A Study of Individual Household Water Consumption

Maisie Borg, Orion Edwards & Sarah Kimpel

Abstract

Over the past several decades concerns have been raised over the amount of water used in California. With higher rates of personal water use, average levels in aquifers across the state have begun to decline. When analyzing how to increase water efficiency and conservation, residential usage stands out as an important factor. Our project's goal is to investigate the weekly per capita indoor water use of three households in Davis, California in an effort to better understand water demands, as well as the best methods to increase water efficiency and conservation. This will be done by individually tracking personal indoor water use. The data gathered will then be used to compare and contrast average overall household water usage to that of the city of Davis, the state of California, and the nation. Doing this enables individuals to gage how much of an impact they have personally on the water system they draw from.

Over the course of one week the residents of all three houses will carefully record each session of water use. Using these data along with calculating the water-flow rate the household totals will be found for weekly average water consumption.

To further our analysis of our residential water use and how we could reduce our impact on the environment, separate calculations will be performed for each household assuming a "Low Flow Scenario." This "Low Flow Scenario" will incorporate in-home water conservation methods such as low-flow fixtures in kitchens and bathrooms, as well as low-flow dishwashers and clothes washing machines. Each type of low-flow fixture and appliance will be evaluated for efficacy (water savings) and cost (excluding variable installation costs). The cost-benefits for each house will then be calculated for each household to be converted to a low-flow regime. These results can then be extrapolated to the larger populations of the city of Davis, the state of California, and the nation in order to determine what are the most cost efficient ways in which to increase water conservation and efficiency.

Our project found that while low-flow devices would increase water conservation and efficiency in every household, the variations in the ways each household used water caused the benefits of low-flow devices to depend on the household in question. These variations make it difficult to extrapolate our data to the general population.

Some limitations within our research include the restricted amount of time data was collected as well as the honor of our housemates while collecting data. Understandably if we collected additional records over a longer range of time our averages would likely be more precise.

Introduction

Our project focuses on individual household water use in Davis, California. Personal and household water use in California is extremely important because residential areas provide the third largest demand for water, after agricultural irrigation, and industrial use (ConSol, 2010). Most indoor household water use is comprised of various factors including showers, toilets, washing machines, dishwashers, and faucets. For simplicity's sake, we exclude exterior water used for landscaping. In order to understand and recommend ways in which to increase water conservation and efficiency in California we must investigate how residential and personal water use is being used on a small scale and on a daily basis.

Most urban and municipal water agencies extract water from sources where withdrawal exceeds recharge. If our society continues to withdraw water at such an unsustainable rate, California will be in a state of water stress by 2020 (Benfield, Kaid, 2012). From there it is an easy downward spiral into a state of water scarcity. This presents a myriad of serious issues. We use water for industry, in our homes and businesses, community spaces, agriculture, recreation, and sanitation. Sanitation is one of the most important aspects of urban water use. Lack of sanitary systems to remove human waste from densely populated areas causes serious health concerns including dysentery and intestinal worms (WHO, 2012). Poor water quality increases the risk of water scarcity worldwide (WHO, 2002).

If we run out of water, or if it becomes scarce as a result of continued unsustainable use, our economic sector will suffer. Workplaces and schools cannot operate without proper sanitation, and many industrial processes rely on water. As water becomes scarcer, it becomes more polluted as anthropogenic inputs become increasingly concentrated. Fertilizers and pesticides from runoff from agricultural lands contaminate our water supply and threaten human, wildlife, and ecosystem health. Rivers and lakes with reduced flows and water depth pose threats to the large variety of wildlife that depend on those ecosystems. Many fishes cannot reproduce without seasonally variable flows, and many wildlife species suffer reproductive ailments due to water contamination exacerbated by increased contaminant concentration (waterpollution.org.uk, 2012).

These factors and concerns ably demonstrate the need for water use reduction. In the United States particularly, urban water demand is drastically higher than the global average.

Objective

Our main objective is to quantify how much water we consume on a daily basis and compare this to the city, state, and national average. This data can then be used to determine the most cost effective ways to improve water conservation and efficiency. Our first task is to measure all sources of water use within our three households for a certain amount of time, surveying only indoor water usage. Since the number of people per household varies, we will then convert this data into gallons per outlet per day in order to compare across different households. Once all data on our personal water use is collected and is in common units it can be compared against city, state, and national averages. This data can then be utilized in order to discover the most cost efficient ways to increase water conservation and efficiency in our households by recalculating water use in a hypothetical "Low Flow Scenario." This will provide us with a guideline for what steps can be taken to increase water conservation and efficiency in households on a city, state, and national level.

Hypothesis

We hypothesize that our in-household options for addressing water conservation and efficiency will be applicable to the larger populations of Davis, California, and the United States, and that data collected during this project will help provide insight into what measures will be cost effective in order to increase the sustainability of our water supplies.

Data Sources

Data will be personally collected by M. Borg, S. Kimpel, and G. Edwards for the three Davis households considered in the project over the course of one week. Indoor water use will be measured in units of time actively using water in minutes per day in the case of faucets and showers, and number of uses per day in the case of clothes washing machines, dishwashers, and toilets. The amount of gallons of water used per minute or per use will be individually collected for each faucet, shower, toilet, clothes washing machine, and dishwasher, using manufacturer's specifications when available.

Data on the average indoor water use per household on the city, state, and national scale will be determined by several different sources: The City of Davis Public Works Department website, a study prepared by ConSol Energy, and the United States Geological Survey website.

Low flow devices in order to calculate the amount of water that could potentially conserved in a hypothetical "Low Flow Scenario" were found from various retailers and environmentally conscious distributors: Showerheads were selected from CASA.com, faucets from Amazon.com, toilets from ItsEasyBeingGreen.com, a clothes washing machine from Lowe's, and a dishwasher from Bosch-home.com. These devices were selected on the basis of lowest price for the most water efficient version.

Methods and Assumption

To collect our data, each household posted sign-in sheets near every water outlet. Sheets were posted near the laundry machine, in the kitchen, and in each bathroom. Each person within the household recorded their water usage on these sheets every time they used a particular water outlet. This water use data was first recorded in either time or number of uses, and then subsequently converted into a total volume calculated using gallons per minute for faucets and showers and gallons per usage for clothes washing machines, dishwashers, and toilets. To determine water usage and baseline efficiency, we measured the use of each fixture. The maximum output of each faucet and shower head was recorded for 30 seconds and that value was used to determine output per minute. To measure toilet water usage per flush, the water supply was turned off and the toilet flushed to void the tank. The tank was then filled in measured increments and these increment were summed to calculate the per flush usage. To calculate volume used for laundry, drum volume was calculated and converted into gallons. This value was then approximated for each smaller size option of laundry loads. Dishwasher water usage was determined by looking up the model number and consulting the product guide.

In order to calculate a “Low Flow Scenario” the final amount of water use from each household was recalculated assuming each output has been replaced with a low-flow equivalent. The price of this replacement for each household was determined by using retail values.

Because each household member was personally responsible for recording their usage data, this method required the assumption that each individual recorded their water use honestly and accurately. Data was collected for one week in each household in an effort to lessen the effects of any outliers on the sample of water used, and to account for weekly trends. After the weekly data was collected, the amount of water each person used was calculated and then summed in order to find the total household indoor water use. Because data was only collected for one week, we can assume that our usage data does not perfectly represent average water use by each household and could be subject to certain random factors that would influence water use during that week. This could be improved by collecting water use data for a longer amount of time.

Calculations/Results

The amount of water used by showers and faucets for each household is calculated using this formula:

(Number of Minutes Running) x (Flow in Gallons per Minute) = *Number of Gallons*

The amount of water used by toilets, dishwashers, and clothes washing machines for each household is calculated using this formula:

(Number of Uses) x (Flow in Gallons per Use) = *Number of Gallons*

Using these formulas for each usage of water in each household we discovered that our households use different amounts of water per day, and that water is used in different ways. Figure 1 shows the weekly average water use for the households in our study and the city, state, and national averages.

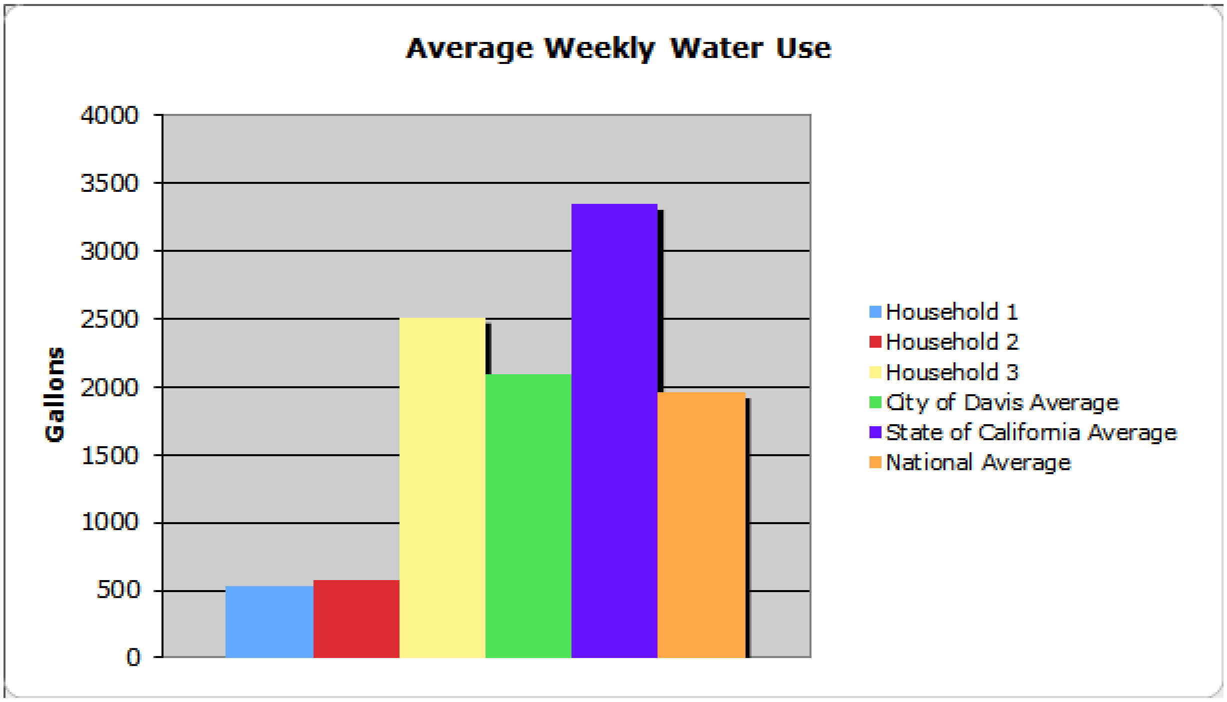

Figure 1

These numbers were determined from the methods mentioned above, a table of the data collected for each household is given in Figure 2 below.

	A	B	C	D	E	F	G	H
1	Household 1	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
2	Kitchen Faucet	9	7	21.41	11.71	5.9	19.71	4.7
3	Bathroom Faucet	4.2	4	5	4.8	4	4.5	3
4	Laundry	0	0	0	0	0	32	16
5	Toilets	8	12	10	12	4	14	6
6	Shower	23.73	50.43	41.53	54.88	43.01	32.63	62.29
7	Dishwasher	0	0	0	0	0	0	0
8	TOTAL	44.93	73.43	77.49	83.39	56.91	102.84	91.99
9	Total Water Use = 531 gallons							
10								
11								
12								
13	Household 2	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
14	Kitchen Faucet	23.44	8.05	15.26	4.107	6.77	0.93	16.1
15	Bathroom Faucet	8.62	5.03	5.77	2.03	1.51	1.98	0.94
16	Laundry	0	0	0	0	0	0	70
17	Toilets	14.4	17.6	14.4	14.4	17.6	11.2	8
18	Shower	21.12	39	50.45	60.75	42.38	52.91	39.25
19	Dishwasher	0	0	0	0	0	0	0
20	TOTAL	67.58	69.68	85.88	81.29	68.26	67.02	134.29
21	Total Water Use = 574 gallons							
22								
23								
24	Household 3	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
25	Kitchen Faucet	10.56	51.745	5.895	2.2303	21.4125	4.8298	11.135
26	Bathroom Faucets	10.388	6.694	3.5292	6.815	4.4182	3.6725	10.3475
27	Laundry	94.235	31.435	0	0	62.8	157.035	62.8
28	Toilets	83.31	97.31	81.22	113.4	72.99	114.04	109.49
29	Shower	96.23	170.38	168.04	221.085	217	262	132.77
30	Dishwasher	0	0	0	7.8	0	0	0
31	TOTAL	294.723	357.564	258.6842	351.3303	378.6207	541.5773	326.5425
32	Total Water Use = 2,509 gallons							

Figure 2

Household 1 had three members and used 530.98 gallons of water a week. Household 2 had four members and used 574 gallons of water a week. Household 3 had eight members and used 2509 gallons of water per week. The average weekly use for a household in California is 3346 gallons of water per week (ConSol, 2012). The national average weekly use per household was 1960 gallons of water per week (EPA, 2012).

In Household 1, 58% of total water was used from the shower, 15% from the kitchen faucet, 12% from the toilets, 9% from laundry, and 6% from bathroom faucets. In Household 2, 53% of water use was attributed to the shower, 17% from the toilets, 13% from the kitchen faucet, 12% from the laundry, and 5% from the bathroom faucets. In Household 3, 51% of total use was used in the shower, 27% was used from the toilets, 16% from the laundry, 4% from the kitchen faucet, and 2% from the bathroom faucet. Despite our variations, there are some similarities in water use proportions. The largest water use in each household is shower usage. In each household surveyed, shower use accounts for at least 50% of water use.

To create a "Low Flow Scenario" in order to determine how much water conservation and efficiency could be increased, we used the same initial data for time and number of uses of each source of water in each household. New data for total water use per household in this “Low Flow Scenario” is then calculated using the amount of water used by each low-flow item selected. For faucets and showers the amount of water used in gallons was calculated using this formula:

(Number of Minutes Running) x (Flow in Gallons per Minute of Low-Flow Device) = *Number of Gallons*

And for toilets, clothes washing machines, and dishwashers the formula used was:

(Number of Uses) x (Flow in Gallons per Use of Low-Flow Device) = *Number of Gallons*

Figure 3 depicts the same data recalculated for a “Low Flow Scenario.”

	A	B	C	D	E	F	G	H
45	Low Flow Scenario:							
46								
47	Household 1	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
48	Kitchen Faucet	8.2	6.4	19.5	10.6	5.9	5.36363636	4.27272727
49	Bathroom Faucet	3.81818182	3.63636364	4.54545455	4.36363636	3.63636364	4.09090909	2.72727273
50	Laundry	0	0	0	0	0	30	15
51	Toilets	3.2	4.8	4	4.8	1.6	5.6	2.4
52	Shower	23.73	50.43	41.53	54.88	43.01	32.63	62.29
53	Dishwasher	0	0	0	0	0	0	0
54	TOTAL:	38.9481818	65.2663636	69.5754545	74.6436364	54.1463636	77.6845455	86.69
55	Total Water Use = 466.95 gallons							
56								
57								
58	Household 2	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
59	Kitchen Faucet	10.56	3.625	6.875	1.85	3.05	0.415	7.25
60	Bathroom Faucet	3.79	2.215	2.54	0.735	0.665	0.875	0.415
61	Laundry	0	0	0	0	0	0	30
62	Toilets	7.2	8.8	7.2	7.2	8.8	5.6	4
63	Shower	21.12	39	50.45	60.75	42.38	52.91	39.25
64	Dishwasher	0	0	0	0	0	0	0
65	TOTAL:	42.67	53.64	67.065	70.535	54.895	59.8	80.915
66	Total Water Use: = 429.52 gallons							
67								
68								
69	Household 3	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
70	Kitchen Faucet	8.06	39.5	4.5	1.7	16.35	3.68	8.5
71	Bathroom Faucets	8.07	4.23	2.51	5.3	3.21	2.71	7.06
72	Laundry	1.5	0.5	0	0	1	2.5	1
73	Toilets	18	17	17	23	18	20	23
74	Shower	50	118	74	88.5	97	121	56
75	Dishwasher	0	0	0	1	0	0	0
76	TOTAL:	85.63	179.23	98.01	119.5	135.56	149.89	95.56
77	Total Water Use = 1172.24 gallons							

Figure 3

In each household, changing out existing fixtures for low-flow alternatives significantly reduced water use: Household 1 currently uses 531 gallons per week which can be reduced to 467 gallons per week with the low-flow devices.

Total Water Saved (Household 1) = 531 gallons/week - 467 gallons/week = *64 gallons*
Water Saved as Percentage (Household 1) = (64 gallons/week) / (531 gallons/week) = *12% water saved/week*

Household 2 currently uses 574 gallons a week – with low-flow alternatives this number could be reduced to 429 gallons per week.

Total Water Saved (Household 2) = 574 gallons/week - 429 gallons/week = *145 gallons*
Water Saved as Percentage (Household 2) = (145 gallons/week) / (574 gallons/week) = *25% water saved/week*

Household 3 currently uses 2509 gallons each week. Introducing low-flow alternatives could reduce the weekly usage to a mere 1172 gallons per week.

Total Water Saved (Household 3) = 2509 gallons/week - 1172 gallons/week = *1337 gallons*
Water Saved as Percentage (Household 3) = (1337 gallons/week) / (2509 gallons/week) = *53% water saved/week*

The benefit to each house varies; some households already implement low-flow fixtures, so their added benefit is proportionally smaller. To determine the cost for each household to convert to all low-flow devices the number of water use sources was multiplied by the cost of the low flow device:

Cost of Converting to "Low Flow Scenario" Per Household = (Cost of low-flow faucet) x (Number of faucets per house) + (Cost of low-flow shower head) x (Number of showers per house) + (Cost of low-flow toilet) x (Number of toilets per house) + (Cost of low-flow laundry machine) + (Cost of low-flow dishwasher) = *Total Cost of Converting to "Low Flow Scenario"*

Household 1 Conversion Cost = ($3.95) x (3 faucets) + ($46.49) x (1 shower) + ($308) x (2 toilets) + ($809.10) x (1 laundry machine) + ($1499) x (1 dishwasher) = *$2,982.44*

Household 2 Conversion Cost = ($3.95) x (2 faucets) + ($46.49) x (1 shower) + ($308) x (1 toilet) + ($809.10) x (1 laundry machine) + ($1499) x (1 dishwasher) = *$2.670.49*

Household 3 Conversion Cost = ($3.95) x (4 faucets) + ($46.49) x (3 showers) + ($308) x (3 toilets) + ($809.10) x (1 laundry machine) + ($1499) x (1 dishwasher) = *$3,387.37*

(Price values collected from: Amazon, CASA, Lowe's, Bosch Home Appliances, and Niagara Conservation, collected on 11/17/2012.)

Each household has a different setup with regards to water outlets, and so the cost of converting to the "Low Flow Scenario" varies. Because of this variation in cost, the cost benefit analysis for each household will be very different depending on how they use their water. For example, the cost of a water efficient dishwasher may not be worth it for household 1 if they wash dishes by hand, or already own a dishwasher that is water efficient. This means that it is difficult to apply a uniform policy of water conservation and efficiency to each household, because the benefits may not outweigh the costs in each scenario.

Conclusions

This project provided several insights into the indoor use of water in our households. Perhaps the most important piece of information that we discovered is that water use varies drastically between different households, both in total water used and in the methods of consumption. While we expected the total amount of water used per household to vary, the vast differences in how this water is used was not entirely anticipated. This wide variation causes several problems with regard to recommending certain actions in order to increase water conservation and efficiency to a wider range of households, because each household uses water in very different ways. When examining the low flow devices used in our study it becomes clear that performing a cost benefit analysis with regard to installing these devices will not yield the same results with each household; variations in the ways water is used may cause certain low flow systems to not be very beneficial relative to the cost of installation. This means that it is impractical for every household to adopt the same water conserving fixtures and appliances, and the ways in which water could be conserved should be examined on a case by case basis.

Recommendations/Limitations

Low-flow devices can be used in order to increase water conservation and efficiency in households, however certain devices may not provide the same benefits for every individual household. Therefore each household should conduct its own cost vs. benefit analysis in order to determine what low-flow devices are applicable to their particular situation. The limitations we faced in our project stemmed from the small sample size, and short time period for data collection. A larger study would be recommended in order to more effectively examine the most cost efficient ways to increase water conservation and efficiency.

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