**SUBSTITUTING RESIDENTIAL RAINWATER HARVESTING AND GREYWATER REUSE FOR PUBLIC
WATER SUPPLY:
TOOLS FOR EVALUATING THE PUBLIC COST**

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Jennifer Ferguson
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Committee Membership

Title: **Substituting Residential Rainwater Harvesting and Greywater Reuse for Public Water Supply: Tools for Evaluating the Public Cost.**

Date Submitted: May 2009

Author: Jennifer Ferguson

Dr. Jens Pohl

Committee Chairman

Architecture Department

Professor Arthur Chapman

Committee Member

Architecture Department

Professor Yarrow Nelson

Committee Member

Civil and Environmental Engineering Department

Abstract

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Jennifer Ferguson

The intent of this project is to provide tools for public administrators to implement and evaluate the cost of an alternative on-site residential water supply using rainwater harvesting and greywater reuse in their jurisdiction. These tools are then applied to the city of San Luis Obispo (SLO), California as a case study to demonstrate how rainwater harvesting and greywater reuse could be implemented to supply all residential potable and non-potable water needs, completely replacing the current centralized publicly-managed water system. Further, energy and direct fiscal costs of the alternative system are compared with the current system. A cost analysis is crucial given that sustainability is heavily linked to appropriately valuing a resource and increasing the visibility of same to the public. Pursuing sustainable water supply options is particularly important given critical water shortages and the need to decouple the energy/water equation in pursuit of reducing energy use and greenhouse gas (GHG) emissions.

A decision tree and other tools were developed as part of this project for use by public administrators to determine the site-specific scope of an alternative residential water supply system. For example, a key question is the capacity of such a system to supply both potable and non-potable water needs. These tools were applied to single family (SF) residences in the case study city of SLO and resulted in an alternative residential system capable of completely substituting for public water supply. Implementation requires a major adjustment of indoor water demand from the SLO average of 55 gallons per capita per day (gpcd) to a 'best practice' water conservation mode of 27 gpcd, including a greywater reuse system for irrigation and toilet flushing.

With demand held constant, the costs of the alternative on-site residential water supply system were then compared to the costs of the current centralized public water system for both the municipality and the consumer in SF residences in SLO. The public water supply costs were based on overall budgeted costs, including implementing a new project the city is partially financing for conveying Nacimiento Reservoir water to SLO. Consumer-billed costs include expected price increases proposed for the next year by the City largely due to the addition of the Nacimiento project. The volumetrically apportioned municipal water supply cost (\$0.0049/gallon) is 37% lower than that billed to the consumer (\$0.0078/gallon), but the wastewater processing cost for the City (\$0.0125/gallon) is 39% greater than that billed to the consumer (\$0.0076/gallon). Thus the combined water supply and wastewater processing costs for the City are only 4% greater than that billed to residential customers. It is notable that the City intends to significantly increase water prices billed to customers over the next several years which would shift the cost analysis in favor of the alternative system.

The alternative system costs were based on operating costs (such as electricity) and the cost of the installed components of the system averaged yearly according to the life of the parts (10-50 years). The municipal cost for water supply (\$0.0049/gallon) was 55% less than the cost for the alternative system

(\$0.0111/gallon), but the cost savings of wastewater processing using the alternative system (\$0.0086/gallon) is 31% less than the municipal cost (\$0.0125/gallon). The alternative systems savings are mostly a result of on-site greywater reuse for irrigation and indicate the scope of the immediate fiscal benefit to the municipality to substitute residential greywater systems for current public wastewater services. To calculate the overall cost difference in terms of both water supply and wastewater costs, the total costs used are as if all SF residences in SLO used the system. Overall, the municipal costs for combined water supply and wastewater processing (\$4,137,598/yr) were 20% less than the alternative decentralized on-site system (\$5,376,735/yr).

The cost to the consumer for current water supply through the public water system (\$0.0078/gallon) is 29% lower than the proposed alternative system (\$0.0111/gallon). The wastewater processing cost to the consumer (\$0.0076) is also 11% less than that of the alternative system (\$0.0086/gallon). On this basis, the consumer cost using expected billing rates (\$4,137,598) is 23% lower using the public water system than the cost of the alternative system (\$5,376,735). Expected water and sewer rate increases may skew these results in favour of the alternative system where it is viable for the consumer to completely replace their water system and remove their household off the public water system to their financial benefit.

The overall energy for water supply and wastewater processing used by the public water system was 34% lower (1,216,849 kWh/yr) than the alternative system (1,855,894 kWh/yr). The alternative on-site system's electrically-driven pump is mostly responsible for this energy use and could be virtually eliminated by using gravity feed, as is common in many parts of the world currently using rainwater harvesting technology. Solar energy is also an effective solution to eliminate fossil-fuel based electricity.

From a fiscal perspective, the alternative system costs are inflated given that an expected drop in supply cost would likely ensue with the economies of scale gained if an entire city was purchasing equipment for the alternative systems. This could override the results of the study showing the alternative system's 20-23% higher fiscal cost than current public water system. Considering the 'no fossil-fuel' energy alternatives and the expected significant drop in supply cost with large scale purchasing, the alternative system provides a promising alternative residential water supply for SLO.

Keywords: rainwater harvesting, rainwater tanks, greywater / graywater reuse, decentralized water supply, public water management, on-site water supply, decoupling water and energy, true cost of water, valuing water, wastewater processing cost, Greenhouse Gas emissions (GHG), sustainable water supply, San Luis Obispo case study, economies of scale, water and electricity, Nacimiento.

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Chapter 1 – Exploring Residential Water Supply

Thesis Objective

This thesis examines the direct fiscal and energy cost of an alternative on-site residential water supply using rainwater harvesting and greywater reuse and contrasts it against volumetrically apportioned municipal costs and consumer-billed costs using a centralized public water management system (water demand being held constant). Fiscal and energy costs have been chosen for their generally agreed significance in the public cost equation.

Evaluating the sustainability of our residential water sources and delivery systems requires an understanding of the true cost of water. Increasing the visibility of the cost of water to the public is also crucial. True public cost should account for all the inputs and outputs of a system and measure them from an environmental, social and economic perspective for sustainability. Pursuing sustainable water supply options is particularly important given critical water shortages and the need to decouple the energy/water equation in pursuit of reducing energy use and Greenhouse Gas (GHG) emissions.

Figure 1 describes the facets of fiscally sustainable water delivery. The ‘true’ cost of water services is commonly unknown to the end user. Frequently, public agencies cannot provide a figure for the total costs of water delivery for their area (although data for each aspect of water supply, distribution and delivery is commonly available separately in diverse areas of budget documents).

Figure 1. True Direct Fiscal Components of Water Delivery. Source: “Water Facts and Trends”. *World Business Council for Sustainable Development (Online)* 2005 available at http://www.wbcsd.org/web/publications/Water_facts_and_trends.pdf

The first step in this process is to develop tools for public administrators to determine the scope of an alternative system for their area; including whether site specific conditions will allow for an alternative system that can provide for both potable and non-potable water needs for the area’s households. One such tool is the decision tree developed in this thesis. These tools are then applied to the case study city of San Luis Obispo (SLO), California. The resulting alternative decentralized system is then compared to the current centralized public water system on the basis of direct fiscal and energy costs.

Introduction

We exist in an era where sustainable ways of inhabiting the planet are coming to the forefront of our consciousness, especially for the subset of human activity related to the built environment. Practices associated with human habitation and their impact on the macro environment are increasingly being reviewed and analyzed for soundness. More and more, the public cost of our actions is viewed more broadly, across disciplines and public agencies. There is more regard for the longer term rather than seeing costs as limited to fiscal or for a financial year only. Viewing projects in terms of sustainability

incorporates a broader and longer term perspective and is increasingly becoming a precursor for projects to receive support.

Examining water management practices for their sustainability is becoming a ‘hotter’ topic as the reality of the limits of viable supplies of water is increasingly understood. Critical water shortages are being experienced locally and internationally with significant numbers of people being affected. Our demand for water, domestically and globally, continues to proportionally outstrip population growth. Viability of alternative water supplies requires an analysis of all inputs and outputs of the systems to determine their sustainability. Consideration of the embedded energy in processing and delivering water to users is a particularly important aspect in terms of both energy use and its direct relationship with Greenhouse Gas (GHG) emissions.

With U.S. buildings being responsible for 48% of all energy use, the role of the building sector in sustainability is critical. Add to that the embedded energy associated with inputting water into buildings and the domination of the building industry in producing GHG becomes clear. With respect to energy alone, rainwater harvesting and greywater reuse would immediately seem to offer advantages as an *in-situ* system given the lack of massive energy costs required to move water in the traditional centralized systems. In addition, a simple comparative with other common alternative supply systems (specifically desalination and groundwater) on the basis of inputs and outputs shows that RHSs offer an attractive possibility as a sustainable option (see Table 1).

Given the varied subjective uses of the term ‘sustainable development’, it is important to provide guidance as to the meaning of this term for the purposes of this study. The 1987 UN Brundtland Commission broadly defined ‘sustainable development’ as development that “meets the needs of the present without compromising the ability of future generations to meet their own needs” (United Nations, 1987). Tony Allan, creator of the ‘virtual water’¹ concept, provides greater definition of those needs when he speaks of sustainability being achieved when “outcomes which are socially, economically and environmentally sustainable are successfully contended” (Allan T. , 2004). Finally, John Asquith, Director of the Sydney Water Catchment Authority, defined environmentally sustainable practices for the water management industry very simply at a 2007 water management conference: “Mimic Nature. Don’t add anything to the environment. Don’t take anything away that isn’t renewable” (Asquith, 2007).

¹ ‘Virtual water’ is a term coined by J.A. Allan (Allan, 2002) meaning water used in the production of a good or service.

True public cost then should account for all the inputs and outputs of the current system and measure them from an environmental, social and economic perspective for sustainability. A focus on cost is considered critical to developing conscientious behaviors around water. Entrenching a public perception of the true value and limits of water as a resource is crucial. From the supply end of the equation, as described in the UN World Water Development Report², any strategies aimed at better valuation of water is a move towards more accountable water management. From the consumer end, more closely connecting urban residents to their water supply through their own on-site system immediately offers opportunities for users to understand cost and limitations of water supply in ways the current system cannot.

Current Practices

There is a growing perception that the way we traditionally manage water resources is unsustainable and there is an accompanying awareness that alternative ways of accessing water and managing our water supply are becoming a higher priority. The United Nations General Assembly has recognized water as crucial to sustainable development by designating the years 2005 to 2015 as the International Decade for Action 'Water for Life'. The following statement by the then UN Secretary-General outlines the critical situation we face globally.

Global freshwater consumption rose sixfold between 1900 and 1995 - more than twice the rate of population growth.....If present trends continue, two out of every three people on Earth will live in (water stressed) conditions by 2025.
(Annan, 2000)

It has been suggested that current water management by centralized public water management authorities worldwide is driven by an emphasis on 'demand management'. Simply stated, this means that the driver for initiatives around water management have been based on meeting increased demand. Commentators suggest that this has been done with poor attention to long term planning and a short term focus. For example, Peter Cullen, Commissioner for the Australian National Water Commission, reasons that a key driver for this behavior is that "water utilities have been seeking to defer expensive augmentations by demand management" (Cullen, 2007). He further argues that water utilities funds have been misapplied through seeing them as lucrative sources of state income rather

² "Water, a shared responsibility" UN World Water Development Report 2, 2006. Ch 12. P.427

than directing the resources to strategies aimed at longer term, better management of water resources. (Cullen, 2007)

By contrast, it is suggested that there has been significantly less focus on 'supply management' until recent pressures on existing water supplies has forced turning to alternative sources (e.g. groundwater supplies, desalination and recycling). It is suggested that this demand driven overall water management approach is equally applicable to the U.S. situation. This report recognizes and builds on the exploration of alternatives as part of a supply management orientation. In addition, the study's premise is to facilitate incorporating maximum possible *in-situ* water supply for a residence to supply all water needs (attempting to reduce public water supply to zero).

Global Water Use

Fresh water available

Figure 2. Global Fresh Water Supplies. Source: "Water Facts and Trends". World Business Council for Sustainable Development. (Online) 2005 available at http://www.wbcd.org/web/publications/Water_facts_and_trends.pdf.

Figure 2 describes readily available global freshwater supplies as 0.5% of the earth's water and equating to 300 million miles³ (1 trillion gallons). According to 'Water Facts and Trends', 50% of all drinking water globally is being sourced from aquifers as at 2005, which represents a rapid expansion of groundwater exploitation since the 1950s (in particular groundwater 'mining', where aquifer supplies are taken at a greater rate than the precipitation in the area can replenish them) (Water Facts & Trends, 2005). It is recognized that water is not currently in short supply in absolute terms. Carmen Revenga quantifies the situation. A primary global difficulty is non-uniform water distribution, with 10 countries

possessing 60% of the water. Global withdrawal trends also give cause for concern. Human withdrawals were about 30% of total supply in 2003. By 2025 human withdrawals are expected to reach 70% of the world's total accessible fresh water supply (Revenga, 2000). Calculations have also shown over-extraction of groundwater by the world's farmers is greater than the global recharge rate by 3.8 cubic miles. Also, in 60% of European cities with greater than 100 000 people, groundwater is being used at a greater rate than it can be replenished (Hoffman A. , 2000). Key factors influencing water use trends are population growth, expansion of business activity and rapid global urbanization which all create upward pressure on water demand. In addition, climate change is producing a downward pressure on supply and increasing uncertainty of water availability (Water Facts & Trends, 2005). The opinion of UNESCO's World Water Assessment Program in their 'World Water Development Report' is that "this crisis is one of water governance, essentially caused by the ways in which we mismanage water" (World Water Development Report 2, 2006).

U.S. Water Use

Figure 3. U.S. Domestic Water Use. Source: "Water Facts and Trends". World Business Council for Sustainable Development (Online) 2005 available at http://www.wbcsd.org/web/publications/Water_facts_and_trends.pdf

The graphic above shows the domestic water use for the U.S. Allan, in his workings relating to the 'virtual water' concept previously discussed, describes the global average breakdown on a per person per year basis: 1m³ (35 ft³) Drinking water + 50-100m³ (1766-3531 ft³) other domestic purposes + >1000m³ (>35,315 ft³) to produce their food. Specifically, the overall U.S. per capita average water use is

2482m³ (87,651 ft³) while Australia averages 1393m³ (49,193 ft³) and Japan 1153m³ (40,718 ft³) (Allan J. , 2002).

Globally, the largest user of fresh water is agriculture, accounting for 70% of total use (Revenge, 2000). U.S. agriculture accounts for 39% of fresh water use (which is also the same fraction used for cooling thermal power plants) (Hoffman A. R., 2004). By comparison, in developing countries the agricultural sector's water-use portion approaches 90% (Water Facts & Trends, 2005). When it comes to U.S. buildings in particular, the USGBC puts U.S. buildings at using 14% of potable water consumed. Of that, 74.4% is attributable to residential needs (Green Building Research, 2008).

Water and the Built Environment

Water is arguably the 'keystone' of human habitation. From the beginning of human civilization (with an emphasis on the greek origins of the word: Civitas meaning 'of the city'), adequate and consistent water supply has been crucial for humans to dwell together on a larger scale. Whether looking at the ancient city of Jericho (7500 BC) with its stable well or the remarkably engineered aqueducts and water systems supplying the cities of ancient Rome around 20 BC, water has been the life blood of our community living and has fueled the growth of our societies. Take away water, and our civilization is at risk.

Examining sustainable water supply options for the built environment is timely. Architects and home designers are building homes that will exist in a future world with increased pressure on all resources, including water. The inputs and outputs of buildings should be fully examined in order to correctly ascertain overall impacts on the macro environment.

Figure 4. Typical Inputs and Outputs of a Building

A failure to investigate and account for the key issues that will be faced by our buildings over the next fifty years (a common benchmark for the life of a building³) is poor planning and design. In fact, the scope of the opportunity for the building industry to recreate the landscape is revealed in data from the AIA Research Corporation that shows by the year 2035 “three quarters of the built environment in the U.S. will be either new or renovated” (Architecture 2030).

When addressing the connection between buildings and direct water consumption, as noted, USGBC data highlights that US buildings currently account for 14% of potable water consumption (Green Building Research, 2008). Add to that the indirect costs to the environment such as the energy involved in transporting water (waste and potable water) to and from centralized locations and the accompanying Greenhouse Gas (GHG) emissions associated with the energy needed to do so; the loss of water through leaky, poorly maintained or old infrastructure; processing water indiscriminately to potable standards (regardless of whether the end use requires it eg. toilet flushing) and it becomes apparent that examining the efficiencies and issues associated with our traditional ways of dealing with water in our buildings has enormous potential.

Greenhouse Gas Emissions and Energy

The increasing focus on Greenhouse Gas (GHG)⁴ and recent public policy attention to same requires attention to the embedded energy equations associated with current water management practices. The following graphics indicate the apportioned energy and electricity use by the U.S. building sector in general.

³ For example, the California State University (CSU) system has a 2003 “Submittal Requirements and Procedures Guide for CSU Capital Projects” that uses a total cost of ownership over 50 years as a basis for designs.

⁴ Legislative targets were set in 2007 for CA, WA, NJ, IA, MN in a joint initiative by 4 State Governors to reduce GHG emissions (Western Regional Climate Action Initiative). 27 Large companies are spearheading a private sector push to shape GHG policy (Climate Action Partnership) (Ball, Nov. 8, 2007)

Figure 5. U.S. Energy Consumption (left) and U.S. Electricity Consumption (right), 2000.
Source: “Architecture 2030”. (Online) 2000 available at
http://www.architecture2030.org/current_situation/building_sector.html.

Figure 5, showing the enormous direct use of energy by the building industry, does not include indirect energy inputs into buildings such as that used to pump, process and transport water on site from a centralized source. When indirect costs of existing water supply systems are accounted for, the significance of the building segment as a dominant factor in U.S. energy consumption, and therefore GHG emissions, becomes increasingly evident. Globally, for example, commercial energy consumed for delivering water is more than 26 quads, representing 7% of total world energy consumption according to Hoffman, Senior Analyst for the Department of Energy (Hoffman A. R., 2004). The California Energy Commission (CEC) estimates that total water-related consumption of all electricity used in that state is 19%, in addition to 30% of all natural gas and more than 80 million gallons of fuel. (California Energy Commission, 2005). The CEC also notes the situation in California where two thirds of the state’s water falls in the north and two thirds of the population lives in the south (Assembly Committee on Water, Parks and Wildlife, 2007); which serves to exacerbate this 19% figure significantly in the southern area of state where water is pumped (using electricity) to meet this greater demand.

Figure 6. CO₂ Emissions by Sector, 2000. Source: “Architecture 2030”. (Online) 2000 available at http://www.architecture2030.org/current_situation/building_sector.html.

Figure 6 depicts the steep increase in carbon dioxide emissions from buildings since the 1960s relative to other sectors. This upward trend in GHG emissions in the building sector indicates factors beyond population growth creating this result, as population growth is a constant variable for all sectors. This again points to the importance of focusing on the building industry in managing GHG emissions given that other sectors, such as industry, are experiencing a leveling out in GHG emissions over time. This document will further consider the impact a viable alternative decentralized water system model would have on energy use / GHG levels.

In summary, this is an appropriate area to turn research attention towards in order to create more sustainable practices which have a neutral or positive effect on the environment – a ‘green’ issue. The ‘Whole Building Design Guide’ sums it up:

... new and existing water resources are becoming increasingly scarce in a number of regions throughout the country; per capita water consumption is increasing annually; water and sewer rates have increased dramatically over the last decade (100-400%); and new water supply options are too costly or altogether unavailable—often resulting in stringent water use requirements in new construction applications. In addition, there is the increasing recognition of the water, energy, and O and M savings that can be realized through the implementation of water saving initiatives. (Bourg, 2008)

Rainwater Harvesting and Greywater Reuse

Rainwater harvesting systems (RHS) may offer an effective alternative water source for buildings. Simply put, a RHS is an “assembly that collects, stores, and distributes rain water for use *in situ*; including water treatment as appropriate to intended use” (Rainwater Harvesting & Purification (Portland Case Study), 2006). These can come in the form of roof or site collection systems. In essence, the RHS creates a decentralized method for accessing and processing water for a building’s use. The common model for providing urban water needs is through retaining rainfall using nearby lakes, rivers or man-made catchments and transporting that water for processing through central plants which is then redistributed to individual buildings. RHSs put responsibility for a household or building’s water needs firmly in the hands of the direct users on their sites.

Besides the evident gains in the energy equation an *in situ* water supply would seem to offer, RHSs would also appear to create significant opportunities for a higher level of conscientiousness for water conservation amongst users than may have been achievable through larger centralized shared community water resources. This is particularly true if pricing is not accurately reflecting the real ‘value’ of water by being significantly subsidized.

Non-potable household applications (e.g. Laundry, toilet flushing) seem an ideal area to substitute water taken from on-site systems. Harvested water for potable applications have a different series of accompanying concerns. For example, decentralizing responsibility for maintaining the potability of such *in situ* water resources and the potential for cross-contamination with community shared water channeled into the building are key issues.

Water quality concerns emerge as a key topic for potable applications. Factors such as the choice of roofing materials affecting mineral quality of roof run-off, its bacteriological quality, atmospheric contamination of rainwater, connections between RHS and the breeding of disease vectors (especially mosquitoes) and the risk of accidents such as children drowning; may all impact on the uptake of RHSs and warrant further research. It would seem however that many of these same issues equally impact current centralized water supplies.

Greywater reuse is another key area where significant water conservation savings may be made. As recognized by UNESCO in 1958 “no higher quality water... should be used for a purpose that can tolerate a lower grade” (Hespanhol, 2003). In the built environment, obvious greywater reuse applications are toilet flushing and garden irrigation. Splitting potable and non-potable water sources

through the creation of dual-plumbed buildings is a common solution to the problem of maintaining safe drinking water sources in buildings. The presence of ‘purple pipe’ indicates the presence of this secondary non-potable water supply in many sites.

It is interesting to question why RHS and greywater reuse systems have not been more widely implemented. The UKs ‘Domestic Roof water Harvesting Research program speculates about RHSs:

Cost, climate, technology, hydrology, social and political elements all play a role in the eventual choice of water supply scheme which is adopted for a given situation. RHS are only one possible choice, but one which is often overlooked by planners, engineers and builders. The reason that RHS are rarely considered is often simply due to lack of information – both technical and otherwise.
(Development Technology Unit - Rainwater Harvesting, 2007)

Legislative barriers are another disincentive for change. In many Western States of the US, such as Seattle, Washington, it has been illegal, until recently, for a household to catch rainwater as rain is considered part of the ‘groundwater’ and owned by a public agency under what is legally called ‘prior appropriation’.⁵ By contrast, many of the southern and eastern states consider groundwater “a regulated riparian system, meaning if you own the land, you own the water underneath it” (A.Abkowitz, 2008). Whether this also applies to the rain that falls upon the land in these southern and eastern states is unknown.

RHS and greywater reuse show great promise in the segment of water conservation design strategies and sustainable building. Identifying key issues affecting uptake and wider acceptance is critical.

Rainwater Harvesting Systems – a Sustainable Option?

As previously noted, a simple but comprehensive view of environmental sustainability is to ‘not add anything to the environment and not take anything away that isn’t renewable’. It is an effective way to assess the sustainability of different water supply options by contrasting the basic inputs and outputs of the systems. Alternative supply options that are becoming increasingly popular, such as desalination

⁵ In accord with the RCW (Revised Code of Washington – a compilation of all permanent laws now in force) 43.27A.020; the jurisdiction of the Department of Ecology is defined where “Water resources” means all waters above, upon, or beneath the surface of the earth, located within the state and over which the state has sole or concurrent jurisdiction. (Washington State Government, 2009)

plants and groundwater supplies can be simply contrast with our decentralized RHS / greywater system at this preliminary stage through a basic analysis of inputs and outputs. A favorable outcome for RHSs from this comparative process reinforces the viability of further investigating this system through studies such as this.

Groundwater

The National Ground Water Association (NGWA) gives further guidance on exactly what sustainability means with respect to ground water.

There is generally no 'extra' water in an aquifer. Water captured by a pumping well will result in some combination of a loss in discharge to surface water at some other location, an increase in recharge from surface water, or a loss of storage in the aquifer. Ground water and surface water are a single resource in constant flux. Because it is impossible to use a natural resource without having some effect on it, zero impact is neither a possible nor a desirable goal. However, by understanding the linkages between ground water and other water-dependant natural resources, we can make informed decisions and sustainable compromises.

(National Ground Water Association, 2004)

These 'sustainable compromises' are in line with Asquith's idea of 'not taking anything away that isn't renewable'. The following excerpt from the work of Prof. Richard Cowen of the Geology Department at UC Davis highlights some of the unsustainable results of ground water extractions.

Some aquifers are permanently damaged by over drafting. In rather loosely packed sediments, the grains in the sediment may be held slightly apart by the water film that saturates them, and as that water is extracted the sediment may compact a little. The compaction releases a lot of water, but it is irreversible. The aquifer cannot be recharged to its former water storage capacity, because the compaction has permanently lowered its porosity and permeability of the aquifer. The lost volume may be visible at ground level as permanent subsidence of the land surface. This has happened in several regions of California. Even without compaction, an aquifer that has been depleted deeply may take a long time to recharge, especially in an arid region, and meanwhile chemical or physical changes can alter its characteristics, degrading its performance. (Cowen, 2006)

The drivers and oversight of over drafting, also called water 'mining', are important to note. For example, in places such as Atlanta, GA, where groundwater extraction is unregulated and aquifer water treated as owned by the subject who owns the land above it, there is a rush to drill wells with no accompanying administrative oversight to either limit the wells or measure extraction rates.

(A.Abkowitz, 2008). In 2008, there were 305 well permits issued – 36% more than for 2006 and 2007 combined. (A.Abkowitz, 2008). This occurred as a result of water restrictions being placed on residents

of a community that continues to be in the midst of longstanding drought. At one point, there was less than 80 days of stored water left in Lake Lanier in October of 2007 - a catchment providing drinking water for 5 million residents (Dewan, 2007). The following excerpt relates the current situation in Atlanta, almost a year later, where water restrictions are skirted by residents through accessing aquifers.

While Atlanta's main water source, Lake Lanier, has sunk 15 feet below desired levels and ordinary families have let their lawns go brown, affluent residents are paying thousands of dollars to hydrologists and drilling companies to scout their estates for underground water to draw from whenever they please.
(A.Abkowitz, 2008)

This is a specific example of the kind of short term demand management strategy which can be applied by agencies (in this case U.S.) with regard to water management. This type of approach was previously highlighted in this document as evident in Australian water management practices. Clearly this has application to the U.S. context.

Specific data on groundwater use for our case study city of San Luis Obispo, describes that 75% of the annual supply for the Central Coast Hydrologic Region (comprising San Luis Obispo, Santa Barbara, Monterey, San Benito and Santa Cruz counties) comes from groundwater sources. Local and some imported surface water supplies make up the rest. (Department of Water Resources (DWR), 2005). In addition, the DWR estimates that California's annual overdraft rate is between one million and two million acre-feet⁶ annually. (Department of Water Resources (DWR), 2004)

When considering RHS as a water supply, there is a question as to whether removing precipitation in a particular area will 'take away' from the surface water / aquifer system. Recharging is further addressed in the NGWA's white paper.

Ground water resources and recharge rates vary locally and regionally across the U.S. and within individual states. Different geologic formations retain water differently. Sand and gravel formations have more pore space to store and release ground water. Precipitation will generally run off in areas overlain with tight solid or hard rock, such as shale or granite, and in developed areas where pavement prevents... infiltration. The underlying geology can result in ground water poor regions even in areas of plentiful rainfall. (National Ground Water Association, 2004)

⁶ See Glossary . 1 acre-foot (AF) is approx. 326,000 gallons.

Clearly, whether RHS is reducing water that would, without intervention, become part of the surface water / aquifer system is a site specific issue and would have to be accounted for in decisions made *in situ*. It would seem then, that RHS and aquifer supply face similar issues on the question of sustainable extraction. There is a potential for RHS to ‘take nothing’ from the environment after a geological assessment to ensure conditions are met where there is no drain on surface water / aquifer systems. Comparatively, accessing aquifers as a water source meets ‘take nothing’ conditions if removal is metered and monitored so as not to overdraft beyond the recharge rate and if precipitation is adequate and able to recharge the aquifer.

It should be noted that it is challenging assessing appropriate levels of water which may be safely withdrawn. Simply put, there is not necessarily a straightforward connection between the ground and surface water systems. It is “complex and site specific” (National Ground Water Association, 2004). There is also significant debate as to whether recharging aquifers is possible or feasible. This would seem to indicate there are larger question marks over the sustainability of aquifer supplied water. Additionally, data suggests over drafting is a worldwide issue. In the U.S. specifically Arizona is withdrawing 520 million cubic yards of groundwater representing twice what is being replaced by recharge from rainfall (Mayell, 2003). The Atlanta example given above describes an aquifer system which has no oversight – indicating a strong likelihood for over drafting.

Desalination

The issues of very high energy use (from an operations and management perspective) and outputs such as hyper salinated water are key considerations when looking at desalination solutions as an alternative water supply.

For example, the capacity of the City of Santa Barbara's desalination plant is 7,500 AF/yr (about 7.16 MGD). In May 1992, the plant produced 6.7 MGD of product water and generated 8.2 MGD of waste brine with a salinity approximately 1.8 times that of seawater. An additional 1.7 MGD of brine was generated from filter backwash. Assuming that concentrations of suspended solids in the seawater feed range from 10 to 50 ppm, approximately 1.7 to 5.1 cubic yards per day of solids were generated, which is equivalent to one to two truck-loads per week (California Coastal Commission, 1993).

On energy used by a typical desalination plant, the California Coastal Commission again supplies data.

Energy use requirements for desalination plants are high. For example, an estimated 50 million kWh/yr would be required for full-time operation of the City of Santa Barbara's desalination plant to produce 7,500 AF/yr of water. In contrast, the energy needed to pump 7,500 AF/yr of water from the Colorado River Aqueduct or the State Water Project to the Metropolitan Water District (MWD) of Southern

California is 15 to 26 million kWh/yr. These energy requirements may be compared to the energy use of a small- to medium-sized industrial facility (such as a large refinery, small steel mill, or large computer center) which uses 75,000 to 100,000 kWh/yr (California Coastal Commission, 1993).

Summary of Inputs and Outputs

The sustainability issues surrounding desalination and groundwater water sources have been contrast with RHS and summarized in Table 1. John Asquith's environmental sustainability criteria mentioned in the introduction of this project ('Mimic nature: don't add anything to the environment, don't take anything away') have been used to provide a basic contrast of the alternative water sources. Preliminary assumptions about RHS systems have been used. For example, given the comparative small distances water will be pumped in an *in-situ* context (in comparison to groundwater sources being pulled up from underground for hundreds of feet, or centralized desalination plants transporting to individual buildings), RHS is considered a very low energy user. Also, Table 1 describes the relationship between energy and GHGs as generally direct with the current predominant sourcing of energy from fossil fuels.

Table 1 indicates RHSs favorability as a more sustainable option with this simple comparison to other systems. Intensive analysis would be recommended for a more thorough assessment. However, this contrast provides the basis for further investigation of RHS, such as provided by this study, with the system's strong potential as a more attractive option from an environmentally sustainable perspective.

Table 1. Simple Assessment of Environmental Sustainability of Current Water Supply Options and RHSs Based on Inputs and Outputs of Systems – Asquith’s ‘Take nothing’; ‘Add nothing’ Criteria.

	Inputs ‘Take nothing’	Energy (O and M)	Embedded GHGs	Outputs: ‘Add nothing’
RHS	If not taking from surface water / aquifer supply then no drain (Added benefit of reduced storm water discharge) Same dangers potentially as Aquifer withdrawal? Difficult to assess Unknown	Very Low	Very Low	N/A
Aquifer	OVERDRAFT danger If not being withdrawn at a greater rate than precipitation can recharge it then no drain However, current practices indicate this is unlikely, therefore considered: High	Medium	Medium	Low
Desalination	Taking large quantities of seawater. An issue? Further investigation required Unknown	Very High	Very high	Medium

Chapter 2 – Development of the Decision Tree

A decision tree has been developed (Appendix A) as a tool for water administrators to evaluate and determine the scope of on-site water supply systems for their jurisdiction. The tree represents a methodical approach to determining generic and site specific aspects of on-site systems for a particular area.

For example, a water system's level of microbial contamination is a key factor for potable consumption. An analysis of harvested rainwater quality studies has resulted in a finding that treatment of rainwater is necessary for potable applications and is recommended in order to meet U.S. Safe Drinking Water Act (SDWA) guidelines. The generic (G) recommendation then is to use a U.V. filtering system to treat the water for drinking to SDWA standards. The tree goes on to describe dealing with site specific (SS) issues around microbial contamination. Tools are provided in the body of this document to guide the decision-maker (such as Best Practice Guidelines and an example of the application of the tree to the case study city of San Luis Obispo, CA). Options for implementation include 'harder' and 'softer' regulatory options. 'Softer' options would include no regulation or a permit process with accountability for the system being shifted towards the end user. Providing educational opportunities or recommendations for the consumer would be a typical approach for administrators choosing actions that lie at this end of the spectrum. Alternatively, administrators might determine that greater accountability for the systems should lie with them and so deem a 'harder' option path more appropriate. Regulations may be put into place around householders using an on-site system such as permitting processes requiring certain conditions be met before residents incorporate on-site systems into their residence for their domestic water needs.

Using the decision tree, this study provides recommendations for a chosen case study city (San Luis Obispo, CA) as to the appropriate path for that particular site to take to incorporate decentralized water systems. The methodological approach used to generate this tree is 'descriptive' as it seeks to find what decision-makers will actually do or have done, and incorporates tools and methodologies to help people make better decisions. In contrast, a 'normative' decision model would seek the optimal or 'best' decision path based on an ideal decision-maker, functioning with absolute rationality and perfect accuracy.

The following provides further information to rationalize the particular approaches taken in the decision tree.

Harvested Rainwater Quality (DT* 1)

*Note: DT refers to the relevant section of the decision tree located in Appendix A

Drinking Water Quality

There is a legislative tree overarching drinking water quality that guides water administrators in the U.S. and follows the same basic formula throughout the states. This begins with the Federal Safe Drinking Water Act which is described below. Generally then at the state level, a state body such as water resource departments and related programs, administer state generated mandates around water supply and drinking water. These must meet or exceed Federal standards. This is followed at a local level by regulations and guidelines administered by particular counties or cities that may meet or exceed Federal or State guidelines.

Measures ensuring accountability for meeting these legislated standards varies. The EPA's current methods of monitoring standards are described in the next section.

The Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) is the overarching federal legislation governing U.S. potable water standards for public water supply. Primarily, this legislation sets national drinking water standards through setting Maximum Contaminant Levels (MCL). This list of contaminants and their MCLs is provided in Appendix B. Two pieces of regulation govern these MCLs.

- The enforceable National Primary Drinking Water Regulations (NPDWR) which may cause health issues and may not be exceeded
- The non-enforceable National Secondary Drinking Water regulations (NSDWR) which may cause aesthetic or cosmetic effects.

However, as noted on the SDWA website, oversight for monitoring MCLs is conducted by state drinking water programs in all but two states (WY and DC) where the EPA has primacy. (Safe Drinking Water Act, 2004). In addition, the EPA notes:

Public water systems are responsible for ensuring that contaminants in tap water do not exceed the standards. Water systems treat the water, and must test their water frequently for specified contaminants and report the results to states. If a water system is not meeting these standards, it is the water supplier's responsibility to notify its customers. ...The public is responsible for helping local water suppliers to set priorities, make decisions on funding and system improvements, and establish programs to protect drinking water sources. (Understanding the Safe Drinking Water Act, 2004)

This excerpt indicates that the current EPA stance is that whilst enforcement of the Act is via the U.S. EPA or the states, monitoring the safety of drinking water is ultimately the responsibility of the supplier and the consumer is expected to weigh-in on the establishment of standards.

More specifically, for example, under the previous administration the EPA indicated in its non-response to finding perchlorate, a toxic ingredient found in rocket fuel, in the drinking water of nearly 400 sites in 35 states by stating that they regard setting boundaries for contaminants as a local issue. "States have the right to establish and enforce drinking water standards and the EPA encourages state-specific situations to be addressed at the local level" (NBC, 2008). California and Massachusetts have already passed laws regulating perchlorate in drinking water. This is an example of how different Federal administrations can have an effect on the functioning of the EPA and the choices made with regard to the SDWA. This move describes a reduction in Federal accountability and a corresponding shift of responsibility to the state level. Alternatively, under different federal administrations, the EPA has sometimes seen increases in Federal accountability for the quality of U.S. drinking water. This serves to illustrate the flexibility inherent in the system.

In addition, the SDWA website notes that private wells serving fewer than 25 persons (serving 10% of Americans) are not under the jurisdiction of the SWDA and are therefore personally responsible for the quality and safety of their drinking water (unless a state has set standards). They recommend once a year tests to see if water meets federal and state standards.

Rainwater Harvesting Systems (RHS) are not specifically provided for in the SDWA. Given the clearly 'non-public' nature of RHSs, it would seem appropriate that they should fall under the same kind of category as 'private wells'. As noted above, private wells, lie outside the bounds of the SDWA and are considered 'self-monitoring'. It is suggested that a similar approach of 'self-monitoring' be applied to RHSs with respect to the SDWA requirements. It may be that a submission may need to be made in the future to the EPA to provide specific direction on the treatment of RHSs under the SDWA should the need arise to formally take such steps.

It is further suggested that the applicable regulations and practices applicable at a local level for private wells water quality testing be applied to RHSs.

This self-monitoring approach is validated by the position taken by Portland authorities where self-administered tests were used to ensure safe drinking water on a domestic rainwater harvesting system

for a residential house in Portland, Oregon which was permitted to supply all its water needs (potable and non-potable) (George, 2000).

Roof and Tank Water Quality

Internationally, rainwater uses and practices vary. In Australia and New Zealand, Pacific Islands, South America and South Asia; rainwater is often used as a drinking water source and for domestic purposes. The U.S and Western Europe more commonly use rainwater once for domestic purposes other than for drinking water, and then discharge it (Heijnen, 2006).

One of the highest users of rainwater is Australia with the Australian Bureau of Statistics stating that over 1.5 million households (19.3%) used rainwater tanks as a source of water in 2007. The state of South Australia (the driest state) had 45.4% of households using rainwater with the next highest user state, Queensland, reporting 22.1% (4602.0-Environmental Issues: People's Views and Practices, 2007). As a result of this extensive societal use of rainwater, much of the research on rainwater harvesting and roof and tank water quality comes from that country. Below is a summary of roof and tank water quality studies. These studies are the basis for conclusions described in later sections (DT 1.1.1 Microbial Contamination; DT 1.1.2 Heavy Metals) which were used to develop the decision tree.

Table 2. Summary of Roof and Tank Water Quality Studies

Scope	Findings	Author /s
Safety of Rainwater for drinking	Appropriate system design, sound operation and maintenance, first flush devices and treatment critical. Few published cases of outbreak in which incidence of disease and stored rainwater was established. Well maintained roof catchments generally safe	(Gould, 1999) (Cunliffe, 2004)
Review of studies connecting disease to rainwater; Study of disease outbreaks	Roof water represents a general health risk	(Lye, 2002) (Merrit, 1999) (Palmer et al, 1983) (Taylor, 2000)
Studies of roof water quality	RHS water generally poor bacterial quality	(Simmons, 2001) (Thomas, 1993)
NSW Department of Health rainwater guidelines	Generally safe to drink with low maintenance (not no maintenance). Protect from direct light (reduce algae growth), care that no lead or bitumen in system, use first-flush diversion devices, desludge, disinfect	(NSW Department of Health, 2007)
2 yr study of urban (high traffic density) residential tanks for 27 units, monitoring physical-chemical and microbial characteristics	Water Quality improves through from the roof to tank to hot water systems treatment chain. <u>Roof water</u> – not compliant <u>Tank water</u> – Compliant with ADWG* (settlement, sorption and bio reaction processes appear to improve quality) Note: concentrations in bottom of tank exceeded standards ⁷ <u>HWS</u> - compliant with ADWG* when operated between 52 - 65 ° C (126 -149 °F)	(Coombes P. et al., 2000)
Study of 1000 under 5 yr olds in rural households	At no greater risk to gastro-intestinal illness than those drinking public drinking water	(Heyworth J. , 2001) (Heyworth J. et al., 1999)
100 water samples for fecal indicators from tanks in Eastern Australia	64% cold water samples and 96% of HWS samples compliant with ADWG* Via HWS, compliant with bathing standards	(Evans, 2007)
First flush systems impact on water quality	Diverting the first 2mm / 5litre (.0788"/1.3 g) removes up to 84% of contaminants	(Coombes P. et al., 2000) (Coombes P. et al., 1999) (Yaziz, 1989)

- Australian Drinking Water Guidelines

⁷ With rainwater tanks natural processes leading toxic substances to fall to the bottom, desludging (removing the bottom layers of sediment) is an effective water quality enhancement method.

U.S. SDWA versus the Australian ADWG

A comparative summary of Australian Drinking Water Guidelines (ADWG) and U.S. SDWA guidelines is provided in Appendix C. Appendix D provides a comprehensive and specific contrast of contaminant levels tested for and the standards set in each country. In general, the standards for the two countries are very similar, except that Australian standards generally exceed U.S. standards in some areas such as pesticides (there are over 100 that the U.S. does not test for, although there are 9 substances that the U.S. tests for and Australia doesn't), phenols (U.S. does not regulate them) and algae. The U.S. is the only developed country testing for asbestos, beryllium, or thallium.

In summary, the similarity of the two countries guidelines is sufficient (or in some areas the ADWG are of a higher standard) so that the findings of the Australian studies using the ADWG as a benchmark for the potability of RHS water can be considered relevant to the U.S. context.

Microbial Contamination (DT 1.1.1)

Given the widespread use of tank water in the Australia, it is notable that the “reports of incidents of illness associated with rainwater tanks are relatively infrequent” (Australian Government Department of Health and Aging, 2004) and contrast with a greater number of health concerns resulting from public water systems (Coombes P. et al., 2003).

However, microbial contamination has been indicated in a number of studies of rainwater. According to enHealth, thermotolerant coliforms (E-coli)⁸ have commonly been identified in rainwater tanks. When further specific testing for pathogens occurs though, detection is not common or present at levels indicating low risk.⁹ (Australian Government Department of Health and Aging, 2004)

⁸ Testing for total coliforms is not considered a suitable indicator of fecal contamination or having health significance according to ADWG. Instead the presence of thermotolerant coliforms can indicate the presence of pathogens (such as Campylobacter, Salmonella, Giardia etc) which should be specifically tested for. (Australian Government Department of Health and Aging, 2004)

⁹ enHealth goes on to highlight that many of the studies indicating connection between disease and rainwater tanks are problematic. For example, one case of Salmonella outbreak was associated with live frogs in the tank (poor maintenance allowing animal access). Another did not isolate responsible bacteria in the rainwater. Hence the report's findings that 'detection is uncommon or levels are at low risk'.

Testing positively for fecal contamination is not surprising given animal and bird droppings present on roofs. Note that ‘first flush’ roof washing systems will remove up to 84% of contaminants. Whilst certain microbes might be present in water, this does not necessarily correlate to an increased risk to the drinker. For example, Heyworth’s 1999 and 2000 study showed a sample of 1000 under five year olds at no greater risk drinking rainwater over tap water (Heyworth J. e., 1999) (Heyworth J. , 2001). In fact, Heyworth’s second 2000 study showed a small but significant decrease in illness associated with consumption of rainwater rather than public water supply. Sinclair suggests caution with the results of this study though as potentially flawed given that participants were not blind to the water source or randomized and may be subject to reporting bias. (Sinclair M. , 2007). She is currently undergoing research to address these issues through a study of 300 households in South Australia due out shortly. Sinclair summarizes the situation well.

Thus despite the long tradition of apparently safe rainwater consumption in Australia and elsewhere, there is still need for a better quantitative estimate of the risk associated with ingestion of untreated rainwater. (Sinclair M. , 2007)

Despite the favourable indications as to the levels of microbial contamination being within acceptable ranges, it is considered appropriate to err on the side of caution and incorporate a UV light irradiation system into our generic alternative model to eliminate risk from potential contaminants to potable water.

Whilst more costly than chlorination, the advantage of a U.V. light filter system, as used in the Portland Case Study, is that it provides continuous assurance of water quality; is relatively low in maintenance and has the advantage of not involving the addition of chemicals (Australian Government Department of Health and Aging, 2004) . Appendix E provides a summary of micro-organism destruction levels by a U.V. light. By contrast, the chemicals added to public centralized systems for disinfection purpose, and their disinfection by-products have themselves become key contaminants of drinking water and are monitored under the SDWA. Salt added to water to soften it has also become a major issue for water administrators with fines being imposed on water administrators whose treated water has saline levels that exceed mandated standards (measured by Total Suspended Solids).

Heavy Metals (DT 1.1.2)

The presence of heavy metals in roof run-off has been investigated by a number of Australian researchers. A recent study by Maygar (Maygar, 2008) described the presence of heavy metals in rainwater tanks. Lead, in particular, showed at higher levels than acceptable under ADWG (Australian Drinking Water Guidelines) and WHO (World Health Organization) standards. Specifically, the study found levels of lead of .35 mg/L (350 ug/L) in one of the tanks. The U.S. SDWA and the California state mandated action levels are both 15 ug/L. The applicable ADWG levels are 10 ug/L. These findings contrast with Coombes 2000 study which found levels of lead in tank water to be less than ADWG.

Maygar et al suggested that the lead flashing on old roofs, built under codes which allowed the incorporation of this material, may have contributed up to 99% of the lead content in the rainwater found in their study. The researchers noted:

1. Removal of lead and other heavy metals from drinking water supplied from rainwater tanks at a household level can be achieved by using commercially available activated carbon filters.
2. The importance of routine tank maintenance to remove sediments from inside the tank and the roof gutters. While some householders looked after their roofs, almost none maintained their rainwater tanks. Research suggests that lead and other metals may leach into the water from the sediment build-up in rainwater tanks; therefore cleaning of the tank every year is recommended, in addition to periodic cleaning of roofs and gutters.

Further, after a literature review, Sinclair et al concluded that the level of metal contamination in tank water is unlikely to exceed ADWG guidelines except where there is a major source of industrial pollution nearby (Sinclair M. et al., 2005).

It is considered that findings of heavy metal contamination in rainwater warrants testing of rainwater initially or periodically, but not incorporation of activated carbon filters into our generic alternative model.

Best Practice Guidelines (DT Tool)

It is concluded that the following practices serve to maximize the quality of harvested rainwater and should be followed as 'Best Practice'. These guidelines have been developed drawing from a number of sources including roof and tank water quality studies previously mentioned in this chapter (Table 2) and other manuals mentioned in Section 3 of this chapter ("Creating a RHS") .

- If above-ground tank: incorporate first flush device; ensure underground tanks are well contained. Studies show that fecal contaminants from roof water are generally from animal or bird droppings. Whilst not necessarily contributing to human illness, these contaminants elevate fecal coliforms. Similarly, underground tanks can be subject to contaminants from soil and run off (contaminants such as pesticides, human and animal excreta) and should be well sealed to prevent soil entry into the system.
- Seal tanks from animal entry, maintain mesh to stop mosquitoes, ensure system design prevents children's entry, mark "Danger – Confined Space" for systems able to be entered for cleaning and maintenance. Animals getting into systems and drowning are a potential source of contamination. Seal against entry, cut back branches. System can be emptied or chlorinated to disinfect. Similarly, as with all standing water, must be secured against mosquitoes to stop breeding. All standing water also presents drowning risk for children, requiring that system include measures to prevent entry by children.
- Supply bathing water via HWS. Coombes (Coombes P. K., 2000) study showed that underground storm water tanks with soil incursion showed fecal coliforms present. When passed through HWS between 126 -149 °F (can be an instantaneous HWS), total bacterial counts conformed with ADWG. If system is not intended for potable purposes, requiring incorporation of a UV filter system, then recommend water used for bathing passed through a HWS which reaches between 126 -149 °F.
- Incorporate roof washer / first flush device. The 'first flush' device in particular has been shown to substantially remove contaminants such as those associated with bird droppings, dust etc. (Studies indicate 'first flush' reduces contaminant levels by up to 84%). Remove first 1.3 gallons of roof water.

- Ensure rainwater is not in contact with hazardous substances. For example, bitumen or asbestos-based roof tiles; lead flashing (can be coated); acrylic paints (leach chemicals on first few run-offs); lead pipe work or paints; no contact with treated wood; gutters kept clear of leaf litter (organic matter feeds bacteria); algae growth inhibited by not allowing light in; no contact with poisonous plants (e.g. oleander);
- Desludge tank when necessary –incorporate into tank design .This bottom layer of sediment is a concentration of contaminants and should be optimally removed every 1-2 years. Soil in bottom also fuels microbial growth. Water should be taken from top 2/3 of tank
- If warranted, test water regularly. If particular contaminants have been found in city water supplies, then it is prudent to test for those contaminant levels regularly in rainwater tanks.
- Concrete, galvanized steel or plastic tank (with food-grade liner for potable purposes). These systems are the most successful in Australia. These can be in the form of tanks/ cisterns, barrels or ‘pillows’ (soft plastic containers for under houses). Other materials such as wood and fiberglass can be used but are less common. Issues to watch for include –
 - Water quality/taste issues for new tank e.g. bitter taste due to leaching of lime into the water from concrete tanks; metallic (steel tank) or plastic taste (plastic tank). Liners prevent this issue and it will also diminish with use of the tank. The first fill water can be used for non-potable uses to avoid problem if no liner used.
 - Immediately repair liner if damaged in cleaning or with chemical. Be aware some coatings are sensitive to sunlight (no light should be let in tank regardless as noted above to inhibit algae growth).
 - Areas subject to significant seismic activity should use more flexible tank materials (not concrete) to avoid cracking.
 - Areas with high fire-risk should consider the highly flammable nature of polyethylene tanks. Australian Building Code accounts for fire safety by requiring tank placement 1.5’ from dwelling which is also recommended for U.S. zones subject to significant fire risk. (Sunshine Coast Regional Council, 2008)

Water Availability for Firefighting (DT 2)

One of the key concerns when substituting centralized for *in-situ* water supply is maintaining adequate water store for fire-fighting efforts. This can be alleviated through requiring the system incorporate a dedicated and adequate rainwater supply with adequate pressure for each dwelling for emergency fire fighting purposes. A community tank could also be considered (Eg One per block). This tank would be fitted with a fire fighting approved fitting to allow speedy hook up in an emergency. This issue must be accounted for in any longer term strategy that sees a complete substitution of centralized water supply for RHSs. However, it is likely that a city approaching complete substitution of systems would progress in stages and that such a feature would not need to be incorporated for some time and is part of a longer term planning process.

Creating a RHS (DT 3)

There are a significant number of guides assisting in the design and installation of a RHS including the Australian Government's "Guidance on the Use of Rainwater Tanks"¹⁰, "Texas Manual on Rainwater Harvesting"¹¹ and "Oregon Smart Guide –Rainwater Harvesting"¹². Figure 7 provides the layout of a system which connects to public water supply for 'topping up' the system. A backflow prevention device is used to stop contamination of public water supply with residence's rainwater supply. In general, pipe carrying non-public water supply is differentiated by labeling or colored purple. This substantially mitigates the risk of cross contamination issues with any pipe that may be carrying public water. A pump and pressure tank is incorporated as is typical in urban RHS to produce adequate pressure for the fixtures.

¹⁰ Source: http://enhealth.nphp.gov.au/council/pubs/documents/rainwater_tanks.pdf

¹¹ Source: http://www.twdb.state.tx.us/publications/reports/RainwaterHarvestingManual_3rdedition.pdf

¹² Source: <http://www.cbs.state.or.us/external/bcd/pdf/3660.pdf>

Figure 7. Typical components of RHS system. Source: (Online) 2006 available at <http://www.rwh.in/>

Ensuring Adequate Supply (DT 3.1.1)

A commonly used water industry study that provides U.S. residential water use data is the American Water Works Association Research Foundation (AWWARF) 'Residential End Uses of Water' report. This report gathered water use data from 1,188 households over four (4) weeks from 12 North American locations. Table 3 shows the results of the study. This is considered typical water use data for a U.S. home and can be used to calculate the appropriate sized rainwater harvesting system or used as a base for verifying or contrasting adjusted data using water conserving fixtures.

Table 3. Residential Water Use Summary. Source: (Online) 1999 available at (AWWARF (American Water Works Association Research Foundation), 1999)

Fixture/EndUse	Avg. gallons per capita per day	Avg. liters per capita per day	Indoor use percent	Total use percent
Toilet	18.5	70.0	30.9%	10.8%
Clothes washer	15	56.8	25.1%	8.7%
Shower	11.6	43.9	19.4%	6.8%
Faucet	10.9	41.3	18.2%	6.3%
Other domestic	1.6	6.1	2.7%	0.9%
Bath	1.2	4.5	2.0%	0.7%
Dishwasher	1	3.8	1.7%	0.6%
Indoor Total	59.8	226.3	100.0%	34.8%
Leak	9.5	36.0	NA	5.5%
Unknown	1.7	6.4	NA	1.0%
Outdoor	100.8	381.5	NA	58.7%
TOTAL	171.8	650.3	NA	100.0%

However, sites that are water conscious will likely use more conservative data based on the installation of the latest water-saving fixtures. In this case, these sites will substitute their desired 'site specific' (SS) data to determine adequate sizing of their RHS. Table 4 provides a useful tool for estimating the demand for monthly indoor water supply using current industry 'best practice' water conserving fixtures. Given that assumptions from the AWWARF study may vary in practice, adjustments can be expected.

However, it is likely these adjustments would be downward as the majority of assumptions are based on the average U.S. family's usage and it is reasonable to expect that a household focused on reducing

water consumption in order to achieve sustainability would reduce their usage. As technology is developing at a rapid pace, further water reductions could be expected. For example, waterless urinals or waterless toilets (composting, incinerating etc) could be applied. A tool for estimating outdoor supply needs is available at <http://www.twdb.state.tx.us>.

The current SLO average single family household monthly irrigation figure of 6,300 gallons per month shown at the bottom of Table 4, is a useful indicator that the greywater derived from an incoming 2018 gallons per month could easily be accommodated by outdoor irrigation needs. Clearly though this reduction in water for irrigation by about one third will require attention to incorporating some plants with reduced water needs in order to match landscaping needs to greywater availability.

Table 4. Adjusted Residential Water Supply Demands Using 'Best Practice' Water-Conserving Fixtures

Fixture	A. Water Consumption using conserving fixtures	B. Assumptions from AWWA RF Residential End Use Study ¹³	C. Number of persons in the household ¹⁴	D. Household monthly demand A x B x C x 30
Toilet				
Dual Flush	.89 gpf average (Caroma Sydney Smart)	5.04 flushes ppd (avg. ULF homes)	3	454
Baths and Showers				
Showerhead: 'low flow' (LF)	1.5gpm (Waterpik Eco-flow 5)	8.8 gpcd (avg. LF homes)	3	792
Bath		1.2 gpcd (avg. all)	3	108
Faucets	1.5 gal/faucet/min (Grohe's WaterCare)	10.9 gpcd (avg. all)	3	981
Appliances or uses measured on a per-use basis (not a per person basis)				
Clothes Washer	11.5 gal/load (LG WM2355C) □	0.37 times ppd (avg. all)	3	128
Dishwasher	3 gal/cycle(Asko D3531XLHD)	.1 times ppd (avg. all)	3	9
Miscellaneous Other				
Total (excluding toilet which uses greywater)				2018
Current average SLO single family household monthly irrigation¹⁵				6300

¹³ From 'Residential End Uses of Water Study' (AWWARF (American Water Works Association Research Foundation), 1999)

¹⁴ Using U.S. Census Bureau Data, the average household size in San Luis Obispo, Ca is 2.1 (average of 2005-07 data). This has been rounded up to 3 persons. (U.S. Census Bureau, 2007)

¹⁵ Based on data supplied by SLO County for outdoor water use (see Table 5. San Luis Obispo - Summary of Key Water Supply Characteristics)

Decentralized Supply Model Calculator (DT 3.1.1)

Raw Data (Change to fit your conditions)	
Catchment Area (sq. ft.)	2,500
Monthly Indoor Demand (gal)	4,950
Outdoor Demand (gal)	1,800
Water in Storage to Begin (gal)	1,000
Tank Size (gal)	10,000

This table provides an example of a spreadsheet for calculating rainwater storage capacity. SLO rainfall data has been used. (Western Regional Climate Center, 2008) $A+B=C$; $DXEXFXG=H$; $H-C$ + water in storage to begin = I. Current SLO indoor and outdoor gpcd (gallons per capita per day) data has been used. The table shows there is not monthly rain to sustain water demands stated past March. Public water supply would supplement from that point forward.

0.62 gallons per square foot of collection surface is considered the industry accepted collection coefficient

A runoff co-efficient value of 0.8 accounts for loss of water (first flush, evaporation, absorption on roof surface and overflow from gutters (Lancaster, 2006) (DEHA, 1999)

A volume of water 'on hand' in the tank will account for dry periods (most days without rain x Average, daily water use = storage volume required on day one of dry spell. (Rainharvesting.com.au, 2008)

	A	B	C	D	E	F	G	H	I
Month	Indoor Demand	Irrigation (Outdoor Demand)	Total Demand	Average Rainfall	Collection surface (ft ²)	gallons/ft ² collection coefficient	Efficiency factor	Rainfall collected (80% Efficiency)	End of month storage (starting with water in storage)
Jan	4,950	0.0	4,950	5.05	2,500	0.62	0.8	6,262	2,312
Feb	4,950	0.0	4,950	4.68	2,500	0.62	0.8	5,803	3,165
Mar	4,950	1800.0	6,750	3.47	2,500	0.62	0.8	4,303	718
Apr	4,950	1800.0	6,750	1.52	2,500	0.62	0.8	1,885	0
May	4,950	1800.0	6,750	0.43	2,500	0.62	0.8	533	0
Jun	4,950	1800.0	6,750	0.11	2,500	0.62	0.8	136	0
Jul	4,950	1800.0	6,750	0.02	2,500	0.62	0.8	25	0
Aug	4,950	1800.0	6,750	0.04	2,500	0.62	0.8	50	0
Sept	4,950	1800.0	6,750	0.27	2,500	0.62	0.8	335	0
Oct	4,950	1800.0	6,750	0.91	2,500	0.62	0.8	1,128	0
Nov	4,950	0.0	4,950	2.16	2,500	0.62	0.8	2,678	0
Dec	4,950	0.0	4,950	4.00	2,500	0.62	0.8	4,960	0

Installing A RHS (DT 3.1.2)

There are a small number of conditions considered necessary to be mandated when installing rainwater tanks on the basis of public good. One is protecting the public water supply from cross -contamination with privately treated rainwater. This requires two provisions be made mandatory.

1/ Installation of backflow prevention devices (when system connected to public water supply). Testing annually by public inspectors for functioning could be considered as this is a medium to high risk.

2/ Labeling pipes using rainwater and greywater distinctly (unless house exclusively uses its own supply)

As described in earlier sections on water quality (DT 1.1.1, DT 1.1.2), current research indicates it is appropriate to only mandate a UV filter in our generic alternative model to deal with the issue of potential microbial contamination. This may shift as more research data becomes available.

With regard to other issues, local conditions will dictate practices considered appropriate for the installation of RHS. Administrators will consider instituting mandatory conditions or provide recommendations for installing systems. In practice, the imposition of conditions is generally cultural. That is, conditions are based on beliefs of the general capacities of residents and translating that to perceived risks to public health and safety or administrator's exposure to legal action. For example, a belief may be held that the risk of householders poorly installing a tank on an unsound footing would be too great to warrant self-monitoring of the installation – particularly in an earthquake-prone area . Conditions would then be mandated – such as compulsory inspection of the built system by a public body such as a Building Division before consumer use. The obvious danger is in creating significant mandated conditions that residences are dissuaded from installing a RHS. Avoiding onerous legislation is critical to successful adoption. In addition, regulations and codes can sometimes be applied to alternate systems that are not equally applicable to the same situation in the built environment – intimating a bias at work not rationally connected to the system itself. An example of this is mandating a particular grade on a gutter in a RHS as an amendment to existing codes. This suggests 'standing water' in a gutter is an issue particular to RHS, but not in normal building practice – which is not the case.

Administrators structure the 'rules' around beliefs in resident's capacity weighed against perceived risks to the public good. There are a number of ways different sites have approached the issue of codifying installation of RHS. Seattle has clarified terms used in the Uniform Plumbing Code (UPC) through amendment and thereby extended the code to cover rainwater harvesting for that area. Sites such as

Portland, Oregon have instituted local changes to their Building Codes to allow for Rainwater Harvesting. Typical categories of issues addressed by Building Division as highlighted by Oregon's amendments:

- Provisions address potable and non-potable water uses
- Rainwater collection surfaces and catchments (materials and slopes)
- First-flush diverters, storage tanks and pumps
- Water treatment and disinfection methods

Typical issues addressed by Oregon's Plumbing Board

- Review and approve plumbing products for use in rainwater systems

Providing for legal clarity around permitted use of rainwater for harvesting by issuing a permit has been instituted by Seattle.

Some examples of conditions specific to rainwater tanks that may be provided for in codes or recommended guidelines

- In areas that freeze , codes should provide for installation of underground tanks, or tanks in basements
- Areas with fire risk should consider the highly flammable nature of polyethylene tanks and provide for placing them 1.5' from dwelling (Australian 'best practice')
- Areas subject to earthquake should provide for adequate footing of tanks. E.g. concrete ring on sand base. This could be inspected by the Building Department for soundness or be self-monitored with risk assumed by householder

These suggestions have been synthesized from Australian and current U.S. practices in accord with this project's 'descriptive' approach (rather than 'normative') as it seeks to find what decision-makers will actually do or have done. Each jurisdiction will address issues as it sees fit in accord with agreements with key stakeholders as to acceptable conditions.

System Components and Potential Sources (DT 3.2)

This list has been developed as an example of where alternative water system components can be sourced. It also serves to provide data for cost estimates of systems in order to create a dollar per gallon which can be contrasted against public water supply. It should be noted that these figures are extremely conservative as economies of scale would dramatically reduce costs. It is recommended that regions develop lists of suppliers of local materials (within 500 miles) in line with green principles supporting regional material use and minimizing transportation of materials.

RHS Components	Details	Website	Cost (at 2/24/09)	Expected Lifespan	Cost p.a.
Gutter Leaf Screen Roof Washer (e.g.1st Flush System) Galvanized Steel Tank	Gutter Leaf Eater	svsprinklerandpipe.com	\$90	10 yrs	\$9
	First flush	svsprinklerandpipe.com	\$80	10 yrs	\$8
	10,000 g tank(installed)	bluescopewaterusa.com	\$7000	50-60 yrs	\$140
	• Sacrificial anodes		\$100	2-3 yrs replace	\$48
	• Ladder		included	50-60 yrs	
	• Lockable access hatch		Included	50-60 yrs	
	• Leaf/debris catchment filter		Included	50-60 yrs	
Underground Tank	• Food grade liner		Included	50-60 yrs	
	Complete system installed. Concrete tank.	lando-landscapearchitecture.com	\$7000	50-60 yrs	\$140
UV Filter	UV Filter (SC-740) 40 GPM (Annual kWh: .80 kWh/yr)	americanairandwater.com	\$799	10 yrs	\$80
Pump	Replacement Lamp:9000 hrs		\$59	lifetime	\$30
	Pompcos S275 1/3 HP motor 115V cast iron model (Annual kWh: 100 kWh/yr)	pompcos.com	\$607	20 yrs	\$ 30
	Pressure tank				
Pressure tank	Super cell 150 (28 gal)	daveyusa.com	\$240	15 yrs	\$16

Note: Items in red are chosen components for alternative system in case study city of SLO

Greywater System Components	Details	Source	Website	Cost (at 2/24/09) [°]	Lifespan	Cost p.a.
Greywater System	up to 17 fixtures (materials only) pump included	Clivus multtrum	clivusmultrum.com	\$5500	50-60 years	\$110
Pump	Pompcos SBW300 8A, 120V, ½ HP Max flow 95 GPM (60 kWh/yr)	Pompcos	pompcos.com	\$425	10 years	\$43
Plumbing costs (new construction)	Estimate additional costs (on top of standard plumbing)			\$3000	Life of system (50 years)	\$60

[°] Pricing for greywater reuse system is based on installed in new construction (rather than retrofit).

Chapter 3: San Luis Obispo - Applying the Decision Tree

The case study city of San Luis Obispo (SLO), CA has been chosen to apply the decision tree and other tools developed for this project for administrators to determine the scope of an alternative system for their area. The resulting alternative decentralized system will then be compared to the current centralized public water system on the basis of direct fiscal and energy costs.

San Luis Obispo (SLO) – Water Supply Details

Table 5 introduces SLO by providing broad details on the city's key water supply characteristics.

Table 5. San Luis Obispo - Summary of Key Water Supply Characteristics

San Luis Obispo	Details
Overarching State body for water	State Department of Water Resources, Planning and Local Assistance, Southern District (www.dpla.water.ca.gov/sd)
State body for oversight of drinking water	Drinking Water Program, California Department of Health, Oversight of 7500 Public Water Systems in 2007 (http://www.cdph.ca.gov/programs/Pages/DWP.aspx)
Hydrologic basin	Central District
City population	44,750
City households	21,510 [□]
City single family households	10,581
Total 2008 water supply	6488 Acre Feet (AF)
Major source	Salinas Reservoir (Santa Margarita Lake: 9 miles) – 68.6%
2 nd source	Whale Rock Reservoir (Cayucos: 17 miles) – 27.0%
3 rd source	Ground Water incl. Pacific Beach Well #1 (Los Osos) – 1.5%
4 th source	Recycled – 1.1%
5 th Source	Additional Conservation – 1.8%
Area's annual residential water consumption (single-family and multi-family)	2.2 billion gallons in 2007 [`]
Current single family residence average gallons per capita per day (GPCD)	70-75 gpcd
Current residential indoor GPCD	55 gpcd

Unless otherwise noted, information source: City of SLO – Ron Munds, Water Conservation Department and the City of SLO Water Resources Report for 2008.

[`] (Online) 2008 available at Source: City of SLO <http://www.ci.san-luis-obispo.ca.us/utilities/treatment.asp>

[□] This figure for total SLO city households is a 3 year average (2005-2007) and is the U.S. Census Category : 'Occupied Housing Units' (vacant units excluded). This figure is taken as equivalent to a combined total for Single Family and Multi Family Dwellings. Source: (Online) 2007 available at U.S. Census Data http://factfinder.census.gov/servlet/ACSSAFFacts?geo_id=05000US06079and_state=04000US06andpctxt=cr

SLO Rainfall Characteristics

Table 6 and 7 provide rainfall data for SLO. Table 6 indicates the variance in precipitation quantities according to catchment location. It is notable that rainfall varies from area to area, although these locations are geographically relatively close. This indicates a strong need for individual assessment of microclimatic conditions by administrators evaluating RHS in their jurisdiction. Table 6 also describes that in 2007 / 08, SLO received 89% of its average rainfall. Table 7 further describes the variances in rainfall over the last decade which gives a fuller picture of rainfall patterns for SLO and the viability of data input into our models. Our models have used data from the Western Regional Climate Center summaries from the Cal Poly weather station averages for the period 1893 to 2008 (Western Regional Climate Center, 2008). The annual average precipitation for this period is 22.66 inches.

Table 6. SLO Area Rainfall Trends. Source: (Online) 2008 available at: City of SLO Water Resources Report 2008

Location	2007/08 ¹⁶	Average	% of Average
City of SLO – Reservoir #1	19.9"	22.4"	89%
Whale Rock Reservoir (Cayucos)	14.0"	19.7"	71%
Salinas Reservoir (Santa Margarita)	21.5"	21.4"	100%

¹⁶ Rainfall through June 1, 2008

Table 7. SLO Population Estimates, Water Use and Rainfall. Source: (Online) 2008 available at: City of SLO Water Resources Report 2008

Year	Population	Total Water Use (acre feet)	Per Capita (gpcd) All users	Rainfall ¹⁷ (inches)
1997	41,807	6,220	133	31.36
1998	42,201	5,853	124	43.54
1999	42,446	6,172	130	16.34
2000	44,174	6,121	124	24.97
2001	44,218	5,886	119	24.53
2002	44,333	6,032	121	22.91
2003	44,225	5,968	120	16.08
2004	44,163	6,239	126	40.09
2005	44,619	6,098	122	30.35*
2006	44,326	5,999	121	10.28*
2007	44,489	6,488	131	19.92*

The development of policy assumptions driving the application of the decision tree requires an understanding of the current acceptable limits regarding greywater reuse and harvested rainwater uses. This is in accord with this project's 'descriptive' approach (rather than 'normative') as it seeks to find what decision-makers will actually do or have done. Table 8 provides data for SLO and draws comparisons with other major west coast cities.

¹⁷ Rainfall amounts for July through June from Cal Poly weather station. Amounts marked thus * are rainfall amounts from County rain gage at City's Reservoir #1

Table 8. Summary of Key Legislative Parameters for West Coast Cities

	San Luis Obispo, CA Allowed? Y or N	Portland, OR Allowed? Y or N	Seattle, WA Allowed? Y or N
Greywater reuse	YES Title 22 ^β	YES Through Building Codes Division (statewide) ☐	YES Uses amended Uniform Plumbing Code (UPC) ☐
Rainwater for toilet flush	NO Title 24 – Must be treated to tertiary standards ^β	YES As per ENB 15.71 [∞] (see below)	YES ☐
Greywater for toilet flush	NO (See above)	YES OSPB Building Code Standards ^α	YES Uses UPC ☐
Waterless toilets	Allowed, though supply piping still required by code ☐	Not found	YES [°]
Rainwater Harvesting	Not addressed	YES Permit issued for interior or interior/Exterior Use ENB-15.71 S 3101.2 and S 3401.1 – One and Two Family Dwelling Specialty Code S 301.2 and Section 601.1 – Plumbing Specialty Code: Ch.16 [∞] If for irrigation only, no permit necessary	YES Permit issued ☐ If non-pressurized or landscape only – not required
Rainwater for potable use	Not addressed	YES The Office of Planning and Development Review (OPDR) reviews through an administrative appeal process on a system by system basis. [∞]	NO According to Dept. of Health.
Backflow Prevention Device	YES Title 17 [®]	YES Only certain approved devices under OAR 333-061-0070 ^μ	YES Health Dept. ☐

^β Source: <http://www.cdph.ca.gov/certlic/drinkingwater/Documents/Lawbook/RWregulations-01-2009.pdf>

[®] Source: <http://www.cdph.ca.gov/certlic/drinkingwater/Documents/Lawbook/dwregulations-01-01-2009.pdf>

^α Source: http://www.cbs.state.or.us/external/bcd/boards/plumbing/boardpack/08/20080411/Plumb_041108_VIIb.pdf

☐ Source: <http://sustainability.ucsb.edu/conference2007/presentations/Elliot-SLO-Water-Conservation.pdf>

☐ Source: http://www.cbs.state.or.us/external/bcd/notices/20080711_greywater_nr.pdf

[∞] Source: <http://www.portlandonline.com/auditor/index.cfm?a=81417&dc=38527>

μ Source: <http://www.oregon.gov/DHS/ph/crossconnection/assembly.shtml>

□ Source: <http://www.seattle.gov/dpd/publications/cam/CAM701.pdf>

° Source: http://www.doh.wa.gov/ehp/ts/WW/Water_Conservation_8-29-07.pdf

□ Source: http://www.seattle.gov/UTIL/Services/Yard/Natural_Lawn_and_Garden_Care/Rain_Water_Harvesting/index.asp

Current Water Quality – San Luis Obispo

Appendix F provides data from San Luis Obispo water authorities showing the results of testing their water supplies for MCLs according to their standards. In summary, San Luis Obispo is below action levels for MCLs (i.e. meet U.S. SDWA standards). This provides a quantitative baseline for current acceptable water quality standards for the case study city of San Luis Obispo that an alternative system could be measured against (based on current acceptable levels of contaminants present in the system).

Policy Development Assumptions

A policy framework is a necessary starting point in order to superimpose guidelines for examining the case study city and applying the decision tree.

The following policy assumptions will drive the application of the decision tree for SLO:

- Continued focus on a demand management strategy that actively targets water-conservation.
- Acceptance of a supply rather than demand management primary orientation. Administrators believe that full investigation of all supply options is crucial to current decisions around urban water management.
- Perceived risks associated with consideration of alternative supply sources have moved from unacceptable to acceptable for reasons such as
 - the acknowledgement of critical water shortage being a greater risk to public health and safety than the perceived risks associated with rainwater harvesting and extensive greywater reuse – a move towards policy trends in other west coast cities
 - the necessary decoupling of the energy and water relationship to reduce GHG
 - reducing risk in emergencies (fire, earthquake) of loss of water due to loss of power
 - understanding that effecting water conservation behaviors in consumers requires a full awareness of residential water consumption habits and the true value / cost of water supply and that *in-situ* residential water supply is a direct pathway to full awareness

- reducing perceived risks through incorporation of standards in the city's RHSs such as
 - eliminating potential cross-contamination through compulsory use of backflow prevention devices and demarcation of rainwater water and greywater residential piping through coloring it purple or use of distinct labeling
 - processing rainwater through a UV filter for potability
 - following recommended 'best practice guidelines' to reduce risk to acceptable levels
- Categorizing RHSs in a similar way as 'private wells' which are non-public, not subject to the same legislative parameters as public water supplies, lie outside the jurisdiction of the SDWA and are 'self-monitored' systems. This approach indicates a 'softer' regulatory approach with residents being provided with recommended practices and standards rather than regulation and oversight of systems by public administrators.
- Adjusted water demands for SLO are based on current best practice conservation standards (see next section). Critical water shortage conditions are assumed with an overarching policy desire for the resident to achieve 'self-sufficiency' with *in-situ* water supply to maximize sustainability of their system and achieve as close as possible a state of 'no reliance' on external public water supply. This will mean, for example, that outdoor irrigation may only come from resident's greywater supplies or the residence will institute xeriscaping principles (no irrigation necessary through use of drought tolerant and native species).
- Longer view considerations associated with a strategy to completely substitute the city's public water systems with *in-situ* residential systems would include providing for
 - available water for firefighting
 - emergency water storage for extremely low rainfall years. The models in this project use average monthly precipitation based on data for SLO from 1893-2008, with the annual average for this period being 23 inches. Extremes in precipitation do occur, such as the lowest recorded annual precipitation of 7.37 inches in 1947.

It is assumed an alternative *in-situ* water system put in place in SLO would incorporate adequate water for firefighting (e.g. community tank for each block) and have access to 'top up' from public supply (lake catchment) in years with uncharacteristically low rainfall.

- Institution of UNESCO’s 1958 principle “No higher quality water should be used for a purpose that can tolerate a lower grade.” (Hespanhol, 2003) The city of SLO has made the necessary regulatory changes to allow for rainwater harvesting for potable purposes or toilet flushing and greywater reuse for irrigation and toilet flushing¹⁸.

Adjusting Water Demand

Table 4 provides an adjusted residential water supply demand for SLO based on using the latest ‘best practice’ water-conserving fixtures. The results show the average SLO household of 3 persons requiring a total water supply of 2472 gallons per month. If greywater is used for toilet flushing and the remainder applied to outdoor irrigation (assuming not xeriscaped), overall monthly water supply needed for the average residence is 2018 gallons.

¹⁸ As noted in

Table 8. Summary of Key Legislative Parameters for West Coast Cities”, San Luis Obispo and California lie outside the trend of widening the scope of acceptable sources of water supply.

Harvested Rainwater Quality (DT 1)

As suggested in sections dealing with the SDWA and the matrix of legislation and regulations overarching water quality that extend down to a local level, it is considered appropriate to overlay on RHSs the applicable regulations and practices adopted at a local level for private wells water quality testing .

According to the Environmental Health Services Division of Public Health for the San Luis Obispo County Health Agency, private wells are tested once, prior to use, for the following contaminants in line with Title 22 of the California Code of Regulations (CCR), Division 4, Chapter 15, Article 4. Note that San Luis Obispo locally waives testing for Asbestos and Perchlorate.

Table 9. CA State Drinking Water Standards for Individual and Shared Wells.

Source: (Online) 2009 available

<http://ww2.cdph.ca.gov/certlic/drinkingwater/Documents/Lawbook/dwregulations-01-01-2009.pdf>

Article 4. Primary Standards--Inorganic Chemicals

§64431. Maximum Contaminant Levels--Inorganic Chemicals.

(a) Public water systems shall comply with the primary MCLs in Table 64431-A as specified in this article.

**Table 64431-A
Maximum Contaminant Levels
Inorganic Chemicals**

<i>Chemical</i>	<i>Maximum Contaminant Level, mg/L</i>
Aluminum	1.
Antimony	0.006
Arsenic	0.010
Asbestos	7 MFL*
Barium	1.
Beryllium	0.004
Cadmium	0.005
Chromium	0.05
Cyanide	0.15
Fluoride	2.0
Mercury	0.002
Nickel	0.1
Nitrate (as NO ₃)	45.
Nitrate+Nitrite (sum as nitrogen)	10.
Nitrite (as nitrogen)	1.
Perchlorate	0.006
Selenium	0.05
Thallium	0.002

* MFL=million fibers per liter; MCL for fibers exceeding 10 um in length.

Table 10. Summary of Variance Between SDWA and Applicable SLO MCL Standards

Contaminant	SDWA MCL (mg/L)	San Luis Obispo MCL (mg/L)
Aluminum	Secondary Drinking Water Standard (non-regulated) 0.05 to 0.2	Secondary Drinking Water Standard (non-regulated) 0.2
Cyanide	0.2	0.15

The decision tree requires a direct comparison of the site specific (SS) MCLs applicable for private wells in San Luis Obispo with those of the SDWA for relevant contaminants. A full comparison of SDWA MCLs and California MCLs (according to CCR) are included for reference in Appendix G .

The two variances are summarized in Table 10. As cyanide is the only primary standard with variance, this will be examined specifically.

Microbial Contamination (DT 1.1.1)

Since MCL standards for San Luis Obispo private wells do not exceed SDWA MCLs, the generic action is relevant for San Luis Obispo.

Action

- *Reduce microbial contamination potential through ‘Best Practices’ (guidelines provided in Ch. 2) and system components*
- *Install appropriate treatment processes.*

UV Filter recommended for use by self-monitoring household

Heavy Metals (DT 1.1.2)

Since MCL standards for San Luis Obispo private wells do not exceed SDWA MCLs, the generic action is relevant.

Action

Encourage ‘Best Practice’ standards met (*guidelines provided in Ch. 2*) by self-monitoring household

No additional treatment recommended

Other Contaminants (DT 1.1.3)

Cyanide

According to the EPA issued guide to National Primary Drinking Water Standards (Appendix B), cyanide is an inorganic chemical whose common source is “Discharge from Steel/ metal factories; discharge from plastic and fertilizer factories”. It is unlikely that a RHS would be vulnerable to cyanide contamination as typically the contaminant originates from run-off. It is determined that cyanide is therefore unlikely to enter RHS system and that the generic action path is relevant.

Action

Encourage ‘Best Practice’ standards met (guidelines provided in Ch. 2) by self-monitoring household

No additional treatment recommended

System Components (Hazardous Substances) (DT 1.2)

Assessing common site specific issues contributing to contamination, San Luis Obispo has

- no major industrial polluter nearby
- common roofing material is bitumen-based composite tiles

Action

1. Eliminate typical contaminants through use of ‘Best Practice’ guidelines (provided in Ch. 2)
2. At the administrators discretion, there are two choices (Hard – a, Soft – b):
 - a. roofs using bitumen-based tiles could be excluded from the program **or** legislate treatments required to offset contaminant (in this case petroleum based bitumen roof tiles)
 - b. Recommend annual self-monitoring w/ resident fully accountable for risks (in line with current EPA approach for private wells and directly comparable to an RHS)

Based on policy assumptions, **self-monitoring is course of action for SLO**

System Components (Physical Components) (DT 1.3)

Action

Increase quality of water through ‘Best Practice’ (guidelines provided in Ch. 2) instituted by self-monitoring household

Importance of Maintenance (DT 1.4)

Action

Increase quality of water through encouraging use of ‘Best Practice’ guidelines provided in Ch.2 (self-monitored)

For convenience, a summary of relevant ‘best practices’ applicable for San Luis Obispo RHSs is listed below

- 1 Above ground galvanized steel or plastic tank lined with food grade liner placed 1.5’ from dwelling (accounts for seismic and fire risk)
- 2 Seal tanks from animal (incl. mosquito mesh) and child entry; reduce potential for entry (branches cut back)
- 3 Elements of system:
 - 3.1 Confirm roof system doesn’t incorporate bitumen/asbestos tiles, lead flashing, treated wood. If fresh acrylic paint, discard first few run-offs.
 - 3.2 Gutter shields for removal of leaf litter
 - 3.3 First flush device (remove first 1.3 gallons of roof water)
 - 3.4 Water taken from top 2/3 of tank
 - 3.5 Confirm algae growth deterred through no light penetration into tank
 - 3.6 Confirm no lead piping in water transport systems
 - 3.7 UV filter
 - 3.8 Confirm RHS incorporates ability to ‘desludge’ tank (remove bottom layer of sediment every 1-2 years)

Water for Firefighting (DT 2)

Action

If San Luis Obispo city determines to incorporate RHSs in all dwellings in the longer term to completely substitute for public water supplies for residences, this plan should include a strategy developing adequate *in-situ* firefighting supplies. It is expected that such a strategy would be a longer view consideration though and is therefore outside this project’s scope.

Creating a RHS (DT 3)

Ensuring Adequate Supply (DT 3.1.1)

As described in this chapter’s “Policy Development Assumptions”, the policy framework for our case city of SLO includes assumptions that critical water shortages have necessitated a move towards maximizing

reliance on *in-situ* water supplies. Total residential water demands have been reduced using ‘best practice’ latest technology water-conserving fixtures. The Site Specific (SS) section of the decision tree will then apply. Chapter 2, Table 4 provides a worksheet based on SLO data and ‘best practice’ water-conserving fixtures which were used to determine an adjusted demand for SLO of 2018 gallons per household per month.

This data has been inserted into the ‘Decentralized Supply Model Calculator’ tool to determine the local rainwater harvesting potential. This is provided in Table 11. The results show that a 10,000-gallon tank is suitable for an average residence in SLO to meet all its water supply needs with the ‘wet’ months filling the tank to capacity by April, and the ‘dry’ months taking total water in storage to its lowest levels of 1,280 gallons by the end of October. It is notable in March that there would be an overflow of 1,314 gallons over and above the tank’s 10,000-gallon capacity which would ideally be saved for emergency supply. For this project however, assume diversion to landscaping needs of any excess.

Table 11. Application of 'Decentralized Supply Model Calculator' to SLO Using Adjusted Demand

Raw Data (Change to fit your conditions)	
Catchment Area (sq. ft.)	2,500
Monthly Indoor Demand (gal)	2,018
Outdoor Demand (gal)	0
Water in Storage to Begin (gal)	1,000
Tank Size (gal)	10,000

	A	B	C	D	E	F	G	H	I
Month	Indoor Demand	Irrigation (Outdoor Demand)	Total Demand	Average Rainfall	Collection surface (ft ²)	gallons/ft ² collection coefficient	Efficiency factor	Rainfall collected (85% Efficiency)	End of month storage (starting with water in storage)
Jan	2,018	0.0	2,018	5.05	2,500	0.62	0.8	6,262	5,244
Feb	2,018	0.0	2,018	4.68	2,500	0.62	0.8	5,803	9,029
Mar	2,018	0.0	2,018	3.47	2,500	0.62	0.8	4,303	10,000
Apr	2,018	0.0	2,018	1.52	2,500	0.62	0.8	1,885	10,000
May	2,018	0.0	2,018	0.43	2,500	0.62	0.8	533	9,696
Jun	2,018	0.0	2,018	0.11	2,500	0.62	0.8	136	7,814
Jul	2,018	0.0	2,018	0.02	2,500	0.62	0.8	25	5,821
Aug	2,018	0.0	2,018	0.04	2,500	0.62	0.8	50	3,853
Sept	2,018	0.0	2,018	0.27	2,500	0.62	0.8	335	2,170
Oct	2,018	0.0	2,018	0.91	2,500	0.62	0.8	1,128	1,280
Nov	2,018	0.0	2,018	2.16	2,500	0.62	0.8	2,678	1,940
Dec	2,018	0.0	2,018	4.00	2,500	0.62	0.8	4,960	4,882

Installing Water Tanks (DT 3.1.2)

Action

(G) 1/ Mandate backflow prevention devices to protect mains water supply when a connection exists and 2/label pipes used for rainwater if the dwelling also has pipes exclusively using public water supply to avoid cross-contamination issues.

(SS) SLO City and County will consider issues relevant to the city as outlined in Chapter 2 regarding 'Installing RHS'. This may occur on a state level also. In line with stated policy assumptions and for the purposes of applying this tree, self-monitoring by households generally applies with public administration responsible for providing recommended courses of action.

The issues considered SS for San Luis Obispo that could be provided through either mandating or recommending a course of action include:

- Fire risk – Highly flammable polyethylene tanks situated at a safe distance from dwelling (1.5')
- Earthquake risk – review by Building codes division of tank installation for soundness of tank footing (e.g. On bare soil, provide a sand bedding and a cement ring to sit tank on)

RHS Components and Potential Sources Lists (DT 3.2)

Chapter 2, section DT 3.2 contains a "RHS Components and Potential Sources List". This list has been developed as an example of where alternative water system components can be sourced. It also serves to provide data for cost estimates of systems in order to create a cost per year which can be contrasted against public water supply. It should be noted that these figures are extremely conservative as economies of scale would dramatically reduce costs. It is recommended that regions develop lists of suppliers of local materials (within 500 miles) in line with green principles supporting regional material use and minimizing transportation of materials.

Chapter 4 - Evaluating Costs

As consumers, a central difficulty with our existing residential water supply context is a lack of understanding of the absolute cost of the current system to each member of the community – the actual or ‘true’ cost. Frequently, we regard the total cost of our water as the cost per gallon of our residential water bill from the local water utility. Based on anecdotal evidence, the true cost of our water system is often not publicly known or difficult to access in diverse areas of publicly-available documents. Often particular users can be charged heavily subsidized prices by utility providers. UNDESA describes the situation.

Around the world, it is rare that water users are charged the full cost of water services. Subsidized irrigation water is justified not only on users’ limited ability to pay but on the (disputed) economic grounds of secondary economic benefits, for example, the boost in agricultural production due to increased availability of irrigation water. For public irrigation systems, the aim is to recover only operating and maintenance costs from users, with initial capital costs covered by the general public budget or donor agency contributions. (UN Department of Economic and Social Affairs, 2007)

These publicly-carried water costs are often referred to by commentators as the ‘hidden’ costs of water as the general public are generally unaware of ‘who’ is precisely paying ‘what’.

A lack of understanding of our consumption and the true costs of all resources is not a sustainable attitude in the reality of a resource-stressed future. Sociological researchers such as Darian and Darian (2006) have tackled the question of the kind of strategies policy makers can use to encourage consumers to voluntarily reduce their water usage.

The first is to make consumers more aware of their usage rates and of the water shortage situation. The second is to increase the psychological, social, and economic benefits of water conservation behaviors. The third is to reduce the monetary and non-monetary costs of reducing water consumption. (Darian, 2006)

Tying residential consumers directly to their water supply through the use of *in-situ* systems is a powerfully direct method of increasing user’s awareness of consumption and their commitment to the benefits of water conservation. A transmission of ‘value’ to the end user is at the core of all successful water conservation strategies.

UNESCO has developed a diagrammatic representation of the kind of costs needed to be understood in the true valuation of the full costs of any water supply system.

Figure 8. Components for the Cost of Water Supply. Source: (Online) 2007 available at http://www.unesco.org/water/wwap/wwdr/wwdr2/pdf/wwdr2_ch_12.pdf

Examples of the kind of costs associated with maintaining the current centralized public water system in our community are summarized below. These costs will include those associated with a choice to not explore alternative sources of supply, such as maximized residential greywater reuse and rainwater harvesting.

Full supply costs (Direct)	Details
Fiscal Costs (per gallon or AF)	Moving and processing potable water to consumer
	Moving and processing wastewater from consumer
	Providing, maintaining, upgrading and expanding infrastructure ¹⁹
	Capital costs including principal and interest payments
Energy Costs (in kWh)	Moving and processing potable water sources
	Moving and processing wastewater

¹⁹ It is difficult to fully assess the costs associated with maintaining existing systems and the costs of leaking and old infrastructure. The California Performance Review (2004) cited a report by the Public Policy Institute of California estimating the state's 'water supply and wastewater treatment systems maintenance backlog' to be about \$40 billion. (California Department of Water Resources (John Andrew), 2004)

Full costs (Indirect)	Details
Opportunity Costs	<p>Loss of opportunity when focusing on meeting increasing demands at sake of full investigation of alternative supply models</p> <p>RHSs reduce requirement for catchment-based drinking water – lost opportunity for less pressure on watershed and its eco-systems</p> <p>Use of <i>in-situ</i> residential water catchments reduces requirement for storm water drainage and costs</p> <p>Loss of benefits of users being directly connected to their water supply and consequences of over consumption</p> <p>The potential increased resiliency of RHSs to climate change / reduced rainfall²⁰</p> <p>Cost of being compelled to use lower quality water sources with limited choice of water supply options.</p> <p>“Less costly treatment options can be used when water utilities start with higher quality source waters, and water supply reliability can simultaneously be enhanced.” (Ca. Dept. of Water Resources, 2005)</p> <p>Less mixing of higher and lower quality waters which facilitates “appropriately matching high quality source waters can reduce the levels of pollutants and pollutant precursors that cause health concerns in drinking water”. (Ca. Dept. of Water Resources, 2005)</p> <p>Fire, earthquake – potential of electricity down and water supplies cut off due to electrical pumps being inoperative</p> <p>Drought – “Overall, the best positioning that SLO County could achieve with regard to planning for droughts is to develop multiple sources of water as opposed to relying on few sources to meet our water needs.” (SLO County Water Resources, 2008)</p>
Externalities	<p>Environmental impacts of energy costs (e.g. GHG emissions)</p> <p>Overall costs of relying on ‘others’ energy sources to keep our ‘necessities for survival’ viable – the enormous power of sustainable choices</p> <p>Costs of ‘over-use’ of current water supply sources (eg land subsidence with over drafting aquifers, watershed degradation etc) – alternative sources of supply reduce pressure</p> <p>Environmental and economic costs of saline added to water.²¹ Less saline added to water systems with increased use of ‘soft’ rainwater</p>

²⁰ Research indicates that when considering climate change, RHSs may offer a more resilient urban water supply that is less susceptible to failure with “catchments exhibit(ing) a disproportionate decrease in yield in response to rainfall reductions, as compared to rainwater tanks...this may be, at least in part, due to the pervious nature of catchments that generally require significant re-wetting following reduced rainfall in order to generate appreciable runoff (whereas)..roof catchments are highly impervious and largely immune to the hysteresis exhibited by catchments in runoff generation .” (Coombes & Barry, 2007)

²¹ “Water high in salinity can cause economic costs through damages to plumbing and fixtures and water-using devices and equipment. One study, conducted in 1998 by the U.S. Department of the Interior and the Metropolitan Water District (MWD), found that for every 100 mg/L decrease in salinity, there is an economic benefit of \$95 million annually to MWD’s customers” (Ca. Dept. of Water Resources, 2005)

This study has focused exclusively on the first segment of UNESCO's 'Cost of Water Supply' diagram – direct full supply costs. Tables 12 and 13 provide a summary of data collected from SLO County and City administrators and budget documents for SLO water supply and wastewater services for all users.

Table 12. Summary of SLO Costs of Potable Water. Source: SLO City and County Records

	2007-2008 AF /yr	2007-2008 \$/yr	2007-2008 kWh/yr
To Consumer			
Water Source of Supply			
Salinas (Santa Margarita) - usual delivery	2,000		2,054,563
Whale Rock (Cayucos) (SLO has 55% share) -usual delivery	4,000		1,488,649
Reclaimed Water - able to deliver	1,000		
Staffing, Contractors, Operat. Exp.,		\$ 1,305,100	
Reservoir Operations: 55% allocation for SLO		\$ 496,540	
Water Delivery to Cayucos Water Treat Plant	5,200		
Water Treatment		\$ 1,757,300	
Total Water Treated Salinas, W.Rock, Reclaimed & Groundwater (delivered)	6,488		
Distribution			
Pumping, Pump /Water Main Maintenance, Fire Hydrants, Testing Quality, Monitoring		\$ 977,600	194,348
Metering, Reading, Backflow Prevention		\$ 394,400	
Utilities Conservation Office		\$ 413,100	
Water Admin. & Engineering		\$ 617,200	
Administration, Engineering			
Future Water Investment - Nacimiento (avail 2010)		\$ 176,000,000	7,711,338
Nacimiento able to deliver	9,655		
Budgeted Delivery to SLO (35%): shared with Atascadero, P.R, Templeton, Cayucos	3,380	\$ 61,600,000	2,698,968
Estimated Interest & Principal Payments p.a.		\$ 5,100,000	
Budgeted O & M Costs p.a.		\$ 1,280,000	
Electricity Costs		\$ 318,000	
Capital costs (budgeted for 2011)		\$ 876,000	
Capital Improvement			
(average p.a of next 4 year budget – Water)		\$ 2,353,300	
Whale Rock Reservoir (avg. p.a. of next 4 yr budget)		\$ 6,250	
Subtotal overall costs – all users (commercial, residential etc)	6,488	\$ 15,894,790	3,737,560

Note: Boxed items, e.g. 3,380 are those contributing to the totals

Table 13. Summary of Cost of SLO Wastewater Services. Source: SLO City and County Records

	2007-2008	2007-2008	2007-2008
Post Consumer	gallons/yr	\$/yr	kWh/yr
Wastewater Collection (Black & Greywater)	1,600,000,000	\$ 826,300	131,298
Sewer Main Maintenance, Lift Station /Pumps, Admin., Monitoring			
Wastewater Pretreatment - not residential		\$ 3,168,600	
Water reclamation facility - Sewage Fund		\$ 389,300	
Wastewater Admin & Engineering		\$ 58,000	3,439,371
Water Reclamation Facility (WRF) - water fund	1,600,000,000	\$ 369,919	
Electricity Costs - Recycled Water Program (incl. Co-gen.)		\$ 12,000,000	
Wastewater reclamation system capital costs		\$ 2,800,000	
State grant		\$ 111,600	
Estimated State Principal Payments		\$ 68,400	
Estimated State Interest Payments (2.45% over 20 years)		\$ 345,000	
SLO Principal Payments		\$ 180,000	
SLO Interest Payments (2.45% over 20 years)		\$ 30,000	
Distribution to Existing & New Customers			716,771
Wastewater Co-generation of elec			
Recycling System -Co-gen. Electricity Costs	71	\$ 5,449	
Capital Improvement (avg. p.a of next 4 year budget)		\$ 14,835,700	
Total Wastewater Costs - all users (commercial, residential etc.)	1,600,000,000	\$ 19,954,900	4,287,440

Note: Boxed items, e.g. 3,380 are those contributing to the totals

Table 14 looks at current municipal costs of the existing system and provides a breakout of the single family (SF) residence costs which have been determined volumetrically. That is, the 10,581 SLO SF residences (see Table 5) using 949m gallons of water represents 45% of the volume of water consumed by SLO city. The 949m gallons of water used is based on SLO city data of an average use by SF residential households of 10 units per month x 748 gallons per unit x 12 months x 10, 581 households (City of San Luis Obispo, 2009). It is considered that the most appropriate way to apportion fiscal and energy costs to residents (rather than commercial users) is volumetrically using the data from Table 12. It is important to note that Table 14 excludes data associated with the city's intended Nacimiento Pipeline project which is expected to provide SLO with an additional 3,380 AF per year of additional potable water via a 45 mile long pipeline. This then creates a data picture of the current municipal cost of water supply excluding this intended additional source of water and based on current volumes and energy consumption.

In summary, the cost of the current public water system per SF household each year has been determined in the following way:

- Water supply cost per household is 45% (proportion water used by SF residences) of the total cost to the consumer (\$8.3m) described in Table 12 apportioned per SF household (10,581). This total cost is also apportioned to the 6.4k AF of water delivered to SF residents to determine the water supply cost per AF and further broken down into a per gallon calculation.
- 45% (proportion of water and also energy used by SF residents) of the total energy required to deliver water to SLO (i.e. 45% of 3.7m kW/h according to Table 12) is apportioned per SF household to derive the water supply energy cost per household. This total residential energy cost is further apportioned per AF of water supplied; and further reduced to a per gallon figure.

Table 15 considers the data from Table 12 and incorporates the impact of the Nacimiento Pipeline project data. Volumetric apportionment has again been used to assign volume of water and energy used by the SF residential segment (e.g. 45% of 3,380AF is 1,521 AF). The marginal cost (cost specifically associated with the Nacimiento project) is calculated (first row). The SF residential portion of 45% of those marginal costs is then determined (second row). The total municipal costs including the impact of Nacimiento are then determined by adding the current SF residential municipal figures to the SF residential marginal costs to produce the municipal total costs with Nacimiento included. Finally, the fourth row provides data for the SF residential consumer household based on the billed cost to the consumer using the increased cost per gallon which the city is looking to implement over the next year if approved by the public through a Proposition 218 hearing process occurring June 11, 2009. (City of San Luis Obispo, 2009). It is important to note that this increase for water supply costs to the city from a current level of \$47.15 per SF household to \$58.65 per SF household (proposed by July 1, 2010) will be the first round of a series of double digit increases in both water and sewer rates which the city of SLO expects to implement through 2012-13 (see footnote 22 accompanying Table 15). The billing rate used in this calculation of costs billed to the consumer by the city is considered conservative as it is a midpoint of a series of expected price rises. In addition, the water derived from the Nacimiento project expected at 3,380 AF per annum will not be fully realized until demand grows and water supply is increased to meet that demand in the coming years. In this way, consumers in 2010 will be paying for water consumed in the future years through funding the Nacimiento project. This must be the case in a demand management system which plans ahead to meet the increased future demands of the city. The figures then reflect a much larger 'gallons per year' figure than will actually be the case in the first years

of the Nacimiento project's implementation. For the purposes of this project, the expected endpoint water supply data of 3,380 AF per year has been used although the per gallon costs will be much higher in the first years when little additional water will be consumed by SLO from the Nacimiento project in comparison to its expected endpoint demands. This significant skew to data must be recognized when drawing system comparisons.

Table 14. Current SLO Municipal and Single Family (SF) Residence Water Supply Costs Source: Derived from Table 12.

Current Municipal Water Supply Annual Costs (excluding Nacimiento impacts)	SLO Water Use AF/yr	SLO Water Use gallons/yr	SLO Cost of Water \$/yr	SLO Energy Use kWh/yr	Cost of Water \$/AF	Cost of Water \$/gallon	Energy Use kWh/gallon
Municipal Cost- all users (commercial, residential etc.)	6,488	2,114,121,288	\$ 8,320,790	3,737,560	\$ 1,282	\$ 0.0039	0.0018
Apportioned Municipal Cost for SF Residential (45% of total)	2,920	951,354,580	\$ 3,744,356	1,681,902	\$ 1,282	\$ 0.0039	0.0018
Current Consumer-Billed Cost for SF Residential	2,920	951,354,580	\$ 5,996,841	1,681,902	\$ 2,054	\$ 0.0063	0.0018

Table 15. Current SLO Municipal and Single Family (SF) Residence Water Supply Costs Source: Derived from Table 12.

Additional Municipal Water Supply: Nacimiento Impact on Annual Basis	SLO Water Use AF/yr	SLO Water Use gallons/yr	SLO Cost of Water Supply \$/yr	SLO Energy Use kWh/yr	Cost of Water Supply \$/AF	Cost of Water Supply \$/gallon	Energy Use kWh/gallon
Municipal Nacimiento Marginal Cost - all users	3,380	1,101,376,380	\$ 7,574,000	2,698,968	\$ 2,241	\$ 0.0069	0.0025
Apportioned Municipal Nacimiento Cost for SF Residential (45% of total)	1,521	495,619,371	\$ 3,408,300	1,214,536	\$ 2,241	\$ 0.0069	0.0025
Municipal Total Costs all SF Residential Users with Nacimiento Included	4,441	1,447,104,291	\$ 7,152,656	2,896,438	\$ 1,611	\$ 0.0049	0.0020
Consumer-Billed Cost with Nacimiento Increase (SF Residential) ²²	4,441	1,447,104,291	\$ 11,346,613	2,896,438	\$ 2,555	\$ 0.0078	0.0020

²² Although this data is based on expected increases due to come into effect over next year, according to the SLO city Water Division Manager, additional annual double digit increases are expected through 2012-13 Source: <http://www.sanluisobispo.com/183/story/707310.html>

Table 16 applies the same processes used to create Table 15, to calculate the wastewater costs for the city and SF residences using a volumetric apportionment strategy. The 672m gallons of wastewater processed is based on SLO city data of an average processing rate by SF residential households of 7 units per month x 748 gallons per unit x 12 months x 10, 581 households (City of San Luis Obispo, 2009). Note that the relationship between the city's water supply and the wastewater processed is a reduction in volume by 30%. This is assumed relationship between water supply and processed wastewater volumes is applied to determine the overall consumer-billed cost incorporating Nacimiento data. Specifically, the expected SLO wastewater processed amount of 3,109 AF, represents a 30% reduction to the overall water supply figure of 4,441 AF per year allocated in Table 15 to SF residences with Nacimiento at full supply.

Table 16. Current SLO Municipal and Single Family (SF) Residence Wastewater Costs. Source: Derived from Table 13.

Current Wastewater System Annual Costs	SLO Wastewater Processed AF/yr	SLO Wastewater Processed gallons/yr	SLO Cost of Wastewater Processing \$/yr.	SLO Wastewater Processing Energy Use kWh/yr	Cost of Wastewater Processing \$/AF	Cost of Wastewater Processing \$/gallon	Energy Use kWh/gallon
Total Municipal Wastewater Costs - all users (commercial, residential etc.)	4,910	1,600,000,000	\$ 19,954,900	4,287,440	\$ 4,064	\$ 0.012	0.0027
Apportioned Municipal Cost for SF Residential (42% of total)	2,062	672,000,000	\$ 8,381,058	1,800,725	\$ 4,064	\$ 0.012	0.0027
Current Consumer-Billed Cost for SF Residential	2,062	672,000,000	\$ 4,305,112	1,800,725	\$ 2,088	\$ 0.006	0.0027
Consumer-Billed Cost with Nacimiento increase (SF Residential)*	3,109	1,012,973,004	\$ 7,731,367	2,714,413	\$ 2,487	\$ 0.008	0.0027

Table 17 looks at the data from DT 3.2 System Components and Potential Sources for the costs associated with the proposed alternative water system incorporating a 10,000-gallon tank, pump, UV filter and pressure tank and a greywater reuse system with installation and O and M costs included. This creates data per SF residential household in SLO for energy and fiscal costs associated with this alternative water supply.

Table 17. Proposed Alternative Water Supply and Wastewater System Costs per Household. Source: Derived from DT 3.2 – Decision Tree Tool.

Alternative Water System Annual Costs per Household	Total Cost (\$)	Life (yrs)	Cost per year (\$)	Energy Use kW/yr
Water Supply				
10,000-gallon tank installed	\$ 7,000.00	50-60 yrs	\$ 140.00	
Sacrificial anodes	\$ 100.00	2-3 yrs	\$ 48.00	
UV Filter	\$ 799.00	10 yrs	\$ 80.00	
Pump	\$ 607.00	20 yrs	\$ 30.00	
Pressure Tank	\$ 240.00	15 yrs	\$ 16.00	
Electricity Costs (\$0.15/kW): UV Filter (.8 kWh/yr)			\$ 0.15	0.8
Electricity Costs (\$0.15/kW): Pump (100 kWh/yr)			\$ 15.00	100
Subtotals			\$ 329.15	101
Wastewater				
Greywater system (incl. pump)	\$ 5,500.00	50-60 yrs	\$ 110.00	
Plumbing	\$ 3,000.00	system life (50 yrs)	\$ 60.00	
Electricity Costs (\$0.15/kW): Pump (60 kWh/yr)			\$ 9.00	60
454 gallons per month processed external to household by municipal system @ \$0.013/g; 0.0027kW/g			\$ 70.82	15
Subtotals			\$ 179.00	75
System Total			\$ 508.15	175

Table 18 looks at the overall costs of the proposed alternative water supply system extrapolated from from Table 17 data for the whole of SLO. Specifically, the cost of the alternative system for SLO SF households each year has been determined in the following way:

- Table 17 SF household water supply cost was determined by totaling the per annum cost of each of the alternative system components (installed 10,000-gallon galvanized steel tank, UV filter, pump and pressure tank and installed greywater reuse system) and electricity cost for running system (101 kWh based on current residential cost of \$0.15 / kWh) as described in Chapter 2, Section DT 3.2. This figure is then multiplied by the 10,581 SF households in SLO to produce the totals for the city.
- The volume of water supplied by the system is 2472 gallons per month (including the 454 gallons per month of greywater used for the toilet) x 12 months x 10,581 SLO SF households for a total of 313m gallons per year for SLO SF residences. Similarly, the wastewater component (30% less volume than the water supply to the house – 1730 gallons per month) is multiplied by 12 months and the number of households for a total of 219m gallons/yr for SLO SF residences.
- Energy used by the alternative system by a SLO SF residence (water supply energy use) is also taken from data Table 17 and amounts to 101 kWh per year. Again this data is multiplied by 10,581 SLO SF households to produce the overall SLO city data for Table 18.
- Blackwater required to be processed by the alternative system (wastewater services per SF household) is 454 gallons (toilet waste only) which will be processed through the public wastewater system at \$0.0076 per gallon (454 g x 12 months x \$0.013 per gallon). Similarly, the annual blackwater processing cost in kWh (wastewater energy cost) is 454 gallons x 12 months X 0.00027 kWh per gallon

Table 19 calculates the costs of the existing municipal system (for the consumer and the municipality) based on the same adjusted demand system used for the alternative system calculations. Some specific explanations for data used:

- The municipal water supply cost per gallon and kWh per gallon for water supply are taken from Table 15 data for the total municipal costs for SLO SF residences with Nacimiento included. Similarly, the consumer cost per gallon of water supplied or wastewater processed is based on the billed cost expected after the first round of city-wide price increases expected in the next

year which is \$0.0078 and \$0.0076 respectively (per gallon). It is considered appropriate to look at the costs of the system using the intended additional water source the city is planning for. As previously highlighted, it should be noted that these costs are conservative as double digit increases are expected annually for some years. Further, the city budgeted estimates for energy usage for the Nacimiento project will be greater for SLO than provided for if electricity used to pump the water from Nacimiento is apportioned according to use. That is, Nacimiento lies 45 miles away from SLO which is the furthest city from the water source of all the collaborating partners (Paso Robles, Atascadero, etc). The city budget reflects a 35% proportional allocation of the energy that would be needed (i.e. the budgeted figure of \$318,000 is close to 35% of the cost of the total kWh estimated for the project, assuming a \$0.14 per kWh charge which is average for current electrical costs to the municipality). This 35% figure matches SLO's 35% investment in the project and intended proportional volume of use.

- Volumes of water supply in gallons per year are calculated using an adjusted demand of 2472 gallons per month so that a similar reduced water demand home is compared on an equal basis to the alternative model. Similarly, an expected wastewater volume being processed is 30% less than the water supplied to the household (1730 gallons/ month)
- The cost of wastewater processing per gallon is taken from the current municipal costs volumetrically apportioned (42%) from whole city costs to determine a figure for SLO SF households (from Table 17).

Table 18. Alternative System Costs Applied to SLO. Source: Derived from Table 17.

Alternative Water System Annual Costs (2472 g /month/household)	Cost \$/gallon	Energy Use kWh/gallon	Supplied/ Processed gallons/yr	SLO Cost \$/yr	SLO Energy Use kWh/yr
Alternative Water Supply System Costs (all SLO SF Residential)	\$ 0.0111	0.0034	313,874,784	\$ 3,482,736	1,066,565
Alternative Wastewater System Total Costs (all SLO SF Residential)	\$ 0.0086	0.0036	219,661,560	\$ 1,893,999	789,329
Complete Alternative System Costs (all SLO SF Residential)				\$ 5,376,735	1,855,894

Table 19. Existing Municipal System Costs with Adjusted Demand. Source: Derived from Table 14,15 and 16.

Existing Municipal System Costs with Adjusted Demand (2472 g /month/household)	Cost \$/gallon	Energy Use kWh/gallon	Supplied/ Processed gallons/yr	SLO Cost \$/yr	SLO Energy Use kWh/yr
Water Supply: Municipal Costs (all SLO SF Residential)	\$ 0.0049	0.0020	313,874,784	\$ 1,551,400	628,233
Water Supply: Consumer Costs (all SLO SF Residential)	\$ 0.0078	0.0020	313,874,784	\$ 2,461,064	628,233
Wastewater Processing: Municipal Costs (all SLO SF Residential)	\$ 0.0125	0.0027	219,661,560	\$ 2,739,578	588,616
Wastewater Processing: Consumer Costs (all SLO SF Residential)	\$ 0.0076	0.0027	219,661,560	\$ 1,676,535	588,616
Total Supply: Municipal Costs (all SLO SF Residential)				\$ 4,290,978	1,216,849
Total Supply: Consumer Costs (all SLO SF Residential)				\$ 4,137,598	1,216,849

Summary of Results

Table 18 and 19 provides data for fiscal and energy costs for an average 3 occupant SF household in SLO that uses ‘best practice’ water conserving fixtures to create an adjusted demand of 2,472 gallons per month. Table 18 specifically provides fiscal and energy data for the proposed alternative water supply system for a SLO SF household using residential rainwater harvesting and greywater reuse. Table 19 provides fiscal and energy data for a SLO SF household using the existing centralized public water system. Table 19 also shows the contrast between the annual fiscal cost that would be billed to the consumer in the adjusted demand household based on dollars per gallon water and sewer rates in comparison to the actual annual costs to the municipality (SLO city administration) to run the same system. More specific points are made below about Table 18 and 19 data.

Water Supply

- The energy use per annum to supply water using the current public water system for SLO SF households is 628,233 kWh per year (at 0.002 kWh/ gallon) whereas the energy use of the alternative water supply system for those same households with water demand constant, is 1,066,565 kWh (at 0.0034 kWh/gallon). In summary, the alternative system uses 438,332 kWh more than the current public water system would to supply water when applied to the whole city with demand constant. This means the current public water supply system uses 41% less electricity than the proposed alternative water supply system would with demand constant in SF households the case study city.
- The municipal cost per annum to supply water using the existing public water system for SLO SF households using adjusted demands is \$1,551,400 (at \$0.0049/gallon) whereas in the same household scenario the consumer cost to supply water is \$2,461,064 (at \$0.0078/gallon) using billing rates expected to be implemented in the next year. This difference of \$909,663 shows that it is costing the municipality 37% less to supply water than consumers are being billed. It is notable that double digit consumer rate increases are expected for several years and that this is the low end expectation for costs to the consumer.
- The municipal cost to supply water per annum for SLO SF households using adjusted demand data (\$1,551,400 at \$0.0049/gallon) is 55% less than the cost of water supply in the same household scenario using the alternative water supply system (\$3,482,736 at \$0.0111/gallon).

- The consumer cost for water supply using expected billing rates for the adjusted demand SLO SF household (\$2,461,064 at \$0.0078/gallon) is 29% less than the fiscal cost for water supply to the same scenario household using the alternative system (\$3,482,736 at \$0.0111/gallon).

Wastewater Processing

- The energy use per annum to process wastewater using the current public water system for SLO SF households is 588,616 kWh per year (at 0.0027 kWh/ gallon) whereas the energy use of the alternative wastewater processing system for those same households with water demand constant, is 789,329 kWh (at 0.0036 kWh/gallon). In summary, the alternative system uses 200,713 kWh more than the current public water system would to process wastewater when applied to the whole city with demand constant. This means the current public wastewater processing system uses 25% less electricity than the proposed alternative water supply system would with demand constant in SF households the case study city.
- The municipal cost per annum to process wastewater using the existing public water system for SLO SF households using adjusted demands is \$2,739,578 (at \$0.0125/gallon) whereas in the same household scenario the consumer cost to process wastewater is \$1,676,535 (at \$0.0076/gallon) using billing rates expected to be implemented in the next year. This difference of \$1,063,043 shows that consumers are being billed 39% less than it is costing the municipality to process wastewater. It is notable that double digit consumer rate increases are expected for several years and that this is the low end expectation for costs to the consumer.
- The alternative system cost to process wastewater per annum for SLO SF households using adjusted demand data (\$1,893,999 at \$0.0086/gallon) is 31% less than the municipal cost of processing wastewater in the same household scenario using the public wastewater processing system (\$2,739,578 at \$0.0125/gallon).
- The consumer cost for processing wastewater using expected billing rates for the adjusted demand SLO SF household (\$1,676,535 at \$0.0076/gallon) is 11% less than the fiscal cost of the same scenario household to process wastewater using the alternative system (\$1,893,999 at \$0.0086/gallon).

Total Costs of System – Water Supply and Wastewater Processing

- The overall energy use per annum using the current public water system for SLO SF households is 1,216,849 kWh per year whereas the overall energy use of the alternative water supply system for those same households with water demand constant, is 1,855,894 kWh. In summary,

the alternative system uses 639,045 kWh more than the current public water system would when applied to the whole city with demand constant. This means the current public water system uses 34% less electricity than the proposed alternative system would with demand constant in SF households the case study city.

- The overall municipal cost per annum of using the existing public water system for SLO SF households using adjusted demands is \$4,290,978 whereas in the same household scenario the overall consumer cost is \$4,137,598 using billing rates expected to be implemented in the next year. This difference of \$153,380 shows that consumers are being billed for the whole water system (water supply and wastewater processing) at just 4% less than it is costing the municipality. It is notable that double digit consumer rate increases are expected for several years and that this is the low end expectation for costs to the consumer.
- The overall municipal cost per annum for SLO SF households using adjusted demand data (\$4,290,978) is 20% less than the cost of water supply in the same household scenario using the alternative water supply system (\$5,376,735).
- The overall consumer cost using expected billing rates for the adjusted demand SLO SF household (\$4,137,598) is 23% less than the overall fiscal cost of the same scenario household using the alternative system (\$5,376,735).

Chapter 5 - Conclusions

The application of the decision tree for SLO provided an alternative water supply solution for the city that completely substituted for public water supply with the installation of a rainwater harvesting system (with best practice features as listed in Chapter 3, Section 1.4) for potable and other domestic purposes, and a greywater re-use system applied to toilets for flushing and the remainder distributed to an outdoor irrigation system.

The data for current municipal and consumer cost to SLO SF householders (in dollars and in energy usage) of the existing public water supply were contrast against the costs of the alternative system. The energy used by the current system (1,216,849 kWh/yr) if all SF households in SLO were using it was considerably lower (34%) than the energy used by the proposed alternative public water system (1,855,894 kWh/yr) with water demands data kept constant in both scenarios. Electricity used in the alternative system is almost entirely due to the pump system, with a small amount used for the UV filter system.

The fiscal cost analysis revealed a number of interesting results. Note that all SLO SF household scenarios (alternative, municipal and consumer-billed) are compared with a constant water demand of 2472 gallons per month per household. The results show there is a significant difference between the consumer-billed cost and a volumetrically apportioned municipal cost for SLO SF residences. The municipal cost is 37% less for water supply at \$0.0049/gallon in comparison to the consumer cost of \$0.0078/gallon based on billing rates likely to be implemented next year. This situation reverses with wastewater processing costs where the consumer is billed at 39% less (\$0.0076/gallon) than what the municipality is paying volumetrically to process the water at \$0.0125/gallon. Looking then at overall costs for both water supply and wastewater processing, consumers billed amount is 4% less (\$4,137,598) than the cost of water to the city (\$4,290,978). Given that the City intends to significantly increase water prices billed to customers over the next several years and that this is the low end expectation for costs to the consumer, this situation will continue to disproportionately increase the cost of water to consumers as opposed to other users on a volume basis.

The comparison between cost to the consumer for current water supply through the public water system versus the proposed alternative system is important for considerations of the feasibility for individual households to go 'off the grid' and be self-sustaining with their water supply. The results

show that the consumer-billed water supply cost expected within the next year (\$0.0078/gallon) is 29% lower than that of the alternative water supply (\$0.0111/gallon). The wastewater processing cost to the consumer (\$0.0076) is also 11% less than that of the alternative system (\$0.0086/gallon). To calculate the overall cost difference in terms of both water supply and wastewater costs, the total costs used are as if all SF residences in SLO used the system. On this basis, the consumer cost using expected billing rates (\$4,137,598) is 23% lower using the public water system than the cost of the alternative system (\$5,376,735). Again, the City intends to significantly increase water prices billed to customers over the next several years and this is the low end expectation for costs to the consumer. These expected increases may skew these results in favour of the alternative system where it is viable for the consumer to completely replace their water system and remove their household off the public water system to their financial benefit. With economies of scale, these figures will also alter significantly, as will be discussed shortly.

The municipal cost for water supply (\$0.0049/gallon) is 55% lower than the cost for the alternative system (\$0.0111/gallon). Looking at wastewater processing, the cost of the alternative system (\$0.0086/gallon) is 31% less than the municipal cost (\$0.0125/gallon). The alternative system's savings are mostly a result of on-site greywater reuse for irrigation and indicate the scope of the immediate fiscal benefit to the municipality to substitute residential greywater systems for current public wastewater services. Overall costs of both water supply and wastewater processing using the municipal supply (\$4,137,598) are 20% less than the alternative water system (\$5,376,735). Again, economies of scale with adaptation of the water supply system will be an important driver of cost considerations.

This study focused exclusively on the fiscal and energy costs of the current and proposed systems. It is important to note that questions of sustainability of a particular system must include a full analysis of all aspects of that system, such as the opportunity costs and externalities associated with retaining the existing system and not investing in RHS and greywater reuse as mentioned in Chapter 4. These include loss of opportunity for less pressure on watersheds with less catchment-based drinking water being withdrawn from the ecosystem, reduced storm water drainage costs, reduced need to add saline as a softener and then remove it in wastewater treatment, reduced potential of cutoff from water supplies during emergencies with electricity outage, less mixing of different quality waters (increased efficiencies) and benefits of consumers being directly connected to their water supply increasing conscientious water-use.

Some of the costs included in this study, such as maintenance costs for existing systems are not considered to be fully provided for by city budgets. As previously noted, estimates by the Public Policy Institute of California are that there is a backlog of maintenance to water and wastewater infrastructure of about \$40 billion dollars (California Department of Water Resources (John Andrew), 2004).

Alternative systems may alleviate some of the need for this investment in infrastructure.

With significant quantities of energy consumed by current systems for pumping water (e.g. total of all water-related consumption of electricity use in California is 19%²³), it would be appropriate to fully investigate potential energy savings of on-site residential water supplies. This exploration of alternative supply may be preferable to the traditional demand management approach of looking to the next closest catchment, further and further away from users as each nearby water source is fully utilized and demand continues to increase. For example, SLO is implementing connection to the Nacimiento water source which is 45 miles away from users. SLO city's current main water source at Santa Margarita is just 9 miles away and the secondary source is some 17 miles away at Cayucos. Nacimiento then represents a massive leap in distance for water supply to travel to the end user.

The decoupling of the energy equation is a crucial component of sustainable water supply. Given their proximity to user, one might expect significant energy savings from RWH and greywater. However, in this study it was found that significant energy was required to pump collected rainwater to storage tanks. Changes can be made to the alternative system to eliminate the need for electrical supply completely. A common practice in Australia is to elevate rainwater harvesting tanks to appropriate levels to ensure adequate pressure to supply SF household fixtures. This would create a corresponding increase in cost of the alternative system in some situations which would require a structurally-sound shelf to carry the heavy load of water to elevate it above the ground to enable gravity feed. If a natural slope in the topography could be used to elevate the holding tank, then this cost could be avoided. A tank at a height of 10ft would provide a 6 p.s.i. pressure which would be sufficient for most fixtures. Some fixtures may need to be adjusted to this lower pressure such as the low-flow shower head used for the adjusted demand model which ordinarily requires a 15 p.s.i. pressure to function.

An environmentally attractive alternative would be to incorporate energy supply systems that do not use fossil fuels for generation such as photovoltaic solar energy panels. To supply such a small amount

²³ See reference p 9.

of annual electricity, only a small panel would be required (i.e. the alternative water system's energy needs of 101kWh/yr would be easily met with one 200-watt panel which is 3' x 5' and retails for about \$1300 installed). These panels lose only about 0.5% efficiency a year and would therefore have an effective life of some 30 to 40 years (an extra \$43 a year. Tempered glass covered panels would readily become part of a roof system collecting rainwater. In conclusion, fossil fuel energy needs of the alternative system could relatively easily be eliminated through either a gravity-fed system or the use of solar energy panels.

The costs of the RHS system as used in this study were also based on current costs for purchase of such a system in SLO. With vast numbers of residences purchasing systems, economies of scale would massively decrease costs involved. In fact, a recent study for the Australian National Water Commission (Marsden Jacob Associates, 2007) gives a good estimation of the scope of price reductions with large scale use as it provides data for the full cost of a RHS in a country where 1.5 million (19%) of households use them. The study showed an average RHS system cost with an above ground 5,000-gallon tank (20kL), pump, plumbing and installation is A\$4917. For the purposes of comparing with the 10,000 gallon system of this project, the average cost of the tank is doubled (A\$5704). Assuming a 20 year pump life and a 50 year tank life, the average cost per annum of the Australian RHS is A\$186 or US\$147 per year (1 USD = 1.26 AUD). Given this study's per annum cost of the RHS system of US\$234 (excluding UV filter system which is not common in Australian systems), expected reduction in cost for the RHS system are in the order of 38% less. It is reasonable to assume an even larger scope in price reduction in the US than Australian experience, given the size of the markets in this country. Even assuming a conservative 38% reduction in the cost of all aspects of the system (including greywater system costs), this would dramatically alter the fiscal cost picture of an alternative water supply system as described in this project. With the results of this project showing a difference in cost in favor of the current public system of just 20-23%; a reduction in the magnitude of 38% would see a swing significantly in favor of the proposed alternative system. In summary, the cost analysis would be adjusted to a more equitable basis of comparison than a public system servicing an entire city versus an alternative system which is virtually unknown in this country and a corresponding small market.

In light of these conclusions, if on-site electricity needs of an alternative system are eliminated through use of a gravity fed or solar powered RHS and large scale purchase reduces the supply cost of the alternative system, there is an enormous opportunity for implementing a less costly, more sustainable,

and possibly more reliable²⁴ water supply system. There is great opportunity for the building industry to recreate the landscape with sustainable practices applied to new construction as the AIA Research Corporation indicates that “three quarters of the built environment in the U.S. will be either new or renovated” by the year 2035 (Architecture 2030). This new construction and / or renovation could provide opportunities for cost-effective implementation of *in-situ* RHS and/or greywater in the residential setting which would also effectively decouple the energy/ water equation.

²⁴ As highlighted in Chapter 4, one of the opportunity costs suggested by studies is the potential increased resiliency of RHSs to climate change / reduced rainfall.

Appendix A - Decision Tree

Decision tree for administrators to determine scope of alternative residential *in-situ* water supply system

DT1: Harvested Rainwater Quality

Issue	Legislative / Best Practice Benchmark	Determination Process: Generic (G) & Site-specific (SS)	Action
DT 1.1.1 Microbial Contamination	Meets SDWA and relevant State guidelines for MCLs	<p>GENERIC</p> <p>Lack of research quantifying risk estimate.</p> <p>Treatment recommended for potable purposes.</p> <p>SITE SPECIFIC</p> <p>Do State / local MCLs exceed SDWA?</p> <p>If N, proceed as per Generic</p> <p>If Y, does system account for its treatment?</p> <p>If Y, proceed as per Generic</p> <p>If N, proceed to action <u>when system does not adequately treat risk</u></p>	<p>1. Reduce potential for microbial contamination through Best Practice Guidelines (see Ch. 2)</p> <p>2. Install appropriate treatment processes.</p> <p>UV filter recommended</p> <p><u>When system does not adequately treat risk:</u></p> <p>Examples of options</p> <p>Harder Option: Local or State Authority accepts some responsibility for private system (e.g. Bi-annual water testing submitted by residence for maintenance of a 'Rainwater Harvesting for Potable Use Permit', once-off testing, potential for receiving clearance after a period of testing to operate at own risk)</p> <p>Softer Option: Follow EPA lead on 'private wells' and do not accept any health risk associated with residential private water systems. Residence fully accountable. Recommendations provided by agency to encourage best practices.</p>

Issue	Legislative / Best Practice Benchmark	Determination Process: Generic (G) & Site-specific (SS)	Action
DT 1.1.2 Heavy Metals	Meets SDWA and relevant State guidelines for MCLs	GENERIC Research suggests holding tank's natural processes of settlement, flocculation produce adequate quality water. Also highlight the importance of non-contact with hazardous substances and importance of maintenance (see Best Practice Guidelines). Unlikely heavy metals an issue unless major industrial polluter nearby (SS issue)	Ensure Best Practice Guidelines met (see Ch. 2) No additional treatment recommended
		SITE SPECIFIC Do State / local MCLs exceed SDWA? If N, proceed as per Generic If Y, does system provide for its treatment? If Y, proceed as per Generic If N, proceed to action <u>when system does not adequately treat risk</u>	<u>When system does not adequately treat risk:</u> Examples of options Harder Option: Require installation of activated carbon filters Softer Option: Recommend annual testing w/ resident fully accountable for decisions on treatment and health risks

Issue	Legislative / Best Practice Benchmark	Determination Process: Generic (G) & Site-specific (SS)	Action
DT 1.1.3 Other Contaminants	Meets SDWA and relevant State guidelines for MCLs	<p>GENERIC</p> <p>The sources of potential contaminants are key. If a contaminant is highly unlikely to be part of a RHS (e.g. source of contaminant is likely to be part of soil run-off and RHS does not allow for the potential entrance of the contaminant into the system) then the particular contaminant may be excluded as a risk</p> <p>SITE SPECIFIC</p> <p>Do State / local MCLs exceed SDWA? If N, proceed as per Generic</p> <p>If Y, is contaminant unlikely to enter system? If Y, proceed as per Generic If N, proceed to action <u>when system does not adequately treat risk</u></p>	<p>Ensure Best Practice Guidelines met (see Ch. 2) No additional treatment recommended</p> <p><u>When system does not adequately treat risk:</u> Examples of options Harder Option: Local or State Authority accepts some responsibility for private system (e.g. Bi-annual water testing submitted by residence for maintenance of a 'Rainwater Harvesting for Potable Use Permit', once-off testing, potential for receiving clearance after a period of testing to operate at own risk) Softer Option: Follow EPA lead on 'private wells' and do not accept any health risk associated with residential private water systems. Residence fully accountable. Recommendations provided by agency to encourage best practices.</p>

Issue	Legislative / Best Practice Benchmark	Determination Process: Generic (G) & Site-specific (SS)	Action
DT 1.2 System Components (Hazardous Substances)	Ensure non-contact with potential contaminants	GENERIC Studies show contact w/ common hazardous substances responsible for contamination	Eliminate contact w/ typical contaminants through following Best Practice Guidelines (see Ch. 2)
		SITE SPECIFIC Are there additional risks inherent to area e.g. area's dominant roofing materials are toxic? If N, proceed as per Generic If Y, does system account for its treatment? If Y, proceed as per Generic If N, proceed to action when system does not adequately treat risk	<u>When system does not adequately treat risk:</u> Examples of options Harder Option: Require treatments according to contaminant OR exclude buildings subject to contaminants from program Softer Option: Recommend annual testing w/ resident fully accountable for health risks

Issue	Legislative / Best Practice Benchmark	Determination Process: Generic (G) & Site-specific (SS)	Action
DT 1.3 System Elements (Treatment Chain)	Ensure appropriate 'treatment chain'	GENERIC Studies show incorporating particular elements (roof washer / water diverter, mesh against leaf litter, lined or flushed holding tank) into system increases quality of water and increases potency of 'treatment chain'	Increase quality of water through following Best Practice Guidelines

Issue	Legislative / Best Practice Benchmark	Determination Process: Generic (G) & Site-specific (SS)	Action
DT 1.4 Importance of Maintenance	Ensure 'best practices' for maintenance followed	GENERIC Studies show good maintenance practices are the key to increasing quality of tank water	Increase quality of water through following Best Practice Guidelines

DT2: Water Availability for Firefighting

Issue	Legislative / Best Practice Benchmark	Determination Process: Generic (G) & Site-specific (SS)	Action
DT 2 Water Availability for Firefighting	Ensure adequate water under pressure available for emergency purposes	GENERIC Long term shift to decentralized water supplies must acknowledge requirement for emergency supplies of water for fire fighting.	Ensure incorporation of adequate water supplies under necessary pressure for each dwelling is incorporated into longer term strategies looking to completely substitute decentralized for centralized systems

DT3: Creating a RHS

Issue	Legislative / Best Practice Benchmark	Determination Process: Generic (G) & Site-specific (SS)	Action
DT 3.1.1 Ensuring adequate supply	Ensure system supply meets average individual resident's needs or use RHS to supplement public supply	GENERIC	
		<ol style="list-style-type: none"> 1. Use standard accepted measures of common residential end use of water (such as AWWARF study) to determine water needs. 2. Determine local rainwater harvesting potential. 3. Analyze RHSs ability to meet needs 	Determine local harvesting potential and analyze results for substitution based on reduced household needs with greywater reuse using Decentralized Supply Model Calculator
		SITE SPECIFIC	
		Use SS measures of residential water use if generic methods are considered not appropriate (eg desire extensive water conservation measures to be incorporated; reduced water needs too stringent, greywater reuse not considered appropriate)	Substitute AWWARF water needs data with SS desired data in Decentralized Supply Model Calculator

Issue	Legislative / Best Practice Benchmark	Determination Process: Generic (G) & Site-specific (SS)	Action
DT 3.1.2 Installing a RHS	Incorporate particular size water tank into the built environment following local codes	GENERIC Create mandatory codes specific to RHS and recommended practices for installation.	<ol style="list-style-type: none"> 1. Mandate backflow prevention devices to protect mains water supply when a connection between systems exists and 2. Label pipes used for rainwater if the dwelling also has pipes exclusively using public water supply to avoid cross-contamination issues
		SITE SPECIFIC Analyze SS issues associated with installing chosen tank into the built environment and consider incorporation of mandatory requirements versus recommended guidelines.	Comply with local SS building codes and consider typical local issues to determine appropriate guidelines for installation of tank.

Issue	Legislative / Best Practice Benchmark	Determination Process: Generic (G) & Site-specific (SS)	Action
DT 3.2 Sourcing elements of alternative water supply system	Provide information on sources for components of system	GENERIC Identifying possible sources for particular elements of system	See System Components and Potential Sources which includes current pricing (see Ch.2)

Appendix B – SDWA List of Contaminants and MCLs

Source: (online) U.S. E.P.A – Safe Drinking Water Act ; <http://www.epa.gov/safewater/sdwa>

EPA National Primary Drinking Water Standards					
	Contaminant	MCL or TT ¹ (mg/L) ²	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Acrylamide	TT8	Nervous system or blood problems;	Added to water during sewage/wastewater increased risk of cancer treatment	zero
OC	Alachlor	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops	zero
R	Alpha particles	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation	zero
IOC	Antimony	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder	0.006
IOC	Arsenic	0.010 as of 1/23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronics production wastes	0
IOC	Asbestos (fibers >10 micrometers)	7 million fibers per Liter (MFL)	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits	7 MFL
OC	Atrazine	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops	0.003
IOC	Barium	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits	2
OC	Benzene	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills	zero
OC	Benzo(a)pyrene (PAHs)	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines	zero
IOC	Beryllium	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries	0.004
R	Beta particles and photon emitters	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation	zero
DBP	Bromate	0.010	Increased risk of cancer	Byproduct of drinking water disinfection	zero
IOC	Cadmium	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints	0.005
OC	Carbofuran	0.04	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa	0.04
OC	Carbon tetrachloride	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities	zero
D	Chloramines (as Cl ₂)	MRDL=4.0 ¹	Eye/nose irritation; stomach discomfort, anemia	Water additive used to control microbes	MRDLG=4 ¹

LEGEND

D	Disinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

	Contaminant	MCL or TT ¹ (mg/L) ²	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Chlordane	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide	zero
D	Chlorine (as Cl ₂)	MRDL=4.0 ¹	Eye/nose irritation; stomach discomfort	Water additive used to control microbes	MRDLG=41
D	Chlorine dioxide (as ClO ₂)	MRDL=0.8 ¹	Anemia; infants & young children: nervous system effects	Water additive used to control microbes	MRDLG=0.81
DBP	Chlorite	1.0	Anemia; infants & young children: nervous system effects	Byproduct of drinking water disinfection	0.8
OC	Chlorobenzene	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories	0.1
IOC	Chromium (total)	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits	0.1
IOC	Copper	TT ⁷ ; Action Level = 1.3	Short term exposure: Gastrointestinal distress. Long term exposure: Liver or kidney damage. People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits	1.3
M	<i>Cryptosporidium</i>	TT ³	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
IOC	Cyanide (as free cyanide)	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories	0.2
OC	2,4-D	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops	0.07
OC	Dalapon	0.2	Minor kidney changes	Runoff from herbicide used on rights of way	0.2
OC	1,2-Dibromo-3-chloropropane (DBCP)	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards	zero
OC	o-Dichlorobenzene	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories	0.6
OC	p-Dichlorobenzene	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories	0.075
OC	1,2-Dichloroethane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC	1,1-Dichloroethylene	0.007	Liver problems	Discharge from industrial chemical factories	0.007
OC	cis-1,2-Dichloroethylene	0.07	Liver problems	Discharge from industrial chemical factories	0.07
OC	trans-1,2-Dichloroethylene	0.1	Liver problems	Discharge from industrial chemical factories	0.1
OC	Dichloromethane	0.005	Liver problems; increased risk of cancer	Discharge from drug and chemical factories	zero
OC	1,2-Dichloropropane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC	Di(2-ethylhexyl) adipate	0.4	Weight loss, live problems, or possible reproductive difficulties	Discharge from chemical factories	0.4
OC	Di(2-ethylhexyl) phthalate	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories	zero
OC	Dinoseb	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables	0.007
OC	Dioxin (2,3,7,8-TCDD)	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories	zero
OC	Diquat	0.02	Cataracts	Runoff from herbicide use	0.02
OC	Endothall	0.1	Stomach and intestinal problems	Runoff from herbicide use	0.1

LEGEND

D	Disinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

	Contaminant	MCL or TT1 (mg/L)2	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Endrin	0.002	Liver problems	Residue of banned insecticide	0.002
OC	Epichlorohydrin	TT8	Increased cancer risk, and over a long period of time, stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals	zero
OC	Ethylbenzene	0.7	Liver or kidneys problems	Discharge from petroleum refineries	0.7
OC	Ethylene dibromide	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries	zero
IOC	Fluoride	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories	4.0
M	<i>Giardia lamblia</i>	TT3	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC	Glyphosate	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use	0.7
DBP	Haloacetic acids (HAA5)	0.060	Increased risk of cancer	Byproduct of drinking water disinfection	n/a6
OC	Heptachlor	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide	zero
OC	Heptachlor epoxide	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor	zero
M	Heterotrophic plate count (HPC)	TT3	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures a range of bacteria that are naturally present in the environment	n/a
OC	Hexachlorobenzene	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories	zero
OC	Hexachlorocyclopentadiene	0.05	Kidney or stomach problems	Discharge from chemical factories	0.05
IOC	Lead	TT7; Action Level = 0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities; Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits	zero
M	<i>Legionella</i>	TT3	Legionnaire's Disease, a type of pneumonia	Found naturally in water; multiplies in heating systems	zero
OC	Lindane	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens	0.0002
IOC	Mercury (inorganic)	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands	0.002
OC	Methoxychlor	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock	0.04
IOC	Nitrate (measured as Nitrogen)	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	10
IOC	Nitrite (measured as Nitrogen)	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	1

LEGEND

D	Disinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

	Contaminant	MCL or TT ¹ (mg/L) ²	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Oxamyl (Vydate)	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes	0.2
OC	Pentachlorophenol	0.001	Liver or kidney problems; increased cancer risk	Discharge from wood preserving factories	zero
OC	Picloram	0.5	Liver problems	Herbicide runoff	0.5
OC	Polychlorinated biphenyls (PCBs)	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals	zero
R	Radium 226 and Radium 228 (combined)	5 pCi/L	Increased risk of cancer	Erosion of natural deposits	zero
IOC	Selenium	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines	0.05
OC	Simazine	0.004	Problems with blood	Herbicide runoff	0.004
OC	Styrene	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills	0.1
OC	Tetrachloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners	zero
IOC	Thallium	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories	0.0005
OC	Toluene	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories	1
M	Total Coliforms (including fecal coliform and <i>E. coli</i>)	5.0% ⁴	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present ⁵	Coliforms are naturally present in the environment as well as feces; fecal coliforms and <i>E. coli</i> only come from human and animal fecal waste.	zero
DBP	Total Trihalomethanes (TTHMs)	0.10 0.080 after 12/31/03	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection	n/a ⁶
OC	Toxaphene	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle	zero
OC	2,4,5-TP (Silvex)	0.05	Liver problems	Residue of banned herbicide	0.05
OC	1,2,4-Trichlorobenzene	0.07	Changes in adrenal glands	Discharge from textile finishing factories	0.07
OC	1,1,1-Trichloroethane	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories	0.20
OC	1,1,2-Trichloroethane	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories	0.003
OC	Trichloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories	zero
M	Turbidity	TT ³	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing micro-organisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.	Soil runoff	n/a
R	Uranium	30 ug/L as of 12/08/03	Increased risk of cancer, kidney toxicity	Erosion of natural deposits	zero

LEGEND

D	Disinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

	Contaminant	MCL or TT ¹ (mg/L) ²	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Vinyl chloride	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories	zero
M	Viruses (enteric)	TT ³	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC	Xylenes (total)	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories	10

NOTES

1 Definitions

- **Maximum Contaminant Level Goal (MCLG)**—The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.
- **Maximum Contaminant Level (MCL)**—The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
- **Maximum Residual Disinfectant Level Goal (MRDLG)**—The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
- **Maximum Residual Disinfectant Level (MRDL)**—The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
- **Treatment Technique (TT)**—A required process intended to reduce the level of a contaminant in drinking water.

2 Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million (ppm).

3 EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- *Cryptosporidium* (as of 1/1/02 for systems serving >10,000 and 1/14/05 for systems serving <10,000) 99% removal.
- *Giardia lamblia*: 99.9% removal/inactivation
- Viruses: 99.99% removal/inactivation
- *Legionella*: No limit, but EPA believes that if *Giardia* and viruses are removed/inactivated, *Legionella* will also be controlled.
- Turbidity: At no time can turbidity (cloudiness of water) go above 5 nephelometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. As of January 1, 2002, for systems serving >10,000, and January 14, 2005, for systems serving <10,000, turbidity may never exceed 1 NTU, and must not exceed 0.3 NTU in 95% of daily samples in any month.
- HPC: No more than 500 bacterial colonies per milliliter
- Long Term 1 Enhanced Surface Water Treatment (Effective Date: January 14, 2005): Surface water systems or (GWUD) systems serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, *Cryptosporidium* removal requirements, updated watershed control requirements for unfiltrated systems).
- Filter Backwash Recycling: The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.

4 No more than 5.0% samples total coliform-positive in a month, (for water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform positive per month.) Every sample that has total coliform must be analyzed for either fecal coliforms or *E. coli* if two consecutive TC-positive samples, and one is also positive for *E. coli* fecal coliforms, system has an acute MCL violation.

5 Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.

6 Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants:

- Haloacetic acids: dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L)
- Trihalomethanes: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L)

7 Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

8 Each water system must certify, in writing, to the state (using third-party or manufacturer certification) that when it uses acrylamide and/or epichlorohydrin to treat water, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows: Acrylamide = 0.05% dosed at 1 mg/L (or equivalent). Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent).

LEGEND

D	Disinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

National Secondary Drinking Water Standards

National Secondary Drinking Water Standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards.

Contaminant	Secondary Standard
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

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Appendix C - Summary of U.S. Versus Australian Drinking Water Standards

Source: On Tap Magazine 2003 http://www.nesc.wvu.edu/ndwc/articles/OT/SP03/Inter_DWReqs.html

Regulated Volatile Organic Compounds

The countries surveyed take a very different approach to regulating volatile and semi-volatile organic compounds than does EPA. Australia's standards are the most similar to the U.S.

Regulated Semi-Volatile Organic Compounds (SOCs)

Pesticides

Australia leads the world when it comes to setting standards for the greatest number of pesticides. This country has set standards for 100 pesticides that are not currently regulated in the U.S. The U.S., however, does set standards for 9 pesticides that Australia does not set standards for. Despite the standards, Australia doesn't require monitoring for these contaminants unless the water system has reason to believe that they may be present in their watershed. But, Australia can boast that it has set much more stringent standards for 16 of its 17 standards for pesticides that are comparable to those of the U.S.

Non-Pesticide SOCs

Significant differences also exist in the non-pesticide SOCs regulated by country. Phenols, which are part of the "Unregulated Contaminant Monitoring Rule" in the U.S., are regulated in Australia and Canada. WHO also established guidelines for this contaminant class.

Radiological Contaminants

In the U.S., increased testing is based on results of gross alpha and gross beta testing. If the standard is exceeded, systems must then test for radium 226 and 228. Based on these results, additional monitoring may be necessary, and water suppliers may need to pursue the primary list of radionuclides. As described in Appendix D, Australia does not set standards for uranium, radon or radium whereas the U.S. does.

Microbial Contaminants

Each country also has significant differences among microbial monitoring requirements. Australia has put far more extensive monitoring suggestions in their guidelines than other countries. Additionally, Australia is one of the leading investigators of algal toxins. While no standards are currently in place, specifications for cyanobacteria, or blue green algae do exist. Based on these counts, monitoring for toxins may be suggested. Currently, cyanobacteria and algal toxins are on EPA's contaminant candidate list (CCL), which is the source for future drinking water regulations in the U.S.

Regulated Primary Inorganic Contaminants

No country besides the U.S. has standards for asbestos, beryllium, or thallium.

Appendix D – U.S. SDWA Standards Versus Australian ADWG (and Others)

Source: National Drinking Water Clearing House (online) http://www.nesc.wvu.edu/ndwc/articles/OT/SP03/Inter_DWRregs.html

Table 1

Comparison of Primary Inorganic Drinking Water Standards
By Country or Organization

Contaminant	US EPA	Australia	Canada	United Kingdom	Germany	European Union	WHO†
	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
METALS							
Antimony	6	3	6	10	10	5	5
Arsenic	10	7	25	50	10	5	10
Barium	2000	700	1000	1000	1000	No	700
Beryllium	4	No	No	No	No	No	No
		Guideline	Guideline	Guideline	Guideline	Guideline	Guideline
Cadmium	5	2	5	5	5	5	3
Chromium	100	No	50	50	50	50	50
		Guideline					
Copper	1300	2000	1000	3000	3000	2000	1000
Lead	15	10	10	50	40	10	10
Mercury	2	1	1	1	1	1	1
Nickel	100	20	No	50	50	20	20
			Guideline				
Selenium	50	10	10	10	10	10	10
Thallium	2	No	No	No	No	No	No
		Guideline	Guideline	Guideline	Guideline	Guideline	Guideline
Non - Metals							
Asbestos	7 mil	No	No	No	No	No	No
	F/L	Guideline	Guideline	Guideline	Guideline	Guideline	Guideline
Cyanide	0.2	0.08 mg/L	0.2 mg/L	0.05 mg/L	0.05 mg/L	0.05 mg/L	0.07
	mg/L						mg/L
Fluoride	4 mg/L	1.5 mg/L	1.5 mg/L	1.5 mg/L	1.5 mg/L	1.5 mg/L	1.5 mg/L
Nitrate	10 mg/L	50 mg/L*	10 mg/L	50 mg/L*	50 mg/L*	50 mg/L*	50 mg/L*
Nitrite	0.1 mg/L	3.0	3.2	0.1 mg/L	0.1 mg/L	0.5 mg/L	3.0
		mg/L**	mg/L**				mg/L**

†The World Health Organization's standards are the basis for both developed and underdeveloped countries standards. They are guidelines based on health and may not be practical for all countries.

*Measured as Nitrate. U.S. standards measured as nitrogen.

** Measured as Nitrite. U.S. standards measured as nitrogen.

Table 2

Comparison of Primary Volatile Organic Drinking Water Standards
By Country or Organization

Contaminant	US EPA	Australia	Canada	United Kingdom	Germany	European Union	WHO
	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Benzene	5	1	5	No Guideline	No Guideline	1	10
Carbon Tetrachloride	5	3	5	3	3	No Guideline	2
1,2-Dichlorobenzene	600	1500	200	No Guideline	No Guideline	No Guideline	1000
1,4-Dichlorobenzene	75	40	5	No Guideline	No Guideline	No Guideline	300
1,2-Dichloroethane	5	3	5	No Guideline	No Guideline	3	30
1,1-Dichloroethylene	7	30	14	No Guideline	No Guideline	No Guideline	30
1,2-Dichloroethene cis	70	60 *	No Guideline	No Guideline	No Guideline	No Guideline	50 *
1,2-Dichloroethene trans	100	*	No Guideline	No Guideline	No Guideline	No Guideline	*
Dichloromethane	5	4	50	No Guideline		No Guideline	20
1,2-Dichloropropane	5	No Guideline	No Guideline	No Guideline		No Guideline	40
Ethylbenzene	700	300	2.4	No Guideline	No Guideline	No Guideline	300
Monochlorobenzene	100	300	80	No Guideline	No Guideline	No Guideline	300
Styrene	100	30	No Guideline	No Guideline	No Guideline	No Guideline	20
Tetrachloroethene	5	50	30	10	No Guideline	10	40
Toluene	1000	800	±24	No Guideline	No Guideline	No Guideline	700
1,2,4-Trichlorobenzene	70	30 **	No Guideline	No Guideline	No Guideline	No Guideline	20 **
1,1,1-Trichloroethane	200	No Guideline	No Guideline	No Guideline		No Guideline	2000
1,1,2-Trichloroethane	5	No Guideline	No Guideline	No Guideline		No Guideline	
Trichloroethene	5	No Guideline	50	30		10	70
Vinyl Chloride	2	0.3	2	No Guideline	No Guideline	0.5	5
Xylenes Total	10.000	600	±300	No Guideline	No Guideline	No Guideline	500
Germany regulates these contaminants specifically.					Total 10		

* Isomers are not regulated. ** Standard is for total Trichlorobenzenes.

Table 3

Comparison of Primary Semi-Volatile Organic Pesticide Drinking Water Standards
By Country or Organization

Contaminant	US EPA	Australia	Canada	United Kingdom	Germany	European Union	WHO
	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Individual Pesticides & Metabolites	See Below †	See Below †	See Below †	0.1 *	0.1 *	0.1 *	See Below †
Sum of Individual Pesticides	No Guideline	No Guideline	No Guideline	0.5 *	0.5 *	0.5 *	No Guideline
Alachlor	2	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	20
Atrazine	3	0.5	5 ††	No Guideline	No Guideline	No Guideline	2
Chlordane	2	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	0.2
1,2-Dibromo-3-Chloropropane	0.2	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	1
Endrin	2	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
Ethylene Dibromide	0.05	1	No Guideline	No Guideline	No Guideline	No Guideline	0.4 15
Heptachlor	0.4	0.05	No Guideline	No Guideline	No Guideline	No Guideline	0.03
Heptachlor Epoxide	0.2	0.05	No Guideline	No Guideline	No Guideline	No Guideline	0.03
Hexachloro Benzene	1	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	1
Hexachloro Cyclopentadiene	50	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
Lindane	0.2	0.05	No Guideline	No Guideline	No Guideline	No Guideline	2
Methoxychlor	40	0.2	90	No Guideline	No Guideline	No Guideline	20
Simazine	4	0.5	10	No Guideline	No Guideline	No Guideline	2
Toxaphene	3	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline

†Pesticides are regulated individually in most countries except in the European Union.

*In the European Union, no individual pesticide or metabolite may exceed 0.1 ug/L. Additionally, the sum of all individual pesticides may not exceed 0.5 ug/L.

††Canada regulates metabolites of atrazine under this standard.

Values listed in black boldface are health values as opposed to guidelines.

Table 3A

Comparison of Primary Semi-Volatile Organic Pesticide Drinking Water Standards

By Country or Organization

Contaminant	US EPA	Australia	Canada	United Kingdom	Germany	European Union	WHO
	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Chlorinated Acid							
Herbicides							
2,4-D	70	0.1	100	No Guideline	No Guideline	No Guideline	No Guideline
Dalapon	200	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
Dicamba	No Guideline	100	120	No Guideline	No Guideline	No Guideline	No Guideline
Dinoseb	7	No Guideline	10	No Guideline	No Guideline	No Guideline	No Guideline
Pentachlorophenol	1	0.01	60	No Guideline	No Guideline	No Guideline	9
Picloram	500	300	190	No Guideline	No Guideline	No Guideline	No Guideline
2,4,5-T (Silvex)	50	10	No Guideline	No Guideline	No Guideline	No Guideline	9
2,4,5-TP	50	0.05	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
Carbamate Pesticides							
Aldicarb	MCL Stayed	1	9	No Guideline	No Guideline	No Guideline	10
Carbaryl	No Guideline	5	90	No Guideline	No Guideline	No Guideline	No Guideline
Carbofuran	40	5	90	No Guideline	No Guideline	No Guideline	7
Oxamyl	200	5	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
Bendiocarb	No Guideline	No Guideline	40	No Guideline	No Guideline	No Guideline	No Guideline
Various Pesticides							
Diquat	20	0.5	70	No Guideline	No Guideline	No Guideline	10
Encothall	100	10	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
Glyphosate	700	10	280	No Guideline	No Guideline	No Guideline	No Guideline
Paraquat	No Guideline	1	10	No Guideline	No Guideline	No Guideline	No Guideline

Values listed in black boldface are health values as opposed to guidelines.

Table 4

Comparison of Primary Semi-Volatile Organic Non-Pesticide Drinking Water Standards
By Country or Organization

Contaminant	US EPA	Australia	Canada	United Kingdom	Germany	European Union	WHO
	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
PAHs							
Benzo (a) pyrene	0.2	0.01	0.01	10 ng/L		0.01	0.7
Benzo (b) fluoranthene	No Guideline	No Guideline	No Guideline			No Guideline	
Benzo (ghi) Perylene	No Guideline	No Guideline	No Guideline			No Guideline	
Benzo (k) fluoranthene	No Guideline	No Guideline	No Guideline			No Guideline	
Benzo 3,4-pyrene	No Guideline	No Guideline	No Guideline			No Guideline	
Fluoranthene	No Guideline	No Guideline	No Guideline			No Guideline	
Indeno (1,2,3-cd) pyrene	No Guideline	No Guideline	No Guideline			No Guideline	
PHthalates							
Di(2-ethylhexyl) phthalate	6	10	No Guideline	No Guideline	No Guideline	No Guideline	8
Di(2-ethylhexyl) adipate	400	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	80
PCBs							
Polychlorinated Biphenyls	0.5 *	No Guideline	No Guideline	No Guideline	0.1 **	No Guideline	No Guideline
Polybrominated Biphenyls	No Guideline	No Guideline	No Guideline	No Guideline	0.1 **	No Guideline	No Guideline
Terphenyls	No Guideline	No Guideline	No Guideline	No Guideline	0.1 **	No Guideline	No Guideline
TREATMENT CHEMICALS							
Acrylamide	Treatment Technique	0.2	No Guideline	No Guideline	No Guideline	0.1	0.5
Epichlorohydrin	Treatment Technique	0.5	No Guideline	No Guideline	No Guideline	0.1	0.4

*PCBs are regulated as the sum of their conversions to decachlorobiphenyl, not individually.

**Germany regulates PCBs, PBBs and Terphenyls. No individual pesticide can exceed 0.1 ug/L & the sum of all pesticides, PCBs, PBBs and terphenyls must not exceed 0.5 ug/L.

Table 4A

Comparison of Primary Semi-Volatile Organic Non-Pesticide Drinking Water Standards

By Country or Organization

Contaminant	US EPA	Australia	Canada	United Kingdom	Germany	European Union	WHO
	ug/L	ug/L	Ug/L	ug/L	ug/L	ug/L	ug/L
PHENOLS							
2-Chlorophenol	No Guideline	300	No Guideline	No Guideline	No Guideline	No Guideline	0.1 -10
2,4-Dichlorophenol	No Guideline	200	900	No Guideline	No Guideline	No Guideline	0.3 - 40
2,4,6-Trichlorophenol	No Guideline	20	5	No Guideline	No Guideline	No Guideline	200
2,4-Dinitrophenol	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
2-Methylphenol	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
OTHER							
Dioxin	3.0 e -05	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline

Table 5

Comparison of Primary Microbial Drinking Water Standards
By Country or Organization

Contaminant	US EPA	Australia	Canada	United Kingdom	Germany	European Union	WHO
BACTERIA							
Heterotrophic Plate Count	≤ 500 colonies/L	≤ 100 colonies / mL	≤ 500 colonies/L	No sig. increase over nrml.	≤ 100 colonies / mL	≤ 100 colonies / mL	No Guideline
E. coli	0/100 mL	0/100 mL	0/100 mL	0/100 mL	0/100 mL	0 /100 mL	0/100 mL
Fecal Coliforms	0/100 mL	0/100 mL	0/100 mL	0/100 mL	0/100 mL	0/100 mL	0/100 mL
Total Coliforms	0/100 mL 5% of Samples*	0/100 mL 5% of Samples*	10/100mL ††† 10% of Samples	0/100 mL 5% of Samples×	0/100 mL 5% of Samples*	0/100 mL	0/100 mL 5% of Samples*
PROTOZOA							
Acanthamoeba	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
Cryptosporidium	(TT) 99.9% Removal	(TT) 99.9% Removal	No Guideline	≤ 1 / 10 L ††††	Not Found	Not Found	Not Found
Giardia lamblia	(TT) 99.9% Removal	#	No Guideline	No Guideline	Not Found	Not Found	Not Found
Naegleria fowleri	No Guideline	##	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
VIRUSES							
Adenoviruses	99.9% Removal	#	Under Review	Not Found	Not Found	Not Found	Not Found
Caliciviruses	99.9% Removal	No Guideline	Under Review	Not Found	Not Found	Not Found	Not Found
Coxsackieviruses	99.9% Removal	No Guideline	Under Review	Not Found	Not Found	Not Found	Not Found
Echoviruses	99.9% Removal	No Guideline	Under Review	Not Found	Not Found	Not Found	Not Found
Enteric Viruses	(TT) 99.9% Removal	#	Under Review	Not Found	Not Found	Not Found	Not Found
Hepatitis Viruses	99.9% Removal	#	Under Review	Not Found	Not Found	Not Found	Not Found
Norwalk Virus	99.9% Removal	#	Under Review	Not Found	Not Found	Not Found	Not Found
Rotavirus	99.9% Removal	#	Under Review	Not Found	Not Found	Not Found	Not Found

†††Canada has a zero specification similar to the rest of the developed world. No sample should contain ≤ 10 colonies and not more than 10% of the samples should be positive.

* No more than 5% of samples may be positive. Positive samples must be analyzed for either fecal coliforms or E. coli. (TT) = Treatment Technique

††††Continuous monitoring at the entry point to the distribution system is required.

#Routine monitoring is not required. If fecal coliforms or E. coli are detected, or an outbreak is detected, monitoring these contaminants may be needed. ##Action required if detected. Routine monitoring not required.

Table 5A

Comparison of Unique Microbial Drinking Water Standards
By Country or Organization

Contaminant	US EPA	Australia	Canada	United Kingdom	Germany	European Union	WHO
<i>Aeromonas Hydrophilia</i>	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
<i>Campylobacter coli</i>	No Guideline	#	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
<i>Campylobacter jejuni</i>	No Guideline	#	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
<i>Mycobacterium Avium</i>	No Guideline	No	No	No	No	No	No Guideline
<i>Intercellulare</i>		Guideline	Guideline	Guideline	Guideline	Guideline	
<i>Pseudomonas aeruginosa</i>	No Guideline	No	No	No	No	0 / 250 mL***	No Guideline
<i>Salmonella spp.</i>	No Guideline	#	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
<i>Shigella spp.</i>	No Guideline	#	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
<i>Vibrio cholera</i>	No Guideline	#	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
<i>Yersinia enterocolitica</i>	No Guideline	#	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
<i>Legionella</i>	No Limit**	#	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
Fecal Streptococci	No Guideline	No Guideline	No Guideline	0 / 100 mL	No Guideline	No Guideline	No Guideline
Sulfite-reducing Clostridia	No Guideline	No Guideline	No Guideline	≤1 / 20 mL	No Guideline	No Guideline	No Guideline
Toxic Algae & Algal Toxins							
Cyanobacteria	No Guideline	1000 - 2000/mL†	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
Microcystin-LR	No Guideline	No Guideline*	No Guideline	No Guideline	No Guideline	No Guideline	1 µg/L
<i>Helicobacter Pylori</i>	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
Microsporidia	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline
<i>Clostridium perfringens</i>	No Guideline	No Guideline	No Guideline	No Guideline	No Guideline	0 / 100 mL††	No Guideline

*No standards are currently in place.

**Removal of 99.9% of Giardia and Viruses will accomplish removal of Legionella.

*** Requirement for bottled waters.

†For counts of 1000 - 2000 / mL, incrsd montng is recmd. Counts ≥2000 per mL require immediate action.

†† Required for systems using surface water.

#Routine monitoring is not required. If fecal coliforms or E. coli are detected, or an outbreak is detected, monitoring these contaminants may be warranted.

Table 6

Comparison of Radiological Drinking Water Standards
By Country or Organization

Contaminant	US EPA	Australia	Canada	United Kingdom	Germany	European Union	WHO
Uranium	30 ug/L	No Guideline	20 ug/L	Not Found	Not Found	No Guideline	2 ug/L
Gross Alpha	15 pCi/L	0.5 Bq/L	0.1 Bq/L*	Not Found	Not Found	No Guideline	0.1 Bq/L
Gross Beta	50 pCi/L	0.5 Bq/L	1.0 Bq/L*	Not Found	Not Found	No Guideline	1 Bq/L
Radon	300 pCi/L**	No Guideline	No Guideline	Not Found	Not Found	No Guideline	
		Total Indicative Dose - 1 mSv/year	Total Indicative Dose - 0.1 mSv/year	Not Found	Not Found	Total Indicative Dose - 0.1 mSv/year	
PRIMARY LIST - Natural Radionuclides (Canada)							
Lead-210	No Guideline	No Guideline	0.1 Bq/L	Not Found	Not Found	No Guideline	No Guideline
Radium-224	No Guideline	No Guideline	2 Bq/L	Not Found	Not Found	No Guideline	No Guideline
Radium-226	5 pCi/L	No Guideline	0.6 Bq/L	Not Found	Not Found	No Guideline	No Guideline
Radium-228	5 pCi/L	No Guideline	0.5 Bq/L	Not Found	Not Found	No Guideline	No Guideline
Thorium-228	No Guideline	No Guideline	2 Bq/L	Not Found	Not Found	No Guideline	No Guideline
Thorium-230	No Guideline	No Guideline	0.4 Bq/L	Not Found	Not Found	No Guideline	No Guideline
Thorium-232	No Guideline	No Guideline	0.1 Bq/L	Not Found	Not Found	No Guideline	No Guideline
Thorium-234	No Guideline	No Guideline	20 Bq/L	Not Found	Not Found	No Guideline	No Guideline
Uranium-234	No Guideline	No Guideline	4 Bq/L	Not Found	Not Found	No Guideline	No Guideline
Uranium-235	No Guideline	No Guideline	4 Bq/L	Not Found	Not Found	No Guideline	No Guideline
Uranium-238	No Guideline	No Guideline	4 Bq/L	Not Found	Not Found	No Guideline	No Guideline

*If screening for Gross Alpha & Gross Beta exceed the limits, then further analysis for the listed Primary radionuclides is required.

Sievert (Sv) = SI unit for effective dose, which "is the sum of all equivalent doses received by all tissues or organs, weighted to account for the different sensitivities to radiation of different organs and tissues in the human body."
(Source Australian Drinking Water Guidelines, 1996, Updated 2001, Chapter 4, Section 4.4, page 4-2).

Bq/L = One transformation per second or approximately 27 pCi/L.

Table 6A

Comparison of Radiological Drinking Water Standards

By Country or Organization

Contaminant	US EPA	Australia	Canada	United Kingdom	Germany	European Union	WHO
PRIMARY LIST Artificial Radionuclides (Canada)							
Cesium-134	No Guideline	No Guideline	7 Bq/L	Not Found	Not Found	No Guideline	No Guideline
Cesium-137	No Guideline	No Guideline	10 Bq/L	Not Found	Not Found	No Guideline	No Guideline
Iodine-125	No Guideline	No Guideline	10 Bq/L	Not Found	Not Found	No Guideline	No Guideline
Iodine-131	No Guideline	No Guideline	6 Bq/L	Not Found	Not Found	No Guideline	No Guideline
Molybdenum-99	No Guideline	No Guideline	70 Bq/L	Not Found	Not Found	No Guideline	No Guideline
Strontium-90	No Guideline	No Guideline	5 Bq/L	Not Found	Not Found	No Guideline	No Guideline
Tritium	No Guideline	No Guideline	7000 Bq/L	Not Found	Not Found	100 Bq/L	No Guideline

Bq/L = One transformation per second or approximately 27 pCi/L.

Appendix E – U.V. Filter and Micro-organism Destruction Levels

Micro-organism Destruction Levels, 2007 (online) <http://www.water-tanks.net/acatalog/UV-Details.html>

Ultraviolet (U.V.) energy at 253.7 nm wavelength required for 99.9% destruction of various micro-organisms (measured in mJ/cm²). For equivalent figures in mWS/cm² [microwatt seconds/cm²], multiply by 1000.

UV Dosage and Dosage: Kill relationship: Doubling the dose required for 90% destruction will produce 99% destruction of the target organism. Tripling the dose will produce a 99.9% destruction of the target organism and so on. An example of the Dosage:Kill relationship for a typical micro-organism (E.Coli) follows – Applied U.V. dose mJ/cm²: Reduction in number of live micro-organisms – 2.2 90%; 4.4 99%; 8.8 99.99%; 11.0 99.999%.

UV Dosages for 99.9% Inactivation			
(corroborated by a number of different sources – see end of table for references).			
Bacteria	UV Dose	Bacteria	UV Dose
<i>Agrobacterium lumenfaciens</i> 5	8.5	<i>Pseudomonas aeruginosa</i> (Environ.Strain) 1,2,3,4,5,9	10.5
<i>Bacillus anthracis</i> 1,4,5,7,9 (anthrax veg.)	8.7	<i>Pseudomonas aeruginosa</i> (Lab. Strain) 5,7	3.9
<i>Bacillus anthracis</i> Spores (anthrax spores)	46.2	<i>Pseudomonas fluorescens</i> 4,9	6.6
<i>Bacillus megatherium</i> Sp. (veg) 4,5,9	2.5	<i>Rhodospirillum rubrum</i> 5	6.2
<i>Bacillus megatherium</i> Sp. (spores) 4,9	5.2	<i>Salmonella enteritidis</i> 3,4,5,9	7.6
<i>Bacillus paratyphosus</i> 4,9	6.1	<i>Salmonella paratyphi</i> (Enteric Fever) 5,7	6.1
<i>Bacillus subtilis</i> 3,4,5,6,9	11.0	<i>Salmonella</i> Species 4,7,9	15.2
<i>Bacillus subtilis</i> Spores 2,3,4,6,9	22.0	<i>Salmonella typhimurium</i> 4,5,9	15.2
<i>Clostridium tetani</i>	23.1	<i>Salmonella typhi</i> (Typhoid Fever) 7	7.0
<i>Clostridium botulinum</i>	11.2	<i>Salmonella</i>	10.5
<i>Corynebacterium diphtheriae</i> 1,4,5,7,8,9	6.5	<i>Sarcina lutea</i> 1,4,5,6,9	26.4
<i>Dysentery bacilli</i> 3,4,7,9	4.2	<i>Serratia marcescens</i> 1,4,6,9	6.16
<i>Eberthella typhosa</i> 1,4,9	4.1	<i>Shigella dysenteriae</i> - Dysentery 1,5,7,9	4.2
<i>Escherichia coli</i> 1,2,3,4,9	6.6	<i>Shigella flexneri</i> - Dysentery 5,7	3.4
<i>Legionella bozemanii</i> 5	3.5	<i>Shigella paradysenteriae</i> 4,9	3.4
<i>Legionella gormanii</i> 5	4.9	<i>Spirillum rubrum</i> 1,4,6,9	6.16

<i>Legionella micdadei</i> 5	3.1	<i>Staphylococcus albus</i> 1,6,9	5.72
<i>Legionella longbeachae</i> 5	2.9	<i>Staphylococcus aureus</i> 3,4,6,9	6.6
<i>Legionella pneumophila</i> (Legionnaire's Disease)	12.3	<i>Staphylococcus epidermidis</i> 5,7	5.8
<i>Leptospira canicola</i> -Infectious Jaundice 1,9	6.0	<i>Streptococcus faecalis</i> 5,7,8	10.0
<i>Leptospira interrogans</i> 1,5,9	6.0	<i>Streptococcus hemolyticus</i> 1,3,4,5,6,9	5.5
<i>Listeria monocytogenes</i>	12.0	<i>Streptococcus lactis</i> 1,3,4,5,6	8.8
<i>Micrococcus candidus</i> 4,9	12.3	<i>Streptococcus pyogenes</i>	4.2
<i>Micrococcus sphaeroides</i> 1,4,6,9	15.4	<i>Streptococcus salivarius</i>	4.2
<i>Mycobacterium tuberculosis</i> 1,3,4,5,7,8,9	10.0	<i>Streptococcus viridans</i> 3,4,5,9	3.8
<i>Neisseria catarrhalis</i> 1,4,5,9	8.5	<i>Vibrio comma</i> (Cholera) 3,7	6.5
<i>Phytomonas tumefaciens</i> 1,4,9	8.5	<i>Vibrio cholerae</i> 1,5,8,9	6.5
<i>Proteus vulgaris</i> 1,4,5,9	6.6		
Moulds	UV Dose	Moulds	UV Dose
<i>Aspergillus amstelodami</i>	77.0	<i>Oospora lactis</i> 1,3,4,6,9	11.0
<i>Aspergillus flavus</i> 1,4,5,6,9	99.0	<i>Penicillium chrysogenum</i>	56.0
<i>Aspergillus glaucus</i> 4,5,6,9	88.0	<i>Penicillium digitatum</i> 4,5,6,9	88.0
<i>Aspergillus niger</i> (bread mould) 2,3,4,5,6,9	330.0	<i>Penicillium expansum</i> 1,4,5,6,9	22.0
<i>Mucor mucedo</i>	77.0	<i>Penicillium roqueforti</i> 1,2,3,4,5,6	26.4
<i>Mucor racemosus</i> (A and B) 1,3,4,6,9	35.2	<i>Rhizopus nigricans</i> (cheese mould) 3,4,5,6,9	220.0
Protozoa	UV Dose	Protozoa	UV Dose
<i>Cryptosporidium parvum</i>	< 10.0	<i>Giardia lamblia</i>	< 20.0
<i>Chlorella vulgaris</i> (algae) 1,2,3,4,5,9	22.0	Nematode Eggs 6	40.0
Blue-green Algae	420.0	<i>Paramecium</i> 1,2,3,4,5,6,9	200.0
<i>E. histolytica</i>	84.0		
Virus	UV Dose	Virus	UV Dose
Adeno Virus Type III 3	4.5	Influenza 1,2,3,4,5,7,9	6.6
Bacteriophage 1,3,4,5,6,9	6.6	Rotavirus 5	24.0
Coxsackie	6.3	Tobacco Mosaic 2,4,5,6,9	440.0
Infectious Hepatitis 1,5,7,9	8.0	0	0

Yeasts	UV Dose	Yeasts	UV Dose
<i>Baker's Yeast 1,3,4,5,6,7,9</i>	8.8	<i>Saccharomyces cerevisiae 4,6,9</i>	13.2
<i>Brewer's Yeast 1,2,3,4,5,6,9</i>	6.6	<i>Saccharomyces ellipsoideus 4,5,6,9</i>	13.2
<i>Common Yeast Cake 1,4,5,6,9</i>	13.2	<i>Saccharomyces sp. 2,3,4,5,6,9</i>	17.6

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Appendix F - San Luis Obispo Current Water Quality

San Luis Obispo City Annual Water Quality Report, 2007 (online) <http://www.ci.san-luis-obispo.ca.us/utilities/documents.asp>

Sampling Results

During the past year we have taken hundreds of water samples in order to determine the presence of any radioactive, biological, inorganic, volatile organic, or synthetic organic contaminants. The table below shows only those substances that were detected in the water. Numerous other substances were tested for, but were not detected and will not appear in the table below. Some of those substances not detected include, but are not limited to, arsenic, asbestos, cyanide, and methyl tertiary butyl ether (MTBE). Although all of the substances listed here are under the Maximum Contaminant Level (MCL), we feel it is important that you know exactly what was detected and how much of the substance was present in the water. The state requires us to monitor for certain substances less than once per year because the concentrations of these substances do not change frequently. In these cases, the most recent sample data are included, along with the year in which the sample was taken.

REGULATED SUBSTANCES							
SUBSTANCE (UNIT OF MEASURE)	YEAR SAMPLED	MCL (MCLG) (MCLD)	PHG (MCLG) (MCLD)	AMOUNT DETECTED	RANGE LOW-HIGH	VIOLATION	TYPICAL SOURCE
Aluminum (ppm)	2007	1	0.6	0.188	ND-0.500	No	Erosion of natural deposits; residue from some surface water treatment processes
Barium (ppm)	2007	1	2	0.091	0.0675-0.114	No	Discharges of oil drilling wastes and from metal refineries; erosion of natural deposits
Chlorine (ppm)	2007	[4.0 (as Cl ₂)]	[4 (as Cl ₂)]	0.80	0.3-1.4	No	Drinking water disinfectant added for treatment
Chromium (ppb)	2007	50	(100)	7.5	ND-15	No	Discharge from steel and pulp mills and chrome plating; erosion of natural deposits
Control of DBP precursors (TOC)* (% removal)	2007	TT	NA	24%	14%-35%	No	Various natural and man-made sources
Fluoride* (ppm)	2007	2.0	1	0.82	0.2-1.0	No	Erosion of natural deposits; water additive that promotes strong teeth; discharge from fertilizer and aluminum factories
Gross Alpha Particle Activity (pCi/L)	2005	15	(0)	0.58	ND-1.16	No	Erosion of natural deposits
Haloacetic Acids* (ppb)	2007	60	NA	16.4	13.6-22.8	No	By-product of drinking water disinfection
Nickel (ppb)	2007	100	12	2	2-2	No	Erosion of natural deposits; discharge from metal factories
Nitrate (as nitrate) (ppm)	2007	45	45	3.5	ND-10.5	No	Runoff and leaching from fertilizer use; leaching from septic tanks and sewages; erosion of natural deposits
TTHMs (Total Trihalomethanes)* (ppb)	2007	80	NA	46.0	37.7-53.2	No	By-product of drinking water chlorination
Turbidity* (NTU)	2007	TT	NA	0.27	0.04-0.27	No	Soil runoff
Turbidity (Lowest monthly percent of samples meeting limit)	2007	TT	NA	100%	NA	No	Soil runoff
Tap water samples were collected from 30 sample sites throughout the community							
SUBSTANCE (UNIT OF MEASURE)	YEAR SAMPLED	ACTION LEVEL	MCLG	AMOUNT DETECTED (90TH NTILE)	SITES ABOVE ACTION LEVEL	VIOLATION	TYPICAL SOURCE
Copper* (ppm)	2007	1.3	0.17	0.159	0	No	Internal corrosion of household plumbing systems; erosion of natural deposits; leaching from wood preservatives
Lead* (ppb)	2007	15	2	1.9	0	No	Internal corrosion of household water plumbing systems; discharges from industrial manufacturers; erosion of natural deposits

SECONDARY SUBSTANCES							
SUBSTANCE (UNIT OF MEASURE)	YEAR SAMPLED	SMCL	PHG (MCLG)	AMOUNT DETECTED	RANGE LOW-HIGH	VIOLATION	TYPICAL SOURCE
Aluminum (ppb)	2007	200	NS	188	ND-500	No	Erosion of natural deposits; residual from some surface water treatment processes
Chloride (ppm)	2007	500	NS	26	24-28	No	Runoff/leaching from natural deposits; seawater influence
Specific Conductance (µS/cm)	2007	1,600	NS	682	571-792	No	Substances that form ions when in water; seawater influence
Sulfate (ppm)	2007	500	NS	52.5	23-82	No	Runoff/leaching from natural deposits; industrial wastes
Total Dissolved Solids (ppm)	2007	1,000	NS	395	340-450	No	Runoff/leaching from natural deposits

*Total organic carbon (TOC) has no health effects. However, TOC provides a medium for the formation of disinfection by-products such as TTHMs and HAAs. The city's TOC reduction requirement varies from 15% to 25% on a running annual average calculated quarterly, with an actual monthly reduction ranging from 14% to 35%.

*The City currently adds fluoride to the treated water produced by the water treatment plant to achieve an optimum target residual of 0.80 ppm. Some limited areas in the City along Los Osos Valley Road receive a blend of surface water and groundwater that may have a lower fluoride level, from 0.3 to 0.8 ppm.

*Amount reported is the running annual average of quarterly samples.

*Turbidity is a measure of the cloudiness of the water. We monitor it because it is a good indicator of the effectiveness of our filtration system. During the reporting year, 100% of all samples taken to measure turbidity met water quality standards.

*The state allows us to monitor less than once per year because the concentration of this substance has been well below Action Levels and does not change frequently.

Appendix G – U.S. VS Ca. MCL Drinking Water Standards

Available (online) at <http://ww2.cdph.ca.gov/certlic/drinkingwater/Documents/DWdocuments/EPAandCDPH-11-28-2008.pdf>

MAXIMUM CONTAMINANT LEVELS AND REGULATORY DATES FOR DRINKING WATER U.S. EPA VS CALIFORNIA NOVEMBER 2008

Contaminant	U.S. EPA		California	
	MCL (mg/L)	Date ^a	MCL (mg/L)	Effective Date
Inorganics				
Aluminum	0.05 to 0.2 ^b	1/91	1 0.2 ^b	2/25/89 9/8/94
Antimony	0.006	7/92	0.006	9/8/94
Arsenic	0.05 0.010	eff: 6/24/77 eff: 1/23/06	0.05 0.010	77 11/28/08
Asbestos	7 MFL ^c	1/91	7 MFL ^c	9/8/94
Barium	1 2	eff: 6/24/77 1/91	1	77
Beryllium	0.004	7/92	0.004	9/8/94
Cadmium	0.010 0.005	eff: 6/24/77 1/91	0.010 0.005	77 9/8/94
Chromium	0.05 0.1	eff: 6/24/77 1/91	0.05	77
Copper	1.3 ^d	6/91	1 ^b 1.3 ^d	77 12/11/95
Cyanide	0.2	7/92	0.2 0.15	9/8/94 6/12/03
Fluoride	4 2 ^b	4/86 4/86	2	4/98
Lead	0.05 ^e 0.015 ^d	eff: 6/24/77 6/91	0.05 ^e 0.015 ^d	77 12/11/95
Mercury	0.002	eff: 6/24/77	0.002	77
Nickel	Remanded		0.1	9/8/94
Nitrate	(as N) 10	eff: 6/24/77	(as NO3) 45	77
Nitrite (as N)	1	1/91	1	9/8/94
Total Nitrate/Nitrite (as N)	10	1/91	10	9/8/94
Perchlorate	-	-	0.006	10/18/07
Selenium	0.01 0.05	eff: 6/24/77 1/91	0.01 0.05	77 9/8/94
Thallium	0.002	7/92	0.002	9/8/94
Radionuclides				
Uranium	30 ug/L	12/7/00	20 pCi/L 20 pCi/L	1/1/89 6/11/06
Combined Radium - 226+228	5 pCi/L	eff: 6/24/77	5 pCi/L 5 pCi/L	77 6/11/06
Gross Alpha particle activity (excluding radon & uranium)	15 pCi/L	eff: 6/24/77	15 pCi/L 15 pCi/L	77 6/11/06
Gross Beta particle activity	4 millirem/yr	eff: 6/24/77	50 pCi/L ^f 4 millirem/yr	77 6/11/06
Strontium-90	8 pCi/L	eff: 6/24/77 now covered by Gross Beta	8 pCi/L ^f 8 pCi/L ^f	77 6/11/06
Tritium	20,000 pCi/L	eff: 6/24/77 now covered by Gross Beta	20,000 pCi/L ^f 20,000 pCi/L ^f	77 6/11/06

Contaminant	U.S. EPA		California	
	MCL (mg/L)	Date ^a	MCL (mg/L)	Effective Date
VOCS				
Benzene	0.005	6/87	0.001	2/25/89
Carbon Tetrachloride	0.005	6/87	0.0005	4/4/89
1,2-Dichlorobenzene	0.6	1/91	0.6	9/8/94
1,4-Dichlorobenzene	0.075	6/87	0.005	4/4/89
1,1-Dichloroethane	-	-	0.005	6/24/90
1,2-Dichloroethane	0.005	6/87	0.0005	4/4/89
1,1-Dichloroethylene	0.007	6/87	0.006	2/25/89
cis-1,2-Dichloroethylene	0.07	1/91	0.006	9/8/94
trans-1,2-Dichloroethylene	0.1	1/91	0.01	9/8/94
Dichloromethane	0.005	7/92	0.005	9/8/94
1,3-Dichloropropene	-	-	0.0005	2/25/89
1,2-Dichloropropane	0.005	1/91	0.005	6/24/90
Ethylbenzene	0.7	1/91	0.68	2/25/89
			0.7	9/8/94
			0.3	6/12/03
Methyl-tert-butyl ether (MTBE)	-	-	0.005 ^b	1/7/99
			0.013	5/17/00
Monochlorobenzene	0.1	1/91	0.03	2/25/89
			0.07	9/8/94
Styrene	0.1	1/91	0.1	9/8/94
1,1,2,2-Tetrachloroethane	-	-	0.001	2/25/89
Tetrachloroethylene	0.005	1/91	0.005	5/89
Toluene	1	1/91	0.15	9/8/94
1,2,4 Trichlorobenzene	0.07	7/92	0.07	9/8/94
			0.005	6/12/03
1,1,1-Trichloroethane	0.200	6/87	0.200	2/25/89
1,1,2-Trichloroethane	0.005	7/92	0.032	4/4/89
			0.005	9/8/94
Trichloroethylene	0.005	6/87	0.005	2/25/89
Trichlorofluoromethane	-	-	0.15	6/24/90
1,1,2-Trichloro-1,2,2-Trifluoroethane	-	-	1.2	6/24/90
Vinyl chloride	0.002	6/87	0.0005	4/4/89
Xylenes	10	1/91	1.750	2/25/89

Contaminant	U.S. EPA		California	
	MCL (mg/L)	Date ^a	MCL (mg/L)	Effective Date
SOCS				
Alachlor	0.002	1/91	0.002	9/8/94
Atrazine	0.003	1/91	0.003	4/5/89
			0.001	6/12/03
Bentazon	-	-	0.018	4/4/89
Benzo(a) Pyrene	0.0002	7/92	0.0002	9/8/94
Carbofuran	0.04	1/91	0.018	6/24/90
Chlordane	0.002	1/91	0.0001	6/24/90
Dalapon	0.2	7/92	0.2	9/8/94
Dibromochloropropane	0.0002	1/91	0.0001	7/26/89
			0.0002	5/3/91
Di(2-ethylhexyl)adipate	0.4	7/92	0.4	9/8/94
Di(2-ethylhexyl)phthalate	0.006	7/92	0.004	6/24/90
2,4-D	0.1	eff: 6/24/77	0.1	77
	0.07	1/91	0.07	9/8/94
Dinoseb	0.007	7/92	0.007	9/8/94
Diquat	0.02	7/92	0.02	9/8/94
Endothall	0.1	7/92	0.1	9/8/94
Endrin	0.0002	eff: 6/24/77	0.0002	77
	0.002	7/92	0.002	9/8/94
Ethylene Dibromide	0.00005	1/91	0.00002	2/25/89
			0.00005	9/8/94
Glyphosate	0.7	7/92	0.7	6/24/90
Heptachlor	0.0004	1/91	0.00001	6/24/90
Heptachlor Epoxide	0.0002	1/91	0.00001	6/24/90
Hexachlorobenzene	0.001	7/92	0.001	9/8/94
Hexachlorocyclopentadiene	0.05	7/92	0.05	9/8/94
Lindane	0.004	eff: 6/24/77	0.004	77
	0.0002	1/91	0.0002	9/8/94
Methoxychlor	0.1	eff: 6/24/77	0.1	77
	0.04	1/91	0.04	9/8/94
			0.03	6/12/03
Molinate	-	-	0.02	4/4/89
Oxamyl	0.2	7/92	0.2	9/8/94
			0.05	6/12/03
Pentachlorophenol	0.001	1/91	0.001	9/8/94
Picloram	0.5	7/92	0.5	9/8/94
Polychlorinated Biphenyls	0.0005	1/91	0.0005	9/8/94
Simazine	0.004	7/92	0.010	4/4/89
			0.004	9/8/94
Thiobencarb	-	-	0.07	4/4/89
			0.001 ^b	4/4/89
Toxaphene	0.005	eff: 6/24/77	0.005	77
	0.003	1/91	0.003	9/8/94
2,3,7,8-TCDD (Dioxin)	3x10 ⁻⁸	7/92	3x10 ⁻⁸	9/8/94
2,4,5-TP (Silvex)	0.01	eff: 6/24/77	0.01	77
	0.05	1/91	0.05	9/8/94

Contaminant	U.S. EPA		California	
	MCL (mg/L)	Date ^a	MCL (mg/L)	Effective Date
Disinfection Byproducts				
Total Trihalomethanes	0.100	11/29/79 eff: 11/29/83	0.100	3/14/83
	0.080	eff: 1/1/02 ^g	0.080	6/17/06
Haloacetic acids (five)	0.060	eff: 1/1/02 ^g	0.060	6/17/06
Bromate	0.010	eff: 1/1/02 ^g	0.010	6/17/06
Chlorite	1.0	eff: 1/1/02 ^g	1.0	6/17/06
Treatment Technique				
Acrylamide	TT ^h	1/91	TT ^h	9/8/94
Epichlorohydrin	TT ^h	1/91	TT ^h	9/8/94
<p>a. "eff." indicates the date the MCL took effect; any other date provided indicates when USEPA established (i.e., published) the MCL.</p> <p>b. Secondary MCL.</p> <p>c. MFL = million fibers per liter, with fiber length > 10 microns.</p> <p>d. Regulatory Action Level; if system exceeds, it must take certain actions such as additional monitoring, corrosion control studies and treatment, and for lead, a public education program; replaces MCL.</p> <p>e. The MCL for lead was rescinded with the adoption of the regulatory action level described in footnote d.</p> <p>f. Gross beta MCL is 4 millirem/year annual dose equivalent to the total body or any internal organ; Sr-90 MCL = 4 millirem/year to bone marrow; tritium MCL = 4 millirem/year to total body</p> <p>g. Effective for surface water systems serving more than 10,000 people; effective for all others 1/1/04.</p> <p>h. TT = treatment technique, because an MCL is not feasible.</p>				

Glossary

Acre-foot (AF) is a unit for measuring the volume of water. One acre-foot equals 325,851 gallons (the volume of water that will cover one acre to a depth of one foot). One million gallons equals 3.07 acre-feet.

1 Part Per Million (PPM) is 1 mg/L (milligram per liter)

1 Part Per Billion (PPB) is 1 ug/L (microgram per liter)

ug/L ÷ 1000 is mg/L

Watts is Amps (I) x Volts (P)

Watts/1000 is Kilowatts or kW

Kilowatts x Hours is Kilowatt Hours or kWh

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