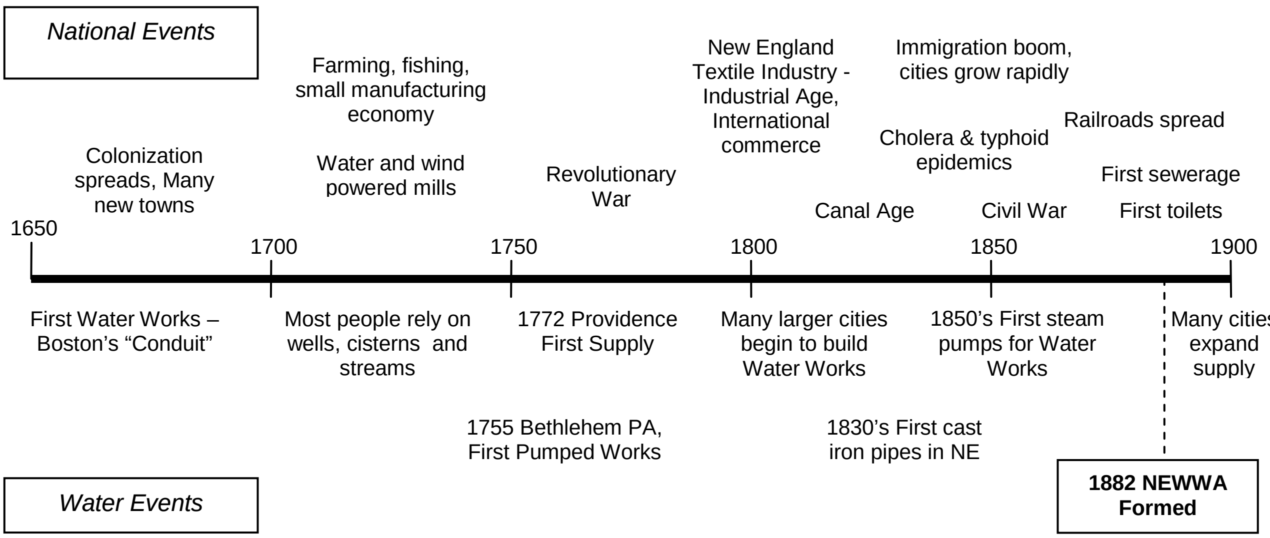
Chapter 1 – Drinking water in the early days

Timeline – Drinking Water Before NEWWA



Water supply existed before NEWWA, so a brief review is in order to document water supply choices made by the earlier practioners.

New England waterways were one of the best things about the region, attracting colonists with ample water to drink, water for power and water for transportation. The first colonies chose locations on the coast for commerce and travel but were mindful to ensure access to pure drinking water. Their original choices reflected their modest size. Often a clear spring or brook would be the chosen center of a new community.

Water in New England before colonization

New England was blessed with features that provided much help to development of early water supplies. For one thing, there were abundant natural ponds and lakes. For another thing, there was enough elevation change and transmissive soil to provide good recharge to rivers and to create springs and artesian groundwater flow. Given the abundance of fresh water in the region, Native Americans camped near it but needed no irrigation or supply works as in drier parts of the country.

New England's river water could be colored and slightly turbid in places from passage through swamps but was generally clearer than that from other parts of the country in that it carried little sediment. The water was generally noted by colonists as being soft and "sweet". Soils were predominantly glacially created with more sand and gravel deposits than clay. With little limestone, the water had very little hardness and was somewhat corrosive.

New England's rivers also had more elevation drop than many other parts of the country. This single feature made the industrial revolution possible since the resulting water power was inexpensive to develop and plentiful throughout the region. Mills sprang up wherever it was possible to install a dam and diversion works. Grist mills and sawmills were the forerunners of much more elaborate manufacturing processes that were driven by water wheels or turbines. This guided much of New England's growth since the worker population followed mill growth.

Rainfall in New England was also fairly consistent throughout the year and relatively plentiful. In spite of adequate rainfall, farming in New England never grew to the size and importance of the U. S. mid-west since the terrain was hilly and the soil quite rocky. Extensive irrigation works were not necessary for the farming that did develop.

The English colonies begin and spread – 1620 to Revolutionary War

Before New England was settled, Virginia had the first permanent English colony in 1607. There had been explorations of the New England coast by many nations but there was little interest in colonization since there were no easy riches to plunder. It wasn't until the beginning of the 1600's that Europe began to see the New England area as source of raw materials for European industries. Desirable resources included crops, wood, fish, furs and other items in demand in the European economy. At this point, colonization became a privatized effort where colonies were chartered by investors with hopes of significant financial returns. This perhaps explains the entrepreneurial spirit that shows up again when water supplies are needed and private investors step up to develop the first water works.

Example of old pump well – Adams House - Quincy MA

English colonists settled in Plymouth MA in 1620, then the Cape Ann area of Massachusetts in 1625, and Boston MA in 1630. These English colonies then spread in all directions in New England, founding offshoots in parts of Rhode Island, Connecticut, New Hampshire, southern Vermont, and Maine (part of Massachusetts until well into the 1800's).

The English weren't the only ones interested in New England. The Dutch settled in New Amsterdam around 1613 and tried to extend their way into Connecticut. The French settled in northern Maine and Canada in the 1620's, reaching down to Northern Vermont along Lake Champlain. Both the French and Dutch were eventually evicted from present day New England but left much in the way of heritage, most notably the names of many towns. State boundaries for present day Massachusetts, Rhode Island, Connecticut and New Hampshire were set by English rulers but not without some controversies. Vermont's boundaries were eventually set as the new state was added after the Revolutionary War. Maine was split from Massachusetts later in pre-Civil War days in a bit of maneuvering to balance slave states with non-slave states.

Typical household dug well from 1700's with bucket on rope pulley

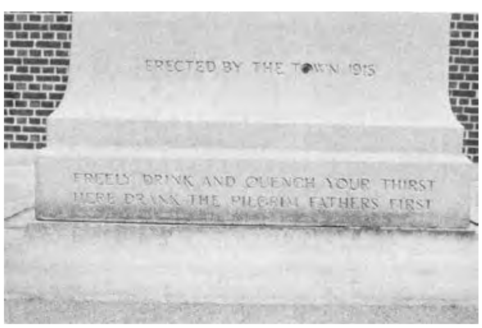
From a water supply standpoint, all settlement in New England was by European settlers and reflected the rudimentary understanding of water, public health and water use technologies that were present in Europe at the time. This meant that the same European habits of infrequent bathing and poor sanitation were transferred to the colonies. The colonies were merely starting with a cleaner slate in terms of having unpolluted water sources to start where Europe had already fouled the waterways near its cities. Water supply technologies such as dug wells and the use of wooden and lead pipes were the rule. Water and wind powered mills provided the power source for anything that could not be accomplished with hand tools.

All early New England cities were coastal in nature, being located in coastal ports (e.g. Boston MA, Portsmouth NH, Portland ME, New Haven CT) or upstream on a navigable river (e.g. Hartford CT, Providence RI, Bangor ME). Even Burlington VT followed this course in that it was settled on a navigable lake. These choices were necessary to allow shipping and commerce but it made life interesting for future water supply planners when residents eventually outgrew local water sources. Other smaller towns popped up at many locations inland as farmers spread and generally bordered on an available river or stream.

The First Water Sources

The first colonies obviously had the first water sources, some of which have been memorialized by the community's residents. These sources were merely a place to bring a bucket and carry home a bucketful or two during the day. Water use habits of the colonists were fairly austere, perhaps several gallons per day per resident. The effort required to bring that amount of weight a fair distance made anything other than essential uses difficult. This was a pretty effective disincentive on bathing and washing and contributed to the general lack of proper sanitation.

Every community had a central water supply point, be it a spring, a well or a river. These were not engineered facilities, but are noteworthy nonetheless. A fine example of a monument to a first drinking water source celebrates the water supply of the original Plymouth colony in



"Freely drink and quench your thirst,
Here drank the Pilgrim Fathers first"

Plymouth's first water source was Town Brook, near the current Mayflower dock

Plymouth's monument to the first water source

Massachusetts. A drinking fountain was dedicated in 1915 at a location on Main Street above Town Brook. The brook, just south of the center of town, was fed from Salton Pond and provided the residents of the town center with potable water until the first water works was built in 1855.

Similarly, Providence commemorated its first water source, the Roger Williams Spring, named for the founding father of Providence Plantation, the colony established by Roger Williams after his exit from Massachusetts in search of religious tolerance. This site, at North Main Street, was designated by AWWA as a National Historic Water Landmark.


Monument to Roger William's spring, Providence's first water source

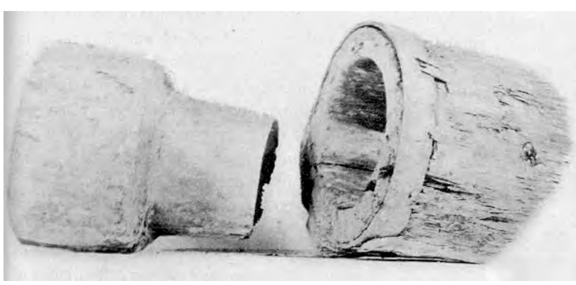
Boston residents put up a plaque at the location of the "Great Spring" at present day Spring Lane, which fed the bulk of the residents in the original community. This spring was the reason why the colonists chose the location that they did after first landing in present day Salem and Charlestown only to find the water sources to be lacking. The "Great Spring" became the center of the rapidly growing community that for a good while was the largest city in the colonies.

It's a pity that the location of the "Conduit" isn't clearly marked at its Dock Square location near Fanueil Hall. This 1652 site was the first actual water works in the US in that it was more than just a place to dip a bucket. Its original purpose was as much to provide fire protection in an area of dense wooden housing as it was meant to supply drinking water. Several uphill springs in the area were connected by means of wooden pipes to a 12' square cistern-like structure in Dock Square that would provide plentiful water for all needs, replenished much more rapidly than a dug well. Once the pipes were laid, it is known that selected homes, those of the people that financed the venture, were then tapped in and provided with running water. Thus, this early water works had intakes, pressure piping, distribution taps and a storage reservoir, albeit on a very modest scale. It helped significantly in subsequent conflagrations in the neighboring areas and served well into the 1700's before becoming too fouled to use. A section of old wooden main from this site graces the NEWWA lobby.


Section of the 1652 "Conduit" pipe, located in NEWWA lobby

The "Conduit", Boston's 1652 supply, the first Water Works in the U.S.

The desire for the convenience of running water in the home wasn't the only driving force that led to development of water works. The need for fire protection was equally important, perhaps even more important at that point. Before brick manufacturing was developed, all housing in the colonies was made of wood, including in most cases, the chimneys. A mud coating was the only protection against flames. Once a fire started, it could very well spread from house to house via the thatched roofs. Colonial homes were generally required to keep cisterns, barrels or other water containers filled for quick response to prevent conflagration. Fire protection was more carefully regulated than water usage or quality, with regulations being adopted to make housing more fire resistant and requirements put on homeowners to be ready to fight fire at any time. Even after brick construction and slate roofs were the norm, wood framing and close proximity in central areas meant a good supply of fire fighting water would be needed.



Examples of wooden pipes from Boston's Jamaica Pond Aqueduct

Moving water around in pipes required workable materials. Colonists had wood in abundance and had knowledge of how to make and join wood pipe sections, a fairly common practice in England. Metal for pipes had to be imported at first until eventually iron works were built. Metal for water pipes was limited to lead initially but in the early 1800's foundries had been able to produce iron plate that could be rolled, riveted and coated with cement to form wrought iron pipe. The production of cast iron pipe in the US began in the early 1800's but the cost was high until improved production methods made it more economical to use by the late 1800's.

Who had the earliest water works? The following table shows the first wood pipe systems, some of which date back well over 200 years.

Water systems built entirely of wood pipes:

City/Town	State	Date	Source	Comments
Boston	MA	1652	Springs	Wood pipes also used in 1796 Jamaica Pond system
Providence	RI	1772	Springs	Providence Water Co., Rawson Fountain Society
Salem & Beverly	MA	1796	Well on Gallow's Hill	Built by Daniel Frye
Portsmouth	NH	1798	Springs	Portsmouth Aqueduct Co.
Worcester	MA	1798	Springs	Built by Dan'l Gooding, later use of Bell's Pond
Peabody	MA	1799	Springs	From Salem & Danvers Aqueduct Co.
Haverhill	MA	1801	Springs/ponds	Haverhill Aqueduct Co.
New London	CT	1802	Spring	Aqueduct Co.
Drewsville	NH	1804	Spring	Smallest village with a water system in 1882
Bridgeport	CT	1818	Springs on Gold Hill	Built by Rev. Elijah Waterman
Hanover	NH	1820	Springs/wells	Hanover Aqueduct Co.
Cambridge	MA	1837	Springs to a reservoir	Cambridgeport Aqueduct Co. supplied a few families
Springfield	MA	1843	Reservoir	Built by Chas. Stearns, taken over by Springfield Aq. Co.
Gorham	NH	1873	Springs	Alpine Aqueduct Co.

Note that the use of wood continued well after metal pipe had become practical and affordable. Wood pipe was still actively installed and used in rural areas like northern New England well into the 1900's. On the other hand, contrary to urban legend, wood pipes in the cities have not been in use since the transition was made to iron pressure pipes in the mid 1800's. An occasional piece of wood pipe may be unearthed in some construction project but modern pressures would have blown it apart long ago, had it been left in service.

Not all of the early water works used wood. Given very low usage, some opted to used a lead pipe of up to 2" or so in diameter which, though limiting, at least may have been easier to keep from leaking than wood. When cast iron first appeared, the size and strength issues were no longer an issue, allowing more capacity and higher pressures for the growing water demands.

The First Metal Pipe Systems through 1850

Community	State	Year metal pipe is introduced	Type – Lead/ Wrought Iron/ Cast Iron	Source at the time
Portland	ME	1812	Lead Pipe	Neck Pond, Munjoy Hill
Montpelier	VT	1820	Lead Pipe	Springs
Dover	NH	1826	Unknown	Springs/pond
Hanover	NH	1829	Lead Pipe	Springs/wells
Durham	CT	1832	Wrought Iron	Cold Spring
Danbury	CT	1833	Lead Pipe	Springs
North Conway	NH	1833	Cast Iron	Artist's Brook
Peabody	MA	1834	WI & CI	Spring Pond
New London	CT	1840	WI & CI	Mill Pond
Worcester	MA	1845	Wrought Iron	Bell's Pond
Chicopee	MA	1845	WI & CI	Brook
Bellow Falls	VT	1848	Cast Iron	Lake Minard
Hyde Park	VT	1850	WI & lead	Springs
Windsor	VT	1850	WI & lead	Dudley Brook

The very early water works from the 1600's and 1700's were by no means complete systems in the sense that we have today. Given the large costs incurred by the private water companies, the expense of a connection was only affordable by the well-to-do and there were no governmental requirements to serve all customers. The poor could always walk to a public well or cistern. The rich folks on the hilltop could have their own well developed or pay a water seller for deliveries.

Access to water was also a function of location since the pipes did not serve all areas. Often the source was barely higher than the area being served so delivery pressures and volumes were limited. Wooden pipes were typically 2"-4" in diameter and early lead pipes were 2" or less so capacities were never what we would consider as robust in this period. Expectations were low and outages were frequent, especially since the wood pipe was notoriously prone to breakage.

Early sanitation

Privies and outhouses were the rule in the 1600's and 1700's. In the more densely settled areas, the facilities were often located in the basement. The waste was held in a tank or pit until the "Nightmen" came to reclaim it for its fertilizer value.

Plaque on Spring Lane in Boston

With the poor understanding of disease, no special precautions were taken around water supply sources. Animals roamed freely, adding copious amounts of waste to drainage that ended up in water sources. People often disposed of unwanted items, ranging from trash to dead animals, into the water body from which they drank. Early industries such as slaughterhouses and tanneries discharged wastes to whatever water body was handy. Cemeteries were located close to urban areas and often in the watershed areas of water sources. An excellent example of this is found on Boston's Freedom Trail where "The Great Spring" on Spring Lane is found one block downhill of 2 graveyards, the Granary Burial Ground and King's Chapel Burial Ground. Needless to say, many early water supplies were in a state of continual contamination. Only when the aesthetics of a fouled supply would become unpleasant were residents discouraged from using it.

Epidemics were frequent and deadly. Communicable diseases like smallpox had visited most of New England with quarantine the typical control strategy. Yellow fever was a seasonal scourge in swampy mosquito areas. Life expectancy was much lower than at present even without the waterborne illnesses of the period. With the close quarters and poor hygiene in poor areas, bacterial and viral illnesses essentially created a reservoir of disease within the community and the wastes from the infected population would be circulated to others, often via the water supply.

Before "germ theory" was advanced as a cause of some diseases, there was a widespread belief that dangerous vapors from unclean areas, called "miasmas", were the cause. There was also a belief among many that poverty, uncleanliness and disease were connected as some sort of punishment for the unworthy, consistent with the religious righteousness of the times. These believers had the expectation that one of water supply's best purposes was for washing down streets and tenement areas to wash away the disease lurking there. Old engravings from the period show horse drawn water barrels being used for street cleaning. Of course, the horses themselves put back as much waste as was washed away at times. Empirical evidence often connected poor water aesthetics to gastrointestinal illnesses at some water sources with resulting loss of confidence among water consumers.

Some famous names that you may not know as early Public Health officials:

Paul Revere – First head of Boston's Public Health Board in 1799.

Benjamin Franklin – In the 1730's, he was the first head of Philadelphia's street cleaning department, a critical public health service given the nature and volume of wastes in colonial days. He later went on to be a strong advocate for sewerage cleanup in Philadelphia. He also started the first fire company there in 1736.

Famous People affected by Waterborne Disease:

- Prince Albert of England died in 1857 of typhoid.
- Abigail Adams, wife of President John Adams died in 1818 of typhoid.
- President Zachary Taylor died of cholera in 1850.
- George Washington was affected by dysentery but survived.
- Louis Pasteur, the influential microbiologist, lost two daughters to typhoid.

Still, with limited population and industry, most of the rivers and large water bodies around New England remained clean through the 1700's and water quality troubles were more local than regional.

The Influence of Europe on American Water Engineering

New England settlers had the benefit of English water engineering examples from which to model their efforts, a mixed blessing at best. Private water companies had been supplying London from as early as 1213. As many as 9 separate water companies supplied parts of the city with water, some from adjacent springs or wells and some directly from the Thames. One water company used water wheels housed in the famous "London Bridge" to pump Thames water up to an uphill cistern for distribution. Of course, all of the Thames withdrawals had serious water quality and sanitation problems, with one unfortunate water company having an intake directly opposite the largest London sewer. With the sanitary problems created by the extremely dense population of this old city, the Thames River was already grossly polluted during this period and featured such colorful periods as the "Great Stink" of 1858. Life expectancy in mid-1800's London was down to 26 years. One notable water supply effort was the "New River", an 18 mile canal built by Sir Hugh Middleton in 1619 that was both an heir to the Roman aqueduct legacy and a forerunner of the modern water diversion from a protected upland source. London would later come to be a leader in sanitary reform but during the early 1800's, the example set for the US was not a particularly progressive one. Other European cities had similar experiences and had the disadvantage of having long ago polluted their available waters.

On the plus side, there was an active scientific community throughout Europe studying such water supply topics as hydraulics and water treatment. Scotland had implemented the earliest filtration of a community water system and France had made many advances in optimizing water withdrawals from a river through early bank filtration systems. European water engineers would continue to be a resource to US engineers during the 1800's. An example of this was noted civil engineer Charles Storrow's major 1830 work "A Treatise on Hydraulics" which was acclaimed in the US as being the best work of its day but was essentially just a compilation of what he had learned in his studies abroad.

Water supply in the rest of the US, New York, Philadelphia, Baltimore
Outside of New England, the major US cities were beginning to seek water supplies. One notable early effort is Bethlehem, PA, home to a Moravian community that developed a piped water supply in 1755 that featured pipes, hydraulically powered pumping and an above ground storage tank to supply homes with running water. The pumping was done with wooden positive displacement pumps and supplied water through wooden pipes. ASCE has recognized this early system as a National Historic Landmark.


Fairmount Waterworks in Philadelphia
Hydraulic pumps in the building to the right supplied water to open reservoirs on the hill where the Philadelphia Museum of Art now sits

The first significant municipal system was the Philadelphia water supply. The city sits at the confluence of the Delaware and Schuylkill Rivers, the former being tidal and the latter having more elevation drop and better water quality. In 1801, Benjamin Latrobe of Philadelphia designed and built the first large scale steam engine for municipal water pumping and used it with the first municipal cast iron pipes to pump from the Schuylkill River to a storage reservoir supplying the city with clean water. Wooden pipes were still the mainstay of the distribution system from the reservoir to the customers. The steam engine eventually proved to be difficult to manage and expensive, leading to a rethinking and reconstruction of the supply works in 1822. The new facility, the Fairmount Waterworks, featured hydraulic pumping using water wheels; it served the city proudly for the rest of the 1800's. This facility was beautifully designed in a neoclassical style that resulted in its current use as part of the Philadelphia Museum of Art as well as being designated as an AWWA and ASCE National Historic Landmark. In its day, the Philadelphia Works were considered the finest in the country until it suffered the same fate as many supplies of its day, i.e. the source water quality degraded to the point that other supplies made more sense.

Since the days of the Dutch settlements of the 1623, New York had been supplied by wells and ponds on Manhattan Island. Water quality of these sources was clearly inferior and availability was much too limited for the island's population, but the politics of obtaining a more plentiful supply were difficult to overcome. It wasn't until 1842 that the flow of the Croton River was dammed and diverted via aqueduct to the center of Manhattan to feed a network of cast iron and wooden pipes. The Aqueduct Bridge over the Bronx River is a particularly notable example of an aqueduct in the old Roman style.

Washington and Baltimore similarly constructed diversion works and aqueducts from an upstream point of their rivers to supply the community mainly by gravity. Other western cities that didn't have the advantage of a river with significant elevation drop had to wait for reliable steam engines to be developed to be successful.

American engineering was in its infancy in the early 1800's with most active practitioners being U.S. Army trained. With few colleges providing engineering programs, many civil engineers came up through the ranks of staff constructing the large civil works of the day. Surveyors and canal builders often became the experts called upon to build water supplies when needed. One such man, John Jervis, was educated on the Erie Canal project and went on to build New York's Croton Dam and Aqueduct, then was further engaged to plan and design Boston's Cochituate Aqueduct. Many other New England engineers went on to consult on the water supplies of the other cities that followed.

Water Supply Entrepreneurs

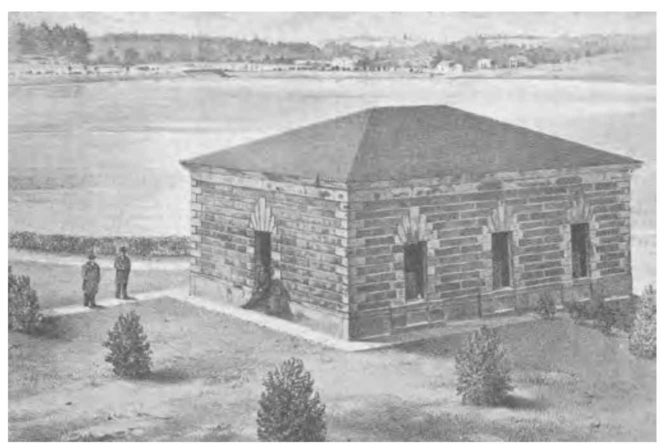
Early water supply wasn't immune from politics and scoundrels. Fortunately, schemes for personal gain were rare but the following is offered as an example:

In New York City in the early 1800's, Manhattan's water supplies were oversubscribed and fouled, leading to a public clamor for improvement. **Aaron Burr** sought a state charter to form the Manhattan Water Co. with the publicly stated mission of securing a supply from the mainland. However, the charter was authorized in a midnight legislative session that somehow included wording that the company could raise excess funds for any purpose. Burr managed to turn the venture into the formation of a successful bank (eventually to become the Chase Manhattan Bank). Unfortunately, he neglected to carry out the water improvements, much to the detriment of the NYC public.

Private vs. public

In almost all cases, the early water supply developers of New England were private water companies that were granted the right to develop the supply. This was mainly the result of the daunting cost of constructing such a supply and the uncertainty that customers would want to pay for the service when, for no cost, they could bring a pail to the local well. Capital funds were typically raised by selling shares with dividends to be paid to shareholders. Service was limited to only the paying customers. Essentially all of the pre-1850 supplies shown in the earlier tables were built by a private water company.

Boston's 1848 Lake Cochituate supply was the first New England water supply developed by a community with its own funds.



Sketch of Boston's Lake Cochituate Intake

Early 1800's – New England Industrialization

Up until the Revolutionary War, New England had an economy based on commerce and limited manufacturing in the large cities, farming and trapping in the smaller inland towns, fishing along the coast and timber in the northern states. Independence brought fundamental changes in the economy as English restrictions on trade and industrialization were lifted. With Europe having its own problems in the early 1800's, the US was poised to become an economic power and a destination for immigrants in search of the land of opportunity.

Lowell Mills on the Merrimack River, supplied from a canal network

After U.S. independence, the U.S. began to pursue industry, which had been pretty much discouraged under British rule. New England had ample water power from rivers so it was naturally attractive for mill development. Manufacturing materials and fuel were supported by the growth of iron and steel mills and coal mines in Pennsylvania. The US south produced vast amounts of cotton (especially attractive for manufacturing after Connecticut resident Eli Whitney's cotton gin is invented), but they couldn't process it to cloth. New England with its river-powered mills took over this job and flourished. Sutter's Mill on the Blackstone River in Providence was the first step in a progression that saw Lowell, Lawrence, Manchester, Holyoke and other cities become major manufacturing centers. While this brought great prosperity, it also added significantly to the waste load being carried by the river downstream of these sites.

At the same time, large scale farming began to shift more to the mid-western states where the land was more easily farmed than rocky and hilly New England. The region's labor force became more concentrated in cities as a result since the needs of manufacturing were still on the upswing. As New England grew, the labor needs of the mills were met at first by the local population, often women and children to a large extent. Employment at a mill was often supplemented by housing in the mill's tenements, adding to the population density in mill cities. With economic problems in Europe, the prosperity of the United States attracted much immigration, not just from England but also from all over Europe. Given the lower wages accepted by immigrants, mills started using immigrants heavily to meet their labor needs. Overall, New England began a period of very rapid population growth that would continue through the rest of the 19th century.

The Need for More Water by the mid 1800's

With rapidly growing population and per capita usage, the first water systems built by the early 1800's reached a stage where they needed more source capacity. The capacities of pipes, storage facilities and other water supply elements were too limiting or, in the case of wood pipes, in too poor condition to continue. Eventually, the water quality of many local sources deteriorated to an unacceptable level for most customers.

As was evidenced in Boston in the 1830's, Jamaica Pond obviously wasn't going to carry the city into the next century. Neither were Providence's springs or many other local sources. The search for the next supply became an exercise in engineering, water quality and politics. The engineers sized the future needs on the best available prediction of population growth and per capita increases, perhaps even a doubling from the current 10 gallons per capita at the time. Of course, they had no way to tell how wrong they would be until more people had access to modern plumbing. Men of wisdom (since there were few real civil engineers yet) were called upon to understand rainfall and flows as necessary to predict available source capacities. The aesthetics of the proposed source had to be studied under summer conditions to predict whether the water would be palatable. The political element often came down to who owned what water rights and what degree of compensation was necessary to do the deal. Of course, all of these early plans were limited or flawed partly due to the poor understanding at the time of the underlying science and engineering necessary to do the job.

Even at this early stage, most water supply builders understood the benefits of going upstream and away from the pollution of the cities to get clean water and elevation for gravity flow. This is a recurring theme for most New England water supplies and one of the reasons why the region suffered less from waterborne disease than many other parts of the country. All of this sets the stage for the events leading up to formation of NEWWA.

Events leading up to NEWWA formation in 1882

Why was NEWWA necessary? The answer is that there were many forces coming into play that were driving the need. It wasn't just a growing public demand for water plumbed into the home or a public expectation that affluence should be accompanied by such conveniences. It was most definitely public health and public safety pressures as understanding about waterborne disease and fire protection issues grew. It was a growing appreciation of the necessary engineering and science to do this difficult job. It was the fact that constructing a water system was a high stakes venture, being the biggest public works project to date in most communities and the most necessary to ensure business prosperity.

Growing water use

The major event of this period was the Civil War, which, like later wars, affected population and resources. New England lost some of its population to the war and to westward migration but overall population increased dramatically throughout the period. Immigration from Europe was vigorous, especially from Ireland. The Irish potato famine occurred from 1844 to 1846 and came at a time when England had its own problems and offered less aid to Ireland, thus starting the immigration wave. In the years following the famine, Ireland had also had epidemics of typhus, scurvy and bacillary dysentery, with the result that in 5 years, Ireland lost ¼ of its population to death (1 million) and migration (2 million), most taking the cheap passage to Boston and New England. Between 1840 and 1860, Boston's population went up by 110%, while its Irish population went from 1 in 50 to 1 in 5.

New England industries continued to prosper, not just from gun manufacturing during the war but all sorts of goods from textiles to complex machinery. Mills were still heavily dependent on water power but the steam engine began to be a viable source of industrial power so that industries were no longer limited by drought flows. Other parts of the country, such as the mid-western states, made use of steam power to become competitive with New England in many heavy industries. Steam engines for the railroads also signaled the end of the Canal Era for transporting goods and allowed much better population mobility throughout the country.

The bottom line was that cities, especially those with manufacturing, continued to grow very rapidly during this period. Cities also grew in terms of annexation of suburbs or adjacent villages. This extended the areas needing water service in many large communities.

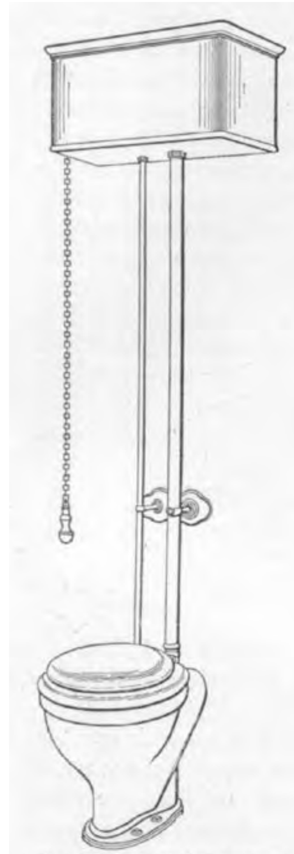


Fig. 41. High-Tank Arrangement of Closet Fixtures.

Early toilet

Growing per capita use

In addition to population growth, the amount needed by the average household had been climbing more rapidly than anyone could have imagined. The impact of plumbing was a major part of this, especially the flush toilet which was becoming an influence in cities. Bathtubs were not as exotic and rare as they once were. Public bath houses offered bathing access for the masses but wealthy people were more likely to install their own facilities. Several inventors had put forward flush tank toilets and eventually solved the sewer gas problems with the S trap design for the bowl. The major hotels in cities began to develop indoor plumbing as an attractive convenience, eventually even providing plumbing for each room.

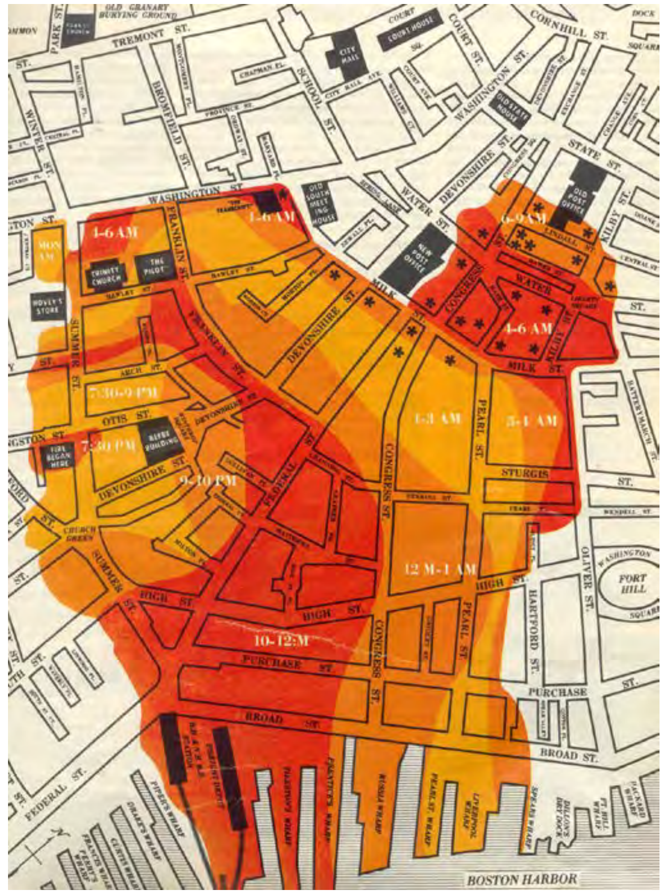
The other factor was the lack of metering on most household services. With only a flat fee to pay, the consumer began to take advantage of the novelty of running water, raising per capita usage by a factor of 10 from the beginning of the 1800's. With the unreliability of supply in some early systems, some people would leave taps open just to not miss the water when available.

Technology Developments

Towards the end of this period, other technology developments change the public's expectations of its utilities. The telegraph had been extended throughout the country. The first radio and telephones were invented. Gaslights had been installed in most cities and Edison's electric light had been invented. Modern conveniences were the rage and the affluent demanded the latest inventions.

Cities had started to develop sewerage works to move the waste away from the people. Collecting sewerage and directing it to the nearest waterway, away from residents, was the normal practice. Often, sewerage was simply directed to the nearest storm drain so that rainfall events would occasionally flush the pipes. This marked the beginning of combined sewers in many urban areas, creating a problematic sewer infrastructure that is still being addressed in the present day. The proliferation of sewer discharges may have improved the aesthetics of urban life but left much to be desired in terms of fouling rivers and streams, especially downstream of inland communities. Large interceptors to collect the sewerage of individual street drains for discharge at more remote outfalls were just beginning to be planned to minimize public impact, with Boston's Main Drain in 1883 being a prime example.

Further development of water resources was slow until the post-Civil War period. Major fires were still a driving force for improvement of distribution systems, the most notable fires of this period being in Boston and Portland. To be fair, it should be noted that each city has a "Great Fire" somewhere in its past. The most destructive fire nationally was Chicago's Great Fire of 1871, which destroyed 18,000 buildings, caused 200 deaths and consequently nearly crippled the insurance industry, with much impact locally on Hartford CT. Boston's Great Fire of 1872 consumed 776 buildings in the heart of the city and was fought over several days by firemen from as far away as Maine. It resulted in 13 deaths and $75 million in damages, again causing bankruptcy of 70 insurance companies. By comparison, Portland's Great Fire of 1866 consumed 1500 buildings and caused $15 million in damages. Responders again included companies from as far away as Massachusetts.



Great Fire of 1872 in Boston, burned the entire area from present Day South Station to Fanueil Hall

These tragedies had repercussions on the water industry. In Boston, there was criticism leveled at the Water Department for having undersized mains in the area. There were no definitive standards on pipe sizes, nor were there any minimum pressure requirements or even standards for hydrants and nozzles. As a result of the 1872 event, Boston revamped its distribution system considerably to increase pipe sizes and available fire flows.

Fire protection measures were evaluated extensively by NEWWA after 1882. The insurance companies learned to minimize their losses by working with the water supply community to ensure effective designs for fire response. The insurance industry began using hydraulic experts like John R. Freeman, one of the more notable hydraulic engineers of the period, to evaluate fire capabilities. Many early NEWWA papers presented nozzle and fire stream studies in support of design standards.

The other aspects of water engineering, e.g. dam construction, pipe laying, storage tanks, etc, were still in their infancy with relatively few experts in any discipline. Every new problem was a learning opportunity and there was a need to share the empirically found solutions to the myriad new problems. As was the custom of the times, water supply operation was like many technical occupations – something to be learned by mentoring in a master/apprentice relationship. This can only take someone only so far in a single water system. Thus, there was a clear need for an ongoing forum among water suppliers, scientists, engineers, vendors, academics, and every other specialty that had a stake in improving the performance of the industry. Enter NEWWA in 1882 to meet this need.

Example of early pipe sizes - 1860 Cambridge MA pipe table, City serves 26,000 persons

Pipe Size	Length	% of Total
20”	180’	0.1%
12”	5950’	4.8%
10”	13180’	10.6%
8”	6000’	4.8%
6”	14955’	12.0%
4”	56263’	45.2%
3”	27989’	22.5%

Note that the majority of pipe is 3” and 4”

Beginnings of Public Health as a Driving Force in Water Supply

In 1882, cholera and typhoid epidemics were still rampant and 2 major misconceptions were still in place, i.e. the mistaken causes of disease and the belief that running water purified any wastes. The “miasma” theory that foul vapors caused disease was still popular since there had been no definitive proof of a disease causing mechanism. The first evidence of waterborne disease was empirical when people drinking from the same source became ill. The finding in 1854 London by Dr. John Snow that users of the Broad Street well developed cholera was a watershed finding for water suppliers and public health authorities everywhere. Microscopes had shown organisms, often called “animalcules” but the connection hadn’t been made that bacteria could be the cause of disease.

Example of early waste discharge impacting household well

This changed in the early 1880’s when news came from Europe that Robert Koch had successfully isolated the anthrax bacteria, cultured it, infected a second host with the culture, then re-isolated the same organism from the second sick host. This was definitive proof that bacteria were the causative agent and it was then obvious that bacteria in the sewage from infected people was the transmission mechanism that had been causing epidemics. Researchers like Koch and others identified many more bacteria like typhoid and cholera to further reinforce the point. “Germ theory” was born.

Now that this was understood in the scientific and the public health communities, they turned to the problem of how to stop sewage contamination of water supplies. This is where the second misconception occured, the idea that moving water would purify waste in a fairly brief travel, a hindrance to planners trying to get water from further upland supplies. Some source water decisions were poorly made as a result. A classic example of this was Albany's decision to use a direct withdrawal from the Hudson River despite numerous upstream community discharges. This proved to be regrettable when the city had numerous typhoid outbreaks that caused deaths for more than a decade to follow until their water treatment was improved. The original decision was opposed by some but supported by some very respected sanitarians, mainly due to the idea of natural purification. Eventually, the bacteria testing methods coming from Europe would provide a means to debunk this idea.

Armed with the idea that sewage was the culprit, public health strategies made it a priority to avoid the hazard. This meant that the less polluted upland supply was the clearly preferred choice. Sewerage and sewage treatment became even more important. When the use of a polluted supply was necessary, now the emphasis would be on ensuring proper treatment.

There was still very little understood about chemical issues in drinking water and there were certainly industries that had been polluting for some time – tanneries, paper mills and the like. Some operations, like paper mills or cloth dying, would literally turn the downstream river colors. When the biological threats in water were so great as to be among the leading causes of death at the time, the chemical threats were subtle in comparison so they received little attention. However, it was clear that water sources were becoming more fouled from both the spread of industries around New England but also from the increasingly complex wastes being discharged by these industries.

Mid 1800's to the 1882 formation of NEWWA - Forces at work

Why was an organization of water supply professionals necessary in 1882? To sum it up:

- Population was rapidly growing, especially in poor urban areas as a result of immigration.
- Per capita use was growing as a result of greater demand for plumbing.
- Water waste was growing in existing systems since metering was still too expensive to be supplied universally.
- Early water sources were becoming inadequate in volume.
- There were growing concerns over poor quality and disease from water and early water sources were becoming more polluted from sewerage and mill wastes.
- Distribution system capacity was becoming an issue, especially in the area of fire protection.
- Knowledge of water supply science and engineering was limited given the lack of technical schools and the reliance on essentially an apprentice system with on-the-job training or mentoring as the educational means.
- Being a fairly new field, there was a lot of uncertainty at the time over the means and methods of water supply – How do you build a safe dam? What pipe material is best? Is this water of adequate quality and how do you improve it? Uninformed solutions to these problems would lead some individual system operators to poor decisions at great public expense in the absence of consultation with fellow water system operators.
- As more cities and towns built water supplies, citizens of other communities demanded similar service, thus creating a rapidly increasing need for more knowledgeable operators and engineers.

Next steps for larger systems

In the period leading up to 1882, most of the larger communities took another step in a series of steps toward their present day supplies. Some needed better pumping technology to allow them to take the next step. Some, like Hartford, went the other way, deciding against costly pumping of an increasingly polluted source and moving to gravity supply from an upland reservoir. Many needed to dam rivers to get enough water, leading them into the difficult process of obtaining land and water rights, not to mention constructing a safe and effective dam. Each had their own challenges and crafted their solutions to fit their circumstances. Burlington VT, for instance, took supply from and discharged its sewerage into the same water body, which led them to engineer a deep water intake some distance from the city.

Many communities decided on public ownership to get the job done. This was partly to exert control over the effort but, often, the main driving force was to pursue the water supply for its public health benefits, which needed to be extended to the urban poor. Planners recognized that the old ways of using polluted wells and cisterns needed to change and safe public water should be accessible to all. Given the successes of many earlier systems, communities were also less fearful of the necessary level of investment.

The water works, in most cases, represented the single largest expense to date for a community and were celebrated accordingly. As with churches and public buildings, many early facilities were architecturally imposing, even grandiose, to assure that the noble mission was properly respected.

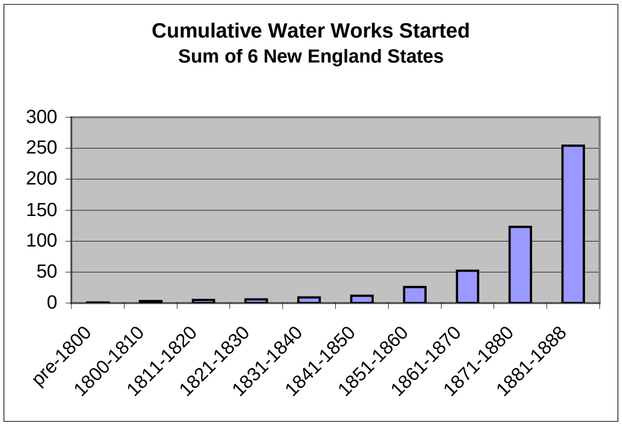
The following reviews the status of the largest New England communities prior to NEWWA:

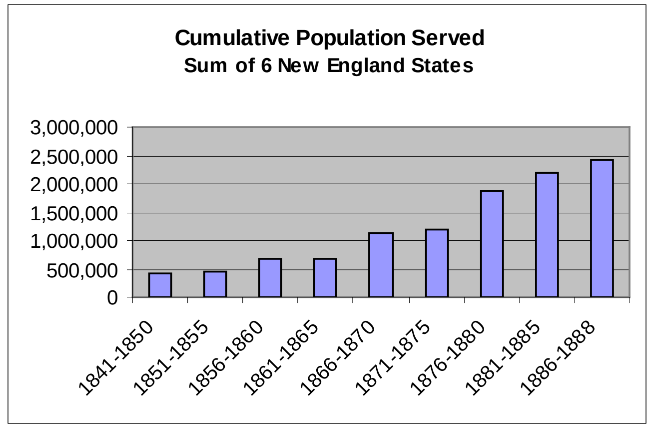
State	**City**	**1850 Source**	**1882 Source**	**Gravity/ Pump**	**Public/ Private**
Massachusetts	Boston Cambridge Worcester New Bedford Fall River Springfield	Lake Cochituate Fresh Pond Bell Pond Acushnet River Watuppa Lake 4 Sm. Reservoirs	Sudbury System Stony Brook Reservoir Lynde Brook Reservoir Acushnet River Watuppa Lake Ludlow Reservoir	Gravity Pumping Gravity Pumping Pumping Gravity	Public Public Public Public Public Public
Rhode Island	Newport Providence	Ponds Springs	Easton's Pond Pawtucket River	Pumping Pumping	Private Public
Connecticut	Hartford New Haven Bridgeport	Connecticut River Mill River Springs	Trout Brook Reservoirs Lake Whitney Ox & Island Brook	Gravity Pumping Pumping	Public Private Private
New Hampshire	Manchester Nashua	Lake Massabesic Pennichuck Brk	Lake Massabesic Pennichuck Brook	Pumping Pumping	Public Private
Maine	Portland	Springs	Lake Sebago	Gravity	Private
Vermont	Burlington	Lake Champlain	Lake Champlain	Pumping	Public

The need for more water operators

The period leading up to 1882 is the beginning of a water supply surge that carries well into the early 1900's. With so many new systems starting up, the qualifications of people stepping in to operate these systems must have been a bit thin. Consider that there were no schools for operators and few qualified engineers. The likelihood is that many stepped into the field with limited technical skills and probably an inadequate understanding of even the limited knowledge of the day.

The following graphs show the rapid growth in this period:





The number of people served by water supplies showed a great increase when the cities with large populations built their water works. Prior to the 1880's, this was still a relatively small percentage of New England communities but a cumulative growth of over 2 million people served is substantial.

The growth in number of water works was even more impressive. In just the decade of the 1880's, over 100 communities started water supplies. Each new water supply had significant responsibilities and risks for the new operators.

The following table documents the sequence of start-ups of New England systems:

Water Systems Started from 1851 to 1882 (Cast Iron or Wrought Iron Pipes)

Community	State	Year	Community	State	Year	Community	State	Year
Hartford	CT	1851	Medford	MA	1870	Newton	MA	1876
Rockland	ME	1851	Melrose	MA	1870	Springvale	ME	1876
Bridgeport	CT	1853	Everett	MA	1871	St. Johnsbury	VT	1876
Northfield	VT	1854	Fall River	MA	1871	Taunton	MA	1876
Cambridge	MA	1855	Farmington	NH	1871	Agawam	MA	1877
Nashua	NH	1855	Fitchburg	MA	1871	Pawtucket	RI	1877
Pittsfield	MA	1855	Northampton	MA	1871	Bethel	CT	1878
Plymouth	MA	1855	Amesville	CT	1872	Cochituate	MA	1878
Rutland	VT	1856	Concord	NH	1872	Lewiston	ME	1878
New Britain	CT	1857	Lowell	MA	1872	Nantucket	MA	1878
Williamstown	MA	1859	Manchester	NH	1872	Torrington	CT	1878
Birmingham	CT	1860	Norwalk	CT	1872	West Randolph	VT	1878
New Haven	CT	1860	South Hadley Falls	MA	1872	Westborough	MA	1878
Stamford	CT	1860	Arlington	MA	1873	Amherst	MA	1879
Stockbridge	MA	1862	Attleborough	MA	1873	Brandon	VT	1879
Winsted	CT	1862	Augusta	ME	1873	Canaan	CT	1879
Salem & Beverly	MA	1865	Easthampton	MA	1873	Island Pond	VT	1879
New Bedford	MA	1865	Holyoke	MA	1873	Waterbury	VT	1879
North Adams	MA	1865	Lawrence	MA	1873	E. Providence	RI	1880
Stonington	CT	1865	Leominster	MA	1873	Fairhaven	VT	1880
Middletown	CT	1866	St. Albans	VT	1873	Greenwich	CT	1880
Norwich	CT	1866	Turner's Falls	MA	1873	Hingham & Hull	MA	1880
Springfield	MA	1867	Waltham	MA	1873	Thomaston	CT	1880
Burlington	VT	1867	Winchester	MA	1873	Uxbridge	MA	1880
Chelsea	MA	1867	Winooski	VT	1873	Central Falls	RI	1881
Portland	ME	1867	Woburn	MA	1873	Chicopee Falls	MA	1881
Rockville	CT	1867	Bar Harbor	ME	1874	Dedham	MA	1881
Great Barrington	MA	1868	Concord	MA	1874	Lee	MA	1881
Somerville	MA	1868	Natick	MA	1874	Newburyport	MA	1881
Waterbury	CT	1868	New Milford	CT	1874	Plymouth	NH	1881
Webster	MA	1868	Westfield	MA	1874	Shelton	CT	1881
Ansonia	CT	1869	Bangor	ME	1875	Southbridge	MA	1881
Auburn	ME	1869	Brookline	MA	1875	Bristol	RI	1882
Keene	NH	1869	Cheshire	MA	1875	Clinton	MA	1882
Malden	MA	1869	Lenox	MA	1875	Fryeburg	ME	1882
Meriden	CT	1869	Lincoln	MA	1875	Gardner	MA	1882
Vergennes	VT	1869	S. Norwalk	CT	1875	Kent	CT	1882
Providence	RI	1870	W. Springfield	MA	1875	Milford	NH	1882
Haverhill	MA	1870	Athol	MA	1876	Milford & Hopedale	MA	1882
Ashburnham	MA	1870	Danvers & Middleton	MA	1876	Northborough	MA	1882
Brockton	MA	1870	Hallowell	ME	1876	Richmond Furnace	MA	1882
Greenfield	MA	1870	Methuen	MA	1876	Wallingford	CT	1882
Lynn	MA	1870	Newport	RI	1876	Warren	RI	1882

Many more communities started after 1882, in fact, the growth spurt didn't abate until well into the 1900's. With this growth came a greater need for sharing experience, larger systems mentoring smaller systems and NEWWA filled this void.