The Sudbury Aqueduct

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Figure 1: Route of Sudbury Aqueduct.
Winding gracefully through nearly 16 miles of Boston’s western suburbs is a serpentine structure of brick, cement, and earth. Although it is a conspicuously man-made edifice, over 126 years of existence its footprint in the landscape has become increasingly subtle. In the minds of local residents, now many generations distant from its creators, it simply is part of the landscape. This is the Sudbury Aqueduct, an erstwhile major component of the water supply for the city of Boston and its surrounding communities. Though the aqueduct no longer transports drinking water, its mere existence carries forth a rich history of Boston’s industrialization and growth. Charting its evolutionary role in the community reveals a surprising number of themes familiar to students of “industrial landscapes:” the circular relationship of supply and demand, the role of work in connecting man to the landscape, the so-called “tragedy of the commons,” and the malleable nature of, well, “nature.”

That a mere element of Boston’s hydraulic infrastructure could convey so much is surprising. Quite frequently, in the study of the above themes, the illustrative cases evoke incredulous reactions along the lines of, “what were they thinking?” But the water system in Boston—one of the oldest in the United States—has a remarkable and unparalleled history of good design, prudent management, and environmental stewardship that seems modern even by today’s rigorously-regulated standards. Certainly, some of the system’s successes have been more the result of good luck than prescience. In maintaining sufficient capacity, for example, two major studies for planning future demand, in 1895 and 1922, employed overly cautious projections of population growth (see Figure 2). These estimates led to the construction of surplus capacity long before it was due. But even with science and fortune on their side, the designers and maintainers of Boston’s water system—the Sudbury Aqueduct in particular—illustrate our story well.
Before Sudbury

The supply of water, as one would expect, has been important to the community since its earliest colonial origins. In 1630, the locals (numbering under 1,000) obtained drinking water from a natural spring on Boston Common. In the colonial boom, that supply was quickly overwhelmed. Records show the installation of a 12-foot wooden cistern near Haymarket in 1652. By 1795, Boston was part of the United States and the Jamaica Pond Aqueduct Company was drawing water from Roxbury. By the late 1840’s, the population of metropolitan Boston had grown to as much as 180,000; coupled with the burgeoning demand for modern plumbing, a more serious supply of water was in order. The demand was met by Lake Cochituate, a man-made reservoir created from a tributary to the Sudbury River. In 1848, 100,000 people crowded the dedication ceremony of the aqueduct which carried Cochituate water to Frog Pond on Boston Common. A milestone for Bostonians at the time, the new Cochituate source promised a supply of 10 million gallons per day (MGD) with a storage capacity of 2 billion gallons.\(^1\)
Shortcomings Apparent

Inevitably, demand would conquer this massive supply. Sure enough, in the words of the Boston Water Works, the “insufficiency of the Cochituate Aqueduct was felt 10 years after its construction.” A summer of little rainfall in 1871 seriously endangered the supply by that autumn, and as the water level in Lake Cochituate fell, engineers brought in pumps to fill the aqueduct that was normally fed by gravity. Drinking water, sanitation, and fire protection were all at stake. The weight of this situation was not lost on the editorial staff of *The Boston Daily Globe*, which in the spring of 1872 breathlessly wrote:

The plentiful supply of good and wholesome water to a large city is, perhaps, the first and most important consideration which can be named, and upon which so many and such vast interests depend, that too much prominence cannot be given to the subject, nor too much light thrown upon the same. In this manner, as it regards Boston, we may say in general terms that our citizens have abundant reasons for thankfulness, and that this department of the city government has been for nearly twenty-five years—since when Cochituate water was first introduced—managed with great circumspection and wisdom. The vast good which is dispensed by this department to our citizens comes to us, like most great blessings, silently, unobtrusively, and always at hand; hence, unless when realizing its deprivation, we are forgetful of the fact how dependent our very existence is, as well as our comfort, upon its ceaseless and abundant supply. So thorough is the system of the department, and so well are its varied responsibilities sustained, that scarcely can we recall, in the period of the last twenty-five years, more than one or two even temporary exigencies when our citizens have realized the least deprivation in their domestic supply of Cochituate water. The latest and most prominent experience being that which occurred last November.³

In response to the crisis, the Cochituate Water Board hired a civil engineer named J.P. Davis and charged him with the task of locating a new source of water within 50 miles of Boston.

The Sudbury System

In February 1872, Davis issued his first report to the C.W.B. suggesting the Sudbury River as the most viable source. Things moved very quickly from there. By April 1872, the governor
of Massachusetts had signed the Sudbury River Act, authorizing the partial diversion of river water. That summer, a hasty temporary connection was made to fill Lake Cochituate directly from the Sudbury, staving off the various consequences of dangerously low water levels in that reservoir.

By the end of the year, J.P. Davis was elected City Engineer for Boston. In January 1873 he released his extraordinarily comprehensive final report on the Sudbury River plan. His findings confirmed that demand had equaled the theoretical 10 MGD supply of the Cochituate system by as early as 1860. His extensive research of area water flows, watershed absorption, and surface evaporative losses confirmed that the Sudbury River would willingly supply the 40 MGD prescribed by his previous report. The Cochituate Water Board ordered him to “proceed forthwith with the construction of the new conduit.” The project stalled for a year and a half under political pressure until the city could be convinced of Davis’s findings, and again as the result of the financial depression of 1874–5. But finally on November 11, 1875, Boston’s City Council voted to instruct Davis to begin work on the Sudbury Aqueduct system.

Building the Sudbury System

Construction of the system began promptly. The city’s purchasing agent was responsible for buying the materials and implements. The work was split among dozens of contractors from within and without the state whose names reflect little in the way of specialization. A great portion of the work would be accomplished by laborers hired directly by the city. The city built “capacious barracks” to accommodate these transient laborers. In 1875 the laborers were paid a daily wage of $1.50 for their efforts, an amount that would later be reduced to $1.25. In 1876 as many as 432 men were employed as day laborers by the city; the number probably grew much higher than that toward the end. Figures about those workers employed by the contractors are nearly nonexistent, but the Boston Water Works places the largest number of
men—contractors and laborers—simultaneously employed by the project at 2,300. The work was surprisingly safe, given the scope: only 6 deaths were recorded in the official record of the project. Three laborers were killed in a cave-in near the Badger Hill tunnel, and another three men died under unspecified circumstances in the Beacon Street tunnel. A very brief strike in 1876 is the only remaining indication of the health of worker-employer relations.

No other official statistics are available on the lives of the men who built the aqueduct. One lifelong Needham resident recalled being taught that they were mostly poor Irish immigrants, which is a reasonable guess for Boston at the time. Though the Irish potato famine was some 25 years removed, smaller waves of Irish immigration to Boston were seen throughout the late 19th century.

The main conduit of the Sudbury system is our Sudbury Aqueduct. It is a cement-lined brick pipeline of rectangular cross-section with an arched roof. The cross-section is equivalent to that of a round pipe 8.5 ft in diameter. It begins at the gatehouses of Farm Pond in Framingham, sloping downward at 1 ft per mile over some 84,000 ft to the Chestnut Hill Reservoir near Cleveland Circle in Brookline. In some places it is completely below ground. In others, particularly near the Newton-Needham border, it sits above the surface like a grassy Indian burial mound some 8 ft tall. It crosses the Charles River dramatically by way of the 500 ft long Echo Bridge, which remains today one of the largest stone-arch bridges in the world. The system was designed to transmit 80 million gallons in 24 hours—a factor of two more than the source was to provide—to allow for future needs.

The aqueduct is actually fed from a network of 7 reservoirs constructed along the Sudbury River. These reservoirs are needed to control the legally-mandated flow rates in various segments of the river, to counteract the effects of seasonal rainfall variations, and to aid in the filtration of runoff from the watershed. The total storage capacity of the reservoirs is 19 billion gallons.

On February 13, 1878 at 11:45 AM, following just 2.5 years of construction, the gates at Farm Pond were opened, unleashing the first flow from the Sudbury River to the Chestnut
Hill Reservoir from whence it was distributed to the city. By 1880 the system of reservoirs along the Sudbury was fully operational. Incredibly, by as early as 1881, the Sudbury River was supplying twice the water of Lake Cochituate.

**The End of the Line**

As one would expect, the Sudbury Aqueduct would not be a lasting solution to Boston’s water needs: its capacity of 40 MGD would quickly be outgrown. But in another way, it lasted a lot longer than expected: the brick conduit was in continuous active use until 1978—one hundred years later—by which time the organization now known as the Massachusetts Water Resource Authority had reached even deeper into the state for other sources. Due to pollution, the Chestnut Hill Reservoir, which is essentially an open lake in the middle of the city, no longer meets the requirements for safely storing drinking water, but the aqueduct is still maintained as a reserve source in the event of an emergency along the newer transmission pipes. The Chestnut Hill Reservoir serves the infrastructure now as a backup source of fire protection water.⁵

**Implications**

The Sudbury Aqueduct exhibits a number of themes frequently encountered in the study of industrial landscapes. Perhaps the most evident from this historical narrative is the circular nature of supply and demand. The experiences of the American Indians notwithstanding, an abundance of resources of any sort in this country’s history has inevitably led to a corresponding growth in consumption. Much like how modern highways, widened to lessen congestion, seem to entice an increase in traffic, improvements to the water supply in Boston made population growth possible, resulting in their rapid obsolescence. This trend continued throughout much of the Sudbury Aqueduct’s active service life.

Incredibly, in spite of the persistent growth of population in the metropolitan Boston
area, the supply capacity of the M.W.R.A. network has grown little since its World War II-era boost to 300 million gallons daily. Following a near-catastrophic water shortage in the 1960’s, caused by years of withdrawals exceeding resupply by rain, a massive conservation effort made significant improvements to the number of citizens who could be served by the existing system. Continued growth is still inevitable, but Boston has demonstrated that there are other, more prudent solutions to the water problem than simply “turning up” the supply.

In performing work on the landscape, it is said, man gets to know nature. This is exceptionally true of the Sudbury Aqueduct project. In an 1899 summary of contemporary water supply books for *The New York Times Saturday Review*, civil engineer J. James R. Croes explains the significance:

In 1875 a very thorough and careful series of gaugings of the Sudbury River in Massachusetts, which was taken for the supply of Boston, was begun under the direction of Mr. Joseph P. Davis, the chief engineer of the new water supply. At the same time observations on the evaporation from water surfaces were instituted, also by Mr. Davis in Boston. These two sets of observations were the most scientifically accurate of any of the kind ever undertaken. The stream gaugings, which have been continuously carried on ever since, were described by their conductor, Mr. Alphonse Fteley, now the chief engineer of the New York Aqueduct Commission. These excellent papers describing with an accuracy of detail nowhere else to be found the relations of rainfall, run-off of streams, and evaporation on a watershed of some 75 square miles area in Massachusetts are very properly accepted as conclusive in the vicinity of Boston.

It took a good while for other parts of the country to follow the good example of Boston in this direction. Even the State of Massachusetts has made no investigations into the run-off of its other streams, reposing on its Sudbury River records, in spite of the fact that fragmentary observations of other streams show the inapplicability of the Sudbury standard to them.6

Indeed, the lengthy 1883 paper by Alphonse Fteley and Frederic P. Stearns, “Description of Some Experiments on the Flow of Water Made During the Construction of Works for Conveying the Water of Sudbury River to Boston,” demonstrates that in the planning and execution of the Sudbury Aqueduct, the engineers made groundbreaking discoveries of not only nature’s quirky environmental mechanisms but also the fundamental physics of water
flow through pipes and over weirs. Thanks to the precociously comprehensive work of these engineers, the construction of the Sudbury Aqueduct, more than that of any other civil engineering work of its time, led man to a closer understanding of nature.

The public water supply is, of course, a vital and communal resource. Biologist Garrett Hardin, in more recent times, identified a mechanism of give and take with shared resources that he called “the tragedy of the commons.” It might be surprising to the modern reader that for a long time, the municipal water supply was considered a “commons” to which all individuals in the area were entitled. For the accusative explanation, we turn again to The Boston Globe’s 1872 editorial on water:

...[The reduction of water rates] could be reached within a month, were it possible to charge all consumers alike; that is, if the small takers paid in the same proportion as the large ones do. Of course it is well known that large consumers pay for the water supplied, by metre, justly and exactly at the rate of three cents per hundred gallons for all which they use, while private houses, and comparatively small consumers pay according to an estimate adjusted between themselves and the agents of the department upon what is deemed an equitable basis; and herein lies, what we conceive to be, the only weak point in the entire system of the department.

There are, to-day, about forty thousand regular takers of Cochituate water on the books of the Water Board, and out of this number there are but eleven hundred who pay by metre for the amount consumed. The officers of the department know very well that the largest consumers are those in the humblest conditions, who, we are sorry to say, are recklessly wasteful, and among whom more water is permitted to run to waste, than the whole aggregate used by the rest of the consumers. The half-inch pipe that supplies one of the class referred to, if left open from carelessness, or to prevent freezing, or for any reason whatever, will run to waste more water during the night, than would supply the largest hotel in the city for twenty-four hours. Those persons who pay for the water by metre soon learn to use it as they use gas, viz.: with reasonable economy, because they know very well if it is wasted, their bill at the end of the quarter will be in a just and exact ratio increased. Indeed, economy would be thus induced among all takers, as it is natural that our convictions should be remarkably acute, when they reach us through that depository situated just below the waist-band, known as the pocket. Now if every person paid by metre, that is, if the 38,900 takers paid on the same basis as the eleven hundred large consumers, the department would be more than self-sustaining to-day, and would pass to account of the sinking fund quarter of a million dollars annually, besides reducing the price of Cochituate to two cents per hundred gallons.
Have we not shown enough to prove that the only just and equitable mode of regulating the charges for water, is by the universal employment of the metre? No reasonable person can for a moment doubt that the 1,100 individuals and corporations who pay by metre, are taxed to a large extent for what is used by the other 38,900 consumers. When the metre system is universally applied, the vast saving induced, will make our supply of water ample for years to come, and the individual charges will be reduced to an infinitesimal amount.\footnote{3}

The \textit{Globe} editors would have to wait 35 years to see their wish come true. Universal water metering was enacted in 1907, kicking off a huge eight-year reversal of growth in per capita water consumption (see Figure 3).

![Figure 3: Boston/Metropolitan Water District Per Capita Water Consumption.\footnote{1}](image.png)

Lastly, the building of the Sudbury Aqueduct demonstrated how pliable our concept of nature is. Lake Cochituate and the Sudbury River reservoirs appear, to the casual observer, almost entirely natural. As they are formed from geography that (with the help of a dam at one end) forms a natural container for water, from a map they look as if they had been there all along. The Chestnut Hill reservoir, lined with stone and situated in a perfectly flat region, is not quite so subtle. But nevertheless, it has become a “natural” part of the landscape: it is surrounded by attractive and well-used footpaths, trees, and gardens, and just this year it officially opened to the public for recreational use. In many ways it appears just like a lake. The Sudbury Aqueduct itself has become something of a magnet for joggers, who can be seen...
throughout the day traversing the worn grass atop the aboveground segments of the conduit. A similar effect is observed at the more modern Quabbin Reservoir, another Boston water facility created dramatically in 1946 by the underwater internment of four towns and six villages along the Swift River. The “wilderness” surrounding Quabbin, while meticulously managed to maintain the quality of water (which to this day is not filtered), has become another unique part of nature, home to countless plants and thriving wildlife that would not exist on its own. Though on a much smaller scale than Quabbin, the Sudbury Aqueduct system has itself become “second nature.”

The water system of Boston is a fascinating subject worthy of more treatment than can be afforded here, but even this tiny example—the Sudbury Aqueduct—demonstrates the remarkable applicability of our concepts of “industrial landscapes” to the most seemingly mundane, “silent and unobtrusive” aspects of the landscapes around us.
References


