World Water Forum College Grant Program
2007 Grant Proposals

College	San Bernardino Valley College
Faculty	Dr. Achala Chatterjee
Project	Gray Water to Green Trees

WORLD WATER FORUM
Innovative Conservation Research and Technology
COLLEGE GRANTS
For Universities and Community Colleges
2007-2009

A. Applicant Information.

College:	San Bernardino Valley Community College
Address:	701 South Mount Vernon Avenue
City, State, Zip Code:	San Bernardino, CA 92410
Website:	www.valleycollege.edu
Make Check Payable To:	San Bernardino Valley Community College

B. Project Type

Applicant:	San Bernardino Valley Community College
First Time—Local Project:	Gray Water to Green Trees

C. Student Information.

Student Project Manager:	Jose Castro
Undergraduate or Graduate:	Undergraduate
Department:	Water Supply Technology
School Address:	701 South Mount Vernon Avenue San Bernardino, CA 92410
Telephone:	909-980-4391
Mobile Phone:	909-200-5958
Email Address:	runjorun5@hotmail.com
Home Address (optional)	10024 Salina Street, Rancho Cucamonga, CA 91730

D. Faculty Information.

Faculty Project Manager:	Achala Chatterjee
Department:	Water Supply Technology
School Address:	701 South Mount Vernon Avenue
City, State, Zip code:	San Bernardino, CA 92410
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Mobile Phone:	951-515-9197
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E. Organizational Background.

San Bernardino Valley College (SBVC) is a Community College located in Southern California The college was established in 1936 and remains an integral contributor to the economic development of the Inland Empire—an area including San Bernardino County. As of the fall 2007 semester, SBVC enrolled approximately 11,500 full time and part time students, and is designated by the Department of Education as a Hispanic-serving institution. Notable student body characteristics are summarized as follows:

Hispanic	40%	Average age	24.1
Female	58%	Full-time (≥ 12 units)	80%

The overall student population at SBVC has decreased from approximately 14,000 in 2004 to 11,500 students in 2007. However, there has been a significance increase in the number of students enrolling in Water Supply Technology (WST) and chemistry courses and a small decrease in biology courses. The net changes in enrollment in spring 2007, compared to spring 2004, are 154% in Chemistry, 146% in WST, and 96% in Biology. Notably, SBVC is the only community college in the Inland Empire that offers courses in Water Supply Technology, drawing students from the low desert (e.g., Palm Springs, Yucca Valley), the high desert (e.g., Victorville) and nearby cities of San Bernardino (e.g., Redlands, Loma Linda, Yucaipa, Riverside, etc.). There are two private providers of water supply technology instruction in the area, but their tuition is substantially higher (approx $190 per unit) compared to SBVC ($20 per unit).

Despite the overall growth in enrollment in WST courses at SBVC, currently these courses consist of less than 9% women. In addition, African American, Asian, Native American, and Hispanic students are underrepresented in WST compared to general enrollment at SBVC. The majority of the students who currently enroll in the program are either already employed by or have close relatives who work for water departments. These students enroll in the courses to obtain state licensure, to continue working in the field, or to advance in their current positions. Traditionally these high paying, stable, full-time jobs with health and retirement benefits have been held by white males, and the demographics of the student population in our WST courses seems to reflect this statistics. Unfortunately, most minority students do not appear to be aware of the opportunities available in the field.

The proposed project is intended to engage the interest of students in courses related to WST. By incorporating hands-on, active-learning experiences in water studies, it is our hope that underrepresented students will take an interest in the water technology field. Since the proposed project will also appeal to the interests of current and future homeowners, it should draw in students of diverse backgrounds from freshman-level general education science courses. This project reflects SBVC mission to provide gateway to higher education and vocational training for no-traditional populations.

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F. Project Description.

Objectives: The objective of this project is to determine the effect of gray water irrigation on potted citrus trees. Specifically, we will buy 20 young (1-2 years old) citrus trees potted in identical soils. Eighteen trees will be watered using subsurface irrigation with gray water from a simulated wash-cycle, using various kinds of laundry detergents and two control trees will be watered using potable water. At regular time intervals, the vitality characteristics of the plants will be assessed and compared to quantitative chemical and biological analyses of the soil. The expected outcome of this project is to find a simple, inexpensive, way to use gray water generated by individual homeowner and use it in the homeowner's yard, supported by sound experimental data. A small greenhouse, housed in the Biology department, will be utilized to house the project so that other growth parameters do not vary. The secondary benefit of this project would be to allow homeowners to grow shade giving, fruit trees inexpensively. If planted strategically, it would reduce summer air-conditioning needs and additionally provide nutritious fresh fruits in their diet.

Significance: The short-term significance of this project is to give our students, in the fields of water supply technology, biology, and chemistry, experience in performing a research-based investigation that will potentially lead to an increased interest in water technology careers. The environmental significance may have an impact in helping to refine California's Gray water law, which is believed by some conservationists to be too restrictive. It is believed that the law may unnecessarily exclude households which might otherwise participate in this important water-conservation effort. The results of the irrigation design, quantitative chemical and biological analysis of the soil conditions, and ultimate condition of the trees will be analyzed and compared to the requirements of the current gray water plumbing code.

Background: Water, which is vital to life, is a renewable resource; however, the current rate of freshwater consumption by human societies is unsustainable. Many communities are depleting their sources of surface water and groundwater at an alarming rate. An estimated 77% of the rivers in North America and Europe have been affected by water diversions that significantly alter the watershed's environmental systems, endangering natural ecosystems and human development alike[1]. According to a study conducted by the University of Victoria, of 29 nations in the Organization for Economic Cooperation and Development (OECD) in 1999, the United States had the highest per-capita water usage,[2] a statistic which is absolutely unacceptable. In the USA, the average per-capita consumption of fresh water (including all water necessary to produce goods and services) is 1,400 gallons per day.[3] Actual household use accounts for about

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[1] Joy Withgott, Scott Brennan, Essential Environment, 2nd Ed. 2007

[2] Organization for Economic Cooperation and Development Factbook 2005, ISBN 92-6-01868-7, Boyd, D. R. Canada vs. the OECD; an environmental comparison, 2001. http://www.environmentalindicators.com/htdocs/about.htm>, December 11, 2007.

[3] World Resources Institute, World Resource: Decisions for the Earth: Balance, Voice and Power. Washington, DC. < http://archive.wri.org/publication_detail.cfm?pubid= 3764#1 >, December 12, 2007. ga.water.usgs.gov

400 gallons[1] of this daily amount, and water-efficient appliances can help to reduce consumption rates, as estimated by the output of gray water.[4] For example, newly constructed homes generate an estimated 35 gallons of gray water per person per day compared to the older home rate of 46 gallons of gray water per person per day.

California is the United States' most populous state and one of the top three states in water consumption. There are two major arteries serving as the sources of surface water for urban and agricultural areas: The Sacramento-San Joaquin Delta (Bay-Delta) and the Colorado River. The use of the available supplies of water has been exacerbated by the state's swelling population, periods of drought, and environmental protection in the Bay Delta. The state Department of Water Resources (DWR) forecasts a gap between water supply and demand by 2020, ranging from 2.4 million acre-feet during normal years to as high as 6.2 million acre-feet in drought years.[5] Because of this projected shortfall in natural supply, it is incumbent on citizens and policymakers alike to devise creative and healthy strategies for households to conserve the fresh water that we use, as well as to utilize the used water that we generate.

Households produce two types of water: black water and gray water. Black water is waste water with high risk of fecal contamination (from toilets) or high organic content such as oils and fats (from kitchen sinks with garbage disposals). From a health perspective, black water is not recommended by any agency for subsequent use, and will not be further discussed here. Gray water, however, has a high potential for recycling as irrigation water for home landscaping, as its source is the waste water that comes from showers, bathtubs, bathroom sinks, utility sinks, and washing machines. Considering that landscape irrigation accounts for about 15% of home water use or about 60 gallons daily per capita[6], it is clear that gray water output (35 – 46 gallons daily per capita) can go a long way toward irrigating home landscape, especially in urban areas. The California gray water standards[7] have been part of the state plumbing code since 1997. However, the intricacy of regulations as well as the system complexity and licensing requirements have discouraged most people from using gray water. Legal gray water systems are rarely installed in suburban homes. The local codes vary significantly, approval is costly, and regulations are hard to navigate. However, anecdotal evidence suggests that many people use gray water without permits[8], especially in older neighborhoods where homes are connected to septic tanks. The amount of fines levied for illegal use of gray water can range as high as $3,000/day. Unregulated, amateur use of gray water potentially causes harm to the environment and groundwater.

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[4] California Energy Commission, www.consumerenergycenter.org/home/appliances/washers.html
[5] California Water Plan Update Bulletin 160-98;
Gleick, P. H.; Loh, P.Gomez, S. V.; Morrison, J. *California Water 2020; A Sustainable Vision.* 1995. http://www.pacinst.org/reports/california_water_2020/>, December 12, 2007.
[6] Greenbuilder.com "sourcebook"

[7] http://www.owue.water.ca.gov/docs/graywater_guide_book.pdf
[8] Dicum, G. The Dirty Water Underground. *The New York Times.* 2007 May 31.

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Involving students in an educational investigation such as of the uses of gray water achieves multiple goals. Students will have enriched hands-on experiences applying principles of the required basic curriculum of engineering, chemistry, and biology, while strengthening their understanding of the vital importance of water conservation in Southern California. Increased awareness of the legalities and environmental concerns related to gray water use will prepare students to act responsibly and participate knowledgeably in local, state, and federal political decision-making processes related to water issues. And, finally, a greater number of non-traditional students will be made aware of the numerous career opportunities available in water supply technology.

Proposed plan for student activities. The major obstacle to the recycling of gray water is that this waste water contains contaminants that could represent health risks to humans and landscape vegetation. Feces (and potential pathogenic microbes that follow the oral-fecal route of disease transmission) can contaminate gray water from bathing and clothes washing. Sodium (which can salinize soil and alter soil pH is a common softening agent in detergents. Products such as bleaches, dyes, and borax can be toxic to plant life. Excess phosphorus harms native plants and can runoff into local water causing algal blooms. Student activities, performed at SBVC, will center on how to assess and mitigate such risks using simulated washing machine waste water, due to simplicity of engineering a diversion.

Water Supply Technology students

I. Evaluate and construct gray water diversion units.
   a. Storage of graywater, especially in underground tanks can provide a place for multiplication of bacteria. Storage units can also become mosquito breeding grounds, and one more place where a human or a pet may come in contact with gray water. Students will investigate currently available device for connecting the washer effluent water directly to irrigate the trees. Current California codes, makes use of storage/surge tanks mandatory.

   b. Type of piping and fitting. How deep should they be buried in ground to prevent contact of pathogens with humans and pets. Evaluate various systems to find the one which is easy to use and not prone to breakdown

   c. Filter systems to reduce sediments and lint which could clog drip irrigation units and clog the soil

II. Research existing regulations regarding the use of grey water in California cities and counties, other dry states such as Arizona, Texas, Nevada, New Mexico and with regulations in Australia.

III. With the help of our partner, Upland Water District, select households with septic systems. Develop a survey form to determine: usage of graywater, whether system is permitted, uses of graywater, source of graywater, how long it has been used, income level of household, if there are children and/or pets in the homes. Conduct the survey.

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Biology students

I. Compare the response of trees irrigated with gray water versus fresh water
II. Evaluate the impacts of gray water on soil ecology
    a. Invertebrate organism density and diversity
III. Microbial organism (fungi & bacteria) density and diversity
IV. Monitoring for health risks - coliform bacteria detection and identification
V. Consider for future research
    a. Seedling germination and growth (sequential tubs with gravel and marsh plants Investigation of mitigating activities
    b. Effect of compost mulches on gray water decomposition rates
    c. Use of simple constructed wetland to purify gray water

Chemistry students

A total of four sets of gray water conditions will be used to water the plants, and the soils will be subsequently analyzed. One control group will be watered with plain tap water from SBVC. Three other gray water conditions will be used, corresponding to two types of laundry soap available at a grocery store (one liquid soap; one powdered soap), and the final soap sample being Oasis Biocompatible soap, which claims to be completely biocompatible with gray water irrigation.[9]

The plain tap water, as well as each of the three gray water samples will be analyzed, prior to watering of the plants, per the procedures outlined below. The gray water (wash-water) samples will be simulated, by preparing a detergent solution at the manufacturer's recommended concentration for doing laundry. Once the growth experiment has begun, the soil samples will be collected periodically, divided into aliquots, and analyzed for the same parameters per the procedures outlined below.

The measurements of the water samples include: pH, turbidity, magnesium and calcium concentrations (water hardness), boron concentration, sodium concentration, and chloride concentration. Except for turbidity, the same measurements will also be performed on the soil cores.

Turbidity. Water samples will be measured in NTU, using hand held Nephelometric turbidity meter.

pH. Water samples will be measured directly. Soil samples will be mixed 1:1 with 0.01 M $CaCl_2$ (to maintain constant ionic strength), and pH will be determined using a calibrated pH meter.

Mg^{2+} and Ca^{2+}. Water samples will be measured directly; soil samples will be mixed 1:1 with deionized water. Samples will be titrated with standardized EDTA, in order to quantitate total concentration of these divalent cations.

[9] www.Bio-pac.com

Boron. The method used will be the azomethine-H procedure.[10] Boron will be extracted from soil using an acetate buffer or treated directly in water samples or aqueous standards. The aqueous extract or solution will be mixed with the azomethine reagent, the color allowed to develop, and the absorbance measured at ~ 430 nm using spectrophotometers (available in the Chemistry Department).

Na^+. Sodium ion concentration of the water samples and 1:1 soil:deionized water will be analyzed using an ion-selective electrode, specific for sodium. A series of aqueous Na^+ standards will be prepared and measured, and a calibration curve constructed. The analytical response of the water and soil samples will be compared to the calibration curve, and the sodium ion content quantitated.

Cl^-. Precipitation of chloride ion by silver ion, to form solid AgCl via a gravimetry scheme, will be used to quantify total chloride. Although a classical method, gravimetry is inexpensive, requires no standardization, and is often more accurate than elaborate instrumentation approaches such as atomic absorption (AA) or inductively coupled plasma (ICP) mass spectrometry or emission spectroscopy.

Anticipated Project Schedule (June 2008 – December 2008)

June 2008 – July 2008

- Evaluate and construct grey water diversion, storage and application devices.
  - Determine type of piping and fitting.
  - Establish optimal pipe depth for efficient watering, while preventing surfacing of applied water.
  - Optimize filter systems to reduce sediments and lint.
- Develop and refine methodology for chemical analysis of water and soil samples.
- Test approach for establishing presence of fecal coliform (via culture).
- Chemically and biologically analyze tap water and simulated gray water samples.
- Procure 20 citrus trees (in duplicate for each control and test group) and record initial characteristics.
- Obtain and analyze initial soil samples (chemically and biologically).
- Develop the household survey format and obtain addresses of homes with septic systems

July 2008 – November 2008

- Assess plant growth by estimating total leaf mass, measuring base diameter
- Obtain soil samples from each plant (at ~ 3 week intervals to yield at least 5 samples)
- Analyze aliquots of each soil sample for desired parameters of pH, turbidity, concentrations of Na^+, Ca^{2+} and Mg^{2+}, B, Cl^-, and fecal coliform.
- Conduct the survey of homes with septic tanks in the Upland Water District

[10] Agricultural and Analytic Environmental Reference. <http://aesl.ces.uga.edu/protected/methods/details/stl-soil/or9.html>

November 2008 – December 2008

- Data analysis
  - Correlate and compare soil data across time (for a given water type) and across water type (for a given point in time).
  - Relate chemical and biological analysis to plant growth and overall health.
  - Identify any trends extracted from the data regarding particular chemical excess or deficiency, as related to plant health.
- Compare the results obtained to the current gray water regulations in California, and propose a plan for household gray water use based on this investigation.
- Analyze the result of the home survey.
- Prepare final report for MWD.
- Submit results to peer-reviewed source, such as the *Journal of Chemical Education*, as a means by which lower-division students can gain relevant and practical laboratory experience at the community college level.

G. Project Management Team

	Name	Title	Address	Phone & Email
1	Achala Chatterjee, Project manager	Instructor, WST	San Bernardino Valley Community College, 701 South Mount Vernon Avenue, San Bernardino, CA 92410	909-384-8522 achatter@valleycollege.edu
2	Ruth Greyraven, Research, Biology	Instructor, Biology	Same as above	909-384-8560 slillard@sbccd.cc.ca.us
3	Sheri Lillard, Research, Chemistry and budget	Instructor, Chemistry	Same as above	909-384-8646 cgreyrav@sbccd.cc.ca.us
4	Jose Castro Technology	Student WST	Same as above	909-200-5958 Runjorun5@hotmail.com

H. 1. Funds Requested

Description	Amount	Notes
Grand funds requested from MWD	$10,000	
Additional Source of Funds	$2,535	Volunteer Time (Achala Chatterjee)
Additional Source of Funds	$2,535	Volunteer Time (Ruth Greyraven)
Project Total	$15,070	

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H. 2. Budget Description

Line Item	Amount	Description
1) Stipends	$5,000	Provided to students (4 @ $1,250 each). Anticipated one WST, one biology, and two chemistry.
2) Lab Fees	$1,500	Laundry detergent: $150 Soil: $150 Plants: $1000 Reagents: $200
3) Office Supplies	---	
4) Consultant	---	
5) Overhead Fee	---	
6) Conference Registration	---	
7) Equipment	$3,500 see note below for justification	Chemistry equipment: $2,000 Water equipment: $900 Irrigation system, plumbing parts: $600
8) Other (Define)		
Total	$10,000	

Budget Notes:

3) It is anticipated that there will be no **office supplies** expenses charged to the project.

4) It is anticipated that there will be no **consultant** expenses charged to the project. All evaluation, management, reporting and compliance will be handled by the college's Office of Research, Planning, and Development.

5) The **overhead fee** has been waived by the college in unanimous support of the project.

6) It is anticipated that there will be no **conference registration** expense.

7) Chemistry equipment includes a benchtop pH/ISE meter with two electrodes (one for pH and one for Na^{+}).
Water equipment include one hand-held Nephelometric Turbidity Meter, one pocket Colorimeter Analysis System,
Irrigation system and plumbing parts include washing machine hook up, three-way diverter valves, pipeline, bends, fittings, subsurface irrigation system

8) There are no **Other** expenses related to this project.

I. Signature Block

	Name	Signature	Date
Faculty Project Manager	Achala Chatterjee	Achala Chatterjee	12/13/2007
Student Project Manager	Jose Castro		12/13/2007
Member Agency Representative	Mark E. Wiley Upland		12/13/07