# Challenges of Greywater Systems on College Campuses

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As water usage continues to grow, implementing technologies to conserve and reuse water become increasingly important on college campuses. Greywater systems are one such solution to conserve potable water use. As college campuses look to grow sustainably, this study is meant to be a tool to help campuses better understand the challenges of greywater systems in a dormitory setting. By analyzing two case studies of operational greywater projects, the feasibility of implementing a greywater system on a prospective campus is assessed, and the potential obstacles are addressed and avoided for future projects. Specifically, the analysis focuses on the design and maintenance of operational greywater projects to determine their respective challenges, lessons learned, and recommendations of future systems. The main recommendations for future projects are to implement larger greywater systems to take advantage of economies of scale, to prevent over-chlorination of greywater, and to train maintenance staff to effectively troubleshoot systems.

**Key Words**: Greywater, College Campus, Case Study, Dormitory, Sustainability, Maintenance

## Introduction

As water demand continues to grow in the United States, water conservation and water efficiency measures become increasingly important, especially when discussing more sustainable projects (EPA, n.d). Water conservation is the effort to use less water to meet needs and is often achieved by selecting fixtures, like low flow toilets, that use less water. Water efficiency is the idea that by being more efficient with the water available, water conservation can occur (Spahr, 2012). In a traditional water system, all a building's water demands are met with potable (drinkable) water. Potential water demands include sinks, showers, toilets, appliances, and irrigation systems. In many cases, not all the water for these uses needs to be potable. For instance, water for toilet flushing and irrigation, while it needs to be sanitary, does not need to be potable.

One of the primary ways to be more efficient with water usage is by using greywater and greywater treatment systems. Greywater is relatively clean waste water and can come from sinks, showers, washers, and dishwaters. A greywater treatment system, also known as a greywater harvesting system or a greywater system, is an on-site treatment system that treats greywater with the intention of reusing that water to meet toilet flushing and/or irrigation needs, so potable water does not have to be used for these uses. By reusing water, potable water can be conserved. The way a greywater system works is by collecting water from any combination of sinks, showers, and appliances, filtering out any particulate, treating the water to a safe condition, and then pumping the water to its intended use, typically to flush toilets, or to provide irrigation to an area. The steps of a typical greywater system can be seen in the list below.

1. Greywater flows into the treatment system and is collected in settling tanks
2. Greywater is pumped through a series of increasingly finer filters
3. Greywater is treated with chlorine to a sanitary condition
4. Treated water is dyed a color to identify it as greywater
5. Treated water is sent to holding tanks
6. Treated water is pumped to toilets for flushing

Greywater systems can vary greatly depending on their size and the intended use of the greywater. Because this research looks to compare two case studies, it is important to look at systems with the same applications so that comparisons can be meaningful. Greywater systems were selected for use and setting. Only systems that used greywater for flushing were analyzed. Greywater systems that served irrigation needs were excluded. Also, within a campus setting, greywater systems could be implemented on a variety of building types. Comparing two different building types may yield results that are difficult to compare. For example, comparing a greywater system in a dormitory to a greywater system in a laboratory may lead to inaccurate comparisons because the challenges that exist for each system may be dependent on the function of the building. To help control for this, only dormitories were selected and compared.

The purpose of this study is to develop a better understanding of greywater treatment systems and their use to meet toilet flushing needs in college dormitories. The research question guiding this study is: what challenges surround the design and maintenance of greywater systems on college campuses? Based off a preliminary understanding of greywater systems, a lack of economic feasibility, and ongoing greywater system maintenance issues are expected to exist.

## Literature Review

Colleges are growing. From 2014 to 2025, college enrollment is projected to increase by 15% (Lederman, 2017). As colleges expand to accommodate the increasing student population, many are looking grow sustainably. The value of sustainability is not new in the realm of higher education, but more colleges are recognizing that students value a campus' commitment to environmental issues (AASHE, 2009). As campuses make good on those commitments, they seek to implement green principles in campus programs and constructions. One of the quintessential tenants of sustainable commitment is the commitment to conserve resources. As campuses look to grow sustainably, one such way is through the use of greywater systems to reduce potable water consumption.

To help understand the state of greywater systems on college campuses, this research used the project catalog from the company Wahaso, Water Harvesting Solutions. Wahaso was selected because of their involvement with one of the case studies analyzed in this research. There are no companies with a long track record of designing and delivering greywater systems of the scale required for a college campus (Hueston, 2018). From their catalog of projects, University of California Los Angeles (UCLA), University of Colorado Boulder, and West Texas A&M were the only projects on a college campus with greywater harvesting systems.

Currently, there are multiple colleges implementing greywater harvesting systems or gauging community interest in systems. Greywater reuse systems were installed at the University of Witwatersrand, Johannesburg and University of Johannesburg in South Africa to gauge the attributes of greywater that were important to the end user, and to test the economic feasibility of greywater reuse systems (Ilemobade et al., 2013). Their study was conducted in response to the growing interest of water reuse worldwide and specifically in South Africa. The study surveyed the users of the system to highlight perceptions of greywater. One of the perceptions included the preference to use greywater for toilet flushing instead of irrigation. Respondents also ranked attributes important to them when using greywater, the top two of which were smell and color. In terms of economic feasibility, both greywater systems were found unfeasible in terms of payback period, net present value, and cost-benefit analysis.

Other schools examined the feasibility for greywater systems on their campuses as well. A feasibility analysis of greywater was conducted at Worcester Polytechnic Institute. A greywater system could reduce freshwater usage, but there is a large initial cost, and the system would require significant planning and the cost of new plumbing infrastructure (Weiler et al., 2012). A system was not determined economically feasible for the campus.

Spahr (2012) examined the challenges that exist for implementing a greywater harvesting system in Boulder Colorado. The system was the Williams Village North greywater system, and at the time of the thesis' publication, the system was not yet operational. This study was comprehensive in its approach to feasibility. It assessed economic feasibility by predicting water use and occupancy data. Predictions were based on surrounding dormitories on the campus. The economic analysis of the project was assessed by the following criteria: physical efficiency, economic efficiency, institutional efficiency, social efficiency, environmental efficiency, technological efficiency, and overall water use efficiency. The study concluded that the greywater system would be positive in every aspect except for the economic and technological efficiencies. This is to say that a system is not economically feasible and that the technology for greywater systems does not exceed the practicality of current technology. Spahr also gauged the feasibility of the greywater system through the legal lens. The study examined the challenges posed by the water rights laws in Boulder, Colorado, and the permitting process the greywater system would have to undergo to see success. What Spahr found was that the scope of this project was not violating municipal water rights, and because the state of Colorado was currently working on regulations regarding greywater use, the permitting process was not well defined. As such, the project would have to work closely with the city of Boulder to ensure compliance and to navigate the changing legal climate.

## Research Design

This research used a case study methodology. The two case studies selected were the Longstreet-Means greywater system at Emory University and the Williams Village North greywater system at the University of Colorado Boulder. This case study analysis compared two greywater systems on college campuses to identify challenges surrounding the maintenance and operation of greywater systems in campus dormitories. By looking at two systems that serve the same purpose, meeting flushing needs of toilets, issues can be uncovered that both systems may experience and ways to improve future systems can be assessed.

An overview of the research steps is provided below.

1. Literature Review
2. Selection two greywater systems to assess
3. Analysis of available design data
4. Interview with key stakeholders of the systems
5. Compare the systems to identify challenges and recommendations to improve greywater systems for future campuses

Research began after reviewing literature and identifying potential case studies. After selecting which case studies to research, publically available data on each system was reviewed. Once the foundational information of each system was established, research shifted to identifying the challenges associated with each system. The primary method of collecting information about the greywater systems was via interviews with the maintenance staff of the system. More so than the other stakeholders of a greywater system (the engineers, designers, owner, or end user) maintenance staff understand what costs, challenges, and everyday maintenance are needed on a system to keep it functional. After the interview, those interviewed were available for follow up questions and clarifications.

There were two interviews conducted, one per case study. Each interview was approximately one hour in length. The goal of each interview was to confirm the understanding found in the independent research was correct, then to identify and understand the challenges of the system, and to hear the recommendations of the interviewee on how to improve the system. Example of interview questions are shown in Table 1.

Table 1

***Example of Interview Questions***

| Category | Questions |
|---|---|
| **Operation** | • Can you confirm the size and scope of your system?<br>• What fixtures contributed greywater to the system?<br>• How long has the greywater system been operational, or how long was it in operation?<br>• How much greywater does the system handle? Is it more than or less than was predicted? |
| **Maintenance** | • How much time each week is devoted to maintenance?<br>• Beyond labor, what kind of materials and cost did you have due to maintenance?<br>• How often did the filters have to be cleaned?<br>• What does maintenance of the system look like? |
| **Challenges** | • What issues and challenges have you or others experienced with the system?<br>• With concerns to maintenance, how would you classify the issues? Are they issues that stem from design? Are they unique challenges from working on a school campus? |

Table 1 (cont.)

***Example of Interview Questions***

| Category | Questions |
| --- | --- |
| **Lesson Learned** | • What lessons have you learned from this system?<br>• If another campus were looking to have a greywater system on campus, what advice would you give them?<br>• Could you share any additional information that will be relevant to know from this greywater system? |

## Results

### *Case Study One: Longstreet-Means Greywater System at Emory University*

The Longstreet-Means system was operational on Emory's campus in 2010 and is no longer operational. At the time of writing, it is currently being converted to part of the campus's reclaimed water system due to ongoing maintenance issues. The results of this case study came from a personal interview with the Operations and Maintenance Supervisor at Emory.

The Longstreet-Means system had an initial cost of approximately $2,000,000 and collected water from the sinks, showers, washers, and dishwashers of the Longstreet-Means dormitory. During its operation, it collected approximately 12,000 gallons of greywater each day. Over the course of a year, the system conserved about 4,000,000 gallons of potable water (Lynch et al., 2009). The water claimed by the treatment system was over triple the dormitories flushing needs, so the greywater system was piped to offset the flushing needs of the two adjacent buildings as well.

The first challenge with the system was treating the greywater to a sanitary condition. The greywater holds a bacteria profile that is an amalgamation of all its collection sources. Because the contents of the greywater fluctuate depending on the source water, the treatment of the water to a sanitary condition is a moving target. The maintenance staff had difficulty getting the amount of chlorine needed for treatment correct. This led to two cases. Either the greywater would be under-chlorinated or over-chlorinated. Under chlorinated water is a health hazard to the end users, so maintenance staff would ere on the side of safety and frequently over-chlorinated the greywater. Over-chlorination of the greywater gradually broke down the rubber components of the toilets that received the treated water and resulted in multiple leaky toilets.

The next issue stemmed from stagnant greywater in the system. As greywater entered the two 3,000 gallon collection tanks, it sat stagnant until it could flow into the filtration portion of the system. So much stagnant greywater created a constant smell in the treatment area that became a constant issue for the maintenance staff. If greywater sits for an extended period, the bacteria in the will begin to propagate, requiring more treatment ("Grey Water Treatment," n.d.). Because of this principle, whenever students left the dormitory for an extended period, for winter holiday and summer holiday, to prevent water sitting stagnant in the system, the system had to be drained and backflushed. Draining the holding tanks required 6000 gallons of greywater to be dumped, and the backflush took an additional 1200 gallons of potable water.

The final issue was the high cost of maintenance, which ultimately led to the decommissioning of the system. In addition to the maintenance required of the issues mentioned above, the system needed extensive regular maintenance. To keep the system operational took twenty man-hours each week. Staff had to come in every other day to open pumps and clean filters because hair and other particulate was constantly clogging the filters. Maintenance was understaffed and undertrained on the system. This prolonged the maintenance process and increased maintenance cost.

At the end of the interview, Lance Brock gave recommendations for future greywater systems. To prevent an ongoing issue of smell, recirculation pumps should be placed in the collection and holding tanks. If the issue of over-chlorination can't be addressed in the treatment system, then the fixtures need to be periodically monitored to replace rubber components on toilets as needed. The system should also select for tanks that can be easily drained and cleaned, to save time on the semi-annual dumping and backflushing. Finally, a campus needs to be prepared for the cost of maintenance. Understaffed maintenance teams drag out the cost of maintenance. In addition, the staff needs to be trained on the science and intricacies of the greywater system to effectively maintain it.

### *Case Study Two: Williams Village North Greywater System at University of Colorado Boulder*

Located at the University of Colorado Boulder, the Williams Village North greywater system is currently collecting about 3,000 gallons of water each day of its operation to offset roughly 66% of the dormitory's needs. It collects water from the sinks and showers in a portion of the building. The initial cost of the system is approximately $1,000,000, with $500,000 accounting for the additional piping and $250,000 for the greywater treatment system itself. The remainder of the cost is an estimation giving by the interviewee as an approximate lump sum of all other items. The results of this case study come from an interview with the technician who maintains the system.

When the system first became operational, like the Longstreet-Means system, it experienced the issue of over-chlorination. Over-chlorination led to damage to the rubber components of the toilets that received the treated water and resulted in leaky toilets. The chlorine also damaged the stainless steel components of the treatment system. The issue of over-chlorination stemmed from technological difficulties regarding the chlorine sensors that were used in the treatment systems. Sometimes the sensors were not operational and had to be troubleshot to work again. When they were operational, they didn't have the ability to read chlorine levels to a level of accuracy that would prevent over-chlorination.

The system needs ongoing maintenance to remain operational. Components often need troubleshooting that the maintenance staff isn't well equipped to deal with. This leads maintenance staff to tinker with the system as if it were a science experiment. In addition, the system was predicted to collect 4,500 gallons of greywater each day to meet all the flushing needs of the building. Collecting only 3,500 gallons causes the system to run dry throughout the day. The constant wetting and drying of the system components decreases their lifespan, which increases maintenance cost. Finally, the system needs to be flushed out and cleaned once a year, when students leave for the summer holiday. Backflushing the system takes about fifty gallons of water each night, and one hundred gallons of water are used to clean the tanks.

Another challenge was experienced with the computerized portions of the control system, the booster pump panel, and the main control panel. CU Boulder's campus has access restrictions in place for their internet security. Because of this, when system software needed to be patched or updated, the company in charge of this could not resolve these issues remotely via the internet. Instead, the system must be downloaded onto flash drives and mailed to the company. The company then must troubleshoot and update the system on their devices, before mailing back an updated system to the campus. This method of troubleshooting is far longer and expensive than allowing access to the company to resolve issues via the internet.

The final issue surrounding the greywater system in Williams Village North is the unused components in the system. There are chlorine sensors for the initial settling tanks, but the greywater isn't treated with chlorine until after it leaves these tanks. These sensors range from $5,000-$8,000. Additionally, there is a redundant pinch valve to the system. Pinch valves are used to shut off the flow of water coming to the system. Each valve costs about $25,000. Some of these components were required due to legal reasons, though the legal challenges of water reuse are not explored in this study because they can vary so much due to location.

To improve systems, Edgar Pinon recommended that the only way systems will make a meaningful impact and increase their economic feasibility is through economies of scale, so a large system is recommended. Eliminating unnecessary components cuts down on cost as well. This greywater treatment system is in the basement of the building, so water must be pumped throughout the building to reach toilets. If the system was instead designed to be gravity fed and placed at the top of the building, pumps would only be needed for the initial collection of greywater, so the system would be more energy efficient and not need as many pumps. Also, many of the issues this greywater system experienced come from technology. As the sensors that are needed improve, the price will decrease and the issue of over-chlorination will be more easily avoided. Lastly, maintenance staff needs the education and ability to maintain the system. By having to outsource the troubleshooting and technological issues, the maintenance process slows down.

## Discussion

Going into the case studies, there was no expectation of economic feasibility. The literature reviewed yielded no projects that had a meaningful payback period. This assumption was echoed in the findings of the research, and again from the interviews conducted. For example, during the operation of Emory University's system was saving about 12,000 gallons of potable water per day. At that time, Emory was purchasing water at rates between $18 to $19 per 1,000 gallons (Brock, 2018). The water savings equated to $216-$228 each day. For a system with an initial cost of $2,000,000, it would take approximately 8,772 to 9,260 days to recoup that cost. That is a payback period of about twenty-five years. Costs for the labor, materials, and equipment could not be determined in the research; however, when the labor cost of twenty hours of maintenance per week, and the cost of equipment and materials are considered, the payback on such a system is easily extended beyond the twenty-five-year mark. Table 2 shows a summary of the two greywater systems.

Table 2

***Greywater System Comparison***

| | **Longstreet-Means System** | **Williams Village North System** |
|---|---|---|
| **Approximate Initial Cost** | $2,000,000 | $1,000,000 |
| **Collection Sources** | Sinks, Showers, Washers, Dishwashers | Sinks, Showers |
| **Greywater Treated per Day** | 12,000 gal. | 3,000 gal. |
| **Challenges** | Over-chlorination, stagnant greywater, high maintenance cost | Over-chlorination, high maintenance cost, technology troubleshooting, unused components |

The case of Williams Village North at University of Colorado Boulder tells a similar story. This system had an initial cost of approximately $1,000,000, saving about 3,000 gallons of water each day, at a rate of $17 per 1,000 gallons, (Pinon, 2018). The system would take about 53 years to pay off, not factoring in maintenance costs. Both payback periods assume year-round operation, which is not the case, but the exact number operational days each year could not be determined.

Both case studies faced the issue of over-chlorination. Williams Village North, unlike Longstreet-Means, was able to resolve the issue of over-chlorination. Williams Village North restructured their treatment schedule. They added iodine to the greywater as it entered the holding tanks, filtered their water with their filtration skid, and only upon the greywater entering the processed water tanks, did they chlorinate it to meet city and state water regulations (Pinon, 2018). By adding chlorine at the end of the treatment process, the water was relatively clean and needed much less chlorine to be a sanitary product, so it made it easier to chlorinate the water within a safe margin, thus eliminating the issue of under or over-chlorinating the water.

Both case studies encountered trouble with the systems that stemmed from a campus setting. Because of a lack of residents in the dormitories, the systems were not operational during periods of the year. Emory had to shut off the system during the summer holiday and the winter holiday break. University of Colorado ran the system throughout the winter holiday and shut off the system during the summer for cleaning and maintenance. University of Colorado also had the issue of campus internet security interfering with the maintenance of their system, as the software needs to be patched or updated.

## Conclusions

This research was conducted to find what challenges were associated with greywater systems on college campuses and how these systems could be improved. Perhaps the largest challenge is the lack of economic returns on a greywater system. The other main challenges included maintenance cost, over-chlorination issues, and campus challenges that included breaks in dormitory occupancy and internet security. As future projects involving greywater come underway, properly planning the greywater system and managing its maintenance are essential to the system's success.

One recommendation for future systems are to make the system large to make a system more cost-effective and to offset a meaningful amount of water. Systems should put measures in place to monitor chlorine levels, and prevent over-chlorination. Measures could be design based, like the Williams Village North System treating greywater first with iodine, or measures could be taken in the form or monitoring and quality control. Also important is to give maintenance staff the tools to be successful in ensuring the system runs smoothly. This means educating staff on the greywater system and giving them to tools and permissions to solve issues timely and effectively.

While the information found through the analysis of these two case studies is useful in helping guide the design and maintenance of future greywater systems for college campuses, the research does have its limitations. Only two case studies were analyzed, so generalizations about greywater systems should be avoided. There is limited availability for research surrounding greywater application on college campuses. There were other colleges with greywater systems that were contacted but none replied to contribute to the research. The importance of this research is closely related to its limitations. There is a lack of availability of information regarding greywater systems for college campuses. Colleges willingly sharing information about their experiences around greywater is integral to those looking to implement greywater systems in the future.

Future research should be done in a few areas. Research should be expanded to other campuses that use greywater, not just for toilet flushing, but also irrigation. While the systems will differ in their design, many of the challenges faced by greywater systems may be present, regardless of the intended system use. Also, research should be done to see how city codes and laws influence the design of greywater systems. While laws vary regionally, understanding the barriers that may shy college campuses away from attempting greywater projects are important to understanding if greywater systems are to become more commonplace.

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