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INNOVATIONS

Final Report on Residential Greywater Reuse Pilot Study

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October 7, 2015

INTRODUCTION

- Madeleine Craig
  - Environmental Engineering, 2012
  - M.A.Sc. Building Science, 2015

- Carl Robb
  - Canplas Industries Ltd.

Presentation Overview

- Background
- Thesis Work
- Application to Canplas' Prototype Recover System
- Key Findings & Conclusions
- Lessons Learned

Background

Current Water Issues

NASA (2014)

SOLUTIONS

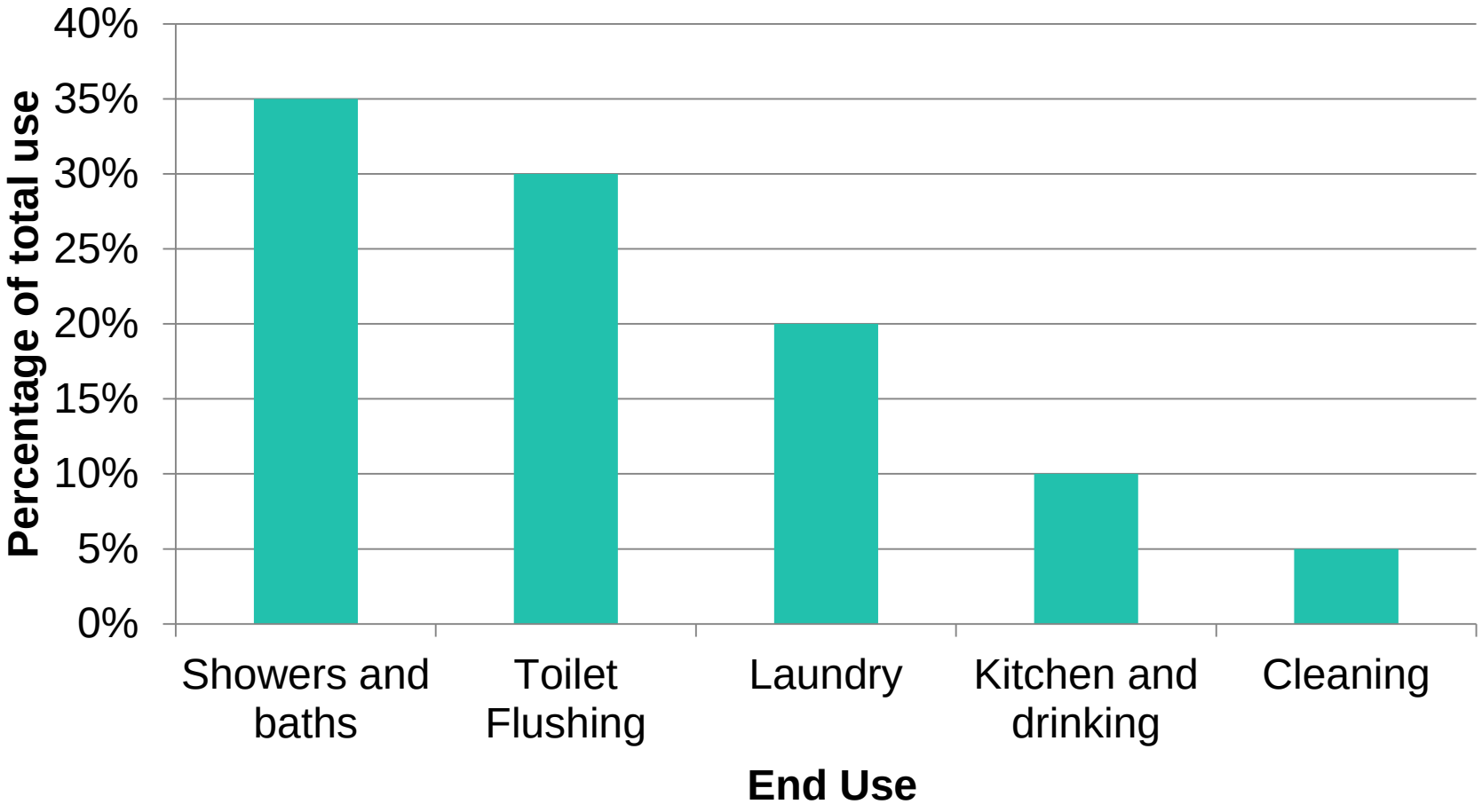
1 Increase Water Rates

HSAX (2010)

2 Reduce Demand

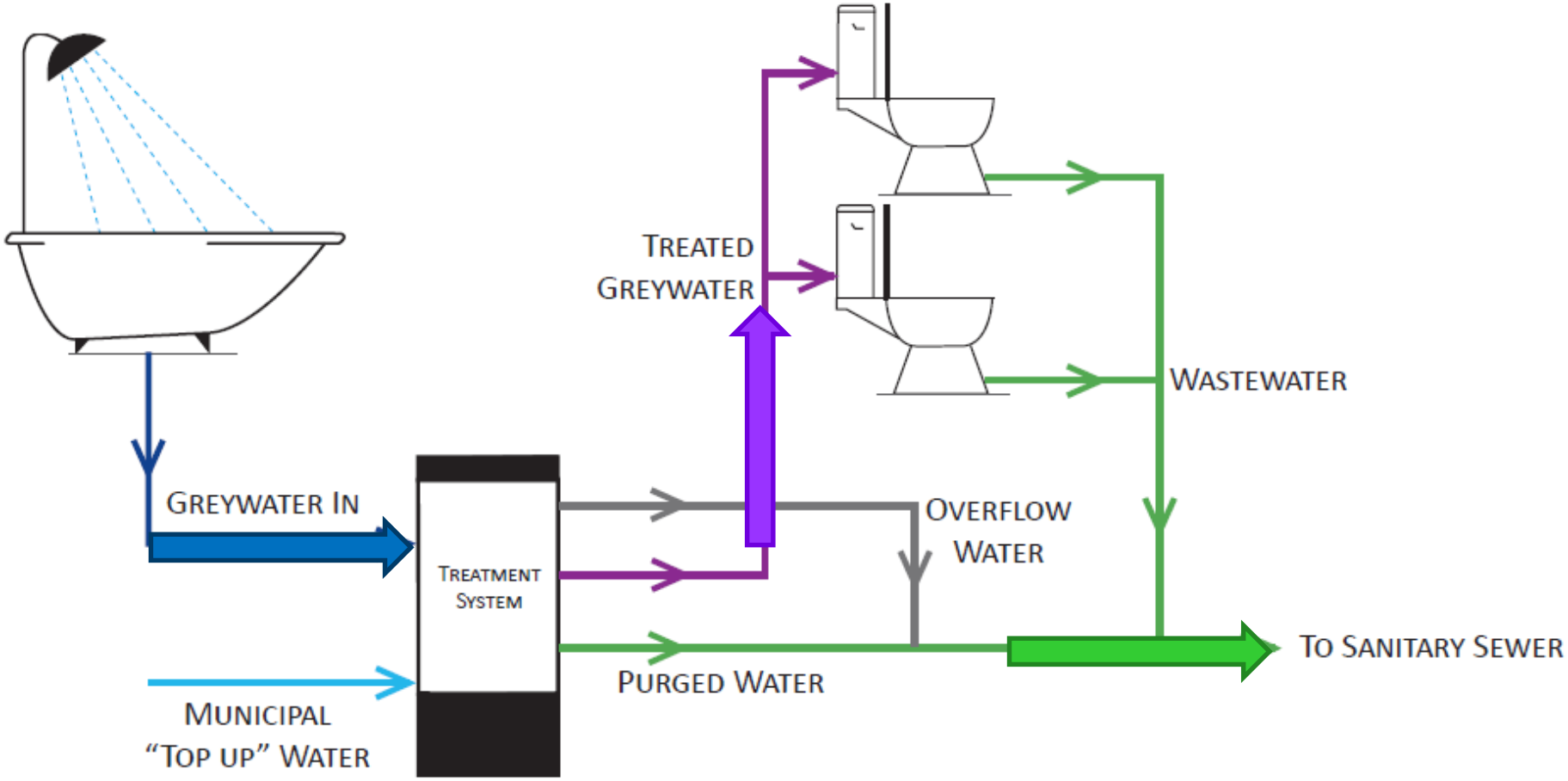
American Standard (2015)

RESIDENTIAL END USES



Environment Canada (2013)

GREYWATER REUSE



Thesis Research

Thesis Research

Development of Metrics

- common metrics through literature review of field studies & standards

Application to Field Study

- Installed in 29 homes
- Tested at 23 homes
- August 2014 – February 2015

Significant Literature

Significant Literature: Academic

Christova-Boal 1995 – Australia	• irrigation & toilet flushing at 4 houses • systems designed for research
Sharvelle et al. 2011-2014 - Colorado	• residence shower water for toilet flushing • system designed for residence
De Luca 2012 - Guelph	• performance in 5 houses • 2 “off the shelf” greywater reuse systems

SIGNIFICANT LITERATURE : STANDARDS

- NSF / ANSI 350 - 1 Standards
- CSA B128.1, .2 & .3 Standards

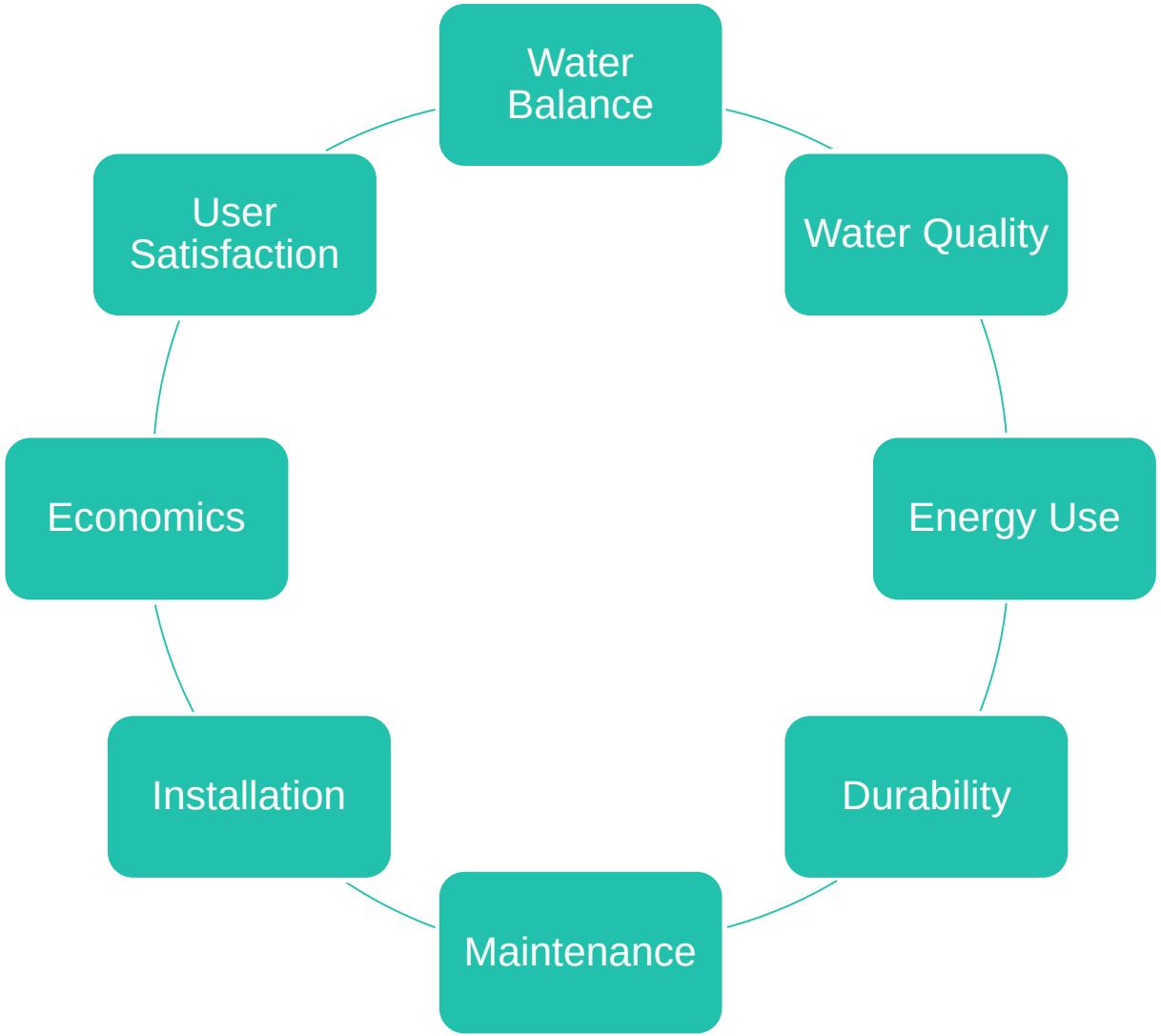
Lab with simulated greywater

- Canadian Guidelines for Domestic Reclaimed Water for Use in Toilet and Urinal Flushing

Focus on water quality

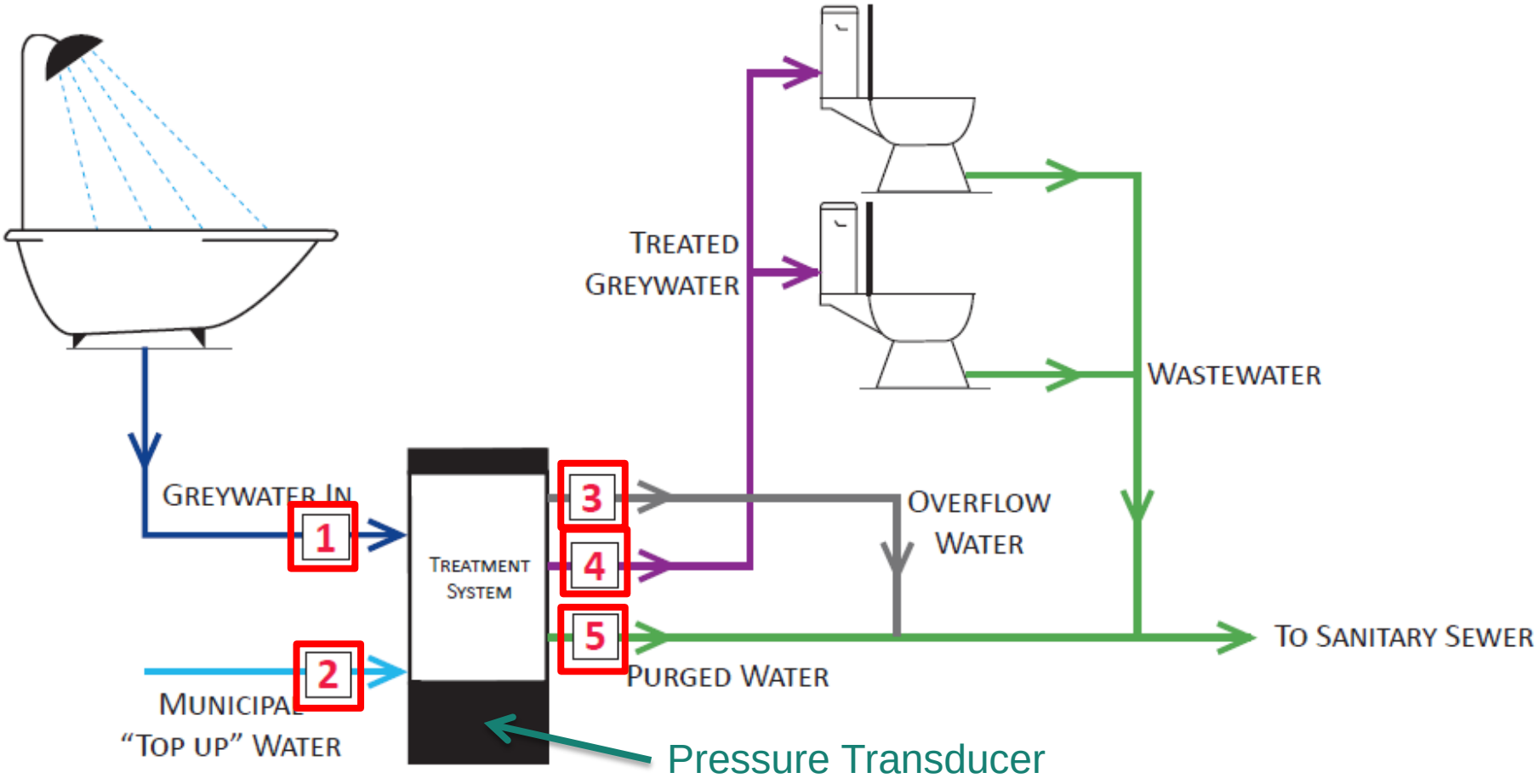
Results

STANDARD TESTING METHODOLOGY

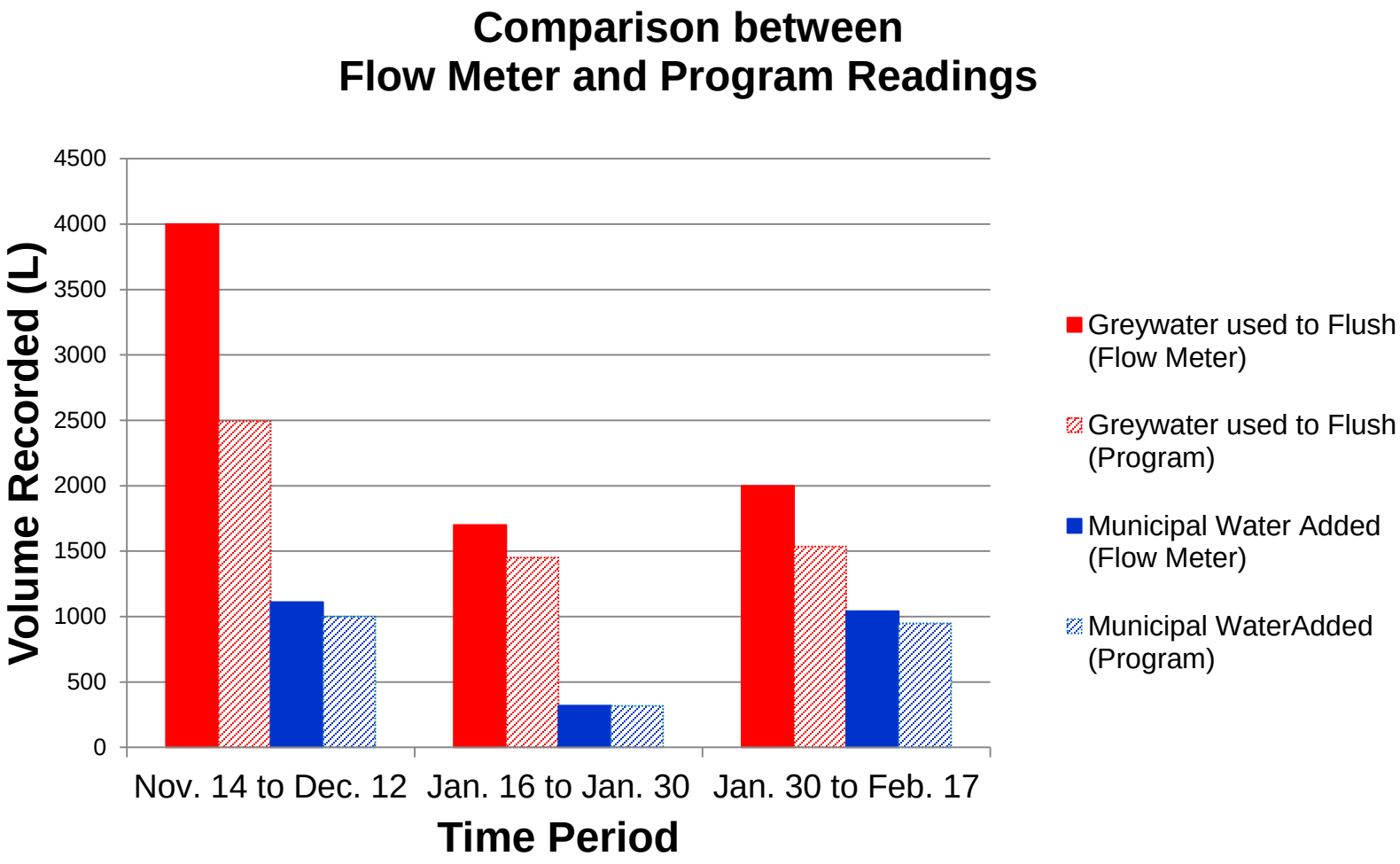


1 Water Balance

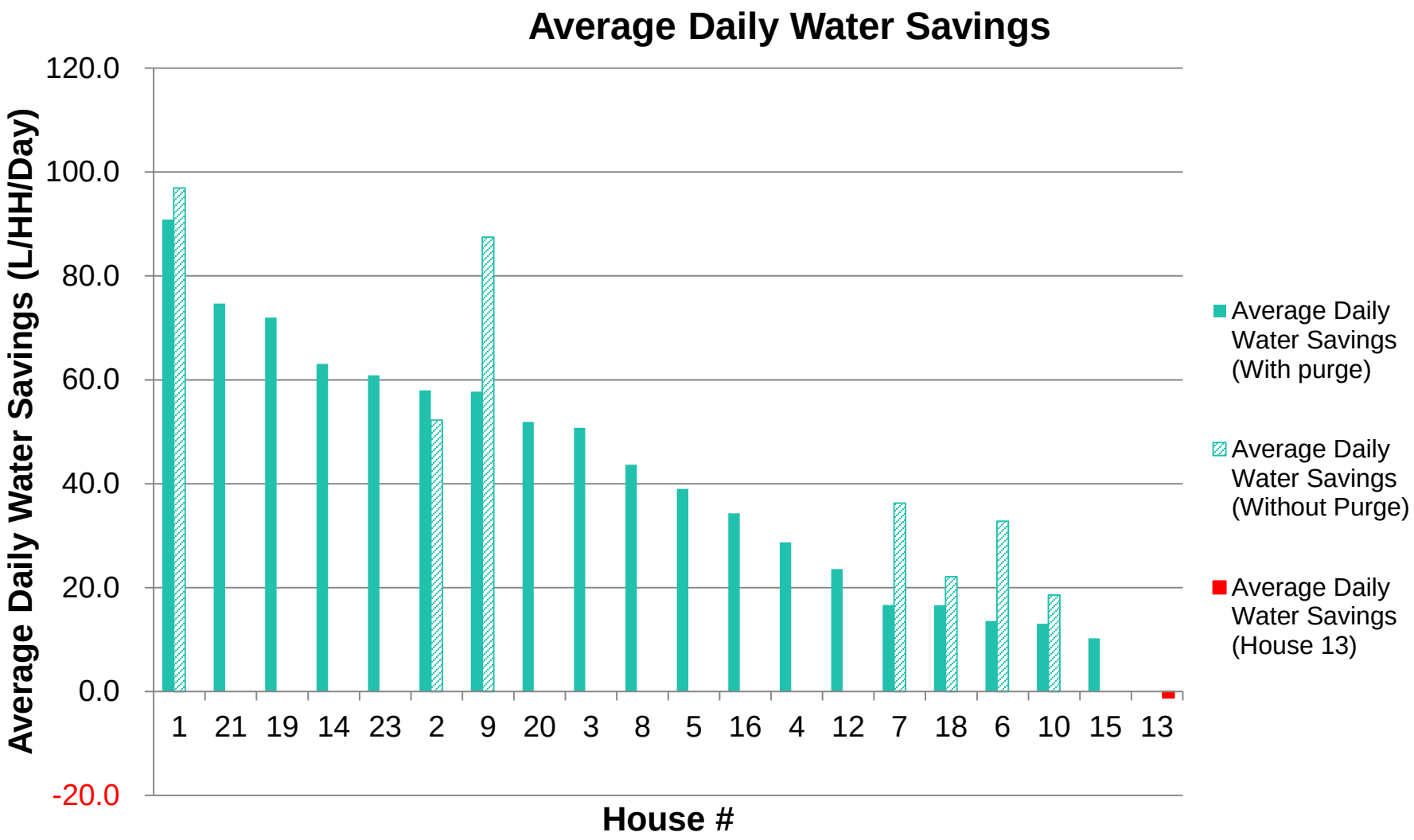
WATER BALANCE



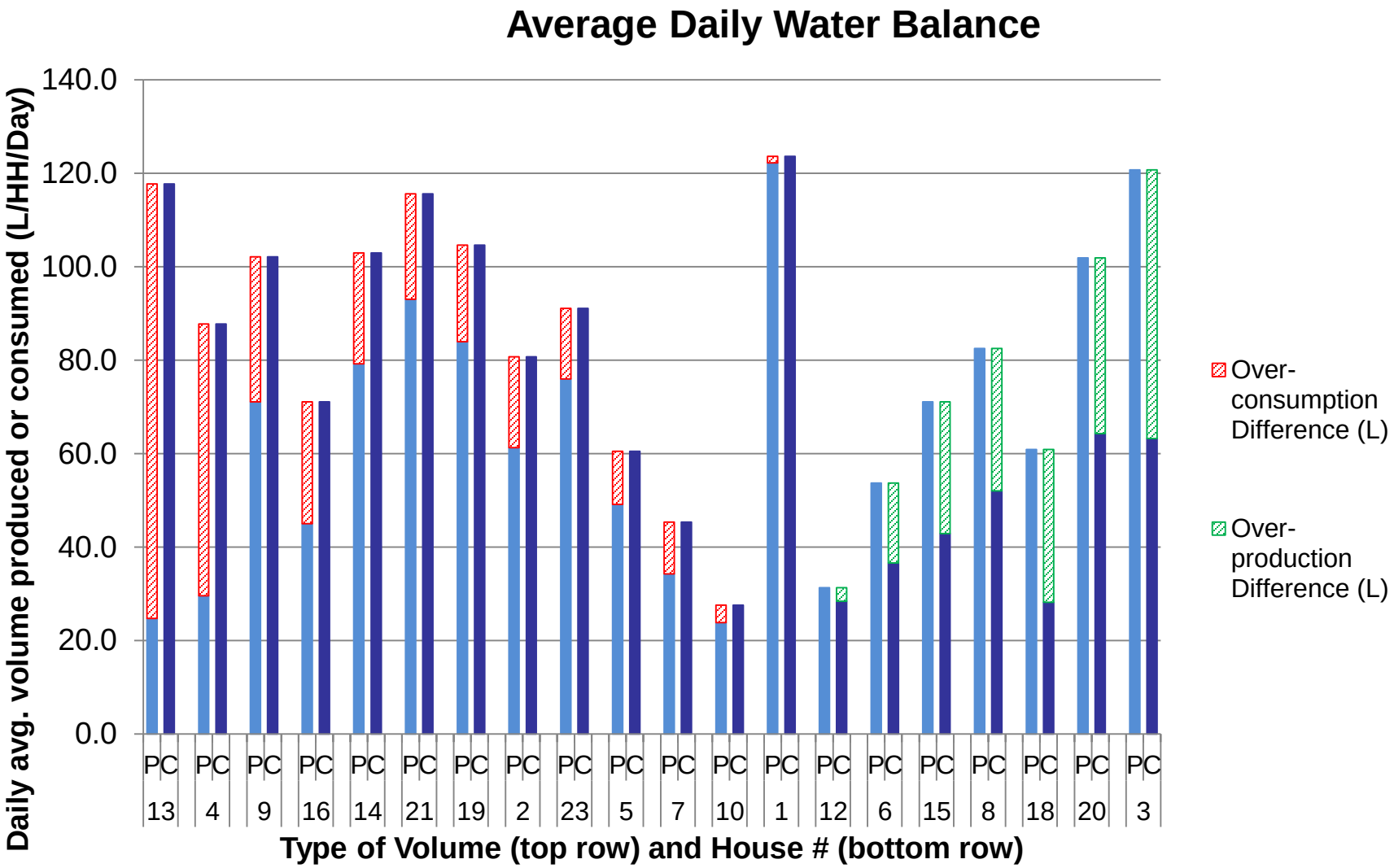
WATER BALANCE VALIDATION



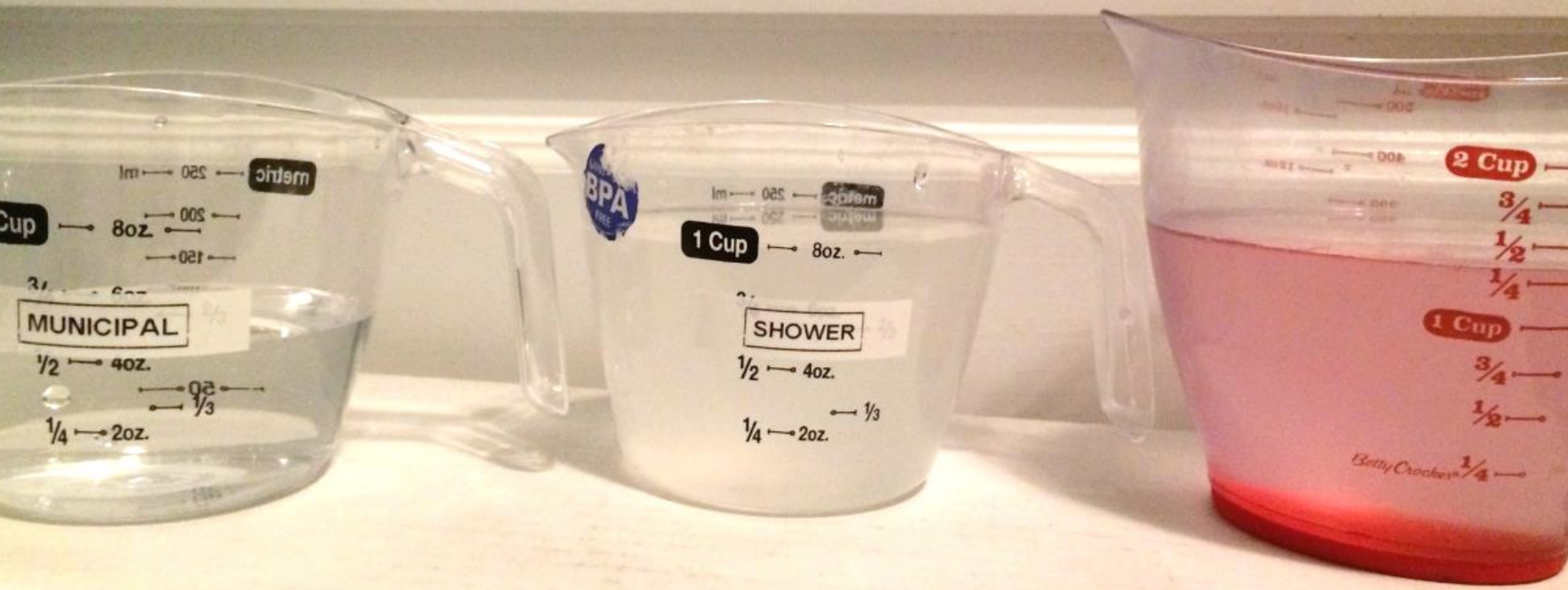
WATER BALANCE



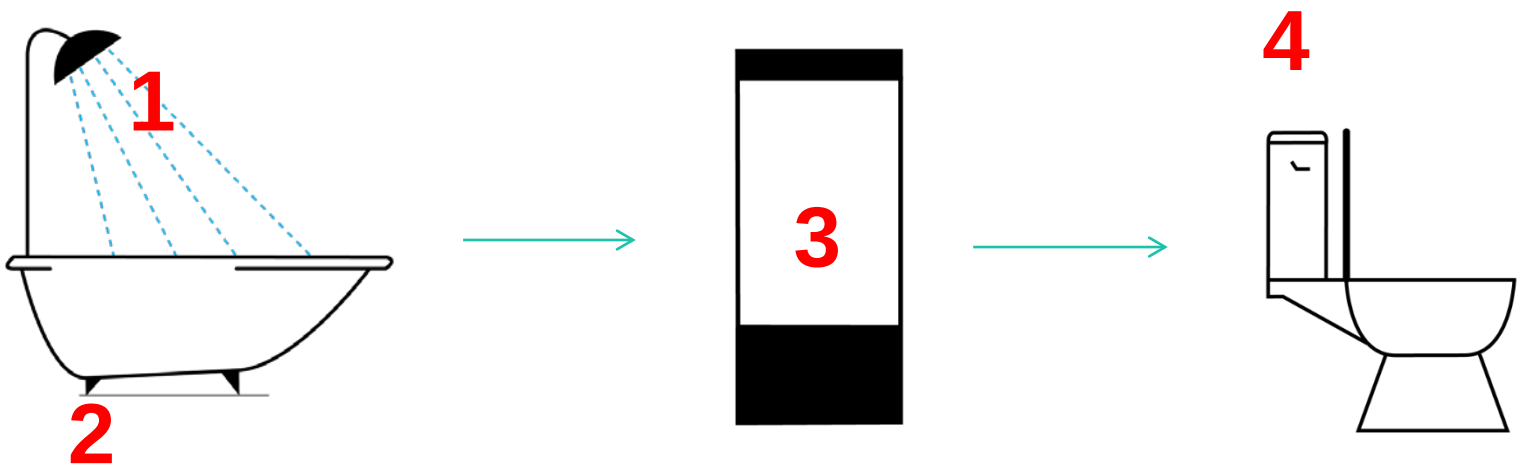
WATER BALANCE



2 Water Quality



WATER QUALITY



WATER QUALITY

- Turbidity
- Hardness
- Odour
- Colour

- Total & Free Chlorine (or disinfectant)
- Temperature
- pH

maxxam.ca (2014)

- BOD_5
- COD
- Fecal Coliforms
- Total Coliforms

Water Quality

Greywater reuse system tank	With Purge			Health Canada Guidelines		
Parameter	Average	# of Samples	Max.	Average	Maximum	% met
BOD_5 (mg/L)	39	24	160	≤10	≤ 20	**38%**
COD (mg/L)	81	24	230			
Fecal Coliforms (CFU/100mL)	<10[1]	24	>200 000	ND[4]	≤ 200	**92%**
Total Coliforms (CFU/100mL)	<10[1]	24	>200 000			
Free Chlorine (mg/L)	2.06	51	9.08			
Total Chlorine (mg/L)	3.05	76	13.75	≥ 0.5		**77%**
Turbidity (NTU)	16.19	91	58.10	≤ 2	≤ 5	**20%**
Colour (cu)	240.85	91	923			
Odour	Chlorine[2]	93	60%[3]			
pH	7.53	71	8.5			
Temperature (°C)	22.61	91	37.6			

3 Energy Use

Energy Use

Energy Consumption
[kWh / day]

- average daily energy consumed by the system

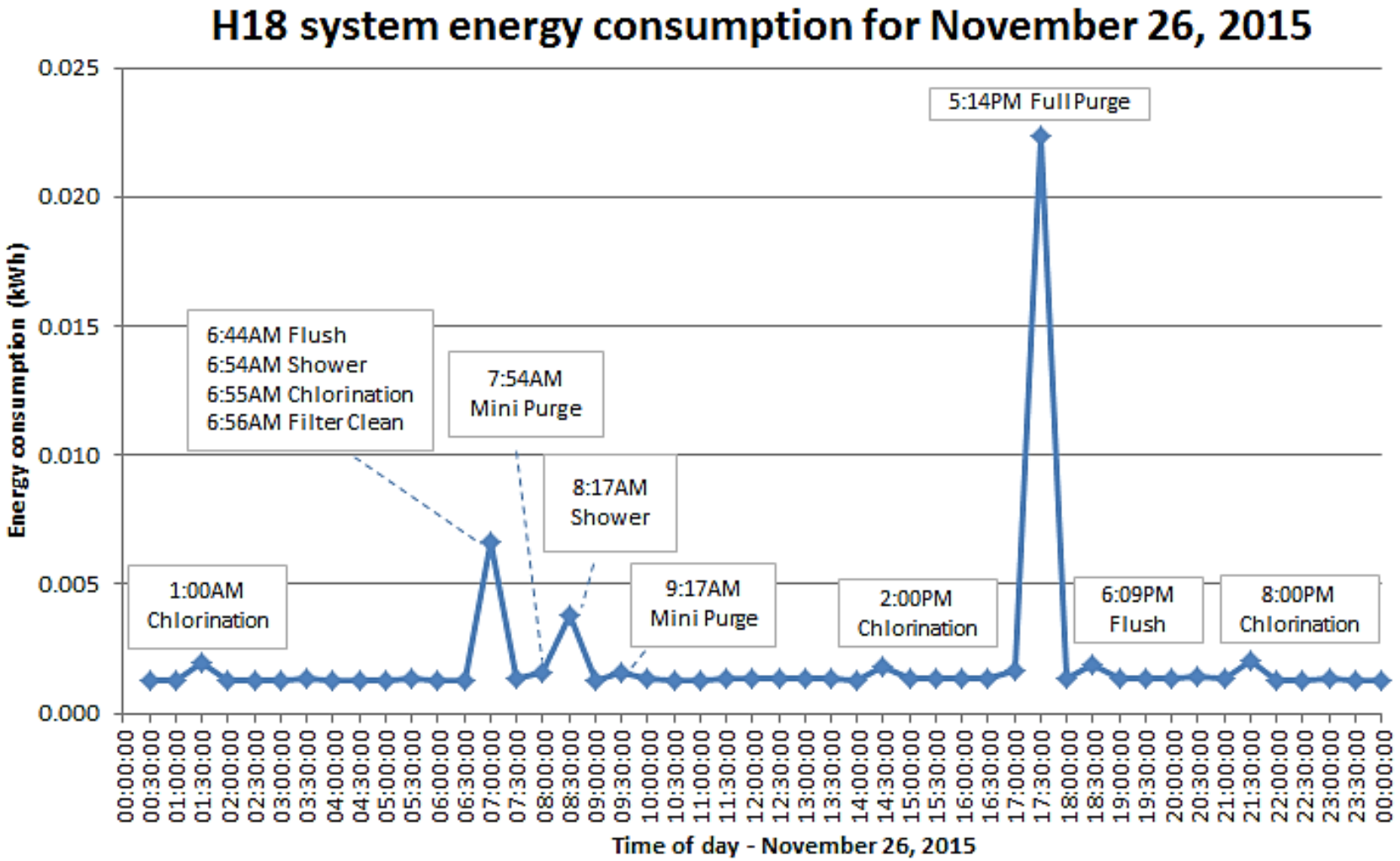
Energy Intensity
[kWh / m^3]

- energy required to extract, treat and distribute 1m^3 of water

Energy Use

House #	Meter	Energy Consumption (Average kWh/day)	Greywater used to Flush (m^3)	Percentage water used to flush that is Municipal (%)	Energy Intensity (kWh/m^3)
18	WeMo	0.070	3.360	44.96	2.763
12	Kill-a-watt	0.07	3.183	19.59	2.37
15	WeMo	0.084	4.336	96.75	2.354
10	Kill-a-watt	0.05	3.063	48.91	1.53
8	WeMo	0.078	4.186	20.10	1.422
6	Kill-a-watt	0.06	2.886	13.13	1.39
7	Kill-a-watt	0.04	4.359	50.54	1.17
20	WeMo	0.067	3.410	18.93	0.909
16	WeMo	0.064	7.027	50.65	0.885
1	Kill-a-watt	0.09	13.214	20.60	0.75
9	Kill-a-watt	0.07	11.126	34.41	0.68
14	WeMo	0.071	11.546	36.86	0.668
19	Kill-a-watt	0.07	3.007	31.61	0.61
Overall Average		**0.069**			**1.346**

ENERGY USE


H18 system energy consumption for November 26, 2015
Energy consumption (kWh)
0.025
0.020
0.015
0.010
0.005
0.000
5:14PM Full Purge
6:44AM Flush
6:54AM Shower
6:55AM Chlorination
6:56AM Filter Clean
7:54AM
Mini Purge
8:17AM
Shower
1:00AM
Chlorination
9:17AM
Mini Purge
2:00PM
Chlorination
6:09PM
Flush
8:00PM
Chlorination
00:00:00
00:30:00
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21:30:00
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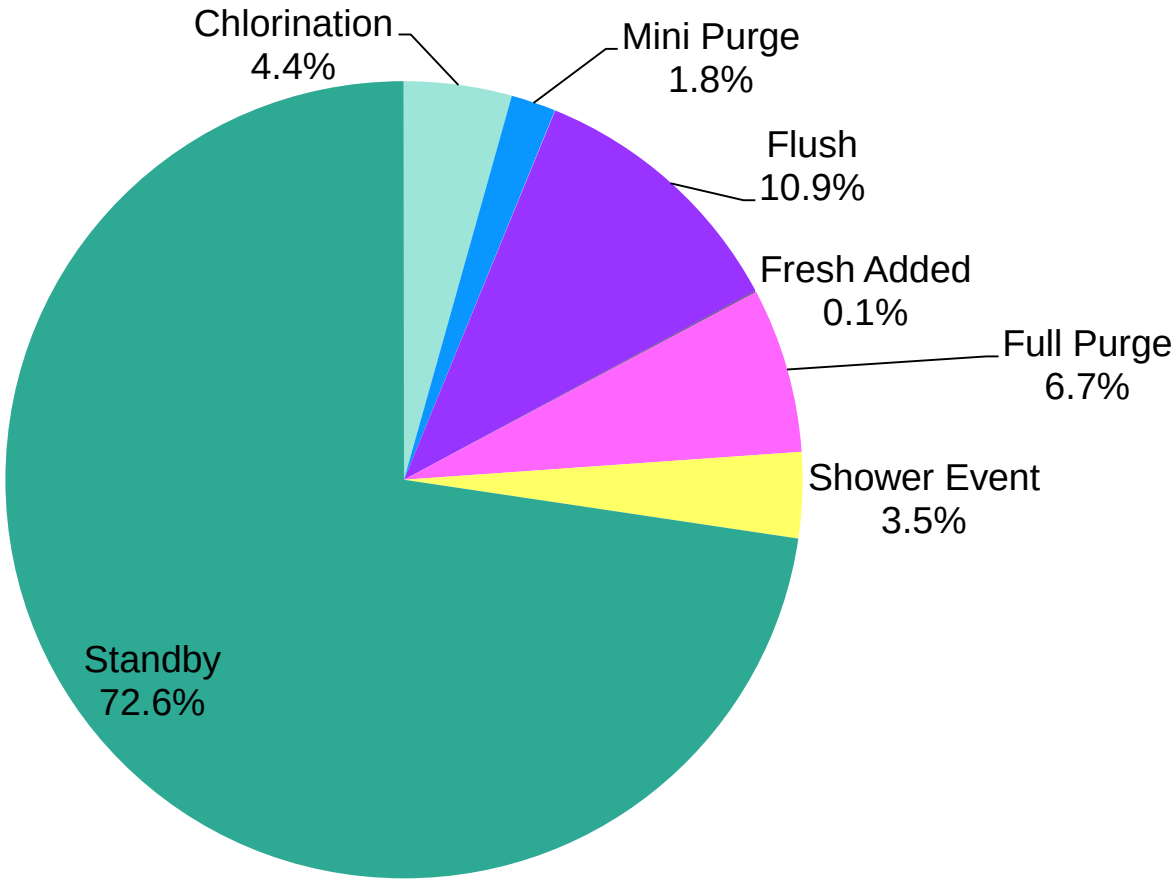
Time of day - November 26, 2015

Energy Use

House 18 from November 12, 2014 to December 9, 2014.



4 Durability

DURABILITY

"when the system does not operate as intended, beyond routine maintenance"

CHECKLIST OF TRADITIONAL ISSUES

Failure	Failure Frequency	
Film Buildup in toilet tank	16 of 20	80%
Flashing notifications	17 of 23	74%
Corrosion	13 of 23	57%
Incorrect time on screen	12 of 23	52%
Clogged greywater filter	11 of 22	50%

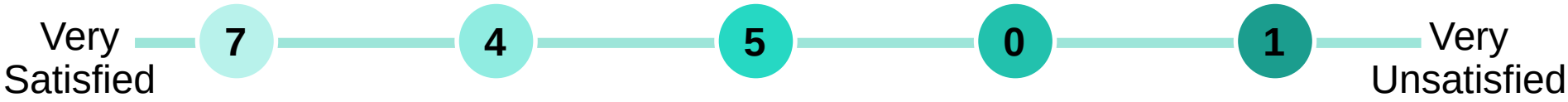
USER SURVEY

Did you experience any of the following technical issues or difficulties with your greywater reuse system?	
Film buildup in toilet tank	13
Noise nuisance	9
Unpleasant "greywater" odour at toilets	8
Chlorine odour at toilets	7
Film buildup in toilet bowl	7
Unable to flush toilets (pump issues)	7

5 Maintenance

Maintenance

Toilet Bowls	Toilet Tanks	Chlorine	Filter
• once/week • “minor impact on toilets”	• 2-3 months • odour & buildup	• 2-3 months	• 5 – 6 months • (2 -3 months)



6 Installation

Installation

Cost of Installation

- Invoices from installation process
- Invoices from repairs

Ease of Installation

- User's opinion of installation process
- *Interview plumbers*

INSTALLATION

BASIC INSTALL

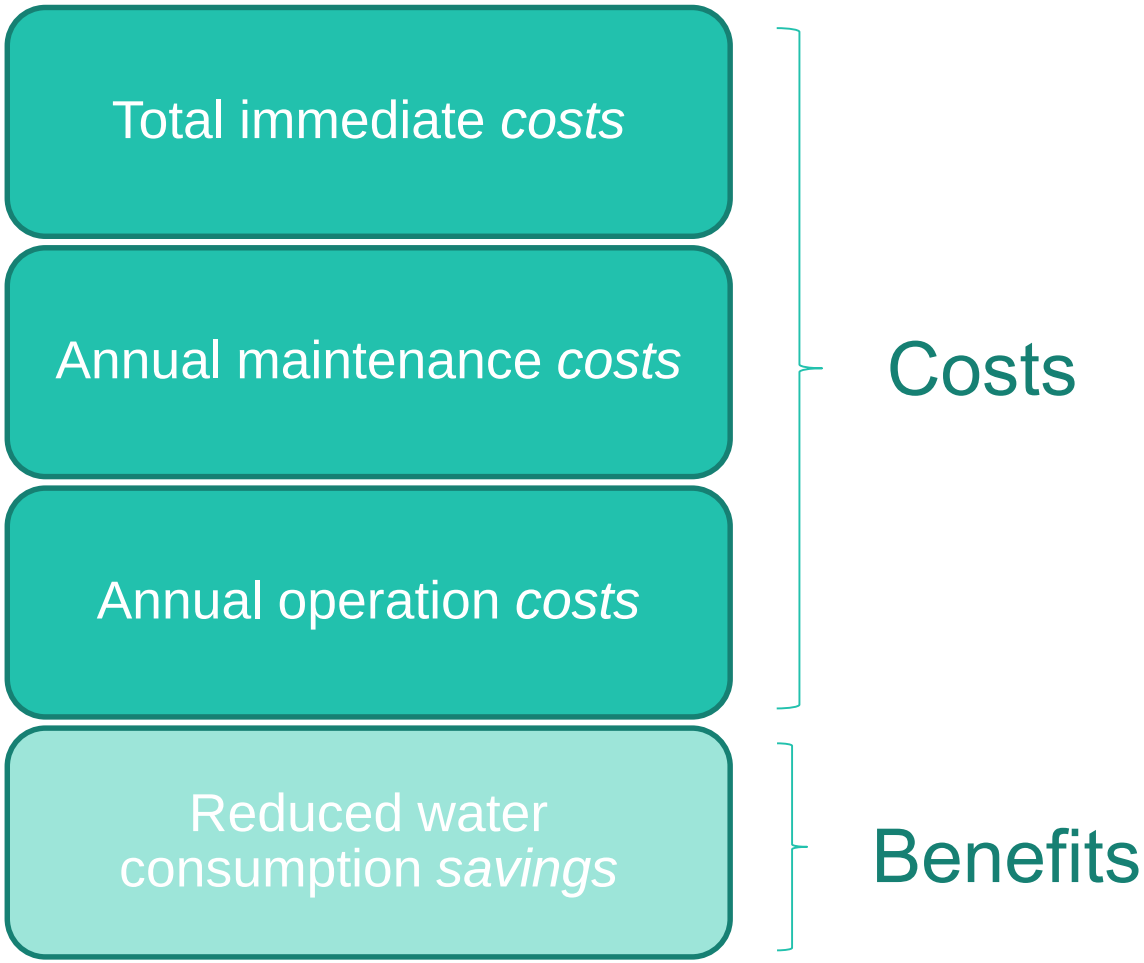
- Roughing-in greywater collection & distribution lines
- Installing system

Existing dual plumbing?	$862.44
One storey basic install?	$1568.13
Two storey basic install?	$2269.24
Difficult install & general contractor repairs?	$2756.40 - $4639.89

7 ECONOMICS


Super Pucks/Su
STABILIZED
CHLORINATING
TABLETS
CONTROLS BACTERIA
AND ALGAE
in Swimming Pool Water
CAUTION
www.canadiantire.ca/poo

ECONOMICS

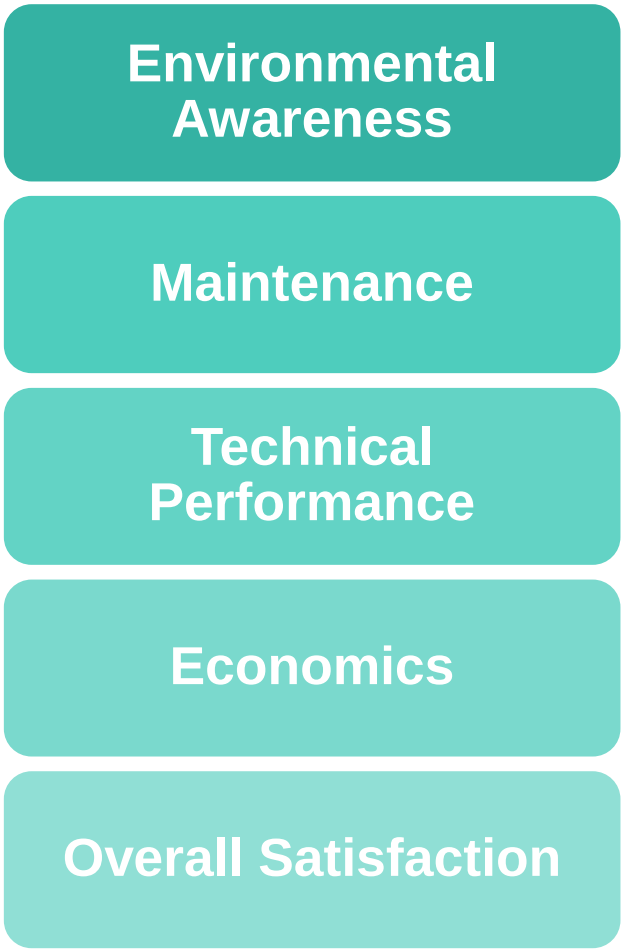

Total immediate *costs*
Annual maintenance *costs*
Annual operation *costs*
Reduced water consumption *savings*
Costs
Benefits

ECONOMICS

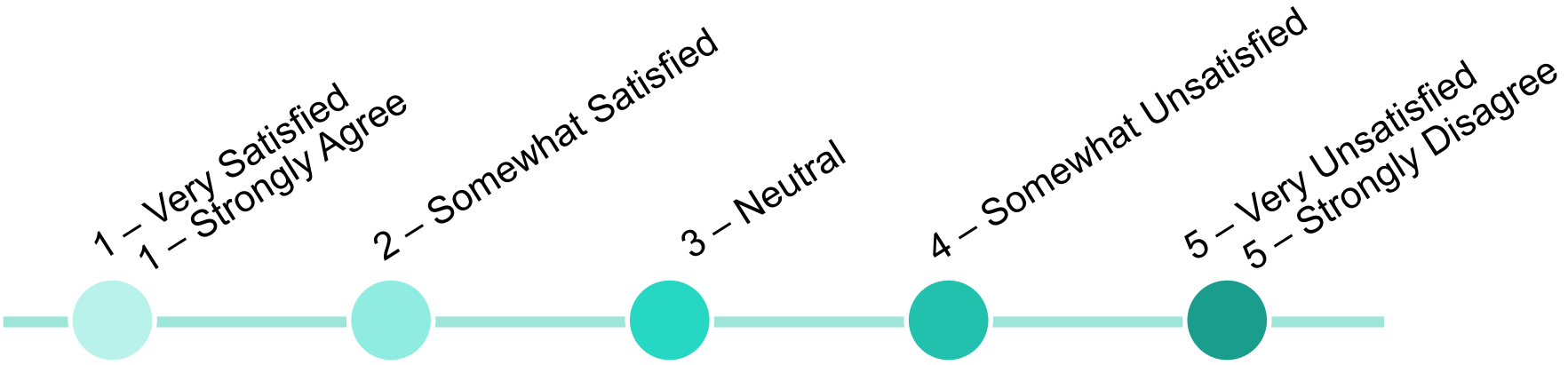
	BEST CASE	AVERAGE CASE	WORST CASE
Total immediate *costs*	$2361.44	$3677.71	$7137.39
Annual maintenance *costs*	$8.04	$52.69	$194.23
Annual operation *costs*	$1.55	$2.68	$6.30
Reduced water consumption *savings*	$157.05	$29.95	$7.61
ESTIMATED PAYBACK PERIOD	**11**	**43**	**52**

8 User Satisfaction

User Satisfaction



User Satisfaction



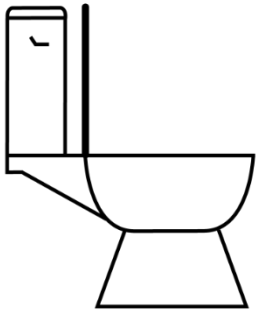
Overall performance of system?	1
Change in water bill?	Unsure, 2
Reliable water supply to flush toilets?	1
“I would recommend this greywater system to someone else”	1
Continue to have system in the house?	1

KEY FINDINGS & CONCLUSIONS

- Feasible and effective way to reduce domestic water demand
- Low energy consumption
- Water quality of “off the shelf” treatment is improving
- Less maintenance than before, but
  proper maintenance ***must*** be performed
- High installation costs →
  greywater reuse is applicable for areas with high water rates
- Generally satisfied users! ☺

Further Research

- Effects of greywater reuse on flush valves
- Accurate collection & validation of water balance data
- Water consumption of different toilet designs



LESSONS LEARNED

- 10 day purge cycle seems to be optimum for water quality and water savings
- Recent updates to filter mechanism have eliminated calcium/soap scum fouling
- More frequent / short duration chlorination cycles is better
- 316 Marine Grade Stainless fasteners required where chlorine is present
- Allowing for sedimentation removal solved many flush valve issues

CONTINUATION: PRIORITY GREEN

Priority Green Clarington: Glen Pleasance

Completed Field Testing in New Homes

3:15pm Napa D

Thank you!

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Household Characteristics

- User Survey #1

Metric	Potentially Influences…
Age of Residents	Water quality
Time spent in the house	Water balance, energy use
Frequency of showering	Water balance, water quality
Number of residents	Water balance
Presence of water softener	Water quality
Location of showers and toilets	Energy use, installation
Personal care products	Water quality
Showering and toilet cleaning products	Water quality
Frequency of cleaning the shower and toilets	Water quality, maintenance

Additional Water Balance

Monitoring Program

Greywater IN

Treated greywater OUT

Purged/ Overflow OUT

Municipal Water IN

Pressure Transducer

Canplas (2014)

Additional Water Balance

Day	Real Date	Event	Hour	Minute	am/pm	Quantity (L)	~Tank Balance(L)
Sunday	08/24/14	Full Purge	3	1	am	-19.375	2.000
		Fresh Added	3	3	am	9.750	11.75
		Gray Added	8	10	am	30.375	42.125
		Chlorination	8	11	am	0.000	42.125
		Filter Clean	8	11	am	1.000	41.125
		Flush	8	23	am	-9.250	31.875
		Flush	8	55	am	-5.875	26.000
		Flush	8	59	am	-13.125	12.875
		Mini Purge	9	10	am	0.000	12.875
		Flush	12	20	pm	-5.000	7.875
		Chlorination	2	0	pm	0.000	7.875
		Flush	7	49	pm	-4.125	3.750

Additional Water Balance

Average Daily Water Balance

- Greywater production versus Greywater consumption

Average Daily Water Savings

- Water used to flush minus freshwater added

Water Balance Summary

	With Purge		No Purge	
Volume	LHHD	LCD	LHHD	LCD
Greywater In	65.8	18.8	-	-
Municipal "top up" water	31.7	9.7	13.5	3.7
Water used to flush toilets	72.3	21.3	-	-
Water purged/emptied	32.6	8.9	12.2	1.9

Water Quality

Greywater reuse system tank	With Purge			No Purge		
Parameter	Average	# of Samples	Max.	Average	# of Samples	Max.
BOD_5 (mg/L)	39	24	160	38	12	100
COD (mg/L)	81	24	230	88	12	250
Fecal Coliforms (CFU/100mL)	$<10^1$	24	>200 000	$<10^1$	11	4 400
Total Coliforms (CFU/100mL)	$<10^1$	24	>200 000	$<10^1$	12	50 000
Free Chlorine (mg/L)	2.06	51	9.08	2.01	13	5.13
Total Chlorine (mg/L)	3.05	76	13.75	2.81	13	7.91
Turbidity (NTU)	16.19	91	58.10	10.92	13	24.60
Colour (cu)	240.85	91	923	181.06	13	327
Odour	Chlorin	93	60%	Chlorin	13	92%

DURABILITY

Flush valve replacement

H1 **H8** **H15** **H19** **H22**


House 8


House 18


House 22


House 7


House 15


House 1*


House 5


House 16


House 6

BLACK MOULD

FILTER CLOGGING

Stressed Situations

Vacations

- Ideally would have recorded planned vacations before hand
- Only went in to vacation mode 2 of 5 times
  - Users turned off water
  - Program issues
- 6 users = very satisfied
- 2 users = somewhat satisfied
- 2 users = neutral
- 1 user = somewhat unsatisfied

Power Outage

- Battery in controller, but it never worked
- Generally the system would restart and function when the power came back on….but sometimes required a manual restart

MAINTENANCE

1) Log sheets
2) User survey

- Toilets
- Chlorine
- Filter

Recommendations:

- at the system and at toilet tanks
- track for at least one full year
- tester should not perform any maintenance!

ECONOMICS

Total immediate *costs*	• Capital cost • Installation cost
Annual maintenance *costs*	• Disinfectant • Filters • Required backflow prevention testing
Annual operation *costs*	• Energy usage (kWh) • Local energy rates ($/kWh)
Reduced water consumption *savings*	• Water and wastewater savings ($m^{3)}$ • Local water and wastewater rates ($/$m^3$)

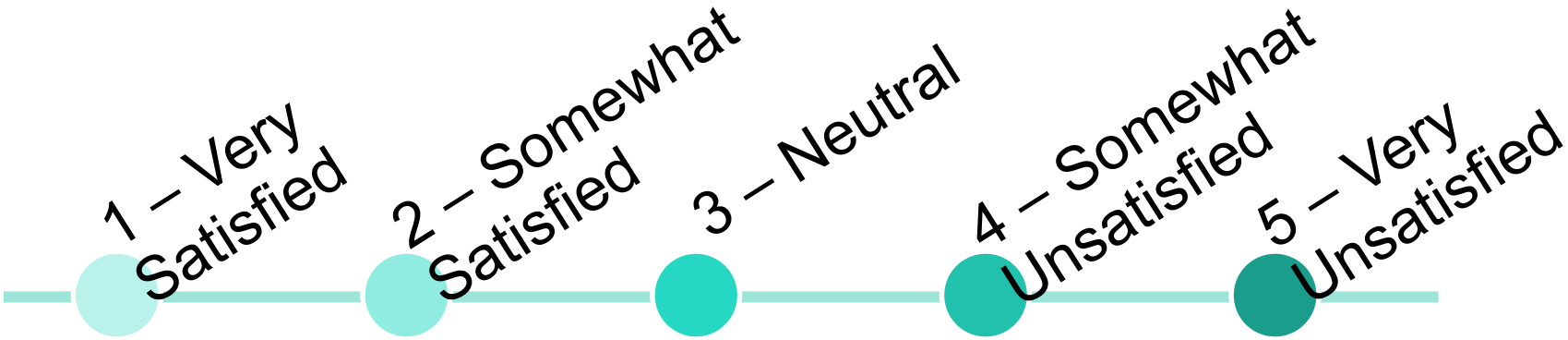
Economics

Scenario	Rebate	Installation	Chlorine Replacement	Annual Test	Energy Use	Water Savings	Combined Water Rates
Best	$1000	$862.44	5 – 6 months	No fee	0.04 kWh/day	96.9 L/day	$4.44/$m^3$
Average	$500	$1677.71	2 – 3 months	$35	0.077 kWh/day	26.0 L/day	$3.15/$m^3$
Worst	No rebate	$4638.39	Monthly	$150	0.18 kWh/day	10.3 L/day	$2.03/$m^3$

ECONOMICS

	BEST CASE	AVERAGE CASE	WORST CASE
Incentive for 5 year payback	$1351	X	X
Incentive for 10 year payback	$236	X	X
Incentive for 20 year payback	✓	$3832	X

User Satisfaction



Silt in System at House 22

Environmental Awareness

House #	Involved in Previous Study?	# of practiced water conservation methods	How did user get a system?	Primary reason for GW reuse?	Recycle in the home?
1	No	7	Approached by Canplas.	To use less fresh water.	3 - Neutral
4	Yes	5	Approached by Canplas.	To adopt innovative technology.	2 - Mostly everything
5	Yes	1	Home-builder recommended a system.	To adopt innovative technology.	3 - Neutral
6	Yes	5	Actively searched for a system.	To use less fresh water.	3 - Neutral
8	Yes	6	Moved in to home with a system.	To save money on water bills.	3 - Neutral
9	Yes	1	Home-builder recommended a system.	To save money on water bills.	2 - Mostly everything
10	Yes	5	Approached by Canplas.	To use less fresh water.	2 - Mostly everything
11	No	2	Moved in to home with a system.	To save money on water bills.	3 - Neutral
12	Yes	6	Moved in to home with a system.	To use less fresh water.	2 - Mostly everything
13	Yes	3	Other: Supplier/installer for Canplas	To use less fresh water.	1 - Everything
15	No	1	Approached by Canplas.	To save money on	4 - Some things

GREYWATER VS. RAINWATER

Greywater

- Benefits
  - Consistent water supply
- Drawbacks
  - Requires more treatment than RW
  - Potential for more maintenance
  - Not seamless WQ yet

Rainwater

- Benefits
  - Cleaner water than GW (less treatment required)
  - More accepted by users (?)
- Drawbacks
  - Crosses building interior/exterior
  - Inconsistent water supply

SINGLE FAMILY VS MULTI-UNIT

- People are more likely to reuse if it's just their wastewater.
- Less transfer of germs, higher risk for Multi-unit
- Maintenance is on homeowners…good/or bad
- Financially more feasible at a bigger scale
  - Apartment buildings can be designed / retrofitted easier

Reduced Flow through WW Pipes

- Penn et al. (2013)
  - Modelled reduced flow and low-flush toilets
  - Not likely that greywater reuse will lead to blockage in existing sewers
  - Also allows sewers in new construction to be built with smaller diameters