**A Graywater Reuse Study in Southern Arizona and the Water Conservation Demonstration Garden in San Diego, California.**

An Essay on a presentation made by Val Little (1) to Diwan al-Mimar on May 31, 2001.

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## INTRODUCTION

In arid regions, the issue of water conservation is one of great significance for the sustainability of water resources. One effective approach to water conservation is the reuse of graywater. Graywater is all wastewater generated in the household excluding toilet wastes. Its sources in homes include sinks, showers, tubs, and washing machines. Graywater recycling is not limited to large-scale projects, for individual households can effectively save and reuse their graywater for irrigating landscapes and flushing toilets (2). Another approach is the incorporation of principles and practices of water conserving landscapes (3). The presentation of Val Little dealt with these two approaches to water conservation. Concerning graywater reuse, Little discussed a residential graywater research study that the Water Conservation Alliance of Southern Arizona (Water CASA) (4) undertook in the greater Tucson (5) area between the years 1998 and 2000. Little also discussed demonstration gardens as tools for educating the public in water conservation, particularly in the creation of water conserving landscapes. More specifically, she presented the example of the Water Conservation Demonstration Garden in San Diego, California.

## RESIDENTIAL GRAYWATER REUSE STUDY

The residential graywater reuse study that Water CASA carried out was supported by the Arizona Department of Water Resources, the Arizona Department of Environmental Quality, and the Pima County Department of Environmental Quality. The study included two parts, each of which examined one aspect of graywater use in the greater Tucson area. The first part was a survey that looked into the number of households that used some portion of the graywater they generated, and examined their graywater resources. The second part examined health concerns relating to the use of graywater, and the potential of graywater for transmitting disease. Little emphasized that the subject of safety relating to graywater reuse is one that needed to be cleared up as it constituted a major obstacle in the way of getting graywater reuse legalized. Consequently, the second part of the study included testing the water quality of residential graywater and the effects of that graywater on the soil that was irrigated with it (6).

Little provided a quick overview of the survey part of the study. She mentioned that the study team mailed a questionnaire to owner-occupied, single-family residences in the area of the study. Survey recipients were asked whether they reuse or do not reuse portions of their graywater. The results of this survey were used to draw tentative conclusions concerning graywater reuse in the Tucson area. It showed that 13 percent of the single-family residences used a portion of the graywater they generated. The survey also showed that those users of graywater did not obtain the permits required by the county in order to reuse their graywater legally. Regulatory agency in Arizona, which is the Arizona Department of Environmental Quality, had specific rules that needed be followed when reusing graywater, and those rules were not taken into consideration by those surveyed. Little added that those 13 percent of households who reuse their graywater translated to somewhere between 20,000 and 30,000 of the households of Pima County, which represents 50,000 to 80,000 persons. According to Little, the results of the study caught the attention of the regulatory agencies, which knew of the illegal reuse of graywater, but were not aware of it being so widespread. The study therefore brought attention to the need to simplify existing regulations for residential graywater reuse, and to create new ones that are based upon "performance standards," an issue that will be discussed in more details below.

In the questionnaire distributed by the study team, people who reused the graywater were asked about their sources for that graywater. Here, Little showed that washing machines came first, bathroom tubs and showers came second, kitchen sinks came third, and bathroom sinks came last.

As for the use of graywater, the answers provided indicated that it is most commonly used for the irrigation of trees. The irrigation of shrubs and grasses came next, and this was followed by the irrigation of potted plants. A few of the respondents even applied graywater to their vegetable or herb gardens.

The questionnaire asked respondents who did not reuse any of the graywater they generated as to why they chose not to do so, and provided them with a number of possible answers. The top reason that the respondents chose is that they did not know how to reuse their graywater. The uncertainty about the safety aspects of using graywater came next. Assuming that reusing graywater is illegal followed. The probable need for permits and inspection came last. Little added that by analyzing the reasons that the respondents offered for not using graywater, the study came up with a potential target audience of over 40 percent of the population of the Tucson area who would be interested in reusing graywater assuming that the right conditions were provided. Consequently, this number could be reached if the reuse of graywater was legal, if the permitting requirements were unconstrained, and if people were given the necessary information on how to reuse graywater. Thus, if such obstacles were removed, a large amount of water saving may very well be achieved.

Little discussed the second part of the study that dealt with risk assessments for the reuse of graywater. This second part of the study looked into the quality of graywater and the factors that determine this quality before and after the graywater is applied to the soil. Little mentioned that a sample of 11 different households that recycled graywater in Tucson was chosen. The sample was intended to be widely representative of Tucson households. Thus, it included households where children lived, where pets lived, where different methods of graywater storage were used, where graywater was obtained from different resources, and where different application systems were put in place for this graywater. The study team wanted the sample to include a broad spectrum of systems that people had devised on their own. The team carried out studies over a period of a year that investigated, on a monthly basis, the graywater those households generated, their graywater-irrigated soil, and their potable water-irrigated soil. Water and soil samples were collected and tested in two different laboratories to determine the level of contamination caused by the use of graywater (7).

The household samples were of different levels of complexity. One of those samples showed a household with the graywater coming exclusively from the kitchen sink. Here, a pipe was installed under the sink. The pipe went through a hole that was cut out of the kitchen wall and led to some trees, which included an Aleppo Pine (*Pinus halepensis*). This sample, according to Little, represents a most simple and direct way of reusing graywater. No filter was included, and the water moved from the sink to the trees through gravity. Such a sample was very helpful for the purpose of the study since it was not mixed with the graywater coming from the washing machine or the bathroom sinks or tubs, thus allowing the study team to examine the quality of the graywater collected from kitchen sinks in particular (8).

Another sample Little discussed is one where the graywater was collected from the washing machine. Here, a very simple system was used that included a plastic garbage can that collected the water from the washing machine, with a hose running out from this can to water the plants in the garden. The system worked well, although its overall visual effect was not aesthetically pleasing. Little added that this way of reusing graywater from the washing machine is typical of other sites included in the study, and also of many other sites in Tucson of which the study team was aware, but which were not included in the study. Of course, such a sample was helpful for the purpose of studying the quality of the graywater coming exclusively from washing machines (9).

An interesting example that Little showed was a household in which six children under the age of ten lived. Little described the woman of the house as an “avid conservationist.” She collected the graywater from the washing machine in two barrels since she was doing a considerable amount of laundry. She had come up with her own “filtration system” that consisted of one of her children’s socks placed at the end of the pipe coming from the washing machine. The sock filtered the water before it went into the graywater storage barrels. She also harvested rainwater (10) from the roof of her house and mixed it with the graywater collected from the washing machine. She installed hoses that went out of the barrels, and that served to irrigate the garden (figure 1). This woman, according to Little, was very efficient and effective in making the best out of relatively primitive resources.

The study also included a household where the washing machine could not be accommodated in a laundry room. Consequently, the owners of the house put the washing machine outside, which is a common arrangement in the older neighborhoods of Tucson. In this particular household, a low-water-using, front-loading washing machine was used. The graywater was collected from the washing machine into a barrel placed beside it. A hose transported the graywater to the vegetable garden of the household (figure 2). This household, according to Little, was of interest to the purpose of the study because the owners had three sources for the graywater they were using. In addition to the washing machine, they incorporated water from the kitchen sink, and also from the bathroom sink and tub. Their three sources of graywater were not mixed together and each source fed a different area of their garden thus allowing the study team to obtain useful and extensive information about graywater reuse.

Little showed a somewhat more sophisticated example for the reuse of graywater that was devised by a creative builder in Tucson. He collected all the graywater coming from the different sources that generated graywater and stored this graywater in a ground tank that had a capacity of about 2,000 gallons (7.57 cubic meters). He installed the necessary piping system and control valves for the collection and distribution of the graywater. The graywater was applied to the garden of the house by means of a drip irrigation system. The plants that the graywater irrigated included wild flowers that he planted outside his lot, which is located along a major Tucson street. As is the case with the other households included in the study, this owner had no permit for his graywater system. According to Little, the process of getting a permit for using graywater was so cumbersome that it was almost impossible to obtain. Little added that even if someone were successful in obtaining the permit, satisfying the requirements of the permit would be an abhorrently expensive task.

The last example Little showed in the context of this study belonged to a house the owners of which had the intention of using graywater and rainwater harvesting extensively prior to the construction of the house. The owners of the house were avid gardeners. They wanted to be able to use water lavishly, but did not want to feel guilty about it. They worked for two years trying to get a permit for installing a graywater reuse system in their house, but failed to obtain the permit. However, they went along and built an underground cistern for collecting graywater and installed all the necessary piping works for it and presented it as a municipal water collection tank to the city plumbing inspectors. As soon as the inspection was over, they hooked up the graywater reuse system and started using the generated graywater to irrigate the plants in their garden.

Little concluded this section of the presentation by mentioning that the results of the graywater reuse study were turned over to the regulatory agency, which is the Arizona Department of Environmental Quality. The results study showed that residential graywater reuse has "huge conservation potential." Also, health risks associated with the residential graywater systems are within the acceptable limits. Those results facilitated this department's efforts to simplify the rules for residential graywater reuse and to create regulations based upon performance standards. New rules for residential graywater reuse that took the findings of the study into consideration became effective as of January 2001 (11). According to the new regulations, people are free to install their own graywater reuse system as long as they satisfy certain requirements. They should accumulate less than 400 gallons (1.51 cubic meters) of graywater per day, which in any case is 4 to 5 times the amount that the average Tucson household would generate. They also should comply with a series of "performance standards." These standards include, among other things, retaining the graywater in the property and not allowing it to run off into the street or to enter other properties. They also require that no human contact take place with the graywater, and that a diversion valve directing the graywater to municipal sewer or septic systems be installed in case there is an overflow of graywater, a blockage in the system, or bleach or dye is added to the graywater. The standards also specify that graywater be applied to plants through flood or drip irrigation systems only; the use of spray irrigation systems is not allowed.

According to the new regulations, people no longer are required to go through the preexisting complicated processes of trying to obtain a permit to install a graywater reuse system. Instead, they can install a graywater system as long as they meet the requirements mentioned above. The authorities only would get involved if there is a complaint about the misuse of graywater. In such a case, the relevant officials would visit the household to inspect the graywater reuse system and consequently work along with the owners to upgrade or adapt this system so that it would meet the required performance standards.

At present, Water CASA is working on the second phase of the study, which incorporates figuring out ways to educate the public and explain to them how they can create their own graywater reuse systems. This second phase also examines a variety of templates that can be used for different possible cases of retrofitting a graywater system into a preexisting house. After all, it is relatively easy to install a graywater system when constructing a new house. However, retrofitting an existing house is more complicated since that usually requires installing a dual plumbing system to separate graywater from black water (water generated from toilets and the kitchen sink). In an existing house, it may not be easy or feasible to access all the drainage pipes and rearrange them within the graywater system.

## THE WATER CONSERVATION DEMONSTRATION GARDEN

The second part of Val Little's presentation dealt with the Water Conservation Demonstration Garden, which is situated within the campus of Cuyamaca College, in the eastern part of San Diego, California (12). Little stated that this garden provides effective examples on how the public in San Diego can respond to San Diego's drought climate and conserve water through detailed real illustrations of the seven principles of xeriscape (13). The garden provides a learning resource center with landscape planting, educational exhibits, and a theatre.

One enters the garden through a sliding entry gate. Just next to the gate is the garden's information kiosk that is built in the shape of a large watering can (figure 3). This is where visitors obtain entry tickets and brochures about the garden. The garden's entry gate leads to a large outdoor concrete-paved lobby where some paving stones that honor the contributors to the garden are placed. Also, a map and a few interpretive signs that outline the different components of the garden are placed close to the entrance area.

Passing through the outdoor lobby, one is presented with one of the garden's educational exhibits, the California Water Story. Here, an interpretive panel shows the sources of San Diego County's potable water and explains the history and importance of water supply to the region. A large diameter section of a water supply pipe with water dropping into a small pond, which is placed near the panel, serves to draw the public's attention to the California Water Story (figure 4).

Little showed how the garden conveys to the public the importance and aesthetic appeal of the use of mulches as one of the principles of xeriscape (figure 5). Applying mulches to the surface of the soil limits water evaporation from the soil, thus reducing the plants' demand for water (14). In the Water Conservation Demonstration Garden, organic and inorganic types of mulches were applied to the soil of a landscaped area, creating attractive patterns. Also, large concrete pipe bins were used as containers for different mulch materials. This serves to encourage the public to interact with the variety of materials that can be used to mulch the landscape since they can handle those materials and even take a sample home with them.

Another area within this garden that Little described is the Water Alternatives Area (figure 6). Here, the different sources of "fit-for-use" water are celebrated. Potable water, graywater, and reclaimed water (15) are contained in labeled tanks. The tanks are evocative of the old water towers and water tanks found in many towns in the United States. Next to the tanks is an interpretive panel that includes illustrations on the different water sources and their applications.

Rainwater harvesting is also emphasized in the Water Conservation Demonstration Garden. A demonstration of a rooftop rainfall harvesting system includes a roof with an oversized downspout that conveys storm water into a cistern (figure 7). Such a representation makes it easy for all to understand the concept of rainwater harvesting. Rainwater not only can be harvested from roofs, but also from floors. In this particular garden, the parking lot is made of pressed gravel so that all rainfall reaching it is stored in the soil. Thus, no water is lost as a result of runoff into the street.

Little also showed an example of how the Water Conservation Demonstration Garden conveyed to the public information on irrigation equipment, particularly those of drip irrigation systems, which are most effective as a water-saving irrigation method (16). Here, a bed that includes the different components of the drip irrigation system such as pipes, valves, filters, emitters, and controllers is presented. These components are laid out before the public so that they can look closely at them, pick them up, and explore them (figure 8).

The garden includes a variety of low-water-using planting materials (17). Some of those are provided with detailed information conveyed in an easy to understand manner (figure 9). Little believes that the manner in which the information is displayed, which emphasizes having the visitors move through the spaces containing the plants, is an effective manner of encouraging the public to learn about the plants. In contrast, a rigid way of introducing such a quantity of information probably would intimidate and turn off the garden visitors.

Plants also are introduced in this garden as functional elements that can be used for the purposes of providing privacy, creating a microclimate, and controlling soil erosion. Little showed how information on soil erosion control was presented in this demonstration garden. This included a simulation of an erosion-susceptible, steeply sloping area where half the area is covered with erosion-proof plants and the other half is left unprotected. The bare soil shows signs of erosion, while the planted area does not. The use of plants reduces the amount and speed of water runoff, thus protecting the soil and resulting in an attractive space.

Another exhibit in the Water Conservation Demonstration Garden that Little showed illustrates the importance of gardening tools and emphasizes the maintenance of the landscape as an important principle of xeriscape. A low-height concrete wall that serves as a retaining wall for a planting bed is decorated with a large variety of gardening tools including clippers, hedging sheers, pruning saws, forks, and shovels that have been fixed on top of the wall (figure 10).

Little showed the garden's Retrofitting Area, which is intended to show homeowners how they can easily replace their high-water-use landscapes with low-water-use ones. This area includes a representation of a house made of see-through materials, and that has low walls. A window frame looks into two backyard scenes. One of the scenes shows a plain backyard planted with turf. The other scene shows a backyard that is similar in area and shape to the first one, but instead has a small area of turf and incorporates low-water-using plants, mulches, and a paved area that serves as a patio. The result is a far more interesting and beautiful backyard than the one landscaped only with turf.

As turf is needed in some areas such as the activity area in a backyard, the garden demonstrates a number of varieties of grasses. Here, seven different kinds of grasses, ranging from the highest water-using grass to the lowest water-using grass, are laid out in a fan-shape pattern. Each grass area is provided with a water-use read out box that states the amount of water that needs to be applied to each area over a certain period of time. Thus, the public can learn that they may use a type of grass that gives the same look as a water-consuming one, but uses far less water. (Figure 11)

The Water Conservation Demonstration Garden also exhibits a variety of hardscaping materials (18) and groundcovers that can be used in lieu of turf areas, thus conserving water. The garden also includes an area that is set up with alternating squares of hardscaping materials, such as bricks, stone, and tiles, as well as a variety of low-water-use groundcover plants (figure 12). The result is an example that is pleasing to the eye, delightful to walk through, and also informative and educational.

The garden includes a theatre with a seating capacity for more than 350 people. The introduction of planted areas between the seating rows of the theater provides a very interesting way of bringing the plants closer to the audience (figure 13). The theater is a place in which seminars, lectures, presentations, and performances take place. It therefore functions as a supporting educational tool that adds to the experiences and information that the public gains by touring the garden. The theater also houses community events, and therefore helps enhance the public's relationship with the garden (19).

It also is interesting to note that the various exhibitions are self-explanatory and incorporate a minimal amount of text. Consequently, the exhibits of the garden convey information to the visitors in an easy and effective manner.

## QUESTIONS AND ANSWERS

The participants raised the issue of the effect of the detergents present in graywater on plants watered by graywater, and also whether graywater could be used for edible plants. Here, it was mentioned that generally it is advised to apply graywater to non-edible plants. It also should be noted that detergents are not necessarily bad for plants. In fact, some detergents contain nitrogen or phosphorus, which serve as nutrients for plants. Chlorinated graywater maybe harmful if used for some sensitive plants, but has no harmful effect when applied to plants common to the Mediterranean region such as oleander (*Nerium oleander*) and rosemary (*Rosmarinus officinalis*). Those were the results of experiments carried out in Tucson, and it is expected that we would get similar results when testing chlorinated water on plants in Amman. However, it was recommended to experiment with the application of graywater to some species of plants in Amman to investigate how they would perform over a five-year period for example. One also can dual plumb the graywater coming out of washing machines by diverting out the graywater that contains chlorine bleach or intense soaps to the sewer system while directing the graywater with lighter detergents and the rinse water to the graywater system.

In this context, it was added that one should be aware of the soil type to which the graywater is applied. In the case of Tucson, an experiment was carried out where graywater was applied to a turf area through the use of a subsurface drip irrigation system, and a similar turf area was drip-irrigated with potable water. The greenness of the graywater-irrigated turf was very evenly green, while the greenness was just along the drip irrigation lines in the potable-water irrigated turf area. The experiment showed that the presence of soap in the graywater helps in dispersing the water through the soil. However, Little noted that this might not necessarily be the case in Amman. There are differences between soils in Tucson and Amman. The soil in Tucson is sandy in character, while Amman generally has clay to clay-loamy soils, which have a higher water holding capacity. Consequently, the soil in Tucson probably takes graywater easier than that in Amman.

Slow dripping probably would be needed when applying graywater to the soil in Amman to avoid surface ponding problems resulting from the clay to clay-loamy soil compositions. In order to get an accurate idea as to how soils in Amman would respond to the application of graywater, experiments on the subject would need to be carried out.

It was added that it is recommended to collect the graywater coming from washing machines in a container to let it cool down before being applied to plants. The use of a container also would help in controlling the amount of graywater applied to a given plant at one time.

A follow up point was that drip irrigation is not commonly used in Jordan on the residential scale. Plants more often are watered with hoses applied to tree wells. Here, Little commented that she herself does not use a drip irrigation system to water her own garden. Instead, she uses a hose pip and moves it around the garden according to the needs of her plants. This allows for one to become more intimately engaged with one's plants. Little added that an irrigation system should not be a high-tech one. Here, it should be kept in mind that most people are not expert gardeners, and therefore using a hose for watering is much easier for him or her than using a sophisticated irrigation system. She added that one simply could place a hose beside a plant and let the water run slowly for a long period of time. Also, the use of tree wells is more compatible than a drip irrigation system when applied to sloped or terraced gardens. Here, one can apply the water to the upper level of tree wells and then direct it to the lower levels by means of pipes or water channels. However, one should make sure not to let water run off their property. In this context, she mentioned that Tucson has a water waste ordinance according to which one is fined if water runs off one's property.

Another question enquired as to whether applying graywater coming from washing machines to plants in Amman would reduce or increase soil alkalinity. Here, it was mentioned that the soil in Amman is of high alkalinity. Consequently, the presence of detergents - which are alkaline in composition - in the graywater will result in increasing its alkalinity. Alkaline soils tie up iron and zinc in forms that are unavailable to plants. It was mentioned that the soil in Tucson also is very alkaline. Therefore, some sensitive plants, such as bougainvillea (*Bougainvillea sp.*), are badly affected if irrigated with graywater. However, some of the Arizona native plants, such as palo verdes (*Cercidium microphyllum* and *C. floridum*) and cacti, have proven to grow fabulously when watered with graywater. Also, it is believed that olive (*Olea europaea*), carob (*Ceratonia siliqua*), and grapes take well to graywater. Once again, it was highly recommended to start experimenting with the application of graywater on different plants in Amman to come up with accurate results that would help in disseminating the use of graywater in irrigation, thus conserving water.

One audience member commented on the issue of rainwater harvesting. He mentioned that rainwater harvesting traditionally had been used in Jordan, and that it still is common in the countryside and even in Amman. He added that as a practicing architect, he often has clients who want to include a rainwater collection system in their single-family residences. He concluded that a number of Jordanians clearly are aware of the importance of rainwater harvesting as a method for water conservation in a country suffering from water scarcity. Here, Little emphasized that rainwater is high quality water and harvesting it is an ethic that should be advocated.

Another audience member raised the point that mulches are not widely used in Jordan, and attributed this to the shortage of forests in the country. In response to this point, Little highlighted the variety of mulches one may use, which include organic and inorganic types. She added that a good mulch source is the green debris from trees that accumulates in one's property. This is always available, costs nothing, provides the plants with nutrients, and acts as a habitat for small creatures that constitute an essential part of the ecosystem.

Another point was raised about the graywater coming from water used for ritual ablutions for the Muslim prayers. Such graywater is generated in residences and also in mosques. It was mentioned that since the graywater resulting from ablutions contains no soap, it should be of very high quality for reuse. The current situation is that this water is being directed into the sewer system. Here, Little mentioned that a project currently is underway for reusing the graywater generated from ablutions in mosques. The graywater would be reused for the purpose of flushing toilets. The project is undertaken by WEPIA (Water Efficiency and Public Information for Action) (20), which also works directly with the imams of mosques to advocate the concept of water conservation in Jordan.

Little was asked how the problem of insects - such as mosquitoes and flies - associated with graywater reuse is addressed in Tucson. She answered that this issue is not significant in Tucson. The soil in Tucson is very permeable and therefore water does not stand at all. Little added that in Tucson people are more concerned about mosquitoes associated with the graywater stored in containers, rather than the graywater lying on the ground. Thus, it is important that graywater storage containers are tightly covered.

One audience member asked for additional information about the differences in water consumption between the various grass types that Little showed when presenting the Water Conservation Demonstration Garden. Here, Little mentioned that the water consumption of high-water-using grasses could be two or three times as much as that of low-water-using grasses. A follow up question inquired about the kind of low-water-using grass that would be suitable for Jordan. It was mentioned that Bermuda grass is the most durable and the least water-consuming grass. Also, Bermuda grass grows incredibly well when irrigated with graywater. When Bermuda grass is left without watering it dries up and turns into a brown color. However, as soon as it is watered, it turns green again. This is because it is a kind of matted grass, which spreads through underground and aboveground stems. In contrast, bunchgrasses, which proliferate by producing lateral branches, are very delicate. They do not tolerate as much traffic as Bermuda grass and tend to get damaged easier. They also have a long dormancy period. However, it was noted that getting rid of Bermuda grass is not easy and usually requires applying certain chemicals to it.

**Prepared by Majd Musa with Mohammad al-Asad**

**NOTES**

(1) Val Little is the Director of the Water Conservation Alliance of Southern Arizona (Water CASA), which is affiliated with the University of Arizona's Water Resources Research Center. Her work concentrates on providing water conservation programs, services, and research for municipal water providers in southern Arizona. She studied landscape architecture at the University of California, Berkeley and anthropology at the University of Arizona in Tucson.

(2) For additional information on graywater reuse, see C. Gerba, T. Straub, J. B. Rose, M. Karpiscak, K. Foster, and R. Brittain, "Water Quality Study of Graywater Treatment Systems," *Water Resources Bulletin* 31(1995): 109-116.

Also see "Residential Graywater Reuse Study" in the Research section of the Water CASA web site.

(3) For detailed information on low-water-using landscapes, see the Water Conserving Landscapes section on this web site. The site includes detailed lists of drought tolerant plants, online publications on water conserving landscapes, a list of print and web-based references that deal with drought tolerant plants and water conserving landscapes, and a list of suppliers for services and materials relating to water conserving landscapes.

(4) The Water Conservation Alliance of Southern Arizona (Water CASA) is an organization affiliated with the University of Arizona's Water Resources Research Center. Its board of directors includes members of the water providers in the area of southern Arizona. Water CASA works in different facets of water conservation such as incentive programs, public information programs, the public policy arena, and research. More detailed information on Water CASA is available in their web site.

(5) Tucson is a desert city of over 440,000 people located in southern Arizona, one of the states of the southwestern United States. The level of precipitation in Tucson amounts to approximately 300mm per year, and the total water demand exceeds the total available renewable supply. Therefore, the issue of water conservation in the different sectors of water use in Tucson is of great significance.

(6) The details of the Residential Graywater Reuse Study are available in the Research section of the Water CASA web site.

(7) The graywater, graywater-irrigated soil, and potable water irrigated soil were analyzed for their content of fecal contamination, particularly the content of *Fecal coliforms*, *Fecal streptococci*, and *Escherichia coli*. *Fecal coliforms* and *Fecal streptococci* are members of two bacteria groups commonly found in human and animal feces. Although they generally are not harmful themselves, they indicate the possible presence of other disease-causing bacteria (such as those that cause typhoid, dysentery, and cholera), viruses, and protozoans. As the direct monitoring of disease-causing bacteria is difficult, *Fecal coliforms* and *Fecal streptococci* are considered an indicator of disease bacteria in the water (i.e. they are used as indicators of possible sewage contamination). *Escherichia coli* is the only coliform that is specific to fecal material from humans and other warm-blooded animals. It is a common inhabitant of the intestine of the healthy humans and warm-blooded animals. However, some strains of *Escherichia coli* are disease-causing. *Escherichia coli* is considered a significant indicator of health risk caused by sewage-contaminated water.

(8) The results of this study showed that the higher level of *Fecal coliform* bacteria was present in the graywater coming from the kitchen sink. Thus, the kitchen sink represents a significant contamination source. This is caused by the large amount of organic matter it contains, which provides nutrient sources for organisms already present in the water. Also, washing meat and poultry may introduce organisms into the graywater collected from the kitchen sink. Thus, the study recommended that the graywater coming from the kitchen sink be excluded from the graywater used for irrigation purposes and directed to the sewage system.

(9) The results of the study showed that the lowest levels of *Fecal coliform* bacteria were found in the graywater coming exclusively from washing machines.

(10) Rainwater harvesting is an effective water conservation tool that provides free water independently from the municipal supply. For additional information on rainwater harvesting, see the documentation of Richard Brittain's presentation, "Casa del Agua and Desert House: Two Residential Demonstration-Research Projects on Water and Energy Efficiency," which is located in the Publications part of the CSBE Water Conserving Landscapes section of this web site.

(11) For additional information on the new regulations for residential graywater reuse that the Arizona Department of Environmental Quality has put in place, see Val Little, *Graywater Guidelines* (Tucson: Water Conservation Alliance of Southern Arizona, 2002). This document also is available online through the Water CASA web site.

(12) The concept for this garden was adopted in 1991 by the East County Water Conservation Committee. It was designed by Jon Powell of the landscape architecture firm Deneen Powell Atelier, Inc, and was opened to the public in 1999. Cuyamaca College was selected as a location for the garden because of its strong horticulture department that had originally created the San Diego Xeriscape Council as the educational vehicle for water conservation in the landscape in the San Diego area.

For additional information on the Water Conservation Demonstration Garden, see the garden's web site at http://www.otaywater.gov/garden/

(13) The seven principles of xeriscape include the incorporation of water-wise planning and design, low-water-use plants, limited grass areas, water harvesting techniques, efficient irrigation systems, mulch, and proper maintenance. For additional information on the principles of xeriscape, see the essay, "The Seven Principles of Xeriscape," and the documentation of Margaret Livingston's public lecture, "Creating Landscapes in Water-Scarce Environments: a Case Study of Tucson, Arizona**."** Both essays are included in the Publications part of the Water Conserving Landscapes section of this web site.

(14) For additional information on the use of mulches as a principle of xeriscaping, see note 13 above.

(15) Reclaimed water is processed wastewater that is subjected to primary and secondary treatment. It requires large-scale treatment plants, in contrast to the simple, private systems used for graywater reuse that were presented in the first part of Little's presentation. Reclaimed water basically is used for the purposes of irrigation.

(16) For additional information on irrigation systems, see the essay "Garden Irrigation" in the Publications part of the Water Conserving Landscapes section of this web site.

(17) In this context, the Water Conservation Garden has educational exhibits that feature plants from different areas of the world that have climates similar to that of San Diego.

For examples of drought-tolerant plants, see the Plant Lists part of the Water Conserving Landscapes section in the CSBE web site.

(18) For additional information on hardscaping, see the essay "Paving Solutions" in the Publications part of the Water Conserving Landscapes section in the CSBE web site.

(19) In this context, it is interesting to note that the 2001 Spring Garden Festival brings 1,450

visitors to the Water Conservation Demonstration Garden. See the garden's web site for additional information on the outreach events organized in it.

(20) WEPIA is a strategic social marketing program of the Academy for Educational Development. It is being implemented in collaboration with the Jordanian Ministry of Water and Irrigation and is funded by the United States Agency for International Development (USAID). WEPIA covers two areas related to water demand management in Jordan. The first looks at the immediate actions towards adopting water efficient technologies, such as water saving devices. The second area addresses the attitudes of the public towards water consumption, with an emphasis on school children.

**List of Figures***

* All images courtesy of Val Little.