Chapter 6 – Managing the Water System

Take away the science and politics and you still have an enterprise to run. This section reviews some of the changes in water system management over the years.

The people who built and ran the systems

The original water systems were private enterprises and were managed for a profit. There were privately run water companies among the early members of NEWWA but the organization became dominated more by staff from the larger public utilities and by consultants and academics. Perhaps this is because the public utilities had a greater need to learn from the organization since many of the newer water works staff were recruited from other municipal areas and didn't have the luxury of being apprenticed into the field. Private water companies at least had the resources to pay for support from experts. Many consulting engineers of the day, on the other hand, studied the more interesting technical problems and shared expertise more freely to help establish the reputation needed to develop more business. Even in the early days, vendors offered much technical help in exchange for a chance to market their product.

Famous Water Supply Managers

Did you know that **P. T. Barnum** once managed the Bridgeport Hydraulic Company? So he did for 15 years, then, of course, he ran off to the circus.

Also, did you know that **Eli Whitney**, the man who invented the Cotton Gin, the machine that began the Industrial Revolution by enabling New England mills to be supplied by ample southern cotton, was the man who developed New Haven's supply? Lake Whitney bears his name and his son Eli Whitney II went

By the late 1800's, many more water supplies were being built and run by public agencies. Systems were usually headed up by either an engineer or someone who had come up through the ranks. While consultants were most often used for the large system improvements, many public service employees became leaders in NEWWA since they very often worked out the solutions to problems that plagued the industry. Field staff were much like today, people who could deal with the hours, the physical nature and underlying complexity of the work.

People/staff/salaries


1896 – Some of New England's finest working on pipe pressure testing using a hand pump

In 1882, a worker's pay was on the order of 20 cents per hour and life expectancy was 47 years. The work week was 6 days per week for a total of about 53 hours. Minimum wage didn't come into play until the 1930's and was only $0.25 per hour at that. There weren't many grades of workers, simply skilled and unskilled laborers, in most communities with a foreman or two and a manager that directed the effort. Operations staffing included many strong backs for shoveling coal and an occasional boiler operator.

By 1960, minimum wage was all the way up to $1.00 per hour and the work week had come down to around 40 hours.

<u>*Labor organization*</u>

There had been some unions in New England in the early 1800's, the need being driven by the oppressive conditions in some mills. Unions did not get truly strong or forceful enough to strike until the late 1800's and did so more in the manufacturing industries. By the early 1900's, strikes were not uncommon and labor unions began to develop true political power. By the early 1900's, unionization had reached most public service agencies including water supplies. There has never been a strike in a New England water supply.

Another significant event in labor/management arrangements was the adoption of Civil Service by the states. The Federal Civil Service Commission was established in 1871. New England States followed with their state Civil Service rules around the end of the 1800's. This had positive effects on employee job security but it also created a significant difference from private industry, in that there was no quick solution to non-performing or problem employees. Some would argue that employee performance in Civil Service situations was never the same. Within Civil Service, the process of testing and being granted status was onerous and the narrowing of job descriptions also took away some of the flexibility that private industry enjoyed.

With the threat of privatization hanging over most municipally operated water supplies, most public utilities have trimmed staffing in recent years. Financial pressures on communities, due to such measures as Proposition 2 ½ in Massachusetts, also forced staff reductions in the water supply as in all public service sectors, even public safety. Tools like automation of operating facilities and improved maintenance planning have allowed for some efficiency in staff utilization. As a result, today's water system employee has broader responsibilities and is generally better trained and qualified than ever.

Training & certification
Operator skill development was always a NEWWA goal but the process was more informal than formal until well into the 1900's. As the level of complexity of treatment systems increased, there was a growing need to address this issue.

The establishment of Water Works schools was first suggested by Robert Spurr Weston during his NEWWA presidency in 1930. The first was held on June 6-11, 1932 at Harvard and MIT with 19 men completing the course. The course was repeated but the thrust of the effort was more purely educational than to support certification.

The next big step was in 1961, when NEWWA appointed a committee on Certification of Water Works Personnel. A Model Plan for voluntary certification was developed by the committee in 1961. The goal of adoption of mandatory certification via state regulations came next. Despite much lobbying by NEWWA, progress on implementation was slow with the states beginning mandatory certification almost a decade later. Maine was first to adopt mandatory operator certification in 1970, followed by Connecticut later in the same year. Vermont and Massachusetts followed in 1971 and New Hampshire in 1979.

Some safety milestones
1800's First use of canaries for gas detection
1814 First particulate removing filter
1854 First use of GAC for vapors
1911 American Society of Safety Engineers
1913 National Safety Council
1918 ANSI
1930's Mouth pipetting in labs, fume hoods
1940's First safety glasses
1970 OSHA standards for chemical safety

The first certification courses were taught at Worcester Polytechnic Institute in 1969. In the following years, courses were given in colleges or high schools throughout New England, including early sessions in New Hampshire, Connecticut and Massachusetts. By 1973, 426 individuals had been certified in this first round. Theses efforts continued, eventually supporting the system of certification that exists today.

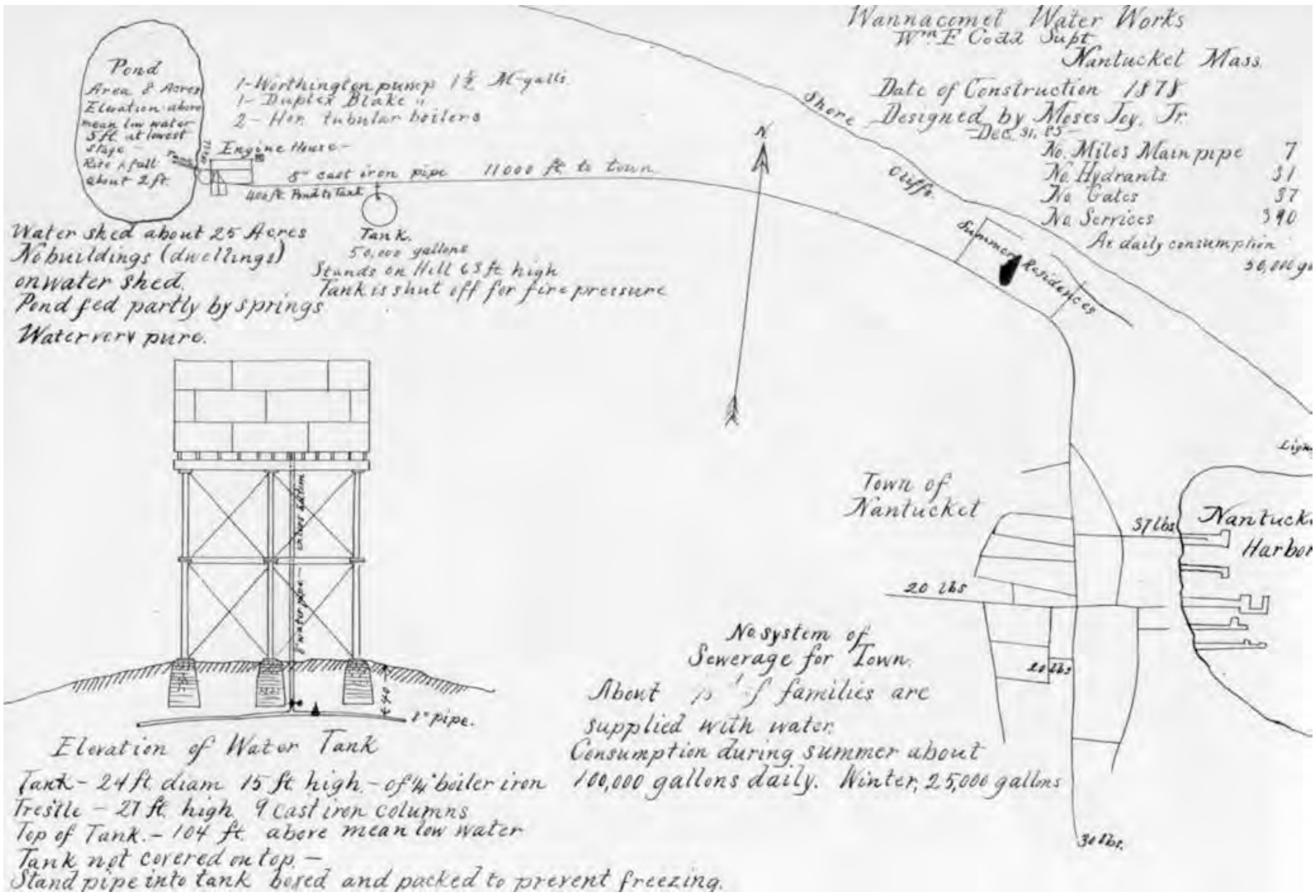
NEWWA Introduced Practices
Since so many water supply systems were just starting out in 1882, NEWWA created committees to provide some examples of proper practices for use by all. This was desperately needed at the time and gave the newcomers a chance to learn and measure themselves against their peers. The following were some of the important early initiatives:

- Annual reports – NEWWA published a standardized format for reporting everything from water sold to fuel used and other statistics.

- Operating statistics – Summaries of such data as "duty" of pumps were published to give some perspective to what reasonable efficiency should be. Since all water suppliers were weather watchers but few could take comprehensive measurements, the publishing of hydrologic data was also a service to smaller systems. Occasional surveys of treatment practices and water quality were done by state public health boards, the predecessors of today's regulators.

- Record-keeping - Distribution system record keeping was described and installation practices (e.g. depth, methods, materials) were noted to help guide smaller systems.

- System maps – An 1887 committee assembled a collection of 27 system maps documenting the member's systems. Since there were other cities outside New England represented on the committee, there were a few nationally prominent systems represented as well (e.g. New Orleans, Louisville).



From NEWWA's 1887 collection of distribution system maps, 27 communities contributed hand drawn sketches of their works, Nantucket's notes a steam pump station, an open top plate iron tank and seven miles of mains.

- Specifications – Given the wide variety of manufacturers for important equipment and the lack of compatibility between different manufacturers, it was essential to get some standardization. Early efforts targeted such items as meter testing and pipe specifications.

- Materials and tricks of the trade – Early Journals occasionally talked about techniques for problem solving, similar to AWWA's Opflow. For example, during the initial 1882 meeting, one savvy tip for keeping eels from clogging service lines was noted (a bit of coiled wire inserted in the main end of the service). The usual topics included such things as effective coatings for preventing corrosion, pipe freezing problems, or whatever the issue of the day may have been.

- Vendor presentations - Industry representatives would come in and describe how some materials were manufactured. This could be a pipe casting representative, a chemical manufacturer or other specialist.

Tools and technology available to the water industry

It's hard to imagine a world without beepers, cell phones, cars and other conveniences that are useful for immediate response to an emergency, but that was the world of the old water supply operator. Some major milestones are noted below:

<u>*Communications*</u>


1951 Portable radio

In the 1800's, messages were sent by horse and rider. This was well illustrated when an early washout of Boston's Sudbury Aqueduct was reported by an operator's heroic ride to the intake to alert operators to shut off the flow. When telegraph came along in 1844, at least a message could be sent to the distant end of the wire, but stations were limited. Telephone came along in the 1870's and was the standard for office and field communication until fairly recently. Telephone worked for facility to facility communications but still limited field crew communications to the occasional pay phone call. Car mounted two way radios were invented in the 1930's primarily for police and fire use but most water utilities did not move to two way radio communications until the 1970's or thereafter. Similarly, handheld two way radios were around from the 1940's but finding one that didn't cause a hernia took until the 1970's or so. Pagers became available as early as the late 1950's but were really popularized in the 1970's much to the annoyance of the spouses of water supply workers. Wide area paging is a 1990's phenomenon. Cellular phones came along in the 1980's, but even then, the early generation required a battery pack the size of a briefcase. Today's tools make accessibility a simple matter to the point that many water operations staff occasionally long for the "good old days".


1929 Portland ME's new emergency truck and lights

Travel

In the 1800's, you were pretty much looking at an extended journey if you wanted to go from the city out to the sources. With this in mind, many systems provided housing adjacent to the water works for their operators or managers just to ensure their presence. The Water Superintendent of the 1800's typically had a horse and buggy available for his use. The first cars were developed in the 1880's but cars really weren't commonly available until after 1908 when Ford began making the Model T. At around this time, many larger water utilities began use of automobiles for managers and emergency crews. Some early NEWWA papers discuss the cost of maintaining automobiles and the benefits there from, concluding that they were much more cost effective than horses. Roads were significantly improved in 1920's and 1930's removing some early constraints on travel. Most major highways like Interstates were added after 1956. The availability of small and reliable communication equipment and the ease of travel has made responding to problems much quicker and easier today.

Engineer's tools

Early calculations were done by hand, usually recorded in careful handwriting in some ledger and verified by a second person's recalculation. Slide rules (invented in the 1700's) were the preferred tool of the engineer until well into the 1970's when electronic calculators became available. Then, for a mere $250 or so, you could get a 4 function calculator, or if you wanted log functions you would fork over an extra $100 or so. Of course, your alternative was to access a mainframe but computer programs in those days involved punch cards and very crude program languages. Personal computers were introduced in the 1980's and have essentially now taken over most forms of calculations and data management in the water supply field. The Internet with all of its resources was conceived in 1970s, then the infrastructure was put in place by late 1980's, allowing it to become widely used by 1990's. The amount of readily available reference material on the internet was a real boon to engineers and water system managers everywhere.

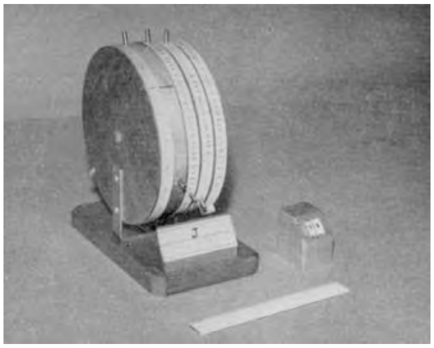
Strangest Hydraulic Test

When the New England Patriot's old Schaefer Stadium was built in 1971, the concern was whether the new water supply system could handle the halftime flush volume. The owner at the time, Billy Sullivan, stationed all of his employees at bathrooms and taps throughout the stadium to conduct what became memorialized in the press as "Superflush". The current Gillette Stadium water supply was featured in a 2004 NEWWA article that noted many well engineered improvements but much less testing drama.

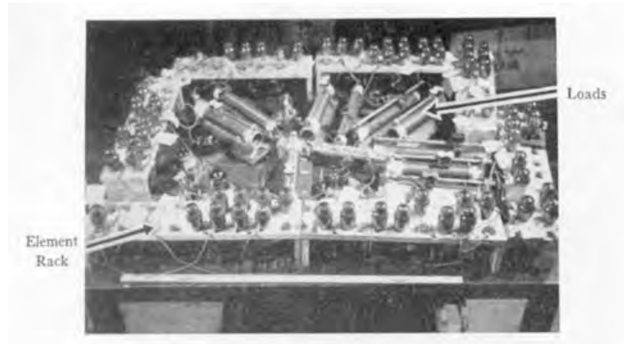
<u>Hydraulic calculations</u>

Flow analysis of pipe networks was always a difficult thing. The Darcy-Weisbach equation had become the standard for pressure pipe hydraulics in 1845 but it was cumbersome to use. In the early days of the organization, Allen Hazen played a role in simplifying the work for the hydraulic engineer by working with G. S. Williams to develop a more empirical approach, the Hazen-Williams equation. This allowed the development of flow/head loss monographs which allowed rapid calculations. This was a huge advance but flow calculations in networks could still only be done by use of simplifying techniques like equivalent pipes. As a result, pipes were more likely to be generously sized.

Slide rule calculators were tried without much acceptance. In 1935, Hardy Cross developed the first practical analysis tool for pipe networks using a balancing error technique. Doing this by hand was a challenge, often involving a plan size sheet to record the iterative calculations, a cumbersome and tedious process. The computer programs designed to do this calculation quickly weren't developed until the 1970's when programming languages had advanced significantly. In the interim, there was much research on practical tools for distribution system designers. Some researchers like the team of H. L. Hazen of MIT and Thomas Camp tried electric analogs as early as the 1930's, using resistance to simulate pipe head loss and current for flows. Another advance was the McIlroy analyzer, developed at Cornell University, which was able to be more easily configured but still required an entire room of hardware. Many New England systems were modeled by the McIlroy analyzer at Tufts University. With the advent of computers, early network analyzing software required fairly powerful minicomputers to operate. Today, a variety of software is available down to even the personal computer level and the analysis software is capable of such features as dynamic simulations, GIS output and water quality modeling.

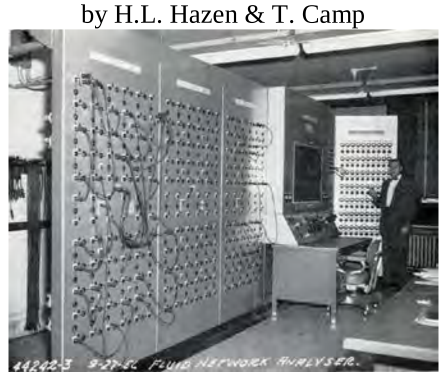


1956 rotary hydraulic calculator



1943 Vacuum tube hydraulic analog calculator developed by H.L. Hazen & T. Camp

1951 early version of McIroy Pipe network analyzer



1957 McIroy Network analyzer built for Philadelphia PA, a similar one was built at Tufts Univ.

Building Things

In case you thought police details were a modern phenomenon

Most structures in the water system require civil site work and heavy construction. In the 1800's, the old tried and true method was hand excavation with picks and shovels. Rock work for dams was typically done by masons, often Italian immigrants. Trenching and pipelaying was either done by hand or occasionally by using a trenching machine, a wood frame apparatus that could pass excavated material from the front of the machine to the rear for backfill. Horses were used for work that required more power than men could handle. By necessity, construction staff became expert in rigging and hoisting using block and tackle, masts and booms and other manual methods. Tunneling was done by hand using drill and blast methods. Explosives were limited to black powder until the invention of dynamite in 1865.

Early earth moving

Horse drawn scrapers for grading

Dam excavation with a steam shovel

Early Pipe Laying

Breaking rock the old way, with a pneumatic jack hammer

Early trenching machine

Early support equipment

1939 Air compressor

1938 Early gunite gun

Kerosene fired lead melter for making pipe joints

Portable gasoline powered dewatering pump

Early Rigging

Trans-loading cast iron pipe from rail to horse drawn carriage for delivery

Pipe rigging at the site using chainfalls

1925 Self propelled crane

Moving a 50,000 lb steam pump base plate from railcar to site

Shipping of pipe, engine parts, or any other weighty pieces was done by rail and then by horse drawn wagons. Steam power was applied to cranes for heavy lifts, bulldozers, and some types of excavators in the late 1800's, but this was cumbersome since the equipment wasn't easily self-propelled. Steam powered equipment was common well into the 1900's

Development of construction equipment paralleled vehicles. Around 1893, the diesel engine opened the door for developing what we consider modern equipment. The engine could easily provide for movement of the machine as well as powering the excavating function. In the 1910's, gasoline powered equipment became much more common, replacing the horse as the prime mover, but the bigger advance was the development of pneumatic tires in 1911. This allowed much more maneuverability in equipment and allowed deployment over roads.

1919 MDC Emergency truck with valve operator mounted beside driver's door

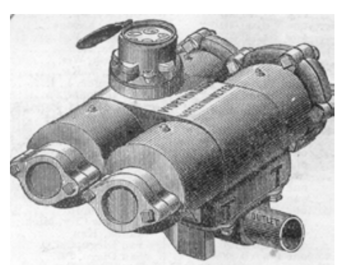
The business of building water works for municipalities has been closely controlled by state laws that normally separate design and construction and ensure competitive bidding. Recent trends in construction practices have included more use of design/build ventures where allowed by legislative permission. Just as with the trend towards more privatization and contract operations in recent years, the design and construction roles may see more untraditional solutions in the future.

Selling the water

Water measurement at the point of sale became very important for control of waste in the latter half of the 1800's when high pressure distribution systems came into play.

Mechanical meters

The first US patent for a water meter appeared around 1850 and relied on measurement using physical displacement, at first using reciprocating pistons. As can be imagined, this made for a fairly large device, as demonstrated by an early Worthington meter that weighed 57 lbs for a 5/8" pipe size. This was not put into wide use due to the expense and inconvenience of such a large device.


1888 Worthington Meter

Disk meters, the true fore-runner of today's residential meters, solved this problem when they came onto the scene around 1880. In the years following formation of NEWWA, there were about 5 or 6 companies with some type of meter available. Locally, one of these was the Hersey Meter Co. who patented a rotary displacement meter in 1885 in Hyde Park MA. Nutating disk type meters came on the scene around 1890. The cast iron frost bottom was added in 1896 to solve cold weather issues. The first major effort at standardization culminated in 1921 as NEWWA, AWWA and the manufacturers agreed on the Cold Water Meter Standard Specification. This was reviewed again in 1930 and 1940 with minor revisions.

Early disk meter ad

Early meter ad – the closest NEWWA came to a "cheesecake" ad


1905 Hersey Compound


1903 Meter testing lab, Burlington VT

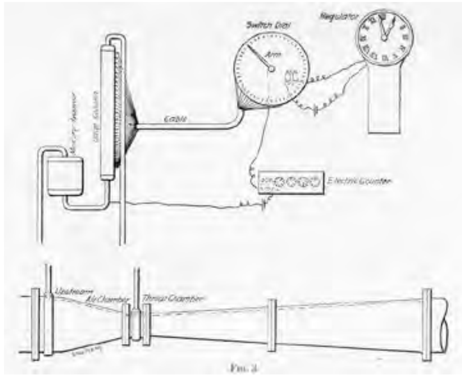
The next big advance was in the early 1920's when oil encased intermediate gear trains replaced open water lubrication to avoid corrosive water problems. The development of magnetic drives in the 1950's allowed complete separation of the gearing from the watertight enclosure. A problem remained: meter readers unable to enter homes when no one was home. This problem was solved in 1964, with the introduction of the mechanical encoder register that allowed remote readouts. Various versions of remote registers outside of the house then became available to simplify the task of collecting readings.

In the past 10-20 years, the advances in Automated Meter Reading systems has been remarkable, progressing from plug-in data dumping devices to radio collection via roving vehicles to stationary radio systems that can collect all meter data in a community via strategically placed antennas. This allows water demands to be reviewed very quickly for problem diagnosis. It also solved the billing frequency problem for communities that needed to go from semi-annual or quarterly bills to a more frequent cycle due to steeply rising operating costs.

Other large meters

The quest for a larger meter for industrial usage led to development of the first turbine meter (known then as a "torrent" meter) that could be used in a pressure pipe in 1896 and, subsequently, the compound meter in 1903 to widen the available flow range. The compound is still the workhorse of the industry for larger service connections like industries and institutions.

Measuring very large flows, such as for the master meter serving the entire community was an issue in the early days. In the late 1800's, there was no practical metering device that could pass a large but variable flow through its body without creating such a large head loss as to create a fire protection problem. This changed in 1891 when Clemens Herschel, one of NEWWA's most respected water works experts, developed the first venturi tube. Being a humble man, he named his newly created device after Giovanni Venturi, the author of the principle of pressure drop at a constriction. Herschel tested prototypes in his Holyoke Water Power Co. lab, then gave a paper on his design in 1887. He then allied with Builder's Iron Foundry in Rhode Island to make the first tube for East Jersey Water Co, the system he was managing at the time. The first New England application was in Worcester MA in the 1890's. Venturis are still the mainstay of large flow measurement.


Early venturi layout, note the mercury manometer


BIF's first venturi tube


Herschel Clemens, inventor of the venturi meter and authority on all aspects of water supply, he later translated the works of Frontinius on the Water Supply of the City of Rome for NEWWA's publication


One of Herschel Clemens lesser known civil engineering projects was the design of the small suspension bridge in Boston's Public Gardens, an ASCE Landmark

It should be noted that Clemens was not the only inventor. Frederick Stearns and Alphonse Fteley had jointly patented a current flow meter for use in the Boston aqueducts, but it didn't have the lasting impact of the venturi which continues to be productive over 100 years later.

Other new technologies for large meter flows came later in the mid-1900's, including magnetic and sonic technologies. These were more suited for specialty applications like water treatment plant flow controls.


1957 Mag Meter in Medfield MA

One of the side effects of reduced consumption in recent years has been that many larger size meters had now become over-sized for their service flow. Some communities have been very successful in recapturing under-registration and reducing unaccounted-for water by "right sizing" these overly large meters.

Controls and Efficiency


1921Motor operated valve


1923 Pump control panel


1957 Foxboro telemetry

Control of water operations was very manual to begin. Steam pumps and treatment plants needed to be attended by operators. The development of electric motors and telephone communication in the early 1900's led to creative use of both technologies in combination to remotely start a function. Frequently positioned control valves were one of the first targets. The use of a water tank elevation signal to start pumps was also a major advance. Circuits were crude and unreliable for much of the early 1900's so only limited remote control was attempted.

Beginning in the post-World War II period, plant automation techniques in manufacturing, and communication advances like microwave transmission, began to bring new possibilities to water system control. Controls began to be based on electrical relays and had to be very physically complex to operate a sophisticated function like those of a water treatment plant. The idea of Supervisory Control and Data Acquisition (SCADA) was tried first by electric and gas utilities, while the water supply industry was cautious. By the 1980's, improvements in the controllers themselves began to allow the complex decision making to be embedded in controller programming rather than hard wired relays. SCADA eventually became the preferred means to perform complex function control and remote control to the point that virtually all new water facilities now feature SCADA controls.

The related benefit of modern control systems has been the shift to unstaffed operation of most operating facilities. This allowed operators to be more centralized and responsive to emergencies while the control systems attend to the boring routine of watching setpoints and starting and stopping functions.

Finances - Follow the money

Rate structures

Before meters, water was traditionally sold by the size of the connection. This led to many issues with water waste as there was no penalty for leaving the water running or allowing leakage to continue. Meters were implemented on the largest users first and most communities eventually managed to get to 100% metering. At this point, most communities adopted rate structures that established a usage based fixed rate but with a minimum charge to cover the cost of managing the account.

As large water users, like manufacturing industries, became dominant political forces in their communities, declining block rates began to appear in the mid 1900's. An argument could be made for this in terms of the cost to the utility being proportionally smaller to serve a large single user but it created a disincentive for controlling usage. By the 1970's, the increasing pressure to conserve water made these declining block rate deals unacceptable. In fact, some communities went directly to increasing block rates. The bottom line was that the price elasticity effect of expensive water and sewer charges in some communities had a dramatic effect on wet industries and helped defer water supply shortfalls. The other related rate topic that received much discussion was the collection of water bills, an age old issue. NEWWA's Journal had many papers on rates in the early days to help newly formed or expanding community systems. Through the years, papers also examined trends in such areas as bonding, enterprise accounting and other financial practices.

External financing

Who paid for the billions of dollars worth of water system projects in New England? For the most part, it was the ratepayers in the communities. However, there were some notable periods where the federal government supported this expense.

The early systems were usually started by a private company, which meant a state charter to operate and funds raised by selling shares in the water system. Eventually, this was replaced by municipalities raising funds through bonding. As long as the economy stayed strong, this continued to be a workable solution, lasting all the way to the Great Depression. Starting in 1929 and lasting through the 1930's, the devastating impact of the Stock Market crash and closing of businesses was most felt by the up to 10 million people that became unemployed. During the Franklin D. Roosevelt's administration, the government's reaction was to spend money to jump start the economy, as well as to try to hire the unemployed to at least a "make work" job. The spending was targeted towards public works, with water supply being one of the main beneficiaries. There were actually a series of initiatives, the largest of which included:

- The Public Works Act of 1933 authorized $3.3 Billion for large projects, including water. This was spread around the country with many New England projects receiving funding, as documented on plaques at many water facilities of the era.
- The Works Progress Administration was created in 1935 and was more targeted to the unemployment issue. Projects again targeted public works but tended to focus on work that could be done by unskilled laborers, such as digging ditches for pipe laying. Many rural water systems were built or improved at this time.

Both the PWA and WPA were completed by about 1939. The next major federal funding mechanism followed on their heels but was specifically targeted to another need of the times, that being war preparations in view of the escalating conflict in Europe. This included:

- In 1940, the Lanham Act created the Defense Public Works program which helped fund works in towns with defense plants. Water supply was considered an important element in supporting the war effort, resulting in the funding of 24 projects in 18 New England communities (7 MA, 6 CT, 2 ME, 1 VT, 1 NH, 1 RI). Communities like Newport RI received funding for dams, pipes, pump stations, filter plants, or covered storage. Title V of the War Mobilization and Reconversion Act continued this funding through to the end of World War II.

After these efforts, the only other significant federal funding provided was for the cleanup of rivers and sources of pollution through such vehicles as the Clean Water Act and Superfund. These were beneficial but did not directly improve water supply infrastructure. The 1974 Safe Drinking Water Act and its subsequent amendments were notable for the absence of any significant funding for expensive compliance projects. The recent Bioterrorism Act of 2002 also had very limited funding for communities despite the significant capital costs of system protection. The aging of water infrastructure is another looming financial issue that may need governmental support at some point.

Future issues for consideration - Public/private

What is the optimum organizational structure and staffing level for a water system? Is cost control the over-riding concern? Is the traditional separation of design, construction and operations the optimum strategy for the future? All good questions that generate strong opinions but that have no definitive answers.

One thing that can be said is that there are emerging trends in the past decade or so:

- Many smaller municipally owned systems continue to struggle with resources.
- Larger municipally owned systems have long struggled with issues like over-specialization of staff and higher staff count than private companies.
- Some publicly owned water systems have been privatized successfully and, conversely, some communities have attempted to withdraw from privatization commitments because of dissatisfaction.
- The larger private water companies, especially the well financed European companies, have been acquiring smaller New England companies.

Where will it end? Stay tuned because the issue will continue to evolve over time.