Water-related Infrastructure in Medieval London

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ABSTRACT: There were elements of London's historic water and wastewater system which were very innovative. In the area of water supply two innovations stand out: (1) the contribution of private capital and enterprise to the construction and operation of major projects and (2) the use of water-wheels under London Bridge to power pumps and lift water for municipal and commercial use. The major disadvantage of the water supply system was its over-dependence on wood and lead. These construction materials made it an early victim of the Great Fire of 1666. In the area of wastewater and pollution control, a key innovation was the enactment of creative laws which attempted to improve sanitation and control the flow of pollutants. Unfortunately there was not a distinct separation between water and wastewater systems. This led to serious contamination of some London's water supply sources.

INTRODUCTION

The Great Fire of 1666 was reported to have started in a dark, narrow lane in the older section of the city near London Bridge. It spread much more quickly than city officials were capable of controlling. Early impressions of the fire were not always accurate. Samuel Pepys in his famous diary writes that he was awaken by a maid-servant who informed him of a fire in the city. He got out of bed and went to a window to inspect the scene. Convincing himself that the fire was not a threat, he returned to bed. Pepys' impression of the Great Fire was soon to change.

For students of London's infrastructure, the Great Fire represents a significant benchmark. The destruction inflicted by the inferno was so complete that few of the secular buildings in the older section survived. Not only did the fire cause destruction to buildings but it also destroyed much of the city's infrastructure. A major fire is always a significant test for water systems, but in an era of wood and lead pipes, wood water-wheels, wood engines, wood pumps, and lead-lined cisterns, it was also a threat to the integrity of water structures. Because the destruction caused by the Great Fire was so devastating, it represents a convenient ending point for a survey of London's historic water-related infrastructure.

To help understand London's water-based systems, this paper will examine: (1) the general evolution of the culinary and wastewater systems; (2) the impact the various systems had on daily life; (3) the operation and maintenance problems of the systems; and (4) the general technological advances which were made.

SOURCES OF INFORMATION

A variety of first-hand written material concerning water-related utilities and general living conditions in London is available. Unlike ancient Rome, however, there is not a great deal of archeological evidence on which to draw (Grimes, 1968). Few medieval secular buildings in London have survived to the present. The Great Fire cleared much of the city and prepared it for rebuilding in brick and stone by Sir Christopher Wren and others (Dorn and Mark, 1981). In addition, many of the buildings which survived the fire did not survive the drastic reconstructions of the nineteenth century. For example, London Bridge was torn down in 1831.

Because of the dearth of structural remains, written records provide the key source of information. City, company, and other records provide remarkable insights into the period. These records have been exhaustively reviewed by such specialty historians as Home (1931), Rudden (1985), Sabine (1937), and Bell (1951) and this paper relies heavily on their work.

The most famous first-hand account of life in mid-seventeenth century is provided by Samuel Pepys. His lengthy diary, which was written in shorthand, contains detailed descriptions of the life of a man in his 20's and 30's engaged in important public service. Pepys was a high-level bureaucrat in the English government who witnessed the chief events of his day including major changes in government, a devastating outbreak of the plague, the Great Fire, and a war with Holland. Luckily for us, Pepys was observant and articulate. His account of the Great Fire is one of the most poignant pieces in the English language.

Figure 1. Samuel Pepys was 33 when he sat for this portrait in 1666, the year of the Great Fire (National Portrait Gallery, London).

Figure 2. An engraving depicts a heavily wrapped Pepys slealthy making his way through London streets during the Great Plague of 1665. (Granger Collection).

Pepys in his diary was brutally honest and bares his shortcomings for all to see. Because of his remarkable candor, an irresistible air of bedroom farce clings to him. He describes his marital infidelities in a strange jumble of languages that deceives no one. Describing one dalliance, he wrote: "had mon plaisir avec elle." But his personal behavior should not detract from his contributions as a chronicler. As Olland (1974, p. 19) points out, greatness should not be defined so narrowly that it is not compatible "with consciously making an ass of yourself."

MEDIEVAL LONDON

The city which perished in the Great Fire was not just the London of Samuel Pepys' era, but a city much older. A city with its feet planted securely in the Middle Ages.

London in the early thirteenth century was a small community situated on the north bank of the Thames River. Including the neighboring areas, it had a modest population of 40,000. By 1666, Londoners numbered over one-half million. The city was the largest in Europe and by far the largest city in England. Bristol, the country's second largest city had a population of just 30,000. By contrast to other countries, England had only one capital, and that was an enormous one. The entire economy of England was ruled by London; the city had an active port which handled four-fifths of the country's foreign trade.

London developed in a very unplanned way. City expansion was affected by its geography, in particular its waterways. Beyond the city walls to the north was a marshy area known as the Moors, headwaters for the Walbrook which flowed down through the center of the city. The stream, together with certain drainage ditches, supplied water to the moat around the city wall. Beyond the walls in western suburb flowed the larger Fleet Stream.

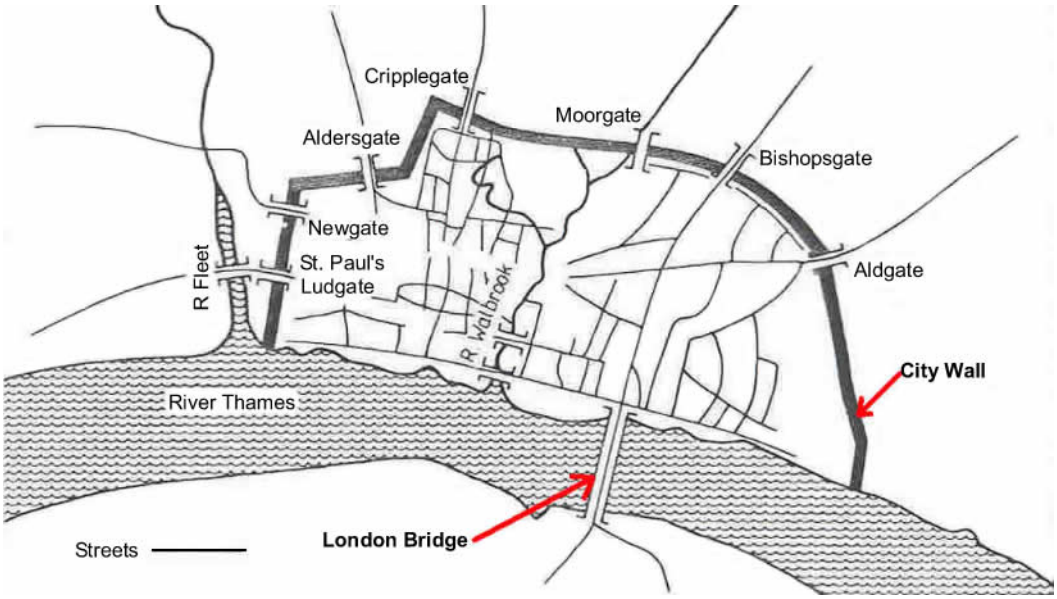

Figure 3. Medieval London (from Wood, p.6).

Within the city walls, houses were clustered in long unbroken lines sandwiching adjacent streets, which were generally narrow and surfaced with cobblestones. The city's streets, dark and evil-smelling, were tortuous and narrow. The timber-framed houses, standing with their gable ends toward the streets, were two, three, and sometimes four stories high, and frequently had each storey projecting beyond the one below. There are two reasons given by historians for the overhang. Bell (p. 11) states that the buildings were so constructed "to afford weather protection." Derwent (p. 8) suggests that the upper storey projected beyond the lower floors so the overhang would counterbalance the contents of the building and keep the floors from sagging. When buildings with overhangs were tenements, the families living in the upper flats must have found it convenient to dispose of undesirable wastes by throwing them out windows onto the streets below (Figure 4).

The wider streets had two gutters, one on each side of the road and separating it from foot-paths next to the house. In the narrower thoroughfares, one single gutter ran down the center of the street. The flow of water in these channels was constant because it contained the rainwater drained off from roofs and the ground, excess water from numerous wells and springs, and much of the slops from tenements.

Historic London was dependent on the Thames River in a sense that modern residents would find difficult to understand. London life was centered around its beautiful, but polluted, waterway almost as much as Venice life was centered around the Grand Canal. Open and broad, with hundreds of two-oared ferries, the river was London's main street. Along its banks was a broken fringe of houses, industries, and landing stages.

London Bridge was one of the most prominent structures in medieval London. Although rivers were extensively used for transport, they were also barriers which had to be dealt with by ground travelers. Ford and ferry crossings could be dangerous, especially when rivers were high; thus bridges, although few and far between, became important commercial and social sites. There has been a bridge across the Thames at London since Roman times. At the start of the thirteenth century, a stone bridge with twenty arches was constructed across the river. Eventually, houses and shops were built along the bridge (Figure 4), as were two of the city's thirteen public latrines. The arches of the bridge housed water wheels used to power water pumps and corn mills. Until the mid-seventeenth century, London Bridge was the only structure crossing the Thames River.

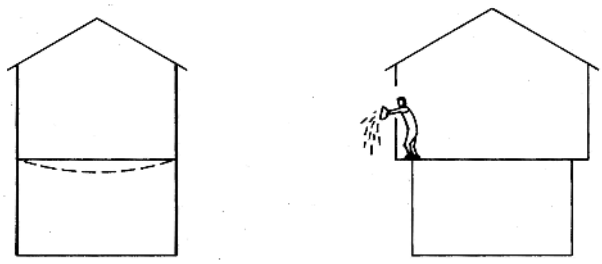

Figure 4. Artist's conception of medieval London tenement house (right). Having an overhang kept the floors from sagging (left). Kitchen and bathroom slops were frequently dumped out second and third story windows onto the street below.

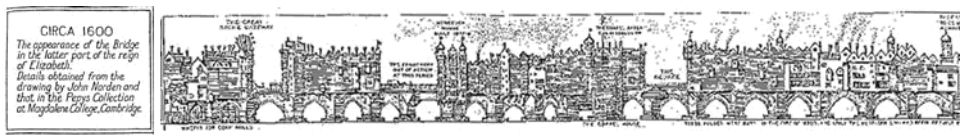

Figure 5. Artist's conception of London Bridge circa 1600. The first arch on the north was used for a water wheel and the first two arches on the south were occupied by wheels for corn mills (Home, 1931).

MUNICIPAL WATER SUPPLY

During the Middle Ages, it was not uncommon for those parts of London which were near the Thames to use the river as their main source of culinary water. Away from the river, houses were built chiefly where there were beds of gravel or loam. These beds afforded a good water supply to shallow wells until an increase in population led to contamination.

There were also a number of springs outside the city which flowed with good drinking water. Fitzstephens, a thirteenth-century chronicler, expresses annoyance at the number of drunkards and at the chastity of the city's women, but he spoke well of the water. He records that near London there were fountains flowing with sweet and wholesome water.

At the beginning of the thirteenth century, the increase in population made the existing water supply insufficient. Authorized in 1236, construction on the Great Conduit was begun in mid-century. Pipes connected the spring at Tybourne with the Great Conduit House in Cheapside. (The term "conduit" was used mainly to refer to the cisterns at the end of the system.) In all, twelve conduit systems were built in London. They were all similar in design. The head of the conduit was placed near a natural spring and the water from the spring was used to fill a nearby cistern or tank. From the cistern, the water flowed through pipes for a distance of a mile or more. At the terminus, the water was stored in a larger cistern equipped with cocks or taps for dispensing the water.

The conduit houses were not only used for storing and dispensing water but also served a secondary function as billboards for moral instruction. When King James I passed through London on his accession to the throne, the conduits were adorned with tacky verses. On the conduit in Cheapside was the following ditty:

> Life is a dross, a sparkle, a span
> A bubble: yet how proud is man!

The conduits were very popular features during major festivals. The Anglo-Saxon Chronicles mention the Cheapside Conduit (as quoted in Foord, 1911, p. 253):

> This year came King Edward I and his Wife from the Holy Land, and were crowned at Westminister on the Sunday next after the feast of the Assumption of our Lady; the Conduit in Chepe ran all the day with red and white wine to drink, for all such who wished.

This noteworthy tradition seems to have been lost in the creases of history.

One cause of problems at the conduit houses was the "alleged" overuse of water by commercial and industrial users. The city records contain numerous entries detailing the difficulties which the authorities had with the conduits. Eventually, it became necessary to appoint keepers of the conduits, and their chief duty was to ensure that the water was not stolen for commercial purposes. In the early fourteenth century, it was decided that

brewers, cooks, and fishmongers should pay, at the discretion of the keeper of the conduit, for the water they used.

Wealthy Londoners living near the route of a conduit pipe sometimes obtained permission to bring a connection or "quill" into their homes. Water was supposedly only piped into the abodes of those lucky enough to have official authorization, but having running water was so desirable that Londoners illegally tapped the conduits. In 1478, a man was convicted of having tapped a conduit where it passed his house, and conveying the water into his private well. The culprit was taken before city officials and punished in an appropriate manner. He was placed on horseback, with a vessel shaped like a conduit on his head. At each of the city's conduits he was required to proclaim his crime while water from the vessel dripped over his face.

Water was provided to individual households by carriers, commonly called "cobs," whose business it was to deliver water from the river or conduits to customers. Some water carriers went about the streets carrying a large tankard on their shoulders, others would carry two 3-gallon wooden tubs hanging from a shoulder-yoke. London's water carriers were organized into a guild or union. About the year 1600, a petition was presented to the House of Commons by the water-tankard bearers of London in which it is stated that they and their families numbered 4,000.

The water carriers' petition provides an interesting look into the operation and maintenance problems associated with London's conduit system. They complained that (as quoted in Foord, 1911, p. 276):

> . . . most of the water is taken, and kept from the said conduits in London by many private branches and cockes, and laid into private dwellings, being suffered also to runne at waste, to the general grievance of citizens, and all others repairing to the same . . .

Various cases of illegal connections are cited in the petition. The effect of these irregularities was to deprive the water carriers of much of their livelihood.

As water in the conduits became scarcer, the "cobs" could not get enough water for their customers. This resulted in disputes between individual carriers which occasionally led to violence. A homely couplet tells of their plight:

> At the conduit striving for their turn
> The quarrel it grows great
> That up in arms they are at last
> And one another beat.

Special orders had to be issued against the use of weapons in order to secure first place at the taps.

Residents and commercial establishments located near the Thames continued to use the river for a culinary supply. Using river water had its own unique set of problems. In one year, it was reported that "the tide from the sea prevailed to such a degree that the water of the Thames was salt; so much so that many folks complained of the ale tasting like salt." Unless care was taken not to get water from the river during certain periods of ebb tide, a similar complaint could have been made at any time. In 1343, residents living along the streets leading to the Thames tried to close the streets and extract a toll from everyone going to the river for water. Access problems aside, the major problem which plagued the Thames was the pollution from the accumulation of dung on the river banks, and from direct discharges into the river.

The sixteenth century saw the onset of England's first industrial revolution and a tremendous growth in London's population. This first revolution, which made England the leading industrial nation in Europe continued until the era of the Great Fire (Braudel, 1984). As London grew, city officials became anxious about the adequacy of London's culinary water supply. But like many modern authorities they were hesitant to construct extensive public works projects. They were willing to transfer the responsibility for water supply projects to private individuals who were interested in making a profit. Capitalism had arrived in the water supply business. The works of two individuals--Peter Morice and Hugh Myddleton--were particularly impressive.

PETER MORICE

London's water flowed from the source to the conduit house by the action of gravity. If water was to be taken uphill from the river it was carried in casks or by water carriers. This situation started to change in 1580 when a Dutchman named Peter Morice applied to city officials for permission to construct a water-wheel and pumps

under one of the arches of London Bridge for the purpose of supplying culinary water to the city. He gave a demonstration of the power of his pump by forcing a jet of water over the spire of the Church of St. Magnus (located near London Bridge). This so impressed city officials that they granted Morice a 500-year lease on one arch. There was at first opposition from the city's water carriers. This hurdle, along with early design problems, were overcome and eventually Morice was granted a lease on two additional arches. At first the water was lifted to the conduit house in Leadenhall, but eventually it was extended to other areas of the city. Figure 6 shows Morice's waterworks under the north arch of the bridge.

Morice's water-wheels and other machinery were destroyed in the Great Fire of 1666 and we have no description of them, but they were replaced by his grandson, and these water-wheels remained under the bridge until the early nineteenth century. In 1731, a description of the existing machinery was published in the Philosophical Transactions of the Royal Society. The three water-wheels worked 52 water pumps, one water-wheel worked 12 pumps, another 8, and the third 16. The wheels could turn in either direction so that they could be driven by the flowing and ebbing tide; the pumps ceased working for a short time when the tide was turning. These pumps were designed to force 132,120 gallons an hour to a height of 120 feet.

We know from litigation following the Great Fire that Morice's waterworks were profitable. After the fire, Mary Morice, widow of one John Morice and a beneficiary under his will, sued her brother-in-law Thomas, trustee of the estate. Thomas, because of the fire, had tried to avoid paying Mary her inheritance, which was a first charge on the profits of the waterworks, and the petition was filed to enforce payment. The evidence given at the trial showed that the water business was a very lucrative one.

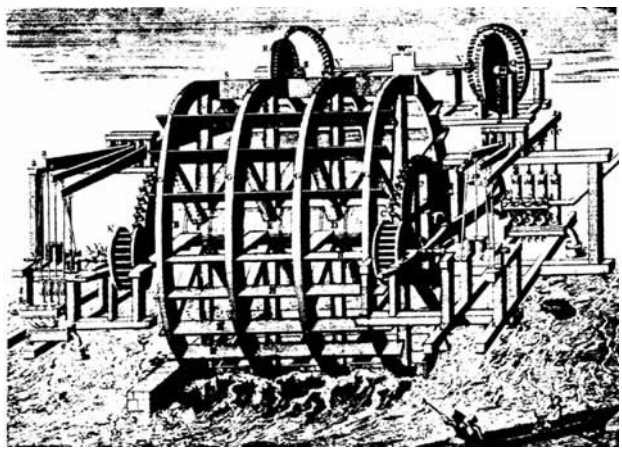

Figure 6. Artist conception of the waterworks under one of the arches of London Bridge.

SIR HUGH MYDDELTON

As impressive as Morice's water-wheels were, his accomplishment has been overshadowed by Sir High Myddelton and his construction of a canal to carry water to London from the Herfordshire springs of Chadwell and Amwell, a distance of nearly 60 kilometers. This engineering feat, begun in 1609 and finished in 1613, was so bold and thorough in design, that the "New River" source, as it came to be called, is still used today forming a valuable part of London's water supply.

The building of the "New River" is one of the legendary feats of London. Sir Myddlelton was Welshman, the sixth son of the Governor of Denbigh Castle. Moving to London, he amassed great wealth as a merchant, goldsmith, and banker; he sat as a member of Parliament; and tradition credits him with promoting the custom of smoking tobacco by puffing with friend Sir Walter Raleigh.

The city government of London was given the power to construct the "New River," but hesitated. An earlier attempt at a similar project had ended in failure causing timidity in the city officials. Myddlelton, however, would not be deterred. If the mayor and citizens of London would not do it, then he would. Only a few years before, the plague had broken out and claimed more than a thousand victims in a week. He felt a supply of pure water for London was imperative.

The job was begun in April 1609, and the difficulties which arose would not surprise contemporary water resource planners. Landowners pleaded that their meadows would be turned into quagmires from seepage from the canal, and that cattle and men would drown in the ditch. Myddelton met all opposition head-on with determination. But his finances were unequal to the strain. In 1610, with the canal only partially complete, worked

stopped and construction remained at a virtual standstill for 2 years. The opposition took their case to Parliament.

To get the project moving again, Myddelton approached the King, a common action for entrepreneurs of the day. Myddelton not only needed financial support, but also needed support against the landowning opposition to his project. The King agreed to pay half the costs of the project and that, in return, he would receive "for ever the one halfe of the benefitt profitt." To raise further capital, Myddelton did what modern entrepreneurs would do, he issued shares. He ended up with a total of 29 investors or "adventurers."

After the royal and private investment and the failure of the opposition in Parliament, construction was resumed. On Michaelmas Day, December 1, 1613, in the presence of city dignitaries, the gates were opened and the water from the "New River" ran into London's reservoirs. On a memorial stone at Amwell are the words: "An immortal work -- since men cannot more nearly imitate the Deity than in bestowing health."

The "New River," a canal 10 feet wide and 4 feet deep, followed a very circuitous 60-kilometer course (about 30 kilometer as the crow flies). The aqueduct had over 40 sluices and was crossed by over 200 bridges. Where roads had to pass under the "New River," water was carried in wooden flumes lined with lead and supported by arches. The most famous elevated section of the aqueduct crossed a stream which had its source in Enfield Chase; a brick arch not only supported the canal, but also the maintenance road along side.

Bringing the water to London was an expensive proposition, as was the construction of the distribution system. Yet the citizenry was in no hurry to pay for the new water. In addition, the "New River" was having difficulties with vandalism, a problem which continued for centuries (as quoted in Rudden, 1985, p. 23):

> (There are) many abuses and misdemeanors daylie committed and onn in and upon said river ("New River"), by lewde and ill-disposed people, in cuttinge the bankes and letting out the said water, to the inconvenience and prejudice of tennantes, casting in dogges and filth, and lettinge in sewers and other fowle and unclean water, to the annoyance of the said water; breakeinge and carreinge away the bridges, vaultes and rayles standinge in upon the river, taking and carryinge water out of the said river in lickquer cartes, tubbs or barrells, and stealing branches and cockes from the pipes, together with many such abuses and annoyances . . .

Despite the large expenditures, there were only 384 users connected to the system in 1615 and they provided a meager income for the company. In order to increase income, attempts were made to put pressure on the citizenry to take "New River" water. A letter was sent to the city asking the corporation to use its authority to require compulsory purchase of the new water. The letter was received, but no attempt was made to force individuals to connect. Despite some heavy-handed efforts, it was not until 1633--20 years from the date of the opening--that profits started to accrue to shareholders of the New River Company.

By 1619--the year of the company's incorporation--the number of tenants had increased to over 1,000 and the water provided by the springs was insufficient. It was decided to tap the nearby River Lea by constructing a diversion structure in the stream. Because the Lea was an important waterway to London, the river bargeman were understandably upset. They protested by removing the dam, which was promptly rebuilt. Disputes simmered and in 1670 the King appointed a committee to resolve the dispute. One of the members of the committee was a young Christopher Wren. The committee entirely exonerated the company: "the pipes drain off from the navigable river (Lea) about one part of thirty parts, which seems to us very little prejudicial to navigation and which could not abate the river half an inch." The problems of navigation were, they found, caused by the millers who had deepened their cuts to take more water than they had needed and, when this obstructed navigation, would let the water out in a "flash" but at a price: "they help those for money whom they have first disabled."

Until 1805, the New River Company could not serve water about the ground floor in any part of London. All their mains were made of wood and the water was shut off at night to prevent waste, which was substantial. (If a fire broke out, it was necessary to send to the head of the "New River" with instructions to turn on the water.) At least a quarter of the water supply was lost because of leakage and the bursting of wooden pipes. Despite the difficulties associated with the use of wooden pipes, they continued in use until the mid-eighteenth century. It was not uncommon to leave the pipes above ground. Matthews ("Hydraulia," 1835, as noted in Foord, 1911) lists two important reasons for leaving pipes exposed: above-ground pipes were less expensive and finding leaks in underground pipes was difficult. The visible portions of the pipes, however, provided a temptation for both legal and illegal connections.

Hugh Myddleton's company eventually became an important economic force in London. In 1695, the three companies with largest capital were the East India Company, the Bank of England, and the New River Company. Until 1904, the Company existed as a private utility and then, when the whole of London's water supply passed to the Metropolitan Water Board, it was transferred into a modern property company to manage its considerable land holdings.

WASTEWATER SYSTEMS

Medieval London had at least 13 public latrines and they were all constructed over streams and rivers. The early construction of such public facilities seems to have been not merely for the convenience of the transient business community, but also for householders and tenants who had no access to private latrines. Apparently it was not uncommon for housing projects to have inadequate facilities.

A constable in 1579 determined that 57 households within Tower Street, containing 85 people, had only three privies. The owners of the tenements usually provided only one large common latrine to serve a group of tenants. Sometimes, however, even one common latrine was not provided. For instance, an inquest in 1421 reported that all the tenements belonging to one Richard Clark were without privies. This undoubtably encouraged tenants to throw their wastes on the street creating a nuisance to pedestrian traffic. Those Londoners, who were lucky enough, had private or semi-private latrines. These were usually located over a running stream, a moat, or a cesspool.

Cesspools, which were occasionally filled with a deodorizing charcoal, were supposedly cleaned by a privy-cleaner. Wastes from cesspools and streets were either deposited in a landfill outside the city walls or on the banks of the Thames River. Figure 7 illustrates the flow of pollutants in medieval London. From the river banks, some the waste and filth was transported away from the city in dung boats, with some the waste used to fertilize area fields.

The Thames, throughout the Middle Ages, continued to be a major source of culinary water. Yet it was fouled from several sources: (1) piles of dung; (2) refuse from ships; (3) inflow from tributary streams; and (4) urban runoff. In 1598, Heutzner, a German traveler, noted that the citizens washed their clothes in the river and its unpleasant odors were on their garments.

In 1347, in response to a king's writ, a proclamation was issued forbidding anyone from throwing rubbish, earth, gravel, or dung into the Thames, the Fleet, or the streams of the city. Such filth was to be taken elsewhere out of the city in carts as before, or else by rakers (medieval garbage men) to places where it would be put in dung boats "without throwing anything into the Thames for the saving of the body of the river . . . and also for avoiding the filthiness that is increasing in the water and upon the Banks of the Thames, to the great abomination and damage of the people."

The streams running through London–Walbrook and the Fleet–were constantly the scene of dumping. The Walbrook was several times the object of clean-up campaigns and anti-dumping ordinances. In the early fourteenth century, it became a fairly common practice to construct individual latrines over the Walbrook. However, by 1345, those people caught with such facilities were forced to remove them. However, by 1374, attitudes had turned around and it became the accepted practice of householders along the Walbrook to build latrines over the stream, and pay for the right to do so. By 1388, latrines were permitted as long as no other refuse was discharged into the Walbrook. Eventually, however, all latrines over the stream were again abolished. By the seventeenth century, urbanization had caught up with Walbrook as it was hidden underground and scarcely needed.

An important aspect of any attempt to clean-up or manage residuals, be it modern or medieval, is legislation and enforcement. London's medieval laws were surprisingly advanced. Numerous laws were passed prohibiting various types of littering and pollution. Relatively stiff fines were supposed to be levied when they were violated. In 1280, an ordinance was passed making citizens who threw rubbish on the street liable to fine. While the fines were initially small, they were gradually increased. The law was also expanded to include watery wastes (kitchen and urinal) as well as solid. A system to reward informants was built into the law in 1414. However, despite rather extensive city efforts, ordinances were frequently disobeyed. The conclusion much be made that London occasionally fell into a rather filthy state.

Much of the filth which accumulated in the streets was a haven for rats. These rats carried the plague bacillus. In the mid-fourteenth century, the plague came into Europe from Asia. It broke out numerous times in London between 1349 and 1665. In 1349, one-third of the city's inhabitants died or left town. Once the plague struck, sanitation systems broke down. We are certain that the London of 1349 was filthy. In that year the King of England had written a letter to the Mayor of London protesting that filth was being thrown from houses by day and night and that city streets were foul with human feces.

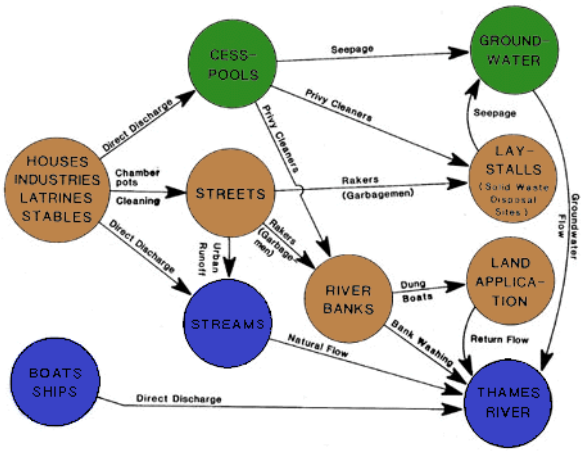

Figure 7. The flow of pollutants (left to right) in London. The ultimate destinations of the majority of residuals were the Thames River, groundwater, laystalls (solid waste disposal sites), and farm land. Particularly disconcerting is the fact that the Thames and groundwater were major sources of drinking water.

THE GREAT FIRE

Catastrophic events hit mid-seventeenth century London. The city was again ripe for an epidemic: poor sanitation was a problem; there were periodic food shortages; and a plague epidemic was moving across Europe. Pepys in an October, 1663, entry noted that the "plague is much in Amsterdam, and we in fears of it here." Ships from Holland to England were quarantined. In December, 1664, one person in London died of the plague; in April, 1665, two; and in May, 43 died. And so it grew until the hot summer, with little rain, and little runoff to cleanse the filth from the streets, furthered the spread of the dreaded disease. "This week," Pepys wrote in August, "died 7,496, and of them 6,102 of the plague." All totaled some 70,000 Londoners, a seventh of London's population, died of the plague in 1665. A great many fled the city. Describing the enervated status of London, Pepys notes that "two shops in three, if not more, generally shut down."

The plague had barely died out when, in September 1666, a second calamity hit the city: the Great Fire. It lasted 4 days and destroyed two-thirds of the central, older portions of the city. The commercial area was burned to the ground; but the political city–Westminster–was saved. Among the structures lost were St. Paul's Cathedral, 87 parish churches, the Guildhall, and 44 livery company halls. About 13,200 house were destroyed and 200,000 were left homeless (Besant, 1903, p. 252).

Circumstances conspired to make the fire a catastrophic event. London was in the throes of a long drought. The flow of springs, which fed the city's conduits, was greatly reduced. The wells, still numerous in city, were low. Additionally, the houses were nearly all made of wood and packed closely together; the stores and warehouses were full of oil, pitch, hemp, flax, and other combustible wares; a strong wind carried the fire from roof to roof and from street to street; and there was a lack of organization and equipment to deal with the fire.

London's water systems, as it turned out, were in no condition to assist in putting out or controlling a major fire. The flames as they started out from London Bridge put the wooden water system of Peter Morice out of commission. But, worst of all, there was a great deal of shortsighted carelessness. In the perplexity and confusion of the early hours of the fire, no authority was respected. Roads were torn up to get at the wooden water pipes. The pipes were cut so that fire buckets could be filled. Cutting the pipes for short-term gain turned out to greatly hamper longer-term firefighting efforts. Water soon ran to waste in some areas while pipes and cisterns were dry in areas where water was most needed.

After a preliminary inspection of the fire scene from the Tower of London and from a boat on the Thames River, Pepys made a report to the King. Pepys recommended that houses had to be pulled down to provide a fire break. The King ordered Pepys to go to the Mayor and command him to spare no house but to pull down whatever was required. Pepys (1978, p. 121) account of his meeting with the Mayor gives a feeling for the desperation at the scene:

> . . . At last met my Lord Mayor in Canning Streete . . . with a hankercher about his neck. To the King's message, he cried like a fainting woman, 'Lord, what can I do? I am spent! People will not obey me. I have ben pull(ing) down

houses. But fire overtakes us faster than we can do it.' That he neede no more soldiers; and that himself, he must go refresh himself, having been up all night. So he left me, and I him, and walked home–seeing people all almost distracted and no manner of means used to quench the fire. The houses too, so very thick thereabouts, and full of matter for burning, as pitch and tar, in Thames Street–and warehouses of oyle and wines and brandy and other things. . .

For 4 days, the Great Fire terrorized London.

Figure 8. The Great Fire, a "horrid malicious bloody flame," said Pepys, sent panic-stricken citizens scrambling into river boats (Bridgeman Art Library, NY).

After the Great Fire, the city was rebuilt, not more beautifully, but more substantially. By royal order, brick and stone replaced wood as the material of buildings; projecting upper stories disappeared; and streets were made wider and straighter. Obstructions like the Great Conduit, which had been destroyed by the fire, were removed to provide a freer flow of traffic.

After the fire, sanitation was improved and London had no further outbreaks of the plague. It seemed natural to assume that Londoners owed their deliverance to the inferno. They owed their resistance to the plague to the reconstruction that followed the fire; brick houses and wide, rubbish-free streets replaced wooden tenements and dark alleys. McEvedy (1988), however, does not accept these explanations. One reason: "other cities in Europe, such as Paris and Amsterdam, became plague-free during the same period–a phenomenon that could not be linked to the Great Fire of London." He theorizes that a new species of plague bacillus may have evolved which was less virulent, acting as a vaccine by conferring on infected humans an immunity to more virulent strains.

CONCLUSIONS

As London grew out of the Middle Ages, its population exploded requiring an evolution in the city's water-related infrastructure. The developing water systems were very much products of their times. Major accomplishments were made by private individuals who had a vision and were willing to risk capital.

When studying London's water systems, it is easy to get overly maudlin. One of London's biographers (Stevens, 1939, p. 179) asks the rhetorical question:

> Is it extravagant or sentimental to suggest that sometimes when turning on a tap, we should see in the mind's eye a picture of Myddleton on horseback surveying the great entrenchment from Amwell to Clerkenwell, the "cobs" fighting for a place in the conduits, or Morrys (Morice) persuading the City fathers to lease him an arch of London Bridge.

While the accomplishments of Myddleton and Morice were considerable and should not be downplayed, their basic motives and the scope of the projects were not significantly different from other entrepreneurs of the era. They were filling a void created by the inaction of city officials. The important innovations of the period relate to private development of the major projects and the use of water-wheels (already widely used in other applications) to drive pumps to lift water for municipal use.

When studying London's historic wastewater systems, it is too easy to be overly critical. It is too easy for historians to judge according to modern standards of cleanliness and sanitation. If these systems were judged according to their own aims and ideals of cleanliness, they were probably not so bad. It must be remembered that Londoners of the era had no knowledge of bacteria, viruses, and other microbes.

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