Where's Your Water?

A reliable water audit is the foundation of proper water resource management.

By Mark Saunders

If you walked into a bank to make a modest withdrawal, you would expect the teller to be able to tell you exactly how much money is in your account, and—with a little help from the branch manager perhaps—how much money the bank had on hand at that given moment. Suppose, however, that the teller asked you to wait a minute, and then went to fetch the branch manager, who graciously led you to her office, offered you a cup of coffee, and said, “We knew how much money we had in the vault this morning, but now that it’s four o’clock, we’ll need just a minute to do a quick tally before we can process your withdrawal.” If your bank operated this way, chances are you would withdraw all your money and find another bank.

Unfortunately, this kind of ambiguous accounting practice is more the rule than the exception when it comes to accounting for water in standard utility distribution systems. “Just as banks provide statements of monies flowing into and out of accounts, the water audit displays how quantities of water flow into and out of the distribution system to the customer,” states Julian Thorton et al, in the book, The Water Loss Control Manual. “Yet, as essential and commonplace [as] the financial balance sheet is to the world of commerce, water audits have been surprisingly uncommon in the world of water supply throughout most of the world.”

Visionary water manager for the city of Aurora, CO, Peter Binney, agrees, saying, “That’s part of the way that people have looked upon water in the past.” “We haven’t been supply limited, partly because of past investments in these systems. Part of it is hydrologically; we had a very wet climate cycle over the past 30+ years. I expect that, as we treat water more as the valuable resource that it is, rather than [as] a commodity—which is heavily subsidized or was paid for back in the 1930s or 1960s—people will become a lot more conservation oriented.”

Historically, water utilities have operated under rudimentary accounting practices. A certain amount of water is “produced” every day, which is then distributed throughout the system. What percentage of that water reached customers, however, was a question that, until relatively recently, many utility managers only had a best-guess estimate, based on customer meter reports. The worst aspect about not knowing how much water is in a particular system at any given time is the potential for massive loss of the resource (millions of gallons a day in some cases)—not to mention revenue.

The United States Geological Survey document, “Estimated Use of Water in the United States in 1995,” states that, of the 40 billion gallons of water withdrawn each day by water utilities, only 34 billion gallons made it to the end-use customers. While 15% is not considered a ‘bad’ non-revenue water number, those 6 billion gallons represent a level of waste and lost revenue no water manager would feel comfortable with.

In an effort to combat these types of losses, the International Water Association (IWA) formed a Water Loss Task Force in 1997. One of the principle goals of the task force was to develop a “workable water audit structure for drinking water utilities.” The American Water Works Association (AWWA) was part of this project, and the results were published in 2000, in the IWA’s publication, “Performance Indicators for Water Supply Services.”

The AWWA Water Audit Methodology Web site states, “The IWA/AWWA Water Audit Method is effective, because it features sound, consistent definitions for the major forms of water consumption and water loss encountered in drinking water utilities. It also has a set of rational performance indicators that evaluate utilities on system-specific features. ... The key concept around this method is that no water is ‘unaccounted for' in the components listed by using either measured for estimated qualities.”

Instead of the imprecise term “unaccounted for,” the AWWA’s Water Loss Control Committee recommends the term “non-revenue” water, which it defines as the difference between system input volume and billed authorized consumption. Regardless of the term, we are still talking about the difference between water put into the system, and the water that is consumed and billed to customers. Finding the sources of this difference, be it on the apparent loss or real loss side of the equation (and fixing them), is one of the top goals of virtually every water manager in North America.

Where a utility begins to audit its distribution system depends upon a variety of factors: the overall age and health of the infrastructure; the state of the supply sources; the customer base, climate, and aridity; and the need to respond to changes in these and other areas.

Auditing Water

"Having a reliable water audit is the foundation of proper water resource management in drinking water supplies," states The 2002 AWWA Leak Detection & Water Accountability Committee Report Overview. "Water and revenue loss recovery stands as one of the most promising and cost-effective water resources initiatives in North America. It makes sense to recover this water and revenue in order to mitigate the effects of droughts and water shortages, and, as proper steps to take before developing new water sources and expensive supply infrastructure."

The challenges to doing a water audit can be daunting: expenses, man-hours, new equipment, and new infrastructures. As the AWWA 2002 report overview mentions, it's much better to start small with a "very preliminary" water audit, rather than waiting until everything's ready to go.

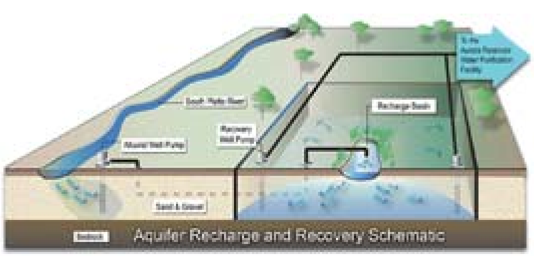
The Birmingham Water Works and Sewer Board (BWWSB) did exactly that, by starting right where they were at, in currently undergoing a new source project. The utility owns all its sources, and, according to Geoff Goodwin, Manager in Charge of Revenue Water, is looking to build another reservoir or a new river intake—either of which would be a half billion-dollar project.

"The board is serious about it," Goodwin says. "We're in a two-year study period right now, where we have several firms working with us to determine the best place, best spot, [and] best option. And we're half way through that time period right now. We're actually looking at starting the new source project in January 2008."

Before the board of directors would approve such an expense, they demanded that non-revenue water (NRW) numbers be at or below 16%. "We started looking at the IWA methodology several years ago and have been working along those lines," he says. "Fortunately, the AWWA has come onboard and modeled themselves after that as well. So, the IWA/AWWA water audit program is basically what we're working on right now."

BWWSB (which has a customer base of 200,000 active taps serving about 800,000 people, five counties, and several other utilities via wholesale meters) began their system-wide project to reduce NRW on the real loss side. Their leak detection survey, along approximately 3,800 miles of main, found slightly more than 100 leaks.

"We only found a handful of leaks that you would classify as large.... I think the single largest leak we found was 400 gallons per minute, and that was due to an installation error a couple of years ago that hadn't been caught," Goodwin says. "We found one other leak that was about 150 gallons per minute. Everything else was relatively small: 10, 20, 30 gallons a minute—a lot of little service leaks that were less than five gallons a minute—little things like that."



The Aquifer Recharge and Recovery System prevents the water from spilling out into the groundwater that doesn't belong to the city of Aurora.

Still, the leakage totals turned out to be slightly over 2,000 gallons a minute—just shy of three million gallons of water per day. At the utility's base rate of $2 per 100 cubic feet (748 gallons), that represents a daily loss of $3,850 in revenue, if the lost water had made it to customers' taps.

To uncover these leaks, Goodwin and company utilized a crew of 11 specialists (with an average of 16 years in the industry), approximately 3,000 Permalog units, plus three acoustic listening devices: an L-Mac, an X-Mac, and an LD-12.

"We started out putting the Permalogs behind our DMA [District Metered Area] stations, and we have since seeded them throughout our highest loss areas," Goodwin says. "Every six weeks or so, we turn up an average of about 20 leaks. The main service area, where we have the largest concentration of Permalog units, took us 14 months to survey manually with our acoustic gear and our team of experts. We can patrol the same area in about four-and-a-half weeks, then go back and spot all the leaks, and be done in two months instead of it taking 14 months before a huge time savings.

"We use the L-Mac as our primary survey tool," he adds. "It does an absolutely knock-down, drag-out job of leak detection on any kind of metal pipe. Then, we get ready to do the actual pinpointing of the leak itself, depending on how large a leak it is and what kind of material the leak is on, we will bounce back over to the X-Mac or the LD-12—both of which function better on PVC and concrete pipe."

BWWSB modeled the DMA part of their real loss program after the Halifax Regional Water Facility, in Halifax, Nova Scotia. Upon visiting the Canadian facility, Goodwin claims it has the most significant DMA program in North America. After running a pilot program for about a year, the savings in money, man hours, and time (not to mention mileage) were convincing. The program also includes a monitoring feature, which sends automatic updates via computer.

“If we get a high flow outside of a 15-percent range on any given night [meaning there are no significant leaks, and, thus, no need to survey the area], then the system automatically sends you an e-mail that tells you where you have a problem,” he says. “We also use data logging on all of our DMA Stations that’s captured on the mainframe computer. It’s all transmitted, so we can look at them on the screen in the office anytime. Soon, that technology will be systemwide. Right now, we’re using it in our high-loss areas to help us quantify things a bit better, so we’ll know where we need to emphasize our main-replacement program,

He describes the system further, stating, “The stations themselves vary, depending on how large of a meter you need, whether or not you can hardwire back to the existing facility, and whether or not you have to put in a full-blown SCADA radio station in there. Those stations vary anywhere from $20,000 to $60,000 a piece ... but, in the long term, they pay for themselves.”

BWWSB’s DMA stations use Marsh McBurney single-point insertion mag meters, as opposed to full-spool or turbine meters, because the former does not detract from the fire flow, and there are no constrictions in the pipe to worry about. Insertion mag meters also allow Goodwin’s crews to install, change, or perform maintenance on a meter, without having to shut down the main or interrupt service. The insertion mag meters are also a very low-cost option, because they do not require a bypass.

Apparent Loss

While real loss water is measured in gallons, and the energy costs of moving the water from source to tap and the chemicals/filtration required to bring it up to drinking water standards, apparent loss is much more valuable. Apparent loss has become an increasingly significant line item on water utility budgets. As with the recovery of any valuable asset, water utilities are looking to recoup the greatest amount of assets with the least expenditure of resources.

For the apparent loss side of BWWSB’s equation, that meant meters and meter testing. Goodwin and company began a program to annually test (and replace if necessary) every meter in the system over 4 inches, and changed every meter between 1 and 4 inches every three years. They also implemented an automated consumption-based notification system. If any meter records excessive consumption, the utility receives an automated notice on a monthly basis. For large, wholesale customers, upgrading the meters proved to be cost-effective, but BWWSB had to cross the counter-intuitive threshold of spending money in order to save money.

Goodwin tells the story about a steel production facility that uses 800 gallons a minute all day, every day, and how the scheduled replacement of the meters on that account went from annually to twice a year.

“At six months, I said ‘no way,’” he says. “So, we started looking around at alternative meter technology. We put in these full-spoon mag meters, and our revenue on that one account went up by $10,000 a month, just because of the accuracy and longevity of the meters. You don’t have to change those meters, you don’t have an insert, and you don’t have any calibration that you have to go through, other than the electronic calibration check on a laptop—which takes about two minutes as opposed to a crew of three doing a confined space entry. So, they pay for themselves quickly. We’re still working back the numbers to find out the volume of water we’ll need to justify putting in a mag, because they are about $2,500 a piece.”

Residents and council members sign the pipe at the July 25 Prairie Waters project's groundbreaking event.

The fruit of BWWSB’s labor to create a tighter, more efficient, delivery system and infrastructure has paid off. In 2007, Goodwin estimates that his leak detection and metering programs combined to save the utility approximately 8 million gallons a day.

Once Upon a Time in the West

The drought of 2002 hit Eastern Colorado hard, sending municipalities all over the front range scrambling to replace the abundant and relatively inexpensive Rocky Mountain snow melt that suddenly came up way short. The winter of 2001-2002 was as dry as the last five winters had been, and then unseasonably high temperatures and hot winds brought one of the driest springs on record. Farmers and municipalities locked horns over water rights, eminent domain, and whether or not urban utilities could ask farmers not to irrigate corn and wheat fields and lease their water for domestic use.

As the temperatures continued to rise, the snow pack feeding the South Plate River fell from a promising 118% of average at the beginning of April, to 65% of average at the month's end. Instead of filling underground wells, that water there was absorbed into the parched earth. Snow clearly wasn't following the plow, and semi-arid Denver Metro area was growing at a record rate.

"The supply side was crashing because of the climate," Binney says. "So, what we've done is codified an annual water management plan that describes all the different programs that we have in place. As we've come out of the drought, what we've done is institutionalized what I'll call the tightness of the system. That's where we're getting these significant savings. We achieved about a 35-percent reduction in demand in our system during the drought. Most of that was end-use efficiencies or restrictions."

These efficiencies and restrictions include things like the watering of backyards, community parks, athletic fields, golf courses, and street medians; car washing; power washing; fire flows; fire department training; hydrant flushing, filling new lines, filling community swimming pools, and unidirectional flushing the distribution system. The city invested $500,000 in two xeriscape gardens to demonstrate to residents that living in a semi-arid environment doesn't have to look like "the rocks of Tucson," Binney says. He has also self-funded the city's water program by raising rates for Aurora's water, which has earned him some dubious distinctions in the local press. He has been vilified as everything from the "Prince of Darkness," to the "Angel of Death."

"When I got here in 2002, 1,000 gallons of water cost $2.02," he says. "This year, it will be between $4.60 and $4.80. To buy a tap onto our system then cost $6,800; this year it will be $20,800. We had to increase the cost of service, so we could build these projects, but it's all being paid for by our customers. We've had to do everything soup-to-nuts to keep this system together."

In that vein, Aurora's water utility is concerned with all aspects of water loss, including an ongoing program of leak detection that employs four full-time specialists and 70 Permalog units (which are rotated every 24 hours—weather permitting). Since the leak detection program in 1987, more than 800 non-surfacing leaks have been discovered. With 1,400 miles of main of varying sizes and materials, Aurora leak detection crews are averaging approximately nine non-surfacing leaks per 100 miles of main.

In addition to locating and repairing non-surfacing leaks, Aurora's leak detection program has reduced its average repair time from six to eight hours, down to four. For a city that lost an estimated 7.5 million gallons in 2007 from 203 water breaks, rapid response time is an important factor in conserving water. Cutting the repair time by almost half has decreased the amount of time water is shut off to customers, and the amount of time traffic has to be diverted. Even though 7.5 million gallons is an acceptable loss for 17 billion gallons per year in production, as Aurora's Manager of Transmission and Distribution Tom Ries puts it, "in this climate, every drop counts."

To improve the utility's overall "tightness," it is in the second year of a three-year Water Loss Initiative. According to Acting Customer Service Superintendent Bob Morphis, the first year (2007) was about developing standard operating procedures and benchmarks for water that can be accounted for, but not metered: Meter testing (in shop and in the field); hydrant service, repair, pressure tests, operation, inspections, flushing, flow tests; water breaks in main and service lines; line replacement; and new-line construction.

"In 2008, the Water Loss Initiative will focus on capturing data from non-Aurora water departments within the city of Aurora, [such as] Aurora Fire Department—fire fighting training and fire emergency estimates, [and] Street Department—street sweeping, Morphis says. "Water theft is another source of water loss, yet very difficult to measure or even estimate. This year's water loss data serves as a starting point for our internal benchmark comparisons."

According to Ries, "The second purpose of the initiative is collecting data for Qualserv, an AWWA Research Foundation project. "It's a way to see how you stack up against other utilities, and what the best management practices are and those types of things. They look at all kinds of parameters: water breaks per 100 miles, water loss accounting—they even go into training for employees—anything you can think of for water and waste water benchmarking."

In addition to reducing water loss through better leak detection methods and more comprehensive accounting of unmetered water, Aurora has embarked on a 3–6 inch Large Meter Replacement and Rehabilitation Capital Improvement Project. This project will replace all 3–6 inch water meters that are not currently fitted or compatible with an Automated Meter Reading (AMR) transmitter.

The utility has approximately 14,176 large meters (1.5–8 inches) in their system that accounts for 51% of revenues. Last year, they field tested 240 meters; of those meters, 43 had “slowed down to the point where we had to either replace them or rebuilt and recalibrate them,” Morphis says.

“Of the two measuring elements in compound meter [high-flow turbine; low-flow, positive displacement] the low-flow element wears out faster, due to continual operation at all flow rates,” he says. “It is easier to monitor the drop in accuracy of a dual register compound meter, because the low-flow register records zero usage when the measuring element is stuck. However, some of these compound meters are totalized into one register, making it difficult to identify if either measuring element is gradually slowing down over time.

“We don’t capture that unless we go out and test it; that’s when we find out that one or both measuring elements have slowed down or hasn’t been running at all,” he adds. “...When the water use jumps drastically higher or lower, we send a service representative out to determine if the customer has a leak or their meter is stuck.”

This field-testing operation allowed the utility to recapture $111,107 in revenue. The city has sole sourced one manufacturer, Badger Meter Inc., on their 76,000 small AMR meters, and is in the process of replacing the remaining 15% of their non-AMR large meters with Badgers as well.

“We didn’t just go with them lock stock,” Morphis says. “We did a comprehensive beta test, and determined that it was the best fit for us with the features that they offer. The AMR gives us the ability to drive through and read the city electronically, rather than walking any portion of that. We’ve had great success with the AMR product.”

While Aurora continues to revamp its award-winning water program (Top Drop award winner in 2007 from the Western Resource Advocates) with improvements in metering and leak detection programs, and religious tracking of snow levels in the Rocky Mountains and local reservoir levels, the pearl of Aurora’s water plan, the Prairie Waters Project, won’t be up-and-running until late 2010.

When completed, this innovative project is expected to move as much as 50 million gallons of water a day, boosting Aurora’s water supply by approximately 3.3 billion gallons per year, and, effectively doubling the value of the city’s $300 million water rights. The project is basically a continuous loop of water.

Because half of Aurora’s water rights are on the South Platte, and Aurora also empties its treated wastewater back into the same river, Binney was able to convince the city to purchase agricultural land downstream and adjacent to the South Platte, install alluvial wells, and basically retrieve the gallon-for-gallon equivalent of their own reusable returned flows. This action creates an endless feedback loop where Aurora uses South Platte water from upstream sources, then send its return flows to a treatment plant that discharges the water back into the South Platte. The water then flows downstream, where it is recaptured in the wells and pumped back to Aurora for additional treatment.

“For every gallon of water that we put into the system for the first time, we can actually generate almost a full gallon of subsequent use out of that water, so we’ve almost doubled the value of the city’s water rights,” Binney says. “It cost us $750 million to do it, but that has secured this community’s future for decades to come.”

The Prairie Waters Project takes advantage of ‘Riverbank Filtration,’ which has been used in Europe for decades, according to Tim Smith, Aurora’s Water Treatment Manager, The premise of Riverbank Filtration is simple: allow the gravel of the riverbank to filter the water. Using alluvial wells along the South Platte River, which are varying distances from the river, water will seep from the river through the ground and into the wells in about seven to 10 days. This natural filtration method removes most of the nitrates, phosphorous, and other organic compounds.

This naturally filtered water is then pumped into an Aquifer Recharge and Recovery System (ARR), which is a several hundred-acre artificial aquifer with a grout curtain, to prevent the water from spilling out into the groundwater that doesn’t belong to the city of Aurora, according to Smith. The purpose of this step in the process is to provide an enhanced biological and organic treatment of the water before it is delivered to the mechanical, physical, and chemical treatment steps.

After the water is in the ARR system for about 30 days, it is taken from wells on the ARR site, and travels through three pumping stations—33 miles—until it reaches the Aurora Reservoir Water Purification Facility. There, the water is softened and treated with an advanced Ultraviolet Advanced Oxidation Process (UV/AOP). After the UV AOP, there is a flocculation and sedimentation process, then a filtration process, followed by an activated-carbon gravity filter. From there, the water is disinfected with chloramines and then sent out into the regular distribution system. “The water from this treatment plant will rival the highest quality of water found in Colorado, and continues the city’s commitment to protecting the city's health and exceeding our customers' expectations for good-tasting, high-quality water from their taps," Binney says.

Las Vegas Valley Water District
According to the AWWA's Professional and Technical Resources on Apparent and Real Losses, "Controlling leakage effectively relies upon a proactive leakage management program that includes a means to identify hidden leaks, optimize repair functions, and upgrade piping infrastructure, before its useful life ends."

The above statement also sums up the massive effort undertaken by the Las Vegas Valley Water District (LVVWD) to stem the real losses issues for this rapidly growing desert oasis. In 2003, the utility purchased 8,000 Permalog units from Fluid Conservation Systems (FCS) at a cost of $2.1 million. The program paid for itself by 2005, and, as of June 2007, they have found and repaired more than 1,070 leaks.

District Systems Manager, Marcellus Jones, estimates that in the last three years, their Permalog program saved more than 282 acre-feet of treated water, which saved the utility $1.2 million, by not having to purchase that water at $4,500 per acre-foot, and an additional $986,000 in treatment and energy costs.

In LVVWD's original deal with FCS, the Permalog units were supposed to last five to seven years, but the utility discovered many of the units unexpectedly quit responding. "What happened with the older units is that water started seeping into the seal and the battery life just wasn't good enough," Jones says. "The units weren't reading correctly. Probably half our units out there just weren't communicating."

Instead of having FCS come out and warrant the defective units, LVVWD agreed to test 500 new units, that work in concert with Firefly technology from Datamatic. These are the same types of Firefly units used for AMR. The only difference is that, instead of a meter, the unit is attached to the Permalog unit in the valve can. Each Firefly unit is attached to the Permalog, communicating to a receiving unit in the meter-reading trucks that communicates with each Firefly. All the information from the Firefly is kept in the utility's Facility View Mapping application, which has each unit on a map that can tell you the exact information from that Firefly, allowing each's history to be stored electronically.

"Basically, it's the same technology as our automated meter reading," Jones says. "Instead of having a technician drive by and get the readings for the Permalog units from a patrolling vehicle, our goal is to have our meter readers collect this data for us as they are reading. That way, our technicians can be assigned to other position in our leak detection program."

The first 500 Permalogs with piggybacked Fireflies went in the ground in early January 2008. "The two companies are working together to attach the Firefly to the Permalog unit," he says. "It's a brand-new technology. We're the first utility that they're dealing with on this issue. We all agree that this technology works, so, we're going to replace all 8,000 units over time."

This kind of merging of state-of-the-art technology and infrastructure, with a long-term plan to reduce both apparent and real losses, and improve the overall "tightness" of the system, allows water managers to get more from their current sources to offset higher demand, and better weather any climate changes on the horizon. "I want the data to come into the office automatically in real time," Jones says. "It's a good wish list and, one Christmas, I hope I get it."

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