**Title**
Embedded Energy in Water Study 3: End-use Water Demand Profile (Final Research Plan)



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# Embedded Energy in Water
# Study 3: End-use Water Demand Profile
# Final Research Plan

**Prepared by**
**Aquacraft Inc.**

**For the**
**California Public Utilities Commission**
**California Institute for Energy and Environment**

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# Executive Summary

Aquacraft Inc. developed this Research Plan in response to CPUC D. 07-12-05 and RFP CP1-007-08. The overarching objective of the Embedded Energy in Water studies is to determine how much of an energy demand reduction can cost effectively be achieved from water use efficiency measures. This study, ***Study 3: End-use Water Demand Profile,*** is designed to provide accurate hourly water use profile data that may be used alongside concurrent studies' information to update the CPUC Water-Energy Measure Calculator. One of the main outputs of the calculator is that it will inform investor owned energy utilities where it is cost effective to include water use efficiency programs in future energy efficiency planning portfolios.

This End-use Water Demand Profile study will measure cold water demands of six end-use (customer) categories. Table ES - 1 provides a summary of the customer categories being examined and the water demand profile categories that will be measured.

**Table ES - 1: End-use category research profiles**

| End-use Category | Water Demand Profile Categories |
|---|---|
| Residential<br>• Normal and Low-income<br>• Single-family | • Baths and showers<br>• Toilets<br>• Clothes washers<br>• Dishwashers<br>• Irrigation<br>• Other uses |
| Residential<br>• Low-income<br>• Multi-family | |
| Commercial | • Domestic/indoor<br>• Process<br>• Continuous |
| Industrial | • Domestic/indoor<br>• Outdoor<br>• Process |
| Public Buildings | • Domestic/indoor<br>• Outdoor<br>• Continuous |
| Agriculture | • Process |

Where data (from previous studies) does not already exist in the six category end uses Aquacraft will use the Flow Trace Methodology to generate hourly demand profiles. Flow trace analysis obtains precise information about water use patterns: Where, when, and how much water is used by a variety of devices including toilets, showers, baths, faucets, clothes washers, dishwashers, hand-held and automatic irrigation systems, evaporative coolers, home water treatment systems, leaks, and more. A software package designed by Aquacraft Inc., Trace Wizard, has been used in numerous demand profiling studies in California, 14 other US States and around the globe since 1996 to analyze flow trace data collected from customer water meters.

## Research Methods in Brief

***Residential Normal and Low-income Single-family***
This research plan methodology for the residential single-family end-use customer category will take advantage of existing data to develop demand profiles. Aquacraft is using hourly demand profile data from a statewide CALFED single-family home demand profile study slated for completion early 2009. This water use data is representative (at the 95% confidence level) of the household water use patterns existing within each of the study's respective 15 water agency service areas (DeOreo, W.B., et al, 2009). Hourly demand profiles will be tabulated for use in the Water-Energy Measure Calculator.

***Residential Low-income Multi-family***
Aquacraft maintains a list of individually metered multi-family properties in several California water agency service areas, from which a sample of the lowest income range will be selected as study sites. From these data sets a representative sample of approximately 150 of low-income sub metered multi-family units will be selected from available properties using random sampling methodology,checking water use patterns for bias against those of the population . Data loggers will also be placed on the meters supplying domestic/indoor uses and the irrigation systems for these properties. The flow trace data collected from the data logging will be analyzed and disaggregated into hourly category water demand profiles using Trace Wizard. These profiles will be tabulated and used to update the calculator.

***Commercial***
Aquacraft maintains a collection of flow trace data from a broad range of commercial customers from which end-use water demand profiles will be generated. These data sets come from the AWWARF Commercial and Institutional End Uses of Water study (2000), the Sacramento Regional Water Authority CI Water Audits study (2005), the CALFED Supermarket Studies (2003) and the Monterey Pre-Rinse Spray Valve study (2003). Candidate study sites from earlier studies as well as any new sites will be separated into sub-categories based on their having the most intense water use on a per site basis and their representing as a sub-category the largest proportion of water use by their category in a water agency service area. The output data from commercial sub-categories will be tabulated into water demand profiles used to update the CPUC Water-Energy Measure Calculator.

***Industrial***
Due to the lack of any known prior research in the industrial category, determining water demand profiles will involve a significant amount of new work. Using a similar methodology as in the commercial customer category Aquacraft will determine which industries are the most significant from the perspective of potable water demands and will select sites that have the highest water use on a per site basis and represent as a sub-category the largest proportion of water use by the industrial category. Flow trace data will be collected from study site water meters and hourly demand profiles tabulated for use in the Water-Energy Measures Calculator.

***Public Buildings***

To address this customer category Aquacraft will select a few public buildings in each of the cities and counties that are currently participating in a statewide CALFED study Aquacraft has been conducting since 2005. The CALFED study sites make up a good cross section of both Northern and Southern California water agency service areas (DeOreo, W.B., et al, 2009). Once the population of accounts is better known a random or saturation sample of public building study sites will include a cross section of sub-categories (ie. Libraries, Govt. Offices, Govt. Laboratories, etc) present in various water agency service areas. Public buildings' water uses will be reviewed and flow trace data logged from their indoor and outdoor water meters. Hourly demand profiles will be generated based on the combined data logging and site visit information. Tabular data will be generated to update the Water-Energy Measure Calculator.

***Agriculture***

For this category end-use Aquacraft will measure water uses and generate hourly demand profiles for agricultural end users who use potable water for cleaning, packing and canning of California fruits, nuts and vegetables. Aquacraft will identify the largest water using agricultural water customers and will select as balanced a sample as possible of agricultural process users who obtain water from potable water systems in various regions of the state. Agriculture facilities' water uses will be determined and flow trace data logged from the water meters serving their process uses. Demand profiles of Process uses will be generated based on the combined site visit information and data logging. Tabular data will provide information necessary to update the Water-Energy Measure Calculator for the agriculture end-use category.

**Table ES - 2: Study 3 contact information**

| Contractor | Name | Phone | Email |
|---|---|---|---|
| California Institute for Energy and Environment | Chris Ann Dickerson, CIEE Project Manager | (510) 562-1034 | cadickerson@cadconsulting.biz |
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# 1.0 Introduction

This research plan was prepared by Aquacraft Inc. for the California Public Utilities Commission (CPUC). The plan describes in detail the specific tasks that Aquacraft researchers will undertake to address the Study 3 Problem Statement and achieve the Goal from RFP CP1-007-08, restated below. Study 3 comprises the research work devoted to obtaining water use profiles that may highlight the energy load profiles at California water/wastewater purveyor service areas, and within the service area of investor owned energy utilities (IOU's).

***Problem Statement***
*The CPUC and its consultants have developed an embedded Water-Energy Measure Calculator to help energy utilities determine the benefits of particular efforts to conserve water. The Water-Energy Measure Calculator will be updated with new data. A metering study of water use is needed to translate a measure installation into a change in the water demand profile that can then be compared with the water demand profile at the water agency to derive the effect a measure would have on the agency's energy load. Some of the information from this study will be used to update the embedded Water-Energy Measure Calculator.*

***Goal***
*The goal of this study is to provide all participants with accurate and current end-user water use profiles.*

The primary purpose of this document is to clearly describe the tasks that will be employed to complete the study of load profiles authorized by the CPUC in December of 2007. The findings of this baseline study will be used along with those of the Embedded Energy in Water Studies 1 and 2 (being performed by GEI Consultants), and the Embedded Energy in Water Evaluation Pilot Studies (performed by Water Pilots Embedded Energy Evaluation Team led by ECONorthwest) to update the Water-Energy Measure Calculator, a spreadsheet tool created for the CPUC to examine the potential electricity and natural gas savings by water agencies associated with water use efficiency measures.

This Research Plan's budget shown below is based on the research tasks as originally proposed by Aquacraft. Following implementation of water demand profile studies there may be changes to the budget allocation across tasks. Aquacraft's research budget for this project is $457,293.

# 2.0 Background and Purpose

In December 2007 the CPUC entered a record of decision (CPUC D. 07-12-05) approving a series of programs and evaluations and studies aimed at reducing the amount

of energy used by water and wastewater utilities for the full range of water collection, conveyance, treatment and distribution from regulated investor owned utilities within the State of California. The record of decision is very specific on the goals and objectives of the program.

The evidence that using water in California places a significant demand on energy resources is clear. Both electricity and natural gas are consumed at the water/wastewater agency level to pump, convey, treat, deliver and treat wastewater for a variety of end uses. A significantly larger amount of energy is consumed to heat water at the customer level. How California end users' water demands actually translate into a measurable energy load profile at the water agency is yet unclear.

The RFP description of Study 3 requests information needed alongside that of other studies to allow specific water conservation measures to be translated into a change in the water demand profile for the supplying water agency that would impact that agency's energy load. According to the CPUC Record of Decision 07-12-050 the overarching purpose of the combined Embedded Energy in Water research efforts is to determine how much of an energy demand reduction can be achieved from water use efficiency measures. This research effort, as well as the findings of the concurrent Embedded Energy in Water Pilot Programs impact evaluation being led by ECONorthwest, will aid the CPUC in determining what water saving measures are cost effective for IOU's to include in their water use efficiency programs in future energy efficiency portfolios.

Various contractors are carrying out concurrent Embedded Energy in Water studies. An effort will be made to ensure the consistent use of terminology between research efforts.

An important feature of the Embedded Energy in Water studies is the relationship between research efforts. For example, Study 2 - ***Water Agency and Operational Component Study & Embedded Energy-Water Load Profiles*** - is designed to generate information on the embedded energy of California water/wastewater agency system operations and their respective water and energy loads profiles. The water demand profile information that is generated in Study 3 will tie into Study 2 as input data. That is, Study 2 will provide information of energy demands at water/wastewater systems, thus linking the hourly end-use demand profiles with the hourly energy use by the agency. At this time it is unclear exactly how a water use efficiency measure impact on end-use demand profiles will impact energy load profiles at the water/wastewater agency. Until the CPUC Water-Energy Measure Calculator is fully calibrated to the Embedded Energy in Water studies' findings, it is understood that any changes in hourly demand profiles resulting from water use efficiency measures *may or may not* affect the hourly energy use of the water/wastewater agency. Additionally, without understanding how each agency meets its hourly water and wastewater treatment demands, which is the focus of Study 2, it cannot be said that a measure change in the efficiency of water use will not affect the energy use of the water agency. The Embedded Energy in Water studies as envisioned by CPUC are all inextricably linked as important inputs to the Water-Energy Measure Calculator and achieving the goals set forth in CPUC D. 07-12-05.

To help visualize this important connection shared between Studies 1, 2 & 3, Figure 1 portrays a modified flow diagram from RFP CP1-007-08. California's water use cycle provides a simple picture of linkages between Study 3 measured water demand profiles and Study 1 & 2 embedded energy in water systems and load profile information.

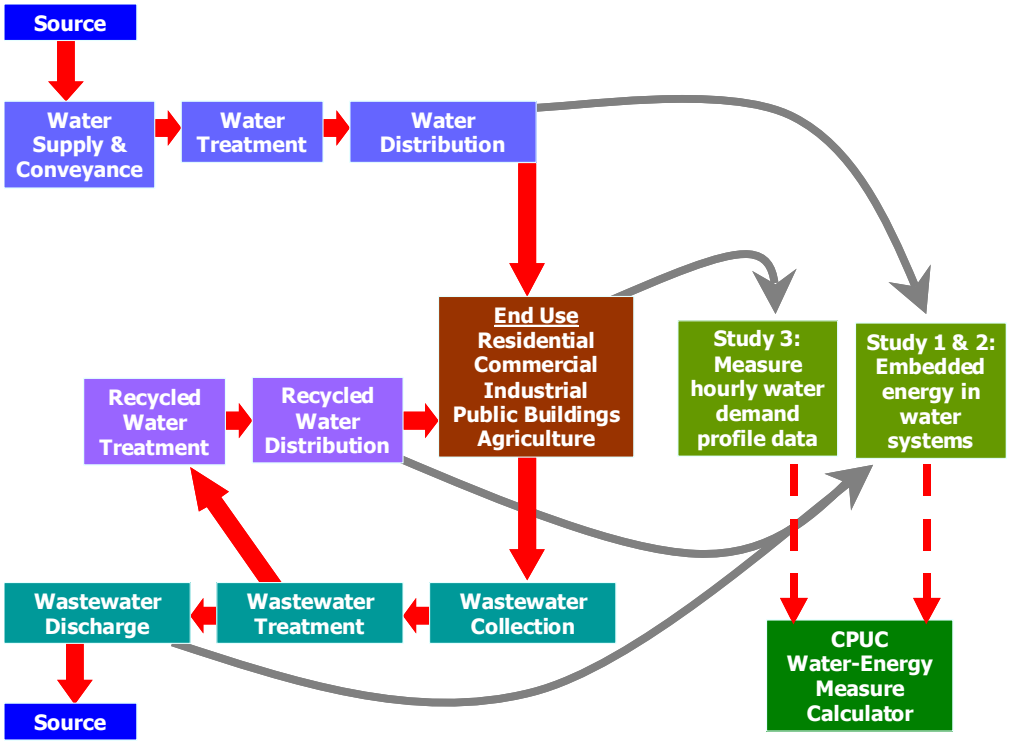



**Figure 1 California Water Use Cycle and Studies 1, 2 & 3**

In the record of decision it was noted that there are two sources of energy savings associated with water use efficiency: cold water savings related water agency activities (both upstream and downstream of the end-user) and hot water savings related to energy used to heat water for end-use purposes. The decision states clearly "it is the former that comprises the embedded savings opportunities that are the focus of these applications." Based on this information the research plan will focus on cold water uses (as discussed in our proposal) and set aside the analysis of hot water uses by the end-user for future studies CPUC D. 07-12-050[1].

[1] CPUC D. 07-12-050 included mention of hot water inasmuch as use of hot water in certain buildings is an end-use that entails delivery of water to the building, and thus those uses are included in the overall water demand profile, but that the energy used to heat the water is not within the scope of the analysis. CPUC confirms that Aquacraft's interpretation of this language is approved for the study plan – the energy needed to heat hot water is not part of the study scope, although the supply of cold water for purposes that eventually involve hot water is part of the scope.

This water demand profile study will examine cold water use by six end-use (customer) categories as listed below:

1. **Residential Normal & Low-income Single-family**
2. **Residential Low-income Multi-family**
3. **Commercial**
4. **Industrial**
5. **Public Buildings**
6. **Agriculture**

This research plan elaborates on the methodologies anticipated for determining the water demand profiles from these categories. Table 1 summarizes the baseline water demand profiles that will be measured, the anticipated sample/participant size and type of data being generated for each end-use customer category.

**Table 1. End-use category research profiles, sample/participant size and data**

| End-use Category | Water Demand Profile Categories | Anticipated Sample OR Participant Size | Source of Hourly Demand Profile Data |
|---|---|---|---|
| Residential<br>• Normal and Low-income<br>• Single-family | • Baths and showers<br>• Toilets<br>• Clothes washers<br>• Dishwashers<br>• Irrigation<br>• Other uses | Sample – TBD | From existing database |
| Residential<br>• Low-income<br>• Multi-family | | Sample – 150 individually metered units | From IRWD, EBMUD and City of San Diego customer flow trace |
| Commercial | • Domestic/indoor<br>• Process<br>• Continuous | Participants – Sub-categories and site data TBD | From existing database |
| Industrial | • Domestic/indoor<br>• Outdoor<br>• Process | Participants – Sub-categories with about 12 study sites | From customer flow trace and site water use review |
| Public Buildings | • Domestic/indoor<br>• Outdoor<br>• Continuous | Participants – 10-30 buildings | From customer flow trace |
| Agriculture | • Process | Participants – Approximately 10 study sites | From customer flow trace and site water use review |

This research plan addresses the requirements of Study 3 as specified in RFP CP1-007-08. As will be detailed below, much of the data requested by the RFP has already been collected by Aquacraft in previous water demand profiling studies and will also be provided by studies currently being conducted in California. By the end of 2008 Aquacraft will have detailed end-use hourly demand profile data from a sample of more than 700 single-family homes sampled from 15 geographically distributed water utilities in California as part of a statewide CALFED funded study. As a result, it will be possible to generate much of the information needed for this study without having to undertake additional field work in the residential single-family end-use category. Similarly, a significant amount of water use data from California's commercial end-use sector already exists, possibly eliminating the need to dedicate resources to collecting these customer data. This means that more time and effort can be spent acquiring better data on the residential multi-family, public buildings, industrial and agriculture categories, for which there exists far less reliable end-use data.

The aforementioned existing residential single-family and commercial end-use data, both in Aquacraft's existing database and which are currently being collected, are in the form of what is referred to as flow traces, which are precise recordings of the flow of water through a meter at 10-second intervals. Typically, these flow traces are 2 weeks long for single-family studies and as short as a few days for commercial accounts. At the 10-second logging interval the flow trace data reveals a surprising amount of detail about water uses. Specifically, it is often possible to recognize individual uses of water from their characteristic peaks, durations, volumes, and shapes on the graph. Since the graphs are all plotted against the time of day, it is possible to extract time series information on many individual or category uses, which will provide the demand profiles required for converting the affects water conservation measures into energy load profile impacts at California water/wastewater systems.

## *2.1 The Basics of Flow Trace Analysis*

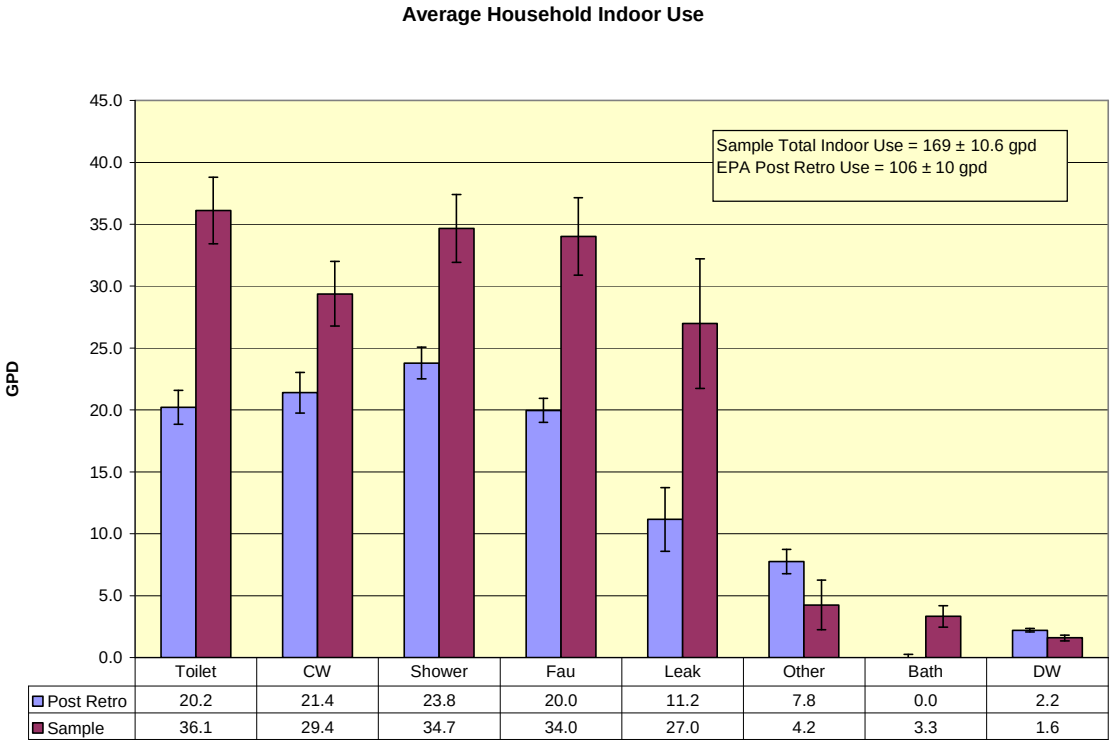
The purpose of flow trace analysis is to obtain precise information about water use patterns: Where, when, and how much water is used by a variety of devices including toilets, showers, baths, faucets, clothes washers, dishwashers, hand-held and automatic irrigation systems, evaporative coolers, home water treatment systems, leaks, and more. The collected data are precise enough that individual water use events such as a toilet flush or a clothes washer cycle or miscellaneous tap use can be isolated, quantified and then identified. This technique makes it possible to disaggregate most of the water use in a residential home and to quantify the effect of many conservation measures, from toilet and faucet retrofit programs to behavior modification efforts. It is also possible to disaggregate water use into more coarse categories. For example the changes in water use from much larger end user categories with large meters serving their water demands (ie. industrial facilities) can be to measured by demand profile changes in domestic/indoor, process and other category water uses.

The flow trace methodology is based on the fact that there is consistency in the flow trace patterns of most residential water uses. A specific toilet will generally flush with the same volume and flow rate day in and day out. A specific dishwasher exhibits the same series of flow patterns every time it is run. The same is true for clothes washers, showers, irrigation systems, etc. By recording flow data at 10-second intervals, a rate determined by Aquacraft to optimize accuracy and logger memory, the resulting flow trace is accurate enough to quantify and categorize almost all individual water uses in each study home.

Trace Wizard is a software package developed by Aquacraft Inc., specifically for the purpose of analyzing flow trace data. Trace Wizard provides the analyst with powerful signal processing tools and a library of flow trace patterns for recognizing a variety of residential fixtures. Any consistent flow pattern can be isolated, quantified, and categorized using Trace Wizard including leaks, evaporative coolers, humidifiers, and swimming pools. Once all the water use events have been isolated and quantified and statistics generated, Trace Wizard implements a user defined set of parameters developed

for each individual study residence to categorize the water use events and assign a specific fixture designation to each event.

Figure 2 shows a typical analysis that can be performed on household flow traces with Trace Wizard software. In this example of a sample of single-family homes, the average baseline water demand profile for each of the domestic categories is shown. These baseline data results are compared against a test group of homes in which the fixtures and appliances (minus the dish washers) were retrofit to best available technology (circa 2000). This provides a clear comparison of the performance of the sample water demand profile against a known benchmark group.




| | Toilet | CW | Shower | Fau | Leak | Other | Bath | DW |
|---|---|---|---|---|---|---|---|---|
| Post Retro | 20.2 | 21.4 | 23.8 | 20.0 | 11.2 | 7.8 | 0.0 | 2.2 |
| Sample | 36.1 | 29.4 | 34.7 | 34.0 | 27.0 | 4.2 | 3.3 | 1.6 |

**Figure 2: Example of water use analysis with flow trace data disaggregated by Trace Wizard**

The hourly water demand profiles that will be generated in this study for the six categories of end uses may reliably be used as benchmarks to predict how much, when and where water is being used.

The flow trace analysis technique and the Trace Wizard software have been used as the fundamental analytic tool in a number of residential, commercial, industrial and institutional water use studies both in the U.S. and worldwide including:

- Heatherwood Residential End-use and Retrofit Studies – 1995-96, Aquacraft
- Westminster Water Use Study – 1998, Aquacraft
- Perth Residential End Uses of Water Study – 1999, Australia
- Residential End Uses of Water – 1999, AWWA
- Commercial and Institutional End Uses of Water – 2000, AWWA
- Pinellas County Utilities Water Conservation Opportunities Study – 2002, Aquacraft

- Seattle Market Penetration Study – 2003, Aquacraft
- Yarra Valley Water District Residential End-use Study – 2003, Australia
- EPA Residential Retrofit Studies (Seattle, EBMUD, Tampa) – 2004, Aquacraft
- Water Efficiency Opportunities in California Supermarkets – 2004, Aquacraft
- Monterey Pre-Rinse Spray Valve Study – 2005, Quantec
- Regional Water Authority of Sacramento CII Studies – 2005, Aquacraft
- Santa Paula Residential End-use Study – 2006, RBF Consulting
- New Zealand Residential Demand Study – 2007, Branz
- Lathrop and American Canyon, CA End-use Studies – 2008, RBF Consulting
- California (CALFED) Residential End-use Baseline Study – 2009, Aquacraft
- Gold Coast Water Residential End-use Study – 2009, Australia

Validation studies have been performed on the flow trace methodology. Numerous studies by researchers across the globe have confirmed the repeatability and reliability of the method's results. Below are two examples of two validation studies that validate the Flow Trace Analysis Methodology when using Trace Wizard.

National Renewable Energy Lab (In progress) Research confirming accuracy of Trace Wizard flow trace desegregation at >90% for indoor residential fixtures. Researcher - Lee Magnusson. To be published in 2009.

DeOreo, W.B., J.P. Heaney, and P.W. Mayer. 1996. *Flow Trace Analysis to Assess Water Use*. Journal of the American Water Works Association. Vol.88, No. 1, January.

## *2.2 Sampling and Participant Selection*

This research plan explains the methods and task that will be employed to ensure researchers study a representative sample from residential single-family & Multi-family end user categories. The industrial end-use category will employ the same methodology as is described in this plan for the commercial category in Section 5.3. The commercial methodology was developed for the 2000 American Water Works Association Research Foundation study, "*Commercial and Institutional End Uses of Water*".

Commercial and industrial category end uses are heterogeneous with highly variable water demand profiles. Therefore, candidate study sites of each of these two will be separated into sub-categories based on their having the most intense water use on a per site basis and their representing as a sub-category the largest proportion of water use by their category. Selection within the high water using sub-categories will be further narrowed down to those candidates that have the highest potential for measures that will lead to water conservation/savings. For example, industrial sub-categories may include high water using manufacturing, processing, refining and energy generation industries. However, the latter sub-category, energy generation facilities, may not offer a significant potential for measurable improvements to the efficiency of water use. For the industrial category it is estimated that a total of 12 complete industrial water use reviews will be

performed on industries representing the major water uses from various water agency service areas in California.

Public Building end-use customer category participants will represent a cross section of buildings from various California water utilities in the northern and southern regions. For the agriculture category Aquacraft will identify the largest water using agricultural water customers and will select as balanced a sample as possible of agricultural users who obtain water from potable water systems in important agricultural regions of the state.

# 3.0 Discussion of Aquacraft Research Plan and RFP CP1-007-08

A key to our understanding of this research project comes from Figure 1 in RFP CP1-007-08 (this is the modified Figure 1 diagram in Section 2.0). That figure shows that this study is aimed at an analysis of water use in California's treated water distribution system at the end-use level. The figure shows a flow diagram in which all of the water to be studied flows from raw water sources, through water treatment systems and distribution systems and then to the end-users. In the problem statement for Study 3 this notion is reinforced in that the language clearly refers to water demand profiles at the water agency. In the context of the RFP "end-use" refers to the category of customer: residential, commercial, industrial, public buildings and agriculture. In other words, at a large scale level rather than the level of individual types of fixtures and appliances. This understanding was the basis for much of the details of the proposal and this research plan.

The first paragraph of our proposal stated the research question, which was how changes in efficiencies of water use at the end-use (customer) level affect energy load profiles at the *water agencies*.

The types of demand profiles that are anticipated in the proposal were hourly profiles of demands for customer categories (i.e. end-uses as defined in the RFP). To the extent that study sites are sub-metered and existing data are available to break demands down into fixtures and appliances this will be done, but the overall goal is to collect accurate time of use data at the customer level and to disaggregate this into demand profiles of domestic/indoor, outdoor, process and continuous uses (see Table 1).

Since the RFP made it clear that the water use cycles in question passed through water treatment and distribution, Aquacraft assumed that profiles for private wells or pumping from decreed surface supplies would not be part of the analysis. This is most applicable for industrial and agricultural end-uses. The implication for agriculture is that Aquacraft would be dealing with a sub-set of agriculture that obtains its water supply from treated supplies, and not for agriculture for the entire state[2].

[2] Aquacraft felt that both CPUC D. 07-12-05 and RFP CP1-007-08 were clear in wanting information that could be translated into the relationship between customer water use profiles and energy demand at the "water agency". Consequently, non water agency water sources are not part of this study. CPUC confirms

Another key element in understanding the RFP involves the extent of sub-metering to be done in disaggregating demands for individual customers. Aquacraft's clear preference and recommendation is to do as little sub-metering as possible and to rely on obtaining as much information from a flow trace obtained from the main water meter serving the site as possible. Aquacraft's experience has been that it is frequently impossible to install sub-meters within public buildings and commercial facilities (and likely in industrial facilities) for disaggregating water use. For example, the plumbing within the building is often inaccessible without tearing into walls, and even if accessible, in many buildings there may be so many cross feeds within the building that no one location can be found that feeds, say, all of the bathrooms in the building, or even all of the bathrooms in on one portion of the building. This leaves the option of attempting to install event loggers on individual fixtures and appliances. Such an effort is not technically impossible, but experience has shown that elaborate networks of data loggers and sensors are prone to errors and failures and would require much more time and budget than is available for this study.

This is not to say that where an opportunity exists to obtain data from major water using devices, such as cooling towers, we will not do so, but these efforts will be based on the opportunity afforded by the facility itself and the value of the data in comparison to the cost of obtaining it.

Aquacraft's preference is to use as much of the data as possible from previous studies to generate water demand profiles at the end-use level without going back to repeat work that has already been done, and thus to save as much budget as possible for doing new work in areas where the data is not there.

The objective of this study is to collect as large a set of demand profiles as possible from the six categories of customers in order to get better information on how their average daily demand affects the hourly demands upon the water agencies. In this research plan's approach, the disaggregating in the non-residential categories (domestic/indoor, outdoor, process and continuous uses) will be more limited than the disaggregate information in residential categories. Our intention is to focus on getting a larger volume of demand profile data from non-residential water agency customers rather than expending a large amount of effort and time in doing highly detailed end-use studies on a small selection of customers.

According to the RFP one of the main goals of the study is to obtain data that will ultimately be used to update the CPUC Water-Energy Measure Calculator. Aquacraft will consider exactly what data this model needs, and will concentrate efforts more on obtaining key output data and less on ancillary information. Although, where there is important ancillary information, such as a study site's IOU energy provider(s) or the CEC climate zone within which it resides, is beneficial to the broader research effort, these data will be recorded.

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that Aquacraft's interpretation of this language in the Decision is approved for purposes of the study; thus limiting the scope of the study in the agricultural domain to water served by water/wastewater agencies.

# 4.0 Discussion of Drought Restrictions and Data

Aquacraft Inc. recognizes the importance of accounting for the impacts of drought restrictions on data collected during the study, but we need to point out that this is not a study of the impact of drought restrictions on hourly demand patterns. On February 28, 2008 Governor Schwarzenegger called for a "plan to achieve a 20 percent reduction in per capita water use statewide by 2020". Then in June 2008 the Governor issued a statewide drought declaration, with Executive Order S-06-08 directing the California Department of Water Resources to take immediate actions that address the state's current and anticipated drought and the associated water supply/delivery limitations. Water agencies are responding by ramping up conservation measures, with some already implementing mandatory water use restrictions. These developments pose challenges to the Study 3 research plan. The Aquacraft research team is aware of this problem and how it might affect the analysis of existing flow trace data being used for determining demand profiles for the Residential Single-family and Commercial end use categories.

Very little of the existing data that we propose to use as input for the current study is impacted by drought restrictions. Consequently, we will not have to make adjustments to those data in order to eliminate impacts of restrictions. Our working hypothesis is that drought restrictions will impact the volumes of use much more than the times of use. For example, we doubt that drought restrictions will cause businesses to change their hours of operation, but would (hopefully) cause them to reduce the volumes of water used during their operating hours. Similarly, irrigation restrictions are not likely to cause people to change the general time of day that they water, but would cause watering to occur on fewer days, and for shorter periods of time. The existing data then is likely to show similar hourly usage patterns, but with varying volumes. In other words, the volumes used my change but the time of use would remain constant. The shapes and the curves of percentages will be less impacted by drought.

It should also be kept in mind for changes in the timing of use to impact water agency energy demands they have to be significant. Shifts need to move volumes of water use from peak electric demand periods to non-peak (or vice-versa). Consequently, if drought restrictions cause small inter-hour changes in water use these are not likely to impact the water energy relationships for the agency.

In order to confirm these hypotheses Aquacraft will first note the specific nature of drought restrictions in place at each of the study sites included in the 2009 data collection effort. Knowing the nature of the restrictions and the types of water use they impact will allow us to make reasonable adjustments for how they might impact water use on the site. For example, if drought restrictions reduce or eliminate the use of evaporative cooling towers we would need to know this, and make appropriate adjustments to the use patterns. A useful way to do this would be to use prior year billing data as a baseline. If irrigation restrictions are in place it should be possible to back out their effect using prior billing data and information about ET and irrigated areas on the site. Each case will have to be handled as a unique situation.

The goal of the drought restriction analysis will be to back out the effect of any drought or other water supply restriction (such as the Endangered Species Act ruling regarding the Delta Smelt) imposed on the sites during the data collection period in order to generate baseline hourly demand profiles for indoor uses, outdoor uses and continuous uses for each site. Given good baseline estimates the demand patterns can then be modified as seems best to account for a wide range of demand management measures.

# 5.0 Research Plan Methodology

## *5.1 Residential Normal and Low-income Single-family*

Aquacraft maintains extensive data sets of water demand profiles from residential single-family customers. These data have been collected from 1995 to the present from cities in California and across North America and come from homes covering the full spectrum of income levels. This research plan methodology for the residential single-family end-use customer category will take advantage of existing data to develop demand profiles for the 6 water use categories. These are baths and showers, toilets, clothes washers, dish washers, irrigation and other uses. In addition, Aquacraft data sets include profiles of leakage and miscellaneous faucet use, which are recommended for inclusion in the water demand profile as well.

For the residential single-family end-use category Aquacraft is using hourly demand profile data from a statewide CALFED study that is slated for completion early 2009. This water use data is representative of the household water use patterns existing within each of the study's respective 15 water agency service areas. It is worth noting here that for each water agency service area the sample of homes studied and their water use patterns may not be representative of the broader energy IOU service area.

As part of the CALFED study a detailed survey of key household characteristics was collected for study homes. According to the CALFED Draft Report, previous studies have shown that several demographic factors are strongly correlated with the amount of water used by single-family customers, the most notable being the size of the home and the number of residents in the home. Other factors (number of customers, customer characteristics, local weather data, the agency's water supply and the customer demands, water and sewer rates, and rate structures), while less strongly correlated, will also be presented for their potential use in characterizing the sample (from the water agency service area) in comparison to the State of California as a whole.

Aquacraft's major studies of single-family water use have generally started with a random sample selection of water agency customers based on historic billing data. Samples are selected such that the annual water use patterns of the sample matches those of the population of single-family customers (within a water agency service area) at the 95% confidence level.

A specific example of this sampling methodology, which uses billed water demand as the sole selection criteria, was used in the CALFED study. A section on the single-family home sampling methods from the CALFED draft report is copied in Figure 3 below to provide more detail on the representativeness of the data that are being used in this research effort[3].

***Redwood City Logging Sample***
*Using the selection procedure described above, the Redwood City staff provided the descriptive statistics for their entire population of single-family homes, and then selected a random group of approximately 1,000 homes from which the logging sample was to be selected. Table 0-1 shows the summary statistics for the three groups of homes. Records were extracted for a total of 15,777 single-family accounts in the Redwood City service area. The average annual consumption of the entire population was 101 kgal. The median annual consumption was 88.3 kgal. The statistics for the 1000 home sample ($Q_{1000}$) matched those of the population very closely, as shown in the table. A total of 70 homes were selected from the $Q_{1000.}$ After houses with less than 15 kgal/yr of consumption, houses which declined to participate and houses that were found to be unusable in the field—for instance because of a bad meter or vacancy—were trimmed from the sample the final group of 60 homes on which loggers were installed had an average annual use of 106 kgal and a median use of 98 kgal. Elimination of the houses with very low, or only partial year consumption caused the mean of the logging group to be slightly larger than the mean of the population, but was thought to constitute a more meaningful sample because of this trimming.*

*Table 0-1: Summary Statistics for Redwood City Logging Sample*

| | ***Population*** | ***$Q_{1000}$*** | ***Log Sample $Q_{60}$*** |
|---|---|---|---|
| | *Kgal* | *Kgal* | *Kgal* |
| *Mean* | *101.09* | *101.66* | *105.89* |
| *95% Conf. Interval* | *1.04* | *4.10* | *13.45* |
| *Median* | *88.26* | *88.26* | *98.36* |
| *Count* | *15777* | *1046* | *60* |

**Figure 3 Example of sampling methodology used in CALFED study**

In the CALFED study flow data recorders (data loggers) were attached to the household water meter and used to collect the flow trace files, which were disaggregated using the Trace Wizard program. The disaggregated data are assembled into water use event databases. In these databases, each water use "event" (i.e. toilet flush, shower, clothes washer cycle, faucet draw, etc.) is a unique record which includes the following statistics: water use category, volume, start time, end time, duration, max flow rate and mode flow rate as well as a unique ID number that identifies the house from which the data were obtained. Also available are survey data linked to the house codes that tell the value of the home and in some cases the income of the home owners. On a small set of approximately 30 homes from EBMUD, flow trace data of hot water demands are also available, obtained from sub-meters installed on the feed lines to hot water tanks. The combined data sets include over one and a half million disaggregated water use events from more than 700 residential single-family homes.

In an effort to determine the end-use water demand profiles for each of the six major residential water use categories (baths and showers, toilets, clothes washers, dishwashers, irrigation uses and other additional uses), Aquacraft will work with existing CALFED study data sets to develop demand profiles. Table 3 provides an example of the tabular

[3] DeOreo, W.B., et al, 2009. CALIFORNIA SINGLE-FAMILY WATER USE EFFICIENCY STUDY ***DRAFT REPORT***.

information that will result from Aquacraft measuring water demand profiles in residential single-family homes. These data are from the 1999 AWWA Residential End-use of Water Study and show what percentage of the total water usage is used on an hourly basis for each category of water use across twelve water agency service areas, including the City of San Diego Water Dept and Las Virgenes Municipal Water District (Mayer, P.W., et al, 1999). This type of data table will be useful in updating the CPUC Water-Energy Measure Calculator.

**Table 3 Output of Single-family home data - % of Total Indoor Water Use By Category**

| Hour of day | Toilets | Showers | Clothes washers | Faucets | Dishwashers | Baths | Other domestic | Total |
|---|---|---|---|---|---|---|---|---|
| 1:00am | 0.7% | 0.2% | 0.2% | 0.2% | 0.0% | 0.0% | 0.1% | 1.4% |
| 2:00am | 0.5% | 0.1% | 0.1% | 0.1% | 0.0% | 0.0% | 0.1% | 0.9% |
| 3:00am | 0.4% | 0.1% | 0.0% | 0.1% | 0.0% | 0.0% | 0.2% | 0.8% |
| 4:00am | 0.3% | 0.1% | 0.0% | 0.1% | 0.0% | 0.0% | 0.3% | 0.9% |
| 5:00am | 0.4% | 0.3% | 0.0% | 0.1% | 0.0% | 0.0% | 0.2% | 1.1% |
| 6:00 am | 0.8% | 1.1% | 0.1% | 0.3% | 0.0% | 0.0% | 0.1% | 2.5% |
| 7:00 am | 1.5% | 2.4% | 0.4% | 0.7% | 0.0% | 0.1% | 0.1% | 5.2% |
| 8:00 am | 2.0% | 2.4% | 1.1% | 1.1% | 0.1% | 0.1% | 0.1% | 6.7% |
| 9:00 am | 1.8% | 2.0% | 1.8% | 1.1% | 0.1% | 0.1% | 0.1% | 7.0% |
| 10:00am | 1.6% | 1.5% | 2.3% | 1.1% | 0.1% | 0.1% | 0.1% | 6.8% |
| 11:00am | 1.4% | 1.2% | 2.4% | 1.0% | 0.1% | 0.1% | 0.1% | 6.3% |
| 12:00pm | 1.3% | 1.0% | 2.0% | 0.9% | 0.1% | 0.1% | 0.3% | 5.6% |
| 1:00pm | 1.3% | 0.7% | 1.9% | 0.9% | 0.1% | 0.1% | 0.1% | 4.9% |
| 2:00pm | 1.2% | 0.6% | 1.7% | 0.8% | 0.1% | 0.0% | 0.1% | 4.5% |
| 3:00pm | 1.2% | 0.5% | 1.5% | 0.7% | 0.1% | 0.1% | 0.1% | 4.1% |
| 4:00pm | 1.3% | 0.5% | 1.4% | 0.8% | 0.1% | 0.1% | 0.1% | 4.2% |
| 5:00pm | 1.4% | 0.6% | 1.4% | 0.9% | 0.1% | 0.1% | 0.1% | 4.5% |
| 6:00pm | 1.6% | 0.8% | 1.4% | 1.1% | 0.1% | 0.1% | 0.1% | 5.1% |
| 7:00pm | 1.6% | 0.9% | 1.4% | 1.3% | 0.1% | 0.2% | 0.1% | 5.5% |
| 8:00pm | 1.5% | 0.9% | 1.4% | 1.2% | 0.1% | 0.2% | 0.1% | 5.5% |
| 9:00pm | 1.5% | 0.8% | 1.2% | 1.0% | 0.1% | 0.2% | 0.1% | 5.1% |
| 10:00pm | 1.6% | 0.8% | 1.0% | 0.9% | 0.1% | 0.2% | 0.1% | 4.7% |
| 11:00pm | 1.6% | 0.6% | 0.7% | 0.7% | 0.1% | 0.1% | 0.1% | 3.9% |
| 12:00am | 1.2% | 0.4% | 0.3% | 0.5% | 0.1% | 0.1% | 0.1% | 2.7% |
| | | | | | | | **Total** | **100%** |

The % of Total Indoor Water Use By Category is useful when interested in overall household water use. But when there are questions regarding a specific measure that will affect household water use in a single category then different tabular data are necessary. Tables 4 and 5 show examples of alternative outputs resulting from Aquacraft measuring water demand profiles in single-family homes, the percentage of total hourly indoor use attributable to individual end-use categories (toilets and showers).

**Table 4 Percentage of total hourly toilet use**

| Hour of day | Toilets |
|---|---|
| 1:00am | 2.4% |
| 2:00am | 1.5% |
| 3:00am | 1.2% |
| 4:00am | 1.1% |
| 5:00am | 1.5% |
| 6:00 am | 2.8% |
| 7:00 am | 5.1% |
| 8:00 am | 6.6% |
| 9:00 am | 6.1% |
| 10:00am | 5.5% |
| 11:00am | 4.8% |
| 12:00pm | 4.4% |
| 1:00pm | 4.3% |
| 2:00pm | 4.1% |
| 3:00pm | 4.1% |
| 4:00pm | 4.3% |
| 5:00pm | 4.7% |
| 6:00pm | 5.2% |
| 7:00pm | 5.3% |
| 8:00pm | 5.1% |
| 9:00pm | 5.1% |
| 10:00pm | 5.5% |
| 11:00pm | 5.3% |
| 12:00am | 4.0% |
| **TOTAL** | **100%** |

**Table 5 Percentage of total hourly shower use**

| Hour of day | Showers |
|---|---|
| 1:00am | 0.9% |
| 2:00am | 0.4% |
| 3:00am | 0.3% |
| 4:00am | 0.5% |
| 5:00am | 1.2% |
| 6:00 am | 5.2% |
| 7:00 am | 11.8% |
| 8:00 am | 11.7% |
| 9:00 am | 9.6% |
| 10:00am | 7.5% |
| 11:00am | 6.0% |
| 12:00pm | 4.8% |
| 1:00pm | 3.5% |
| 2:00pm | 2.9% |
| 3:00pm | 2.5% |
| 4:00pm | 2.6% |
| 5:00pm | 3.0% |
| 6:00pm | 3.9% |
| 7:00pm | 4.3% |
| 8:00pm | 4.3% |
| 9:00pm | 4.1% |
| 10:00pm | 4.0% |
| 11:00pm | 2.9% |
| 12:00am | 2.2% |
| **TOTAL** | **100%** |

Hourly end-use profiles may be expressed in terms of the percent of total by category in order to normalize the results, and make them easier to apply to a wider variety of homes in each water agency service area. Furthermore, customer information may also be used to see if relationships exist in the water demand profiles with respect to either income of the homeowners or estimated value of the homes. Figure 4 displays and example of the type of analysis that will be possible with these data. This particular analysis (a plot of the data in Table 3) shows the single-family residential hourly demand profile for indoor uses (Mayer, P.W., et al, 1999).

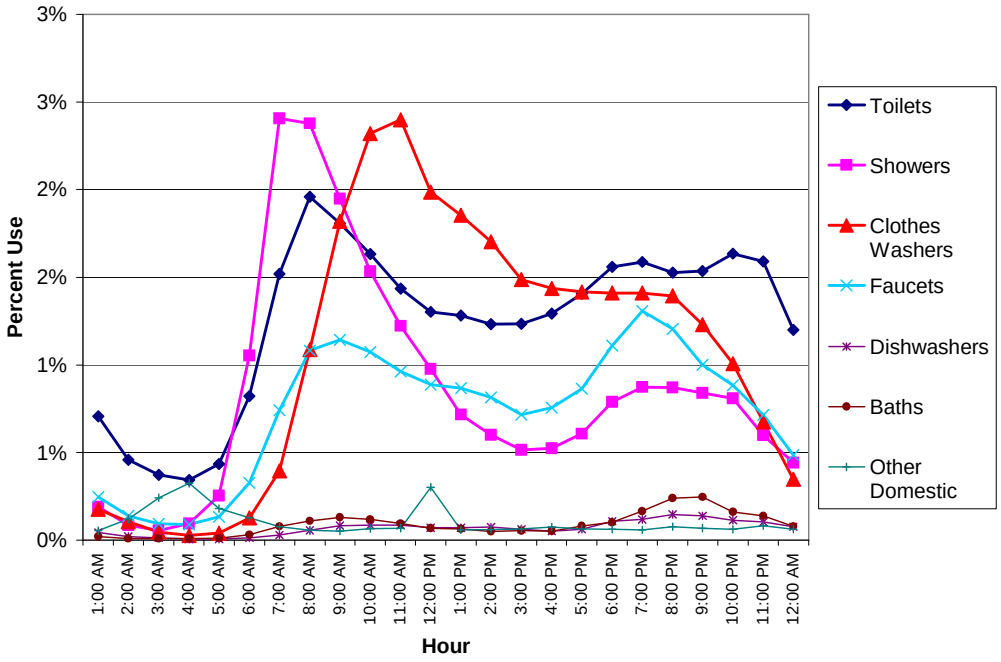


**Figure 4 Disaggregated indoor hourly use patterns, averaged across 12 study sites**

## *5.1.1 Residential Single-family - Tasks*

### Task 1. Assemble data from previous single-family studies in California.

As mentioned above, Aquacraft maintains a large data set of single-family residential flow traces in California and from many water agency service areas in both northern and southern regions. Over the past two years Aquacraft has obtained detailed end-use data from representative samples of single-family homes in both northern and southern California cities as part of a CALFED funded research project[4]. The overall sample, which includes approximately 700 households, should provide an excellent cross section of residential demands in the State. The customer sites where these data were collected

[4] Aquacraft Inc. is the lead firm in this study of water demands from single family homes began in 2005 and is scheduled for completion December 2008. Fifteen water utilities throughout the State of California have participated in the study resulting accurate disaggregated water use data from over 700 households.

were sampled from their respective water agency customer list based on historic billing data. In each case the sample was selected such that the annual water use patterns of the sample matches those of the population of single-family customers at the 95% confidence level. Aquacraft proposes to use the end-use data collected from the CALFED research in this study task to develop water demand profiles for single-family homes.

### Task 2. Create time series summaries by individual water use for these homes.

The hourly water demand profiles have been determined using analysis with Trace Wizard software. These same disaggregated flow trace data, which are stored according to a unique ID will be collected from the Aquacraft database. Accompanying these data are detailed survey data, also stored in the Aquacraft database with a unique ID. Indoor and domestic uses will include toilet flush, shower, clothes washer cycle, faucet draw, dishwasher, bath, water softening, leaks, irrigation use etc.

### Task 3. Normalize category water use into demand profiles showing percent of category use on hourly basis.

Using the extensive data set from the CALFED California end-use study, Aquacraft will construct hourly demand profiles of water demands similar to those presented in Figure 2. These profiles will include total use, indoor use, outdoor use, and use by each identified fixture. These diurnal curves will show the volumes of water used for each category and the percent of the daily category use occurring during each hour. These demand profiles will be used by the Water-Energy Measure Calculator to determine peak, off-peak, and continuous flow components of residential water demand in the homes.

### Task 4. Analyze profiles for range of home values to identify which categories of use are affected by key economic factors such as income, home value, and cost of water.

Using the survey response data from the CALFED study, Aquacraft will evaluate the economic factors that may influence water use. Included in this analysis will be income, demographic data (number and age of occupants), and the cost of water paid by each customer as well as the water rate structure employed by the agency. Both historic billing data and data logged end-use data can be used for this task. The impact of income and other factors on peak, off-peak, and continuous demand will also be examined.

### Task 5. Evaluate differences in indoor water use patterns based on income (or surrogate value).

How do economic difference impact water use? This important question will be tackled using the data set developed for Task 4. Household income will be used as the independent variable and indoor water use as the dependent variable in a regression analysis. If differences are found they will be further examined using the available disaggregated end uses. If income impacts indoor use, which uses are particularly effected? Multivariate regression models developed for the CALFED study will be used to examine this and other questions. Key differences such as the price of water and

regional climate will be controlled for in the model. The impact of income and other factors on peak, off-peak, and continuous demand will also be examined.

### Task 6. Determine separate profiles for irrigation use for homes with and without sprinkler systems.

Using the data from the CALFED study, homes with an in-ground sprinkler system will be identified as will homes that manually irrigate. Aquacraft has conducted this type of analysis comparing these two groups on several occasions in the past and it often presents a distinct contrast.

Once the two groups are identified, demand profiles will be developed based on both gallons per day of irrigation use and the percent of total demand occurring on an hourly basis. This will allow water demand curves to be modified based on the best estimate of local demands. Demands can also be examined in terms of gallons per household per day for peak and off-peak periods. Irrigation is a key component of the peak day demands at many utilities. With this in mind, irrigation demands will be examined and data sets developed that can be used in a wide variety of modeling tools for years to come. Aquacraft will compare annual domestic/indoor water demand (measured from flow trace data) with a study site's billed historic water use. Since domestic/indoor water uses do not typically change from month to month, then monthly water use in excess of that volume will be considered a good estimate of monthly irrigation use; thus capturing the seasonal variation of irrigation water demand.

### Task 7. Prepare report on results with profiles.

The results of these tasks will be developed into a clear and concise report along with the flow profiles developed. In addition, electronic data sets in Excel format will be provided that can be used for modeling purposes.

The report will describe the full methodology employed in the study including all sampling, data collection, data preparation, and analysis. Results will be summarized into an executive summary and also presented in full detail in the body of the report. The report will also include a full bibliography.

## *5.2 Residential Low-income Multi-family*

Aquacraft maintains a considerable database of annual water use by multi-family customers, collected as part of the 2004 National Sub-metering and Billing Allocation Program Study (available for free download from www.aquacraft.com), but these data are not disaggregated by apartment unit or disaggregated into individual water uses (Mayer, P.W., et al, 2004). Rather, most of the multi-family data are from a single master meter serving a number of units. However, Aquacraft does have a list of individually metered multi-family properties in California from which a sample of the lowest income range will be selected. This list will also be supplemented by selecting additional low-income, individually metered (i.e. sub-metered) properties in California. Additionally, Aquacraft has performed demand profiling research throughout California and maintains a good

working relationship with various water agencies known to have a good number of sub metered multifamily customers.

From these data sets a sample of approximately 150 of low-income sub metered multi-family units will be selected and data logged in the same way that single-family homes were logged in the CALFED study. Data loggers will also be placed on the meters supplying the irrigation systems for these properties. The flow trace data collected from the data logging will be analyzed and disaggregated using Trace Wizard into the category water uses (baths and showers, toilets, clothes washers, dishwashers, irrigation uses and other additional uses). Using this methodology, disaggregated water use information will then be available for the domestic and irrigation demands for a sample of low-income multi-family properties, creating a similar data set to those created for the single-family accounts.

Similarly to Aquacraft's major studies of single-family water use sample selection discussed in Section 5.1, a random sampling methodology that uses historic water use patterns as the sole selection criteria will be used in the residential low-income multi-family end-use category. Using water agency customers' historic (monthly or bimonthly) billing data, samples will be selected such that the annual water use patterns of the sample matches those of the population of multi-family customers (within the respective water agency service area) at the 95% confidence level. For each water agency service area the sample of homes studied and their water use patterns may not be representative of the broader energy IOU service area.

Since the same end-use water demand profiles for each of the six major residential water use categories (baths and showers, toilets, clothes washers, dishwashers, irrigation uses and other additional uses) will be generated for multi-family homes as was single-family homes, Aquacraft will develop a database of disaggregated water use events for the logged multi-family units. Tables 3-5 in Section 5.1 of this Research Plan provide an example of the type of tabular information that will result from Aquacraft measuring water demand profiles in residential multi-family homes. These tabular data outputs will be used to update the CPUC Water-Energy Measure Calculator.

### *5.2.1 Residential Multi-family – Task Description*

#### Task 1. Identify candidate low-income, individually metered multi-family properties from the National Sub-metering study and other California sites.

As part of the 2004 National Sub-metering Study post card surveys were mailed to all of the multi-family properties in 12 large water providers in the U.S.. Two of these, EBMUD and San Diego City were in California. The purpose of this survey was to determine the billing method used for water at the properties (Mayer, P.W., et al, 2004). In addition, we know that Irvine Ranch Water District (IRWD) has a large number of individually metered multi-family properties. Consequently, we can use this information to obtain the names and addresses of individually metered multi-family properties in

three large water agency service areas in California. Table 6 shows the water utilities and the expected number of multi-family properties/units.

**Table 6: Numbers of sub-metered multi-family properties in three California water agencies**

| Agency | Number of Individually Metered Multi-family properties |
|---|---|
| Irvine Ranch | 4657 (units) |
| San Diego City | 42 |
| EBMUD (Oakland) | 8 |

At this point we do not know the number of individual units contained in the San Diego and Oakland properties, and we do not know how many properties the IRWD units are located in, but we do know that these three agencies contain individually metered multi-family apartments. The exact numbers will need to be determined as part of the data collection process. Aquacraft will identify low-income properties through interviews with local officials and use of HUD and Section 8 criteria.

## Task 2. Solicit participation from key water/wastewater utilities.

Aquacraft will request the co-operation of IRWD, San Diego and EBMUD. Since Aquacraft has performed a significant amount of research in these water agency service areas and maintain a good working relationship with them, their co-operation in this study is anticipated.

## Task 3. Obtain historic billing data from participating water utilities.

Three years of historic customer billing data from the targeted individually metered multi-family households will be acquired from participating water utilities. Typically these data are recorded and the water customer billed either monthly or by-monthly, providing a coarse record of total annual water use patterns. Included in this tabular data will be a customer ID number (to maintain confidentiality), address, water meter ID number and water meter size, make and model, as well as historic monthly usage data.

## Task 4. Select a random sample of 150 multi-family units for end-use monitoring.

Survey responses were originally envisioned in the proposal to provide a population of units to sample from. The survey will not provide essential information for the study, and will greatly limit the number of eligible units for logging. Given the requirement that this study focus on low- income units a response rate greater than 10% cannot be expected, thus limiting the size of our population. This Research Plan mentions Aquacraft's 2004 National Sub-metering Study. This study did not consider income a selection criterion. Out of the 15,697 units surveyed only 2,345 responded, a response rate of 16.4%. From Aquacraft's experience in studies that utilized a survey instrument, it is not believed that the responding population from this study will be large enough to assure obtaining the necessary 150 unbiased responses.

In place of the a-priori surveys Aquacraft will obtain information from property managers about the nature of the residences at the time of the field visits. This information will represent 100% of the study units and will allow evaluators to confirm that they are typical of other low-income multi-family units. The attributes of this on site data

gathering will include the number of bedrooms in the units (which serves as a proxy for the number of residents), whether the units have clothes washers, and the definition used to classify them as low income.
Aquacraft does have a list of individually metered multi-family properties in California from which a sample of the lowest income range will be selected. Study sites are anticipated at individually metered multi-family units known to exist in the IRWD, San Diego and EBMUD water agency service areas. The plan is to choose a random sample of 150 low-income units at 50 units per study site. This should provide sufficient data at each site to obtain statistically meaningful results for each site. The goal will be to insure that the sample groups' water use statistics match those of the populations from which they were drawn at each site.

The sample residences will be selected using a random process that stratifies on the basis of the customers' annual water use patterns (from historic billing data). This maximizes the probability of having an unbiased sample that matches the water use characteristics of the population. No attempt will be made to select homes on the basis of geography or other demographic parameter. Water use is the sole selection criteria. The following steps will be followed for selecting samples in each agency:

- A complete list of the low-income multi family billing data will be obtained for the most recent calendar year just prior to the logging year.
- The file will be screened to eliminate incomplete records (i.e. partial years of data eliminated).
- The very low water users and very high water users will be eliminated (approximately the top and bottom 5 % of the records).
- The remaining records will be sorted from lowest to highest annual use.
- The total number of records will be noted and divided by the number of study homes to be selected from the agency (i.e. 50). This will create a group of sub-groups from which the sample residences will be selected. The number of units in each sub-group will equal the total number of accounts divided by 50, the number of sample units. For example, if there are a total of 4000 billing accounts for a given site then for a 50 home sample there will be 50 sub groups of 80 units per group for that site.
- A random number, n, between 1 and 80 will be chosen.
- The $n^{th}$ record in each subgroup will then be selected as the sample home. Provisions will be made to insure that a supply of replacement units will be available for units that for any reason have to be replaced.
- The water use statistics of the sample group will be checked to insure that they match those of the population.
- The information for each of the selected residences will be entered into the project database.

Aquacraft knows from experience that this procedure produces samples matching the water use statistics of the population from which they are drawn. Using the data from San Francisco customers obtained for the CALFED California Single Family Home study as an example, as shown in Figure 5, one can see that the relative percentage of the sample lying in each consumption bin was almost identical to the percentage of the

population of all single family customers. Because the proportion of both the sample and the population in each consumption bin is the same the data do not need to be weighted. The lack of need to weight can also be seen from the fact that the statistics for the two groups are the same.

**Table 0-6: Example of Statistics between samples and populations**

| | Population | Sample |
|---|---|---|
| Mean | 65 ± 0.37 | 64 |
| Median | 56 | 56 |
| Number | 52,349 | 825 |

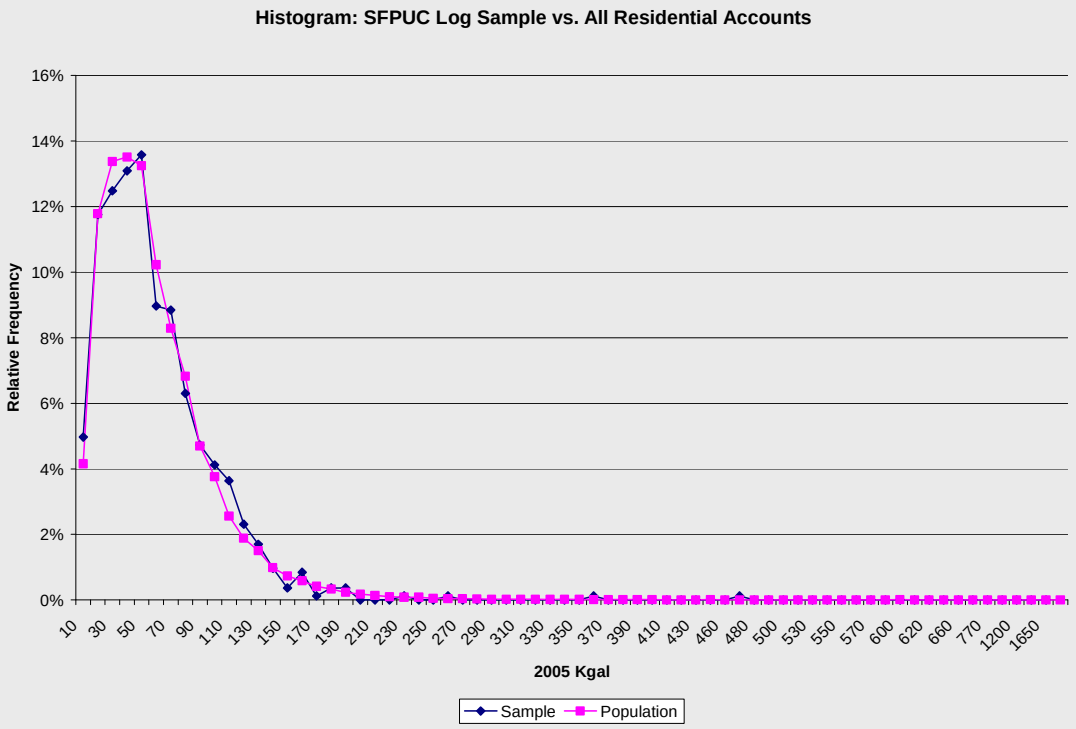


**Figure 5: Comparison of histograms between sample and population for the San Francisco Public Utility service area (DeOreo, W.B., et al, 2009)**

An example of where weighting would be required would be if we had chosen to over sample from the top 25 percentile of the population water users. If we had chosen twice as many homes from this group then a weighting factor of 0.5 would have to be applied to those homes water use in order to avoid biasing the results upward. If we had done this then the simple mean water use of the sample would have been higher than that of the population since it would have contained twice as many homes from the top 25$^{th}$ percentile.

## Task 5. Site visit to obtain flow trace data from 150 low-income multi-family units.

Field technicians will attach flow trace data recorders (data loggers) to each household water meter as well as the meters serving landscape irrigation. Data loggers will remain

on site for two weeks, after which field technicians will return, remove them from the water meter and download the recorded data. A total of 150 units' water meter flow traces will be logged in an effort to acquire at least 120 good data recordings. It is not uncommon for a small number of data logging events to fail to record usable information. At the time of the site visit the manager of the property will be interviewed to determine any other water uses at the site such as laundries, clubhouses, pools, spas and irrigation. Depending on the number and nature of the other water uses and meters at the site, plans will be developed to obtain the necessary data for demand profile determination.
In the simplest case we may be able to install loggers on the "other" water meters and use the demand profiles that are obtained along with the agency billing data in order to develop profiles for the entire year. This would require that the shapes of the profiles obtained during the initial logging were judged to be representative of annual use patterns. If such an assumption cannot be made it may be necessary to return to obtain additional flow traces during subsequent months.

### Task 6. Disaggregate flow trace data using Trace Wizard.

Flow trace data collected from individually metered multi-family home water meters will be disaggregated into the household water demand profiles by category. Each water use "event" (i.e. toilet flush, shower, clothes washer cycle, faucet draw, etc.) constitutes a unique record which includes the following statistics: water use category, volume, start time, end time, duration, max flow rate and mode flow rate as well as a unique ID number that identifies the house from which the data were obtained.

### Task 7. Develop central database and demand profiles.

All of the event data for the multi-family residences will be combined into a single database from which summaries will be generated. This will allow the water use to be sorted by use category and time of day in order to generate the required demand profiles. Profiles can be created for different groups of residences (those with and without clothes washers or high efficiency toilets, for example.)

Demands for other users such as irrigation, central laundries and possibly pools will be created from the billing and flow trace data obtained from meters serving these demands.

### Task 8. Prepare report on findings

The report will include a description of the goals, methodologies and results of this analysis. The focus will be on the multi-family demand profiles by category as required for the input to the Water-Energy Measure Calculator.

## *5.2.2 Residential Multi-family – Discussion*

There was discussion about the need to obtain demand profiles for both indoor and outdoor uses on low-income multi-family properties. The proposal by Aquacraft included installation of loggers on the water meters feeding the outdoor uses on the properties. A combination of logger data and billing data will be used to characterize water demand profiles outdoors. Additionally, to aid in characterizing outdoor irrigation profiles Aquacraft will obtain high resolution remotely sensed data for each property

studied and estimate the annual irrigation application based on GIS landscape analysis and billing data (assuming separate irrigation meters). Time of day data will be obtained for irrigation from the flow traces obtained from the irrigation meters as well as timer settings. Loggers will remain on the irrigation meters for at least 15 days during the irrigation season to get reliable data on hourly use patterns. Aquacraft will assume that the hourly use pattern observed during the logging defines the typical peak vs. off-peak irrigation window and attempt to confirm this with interviews of the property manager. This will allow the use of the billing data in combination with the logging data to generate irrigation and other outdoor use profiles for periods other than when the loggers are installed at the site; thus capturing the seasonal variation of irrigation water demand Each site irrigation demand profile will be corrected for changes in weather. High resolution remotely sensed data might also be used in a GIS landscape analysis to further aid in characterizing outdoor irrigation profiles.

Initially there was concern that only homes from IRWD would be included in the study. With the addition of individually metered properties from San Diego and EBMUD, Aquacraft will have a much broader mix of sites in both Northern and Southern California and in three of the four IOU service areas.

Concurrent to this study is the ongoing effort of the CPUC Embedded Energy in Water Pilot Program for Multi-family low-income HET retrofits. The fundamental similarity between these two efforts is that they both require measuring baseline (OR pre-retrofit) flow trace data from individually metered low-income multi-family units. Multi-family home sites are currently being selected for the Embedded Energy study. Since there is overlap between these two studies then it will be both efficient and beneficial to supplement this Water Demand Profile study's sample (and data) with that of the Embedded Energy study.

## *5.3 Commercial*

RFP CP1-007-08 specifies that both small and large commercial buildings are to be included in this determination of water demand profiles. However, since the distinction between small and large commercial is oftentimes difficult to make, the discussion below refers to all commercial accounts. Aquacraft will follow the definition used in CPUC sponsored IOU programs to distinguish between small and large commercial customers.

Aquacraft maintains a collection of flow trace data from a broad range of commercial customers from which end-use water demand profiles can be created. These data sets come from the AWWARF Commercial and Institutional End Uses of Water study (2000) (CIEUWS), the Sacramento Regional Water Authority CI Water Audits study (2005), the CALFED Supermarket Studies (2003), the Monterey Pre-Rinse Spray Valve study (2003), and other studies conducted outside of California[5]. The commercial customers

[5] Dziegielewski, B., et al, 2000. Commercial and Institutional End Uses of Water.
Aquacraft, 2005. Commercial and Industrial Water Efficiency Reviews 2005 Project Report, Boulder.
Aquacraft, 2003. Demonstration of Water Conservation Opportunities in Urban Supermarkets, Boulder.

for whom data has been collected include members of what have been found in earlier studies to be the key demand categories that represent the majority of commercial water use in the urban sector. Since large samples of commercial users already exist, Aquacraft will use existing data sets to assemble hourly demand profiles for domestic and process uses and continuous uses such as cooling and leakage (where present).

Leveraging Aquacraft's existing data sets of commercial use requires a list of key commercial end user categories be created. After preparing this list, Aquacraft will confer with the project managers to determine if additional data on large commercial properties, such as regional shopping malls, should be included. Aquacraft recommends concentrating on the data already available and developing hourly demand profiles for these customers, supplemented with limited new empirical data to fill in any gaps.

The methodology for selecting participant sites for the commercial (and industrial) end uses was developed for the 2000 American Water Works Association Research Foundation study, "*Commercial and Institutional End Uses of Water*". This study's objective was, among other goals, to develop benchmarks for important commercial categories existing in five water agency service areas. Four of the utilities are in California: Los Angeles Dept. of Water and Power, Irvine Ranch Water Dist., City of San Diego Water Utilities Dept., and City of Santa Monica. This Research Plan will use demand profile data from these service areas that was measured in Dziegielewski et al (2000).

As mentioned in Section 2.2 commercial, and industrial category end uses are heterogeneous with highly variable water demand profiles. Therefore, candidate study sites from Dziegielewski et al (2000) were separated into sub-categories based on their having the most intense water use on a per site basis and their representing as a sub-category the largest proportion of water use by their category. Since the overarching objective of the Embedded Energy in Water Studies is to determine what an IOU energy demand reduction potential is by implementing water use efficiency measures, then the selection of candidates - from existing Aquacraft data - within the high water using sub-categories will be further narrowed down to those facilities the greatest potential for measures that will lead to water savings. At this time it is unknown if other commercial categories will be added for demand profiling.

The output data from commercial sub-categories will be tabulated into water demand profiles for the three water use categories (domestic/indoor, process and continuous uses). Table 8 provides an example of how the water demand profiles will be tabulated by percentage of total water use by category, for use in the CPUC Water-Energy Measures Calculator.

**Table 8 Output of commercial data - % of Total Water Use By Category**

| Hour of day | Domestic/indoor | Process | Continuous |
|---|---|---|---|
| 1:00am | % | % | % |
| 2:00am | % | % | % |
| 3:00am | % | % | % |
| 4:00am | % | % | % |
| 5:00am | % | % | % |
| 6:00 am | % | % | % |
| 7:00 am | % | % | % |
| 8:00 am | % | % | % |
| 9:00 am | % | % | % |
| 10:00am | % | % | % |
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| 6:00pm | % | % | % |
| 7:00pm | % | % | % |
| 8:00pm | % | % | % |
| 9:00pm | % | % | % |
| 10:00pm | % | % | % |
| 11:00pm | % | % | % |
| 12:00am | % | % | % |
| | | **Total** | **100%** |

As with the residential categories it may be important to generate output tables showing how a specific conservation measure will affect water use in a single category. Tables 9 and 10 show examples of alternative outputs resulting from Aquacraft commercial data, which will provide percentage of total hourly use attributable to individual categories.

**Table 9 Percentage of total hourly process use**

| Hour of day | Process |
|---|---|
| 1:00am | % |
| 2:00am | % |
| 3:00am | % |
| 4:00am | % |
| 5:00am | % |
| 6:00 am | % |
| 7:00 am | % |
| 8:00 am | % |
| 9:00 am | % |
| 10:00am | % |
| 11:00am | % |
| 12:00pm | % |
| 1:00pm | % |
| 2:00pm | % |
| 3:00pm | % |
| 4:00pm | % |
| 5:00pm | % |
| 6:00pm | % |
| 7:00pm | % |
| 8:00pm | % |
| 9:00pm | % |
| 10:00pm | % |
| 11:00pm | % |
| 12:00am | % |
| **TOTAL** | **100%** |

**Table 10 Percentage of total hourly continuous use**

| Hour of day | Continuous |
|---|---|
| 1:00am | % |
| 2:00am | % |
| 3:00am | % |
| 4:00am | % |
| 5:00am | % |
| 6:00 am | % |
| 7:00 am | % |
| 8:00 am | % |
| 9:00 am | % |
| 10:00am | % |
| 11:00am | % |
| 12:00pm | % |
| 1:00pm | % |
| 2:00pm | % |
| 3:00pm | % |
| 4:00pm | % |
| 5:00pm | % |
| 6:00pm | % |
| 7:00pm | % |
| 8:00pm | % |
| 9:00pm | % |
| 10:00pm | % |
| 11:00pm | % |
| 12:00am | % |
| **TOTAL** | **100%** |

### *5.3.1 Commercial - Tasks*

#### Task 1. Assemble CI data files and commercial customer information

Figure 5, which contains a table that has been copied from Dziegielewski et al (2000) shows the list of commercial (and institutional) categories that were found to be the most important in explaining urban CI water use within municipal water systems. These data were based on a detailed analysis of the billing data obtained from five large water agencies: Los Angeles, Irvine Ranch, City of San Diego, City of Santa Monica and City of Phoenix. The water use by commercial categories is typically not a large percentage of the total commercial demand in water agency service areas. The commercial sub-categories in Figure 6 below represent about 25% of the total water agency demands. Consequently, they represent the most logical target for inclusion in the demand profile study.

| Customer category description | Average annual daily use (gpdc)* | Coefficient of variation in daily use (gpdc)† | Percent of total CI use (%) | Percent of CI customers (%)‡ | Percent seasonal use (%)§ | Scaled average daily use (gpdc)** |
|---|---|---|---|---|---|---|
| Urban irrigation | 2,596 | 8.73 | 28.48% | 30.22% | 86.90% | 739.0 |
| Schools and colleges | 2,117 | 12.13 | 8.84% | 4.79% | 57.99% | 187.0 |
| Hotels and motels | 7,113 | 5.41 | 5.82% | 1.92% | 23.07% | 414.0 |
| Laundries/laundromats | 3,290 | 8.85 | 3.95% | 1.38% | 13.35% | 130.0 |
| Office buildings | 1,204 | 6.29 | 10.19% | 11.67% | 29.04% | 123.0 |
| Hospital/medical office | 1,236 | 78.50 | 3.90% | 4.19% | 23.16% | 48.0 |
| Restaurants | 906 | 7.69 | 8.83% | 11.18% | 16.13% | 80.0 |
| Food stores | 729 | 16.29 | 2.86% | 5.20% | 19.37% | 21.0 |
| Auto shops | 687 | 7.96 | 1.97% | 6.74% | 27.16% | 14.0 |
| Membership organization | 629 | 6.42 | 1.95% | 5.60% | 46.18% | 12.0 |
| Car washes | 3,031 | 3.12 | 0.82% | 0.36% | 14.22% | 25.0 |

* gpdc: gallons per day per customer
† Percent of CI customers pertains to CI customers in sites that have respective category only.
‡ Coefficient of variation in daily use: The ratio of standard deviation of daily use to average of daily use.
§ Percent seasonal use = [(total annual use - 12 x minimum month use ] / total annual use
** Scaled average daily use = average annual daily use in category x percent of total CI use attributed to the category.

**Figure 6 CI Categories described in CUEUWS (Dziegielewski, B., et al, 2000)**

In this task all of the flow profiles collected as part of the study by Dziegielewski et al (2000) and other commercial studies will be collected and assembled into a database for creation of the demand profiles. Data are currently available for: schools (elementary and secondary), hotels, office buildings, restaurants and food stores.

As part of the current study Aquacraft has an opportunity to fill in data gaps and add information for more customer sub-categories. This is a question that should be discussed with the advisory team. Options to consider include:

- Collecting demand profiles specific for urban irrigation, which is the main water user within the CI group.
- Studying total water use at a sample of large commercial developments (malls). In this task a large commercial site would be analyzed as a distinct entity, and all water meters feeding the entire project (both indoor, outdoor and process) could be logged, and demand profiles created for the entire entity.
- Obtaining demand profiles for some of the other categories shown in Figure 6 such as car washes, membership organizations, laundries.
- Conduct studies of demand profiles at hospitals focusing on major water using processes.

## Task 2. Sort by customer sub-category

All of the flow traces, from both existing and new sources, will be collected and sorted according to sub-category. The sub-categories will represent those shown in Figure 6 and any additional sub-categories selected for further study.

Commercial end uses are heterogeneous with highly variable water demand profiles. Therefore, candidate study sites will be separated into sub-categories based on their having the most intense water use on a per site basis and their representing as a sub-category the largest proportion of water use by the commercial category. Selected sites

will be those representing the major commercial water uses from various water agency service areas in California. The selection process will also filter out those candidate sites that do not have a potential for water conserving measures at their facilities.

### Task 3. Disaggregation of data

Water use at the sites will be disaggregated into the major categories of domestic indoor uses, process uses and continuous uses such as cooling and leakage.

### Task 4. Obtain additional demand profiles from missing customer water use categories identified by the client and Aquacraft

As discussed above, Aquacraft can add more sub-categories of commercial end-use data based on discussions with the project advisors.

### Task 5. Create hourly demand profiles by category

The database of events will be sorted according to category use, disaggregated use and time of day. This will allow demand profiles for each commercial category to be created as required by the RFP CP1-007-08 for use in the Water-Energy Measure Calculator.

### Task 6. Analyze results and prepare report

Results will be presented for each category as hourly demand profiles for both total water use and percent of total use during each hour of the day. Total use will be highly variable as a function of the type and size of the customer, but the profiles based on percent of total should be much more consistent within sub-categories.

## *5.3.2 Commercial - Discussion*

There is a large amount of flow trace data already available for commercial customers from the various studies listed in the proposal. This is an excellent source of information for the current study, and one that Aquacraft anticipates using to its full potential. That is, it is anticipated that Aquacraft will spend a lot of time in collecting and re-analyzing these files. We anticipate collecting additional data from new customer categories, but wish to discuss this further with the project advisors prior to making a decision.

## *5.4 Industrial*

Determination of water demand profiles for industrial users will involve a significant amount of new work. Using the results from the literature review, and in consultation with other project stakeholders and water utilities, Aquacraft will determine which industries are the most significant from the perspective of potable water demands. If any flow profile studies have been done, these will also be included in this study. Water agency billing data may also be useful. It will however, be necessary to perform a number of water use reviews and sub-metering studies to obtain the desired information. For this category, a 1-year schedule may present a problem. It may not be possible to obtain the necessary permissions and commitment on the part of the industrial customers

to provide access to their plants and co-operate with the instrumentation required to obtain the data.

Industrial category end uses are heterogeneous with highly variable water demand profiles. Therefore, using the same methods used in Dziegielewski et al (2000) for the commercial (and institutional) end-use sub-category selection, industrial sites will be separated into sub-categories (ie. Manufacturing, Processing, Refining, etc) based on their having the highest water use on a per site basis and their representing as a sub-category the largest proportion of water use by the industrial category. Those industrial facilities demonstrating the greatest potential for measures that will lead to water savings will serve as candidate study sites.

For this end-use category it is estimated that a total of 12 complete industrial water use reviews will be performed on industries representing the major water uses in California. Working with the facilities management staff for the 12 sites Aquacraft will prepare schematics of the water use systems in the plants. Inflows and measuring points from both potable and non-potable sources (including recycled water) will be identified. All significant water using fixtures, devices and processes will be noted. Sub-meters will be installed on the supply lines for key water uses wherever possible. Data loggers will be connected to the main meters and all installed sub-meters and 30 days of continuous flow data will be recorded. From this, hourly end-use flow profiles will be created for each of the 12 sites. The analysis will filter out any recycled water so that only hourly demands from potable water (from the local agency) will be included in the analysis. A report on the hourly demand profiles for the major industries will be prepared.

The tabular output data that will be generated from industrial sub-categories water demand profiles will resemble those discussed in Tables 8-10 in Section 5.3 for commercial end uses. The only difference is that the demand profiles will be disaggregated into two categories of water use, domestic/indoor, outdoor and process uses. Tabular information will be used in the CPUC Water-Energy Measures Calculator.

### *5.4.1 Industrial - Tasks*

#### Task 1. Literature review

A review of existing literature will be undertaken to determine which categories of industry are likely to have the greatest water demands on the various water agency service areas. The focus will be on establishing linkages between industry water use, treated water agencies, and energy demands upon IOU's; not upon industrial uses from independent or private water supplies such as wells or substitute supplies such as recycled water.

As part of the literature review Aquacraft will request that the main water agencies provide a list of their top industrial uses so that this information can be included in the analysis of target industries.

## Task 2. Identification of target industries

Based on the results of the literature review, a list of target industries will be prepared as candidates for demand profiling. As is being done for the commercial customer category the ideal candidates will be the industries that have the most intense water use on a per site basis and which represent as a sub-category the largest proportion of water use by the industrial category.

## Task 3. Solicitation of Industrial customers for participation

Once the target industries have been identified Aquacraft will send out letters inviting their participation in the CPUC-CIEE demand profile study. This will involve several layers of contacts. It is anticipated that the water agencies will be able to assist in setting up meeting and introductions with the industries that they serve. It may also be possible to make direct contacts through mail or telephone, or trade organizations. However this is done, it is critical that we reach the proper persons in each organization with the authority to make decisions and that as many of the target categories be reached as possible.

The invitations will explain the goals of the study and why it is important for the study to obtain industry support. The benefits of participation will include possible insights into water and energy conservation by the companies that may prove economically beneficial to them, irrespective of the other objectives of the study. Obtaining the demand profiles will assist their respective potable water purveyors in reducing their energy requirements, and improve the overall energy efficiency of their water purveyors' systems, upon which the state economy rests. The invitation will qualify why participating in the study is a benefit to industrial end users in the long run.

The industrial customers will be asked to provide the research team with copies of their historic billing records (from the water agencies) or authorization to obtain this from the agencies. Aquacraft will also ask for access to their water meters and to the water infrastructure on the industrial site so that field technicians can prepare flow schematics and identify all sources of water and points of use.

The goal will be to obtain consent from approximately 12 industrial customers to participate in the demand profiling study.

## Task 4. Water use review and sub-metering

Participating industrial customer sites will be visited three times. The first visit will serve to inform the field technicians of the type of process cold water uses occurring on a regular basis and to determine what water meters are present and if any sub-metering is necessary. A licensed and fully insured plumber will be contracted to install any sub-meters. This initial visit will be coordinated with facility managers. A second site visit will involve installing data loggers on the property's main water meters and any sub-meters that have been installed. The data loggers will remain on site for a period of two weeks, after which the field technicians will return to remove them and download their data. This third and final site visit will also include a review of the site's process water usage to aid in disaggregating the water demand profiles.

### Task 5. Data collection and analysis

There will be three types of data collected in this water demand profile study: general site information, water use review data, historic water billing data and flow trace data from meters and sub-meters.

The general site information will include data such as the industrial classification of the industry, hours and days of operation, number of employees, etc. A water use review of the facility processes will reveal information regarding the types of process present, duration and frequency water using processes, existing water meters on process equipment, sources of water used in the facility (ie. well water, recycled water), waste water disposal methods, etc. Historic billing data will be used alongside general information and flow trace data to aid in characterizing the seasonal variation of irrigation demand. The flow trace data will be logged from the site meter(s) and sub-meters and analyzed with Trace Wizard software.

The combined data will be disaggregated into water demand profiles of domestic indoor uses and process uses. Results will be presented for each category as hourly demand profiles for both total water use and percent of total use during each hour of the day. Total use will be highly variable as a function of the type and size of the customer, but the profiles based on percent of total should be much more consistent within categories.

### Task 6. Preparation of report on industrial hourly water demand profiles

The demand profiles for the disaggregated water use profiles will be created. A report on the methodology and results will be prepared.

## *5.4.2 Industrial - Discussion*

Aquacraft anticipates that the selection of the types and locations of industries to be studied will be a collaborative effort. As with all other categories of customers Aquacraft will focus on use of treated water from local water agencies. Aquacraft will include recycled water where necessary and where its use may affect the energy use at the wastewater agency. We foresee two possible alternatives here: 1) Water that is recycled (OR partially treated) by the wastewater agency and delivered to customers as recycled (non-potable) water for irrigation/industrial purposes will be identified, and Aquacraft will measure the hourly demand profiles of "Outdoor, Domestic/indoor, Continuous, & Process Uses" since they affect energy use at the wastewater treatment plant for non-potable treatment and delivery and for re-treating any returned wastewater. 2) Water that is recycled at the customer site for reuse on site will be identified/quantified. This water will not be counted a second time in the potable water demand profile, but will count in the wastewater profile if returned to the wastewater system.

There is a question about whether a 1-year schedule will be adequate for this category given the time it may require to obtain consent from the business owners to participate.

The plan is to select a sample of 12 companies from the most significant industries to study. The proposal included performing water reviews and sub-metering the sites. If Aquacraft focused on obtaining flow profile data from the main meters, with limited sub-metering, it would be easier to obtain participation from the industrial customers, and the study could also include more sites in the analysis. This goes back to the question about what the main goal of the study actually is[6].

## *5.5 Public Buildings*

The preferred method of addressing this customer category will be to select a few public buildings in each of the cities and counties that are currently participating in the CALFED California Single-family Water Use Efficiency Study[7] Aquacraft has been conducting since 2005. The CALFED study sites make up a good cross section of both Northern and Southern California (DeOreo, W.B., et al, 2009). Since Aquacraft has already established a working relationship with 15 water agencies in the north and south, they are an excellent start. Aquacraft plans to collect as many of the flow trace files from previous public building studies and include them in this analysis.

The selection of Public Building study sites will include a cross section of sub-categories (ie. Libraries, Govt. Offices, Govt. Laboratories, etc) that are present in various water agency service areas.

Participating public buildings' water uses will be reviewed and flow trace data logged from their indoor and outdoor water meters. Demand profiles of domestic/indoor, outdoor and continuous uses will be generated based on the combined data logging and site visit information. Tabular data resembling the Tables 8-10 in Section 5.3 will provide information necessary to update the Water-Energy Measure Calculator.

### *5.5.1 Public Buildings – Tasks*

#### Task 1. Request participation from key California water providers.

We will request information on public water accounts from the 15 water agencies that participated in the CALFED Single Family study. Information on the numbers and types of public building in their service areas will be sought. As part of this task the types of buildings to be included as "public" will be determined, and a review of the water literature will be conducted to assist with this effort. It will be assumed that the category will include government offices, libraries, court houses and recreation centers. Schools,

[6] Installing sub-meters will be expensive and will require shutting down water service to the building while a plumber performs the work. It may also be difficult to recruit participants as there is usually a strong desire on behalf of building and property mangers to avoid any tampering with expensive mechanical systems. All parties in this effort will require sufficient liability coverage should something go awry.
[7] The following utilities are participating in the California SF End-use Study: EBMUD, LADWP, City of Davis, North Marin Water District, San Francisco Water Department, Redwood City, City of San Carlos, San Diego County Water District, City of San Diego, Las Virgenes MWD, Irvine Ranch WD.

universities and hospitals were considered as institutional or industrial uses and were not intended for inclusion as part of this task.

## Task 2. Select participant Public Buildings.

From the responses by the water agencies Aquacraft will prepare a summary of water use by public building categories and use it to select a cross section of these types of buildings from the various agencies. It would be desirable to have one or more buildings from each of the agencies selected for the study in order to have as great a geographical area as possible included in the study. Once Aquacraft knows the number of public building accounts it has to work with, 10 to 30 buildings will be either randomly sampled or saturation sampled.

## Task 3. Obtain historic water consumption data from participating water agencies.

Historic billing data will be obtained for all water meters supplying the selected buildings for the study. All water meters that serve the selected public buildings will be identified so that historic billing data can be obtained. The historic water use data will be summarized into monthly and annual tables.

Correctly identifying the meters present at the buildings will be important and will require the assistance of the water agency personnel. An initial trip to the sites will be devoted to assessing the meters and verifying that all of them have been correctly identified and are accessible.

## Task 4. Conduct a review of the buildings to identify major water using fixtures, appliances, and processes.

Each of the buildings selected for the study will be visited and a review of the water using fixtures and appliances will be conducted. We will not attempt to do a complete audit of water use for each fixture, but will rely on cataloguing the devices present and information on their use rates to estimate where the water use from the main water meter is going. Where irrigation timer equipment is used the settings will be recorded.

## Task 5. Obtain flow trace data from buildings

The building's main water meter or combined meters and any sub-meters will be fitted with data loggers and the flow trace data recorded for a period of one week. After the logging period is complete data loggers will be removed and their data downloaded. It may be necessary to re-log meters from which invalid or incomplete data were obtained.

## Task 6. Disaggregate and analyze flow trace data

Flow trace data logged from Public Building water meters will be analyzed and disaggregated using Trace Wizard software. Since the meter(s) serves many water uses throughout the day the water use will be broken down into domestic/indoor daytime uses, continuous uses (eg cooling and leaks) and outdoor uses for irrigation. The demand profiles for each of these categories of use will be determined. For irrigation profiles the seasonal variation in water uses will be estimated using the combined historic billing

data, review of irrigation equipment and disaggregate flow trace data. High resolution remotely sensed data might also be used in a GIS landscape analysis to further aid in characterizing outdoor irrigation profiles.

### Task 7. Prepare report on Public Building demand profiles.

The demand profiles for the identified water use categories will be created. A report on the methodology and results will be prepared.

## *5.5.2 Public Buildings - Discussion*

RFP CP1-007-08 talked about in-line metering to determine demand profiles. The proposal by Aquacraft contemplated using flow traces obtained from the main indoor and outdoor meters, combined with a water use review, providing information on the types of fixtures, appliance and water using devices and processes present in order to estimate the profiles. The term in-line meters is vague, and could mean anything from individual meters on each feed line to every fixture and appliance or a single meter feeding the main line for the entire building. Aquacraft will limit the number of separate meters to the minimum necessary to meet the data needs for the project. For example, if major water using devices, like cooling towers, are present meters will be installed, and Aquacraft will obtain flow trace data on these sub-meters. Aquacraft will not attempt to install individual meters or loggers on individual plumbing fixtures.

## *5.6 Agriculture*

This research plan assumes that the "Agricultural" customer category includes agricultural water users who obtain their water supply from potable water supplying water utilities rather than from regional water agency/irrigation district systems or decreed raw water rights. That is, Aquacraft will measure water uses and generate hourly demand profiles for agricultural end users who use potable water for cleaning, packing and canning of California fruits, nuts and vegetables.

As an example, to prevent post harvest decay of produce most packers will periodically clean and disinfect harvesting containers. Packaging surfaces are washed in chlorinated water immediately after encounters with decaying fruit, as well as periodically during the day (lunch breaks, etc.) Fruits can be floated in water and rinsed afterwards prior to being dried and packaged. California is the source of nearly half of the fresh fruits, vegetables, and nuts consumed by across the Nation. Additionally, the state provides food for the international market, accounting for 15% of the Nation's total agricultural export (Cooley, H., et al, 2008;IFAS, 2008).

For the agriculture category Aquacraft will identify the largest water using agricultural water customers and will select as balanced a sample as possible of agricultural process users who obtain water from potable water systems in various regions of the state. Participating agriculture facilities' water uses will be determined and flow trace data logged from the water meters serving their process uses. Demand profiles of process uses

will be generated based on the combined site visit information and data logging. Tabular data resembling the Tables 8-10 in Section 5.3 will provide information necessary to update the Water-Energy Measure Calculator for the agriculture end-use category.

## *5.6.1 Agriculture – Tasks*

### Task 1. Identify agricultural processing facilities using potable water from water utilities

Identify main areas where agricultural activities are occurring and obtain from the water agencies the largest agricultural water customers. Information related to the types and sources of water used at the targeted customers will be collected.

It is anticipated that agricultural processing plants will has a combination of water supplies that include both treated water from water agencies and water from private, non-potable sources, such as wells. Water is typically used at these plants used for washing, preparing and canning the produce.

Water use at some California plants begins in June and ends in October as the peach, apricot, tomato and pear crops come in for processing. Over 700,000 tons of fruit are processed at three known plants in the Sacramento area each year, and they would be excellent examples of the kinds of agricultural users that impact water agency demands.

### Task 2. Solicit and obtain participation from a sample of (approx. 10) agricultural customers

Based on results from Task 1 Aquacraft will locate as balanced a sample as possible of approximately 10 agricultural users who obtain water from potable water systems located in important agricultural regions of the state.

### Task 3. Conduct site visits and water use analyses

The purpose of the site visits is to quantify the actual hourly use patterns of the customers for both crop irrigation (if any) and produce processing from treated water sources. Aquacraft will also identify water that is acquired from private wells or from recycled water sources. Since agriculture is highly seasonal in nature, then process water use should be tracked over a full growing and processing cycle (season).

The key to success with this task will be to identify agricultural customers, obtain permission for the study, and to develop a familiarity with their operations. The Sacramento area has many food growing and processing companies, and may be a good place to start, but Aquacraft will seek to obtain processing information from other regions of the state.

### Task 4. Install meters and loggers

The participating agricultural customer sites will be visited three times. In the initial visit the field technicians will determine of the type of process uses occurring on a regular

basis and to determine where water meters are present and if any sub-metering is necessary. A licensed and fully insured plumber will be contracted to install any sub-meters. A second site visit will involve installing data loggers on the property's main water meters as well as on any sub-meters that have been installed. Data loggers will remain on site for a period of two weeks, after which the field technicians will return to remove them and download their data. This third and final site visit will also include a review of the site's processes, which will aid in disaggregating the water demand profiles.

### Task 5. Analyze data and prepare hourly demand profiles.

Aquacraft will perform water use reviews and obtain flow traces of agricultural process operations. The data from these reviews and traces will be used to create the hourly water demand profiles.

### Task 6. Prepare report on demands

The demand profiles for the water use profiles will be created. A report on the methodology and results will be prepared.

## *5.6.2 Agriculture - Discussion*

The main area where there clarification was needed in the development of this Research Plan's focus on agriculture end-use was whether CPUC D. 07-12-05 and RFP CP1-007-08 required a statewide analysis of irrigation water use or whether agricultural process water used from potable supplies was required. Aquacraft and the CPUC-CIEE Work Group Advisory Committee agreed that both the record of decision and RFP were clear in wanting information that could be translated into the relationship between customer water use profiles and energy demand at the "water agency". As a result, non water agency water sources are not part of this research effort.

However, it is recognized that agricultural irrigation demand accounts for largest category of water use in California. Omitting this significant water demand and the embedded energy (natural gas and electricity) for pumping and conveyance highlights the limitation of this research as envisioned by the CPUC D. 07-12-05[8].

# 6.0 Research Plan Timeline

This research plan is currently evolving with regard to timing of task implementation. A more accurate and detailed timeline will be developed when research task schedules are known. The Monthly Project Update Reports will include fully documented and complete analysis datasets. Table 11 shows the anticipated schedule of deliverables at this time.

[8] Since nearly "60% of the total water supply-related peak day electrical demand in California" comes from agricultural groundwater and surface water pumping, then an analysis of this large portion of state electricity demand is beyond the scope of this demand profile study, and worthy of a study of it own. From DRRC, 2007. Water Supply-Related Electricity Demand in California.

**Table 11 Deliverables and Schedule**

| **Deliverable** | **Schedule** | |
|---|---|---|
| CPUC-CIEE WG Meetings | July – November 25, 2008 | |
| Draft Research Plan | November 25, 2008 | |
| Public Comment Workshop | December 10, 2008 | |
| Submit Final Research Plan | January 7, 2009 | |
| Research Plan Implementation | January 9, 2009 | |
| Literature Review | February 15, 2009 | |
| **Project Database & Update Reports** | **PROFILES** | **REPORT** |
| Residential Single-family | August 09’ | September 09’ |
| Residential Multi-family | February 10’ | March 10’ |
| Commercial | December 09’ | February 10’ |
| Industrial | June 10’ | July 10’ |
| Public Buildings | December 09’ | February 10’ |
| Agriculture | July 10’ | August 10’ |
| Draft Technical Report | August, 2010 | |
| Public Review of Draft Technical Report | September, 2010 | |
| Final Technical Report | October, 2010 | |

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