TECHNICAL MEMORANDUM

on

GRAYWATER

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Executive Summary

Water supplies in the Las Vegas Valley area are becoming limited due to potential shortages in the Colorado River combined with continued population growth, and local agencies are interested in evaluating additional means of increasing their water portfolio. They recognize that the use of graywater may be a potential source of decreasing the demand on potable supplies and commissioned this technical memorandum to summarize available information on water quality, health considerations, regulatory standards/guidelines, and use of untreated graywater by homeowners for outside irrigation purposes.

Graywater is wastewater which is not expected to be grossly contaminated by feces or urine and is generally defined as all wastewater generated in a household except toilet wastes. This could include water from bathtubs, showers, kitchen and bathroom sinks, clothes washing machines, laundry tubs, and dishwashers; however, kitchen sinks and dishwaters usually are not incorporated into graywater flow due to high organic content that may cause oxygen depletion and increased microbial activity of the graywater and the possibility that the wastewater may contain food borne pathogens.

Graywater use is increasing in the United States, where as many as 7 percent of households report some use of graywater; many, particularly in rural areas, without obtaining regulatory permits or approval. Some large cities such as Los Angeles, allow the use of graywater, but the extent of the practice in large cities is not well-documented in the literature. While the main reason for implementing graywater systems is to reduce the overall use of potable water, at least one study determined that households that implemented graywater systems for garden irrigation actually increased their domestic water consumption by an average of more than 45 gallons/day. Untreated graywater is used for outside irrigation of turf, plants, or crops. Untreated graywater systems may be as simple as collecting and dispersing the water on single-family residential premises by buckets or may include much more sophisticated collection, piping, and dispersal systems with surge or storage tanks and coarse screening or filtering to remove particulate matter. The amount of graywater produced in a home varies from place to place, ranging from about 20 to 60 gallons/capita/day (50 to 150 gallons/household/day). Most homeowners do not use all of the available graywater produced in their homes, and actual quantities of graywater used are generally considerably less than the amount of graywater produced.

Graywater may contain: microorganisms (some of which are likely to be pathogenic); chemicals that include dissolved salts such as sodium, nitrogen, phosphates, and chloride, and organic chemicals such as oils, fats, milk, soap and detergents; or particles of dirt, food, lint, sand, etc. Graywater may also contain oils, paints, and solvents from household activities that could have detrimental effects on areas irrigated with the graywater. Graywater is contaminated with human and animal excretions from bathing, food preparation, and from clothes washing. Because it is not practical to analyze wastewater for all of the pathogenic organisms that may be present, sampling for organisms that are indicative of the presence of fecal contamination and the potential presence of pathogenic organisms originating from human fecal matter is universally used. Based on the high concentrations of indicator organisms found in graywater, all forms of graywater are deemed to be capable of transmitting disease, and pathogens have been found in some graywater sampled.

Several states have regulations directed at graywater use that generally are quite similar in their requirements. Use of untreated water from kitchens and dishwashers is often prohibited. Virtually all agencies that regulate graywater use state that untreated graywater is a hazardous substance that has a high probability of containing pathogenic microorganisms and caution that direct and indirect contact with the water presents a health risk. Most authorities emphasize that the introduction into the graywater of pathogens from the washing of heavily soiled laundry and diapers be avoided and that graywater should not be used when there is an infectious illness in the household (e.g. diarrhea, hepatitis, measles, or intestinal parasites).

Graywater contains many chemical constituents, such as nutrients, sodium, oils, fats, soaps and detergents, boron, and chlorides. Depending on concentration, many of these substances can be detrimental to plants and soil structure, although information is sparse as to whether some of these constituents will accumulate in soil to sufficient levels to harm plants or be transported past the root zone to groundwater. Graywater tends to be slightly alkaline, and many plants don't thrive if irrigated with graywater having elevated alkalinity. While many graywater systems have been in operation for a number of years with no observed detrimental effects on vegetation or soil, some harmful effects take many years to manifest themselves, and there is a lack of long-term studies on the effects of many of the chemicals and other parameters in graywater.

The costs of graywater systems vary with their complexity and capabilities. For untreated graywater systems, installation and operation costs range from a few hundred dollars to more than one thousand dollars, not including irrigation system costs.

Introduction

Where homeowner graywater systems have been implemented, the water is used either directly without any treatment or after treatment to improve the quality of the water. This document provides information on water quality, health considerations, regulatory standards/guidelines, and use of untreated graywater by homeowners for outside irrigation purposes. Untreated graywater systems on single-family residential property may be as simple as collecting and dispersing the water in buckets or may include much more sophisticated collection, piping, and dispersal systems that may include coarse screening or filtering to remove particulate matter and surge or storage tanks. Further, this technical memorandum focuses on potential health effects associated with graywater and provides minimal information on environmental effects (effects on soil, plants, etc.). Information related to graywater treatment systems is not included in this document. While state or local regulations or guidelines related to graywater exist in some areas, the amount of available information on graywater related to graywater quality and use is surprisingly sparse.

Controls on the construction and use of graywater systems are primarily based on the potential threat to human health and the potential long term impact of graywater on plants and the soil. Data reported in the literature consistently demonstrate that graywater contains high levels of pathogen indicator organisms and other potential pollutants. None of the publications reviewed indicated that untreated graywater is acceptable for toilet flushing or other uses within a home.

Household wastewater is divided into two distinct wastewater streams. Wastewater generated in a household that is grossly contaminated by feces or urine is called blackwater, i.e., wastewater from plumbing fixtures designed to receive human excrement or discharges, such as toilets and urinals. Graywater (sometimes called “greywater,” “gray water,” or “grey water”) is wastewater which is not expected to be grossly contaminated by feces or urine and is generally defined as all wastewater generated in a household except toilet wastes. This could include water from bathtubs, showers, kitchen and bathroom sinks, clothes washing machines, laundry tubs, and dishwashers. Kitchen sinks and dishwaters usually are not incorporated into graywater flow due to high organic content that may cause oxygen depletion and increased microbial activity of the graywater and the possibility that the wastewater may contain food borne pathogens.

Volume of Graywater Generated and Used

Household graywater use for landscape irrigation is increasing in the U.S. A literature review by Roesner et al., [2006] indicated that 7 percent of households in the U.S. were using graywater in 1999 and that the use was considerably higher in some states. While some large cities, such as Los Angeles [City of Los Angeles, 2008] have rules or ordinances that allow the installation of graywater systems that conform to state and local regulations, the extent of the practice in large cities is not well-documented in the literature. Most graywater users do not treat the graywater prior to using it for irrigation. In sewered areas where household wastewater is already discharged to a sewer, graywater is often diverted from an existing sewer system to a relatively small land application system (see Figure 1). Conversely, graywater systems in unsewered areas are considered differently in that there is no option to divert wastewater to a sewer system if the land application system fails. In such areas, graywater use may be considered principally as a disposal mechanism rather than use of a resource that can be beneficially utilized.

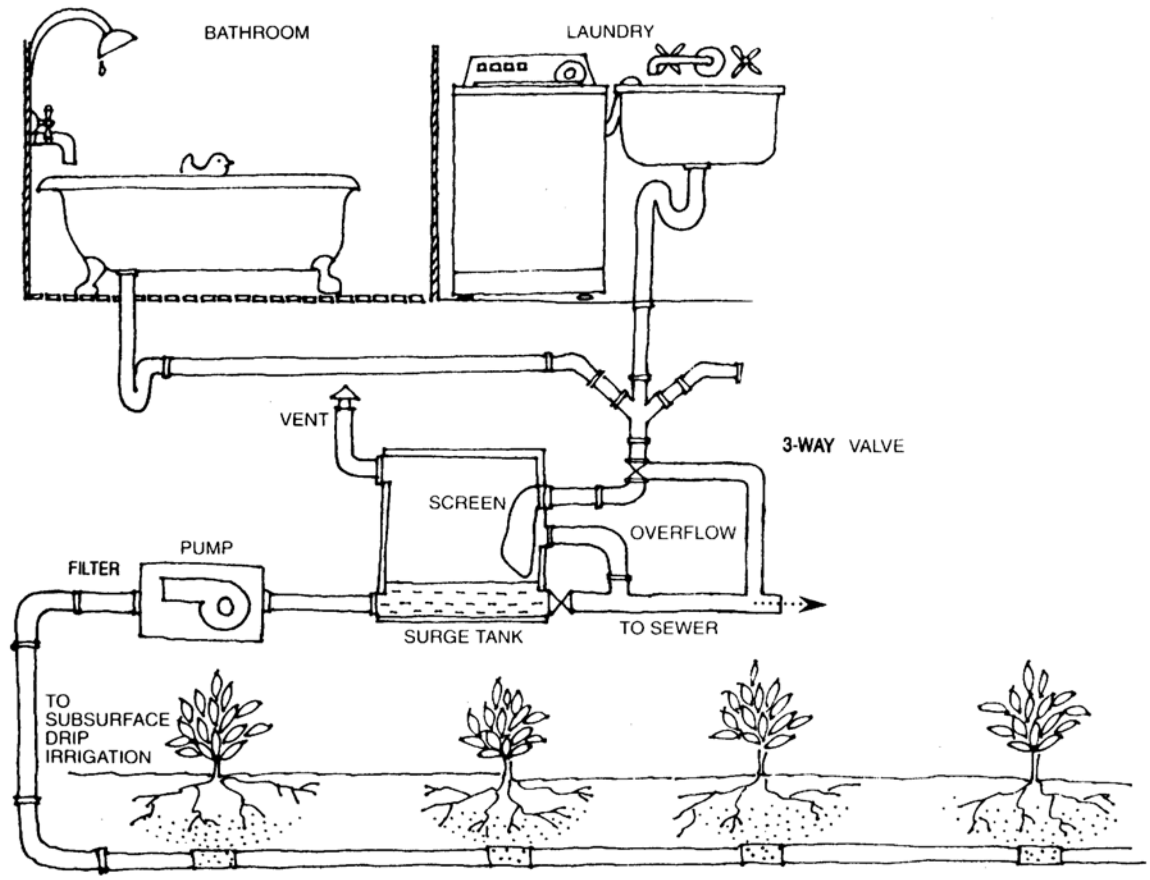

Figure 1. Example Graywater System for Irrigation with Untreated Graywater [California Department of Water Resources, 1995]

A recent study in Australia, where rebates were given to homeowners for installation of water saving devices, determined that households that implemented graywater systems for garden irrigation using subsurface irrigation methods actually increased their domestic water consumption by an average of more than 45 gallons/day (16,700 gallons/year) [Henstridge et al., 2008]. The authors speculated that this may be attributable to homeowners rationalizing that they can use more potable water because they are “making” irrigation water but indicated that additional research is needed to accurately determine why the homeowners increased their potable water use.

Household graywater volumes vary from area to area and also vary according to the definition which wastewater sources are included as graywater. It has been estimated that, in California, an average household produces approximately 24 to 36 gallons of graywater per person per day. This equates to about 43,800 gallons/year for a typical household of four people [California Department of Health Services, 1998]. A report prepared by the City of Los Angeles [City of

Los Angeles, 1992] reported that a literature study found that graywater generation ranged from 21 to 59 gallons/capita/day, and that the ratio of graywater to total household wastewater ranged from 53 to 81 percent. The report also presented an estimate of the various types of water use in a suburban home, as follows:

- Toilet 34.1%
- Kitchen 12.0%
- Bathroom 24.5%
- Laundry 23.2%
- Miscellaneous 6.2%

A report from Australia [NSW Health, 2000] indicated that the percentages of various types of water use within a household were similar to that described above. The ratio of graywater to total household use was 68 percent with an average household use of 106 gallons/day, resulting in graywater availability of about 72 gallons. Typically, however, not all available graywater is reused.

Roesner et al. [1999] estimated that graywater constitutes about 50 percent of the total wastewater generated within an average household (about 69 gallons/person/day, based on an average household of 2.6 persons. This would result in about 90 gallons/day of graywater available for outside use. Another study of indoor residential water use in 12 cities in the U.S. determined that graywater constitutes 40 percent of the water used, not including dishwasher and kitchen sink wastewater (See Figure 2).

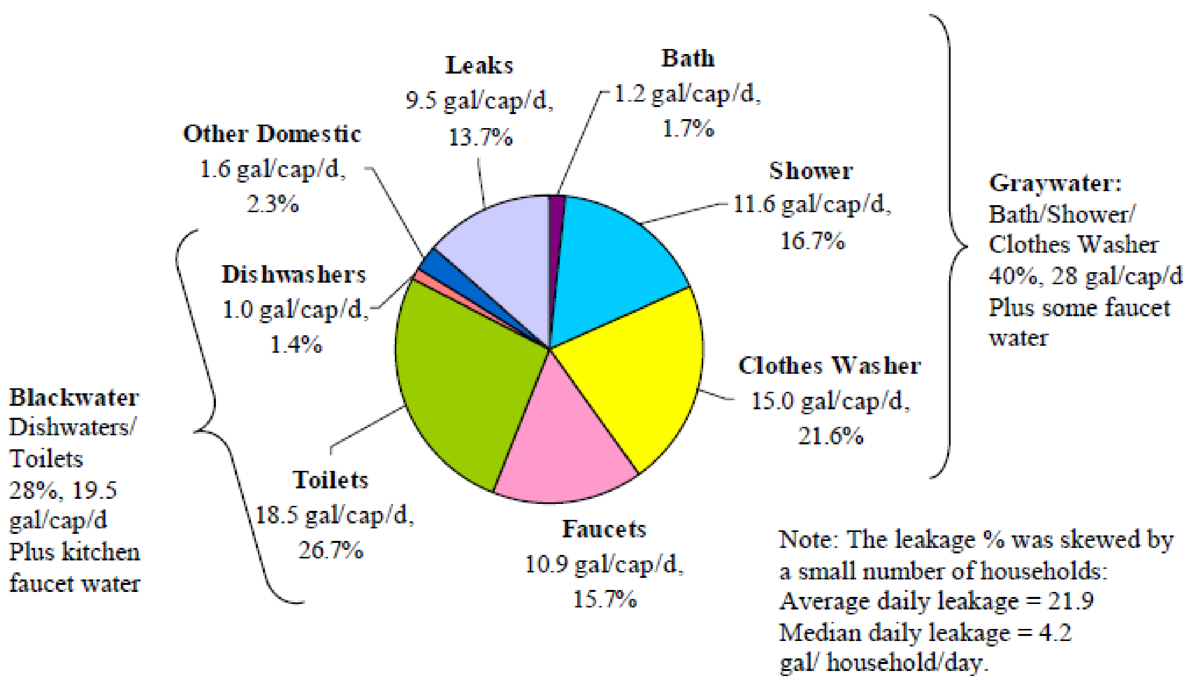

Figure 2. Average Indoor Residential Water Usage for 12 North American Cities [Mayer and DeOreo, 1999]

Case Study: Pima County, Arizona

A study of graywater use in the Tucson area by the Water Conservation Alliance of Southern Arizona (Water CASA), based on the results of a survey of almost 600 respondents of which 40 households reported graywater use, found that graywater use in the different areas surveyed varied from 1.5 to 20 percent, with the average for all areas being 8.4 percent [Water CASA, 2004]. Taking demographics and other factors into account, the authors of the study estimated that approximately 13 percent of single family residences and manufactured homes in Pima County use graywater. This corresponds to roughly 20,000 to 30,000 households. The authors of this study suggested that factors that may increase the likelihood of graywater use include:

- older homes
- lower value homes
- manufactured housing
- lower income levels
- septic tanks

The Water CASA study indicated that the above factors appeared to be consistent with assumptions about what motivates some people to reuse graywater, including the following:

- environmental sensitivity
- water conservation ethic
- desire to reduce one's water bill
- desire to reduce one's sewer bill or prolong the life of a septic system

Most households surveyed by the Water CASA study tap only one source of graywater. The most frequently tapped source of graywater was from clothes washers, accounting for 66 percent of all graywater sources. Other sources were bathroom tubs/showers (15 percent), kitchen sinks (10 percent), bathroom sinks (5 percent), and other sources (4 percent). Only two of the 49 households that reported that they use graywater stored it in large above-ground tanks prior to use, and five reported that they provide some form of treatment prior to reuse, including two that filter the water and one that uses bleach in the clothes washer.

Surface irrigation was the most common application method (34 percent), followed by garden hose (20 percent) and by bucket (15 percent). Other reported application methods included below ground methods that were not identified (11 percent), soaker hose (8 percent), bubbler (3 percent), and other methods that included large, fixed pipes, trenches, and bucket-like trenches. None of the respondents reported that they used drip irrigation to apply the graywater to vegetation. A list of the uses made of the graywater by the 49 respondents who indicated that they use graywater is provided in Table 1.

The Water CASA revealed that more than 90 percent of the 581 survey respondents reported that they did not use graywater for one or more reasons. The reasons for not using graywater are summarized in Table 2.

Table 1. Type of Graywater Uses (from Water CASA Study).

Type of Use	Number of Households
Shade/ornamental trees	30
Shrubs	18
Grass	13
Fruit/nut trees	8
Potted plants	6
Annual/bedding plants	5
Wild flowers	4
Vegetable/herb gardens	4
Compost	0
Other (not identified)	5

Table 2. Reasons for Not Using Graywater (from Water CASA Study)

Reason	Number of Households
Don't know how	166
Not worth the cost	95
No use for the water	94
Need information/assistance	91
Not sure safe/sanitary	88
Water not near use	67
Water is salty/chemistry	42
Isn't worth trouble	41
May be illegal	36
Not enough time	35
May need a permit	14
May need inspection	9
Tried permit, gave up	3
Other	89

Some of the study findings stated in the Water CASA report that are related to the microbial quality of the graywater sampled are as follows:

- Fecal coliforms were consistently detected in all samples from all sampling sites. The concentrations exhibit seasonal variation and were significantly higher in households including the kitchen sink in their graywater than in houses excluding the kitchen sink, indicating that it is a major contamination source thus supporting a recommendation that kitchen sink water should be excluded from graywater used for irrigation purposes, since it carries what is potentially the greatest risk of exposure to enteric pathogens. Fecal coliform levels in graywater were also significantly higher in households with children, those with animals, and those using in ground storage tanks.

- *E. coli* were detected in samples from all sites and were higher in houses using in ground storage and in houses using kitchen sink graywater. Children, animals, and storage in a household appear to have a small impact on *E. coli* levels in graywater.
- Although samples were limited (6 sampling sites), no protozoan parasites (*Giardia* and *Cryptosporidium*) were detected.
- Coliphage were detected in only one graywater sample. The authors of the report suggested that this finding indicates that coliphage are not a good indicator of graywater quality.

Graywater Quality

The composition of graywater varies according to the source water. Some common constituent characteristics according to source are provided in Table 3.

Table 3. Graywater Characteristics by Source

Water Source	Characteristics
Automatic clothes washer	Bacteria, viruses, bleach, foam, high pH, hot water, nitrate, oil and grease, oxygen demand, phosphate, salinity, soaps, nitrates and phosphates, sodium, lint and other suspended solids, and turbidity
Automatic dish washer	Bacteria, foam, food particles, high pH, hot water, odor, fat, oil and grease, organic matter, oxygen demand, salinity, soaps, suspended solids, and turbidity
Bath tub and shower	Bacteria, hair, shampoos, hair dyes, toothpaste, body fats, hot water, odor, organic matter, oil and grease, oxygen demand, soaps, lint and other suspended solids, and turbidity
Evaporative cooler	Salinity
Sinks, including kitchen	Bacteria, food particles, hot water, odor, oil and grease, organic matter, oxygen demand, soaps, detergents, suspended solids, and turbidity
Swimming pools	Chlorine, salinity, organic matter, suspended solids

Source: Adapted from New Mexico State University [1994] and Western Australia Department of Health [2002]

The characteristics of graywater produced by any household are subject to considerable variation at any particular site and depends on factors such as number of occupants, individual lifestyles and water usage patterns, whether young children are living in the house, health of the residents, medications and waste products disposed of in sinks, household products used by the residents for personal hygiene and cleaning purposes, and the sources of wastewater included in the graywater mix [NSW Health, 2000: Eriksson et al., 2002].

Graywater may contain: microorganisms (some of which are likely to be pathogenic); chemicals that include dissolved salts such as sodium, nitrogen, phosphates, and chloride, and organic chemicals such as oils, fats, milk, soap and detergents; or particles of dirt, food, lint, sand, etc. Due to the exclusion of toilet wastes, graywater generally contains lower levels of suspended solids and nitrogen compounds than typical untreated domestic wastewater; however, graywater that includes wastewater from laundry facilities, kitchen sinks, and/or dishwashers can contain higher concentrations of phosphorus than typical untreated wastewater due to the presence of detergents in those waters. Organic constituents in graywater provide food for microorganisms in the water and, thus, support their growth [NSW Health, 2000]. Graywater may also contain oils, paints, and solvents from household activities that could have detrimental effects on areas irrigated with the graywater. The chemical and microbial quality of graywater has been documented by a variety of sources in the literature and is summarized in Table 4.

Public Health Considerations

People vary in their susceptibility to disease. The young, elderly and immuno-compromised are more susceptible than the general population, and some people may be carriers of pathogenic microorganisms without showing any symptoms of the disease. Graywater is contaminated with human and animal excretions from bathing, food preparation, and from clothes washing. Based on the high concentrations of indicator organisms found in graywater, all forms of graywater are capable of transmitting disease.

The potential for disease transmission is principally through the fecal-oral route where graywater may be directly ingested through contaminated hands, or indirectly ingested through contact with contaminated items such as grass, soil, toys, garden implements, and diversion or treatment devices while they are being serviced. Transmission may also occur through inhalation of irrigated spray, by penetration through broken skin, by insect vectors such as flies, and other vectors such as rats and mice. Household pets may transmit disease by tracking and carrying graywater into the home or when petted by children.

People also can potentially be exposed to pathogens that may be present in graywater by handling plants or crops irrigated with graywater, accidentally ingesting soils irrigated with graywater, or coming into contact with ponded graywater or surface waters contaminated with graywater runoff. Under favorable conditions, pathogens can survive for long periods of time on crops or in water or soil. While various pathogens exhibit a wide range of survival characteristics, environmental factors that affect survival include moisture content (desiccation generally adversely affects survival), soil organic matter content (presence of organic matter aids survival), temperature (longer survival at low temperatures), humidity (longer survival at high humidity), pH (bacteria survive longer in alkaline soils than in acid soils), amount of rainfall, amount of sunlight (solar radiation is detrimental to survival), protection provided by foliage, and competitive microbial fauna and flora. Survival times for any particular microorganism exhibit wide fluctuations under differing conditions and range from a few days to several months [Feachem *et al.*, 1983].

Another potential route for human exposure is contamination of groundwater, particularly if irrigation takes place in close proximity to private homeowner drinking water wells. However, Roesner et al. [2006] postulated that “given the wide-spread distances between current graywater applications and the small quantity of water applied at any given location, it would seem that threat of groundwater pollution of public water supplies is small.”

Table 4. Graywater Quality

Constituent or Parameter	Source of Graywater			
	Composite	Bath/Shower*	Laundry Wash	Laundry Rinse
Temperature (^oC)	21.6 – 28.2			
pH (units)	6.5 – 8.7			
EC (µS/cm)	325 – 1140	82 – 250	83 – 880	
COD (mg/L)	52 – 622	96		
BOD (mg/L)	26 – 291	45 – 330	10 – 520	
TSS (mg/L)	7 – 330	37		
Turbidity (NTU)	22 – <200	28 - 96	39 - 296	14 - 29
NH_4-N (mg/L)	0.02 – 25.4	0.11 – 0.37	0.1 – 3.47	0.06 – 0.33
NO_3-N (mg/L)	<0.02 – 0.98			
Total N (mg/L)	1.7 – 6.4			
PO_4 (mg/L)	1.4 – 35			
Total P (mg/L)	0.28 – 27.3			
Sulfate (mg/L)	0.3 – 110			
Chloride (mg/L)	3.1 – 141			
Hardness (mg/L)	15 – 144			
Alkalinity (mg/L)	149 – 382			
Ca (mg/L)	20.6 – 78			
K (mg/L)	5.9 – 7.4			
Mg (mg/L)	1.7 – 31.4			
Na (mg/L)	29 – 415			
Total bacteria (CFU/100 mL)	4.0×10^7 – 6.1×10^8	1.0×10^7 – 1.0×10^8	1.0×10^7 – 1.0×10^8	1.0×10^7 – 1.0×10^8
Total coliform (CFU/100 mL)	6.0×10^3 – 1.9×10^8	2.7×10^1 – 2.4×10^7	199 – 3.3×10^5	56
Fecal coliform (CFU/100 mL)	1.82×10^4 – 7.94×10^6	<10 – 2×10^8	2×10^1 – 10^7	
Fecal streptococci (CFU/100 mL)	2.38×10^2	1.9×10^1 – >2.4×10^5	<3 – <2.4×10^5	<3 – <2.3×10^3
E. coli (CFU/100 mL)	<1×10^2 – 1.0×10^6	3.9×10^5		
Fecal enterococci (CFU/100 mL)	Not detected – 2.4×10^2	2.5×10^3		2.5×10^4
Pseudomonas aeruginosa (CFU/100 mL)	2.0×10^4			
Clostridium perfringens spores (CFU/100 mL)	2.0×10^3			
Salmonella veltereden (MPN/L)		Detected but not quantified		
Giardia (organisms/L)		0.5 – 1.5		
Coliphages	<1 – 2.0×10^3			

* Some samples included water from bathroom sinks.

Source: Adapted from Rose et al. [1991] ; Eriksson et al. [2003] ; Casanova et al. [2001] ; Western Australia Department of Health [2002]; California Department of Health Services [1998]; Jeppesen [1996]; Christova-Boal et al. [1995]; Christova-Boal et al. [1996]; Ottoson and Stenstrom [2003]; California Department of Health Services [1979]; City of Los Angeles, [1992]; Birks and Hills [2005]

Sampling of graywater and other wastewaters for specific pathogenic organisms is seldom done, and testing for all potential pathogens is never done due to cost and other reasons. Because it is not practical to analyze wastewater for all of the pathogenic organisms that may be present, sampling for organisms that are indicative of the presence of fecal contamination and the potential presence of pathogenic organisms originating from human fecal matter is universally used. Examples of commonly used indicators are total coliforms, fecal coliforms (a thermotolerant subgroup of the total coliform group), *Escherichia coli* (*E. coli*) (a subgroup of fecal coliforms), fecal streptococci, enterococci (a subgroup of fecal streptococci). The total coliform analysis includes enumeration of organisms of both fecal and nonfecal origin, while the fecal coliform analysis is specific for coliform organisms that are found in gastrointestinal tracts of warm-blooded animals. Therefore, fecal coliforms are a more reliable indicator of fecal contamination than total coliforms and are often used as an indicator of the potential presence of pathogenic organisms originating from human fecal matter. The absence of fecal coliform organisms and other indicator organisms does not necessarily indicate an absence of pathogens. Pathogenic organisms may be present that are not associated with fecal material, such as those causing food spoilage.

Most of the indicator organism levels shown in Table 4 are well above accepted safety levels set by regulatory agencies for wastewater or reclaimed water where there may be human contact with the water. Table 4 also includes two pathogenic microorganisms (*Salmonella veltereden* and *Giardia*) that one study found to be present in graywater. Thus, the data demonstrate that graywater could pose a potential risk to people coming into contact with it [World Health Organization, 2006]. But there is controversy regarding whether the indicator organism concentrations are an accurate indicator of the actual health threat posed to people who come into direct contact with graywater, because fecal coliform concentrations have been observed to multiply in graywater, whereas some pathogens tend die off rapidly. A review of the literature by Roesner et al. [2006] did not indicate that any illnesses due to contact with graywater have been reported. This does not necessarily mean that illnesses have not occurred and does not discount the possibility of disease transmission [Nolde, 1999].

Pathogens can enter graywater by several mechanisms. For example, pathogens associated with fecal material can enter graywater during showering, bathing, and laundering of fecally contaminated laundry (e.g., diapers). Pathogens can also be introduced to graywater by food handling in the kitchen if kitchen wastewater is included in the graywater [Ottoson and Stenstrom, 2003]. Pathogens of concern in wastewaters in general include: bacteria such as enterotoxigenic *E. coli, Salmonella, Shigella, Vibrio cholerae, Campylobacter*, and *Legionella*; protozoans such as *Giardia lamblia* and *Cryptosporidium parvum*; and viruses such as enteroviruses, hepatitis A, rotavirus, and Norwalk virus.

A one-year evaluation of five individual house graywater systems installed for research purposes in the United Kingdom, where graywater from bathroom sinks, baths, and showers was filtered through 50-μm mesh filters and disinfected with chlorine tablets prior to recycling for toilet flushing, found numerous problems with reliability of the systems [Birks et al., 2003]. The problems included blockage of the filter, pump failure, and lack of disinfection due to homeowners not replacing exhausted disinfection tablets. It was reported that homeowners were unable to adequately maintain the graywater systems to ensure that they were operational. While filter blockage and pump failure would simply result in graywater being sent to the sewer system rather than being reused, failure to disinfect graywater used within a house for toilet flushing raises significant health concerns.

A year-long study of eight graywater test systems (two of which provided no treatment of the water and the rest included filtration by either bag filters or sand filters) installed at residences in Los Angeles found that the graywater contained from 20 to more than 1.6 x 10^5 total coliform organisms/100 mL and from nondetectable to more than 1.6 x 10^5 fecal coliform organisms/100 mL [City of Los Angeles, 1992]. The graywater was analyzed for four pathogens (*Salmonella, Shigella, Entamoeba hystolitica, and Ascaris lumbricoides*) at each site. None of the analyses indicated the presence of these pathogens in the graywater except for one sample that was positive for *Ascaris lumbricoides*.

A 1991 study by Rose et al. [1991] determined the microbial and chemical composition of graywater at several residences. Some of the residences had children and some did not. Combined bathing water and washing water flows had an average of 10^4 to 10^6 total coliform colony-forming units (CFU)/100 mL and standard plate count bacteria (SPC) ranged from 10^5 to 10^{10} CFU/100 mL. Families with small children produced wash cycle graywater containing 10^6 CFU/100 mL. An increase of one order of magnitude in coliform and SPC bacteria was observed when graywater was stored. *Salmonella typhmurium and Shigella dysenteria* seeded in graywater were found to persist for several days. Poliovirus type 1 seeded to graywater decreased 90 percent at 17 ^{o}C after 6 days of storage; warmer temperatures increased the survivability of Poliovirus. These data imply that there may be some risk associated with reuse of graywater when these pathogenic bacteria or viruses are being excreted by an individual producing the graywater [Rose et al., 1991]. Another report indicated that fecal coliforms have been found to multiply by 10 to 100 times during the first 14 to 48 hours of storage before gradually declining and that significant levels of pathogens have been found in stored graywater after eight days [NSW Health, 2000]. That report further stated that "While it is unlikely for pathogens to grow in greywater the low infective dose (numbers of organisms needed to cause disease) of some pathogenic micro-organisms are still of concern." and that "It is therefore concluded that greywater must not be stored, other than temporarily in a surge tank, unless adequately treated." EPA Victoria [2008] also recommends that graywater not be stored for more that 24 hours.

Numerous studies have inferred fecal contamination of graywater via the presence of indicator organisms. The ranges of several findings are reported in Table 4. The presence of indicators does not always indicate the presence of pathogens. For example, in a study of graywater produced by four households in Australia, Christova-Boal et al., [1996] reported nondetectable levels of *Salmonella, Campylobacter, Giardia,* and *Cryptosporidium*, despite the presence of several indicator organisms. Several studies indicated that concentrations of indicator organisms were typically higher in graywater derived from bathroom showers and sinks than graywater originating from laundry water [Siegrist, 1977; Rose et al., 1991; Christova-Boal et al., 1996]. Also, families with children generally produce graywater with higher levels of indicator organisms than families with no children [Rose et al., 1991; Casanova et al., 2001]. Although one study found no difference in total and fecal coliform numbers with and without garbage disposal waste, levels of some food borne pathogens, such as *Salmonella* and *Campylobacter*, can be higher in graywater if kitchen waste is included, due to washing of meat, poultry, and raw produce [Roesner et al., 2006].

A water quality study of untreated graywater from baths, showers, and bathroom sinks at a university housing complex in the United Kingdom found that one sample (out of eight samples analyzed) contained *Salmonella veltereden* [Birks and Hills, 2005]. The concentration of this pathogenic organism, which is a common species associated with food poisoning from partially cooked meat and shellfish, was not provided in the paper that documented the study results. *Giardia* was found in five of eight samples analyzed and ranged from 0.5 to 1.5 organisms per liter. *Cryptosporidium*, *E. coli* 0157:H7, *Legionella pneumophila*, and enteroviruses were not detected in any of the graywater samples.

In recognition of the fact that untreated graywater is likely to contain pathogenic organisms, the World Health Organization [2006] report on graywater states that "For untreated greywater, the possibility of human contact should be avoided. Greywater, therefore, should not be used for the irrigation of lawns, unless they are for ornamental purposes only and are not used by children or household animals, or are irrigated by subsurface irrigation systems that reduce the risk of human contact. However, surface irrigation is permitted provided that the user is careful to avoid contact with the greywater." The report further states that "Irrigation of vegetables that will be cooked before they are eaten is also permitted, provided that the greywater makes no contact with the vegetables. However, irrigation of vegetables that have contact with the ground (such as potatoes), or those that are likely to be eaten raw (such as lettuce, carrots, and tomatoes), should be avoided, in addition to leafy edible plants (such as mint and parsley)."

Public health concerns related to graywater use expressed by regulatory agencies and utilities are echoed by the public. A survey report prepared by Alpha Communications, Inc. and H20UTREACH [2008] found that 81 percent of those interviewed in Southern Nevada considered public safety to be their greatest concern. Further, almost 63 percent of the respondents believed that graywater systems would not reduce consumptive use and would be cost prohibitive.

Environmental Considerations

Graywater contains many chemical constituents, some of which are beneficial in appropriate concentrations (e.g., nutrients such as nitrogen and phosphorus), but many that are detrimental to plants and soil structure. The main adverse effects of graywater on soil are: a tendency to raise soil alkalinity and salinity; a reduction in the ability of soil to absorb and retain water; and an increase in alkalinity due to the presence of sodium, potassium or calcium salts in the graywater, particularly from laundry detergents. Detergent and laundry products also contain other chemicals that are harmful to plants, such as boron, chlorides and peroxides. High concentrations of boron, for example, are very toxic to most plants. Plant damage from exposure to excessive amounts of boron is first displayed by a burnt appearance to the edges of the leaves. Other symptoms of boron toxicity include leaf cupping, chlorosis, branch dieback, premature leaf drop and reduced growth [World Health Organization, 2006].

The New South Wales Department of Health [NSW Health] cautions that graywater may harm the environment in the following ways:

- by overloading the land application system with nutrients;
- by exceeding the hydraulic loading the land application system with water causing run off of polluted water to stormwater drains, rivers, streams and other peoples property;
- by raising the water table which may affect foundations of houses and causes the soil to become permanently boggy;
- by causing the soil to become permanently saturated, prevent plants from growing and cause odors;
- by altering the soil salinity;
- by altering the soil permeability;
- by changing the soil pH;
- by altering the soil electrical conductivity;
- by altering the soil sodicity;
- by altering the soil cation exchange capacity;
- by altering the soil phosphorus sorption capacity;
- by altering the soil dispersiveness; and
- by degrading the soil with chemical impurities which affect the properties of the soil to assimilate nutrients or water.

The literature indicates that a number of chemicals in typical graywater are known to potentially harm plants; however, information is sparse as to whether some of these constituents will accumulate in soil to sufficient levels to harm plants or be transported past the root zone to the groundwater. Roesner et al. [2006] reported that "Although there are a number of graywater systems that have been in operation for some years with no obvious detriment to vegetation, the scientific documentation is lacking." A two-year study on plants irrigated with graywater in residential areas found that, other than a slight increase in boron, no salts had accumulated in either the plants or soil [National Small Flows Clearinghouse, 2002]. A one-year graywater pilot project in Los Angeles [City of Los Angeles, 1992] found that sodium and the sodium adsorption ratio (SAR) increased over the course of the study, but no negative effects on plant growth or the quality of the landscape plants were observed. The authors of that study acknowledged that any harmful effects may take several years to manifest themselves.

Graywater tends to be slightly alkaline. Shade-loving and acid-loving plants do not thrive if irrigated with graywater having high alkalinity. Following is a list of some of the plants that are not suited to alkaline conditions: impatiens; begonias; ferns; foxgloves; gardenias; cape jasmine, English yew, bunchberry, protea, Carolina laurel cherry, bald cypress, hemlock, Chinese wisteria, philodendrons; camellias; primroses; azaleas; violets; rhododendrons; bleeding hearts; oxalis; and hydrangeas. Additional plants that are especially susceptible to high sodium and chloride, that may be present in graywater, are: crape myrtle; redwoods; star jasmine; holly; and deodar cedar [California Department of Water Resources, 1995; Center for the Study of the Built Environment, 2003].

Cost of Graywater Systems

The cost of a graywater system varies with its complexity and capabilities. One study [City of Los Angeles, 1992] estimated price ranges based on information provided by manufacturers and installers as follows (the costs are in 1990 dollars):

- $400 to $800: Applies to low-technology systems that tap the discharge from washing machines only. The lower-end of the price range applies to the do-it-yourself installation, and the upper end to professional installation.
- $1,000 to $1,500: Applies to systems where all potential graywater sources are connected to the system. The collection and distribution system is relatively simple and low-technology. The total cost depends on the number of graywater sources connected.
- $2,500 to $5,000: Applies to fully automatic graywater systems that are connected to nearly all sources of graywater in a home and possibly backed up by potable water systems when graywater may not be available. The only intervention on the part of the resident is to switch the system off when it is no longer needed during periods of heavy rainfall.

Graywater guidelines issued by Water CASA [Little, no date] estimate that it would cost from $135 to $1250 to retrofit a home for graywater use. The costs include washing machine and shower/bath hookups, storage tank, storage parts, and a pump. Irrigation system costs are not included in the above-stated estimated costs. The guidelines estimate that the costs in new construction could be one-half of the cost to retrofit a system into existing homes. Costs to construct graywater system with treatment systems can cost $5000 or more.

Graywater Regulations

Several – but not all – states have regulations directed at graywater. In Colorado, for example, the Colorado Department of Public Health and Environment does not separate graywater from blackwater in its regulations. The treatment, disposal, and potential use of graywater are regulated by the Colorado Guidelines on Individual Sewage Disposal Systems and applicable county Individual Sewage Disposal System (ISDS) regulations. If graywater is used to irrigate below the soil surface, but within the root zone (above frost line), a local permit plus monitoring is required. Many county ISDS regulations prohibit the issuance of any type of individual sewage disposal system permit for a lot within 400 feet of service by a municipal or community sewage treatment facility. Many municipalities have similar connection and usage requirements that technically prohibit the use of graywater in urban areas [Colorado Division of Water Resources, 2003].

Some cities have their own rules or ordinances directed at graywater. For example, Tucson, Arizona, recently adopted an ordinance that requires all new residential dwelling units built after June 1, 2010, include graywater collection systems [City of Tucson, 2008]. The ordinance only requires installation of plumbing that could be connected to a graywater system for landscape irrigation and does not require that graywater be used by a homeowner.

Regulations for Arizona, California, and Nevada are summarized below. The complete texts of those regulations are provided in the Appendices.

Arizona

The Arizona Department of Environmental Quality (ADEQ) published regulations for residential graywater use in 2001 [Arizona Department of Environmental Quality. 2001]. The basic requirements are that residents must adhere to the guidelines for a Reclaimed Water Type 1 General Permit. A Type 1 General Permit requires no formal notification to the department, no review or design approval, and no public notice, reporting, or renewal. While a formal permit for permission to use graywater is not required, graywater users must comply with ADEQ best management practices. The best management practices to comply with Arizona's rules for graywater use are as follows:

- "First and foremost, avoid human contact with gray water, or soil irrigated with gray water.
- You may use gray water for household gardening, composting, and lawn and landscape irrigation, but use it in a way that it does not run off your own property.
- Do not surface irrigate any plants that produce food, except for citrus and nut trees.
- Use only flood or drip irrigation to water lawns and landscaping. Spraying gray water is prohibited.
- When determining the location for your gray water irrigation, remember that it cannot be in a wash or drainage way.
- Gray water may only be used in locations where groundwater is at least five feet below the surface.
- Label pipes carrying gray water under pressure to eliminate confusion between graywater and drinking water pipes.
- Cover, seal and secure storage tanks to restrict access by small rodents and to control disease carrying insects such as mosquitoes.
- Gray water cannot contain hazardous chemicals such as antifreeze, mothballs and solvents. Do not include wash water from greasy or oily rags in your graywater.
- Gray water from washing diapers or other infectious garments must be discharged to a residential sewer or other wastewater facility, unless it can be disinfected prior to its use.
- Surface accumulation of gray water must be kept to a minimum.
- Should a backup occur, gray water must be disposed into your normal wastewater drain system. To avoid such a backup, consider using a filtration system to reduce plugging and extend the system's lifetime.
- If you have a septic or other on-site wastewater disposal system, your gray water use does not change that system's design requirements for capacity and reserve areas" [Arizona Department of Environmental Quality, (no date)].

The general permit is meant for private residential use only. Graywater must be used on the site where it is generated. The area of use cannot be accessible by the public. Under this general permit, graywater can only be used for irrigation – not for dust control, cooling or other water uses. Both underground and surface application of graywater is allowed, but only drip or flood irrigation with graywater is allowed for surface irrigation. Spray irrigation is not permitted due to the potential for inhalation or drifting off-site. Graywater flow must be less than 400 gallons per day.

California

California has an extensive set of graywater standards that were most recently revised in 1997 and included in the California Plumbing Code [1997]. The regulations – which require installation of a 140-mesh (115-µm) screening filter and a surge tank – state, in part:

"The provisions of this Appendix shall apply to the construction, installation, alteration and repair of graywater systems for subsurface landscape irrigation. The graywater system shall not be connected to any potable water system without an air gap and shall not result in any surfacing of the graywater. Except as otherwise provided for in this Appendix, the provisions of the Uniform Plumbing Code (UPC) shall be applicable to graywater installations.

Graywater is untreated waste water which has not come into contact with toilet waste. Graywater includes waste water from bathtubs, showers, bathroom wash basins, clothes washing machines, and laundry tubs, or an equivalent discharge as approved by the Graywater is untreated waste water which has not come into contact with toilet waste. Graywater includes waste water from bathtubs, showers, bathroom wash basins, clothes washing machines, and laundry tubs, or an equivalent discharge as approved by the Administrative Authority. It does not include waste water from kitchen sinks, photo lab sinks, dishwashers, or laundry water from soiled diapers.

(a) Graywater may contain fecal matter as a result of bathing and/or washing of diapers and undergarments. Water containing fecal matter, if swallowed, can cause illness in a susceptible person. Therefore, graywater shall be not be contacted by humans, except as required to maintain the graywater treatment and distribution system.
(b) Graywater shall not include laundry water from soiled diapers.
(c) Graywater shall not be applied above the land surface or allowed to surface and shall not be discharged directly into or reach any storm sewer system or any water of the United States.
(d) Graywater shall not be used for vegetable gardens."

The California Department of Health Services (now California Department of Public Health) produced a "Graywater Technical Paper" in 1998 [California Department of Health Services, 1998] that provided guidelines for graywater use in that state. The document addresses health precautions, design considerations, and other considerations. Some relevant excerpts from the technical paper are as follows:

"Graywater is untreated water that has not come into contact with toilet or kitchen wastes. It includes used water from bathtubs, showers, bathroom washroom basins, and water from clothes washing machines and laundry tubs. It does not include wastewater from kitchen sinks, dishwashers, toilets, or laundry water from soiled diapers. Because graywater is not treated or monitored for the reliable removal of bacteriological and chemical constituents, its use has currently been restricted to the following conditions:

1. Approved for residential, commercial, industrial, and multi-family projects
2. Only approved for landscape irrigation
3. Not intended for irrigation on edible portions of food crops

4. Irrigation with gray water shall be below ground to mitigate nuisance and health concerns”

“Graywater contains total coliform and fecal coliform densities similar to raw wastewater. Because of the coliform levels found in graywater and other chemical constituents that may be found in graywater flows, the Department recommends that the following public health protection measures be followed:

1. Direct connections between graywater and domestic water plumbing systems should not be permitted.
2. Graywater systems shall be supplemented with domestic water only through an approved air gap separation.
3. Human contact with graywater flows shall be minimized.
4. Rubber gloves should be used when repairing and maintaining graywater system components.
5. Proper hygiene techniques should follow graywater system repair and maintenance activities.
6. Graywater irrigation techniques shall be employed that prevent surface runoff and surface spraying. Surface ponding of graywater should be avoided.
7. Consumers using graywater systems should be instructed on graywater handling practices and associated health impacts resulting from the misuse of graywater.
8. Graywater should not be used on edible portions of food crops.
9. Graywater piping should be clearly laid out and appropriate signage should be posted that details which pipes and appurtenances are part of the graywater system. Nonpotable signs should be posted on graywater system components.
10. All graywater storage tanks shall be equipped with a lid that restricts the access of children or other untrained persons.
11. Graywater irrigation and holding facilities shall not be located within 50 feet from a domestic groundwater source (well or spring). Greater distances may be required based upon site conditions and local geology.
12. Detailed irrigation piping maps of domestic and graywater irrigation systems should be maintained on-site.
13. Installers of graywater systems should provide the owner with an operations and maintenance plan detailing steps that need to be taken to maintain the system and provide troubleshooting techniques to evaluate and correct system problems.
14. Graywater storage for excessively long times promote the regrowth of bacteriological colonies and may cause odor problems. Graywater systems should be designed to minimize stagnation times.”

Nevada

Nevada’s graywater regulations were added to the Nevada Administrative Code adopted in 1999 [Nevada Administrative Code. 2008. Chapter 444, Sanitation. Nevada Administrative Code, Carson City, Nevada]. The Nevada regulations define graywater as untreated household wastewater that has not come into contact with toilet waste, but wastewater from kitchen sinks or dishwashers is excluded from the definition of graywater.

Graywater can be used only for a single-family dwelling via underground irrigation on the site of the dwelling that discharges the graywater to the irrigation system, and a permit must be obtained by a homeowner prior to construction, alteration, or installation of a graywater system. The permit application must include detailed plans of the system, detailed plans of the existing and proposed sewage disposal system, and data from percolation tests. Other requirements are provided in the Appendix.

Australia Guidelines

Some regulatory agencies in Australia allow untreated graywater use only by bucketing the water to trench irrigation systems. In the Perth area, health guidelines dictate either primary treatment via a sedimentation tank or secondary biological treatment is required for below ground trench irrigation and spray or drip irrigation [Western Australia Department of Health, 2002]. Secondary treatment would have to achieve a biochemical oxygen demand (BOD) of 20 mg/L, suspended solids of 30 mg/L, and be disinfected to achieve not more than 10 thermotolerant coliforms/100 mL. The guidelines state that all forms of graywater are capable of transmitting disease and present measures to mitigate the potential for disease transmission and damage to plants, including the following:

- Select garden friendly detergents. Only biodegradable products and products with low phosphorus, sodium, boron, chlorine and borax should be used. Bleaches and fabric softeners should be used sparingly.
- Apply graywater in several locations rather than one single point, so that pooling of graywater does not occur.
- Apply graywater to areas that are not readily accessible to children and household pets.
- Don't use graywater from the washing of nappies (i.e., diapers) and soiled clothing.
- Don't use graywater when a household resident has an infectious disease such as diarrhea, infectious hepatitis, intestinal parasites, etc.
- Don't discharge graywater on edible plants or where fruit fallen to the ground is eaten.
- Don't store graywater. Stored graywater will turn septic giving rise to offensive odors and provide conditions for microorganisms to multiply.
- Don't let your graywater go beyond your property and cause a nuisance for your neighbors.
- Don't over water. Over application of graywater may clog the soil causing the pooling of graywater, which can result in the development of unsightly areas of gray/green slime. This slime is caused by the presence of soaps, shampoos, detergents and grease in graywater. The accumulation of slime can cause odors, attract insects and cause environmental damage.
- Plants of the Proteaceae family evolved in low phosphorus soils and are therefore susceptible to excess phosphates. These plants are not really suited to graywater reuse and include grevillea, hakea, banksia and silky oak. Shade loving and acid loving plants do not like the alkalinity of graywater. These include azaleas, camellias, gardenias, begonias, and ferns.

NSW Health [2000] in Australia recommends that local authorities in New South Wales consider several recommendations when evaluating domestic graywater treatment systems, including the following to ensure that the potential to transmit disease has been minimized:

- final inspection of the graywater system by the local authority and written consent prior to commission the graywater system is a statutory requirement;
- installation must be carried out by licensed plumber/drainer;
- operation and maintenance of the system should be the owners responsibility;
- the owner of the premises must obtain an approval to operate the system;
- minimum maintenance requirements specified by the manufacturer should be adhered to;
- the treatment system (if there is one) should meet relevant health and plumbing requirements;
- there should be no connections to, or augmentation from the mains water supply;
- untreated and undisinfected graywater can only be used for subsurface irrigation;
- treated and disinfected graywater may be utilized for sub-surface irrigation, surface irrigation in dedicated non-trafficable areas, and toilet and urinal flushing when treated to the higher level;
- the land application system must be appropriately sign posted that graywater is being reused and that contact must be avoided;
- the dedicated land application must not used for active recreation such as a children's play area, BBQ area, etc.
- avoid storage of graywater except for surge attenuation, unless treated and disinfected;
- contamination of the ground water must be prevented;
- surface ponding or surface run-off of graywater must not occur and graywater must be contained within the confines of the disposal area;
- graywater should not be used for irrigation during periods of wet weather;
- there should be an ability to distinguish plumbing which contains recycled graywater and to prevent cross connection to the water supply;
- a backflow prevention device must be installed to protect the potable water supply;
- a connection to the sewer must be maintained so as to enable isolation of the land application system; and
- graywater must not be used for irrigation of edible plants which are consumed raw.

Findings and Conclusions

Findings and conclusions related to untreated graywater, based on the literature reviewed during preparation of this technical memorandum, are summarized below.

- Graywater is defined as any wastewater produced within a home except for toilet wastewater, which is sometimes referred to as "blackwater."
- The quantity of graywater produced in a home varies from about 20 to 60 gallons/capita/day (50 to 150 gallons/day/household) in the U.S. Actual quantities of graywater used are generally considerably less than the amount of graywater produced, because not all of the available sources of graywater are typically used by homeowners.
- About one-half of all household wastewater produced could be diverted as graywater.
- The use of graywater is increasing in the U.S., and approximately 7 percent of households in the U.S. reportedly reuse at least a portion of the graywater produced in those households.
- Graywater systems are intended to reduce the amount of potable water used by homeowners, although in one study area households that implemented graywater systems

actually increased their domestic water consumption by an average of more than 45 gallons/day.

- Untreated graywater cannot be used inside a home and is used almost exclusively for outside irrigation purposes.
- Graywater use is more prevalent in unsewered rural areas where septic tanks are prevalent than in urban areas that have existing sewerage collection and treatment systems.
- The high concentrations of indicator organisms found in graywater indicate the presence of fecal contamination; thus, graywater is deemed capable of transmitting disease.
- The concentrations of total and fecal coliforms and other indicator organisms in graywater are well above accepted safety levels set by regulatory agencies for reclaimed water where there may be contact with the water.
- Sampling graywater for pathogenic organisms is seldom done, and testing for all potential pathogens is never done. Where sampling has been done, the water has been analyzed for only a few specific pathogens, and most – but not all - analyses have been negative for the presence of the pathogens.
- Graywater standards, guidelines, and informational brochures from regulatory agencies and communities uniformly state that graywater is likely to contain pathogenic organisms and is potentially hazardous to human health.
- Several states have graywater regulations. Most regulatory agencies that have graywater regulations or guidelines either prohibit or recommend against the use of graywater from kitchen sinks and dishwashers. Regulations in some states prohibit the use of laundry water from soiled diapers or other infectious garments.
- Many chemical contaminants in graywater are detrimental to plants and soil structure.
- The cost to construct and operate a graywater system using untreated graywater depends on the complexity of the system and ranges from a few hundred dollars to more than one thousand dollars, not including irrigation system costs.

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APPENDICES

Examples of
State Graywater Regulations

APPENDIX A

Arizona

R18-9-701. Definitions

4. "Gray water" means wastewater collected separately from a sewage flow that originates from a clothes washer, bathtub, shower, and sink, but does not include wastewater from a kitchen sink, dishwasher, or toilet.

R18-9-711. Type 1 Reclaimed Water General Permit for Gray Water

A. A Type 1 Reclaimed Water General Permit allows private residential direct reuse of gray water for a flow of less than 400 gallons per day if all the following conditions are met:

1. Human contact with gray water and soil irrigated by gray water is avoided;
2. Gray water originating from the residence is used and contained within the property boundary for household gardening, composting, lawn watering, or landscape irrigation;
3. Surface application of gray water is not used for irrigation of food plants, except for citrus and nut trees;
4. The gray water does not contain hazardous chemicals derived from activities such as cleaning car parts, washing greasy or oily rags, or disposing of waste solutions from home photo labs or similar hobbyist or home occupational activities;
5. The application of gray water is managed to minimize standing water on the surface;
6. The gray water system is constructed so that if blockage, plugging, or backup of the system occurs, gray water can be directed into the sewage collection system or on-site wastewater treatment and disposal system, as applicable. The gray water system may include a means of filtration to reduce plugging and extend system lifetime;
7. Any gray water storage tank is covered to restrict access and to eliminate habitat for mosquitoes or other vectors;
8. The gray water system is sited outside of a floodway;
9. The gray water system is operated to maintain a minimum vertical separation distance of at least five feet from the point of gray water application to the top of the seasonally high groundwater table;
10. For residences using an on-site wastewater treatment facility for black water treatment and disposal, the use of a gray water system does not change the design, capacity, or reserve area requirements for the on-site wastewater treatment facility at the residence, and ensures that the facility can handle the combined black water and gray water flow if the gray water system fails or is not fully used;
11. Any pressure piping used in a gray water system that may be susceptible to cross connection with a potable water system clearly indicates that the piping does not carry potable water;
12. Gray water applied by surface irrigation does not contain water used to wash diapers or similarly soiled or infectious garments unless the gray water is disinfected before irrigation; and
13. Surface irrigation by gray water is only by flood or drip irrigation.

B. Prohibitions. The following are prohibited:

1. Gray water use for purposes other than irrigation, and

2. Spray irrigation.

C. Towns, cities, or counties may further limit the use of gray water described in this Section by rule or ordinance.

R18-9-719. Type 3 Reclaimed Water General Permit for Gray Water

A. A Type 3 Reclaimed Water General Permit allows a gray water irrigation system if:

1. The general permit described in R18-9-711 does not apply,
2. The flow is not more than 3000 gallons per day, and
3. The gray water system satisfies the notification, design, and installation requirements specified in subsection (C).

B. A person shall file a Notice of Intent to Operate a Gray Water Irrigation System with the Department at least 90 days before the date the proposed activity will start. The Notice of Intent to Operate shall include:

1. The name, address and telephone number of the applicant;
2. The social security number of the applicant, if the applicant is an individual;
3. A legal description of the direct reuse site, including latitude and longitude coordinates;
4. The design plans for the gray water irrigation system;
5. A signature on the Notice of Intent to Operate certifying that the applicant agrees to comply with the requirements of this Article and the terms of this Reclaimed Water General Permit; and
6. The applicable permit fee specified under 18 A.A.C. 14.

C. The following technical requirements apply to the design and installation of a gray water irrigation system allowed under this Reclaimed Water General Permit:

1. Design of the gray water irrigation system shall meet the on-site wastewater treatment facility requirements under R18-9-A312(C), (D)(1), (D)(2), (E)(1), (G), and R18-9-E302(C)(1), except the septic tank specified in R18-9-E302(C)(1) is not required if pretreatment of gray water is not necessary for the intended application;
2. Design of the dispersal trenches for the gray water irrigation system shall meet the on-site wastewater treatment facility requirements for shallow trenches specified in R18-9-E302(C)(2);
3. The depth of the gray water dispersal trenches shall be appropriate for the intended irrigation use but not more than 5 feet below the finished grade of the native soil; and
4. The void space volume of the aggregate fill in the gray water dispersal trench below the bottom of the distribution pipe shall have enough capacity to contain two days of gray water at the design flow.

D. The Department may review design plans and details and accept a gray water irrigation system that differs from the requirements specified in subsection (C) if the system provides equivalent performance and protection of human health and water quality.

APPENDIX B

California

Revised Graywater Standards

On March 18, 1997, the Building Standards Commission approved the revised California Graywater Standards (attached Appendix G). The most significant change in the standards is that gray water systems can now be used in commercial, industrials, and multifamily projects, as well as single-family residences.

Other changes include: (1) that only one irrigation zone is now required (rater than the previous two); (2) filters are to be sized appropriately to maintain the filtration rate rather than the previously prescribed 1-inch filter; and (3) a new procedure for estimating gray water discharge has been added for commercial, industrial, and institutional projects.

APPENDIX G

GRAYWATER SYSTEMS

Title 24, Part 5, California Administrative Code

G 1 Graywater Systems (General)

(a) The provisions of this Appendix shall apply to the construction, installation, alteration and repair of graywater systems for subsurface landscape irrigation. The graywater system shall not be connected to any potable water system without an air gap (~~a space or other physical device which prevents backflow~~) and shall not result in any surfacing of the graywater. Except as otherwise provided for in this Appendix, the provisions of the Uniform Plumbing Code (UPC) shall be applicable to graywater installations.

(b) The type of system shall be determined on the basis of location, soil type, and ground water level and shall be designed to accept all graywater connected to the system from the building. The system shall discharge into subsurface irrigation fields and may include surge tank(s) and appurtenances, as required by the Administrative Authority.

(c) No graywater system, or part thereof, shall be located on any lot other than the lot which is the site of the building or structure which discharges the graywater; nor shall any graywater system or part thereof be located at any point having less than the minimum distances indicated in Table G-1.

(d) No permit for any graywater system shall be issued until a plot plan with appropriate data satisfactory to the Administrative Authority has been submitted and approved. When there is insufficient lot area or inappropriate soil conditions for adequate absorption of the graywater, as determined by the Administrative Authority, no graywater system shall be permitted. The Administrative Authority is a city or county.

(e) No permit shall be issued for a graywater system which would adversely impact a geologically sensitive area, as determined by the Administrative Authority.

(f) Private sewage disposal systems existing or to be constructed on the premises shall comply with Appendix I of this code or applicable local ordinance. When abandoning underground tanks, Section 722.0 of the UPC shall apply. Also, appropriate clearances from graywater systems shall be maintained as provided in Table G-1. The capacity of the private sewage disposal system, including required future areas, shall not be decreased by the existence or proposed installation of a graywater system servicing the premises.

(g) Installers of graywater systems shall provide an operation and maintenance manual, acceptable to the Administrative Authority, to the owner of each system. Graywater systems require regular or periodic maintenance.

(h) The Administrative Authority shall provide the applicant a copy of this Appendix.

G 2 Definitions

Graywater is untreated waste water which has not come into contact with toilet waste. Graywater includes waste water from bathtubs, showers, bathroom wash basins, clothes washing machines, and laundry tubs, or an equivalent discharge as approved by the Administrative Authority. It does not include waste water from kitchen sinks, photo lab sinks, dishwashers, or laundry water from soiled diapers.

G 3 Permit

It shall be unlawful for any person to construct, install or alter, or cause to be constructed, installed or altered any graywater system in a building or on premises without first obtaining a permit to do such work from the Administrative Authority.

G 4 Drawings and Specifications

The Administrative Authority may require any or all of the following information to be included with or in the plot plan before a permit is issued for a graywater system:

(a) Plot plan drawn to scale completely dimensioned, showing lot lines and structures, direction and approximate slope of surface, location of all present or proposed retaining walls, drainage channels, water supply lines, wells, paved areas and structures on the plot, number of bedrooms and plumbing fixtures in each structure, location of private sewage disposal system and 100 percent expansion area or building sewer connecting to public sewer, and location of the proposed graywater system.

(b) Details of construction necessary to ensure compliance with the requirements of this Appendix together with full description of the complete installation including installation methods, construction and materials as required by the Administrative Authority.

(c) A log of soil formations and ground water level as determined by test holes dug in close proximity to any proposed irrigation area, together with a statement of water absorption characteristics of the soil at the proposed site as determined by approved percolation tests. In lieu of percolation tests, the Administrative Authority may allow the use of Table G-2, an infiltration rate designated by the Administrative Authority, or an infiltration rate determined by a test approved by the Administrative Authority.

(d) A characterization of the graywater for commercial, industrial, or institutional systems, based on existing records or testing.

G 5 Inspection and Testing

(a) Inspection

(1) All applicable provisions of this Appendix and of Section 103.5 of the UPC shall be complied with.

(2) System components shall be properly identified as to manufacturer.

(3) Surge tanks shall be installed on dry, level, well-compacted soil if in a drywell, or on a level, three inch concrete slab or equivalent, if above ground.

(4) Surge tanks shall be anchored against overturning

(5) If the irrigation design is predicated on soil tests, the irrigation field shall be installed at the same location and depth as the tested area.

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

(7) Graywater stub-out plumbing may be allowed for future connection prior to the installation of irrigation lines and landscaping. Stub-out shall be permanently marked "GRAYWATER STUB-OUT, DANGER UNSAFE WATER."

(b) Testing

(1) 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.

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

Article I. G-6 Procedure for Estimating Graywater Discharge

(a) Single Family Dwellings and Multi-Family Dwellings

The Administrative Authority may utilize the graywater discharge procedure listed below, water use records, or calculations of local daily per person interior water use:

1. The number of occupants of each dwelling unit shall be calculated as follows:

First bedroom	2 occupants
Each additional bedroom	1 occupant

2. The estimated graywater flows of each occupant shall be calculated as follows:

Showers, bathtubs and wash basins	25 GPD/occupant
Laundry	15 GPD/occupant

3. The total number of occupants shall be multiplied be the applicable estimated graywater discharge as provided above and the type of fixtures connected to the graywater system.

(b) Commercial, Industrial, and Institutional Projects

The Administrative Authority may utilize the graywater discharge procedure listed below, water use records, or other documentation to estimate graywater discharge:

1. The square footage of the building divided by the occupant load factor from UPC Table 10-A equals the numbers of occupants.

2. The number of occupants times the flow rate per person (minus toilet water and other disallowed sources) from UPC Table I-2 equals the estimated graywater discharge per day.

The graywater system shall be designed to distribute the total amount of estimated graywater discharged daily.

G 7 Required Area of Subsurface Irrigation

Each irrigation zone shall have a minimum effective irrigation area for the type of soil and infiltration rate to distribute all graywater produced daily , pursuant to Section G-6, without surfacing. The required irrigation area shall be based on the estimated graywater discharge, pursuant to Section G-6, size of surge tank, or a method determined by the Administrative Authority.

If a mini-leachfield irrigation system is used, the required square footage shall be determined from Table G-2, or equivalent, for the type of soil found in the excavation. The area of the irrigation field shall be equal to the aggregate length of the perforated pipe sections within the irrigation zone times the width of the proposed mini-leachfield trench.

No irrigation point shall be within five vertical feet of the highest known seasonal groundwater nor where graywater may contaminate the groundwater or ocean water. The applicant shall supply evidence of ground water depth to the satisfaction of the Administrative Authority.

G 8 Determination of Irrigation Capacity

(a) In order to determine the absorption quantities of soils other than those listed in Table G-2, the proposed site may be subjected to percolation tests acceptable to the Administrative Authority or determined by the Administrative Authority.
(b) When a percolation test is required, no mini-leach field system or subsurface drip irrigation system shall be permitted if the test shows the absorption capacity of the soil is less than 60 minutes/inch or more rapid than 5 minutes/inch, unless otherwise permitted by the Administrative Authority.
(c) The irrigation field size may be computed from Table G-2, or determined by the Administrative Authority or a designee of the Administrative Authority.

G 9 Surge Tank Construction (Figure 1)

(a) Plans for surge tanks shall be submitted to the Administrative Authority for approval. The plans shall show the data required by the Administrative Authority and may include dimensions, structural calculations, and bracing details.
(b) Surge tanks shall be constructed of solid, durable materials, not subject to excessive corrosion or decay and shall be watertight.
(c) Surge tanks shall be vented as required by Chapter 9 of this Code and shall have a locking, gasketed access opening, or approved equivalent, to allow for inspection and cleaning.
(d) Surge tanks shall have the rated capacity permanently marked on the unit. In addition, "GRAYWATER IRRIGATION SYSTEM, DANGER - UNSAFE WATER" shall be permanently marked on the surge tank.
(e) Surge tanks installed above ground shall have an overflow, separate from the line connecting the tank with the irrigation fields. The overflow shall have a permanent connection to a sewer or to a septic tank, and shall be protected against sewer line backflow by a backwater valve. The overflow shall not be equipped with a shut-off valve.
(f) The overflow and drain pipes shall not be less in diameter than the inlet pipe. The vent size shall be based on the total graywater fixture units, as outlined in UPC Table 7-5 or local equivalent. Unions or equally effective fittings shall be provided for all piping connected to the surge tank.
(g) Surge tanks shall be structurally designed to withstand anticipated loads. Surge tank covers shall be capable of supporting an earth load of not less than 300 pounds per square foot when the tank is designed for underground installation.
(h) Surge tanks may be installed below ground in a dry well on compacted soil, or buried if the tank design is approved by the Administrative Authority. The system shall be designed so that the tank overflow will gravity drain to a sanitary sewer line or septic tank. The tank must be protected against sewer line backflow by a backwater valve.
(i) Materials

(1) Surge tanks shall meet nationally recognized standards for non potable water and shall be approved by the Administrative Authority.
(2) Steel surge tanks shall be protected from corrosion, both externally and internally, by an approved coating or by other acceptable means.

G 10 Valves and Piping (Figure 1)

Graywater piping discharging into a surge tank or having a direct connection to a sanitary drain or sewer piping shall be downstream of an approved waterseal type trap(s). If no such trap(s) exists, an approved vented running trap shall be installed upstream of the connection to protect the building from any possible waste or sewer gasses. Vents and venting shall meet the requirements in Chapter 9 of the UPC. All graywater piping shall be marked or shall have a continuous tape marked with the words "DANGER - UNSAFE WATER." All valves, including the three-way valve, shall be readily accessible and shall be approved by the Administrative Authority. A backwater valve, installed pursuant to this Appendix, shall be provided on all surge tank drain connections to the sanitary drain or sewer piping.

G 11 Irrigation Field Construction

The Administrative Authority may permit subsurface drip irrigation, mini-leach field or other equivalent irrigation methods which discharge graywater in a manner which ensures that the graywater does not surface. Design Standards for subsurface drip irrigation systems and mini-leach field irrigation systems follow:

(a) Standards for a subsurface drip irrigation system are:
(1) Minimum 140 mesh (115 micron) filter with a capacity of 25 gallons per minute, or equivalent, filtration, sized appropriately to maintain the filtration rate, shall be used. The filter back-wash and flush discharge shall be caught, contained and disposed of to the sewer system, septic tank, or with approval of the Administrative Authority, a separate mini-leach field sized to accept all the back wash and flush discharge water. Filter backwash water and flush water shall not be used for any purpose. Sanitary procedures shall be followed when handling filter back-wash and flush discharge of graywater.

(2) Emitters shall have 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 manufacture for subsurface use and graywater use, and shall have demonstrated resistance to root intrusion. For emitter ratings refer to: Irrigation Equipment Performance Report, Drip Emitters and Micro-Sprinklers, Center for Irrigation Technology, California State University, 5730 N. Chestnut Avenue. Fresno, California 93740-0018.

(3) Each irrigation zone shall be designed to include no less than the number of emitters specified in Table G-3, or through a procedure designated by the Administrative Authority. Minimum spacing between emitters is 14 inches in any direction.

(4) The system design shall provide user controls, such as valves, switches, timers, and other controllers as appropriate, to rotate the distribution of graywater between irrigation zones.

(5) All drip irrigation supply lines shall be polyethylene tubing or PVC class 200 pipe or better and schedule 40 fittings. All joints shall be properly solvent-cemented, inspected and pressure tested at 40 psi, and shown to be drip tight for five minutes, before burial. All supply lines will be buried at least eight inches deep. Drip feeder lines can be poly or flexible PVC tubing and shall be covered to a minimum depth of nine inches.

(6) Where pressure at the discharge side of the pump exceeds 20 pounds per square inch (psi), a pressure reducing valve able to maintain downstream pressure no greater than 20 psi shall be installed downstream from the pump and before any emission device.

(7) Each irrigation zone shall include a flush valve/anti-siphon valve to prevent back siphonage of water and soil.

(b) Standards for a mini-leach field system are:

(1) Perforated sections shall be a minimum 3-inch diameter and shall be constructed of perforated high density polyethylene pipe, perforated ABS pipe, perforated PVC pipe, or other approved materials, provided that sufficient openings are available for distribution of the graywater in the trench area. Material, construction and perforation of the piping shall be in compliance with the appropriate absorption field drainage piping standards and shall be approved by the Administrative Authority.

(2) Clean stone, gravel, or similar filter material acceptable to the Administrative Authority, and varying in size between 3/4 inch to 2 inches shall be placed in the trench to the depth and grade required by this Section. Perforated sections shall be laid on the filter material in an approved manner. The perforated sections shall then be covered with filter material to the minimum depth required by this Section. The filter material shall then be covered with landscape filter fabric or similar porous material to prevent closure of voids with earth backfill. No earth backfill shall be placed over the filter material cover until after inspections and acceptance.

(3) Irrigation fields shall be constructed as follows:

	Minimum	**(a) Maximum**
Number of drain lines per irrigation zone	1	---
Length of each perforated line	---	100 feet
Bottom width of trench	6 inches	18 inches
Total depth of trench	17 inches	18 inches
Spacing of lines, center to center	4 feet	---
Depth of earth cover of lines	9 inches	---
Depth of filter material cover of lines	2 inches	---
Depth of filter material beneath lines	3 inches	---
Grade of perforated lines	level	3 inches/100 feet

Section 1.02 G 12 Special Provisions

(a) Other collection and distribution systems may be approved by the Administrative Authority as allowed by Section 301 of the UPC.
(b) Nothing contained in this Appendix shall be construed to prevent the Administrative Authority from requiring compliance with stricter requirements than those contained herein, where such stricter requirements are essential in maintaining safe and sanitary conditions or from prohibiting graywater systems. The prohibition of graywater systems or more restrictive standards may be adopted by the Administrative Authority by ordinance after a public hearing.

G 13 Health and Safety

(a) Graywater may contain fecal matter as a result of bathing and/or washing of diapers and undergarments. Water containing fecal matter, if swallowed, can cause illness in a susceptible person. Therefore, graywater shall be not be contacted by humans, except as required to maintain the graywater treatment and distribution system.
(b) Graywater shall not include laundry water from soiled diapers.
(c) Graywater shall not be applied above the land surface or allowed to surface and shall not be discharge directly into or reach any storm sewer system or any water of the United States.
(d) Graywater shall not be used for vegetable gardens.

Table G-1 Location of Graywater System.

Minimum Horizontal Distance (in feet) From	Surge Tank (feet)	Irrigation Field (feet)
Buildings or Structures (1)	5ft (2)	8ft (3)
Property line adjoining private property	5ft	5ft (4)
Water supply wells (5)	50ft	100ft
Streams and lakes (5)	50ft	50ft
Seepage pits or cesspools	5ft	5ft
Disposal field & 100% expansion area	5ft	4ft (6)
Septic tank	0ft	5ft (7)
On-site domestic water service line	5ft	5ft (8)
Pressure public water main	10ft	10ft (9)
Water ditches	50ft	50ft

Notes: When mini-leach fields are installed in sloping ground, the minimum horizontal distance between any part of the distribution system and ground surface shall be fifteen feet.

(1) Including porches and steps, whether covered or uncovered, but does not include car ports, covered walks, driveways and similar structures.
(2) The distance may be reduced to zero feet for above ground tanks if approved by the Administrative Authority.
(3) The distance may be reduced to two feet.
(4) For subsurface drip irrigation systems, 2 feet from property line.
(5) Where special hazards are involved, the distance may be increased by the Administrative Authority.
(6) Applies to the mini-leach fields type system only. Plus two feet for additional foot of depth in excess of one foot below the bottom of the drain line.
(7) Applies to mini-leach field only.
(8) A two foot separation is required for subsurface drip systems.
(9) For parallel construction or for crossings, approval by the Administrative Authority shall be required.

Table G-2 Mini-Leach Field Design Criteria of Six Typical Soils.

Type of Soil	Minimum sq. ft. of irrigation area per 100 gallon of estimated graywater discharge per day	Maximum absorption capacity, minutes per inch of irrigation area for a 24-hour period
1. Coarse sand or gravel	20	5
2. Fine sand	25	12
3. Sandy loam	40	18
4. Sandy clay	60	24
5. Clay with considerable sand or gravel	90	48
6. Clay with small amount of sand or gravel	120	60

Table G-3 Subsurface Drip Design Criteria of Six Typical Soils.

Type of Soil	Maximum emitter discharge (gal/day)	Minimum number of emitters per gpd of graywater production
1. Sand	1.8	0.6
2. Sandy loam	1.4	0.7
3. Loam	1.2	0.9
4. Clay loam	0.9	1.1
5. Silty clay	0.6	1.6
6. Clay	0.5	2.0

Use the daily graywater flow calculated in Section G-6 to determine the number of emitters per line.

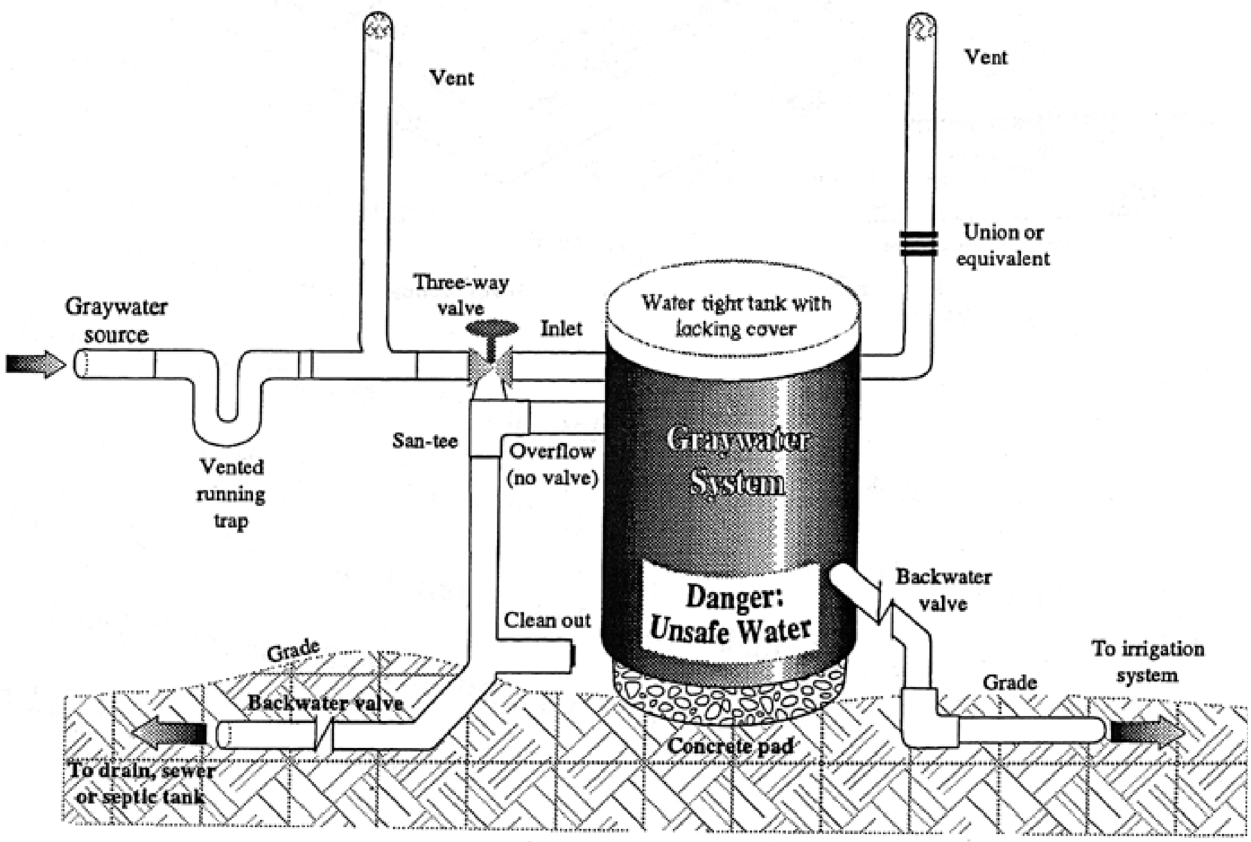


Figure 1-Graywater System Single Tank-Gravity (conceptual)

APPENDIX C

Nevada

NAC 444.7616 "Graywater" defined. (NRS 439.200, 444.650) "Graywater" means untreated household wastewater that has not come into contact with toilet waste. The term includes, without limitation, used water from bathtubs, showers and bathroom washbasins, and water from machines for washing clothes and laundry tubs, but does not include wastewater from kitchen sinks or dishwashers.

(Added to NAC by Bd. of Health by R129-98, eff. 3-25-99)

NAC 444.837 System utilizing graywater for underground irrigation: General requirements. (NRS 439.200, 444.650)

1. Graywater may be used for underground irrigation if approved by the administrative authority. A homeowner must obtain a permit to construct, alter or install a system that uses graywater for underground irrigation from the administrative authority before such a system may be constructed, altered or installed.

2. A system that uses graywater for underground irrigation:

(a) May be used only for a single-family dwelling.

(b) Must not be used in soils which have a percolation rate that is greater than 120 minutes per inch.

(c) Must consist of a three-way diversion valve, a holding tank for the graywater and an irrigation system.

(d) May be equipped with a pump or siphon, or may rely on gravity to cause the water to flow to the irrigation system.

(e) Must not be connected to a system for potable water.

(f) Must not result in the surfacing of any graywater.

3. A system that uses graywater for underground irrigation, or any part thereof, must not be located on a lot other than the lot which is the site of the single-family dwelling that discharges the graywater to be used in the system.

(Added to NAC by Bd. of Health by R129-98, eff. 3-25-99)

NAC 444.8372 System utilizing graywater for underground irrigation: Application to construct, alter or install system; design criteria. (NRS 439.200, 444.650)

1. An application to construct, alter or install a system that uses graywater for underground irrigation must include:

(a) Detailed plans of the system to be constructed, altered or installed;

(b) Detailed plans of the existing and proposed sewage disposal system; and

(c) Data from percolation tests conducted in accordance with NAC 444.796 to 444.7968, inclusive.

2. A holding tank for graywater must:

(a) Be watertight and constructed of solid, durable materials that are not subject to excessive corrosion or decay.

(b) Have a minimum capacity of 50 gallons.

(c) Have an overflow and an emergency drain. The overflow and emergency drain must not be equipped with a shutoff valve.

3. A three-way diversion valve, emergency drain and overflow must be permanently connected to the building drain or building sewer and must be located upstream from any septic tanks. The required size of an individual sewage disposal system must not be reduced solely because a system that uses graywater for underground irrigation is being used in conjunction with the individual sewage disposal system.

4. The piping for a system that uses graywater for underground irrigation which discharges into the holding tank or is directly connected to the building sewer must be downstream of any vented trap to protect the building from possible sewer gases.

5. The estimated discharge of a system that uses graywater for underground irrigation must be calculated based on the number of bedrooms in the building, as follows:

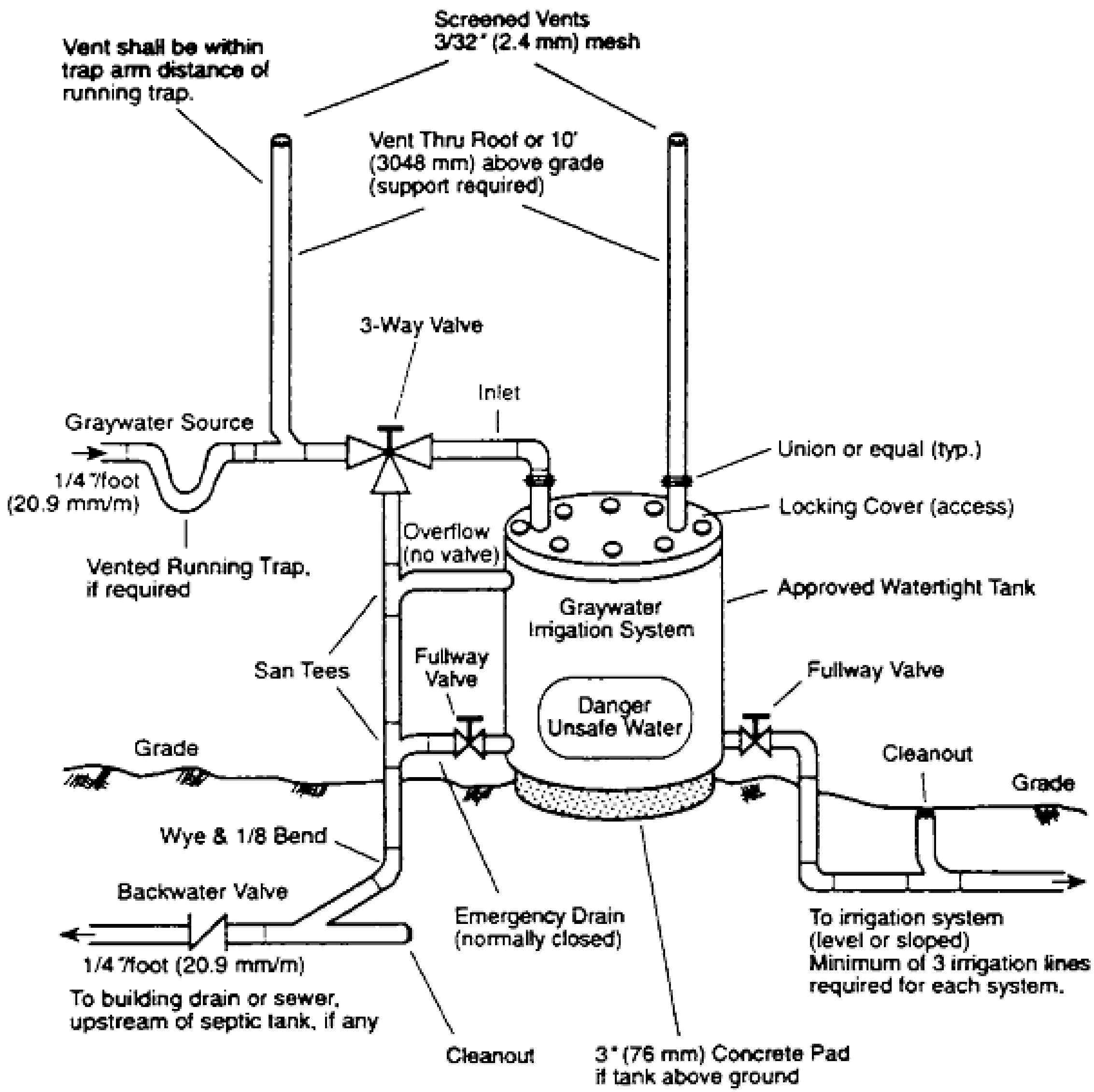
(a) For the first bedroom, the estimated discharge of graywater is 80 gallons per day; and

(b) For each additional bedroom, the estimated discharge of graywater is 40 gallons per day.

6. The absorption area for an irrigation system that includes a system that uses graywater for underground irrigation must be calculated in accordance with the following table:

Percolation Rate (minutes per inch)	Minimum Square Feet Per 100 Gallons Discharged Per Day
0-20	20
21-40	40
41-60	60

7. The following is a diagram of a system that uses graywater for underground irrigation:
(Added to NAC by Bd. of Health by R129-98, eff. 3-25-99)


Screened Vents
3/32" (2.4 mm) mesh
Vent shall be within
trap arm distance of
running trap.
Vent Thru Roof or 10'
(3048 mm) above grade
(support required)
3-Way Valve
Inlet
Graywater Source
1/4"/foot
(20.9 mm/m)
Union or equal (typ.)
Locking Cover (access)
Overflow
(no valve)
Vented Running Trap,
if required
Approved Watertight Tank
Graywater
Irrigation System
San Tees
Fullway
Valve
Fullway Valve
Danger
Unsafe Water
Grade
Cleanout
Grade
Wye & 1/8 Bend
Backwater Valve
Emergency Drain
(normally closed)
To irrigation system
(level or sloped)
Minimum of 3 irrigation lines
required for each system.
1/4"/foot (20.9 mm/m)
To building drain or sewer,
upstream of septic tank, if any
Cleanout
3" (76 mm) Concrete Pad
if tank above ground