



Our Mission

Founded in 1995, Aquacraft, Inc. is a water engineering firm dedicated to increasing the amount of water available for human use and the environment through better understanding of water demands and the factors that affect them. It is impossible to manage a resource unless one understands how it is used...and sometimes misused. Since its beginning Aquacraft has developed a set of techniques and tools for getting more precise information on water use, and then applying this information to practical problems.

“Nations fight over oil, but there are substitutes for oil. There are no substitutes for water”

Senator Paul Simon. “Tapped Out”

We are also committed to exploring ways that reuse of water through processes like thermal desalination and cogeneration of distilled water using waste heat from power plants can provide for local and renewable potable water supplies. If these systems are coupled with the new generation of nuclear power plants a truly sustainable water and power system can be provided for human civilization for literally thousands of years. We seek ways to foster this type of water/energy integration; what we refer to as the Real Water/Energy Nexus.

Water End-Use Studies

It is difficult to design a water management plan without knowing the uses to which water is placed in a system. This starts from how billing data are disaggregated into customer categories, and extends down to how much water is used by households for individual uses. Aquacraft developed a method for disaggregating residential end uses of water using a single flow trace file obtained from the utility owned water meter.

Flow trace analysis is to billing data as a microscope is to normal vision or as a prism is to light. Instead of relying on one reading to the nearest gallon or cubic foot per month flow traces consist of readings at 10 second intervals down to the nearest .01 gallons. (The internal magnets in most standard water meters can provide this level of resolution.) At this resolution it is possible to break residential water use down to individual events. Flow trace data can provide a complete picture on the current state of water use efficiency in your residential water customers including how much water conservation potential is remaining in the group and where it is.

By using flow trace analysis a water agency can get an accurate determination of both its current levels of water use efficiency and the potential remaining for reducing demands



Figure 1: Portable data logger for collecting flow traces

In larger commercial, institutional and industrial applications collection of higher resolution data using data loggers and sub-meters can provide significant improvements in the accuracy of water use audits. Aquacraft has done several studies on ICI customers in which sub-meters were used to break out water use for cooling, leakage, irrigation and other key use categories for demand analyses.

Trace Wizard[®] Analysis Software

The heart of the flow trace system is the Trace Wizard[®] program, developed by Aquacraft to convert the raw flow trace file into a disaggregated database of end uses of water. Here is a brief description of how it works.

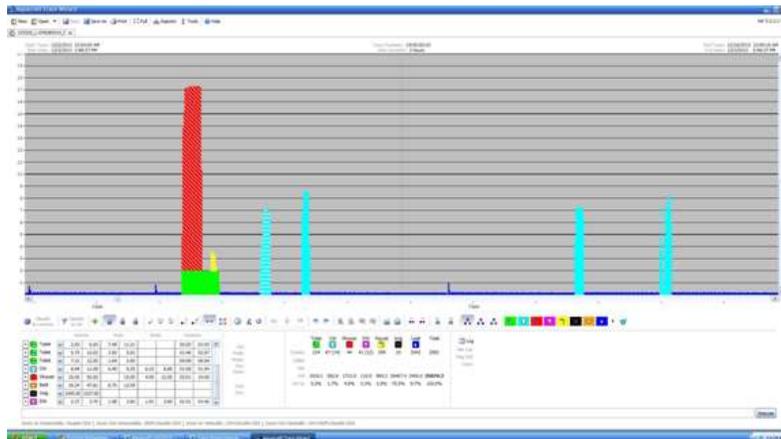


Figure 2: Trace Wizard Analysis Software showing individual events classified by type

Aquacraft has spent years developing software to assist with the analysis for flow trace data. Our Trace Wizard program can take high resolution data (0.01 gal at 10 second intervals) from a residential water meter and break it down into individual water use events: each of which is classified by its end-use, volume, duration, flow rate and start

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time. This makes the data from the meters useful for highly detailed analyses of water use. An example of such an analysis is shown in Figure 3, which shows the gallons per household per day for individual end uses (obtained from flow trace analysis) in comparison to benchmarks for future, high efficiency homes. The difference between the actual use and the benchmark represents potential water savings.

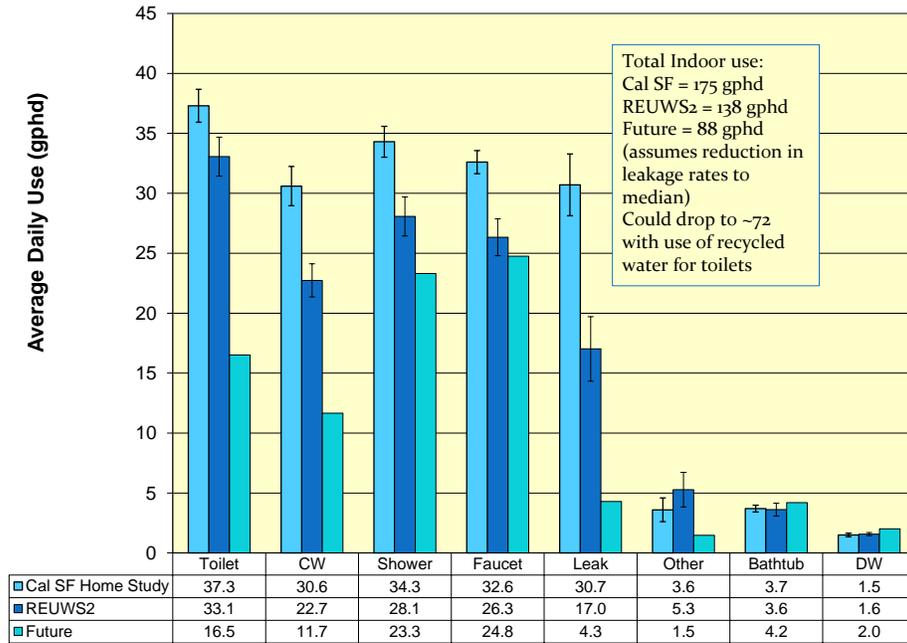


Figure 3: End uses results for 2 study groups showing comparison to benchmark for future high efficiency homes.

Another useful output from the end use data is the percentage of homes in the system that meets performance criteria for clothes washers, showers and toilets. These three parameters have direct bearing on the potential for future conservation potential, and they are also among the key inputs in our residential demand forecasting model. Figure 4 shows the percentage of homes from the California SF Home Study (2007) and the REUWS2 sample (2010) that meets or exceeds the efficiency standards for these devices. The conservation potential in the populations will not be reached until the percentages for all three categories approach 100%. End use studies allow these data to be obtained in a statistically sound and anonymous manner.

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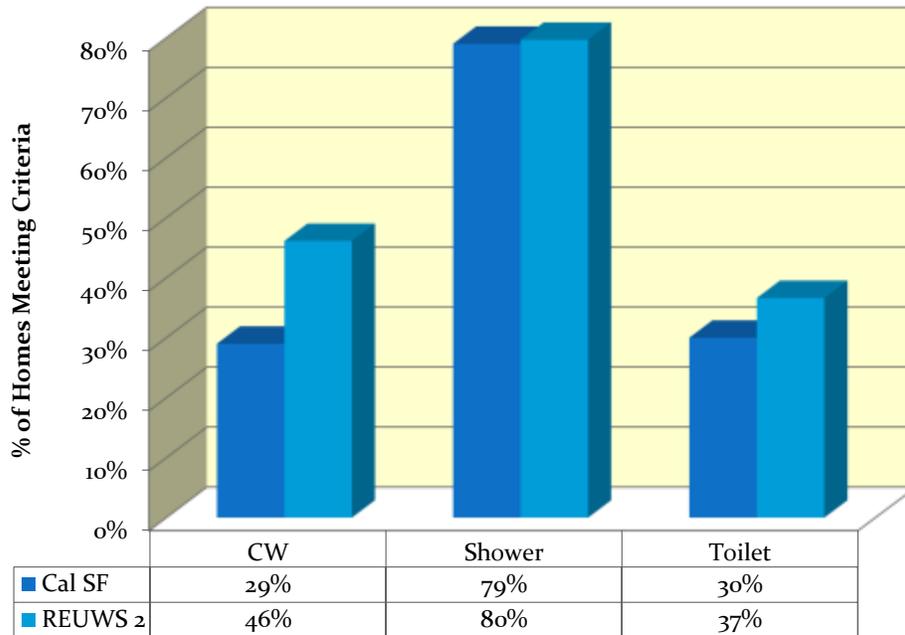


Figure 4: Compliance rates for single family households

Evaluation of Water Conservation Programs

Many water conservation programs appear to offer significant theoretical water savings, but in the real world their performance usually varies from theory. Aquacraft can help determine how your conservation programs are actually affecting your water use. By applying statistical techniques to your water billing data and program records the performance of most programs can be determined after accounting for confounding effects of the economy, weather and general changes to demands caused by restrictions and drought. The results are somethings surprising.

Demand Forecasting

Aquacraft has created a residential demand forecasting model based on the results of nearly 4000 homes that were part of end use studies on single and multi-family residences in the United States and Canada. This model uses the variables that have proven to best predict indoor and outdoor residential water use. The model deals with existing and new household single family and multi-family households separately and on a monthly time step. Because the model is based on empirical data rather than theory it shows how household water use actually changes with occupancy, efficiency of fixtures and appliances, leakage, ET, irrigated areas and other key water use parameters. It can operate over a variable study period for as many years as the user has reasonable housing and population data available. It can track as many scenarios as one wishes to construct. Two samples of the output are shown below.

Figure 5 shows the annual water demands produced by out end use model for the baseline case and five conservation programs ranging from just passive savings to combinations of

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indoor and outdoor programs. In Figure 6 the annual savings from these programs are shown relative to the passive case. Notice how savings decline in future years as saturations are reached in the community for efficient devices and appliances.

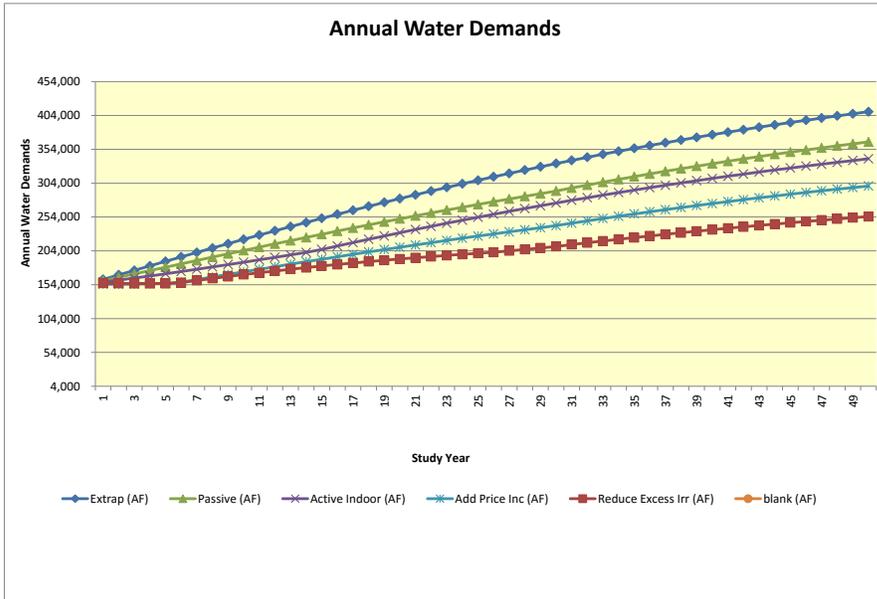


Figure 5: Sample annual output from demand model showing baseline and 4 scenarios

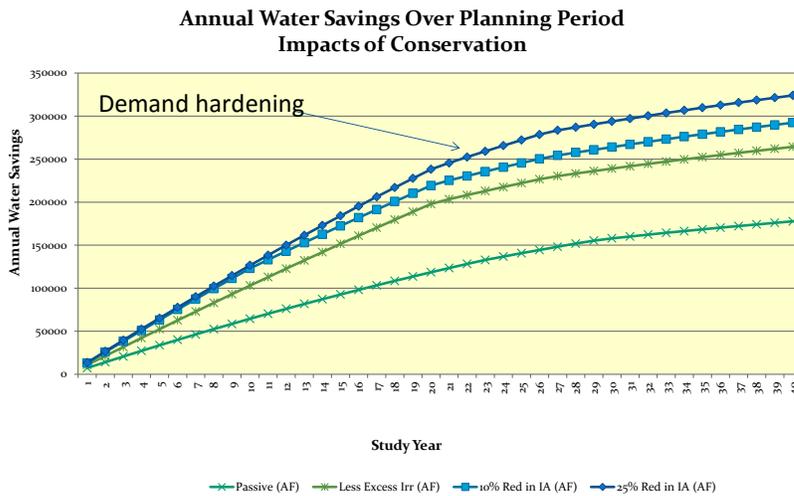


Figure 6: Comparison of annual water savings from four conservation scenarios

Analysis of Landscape Demands

Understanding the patterns for landscape water use is important in designing landscape conservation plans. As part of the end use studies Aquacraft performs analyses of the landscape water use in terms of actual application versus theoretical requirements. In our studies the end use analysis provide better accuracy for both indoor and outdoor waters use, so the results are better indicators of the true rates of excess (and deficit) irrigation in the system.

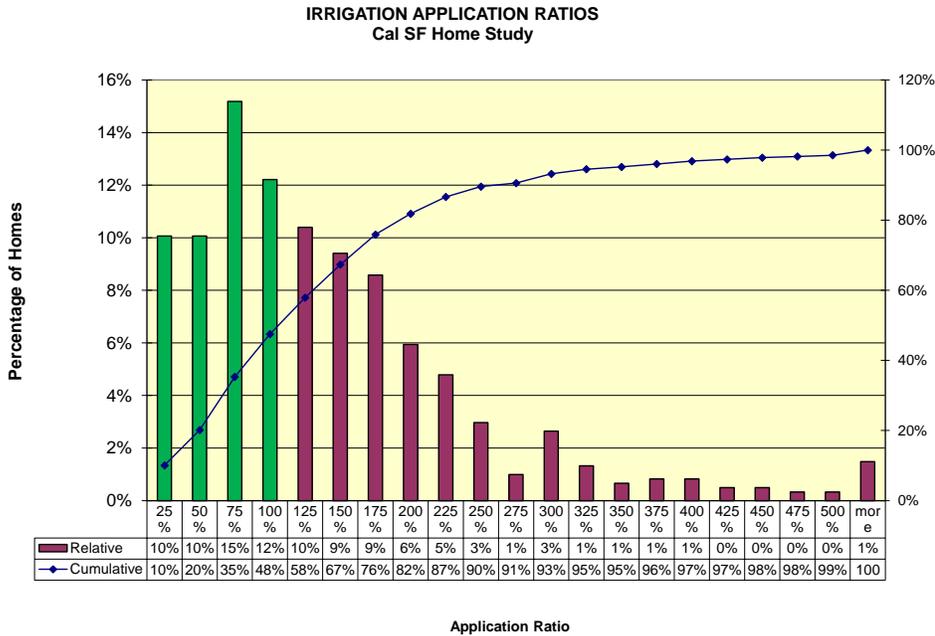


Figure 7: Distribution of irrigation application ratios in study group based on end use analysis

Aquacraft has developed a web based application for allowing both private citizens and professional landscape managers to measure their landscape area and determine its theoretical irrigation demand. (see: <http://mywaterbudget.com>)

Water Budget Rate Structures

Aquacraft designed the water budget rate structure for the City of Boulder, which has been successfully implemented and supported by the citizens since around 2007. This system assigned a specific monthly water budget to all customers based on their category, occupancy rates and irrigated areas. Users who stay within their budgets pay for water at the average cost. As use increases beyond the budget the cost for water is based on the annualized cost of new, firm yield, supply under current market conditions. Use beyond this range creates charges based on penalties for over-use (waste) of water. In addition, the rate structure includes drought sur-charges so that in times of drought rates automatically increase to compensate for the reduced usage, and revenue stability is ensured.

Aquacraft Staff

William B. DeOreo, M.S., P.E., President Bill DeOreo is the founder and principal engineer of Aquacraft. With over 30 years of experience as a water engineer in Colorado, he specializes in water resources planning and management. Bill graduated from Boston University and the University of Colorado, Boulder. He is a member of American Society of Civil Engineers, and the American Water Works Association.



Bill has been Principal Investigator on a number of large water demand research projects in the United States and around the world. He developed the concept of flow trace analysis while exploring the use of high resolution flow data for residential water use analysis. This led to the creation of the Trace Wizard© software which has been used for most of the detailed residential end use analyses since the seminal Residential End Uses of Water Study, conducted for the Water Research Foundation in 1999.

Leslie Martien, Water Resources Engineer



Leslie Martien joined Aquacraft in 2002 after completing her Bachelor of Science in Water Resources and Environmental Engineering at the University of Colorado. Her work with Aquacraft includes residential and commercial audits, water efficient landscape design and system planning projects evaluating new conservation technologies. She provides training to engineers and utility staff interested in utilizing Aquacraft's Trace Wizard and Meter Master programs. Leslie continues her association with the University of Colorado as a guest speaker and as an industry representative. She serves

on CU's Joint Evaluation Committee to review the objectives and outcomes of the undergraduate programs in Water Resources and Environmental Engineering. She is an editor for and regular contributor to the Colorado WaterWise newsletter and serves on the Colorado WaterWise Annual Event committee.

Matt Hayden, Application Developer and WR Engineer

Matt Hayden joined Aquacraft in 2005 and is a specialist in applied mathematics and computer sciences. His specialties are related to a wide variety of computer programming, large database management, statistical analyses and modelling of complex systems.

Matt has been responsible for taking raw billing data from scores of diverse utilities and converting them into usable datasets for water use analyses. He is an expert at SQL programming and design of hardware and software necessary to host large datasets on local and web based servers. He has worked as a programmer for web security and understands the requirements for maintaining safe and secure servers. His has field experience on projects where he has been responsible for design and implementation of data acquisition systems for complicated water audits. He understands the variety of metering, sub-metering, data logging and data transmission systems available for this type of work. In addition, his programming skills allow him to develop systems for automating the data management aspects of projects.



Matt is well versed with the use of the types of analytical software used for creation of forecasting models. He is an expert in use of Excel, Access, SQL programming, and the Statistical Program for the Social Sciences (SPSS). In addition, he has a wide range of programming and computer science skills that are needed for advanced analysis. He was the lead analyst for the California Single Family Water Use Efficiency Study, the Albuquerque Single Family Water Use and Retrofit Study, The Abu Dhabi End Use Study and worked as the chief database specialist on the Residential End Uses of Water Study Update, in 2014.

Matt has a B.S. in Applied Math (College of Engineering, University of Colorado, Boulder, 2002) and graduate-level computer science experience in data mining techniques and cutting-edge database applications.

Services Provided

Water Demand Analysis

At Aquacraft, we believe that the foundation of a sound demand management program is accurate information on the specific end uses of water, which allows one to both predict the theoretical impacts of water management options, and to measure their actual savings efficiently.

To provide the type of information needed to better understand demands, Aquacraft, Inc. has pioneered a method for collecting and disaggregating water use information from municipal customers through a single flow trace obtained from the customer's water meter. Using Trace Wizard[®], a signal processing software package developed by Aquacraft, information on where and how customers are using water can be easily obtained. In single family homes Trace Wizard helps disaggregate water use into all of the major end uses (e.g. toilets, showers, clothes washers, irrigation, leaks etc.)

In larger commercial and industrial customers Trace Wizard is a tool that can be used to differentiate between domestic uses, process uses, continuous uses (cooling, etc.), leaks, and irrigation. For more precise analysis we recommend sub-metering large fixtures such as cooling towers and R/O systems.

Since 1994 Aquacraft has obtained flow trace data on thousands of single family homes and hundreds of commercial, industrial and institutional users. The information for these traces have been placed into end-use and peak demand databases which, when combined with survey information, provide excellent data on where, when, and how water is being used by a wide variety of customers.

Water Surveys and Field Studies

In order to accommodate larger data collection efforts and field analyses, such as the statewide study of residential water use in California, Aquacraft equipped a van as a mobile office and workstation.

Pictured at right, the "Aquacraft" carries 100 data loggers for doing flow trace analysis on water meters, and has a comfortable cabin with a desk and charging system for multiple laptop computers and the loggers. This van can be brought to your site for data collection. In some cases you can rent it to do your own data collection, and we will include analysis of the data as part of the rental price.



Figure 8: Aquacraft's mobile work station for data logging and field studies

Having the mobile workstation of this kind allows us to conduct long-term field studies and complex audits without having to worry

about having the right tools and equipment with us. The GPS navigation and mapping system is useful for finding job-sites and then mapping them (e.g. for determining irrigated areas).

Database and Software Application Development

Aquacraft develops database and software applications for tracking and evaluating water use. Our staff has substantial software development, engineering, and project management talent. In 2004 Aquacraft developed a web-based database for the US Environmental Protection Agency to track potential water efficient products for the proposed “Water Star” market enhancement program. Aquacraft’s database applications for studies such as the *Residential End Uses of Water* (1999, AWWA) and the more recent Seattle, EBMUD, and Tampa residential retrofit studies (2000-2004, US EPA) have been used by consultants, researchers, and utility professionals to evaluate water conservation effectiveness. Aquacraft’s Trace Wizard[®] Water Use Analysis Software application has been used by researchers and utility professionals in the United States, Europe, Australia, and the Middle East to evaluate residential, non-residential, and irrigation of water use.

Water Conservation Planning and Program Evaluation

Once data has been collected and a model created, the next logical step is to apply this information to real life situations. We have applied the vast amount of information collected in Aquacraft’s research work to the creation of cost-effective long-term water efficiency programs and demand projection models for urban providers. Aquacraft develops water conservation plans that include the long-term impacts of water conservation on water supply, capital requirements and financial aspects of utility operation.

Integrated Water Demand and Financial Modeling

Aquacraft is a leader in integrated resource planning. We developed the demand forecasting and system operations model for the Colorado Water Conservation Board’s CIRCE model, which was one of the first attempts to integrate the impacts of water conservation programs on water operations, system revenue, and long term finances. We have used successors to this model to assess the impacts of various conservation scenarios for clients such as Boulder, Westminster and Thornton, Colorado.

Other Capabilities

Aquacraft can provide services related water rights engineering (including expert testimony), hydraulic analysis and calibration of hydraulic models, environmental data collection, peak demand evaluation, and statistical analysis.

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Billing Rates (2015-16):

Category	Rate/hour
Expert Testimony	\$250
Principal Engineer	\$200
Project Engineer/Senior Data Analyst	\$150
Analyst	\$100
Technician	\$75

Recent Projects and References

The following provides a list of some of Aquacraft's projects. The date in parentheses is the year in which the report was or will be published.

Analysis of Actual Water Savings from Weather Based Irrigation Controllers (2015)

This report provided empirical information about the performance of WBICs for water conservation through an examination of actual water use for over 1000 WBIC sites in the Santa Clarita Valley of California. The report started from the monthly billed consumption provided by the agencies for the entire single family populations of the four major water providers in the area (Santa Clarita Water Division, Valencia Water Company, Newhall County Water District, and Los Angeles County Waterworks District #36). From this, the WBIC homes were identified from the billing data, and tables of weather-corrected outdoor water use for each of the WBIC sites and for a Control group were assembled. This allowed a pre-post and a side-by-side comparison of weather-corrected outdoor water use to be performed. The results showed that random distribution of the devices tended to *increase* water use, while distribution that was targeted to high users (with high application ratios) could save significant amounts of water.

Residential Demand Forecasting Model (2015)

Aquacraft has developed a model of residential water demands based on end use data that we have collected on nearly 4000 homes over a 20 year period. The key thing about this model is that it is empirical, not theoretical. It is based on observations of how actual household water use changes in response to changes in parameters such as occupancy rates, efficiency levels, mixes of housing type, economic factors, employment, irrigated areas and irrigation habits. The model uses approximately 24 variables for existing and new single family and multi-family households to predict household water use. Each of them can be programmed to change by a specific amount or percent each year (within limits) and the total demand is then calculated with the changes for each year. This allows changes in total and per capita water use to be tracked over the study period (defined by the user).

Residential End Study in Abu Dhabi (2014)

The United Arab Emirates obtain almost all of its drinking water from desalinated seawater. At the same time the Emirates have one of the highest per capita water uses in the world. The UAE had a strong desire to get information on the reason for this use pattern, and to obtain a better understanding on how waste and excess use could be reduced. Working with Dornier Consulting, Aquacraft performed end use analyses on a sample of ~150 homes with data collected for 3, 2 week periods (June, September and December) in 2013. The data were collected using cell phone based (GSM) data-loggers and high resolution meters. This eliminated the need to go to the homes to collect data. The data were transmitted by the local consultants to Aquacraft via the internet and analyzed in Boulder. Local consultants performed surveys on the homes and provided

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this information to Aquacraft. The combination of the end-use data and survey information allowed household and per capita water use to be determined for each end-use and use patterns analyzed over time. Mathematical models of water use were prepared in order to determine which factors best explain use, and might be useful in design of water demand management programs.

Contact: Mr. Thomas Kern, Dornier Consulting GmbH, Thomas.kern@dornier-consulting.com

Residential End Uses of Water Update (2016)

Aquacraft is the principal investigator on a research project to update the 1999 Residential End Uses of Water study, sponsored by the Water Research Foundation. 26 water utilities from the US and Canada are participating in this project which includes a detailed analysis of the end uses of water use 9 utilities. This study, slated for publication in 2014 will provide the most up to date information on where water is used in the single-family residential setting across North America. The project will evaluate changes in water use and will identify the saturation rate of water efficient fixtures and appliances. This project is also measuring hot water use in a sample of approximately 100 homes spread across the 9 water agencies. The report has been released to the client in draft form and is anticipated to be published by the middle of 2014.

Contact: Ms. Maureen Hodgins, Water Research Foundation, (303) 734-3465

Report On In-Home Water Use Patterns In Single Family Homes From Jordan (2011/2008)

This report provides detailed information on single family water use patterns within a study group approximately 95 homes located throughout Jordan. The study used data obtained from water meters and data loggers attached to the outlets of the roof tanks that supplied the domestic water to the homes. The data from the water meters was collected at 10 second intervals with a resolution of .05 liters per pulse. At this resolution it was possible to disaggregate the water use in the homes into individual water use events, and to categorize the events by end-use. The houses in the study group were also surveyed to provide demographic information. This allowed the research team to determine household and percapita water use directly from the customer meter in a non-intrusive manner, and in a way that eliminated uncertainties caused by leakage in the distribution system or the storage tanks.

Contact: Dr. Mohamed Chebanne, Water For Life Solutions, mchebaane@w4ls.com 571-535-0141

Albuquerque/Bernalillo County Single Family Water Use Efficiency Study (2011)

The Albuquerque Bernalillo County Water Utility Authority (ABCWUA) established a goal of reducing its overall water use to 150 gpcd by 2014. Given the fact that nearly half of the water use in the system is devoted to single family residential uses the Authority determined that it would be beneficial to conduct a detailed investigation of the current water use patterns of its single family customers, and to determine the potential water savings available within the group. Towards this end the Authority contracted with Aquacraft, Inc. to conduct a baseline study of single family water use conducted on a

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representative sample of customers. A second component of the study was a retrofit study on a group of 29 homes chosen from the baseline group. This retrofit group had their fixtures and appliances upgraded to high efficiency devices and their water use was measured afterwards to determine the potential savings from the program.

This study demonstrated that by switching to high efficiency (Water Sense) fixtures and appliances in it single family residences domestic use could be reduced to 101 gphd, or 31 gpcd from its current average of 138 gphd and 49 gpcd . The total projected indoor water savings for the entire population of over 151,000 single family accounts, was estimated to be 8724 AF from just interior retrofits. This represents a 20% reduction in total single family residential demands. Because many homes in Albuquerque do not irrigate, or irrigate very little, estimated outdoor savings from elimination of excess irrigation was only 675 AF and this was projected to occur mainly on the top 3200 outdoor users.

SWSI 2011 Municipal and Industrial Water Conservation Strategies

In support of the Statewide Water Supply Initiative (SWSI), the Interbasin Compact Committee (IBCC), and other water conservation efforts throughout the state, the CWCB has developed several work products which provide technical detail related to water conservation planning. The purpose of this report was to incorporate recent water conservation-related efforts into the SWSI 2010 update, update the range of potential future water conservation savings, and provide water conservation strategies that can contribute toward meeting the projected 2050 M&I water supply gap and help address Colorado's future municipal and industrial (M&I) water needs.

Contact: Mr. Kevin Reidy, CWCB (303) 739-7387

Water Budgets and Rate Structures: Innovative Management Tools

Aquacraft was principal investigator on this AwwaRF study of the uses of water budget based rate structures for improving water resource management. The study defined what a water budget rate structure is, and how such system can improve overall water resource management. Key elements of the analysis included improved equity and flexibility for the customers, more responsive demand management for the utilities, financial integrity and improved drought response. Barriers to implementation of water budgets and case studies were included in this AWWARF research report.

Contact: Ms. Susan Turnquist, AwwaRF, (303) 347-6124

Colorado Drought And Water Supply Update (2007)

This report was designed to provide a snapshot of water planning related to drought and conservation in Colorado in 2007. The study used a telephone survey conducted on all major water providers in the state to assess the current (as of 2007) level of drought being experienced by the suppliers, the degree to which they had recovered from the severe drought of 2002, and the planning and research needs that they identified.

Contact: Mr. Kevin Reidy, CWC|B (303) 739-7387

California Single Family Water Use Efficiency Study (2011)

In this major comparative study of residential water use, water use was measured from random samples of single-family homes selected to be representative of the populations in 10 major California water agencies. The water use in these homes was analyzed in detail using both billing data and flow traces, which allowed water use to be disaggregated by end-use. The indoor and outdoor water use efficiencies were determined so that the current state of water use, and the potential for future water savings through conservation could be determined. Comparisons were made to the information obtained as part of the REUWS study (1999), which collected water use data in 1996-1997. Over 700 houses were studied.

Contact: Ms. Fiona Sanchez, Irvine Ranch Water District, (949) 453-5325

Water Use in New Single Family Homes (2011)

The focus of this study was to determine whether new single family homes use more or less water than existing homes. For this study the breakpoint between new and existing homes as chosen as January 1, 2001. The analysis included surveys to both new and existing customers so that the factors that affect water use could be corrected for (such as the number of residents, the size of the lot and home, etc.). A total of nine water agencies across the US participated in the study. Random samples of 40 new homes were chosen from each study site. These homes were visited so that flow traces could be obtained for end-use analysis, and that the water using fixtures and appliances present in the homes could be identified precisely. Information on landscapes and irrigation systems was collected at these homes so that the irrigation water use and application rates could be determined.

Contact: Ms. Stephanie Duer, Salt Lake City Water Dept., (801) 483-6860

Analysis Of End Uses In Ten Homes In Phoenix For Comparison And Verification (2010)

The purpose of this study was to make comparisons between water use data recorded by a number of residents on paper log sheets and the results of flow trace analysis performed on data obtained from the customer water meter, and analyzed using the Trace Wizard program. To provide comparison, volunteers were asked to manually log their water using events. Ten sites were successfully data logged for eleven days in August 2010. The general goal was to attempt to provide a degree of verification for the Trace Wizard analysis based on the recorded events of the customers.

Contact Mr. Douglas Frost and Adam Miller, City of Phoenix WSD, 602-262-4575

Establishment of Water Budget Rate Structure for Boulder, CO

Bill DeOreo served privately as an advisor to the City of Boulder City Council members and Water Resources Advisory Board while the City was actively studying and then implementing its water budget system. As part of this process he took a lead role with the development of the blocks and rates and determination of appropriate budgets for residential and irrigation users. The final system, adopted by the City was based on the

structure they outlined at the beginning of the effort. They also worked on integration of the water budget rate structure into the City's drought response plan.

Contact: Mr. Jim Knopf (303)494-8766; Mr. Ken Wilson (303)999-1931

California Embedded Energy in Water Studies: End-Use Water Demand Profiles. (2011)

“Embedded energy in water” refers to the amount of energy that is used to collect, convey, treat, and distribute a unit of water to end-users, and the amount of energy that is used to collect and transport used water for treatment prior to safe discharge of the effluent in accordance with regulatory rules. In 2007, the California Public Utilities Commission (CPUC) authorized water-energy pilot projects and three studies designed to (a) validate claims that saving water can save energy, and (b) explore whether embedded energy savings associated with water use efficiency are measurable and verifiable.

As part of this effort, The End-Use Water Demand Profile Study was conducted by Aquacraft, Inc. under contract to the CPUC, Energy Division to provide more accurate hourly water use profile data than have previously been available. The study examined cold-water use for six end-user (customer) categories, plus urban irrigation. Flow trace analysis was conducted in order to provide precise information about water use patterns: where, when, and how much water is used by a variety of devices at the sites that were studied in the analysis. The results of the study include 24-hour end use water demand profiles for each category.

Contact: University of California, Center of Energy and Environment , Mr Edward Vine. edward.vine@uc-ciee.org

California Embedded Energy in Water Pilot Programs Impact Evaluation (2011)

Past research has shown that there is considerable energy that is required to obtain, treat and distribute water supplies to end-use customers. In response to these findings, the California Public Utilities Commission (CPUC) approved the Embedded Energy in Water Pilot programs, through which California's largest energy Investor-Owned Utilities were directed to develop partnerships with water agencies, implement specific water conservation and energy efficiency programs, and measure the embedded energy savings. Aquacraft conducted impact evaluations for CPUC for Pilot programs involving pH Controllers on cooling towers, high efficiency toilets in low income multi family residences. For each program, changes in water use pre and post of the intervention were measured directly and analyzed to show how much water (and energy) was saved through the intervention.

IRWD Multi-family Housing Water Study (2009)

There are over 48,000 multi-family households served by the Irvine Ranch Water District (IRWD), and they account for approximately 10% of all water deliveries from the system, or 8307 acre feet of treated water deliveries. Fortunately, over 26,000 (54%) of these customers are individually metered. This provides an excellent opportunity to study the water use patterns of the multi-family customers in detail. The IRWD wished

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to undertake a study of multi-family water use in order to improve their methodology of setting indoor water budgets for multi-family accounts, and contracted with Aquacraft, Inc. to undertake the project.

Using a combination of billing data and surveys Aquacraft evaluated the water use patterns in the multi-family customers in the Irvine Ranch Water District. Due to the high number of individually metered multi-family accounts in Irvine it was possible to do regression analyses on the annual and seasonal water use for a large selection of customers by linking their consumption to results of surveys mailed to the customers. This study focused on evaluation of the factors that affect water use in multi-family residences.

This data collected as part of this study showed that the existing method used by IRWD for calculating multi-family water budgets over estimates the required amount of water for each unit. The existing system assumes a linear relationship of 75 gpd per person for indoor uses and allows 100% of ET for outdoor allocation. Under the system that was in place when the study was done nearly 90% of all customers were at or below their budget. The study recommended decreasing budgets to the extent that approximately 70% would be at or below the budgets and 30% of the customers would receive a price signal to reduce their consumption.

Content Development for the Alliance for Water Efficiency

Renee Davis has helped edit the Alliance for Water Efficiency's Water Efficiency Watch newsletter - the premier water conservation e-newsletter. Renee and Aquacraft staff developed the resource library for AWE.

Eastern Municipal Water District – Water Efficient Guidelines for New Development

Aquacraft prepared a set of detailed, voluntary water efficiency guidelines for new construction in the Eastern Municipal Water District that go beyond current building codes and standards to increase water use efficiency.

City of Westminster Residential Demand Study and Conservation Plan Preparation

Aquacraft conducted a residential end use study in Westminster, Colorado to determine water use patterns and the level of water efficiency achieved. This information was then used in support of preparation of new water conservation plan for the City.

Northern Water Conservation Survey and Plan Development

The Northern Colorado Water Conservancy District hired Aquacraft to conduct a survey of its' 45 municipal members. The results of the survey were used to update Northern's water conservation plan for the Bureau of Reclamation.

Guidebook of Best Practices for Municipal Water Conservation in Colorado

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On behalf of Colorado WaterWise, Aquacraft prepared an extensive written guidebook of voluntary conservation best practices for utilities in Colorado. The guidebook was developed as a tool for improving and enhancing water efficiency and was written specifically for water professionals. The guidebook includes information on 14 best practices including: implementation approach and methods, likely costs, anticipated water savings, barriers, and challenges.

Colorado State Water Supply Initiative Municipal and Industrial Conservation Strategies

In support of the Statewide Water Supply Initiative (SWSI), the Interbasin Compact Committee (IBCC), and other water conservation efforts throughout the state, the CWCB contracted with Aquacraft to develop the conservation strategies section of the 2010 SWSI update. The purpose of this project was to:

- Incorporate recent water conservation-related efforts into the SWSI 2010 update,
- Update the range of potential future water conservation savings, and
- Provide water conservation strategies that may contribute toward meeting the projected 2050 M&I water supply gap] and help address Colorado's future municipal and industrial (M&I) water needs.

Water Conservation: Customer Behavior and Effective Communications

The objective of this WaterRF research study was to evaluate the linkages and relationships between water conservation behavior of residential customers and the communication approaches that seek to influence that behavior. Aquacraft was a subcontractor to ICF International and together implemented this evaluation through a multi-method approach including: telephone interviews with water agency personnel, surveys of residential water customers, analyses of current and past billing records, in-depth case studies of water agencies and their conservation communication campaigns, and an evaluation of communication methods implemented by six participating utilities.

Evaluation of California Weather-Based "Smart" Irrigation Controller Programs

Aquacraft conducted a multi-year study of smart irrigation controllers in California. Data from installation of over 3,000 smart controllers in both northern and southern California were analyzed. Actual weather normalized irrigation applications were determined for each site before and after the smart irrigation controllers were installed. The systems were evaluated both on the basis of how much water they saved, and on how well they were able to match irrigation applications to the theoretical irrigation demands. The results of the analysis were mixed. The controllers as a group brought the applications closer to the theoretical demands, but there was a substantial residual amount of over and under irrigation in the group after the controllers were installed. Water savings were found to depend heavily on the amount of pre-install over-irrigation. Annual weather normalized water savings for the group as a whole averaged around 50 kgal per year. One of the key findings of the study was that screening for over-irrigators as candidates for future interventions could double the potential savings and substantially reduce the expected implementation costs. Recommendations are included for future research.

City of Greeley Water Conservation Plan

This Water Conservation Plan for the City of Greeley was developed to establish clear goals and to outline programs and measures to meet those goals that will ensure a healthy and sufficient water supply for the future. Aquacraft worked with Greeley to establish a goal of reducing demand by 8.2 percent directly through its conservation program efforts over the period from 2010 to 2030 compared with projected future demand without conservation. The net impact of this program is an estimated cumulative savings of 144 acre feet per year that will yield a total savings of slightly over 3,000 acre feet of water by 2030. Greeley's water conservation plan was approved by city officials and the by the Colorado Water Conservation Board.

City of Fort Collins Water Conservation Plan

The City of Fort Collins Utilities provides water, wastewater, stormwater and electric services to the Fort Collins community. In 2007, the Utilities served 8.8 billion gallons of water to approximately 128,000 people. The City views the water conservation program as an important proactive response to supply variability and climate change. Aquacraft worked with the City to prepare a water conservation plan that was vetted through a rigorous public process and approved by the Fort Collins City Council and the Colorado Water Conservation Board.

Alexander Dawson School

The goal at this school is to increase student enrollment by 60% over the next ten years without increasing their current level of water consumption. This reduction had to be achieved through improving the efficiency of indoor uses and the swimming pool; all non-consumptive uses were provided by non-potable water. This private school consists of a high school, middle school, and elementary school, a dining hall, and nine single family homes. In addition, there is an athletic center, art center, library and language buildings, maintenance, and various ancillary buildings designed to support the various activities on campus. The water efficiency audit performed by Aquacraft provided effective and efficient means for reducing water use at the current level of 22 gallons per student per day to 14 gpsd.

Colorado Drought and Water Supply Assessment

Aquacraft conducted a survey of water providers and water districts across the state to determine their water supply challenges, anticipated population growth, current water conservation programs, and drought preparedness. Working with the Colorado Water Conservation Board's Office of Water Conservation and Drought Planning, Aquacraft designed and implemented the survey and prepared a report for the State based on the findings.

Denver Water Library Audits

The primary goal of this project was to carefully examine indoor water use at 22 Denver Public Library branches and irrigation at 18 of those branches to determine what cost-effective water conservation measures could be successfully employed to reduce demand.

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Site audits were used to develop recommendations for best conservation measures; data logging was used to confirm site audit data and provided additional information on toilet volumes, peak usage, leakage, and zone-by-zone irrigation usage. Potential water savings were projected for each site as well as for the 22 facilities as a whole. The recommended conservation measures, when implemented, will provide a savings of nearly 15 acre-feet annually.

Denver Water Recreation Center Audits

The primary goal of this project was to provide water conservation recommendations that would reduce demand at 30 Denver recreation centers and six outdoor pools. Water conservation measures were thoroughly examined to determine any negative or limiting factors that might be associated as well as any potential problems that might occur through equipment or process changes. The extent to which leaks were a problem at each site was documented. All fixtures and appliances were documented and where possible flow data was recorded. Flow data was recorded at each site and evaluated for peak usage, leaks, and other process uses. The recommended conservation measures, when implemented, resulted in a savings of just over nine acre-feet annually.

City of Aurora Water Conservation Plan

Aurora Water serves approximately 306,908 people with 73,000 connections. Aurora contracted with Aquacraft to prepare a water conservation plan for the City that would comply with all the State of Colorado requirements. Aquacraft worked closely with City staff and prepared a plan that was adopted and implemented by the City and approved by the State.

Water Conservation Planning Support, Colorado Water Conservation Board

The Colorado Water Conservation Board (CWCB), Office of Water Conservation and Drought Planning has a rigorous set of requirements that water conservation plans must meet in order to receive official approval from the State of Colorado. The CWCB contracted with Aquacraft to provide a detailed technical review of water conservation plans submitted to the State and to identify areas that met and did not meet statutory requirements. Through this process, Aquacraft reviewed approximately 20 water conservation plans for the CWCB.

Denver Water Residential Water Use and Drought Response Study

Denver Water was an original participant in the Residential End Uses of Water study. In 2005, Aquacraft returned to the same sample of 100 homes in Denver and measured water use during the same time of year. The purpose of this study was to determine how water use patterns have changed over the past 10 years and to what extent demand reductions achieved in response to the drought of 2002 will be permanent.

Evaluation of Water Savings from Pre-Rinse Spray Valves in Restaurants

Aquacraft developed and implemented a micro-metering system to measure the water used for rinsing dishes in restaurants. Measurements were taken before and after

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installation of low-flow pre-rinse spray valves using data loggers on water meters and dishwasher motors. Having dishwasher use data allowed the water use to be adjusted for variations in kitchen use.

Sacramento CII Water Use Reviews

Substantial conservation potential exists in the commercial, industrial, and institutional sector. Aquacraft conducted detailed water use reviews on a wide variety of sites in the Sacramento area. The reviews included an analysis of historic consumption, inventory of all water using fixtures, appliances, and equipment, and flow trace analysis to determine current state of efficiency. Each site was presented with a detailed water use analysis including recommendations for cost effective conservation improvements.

Santa Paula, CA Residential Baseline Study

Working with RBF, Aquacraft conducted a study of the baseline residential demands in Santa Paul, CA. This study involved collecting precise end use data using Aquacraft's flow trace analysis technique as well a surveys of residents.

MASCO Environments for Living Evaluation

Aquacraft participated in a study of the water and energy savings achieved through the construction of new homes under the MASCO Environments for Living program. This study included analysis of the water savings impacts of high efficiency toilets, clothes washers, showerheads, faucet aerators and on-demand hot water systems. The impact of water efficient landscape designs coupled with properly installed weather based irrigation controllers was evaluated as well.

University of Colorado Mountain Research Station Conservation Plan

Aquacraft conducted a detailed demand audit and prepared a water conservation plan for the CU Mountain Research Station, located near the Continental Divide at 10,500 ft. above sea level.

City of Carnation Water Conservation Demand Analysis

In late 2004 Aquacraft worked with the Pacific Institute, Carollo Engineers, and King County, Washington to determine the conservation potential evaluate the cost-effectiveness of water conservation in new and existing homes and businesses in the City of Carnation. Carnation is a small town that is currently not sewered. The County and the City are working together to provide a sanitary sewer system and treatment facility.

EPA Water Efficiency Market Enhancement Program

Working with D&R International and ERG, Aquacraft assisted in the design of the market enhancement program (aka "Water Star"), and played a key role in evaluating products and product categories that could receive an efficiency label. Aquacraft developed a web-based database for this project that has been used by the project team and EPA to collect and track information on efficient products and categories.

National Multiple-Family Submetering and Allocation Billing Program Study

Aquacraft lead a team that examined the impacts of submetering and RUBS billing in the multi-family sector. This national study is of critical importance to the water industry and provides some of most statistically rigorous examinations of the impacts of metered and allocation billing. The study looked at the entire phenomena of submetering and allocation billing techniques examining the potential water savings, regulatory issues, utility concerns, water rates, and regulatory climate.

Seattle Market Penetration Study

The Seattle Market Penetration Study was designed to enable Seattle Public Utility (SPU) to assess the effectiveness of their water conservation programs and the extent to which their customers have reduced water consumption through behavioral changes and conversion to water conserving fixtures and appliances.

University of Colorado – Student Housing Performance Contract

Working with the Brendle Group and the Siemens Corporation, Aquacraft conducted an investment grade audit of irrigation systems on the CU Boulder campus and provided technical support for interior retrofit audits. Numerous facility improvement measures were identified that should greatly improve irrigation efficiency at CU.

AwwaRF Value of Water Study

Working with Stratus Consulting, Aquacraft developed case studies and provided end use information for the Value of Water Study, funded by the American Water Works Association Research Foundation.

Water Conservation in Urban Supermarkets,

Urban supermarkets are major water users, especially their cooling equipment for refrigeration. This was a two year study that performed detailed evaluations of three options under investigation by the Los Angeles Department of Water and Power for increasing the cycles of concentration in evaporative condensers in urban supermarkets. After baseline data were collected a total of six stores were retrofit with the systems under study: alkalinity control, and two variations of electronic scale controllers. The operation of the system in terms of both water use and the scale potential in the coolers was investigated. Other water conservation options in the stores were investigated. This study documented that a typical supermarket in Southern California can save up to 700 kgal/year, cost effectively, by implementing advanced treatment in its cooling systems plus a range of simple water conservation throughout the rest of the store.

Weather-Based Irrigation Controller Research and Support

Aquacraft has evaluated and tested the WeatherTRAK ET-based sprinkler control system – an advanced sprinkler controller that adjusts irrigation based on prevailing weather conditions. Results from the studies showed this system can be used to manage irrigation water demands and had good customer acceptance.

Seattle, EBMUD and Tampa Interior Retrofit Projects

These projects carefully evaluated the impact of interior plumbing and fixture retrofits on single family homes. A sample of approximately 30 homes was selected in each city and baseline water use and customer information data were obtained. Next the homes were retrofit with best-available-technology toilets, clothes washers, showerheads, and faucet aerators. Post retrofit water data were collected and analyzed using flow trace analysis technology. The results show precise impacts of high efficiency plumbing fixtures and appliances on single family homes on a per household and per capita demand basis. Customer satisfaction ratings were also obtained.

Water Efficient Home Web Site (www.h2ouse.org)

Working with the California Urban Water Conservation Council, Aquacraft developed substantial content for the virtual water efficient home web site. Aquacraft also assisted in developing the original design for the award winning site.

Colorado Department of Human Services Water Rights Study

The Department of Human Services has been charged with achieving a 20% reduction of all utilities in the current fiscal year. Aquacraft is working in association with Long Energy to determine the water rights available to DHS and the most efficient use and distribution of their water resources.

Pinellas County Utilities Water Conservation Opportunities Study,

Pinellas County Utilities, located just west of Tampa, Florida, has an active water conservation and alternative supplies program. They came to Aquacraft and asked, “Where can we go from here to save water?” This study measured water use in samples of single-family and multi-family homes and made recommendations for future water conservation programs that could achieve the most savings in this specific community.

Dacono Water Supply and Conservation Plan,

The Town of Dacono, Colorado anticipates significant growth in the coming years and needs to plan for a secure water future. Aquacraft developed a long-term water demand forecast and conservation model that projected the impact of future development on supply for the town. We also created a subdivision demand forecasting tool that the Town can use to determine how much water and what water rights a new development must dedicate as a condition of incorporation.

Irrigation Demand Study for East Cherry Creek Valley Water District

The East Cherry Creek Water District (ECCWD), located near Aurora Colorado plans to build a raw water distribution system in the next few years, but was uncertain how much land could be irrigated given the limitations of their water rights, storage, and pumping capacity. Aquacraft used micro flow metering technology to measure peak demand in 29 different irrigation systems that could potentially be served by the raw water system. These results were used to develop a model to help size the system and determine how much land can be served by the system.

Water Conservation Plan for City of Bozeman, MT,

The City of Bozeman is situated in Gallatin Valley of Montana at the headwaters of the Missouri River. Growth rates are high and the citizens place a very high value on the quality of their environment. Mr. DeOreo developed an integrated water demand/financial model, which showed the impacts of various water conservation options on the both water demands, capital spending and system finances. This model allowed the town to assess the potential of water conservation to delay several water treatment and storage projects.

Commercial and Institutional End Uses of Water, AWWARE,

This study set out to collect and analyze data on commercial and institutional end uses of water in five cities. This study developed information on the most significant commercial and institutional customers in typical municipal water systems and the purposes for which these customers use water. Aquacraft performed detailed water audits and implemented a variety of water use measurement programs to determine where water is used in these settings. Report is available for purchase from AWWA.

Residential End Uses of Water Study, AWWARE,

In this three year project, funded in combination by the American Water Works Association Research Foundation and 14 cities across the US and Canada, disaggregated water use data were obtained from nearly 1200 single family residences. In addition to characterizing water use in the single-family sector, these data were used to develop a model of residential water use based on the demographic characteristics of the households and the specific water using fixtures and appliances present.

The database developed for this study includes a table of over 1.9 million individual water use events that have been analyzed according to end use, volume, start time, flow rate, and duration. These were obtained from scientifically selected samples from the single-family residential customers in each city. The database also includes a table of daily use for each household and extensive survey information that provides information on physical and demographic characteristics.

Industrial, Commercial, and Irrigation Water Study and Conservation Plan, Westminster, CO,

The goals of this project were to evaluate ICI water demands in Westminster, identify and evaluate potential conservation programs, develop a long range conservation plan and demand tracking tools, and pilot test various conservation measures.

Analysis of Southern Nevada Xeriscape Project,

Aquacraft performed a detailed evaluation of a Xeriscape conversion program in Las Vegas. Fifty participants in the program were compared against 50 traditionally landscaped customers. Flow trace analysis techniques were used to separate indoor and outdoor consumption in the 100 study houses. Significant savings were found among Xeriscape homes. Report is available from Aquacraft.

Water Conservation Futures Study, City of Boulder, CO,

The City of Boulder is fortunate to have an abundant supply of high quality water, and they do not project any shortages in water supply between current conditions and build out. Nonetheless, the City recognizes that there are demand management issues to address both from the perspective of equity in the billing system and in the need to identify other potential uses for its water resources (such as in-stream flow maintenance). Aquacraft is part of the team hired by the City to conduct an analysis of the future of water conservation in Boulder.

Water Conservation Plan, City of Thornton, CO,

The City of Thornton is faced with one of the highest growth rates in Colorado, and a very expensive new water supply. The impacts of water conservation on their system could be dramatic. Aquacraft, in conjunction with HDR consultants completed a water conservation plan for Thornton to determine the impact of a range of conservation measures on the City's water supply. All conservation measures will be compared to the City's structural alternatives in terms of yield and cost.

Water Efficiency in Water Wise and Standard New Homes,

Aquacraft conducted a study in Westminster Colorado to determine how water use in specially designed "Water Wise" homes compares with other new homes built at the same time. This project will measure the impact of the 1993 Federal plumbing codes compared to homes equipped with advanced efficient plumbing fixtures including conserving clothes washers and re-circulating hot water systems. Aquacraft's flow trace analysis technique was used to measure end uses in each of the 40 participating study homes.

Tucson Older ULF Toilet Study,

Aquacraft provided hardware, software, and technical support for a project that evaluated the performance of ULF toilets that were placed into service in the early 1990s. It was suspected that these fixtures no longer operate at a flush volume of 1.6 gallons, thus potentially reversing conservation savings.

Evaluation of Soil Moisture Sensors in Field Applications,

Working with the City of Boulder, Aquacraft tested the efficacy of the Watermark soil moisture sensor system in a variety of settings including single-family residential, multi-family residential, commercial, and urban parks. Results show that these devices, while not perfect, can be an effective tool for controlling automatic irrigation systems and limiting application rates to ET.

Comparison of Demand Patterns among Residential and CI Customers, Westminster, CO,

Westminster, Colorado is a growing community in the Denver metropolitan area. The city is working on the development of a cost of service based rate system. In order to assist with this effort Aquacraft has collected flow trace data on a series of single family, multi-family, irrigation, and commercial accounts during peak demand period for the

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City. These data have been used to develop daily and hourly peaking factors for each category and a set of normalized demand parameters for use in projecting demands in future customers.

Westminster, Peak Demands Study,

As part of its water planning process, the City of Westminster needed information on daily and hourly peaking factors for its major classes of customers. Aquacraft conducted a baseline study of peak use in single family, multifamily, irrigation, and commercial/industrial customers for the City. This study generated peak use factors as ratios to average day demands and in terms of gallons per day per unit.

Centennial Valley Water GIS,

In order to determine the amount of wastewater being generated from an area of mixed development in Louisville, CO., Aquacraft developed a geographical information system which linked water billing and mapping information, thus allowing determinations to be made on deliveries of treated water to areas tributary to any specified portion of the sanitary sewer system. This system showed in which areas large discrepancies existed between measured wastewater flows and treated water deliveries and identified areas of probable I&I into the sanitary sewer system.

MCDB Water Use Study,

The University of Colorado faced a wastewater Plant Investment Fee of \$219,000 for an expansion to the Molecular Cellular and Developmental Biology building on the Boulder Campus. A detailed study and water audit of the water and wastewater flow patterns and waste loadings was conducted which determined that the appropriate charges would be \$52,000, a savings of \$167,000.

Colorado Water Conservation Model,

In order to implement the 1991 Water Conservation Act, the State of Colorado authorized the development of an integrated water system operations and economic model (CIRCE) which will allow system managers to assess both the hydrologic and financial consequences of alternative water management strategies. This allows an objective assessment of the relative benefits of both structural (supply side) and non-structural (demand side) projects.

Partial List of Clients

Alexander Dawson School, Louisville, CO
Albuquerque Bernalillo County Water Utility Authority
Alliance for Water Efficiency
American Water Works Association Research Foundation
Aquasan Network Inc.
Arizona Municipal Water Users Association, AZ
Arkansas River Ranch LLC
Black and Veatch Consultants
California Urban Water Conservation Council
California Public Utilities Commission
Carollo Engineers (Carnation)
Castaic Lake Water Agency, CA
City of Boulder, CO
City of Bozeman, MT
City of Dacono, CO
City of Glenwood Springs, CO
City of Greeley, CO
City of Lompoc, CA
City of Phoenix, AZ
City of San Antonio, TX
City of San Diego, CA
City of Scottsdale AZ
City of Tampa, FL
City of Tempe, AZ
City of Thornton, CO
City of Westminster, CO
Development Alternatives International (Jordan)
Denver Board of Water Commissioners, Denver CO
Denver Water
Dornier Consultant GmbH (Abu Dhabi)
East Bay Municipal Water District
East Cherry Creek Valley Water District
Eugene Water and Electric Board, OR
Gold Coast Water Utility, Australia
Hazen and Sawyer, Inc. (Phoenix)
Hillsborough County Water Department, FL
IAPMO
Irvine Ranch Water District, CA
Kohler Company
Las Vegas Valley Water District
Las Virgenes Municipal Water District, CA
MASCO Building Services Co.
Metropolitan Water District of Southern California, CA
National Renewable Energy Laboratories, Golden CO

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New Mexico State Engineer
Nexant, Inc.
Otay Water District
Pinellas County Utilities, FL
Quantec Consultants (Santa Cruz)
RBF Consultants (Santa Paula)
Regional Municipality of Waterloo, Ontario
Salt Lake City, UT
San Diego County Water Authority
Santa Clara Water Department, CA
Seattle Public Utilities, WA
Singapore Public Utilities Board
Southern Nevada Water Authority
Southwestern Colorado Water Conservancy District
Tampa Bay Water
University of Louisville
U.S. Bureau of Reclamation
U.S. Environmental Protection Agency
U.S. Department of Justice
University of Colorado, Boulder
Walnut Valley Water District, CA
Water Research Foundation
Water District #1 of Johnson County, KS
WSV Partners
Yarra Valley Water District, Australia