City of San Diego 2005
Instant Hot Water Delivery System Pilot Project

"Avoiding Water Waste with Convenience"

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Water Resources Management Program

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I. INTRODUCTION

On average the San Diego region receives only 9.3 inches of rainfall annually and imports approximately ninety percent of its water supply from northern California and the Colorado River. Given the heavy reliance on imported water, the City of San Diego's (City) Water Department (Department) is committed to identifying and securing alternative sources of water, and actively pursues opportunities to investigate potential methods to save and use water wisely. In 1997, the Department set an objective to incrementally increase water savings through conservation to 26,000 acre feet (AF) each year by 2005 as part of its overall Strategic Plan for Water Supply. The City is a signatory to the California Urban Water Conservation Council's (CUWCC) 1991 Memorandum of Understanding Regarding Urban Water Conservation in California. CUWCC has established 14 Best Management Practices (BMPs) and assists water agencies throughout the state to implement these BMP's in an effort to integrate urban water conservation into the planning and management of California's water resources. CUWCC has designated instant hot water delivery systems as a Potential BMP for achieving long term water conservation. As such, these systems are worthy of further study to determine their effectiveness as an indoor water conservation tool.

To date, few studies have evaluated the water savings potential of instant hot water recirculating systems (recirc systems). Literature published by a manufacturer-sponsored study[1] claims that the use of residential recirc systems can result in potable water savings of up to 40 gallons per day (GPD) or 15,000 gallons per year (GPY) for an average single-family household. This study utilized a set of assumptions about average plumbing layout, size, and water use habits of the household. Mathematical formulas and methodologies were then applied to calculate potential water and energy savings derived from recirc systems. Two small field studies (in San Jose and Palo Alto) reported a positive correlation between residential recirc systems and water savings, but were somewhat inconclusive as to the quantity of water savings. Recently, the City of Oceanside adopted an ordinance applicable to new residential construction which establishes maximum hot water arrival times to fixtures throughout a home. The ordinance sets performance standards and allows the home builder flexibility in how those standards are met, whether it be through the design of effective plumbing configurations, use of recirc systems, or other methods. The City of San Antonio's water utility, San Antonio Water Systems, is currently offering a $150 rebate to customers with the installation of a specific brand of recirc system.

Utilizing grant funding made available from the Metropolitan Water District of Southern California (MWD) Innovative Conservation Program, the Department conducted this pilot project to study the effectiveness of the Autocirc (one of several recirc systems currently available on the retail market) as a water conservation appliance in detached single-family households. The project focus was to collect data on actual water savings (if any) realized in one room in the test home when using the Autocirc. Using this data, the potential cumulative water savings and wastewater reductions throughout the house were estimated. The study also examined customer satisfaction with the recirc systems.

II. DISCUSSION

A. How the System Works

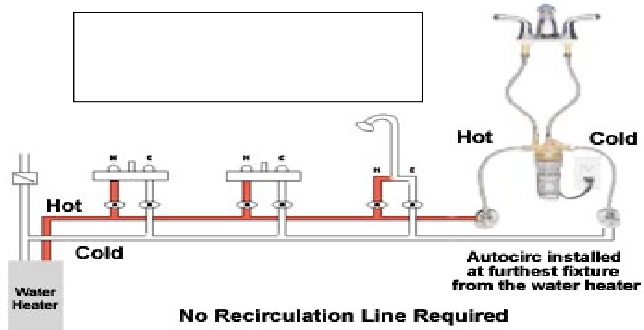
The recirc system has been touted as an efficient and effective tool to deliver hot water to plumbing fixtures. The recirc system eliminates the need to discharge water that has cooled while sitting in the hot water line between the central water heater and end use fixtures. The device consists of small pump and valve and is installed under the sink with the longest wait for hot water. This is typically the fixture located furthest away from the central water heater, which is often found to be the master bathroom or kitchen.

Figure 1: Autocirc Device

Source: Laing, Inc.

A retrofitable recirc system does not require a dedicated plumbing line to return cooled hot water to the central water heater. The system consists of a valve, pump, and internal thermostat sensor. A temporary "loop" is created between the home's internal hot and cold water plumbing lines allowing the cooled hot water sitting in the hot water line to be pumped past the end-use hot water fixture into the cold water line, and back to the central hot water heater. The internal thermostat located at the recirc device registers the temperature increase as soon as hotter water arrives from the central heater, signaling the pump to turn off and close the valve to the cold water line. As the valve closes, the plumbing system returns to its conventional form and function. By installing the device at the hot water fixture furthest from the central hot water heater, instant hot water is also available to all other hot water fixtures located along the same hot water line "above" the recirc device.[2]

Figure 2: Autocirc Plumbing Configuration



Source: Laing, Inc.

There are several manufacturers currently producing retrofitable recirc units for the residential market, including Laing, Metlund, Grunfus, and Tyco. The concept behind the various retrofitable systems is similar, each offering slight variation in design, all using the home's cold water line to return cooled hot water to the central water heater. The Autocirc is characterized as a "time and temperature" controlled system. Operational time can be set whereby the pump will automatically recirculate water back to the central water heater when it has cooled below 85 degrees. For example, if it is anticipated that the periods of greatest demand for instant hot water is between 6 and 8 AM, and again between 8 and 10 PM, the system can be set to recirculate when the water cools below 85 degrees during those time periods. The more accurately these time settings reflect the actual times that hot water is used by members of the household, the greater the potential for water and energy savings, and the more likely hot water will be instantly available at the tap on demand.

The opportunity for energy savings does appear to exist with the use of recirc systems. Theoretically, through the use of a recirc device less energy is spent because the central water heater must only reheat the cooled hot water that is returned through the internal cold water line, versus the typically colder water coming in from the municipal water system. However, the evaluation of energy savings potential resulting from the use of recirc systems is beyond the scope of this study.

B. Pilot Project Methodology, Design, and Data Collection

This study evaluated the change in quantity of warm-up water produced before and after the installation of a recirc system at eight single-family homes located throughout the City of San Diego. One single-family residence from each of City Council Districts 1,2,3,4,6,7 and two single-family residences from District 5 were selected to participate in the project. Each participating household was given an Autocirc, donated by San Diego-based manufacturer, Laing, Inc. Each participant completed a preliminary survey to characterize water use habits of those residing in the home. Participants determined the hot water plumbing fixture with the longest wait for hot water to arrive (Appendix A includes a summary of responses to the preliminary questionnaire). A floor plan diagram was also submitted depicting the location of each hot water fixture (not including dishwasher or washing machine). The recirc system was installed in the bathroom in all but one home. Test home #4 installed the system at the kitchen sink.

To determine the plumbing configuration of the home, participants recorded the time required for usable hot water to arrive at each hot water fixture throughout the house. (Warm-up water is the term used to describe the cooled hot water that goes wasted down the drain at the end use fixture before desirable hot water arrives.) Each time measurement was taken when hot water had not recently been demanded. This ensured that the hot water pipes were relatively cool when the hot water arrival time was measured. (Hot water demanded only when cooled hot water is standing in the pipes is termed a "cold start" demand for hot water. The term "use-event" refers to the occurrence of a single "cold start" hot water use-event in the test room.) Finally, participants provided the flow rate for each hot water fixture in gallons per minute (GPM). Warm-up water waste was calculated using flow rate multiplied by hot water arrival time.

Participants recorded hot water arrival times each time a fixture was used in the test room for seven consecutive days (Phase I). Once the Autocirc was installed participants recorded hot water arrival times in the same way for another seven consecutive days (Phase II). The Autocirc was set to operate 24 hours each day (timer function was not used) during Phase II[3]. (Appendix B provides raw data collected by participants during Phases I and II.) Participants determined when usable hot water had arrived at the fixture by sense of touch. To conclude, pilot project participants completed a Final Survey (responses to the survey questions are summarized in Appendix C).

As mentioned, the quantity of warm-up water waste produced was determined by multiplying the fixture flow rate by the hot water arrival time. This calculation was made for each use-event in Phases I and II. Subtracting the average quantity of warm-up water produced per use-event in Phase II from the average quantity of warm-up water produced per use-event in Phase I determined the average decrease in water waste at the fixtures in the test room resulting from the use of the Autocirc. Water saved per use-event for all test rooms was then averaged.

Figure 3: Formula and Example of Average Per Use-Event Calculation

Formula:
I) Phase I hot water arrival time x fixture flow rate = gallons of warm-up water produced.

II) Phase II hot water arrival time x fixture flow rate = gallons of warm-up water produced.

III) Phase I avg. production of warm-up water per use-event (over the 7 day data recording period).
- Phase II avg. production of warm-up water per use-event (over the 7 day data recording period).
= Decrease in the avg. amount of warm-up water produced per use-event.

Example:
120 seconds = avg. per use-event hot water arrival time in Phase I
- 30 seconds = avg. per use-event hot water arrival time in Phase II
= 90 seconds - decrease in avg. amount of warm up water produced

90 seconds = 1.5 min. x 2.5 gpm = 3.75 gallons
The average decrease in warm-up water produced between Phase and II = 3.75 gallons.

Anecdotally, water savings resulting from the use of a recirc system depend largely on characteristics of the home and on the hot water use habits of household members. Warm-up waste is determined by such variables as the frequency of hot water use and the time of it is used, distance between the central water heater and end use fixtures, plumbing layout, location of the internal hot water line (slab, attic, wall), and ambient air temperature. Table 1A illustrates that a hot water arrival times are not exclusively dependent on the distance between the central water heater and the fixture with the longest wait for hot water. This suggests that other variables must influence on hot water arrival times as well.

Table 1A
Correlating Distance from Hot Water Heater to End Use Hot Water Fixture & Hot Water Arrival Time (Before Autocirc is Installed)

Test Home:	#1	#2	#4	#6	#7	#8	#9
Distance from hot water heater to fixture with longest wait for hot water:	75'	10'	45'	25'	25'	24'	25'
Hot water arrival time at that fixture (seconds):	90	55	75	>40	40	135	30

C. Study Results and Actual Data Interpretation

Each of the reported data sets showed a decrease in "cold start" hot water arrival time between Phase I and Phase II. Table 1 provides the average water savings and wastewater reductions for each test room. Results are expressed in gallons and as a percentage. The average reduction in water waste for all test homes was *two gallons per use-event*, representing a 68% decrease in warm-up water waste and a commensurate reduction in the amount of wastewater produced. According to the data, once the Autocirc was operational, hot water arrived at the tap sooner *each time it was demanded*, and in every household participating in the study.

Table 1
Average Per Use-Event Decrease in Warm-Up Water Waste At the Test Room, After Autocirc is Installed

Test Home:	#1	#2	#4	#5	#6	#7	#8	#9	AVG.
Average decrease in "cold start" warm-up water waste between Phase I and II (in gallons)	2.3	0.9	1.1	0.8	5.4	1.6	3.3	0.50	**2.0**
Average decrease in "cold start" warm-up water waste between Ph I and II (expressed as a percentage).	75%	50%	36%	74%	75%	96%	74%	66%	**68%**

Projected annual reductions in warm-up water waste and wastewater production are shown in Table 3, and assume just one "cold start"" hot water use-event per household per day, equating to an annual water savings of 726 gallons[4]. Assuming the productive life of a recirc system to be ten years[5], the cumulative reduction in water waste would be 14,200 gallons (19 HCF). Wastewater production would also be reduced by 14,200 gallons. This means the consumer avoids $18 in water fees and $32 in sewer fees over the life of the system.[6] Again, these projections are based upon water savings derived through the use of the Autocirc *just once per day*, an exceedingly conservative estimate of hot water use in a typical single family household, considering that the test homes participating in this study had an average of seven hot water fixtures, and the average household size in San Diego in 2003 was 2.86 people.[7]

D. Whole House Conservation Projections

As mentioned, estimating the extent to which recirc systems can reduce whole-house water savings is challenging due to the large number of influencing variables unique to each household. In order to quantify whole-house water savings, the typical frequency of hot water demand by a household must be estimated. Table 2 provides results from the final survey on the frequency of hot water demand by each household in a 24-hour period. On average, hot water use is demanded 15.9 times per day. The average household size is 2.6 people. A strong trend in the frequency of hot water use and the variables listed in Table 2 is not apparent. However, these household variables serve as a reference point to develop whole-house projections based on varying household hot water use frequency over a day, year, and life of the system, as depicted in Table 3.

Table 2
Typical Daily Frequency of Household Hot Water Use-Events
(Final Survey Question #7)

Test Home:	#1	#2	#4	#5	#6	#7	#8	#9	AVG
Number of people living in the home	5	2	1	na	2	2	3	3	**2.6**
Kitchen Frequency	4	4	16	na	5	5	20	3	**8.1**
Bathroom Sink Frequency	2	4	5	na	2.5	4	6	6	**4.3**
Shower Frequency	1.5	2	1	na	2	2	3	3	**2.2**
Total Daily Frequency	7.5	10	22	na	9.5	11	29	12	**15.9**
Projected whole-house Savings (typical daily hot water use x 1..5 gallons/ use event. Example: household #1: 7.5 x 1.5 =11.25 GPD)	11.25	15	33	na	14.25	16.5	43.5	18	**21.6**

Whole-House Scenario Highlights

This report develops several scenarios to project potential "whole house" water savings and wastewater reduction potential through the use of recirc systems. All projections are based upon the actual results of the pilot project which amount to an average water savings of two gallons per each "cold start" hot water use-event. Six scenarios on whole-house water savings are presented in Table 3, along with a Manufacturer's Scenario[8]. The manufacturers scenario applies the variables used in study sponsored by Laing, Inc in 2001, using the City's current residential water and sewer rates in order to provide a relevant comparison between it and Scenarios #1 - #6. Also, a downward adjustment to the average water savings of 25% is applied to Scenario's #1 - #6, effectively reducing water savings to 1.5 gallons per use-event, down from 2.0 gallons per use event. The purpose of this adjustment is to correct for the likelihood that hot water fixtures located outside the test room are relatively closer to the central hot water heater, and therefore a smaller quantity of warm-up water waste is produced at those fixtures. Each scenario presented in Table 3 projects water and sewer savings over one year and over the life of the system. An annual increase in water and sewer rates of 4% is assumed.

Table 3A
Snapshot of Projected Water and Wastewater Reductions
& Cost Avoidances Due to Autocirc

Scenario	Daily Reduction in Warm-Up Water Waste (GPD)*	Annual Water Saved Per System (Gallons)	Cumulative Water Savings Over Life of System (HCF)	Total Cost Avoidance from Reduced Water Fee (@ $1.54/HCF)**	Total Cost Avoidance from Reduced Wastewater Fee (@$2.75/HCF)*	Combined Cost Avoidance Over Life of the System
#1	4	1,558	21	$39	$69	$108
#2	6	2,179	29	$54	$96	$150
#3	9	3,268	44	$81	$144	$225
#4	12	4,358	58	$108	$192	$300
#5	18	6,537	87	$162	$289	$450
#6	22	8,171	109	$202	$361	$563
Manufacturer	33	11,970	160	$296	$528	$824

Note: Descriptions of different scenarios are provided in Table 3.
* Scenarios #1 - #6 reflects a 25% adjustment for variations in quantity of warm up water produced at water fixtures throughout the house.
**Assumes a 4% increase in water and sewer rates annually and a 10 year life-of-device.

Table 3A provides a snapshot of the projections for each scenario, while Table 3 provides greater detail and additional information. Scenario #1 is based on the average household size in San Diego County of 2.86 people, and assumes that hot water use occurs one time per day by each member of the household for a total of 2.86 daily use-events. Using these assumptions, total water conservation is projected to be just over four GPD (1,558 GPY), for a reduction in water warm-up water waste of 21 HCF over the life of the system. Cost avoidance from water fees over the life of the system is projected to be $39, while total cost avoidance in sewer fees is estimated at $69, for a combined total cost avoidance of $108. This reduction in water use represents a 2.5 % decrease in total indoor water use (assuming an average indoor use of 7 HCF per month).

The Manufacturer's Scenario included in Table 3A incorporates household size, water savings, and number of hot water use-events as developed in Laing's 2001 study. It assumes a household size of four people and 15 daily hot water use-events for a total annual water savings of 11,970 gallons due to the use of the Autocirc. The 25% adjustment made for Scenarios #1-#6 is not made in the Manufacture's Scenario, as the methodology used adjusted for variations in warm-up waste produced throughout the house. Using the City's current water and sewer rates in the Manufacturer's Scenario, the customer cost avoidance in water is estimated at $296 over the life of the system. Projected savings in sewer fees is estimated at $528 for total cost avoidance of $824. In this scenario where 160 HCF of water were conserved, we could estimate an annual decrease in an indoor water use of 19% (again assuming an average indoor use of 7 HCF per month).

Scenario #5 estimates a daily warm-up water reduction of 18 GPD, equating to a savings of 6,537 GPY, representing a 10% decrease in indoor water use. By comparison, the most liberal water conservation assumptions applied in Scenario #6 uses the same number of daily hot water use-events as the Manufacturer's Scenario (12), but applies the 1.5 gallon reduction in warm-up water per use-event when projecting annual savings. Warm-up water reductions projected under Scenario #6 were not as great (22 GPD) when compared to those presented in the Manufacturer's Scenario (33 GPD). Note,

TABLE 3

	Actual Water Waste Avoidance per Pilot Project Results	Scenario #1	Scenario #2	Scenario #3	Scenario #4	Scenario #5	Scenario #6***	Manufacturer Scenario****
	actual average water waste avoidance observed in study.	projection of average whole house water savings (2003 US Census stats)	projection of average whole house water savings	projection of average whole house water savings	projection of average whole house water savings	projection of average whole house water savings	****projection of average whole house water savings	projection of average whole house water savings.
Number of daily cold start use-events per person:	1	1	1	2	2	3	5.24	3.75
Number of people per household:	1	2.86	4	3	4	4	2.86	4
Total cold start use events/household/day:	1	2.86	4	6	8	12	15	15
Daily warm up water waste avoidance in gallons (based on an average of 1.99 gallons of warm up water waste/ cold start use event (measured at the fixture(s) located furthest from the central heater), as per pilot study results. Manufacturer scenario uses differing methodology to determine total daily water waste figure.	2	5.69	8	12	16	24	30	33
Daily warm-up water avoidance (in gallons): 25% reduction in water waste savings per use event to reflect reduced distances between secondary hot water fixtures and central water heater when additional cold starts occur throughout the home. All figures below use this reduction factor.	2	4	6	9	12	18	22	33
Annual water waste avoidance (in gallons)	726	1,558	2,179	3,268	4,358	6,537	8,171	11,970
Annual wastewater avoidance (in gallons)	726	1,558	2,179	3,268	4,358	6,537	8,171	11,970
Combined water and wastewater avoidance (in gallons)	1,453	3,116	4,358	6,537	8,715	13,073	16,341	23,940
Percent reduction in indoor water use (based on typical use of 7 hcf/month)	1.2%	2.5%	3.5%	5.2%	6.9%	10.4%	13.0%	19.1%
Annual Water Cost Avoidance to Customer (water = $1.54/hcf)*	$1.50	$3.21	$4.49	$6.73	$8.97	$13.46	$16.82	$24.64
Annual Wastewater Cost Avoidance to Customer (wasewater = $2.75/hcf)*	$2.67	$5.73	$8.01	$12.02	$16.02	$24.03	$30.04	$44.01
Annual combined water and wastewater cost avoidance	$4.17	$8.93	$12.50	$18.74	$24.99	$37.49	$46.86	$68.65
Water Cost Avoidance to Customer over 10 year life of device (water = $1.54/hcf) - future value**	$18	$39	$54	$81	$108	$162	$202	$296
Wastewater Cost Avoidance to Customer over 10 year life of device (wastewater = $2.75/hcf) - future value**	$32	$69	$96	$144	$192	$289	$361	$528
Combined water and wastewater cost avoided over 10 year life of device - future value*	$50	$107	$150	$225	$300	$450	$563	$824
Cumulative Water Avoidance Over 10 Years Per Household (in hcf)	19	42	58	87	117	175	218	320
If 500 homes installed device, what would cumulative water savings be in first year?(in AF):	1.1	2.4	3.3	5.0	6.7	10.0	12.5	18.4
If 1000 homes installed device, what would cumulative water savings be in first year?(in AF):	2.2	4.8	6.7	10.0	13.4	20.1	25.1	36.7
If 2500 homes installed device, what would cumulative water savings be in first year?(in AF):	5.6	12.0	16.7	25.1	33.4	50.1	62.7	91.8

** As of 3/1/05 residential water rate = $1.54/HCF; residential sewer rate = $2.75/HCF.
* Life of device is assumed to be 10 years. Future value assumes a 4% annual increase in water and sewer rates.
*** Scenario #6 holds total cold starts/day equal to manufacturers study (15) and also uses US Census Bureau avg. houshold size of 2.86.
**** San Diego rates for water & sewer are used in the Manufacturers Scenario to allow accurate cost comparison between scenarios presented here.

Scenario #6 most closely approximates the average number of daily hot water use-event in our test homes (see responses to the final survey - Table 2).

E. Costs and Benefits – Customer Perspective

As a point of reference, estimates of the purchase price and installation costs for recirc systems offered by two companies, Metlund and Laing, are compared in Table 4. As described earlier, Laing's Autocirc is a "time and temperature control system", whereas the Metlund D'Mand requires the user to push a button, causing cooled water to instantly recirculate and bring hot water from the central heater only when demanded. Both systems require an 'always-on' electrical outlet (ideally located in the cabinet under the sink where the recirc system is installed).

Table 4
Consumer Purchase and Installation Cost Estimate

Recirc System	Retail Cost of System	System Installation Cost	Electrical Outlet Installation Cost	Cost of Additional Parts	Total Cost
Laing Autocirc	$200	$75 - $125	$100 - $150	$25	$320 - $455
Metlund D'Mand	$ 300 - $700	$75 - $125	$100 - $150	$0	$400 - $925
Assumption	$200	$100	$125	$25	$450

Purchase and installation of a recirc system in the San Diego region is estimated on the low side at $320 (if the system is installed by the homeowner, and a professional electrician installs the power source under the sink) to upwards of $925 for the more expensive recirc system models (if a professional performs both the plumbing and electrical installations). For purposes herein, a conservative estimate of $450 will be used to represent total cost to purchase and install a recirc system like the one used in our test homes.

Incentivizing the System – Customer Perspective

When assuming a purchase and installation cost of $450, the point at which a recirc system would effectively pay for itself through reduced water and sewer fees can be estimated. Table 5 shows potential water and wastewater fee avoidance when a recirc system is used for ten years. *Such cost avoidances over the life of the device fully offset the consumer's up front purchase and installation costs for a recirc system if a household realizes a reduction in 17.5 GPD (6,400 GPY) of warm-up water waste and an equivalent 17.5 GPD reduction in wastewater.* These savings are achievable if a household demands hot water 11 to 12 times a day. Put in perspective, each person in a three-person household would need to demand hot water four times per day to achieve the 17.5 GPD reduction in warm-up water waste.

Looking back at Table 2, the average frequency of hot water use in our test homes is 15.9 times per day, which equates to a reduction in warm-up water use of nearly 24 GPD. This exceeds the requisite 17.5 GPD "break-even" point, deeming the system a good investment from the consumer's point of view. The added convenience of instant hot water has value to the consumer, however a monetary estimate of that value is not assigned here. A $75 cash incentive would decrease the purchase price of the system, in effect diminishing the requisite 17.5 GPD conservation levels to 14.6 GPD before the system pays for itself. Alternatively, if water savings were held at 17.5 GPD, the incentive would act to abbreviate the time (number of years) required for the appliance to pay for itself through the avoidance of water and sewer fees.

Table 5
Water and Wastewater Consumer Break-Even
(Assuming Up-Front Investment in System of $450, and $375 w/ $75 Incentive)

	Water Saved (GPD)	Wastewater Reduced (GPD)	Annual Reduction in Warm-Up Water & Wastewater (GPY)	Water Saved Over Life of the System (AF)	Combined Water & Sewer Rate = $1146/AF)	Consumer (cost)/savings if up from cost = $450	Consumer (cost)/savings if up front cost = $375 ($75 Cash Incentive)
Actual savings:	2	2	1,452	.02	$51	($399)	($324)
Scenario # 2	6	6	4,358	.07	$153	($297)	($222)
Scenario # 3	9	9	6,536	.10	$230	($220)	($145)
Scenario # 4:	12	12	8,800	.13	$309	($141)	($66)
Break-Even w/ $75 incentive	**14.6**	**14.6**	**10,658**	**.16**	**$375**	**($75)**	**($0)**
Break-Even - No Incentive	**17.5**	**17.5**	**12,793**	**.20**	**$450**	**($0)**	**$75**
Scenario # 5:	18	18	13,074	.20	$460	$10	$85
Scenario # 6:	22	22	16,342	.25	$575	$125	$200
Manufacturer Scenario:	33	33	23,940	.37	$842	$392	$467

F. Costs and Benefits – Water Department Perspective

Based on the results of this study, the City might consider incentivizing recirc systems to encourage its widespread use in order to promote water conservation. Rudimentary estimates as to the operating and administrative costs of a utility-sponsored incentive program can be developed by reviewing cost structures of the High Efficiency Washing Machine (HEW) Instant Voucher Program and the Ultra Low Flush Toilet (ULFT) Voucher Program. The City currently partners with San Diego County Water Authority (CWA) and MWD to provide these programs. Each partner provides a contribution toward the value of the voucher and the cost of contracting with Honeywell Data Management Corporation to administer the program.

Currently, the City's cost to participate in the HEW Instant Voucher Program is approximately $31 per voucher, not including internal administrative costs. In order to derive a rough estimate of the costs to provide a similar program for recirc systems, the HEW and ULFT voucher programs cost structure is used (see Table 6). An average cost per voucher of $34.10 is assumed, which includes the value of the incentive and the $31 fee (Honeywell's charge and a portion of the cash incentive) plus 10% for internal administrative costs. The assumption is that the City, MWD, and CWA would contribute a portion to cover a voucher processing fee and the financial incentive, as is the case with the residential HEW and ULFT incentive programs. Voucher values are currently $100 per HEW and $75 per ULFT.

Table 6
Estimated Water Department Cost to Provide Recirc System Voucher Program

Quantity:	1	500	1,000	2,500
City Contribution to cash incentive*:	$31	$15,500	$31,000	$77,500
City administrative overhead @ 10%:	$3	$1,550	$3,100	$7,750
Total cost per voucher:	**$34**	**$17,050**	**$34,100**	**$85,250**

*Assumes that MWD and CWA will contribute equally as in the ULFT and HEW programs

Table 7 illustrates potential cumulative impact on water savings and sewer reductions attributable to the recirc system. The first column represents savings generated by one recirc system over its assumed ten year life. The Break-Even Scenario shows that if 500 recirc systems were installed, total water savings produced over ten years is 45 AF. These savings translate into $17,000 in avoided raw water purchases by the Water Department (at the current raw water rate of $381/AF). The estimated cost to administer an incentive program of $34.10 per voucher is fully offset by the cost avoidance derived through a decrease in water demanded. Further, at the current sewer treatment rate of $1621/AF, the City's Metropolitan Waste Water Department (MWWD) would realize a cost avoidance of $72,500. Table 7 provides these quantity and cost savings projections for the installation of 1000 and 2,500 systems as well.

Table 7
Annual Water and Sewer Savings to the Utility

(Cumulative water and wastewater avoidance with 1, 500, 1,000 and 2,500 devices in service for 10 years.)

	1 Device			**500 Devices**			**1,000 Devices**			**2,500 Devices**		
	GPD Saved	**$ Water**	**$ Sewer**	**Acre Feet**	**$ Water**	**$ Sewer**	**Acre Feet**	**$ Water**	**$ Sewer**	**Acre Feet**	**$ Water**	**$ Sewer**
Actual Savings:	2	$8.50	$36	11	$4,244	$18,058	22	$8,489	$36,116	56	$21,222	$90,290
Scenario # 2	6	$25	$108	33	$12,739	$54,199	67	$25,478	$108,398	167	$63,695	$270,995
BREAK EVEN	**8**	**$34.10**	**$145**	**45**	**$17,050**	**$72,539**	**89**	**$34,099**	**$145,079**	**224**	**$85,248**	**$362,697**
Scenario # 3	9	$38	$163	50	$19,105	$81,286	100	$38,211	$162,572	251	$95,527	$406,430
Scenario # 4:	12	$51	$219	68	$25,723	$109,443	135	$51,447	$218,885	338	$128,617	$547,213
Scenario # 5:	18	$76	$325	100	$38,217	$162,597	201	$76,434	$325,194	502	$191,084	$812,985
Scenario # 6:	22	$96	$406	125	$47,770	$203,240	251	$95,539	$406,480	627	$238,848	$1,016,200
Manufacturer Scenario:	33	$140	$595	184	$69,979	$297,734	367	$139,959	$595,468	918	$349,897	$1,488,669

Formula used to determine water and sewer cost avoidances: Using Actual Savings as the example: 2 GPD water savings x 365 days per year = 726 GPY /325,851G/AF x $381/AF x 10 years = estimated cost avoidance in water fees over 10 years from one recirc system.

Note: Table 7 uses the Utility's raw water cost ($381/AF) to calculate cost avoidance. Table 3 uses the retail cost of water to calculate customer cost avoidance.

Table 7 shows that if a recirc system reduces water use (and therefore water demand) by eight GPD or more, the Department could feasibly provide a financial incentive supported by the associated avoidance in raw water purchases. Transferring those avoided costs to a cash incentive for recirc systems might effectively motivate customers to install these relatively expensive water conserving appliances. Our assumption is that the cost to incentivize one system is $34.10. The water savings required to offset incentive costs are shown in Table 8. At a cost of $34.10 per voucher, the Department's cost to provide the incentive would be offset if the recirc system effectively reduces water demand by eight GPD over ten years. Note, our test homes indicate that on the average hot water is demanded slightly over 15 times per day per household. At a water savings of 1.5 gallons per use-event, average savings is 22 gallons per day - well above that requisite eight GPD break even point.

Table 9 takes these calculations one step further and illustrates potential water savings if 500 systems installed per year for ten years. At total of 5,000 systems, conservation would equal 45 AF, and result in an avoidance of $34,000 in raw water purchases. Associated sewer treatment cost avoidances would equate to $72,600. Table 9 also shows potential cumulative water conservation and cost avoidances over a ten year period if 1,000 and 2,500 system are installed annually. Cumulative water savings would clearly have a positive impact on the amount of raw water demanded and wastewater treated by the City.

Table 8

Department Incentive Break-Even Analysis ($381/AF for Raw Water)

	GPD Saved	**Cost Savings from 1 Unit Over 10 Years**	**Cost Savings from 500 Units Over 10 Years**	**Cost Savings from 1000 Units Over 10 Years**	**Cost Savings from 2500 Units Over 10 Years**
Actual savings:	2.0	($25.61)	($128,056)	($25,611)	($64,028)
Scenario # 2:	6.0	($8.62)	($4,311)	($8,622)	($21,555)
BREAK EVEN:	**8.0**	**($0.00)**	**($0)**	**($0)**	**($0)**
Scenario # 3	9.0	$4.11	$2,055	$4,111	$10,277
Scenario # 4:	12.1	$17.35	$8,673	$17,347	$43,367
Scenario # 5:	17.9	$42.33	$21,167	$42,334	$105,834
Scenario # 6:	22.4	$61.44	$30,720	$61,439	$153,598
Manufacturer Scenario:	32.8	$105.86	$52,929	$105,859	$264,647

Calculation: using Actual savings as example - Table 7 shows cumulative raw water avoidance to the Department= $8.50, Estimated cost to administer incentive program = $34.10 per voucher. $8.50 - $34.10 = -$25.60.

Table 9

Cumulative Water and Sewer Avoidances
(At Department Break-Even of 8 GPD)

Systems Installed Annually	**Cumulative Installations Over 10 Years**	**10 Year Total (AF)**	**Raw Water cost/AF**	**Cumulative Raw Water Cost Avoidance**	**Sewer Cost/AF**	**Cumulative Sewer Cost Avoidance**
500	5,000	45	$381	$17,071	$1,621	$72,630
1,000	10,000	90	$381	$34,142	$1,621	$145,890
2,500	25,000	224	$381	$85,355	$1,621	$363,851

G. Evaluating the Recirc System as a Conservation Tool

Table 10 provides a comparison of indoor water conservation systems and programs currently supported and/or promoted by the City as part of its ongoing demand management strategy to reduce its dependence on imported water. Recirc systems offer the opportunity to save as little as 1.2% of the total indoor water use of a typical residential unit (when assuming average total indoor use of 7 HCF/month), as per demonstrated by actual warm-up water waste reductions observed in the pilot project test rooms. On the up side, these systems might offer as much as a 19% reduction in indoor water use, as reflected by the 33 GPD savings assumed in the Manufacturer's Scenario. Given the City's current water and sewer fees, the household that reduces water use by 14 to 15 GPD will avoid costs over the estimated ten year life-of-the-device that will completely offset the average upfront purchase and installation cost of an Autocirc. Furthermore, at a water savings rate of 14-15 GPD, the typical household would reduce total indoor water use by nine to ten percent. From the utility's perspective, a daily reduction in demand of eight gallons is needed for the Department to recover the costs of incentivizing the system (at an estimated incentive of $75-$100 per unit) (Table 8). An eight GPD reduction equates to an estimated five percent reduction in indoor water use by a typical household.

Through its many conservation programs and efforts, the City currently reduces the demand for raw water by approximately 23,000 AFY. Based on the positive results of this pilot project, the addition of an incentive for recirc systems would be a complementary addition to the City's current demand-management strategies, and could expand indoor water savings opportunities without a negative fiscal impact to the Department.

Table 10
Comparison of Annual Water Savings from
Indoor Conservation Systems and Programs

Water Conservation System / Program	Per Unit Conservation	Gallons Saved per Household per Year	Percentage of Total Indoor Water Use (7 HCF/month avg.)
Recirculating Hot Water System	1.5 gallons per hot water-use event	726 – 11,970	1.2% - 19%
Ultra Low Flush Toilet (ULFT)	28 gallons per day per ULFT	20,500	33%
Residential Survey Program	24 gallons per survey	8,750	14%
Low Flow Shower Head Replacement	16 gallons per household per day	5,850	9.3%
High Efficiency Washing Machine (HEW)	14 gallons per load of laundry	5,000	8.1%

H. Participant Feedback

The participant responses to the final survey provided real insight into the customer's perception of recirc systems (Appendix C summarizes final survey responses). As discussed, hot water arrival time was reduced in every test home reporting data (Table 1). Seven of the eight participants responding to the final survey indicated that they would recommend a recirc system to others. 75% considered the installation an easy one to perform, with the average installation requiring about one hour. 62% responding participants hired a plumber or handyman to install the system. All but one needed to install an electrical outlet under the sink. 86% of the respondents did not consider the pump bothersome because it was too loud.

Once the Autocirc was operational, two participants experienced a trend in which hot water arrived quickly at the tap, followed by cool water for a period of time before becoming hot again. This phenomenon is difficult to explain in certain terms. Perhaps it could be interpreted that the hot water line is routed in an outside wall or through a concrete slab before the entering the test room where the fixture was located. The hot water sitting in the line was perhaps exposed to the cooler outside air or relatively cooler concrete, causing the water temperature to drop. Water located in that stretch of pipe would be relatively cooler than the water located in the line near the Autocirc's thermostat, thereby accounting for the 'hot water - cool water - hot water' phenomenon.

The following are written comments were provided by test home participants and contain general insights and experiences with the recirc system during the project.

Test Home #1: "This system was very useful for our upstairs bathroom - the furthest bathroom from the water heater. Before the circulating pump was installed, it would take over one minute for the water to heat up in the shower. We are very happy to know that we are saving water and energy through the use of the pump. It is a very useful addition to our home. Thank you for the opportunity to test the pump."

Test Home #4:"I highly recommend them, though I have used a different one in a previous house which I think is more efficient. Also, due to the pipes running under the house and the times I had it set, it was somewhat noisy."

Test Home #5: "I like not having to wash my hands in cold water. I like the idea of not wasting water by letting it run so long before it gets hot - enough to do what I need to do it: wash dishes, showering or washing clothes, etc…"

Test Home #7: "I believe the convenience of having instant hot water when and where it is needed is the biggest advantage of having the Autocirc pump installed. It is also self satisfying to know that water is not wasted."

Test Home #8: "1. The heater, although it provided hot water after 3-5 seconds, most times went cold for a period from 7 - 30 seconds; 2. When connected I could hear the pipes in the walls and floors during the night creaking as they were heated up and cooled; 3. We have solar electric so use of electricity is really not a concern."

Test Home #9: "Because our water pipes run through the slab we often have cold water in the pipe even though the water at the pump is still hot. When you turn the hot water on, you initially get hot water, then cold water, then hot again. A more effective system would be to have the pump circulate in response to the press of a button. Then the hot water could be circulated when needed, and would not get a chance to cool."

III. SUMMARY AND RECOMMENDATIONS

Based on the study results the Autocirc was successful in reducing the wait time for hot water to arrive at the fixture located furthest from the homes central water heater. Estimates based on whole house water savings show that cost savings derived from the reduction of 17 to 18 GPD of warm-up water waste per household will fully offset the up-front costs to purchase and install a recirc system. If a financial incentive of $75 toward the purchase of a recirc system were offered to the consumer in the form of a cash incentive or voucher, this "break-even" point where the system pays for itself would occur if 14 to 15 gallons were conserved per household per day.

From a utility's perspective, a reduction in water use of at least eight GPD per household must be achieved for the Department to realize proportionate savings derived from a decrease demand for water spurring the subsequent need to purchase less raw water from wholesalers. In this case, the Department could offer a financial incentive at a cost of $34 per voucher. These figures reflect the assumption that an incentive program could be modeled after the successful residential ULFT and HEW voucher programs, whereby contributions from the City and other regional water agencies (MWD and CWA) would together share the costs of providing a financial incentive to the customer of $75 per system.

We can estimate that if 500 recirc systems were installed annually every year for ten years, cumulative demand for raw water would drop by 45 AF (4.5 AFY). Associated avoidance in raw water purchases (at $381/AF) would equate to $17,000 and sewer treatment cost avoidance would be $72,600 (at $1621/AF). If 1000 systems were installed annually every year for ten years, cumulative water conservation of 90 AF would result in a savings to the Department of $34,000. At these conservative levels, recirc systems would provide a positive increment to the City's current conservation levels achieved through the existing programs that reduce the City's potable water demand by over 23,000 AF annually. In a city of 1.25 million residents and growing, these estimates are just a starting point for the potential of water savings attainable from recirc systems in both existing and newly constructed homes.

The size of this pilot project is too small to provide statistically significant data, and as such further study on the performance of these systems is recommended. A large population survey is needed to develop a profile of household characteristics affecting the potential for warm-up water waste reductions through the use of recirc systems. The City has been awarded grant funding by the California State Department of Water Resources to pursue these efforts.

Based upon the results of this pilot project, the City could consider providing a pilot program that offers consumers a cash incentive on the purchase price of recirc systems. Conducting a pilot with a limited number of vouchers would provide the Department an opportunity to further study water savings potential and determine the level of customer interest in these systems while limiting the City's financial commitment.

The energy savings potential offered by recirc systems is also in need of further study. Some estimations peg annual energy savings potential at $200 per year per system. If this is the case, the pay back period for consumers to recoup their up-front investment in the system would occur in just a few years, and/or would require less extensive water savings over the assumed ten year life of the system. Gas and electric utilities are encouraged to conduct their own studies on the matter. Assuming positive results in energy conservation, potential future collaboration between water and energy utilities may offer greater opportunities to promote the value of recirc systems to common customers while effectively reducing the local demand for energy and water supply.

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[1] Laing, Inc.'s 2001 report entitled "Economic Operating Costs for Laing Instant Hot Water Recirculating Systems".

[2] Water located in the branch line (line between the trunk line and the hot water fixture) will not be recirculated.

[3] Some participants set their system to operate during specific bands of time, and in those cases adjustments were made when analyzing the data.

[4] City of San Diego water rates: $1.54/HCF for the first 7 HCF; sewer rates are $2.75/HCF. 1 HCF = 748 gallons.

[5] Literature on Metlund's website states a useful life of 15 to 20 years and a 3 year warranty for the D'MAND system. Laing Autocirc estimates a useful life for the Autocirc between 10-12 years due to failure of the rotor impeller, which is an easily replaceable part.

[6] Projections are based on a four percent increase in water and sewer rates annually.

[7] The 2003 US Census average household size in San Diego is 2.86 people (includes both single and multi-family dwellings).

[8] Laing, Inc. published a report in 2001 entitled "Economic Operating Costs for Laing Instant Hot Water Recirculating Systems". The cost study was prepared by Edward Saltzberg and Associates, Consulting Mechanical Engineers. Basic Assumptions used for the Autocirc are as follows:

1. The hot water heater is approximately 60 feet from the master bedroom.
2. The residence is three bedrooms with four occupants.
3. Assume that without the Autocirc, a hot water faucet is turned on a minimum of 15 times/day (4times/day in master bathroom sink; 3 times/day in second bathroom sink; 2 times/ day in master shower; 3 times/ day in second bathroom shower; 4 times/ day in kitchen sink).
4. Assume a 3 minute wait for water at the master shower. The shower flow rate is 2.5 gpm. Once the Autocirc is installed the wait time for hot water is 15 seconds, for a total of 1.25 gpd is wasted at the master bathroom shower.
5. Assume a 1.5 minute wait for the shower in the second bathroom with fixture flow rate of 2.5 gpm. After the Autocirc is installed the wait time for hot water is 10 seconds to get hot water, with a waste of .8 gpd.
6. Assume a 2 minute wait at the kitchen sink, with a fixture flow rate of 2.5 gpm. After the Autocirc is installed there is a 15 second wait to get hot water, for a total of 1.25 gpd of wasted water.
7. Assume that seven times a day when the hot water is turned on there is some hot water in the supply piping due to someone else previously using hot water at another fixture. Therefore, the wait for hot water would be less, say 30 seconds average time delay.
8. Assume in the bathrooms the hot water is turned on at the sinks at least 7 times/ day in which there is approximately a 30 second wait to get hot water, The fixtures have a flow rate of 1.5 gpm. After the Autocirc is installed there is a 10 second wait for hot water to arrive, for a total of 1.75 gpd of wasted water.
9. Assume the Autocirc is set to recirculate cooled hot water 16 hours/day between 6 am and 10 pm.
10. There will be slight discharge of heated cold water from the master bathroom sinks. If the sink is used 4 times/day and the cold water runs for 10 seconds per operation, there is 1 gpd of wasted water at the master bathroom sink.
11. Total water saved over the year was assumed by Manufacturer to be 11,970 gallons.