Chapter 2: Residential Buildings

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2.1 Introduction

As Chapman University's student population continues to grow, the residence halls play an increasingly important role when it comes to resource consumption. Residential buildings are used 24 hours a day, 7 days a week year-round, while academic buildings are primarily used 9am-5pm Monday through Friday. The residence hall complex also contains a cafeteria and a significantly higher number of bathrooms and showers than academic buildings. Because of this, the residence hall complex uses approximately 50% of the total water used at Chapman, making it an important component of this audit. This section of the Chapman 2013 Water and Landscaping Audit will investigate areas of high water use in the residence halls and identify areas that can be improved. It is in Chapman's best interest to try and reduce water consumption in an effort to keep costs down and minimize its impact on water use in California. The main goals of this chapter are as follows:

- Up-to-date water use information of residential buildings
- A more in-depth study of water use in the Randall Dining Commons
- Evaluating how the cooling towers affect water use
- Assessing student views on water and landscaping in the residential area
- Reviewing Chapman's current residential landscaping practices
- Identifying areas of high water usage and making recommendations for changes

2.2 History of Residential Buildings at Chapman

2.2.1 Overview

Previous to the Chapman University 2013 Environmental Audit, Chapman had not been tracking water use. The 2013 Audit was the first time that Chapman's water bills had ever been compiled and analyzed. With water use data now being analyzed, Chapman has continued to take steps to reduce water use in the 2013-2014 academic year. While some of the previous accomplishments were listed in 2013 Audit, the achievements of the audit and achievements since should be recognized. Some of these accomplishments are described below.

However, few steps have been taken in terms of reducing water use specifically for landscaping in the residence halls. While sprinklers are only used late at night to reduce water loss from evaporation, water-saving actions such as installing smart irrigation systems, more efficient irrigation systems, or drought-tolerant plants have not yet been implemented.

2.2.2 Historical Water Usage

The 2013 Audit compiled campus-wide water usage for the first time. **Table 2.1** shows residential area water usage in hundred cubic feet (hcf), water cost, and cost per person from 2009-2012. Much of the increase was due to the increased resident student population, which rose from 1,773 students in 2009-2010 to 1,926 students in 2011-2012. Even with the increased resident population, however, the cost of water per person in the residence halls has also increased.

Table 2.1. Residential water usage, cost, and cost per person from 2009-2012.

Academic Year	Water Usage (hcf)	Water Cost	Residential Student Population	Water Cost/Person
2009-2010	43,752	$92,944	1,773	$52.42
2010-2011	45,321	$102,359	1,971	$51.93
2011-2012	48,219	$121,728	1,926	$63.20

2.2.3 Past accomplishments

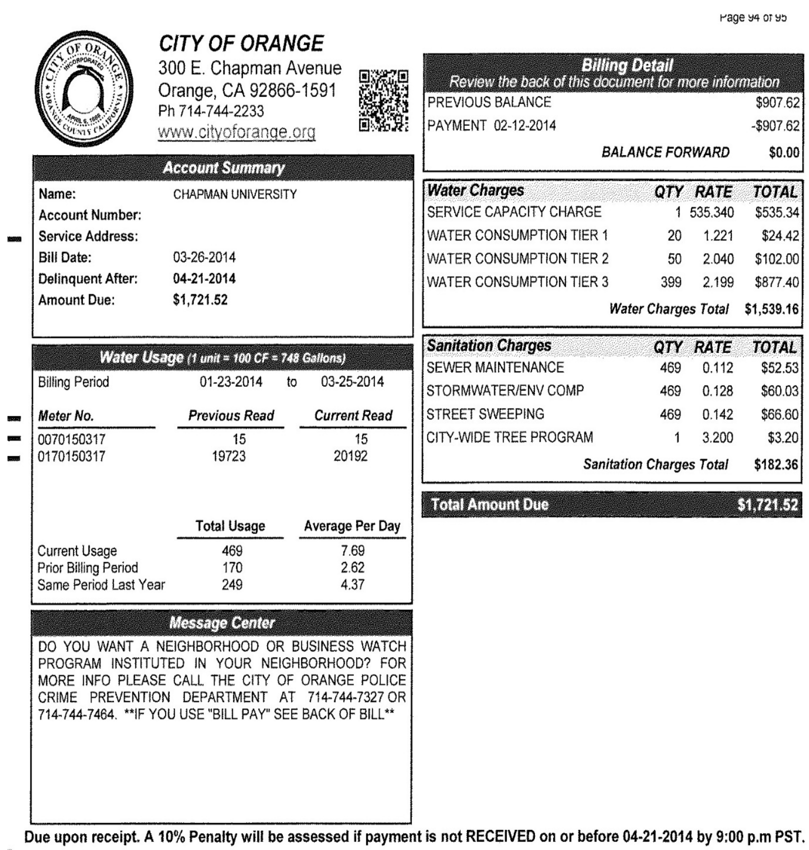
Many of Chapman's past achievements in water use reduction were stated in the 2013 Audit, but not all pertained to Chapman's residential buildings. An achievement that was necessary for much of the work done in the 2013 Audit was the compilation of all water cost and water usage data from scanned PDFs of water bills to a Microsoft Excel spreadsheet for the years 2009-2011. There have been some notable achievements in water use reduction in the residence halls. In Randall Dining Commons, Sodexo has installed an Ecolab Apex dishwashing system, which is much more efficient than the previous version, saving both water and energy (Sodexo, 2008). Another water-saving measure includes the installation of 262 Toilet Guardians in Henley and Pralle-Sodaro Residence Halls during the summer of 2012 (2013 Audit). As stated in the 2013 Audit, the device is designed to detect leaks, alert facilities, and shut off the water flow from toilets when water has been running for longer than the normal period of time. This prevents both loss of water and potential damage to buildings from overflowing toilets. The Toilet Guardian is battery operated and designed only for manual toilets.

2.3 Current Status of Residential Buildings at Chapman

2.3.1 Water Use Data 2009-2013

Background

While the 2013 Audit focused on the years 2009-2011, this chapter analyzes all of the residential buildings over a 5 year time period (2009-2013). The 2013 Audit calculated that roughly half of all water usage on Chapman's campus occurs in the residence halls. Similarly, it also included the sanitation charges on the bimonthly water bill, as those charges are part of the total cost of the water bills. These sanitation charges include sewer maintenance, storm water compliance, street sweeping, and the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CITY OF ORANGE
300 E. Chapman Avenue
Orange, CA 92866-1591
Ph 714-744-2233
www.cityoforange.org

Billing Detail
Review the back of this document for more information

PREVIOUS BALANCE	$907.62
PAYMENT 02-12-2014	-$907.62
BALANCE FORWARD	$0.00

Water Charges	QTY	RATE	TOTAL
SERVICE CAPACITY CHARGE	1	535.340	$535.34
WATER CONSUMPTION TIER 1	20	1.221	$24.42
WATER CONSUMPTION TIER 2	50	2.040	$102.00
WATER CONSUMPTION TIER 3	399	2.199	$877.40
Water Charges Total			$1,539.16

Sanitation Charges	QTY	RATE	TOTAL
SEWER MAINTENANCE	469	0.112	$52.53
STORMWATER/ENV COMP	469	0.128	$60.03
STREET SWEEPING	469	0.142	$66.60
CITY-WIDE TREE PROGRAM	1	3.200	$3.20
Sanitation Charges Total			$182.36

Total Amount Due $1,721.52

Account Summary

Name:	CHAPMAN UNIVERSITY
Account Number:	
Service Address:	
Bill Date:	03-26-2014
Delinquent After:	04-21-2014
Amount Due:	$1,721.52

Water Usage (1 unit = 100 CF = 748 Gallons)

Billing Period 01-23-2014 to 03-25-2014

Meter No.	Previous Read	Current Read
0070150317	15	15
0170150317	19723	20192

	Total Usage	Average Per Day
Current Usage	469	7.69
Prior Billing Period	170	2.62
Same Period Last Year	249	4.37

Message Center

DO YOU WANT A NEIGHBORHOOD OR BUSINESS WATCH PROGRAM INSTITUTED IN YOUR NEIGHBORHOOD? FOR MORE INFO PLEASE CALL THE CITY OF ORANGE POLICE CRIME PREVENTION DEPARTMENT AT 714-744-7327 OR 714-744-7464. **IF YOU USE "BILL PAY" SEE BACK OF BILL**

Due upon receipt. A 10% Penalty will be assessed if payment is not RECEIVED on or before 04-21-2014 by 9:00 p.m PST.

Figure 2.1 Sample water bill for a single Chapman water meter.

city-street tree program (**Figure 2.1**).

Annual Water Usage

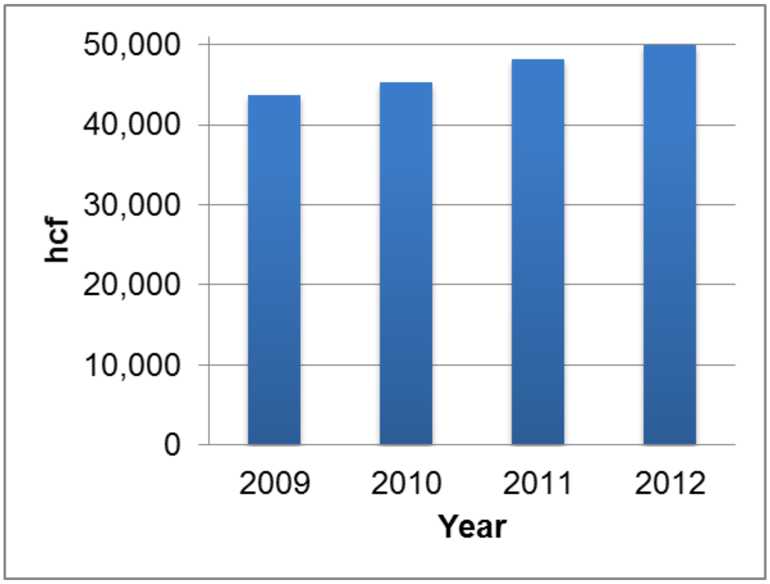

Figure 2.2 *Water usage (in hcf) for the residential buildings each academic year.*

The increase in residence hall water consumption from 2009-2012 is pictured in **Figure 2.2**. For the 2012-2013 academic year, the water usage of the residential buildings was 49,910 hcf. One hcf is roughly equivalent to 748 gallons. This equates to over 37,000,000 gallons of water. This was a 14% increase from the 2009-2010 academic year, where the water usage of all residential buildings was 43,752 hcf, or roughly 33,000,000 gallons of water. In the 2012 academic year, Chapman used ~4,000,000 more gallons of water than was used in the 2009 academic year. This equates to using enough water to fill over six Olympic-sized swimming pools.

Annual Water Cost

Since 2009, annual water cost has been increasing steadily in the dorms, with Chapman spending $92,944 on residential building water cost in 2009 and $165,627 on water in 2012. **Figure 2.3** compares the increase in water costs for all residential buildings from the last four academic years. From 2009 to 2012, there has been a 78% increase in the total cost of water for Chapman's residential buildings. While the cost increase is partially caused by the City of Orange's increase in pricing rates, there has been a general increase in the on-campus student resident population that also contributes to the increase (See **Table 2.2**).

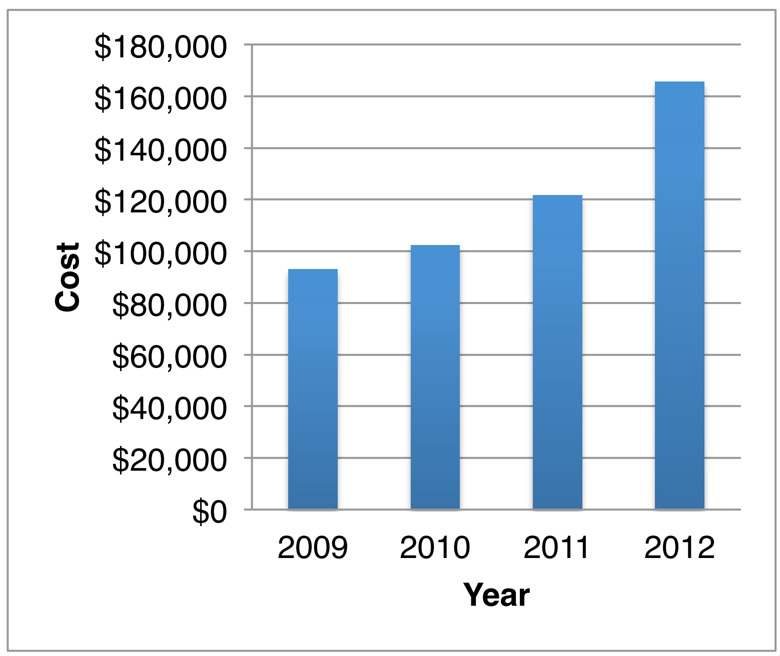

Figure 2.3 *Water cost for the residential buildings each academic year.*

Water Usage of Buildings

To better understand where water is consumed in the residential buildings, the water usage of each building was separated over each year. As stated in the 2013 Audit and seen in **Figure 2.4**, there are no discernible patterns in overall water use over each year, as individual buildings' water use and occupancy fluctuate up and down from year to year. An unusual spike in water use in Henley Hall in the 2011-2012 and 2012-2013 academic years is worth noting, as this was not caused by an increase in dorm population that year (See **Table 2.2**). While residence hall occupation could play a role in the fluctuation, the same uneven patterns are identified in **Figure 2.5**, where water usage is normalized per person. An important note to make is that the data for Morlan Hall and Harris Apartments in the 2013 Audit is incorrect. When analyzing the data for the 2014 Audit, it was discovered that the 2013 Audit only used one month's water use and cost for Morlan and Harris, rather than the entire year. This artificially gave it a lower usage than all of the other residence halls.

Using the correct data, Morlan and Harris actually have the second highest water use between all the residential buildings. As its water usage per person is also relatively high, the higher rates of water use in this dorm is likely due to the age of the buildings, as well as the presence of kitchens in Harris Apartments.

The Sandhu Residence Hall and Conference Center consumes the greatest amount of water of all residential buildings. This is likely because the Randall Dining Commons, the only dining hall on campus, is in the same building and shares the same water meter. This is also mirrored in the high rate of water use per person in Sandhu, as students who utilize the Dining Commons are not calculated into the water use per person.

Following Morlan and Harris in terms of water use would be Pralle-Sodaro and Henley Halls. These residence halls, while built in different years, have similar setups and high rates of residence. While overall water usage is relatively high, water usage per person is approximately average across all residential buildings. This is because in the 2010-2011 academic year the majority of rooms in these buildings increased to three people instead of two.

Glass Hall also consumes >5,000 hcf/year, as it contains regular student rooms as well as a tower housing several full apartments. Davis Apartments had the lowest rates of water usage of any main campus residential building. This is largely explained by the fact that the average population of Davis Apartments is considerably lower than the other residential buildings. But because every apartment in Davis has a full kitchen, it has the second highest rate of water usage per person, preceded only by Sandhu Residence Hall.

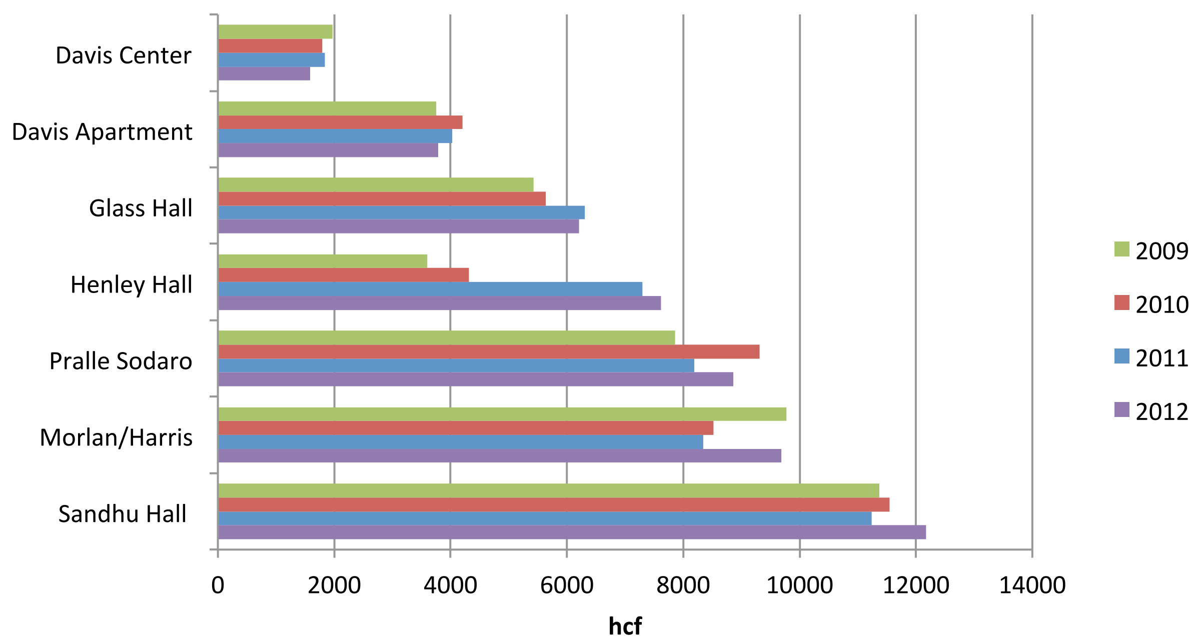

Figure 2.4 *Water usage of residence halls each academic year sorted from least to greatest based on 2011 data.*

The least water usage per building is still the Davis Center, which is explained by the presence of only offices, a central bathroom, and a resident laundry facility. Because it does not have any residents, it was not included in the water usage per person calculations.

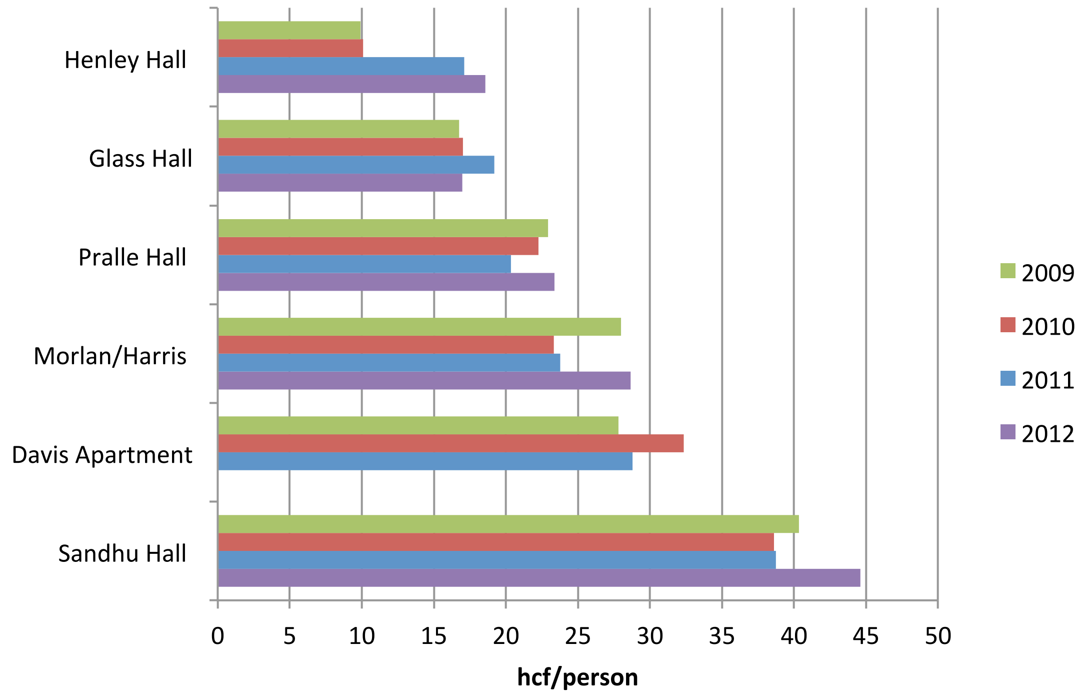

Figure 2.5. *Water usage per person in the residence hall each academic year sorted from least to greatest based on 2011 data. Davis Apartment 2012 data was not included.*

Table 2.2. *Average residence hall populations each academic year*

Residence Hall	2009	2010	2011	2012
Davis Apartments	135	130	140	N/A*
Glass Hall	324	331	329	281
Henley Hall	363	428	427	410
Morlan Hall/Harris Apartments	349	365	351	338
Pralle-Sodaro Hall	343	418	402	379
Sandhu Residence Center	282	299	290	273
Total	**1796**	**1971**	**1939**	**1679***

*Data was not received at time of publication

2.3.2 Water Runoff Sampling; Herbicide and Pesticide Use

To better understand the effects that artificial turf and traditional grass areas have on the nearby environment, various water samples were taken across the university. One sample was collected from the artificial turf field on campus, Wilson Field. This sample was tested for the heavy metals zinc and copper, which have been found in other artificial turf studies to be above the legal limits for storm water runoff samples (Connecticut Department of Environmental Protection, 2010). This sample was taken by finding the area where a drain is located on Wilson Field, and then artificially creating runoff by pouring a bucket of filtered water onto the turf. The runoff was then collected repeatedly using a clean turkey baster until the sample container was full. These samples were analyzed in house with the use of atomic absorption spectroscopy.

In this sample, zinc concentrations were almost 8 mg/L (See **Table 2.3**), substantially higher than the secondary maximum contaminant levels (SMCLs) of 5 mg/L. SMCLs are unenforced guidelines to assist public water systems in managing drinking water (EPA, 2013). While this concentration is above the SMCL, this may have been affected by the use of tap water to generate runoff, which may have increased the zinc concentration. The City of Orange does not report zinc concentrations in their yearly water quality report, so these concentrations cannot be compared (City of Orange, 2012). The elevated levels of zinc were likely caused from the presence of recycled tires in the artificial turf, as zinc (Zn) is used extensively in the production of car tires (State of Washington Department of Ecology, 2008). While the SMCL for Zn is 5 mg/L, Zn concentrations as low as 0.12 mg/L can have adverse effects on aquatic environments (Oregon Department of Environmental Quality, 2014). Therefore, further studies on artificial turf should be taken to determine the potential environmental effects. This should also be considered when artificial turf might replace traditional lawns.

Copper concentrations in this sample were well below the SMCL, with a concentration of 0.11 mg/L. When compared to the City of Orange's water quality report, this concentration was equivalent to the 90% average for copper concentrations (City of Orange, 2012). Therefore it is unlikely that runoff from the artificial turf on Wilson Field contains elevated copper concentrations.

The other set of samples taken were sprinkler runoff from lawn areas in the residential area. This includes one sample from Morlan lawn and another from the Rec Yard across from Henley Hall. These samples were analyzed for glyphosate, the main ingredient in the pesticide RoundUp (used across campus by Valley Crest). The EPA has sent a maximum contaminant level (MCL) for glyphosate in drinking water at 0.7 mg/L or 700 ppb and an MCL of 10 mg/L or 10 ppm (EPA, 2014). These samples were collected using a clean turkey baster, with runoff being collected repeatedly until the sample container was full. These samples were then sent to WECK Labs to test for the presence of glyphosate. Both samples contain no detectable levels of glyphosate, meaning current use of RoundUp at Chapman has no effect on the local or nearby environments.

Figure 2.6a. *Glyphosate sample site 1 (Rec Yard).*

Figure 2.6b. *Glyphosate sample site 2 (Morlan Quad).*

Table 2.3 *Metal concentrations in artificial turf run-off sample from Wilson Field.*

Metal	Secondary Maximum Contaminant Levels(mg/L)	Sample Concentration (mg/L)
Zinc	5	7.951
Copper	1	0.1101

2.3.3 Davis Community Garden

Figure 2.7. *Current state of the Davis Community Garden, April 2014.*

The Davis Community Garden was established in 2013 by students, faculty, staff, and from the generous donations of 16 departments on campus. The garden is located in the Davis Quad in the residential area. It is approximately 12.5 meters long by 8 meters wide and contains 16 beds that are able to be reserved by students, faculty, staff and classes. As a new addition, it is important to look at the Community Garden for the 2014 Audit and its impact on water used for landscaping in the residence halls.

Crystal Wang, a student worker with the position of Civic Engagement Assistant from Student Engagement was contacted in order to find out levels of use of the garden. The Davis Community Garden was officially opened in fall 2013. In fall 2013, only 6 planter beds were used. In spring 2014, all 16 beds were reserved and are currently being used. Since the installation of the garden, no change could be seen in the water bills for the Davis

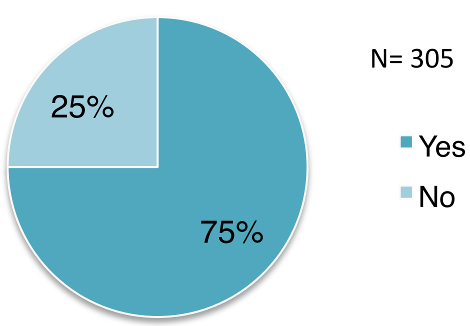

Figure 2.8a. *Are you aware that there is a Davis Community Garden that has beds that can be reserved by any Chapman Student?*

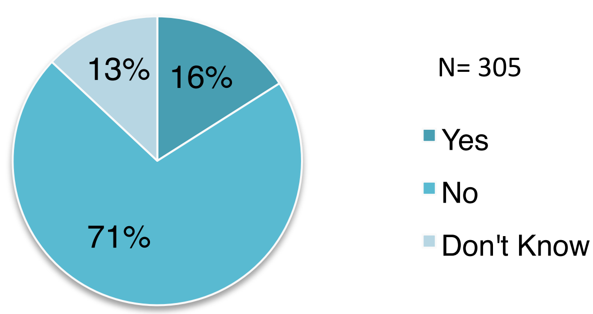

Figure 2.8b. *Have you ever used or planned to use the garden?*

Buildings between 2012-2013 and 2013-2014. We were told that Crystal waters the plants once a week and other students water their plants weekly. There is no useful data on water use with respect to the garden, but there has been no discernible increase in water use for landscaping since the installation of the community garden.

The 2014 Chapman Environmental Audit Survey: Water Use and Landscaping asked "Are you aware that there is a Davis Community Garden that has beds that can be reserved by any Chapman student?" 75% of residents said that they were aware of the community garden (**Figure 2.8a**). Those who were aware of the community garden were then asked, "Have you ever used or planned to use the garden?" The majority, 71% responded 'No', while 16% said 'Yes' and the remaining 13% responded 'Don't Know' (**Figure 2.8b**).

2.3.4 Randall Dining Commons

Randall Dining Commons is located within the Sandhu Residence Hall, which is likely the reason Sandhu's water use is much higher than other residential buildings. Because of this, the practices involving water use in the Randall Dining Commons should be understood in order to determine if any water saving practices can be recommended. Eric Cameron, General Manager of Chapman University Restaurant Services, was contacted in order to have a complete understanding of water use practices in the dining commons.

From this interview, a variety of information was gathered about water use practices in the dining hall. For example, in the past the kitchen floors were cleaned by a continuously running hose, but Sodexo now uses a best practice for cleaning floors. This uses 30-40 gallons of soap solution and 60-80 gallons of water twice daily. For dishwashing in the dish carousel and dish machines, water is recycled throughout each meal period, with up to 3 meal periods a day. The highest areas of water usage reported in the dining halls are likely from ice produced at the soda fountains. It was also reported that Sodexo uses best practice training for water usage in hand washing, cleaning, and food preparation.

While gaining information on water use practices was beneficial, this audit was unable to generate data on how much water is used specifically by the Randall Dining Commons as it does not currently have its own water meter.

2.3.5 Showerheads

In the summer of 2014 all the showerhead fixtures in the Residential Buildings will be changed from the current stock featuring 2.5 gallons per minute (gpm) flowrates to 1.5 gpm flowrates. The 2013 Audit recommended Niagara Conservation Earth showerheads, which have a flow rate of 1.5gpm. The relative savings of the Niagara Conservation Earth showerheads have been calculated using the following assumptions:

- Average student takes a 12-minute shower, calculated from 2014 Survey responses (refer to **Table 2.7**)
- Students that live in the residence halls take an average of 0.95 showers per day, which was calculated from 2014 Survey responses (refer to **Table 2.8**). The previous audit used the EPA estimate average of 0.5 showers per day.
- The average dorm population is 1647 (refer to **Table 2.9**) and students spend 245 days in the residential buildings based on the academic calendar.
- Cost of water is $2.25 per hcf
- 2.5 gallons per minute x 12 minute shower = 30 gallons/shower and 1.5 gallons/minute x 12 minute shower = 18 gallons/shower

Table 2.4. *Calculated savings from new showerheads.*

	Gallons per 12 minute Shower	Daily Total Water Usage (gallons/ day)	Residential Shower Yearly Water Usage (gallons/year)	hcf	Water Cost/year
Current Shower Heads (2.5 gpm)	30	46,930	11,497,850	15,371	$34,585.78
Retrofit Shower Heads (1.5 gpm)	18	28,158	6,898,710	9,223	$20,751.47
Water Savings		**18,772**	**4,599,140**	**6,148**	**$13,834**

To calculate the payback period of the showerheads the following information was necessary:

- There are a total of 751 bathrooms in the residential buildings
- The total cost of the Niagara Conservation Earth showerheads ordered was $5021, based on $6.19 per showerhead, excluding additional labor costs as these changes will occur during the dorm turnovers in Summer 2014 and will not be billed separately.
- The total savings in dollars is estimated to be $13,800 (**Table 2.4)**

Table 2.5 *Payback period of showerheads.*

Total Cost of Investment	**$5,021**
Savings/year	$13,834
Payback (years)	0.363

The table above shows that the payback period from switching to a lower flow showerhead would be just over 4 months. This differs from the calculation made in the 2013 Audit, which showed an 8-month payback period as it used an estimate of 0.5 showers per day (EPA, 2008).

2.3.6 Cooling Towers

The residence halls have one cooling tower, RD-060, in North Morlan, and one chiller, AAON LL-365, located in Sandhu. It is important to look as these as a component of the audit as cooling equipment uses large amounts of water each day. By looking at Chapman's current cooling systems, an estimate of their average water use can be determined.

The LL-365 chiller, the newer of the two, is a relatively efficient model. It has energy savings of 20-40% and reduces overall water consumption by 20% or more (Olympic International, 2014). On average this chiller has a flow rate of 15.52 gpm. With a run time of approximately 6 hours per day it can be estimated that Chapman University spends roughly $17 per day on water costs associated with this chiller alone (see **Table 2.6**).

Table 2.6 *Cost of water associated with chiller.*

LL-365 Daily Run-Time (Minutes)	Flow Rate (gpm)	Gallons/ Day	hcf	Cost of Water
363	15.52	5,633.76	7.53	$16.94

Because the run-time of the chillers in residence halls is not tracked , a comparable chiller at Knott's Studios was used to calculate the daily run time. The second of the two, RD-060, is a much older model. There is very little information known about this cooling tower, therefore water use and costs associated with this model cannot be estimated. It has been reported that Sandhu's site is currently operating at cycles of concentration below 3.0, which equates to a less efficient amount of water use (Refer to section 1.3.3).

2.3.7 Weather Based Irrigation System

Chapman University's Facilities Management has purchased a weather-based irrigation system that will be installed in the residence halls over the summer of 2014. Switching to this new weather based system will have benefits such as detecting leaks automatically, preventing both under- and over- watering, and saving time and manpower. It is anticipated that this system will lead to large savings in water used for irrigation. However those savings cannot be estimated given the current parameters. The system will be purchased at approximately $30,000 (excluding taxes). Over the next few years, tracking the changes in water consumption of the residence halls should be done to calculate any savings from this new system.

2.4 Survey Analysis

The 2014 Survey was used to gain a better understanding of the water consumption habits in residential buildings, as well as students' views toward landscaping specifically in the residence halls. Out of a total of 1057 students who replied to the survey, 305 live in the residence halls.

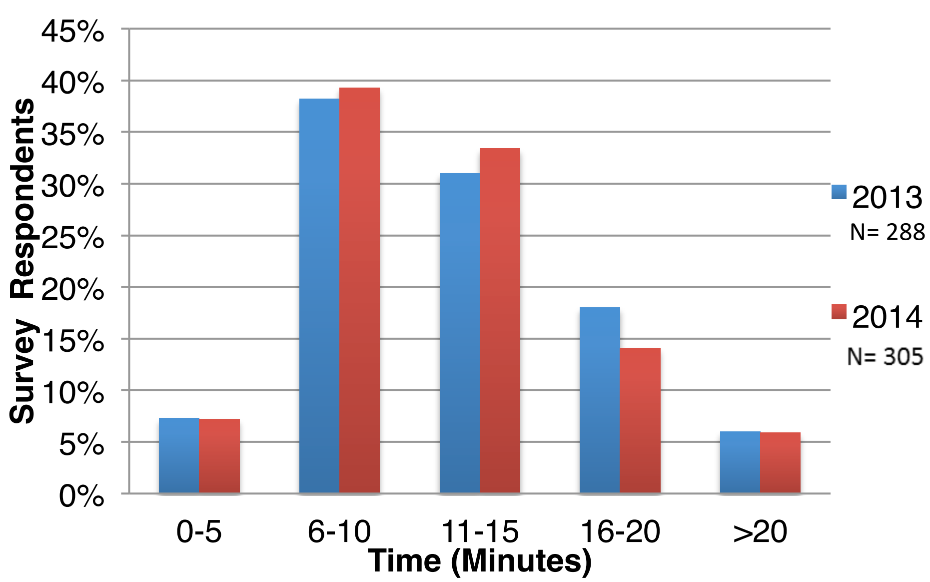

Figure 2.9 Reported shower durations by on-campus student residents.

The first question asked was, "On average, how long are your showers?" Even though this question was asked in the 2013 Survey, it was necessary to repeat the question, to get up-to-date information to correctly calculate any potential savings.

The results were very comparable to those in 2013. The average shower length from the 2013 Survey was approximately 12 minutes and remained the same in the 2014 Survey (See **Figure 2.9**).

The second question asked was, "How likely would the installation of a shower timer (**Figure 2.11**) help you be more mindful of your time spent in the shower?" When analyzing respondents with an average shower >10 minutes, the results show a positive feedback with just over 70% saying a shower timer would 'likely' or 'very likely' help them be more mindful of their time spent in the shower. About 17% said that the installation of a shower timer would have no influence.

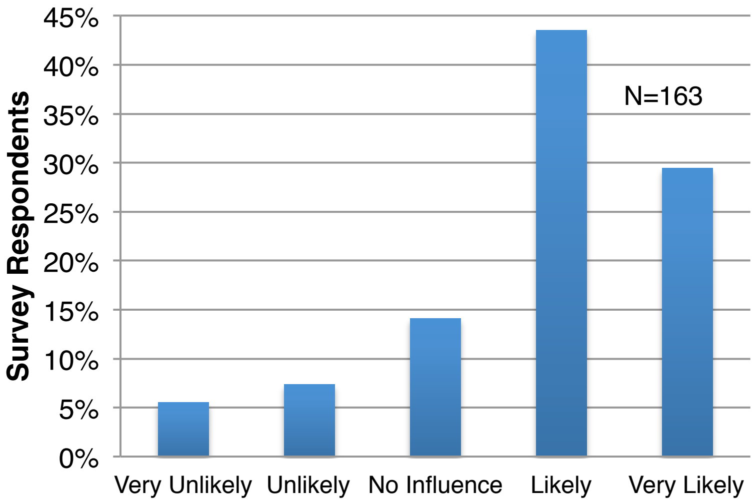

Figure 2.10. Likeliness of a shower timer affecting shower length.

Figure 2.11. Sample shower timer (http://www.rippleproducts.com/cartimages/NEW-Mini-Sand-Timer.jpg)

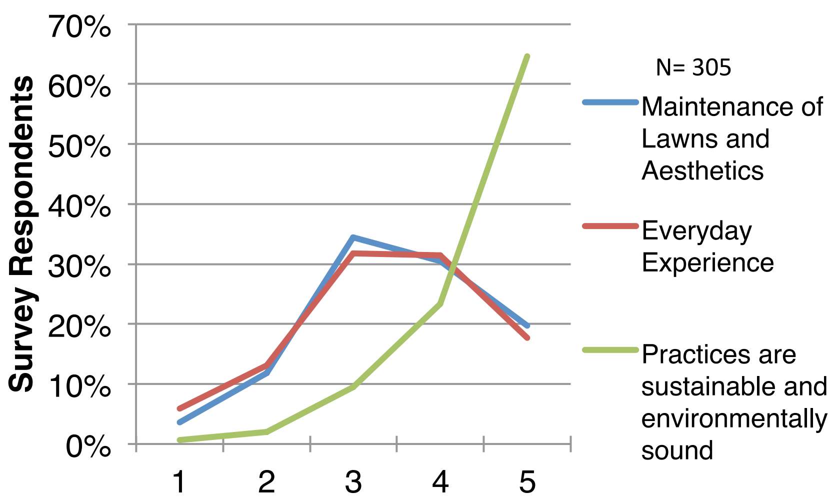

Figure 2.12. *Importance of landscaping practices.*

Three questions were asked regarding students' views towards landscaping, specifically in the residence halls. Students ranked the following questions on a scale of 1 to 5, with 1 being of little importance and 5 being of high importance:

1. "Maintaining lawns and aesthetics is an important use of resources at Chapman."
2. "The landscaping of the campus is an important part of my everyday experience."
3. "Landscaping practices at Chapman should be sustainable and environmentally sound."

Figure 2.12 shows that the majority of students chose the middle ranking (3) when asked if the maintenance of lawns and aesthetics is an important use of resources and if the landscaping as an important part of their every-day experience. However, when asked how important it was that landscaping practices are sustainable and environmentally sound, over 65% of students ranked it at a level of high importance (5). This shows that students think it is more important to have sustainable and environmentally sound landscaping practices over the general appearance of the campus.

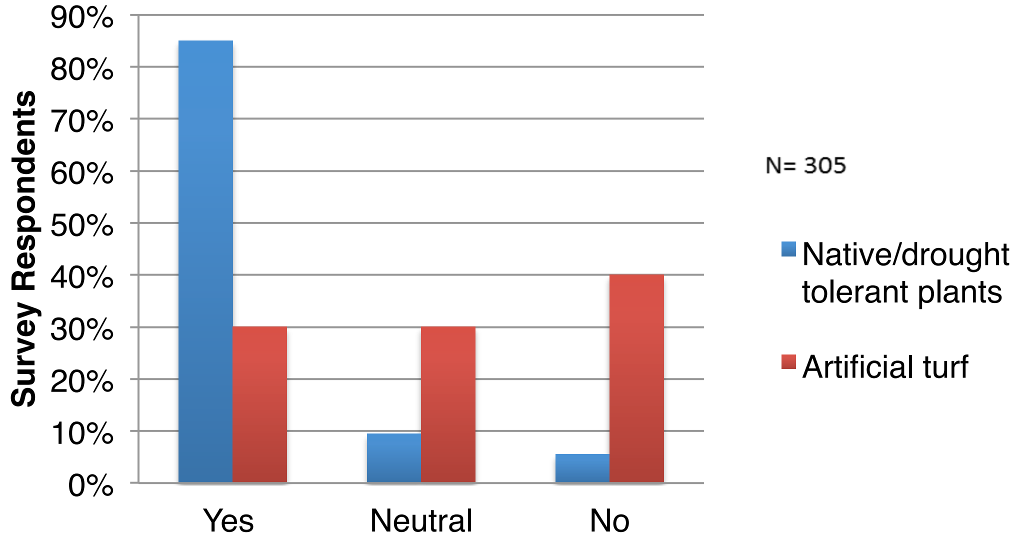

Figure 2.13. *Support the change of native/drought tolerant plans and artificial turf.*

2.5 Concluding Assessment

2.5.1 Areas of progress

Chapman and its partners are continuing to make changes in how they operate in the residential areas of campus and are continuing to replace outdated equipment with more efficient models. An example includes the investigation of installing a new dishwasher that is more efficient than the current APEX Ecolab dishwasher located in Randall Dining Commons. Another example is the current plan to replace the manual irrigation system campus-wide with a weather-based irrigation system that relies on accurate weather data to reduce excess watering. A significant accomplishment was the recent purchase of the Niagara Earth Conservation showerheads, which use 40% less water than the current model. The new showerheads will be installed in summer 2014. The last example would be the installation of the AAON LL-365 model chiller in Sandhu, which is relatively efficient compared to other models and saves roughly 20% in water and electrical usage (Olympic International, 2014).

2.5.2 Areas in which to improve

A major area of improvement for Chapman's understanding of its total water usage would be the installation of more water meters across campus, both for buildings as well as irrigation. More accurate metering will facilitate the generation of detailed water use data to easily identify areas of improvement in water usage. Currently irrigation systems are often tied together or tied in with building water meters, making it impossible to determine landscaping water usage in specific areas. In the residence halls, the ideal locations for installation of water meters would be for each landscaping area. While Henley and Sandhu currently have landscaping-specific water meters, areas such as the Davis Apartments landscaping area and the Morlan Hall landscaping area do not have separate meters. Because of this, it is difficult to track how much water these areas are using.

Currently, the cooling towers in the dorms are not monitored. Monitoring these would give a more accurate view of the water use associated with the LL-365 chiller and the RD-060. Determining the efficiency of these cooling towers would allow for future recommendations to be made, including replacing the older RD-060 cooling tower with a more efficient version.

A final area of improvement would be to have the continued installation of low-flow faucets, urinals, and toilets in place of less efficient models. While it may not be cost-effective to replace all water fixtures immediately, when a less efficient model does break the installation of the most efficient model available would be ideal. The current procedure doesn't demand that the most efficient model is installed, just a model that is already on hand. Continually replacing low-flow showerheads and faucets will also reduce water usage, with relatively short payback periods.

2.5.3 Existing gaps in knowledge

The largest gap in knowledge would be the lack of detailed metering for irrigation. While residential buildings have separate meters for some areas of landscaping, it is still difficult to discern where all the sources for irrigation originate. By installing meters in appropriate places so that individual landscaping areas could be studied, irrigation water use can be properly tracked to ensure the most efficient use of irrigation and to quickly detect leaks. As stated in Section 2.5.2, by installing water meters for the landscaping areas in Davis Apartments and Morlan Hall, water usage pertaining to those landscapes could be more easily understood, leading to finding areas of potential water use savings.

Another current gap in knowledge would be the amount of water used specifically for the Randall Dining Commons. While it is known how much water the entire Sandhu Residence Hall and Conference Center uses, we do not properly understand how much of that water is used by residences and how much is used by the Dining Commons. By properly metering Randall Dining Commons, the Sandhu Residence Hall water use can be more properly compared with the other dorms, rather than simply assuming Randall Dining Commons causes the increased water usage in this residential building.

2.6 Recommendations

2.6.1 Low cost/effort

- As stated in the 2013 Audit, Chapman's residence halls should hold water competitions to reduce the amount of water used per student.

While the prize for the winning residence hall would be a slight investment, the competition will likely more than pay for itself. At Emory University, a campus wide water competition saved over 5,000 hcf (1.5% of yearly water usage) of water in one month alone (Martin, 2013). At Chapman that would result in saving almost $1700 per year.

- Implement a system where water bills are converted into Microsoft Excel format to more easily track water usage over time.

Currently water bills are only saved as scanned PDFs. Manually inputting months of data at a time can lead to mistakes in accurately reading and reporting the data, including the mistake in the 2013 Audit mentioned earlier. Starting this system will likely require no initial investment, but with the ability to easily track water use over time, areas of water-savings will be easier to pinpoint. As individual water bills are reviewed when water bills are paid, the employee in charge of billing could have a prefabricated spreadsheet to input water use and water cost data. The only cost involved would be the larger amount of man hours associated with inputting the water bill data into the spreadsheet, as well as the initial time needed to create the spreadsheet. A sustainability intern could create a working spreadsheet in a short period of time. This will lead to a more complete overview of water use on campus.

2.6.2 Moderate cost/effort

- Install shower timers (See Figure 2.11) in all residential showers to allow residents to be more conscious of their water use over time.

70% of resident survey respondents from the 2014 Survey that had a shower time greater than 10 minutes reported that a shower timer would help them be more mindful of time spent in the shower. Even a two minute reduction in shower time would pay back the installation of shower timers in ~5 months (Table 2.10).

- Implement a more aggressive chemical treatment process by working with Capture H2O to increase the cycles of concentration of the cooling towers from just below 3.0 to 6. [(Water Treatment Audit, 2013) and section 1.3.3.]

Doubling the cycles of concentration would result in a 20% reduction, reducing water use per day to 1126.15 gallons, and a savings of up to $1100 per year (Table 2.11).

2.6.3 High cost/effort

- Replace the older cooling tower in North Morlan with a more efficient version.

As there is little information on this cooling tower we cannot estimate any savings associated with it, but knowing that it is an older model that likely uses more water than the comparable chiller LL-365 chiller, it is recommended that it be replaced.

- Increase the size of the Davis Community Garden to allow more people to benefit from it without dramatically increasing water usage.

The Davis Community Garden does not currently have a quantifiable impact on water use in the residential buildings. However, it is considered a challenging recommendation as it has no current return on investment. Crystal Wang reported that there has still been demand for the garden despite all the beds being full. This reflects its popularity despite the 70% of survey respondents stating that they have never used or planned to use it. As the garden is open to use by all students, faculty and staff this percentage may not accurately reflect the garden's popularity as only residential students were polled.

2.6.4 Future areas of research

Areas that could be researched could include the installation of a greywater irrigation system in all new residential buildings. The installation of a greywater system is significantly cheaper in a new building than when retrofitting an existing building. This could likely result in a large reduction in water used for irrigation and flushing toilets on campus.

Another future area of research would include the installation of a rainwater catchment system on campus to be used for irrigation. Instead of allowing water to runoff of buildings into the storm drain, it could be captured and collected to be used in times of little rainfall, rather than relying on water from an outside source. At Emory University, two residence halls use solar powered pumps to flush toilets with the collected water (Emory University, 2014). While rainfall occurs more often in Atlanta, GA then here in Southern California, similar measures could be used to collect rainfall for future irrigation.

As stated in section 2.6.3 not all populations were used to gather data on the community garden, therefore its demand is not accurate. In the future, survey questions should be asked to all aspects of Chapman's population, garden usage should also be monitored more closely to reflect its popularity and ensure continuous usages.

It is unclear how much water the new Weathermatic weather-based irrigation system will save. By tracking future water bills for the next few years, an estimate of water savings can be derived.

2.7 Contacts

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2.9 Appendices

2.9.1 Data tables

Table 2.7: *Calculations showing average shower length*

Time Intervals (minutes)	Median Time (minutes)	Proportion of Students	Median x Proportion (minutes)
0-5	2.5	0.0721	0.18025
6-10	8	0.3934	3.1472
11-15	13	0.3344	4.3472
16-20	18	0.1410	2.538
>20	25	0.0591	1.4775
Total	**-**	**-**	**11.69**

- Assumption: People that take longer than 20 minutes to shower will take a shower anywhere in between 20-30 minutes, generating a median of 25 minutes.
- Average shower time of 11.69 minutes is rounded up to 12 minutes.

Table 2.8 *Calculations showing average showers taken per day.*

Showers/ week	Median (showers/week)	Proportion	Median x Proportion (showers/week)	Showers/day
3-5	4	0.275	1.1	-
6-8	7	0.59	4.15	-
9-11	10	0.095	0.95	-
11-14	12.5	0.036	0.45	-
Total	-	-	**6.66**	**0.95**

Table 2.9 *Average dorm population.*

Semester*	Dorm Population
Fall 2012	1734
Spring 2013	1640
Fall 2013	1673
Spring 2014	1627
Average	**1647**

*Excluded Fall 2012 as it is an outlier

Table 2.10. *Shower timer costs.*

Cost/Shower Timer	Number of Shower Timers	Total Initial Investment
$0.50	1000	$500

Number of Showers	Days/year	Showers/Day	Minutes saved/shower	Flow rate (gpm)	Gallons saved/ year	Hcf saved/ year	Cost/ Hcf
751	245	0.95	2	1.5	424,536	567.56	$2.25

Savings/Year	Payback Period	First year savings
$1277	0.40 years	$777

Table 2.11. Savings associated with doubling the cycles of concentration.

Cycles of Concentration	Gallons/day	Hcf	Water cost/day	Cost/ year
3.0	5,633.76	7.53	$16.74	$6110.10
6.0	4,507.01	6.03	$13.56	$4949.40
Savings	1126.15	1.5	3.18	$1160.70