Assessment of Drinking Water at UBC: A consideration of water quality, energy and economic costs, with practical recommendations

A self-directed group project for ENVR 400

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About the Authors

Allina Tran

Allina is in her final year of the Environmental Science Program at UBC. Oceanography, terrestrial water, meteorology and physical geography courses taken within her chosen area of concentration, Land, Air, and Water provides her the knowledge to investigate current environmental concerns from a dynamic interconnected perspective. Through a geographical biogeosciences field course, she has also gained field sampling, instrumentation, surveying and mapping techniques while further refining her abilities in data analysis. Past work experiences as a coordinator for a youth at risk summer program with aims to incorporate/promote more environmentally sustainable practices, has also first handedly expanded Allina's understanding of the complexity and energy required to bridge the gap between science and social aspects of environmental issues.

Beatrice Li

Beatrice Li is a fourth year Environmental Science student in the Faculty of Science at UBC. Within her chosen area of concentration, Land Air Water, she has completed a wide variety of courses that have equipped her with knowledge and skills in environmental chemistry, oceanography, meteorology and physical geography. In addition, courses in environmental science and social geography have helped her develop a good understanding of the environmental issues we currently face. Past experience in group class projects includes:

- Using GIS to develop a multi-criterion model for finding ideal locations for senior care facilities in the City of Vancouver.
- Field sampling using sensory equipment to collect data for statistically comparing the photosynthetic rates of Lodgepole Pine saplings found in different canopy conditions in the Kananaskis Valley. Microsoft Excel was used to analyze data and results were presented in electronic poster format.

Darcy McNicholl

Darcy McNicholl is a graduating student in Environmental Science with an AOC in Ecology. She has a primary interest in biology and is currently working as a lab assistant for Bill Harrower in the Beaty Biodiversity Center classifying insects collected from pit fall traps. Darcy has also had a considerable amount of field experience not only working for Harrower in the Lac du Bois grasslands but also through volunteering in South Africa, Namibia and Costa Rica. Darcy has her level one field guiding certification in South Africa, in addition to her advanced biological surveying qualification through BTEC. Her skills include telemetry, computer programming using Python, invertebrate identification and small mammal trapping. Although her focus is in biology Darcy is keen on addressing environmental issues that pertain to everyday life, and does so by being an active member of the Environmental Science Student's Association (ESSA). She is the director of finance and is heavily involved in planning events for environmental science students as well as outreach such as Career fairs and giving lectures to elementary school classes at University Hill on environmental issues.

Josh Noble

Josh Noble is a fourth year Environmental Science student in the faculty of Science at the University of British Columbia. His area of concentration and interests lies in the Land, Air and Water category of the program. The completion of a spectrum of courses within the program has given him knowledge on subjects such as: atmospheric sciences and meteorology, oceanography, environmental sciences and Geographic Information Systems. In the GIS courses he mapped new bike routes for Vancouver and is currently working on mapping salmon spawning routes. Throughout his undergraduate degree he has used Excel to perform many analytical analyses such as the phytoplankton blooming cycles in the Strait of Georgia. Throughout Josh's post secondary education he has worked cooperatively and effectively on many group projects.

Katherine Van Dijk

Katherine Van Dijk is a fourth year Environmental Science student in the land, air and water area of concentration. With a variety of classes, she has experience in oceanography, atmospheric science, soil science, ecology, as well as a background in astronomy, physics and mathematics. Completed projects include an individual study of phytoremediation in regards to mine contamination, and modelling the spread of forest fires using cellular automata. She has also worked in many group endeavours including analyzing the nutrient concentrations in the Western English Channel, and the effects of pollutants in the Yangtze River. She shares Darcy's interest in environmental problems which affect everyday life, particularly those quality and conservation, fair trade, sustainable agriculture, and mine contamination.

Nicole Lee

Nicole Lee is in her fourth year of studies in the Environmental Sciences program at UBC. She is interested in aquatic systems and her courses have reflected this, within her chosen Area of Concentration of Ecology. Success in courses in environmental sciences, biogeography, ecology, and GIS, have provided her with a skill set that includes the abilities to collect, compile, and analyze data through statistical means, critically review scientific papers and write research and project proposals, and to use ArcMap10 to answer spatial questions. In 2010, she worked in a group of four to develop a Wastewater Management Plan Proposal for the UBC Point Grey Campus as part of the Applied Sustainability: UBC as a Living Laboratory (APSC 364) course. In the summer of 2011, she gained experience collecting field samples, mapping topography with Total Station equipment, and recording data. Course projects, labs, and field work have allowed her to work effectively both independently and as part of a team.

Executive Summary

Introduction

Students, faculty, and staff at the UBC Vancouver campus currently have three choices for drinking water; tap water from drinking fountains, bottled water sold at food service locations and vending machines, and water filtered by various additional filtration systems. These three drinking water systems each have different environmental, economic, and health implications. People have begun to question the necessity of the bottled water industry due to increasing awareness of its environmental costs. However, UBC students, staff and faculty may still choose bottled water over tap water if they have concerns or misconceptions over tap water quality. In response to concerns over the environmental impacts of bottled water and tap water quality, the UBC Alma Mater Society (AMS) has invested in the installation of water filtration units known as WaterFillz stations. There have been previous student papers written to compare the environmental, economic and social implications of these three drinking water choices; bottled water, tap water, and WaterFillz filtered water. While these papers have provided a good overview of the general impacts of the three drinking water options, our project aims to further develop the analysis by exploring questions in a more systematic and quantitative way.

Research Objectives

Environmental Implications

1a) Estimate and compare embodied energy costs of the bottled water, tap water, and WaterFillz systems and identify system components which contribute the most.

1b) Qualitatively discuss other environmental implications such as waste generation and recycling.

Water Quality Assessment

2) Determine whether heavy metal contamination of campus tap water merits cause for concern.

Economic Considerations

3a) Quantify the economic implications of the potential removal of bottled water from UBC campus.

3b) Compare the economic costs of three different water filtration systems; Elkay, Brita, WaterFillz.

Recommendations for the placement of WaterFillz stations

4) Make recommendations for where to install additional WaterFillz units on campus, based on conclusions of the water quality assessment combined with survey responses and building traffic data.

Section 1: Environmental Implications

Environmental impacts of the drinking water options (bottled water, tap water + reusable bottles, WaterFillz filtration + reusable bottles) are compared through quantitative assessment of the energy consumed in all steps leading up to the consumption of water by the consumer, using a systems-based approach. Waste generation and recycling for these systems are qualitatively discussed. We found that the energy impact of bottled water scenarios (280 -3340 MJ), based on the 591 ml Dasani bottle, is considerably larger than tap water + reusable bottles scenarios (8.05 -734 MJ) even after the addition of WaterFillz stations to tap water + reusable bottle scenarios (22.9 – 749 MJ). The main contributor of energy costs to the bottled water system is the production of plastic disposable bottles, followed distantly by the cost of transportation. The main contributor of energy costs to the tap water system is energy used in heating water for washing of reusable bottles. Washing bottles in cold water significantly lowers energy costs. Steel appears to be the least energy intensive reusable bottle material, followed by durable plastic and aluminum in increasing order.

Not included quantitatively in our calculations are any credits or savings that may be gained for materials that are recyclable. Each of our three examined systems has components that can be recycled; plastic or metal bottles and steel or plastic WaterFillz parts. We found that while the recycling of the disposable plastic bottles reduces the amount of virgin material required for products down the line, the recycling of the bottles does not contribute directly to material for new plastic bottles. Materials used to package both disposable and reusable bottles for shipping or selling can contribute to waste generation. Used filters and bleach used for periodic disinfection of WaterFillz units would also contribute to waste generation.

Section 2: Water Quality Assessment

Our water quality assessment focuses primarily on the concentration of Copper, Zinc and Lead in campus water, and investigates the concentration of these metals from a few chosen buildings at UBC. Using water quality data from Plant Operations, in combination with results of our own water quality testing experiments, we found elevated concentrations of Copper and Zinc in Totem Residence and Earth and Ocean Science (EOSC) Main while Fred Kaiser, Geography, Buchanan A and Scafe contained moderate concentrations. Metal concentrations in Dasani bottled were found to be the lowest (too low to be detected) followed by WaterFillz filtered water and the water from water fountains in the Student Union Building (SUB). We also observed a decline in metal concentration as the week progressed and with increasing flushing time.

Because our test results for copper, zinc and lead concentrations all fall within the

Canadian Health Guidelines, we conclude that tap water on campus provides no prominent health risks but the installation of better plumbing and filtration units would improve the current water quality. Our results also show that the WaterFillz stations can effectively lower metal concentrations, if that is still desired.

Section 3: Economic Considerations

The economic analysis considered the loss of profits for the AMS and UBC Food Services should they stop selling bottled water. Although these are important sources of revenue, if the costs were to be spread out among students in the form of fees, the cost to students would be fairly negligible. We also considered these, and other costs to students. Buying bottled water regularly is very expensive for students when compared to using re-useable water bottles, which pay for themselves after only five to eight refills, depending the bottle purchased.

Three options were compared for providing filtered water, namely the WaterFillz kiosks, Brita Hydration Station, and an Elkay model. After five years of running costs, the WaterFillz were found to be the most economical because of considerably larger filters which do not need to be replaced nearly as often as the other models. The WaterFillz Station came out cheaper with or without considering the costs of energy required to run the systems. This is important to consider some of the models have the option of no refrigeration, thus changing the energy demands, and the WaterFillz may be run off of solar power.

Some suggestions for recouping the costs of no longer selling bottled water are to advertise on the WaterFillz kiosks, have fundraisers and collect donations, possibly increase student fees and sell more re-useable water bottles.

Section 4: Recommendations for the placement of WaterFillz units

Ideal potential locations for additional WaterFillz stations are identified by synthesizing water quality data, building traffic data, water fountain accessibility data and survey results (survey, Appendix A). With consideration of all factors, we recommend placement of water filtration stations in the following buildings:

Geography	Totem	Swing
Buchannan	Scarfe	Civil & Mechanical engineering
Woodward	Forestry	Macmillan
EOSC	Math	Hugh Dempster
Sauder		

Buchannan and Woodward had the highest student traffic to water fountain ratios and were identified in our survey as popular locations for water fountains use. EOSC, Totem, Geography and Scarfe are included because of relatively high metal concentrations, although still within Canadian health guidelines. Forestry, Swing, Civil & Mechanical engineering, Math, Hugh Dempster and Macmillan are included because they were found to have only 0-1 water fountains. Sauder is included because of high student traffic.

Introduction

Background

Students, faculty, and staff at the UBC Vancouver campus currently have three choices for drinking water; tap water from drinking fountains, bottled water sold at food service locations and vending machines, and water filtered by various additional filtration systems. These three drinking water choices have different origins, and as a result, contribute different environmental, economic, and health considerations that must be taken into account by the University to enable well-informed and responsible drinking water decisions.

Bottled water, defined as drinking water packaged and sold in plastic bottles intended for single use, has significantly risen in popularity in North America over the past decade. At the same time, people have begun to question the necessity of the bottled water industry given increasing awareness of environmental costs. People are also realizing that readily available tap water may not necessarily be of lesser quality than that sold in a bottle. Currently in existence is the campus bottled-water-free zones campaign, a Polaris Institute initiative in collaboration with the Canadian Federation of Students and the Sierra Youth Coalition. Their aim is to “challenge the corporate control of water one space at a time by raising awareness and action on the bottled water industry and calling for the re-building and maintaining of safe and accessible public tap water systems for all” (Anon. 1, from the *Inside the Bottle* website, accessed Oct. 2011). As of 2008 there were over 50 bottled water free zones on 21 campuses (Anon. 2, from the *Inside the Bottle* website, accessed Oct. 2009). In these spaces, bottled water cannot be purchased or used, and alternatives are promoted and provided. This is part of a growing movement in which universities of all sizes are partaking. This includes the majority of locations at Canada’s largest university, the University of Toronto’s St. George campus (Anon. 3, *University of Toronto Media* website, accessed Oct. 2011).

According to our survey of UBC Vancouver students, faculty and staff; primarily undergraduate students, 8% and 10% of survey respondents claim purchasing bottled water is their means of accessing drinking water on campus and off campus respectively. 75% of survey respondents have heard of previous initiatives to remove bottled water from campus. Survey questions, detailed information of survey methods and participant demographics can be found in Appendix A.

Although the water supplied to UBC from Metro Vancouver is considered to be some of the world’s safest, students may still have concerns over tap water quality. This may be caused by signs next to most fountains on campus, which instruct students to allow the water to flush for 3 minutes in order to avoid consuming metals. Even though most students are environmentally conscious, and choose to carry re-useable water containers, they are not willing to wait that amount of time to access drinkable water. Survey respondents identified concerns over hygiene and unsatisfactory water taste and temperature as main deterrents from drinking from campus water fountains. 13% of survey respondents agreed with the statement of "I am too worried about the water quality [of water fountains] to drink" (survey, Appendix A).

In response to concerns over the environmental impacts of bottled water and tap water quality, the UBC Alma Mater Society (AMS) has invested in the installation of water filtration units known as WaterFillz stations. WaterFillz kiosks are equipped with the latest purification equipment that run on 12-55W electricity, with the option of solar power. These stations are meant to allow students to use purified tap water to refill their own bottles and eliminate the need to purchase bottled water.

Existing Research

To date several research projects have been undertaken by students involved in the SEEDS (Social Ecological Economic Development) Program at UBC. Shariatzahdeh *et al.* (2010) conducted "An Investigation into Water Bottles and WaterFillz Units" which evaluated some environmental impacts of water bottles, economical aspects associated with water bottles and WaterFillz, plastic pollution, and social aspects, including the quality of bottled water. Overall, they recommend the use of WaterFillz stations as a more sustainable drinking water source on the UBC campus, although their calculations were not tailored specifically to the demand of the potential users on campus. Another paper from Kanda *et al.* (2010) also looked at the impact of water bottles, and WaterFillz stations on campus. Although mostly from an economical perspective, the environmental and social aspects were also evaluated. It was noted that in 2007, 20-30 million PET water bottles went to Metro Vancouver landfills. This SEEDS project student survey, found that 52% of students either required or preferred filtered water (Kanda *et al.*, 2010).

While these papers have provided a good overview of the general impacts of the three drinking water options, our project aims to further develop the analysis by exploring questions in a more systematic and quantitative way.

Research Objectives

Section 1: Environmental Implications

1a) Estimate and compare embodied energy costs of the bottled water, tap water, and WaterFillz systems and identify system components which contribute the most.

1b) Qualitatively discuss other environmental implications such as waste generation and recycling.

Section 2: Water Quality Assessment

2) Determine whether heavy metal contamination of campus tap water merits cause for concern.

Section 3: Economic Considerations

3a) Quantify the economic implications of the potential removal of bottled water from UBC campus.

3b) Compare the economic costs of three different water filtration systems.

Section 4: Recommendations for the placement of WaterFillz stations

4) Make recommendations for where to install additional WaterFillz units on campus, based on conclusions of the water quality assessment combined with survey responses and building traffic data.

Section 1 Environmental Implications

1.0 Section Scope

Environmental impacts of the drinking water options are compared through quantitative assessment of the energy consumed in all steps leading up to the consumption of water by the consumer, using a systems-based approach. Energy required by these systems is also expressed in terms of carbon dioxide equivalents, a unit of increasing prevalence in recent years used to emphasize the link between our actions and climate change; a potent greenhouse gas when in the atmosphere, CO_2 and other gases re-radiate heat to the earth, contributing to warming. Waste generation and recycling for these systems are qualitatively discussed.

1.1 Estimates of Energy Impacts

Energy impacts of for each of the three drinking water options (bottled water, tap water + reusable bottles, WaterFillz filtration + reusable bottles) were estimated by first defining each system by various possible pathways up the supply chain and then defining a functional unit for comparison among the three systems. We then collected data needed to calculate total energy consumption for defined model scenarios that follow specific pathways. Ideally, all of the calculations would have been done with context specific data from primary sources; however, due to limited data available, we had to rely heavily on secondary sources. The following sections describe and explain values derived for each system component. Tabulated results are presented at the end of each discussion of a system.

Functional unit

In a systems-based analysis, each system is evaluated on the basis of performing a defined function. The functional unit selected for this analysis is delivering 875 litres of drinking water to a single consumer. This unit is an estimate of the amount of water a person might consume on campus in 5 years if he or she were to drink 1*l* of water on campus every day (half of the daily requirement), 5 days a week, for 8 months of the year.

Bottled Water System

The bottled water system is defined as consisting of the following components:

- Manufacturing of bottles, caps, and packaging
- Municipal water treatment
- Additional water treatment
- Bottle filling
- Transport of packaged and filled bottles
- Possible chilling of bottles

A visual representation of how we defined the bottled water system is given in Figure 1.

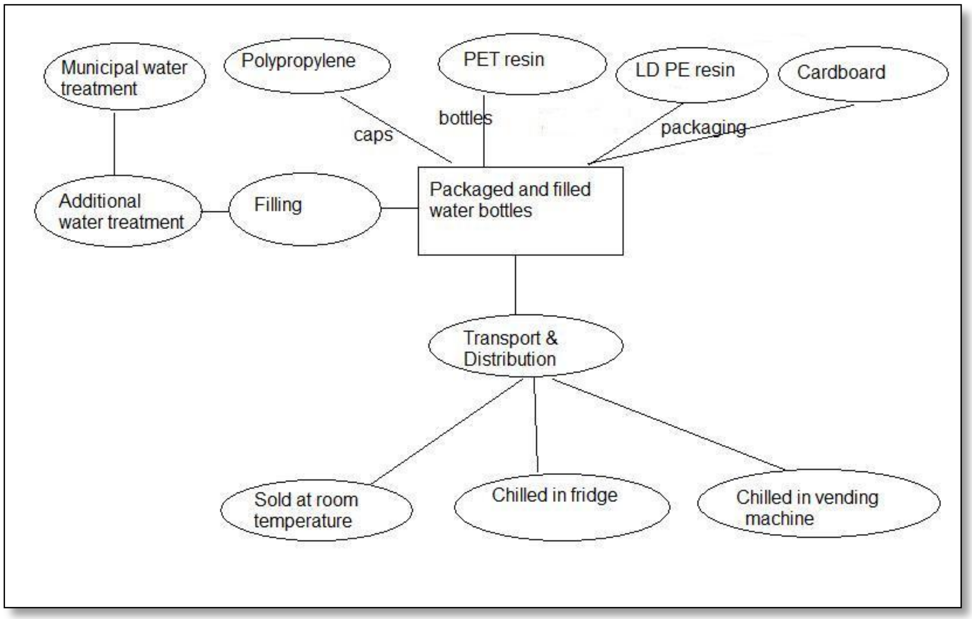

Figure 1: Systems pathways diagram for bottled water system.

Bottle manufacturing

For our analysis, we modeled all disposable water bottles as 591ml capacity bottles made from polyethylene terephthalate (PET) plastic, with polypropylene caps. This is based on the Dasani brand 591 ml bottle, which is the most popular bottle sold on campus, as it is the only bottled water product carried by all UBC Food Services outlets. As in all traditional plastics, PET and polypropylene are made from petroleum and natural gas products. Although Dasani has recently switched to using PET plastic which contains "up to 30% plant-based material," we were unable to account for this because of the limited information available (Dasani® website, accessed March 2012). A detailed breakdown of energy consumption in the PET and polypylene plastic manufacturing process can be found in Appendix B.

Each 591 ml Dasani bottle is made of 18.6g of PET plastic (since we cannot account for plant-based material) and has a 2.0g cap made from polypropylene (Gleick & Cooley, 2009). Scaling to the functional unit of 875 *l* (or 1480.5 Dasani bottles), the energy required to produce the 27.5 kg of PET plastic bottles and 2.96 kg polypropylene caps is 2280 and 270 MJ respectively. These energy rates are quoted from the *Life Cycle Assessment of Drinking Water Systems: Bottle Water, Tap Water, and Home/Office Delivery Water* prepared for the state of Oregon by Franklin Associates (2009). Many of the energy estimates used in our analysis are based on numbers released in their report. A detailed breakdown of steps included and energy requirements can be found in Appendix B.

Water treatment and bottle filling

Dasani bottles shipped to UBC Point Grey campus are filled at Coca-Cola Bottling Ltd. in Port Coquitlam using municipal tap water, where it undergoes additional water treatment before bottling. Tap water is treated and supplied by Metro Vancouver.

It is difficult to accurately estimate the energy used by Metro Vancouver to treat and transport a specific unit of water because the water transmission system is a complex system made up of three source water treatment facilities; Seymour-Capilano Filtration Plant, Coquitlam Water Treatment Plant and Capilano Chlorination Plant, eight secondary disinfection sites, 15 pump stations and 22 reservoirs (T. Jivraj of Metro Vancouver, email communication, March 16 2012). The partitioning of water treated by each facility and the route taken by water arriving at a certain destination varies with system inputs and outputs, as well as any re-routing occurring due to construction. Recorded energy consumption data is only currently available for Seymour-Capilano Filtration Plant. This plant is the newest of three treatment plants and treats by microfiltration and UV disinfection. According to the Metro Vancouver website, construction of a tunnel system to the Capilano source to the filtration plant is currently underway and should be completed by 2013. Coquitlam water treatment plant currently employs ozone and chlorine treatment, with plans to complete an additional UV disinfection facility by late 2013 (Metro Vancouver, 2011).

For the purposes of this analysis, we assumed the Seymour-Capilano Filtration Plant (SCRP) treats 2/3 of a given amount of water in the system while the Coquitlam Water Treatment Plant (CWTP) treats the other 1/3. These assumptions were based on monthly averages of daily flows in the year 2011 which indicate that, on a monthly basis, SCFP treated 40-74% of total flow while CWTP treated 25-48%. Simple manipulation of energy consumption and flow data from the SCFP gives a mean energy consumption rate of 1.55kWh / 1000000 *l* treated. This value is smaller than most energy consumption rates given in other assessment reports most likely because the SCFP facility was built with objectives for energy efficiency and energy recovery. According to Franklin Associates, the energy consumption rate for municipal water treatment using ozone is 169 kWh / 1000000 *l*. SWB Consulting Inc. estimates a value of 130 kWh / 1000000 *l* for ozone pre-treatment (30 kWh) and disinfection (100 kWh). We will therefore assume the energy consumption rate of ozone treatment at the CWTP is 150 kWh/ 1000000 *l*. The amount of energy used by Metro Vancouver to treat 875 litres of water is then calculated as 0.0447 kWh (161 kJ). This number is an under-estimate because it does not include energy required to pump water through the system and that needed to create and dispense chlorine. Data used for the calculations above can be found in Appendix B.

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According to the Dasani website, source water undergoes multiple steps of additional treatment before bottling. In order, steps include initial filtration, granular activated carbon filtration, reverse osmosis, UV disinfection, re-addition of select minerals and ozone treatment. Using the same ozone treatment energy consumption rate as before, and the rate of 13.2 kWh / 1000000 *l* for UV treatment (Franklin Associates, 2009), the energy required for additional water treatment of 875 *l* is calculated as 0.514 MJ. According to Franklin Associates, filling of the bottles is mechanical process in which bottles are cleaned, filled with water and capped. Filling 875 *l* contributes another 2.25 MJ. Numbers have not been found detailing energy usage of granular activated carbon (GAC) filtration and mineralization. If we assume that filtration is primarily gravity driven, it would therefore contribute none, or very little to the energy impact. It is unfortunate that the energy involved in the mining and processing of the added minerals could not be accounted for, however, it can be argued that the amount of minerals added for 875 *l* is so small such that it would make very little contribution to the overall results. For example, if according to the Dasani website, each 240ml serving contains 0.84 mg of potassium, then there would only be 3.1 g of potassium added to our entire functional unit of 875 *l*. Reverse osmosis was found to dominate the water treatment costs at 20.4 MJ for 875 *l*, calculated using the energy consumption rate in the report by Franklin Associates (2009).

Packaging

Dasani bottles are shipped to UBC Food Services in cases of 24 bottles. Each set of 24 is wrapped in 38 g of plastic shrink wrap and supported by 64 g of corrugated cardboard. These and all other masses stated in this report, unless otherwise cited, we determined by use of a Polder® digital kitchen scale. Using the energy rates from Franklin Associates for plastic film and corrugated cardboard, we calculated that, for 1408.5 bottles (the amount required to hold 875 *l*) the cardboard portion amounts to 36.8 MJ of embodied energy and the plastic 194.3 MJ**.** A detailed breakdown of steps included and their energy requirements, as quoted from Franklin Associates, can be found in Appendix B.

Transport

Bottled Dasani water is shipped to UBC campus from Coca-Cola Bottling Ltd. in Port Coquitlam, approximately 35 km away, an average of Google Maps' top two suggested driving routes. Shipments are carried via a full semi truck and trailer combination (L. McGowan of UBC Food Services, email communication, February 15, 2012). Starting in 2008, Coca-cola began using Kenworth diesel-electric T370 hybrids (Fleet Owner, 2009) and these hybrids have been seen on UBC campus. The weight for a T370 hybrid by Kenworth is about 26, 000 lb (IRS, 2012) Duggan of Kenworth Truck Company boasts "11-14 miles per gallon compared to 6 to 7 miles per gallon with [the company's] standard medium trucks." The Coca-cola website describes trucks to be 30% more fuel efficient than traditional trucks. On the conservative side of fuel savings, we will use the low end of the reduction of about 30% of fuel used, compared with the calculations for a traditional truck (Gleick & Cooley, 2009). Additional weight may be added by the products carried in the truck, but it is difficult to quantify the amount. We consider the cases where the truck is empty and where the truck is carrying half its payload (Kenworth, 2009).

Deliveries to UBC occur on Mondays, Wednesdays, and Fridays; distributors at UBC receive shipments one to three times a week based on need. During the course of year, bottled water accounts for 3% of what is shipped to the campus (L. McGowan of UBC Food Services, email communication, February 15, 2012). In 2011, this was equal to 67166 cases of 24 bottles (McGowan, 2012), amounting to 1,611,985 bottles of Dasani water. Since water has the potential to be shipped on each of those three days, in the worst case scenario, water would be carried in three shipments per week, accounting for 3% of the overall carbon cost. For a 12 month period, three shipments a week amounts to 148 delivery days, if the 8 Statutory Holidays that fell on Mondays, Wednesdays, and Fridays in 2011 are removed. At 35 km between source and destination, this totals 10,360 km for rounds trips in 2011. It should be noted that trucks may not take direct routes if also delivering to other buyers. Taking into consideration all of these factors (except for non-direct routes), transportation costs for one unit of water are 6.04 MJ for an empty truck and 26.9 MJ for a truck carrying half its payload.

Chilling

An unofficial survey of 8 beverage vending machines around campus that supply Dasani water bottles revealed operation of 115 volts for all models and 9.0 or 10.0 amps; a mid-value of 9.5 was used in calculations. Overall, one vending machine was found to contribute 13016 kg CO_2e (34,452 MJ) in one year. That is within the range for Energy Star® Tier II-rated vending machines (Version 2.0); some of the surveyed models displayed stickers advertising their compliance with the standard. However, it is not possible with the data available to find a specific energy cost per bottle as the usage of vending machines varies greatly between each machine, which determines the turnover rate of the bottles, and consequently, how long the bottles are refrigerated for. The next portion of the calculation we acknowledge is a back-of-of the-envelope calculation, and should be interpreted with a critical mind. UBC Food Services sells 1,611,985 bottles in a year. On average, that is 4,416 bottles a day. A functional unit of water accounts for 34% of the average number of water bottles sold in a single day. If all of those 875 *l* could be sold within a single day (34% of the daily sales), they would take up 5.3 vending machines (many of the vending machines observed could hold up to 280 bottles at one time). If all 875 *l* were sold within a day, in that 24 hour period 5.3 vending machines contribute 500 MJ. No calculations were made for other types of refrigerators on campus (e.g. those found at food outlets), since they vary so greatly in size, and in some locations hold a variety of other products such as other beverages and food items.

Table 1. Bottled Water Scenario 1 –Sold at Room Temperature			
	Energy consumed (MJ)	**Carbon equivalent (kg CO_2 equivalent)**	**Processes**
Bottles	2280	862	Creation of PET resin Stretch blow moulding to form bottles
Caps	276	104	Creation of Polypropylene resin Injection moulding to form caps
Packaging	231	87.3	Creation of Low Density Polyethylene resin Plastic film extrusion Creation and cutting of cardboard
Municipal Water Treatment	0.161	0.0608	Filtration, Ozone, Chorine & UV
Additional water treatment	20.9	7.89	Filtration, UV light, Ozone, and Reverse osmosis (largest contribution); Remineralization not accounted for
Filling	2.25	0.85	Cleaning, filling, capping
Transport	6.04 – 26.9	2.28 – 10.2	Truck transport from Port Coquitlam (empty truck; truck carrying half its payload)
Total :	2820 - 2840	1065 - 1073	

Table 2. Bottled Water Scenario 2 –Sold in Vending Machine			
	Energy consumed (MJ)	**Carbon equivalent (kg CO_2 equivalent)**	**Processes**
Bottles	2280	862	Creation of PET resin Stretch blow moulding to form bottles
Caps	276	104	Creation of Polypropylene resin Injection moulding to form caps
Packaging	231	87.3	Creation of PET resin Plastic film extrusion Creation and cutting of cardboard
Municipal Water Treatment	0.161	0.0608	Filtration, Ozone, UV (Chlorine not included in calculations)
Additional water treatment	20.9	7.89	Filtration, UV light, Ozone, and Reverse osmosis (largest contribution);

			Remineralization not accounted for
Filling	2.25	0.85	Cleaning, filling capping
Transport	6.04 – 26.9	2.28 – 10.2	Truck transport from Port Coquitlam
Chilling in vending machine	500	189	
Total :	3320 - 3340	1254 - 1262	

Tap water with reusable bottles system

The tap water with reusable bottles system is defined as consisting of the following components:

- Manufacturing of reusable bottles and caps
- Transport of reusable bottles from manufacturer to consumer
- Municipal water treatment
- Washing of reusable bottles

A visual representation of how we defined the tap water system is given in Figure 2.

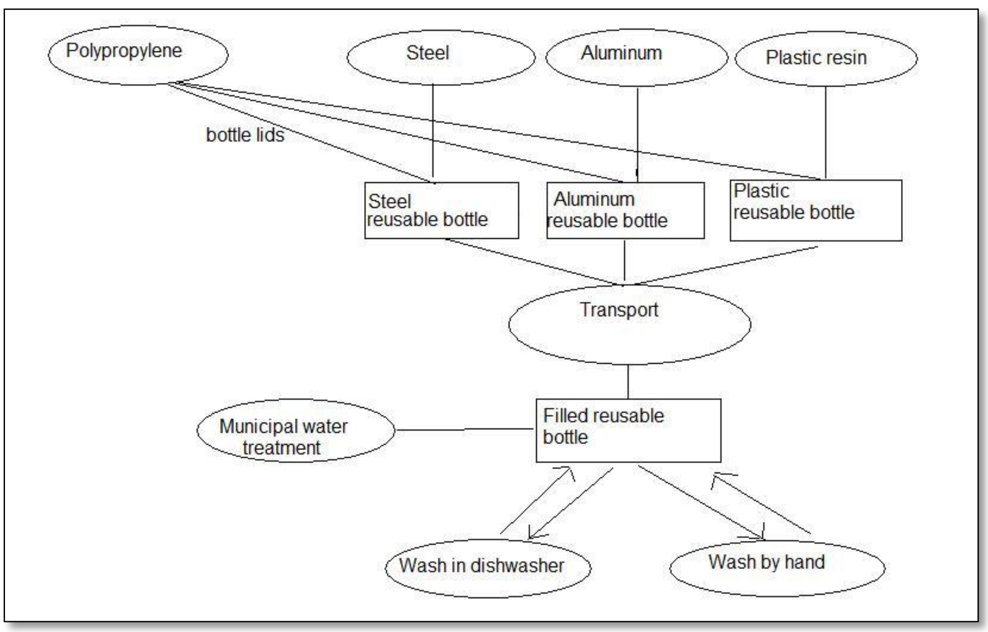

Figure 2: System pathways diagram for tap water and reusable bottles system.

Reusable Bottle Manufacturing

Bottles made from steel, aluminum and durable plastic were all considered in separate scenarios in our analysis. All of our model bottles have simple small screw cap enclosures in attempts to minimize variation. Larger caps for larger openings or more complicated enclosures with various drinking spouts are available to consumers but would unlikely change the results of our analysis by any meaningful amount. Our model steel bottle weighs 124 g and holds 650 m*l*.

The plastic enclosure weighs 15 g. Steel is made from iron ore, limestone and coal products. Our model aluminum bottle weighs 96 g and holds 600 m*l*. The plastic enclosure weighs 13 g. Aluminum is made from bauxite, limestone, coal, and petroleum products. Our model reusable plastic bottle weighs 76 g and holds 500 m*l* and the plastic enclosure weighs 13 g. Durable plastic bottles, such as those of the Nalgene brand, were previously made from polycarbonate but because of health concerns with bisphenol-A (BPA), a chemical used in the production of polycarbonate, Nalgene has switched to the BPA free Eastman Tritan copolyester made by Eastman Chemical Company. Eastman Tritan copolyester is also used by Contigo, another popular plastic reusable water bottle brand.

Although manufactures of reusable bottles claim one bottle can last a lifetime, we think it is more reasonable to assume that a bottle might be lost, damaged, or even go out of fashion such that one would replace it once every few years. If we assume the model bottles were replaced once every 3 years then 2 bottles would be needed over 5 years. This amounts to 248 g steel, 192 g aluminum, and 152 g durable plastic, as well as either 26, 30 or 26 g worth of polypropylene lids respectively. A detailed breakdown of the energy required to manufacture the metal bottles and their caps, according to numbers quoted from Franklin Associates, can be found in Appendix B. A detailed breakdown of the energy required to manufacture the reusable plastic bottle is unavailable because only a brief summary of a life cycle assessment report for that material has been released.

Bottle transport

Our model steel bottle was manufactured in China and our model plastic bottle is most likely manufactured in China. Our model aluminum bottle was manufactured in Frauenfeld, Switzerland, where all SIGG brand bottles are made. SIGG is the largest manufacture of aluminum bottles. Long-distance transport can contribute a large amount to the energy consumption of a water delivery system. The following table by Gleick and Cooley (2009) gives energy estimates according to mode of travel, cargo weight and distance traveled.

Table 3. Transportation energy costs. Source: Gleick & Cooley (2009), who cite US Department of Energy (2007); Natural Resources Canada (2007).

Cargo ship/ocean ($MJ\ t^{-1}\ km^{-1}$)	Air cargo ($MJ\ t^{-1}\ km^{-1}$)	Rail ($MJ\ t^{-1}\ km^{-1}$)	Heavy truck ($MJ\ t^{-1}\ km^{-1}$)	Medium truck ($MJ\ t^{-1}\ km^{-1}$)
0.37	15.9	0.23	3.5	6.8

It is therefore unfortunate that not enough information could be gathered to make meaningful estimates of energy consumption by transportation for the reusable bottle scenarios. Firstly, neither SIGG customer service representative nor steel bottle distributor, Econ Promo, knew the route of travel taken by the model bottles. Secondly, the cargo weight that can be attributed per bottle, once the weight of all additional packaging and cargo containers have been factored in is impossible to know without in depth knowledge of the shipping practices of a specific manufacturer. While it may be reasonable to assume that the weight of additional packaging for the transport of bottled water is negligible compared to the weight of the filled bottles, this same assumption cannot be made for lightweight empty reusable bottles.

Water treatment

Tap water available on UBC Point Grey campus is treated and supplied by Metro Vancouver. Calculations of energy consumption by municipal water treatment have already been discussed in the previous water treatment section of the bottled water system.

Washing

Estimates for water and energy usage in hand washing of bottles were done based on direct replicate measurements of water used by project group members for hand washing bottles. The average amount of water used to wash a single 500 m*l* and 650m*l* bottle was measured to be 1.09 and 0.93 *l* respectively. Figure 3 and Figure 4 show the range and variation between replicate washes and individual washing habits. A plausible reason to explain why the larger bottle appears to require less water to wash is because replicates of washing the 500 m*l* bottle were always competed before replicates for the 650 m*l* bottle. It is possible that people were unintentionally becoming increasingly efficient with water usage with subsequent washes. For the purpose of this analysis, we use the average of the two values, 1.01 *l*, as the amount of water used for a single wash of either size bottles.

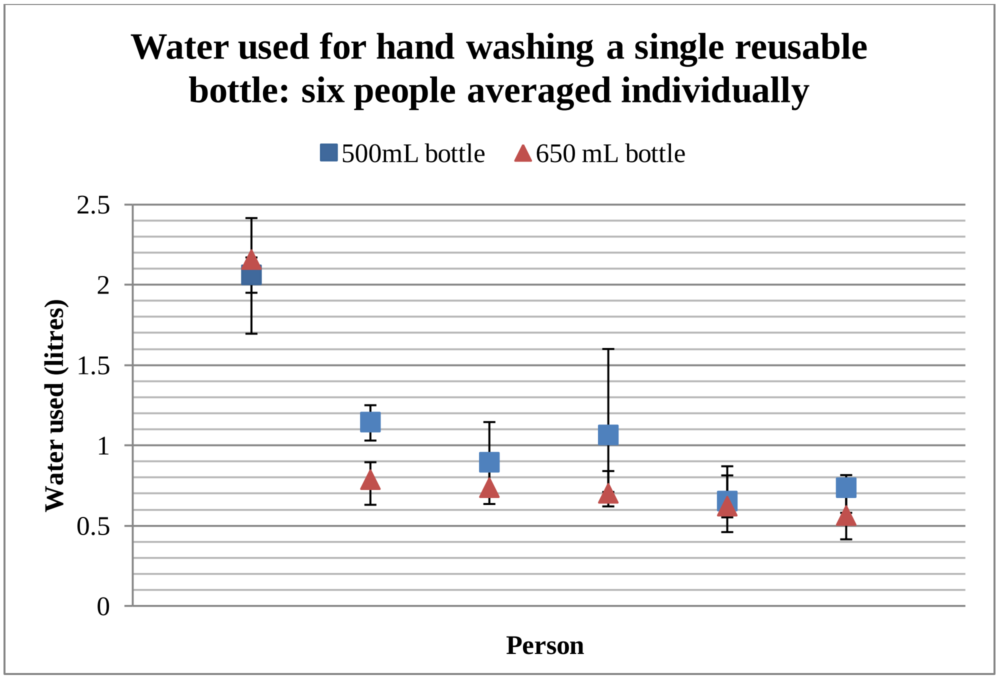

Figure 3: Water used for hand washing a single reusable bottle, averaged individually for 3 replicate washes by each person, for each bottle. Range for replicate washes is presented as error bars. Raw data in presented in Table 4.

Table 4. Water used to wash bottles

Water used to wash 500ml capacity reusable bottle (ml)						
	Beatrice	Nicole	Josh	Darcy	Allina	Katherine
rep 1	2065	1030	1145	1600	552	815
rep 2	1950	1155	700	885	595	580
rep 3	2170	1250	840	710	813	815
Water used to wash 650ml capacity reusable bottle (ml)						
rep 1	2360	835	890	620	535	415
rep 2	1695	630	685	645	460	530
rep 3	2415	895	635	840	870	745

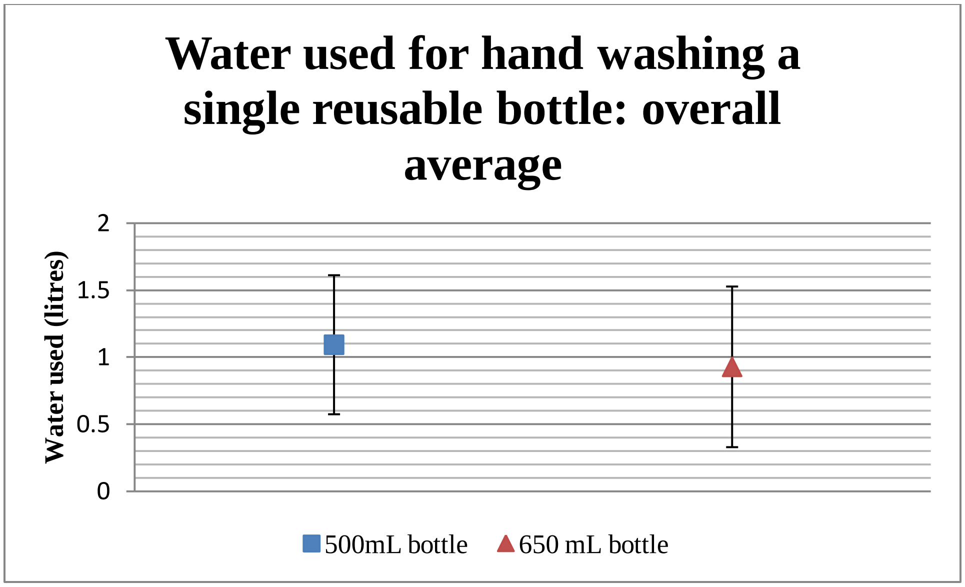

Figure 4: Overall average of water used for hand washing a single reusable bottle. Standard deviation is presented using error bars. Raw data presented in table 4.

It was calculated that if the 500 m*l* plastic bottle, 600 m*l* aluminum bottle and 650 m*l* steel bottle were to be washed by hand every time it was refilled, that would require and 1767.5 *l*, 1472.9 *l*, and 1359.6 *l* of water respectively as a result of the consumption of 875 *l* of drinking water. Table 5 lists water usage for hand washing if bottles were washed once every 2 and 8 refills. Energy consumption was calculated from this water usage to account for water treatment and the heating of water to from 8°C to 40°C using the specific heat capacity of water.

Table 5. Water usage for hand washing bottles depending on frequency of washing

Water used (litres) if...			
	Washed every refill	Washed every 2 refills	Washed ever 8 refills
500ml bottle	1768	884	221
600ml bottle	1473	737	184
650ml bottle	1360	680	167

Water and energy usage estimates for washing using a dishwasher are based on estimates made in a Life Cycle Assessment done by Franklin Associates. According to their report appendix, it can be assumed that an average residential dishwasher can wash 110 reusable containers in a full load, using 4 to 6 gallons (15-23 *l*) of water and 1.43 kWh of power per cycle. This does not include the energy used to heat the hot water supplied to dishwater, only the energy used in additional heating of the water as well as pumping and spraying functions. According to BC Hydro's tips for efficient dishwashing, "older dishwashers use 30 to 53 litres of water. Newer models (after 1994) use 15 to 38 litres. More energy-efficient models use less than 20 litres of water for a cycle." For the purpose of this analysis, we assume one dishwasher cycle uses 1.43 kWh and 15-38 *l* of water heated to from 8°C to 60°C. Overall, this amounts to 8.41-

13.4 MJ / 110 washes. When the amount of energy used to treat the 15-38 *l* of water is added, the total energy is 8.42 – 13.5 MJ /110 washes.

Table 6. Tap + Reusable bottle Scenario 1PHWC –500ml Reusable plastic container							
	Energy Consumed (MJ)			**Carbon equivalent (kg CO_2)**			**Processes**
Bottles (2)	20.0			7.57			Creation of copolyester Moulding into bottle
Caps (2)	2.54			0.958			Creation of Polypropylene resin Injection moulding to form caps
Transport	Not enough information						Most likely, ocean travel from China and some truck transport
Municipal Water Treatment	0.161			0.0608			Filtration, UV, Ozone (Chlorine not included in calculations)
Washing by hand in cold water	**Every fill** 0.325	**Every 2 fills** 0.162	**Every 8 fills** 0.41	**Every fill** 0.122	**Every 2 fills** 0.0612	**Every 8 fills** 0.0155	
Total :	23.1	22.9	22.6	8.72	8.65	8.55	

Table 7. Tap + Reusable bottle Scenario 2PHWH –500ml Reusable plastic container							
	Energy Consumed (MJ)			**Carbon equivalent (kg CO_2)**			**Processes**
Bottles (2)	20.0			7.57			Creation of copolyester Moulding into bottle
Caps (2)	2.54			0.958			Creation of Polypropylene resin Injection moulding to form caps
Transport	Not enough information						Most likely, ocean travel from China and some truck transport
Municipal Water Treatment	0.161			0.0608			Filtration, UV, Ozone (Chlorine and pumping not included in calculations)
Washing by hand in warm water (40°C)	**Every fill** 237	**Every 2 fills** 119	**Every 8 fills** 29.7	**Every fill** 89.6	**Every 2 fills** 44.8	**Every 8 fills** 11.2	
Total :	260	141	52.2	98.1	53.3	19.7	

Table 8. Tap + Reusable bottle Scenario 3PDW –500ml Reusable plastic container			
	Energy Consumed (MJ)	**Carbon equivalent (kg CO_2)**	**Processes**
Bottles (2)	20.0	7.57	Creation copolyester Moulding into bottle
Caps (2)	2.5	0.958	Creation of Polypropylene resin Injection moulding to form caps

Transport	Not enough information				Most likely, ocean travel from China and some truck transport
Municipal Water Treatment (875L)	0.161		0.0608		Filtration, UV, Ozone (Chlorine and pumping not included in calculations)
Washing by dishwasher (15-38 L heated to 60°C)	**Everyday** 67.0 -107	**Once a week** 13.4-21.4	**Every Day** 25.3-40.4	**Once a week** 5.06-8.07	
Total :	89.5 - 129	36.0 -43.9	33.8-48.9	13.6-16.6	

Table 9. Tap + Reusable bottle Scenario 4SHWC –650ml Reusable steel container							
	Energy Consumed (MJ)			**Carbon equivalent (kg CO_2)**			**Processes**
Bottles (2)	4.93			1.86			Steel production Casting into bottle
Caps (2)	2.93			1.11			Creation of Polypropylene resin Injection moulding to form caps
Transport	Not enough information						Most likely, ocean travel from China and some truck transport
Municipal Water Treatment	0.161			0.0608			Filtration, UV, Ozone (Chlorine and pumping not included in calculations)
Washing by hand in cold water	Every fill 0.250	Every 2 fills 0.125	Every 8 fills 31	Every fill 0.0944	Every 2 fills 0.0472	Every 8 fills 0.0117	
Total :	8.27	8.15	8.05	3.12	3.07	3.04	

Table 10. Tap + Reusable bottle Scenario 5SHWH –650ml Reusable steel container							
	Energy Consumed (MJ)			**Carbon equivalent (kg CO_2)**			**Processes**
Bottles (2)	4.93			1.86			Steel production Casting into bottle
Caps (2)	2.93			1.11			Creation of Polypropylene resin Injection moulding to form caps
Transport	Not enough information						Most likely, ocean travel from China and some truck transport
Municipal Water Treatment	0.161			0.0608			Filtration, UV, Ozone (Chlorine not included in calculations)
Washing by hand in warm water (40°C)	Every fill 182	Every 2 fills 91.2	Every 8 fills 22.4	Every fill 68.9	Every 2 fills 34.5	Every 8 fills 8.46	
Total :	190	99.3	30.46	80.0	37.5	11.5	

Table 11. Tap + Reusable bottle Scenario 6SDW –650ml Reusable steel container			
	Energy Consumed (MJ)	**Carbon equivalent (kg CO_2)**	**Processes**
Bottles (2)	4.93	1.86	Steel production Casting into bottle

Caps (2)	2.93		1.11		Creation of Polypropylene resin Injection moulding to form caps
Transport	Not enough information				Most likely, ocean travel from China and some truck transport
Municipal Water Treatment (875L)	0.161		0.0608		Filtration, UV, Ozone (Chlorine not included in calculations)
Washing by dishwasher (15-38 L heated to 60°C)	**Everyday** 51.5 -82.2	**Once a week** 12.9 – 20.5	**Everyday** 19.5 – 31.09	**Once a week** 4.87 – 7.76	
Total :	59.5 – 90.2	20.9 -28.6	22.5 – 34.1	7.89 – 10.8	

Table 12. Tap + Reusable bottle Scenario 7HWC –600ml Reusable aluminum container							
	Energy Consumed (MJ)			**Carbon equivalent (kg CO_2)**			**Processes**
Bottles (2)	46.0			17.4			Creation of aluminum ingot Casting into bottle
Caps (2)	2.54			0.958			Creation of Polypropylene resin Injection moulding to form caps
Transport	Not enough information						Ocean travel from Switzerland and some truck transport
Municipal Water Treatment	0.161			0.0608			Filtration, UV, Ozone (Chlorine not included in calculations)
Washing by hand in cold water	Every fill 0.270	Every 2 fills 0.162	Every 8 fills 0.034	Every fill 0.102	Every 2 fills 0.0612	Every 8 fills 0.0128	
Total :	49.0	48.9	48.7	18.5	18.5	18.4	

Table 13. Tap + Reusable bottle Scenario 8SHWH –600ml Reusable aluminum container							
	Energy Consumed (MJ)			**Carbon equivalent (kg CO_2)**			**Processes**
Bottles (2)	46.0			17.4			Creation of aluminum ingot Casting into bottle
Caps (2)	2.54			0.958			Creation of Polypropylene resin Injection moulding to form caps
Transport	Not enough information						Ocean travel from Switzerland and some truck transport
Municipal Water Treatment	0.161			0.0608			Filtration, UV, Ozone (Chlorine not included in calculations)
Washing by hand in	Every	Every 2	Every	Every	Every	Every	

warm water (40°C)	fill 198	fills 98.9	8 fills 24.7	fill 74.7	2 fills 37.4	8 fills 9.33	
Total :	246	148	734	93.1	55.8	27.7	

Table 14. Tap + Reusable bottle Scenario 9SDW –600ml Reusable aluminum container					
	Energy Consumed (MJ)		**Carbon equivalent (kg CO_2)**		**Processes**
Bottles (2)	46.0		17.4		Creation of aluminum ingot Casting into bottle
Caps (2)	2.54		0.958		Creation of Polypropylene resin Injection moulding to form caps
Transport	Not enough information				Ocean travel from Switzerland and some truck transport
Municipal Water Treatment (875L)	0.161		0.0608		Filtration, UV, Ozone (Chlorine not included in calculations)
Washing by dishwasher (15-38 L heated to 60°C)	Everyday 55.8 -89.0	Once a week 13.9 – 22.2	Everyday 21.1 – 33.7	Once a week 5.27-8.41	
Total :	104 -138	62.6 -70.9	39.5 – 52.0	23.7 – 26.8	

WaterFillz with Reusable Bottles System

The WaterFillz with reusable bottles system has all of the same components of the tap water system:

- Reusable bottles and caps manufacturing
- Transport of reusable bottles from manufacturer to consumer
- Municipal water treatment
- Washing of reusable bottles

With the addition of components:

- WaterFillz kiosk manufacturing
- Transport of WaterFillz kiosk to campus
- WaterFillz operation
- WaterFillz maintenance

A visual representation of how we defined the reusable bottle with WaterFillz filtration system is given in Figure 5.

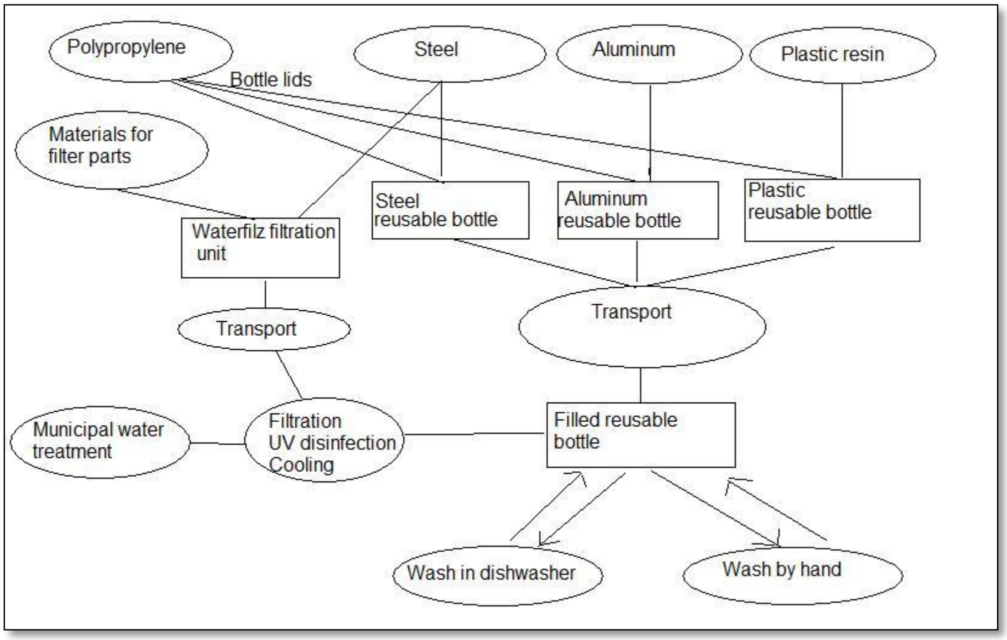

Figure 5: System pathways diagram of WaterFillz system.

WaterFillz Manufacturing

Detailed data have not been obtained regarding the composition of the WaterFillz kiosks as attempts to contact company representatives have been unsuccessful. No specific and locatable material information is available online. An Industrial patent design exists in the U.S. for the kiosk (Patent #D651686); however, by nature it only details qualitative dimensions and provides no mention of material. A report by four Applied Sciences 261 students at UBC approximated the WaterFillz unit as composed of 92 kg of steel – 92 kg being the total weight of the device (Chang *et al*, 2010). While this approximation cannot be without error as it assumes no other materials comprise the unit when it is known at least that it contains a filter inside and an exterior covered in some sort of plastic, using a value of 92 kg allows for a ballpark estimate of energy and carbon dioxide costs, so that a general comparison can still be made between the three drinking water options. It is important to note that this manufacturing is a one-time cost of 1826 MJ. The cost of production per unit of water will diminish as more and more water is drawn through the filter and into consumers' reusable containers. At the present time, the kiosk has been in the Student Union Building for one and a half years, so factoring in the amount of time it takes to dispense 875 *l* of water, over its current lifetime, the manufacturing of the unit is 6.69 MJ. While the WaterFillz kiosks do have digital counters displaying that "our world is [some number of] bottles lighter," we were unable to receive confirmation from Safe Star on what constitutes a bottle.

Transportation

A one-time round trip delivery of the WaterFillz unit from its distribution centre at Unit

301, 19133-26 Avenue in Surrey accounts for 2.74 kg CO_2e (7.27 MJ) if driven by a 5,000 kg truck, using the numbers provided by Gleick and Cooley for a medium truck (2009), and if both of the two existing WaterFillz units were delivered to campus in the same trip. A travel distance between locations of 57.8 km was used, as the average of the top two routes suggested by Google Maps.

WaterFillz Operation

The method of treatment that takes place within a WaterFillz unit includes treatment by sediment filtration at 5 microns, carbon block filtration at 0.5 microns, and UV purification (WaterFillz website). Additionally, water is refrigerated to maintain a temperature of 3°C (38 F). Safe Star describes their units as dispensing water at a rate of 1 *l* / 20 seconds, at up to 55 W at peak flow (WaterFillz website). To dispense 875 *l* of water, 17,500 seconds are required, and at peak water flow, 962.5 kJ.

WaterFillz Maintenance

According to the WaterFillz website, annual maintenance of WaterFillz kiosks involve removal and replace filters every 96 000 *l* filtered, changing of the UV bulb every 12.5 months, and disinfection by chlorine bleach flush every 6-12 months. We were unable to make estimates of energy costs of maintenance because we were unable to obtain details on filter parts or the disinfection process. We estimate that energy costs for maintenance would primarily consist of energy consumed in the production of filters, UV bulb production and chlorine bleach but we were unable to find enough information to make any quantitative estimates. We believe it is reasonable to assume; however, that the maintenance component would be small compared to the other system components because our functional unit of 875 *l* is only 0.9% of 96 000 *l*.

Table 15. Table Additional energy costs to tap water system by WaterFillz filtration

	Energy Consumed (MJ)	Carbon equivalent (kg CO_2)	Processes
Manufacturing (1 unit)	6.69	2.52	Creation of steel exterior (information on all other parts unknown)
Transport (1 round trip)	7.27	2.74	Mid size truck transport from Surrey
Operation	0.963	0.364	Filtration and UV disinfection
Maintenance	Not enough information		
Total :	14.9	5.62	

Summary of energy assessment results

- The energy impact of bottled water scenarios is considerably larger than scenarios for tap water and reusable bottles. See table 16.

Table 16: Overall comparison of energy costs between three systems

	Energy costs range for all scenarios (MJ)	Mean energy costs averaged over all scenarios (MJ)	Primary influencing factors
Bottled Water System	2820 - 3340	3080	-Production of plastic bottles
Tap Water system	8.05-734	101	-Washing habits: wash frequency and water temperature
WaterFillz system	22.9 - 749	116	-Cost of unit manufacture and transport

•Without factoring in the energy costs of WaterFillz maintenance, energy costs of the bottled water system are still higher than if the WaterFillz energy impacts were added to tap water scenarios.

•The main contributor of energy costs to the bottled water system is the production of bottles, followed distantly by the cost of transportation.

• The main contributor of energy costs to the tap water system is energy used in heating water for washing of bottles. Washing bottles by hand in cold water is always less energy intensive than using a dishwasher while hand washing in warm water will be more energy intensive than using a dishwasher unless bottle is washed less frequently than every 8 refills.

• Steel appears to be the least energy intensive reusable bottle material, followed by durable plastic and aluminum in increasing order.

1.2 Recycling and waste generation

Not included quantitatively in our calculations are any credits or savings that may be gained for materials that are recyclable. Each of our three examined systems have components that can be recycled. For the bottled water system, the plastic bottles can be returned, and for the tap water system, the metal or plastic bottles. Theoretically, the steel, plastic, and other components of the WaterFillz kiosk could be recycled; the possibility remains that Safe Star might reuse the material for new units, but we do not have information about this.

The recycling of PET plastic water bottles (and HDPE resin) in Metro Vancouver results in the conversion of the plastic into pellets, which have potential end uses as "new containers, strapping materials, and fibres" (ENCORP Pacific, 2010). While the recycling of the bottles reduces the amount of virgin material required for products down the line, the recycling of the bottles does not contribute directly to material for new Dasani bottles. Some energy savings could be credited toward the manufacturing process, but has not been included in the scope of this report. The 2010 ENCORP Annual Report revealed at 76.3% national recycling rate for bottles less than or equal to 1 *l* capacity. If recycling were incorporated into this analysis, another consideration would be the additional transport cost to the recycling plant located in Vancouver (ENCORP Pacific, 2010).

Reusable bottles and the WaterFillz components could similarly be recycled. In Vancouver, North Star Metal Recycling, for example, offers a site at which to deposit used metal products that will later be recycled (North Star website, accessed Mar. 2012). For steel, which can comprise reusable bottles and WaterFillz kiosks, an estimate of 75% of energy can be conserved through its recycling when compared with using all new materials (North Star website, accessed Mar. 2012). This may reduce a significant portion of the energy costs of manufacturing; however, if the lifespan of the WaterFillz station proves to be sufficiently long, then the manufacturing cost may be all together negligible. There is no locatable document on the unit's lifespan, likely because it is a relatively new item. The earliest record we found was the placement of a WaterFillz kiosk at UBC Kelowna in June 2009 (Hamlin, 2010). Another consideration related to steel and other material recycling is whether or not the general public is knowledgeable and diligent about proper recycling of these materials.

Components of the WaterFillz system that would contribute to waste generation are old filters and bleach used for periodic disinfection. It was not calculated what these contributions would be, but they have the potential to add up if for a heavily used kiosk or for multiple kiosks. Similarly, reusable bottles are often shipped and possibly sold with additional packaging, which would add to the over energy requirement for that system.

1.3 Discussion of limitations

In this complicated world, there is value in being able to compare things in a quantitative and definable way to aid in decision making. However, this same complexity can make it difficult to accurately represent the studied systems, and as a result, assumptions need to be made to where variation is present. One example is the multitude of reusable bottles available of different brands, materials, and sizes. For the sake of our project, we focused on two model bottles. Another example is how the amount of water it takes a person to wash a reusable bottle depends completely on the person. In an assessment in "How Bad Are Bananas? The carbon Footprint of Everything," washing dishes by hand can require either less or more water than if the dishes were washed with a dishwasher, depending on the person – a range from 0.540kg to 8 kg CO_2e (Berners-Lee, 2011).

There were some components of the drinking water systems where we were not able to obtain data for a variety of reasons. They include the number of bottles per vending machine per time, and other information that companies (i.e. Safe Star, Coca-Cola) consider to be proprietary. Where we were not able to obtain energy numbers specific to the systems studied, we drew on studies done in similar circumstances. However, the use of calculated energy consumption for, example, UV disinfection, may vary from one plant to the next. We fully acknowledge that there may be sources of error where we used numbers calculated for systems other than drinking water options at UBC campus.

We express costs in terms of kg CO_2e to emphasize that the cumulative consequences of our actions are tangible. However, we must emphasize that CO_2 equivalents are not actual CO_2 emissions, but expected emissions that arose from the performing of various tasks, based on calculations. We used an online converter provided by the US EPA. Also important is to consider what magnitude of change that these CO_2 equivalents amount to.

This analysis is not a life cycle assessment. We have defined our scope as beginning from manufacturing and ending at the consumer. Surely, post-consumer uses of the material would play a role in an entire life cycle assessment; however, we did not choose to focus our analysis on consumer behaviour choices regarding recycling. That, in itself, is another full study.

We stress that there are many other factors in an environmental assessment in addition to energy consumption and solid waste generation. For example, the summary of preliminary results by of a Life Cycle Assessment done by Franklin Associates for Eastman Chemical Company, reveals that smog formation potential, based on NO_x equivalents are significantly higher for reusable steel and aluminum bottles when compared to bottles made from Eastman Tritan copolyester. While the release of other airborne or waterborne pollutants from the production of the bottles and other materials involved in our systems were not investigated in our analysis, we would like to acknowledge that a 2009 report prepared for Toxic Free Canada (Griffin, 2009) identified were the release of toxins in the manufacturing process of polyethylene terephthalate (PET) plastic bottles as a primary environmental concern. Pollutants listed in their report include “carcinogens ethylene oxide, benzene, methylene chloride, ethylbenzene and the reproductive toxicant toluene” (Griffin, 2009).

Comparing the drinking water options in terms of energy consumption and CO_2e is one way to quantitatively perform the analysis. When it comes to decision making, other environmental concerns should be considered also, such as land displacement and the effects that has on the biodiversity and species composition of the area. Other factors that are economic and social in nature should be considered, since in order for the least environmentally damaging option to be least environmentally damaging, society has to use it in the way it was intended. If there is social resistance, then any efforts to implement that option may be counterproductive, being overall more damaging than other potential options. Similarly, if money is a limiting factor, choosing a very expensive but environmentally justifiable option may be offset by cutbacks in spending in other categories.

Section 2 Water Quality Assessment

2.0 Background

The quality of available drinking water on campus is a critical element in comparing fountain water against bottled water. In some cases water quality concerns prevent the student body from drinking from fountains due to the uncertainty of their possible contaminants. We have chosen to focus on three heavy metals, copper, iron and lead which are found in tap water. They are a few of the most commonly found metals in drinking water, most detectable and thus of health concern.

Copper

Copper is an essential element and is required in many enzymatic reactions. It is required for iron transport and accordingly a copper deficiency can also result in anemia. Other functions requiring copper include; pigmentation, control of neurotransmitters and neuropeptides, maintenance of connective tissue in lungs, bone, and elastin in the cardiovascular system, oxidative metabolism, brain functioning, and phospholipid synthesis (Health Canada, 2011). Health Canada recommends 2 mg/day of copper (or 30 μg/kg body weight per day) with less considered a deficiency. Copper has been proven toxic when 15mg or more has been ingested. 5.3 mg/day was the lowest oral dose where a minor symptom such as local gastrointestinal irritation was seen (Health Canada, 2011). According to Health Canada, "the hazard from dietary intakes of up to 5 mg/day appears to be low". In addition, copper clearance from the body can occur within hours and not likely to accumulate in the body. Metabolism of most metals is partly dependent on body weight.

Health Canada estimates on an average day, a 70 kg adult drinking 1.5 *l* water per day and inhaling 20m^3 air will intake < 0.004mg copper from the air, 2.2 mg from food and 0.264 mg (average concentration of copper 0.176 mg/*l*) from water for a combined total daily intake of 2.467 mg. Worth considering however, a recent study of copper requirements found modern American diets to be lower in nutrition with a copper range in the 1mg/day value indicating a lower daily total intake of copper than stated.

Domestic water systems using copper piping can cause green staining of laundry and plumbing fixtures at concentrations as low as 1.0 mg/*l* (Health Canada, 2011). Considering all the above and that the taste threshold for copper in distilled water is between 2.4-3.2 mg/*l* (copper in water has an unpleasant, astringent taste), Canada's aesthetic objective of ≤ 1.0 mg/*l* for copper is protective of health and also contributing minimally to daily nutritional requirements.

Zinc

Zinc is also an essential element, regarded as non-toxic and thus also has an aesthetic objective of ≤ 5.0 mg/*l*. Zinc is required for metabolism, including the replication and translation of genetic material. Water with concentrations greater than 5.0 mg/*l* may "be opalescent, have a greasy film when boiled and have an undesirable astringent taste" (Health Canada, 2011). The United States Recommended Daily Allowance (RDA) is 15mg/day for adults. By Canada's standards, daily requirements range from 4mg to 10mg per day depending on age and sex with pregnant/new mothers possibly requiring up to 16mg/day. Based on Canada's estimates an average "normal" person will take in 0.7μg from the air, 13-16.1mg from food and ≤ 13.0μg from drinking water for a total daily intake of 13.01-16.11mg with food accounts for over 99% of the source. Of consideration, roughly only 33% of zinc is absorbed in humans with zinc from drinking water being more bioavailable than from food. Zinc absorption can reach a point of saturation which most likely explains why the toxicity from dietary zinc has yet to be reported.

Lead

The maximum acceptable concentration (MAC) for lead in drinking water is 0.010 mg/*l* (Health Canada, 2011). This value is based on Acceptable Daily Intake (ADI) for an averaged-weight two year old. This standard takes into consideration the chronic effects of lead for the most vulnerable group of society. Lead is a cumulative general poison and can severely affect the central nervous system (Health Canada, 2011). MAC for lead accounts for chronic effects and thus is more the guideline for average concentrations in water over longer periods of time. Inconsistent intakes of lead concentrations greater than Canada's set standard (within reason) does not pose any serve health risks.

Total intake/uptake of lead of an adult is estimated 63.7 μg and 6.7 μg respectively. The breakdown of intake between air, food, dust & dirt and water 1.2 μg, 52.5 μg, 2.8μg and 7.2μg consecutively. The breakdown of uptake is as followed, 0.48 μg, 5.25 μg, 0.28 μg and 0.72 μg consecutively. The value used for average concentration of lead in drinking water was 4.8 μg/*l*.

2.1 Section Scope

This assessment focuses primarily on the concentration of Copper, Zinc and Lead in campus water, and displays the concentration of these metals from a few buildings chosen at UBC. Heavy metals alone are not the only concern in drinking water, *E. coli* and pathogens also have implications on human health. We assumed that the quality of drinking water was directly correlated with the concentration of heavy metals, however with a greater budget and time frame an assessment of biological pathogens may also be conducted.

2.2 Methods of Sampling and Analysis

Eleven buildings on campus were selected, including a sample of bottled water and the WaterFillz station located in the SUB. Buildings were chosen based on available Plant Ops water quality data, shown in Appendix C, to be compared against as well as buildings not available by Plant Ops such as Earth and Ocean Science Main and CIRS. These buildings were of interest because of their age and pipes, CIRS was expected to have a higher water quality with new plumbing based on its recent construction and EOSC was expected to have higher lead concentrations since the building contained lead plumbing. The sampling was conducted on a Monday morning to obtain the best estimate of initial fountain flow, based on the assumption that as fountains are used throughout the week the heavy metal concentration declines as stagnant water in plumbing is flushed. Turbidity of water sampled was not measured however we have estimates of turbidity levels available in Plant Ops data. Our primary interest was associated with the concentration of heavy metals, given the limited time frame and funding available for this assessment, analysis of organic pathogens within drinking water was not possible.

Preparation for sampling and sample analysis was conducted in the Pacific Center for Isotopic and Geochemical Research (PCIGR). 50mL Falcon tubes were soaked in a Citranox solution (tr amt, <1%, soap solution) on a hot plate at 50°C from January 19th - 25th 2012. Tubes were rinsed 2-3 times with MQ H2O until no more foam, and placed in containers of 10% nitric acid solution and heated at 50°C on a hot plate for 24 hours. Tubes were rinsed in MQ H20 and placed to dry in Tracer lab inside a laminar fume hood. Once dried, the tubes were labeled and pre-weighed before sampling, this procedure was critical to removing contaminants from tubes. During the sampling process the fountains were run for 60 seconds before sample was collected, observations of each site were recorded in addition to time of sample. Samples were acidified using nitric acid the morning of sampling and analyzed using the Agilent 7700xICP-MS.

2.3 Results

The results of this analysis are presented in Figures 6-9. Figure 6 shows the concentrations of Zinc and Copper across campus, Dasani bottled water was also analyzed, however the concentration of metals was so low that it did not register during analysis. These results show elevated concentration of copper and zinc in Totem Residence and Earth and Ocean Science (EOSC) Main, while Fred Kaiser, Geography, Buchanan A and Scarfe contained moderate concentrations (100-300 ppb). The WaterFillz station and the SUB water fountain had the lowest overall concentrations, with the exception of Dasani bottled water. Figure 7 indicated an elevated concentration of Lead in EOSC Main, in comparison to the other buildings which contained less than 1.00 ppb of Lead.

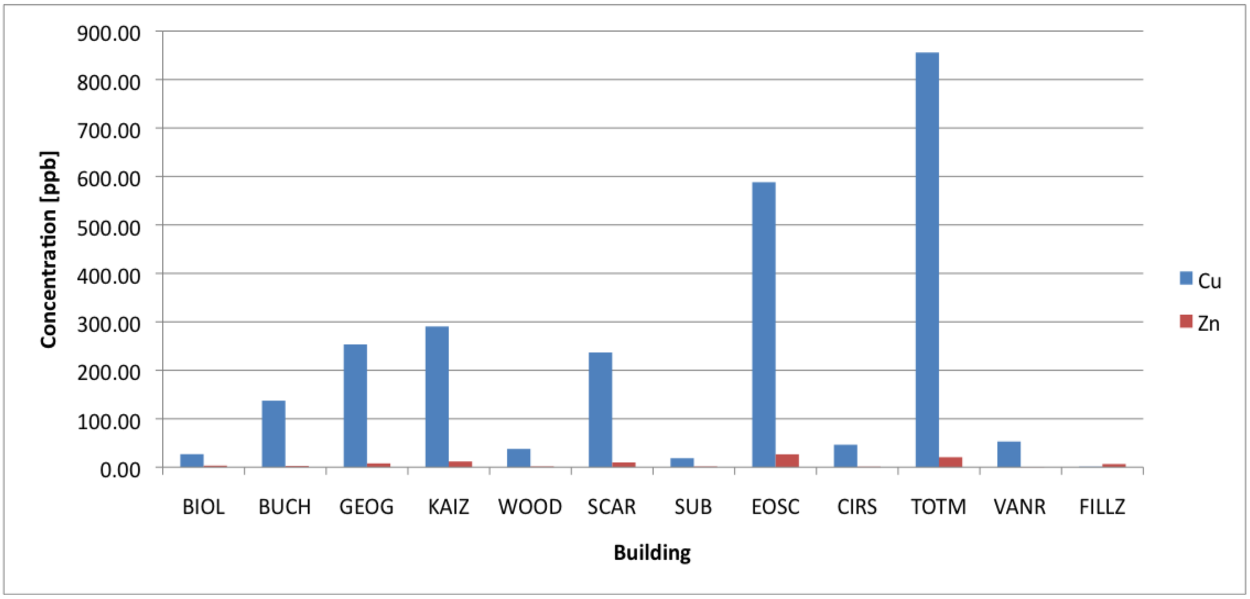

Figure 6: Analysis of Copper and Zinc concentrations in campus drinking fountains, analyzed in the PCIGR Lab, using initial standards against synthetic standards. Results are presented in [ppb]. Sampled between 0800-1000 hours on January 30th 2012. Canadian Health Guidelines for Cu < 1 ppm, Zn < 5 ppm (Health Canada, 2010).

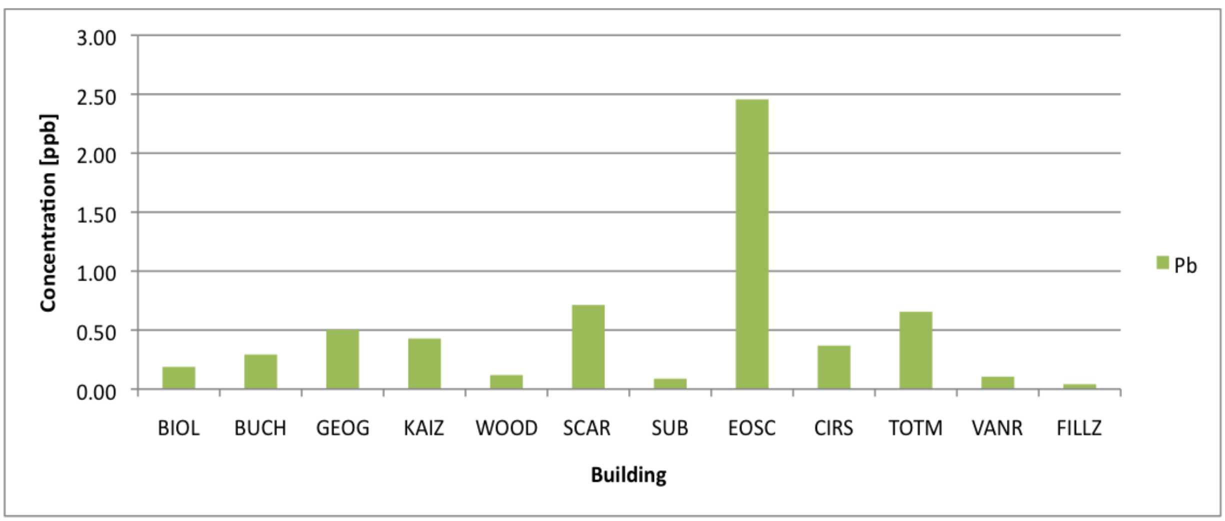

Figure 7: Analysis of Lead in Campus drinking fountains, analyzed in the PCIGR Lab concentrations are presented in [ppb]. Sampled between 0800-1000 hours on January 30th 2012. Canadian Health guidelines recommend Pb < 10 ppb (Health Canada, 2010).

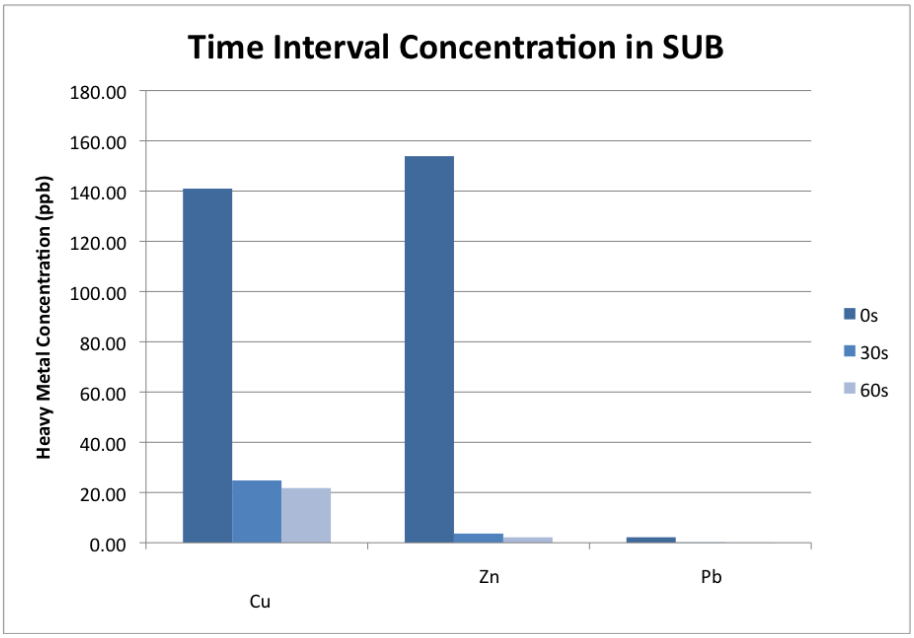

Figure 8: Time interval sample of copper, zinc and lead concentrations in the Student Union Building, using intervals of 30 seconds. Results are presented in [ppb] and sampled on February 27th 2012. Canadian guidelines recommend concentrations of Cu < 1 ppm, Zn < 5 ppm and Pb < 1 ppb (Health Canada, 2010).

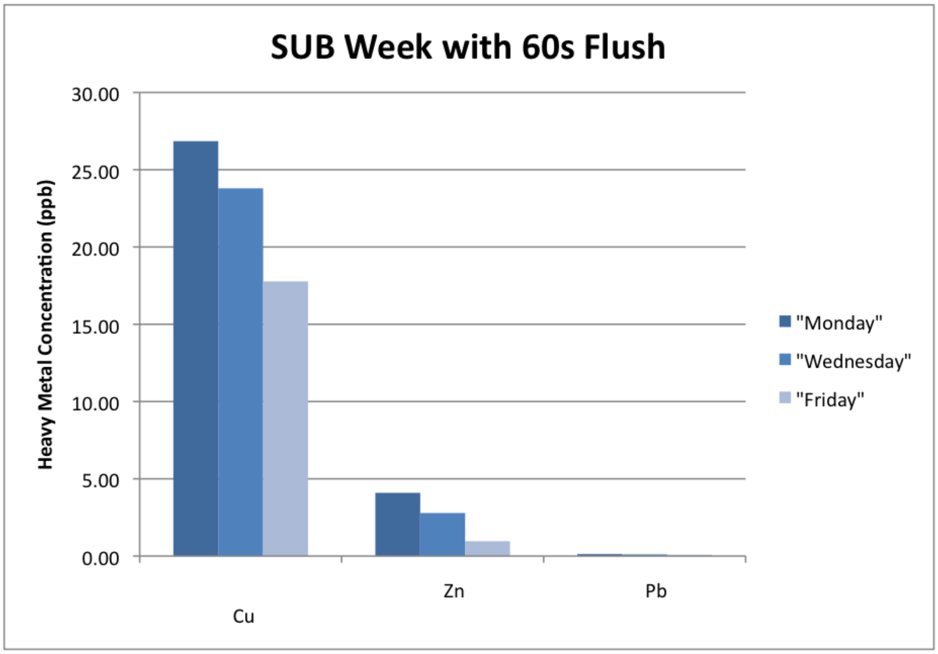

Figure 9: Daily variation of copper, zinc and lead concentrations in the Student Union Building concentrations over one week, sampled on Monday, Wednesday and Friday of February 27th 2012 and presented in [ppb].

Figure 8 displays the benefit of running the fountain water for at least 30 seconds in order to reduce the concentration of metals before drinking. Samples taken throughout the week (figure 9) also showed a decline in concentration as the week progressed, this supports our prediction that as the fountains are being used and water is flushed through the pipes the concentration of trace heavy metals declines.

2.4 Discussion

The results of our water quality assessment indicate that the concentrations of trace heavy metals (Copper, Zinc and Lead) do not exceed the recommended levels stated in the Canadian Health Guidelines. This analysis shows that all the buildings supply adequately safe drinking water, although some samples showed greater concentrations than others. Our results also show that the WaterFillz station contained the lowest concentration of heavy metals in comparison with other campus fountains. The concentration of metals also declined when fountains were flushed before sampling (30 seconds) and through the course of the school week as students used water facilities. Furthermore, this suggests that although fountain water does not pose any significant health risks, installation of better plumbing and filtration units would improve the current water quality.

Section 3 Economic Considerations

3.0 Background

One of the major reasons why UBC has not become a bottle free campus so far, is because of the inevitable costs associated with the loss of profit from bottled water sales, costs associated with providing alternate purified water, and a lack of student action. Thus far mostly small groups of students have pushed for the removal of bottled water. Several analysis have been conducted over the economic costs of different options available (Papers reviewed: Pritchard, D., Douglas, A. & Zhang, J. (2010); Kanda, K., Brar, T., Ho, R. & Yeh, R. (2011); and Shariatzadeh, A., Farahbakhsh, S., Abed, A. & Salem, M. (2010)).

3.1 Section Scope

We reviewed the recommendations of previous papers in addition to performing our own analysis. Costs and profits associated with the sale of bottled water and the potential cost for the removal of bottled water are discussed. The costs and benefits of three different filtration systems are considered compared; the WaterFillz, as believed the cheapest in the long term by the AMS, Brita "hydration stations", and Elkay water fountains/bottle filling stations. Finally, suggestions for recuperating losses are given.

3.2 Current costs and profits

Bottled water revenue

Currently, according to AMS Sustainability Co-ordinator Justin Ritchie, the AMS makes about $60,000 a year from bottled water sales (personal communication, March 21, 2012). Director of Food Operations Loriann McGowan (email communication, February 15, March 8, 19, and 23, 2012) informed us that the loss in their gross margin from bottled water sales (assuming no customers moved to other beverages) would be $67,000, or around $1.30 per bottle (since they sold 49,879 bottles of water). This seems a considerable amount per bottle, but usually the funds would help cover the cost of other items which have a higher food cost, and the deliveries. Without bottled water sales, the number of deliveries (and thus their costs excluding purchasing the water itself) we assume would remain roughly the same as bottled water comprises 3% of what comes to campus in the delivery trucks. (The company never sends an empty truck, so it would be accommodated for by product for other customers, but the cost to UBC is assumed to be the same).

However, the report by Sadowski and Willock (2010) found significantly higher revenues and sales for UBC Food Services, $300,000 of revenue and 178,000 bottles. After further investigation on the letters available in their Appendix A the values received actually encompass both AMS and UBC Food Services outlets, as well as vending machines and sales within

Athletics, and is in fact gross sales, not revenue. The report they received was also close to the 2010 Vancouver Olympics for which there has been a decline in sales compared to the national average (11.95% as opposed to 8.9%).

Cost to students

Dasani water bottles retail: $1.92 CAN, including tax (20 oz, 591 ml), at UBC Food Services outlets.
Reusable water bottles sold at the UBC bookstore (UBC Bookstore, 2012):

- UBC Nalgene water bottles: $9.99 for 16 oz (473 ml) or
    - $15.95 for both 24 oz (710 mL) and 32 oz (946 ml) bottles ($17.07 incl. tax)
- Stainless Steel Sauder Water Bottle: $11.95, 20oz (591 ml) ($13.38 incl. tax)

Student living on campus, or visiting campus do not directly pay for tap water (covered through student fees) so the only possible cost would be a re-useable water bottle, these may be given out for free in some cases as prizes, or will cost around $10 - $22 CAN. A Sauder Stainless repays itself after just 7.0 fills, a 24 oz bottle pays for itself after 7.4 fills, and the 32 oz bottle (which is more cost effective) has paid for itself after only 5.5 fills.

Average daily water consumption of Canadians is 1.5 *l* (Health Canada, 2010) then if all a student's water was from Dasani water bottles (that is 2.5 bottles a day), they'd pay $1,778.68 every year, just to drink water (and waste 926 plastic bottles). This may be unrealistic however in that some students drinking bottled water may purchase it only occasionally. While only 8% said they buy bottled water, 15.33% said they would "switch to refillable water bottles," 5% buy bottled water off campus, and 2% would buy other bottled products. Since the question in our survey asking students usually access water only allowed one option, we are lead to believe, that while 7-8% wrote the drink bottled water, at least 15% (those that chose they would "switch" to refillable bottles), and a maximum of 29% (excluding any who chose that they would not be affected) buy bottled water some of the time.

While this is clearly a cheaper option for students, there would likely be higher associated costs due to lack of funding for AMS services previously covered by bottled water sales. According to Justin Ritchie, about half of their profit goes to UBC, the other half to AMS services. If students had to pay for all the loss of profits (for the AMS) in their student fees, that would be $1.25 each per year (assuming we have 48,000 students) (UBC Enrolment Services (2012)). Keep in mind that's less than the cost of a single bottle of water! If students paid for both the UBC Food Services (assuming $67,000) and AMS losses ($60,000), it would be $2.64/yr. For 4 years at university, that a whole $16 maximum (assuming $3 fees), the same as a 24 oz re-useable bottle, or about 3 cups of speciality coffee. Naturally, this spreads the cost among students who may never drink bottled water (for example the 71% of our surveyed students who chose they would be unaffected by the removal of bottled water). However, for

UBC to ban bottled water in exchange for increased free services and upgraded water systems (WaterFillz/other), such fees might be considered reasonable.

3.3 Comparing WaterFillz to Elkay & Brita

The AMS has opted for the use of the WaterFillz stations primarily for their analysis on the long term costs of these as compared to Elkay or Brita filters. The initial costs are indeed much less expensive for the alternatives, however, the reasoning for AMS's choice was that their filters had to be replaced more often and/or were more expensive. For our analysis this was somewhat difficult to compare as there are many different models of filters available from Elkay, and neither Elkay nor Brita may have the same features as the WaterFillz. Using information from company websites and previous papers, Table 17 presents the costs associated with WaterFillz and specific models of the alternative choices.

Table 17. Comparing costs for three different filtration systems

Brand	WaterFillz	Brita	Elkay
Model	Revenue model	Brita® Hydration Station™ Recessed Mount (2000)	EZH2O - LVRCGRN8 combo water fountain & bottle fill
Initial Cost	$7,500 educational institutions + tax (D. Klaassen, personal communication, March 21, 2012)	$1,339.95 - 2,150 CAN $1744.98 median value	$1,780 US**
Discounts	Offered us discount if bought in bulk, which AMS was considering First decal wrap free A little extra for "digital media screen for campus info sponsorship or advertising"	Currently has a special offer $30 off	N/A
Filters (specs)	Combined Sediment Filtration and Carbon Block Filtration (Replacement every 6-12 months, depending on usage) $96 UV light (Replacement every year) $96 Refurbish kit: includes replacement lines and filter & UV bulb. Lines may need replacing every two years or so. 25,000 gallons (96,000L) Completely recyclable Higher yield available (D. Klaassen, personal communication, March 27, 2012)	9,464L(2,500 gallon) Carbon block $79.95 Calculated = Replace every 18.25 days Assuming 25,000 gallons used in 6 months	11,356L (3,000 gallon) Activated Carbon $125 Calculated = Replace every 21.9days Assuming 25,000 gallons used in 6 months
Electricity*	55W 110V Can be run off solar power	11W (calculatedǂ from 0.1Amp) 110V	518W (calculatedǂ from 4.5Amp) 115V

Long term costs for 5 years (excluding energy costs)	$9,524.32 + tax (12%) = $10,667.24 Includes a second decal wrap ($500) Excludes additional cost of digital media screen. Includes energy costs	$9,726.84+ tax (12%) = $10,894.06 Including $30 discount	$12,990.67+ tax (12%) = $14,549.55

*Costs 3.5¢/kWh (BC Hydro, 2012)
**Mar 22, 2012, 1:1 exchange rate
ǂ Contractors, Depot (2012).

Calculations were made to determine how often filters would need replacing, if they serviced 25,000 gallons of water in 6 months. We concluded that the WaterFillz are indeed the most economic option in the long term. This is presuming we do not buy any other decals (as the first one is free one). The energy use (and thus cost) of WaterFillz stations are quite low, and may be made even lower by either incorporating solar power (not available on other models) or if cooling is not a concern, however according to our survey, it is important since 20.77% of student choose not to drink from fountains due to reasons of taste or temperature preference.

3.4 Suggestions for recouping funds

A few ways of recouping funds would be through advertisements on WaterFillz stations, we can employ either custom decals (which may be bought out by the company wanting advertisement) or simply having logos for contracted vendors. UBC Food Services and the AMS may also opt for selling re-useable water bottles. The WaterFillz website assumes a $5 profit per re-useable water bottle, given our survey, 15.33% of students would switch to re-useable bottles, assuming half of them do so, that's 7.7% of students or 3,679 students. Assuming a $5 profit, that is $18,395 of revenue. Only a few people will move to other bottled beverages according to our survey (2%), with others buying bottled water off campus (5%), however the extra profit from those buying other beverages is negligible as other beverages do not provide as much profit, and there were very few people choosing this option.

As mentioned, the costs could be spread out among the students as a fee to help provide cleaner water. While the cost is not significant, from past experience it is likely to be an unpopular option. Students who would like to see it banned could make donations to help buy new stations, as it doesn't take much if there are enough people interested in making a difference on campus. Alternatively entertaining fundraisers like dance parties, or something in accompaniment to storm the wall and triathlons events may also be effective.

For UBC one of the largest incentives is political. As other campuses move towards being bottle free campuses, this is a concern for reputation. As well, there are many incentives and sustainability goals which could be assisted through this move towards sustainability. There are also "unseen profits" due to increased interest from students, staff, faculty, or researchers who may want to study, work, or conduct research while being a part of a more sustainable campus.

Section 4 Recommendations for the placement of WaterFillz Stations

4.0 Section Scope

Best potential locations for additional WaterFillz stations are identified by synthesizing water quality data, building traffic data, fountain availability data and survey results (survey, Appendix A).

4.1 Analysis and results

Water Quality

After taking samples in various buildings across campus, to test water quality and health implications, we found that the heavy metal concentrations were all under the Canadian health code regulations. However, there were some buildings with higher metal concentrations than others that would benefit from having a WaterFillz filtration kiosk. Out of the buildings we tested, Earth and Ocean Sciences Main (EOSM) building had the highest lead concentrations (Figure 7), with Neville Scarf and Totem residence also showing elevated copper concentrations in Figure 6. Specifically, EOSM would benefit from a WaterFillz unit since it has lead pipes throughout the building which may cause problems in the future.

Building Traffic

Data on the student enrollment in each classroom was retrieved from UBC building operations. This allowed us to compile the data and produce numbers for student traffic in each building on a per week basis. Figure 10 shows all of the classroom buildings that have over 10,000 students going in and out of the classrooms each week. They represent the top 17 student traffic buildings. With these numbers we can see which buildings are in need of water filling stations or more water fountains to cope with the loss of bottled water on campus.

Water Fountain availability

We also obtained data on water fountain availability through UBC building operations and were not surprised to find several buildings with zero fountains. However, it is surprising that some of these buildings are in the top 17 most visited classroom buildings on campus. These buildings are described above and all have student traffic higher than 10,000 students per week. Although data on water fountain availability was provided, whether fountains were functional and the overall condition of each fountain is unknown. If UBC is to move towards a more sustainable campus and remove bottled water, there needs to be an increase in water fountains and upkeep along with water bottle refilling stations.

Table 18. Student traffic and water fountain availability

Building (Highest to lowest student traffic)	Student Traffic (students/week)	Number of Water Fountains in the Building
Woodward	257580	4
Buchanan Lecture Halls	150396	2
Sauder	49194	3
Chemistry	39787	3
Neville Scarfe	28435	8
Swing	25744	0
Geography	22732	2
MacLeod	22172	4
Hennings	20636	2
Forest Sciences	19910	0
Hugh Dempster	19110	1
LSK	16855	2
IKB	15959	8
MacMillan	15859	1
Civil and Mechanical Engineering	14826	0
Mathematics	13720	0
Biological Sciences	12705	4

Student traffic shown as number of students enrolled in each building per week. Each building shown has enrollment greater than 10,000 students representing the top 17 buildings on UBC campus. Data only represents classroom enrollment and does not represent all building traffic. Data retrieved from UBC building operations.

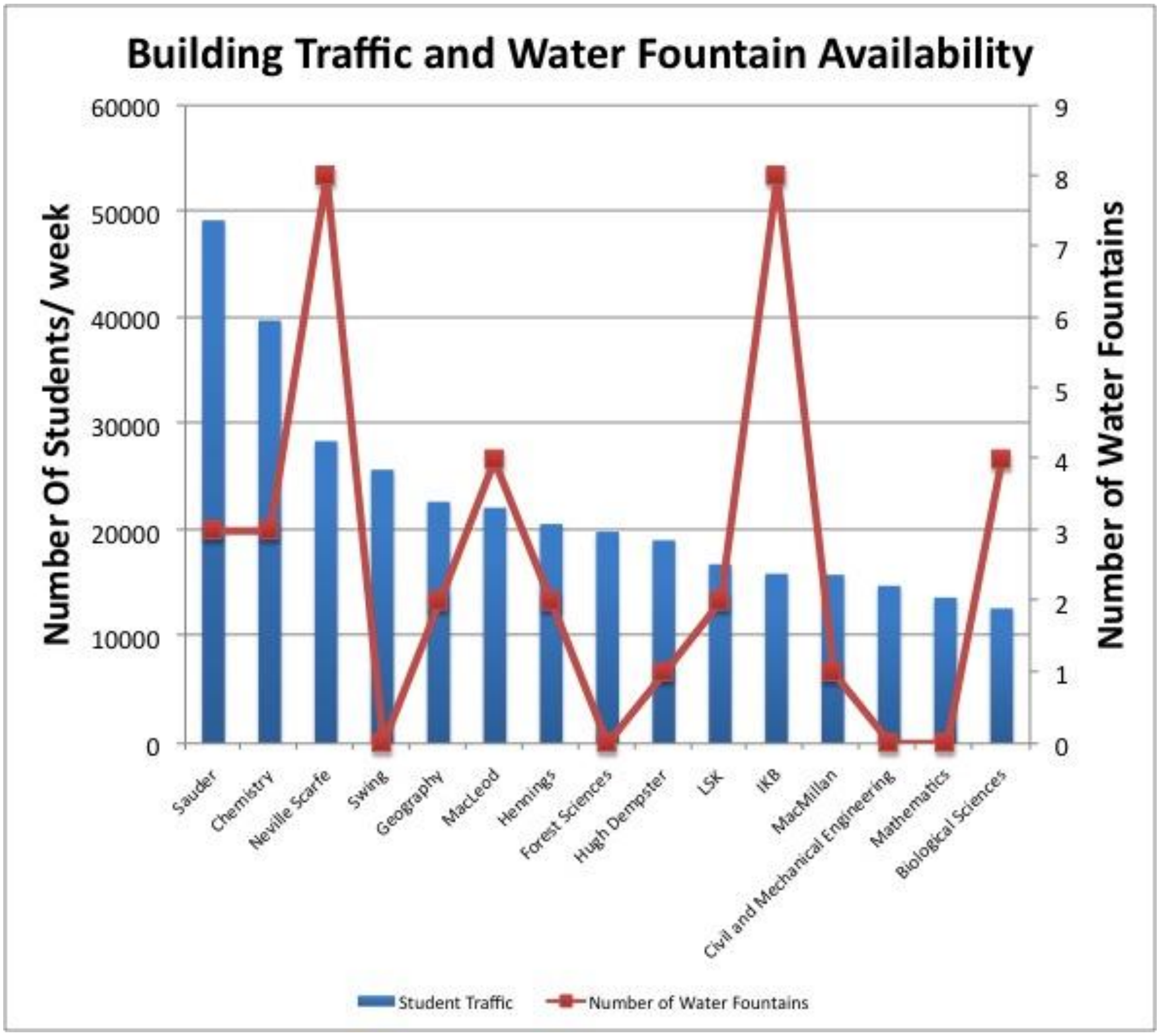

Figure 10. Student traffic and water fountain availability. Student traffic shown as number of students enrolled in each building per week. Woodward and Buchanan (top 2 student traffic buildings) are not shown in order to better show the student traffic of the other buildings. Each building shown has enrollment greater than 10,000 students representing the top 15 buildings on UBC campus. Data only represents classroom enrollment and does not represent all building traffic. Data retrieved from UBC building operations, listed in table 18.

Survey Input

We included questions in our survey that ask for input on which buildings students drink water in most. Figure 11 tells us that most students are accessing water on campus from the Student Union Building (SUB) most followed by Irving K. Barber and Sauder School of Business. Another goal of the survey was to gather information on the drinking water habits of students on campus. Figure 12 shows us that about 82% of students are currently bringing their own reusable water bottles, and that only 8% of students are buying bottled water. Similarly, figure 13 shows us that 71% of students would not be affected if bottled water was banned from UBC campus, and another 15% said that they would switch to reusable water sources. We can clearly see from the survey results where most students are retrieving their water. This information is important when considering where additional water filling stations should be placed. In conclusion, we can state that students would cope well with a plastic bottle free campus.

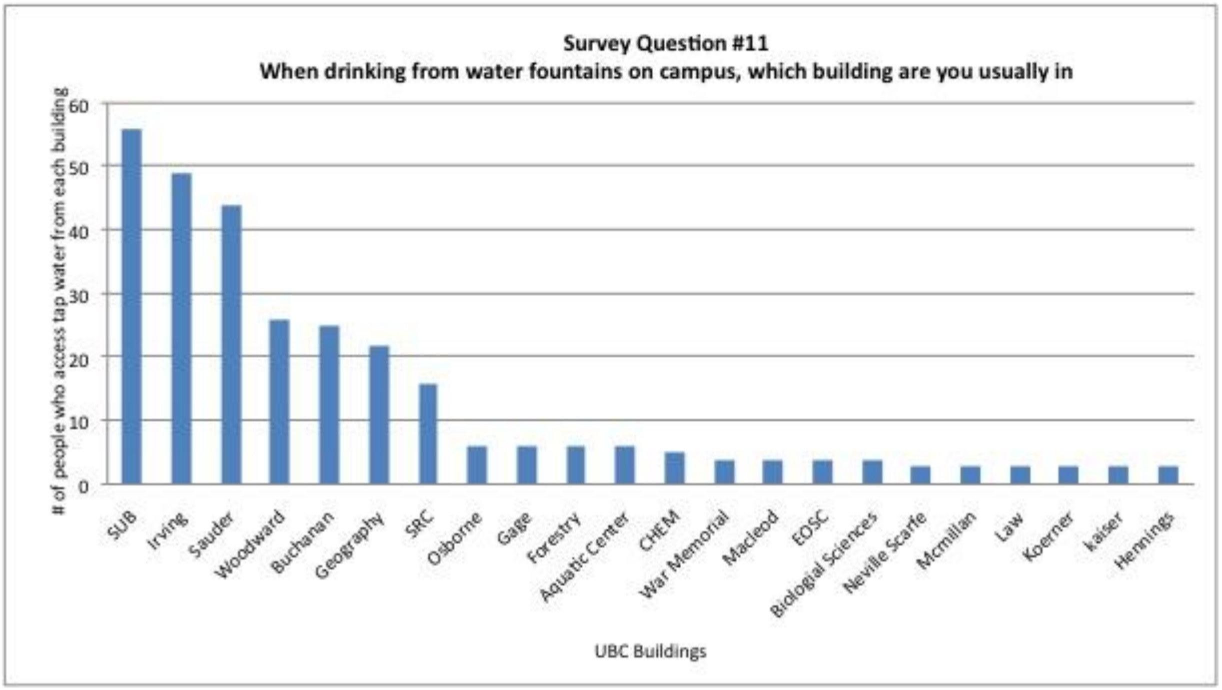

Figure 11. Where students most often drink from water fountains on UBC campus. This data was retrieved through a survey of the student body.

How do you access water while on campus?		
I carry a reusable water bottle with water from home	118	39.33%
I carry a reusable water bottle and fill it at campus fountains/taps	94	31.33%
I carry a reusable water bottle but refill only at Waterfillz stations in the SUB.	35	11.67%
I buy bottled water	24	8.00%
I drink from the fountain	21	7.00%
I do not drink water on campus	8	2.67%

Figure 12. Survey result for question number 3 of a survey conducted on the student body at UBC campus.

Figure 13. Survey result for question number 7 of a survey conducted on the student body at UBC campus.

4.2 Recommendations

With consideration to all the above information collected, the buildings we recommend placement of water filling stations to include:

Geography	Totem	Swing
Buchannan	Scarfe	Civil & Mechanical engineering
Woodward	Forestry	Macmillan
EOSC	Math	Hugh Dempster
Sauder		

Geography, Buchannan, and Woodward appeared in all categories taken into consideration. Survey results of Q11 (Figure 12) showed Woodward and Buchannan to be popular locations where water fountains are used (survey, Appendix A). As well, these two buildings had the highest student traffic to water fountain ratio and also found to have cooper, zinc and lead in our tested samples, although all levels were lower than Canada's guidelines. Geography currently has two water fountains however it should be considered for a WaterFillz station based on our water sampling results. It had slightly higher concentration of copper and lead among the tested buildings and was just above the Canadian average concentration of copper, 0.176mg/L, although still far lower than guidelines. Considering lead is associated with the most health risks, EOSC, Totem and Scarfe, as mentioned previously should also be considered for a WaterFillz station. Sauder is recommended for a water filling station since it is a high traffic area. Lastly, high traffic building with 0-1 water fountain that should also be considered for WaterFillz station or alternative means include Forestry, Swing, Civil & Mechanical engineering, Math, Hugh Dempster and Macmillan. The SUB was not considered for a WaterFillz since two WaterFillz stations currently exist there. Similarly, we did not recommend placing a WaterFillz station in Irving since our data and observations indicated that there are adequate well maintained water fountains to supply the volume of students. Of equal importance, students in Irving already have access to existing water fountains. As previously mentioned, however, data on student traffic is based on classrooms and does not account for library traffic thus more water stations could possibly be required.

4.3 Discussion of limitations

Since the data retrieved from building operations only includes those with classrooms, there are multiple high traffic buildings that may be overlooked when seeking optimal places for putting water filling stations. Places such as libraries, where thousands of students come to study and do work throughout the school year. Also, commons blocks for the residences on campus have many students going in and out of them every day on their way to and from class, and would benefit from having water filling stations readily available. One of the largest recommendations from students for where to put new WaterFillz stations was the Student Rec Centre (SRC). This building has a high volume of students each day along with an amplified need for water availability due to all of the exercise in the gym along with the Rec sports upstairs. Students also expressed interest in having WaterFillz stations in libraries and department buildings.

Acknowledgements

The chemical analysis, supply of materials, and experiment advice for this study was conducted under the direction of the PCIGR lab, courtesy of Vivian Lai, Diane Hanano and Dominique Weis. Information on student traffic was provided by UBC Classroom Services and age of campus buildings was supplied by UBC Building Operations manager Peter Jia. UBC Facilities Manager, James Bellavance also provided data on concentration of campus fountains within buildings. Caro Analytical Services sampling coordinator Nicolas Carajales took us through the procedure of UBC's water sampling collection.

We would like to thank the following people and associated entities for releasing requested data and for answering our questions: Tameeza Jivraj of Metro Vancouver, Loriann McGowan of UBC Food Services, Donna Klaassen of the SafeStar Manufacturers of WaterFillz, and AMS sustainability coordinator Justin Ritchie.

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Appendix A: Survey Details

Survey Methods

After gaining approval from the ethics board (BREB # H11-03343), we surveyed through both online and in person methods. Online versions of the survey were shared with friends and acquaintances through social networks such as Facebook. Also, a few instructors of large classes were contacted with requests to help direct traffic to online surveys, resulting in students from Geog 310 and Geog 312 (which are non-specialized courses) having participated.

Our target areas for conducting surveys in person were common places such as the SUB and Irving K Barber. In attempt to ensure a fair representative of the campus body, paper surveys were also conducted in areas of campus where some groups may not have been represented. These areas included Sauder, Forestry, Koerner, Woodward, and Geography. Due to resource and time limitation we did not have the ability to conduct surveys in every building fully ensuring representation from every UBC group.

Survey Demographics

In total we were able to collect 300 completed surveys. 120 were collected through paper surveys while the rest through social networks including Facebook and Professor directed traffic. We acknowledge that the surveying technique through social networks and the selection of surveyed areas may possibly contribute a certain bias. However, the focus of this study was to improve drinking water sources for the larger population of UBC and thus our bias of seeking high volume areas is intentional. The breakdown of where paper surveys were collected can be seen in Figure A1 below. Figure A2 shows the breakdown of survey participates who identified themselves as undergraduate students, graduate students, or UBC faculty and staff. Also provided will be the breakdown of survey participants who live on and off campus in Figure A3. Considering many graduate, staff and faculty departments provide their members with benefits, such as access to a full kitchen, the greater than 90% representation of people surveyed being undergraduates is to advantage of this project.

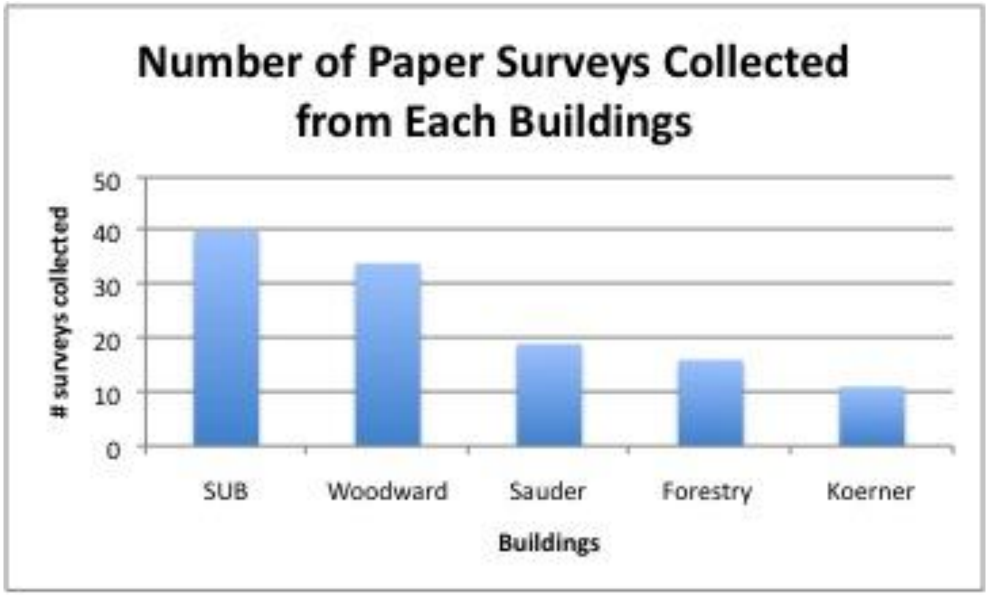

Figure A1: Number of Paper Surveys Collected from various buildings.

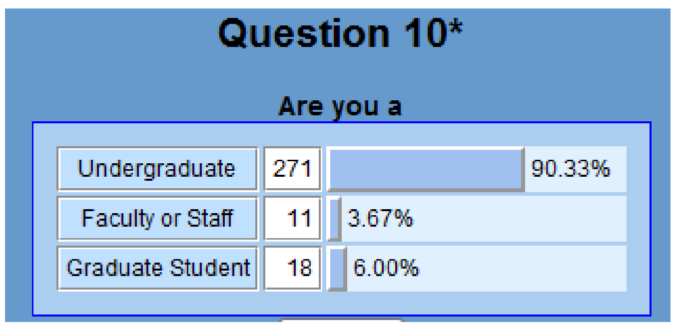

Figure A2: Number and percentage of survey participants who identified themselves as undergraduate students, graduate students or faculty and staff.

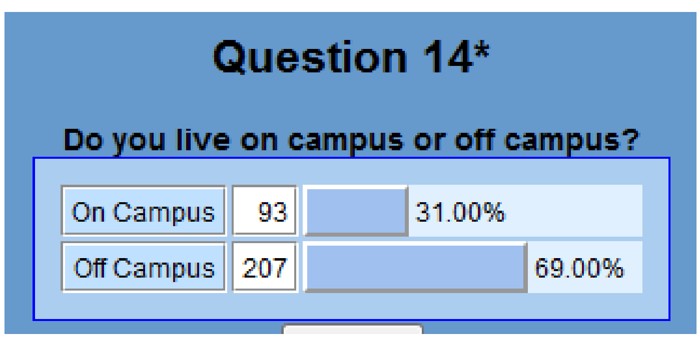

Figure A3: Number and percentage of survey participants who live on or off campus.

Survey on Campus Drinking Water

How do you access water while on campus?
a) I buy bottled water
b) I carry a reusable water bottle with water from home
c) I carry a reusable water bottle and fill it at campus fountains
d) I carry a reusable water bottle but refill only at water fill stations in the SUB.
d) I drink straight from fountains
e) I do not drink water on campus

When you drink from water fountains
a) I drink from the fountain right away
b) I flush the water for a few seconds
c) I flush the water for a full minute to 3 minutes as advised by signs
d) I am too worried about the water quality to drink

Reasons for not drinking from water fountains
(you may circle more than one)
a) hygiene
b) taste/temperature
c) drink coffee or tea instead
d) not thirsty
e) concern over the water quality
f) other: ___________________

If bottled water was no longer available on campus I would
a) not be affected
b) buy water bottles off campus
c) switch to re-filling reusable bottles
e) drink straight from the water fountains
f) other: ___________________________

How do you access drinking water off campus
a) tap water
b) bottled water
c) filtered water
d) water coolers

Are you a
a) Undergraduate
b) Faculty or Staff
c) Graduate Student

When drinking from fountains on campus which building are you usually in?

Building(s): _________________________

Where would you want a water filtration station? (you may circle more than one)
a) In department buildings
b) In libraries
c) Next to food franchises

Do you live on campus or off campus?
a) On Campus
b) Off Campus

Did you know about previous initiatives to remove bottled water on campus?
a) Yes
b) No

Appendix B: Energy Assessment Data

1. Detailed breakdown of energy consumption for manufactured products

Data source: Franklin Associates. (2009). *Life Cycle Assessment of Drinking Water Systems: Bottled Water, Tap Water, and Home/Office Delivery Water: Final Peer-Reviewed Appendix. Prepared for the State of Oregon Department of Environmental Quality*. (09-LQ-104). Retrieved from http://www.deq.state.or.us/lq/pubs/docs/sw/LifeCycleAssessmentDrinkingWaterAppendix.pdf

Sourced data includes process energy (1000 BTU/ 1000 lbs) and amount of material used in each step (lbs /1000 lbs final). All other values have been calculated based on those.

Aluminium	Process energy (BTU/lbs)	Process energy (kJ/kg)	Carbon equivalent (kg CO_2 equiv/kg)	Material Used (kg / 1000 kg final)	Energy per step (kJ/1000 kg final product)	Carbon equiv per step (kg Co2 equiv/1000 kg final product)
Salt mining	955.7	2222.803	0.839609	125	277850.4	104.9511
Sodium Hydroxide creation	11329.8	26351.28	9.953539	143	3768233	1423.356
Limestone mining	79.9	185.8344	0.070194	165	30662.68	11.58207
Lime Manufacture	2701	6282.088	2.372902	88	552823.7	208.8154
Bauxite Mining	442	1028.02	0.388309	5095	5237763	1978.435
Alumina production	7080	16466.93	6.219974	1930	31781177	12004.55
Coal Mining	548	1274.559	0.481433	409	521294.7	196.9061
Metallurgical Coke Production	187	434.9317	0.164285	373	162229.5	61.27816
Crude oil extraction	20887	48579.77	18.3498	106	5149456	1945.079
Petroleum coke production	1713	3984.16	1.504917	105	418336.8	158.0163
Anode production	3146	7317.086	2.763847	455	3329274	1257.55
Smelting	74688	173712.2	65.61545	1000	1.74E+08	65615.45
Igot casting	2355	5477.348	2.068932	1000	5477348	2068.932
Casting	3945	9175.43	3.46579	1000	9175430	3465.79
Total					**239594048**	**90500.69**

Steel	Process energy	Process energy	Carbon equivalent	Material Used	Energy per step	Carbon equiv per

	(BTU/pound)	(kJ/kg)	(kg CO_2 equiv/kg)	(kg / 1000 kg final)	(kJ/1000 kg final product)	step (kg Co2 equiv/1000 kg final product)
Limestone mining	79.9	185.8344	0.070196	124.8	23192.14	8.760446
Lime manufacture	2701	6282.088	2.372955	23	144488	54.57796
Iron ore mining	961	2235.13	0.844283	1088.9	2433833	919.3402
Coal mining	548	1274.559	0.481444	446	568453.4	214.7238
Metallurgical Coke Production	187	434.9317	0.164288	404.9	176103.8	66.52031
Oxygen Production	662	1539.705	0.581598	91	140113.1	52.92541
Pellet Production	276	641.9312	0.242479	741	475671	179.6769
Sinter production	230	534.9427	0.202066	494	264261.7	99.82048
Scrap procurement	1795	4174.879	1.576991	357.6	1492937	563.9321
pig iron production	924	2149.074	0.811777	871	1871844	707.0579
Steel production in BOC	1340	3116.623	1.177253	1000	3116623	1177.253
Casting	3945	9175.43	3.465867	1000	9175430	3465.867
Total					**19882949**	**7510.455**

PET	Process energy (BTU/pound)	Process energy (kJ/kg)	Carbon equivalent (kg CO_2 equiv/kg)	Material Used (kg / 1000 kg final)	Energy per step (kJ/1000 kg final product)	Carbon equiv per step (kg Co2 equiv/1000 kg final product)
Crude oil extraction	20887	48579.77	18.35021	595	28904965	10918.37
Petroleum refining	1558.1	3623.888	1.368864	575	2083735	787.0966
Natural gas extraction	24094	56038.73	21.1677	233	13057025	4932.075
Natural gas processing	1123	2611.916	0.986608	227	592904.9	223.96
Methanol manufacture	1782	4144.643	1.56557	553	2291988	865.7603
Carbon monoxide and Acetic Acid manufacture	4799.3	11162.39	4.216409	37.2	415241	156.8504
Ethylene manufacture	1207.4	2808.216	1.060757	200	561643.3	212.1515
Oxygen manufacture	662	1539.705	0.581598	223	343354.1	129.6963
Ethylene oxide manufacture	2859.17	6649.965	2.511914	254	1689091	638.0263
Mixed xylenes	1019	2370.029	0.895239	521	1234785	466.4196
Paraxylene	3989	9277.767	3.504523	521	4833716	1825.856

extraction						
PET production	5960	13861.99	5.236138	1000	13861993	5236.138
Blow moulding	5619	13068.88	4.936554	1000	13068882	4936.554
Total					**82939324**	**31328.96**

Polypropolyene	Process energy (BTU/pound)	Process energy (kJ/kg)	Carbon equivalent (kg CO_2 equiv/kg)	Material Used (kg / 1000 kg final)	Energy per step (kJ/1000 kg final product)	Carbon equiv per step (kg Co2 equiv/1000 kg final product)
Crude oil extraction	20887	48579.77	18.35021	376	18265995	6899.677
Petroleum refining	1558.1	3623.888	1.368864	374	1355334	511.955
Natural gas extraction	24094	56038.73	21.1677	851	47688963	18013.72
Natural gas processing	1123	2611.916	0.986608	827	2160054	815.9248
Proylene	635	1476.907	0.557877	996	1470999	555.6456
Polypropylene manufacture	1665	3872.52	1.46278	1000	3872520	1462.78
Injection moulding (for caps)	7976	22769.95	8.600972	1000	22769951	8600.972
Total					**97583817**	**36860.67**

Low Density Polyethylene	Process energy (BTU/pound)	Process energy (kJ/kg)	Carbon equivalent (kg CO_2 equiv/kg)	Material Used (kg / 1000 kg final)	Energy per step (kJ/1000 kg final product)	Carbon equiv per step (kg Co2 equiv/1000 kg final product)
crude oil	20887	48579.77	18.35021	282	13699496	5174.758
petroleum refining	1558.1	3623.888	1.368864	273	989321.4	373.6998
Nat gas extraction	24094	56038.73	21.1677	935	52396217	19791.8
Nat gas processing	1123	2611.916	0.986608	910	2376843	897.8132
Ethylene	1207.4	2808.216	1.060757	1008	2830682	1069.243
LD PE resin manufacture	3861	8980.06	3.392069	1000	8980060	3392.069
polyethylene film (packaging)	2153	5007.529	1.891511	1000	5007529	1891.511
Total					**86280148**	**32590.9**

2. Metro Vancouver water treatment energy consumption and flows

Data Source: Tameeza Jivraj (email correspondence, March 2012)

2011	SCFP Total kWh	SCFP Total Flow (ML/d)	Capilano Total Flow (ML/d)	Coquitlam Total Flow (ML/d)	Total Monthly Source Flows (ML/d)
January	985,239	21,675	79	7,545	29,299
February	865,847	19,430	27	6,781	26,238
March	908,605	21,022	142	7,857	29,022
April	749,510	20,391	976	7,531	28,897
May	673,639	13,563	7,889	8,935	30,387
June	668,361	13,823	8,696	10,474	32,994
July	744,542	17,600	9,327	10,667	37,595
August	797,419	18,561	9,934	13,451	41,946
September	769,239	14,718	10,293	11,422	36,433
October	815,381	18,691	125	12,050	30,866
November	883,819	17,789	88	10,543	28,420
December	965,884	14,500	129	14,008	28,638
Total	**9,827,484**	**211,764**	**47,706**	**121,266**	**380,736**

Appendix C: Water Quality Data

Biological Sciences	**Immediate/Nov2011**	**60sec/Nov2011**	**Immediate/Aug2011**	**60sec/Aug2011**	**Immediate/Nov2010**	**60sec/Nov2010**
Coliforms, Total	<1	<1	<1	<1	<1	<1
E. coli	<1	<1	<1	<1	<1	<1
Temperature	17	8.8	21	11	19	12
Hardness, Total	11.4	8.77	<12.9	<12.9	12.4	11.3
Turbidity	0.1	0.2	0.3	0.2	0.14	0.12
pH	6.8	6.81	5.68	5.87	7.1	6.7
Aluminum	<0.050	0.058	0.08	0.113	<0.050	<0.050
Antimony	<0.0200	<0.0200	<0.0010	<0.0010	<0.0010	<.0010
Arsenic	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<.0050
Cadmium	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Calcium	4.2	3.2	<5.0	<5.0	4.7	4.3
Copper	0.655	0.0485	0.897	0.108	0.528	0.0409
Iron	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Lead	0.0068	0.001	0.0082	0.0017	0.0101	0.0017
Mercury	<0.00020	<0.00020	<0.00020	<0.00020	<0.00050	<0.00050
Potassium	<0.20	0.22	0.49	<0.20	0.23	0.21
Sodium	1.81	2.9	1.64	1.58	2.07	1.87
Zinc	<0.040	<0.040	<0.040	<0.040	0.027	0.01
Year Built	1948					
Renovation Date	2011					
Buchanan D	**Immediate/Nov2011**	**60sec/Nov2011**	**Immediate/June2011**	**60sec/June2011**	**Immediate/Nov2010**	**60sec/Nov2010**
Coliforms, Total	<1	<1	<1	<1	<1	<1
E. coli	<1	<1	<1	<1	<1	<1
Temperature	17	12	23	16	18	14
Hardness, Total	10.5	10.5	<12.9	<12.9	12.5	13.3
Turbidity	0.1	0.2	0.3	0.2	0.14	0.09
pH	6.84	6.78	6.28	6.33	6.7	6.9
Aluminum	0.054	<0.050	<0.050	0.095	<0.050	0.071
Antimony	<0.0200	<0.0200	<0.0010	<0.0010	<0.0010	<0.0010

Arsenic	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Cadmium	<0.00010	<0.00010	<0.00010	<0.00010	0.00012	<0.00010
Calcium	3.9	3.9	<5.0	<5.0	4.7	5.1
Copper	0.247	0.097	1.15	0.252	0.437	0.0688
Iron	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Lead	<0.0010	<0.0010	0.0033	<0.0010	0.0011	<0.0010
Mercury	<0.00020	<0.00020	<0.00020	<0.00020	<0.00050	<0.00050
Potassium	<0.20	<0.20	<0.20	0.23	0.16	0.18
Sodium	1.87	1.92	1.74	1.84	1.82	1.71
Zinc	<0.040	<0.040	<0.040	<0.040	0.012	<0.010
Year Built	1960					
Renovation Date	2007					
Kaiser	**Immediate/Nov2011**	**60sec/Nov2011**	**Immediate/June2011**	**60sec/June2011**	**Immediate/Nov2010**	**60sec/Nov2010**
Coliforms, Total	<1	<1	<1	<1	<1	<1
E. coli	<1	<1	<1	<1	<1	<1
Temperature	18	17	23	22	21	16
Hardness, Total	10.7	14.2	<12.9	<12.9	12.9	11.8
Turbidity	0.2	0.2	0.4	0.2	0.07	0.06
pH	6.84	6.67	6.15	6.31	6.5	6.5
Aluminum	<0.050	0.057	0.051	0.106	<0.050	<0.050
Antimony	<0.0200	<0.0200	<0.0010	<0.0010	<0.0010	<0.0010
Arsenic	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Cadmium	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Calcium	3.9	5.3	<5.0	<5.0	4.9	4.4
Copper	0.368	0.256	0.914	0.222	0.384	0.129
Iron	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Lead	0.0016	0.0026	0.002	0.0016	0.0017	<0.0010
Mercury	<0.00020	<0.00020	<0.00020	<0.00020	<0.00050	<0.00050
Potassium	0.28	<0.20	<0.20	0.22	0.23	0.22
Sodium	1.95	1.87	1.76	1.89	2.07	1.97
Zinc	<0.040	<0.040	0.043	<0.040	0.039	0.011
Year Built	2005					
Renovation Date	na					
Geography	**Immediate/Nov2011**	**60sec/Nov2011**	**Immediate/June2011**	**60sec/June2011**	**Immediate/Nov2010**	**60sec/Nov2010**
Coliforms, Total	<1	<1	<1	<1	<1	<1

E. coli	<1	<1	<1	<1	<1	<1
Temperature	20	10	21	11	23	16
Hardness, Total	10.3	10.4	<12.9	<12.9	12.9	12.8
Turbidity	0.2	0.2	1.3	0.7	5.88	0.25
pH	6.87	6.99	5.97	5.89	6.4	6.9
Aluminum	<0.050	0.06	0.12	0.207	0.403	<0.050
Antimony	<0.0200	<0.0200	<0.0010	<0.0010	<0.0010	<0.0010
Arsenic	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Cadmium	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Calcium	3.8	3.8	<5.0	<5.0	4.9	4.8
Copper	0.503	0.0854	1.35	0.388	2.36	0.0946
Iron	<0.10	<0.10	0.15	0.21	0.72	0.12
Lead	0.001	<0.0010	0.0038	0.0045	0.0143	<0.0010
Mercury	<0.00020	<0.00020	<0.00020	<0.00020	<0.00050	<0.00050
Potassium	0.29	<0.20	<0.20	<0.20	0.34	0.35
Sodium	2.07	1.87	1.55	1.61	1.91	1.93
Zinc	<0.040	<0.040	<0.040	<0.040	0.019	0.01
Year Built	1925					
Renovation Date	na					
Woodward	**Immediate/Nov2011**	**60sec/Nov2011**	**Immediate/June2011**	**60sec/June2011**	**Immediate/Nov2010**	**60sec/Nov2010**
Coliforms, Total	<1	<1	<1	<1	<1	<1
E. coli	<1	<1	<1	<1	<1	<1
Temperature	22	8.5	17	8	13	12
Hardness, Total	10	9.8	<12.9	<12.9	12.5	12
Turbidity	0.3	0.2	0.6	0.3	0.32	0.13
pH	6.98	6.82	6.44	6.52	6.7	6.8
Aluminum	0.067	0.083	0.134	0.104	0.114	0.068
Antimony	<0.0200	<0.0200	<0.0010	<0.0010	<0.0010	<0.0010
Arsenic	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Cadmium	<0.00010	<0.00010	0.00011	<0.00010	<0.00010	<0.00010
Calcium	3.7	3.6	<5.0	<5.0	4.7	4.5
Copper	0.362	0.0915	0.364	0.145	0.503	0.0784
Iron	0.11	<0.10	<0.10	<0.10	<0.10	<0.10
Lead	<0.0010	<0.0010	0.0017	<0.0010	0.0028	<0.0010
Mercury	<0.00020	<0.00020	<0.00020	<0.00020	<0.00050	<0.00050
Potassium	<0.20	<0.20	<0.20	<0.20	0.15	0.13

Sodium	2.04	2.12	1.83	1.79	1.73	1.6
Zinc	<0.040	<0.040	<0.040	<0.040	0.03	0.011
Year Built	na					
Renovation Date	na					
Neville Scarfe	**Immediate/Nov2011**	**60sec/Nov2011**	**Immediate/June2011**	**60sec/June2011**	**Immediate/Nov2010**	**60sec/Nov2010**
Coliforms, Total	<1	<1	<1	<1	<1	<1
E. coli	<1	<1	<1	<1	<1	<1
Temperature	18	13	20	14	19	17
Hardness, Total	10.6	8.74	<12.9	<12.9	11.8	11.2
Turbidity	0.2	0.1	0.2	0.2	0.06	0.06
pH	6.61	6.82	6.37	6.3	6.7	6.9
Aluminum	<0.050	0.055	<0.050	0.112	<0.050	<0.050
Antimony	<0.0200	<0.0200	<0.0010	<0.0010	<0.0010	<0.0010
Arsenic	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Cadmium	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Calcium	3.9	3.2	<5.0	<5.0	4.4	4.2
Copper	1.19	0.273	1.89	0.53	1.27	0.278
Iron	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Lead	0.0034	<0.0010	0.0058	<0.0010	0.0021	<0.0010
Mercury	<0.00020	<0.00020	0.00021	<0.00020	<0.00050	<0.00050
Potassium	<0.20	<0.20	<0.20	0.22	0.22	0.29
Sodium	1.86	2.81	1.81	1.83	2.12	1.84
Zinc	<0.040	<0.040	<0.040	<0.040	0.024	<0.010
Year Built	1962					
Renovation	na					
Vanier	**Immediate/Nov2011**	**60sec/Nov2011**	**Immediate/June2011**	**60sec/June2011**	**Immediate/Nov2010**	**60sec/Nov2010**
Coliforms, Total	<1	<1	<1	<1	<1	<1
E. coli	<1	<1	<1	<1	<1	<1
Temperature	21	9.2	26	12	19	13
Hardness, Total	12.9	9.84	18.2	<12.9	12.1	12.6
Turbidity	0.2	0.2	<0.1	0.3	0.17	0.1
pH	6.96	6.86	6.26	6.6	6.7	6.9
Aluminum	<0.050	<0.050	<0.050	0.105	<0.050	0.05
Antimony	<0.0200	<0.0200	<0.0010	<0.0010	<0.0010	<0.0010
Arsenic	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

Cadmium	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Calcium	4.8	3.6	6.9	<5.0	4.6	4.8
Copper	0.0428	0.015	2.7	0.0692	0.141	0.0175
Iron	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Lead	<0.0010	<0.0010	0.0044	<0.0010	<0.0010	<0.0010
Mercury	<0.00020	<0.00020	<0.00020	<0.00020	<0.00050	<0.00050
Potassium	<0.20	<0.20	0.26	0.31	0.29	0.33
Sodium	2.3	2.26	1.96	1.84	1.83	1.82
Zinc	<0.040	<0.040	0.115	<0.040	0.013	<0.010
Year Built	1968					
Renovation	na					
SUB	**Immediate/Nov2011**	**60sec/Nov2011**	**Immediate/June2011**	**60sec/June2011**	**Immediate/Nov2010**	**60sec/Nov2010**
Coliforms, Total	<1	<1	<1	<1	<1	<1
E. coli	<1	<1	<1	<1	<1	<1
Temperature	16	8	16	8	13	11
Hardness, Total	9.7	10.1	<12.9	<12.9	12.1	13.1
Turbidity	0.7	0.3	0.6	0.6	0.14	0.14
pH	6.94	6.79	6.68	6.87	6.8	6.6
Aluminum	0.059	0.072	0.12	0.128	0.083	0.083
Antimony	<0.0200	<0.0200	<0.0010	<0.0010	<0.0010	<0.0010
Arsenic	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Cadmium	<0.0001	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Calcium	3.6	3.7	<5.0	<5.0	4.6	5
Copper	0.167	0.0472	0.549	0.0958	0.137	0.0424
Iron	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Lead	<0.0010	0.0012	<0.0010	<0.0010	<0.0010	<0.0010
Mercury	<0.00020	<0.00020	<0.00020	<0.00020	<0.00050	<0.00050
Potassium	<0.20	<0.020	<0.20	<0.20	0.16	0.17
Sodium	2.09	2.15	1.79	1.81	1.62	1.87
Zinc	<0.04	<0.040	<0.040	<0.040	0.094	<0.010
Year Built	1968					
Renovation Date	na					
Totem	**Immediate/Nov2011**	**60sec/Nov2011**	**Immediate/June2011**	**60sec/June2011**	**Immediate/Nov2010**	**60sec/Nov2010**
Coliforms, Total	<1	<1	<1	<1	<1	<1
E. coli	<1	<1	<1	<1	<1	<1

Temperature	16	8.8	23	20	16	13
Hardness, Total	10.7	9.38	<12.9	<12.9	11.3	12.4
Turbidity	0.6	0.4	0.3	0.3	0.12	<0.05
pH	6.86	6.63	6.26	6.49	6.1	6.5
Aluminum	<0.050	0.06	0.062	0.086	<0.050	<0.050
Antimony	<0.0200	<0.0200	<0.0010	<0.0010	<0.0010	<0.0010
Arsenic	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Cadmium	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00016
Calcium	4	3.5	<5.0	<5.0	4.2	4.7
Copper	0.0668	0.0371	0.693	0.892	0.136	0.0714
Iron	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Lead	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Mercury	<0.00020	<0.00020	<0.00020	<0.00020	<0.00050	<0.00050
Potassium	<0.20	<0.20	0.22	0.25	0.21	0.22
Sodium	1.91	2.47	1.89	1.83	1.97	1.98
Zinc	<0.040	<0.040	0.07	<0.040	0.034	0.013
Year Built	1927					
Renovation	2007					
Plant Ops Data available from http://riskmanagement.ubc.ca/environment/water-quality. Boron, Barium, Magnesium, Manganese, Seleium						
Uranium and Silicon were removed from the data set due to constant low concentrations within Canadian Water Quality Guidelines. Building age and renovation date aquired from Building Operations UBC. Heavy Metal concentrations are presented in ppm.						