Reducing Potable Water Demand in the Campus Instructional Facility (CIF)

By: Juliette Deley, Ethan Kimbarovsky, Alex Sherman, and Sam Sorkin

December 9, 2023

Milestone #3

CEE 190

Reducing Potable Water Demand in the Campus Instructional Facility

Introduction

Currently, Illinois is using water at an unsustainable rate. Researching methods of water conservation is necessary in order to avoid the depletion of the Mahomet Aquifer in central Illinois. Unsustainable water usage, combined with drought – 59.1% of the state of Illinois (including the Urbana-Champaign area) is classified as abnormally dry with the moisture index being between -1.0 and -1.9 (National Integrated Drought Information System 2023, **Figure 1**) – makes the depletion of the Mahomet Aquifer an urgent issue in the Urbana-Champaign area. With the majority of counties in central Illinois drawing water from the Mahomet aquifer, water demands are only predicted to be met through 2050 (iCAP 2011). Depletion of the Mahomet Aquifer would negatively affect residents and businesses in the state of Illinois. Although water demand is an issue across Illinois, this study will focus on reducing the potable water demand of the Campus Instructional Facility (CIF) on the University of Illinois Urbana-Champaign (UIUC) campus (**Figure 2**). The CIF was chosen as the location for this study due to it being a modern building which is able to track its water usage, meaning there is plenty of data available. Furthermore, the CIF receives large amounts of traffic due to the amount of classes hosted and the cafe located on the ground floor resulting in large amounts of water use. For this reason, the CIF is an excellent candidate for implementing a solution to reduce potable water usage.

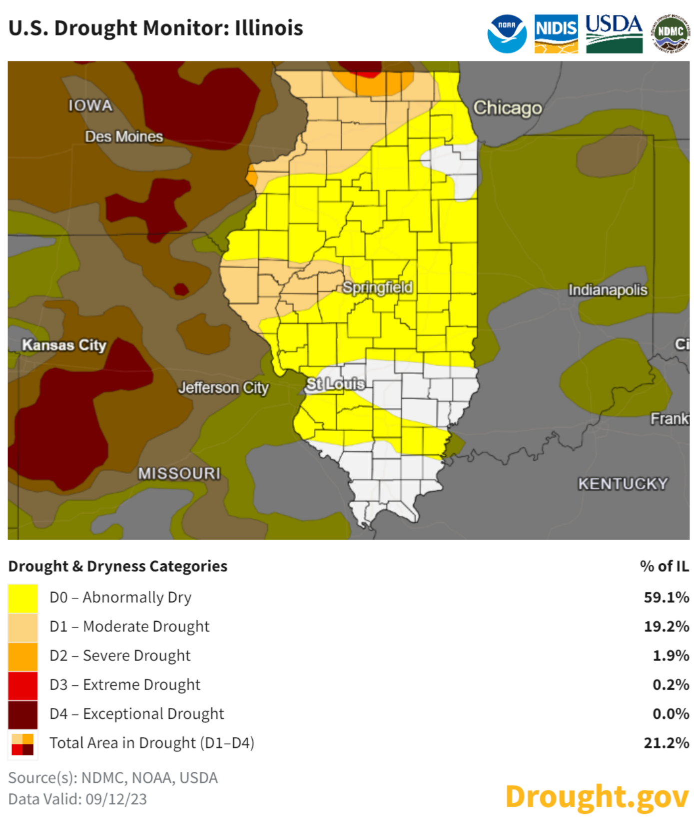

Figure 1. Regions of drought in Illinois (Adapted from National Integrated Drought Information System 2023)

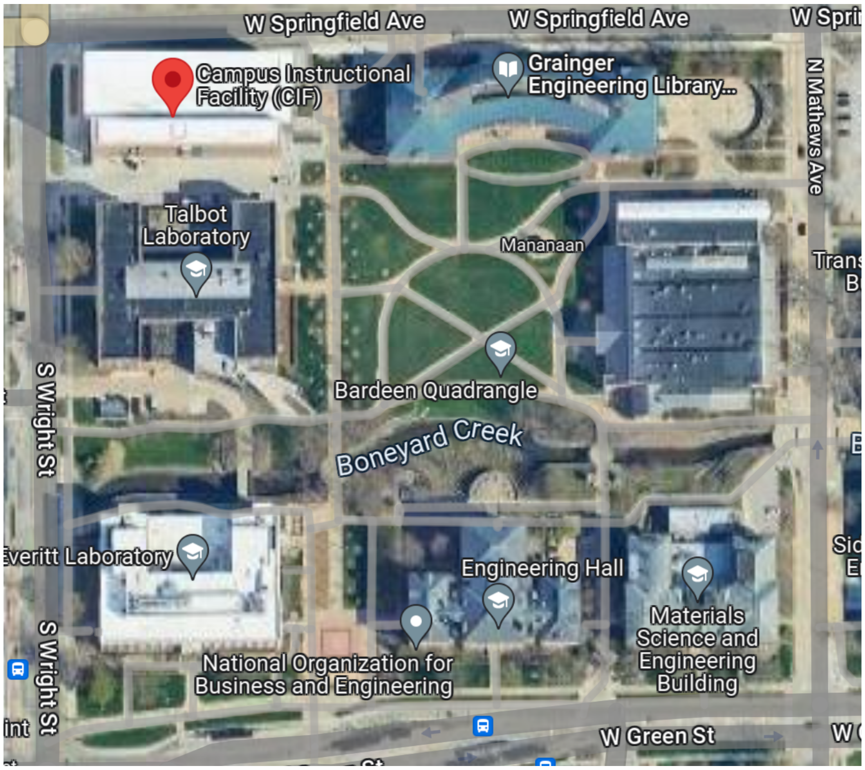

Figure 2. Location map for CIF (Adapted from Google Maps 2023)

In the past, UIUC has explored multiple options to increase the efficiency of its water consumption. UIUC has implemented dual flush toilets, which reduce the amount of water used by 60% per flush (Institute for Sustainability, Energy, & Environment 2022). However, this method depends on individual users using the water saving flush to reduce the water consumption. In addition to installing dual flush toilets, UIUC has also upgraded its plumbing system to reduce the amount of leaks (Institute for Sustainability, Energy, & Environment 2022). It is unclear how much water is being saved from upgrading the plumbing system because there was no quantifiable data about the plumbing system specifically; however, it is assumed that the reduced amount of leaks reduced the potable water consumption. While this decreases the total water usage resulting from a reduction in water loss from leaks, it does not decrease the water demand.

A possible new solution would be to implement a greywater system in CIF. Greywater is relatively clean wastewater that does not contain toxic chemicals or excrement (Ghaitidak and Yadav 2013). The greywater system would help reduce potable water usage by reusing the water from sinks and water fountains to flush toilets. Furthermore, excess greywater could be used to irrigate surrounding plants (Oteng-Peprah et al. 2018). A common argument against the usage of greywater to irrigate plants is that it is harmful for the environment, however, research has found that greywater causes negligible effects to surrounding areas (Filali et. al 2022). Greywater can reduce the water demand on the Mahomet Aquifer but would be expensive and difficult to schedule. Currently, there is no clear legislation regarding the use of greywater in Illinois (Cabonargi and Hansen 2011). However, this is expected to change as water becomes increasingly limited.

Objective

The objective of this study was to determine the feasibility of reducing the potable water demand of CIF by using recycled greywater. The feasibility study looked at construction costs and water conservation to determine feasibility. Benefits of the projects included reducing the potable water demand of CIF and a decreased campus water bill. Negatives of the projects included initial construction costs and the unclear greywater regulations that would prevent the immediate implementation of the solution. The final project report will be delivered to a panel of judges appointed by the University of Illinois on December 6th.

Methodology

The main tasks of this study were to review studies regarding the effectiveness of greywater on reducing potable water demand, evaluate the benefits and negative consequences of implementing a greywater system, and determine the project's financial feasibility. These broad tasks were broken into subtasks to consider the multitude of variables that went into each aspect of the project. All tasks were completed, and no significant changes were made to the scope of the study.

Case Studies and Literature Review

In a literature review, multiple scholarly sources were reviewed in order to determine if the use of a greywater system could potentially reduce the potable water demand of the CIF. Many case studies were also done to determine possible challenges the implementation of a greywater system might face. A case study of a similar building on campus (Business Instructional Facility) with a greywater system was also done to ensure greywater systems could be compatible with UIUC standards. Based on the literature review and case studies, it was determined that a greywater system could reduce the potable water demand of the CIF. Once this was decided, further literature review was conducted in order to determine the origin of the greywater supply. The origin of the greywater was determined to be the sinks and water fountains of the CIF due to the consistency of their supply of recyclable water.

Water Conservation Data Collection and Evaluation

The data used in the study was provided by UIUC Facilities and Services through the EBS Web System which tracks UIUC utility usage and cost. Data was collected and compiled on the total water usage of CIF and the utility cost of the CIF water. Since the CIF does not track greywater production, a similar campus building, the Business Instructional Facility (BIF) was used as a comparison. This information helped create comparisons between the existing greywater system, and a possible greywater system in the CIF. Possible uses of greywater and a calculation of the total water savings resulting from the project were also confirmed.

Financial Feasibility

To determine financial feasibility, a parametric cost estimate was conducted. The cost of similar greywater system installation projects were obtained and scaled by square footage to the size of the CIF to provide an estimated cost. The projected cost for the project was determined by using the average scaled cost of the similar greywater projects. The payback period for the project was determined by dividing the projected cost of the project by the projected yearly savings of the project. See **Appendix A** for the specific calculations for projected cost and payback period.

Results and Discussion

The first task of this project was to perform a literature review and analyze similar projects to determine if installing a greywater system could be a viable solution in reducing potable water demand. In the literature review it was found that greywater has the potential to reduce potable water consumption because it is relatively inexpensive to treat and has a low potential to harm the environment (Redwood 2008). This means that greywater could be used for the CIF.

Water Consumption

A study on water consumption in educational buildings found that of total water consumed, about 40% could be recycled as greywater and about 30% was used to flush toilets (Surendran and Wheatley 1998). This means that the potable water consumption of CIF could potentially be decreased by 30%, and the remaining 10% of greywater produced by the building can be used for other purposes as discussed later.

Another important aspect of the first task was determining the source of greywater. The sources considered for this project were greywater producers from within the CIF, rainwater, and a combined system of greywater producers and rainwater. Ultimately, it was decided that the source of greywater for this project will be specifically CIF greywater producers. Rainwater was not chosen due to its intermittency. The combined rainwater and CIF system was not chosen because of the additional cost of adding a rainwater capturing system. The sources of greywater were chosen to be the CIF only system because of the consistent supply and availability of recycled water. **Figure 3** illustrates a similar system that is being proposed for the CIF. Greywater will be taken from sinks and water fountains for the purposes of this project and will be used for toilet flushing and garden irrigation depending on the greywater production and potable water demand.

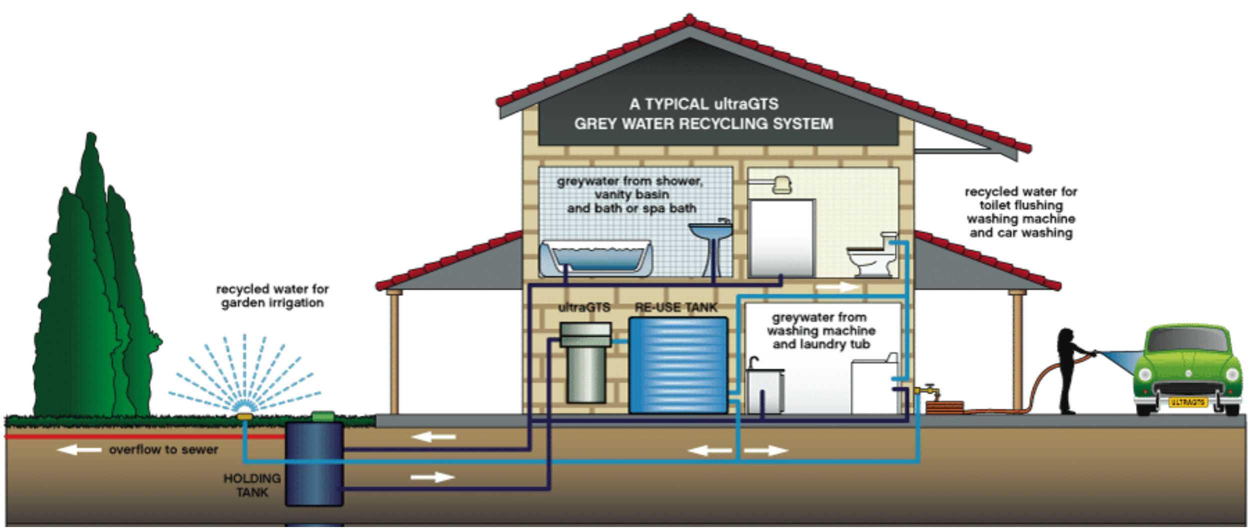

Figure 3. A replica of a greywater system (Adapted from Econocycle n.d.)

The CIF does not measure greywater production data, and as a result, a comparable educational building on the UIUC campus, the Business Instructional Facility (BIF), which does track the daily production of greywater from sinks and water fountains, will be used to estimate greywater production data for the CIF. In order to accurately estimate the greywater production in the CIF, BIF greywater consumption data must be scaled. This was done by taking the percentage of total water usage in the month of September 2022 from both buildings, and creating a ratio. September 2022 was chosen as the month of campison because it is during a standard school year post-pandemic. Given that both buildings are similar in their purpose, facilities, and size, using a ratio is an accurate comparison strategy. As shown in **Figure 4**, the BIF produced 10.91 kgal of greywater in September of 2022 and used a total of 76.31 kgal of water. That means that the ratio of greywater produced to total water used is (0.143):(1.0). The CIF total water usage in September 2022 was 32.36 kgal, and using the ratio, the estimated greywater production in the CIF was 4.63 kgal. Given that September 2022 was a low usage month for the CIF and an average usage month for the BIF, that number may be artificially low, and more greywater may be produced than estimated. Generally though, this figure shows that on average 14.3% of the total water usage can be recycled as greywater in the CIF, which is much significantly lower than the estimated 40% found in the study, making that statistic inaccurate for the purposes of this report (Surendran and Wheatley 1998). Since neither the BIF or CIF track toilet water use, the study's statistic of 30% of water used in educational facilities flushes toilets is assumed to be true for this feasibility study.

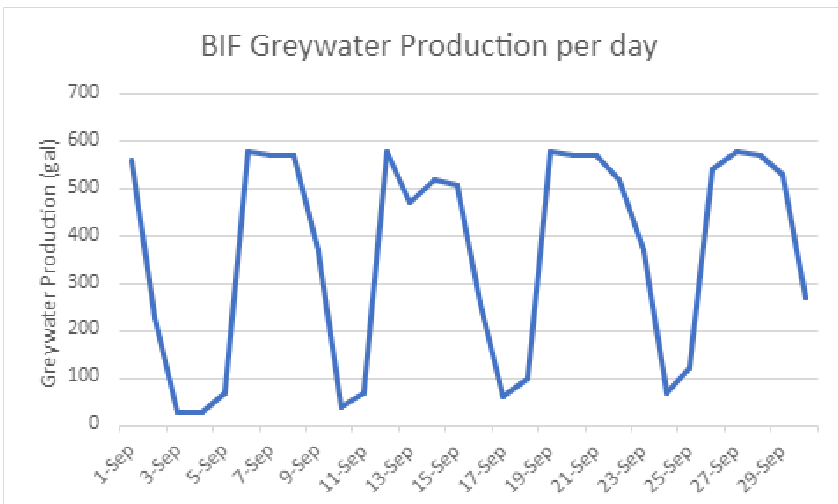

Figure 4. Business Instructional Facility (BIF) daily greywater production (adapted from EBS Web eDNA Billing System)

Data collected on the water usage in the CIF indicates that the mean usage per month is around 57.5 kilogallons (kgal) (**Figure 5**). This indicates a consistent water use in the CIF, and projects to serve well in a greywater system, being that a lower amount of potable water will be necessary to serve greywater functions. Scaling the 14.3% figure to this average usage per month for the CIF reveals an average greywater production of 8.22 kgal/month, which would reduce the water consumption by toilets from 17.3 kgal/month to 9.2 kgal/month. These characteristics separate the CIF from other education buildings on the UIUC campus, projecting that a greywater system in this building may be feasible for reducing potable water demand.

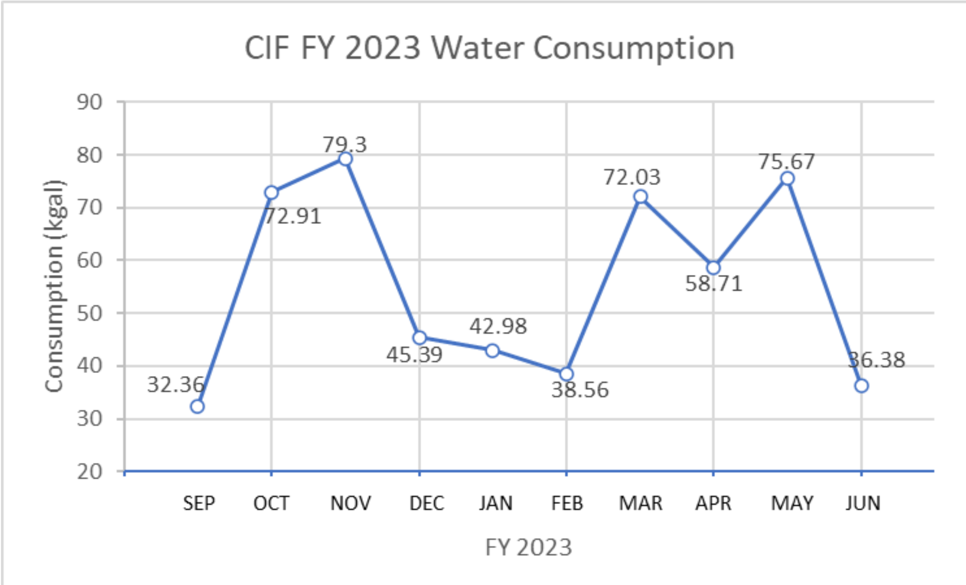

Figure 5. FY 2023 (SEP-JUN) water consumption of CIF (adapted from EBS Web eDNA Billing System)

Water Cost Data

Table 1. CIF fiscal water consumption rates (EBS Web eDNA Billing System)

1545 - Campus Instructional Facility									
	FY 2022			FY 2023			FY 2024		
	Cost	Billing Days (Average)	Degree Days	Cost	Billing Days (Average)	Degree Days	Cost	Billing Days (Average)	Degree Days
JUL	$22,002.99	32	288	$21,541.99	90	356	$26,391.45	34	334
AUG	$15,592.00	30	339	$22,509.91	30	286	$25,188.38	24	281
SEP	$19,175.98	32	220	$21,811.37	30	219	$31,429.80	30	148
OCT	$19,366.19	28	280	$34,862.26	29	365	$27,593.63	29	--
NOV	$20,725.49	30	758	$19,902.57	30	678	--	--	--
DEC	$16,158.83	30	786	$16,551.73	30	1094	--	--	--
JAN	$16,859.99	30	1324	$32,580.96	76	960	--	--	--
FEB	$16,103.26	30	1099	$23,002.10	31	812	--	--	--
MAR	$17,352.52	24	701	$20,509.39	27	771	--	--	--
APR	$16,795.49	32	505	$21,377.68	30	374	--	--	--
MAY	$15,648.60	27	251	$21,717.83	29	173	--	--	--
JUN	$11,578.47	30	292	$23,052.07	30	239	--	--	--
Overall	$207,359.80	29	6,843	$279,419.86	38	6,327	$110,603.26	29	763

The data in **Table 1** was provided by Kate Brewster, the Information Technology Specialist for the Facilities and Services Department. As shown in **Table 1**, the CIF currently uses an average of $243,000 worth of water every year. If greywater were to account for 14.3% of the current total water use, the average yearly water bill would decrease to around $208,000. Increasing inflation rates and water scarcity lead to assumptions that the cost of water will continually increase (Bluefield Research 2021). Additionally, UIUC enrollment rates continue to grow as years go by, meaning that the university's overall water demand will increase.

Cost Estimate

Table 2 is a top-down cost estimation of the proposed solution. Using similar greywater system installation projects, the project cost was estimated to be $293,500. The main assumption made during the cost estimation was that the cost per square foot of installing a greywater system would hold constant when scaled up and did not depend on location. In addition, these greywater systems were implemented simultaneously with the construction of the building, while the CIF has already been built and would need to remove parts of the current plumbing system. It is important to keep in mind that the partial deconstruction required to implement a greywater system in the CIF was not calculated in this cost estimate.

Table 2. Parametric cost analysis citing previous greywater projects

Project	Installation Cost	Size of Building (sq. ft)	Cost/sq. foot	Scaled Cost (CIF = 124,000 sq. ft.)
CSU Case Study (Roesner and Shareville 2015)	$66,500	146,870	$0.45	$55,800
Arch Nexus SAC (n.d. 2019)	$50,000	8,252	$6.06	$751,440
Business Center (Munoz 2016)	$119,210	326,000	$0.37	$45,880
			Projected Cost	**$293,500**

The projected cost of the greywater system implementation adjusted for inflation is $293,500. Since the greywater system saves 14.3% of current used potable water, the CIF would save $35,000 yearly in its water bill, with a projected project implementation payback period of 8.4 years. Specific calculations deriving the figures in **Table 2**, the yearly savings, and the payback period are located in **Appendix A**. Based on the payback period, implementation of a greywater system is financially feasible in the CIF.

Conclusions

This study examined the feasibility of reducing the potable water demand of the CIF, located on the University of Illinois Urbana-Champaign's campus, using a greywater system. Due to increasing water shortages in Illinois, 59.1% of the state is classified to be abnormally dry, including the location of UIUC, a solution to reducing potable water demand is necessary (National Integrated Drought Information System 2023). The proposed solution, which was decided through extensive literature review and data collection, was a greywater filtration system, which reduces potable water demand by recycling water from sinks and water fountains then using it to flush toilets. Data was collected regarding current water consumption rates in the CIF and comparing it to BIF greywater production to predict that the CIF could reuse 14.3% of its current water consumption as greywater. Through a top down cost estimation, it was estimated that project implementation would cost around $293,500 and would have a payback period of approximately 8.4 years. It is important to note that since the CIF has already been built, removing current plumbing in the CIF would be necessary to implement and has not been calculated into the cost estimation. The results of the study support the hypothesis that a greywater system is justified and the project should proceed to the preliminary design phase in preparation to seek public feedback.

Acknowledgements

We would like to thank Kate Brewster from Facilities and Services for providing us with essential CIF and BIF water consumption data. We would also like to thank Professor Schmidt for guidance and feedback on the content of the report. Additionally, we would like to acknowledge the help we have received from Professor Roesler and Professor Henschen.

Disclaimer

This report was made for academic purposes only and is not for professional use. Any recommendations that were made in the report may be based on incomplete information and data due to limited time.

This space was intentionally left blank.

References

Bluefield Research. 2021. “U.S. Municipal Water & Wastewater Utility Rate Index.” Accessed November 26, 2023. https://www.bluefieldresearch.com/research/u-s-municipal-water-wastewater-utility-rate-index-2021/

Cabonargi E, Hansen I. 2011. “Water Reuse Handbook.” Accessed October 9, 2023. https://icap.sustainability.illinois.edu/files/projectupdate/7640/WaterReuseHandbook_August2011_0.pdf

Econocycle. n.d. “Greywater Systems.” Accessed November 29, 2023. https://econocycle.com.au/greywater-systems/

Filali H, Barsan N, Souguir D, Nedeff V, Tomozei C, Hachicha M. 2022. “Greywater as an Alternative Solution for a Sustainable Management of Water Resources—A Review.” Accessed October 9, 2023. https://doi.org/10.3390/su14020665

Ghaitidak D, Yadav K. 2013. “Characteristics and Treatment of Greywater- A Review.” Accessed October 28, 2023. https://link.springer.com/article/10.1007/s11356-013-1533-0

Google Maps. 2023. *Google*. Accessed October 9, 2023. https://www.google.com/maps/@40.0910537,-88.235935,14z?entry=ttu

Illinois Climate Action Plan University of Illinois Urbana-Champaign (iCAP). 2011. “Key Objective: 4.1 Reduce Water Consumption.” Accessed September 18, 2023. https://experts.illinois.edu/en/publications/meeting-east-central-illinois-water-needs-to-2050-potential-impact

Illinois Climate Action Plan University of Illinois Urbana-Champaign (iCAP). (2019). “Install Low Flow Fixtures throughout Campus.” Accessed October 31, 2023. https://icap.sustainability.illinois.edu/project/install-low-flow-fixtures-throughout-campus

Institute for Sustainability, Energy, & Environment. 2022. “Key Objective: 4.1 Reduce Water Consumption.” Accessed September 14, 2023. https://icap.sustainability.illinois.edu/objectives/41-reduce-water-consumption

Munoz, N. 2016. “What Is The Economic Feasibility Of Implementing Grey Water Infrastructure At The Citywide Level?” Accessed November 3, 2023. https://repository.usfca.edu/cgi/viewcontent.cgi?article=1370&context=capstone

National Integrated Drought Information System. 2023. “Illinois.” *Drought.gov*, Accessed September 16, 2023. https://www.drought.gov/states/illinois#current-conditions

(n.d.) 2019. “*On-site water systems: Financial Case Studies*.” Accessed November 5, 2023. https://living-future.org/wp-content/uploads/2022/05/2019-Water-System-Financial-Case-Studies-1.pdf

Oteng-Peprah M, Agbesi Acheampong M, deVries N. 2018. “Greywater Characteristics, Treatment Systems, Reuse Strategies and User Perception-a Review.” *Water, air, and soil pollution* vol. 229,8 (2018): 255. Accessed September 17, 2023. doi:10.1007/s11270-018-3909-8

Redwood M. 2008. “Greywater Irrigation: Challenges and Opportunities.” Accessed October 27, 2023. https://www.cabidigitallibrary.org/doi/epdf/10.1079/PAVSNNR20083063

Roesner L, Sharvelle S. 2015. “Graywater Reuse A Case Study at Colorado State University.” Accessed October 24, 2023.
https://watereuse.org/wp-content/uploads/2015/09/Presentation-Colorado-2014-Workshop-Graywater-Reuse-A-Case-Study-at-Colorado-State-University.pdf

Surendran S, Wheatley A. 1998. “Grey-Water Reclamation for Non-Potable Re-Use.” Accessed October 26, 2023. https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1747-6593.1998.tb00209.

University of Illinois. (2023). “University of Illinois facilities and services.” Accessed October 18, 2023. https://archive.fs.illinois.edu/services/utilities-energy/business-operations/utility-rates.

This space was intentionally left blank.

Appendix A

Cost Estimate Calculations:

CSU Case Study (Roesner and Shareville 2015)
CSU Building Square Footage: 146,870 CIF Square Footage: 124,000
CSU installation cost: $66,500 / (2729m^2 = 29,374* 5 = 146,870 sq. ft.). ft = $0.45 per sq. ft
Scaled CIF Installation Cost: $0.45 per sq. ft * 124,000 sq. ft = $55,800

Arch Nexus SAC (n.d. 2019)
Arch Nexus SAC Square Footage: 8,252 CIF Square Footage: 124,000
Arch Nexus Installation Cost: $50,000 / 8,252 sq. ft = $6.06 per sq. ft
Scaled CIF Installation Cost: $6.06 per sq. ft * 124,000 sq. ft = $751,440

Business Center (Munoz 2016)
Business Center, Melbourne, Australia
Business Center Square Footage: 326,000 CIF Square Footage: 124,000
Business Center Installation Cost: $119,210 / 326,000 sq. ft = $0.37 per sq. ft
Scaled CIF Installation Cost: $0.37 per sq. ft * 124,000 sq. ft = $45,880

Inflation Rate: 3.2%
Projected Cost: ($55,880 + $751,440 + $45,880) / 3 = $284,400 * 3.2%= $293,500

Payback Period Calculations:

Average pre-greywater yearly water bill (for CIF): $243,000 (from **Table 2**)
Projected yearly water bill with greywater savings (for CIF)= $243,000 - ($243,000 * 14.3%)= $208,000
Projected Yearly Savings: ($243,000 - $208,000) = $35,000
Payback Period: ($293,500 dollar installation cost / $35,000 savings per year) = 8.4 years

This space was intentionally left blank.

Group Reflections

Throughout the semester, many key decisions were made about the data collection and analyzation process. These decisions included the location of the project, what data to collect, and using BIF data as a reference for the CIF. These decisions were important because they determined the structure in which the feasibility study was based, influencing the overall feasibility determination. We based these decisions off the amount of data available, the relevancy to our project (for the data collection), and the extent to which could be accomplished during our limited time frame. Initially, a mistake we made during our cost estimation was comparing the cost of installing a greywater system to the amount of people using the building, rather than the water consumption and square footage, which is a much more accurate comparison. Another mistake that we made was basing a large portion of our analysis off of a statistic that was proved to be false for our specific project. Throughout this project, we learned to ask more questions about the data that we received. We learned that we must do this to make sure that we actually understand what the data is saying and to make sure that we have the correct data. We also learned that we have to be very careful when reaching out to people because we accidentally emailed the wrong person which set us a few days behind schedule. Some of the limitations in our data is that CIF does not track greywater consumption, therefore we had to use data from another building, the BIF, and scale it to the CIF's water demand. In the future, more background information should be looked into before deciding on a building location to ensure that all data necessary for the feasibility analysis is tracked or available. Another aspect we could have implemented if more time was given was calculating replumbing costs through a detailed, bottom-up cost estimate to create a more accurate result.

The CEE495 peer mentor did not have a large role in our project. The peer mentor did not show up for half of the meetings, and when they did no criticisms of our work were provided. The TAs also had no role in mentoring for our project because there was no need to discuss with them. The instructors had a large role in the mentoring of our project. Instructors, especially Professor Schmidt, helped with the formatting of the report and gave advice on specific and efficient data collection.