<table>
<thead>
<tr>
<th>College</th>
<th>CSU LONG BEACH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faculty</td>
<td>Dr. Sultana</td>
</tr>
<tr>
<td>Project #006</td>
<td>Performance Analysis of Rainwater Tanks</td>
</tr>
</tbody>
</table>
Performance Analysis of Rainwater Tanks at CSULB

Submitted to:
The Metropolitan Water District of Southern California
700 North Alameda Street
Los Angeles, CA 90012

Attention:
Ms. Benita Lynn Horn, 10th Floor- Room 322

Project Strand: Local
Total Amount Requested from MWD: $10,000

Submitted by:
California State University, Long Beach
1250 Bellflower Blvd.
Long Beach, CA 90840

Rebeka Sultana, Ph.D., Faculty Project Manager, Principal Investigator
Marvie Baconawa, Student Project Manager

December 15th, 2017
Project Title: Performance Analysis of Rainwater Tanks at CSULB

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Rebeka Sultana, Ph.D., Faculty Project Manager, Principal Investigator
Marvie Baconawa, Student Project Manager
California State University, Long Beach

Project Summary:
Rainwater tanks are an attractive alternative to save water even in semi-arid climates like Southern California where the annual average rainfall is about 19 inches/year. But, the efficiency of these tanks depends on the size of the tank and water demand. This proposed study seeks to develop a spread sheet based water balance model to evaluate performance and design of rainwater tanks using long-term historical rainfall data. The model will be applied to California State University, Long Beach campus which spends more than $800,000 yearly for major water consumption. Whenever it rains, the model will store roof top runoff in the tank and used for campus landscape irrigation. Demand deficit will be met by public water supply. Objective of the modeling effort is to determine reliability of the tanks for different climatic conditions (dry, average and wet years) as well as return of investment. It is expected that implementing rainwater tanks, the campus can save up to 25 million gallons of water per year by only capturing runoff from 50% of its roof area. The project will give opportunity to the student to learn key rainwater harvesting issues. The results will be used to develop teaching material and outreach activities.
### CONTACT INFORMATION

1. **College**  
   California State University, Long Beach

   **Department**  
   Civil Engineering and Construction Engineering Management  
   California State University, Long Beach  
   1250 Bellflower Blvd., Long Beach, CA 90840

   **Make Checks Payable to:** CSULB Foundation

2. **Application Strand**  
   **LocaL** “Performance Analysis of Rainwater Tanks for CSULB”  
   **X**

### LOCAL “Performance Analysis of Rainwater Tanks for CSULB”

3. **Faculty Project Manager (PI)**  
   Rebeka Sultana, Ph.D.

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   Rebeka.Sultana@csulb.edu

4. **Student Project Manager**  
   Marvie Baconawa

   **Undergraduate or Graduate**  
   Undergraduate Student

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   Maria Reyes

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   Maria.Reyes@csulb.edu
**Institutional Background**

California State University Long Beach (CSULB) is the third largest campus of 23 campuses of the California State University (CSU) system and one of the largest universities in the state. CSULB is recognized as a university with outstanding education at an affordable cost and one of the largest and most culturally diverse universities in the world which makes the university an attractive option for incoming students. In Fall 2017, CSULB received more than 96,000 student application and finally admitting more than 37,000 students. Of the 36,822 students enrolled in the 2014-2015 academic year, ethnicity of student body distributed as follows: 36% Hispanics, 22% Asian American, 21% Caucasian, 4% African Americans, and 1% Native Americans admitting nearly 40% of the student from underrepresented groups. Because of the large number of Hispanic student body, CSULB has been designated as a Hispanic-Serving Institution by the U. S. Department of Education in 2007 and has been ranked as one of the top 10 universities in the nation to award degrees to Hispanics. Long Beach State is one of the West Coast’s top universities in terms of student body racial diversity, being named the 5th most diverse university in the West by U.S. News & World Report.

The university has been also ranked 4th or 5th (depending upon the year) by *U.S News & World Report* as the best public regional university in the western United States. In 2014, *Time* magazine ranked CSULB the 10th best value in the nation among all universities and colleges using new criteria defined from the White House that include accessibility and affordability with academic excellence. Princeton Review also ranks CSULB as a top 75 “Best value” university from the list of 150. The University is committed to being an outstanding teaching-intensive, research-driven university that emphasizes student engagement, scholarly and creative achievement, civic participation, and global perspectives which is reflected in the CSULB’s Mission statement: “California State University Long Beach is a diverse, student centered, globally-engaged public university committed to providing highly-valued undergraduate and graduate educational opportunities through superior teaching, research, creative activity and service for the people of California and the world”.

Among seven colleges in CSULB, the College of Engineering (COE) is the third largest college by the number of students’ enrollment in Fall 2015. As COE continues to grow and evolve, the college will remain dedicated to its mission: “to develop innovators who design and implement practical solutions to meet the ever-changing societal challenges of today and tomorrow”. The COE has established different programs and activities to engage students in hands-on activities that make the graduating student competitive to local engineering firms and agencies. For the best value for engineering careers, Payscale.com ranks the college as 7th in the nation. American Society of Engineering Education (ASEE) also recognizes the college in several other categories.
Among five departments, the Department of Civil Engineering and Construction Engineering Management (CECEM) is the second largest department in the College of Engineering. The program offers ABET accredited B.S. and M.S. degree in five specialty areas including structural, geotechnical, transportation, environmental and water resources engineering. The department has 20 full-time faculties with excellent records of research and professional experience. The faculties strive to achieve the program mission: “to educate and prepare students to succeed in the civil engineering profession by providing them with essential technical tools and skills which will enable them to perform current and future civil engineering tasks and to promote the need for lifelong learning”. They train the students with in class examples and involve both undergraduates and graduate students in their research projects to get hands-on experience. In 2005 and 2011, Dr. Antonella Sciortino and her team of students from the CECEM department received student grants from the Metropolitan Water District World Water Forum to conduct research on water conservation in a local community. Dr. Sultana, the current PI, and her graduate student have received Metropolitan Water District World Water Forum’s grant in 2015. They have presented their research at various regional and national conferences, published conference proceeding and with the final results, recently submitted a journal paper. Dr. Pitiporn Asvapathanagul and her students have also received this grant in 2015. This grant opportunity has encouraged our awardee students to grow professionally and encouraged them to continue their post graduate studies.

PROJECT DESCRIPTION
Introduction and Background
About 30% of California’s water resources depend upon winter precipitation and spring snowmelt runoff from the Sierra Nevada mountain range [1]. But, the state’s finite water supply is susceptible to drought [2]. Drought, simply defined as the difference between supply and demand of water, is an inevitable recurring phenomenon of this region. Therefore, in 2009, Senate Bill X7-7, also referred to as the 20x2020 Water Conservation Plan, set forth a statewide goal to achieve a 20 percent reduction in urban water use by the year 2020. But, the most recent drought years of 2014-2016 prompted Governor Brown to declare a state of drought emergency in January 2014, calling for voluntary water conservation measures to be taken throughout the state. CSU Interim Vice Chancellor responded by issuing a system wide memorandum asking all CSU campuses to reduce water usage in all possible areas. As the drought persisted, Governor Brown in April 2015 issued an Executive Order calling on the State Water Resources Control Board to issue mandates for water conservation to reduce urban water use by 25%. This was the first time water conservation had ever been mandated by the state [3].

In April 2017, following a very wet winter and successful conservation measures, Governor Brown ended the drought state of emergency in most of California, while maintaining water reporting requirements and prohibitions on wasteful practices, such as watering during or right
after rainfall. While the drought emergency is over for now, the mandate to achieve the 20% reduction still stands. CSULB acknowledges this urgent call to action and continues to take necessary steps to help achieve the water use reduction goal [3].

As part of CSULB’s overall sustainability goals, the campus has been implementing water conservation projects including transitioning to drought tolerant landscaping, converting landscape areas to drip irrigation, use of waterless and low flow urinals, installing touch free automatic faucets with low flow restrictors, installing weather based central irrigation controllers, and using reclaimed water for irrigation [4].

However, the campus has not yet considered rainwater harvesting potential in its water conservation project. Rainwater harvesting is an increasingly common practice in the US and other water stress regions as an attractive alternative for potable and non-potable (i.e., lawn irrigation) water use [5-]. A recent study by Summerville and Sultana (2017) have shown in semi-arid Southern California, from a 2-year design storm a city can save up to 2.8 million liters of water by installing a single 55-gallon size rain barrel. By increasing number of rain barrels, 29 million liter of conservation can be achieved. But, using a storage tank equivalent to 55 rain barrels the city can save 123 million liters [10].

The storage tank, from here on rainwater tank collects rain water runoff from roof top and so the reliability of the tanks is limited to the size of the roof top area [11]. Due to the size of residential lots and roof tops, the return period of investment for this rainwater tank can be 15 to 20 years [12]. This long return period of investment often discourages residents to adopt rainwater tanks. But, roof tops of commercial area are much larger footprint and as a result the payback period can be much shorter. Therefore, the primary objective of this project is to assess

(1) Size and location of rainwater tank within CSULB that can maximize reliability in water saving potential?
(2) Return of investment period.

The proposal seeks to develop a spreadsheet based water balance model for CSULB campus. To assess overall benefit of rainwater tanks, modeling of the tank water distribution system is much less costly than building the prototypes [4]. In addition, through model simulation, wide range of system design can be evaluated in a relatively short time to obtain optimum result. The project goal is contribute to CSULB’s campus wide Water Action Plan.
**METHOD**

**Water Balance Model:**
A spreadsheet based daily water balance model will be developed which will consider daily rainfall, contributing catchment (roof) area, losses due to leakage, spillage and evaporation, storage (tank) volume and landscape irrigation water uses. The daily runoff volume will be calculated from daily rainfall amount by multiplying the rainfall amount with the contributing roof area and deducting the losses. For this study, a 10% deduction loss will be applied to account for losses due to leakage, spilling and evaporation [13]. The model will assume that the generated runoff volume will fill the storage tank. If the accumulated runoff volume is bigger than available storage volume, excess water (overflow) will be deducted from the accumulated runoff. Then the available storage volume will be compared with the accumulated daily water demand.

![Flowchart of Water Balance Model](image)

*Fig 1. Water balance model for rainwater tank*

When sufficient amount of water is available in the storage tank, daily water demand for irrigation will be fulfilled using the water from the tank. Amount of water use(s) will be deducted from the daily accumulated/stored runoff amount. The model will assume the
remaining water demand will be met from the public water supply. Water balance model is described using the above flow chart where, $P$, $TW_t$, $TW_{t-1}$, and $W_{\text{demand}}$ are rain, tank water at time $t$ and $t-1$, and irrigation water demand, respectively.

Reliability of the tank will be calculated using the following equation:

$$R = \frac{N \times D_S}{NY \times D_R} \times 100\%$$

(1)

where, $R$ is reliability in percentage, $N$ is the number of day tank water was more or equal to the water demand, $D_S$ is the supplied demand, $NY$ is the number of days in a year, and $D_R$ is the demand requirement, respectively.

The model will be run using historical rainfall data including various climatic conditions – average, dry and wet years. Various tank sizes will be considered to find the optimum size that maximizes reliability under various climatic conditions.

The data required to develop the model is historical rainfall data, rooftop area, irrigation water demand and cost of water currently used for irrigation. The rainfall data will be collected from the National Climatic Data Center (NCDC), and rooftop area, water demand and cost data will be collected from the Facilities Management, CSULB.

**Project Study Site**

The site selected for this study is California State University Long Beach. The 322 acre campus is located at the crossroads of three major freeways and serves more than 37,000 students. This is the third largest campus of the 23-school California State University system.

The campus relies on water heavily and spends nearly $80,000 yearly to provide landscape irrigation, heating and air conditioning, domestic water use, dining services and campus swimming pools. According to the Water Action Plan final draft, CSULB has dropped water usage by 10% from 2014-2016 by transitioning to drought tolerant landscaping, converting landscape areas to drip irrigation, using waterless and low flow urinals, installing weather based central irrigation controllers and using reclaimed water for irrigation [3]. But, the campus is still making an effort to conserve water to reach 20 percent reduction in water usage by the year 2020. Water conservation using rainwater tank is an option that the campus did not implement yet. This study will provide tank reliability and payback period analysis which will assist Facilities Management’s decision making prior to the application of this conservation measure.

**ANTICIPATED OUTCOMES**

The anticipated outcomes of this modeling effort are both short term and long term. The immediate outcome of the project will be a development of water balance model for CSULB.
But the model will be transferable to any residential, commercial area to evaluate reliability of any given tank size. The results will help in identifying potential size and location of rainwater tank at CSULB in terms of maximizing campus’ objectives on water conservation plan.

If the system is adopted by the campus, in the long term, within CSU campuses CSULB will stand as an example of a sustainable system for water conservation. The system will save thousands of dollars spent yearly for landscape irrigation.

The study will give the opportunity to the undergraduate student to work with water balance model. She will learn design optimization, cost analysis and various other factors that affect decision making. She will learn data analysis and presentation of results. The student will also have the opportunity to share the results at regional and national conferences.

Finally, the results from this study will be used to develop lecture material and outreach activities to reach a larger audience of students and communities encouraging to adopt rainwater tank as an reliable water conservation option.

**Projected Project Benefits**

The modeling results from this project are expected to provide detail outcome of applying rainwater tank to conserve water. The campus can benefit from this study in the following areas:

1. **Makes more water available:** The objective of developing water balance model is to compute rooftop runoff and use it for irrigation. With an average annual rainfall of 19 in/year, it is expected that implementing rainwater tanks, the campus can save up to 25 million gallons of water per year by only capturing runoff from 50% of campus roof area.

2. **Savings on water bills:** The 322 acres of CSULB campus beautifully landscaped and maintained by irrigation. By using rainwater tanks, the campus can save $50,000 of water bills annually.

3. **Sustainable environment for the communities:** By conserving water, the entire community will benefit in is reduced demand on public water supply which will reduce cost of providing clean water. The community will benefit a sustainable environment and set up an example for other college campuses.

**FACULTY AND STUDENT EXPERTISE**

The proposed project will be carried out by a team of an undergraduate student and a faculty member at CSULB. The Faculty Project Manager, Dr. Rebeka Sultana is an Assistant Professor in the Department of Civil Engineering and Construction Engineering Management. Her area of expertise is Water Resources with a focus on hydrologic modeling, land surface modeling, and application of Remote sensing data in hydrology. Dr. Sultana teaches courses in Fluid
Mechanics, Engineering Hydraulics, Water Resources Engineering, Urban Surface Water Management, Advanced Hydrology, and GIS application in Water Resources. She is the author and co-author of several journal publications in her area of expertise. She has been working at CSULB since 2011 and since then she has advised several undergraduate and assisted the undergraduate students to receive CSU’s Water Resources Policy Initiative (WRPI) and US Department of Agriculture (USDA) internship to conduct research under her supervision. She has also advised several graduate students to towards their Master degree. Dr. Sultana and her graduate student received MWD World Water Forum award in 2015 and have presented their results at several regional and national conferences, published conference proceeding and submitted a journal paper. For this project, Dr. Sultana will be responsible to develop the water balance model and training model simulation to the undergraduate student.

Marvie Baconawa, the student project manager, will be a senior undergraduate student in the department of Civil Engineering and Construction Engineering Management (CECEM). Growing up in coastal areas of California, she has seen the impact of floods, droughts and challenges of local communities. Her interest in water issues has prompted her to choose Civil engineering as her major. Marvie has been one of the top 5% of student in all the three classes she took with Dr. Sultana. Her analytical skills helped her achieve good grades in these classes and will enhance the success of this proposed project.

**PROJECT TIMELINE**
The spreadsheet based water balance model requires data collection of the local rainfall, landscape irrigation water demand at CSULB and identifying buildings and rooftops from where rain water runoff will be collected. Once, the data is collected the model will be build and analyzed for different climatic conditions. If funded the following scheduled will be followed to achieve the project goal.

<table>
<thead>
<tr>
<th>Timeline</th>
<th>Project benchmarks</th>
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<tr>
<td>Summer 2017</td>
<td>Agreement executed, funds are disbursed to the college</td>
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<tr>
<td>Summer 2018-Fall 2018</td>
<td>Data collection, Water balance model development, Deriving results, Result analysis</td>
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<td>Spring 2019</td>
<td>Completion of the project, host community outreach event. and technical report</td>
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<tr>
<td>Spring 2019</td>
<td>Prepare technical report, present results at conferences. Attend MWD expo featuring student projects, presentations</td>
</tr>
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**PROJECT MANAGEMENT TEAM**

The following is the list of members of the project management teams.

<table>
<thead>
<tr>
<th>Timeline</th>
<th>Title/Organization</th>
<th>Address</th>
<th>Phone/Email</th>
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<tbody>
<tr>
<td>1</td>
<td>Rebeka Sultana, Ph.D</td>
<td>1250 Bellflower Blvd, Long Beach, CA 90840</td>
<td>562-985-5135 <a href="mailto:Rebeka.Sultana@csulb.edu">Rebeka.Sultana@csulb.edu</a></td>
</tr>
<tr>
<td>2</td>
<td>Marvie Baconawa</td>
<td>2815 West Carson Street, Torrance, CA 90503</td>
<td>530-488-8748 <a href="mailto:bmarvbee@gmail.com">bmarvbee@gmail.com</a></td>
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**BUDGET**

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<td>Matching Funds</td>
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**TOTAL** $12,500

**BUDGET BREAKDOWN**

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<td>Student stipend + 10.68% benefit – Marvie Baconawa</td>
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<tr>
<td>Salary</td>
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<td>Faculty salary for Summer Effort + 8.85% benefits</td>
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<td>Publication</td>
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**Total** $10,000
Support letter from Kaylee Weatherly, LB Water Department and Paul Wingco, Interim Director, Facilities Management, CSULB are attached.
References


Certificate of Participation

presented to

REBEKA SULTANA
CALIFORNIA STATE UNIVERSITY LONG BEACH
Thank you for participating in the
Southern California World Water Forum
College Grants Program on Innovative Conservation Technology, Communication and Policy.

October 13, 2017