Restroom Water Reduction Potential at an Urban University

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Abstract

A water audit was conducted at a variety of University of Illinois at Chicago (UIC) campus buildings to help evaluate the potential to conserve water and save the university money. These buildings are unique in many different aspects and together are a good representation of an urban university infrastructure. Data was collected by performing a water audit on faucets, urinals, toilets, and showers. In the findings, the data suggests it is necessary to upgrade the majority of the fixtures to green retrofits. Green retrofits are fixtures that meet at least the federal and EPA standards. In one scenario of an audit of a university building, the payback was found to be less than two years with a yearly savings of $72,000 and the potential to save 9.4 million gallons of water per academic year. The study also suggests that these upgrades, if applied, could lead to a more sustainable campus.

Keywords: flow rate; retrofit; sustainable university campus; water audit; water conservation; water savings

Introduction

The University of Illinois at Chicago (UIC) is the largest university in the Chicagoland area with roughly 29,000 students attending[1] and 117 buildings (nearly 15 million square feet), including a medical center, on 240 acres. It was founded in 1913 and is a research-oriented university located close to the heart of downtown Chicago. As signatory to Second Nature's Climate Statement, UIC has made public its commitment to climate action and resiliency planning.[2] This study was the first step in establishing water-reduction goals and strategies for this urban campus.

In order to make the university a more sustainable place, select buildings across the campus had a water audit conducted by the Office of Sustainability in the summer of 2015. Its primary objective was to save money and actively conserve water. Significant water price increases in the last few years and future projected increases made this issue more pertinent. The buildings studied were as follows: Addams Hall (AH), Behavioral Science Building (BSB), Burnham Hall (BH), College of Medicine (CMET), Lecture Center East (LCE), Paulina Street Building (PSB), Richard Daley Library (LIB), School of Public Health and Psychiatric Institute (SPHPI), Science and Engineering Offices (SEO), Science and Engineering South (SES), Stevenson Hall (SH), Student Center East (SCE), Student Center West (SCW), Student Residence and Commons West (SRCW), Student Services Building (SSB), Taft Hall (TH), and UIC Sport and Fitness Center (SFC).

The buildings chosen for the study differ in terms of year of construction, amount of renovations and the daily usage. These include high traffic buildings such as the student centers, classroom buildings, office buildings, research buildings, fitness facilities, and a library. The first step was to characterize the buildings in

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Table 1. Average Water Consumption for Faucets, Urinals, and Toilets for Each of the Buildings Audited

Building	Faucets, Gallon per Minute (GPM)	Urinals, Gallon per Flush (GPF)	Toilets, Gallon per Flush (GPF
Addams Hall (AH)	2.13	2.00	8.30
Behavioral Science Building (BSB)	1.29	2.89	6.02
Burnham Hall (BH)	1.46	2.22	4.83
College of Medicine (CMET)	1.80	2.86	8.34
Lecture Center East (LCE)	0.93	4.49	7.13
Paulina Street Building (PSB)	2.35	11.80	6.95
Richard Daley Library (LIB)	0.50	2.12	3.94
School of Public Health Psychiatric Institute (SPHPI)	1.64	2.26	6.69
Science and Engineering Offices (SEO)	2.27	2.86	5.25
Science and Engineering South (SES)	5.20	2.56	4.81
Stevenson Hall (SH)	0.94	3.85	6.14
Student Center East (SCE)	1.71	2.73	8.67
Student Center West (SCW)	1.34	3.09	6.97
Student Residence and Commons West (SRCW)	2.04	0.00	7.05
Student Services Building (SSB)	1.97	2.18	4.08
Taft Hall (TH)	3.29	1.78	49.85
UIC Sport & Fitness Center (SFC)	1.68	4.45	10.83
Federal Standard	2.20	1.00	1.60
U.S. EPA Standard	1.50	0.50	1.28

terms of their restroom plumbing, the restroom water consumption, and potential savings if upgrades were made. The study focused on the three specific plumbing fixtures: faucets for sinks and showers, urinals, and toilets.

These facilities were constructed between 1931-1993 (see Table 2 for information). The goal of the study was to compare current performance to current standards. This can be done by comparing the average flow rates with the EPA and federal standard. The Environmental Protection Agency was created to protect human health and the environment. Similarly, the federal standard for water consumption, is set by the U.S. government. The university's water audit data was compared to these two standards.

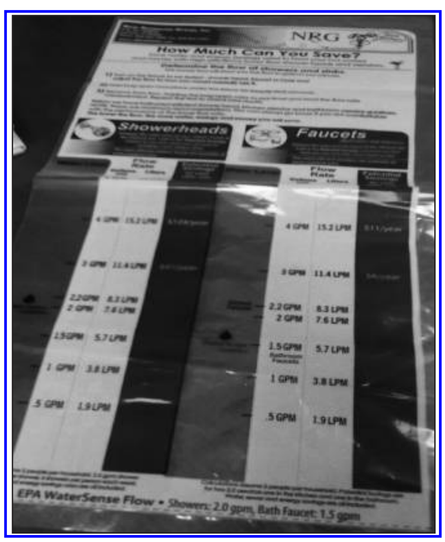

Figure 1. Flow Bag used in the study

Materials and Methods

When conducting the water audit, various steps were taken to gather flow rates. Walkthroughs were conducted for each building being assessed and areas of water use were noted. The tool used to gather flow rates of any faucets or shower heads was a flow bag, as shown in Figure 1. The flow bag is used by placing the open end under the faucet for a predetermined period of time (see Figure 2). During this water audit, the time was set to five seconds, during which the bag fills with water and then is removed. The volume of water collected is measured and then calculated in gallons per minute.

In order to obtain a flow rate on toilets and urinals, the flush time was measured by water evaluators who listened and watched until the water completely flushed, recording the time it took for the urinal or toilet to completely flush. Once the

Table 2. Building Overview Count Based on Water Audit Data

Building	Faucet Count	Urinal Count	Toilet Count	Square Feet	Year Built
Addams Hall (AH)	4	5	5	16,609	1963
Behavioral Science Building (BSB)	20	29	23	263,985	1967
Burnham Hall (BH)	20	29	23	32,461	1963
College of Medicine (CMET)	42	24	25	189,314	1931
Lecture Center East (LCE)	6	7	4	10,185	1963
Paulina Street Building (PSB)	13	4	15	44,225	1971
Richard Daley Library (LIB)	24	12	36	264,105	1963
School of Public Health Psychiatric Institute (SPHPI)	2	1	2	323,525	1957
Science and Engineering Offices (SEO)	11	9	12	140,554	1966
Science and Engineering South (SES)	10	17	13	456,722	1968
Stevenson Hall (SH)	5	9	7	33,983	1966
Student Center East (SCE)	83	25	69	296,819	1964
Student Center West (SCW)	21	21	12	83,167	1964
Student Residence and Commons West (SRCW)	25	0	11	79,788	1993
Student Services Building (SSB)	20	29	23	259,144	1972
Taft Hall (TH)	7	9	20	23,364	1963
UIC Sport & Fitness Center (SFC)	4	2	6	86,013	1979

Figure 2. Water-use evaluator noting the marked flow rates of a faucet

flush time was recorded, it was entered into a water auditing program, Maddaus Water Management Audit Tool (MWMWAT) v2.5.1, which is a program for modeling water usage and efficiency measures. This program allows the user to input the measured flush time and then it outputs the calculated gallon per flush rating. After the data for each faucet, toilet, and urinal was also recorded, a graphical analysis of average water use for each type of fixture was charted alongside the recommended U.S. EPA and federal standards as shown in Figures 3 and 4.

In order to calculate the estimated water cost savings for faucets, Formula 1 was used. The water and sewer charges were calculated from past bills. The university pays, on average, about $7.62 per 1,000 gallons to the City of Chicago. The annual cost calculation was based on one academic year (i.e., two semesters of 154 days each); summer term was not included. Also, it is important to mention that since traffic flow varies in different buildings, the restroom usage varies accordingly.

Formula 1 is broken down as follows: Let G_f be equal to the average gallon per minute flow rate of faucets and G_{ut} be equal to the average gallon per flush of urinals or toilets. Similarly, let P be equal to the foot traffic (people per day) of the building being examined and U equal to the number of times used per person each day. Furthermore, let T be equal to 0.5 minute which is equal to the time it takes for an individual to wash their hands per restroom use.[3] The result is S_c, the cost savings per academic year for faucets.

$$S_c=(G_f)\text{x}(P)\text{x}(U)\text{x}(T)\text{x}\left(\frac{1kgal}{1000\text{gal}}\right)\text{x}\left(\frac{\$7.62}{kgal}\right)\text{x}\ \frac{154\ days}{one\ academic\ year}$$

Formula 1. Estimated cost savings for faucet per academic year.

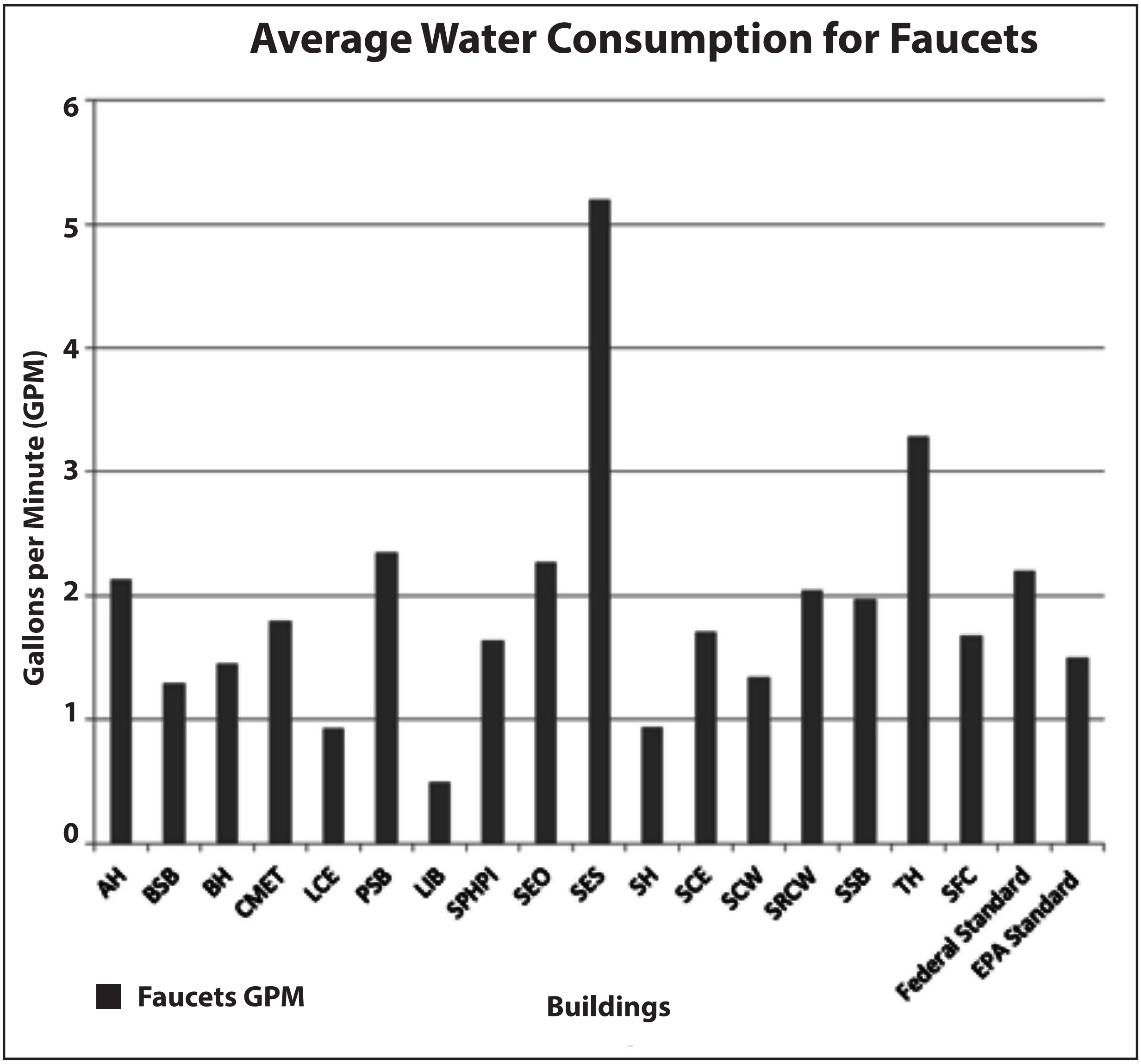

Figure 3. Average water consumption for faucets in gallons per minute

To calculate the estimated water cost savings for urinals or toilets, some other assumptions were made as well. It was assumed that men use the urinal and toilet each one time per day. Whereas, women use the toilets two times a day.[3] All other assumptions are held constant from formula 1. The formula to calculate urinal or toilet estimated cost savings can be found in formula 2.

To determine the amount of water that will be saved with an upgrade, formula 3 calculates the water savings for faucets and formula 4 calculates the water savings for urinals and toilets. formula 3 is defined as:

$$S_c=(G_{ut})\text{x}(P)\text{x}(U)\text{x}\left(\frac{1kgal}{1000\text{ gal}}\right)\text{x}\left(\frac{\$7.62}{kgal}\right)\text{x}\left(\frac{154\ days}{one\ academic\ year}\right)$$

Formula 2. Estimated cost savings for urinals or toilets per academic year.

Let S_w be equal to the water savings per one academic year and let G_f, *current* and G_f, *upgrade* be equal to the average gallon per minute and the listed gallon per minute of the upgrade, respectively. Similarly, Formula 4 is defined as: Let G_{ut}, *current* and G_{ut}, *upgrade* be equal to the average gallon per flush and the listed gallon per flush of the upgrade of the urinal or toilet, respectively. The total gallons saved per academic year would be the sum of formula 3 and formula 4.

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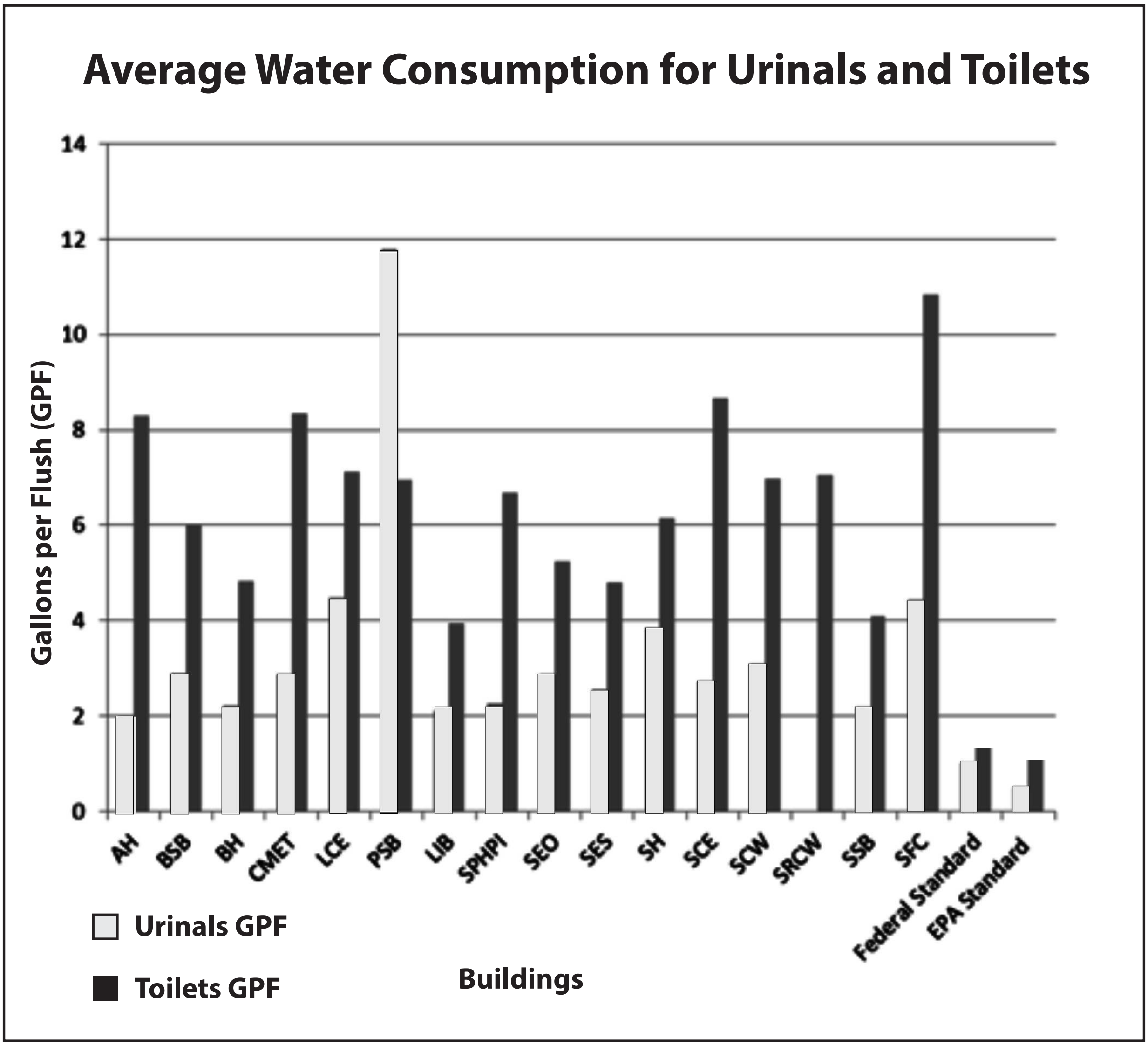

Figure 4. Average water consumption for urinals and toilets, in gallons per flush

Discussion

Lecture Centers

A water audit was conducted on the following Lecture Center restrooms: Addams Hall (AH), Burnham Hall (BH), Lecture Center East (LCE), Stevenson Hall (SH), and Taft Hall (TH). All these buildings are located on the east campus where a majority of the people who use these lecture halls are students. This implies that there is heavy foot traffic during the academic year, particularly during the week.

$$S_w = [G_{f,\ current} - G_{f,\ upgrade}]\text{x}(P)\text{x}(U)\text{x}(T)$$

Formula 3. Estimated water savings for faucets per academic year

$$S_w = [G_{f,\ current} - G_{ut,\ upgrade}]\text{x}(P)\text{x}(T)$$

Formula 4. Estimated water savings for urinals or toilets per academic year

AH, BH, and TH are connected with skyways and together these sister buildings are known as the BAT cave. People entering from one building can leave from another building. For this study, it is assumed that the traffic flow is not affected by the other two buildings. Furthermore, the African American Cultural Center is located in Addams Hall, while the Honors

College can be found in Burnham Hall, and the Asian American Resource and Cultural Center is in Taft Hall. These places have full-time employees present which needs to be taken into consideration, if a full cost savings analysis is desired.

In some buildings, the average water consumption of the faucets exceeded the EPA and federal standards. Similarly, the flow rate of toilets was higher than the recommended EPA and federal standard. (See Table 1 and Figures 3 and 4.)

Student Centers

The Student Centers on campus are the community centers of the university. These are places that promote student interaction while also containing multiple lounges, computer labs, event spaces, kitchen and dining facilities for students, staff, and visitors. At UIC, there are two Student Centers located in east and west campus. Because the student centers are used for many things, one will find that these two buildings have the greatest foot traffic of any buildings at UIC. Around 19,000 students enter these buildings every day during a regular semester. This volume of foot traffic indicates a high frequency of restroom use. Every restroom in this building has at least one toilet running inefficiently; that is, its audited gallon per flush (GPF) was greater than that set by the standards. Furthermore, the urinals in the SCE tower on floors three, five, six, and seven have a door sensor that causes the urinals to flush continuously when the door is open.

Student Center West (SCW) is less than one-third the size of Student Center East and, correspondingly, has a lower traffic flow. As the data in Tables 1 and 4 illustrate, the water from the urinals and toilets is consumed more than the EPA and federal standards. However, the average gallon per minute rate for faucets was 1.34 GPM which is lower than the EPA and federal recommended standards. This might be attributed to the many low-flow aerators that were pre-existing in the restrooms.

Special Buildings

The Richard Daley Library and the UIC Sport and Fitness Center are considered special because they are both unique buildings. The restrooms in the Richard Daley Library was remodeled a few years ago and the upgrade included the faucets, toilets, and urinals. The water audit for this building was conducted and the data showed that only the faucets had flow rates that met the standards: The average gallon per minute flow rate was 0.50 GPM, which is lower than both the EPA and federal standard. In contrast, the flow rates for the urinals and toilets tested higher than the EPA and federal recommended standard. (See Table 1 and Figure 3 and 4.) During the water audit, water-use evaluators noticed the automatic flush systems installed with the toilets were oversensitive. They flushed even when someone walked past a bathroom stall.

The UIC Sport and Fitness Center was built in 1979 and renovated in 2002. It is one of the newer buildings on the university campus. It houses fitness facilities, locker rooms, open gym, basketball courts, and a swimming pool, among other amenities. The water flow rates in the restroom faucets averaged 1.68 GPM, which is exceeds the EPA and federal standard rates. However, the urinals and toilets had an average flow rate found to be 4.45 GPF and 10.83 GPF, respectively, which is far short of the standards.

Multipurpose Building

The Behavioral Sciences Building, College of Medicine, School of Public Health Psychiatric Institute, and Science and Engineering South are multipurpose buildings with a wide range of uses, from science laboratories to departmental offices, lecture halls, auditorium, and computer labs. Because of their constant use, it is assumed that heavy traffic flow can be expected during the academic year. Further, the buildings with the research laboratories are also assumed to be occupied year around. All in all, restroom usage is at its height when classes are in session just like the other buildings when classes are in session (see Table 1 and Figures 3 and 4).

Student Residence Hall

There are four residence halls in east campus at UIC but the SRCW was chosen for the audit. Because this is a dormitory, foot traffic is heaviest during the academic year and this would mean that the restroom foot traffic will also be the heaviest during the academic year. In SRCW, there are no urinals in the men's restrooms, so the flow rate was set at 0.0 GPF. The gallon per flush flow rate of the toilets averaged 7.05 GPF, which falls far short of recommended standards. The restroom faucets averaged 2.04 GPM, which does not meet the EPA standard, but slightly exceeds the federal standard.

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Office Buildings

Office buildings on campus were also examined in this case study. These buildings consist of Paulina Street Building (PSB), Science and Engineering Offices (SEO), and Student Services Building (SSB). Many of the office buildings have full-time employees present year around and most of the foot traffic can be assumed to be from faculty and staff. None of the three fixture averages met the EPA and federal standard.

Suggested Equipment Modifications

As a nation growing in population size and consumer demand, a pivotal point is vital for the stability of the environment, achievable by decreasing the overconsumption of natural resources, especially because the average American consumes about 80-100 gallons of water per day.[4] In regard to this study, installing water conserving fixtures in the university restrooms can have a positive impact on the surrounding environment and will save the university money. Although UIC is located near the five Great Lakes, where fresh water is in abundance, this study will lead to other sustainable practices if the university implements the following proposed retrofits.

Currently, most of the university's restrooms are not equipped with efficient water-consuming fixtures. Upgrading to new, water-saving equipment will save water and also make the restrooms more attractive. The easiest fix is also an inexpensive one: Add low-flow aerators of 0.50 GPM to each faucet instead of replacing the faucets entirely. Low-flow aerators cost a few dollars and meet the EPA and federal standards. The water auditors recommended that the campus faucets be retrofitted with Neoperl 0.5 GPM dual-thread aerators[5]—the cost: $3.04 each.

For the urinals, the most sustainable solution to save the most water involves the installation of an automatic flushing system. The proposed retrofit is a Zurn 0.5 GPF Aqua Sense AV Exposed Urinal Flush Valve[6] at a cost of $308.95 per unit. Currently, the university restrooms have urinals with a water flow rate of 1.5 or 1.75 GPF. This means that with the urinal retrofit there also needs to be an upgrade of the urinal itself—the proposed urinal retrofit is a Zurn 0.5 GPF/1.0 GPF Urinal[7] at a cost of $149.43 per piece. The removal of the old unit and the installation of the new is estimated to take four hours. Another advantage of an automatic flushing system is that it eliminates direct contact with the urinal, making it more sanitary. This urinal flushing system includes an override button for users to manually press if needed.

Some university restroom toilets are equipped with manual flush handles; others have an automatic flushing system. These systems can be oversensitive, often flushing before the user has finished using the toilet and again when the user leaves the stall. This results in wasted water and an uncomfortable experience. The best option would be to replace all the current toilet valves and handles with an advance dual flush handle system, which gives the user the ability to flush up for liquid waste (1.1 GPF) or down for solid waste (1.6 GPF). The proposed retrofit is a Sloan WES-213 Tune-Up Kit[8] at a cost of $60.87 per unit. As with the urinals, the flush valves on most of the university toilets are not compatible with the dual flush handles, requiring installation of new compatible toilet bowls. The proposed upgrades for the toilets are the American Standard Afwall Millennium 1.1 - 1.6 GPF FloWise[9] at a cost of $235.00. The labor time to install the toilet retrofits is estimated at four hours per toilet and urinal bowl.

Estimated Cost Savings Sample Calculations

If the university decided to invest in the recommended fixtures, then it will save both money and water. The payback time period is very short and the results will be noticeable. For example, if the university were to upgrade the three fixtures examined in this case study (faucets, urinals, and toilets) for only Student Center East, then a total cost savings can be computed as follows. It is known that the foot traffic of SCE is 19,000 people per day. With this traffic flow, two conservative scenarios are applied. For scenario 1, let the restroom usage be 10 percent of the foot traffic that occurs in SCE. And for scenario 2, let the restroom usage be 25 percent of the foot traffic that occurs in SCE.

For one academic year the university would save a total of $28,808.82, if scenario 1 is applied. If scenario 2 is applied, then the university would save a total of $72,022.04 per academic year. Both scenarios 1 and 2 were calculated by summing the results of formulas 1 and 2. Additionally, the estimated water savings, in gallons, in SCE, when scenario 1 is applied, is 3,780,685 gallons per academic year. And for scenario 2, it is estimated that SCE would save 9,451,711.5 gallons per academic year. These estimated water savings were calculated by summing the results of formulas 3 and 4.

If the university were to invest in the fixtures recommended because of this study, it would conserve water use and save money. The payback time for the investment is very short and the results would be noticeable to the university administration.

To estimate the financial savings, the Student Center East was used as a model from which data could be extrapolated. SCE and SCW were chosen because they are both large buildings with impressive potential water and money savings. Including an upgrade of faucets, urinals, and toilets and using the approximate foot traffic of the building of 19,000 people per day, two scenarios were created. In scenario 1, the restroom usage was estimated to be 10 percent of the foot traffic in the building; for scenario 2, the restroom usage was estimated to be 25 percent of the foot traffic in the building. Adding the results of formulas 1 and 2, the university would save a total per academic year of $28,808.82 in scenario 1 and $72,022.04 in scenario 2. To estimate water savings, adding the results of formulas 3 and 4 shows that the university would save 3,780,685 gallons of water per academic year in scenario 1 and 9,451,711.5 gallons of water per academic year in scenario 2.

Over the last five years, water prices have increased annually by 15 percent in the City of Chicago.[10] As water prices rise, the cost of implementing these retrofits would prove to be a sustainable decision given the savings in water usage. It would also be a fiscally prudent decision given that the entire cost to retrofit all of Student Center East restrooms is estimated to be $82,092.51, which includes the cost of labor (plumbers are paid $65/hr.). The payback time period for scenario 1 is projected to be less than three academic years; for scenario 2, it is just over one academic year.

Conclusion

Water is a limited and essential resource. The UIC Climate Action Plan includes implementation of a water conservation plan that will yield significant water and energy savings on campus. This Action Plan covers what the university

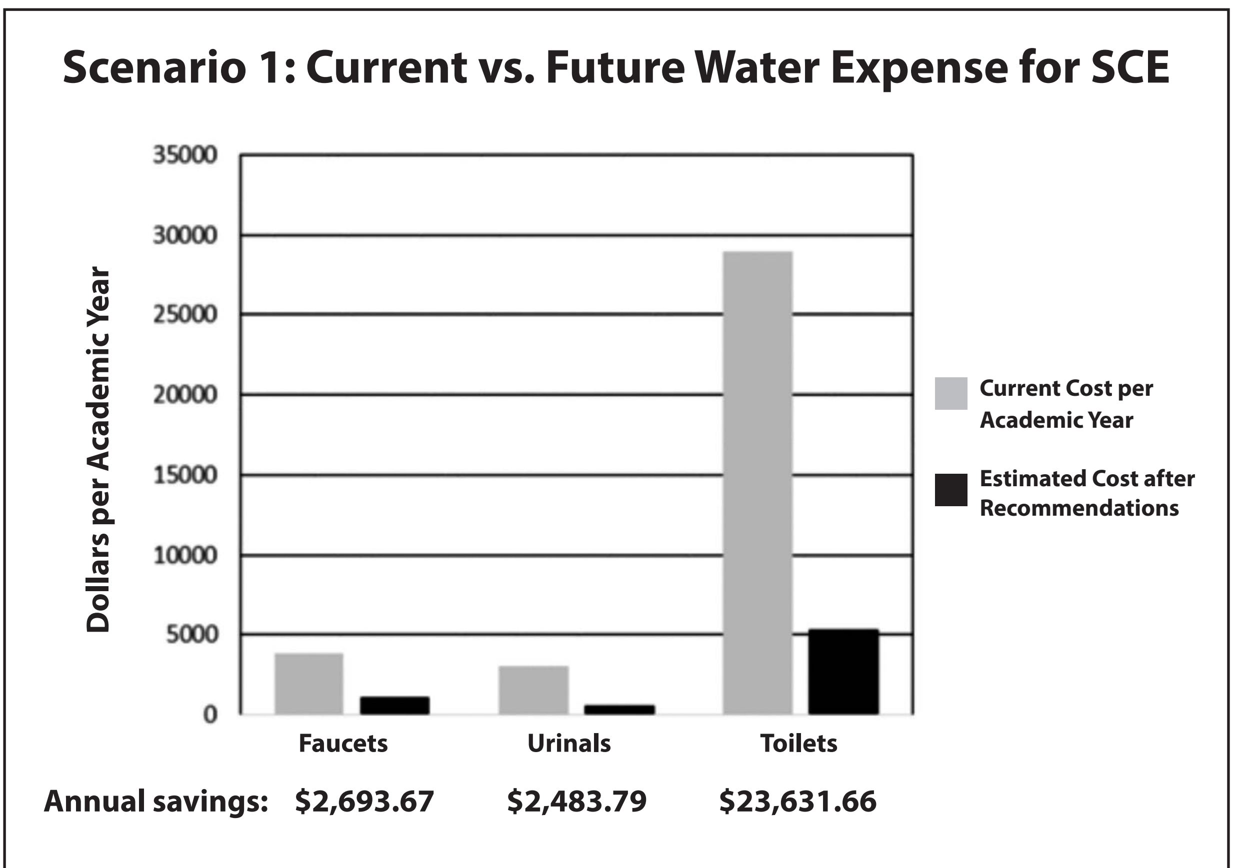

Figure 5 Scenario 1. Current cost per academic year versus estimated cost after recommendations for Student Center East

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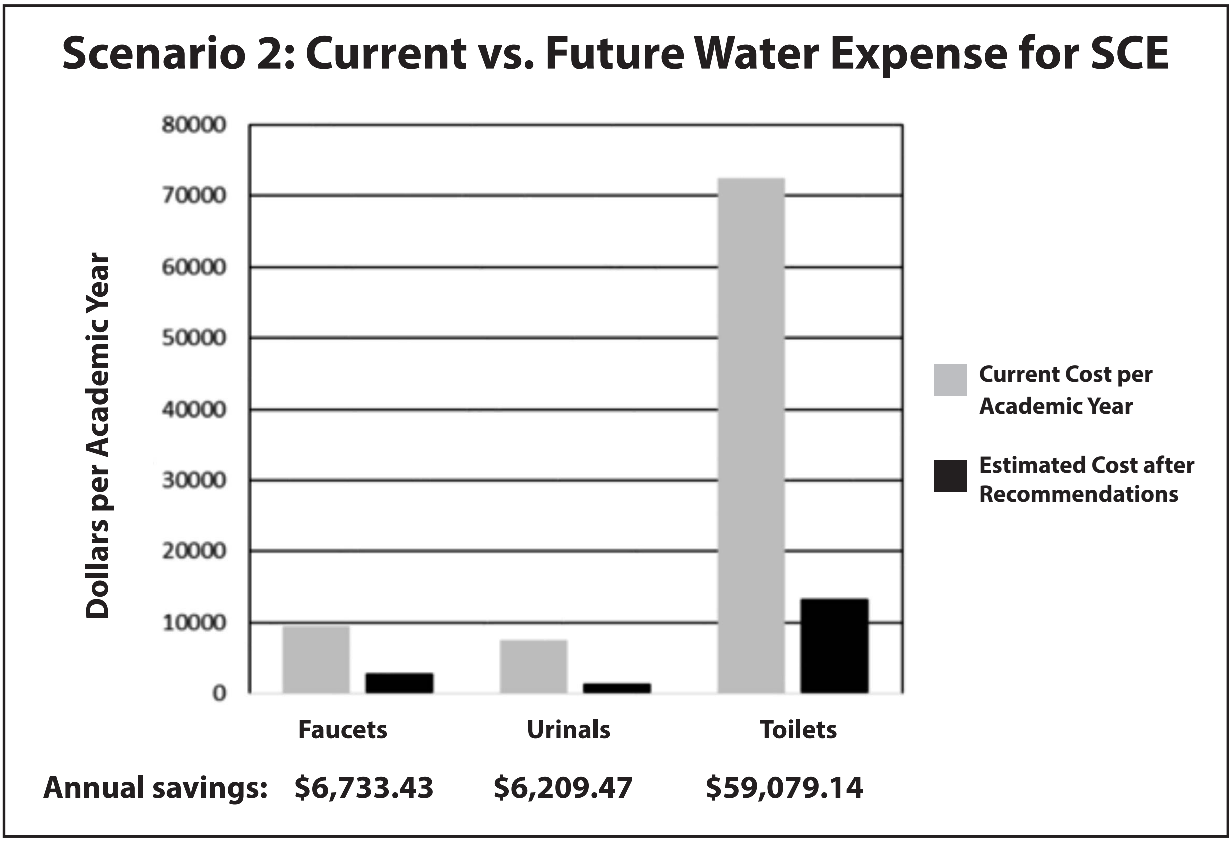

Figure 6 Scenario 2. Current cost per academic year versus estimated cost after recommendations for Student Center East

must focus on in regard to sustainability. The water audit described in this article provides insight into a strategy that mirrors the goals in the UIC Action Plan: "to seek out water and energy savings in its building operations."[11] The goal of the water audit was to determine the extent of overconsumption of water in campus buildings and address ways to alleviate the problem. The proposed remedies developed from the audit are relatively easy fixes that have sustainable benefits. To put them into effect, however, the cooperation of all associated parties will be needed, for example, approval by the chancellor, the Office of Sustainability involvement, the building manger's approval and involvement, and especially students awareness of what is taking place. As state funding for public universities has decreased over the last decade and continues to do so, water conservation will be one key to reducing operating costs. With this study, the university can help fulfill its goals and complete part of the Climate Action Plan.

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Author Disclosure Statement

No competing financial interests exist.

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