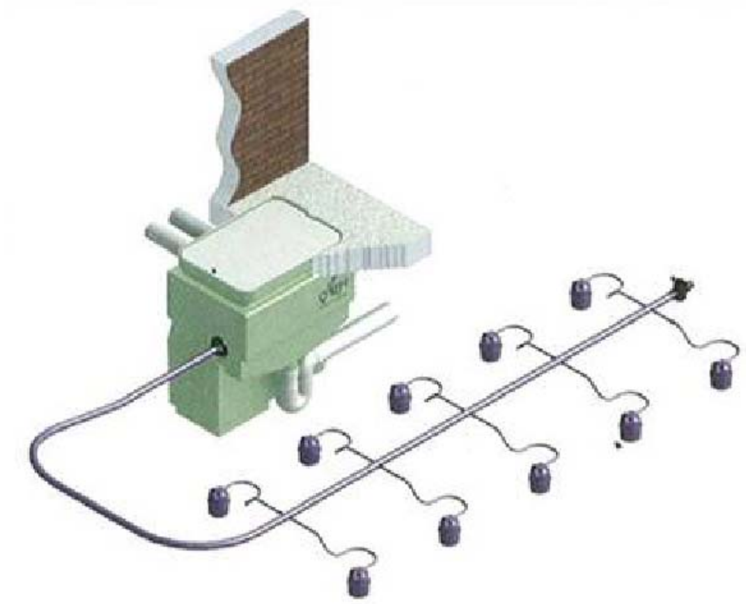
The relevant standard governing on-site disposal is AS/NZS 1547:2000: On-site domestic wastewater management. While this deals with treated effluents, typically wastewater, the latest draft revision of AS/NZS 1547 (v6.0 DR07920) states that: "Although this Standard covers the subsurface land-application of greywater after primary treatment, it does not cover greywater reuse by the direct application onto land or by other means, nor does it provide details of greywater diversion systems."

Subsurface Irrigation

Subsurface irrigation is an efficient watering technique. Systems consist of irrigation tubing or pods and irrigation tubing placed underground at the root depth of approximately 200mm. The water goes straight to the roots of plants, reducing evapotranspiration and runoff.

Subsurface Greywater Irrigation Systems

The proposed greywater system to be installed in conjunction with rainwater tanks is a subsurface irrigation network that automatically distributes greywater to the garden. Recycled water is not stored in a holding tank, (thereby reducing the risk of pathogens developing in storage) but immediately diverted under the garden after preliminary treatment (removal of large solids). An example of the subsurface irrigation system is shown in Figure 2 below.



- **Figure 2: A subsurface irrigation network**

It is vital that greywater system installations meet the required standards allowing diversion to the wastewater network for overflows and during periods of rain. Automated systems, with automatic switching would be preferable.

Similar systems to the one described above were tested by Veneman (2002) in Commercial applications in the US. It was found that the systems were highly effective at utilising the soil to remove indicator organisms and Nitrogen.

Research of the overseas systems suggests that similar (untreated) greywater systems are extensively in use with no evidence of disease resulting from single dwelling greywater reuse systems Brown (2007). Research of the German experience where they have had greywater recycling in Berlin for in excess of 10 years, shows most greywater (for irrigation, toilet flushing and cleaning) is typically treated by small package Sequenced Batch Reactors (SBRs), prior to reuse.

Greywater

Constituents

In its simplest form greywater is defined as domestic wastewater excluding toilet waste and may include wastewater arising from

- A hand basin
- Kitchen
- Bath and shower
- Laundry

A more in depth analysis of the constituent properties and characteristics of greywater flow can be found in the Ormiston and Associates report.

Kitchen Greywater

"Kitchen wastewater is heavily polluted physically with food particles, oils, fats, and other highly pollutant waste and is often more pollutant than blackwater or raw sewage. It readily promotes and supports the growth of micro-organisms. Because of the solid food particles and because fats can solidify kitchen wastewater may cause blockages in land application systems unless treated or removed from greywater.

Microbiologically, extremely high concentrations of thermotolerant coliforms ($2x10^9$ cfu/100mL) have been found in kitchen greywater but the more usual concentrations appear to be in the range of less than 10 to 10^6cfu/100mL. Such high levels are again indicative of raw sewage and on occasions kitchen greywater may be more contaminated with micro-organisms than raw sewage. The high thermotolerant coliform concentrations sometimes found in kitchen greywater is cause for concern and must be managed effectively to prevent disease transmission. Kitchen greywater is chemically polluted as it also contains detergents and cleaning agents and where dishwashers are used the greywater is very alkaline from the detergent. Kitchen greywater may be harmful to soils by altering its characteristics in the longer term." NSWHealth (2000)

Bathroom

"The bathroom (hand basin, shower and bath) generates about 38% of the household wastewater flow (55% of greywater) and is considered to be the least contaminated type of greywater. Microbiologically, thermotolerant coliform concentrations have been assessed in shower and bath water to be in the range of 10^4 to 10^6 cfu/100mL. As people often urinate in showers and baths concern is often expressed about the increased health aspects of inappropriate disposal. While urine in a healthy person is sterile, some bladder infections may pass microorganisms in urine. However, the potential for these organisms to survive and cause infection is considered remote. The ammonia in urine is beneficial to plants but may harm the environment if not adequately dispersed. Wastewater from hand basins is more pollutant than bath or shower greywater. Soap is the most common chemical contaminant found in bathroom greywater and other common contaminants are from shampoo, hair dyes, toothpaste and cleaning chemicals. All of these contaminants are believed to adversely affect land applications systems and are difficult to remove from the wastewater. Biocidal soaps have little effect on reducing the bacterial load in greywater." NSWHealth (2000)

Laundry

"Laundry wastewater represents about 23% of household wastewater (34% of greywater). Greywater from the laundry improves in quality from wash water to first rinse water to second rinse water. Microbiologically, thermotolerant coliform loads varied from 10^7 cfu/100mL when nappies were washed to 25 cfu/100mL for 2nd rinse water. Wash cycle water contains higher chemical concentrations from soap powders and soiled clothes (sodium, phosphate, boron, surfactants, ammonia, nitrogen) and is high in suspended solids, lint, turbidity and oxygen demand and if applied to land untreated can lead to environmental damage as well as posing a threat to public health. 1st rinse and 2nd rinse laundry greywater still contain a pollutant load and still pose a threat to public health, although greatly reduced. Also the laundry tub is sometimes used to irresponsibly ……. dispose of harmful substances such as paints, solvents, pesticide and herbicide residues further increasing the pollutant potential. Domestic pets which may often be washed in the laundry tub are a further source of contamination." NSWHealth (2000)

A-Boal *et al* (1995) found that the physical and chemical parameters such as pH, salinity, sodium and aluminium content reached unacceptably high levels when compared with standard wastewater irrigation guidelines (e.g., Environment Protection Authority Victoria, 1991). These levels were observed particularly in the laundry greywater samples and were clearly related to the compounds in the laundry detergents.

Patterson (2006) found that labelling and industry standards around the use of Phosphorous, Sodium and pH in laundry detergents are lacking. The research included analysis of 54 powder and 41 liquid laundry detergents, it highlighted the variability in Sodium and Phosphorus concentrations in laundry detergents, especially in powder form. It should be noted that some liquid detergents have lower levels of Phosphorous and Sodium making them more appropriate for reuse.

General Characteristics

The variability of greywater characteristics are of concern, research and the Ormiston Associate report commonly identifies variability in the characteristics of the greywater at a given site. This quality may present problems in designing irrigation systems correctly. A study with a large population base may be appropriate and of use nationally to more accurately define the characteristics, identify reasons for variability and margins of variability.

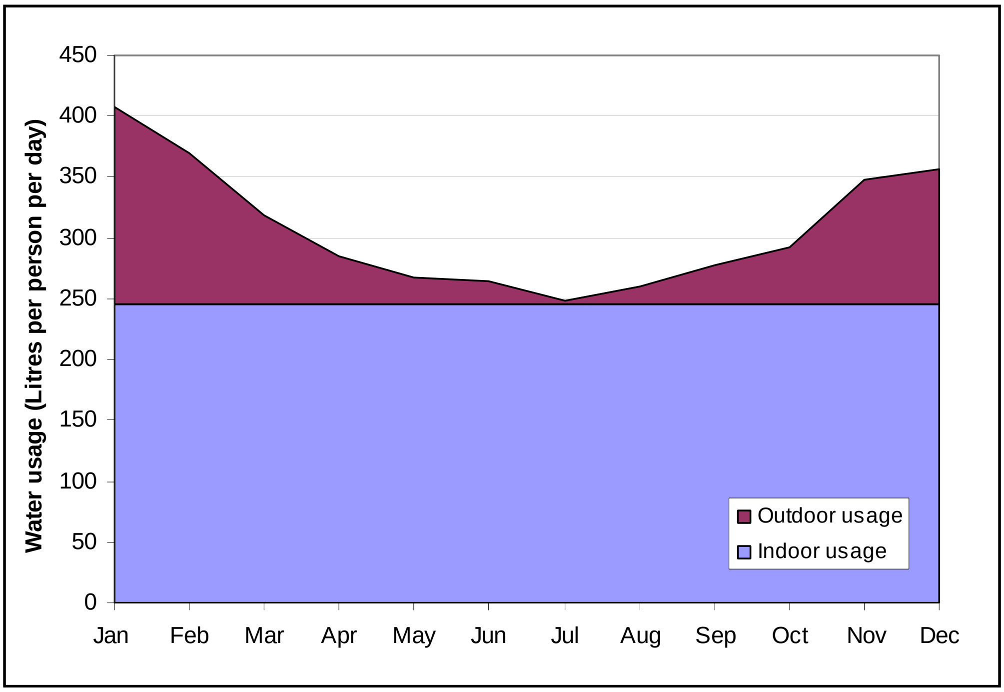
Flows

Wastewater flows are typically divided as in Table 1, below:

- **Table 1 Indoor Distribution of Wastewater (SKM 2008)**

Category	Percentage of Daily Indoor Water Use
Kitchen	7
Bathroom	18
Laundry	18
Toilet	25
Hot Water	32

A typical indoor water use in Kapiti is 245 Litres per person per day (SKM 2008). Approximately 68% of this indoor flow is deemed reusable for greywater (remembering Toilet and Kitchen water is unsuitable for reuse due to high microbiological, fats and solids concentrations, and we are excluding laundry sinks to reduce the potential for solvents etc.). Typically there will be in the order of 160L/p/day available for greywater reuse. Refer to Figure , below for the typical demand profile of indoor and outdoor mains water use.



- **Figure 3: Monthly demand for water distributed between indoor and outdoor uses (SKM 2008)**

Managing Greywater Sources

The proposed greywater irrigation system only has preliminary treatment (large solids removal). The high microbiological, fats and solids concentrations present in kitchen greywater make it unsuitable for untreated greywater reuse. For this reason the kitchen will not be considered as a source of greywater.

The probability and risk of human exposure to pathogenic bacteria from bathroom greywater is considered low with the proposed subsurface greywater reuse system. Given the large quantities of bathroom greywater, it is included in the proposed reuse scheme. Resident education is required to ensure no potentially harmful cleaning products are used.

Given the risks identified in the literature review process, SKM proposes to exclude the greywater from laundry sinks in the proposed scheme. It is considered that the quality and relative quantity of laundry sink water does not warrant the possible chemical and biological risks it poses.

While concerns are raised in the literature about the quality of washing machine water, with resident education the chemical risks can be managed at a point source level. If nappies are washed the greywater system must be diverted to the sewer.

Risk Assessment

What impact will greywater have on the different Kapiti Soils?

Greywater will have an impact on all of Kapiti's soil, this effect has not been determined in a New Zealand context Lenoard *et al* (2005). Overseas research, mostly from Australia suggests that the type of soil, greywater quality and the greywater application rates will govern the impact that greywater will have. Greywater will typically affect the soil either chemically or hydrologically.

Chemically Effects

Soil chemistry governs the ability of a given soil to retain or release ions (nutrients). Ions are vital for plant and microbial life in the soil, which in turn allow the removal, or transportation of these ions. Most soil chemistry is governed by the soil and soil components electric charge. The development of electric charge in soils is associated with the small colloidal particles of both organic and inorganic soil constituents. The charge arising from these materials can be separated into two categories, permanent charge and pH-dependant variable charge.

Permanent charge in soil arises from the substitution of minerals within clay. Typically soil carries a net negative charge, allowing for the retention of positively charged ions such as Potassium or Sodium.

Variable charge in soil arises from the ionic charge of the acid or base added to the soil. Low pH values in the soil will mean that the soil will have a net positive charge while a high pH will mean the soil will have a net negative charge.

Cation (positively charged ions) exchange is the process by which cations are exchanged with soil particles, either by:

- Addition through wastewater or fertiliser
- Uptake by the roots of a plant
- Uptake and then subsequent immobilization by micro-organisms

Anion (negatively charged ions) e.g. phosphate or chloride, can be either exchanged like cations or retained by adsorption.

Overloading nutrients

Nitrogen Leaching

The majority of nitrogen is retained in the soil for plant up take, nitrate (NO_3-), however, is not retained by the soil, due to its negative charge it is repelled by the cation exchange sites. Therefore it is readily leached through the soil.

In most areas of New Zealand nitrate leaching occurs mainly in late autumn, winter and early spring when there is an excess of rainfall over evapotranspiration. During this time Nitrogen uptake is at its lowest by plants and nitrate may be present in significant quantities.

Soil structure has a vital role to play in leaching rates, with sandy soils, for example far more readily leech nitrate than clay soil would under the same climatic conditions.

Ongoing monitoring of drinking water sources must be conducted and safety zones around drinking water sources must be carefully planned.

Phosphorous Leaching

Phosphorous is a vital plant nutrient that aids in plant growth. In most situations phosphorous is immobile in soil, but leaching can occur in sandy soils. Phosphorous has no known direct human health effects, but it is often the limiting factor in algal growth, meaning if concentrations are kept to a minimum algal growth can be controlled.

Boron Toxicity

Boron is a vital micronutrient to plants. I can, however, become toxic to plants at concentrations little more than the minimum required.

Altering Salinity

Soil salinity is measured by its electrical conductivity in microSiemens per centimetre (mS/cm) or by measuring the total dissolved solids.

Soils are not typically affected by salinity in New Zealand. Irrigation of water with a salt content can raise the salinity, when the salinity exceeds 4 mS/cm it is considered saline. Salinity affects osmosis, ion toxicity and can degrade physical soil conditions. Salt accumulation can be especially detrimental to young plants where relatively low concentrations can cause damage.

When examining greywater use, the build up of sodium, chloride and boron ions in the soil are of concern as these ions can be phototoxic in high concentrations. Household detergents contain boron and water softeners contain sodium and chloride. Toxicity is increased if plants are irrigated during periods of high temperature and low humidity. Saline water can cause leaf damage if applied to the plant’s leaves. Salinity reduces water uptake in plants by decreasing the osmotic potential of the soil. Subsequently, the plant has to use more energy to obtain water and therefore has less energy available for growth.

The relative effect of greywater on soil salinity depends greatly on the detergents (whose sodium concentration varies greatly Patterson, 2006).

Cation Exchange Capacity

Cation Exchange Capacity (CEC) is a quantifiable measure of the soils ability to hold exchangeable cations, i.e. the quantity of negative charges existing on the surfaces of clay and organic matter. CEC is measured in centimoles of positive charge per kilogramme of soil or cmol/Kg. Many essential plant nutrients exist in the soil as cations and are accumulated by plants in this form. Typical values of CEC in New Zealand vary from 5 to 30cmol/Kg. The higher the clay and organic content of the soil the higher the CEC.

CEC of the Kapiti's soils is assumed to be low, due to the lack of clay and organic matter in sand/gravel. Weathered Greywacke could have higher CEC than clay. Levels of organic matter, however, would be low in weathered rock. This lack of CEC may mean nutrients are not retained in the soil and instead are leached.

A positive long term outcome of greywater application is that the organic layer would build up from the nutrients present in the greywater. In time this would increase the CEC.

Anion Exchange & Adsorption

Although most soils carry a net negative charge, individual sites on a soil colloid may be net positively charged, allowing the exchange of Anions much like Cations are on colloids.

Anion adsorption is the process where by an anion becomes attached to the external or internal surfaces of soil particles and become less readily available for plant uptake and leaching. This form of adsorption creates a chemical bond between the soil and the anion.

pH / Sodacity

Alkalinity and acidity of the soil is measured by pH. The typical pH value of healthy soil is between 4.5 and 8.5. For many plants optimum plant growth occurs at pH 6-7. Some laundry detergents have a high pH, the addition of which may affect plant health. Greywater pH varies between 5 and 10, with the mean being reported as 8.1, however, the sample sizes and standard deviations are unknown, with literature commonly commenting on the variability of pH from site to site.

Soil sodacity describes the sodium concentration in the soil, it is represented as exchangeable sodium percentage (ESP). Soils which have over 13% of their CEC taken by ESP are considered sodic soils. When the soil becomes sodic the soil structure begins to break down and the colloidal organic matter dissolves. High sodium concentrations change the soil structure and can lower the natural permeability by impairing the infiltration of water into the soil.

Greywater discharge pH will vary depending on the detergents and soaps that residents are using. pH will affect solubility and fixation of some nutrients in soils. Increased pH increases CEC. A pH of range of 4.5 to 8.5 is suitable depending on the plants, greywater will typically increase pH.

Physical Effects

Becoming Permanently Boggy

If greywater is discharged year around it may lead to the soil becoming permanently boggy. Greywater reuse should not be permitted in extended periods of wet weather. During this time greywater should discharge to the sewer. Soils along coastal areas of Kapiti are sand, grading inland to gravel so if the depth to rock head is greater than 1m, in many places the land becoming boggy is not a major risk. However there are also significant parts of the region where development has either occurred, or is being promoted, in areas periodically affected by high groundwater levels. Some consideration of groundwater levels will need to be given in identifying areas appropriate for groundwater disposal.

Further east, Greywacke is indicated with no overlying drift deposits. The presence of faults in the Greywacke, especially around Paraparaumu and Waikanae infer that the greywacke in this area is likely to be fractured. Belts of broken formation and belts of broken formation and coherent strata are also indicated throughout the rest of the Kapiti area. Therefore, the bedrock is likely to be porous in fractured areas and impermeable (leading to possible waterlogging) in coherent areas.

As mentioned early in this report SKM recommends that greywater systems have a soil moisture probe to automatically divert the greywater to the sewer when the soil is saturated.

Permeability

If greywater salinity is too high this may lead to a collapse of the soil structure increasing the soil permeability.

Is greywater reuse suitable in all soils and terrain?

Some planning will be required before the go ahead can be given for greywater reuse. In short, greywater reuse is not suitable on all sites and terrain, however a GIS prepared system, in conjunction with flood hazard maps, New Zealand Soil Maps etc, would highlight the areas where greywater reuse would be appropriate.

Table 2, below, provides a description of possible risks and consequences.

▪ **Table 2: Greywater Reuse Risk / Limitation Matrix (Queensland, 2007)**

Site feature	Minor Limitation	Moderate Limitation	Major Limitation	Problem
Flood potential	Below 1:100 year usage	Below 1:20 year usage		High runoff and contamination risk
Exposure	High sun and wind exposure		Low sun and wind exposure	Poor evapotranspiration
Slope %	0–10	10–20	>20	Run-off, erosion
Landform	Hill crest, convex side slows and plains	Concave side slopes & foot slopes	Drainage plains and incised channels	Groundwater pollution hazard Resurfacing hazard
Run-on and upslope seepage	None–low	Moderate	High–diversion not practicable	High runoff and contamination risk
Erosion potential	No signs of erosion potential present		Signs of erosion, eg rills, mass movement and slope failure, present	Soil degradation and transport, system failure
Site drainage	No visible signs of surface dampness		Visible signs of surface dampness, such as moisture–tolerant vegetation (sedges and ferns), and seepages, soaks and springs	Groundwater pollution hazard Resurfacing hazard
Fill	No fill	Fill present		Subsidence, variable

				permeability
Buffer distance	See table 1 QPW code			Health and pollution
Land area	Area is available		Area is not available	Health and pollution risks
Rocks and rock outcrops (% of land surface containing rocks >200 mm diameter)	<10%	10–20%	>20%	Limits system performance
Geology/ regolith			Major geological discontinuities, fractured or highly porous regolith	Groundwater pollution hazard

- **Table 3 Greywater Reuse Risk / Limitation Matrix, Part 2 (Queensland, 2007)**

Soil Feature	Minor limitation	Moderate limitation	Major limitation	Restrictive feature
Depth to bedrock or hardpan (m)	>1.0	0.5 – 1.0	<0.5	Indicates potential for excessive runoff and/or water logging
Depth to high episodic/ or seasonal watertable (m)	>1.0	0.5 – 1.0	<0.5	Groundwater pollution hazard, resurfacing hazard
Soil permeability Category	2b, 3 and 4	2a, 5	1 and 6	Excessive runoff, water logging and percolation
Bulk density (g/cm3) Sandy loam	<1.8		>1.8	Indicates permeability

Loam & clay loam	<1.6		>1.6	
Clay	<1.4		>1.4	
Electrical conductivity (dS/m)	< 4	4 – 8	> 8	Excessive salinity undesirable

Topography

The topography of a potential greywater usage area requires assessment. There is a risk of erosion and run-off on slopes of more than 20%. Continuously discharging water entering the ground increases pore water pressure which can cause instability on sloping ground.

There is also the possibility of greywater runoff to other down hill sections. This may cause surface erosion and possibly slope instability as well as possible contamination off site.

Areas of existing landslide deposits, for example an area indicated on the geological map to the east of Paekakariki, should be excluded from greywater usage. Site specific observations should be undertaken to ensure that any other areas of landslide deposits are excluded.

Fill – Subsidence, variable permeability

There are no areas of fill indicated on the geological map. However, small areas of fill may have been locally placed throughout the area and ground conditions should be visually checked on each individual proposed site.

Rocks Outcrops

The surface area of a given site can have a maximum of 20% coverage of rocks > 200mm.

Depth to rock

If the depth to rock is too shallow it can result in water logging as water sits on top of rock. On sloping surfaces, this will result in run off. It can cause difficulty in trench and pipe installation

Major geological discontinuities, fractured or highly porous regolith

Belts of broken formation due to tectonic movement are indicated on the geological map throughout the Kapiti area. Faults concentrated in Paraparaumu and Waikanae areas. Fractures and faults may act as preferential pathways for the greywater to contaminate underlying groundwater. Unfractured outcropping Greywacke can result in water logging as water sits on top of rock. On sloping surfaces, this may result in run off and subsequent erosion. Soils are sand, gravel or sandy gravel. These soils are likely to be highly permeable resulting in excessive percolation. Groundwater pollution risk by nutrients and pathogens exists in these areas. It is recommended that the properties of the soil be tested to ascertain the potential of soil to absorb water i.e. bulk density indicates permeability.

Groundwater Depth

The depth to water table is a critical consideration. If the water table is too shallow, there is risk of groundwater pollution

Buffer Distance

Buffer distances will have to be established to ensure greywater does not seep into a water body. The GWRC provisions require a minimum distance of 20m. Buffer distances based on predicted flood levels should also be considered.

Texture

Some clays may not be suitable due their low permeability, poor infiltrability, and internal drainage. A very sandy soil may also be unsuitable due to the lack of cation exchange and anion adsorption sites.

What process can the Council implement to ensure the greywater discharge will not cause damage to the soil or cause surface ponding?

As discussed in the previous section a carefully prepared GIS plan would play a major part in eliminating areas where greywater reuse is not feasible (i.e. below a given level in the flood hazard plans), due to the risk of ponding.

Soils with existing dampness must not be irrigated with greywater. Ideally sites need to maximise evapotranspiration, by being exposed to sun and wind.

Sensible restrictions should be placed on the application rates of greywater on a given site with a given soil type. Queensland (2006) provides some sample calculations of how a greywater system can be sized for a given residential site. Similar fact sheets could be prepared for relevant stakeholders in the KCDC area.

Care must be taken in how each property is granted the right to install a greywater reuse system. SKM consider that any new greywater system must be commissioned through a building consent process whereby physical aspects of the system can be inspected by qualified council staff.

Actual damage of the soil may occur due to chemical processes. Sodium concentration in the soil is critical to the soils well being. If the sodium concentration becomes too high it will displace calcium in the soil and cause deflocculation of the soil particles. This will result in the deterioration of the soil structure and decrease the soils infiltrability. This can be reversed by the addition of lime or gypsum. Therefore careful ongoing monitoring will be required on greywater reuse sites and public education to look out for the signs of something going wrong.

What impact will greywater have on the water use and disposal over time?

As discussed in the introduction the introduction of a greywater system and a rain tank will reduce average water consumption 35% in a property with greywater reuse, most of this is reduction is due to the rain tank, however. The impact of a greywater system is mainly noticed during peak water demand (from the mains) when the demand will be reduced by 43%.

Wastewater flows will be reduced while the greywater system is active, most likely during the last two months of spring, summer and the first two months of autumn. 32% of indoor demand is for the toilet and the kitchen. As these sources are not appropriate for greywater reuse, the remaining 68% is readily available as a greywater source. Assuming favourable ground conditions this 68% could be diverted from the wastewater network, significantly reducing wastewater flows over the summer months.

During this period, if greywater is widely in place, sections of the wastewater network *may* not achieve self cleansing velocities. Without investigating the wastewater networks, infiltrations rates and network gradients, this is conjecture to some extent. This is perhaps the biggest area of concern for large scale greywater reuse in the short term. This risk can be dealt with by changes to design codes to ensure wastewater networks remain effective in operation.

Are the provisions in the Greater Wellington Regional Council "Discharge to land" provisions adequate to protect the water cycles?

Greater Wellington Regional Council (GWRC) discharges to land provisions, relating to greywater, are as follows:

Rule 1: discharge of contaminants not entering water is a **Permitted activity.**

> *Option 4:* outlines the uses and dispersal of a greywater system for outdoor subsoil irrigation; as the greywater is not directly entering a water body, it is therefore a **permitted activity.**

Rule 4: Grey-water is allowed to be discharged onto or into land as a **permitted activity** provided **(conditions for the discharge of grey water)**:

a) Does not exceed a maximum daily volume of 2000 litres;
b) Is more than 20m from any surface water body, farm drain, water supply race or the coastal marine area; and
c) Does not cause ponding on, or runoff from the disposal area.

Definition of Greywater

> '*the wastewater from sinks, basins, baths, showers and similar appliances, but not including any toilet wastes. Also known as sullage.*'

The Daily limit set in rule 4 is too high to effectively or safely govern greywater reuse.

If 2,000 L/day were discharged on a 500m² sandy section for example with a 150m² footprint home. AS/NZS 1547:2000 states the Design Irrigation Rate (DIR) for sand is 35mm/week, the area required for irrigation would be:

$$Area = \frac{2000\frac{l}{day} \times 7days}{35mm/week} = 400m^2$$

This is obviously not possible on the example site may lead to irrigation system that overloads the soil as people take advantage of the 2,000L/day limit.

At the rates recommended in the PURRS Report (70% of the indoor flow of 245L/person/day SKM, 2008) the site would be expected to treat the flows for an average of 2.4 people, therefore 0.7x2.4x245=411 L/day. Requiring an area of:

$$Area = \frac{411\frac{l}{day} \times 7days}{35mm/week} = 82m^2$$

This clearly shows that the 2,000L is too high to be an effective policing tool.

While the provisions also state that greywater application must not cause runoff or ponding on the site. Without proper design as outlined above the level of greywater application maybe too high

KCDC must ensure that the consenting for greywater reuse take more into account than the simplistic GWRC provisions. Another factor that must be considered when applying restrictions is that a "one shoe fits all" approach will not exist and thought must be given to alternative development styles. The use of corporate body land as a possible irrigation area instead of only within the immediate section of the given home is an example of this.

Queensland (2007-2) raises a variety of restrictions on the potential locations for Greywater Reuse sites refer to Table 4, Table 5 and Table 6, below. These should be taken into account not only to more effectively protect the water cycle but also to protect the greater environmental and human health.

- **Table 4: Setback distances for subsurface land application area for a greywater treatment plant or an on-site sewage treatment plant**

Feature	Horizontal Separation Distance (metres)		
Distance from the edge of trench/bed excavation or subsurface irrigation distribution pipework to the nearest point of the feature	**Down slope**	**Up slope**	**Level**
Property boundaries, pedestrian paths, footings of buildings, walkways, recreation areas, retaining wall footings.	2	4	2
In ground swimming pools.	6	6	6
In ground potable water tank.	6*	6*	6*

* Note: For Primary effluent the distance from an in-ground potable water tank must be 15 metres.

- **Table 5: Setback distances from a greywater diversion device**

Feature	Setback Distance (meters)
Property boundaries, pedestrian paths, and driveways.	1.0
Footings of buildings.	1.5
Retaining wall footing.	1.0
In ground swimming pool surrounds.	1.0
In ground potable water tank.	6.0
Bores intended for human consumption.	30

- **Table 6: Setback distances for on-site sewerage facilities and (subsurface) greywater use facilities**

Feature	Separation Distance (meters)
Top of bank of permanent water `course; or Top of bank of Intermittent water course; or Top of bank of a lake, bay or estuary or, Top water level of a surface water source used for agriculture, aquaculture or stock purposes or; Easement boundary of unlined open stormwater drainage channel or drain. Bore or a dam used or likely to used for human and or domestic consumption	50
Unsaturated soil depth to a permanent water table (vertically)	1.2

What source control measures can people do to reduce impact of greywater on natural systems?

Source control is a vital part of the sustainability of greywater reuse. It must be ensured that any greywater reuse system can be simply switched over to the sewer, preferably automatically (with a manual override). It should be noted that this is a requirement of any greywater system in Queensland.

When a resident cleans their drains using a drain cleaning chemical, the resultant discharge would have significant impacts on the receiving soils and plants. People will need to be educated to switch over their reuse system to the reticulated sewer when ever using harsh chemicals.

Similarly, during the period of mid autumn to mid spring, the reuse system should constantly be diverted to the sewer to ensure that the ground does not become overloaded hydraulically, from increased rainfall. The lower temperatures will also result in reduced plant and microbiological activity, resulting in reduced nutrient uptake which may leach to groundwater as a result.

The selection of cleaning products, especially laundry detergent, can have a significant impact on the greywater quality. Literature suggests the selection of laundry products (preferably liquid) that are low in phosphorous, sodium and nitrogen.

Residents could also consider using washing machines and dishwashers that are designed to use both less water and less detergent.

Further resident education programmes should be run to educate people in what not to tip down the drain (especially when their greywater system is in use). Paint, for example could have a significant impact. Queensland (2007) suggests the following recommendations to residents:

- Valves to isolate sections of plumbing
- No use of the system in winter.
- Use products with 0.05% and less of phosphorous
- Laundry detergents low in sodium
- Liquid detergents are better
- US EPA recommends products with less than 0.75g/L of Boron
- No paints oils or greases
- No drain cleaners
- Avoid bleaches and softeners

A two year trial was run in Victoria, studying the impacts of domestic greywater systems, although to what standard they were designed and constructed is unknown. A-Boal *et al* (1995), suggests the following on-going maintenance was required for the good operation of a greywater irrigation system.

- Regular and time-consuming filter maintenance activities will be required. Other maintenance will be required from time to time.
- Access to screens and filters in under-floor tanks may prove difficult if they are constrained to locations that result in restrictions or limitations on clearances.
- Adequate skin and face protection measures should be used by persons servicing filters (and other components of the system which are "dirty").
- Filter residues (or disposable filters) must be disposed of in a safe manner.
- If greywater is to be used for irrigation, it is essential that appropriate soaps and detergents are used to minimise any likely environmental problems.
- Strong owner/resident interest and motivation will be required if systems are to be properly operated and maintained.

Is the NSW Health document suitable in avoiding, mitigating or remedying the risks greywater poses to the wider environment?

The soils in Kapiti also pose unique challenges and opportunities that are not covered in depth in the New South Wales Health document. While it is informative, so equally is the Queensland Government document (Queensland, 2007). Which is especially aimed at giving guidance to local councils on greywater reuse, it was released in December 2007 making it the most up to date document in Australia. It is recommended that work begins on a clean slate, taking sections from the likes of the NSW Health and Queensland Government documents, but focussing on Kapiti with local investigation, research and planning.

In general terms however, we believe that both of these codes are too permissive for us to follow in New Zealand. There are a number of potential impacts associated with greywater reuse that is covered by these codes that we do not believe will be readily acceptable in New Zealand.

SKM is recommending a specific technology (subsurface trickle irrigation) for greywater reuse in the Kapiti Coast District that reduces the great majority of risks associated with greywater. In particular the storage of greywater, and consequent requirement for greywater treatment systems that will have to be maintained and regulated, will increase the costs and risks associated with greywater. We believe it would be better for KCDC to begin by preparing a code of practice that covers the implementation of this low risk solution. As research is undertaken on the impacts associated with this solution, both in Kapiti and abroad, this could be reviewed and a more permissive code developed.

Recommendations

- KCDC must prepare their own regulations and a code of practice tailored to the Kapiti Coast focusing on one technology (sub surface irrigation, with soil moisture probe and automatic diversion).
- Installation of greywater systems must be part of the building consent process and be inspected by trained council staff.
- Sources of Greywater should not include any water from the Kitchen, Toilet or the Laundry sink.
- Public education will be vital to the sustainability of greywater reuse.
- A study to establishing the true concentrations of various constituents in greywater would make greywater reuse management more effective.
- Preliminary and ongoing soil and drinking water source testing, must be implemented
- The preparation of GIS plans can be used to identify areas that are or are not suitable for greywater reuse from the range of criteria identified in this report and of ongoing testing.
- Further work must be done on the effect of increased solids and fats content of wastewater on receiving private laterals and public sewers during periods of intense greywater reuse.

SKM believes a properly installed and maintained subsurface greywater irrigation system can successfully isolate or minimise the risks highlighted in this and the Ormiston and Associates report, in areas where greywater reuse is deemed appropriate.

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