Increasing Water Supply for Residential Growth through Greywater Use

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Our population is growing. To support that growth, a viable fresh water supply and supporting water and wastewater treatment infrastructure is needed. Infrastructure for water supply and treatment is difficult, expensive, and time-consuming to develop. Greywater offers an opportunity to stretch our water supply. Current water saving strategies are reaching a point of diminishing returns. To supply the growing demand, a two-pronged approach of retrofitting existing structures and incorporating greywater systems into new structures is needed. This could delay the need to invest in new infrastructure or at least allow an existing system to function until the new water supply infrastructure is developed. Regional and national examples are provided.

Key Words: Water infrastructure, residential growth, greywater systems, greywater toilets

Introduction

The continued development of residential housing is dependent on adequate infrastructure and resources. Typical onsite infrastructure includes: water, sewer, electric, gas, and phone. Offsite infrastructure includes streets, curb & gutter, sidewalks, and main onsite infrastructure systems for onsite lot hookup. In addition to infrastructure requirements are the many amenities associated with neighborhoods: schools, shopping, churches, parks, trail systems, and public protection for police and fire. While each of these services is important to the developer and eventual homeowner, the provision of a sustainable water supply may be the most problematic. Individual water supply systems depend on adequate long term supplies from a natural water source. Typical sources are rain, snow, and underground aquifers. In addition to natural sources for water, an adequate storage facility must also be in place providing enough capacity for all water users (residential, commercial, manufacturing, and industrial) while still providing a minimum stream flow to support the natural environment.

The need for new residential housing stock is a function of population growth and with the world population pushing 7 billion inhabitants the demand on the earth's fresh water resources, rivers, lakes, and underground aquifers, will increase past the estimated 54% of current usage (2003 International Year of Freshwater, nd). The impact of residential water use in the U.S. is estimated to be 8% of the total potable water use (Solley, Pierce, and Perlman 1995). While 8% appears low this equates to about 98,800 Million L/day (Solley, et al. 1995). The breakdown for the "average" family water use by fixture type is approximately: bathroom, showers and hand basins 26%, laundry 15%, gardens 34%, kitchen 5%, and toilets 20% (Christova-Boal, Eden, and McFarlane 1996). Based on the usage estimates and the continual demand for new residential construction, the provision of sustainable water systems must be adequately addressed to ensure development can occur in the residential sector.

The demands of creating this type of water system include a long term planning component which could take over a decade from concept to final design and construction. This long lead time is a function of federal requirements for environmental impact assessment (EIA), environmental impact statement (EIS), the consideration of state water laws, and solving potential conflicts among potential user groups. Other factors include constructing or expanding a water treatment plant, right of way issues, transmission lines and pumping facilities. Even if the water system is eventually built and put on line, an additional need is created for wastewater treatment and the associated infrastructure of sewer lines, treatment plants, and discharge permits. In addition, when surface storage is required, an adequate site must be found for a new reservoir or other holding facility. During this planning process the impact of increased construction costs may be considerable to the point where the project may lose long term viability.

The impact on development of this long term process to supply water can be devastating. Rural towns, cities, and major metropolitan areas each face their own obstacles to achieving a reliable long term water supply. Once the water supply is attained, there are few methods available to the water utility to control the demand for water from the end user. These methods may include base pricing and tiered use rates, mandatory reductions for outside water usage, and fines for excessive water use or violation of ration limitations. In rare cases, the water supply may be cut off but this type of remedy may only be temporary due to public health concerns.

Background

Current trends in water use include the acquisition of water rights outside the natural drainage areas in which the use takes place and downstream reuse of treated wastewater. Southern California is a perfect example of a situation where demand far outpaces the supply so massive water projects are build to transfer water from the northern regions of the state to serve the needs of the southern cities. There is an ever looming question about renegotiating the Colorado River compact from 1922 due to over allocation of the river water among the party states. In fact, John McCain during the 2007 presidential campaign mentioned that he came to Colorado to "take your water" while referring to the need to reopen negotiations on the compact to address the water usage of the seven member states (Robertson, 2008). The same in happening in the lower Midwest but the grab for water involves crossing state lines. The Dallas Ft Worth metro-plex is trying to bring water in from the Lake Texoma region in neighboring Oklahoma.

The recent drought in Georgia sparked talk of turning a ten thousand acre tract of land into a series of deep water lakes to serve as the raw water supply to Atlanta; without such action the growth of Atlanta may be limited. While Atlanta struggles to ensure its water supply downstream, states are concerned as well for their water supplies due to increasing demands on existing water supplies from cities like Atlanta. The state of Alabama recently sued the Army Corps of Engineers to protect its water rights from the Chattahoochee and Etowah Rivers, both downstream from Atlanta (Arcadis, n.d.).

The Midwest states of Colorado, Nebraska, and Kansas have been fighting about water in the Republican River basin for decades. In 1998 Kansas filed suit in the U.S. Supreme Court against Nebraska for violation of terms of the Republican River compact. Similar suits from both Kansas and Nebraska have been filed against Colorado, the headwater state for the Republican River (Kansas Department of Ag, 2009).

Water Usage Reduction Strategies

Water reduction strategies can be voluntary, mandated, or economic in nature. These strategies can be used individually or in concert with one another to meet the water management strategies of the water provider. Some of the more common ways to control residential water usage is through plumbing codes, public policy, and consumer awareness. The goal of water managers is to ensure wise water use in the built environment by matching water supplies with demand. The goal of water planners should also include the identification of potential methods that may be employed to decrease the future demand for new water supplies needed by development in an effort to make the long term planning process for new water sources less impactful on the residential construction industry.

A review of several model building codes reveals several prescriptive code items that are requirements in plumbing a residential structure. Some of the most common requirements are the use of low flow toilets and shower heads and faucets with flow restrictors. There can be local building code requirements that affect outdoor water usage by requiring that the builder leave a certain type, quantity, and quality of soil on the lot for final grading. Typically developers and builders sell the topsoil off a property and use the spoils of excavation to backfill and grade the property. The resulting poor soil does not have the nourishment to sustain grass, trees, and shrubs without high volumes of water, almost hydroponic growth. In addition, common best practices for outdoor landscape include mulching beds, aeration of soils to break down compaction and increase water infiltration, and grouping similar plant types together to reduce excessive watering (Sandy Springs, 2009).

Other water use limitations can come from public policy where the day and duration of watering is limited due to a short term drought. Staggered watering days based on addresses are quite common in the high desert states. Other requirements may be the replacement of landscaping to a xeric type of plant that has low water demands. This type of policy was the norm in Las Vegas in recent years as the water level in Lake Mead dropped to record low levels as growth was sprawling across the desert. The Scripps Institution of Oceanography in 2008 predicted that Lake Mead, the main water supply for Las Vegas, had a 50% chance of being dry as early as 2021 (Hooton, 2008). The City of Sandy Springs, GA is offering a water conservation permit incentive program. Under this program residential building permit customers can apply for bronze, silver, gold, or platinum level conservation turtles which have an associated permit rebate ranging from 30% to 100%, based on meeting specific water saving criteria for each level (Sandy Springs, 2009).

The City and County of San Francisco adopted residential water conservation ordinance amendments in an effort to make sure that water wise conservation measures will be implemented that will reduce demands on the water resources available to the city in an effort to help the economy and residents prosper. Some of the techniques mentioned in the amendments include: proof of compliance with minimum water conservation measures, compliance with major renovation or improvement, transfer of title conservation inspection, and the replacement of all high volume flow fixtures with low flow fixtures (San Francisco Public Utilities Commission, 2009). Atlanta posted 9 water-saving tips on its website Atlantawatershortage.com. These public awareness tips include: take short showers, collect shower water to use on outdoor plants, turn off the water while you brush your teeth, don’t use the toilet as a trash receptacle, upgrade water fixtures to low flow, hand wash your dishes, upgrade water using appliances, and use the disposal sparingly (City of Atlanta, n.d.).

In some cases, the water provider may put a moratorium on new water taps and increase rates on current users in addition to calls to cut back usage. One of the common trends of calls to reduce water use is an increase in the monthly water bill to make up the revenue shortfall caused by lower usage. This unintended consequence of conservation makes it hard for the water utility to pay the debt service on the infrastructure. This situation also raises the question of how do you add users to a water system already constrained by water supply problems? In most cases, the water supplies fluctuate with seasonal precipitation so the shortfall may be quickly forgotten once precipitation falls paving the way for residential development as usual. While the water battles, building codes, and public policy options exemplify the severity of the scarceness of water, there are several non-traditional or less accepted methods of reducing water usage in residential settings which may yield water savings thru demand reductions. One such method that is gaining acceptance is the use of greywater to satisfy some indoor and outdoor demands.

Greywater

Greywater has been defined as the waste water that comes from all indoor fixtures except toilets. Although non-toilet fixtures do not produce water with “human contaminates”, this water still contains a high level of many microorganisms which include: fecal coliforms, total coliforms, lipids, tea, coffee, soluble starch, dairy products, and clay and glucose from kitchen sinks. In addition, water from bathrooms and laundry add several detergents, bleaches, soaps, sand, perfumes, and shampoos (Eriksson, Auffarth, Henze and Ledin 2002). The storage of this water also presents challenges to the potential user in the form of odors that emit from the growth of the previously listed microorganisms. For these reasons the most often cited concerns for using greywater as a replacement for fresh water are storage and distribution. However, through proper storage and onsite treatment of greywater, these concerns can be mitigated or eliminated (Jeppesen, 1996). Once these concerns are addressed, the potential water reduction impacts from greywater use in residential settings could prove very beneficial in addressing water consumption issues. As recent as 2006, Frieder and Hadari estimate that these savings could reduce individual in-house use by 40-60 L/d per capita (2006).

In the commercial sector, the use of greywater in large scale buildings is not without precedent. The UK’s Millennium Dome reclaims greywater from hand wash-basins, rainwater from the dome’s roof and groundwater; supplying up to 500 m^3 per day to flush toilets and urinals on the site (Smith, Khow, Hills and Donn 2000). The Solaire, a high rise residential building in New York City, treats its wastewater to produce 94,635 Liters (L) of treated water per day: 34,069 L for toilet flushing, 43,532 L for the building’s cooling towers and 22,712 L for landscape irrigation (Wilson 2008). Approximately 1/5 of residential water use is for toilet flushing and 1/3 is for landscape irrigation (Christova-Boal et al. 1996, Oasis Design 2008). Also, 50% - 80% of residential wastewater is greywater (Oasis Design 2008). To effectively increase water supply, greywater can be used for toilet flushing in residential settings. To have a significant effect on a system, new residential units must incorporate greywater toilet systems and existing residential toilets must be retrofitted. A regional example that supports this finding follows.

Case Study: Glade Reservoir

The creation of a new reservoir to support growth in Northern Colorado is currently under study. If built, Glade Reservoir would hold 40,000 acre-feet of water and support the fresh water needs of Fort Collins, Loveland, and the surrounding communities. The process of planning and building this reservoir is estimated to take 10 – 15 years. After the site was chosen, the Army Corps of Engineers performed an environmental impact assessment (EIA) and determined there was a need for an environmental impact statement (EIS). Both processes have a public comment period and comments are considered and addressed in the final report. During this period of time, groups that oppose and support the project are posturing themselves in the political arena in an effort to achieve their respective goals. Some of the major issues raised in this project were: maintaining minimum stream flows, rerouting a major highway, the need for the project, and if there was actually enough unclaimed water to fill the reservoir.

A case study was performed to determine the impact of greywater for toilet flushing on the freshwater needs for the Fort Collins and Loveland communities; two of the proposed owners of the new reservoir. The 2010 and 2025 population estimates for these two communities are shown in Table 1. Households are calculated based on the estimate of 2.52 people per household in Larimer County, Colorado (US Census Bureau, n.d.).

Table 1

Estimated population for Fort Collins, Colorado and Loveland, Colorado in 2010 and 2025 (US Census Bureau, n.d.)

	Population	**Households**
2010 Population	210,678	83,602
2025 Population	287,696	114,165
Increase 2010 - 2025	77,018	30,563

The average household consumption of freshwater in these communities is shown in Table 2. Daily per capita freshwater consumption in Colorado is based on consumption in 2005 (USGS, 2009). The number of gallons per year per household is calculated by multiplying per capita consumption by number of people in the household by the number of days in a year. Number of gallons per acre-feet is a conversion factor. Average household consumption in acre-feet per year is calculated by dividing the consumption in gallons per year by the conversion factor.

Table 2

Average household freshwater consumption for Fort Collins, Colorado and Loveland, Colorado

	Data
Consumption per capita in gallons per day	121
People per household	2.52
Days per year	365
Consumption per household in gallons per year	111,296
Conversion factor – gallons per acre-feet	325,851.43
Average household consumption in acre-feet per year	0.34

Now that the average freshwater consumption per household in these communities is estimated along with the projected number of people (and therefore households) entering the area, an analysis of the impact of greywater use for flushing was performed. Table 3 shows the amount of freshwater that can be saved for each person that uses toilets that use greywater for flushing. Average flushes per day per person are 4 to 5 so a conservative value of 4 was used. A low flow toilet uses 1.6 gallons per flush while a traditional toilet can use as much as 5 gallons per flush. Again, to remain conservative, 1.6 gallons was used for the estimated savings.

Table 3

Freshwater savings per capita for flushing with greywater

	Data
Number of flushes per capita per day	4
Gallons per flush	1.6
Greywater flushes in acre-feet/year/person	0.00717

If all new homes built in the region included toilets with greywater systems, a significant amount of freshwater savings would result. The impacts of that option are shown in Table 4. The total freshwater savings due to new homes using greywater toilets is calculated by multiplying the greywater flushes per person by the increase in population from 2010 to 2025. 552 acre-feet per year is the equivalent annual consumption of 1,617 households in the area, which is 5.3% of the projected increase in demand for freshwater due to new households.

Table 4

Freshwater savings if all new homes built in Fort Collins, Colorado and Loveland, Colorado use greywater toilets

	Data
Total freshwater savings in acre-feet/year	552
Number of homes in equivalent annual consumption	1,617
Percent of new homes covered	5.3%

Only incorporating greywater toilets in new residential construction has a minor impact on the population growth for the area. If existing homes are retrofitted with greywater toilets in addition to using greywater toilets in new construction, the resulting impacts are more significant. Table 5 highlights those impacts. Nearly one-fifth of the new growth could be accommodated by switching to greywater toilet systems. That reduces the freshwater demand in the area thereby reducing the amount of new capacity needed for freshwater and wastewater infrastructure.

Table 5

Freshwater savings if all new and existing homes in Fort Collins, Colorado and Loveland, Colorado use greywater toilets

	Data
Total freshwater savings in acre-feet/year	2,062
Number of homes in equivalent annual consumption	6,038
Percent of new homes covered	19.8%

US Perspective

The Glade Reservoir regional case study implies that current freshwater demand can be reduced, or future freshwater demand can be compensated for, with the use of greywater toilet systems. If greywater toilet use is expanded to the national level, the results are even more impressive. The 2010 and 2025 population estimates for the United States are shown in Table 6. The number of households is calculated based on the estimate of 2.59 people per household (US Census Bureau, n.d.).

Table 6

Estimated population for the US in 2010 and 2025 (US Census Bureau, n.d.)

	Population	Households
2010 Population	310,233,000	119,781,081
2025 Population	357,452,000	138,012,355
Increase 2010 - 2025	47,219,000	18,231,274

The average household consumption of freshwater in the US is shown in Table 7. Daily per capita freshwater consumption in the US is based on average consumption in 2005 (USGS, 2009). Note that it is significantly less than the per capita consumption in Colorado. The number of gallons per year per household is calculated by multiplying per capita consumption by number of people in the household by the number of days in a year. Number of gallons per acre-feet is a conversion factor. Average household consumption in acre-feet per year is calculated by dividing the consumption in gallons per year by the conversion factor.

Table 7

Average household freshwater consumption for the US

	Data
Consumption per capita in gallons per day	98
People per household	2.59
Days per year	365
Consumption per household in gallons per year	92,644
Conversion factor – gallons per acre-feet	325,851.429
Average household consumption in acre-feet per year	0.284

The freshwater savings per capita due to greywater flushing is 0.00717 as shown in Table 3. If all new homes built in the US included toilets with greywater systems, a significant amount of freshwater savings would result. The impacts of that option are shown in Table 8. The total freshwater savings due to new homes using greywater toilets is calculated by multiplying the greywater flushes per person by the increase in population from 2010 to 2025. 338,509 acre-feet per year is the equivalent annual consumption of 1,190,614 households in the US, which is 6.5% of the projected increase in demand for freshwater due to new households.

Table 8

Freshwater savings if all new homes built in the US use greywater toilets

	Data
Total freshwater savings in acre-feet/year	338,509
Number of homes in equivalent annual consumption	1,190,614
Percent of new homes covered	6.5%

Only incorporating greywater toilets in new residential construction has a minor impact on the population growth for the US. This was very similar to that seen in the Glade Reservoir case study. If existing homes in the US are retrofitted with greywater toilets in addition to using greywater toilets in new construction, the resulting impacts are more significant. Table 9 highlights those impacts. Nearly half of the new growth could be accommodated by switching to greywater toilet systems. That reduces the freshwater demand in the US thereby reducing the amount of new capacity needed for freshwater and wastewater infrastructure.

Table 9

Freshwater savings if all new and existing homes in the US use greywater toilets

	Data
Total freshwater savings in acre-feet/year	2,562,542
Number of homes in equivalent annual consumption	9,013,052
Percent of new homes covered	49.4%

Conclusion

One of the challenges facing future residential development is the ability to provide new and sustainable water supplies in a cost effective manner. Without cost effective water, the first costs of new neighborhood development may outpace the housing markets' ability to absorb the costs associated with individual lot development unless density factors are increased. As the US population increases, the demand for new freshwater sources and supporting infrastructure also increases. These case studies provide a potential opportunity for accommodating growth by reducing demand for freshwater through the use of greywater for toilet flushing. The fact that the freshwater consumption of almost 50% of all new households can be covered by retrofitting all existing houses and building new houses with greywater toilet systems is quite significant. This study only looked at greywater toilet systems. There are even more freshwater conservation opportunities if residential landscape irrigation systems are converted to greywater systems. On a larger infrastructure level, non-potable water could be used for fire supply, although this would require a stand-alone infrastructure for fire supply which is currently supplied from freshwater supply lines. In addition to evaluating the impacts on freshwater supply, water and wastewater treatment, and supporting infrastructure, these opportunities should also be studied from a life-cycle cost and an environmental life-cycle assessment perspective. Truly sustainable development must assess social, environmental, and economic impacts. This future research should identify cost effective methods that can be used to reduce water consumption in residential structures to better answer the question: is there an identifiable water policy that would support continued growth while keeping rates constant or possibly lowering them?

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