Memorandum

To: Water Supply Advisory Committee members

From: Robert Raucher, Stratus Consulting Inc.

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Subject: Update on graywater alternatives and their potential application in Santa Cruz

There has been considerable interest in the potential application of graywater systems in many locations, including Santa Cruz. This memorandum provides a brief overview of some of the key options for applying graywater systems in the Santa Cruz Water Department (SCWD) service area, and their associated potential water supply and cost implications.

1. What Are Residential Graywater Systems?

Graywater typically refers to wastewater collected from the drains of bathroom sinks, tubs and showers, and laundry facilities of homes. Wastewater from kitchen sinks and dishwashers is typically precluded from graywater recycling by state policies and regulations, because of concerns over pathogens. Graywater also does not include water flushed from toilets (referred to as “blackwater”), because of concerns over pathogens present in untreated human waste.

Graywater systems collect and apply graywater for beneficial uses. The simplest and least-expensive systems apply untreated graywater to outdoor irrigation (i.e., subsurface applications). These include residential “laundry-to-landscape” (L2L) systems that are available at a modest cost. These are promoted and subsidized by some water departments (including SCWD), and are relatively easy to retrofit into existing homes.

Residential graywater systems may also include some form of suitable treatment that enables indoor use for toilet flushing in addition to outdoor irrigation use. This type of system is reflected in the Consolidated Alternative (CA) for Home Water Recycling (CA-05). These graywater systems are more complex and expensive than L2L-type systems, due to the addition of treatment units, storage tanks, and the additional plumbing (and perhaps pumping) required to capture graywater from numerous sources within the home and to deliver the treated graywater for toilet flushing. These requirements (especially the additional plumbing) make these graywater systems more suitable for new homes under construction than for existing residences (where the necessary plumbing retrofits typically are complex, disruptive, and expensive).

Graywater systems may also be designed and applied for larger entities, such as multifamily residential units, and commercial and industrial settings. The regulatory feasibility, costs, complexity, and potable water supply savings for commercial or other larger-scale applications are very application-specific. We do not currently have reliable empirical information on these larger-scale graywater applications.

2. What Do Residential Graywater Systems Cost?

Graywater system costs vary widely depending on their size and complexity. Even within the range of household-sized units, the simplest systems that reuse water from washers for irrigation purposes can be installed by homeowners for as little as a few hundred dollars, whereas more complex sand filter or other treatment systems can be installed professionally for over $15,000 (SFPUC, 2012).

Information on installing do-it-yourself systems is widely available online, and some water utilities provide subsidies for material costs. The San Francisco Public Utilities Commission (SFPUC) has offered a $112 subsidy toward a basic $117 graywater kit that can be installed by a homeowner without plumbing skills and without a permit (Kehoe, 2014). Costs increase if a pump or filtration system is also needed.

Some systems that are more complex than L2L kits can still be installed by homeowners with basic plumbing and electrical skills, which may reduce out-of-pocket installation costs significantly. Household graywater system prices increase with complexity in both additional labor and capital, as well as operation and maintenance (O&M) costs associated with periodically replacing hardware, especially if they are professionally installed and/or must be professionally maintained.

Overall, data suggest homeowner do-it-yourself systems can cost from under $200 (for a very basic L2L system such as offered in San Francisco) up to $1,500, with the higher end of the range typically including a pump. Adding a sand filter or other treatment system appears to increase per-household costs into the $5,000 to $15,000 range, depending in part on whether a professional is hired to install the system (SFPUC, 2012).

3. Graywater Systems for Existing Single-Family Residences (L2L)

As noted above, L2L and similar systems are applicable for existing homes (whereas more complex systems are more feasible for homes under construction or undergoing major renovations). This is due to the cost, extent of living space disruption, and impracticality (or infeasibility) of retrofitting more elaborate graywater systems into an existing, occupied dwelling.

Typical L2L configurations and costs

The most basic L2L system consists of piping from the discharge point on the clothes washer that drains into an outdoor, covered irrigation system (e.g., a drip system), and includes a valve that enables the user to select whether the effluent from a given wash load or cycle will go to the irrigation system or into the wastewater (i.e., sewer) line. Such a simple system may cost between $120 and $1,300, depending in large part on whether the homeowner installs the system themselves. These costs are based on information provided by SFPUC and the City of Long Beach, which have run pilot L2L programs in their respective service areas. The costs would be higher for a system that includes water treatment, pumping, and/or that adds in the irrigation system itself.

SCWD currently sponsors a L2L program, offering a rebate of $150 for what is estimated by Maddaus Water Management to be a total $450 system cost (i.e., customers would need to cover about $300 of the expense on their own). This program is also included in the revised "Program C recommended" CA-03. Because this graywater program is already in place, as well as being embedded in a CA program, it is not added to our list as a potential, standalone CA.

Potential water savings

Water savings from an L2L application may be estimated based on the amount of water discharged by a typical household's laundry machine, assuming all the washer effluent is used to replace potable water that otherwise would have been used for irrigation. Water savings thus depend on whether the graywater fully replaces potable water use for irrigation, or instead supplements some potable water irrigation. An additional factor is how many customers might opt to install and use such a system (participation in the SCWD program appears to be very low, with reportedly only two households enlisting in the rebate program in 2014).

The level of washer discharge varies by the type of machine (e.g., high-efficiency machines versus older models), the number of loads run per household per week, whether bleach is used in a load (in which case it may be recommended that the effluent is sent to the sewer rather than to the landscape), and whether the discharge from both the wash and rinse cycles (or only the rinse cycle) are used for irrigation. Current estimates for laundry-produced graywater range from 15 to 30 gallons per load for high-efficiency washers, depending in part on whether effluent from both wash cycles are captured. Assuming year-round use, annual graywater production from washers is estimated to be in the neighborhood of 2,000 to 7,000 gallons per household (Bill Maddaus, personal communication; LADWP, 2010). As washers become increasingly water efficient, and as households respond to drought conditions by running fewer loads, the amount of available graywater will likely decline.

The level of potential potable water supply savings associated with home graywater systems depends on whether all the graywater produced is applied to irrigation. In settings such as Santa

Cruz, where precipitation patterns are highly seasonal and irrigation demands tend to be focused within a six-month period, the amount of available graywater actually used for productive irrigation may be half of the annual total of potential graywater production.

It also is worth noting that where actual water-use data have been systematically collected in L2L pilot programs, in San Francisco and Long Beach, the data reveal that the majority of participating households have actually *increased* their use of potable water after installation of an L2L system (by 700 gallons per month) (Gallup, 2014; Kehoe, 2014). These data come from a small sample over limited time periods, so additional empirical information is needed. Nonetheless, what data exist indicate that potable water use does not necessarily decline with the application of L2L graywater systems in single-family residences.

4. Graywater Systems for New Residential Construction (CA-05: Home Water Recycling)

A more elaborate residential graywater recycling system applicable to new home construction is included as CA-05 (Home Water Recycling). This option has been evaluated and presented in the CA materials circulated to the Water Supply Advisory Committee (WSAC), and that information is summarized here. The graywater system is based on an NSF-certified treatment package developed, patented, and marketed by NexusEWater, and now in pilot applications in three new homes in Southern California.

This CA entails a residential graywater system that captures and stores effluent from all the graywater sources in the home, treats that graywater with a certified filtration and ultraviolet (UV) disinfection system, stores the treated graywater in a tank until needed, and pipes the treated graywater for indoor toilet flushing and outdoor irrigation uses. It is unclear whether pumps and pumping are included in the design and cost estimates, but this would likely be needed in most applications.

The system upfront costs total $5,700 per home, including $4,500 for the equipment and an estimated $1,200 in additional plumbing costs for new construction sites. Professional installation is required, and annual maintenance costs for materials amount to about $200 per year. Professional (i.e., third-party) maintenance is likely (at an unknown cost), although handy and diligent homeowners can probably perform the necessary filter cartridge replacement and other tasks. The installation costs reported above include pre-paid service visits in the first two years. The equipment has a 12-year projected lifespan, after which about $2,000 of equipment replacement is anticipated. Thus, the estimated present value total costs to a new homeowner is $10,600 for a system installed today that is maintained and operated for 23 years.

The system has the capacity to collect and treat up to 200 gallons per day, or 73,000 gallons per year. However, estimated water use for toilet flushing and outdoor irrigation in new homes in Santa Cruz is estimated to be about 18,470 gallons per year. This latter figure reflects the potential potable water savings that may be anticipated for each new home constructed in the SCWD service area (assuming this system was installed in each new single-family home). Given the number of new homes anticipated in the service area by 2030 is 840, the combined water savings that may be realized by year 2030 is estimated to be 15.5 million gallons per year.

5. Rainwater Harvesting Systems

Some WSAC members have expressed interest in the potential viability of rain barrels, cisterns, and other such rainwater harvesting systems (RHS) as a water-saving approach for Santa Cruz. This section provides a brief discussion of the RHS options and also describes why RHS approaches are not likely to be very useful in settings with distinct seasonal precipitation patterns, such as Santa Cruz

5.1. Typical RHS Configurations and Costs

Household RHS typically consist of rain barrel or cistern collection systems. The cost of a residential-scale rain barrel is estimated in the $60 to $100 range. Some of this cost may be provided through utility subsidies. Rain barrels vary in size and material, with a typical barrel holding up to 35 gallons of roof runoff (Pitt et al., 2011, 2013). The water is typically collected from rooftop areas and conveyed to the barrel(s) via gutters and downspouts. Operating costs tend to be negligible when households divert the stored water to outdoor landscape irrigation (assuming no pumping or treatment is applied). The barrel lifetimes are assumed to be 20 years.

For larger cistern-based household systems, data available for two homeowner-constructed rainwater harvest systems from Pitt et al. (2011) indicate an upfront cost of about $1,400 to $1,500. One system is located in Montana and entails a 2,500-gallon storage tank that draws water collected from a 925 square-foot roof, including a first-flush diverter and a pump. The storage tank cost $800 and the gutters about $350, making up the majority of the $1,400 initial cost. The second system, located in Portland, Oregon, includes a 1,500-gallon tank with filters ($800), UV disinfection ($350), a backflow prevention device ($120), and other components, for a total cost of $1,500.

A number of commercial enterprises provide RHS for residential buildings. There are no published costs available but these systems generally cost up to about 10 times the costs of above home-owner built systems (Robert Pitt, University of Alabama, personal communication). The advantages of the commercial systems are the vendor’s relationships with local regulators and knowledge of the regulations, professional design and installation, and greater confidence concerning safety issues. Since local and regional regulations pertaining to rainwater harvesting and its use vary greatly throughout the country, the extra service provided by the commercial suppliers of these systems may be beneficial.

Rooftop stormwater harvesting may also be applied in larger contexts, such as commercial buildings or building complexes. For example, the Frankfurt/Main Airport in Germany installed six 26,000 gallon (100 m^3) cisterns to capture rooftop runoff for toilet flushing and outdoor irrigation. The system cost $109,000 (updated from 1993 to 2014 USD) and saves 26 million gallons per year, for an effective cost of $4.19 per thousand gallons (Pitt et al., 2011). O&M costs are not available.

5.2. Single-Family Home Rain Barrel Systems

Potable water savings for a basic rain barrel system – consisting of two 35-gallon barrels storing rainwater collected off the roof – are estimated in the range of 1,250 to 4,250 gallons per year for a household with a quarter-acre lot and a home with 1,500 square feet of roof surface area (based on Pitt et al., 2011, reflecting a range of precipitation patterns across the United States). This assumes the harvested rainwater is fully used to displace potable water for yard irrigation at levels that meet typical plant needs, as driven by local evapotranspiration (ET) deficit rates. The range in per-household potable water savings reflects different geographical regions of the United States and their respective rainfall, ET, and other relevant variables. Implicit in these savings estimates are the routine filling of the rain barrel from periodic rain events, the emptying of these tanks for irrigation during dry periods between precipitation events, and an assumption that the harvested water fully displaces potable supply (e.g., that potable water irrigation decreases fully by the amount that the rain barrels provide).

Based on a 2-barrel system costing an average of $160, water supply savings imply a 4- to 19-year payback period (applying a 5.0% discount rate and a $10 per 1,000 gallon marginal water price, including wastewater charges as well). The wide range in estimated payback periods is driven by local precipitation patterns and the opportunities they provide (or lack) for having rainwater available to meet ET needs. The short payback period corresponds to Midwestern areas (e.g., Lincoln, NE) where precipitation timing and irrigation needs are better aligned for rain barrel use. The longer payback period reflects a relatively arid southwestern U.S. community (e.g., Los Angeles), and other regions with distinct wet and dry seasons in which irrigation needs do not coordinate well with time periods when rainfall is available (Pitt et al., 2011, 2013).

Rain barrels and other RHS have very limited water supply savings benefits when precipitation has very distinct seasonal wet and dry periods. In such settings, irrigation demands coincide with seasonal dry periods when rainwater is rarely available to fill barrels. Conversely, when rain is available in wet months, there is no productive use for barrel-supplied irrigation water. This situation applies to locations such as Santa Cruz.

It is possible that other benefits may be important for some households and communities, regardless of anticipated water savings and financial paybacks. Potential societal and environmental benefits may include aspirational "green" values for participants, and/or other benefits such as creating a more direct hands-on appreciation of the water cycle and the amount of water applied to outdoor landscapes. The popularity of rain barrel programs, despite the relatively long fiscal pay-off periods in some regions, may be indicative that cost-effectiveness is not the prime motivation for households choosing to adopt these measures.

5.3. Residential RHS Using Cisterns

Rainfall collected from residential rooftops may be diverted and stored in various-sized tanks that may be considerably larger than rain barrels. These cisterns may be placed on rooftops, on the ground adjacent to the home, or may sometimes be buried underground. Water collected in these systems may be applied to a wide range of potential uses, including exterior irrigation as well as a range of possible indoor uses. Indoor water uses typically would require some form of water treatment (e.g., filtration and/or disinfection), depending on the intended use (e.g., toilet flushing).

Costs

The cost of RHS using storage tanks depends on several factors, including size and placement, the need for new collection equipment, as well as the extent to which treatment, pumping, and/or plumbing is required. For this illustration, costs are based on storage tanks with a capacity of about 1,500 to 2,500 gallons, placed aboveground adjacent to the home (a water tank of about 2,200-gallon capacity requires about 50 square feet of surface area, and about 6 feet of height). Costs for such tanks may run about $800, and associated diversion and/or simple treatment systems may increase costs to $1,500 or more, for do-it-yourself homeowner installation and operation. More elaborate, contractor-supplied and installed units may cost up to $15,000 (based on Pitt et al., 2011). Burying these tanks would add additional expense (perhaps considerably).

Potential water-savings benefits

As noted above for rain barrel systems, potable water savings for a water tank with a 2,200-gallon capacity depend on the region and associated seasonal precipitation levels and patterns, as well as the intended water uses (irrigation alone, toilet flushing alone, or a combination of both if stored water volumes suffice).

For outdoor landscape irrigation, water savings across the United States are estimated to range between 5,250 and 20,250 gallons per household per year, depending on region (Pitt et al., 2011, 2013), assuming a quarter-acre lot and a 1,500 square-foot roof area feeding the tank (and assuming fairly high levels of outdoor irrigation). As with rain barrels, the potential for water savings is highly region-dependent, with the low-end savings estimate based on precipitation and ET values for the southwest United States, including California (and the high-end savings reflecting the mid-western United States). If toilet flushing is included as well as outdoor irrigation, Pitt et al.'s (2011) estimated potential per-household water savings increase to 7,000 to 27,500 gallons per year (with the range being regionally driven according to precipitation patterns).

In regions such as Santa Cruz, with seasonally driven precipitation patterns that do not coordinate well with irrigation needs, the payback period is over 50 years for either an irrigation-only, cistern-based system or a system that supplies both irrigation and toilet flushing. However, it is possible that other benefits may be very important for some households and communities, thereby incentivizing broader use of such rainwater capture systems.

References

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