Planning for Water Resource Management

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PLAN 597

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PLAN 597: Planning for Water Resource Management
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Assignment #1: Data Analysis

Water consumption in the Biological Sciences Complex: A comparison between the 3 wings.

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Overview:

This analysis aims to first explore the trends and changes in water consumption in each of the three wings of the UBC Biological Sciences Complex over a one and a half year period and then to compare the water usage between the three wings (South and West Wing- renovated with water management improvements, North wing- not renovated). Using the North wing as a control, the effectiveness of the new water management system in the renovated wings and its impact on water consumption will be examined.

Building information:

The Biological Sciences Complex, originally constructed in 1950, has three wings: South (completed in 1959), West (completed in 1968) and North (completed in 1974). This complex houses lecture rooms, offices and research laboratories. In 2011, as part of the UBC Renew project, a program that renovates instead of demolishes deteriorating buildings, the Biological Sciences Complex's South and West wings underwent 22 months of renovation that included the following building improvements:

- Seismic upgrade
- New life safety systems
- New back-up generators to provide emergency light, ventilation, and animal life support
- New fume hoods, lab furniture and storage facilities
- New building HVAC system
- Upgrades of existing windows and skylights
- Installation of Sun Central natural daylight system
- Building envelope improvements
- **High efficiency equipment in HVAC systems**
    - **Water source heat pumps for heating and cooling**
- **High efficiency plumbing fixtures**
- Redesign of lab, office and classroom spaces

This $64 million renovation was completion in August 2011 and is expected to help save 15,170,313 MJ and $209853 per year. Both of the South and West wings have applied for LEED Gold certification and have been awarded the Canadian Green Building Award in 2012.

Data analysis:

Raw data of water consumption used in this analysis is extracted from the Ion meter software. The values used is the daily recorded water usage measurement (given in m^3 but converted to cm^3) for each of the three wings of the Biological Sciences Complex divided by the area (m^2) of each wing.

The water meters are only installed after the renovation of the two wings, therefore data before the renovated date is not available, making a before and after-renovation comparison impossible.

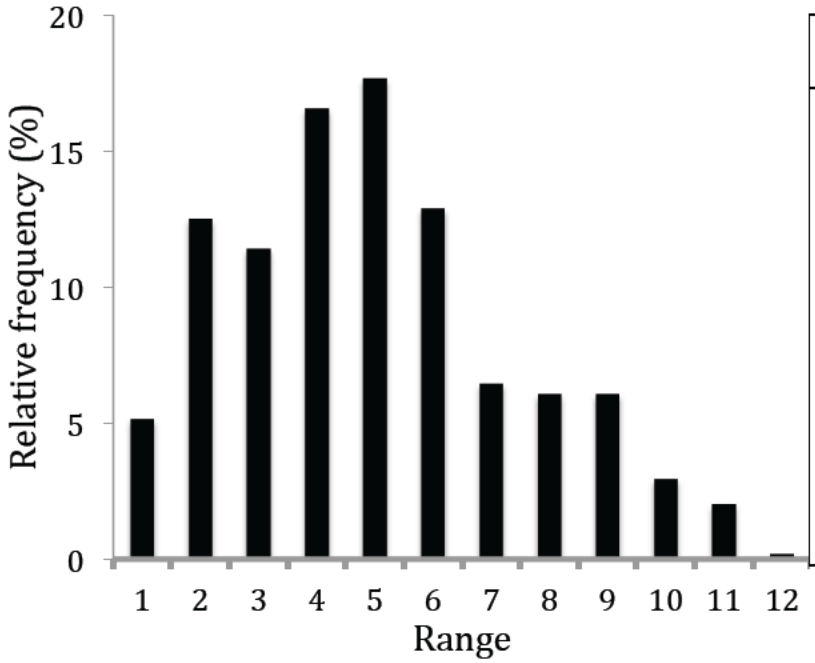
Because the before- renovation is not available, in order to find out whether water management improvements made during the renovation have an impact on water consumption, a comparison between the un-renovated North wing and the renovated South and West wing will be made. As the size of each wing is different, the daily water usage in cm^3 per m^2 will be used as the unit of comparison (Area of each wing in Appendix 1).

Daily measurements were chosen as the measuring frequency for analysis because there are some daily measurements missing in some of the months for North wing, therefore, it would be impossible to find out the monthly water consumption for the months with missing daily values.

Bio Sciences South

Table 1. Statistic summary of daily water consumption in Bio Sciences South measured between April 10, 2013 to October 5, 2014. Water consumption values are measured in cm^3/m^2. n= 543.

	Daily water consumption
Mean	80005.11
Median	75894.47
Max	182237.08
Min	18612.22
Range	163624.86
Variance	1107210801
Standard deviation	33274.78



Range	Water consumption range (cm^3/m^2)
1	18612.22-32247.62
2	32247.62-45883.03
3	45883.03-59518.43
4	59518.43-73153.84
5	73153.84-86789.24
6	86789.24-100424.65
7	100424.65-114060.05
8	114060.05-127695.46
9	127695.46-141330.86
10	141330.86-154966.27
11	154966.27-168601.67
12	168601.67-182237.08

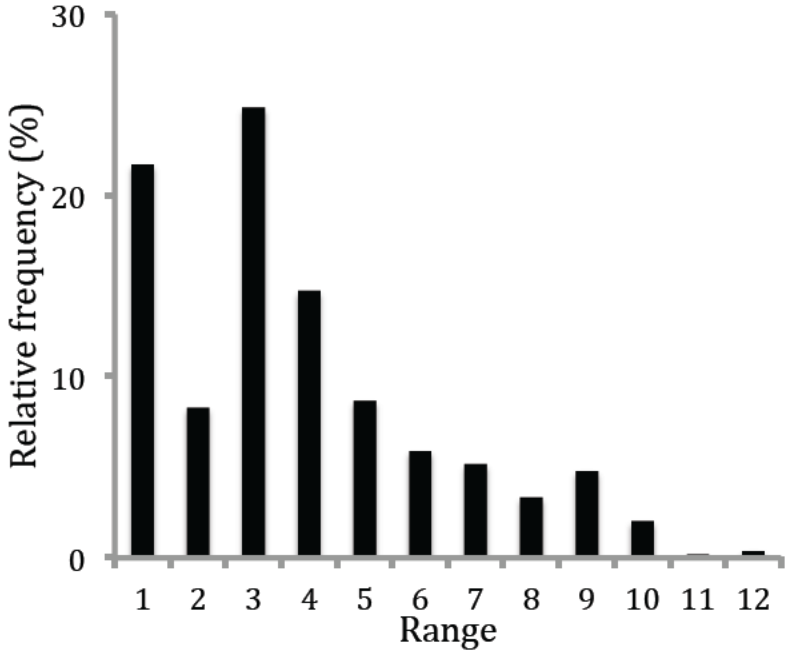
Figure 1. Histogram of daily water consumption per m^2 in Biological Sciences Building- South wing between April 10, 2013 to October 5, 2014.

The histogram of the daily water consumption per m^2 for the South wing follows a relatively normal distribution. The histogram is symmetrical, which reflects that the mean is relatively close to the median (Table 1). The range of water consumption values most frequently recorded is in the range of 73153.84 to 86789.24 cm^3/m^2 (Range 5), accounting for 17.68% of all measurements. The frequency of measurements recorded within the study period decreases as the water consumption decreases and increases.

Bio Sciences West

Table 2. Statistic summary of daily water consumption in Bio Sciences West measured between April 10, 2013 to October 5, 2014. Water consumption values are measured in cm^3/m^2. n= 543.

	Daily water consumption
Mean	2016.16
Median	1757.59
Max	7255.86
Min	24.84
Range	7231.02
Variance	2206209.82
Standard deviation	1485.33



Range	Water consumption range (cm^3/m^2)
1	28.84-627.42
2	627.42-1230.01
3	1230.01-1832.59
4	1832.59-2435.18
5	2435.18-3037.76
6	3037.76-3640.35
7	3640.35-4242.93
8	4242.93-4845.52
9	4845.52-5448.10
10	5448.10-6050.69
11	6050.69-6653.27
12	6653.27-7255.86

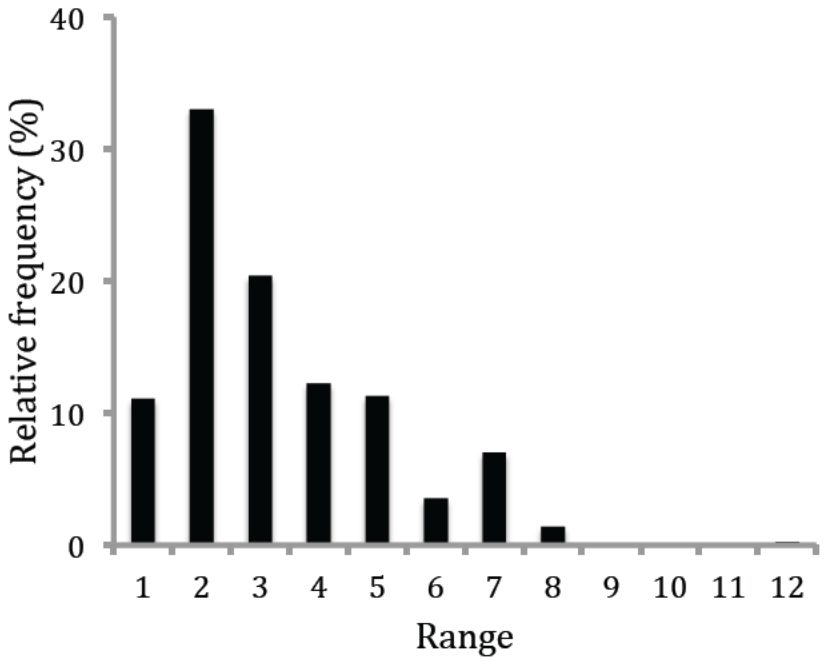
Figure 2. Histogram of daily water consumption per m^2 in Biological Sciences Building- West wing between April 10, 2013 to October 5, 2014.

Figure 2 shows that the daily water consumption measurement is skewed to the right, which suggests that a few high water consumption readings have brought up the mean. This indicates that the mean daily water consumption should be lower if not for the isolated days with higher water consumption. It is also interesting that the lowest range of water consumption values are recorded as the second most frequent, but the next range of values is recorded much less frequently. One possible explanation for this anomaly could be that there is a lab equipment in the West wing that consumes a significant and constant amount of water and is operational only half of the time. Assuming the distribution of all other water consumptions stay relatively the same, when the laboratory is not operational during the studied period, the readings will be low, increasing the frequency of the readings in range 1 and for the other half of the time when it is in operation, it consumes the same amount of water daily for a period of time, resulting in a high frequency of days with similar water usage, explaining the high frequency of range 3. The amount of water it consumes daily should equal to the value recorded in range 1 subtracted by value recorded in range 3.

Bio Sciences North

Table 3. Statistic summary of daily water consumption in Bio Sciences North measured between April 10, 2013 to October 5, 2014. Water consumption values are measured in cm^3/m^2. n= 515.

	Daily water consumption
Mean	3808.64
Median	3460.78
Max	10130.89
Min	1936.67
Range	8194.23
Variance	1481990.08
Standard deviation	1217.37



Range	Water consumption range (cm^3/m^2)
1	1936.67-2619.52
2	2619.52-3302.37
3	3302.37-3985.22
4	3985.22-4668.07
5	4668.07-5350.93
6	5350.93-6033.78
7	6033.78-6716.63
8	6716.63-7399.48
9	7399.48-8082.34
10	8082.34-8765.19
11	8765.19-9448.04
12	9448.04-10131.89

Figure 3. Histogram of daily water consumption per m^2 in Biological Sciences Building- North wing between April 10, 2013 to October 5, 2014.

This histogram is skewed to the right, indicating that the high level of daily water consumption (10131.89 cm^3/m^2) is an anomaly resulted from an isolated event that spiked up the water consumption for that particular day. This also means that the mean daily water consumption for North wing is brought up due to this one measurement.

Comparison between the three wings of the Biological Sciences Complex (North is not renovated, South and West are renovated):

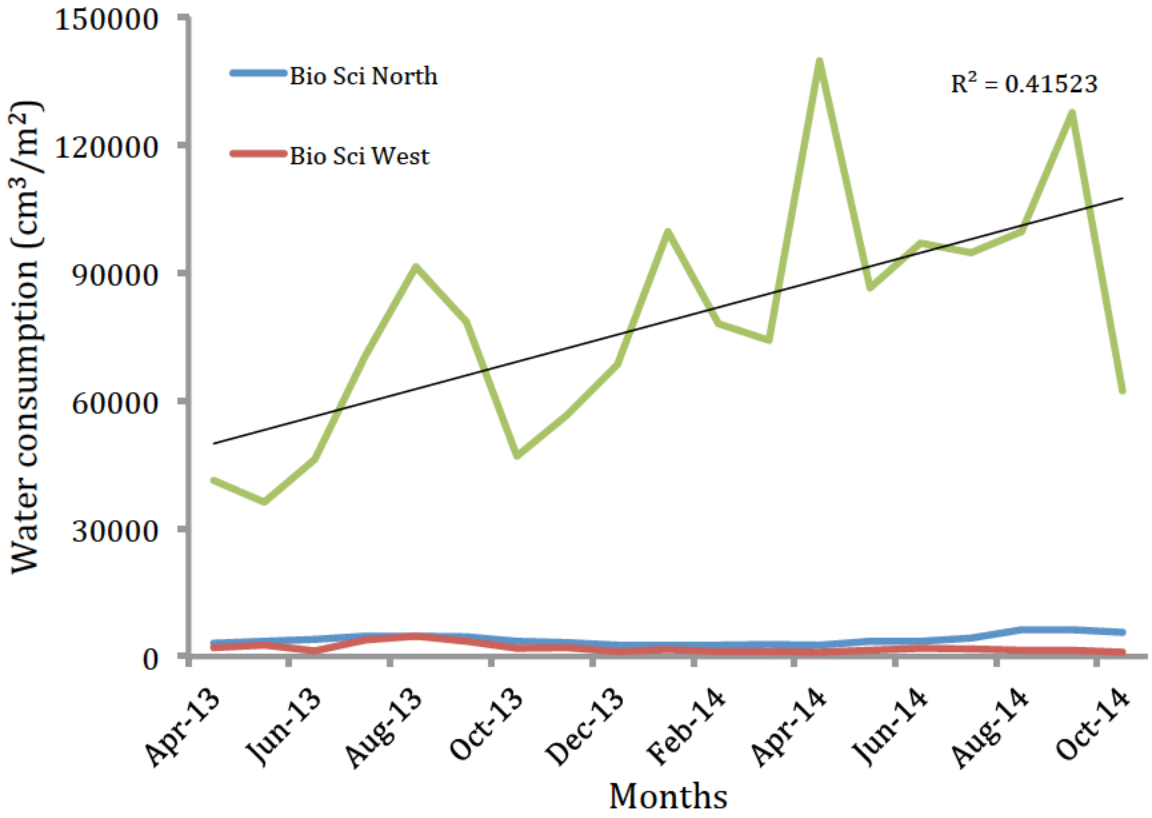


Figure 4. Daily water consumption of Biological Sciences South wing, West wing and North wing the from April 2013 to October 2014.

As shown in Figure 4, the daily water consumption in the South wing fluctuates throughout the year and appears to have a general increasing trend (R^2=0.41523). More importantly, the daily water consumption per m^2 in the South wing is orders of magnitude greater than the daily consumption in both the West and North wing. This is a surprising result because the South wing has undergone renovation and should have lower consumption compared with the North wing. This large difference of daily water consumption may be explained by the type of laboratories that are located in each wing. All three wings consist of offices, lecture rooms and laboratories, however, the laboratories in the South wing includes the wet lab, the aquatic research lab and the water tanks, which all have a much higher water demand than other laboratories.

This implies that we cannot base the efficiency of a water management system on water consumption values alone, the level of efficiency and sustainability of a building or water management system should be dependent on the function of the building.

Comparison between Bio Sciences North (not renovated) and Bio Sciences West (renovated):

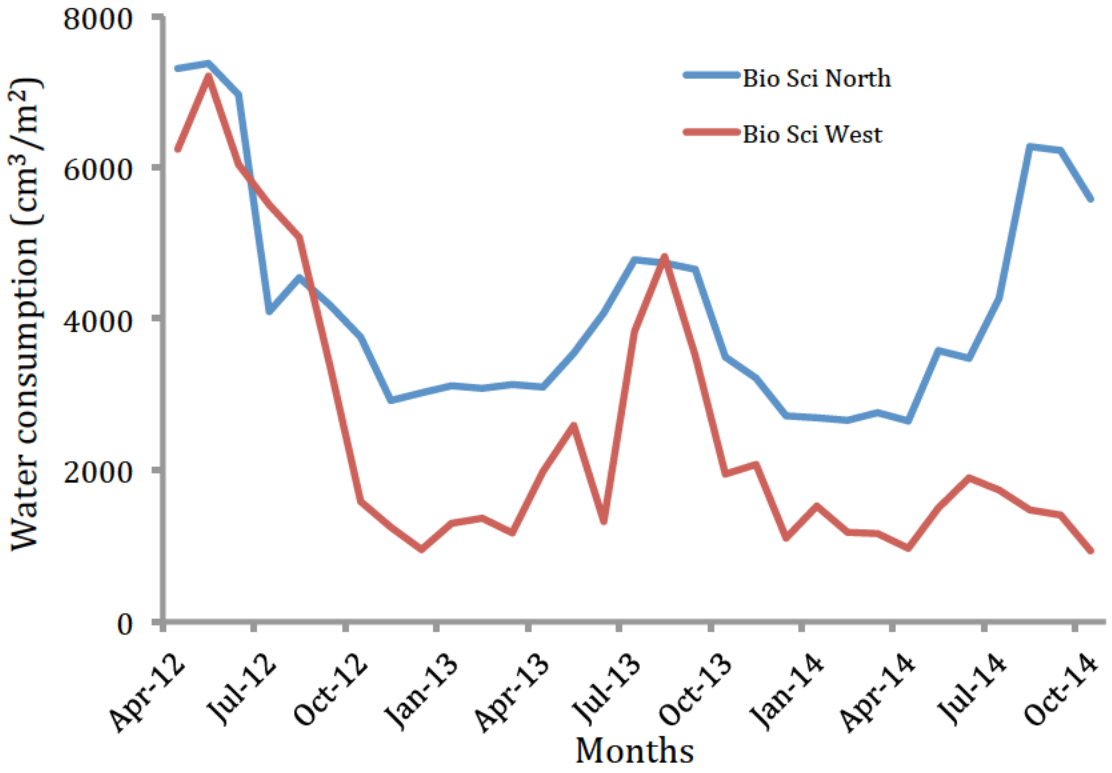


Figure 5. Daily water consumption of Biological Sciences West wing and North wing the from April 2012 to October 2014.

Although the South wing has whole different range of water consumption due to its laboratory usage, the West and North wings have consumption values in a similar range. When the daily water consumptions of the West and North wings are compared, it appears that both wings follow a similar trend, with regular peaks and troughs throughout the year (Figure 5). Daily water consumptions for both wings seem to peak during the summer semester (May-September). Even though the student flow normally decreases during the summer months, the Biological Science Complex is still occupied during the summer for summer courses. But perhaps what contributes the most to the increase in water consumption is the increase in research activities and laboratory usage. Graduate students and professors that would have been doing research part-time during the school year would generally resume their full- time research during the summer. The increase in the laboratory activities may be the reason for the increased water consumption.

Table 3. Two-tail unpaired t-test for mean daily water consumption between Biological Sciences North and Biological Sciences West. ($p<0.05$)

	Bio Sci North	Bio Sci West
Mean	3808.64	2016.16
Standard deviation	1217.37	1485.33
Sample size	515	543
t	27.22	
df	1056	
p-value	4.5464E-124	

Figure 5 illustrates that not only do the North and West wings follow a similar trend in terms of water consumption throughout the year, it also shows that daily water consumption in the North wing (un-renovated) is consistently higher than the consumption in the West wing (renovated). Statistically, when the mean daily water consumptions of the two buildings are compared, the p-value is much smaller than 0.05 (Table 3), which indicates that there is a greatly significant difference between the means for daily water consumption in Biology Sciences North and Biology Sciences West. This in an important result as it shows that the renovation in the West wing is effective in decreasing water consumption.

Conclusion

By comparing the North and West wings of the Biological Sciences Complex, we are able to see a clear decrease in daily water consumption. This is evidence that the new water management system installed during the renovation is effectively decreasing water consumption in the building. Not only does this positive result reinforce our need for better water management systems, but the success of the system improvement can also encourage and advocate for future renovation projects on campus.

Unfortunately, in terms of the South wing, it is impossible to evaluate the effectiveness of the new water management system without the before-renovation water consumption data. It simply does not make sense to compare buildings with different operations and different levels of water demands.

APPENDIX

Appendix 1. Area of the Biological Sciences Building Wings

	Area (m^2)
Biological Sciences Building- North	5577
Biological Sciences Building- West	8021
Biological Sciences Building- South	5534