CHAPTER 2
OVERVIEW OF THE DEVELOPMENT OF DRAINAGE IN EUROPEAN AND AMERICAN CITIES THROUGH THE NINETEENTH CENTURY

Sewerage practice was only approaching rational, scientific principles in the second half of the nineteenth century, despite the ancient history of sewerage engineering. During the early modern period, drainage for the removal of rainwater and groundwater in urban settings was uniformly viewed as part of the more general issue of sewerage. Until the concept of separate systems of drainage and sewerage was developed by professionally trained engineers, from 1880 on, urban drainage and sewerage were synonymous. In fact, engineering terminology continued to refer to urban drainage and sewerage beneath the rubric of sewerage well into the twentieth century (cf. Marston 1912, Metcalf and Eddy 1914), and removal of rainwater and house sewerage were frequently expected to utilize the same infrastructure. In addition, it was only in the last third of the nineteenth century that the public was willing to countenance significant taxation to build expensive infrastructure systems to deal with municipal drainage and sewerage. Construction of municipal drainage and sewerage systems was part of a more general trend in American and European cities to take action in the interest of public health. These endeavors were undertaken with a view toward the economic development and growth of municipalities. In the formative period of American drainage and sewerage practice, American planners were heavily influenced by experience in Europe (Metcalf and Eddy 1914:1).

The earliest sewerage works in Europe, during the classical era, were principally concerned with surface drainage and the abatement of public nuisances. Ancient Rome was one of the earliest cities to develop an extensive sewer system. However, most residences were not connected to Rome's great underground drains. Public sanitation centered around private or public latrines and privies, and large amounts of ordure found its way into street gutters, where it was irregularly washed into the public sewers by the action of rain or irrigation. The circumstances were even worse in European cities of the medieval and early modern world, where civil engineering lagged behind that of the Romans. Urban environments were remarkably filthy and unhealthy. In general, underground sewers were designed to carry storm water rather than human and household wastes. Street gutters were characteristically choked with human and animal excrement, and cities in poorly-drained landscapes festered in foul mud. Without any available scientific knowledge of hydraulics or topographical science, efforts to improve drainage or sewerage systems were universally piecemeal and ineffective. In fact, no marked progress was made in drainage and sewerage systems in Europe from the classical era to the early 1830s (Metcalf and Eddy 1914:1-2, 10-14; Tchobanoglous 1981:2-3; Cohn 1966:44)

The beginning of the modern era of drainage and sewerage systems began in Paris. As early as 1808, a comprehensive study was undertaken to determine the sewerage needs of the city. There were 14½ miles of drains in Paris in 1808, but only about 10½ miles were added by 1832. In that year, an epidemic of cholera in Paris led authorities to make a topographical survey of the city in preparation for a planned system of drainage. The system was to be based on topographical features rather than administrative boundaries, which avoided many delays encountered in subsequent efforts to modernize drainage in London, and even some American cities. The system construction begun in Paris in 1833 concerned drainage, and not house sewerage, and therefore has received less attention than some later efforts elsewhere. Many of the low-lying streets along the Seine were raised above the level of any expected flood; old drainage sewers were reconstructed or abandoned; and the cross-section of streets changed from concave to convex. For the ease of cleaning by workmen, the new sewers built in Paris after 1833 were made 6' or more high, so the workmen could stand up in them. These large sewers were intended to remove street refuse as well as rainwater. The solid sewage was mostly removed from the flow in collectors, and the greater part of the sludge and water was discharged into the river. While much of the water from rainfall was diverted into large "house drains," human and household wastes were not discharged into the sewers but into cesspools. The cesspools were not a satisfactory long-term solution to the sewerage problem, and a debate ensued over whether "dry carriage" or "water carriage" of human and household wastes was preferable. In the "dry carriage system", wastes are collected in dry containers, which are removed and exchanged at regular intervals. In the "water carriage" system, wastes are flushed into the sewers, and this became standard practice in the United States. In 1880, the Paris sewers began to be connected with sewage drains from houses (Metcalf and Eddy 1914:10-14; Tchobanoglous 1981:2-3; Cohn 1966:44).

In 1842 a conflagration destroyed the older part of the city of Hamburg, and it was decided to rebuild it with, among other features, a new sewerage system. W. Lindley, a leading English engineer, designed the system, considered the first truly modern system for removal of rainwater and household wastes. The sewers of Hamburg remained among the most advanced in the world for a generation. However, the building of the sewers of Hamburg was an exceptional situation in which it was possible to plan streets and sewers together to best answer the needs of the community and local topographical conditions (Metcalf and Eddy 1914:2-3; Cohn 1966:44-45). More typical of the mid-nineteenth century experience in Europe was London, England, whose sewerage history was also studied closely by American engineers. Until 1815, human wastes could not be disposed of directly into London sewers. By the 1840s, London's population numbered over two million, living in several hundred thousand households. Awareness of the need for sewerage reform and development led to the first comprehensive study of the metropolis for the purpose of planning sewerage improvements. In 1847, the first official engineer's report on sewerage and drainage in London contained the following description, which could have been said about almost any large city in Europe or America:

> There are hundreds, I may say thousands, of houses in this metropolis which have no drainage whatever, and the greater part of them have stinking, overflowing cesspools, and there are also hundreds of streets, courts and alleys that have no sewers; and how the drainage and filth are cleaned away and how the miserable inhabitants live in such places it is hard to tell… I have visited very many places where filth was lying scattered about the rooms, vaults, cellars, areas, and yards, so thick and so deep that it was hardly possible to move for it. I have also seen in such places human beings living and sleeping in sunk rooms with filth from overflowing cesspools exuding through and running down the walls and over the floors… the effects of the effluvia, stench and poisonous gases constantly evolving from these foul accumulations were apparent in the haggard, wan and swarthy countenances and enfeebled limbs of the poor creatures whom I found residing over and amongst these dens of pollution and wretchedness… [quoted in Metcalf and Eddy 1914:4]

Also in 1847, a cholera epidemic raged in India and fear arose that a similar epidemic might break out in London. This stimulated the formation of a unified sewerage board to improve sanitation practices. In the same year, London issued an edict that required that all privies drain into the sewers which were already present. Cholera epidemics in 1849 and 1852-1854 further motivated sanitation improvement efforts (Metcalf and Eddy 1914:4-5; Tchobanoglous 1981:2-3; Cohn 1966:44).

The engineering of London's sewerage and drainage provided a laboratory of experience that influenced American practice later in the century. In particular, the engineers of the London system underestimated the requirements of the metropolis for sewerage and drainage capacity, and consequently constructed a system with features that were too small. In addition, Parliament began national regulation of sanitation in 1848 and regulation of nuisance pollution in 1855 (Metcalf and Eddy 1914:5-8).

The sewerage situation was similar in European and American cities in the early-nineteenth century. In the United States, drainage efforts were often constructed by individuals or inhabitants of small districts, at their own expense and with little or no public supervision. In the early part of the nineteenth century, water boards were not infrequently in charge of drainage works. The sewers which were constructed were usually for storm water and not for human wastes (Metcalf and Eddy 1914:14-15). Human wastes were, for example, excluded from Boston's sewers until 1833 and from Philadelphia's until 1850. Prior to 1850, sewerage facilities in most American cities were the same as those in rural areas. Privies or water closets were utilized, and these often emptied into vaults or cesspools. Waste material either soaked into the ground or was hauled away in wagons. Kitchen waste in many cities ran into ditches along the streets. Often, these ditches also carried urine and fecal matter because only inadequate numbers of privies were present in congested districts. For instance, in Cincinnati in 1865, there was only one privy associated with a two-story tenement house inhabited by 102 individuals (Glaab and Brown 1983:77). The irregular flow of badly-engineered street gutters found its way into drainage sewers, many of which were constructed along natural watercourses, such as small brooks. Frequently these sewers were large and of insufficient grade, with the result that the waste matter released in them accumulated and decomposed, producing a serious public nuisance (Metcalf and Eddy 1914:17).

American urbanites began to confront sanitation problems forcefully in the mid-nineteenth century. The quality of life and the health of most city dwellers was obviously threatened by a lack of sanitation. There was no garbage collection. Excrement and other filth lay in the streets and gutters. Many cities had no pure water supply, and smoke from factories polluted the air. Epidemics decimated urban populations. However, many Americans blamed the unhealthy conditions of city life on human infirmity. The native poor and new immigrants also became the scapegoats for these problems (Schultz and McShane 1978:397-398; Baudier 1955b:11).

In 1849, New York City created a municipal department of sewers. At that date, the city had only 70 miles of sewers. Eight years later, there were 158 miles, but these served only about one-quarter of the city. Brooklyn constructed sewers designed for the transport of sewage between 1857 and 1859 (Cohn 1966:47). This early Brooklyn system was designed by Julius W. Adams. In 1866, a cholera epidemic stimulated New York to organize a Metropolitan Board of Health. One aspect of its sanitation program was to require the disinfection of privies, indicating that the sewerage system was far from complete by that date (Glaab and Brown 1983:77-78). In 1857, a report was issued concerning poor sanitation conditions in Philadelphia. The report urged that "There should be a culvert on every street, and every house should be obligated to deliver into it by underground channels all ordure or refuse that is susceptible to being diluted." Construction of Philadelphia's sewer system began shortly thereafter (Cohn 1966:47). In 1858, Chicago began rudimentary sewer construction from designs by E.S. Chesbrough (Metcalf and Eddy 1930:10).

Not all sewerage improvements in the 1850s and 1860s were undertaken by northern cities. Charleston, South Carolina constructed a unique sewerage system, without any slope to the sewers; tidal action flushed the sewers of solid matter. In the Mid-West, St. Louis began construction of a large sewer, draining storm flows from 6400 acres of the city, in 1864 (Metcalf and Eddy 1914:18, 22).

Through the 1870s, private vaults and cesspools were still in use to deal with house wastes in most American cities. In 1877, there were approximately 82,000 such facilities in use in Philadelphia, 56,000 in Washington, and 30,000 in Chicago (Glaab and Brown 1983:172). Although privies were still in use in Chicago in 1877, that city had begun to construct a sewerage system in 1871. As part of the effort, the direction of flow of the Chicago River was changed so that it ran to the Illinois River rather than into Lake Michigan. Despite Chicago's efforts, conditions in 1880 were apparently similar to those in New Orleans in the same year (see Chapter 3). The *Chicago Times* reported in that year that:

> The [Chicago] river stinks. The air stinks. People's clothing, permeated by the foul atmosphere stinks... No other word expresses it so well as stink.

> A stench means something finite. Stink reaches the infinite and becomes sublime in the magnitude of odiousness [quoted in Glaab and Brown 1983:172].

Other northern cities that began sewerage efforts in the post-Civil War period were Providence, Rhode Island, which began a system designed by J. Herbert Shedd in 1874, and Boston, which began a system designed by E.S. Chesbrough, Moses Lane, and Dr. C.F. Folsom in 1876 (Metcalf and Eddy 1930:10).

Despite the example of Charleston, many Southern cities instituted comprehensive efforts to solve the problems of sewage disposal only after 1878. A yellow fever epidemic in the Mississippi Valley in that year stimulated an intense concern among business leaders about public health in a number of urban centers. The epidemic resulted in 20,000 deaths and the loss of hundreds of millions of dollars in business revenues. Earlier in the nineteenth century, outbreaks of yellow fever, as well as cholera and smallpox, were recognized as having an adverse economic effect in addition to representing major causes of mortality. However, the diseases were often viewed simply as part of doing business in cities which were located in inherently unhealthy areas (Ellis 1969a:197-198, 203-207).

The 1878 outbreak of yellow fever, which stimulated much concern with public sanitation in the American South, began in New Orleans. By August 1878, approximately one-fifth of New Orleans' population had fled, and in doing so they spread the disease to other Southern cities. Many cities invoked a quarantine, but New Orleanians still managed to find refuge there. When the first case was reported in Memphis, a "human stampede" resulted. Less than half of Memphis' population of 48,000 remained in that city three days later (Ellis 1969b:346-347). Despite a growing awareness of the importance of public health and the development of infrastructure, systematic improvements in New Orleans' drainage and sewerage would not occur in the 1870s, or even the 1880s, but in the second half of the 1890s (see Chapters 3 and 4).

Of great importance to the history of drainage in New Orleans is the development of concepts of separate systems of sewerage and drainage, in which house sewage and rain water are kept nearly or completely distinct. The designer of the first separate system is not definitely known, but the principle was strongly advocated as early as 1842 by Edwin Chadwick, who has been called "the father of sanitation in England." Chadwick did much to encourage sanitary efforts in British cities and countryside, but his own designs were severely flawed. Chadwick was:

> …a man of convincing address, great self-reliance and enthusiasm, and strong imagination which was unfortunately not restrained by technical knowledge. As a result he advocated, even in meetings of engineers, so-called hydraulic principles and some features of design that were wholly incorrect and at last resulted in his being publicly branded as a charlatan at a meeting of the Institution of Civil Engineers at which he was in attendance [quoted in Metcalf and Eddy 1914:23].

Chadwick was similar in some respects to a prominent proponent of separate systems in the United States, Colonel George E. Waring, Jr., who is discussed in greater detail below. Despite Chadwick's shortcomings, the principle of separation of house sewage from rain water was recognized as advantageous in certain settings, and was developed along rational lines by a number of leading English engineers, notably Sir Robert Rawlinson. American engineers devoted much study to separate systems, and early on recognized the less frequent but more intense character of American rainfalls, relative to those of Great Britain. The heavier rains in North America allowed sewer systems to be designed without the elaborate flushing provisions utilized in many European cities. Separate systems were manifestly advantageous wherever the surface drainage could be cared for satisfactorily at a low cost, without the use of large combined sewers receiving both house-sewage and rain water. Separate systems were designed almost simultaneously by Benezette Williams for Pullman, Illinois, and George Waring for Memphis (Metcalf and Eddy 1914:24).

Memphis, like New Orleans, had serious public health problems resulting from inadequate drainage and sewerage. Yellow fever claimed more than 2,000 lives in Memphis in 1873, and another 5,635 in 1878-1879. In 1878, an Auxiliary Sanitary Association was formed in Memphis, which undertook public works that included employing laborers to clean streets and alleys and to empty privies. A public latrine project was also begun. The Legislature authorized unusual taxation and administrative methods in the stricken city, whose affliction aroused the sympathy of the whole nation and was largely responsible for the formation of the National Board of Health. A committee of the Board sent Col. George Waring to Memphis, which was inspected and surveyed under his supervision. The maximum sum that could be raised by taxation for sewers was $368,702; so critical was the need for sewerage that it was necessary to make this money go as far as possible. Waring designed a separate system in which rainwater was to be excluded from the sewers, the mains of which were to be of pipe 10" to 20" in diameter. Waring received patents on his separate sewerage system in 1881 and 1883. A similar sewerage system in Croydon, England, had proved a failure almost thirty years before, and problems with Waring's designs became apparent well before the system proposed in 1880 was completed. By 1882, some of the main lines were already taxed to their full capacity, and hundreds of obstructions had been cleared at great effort and expense. By 1885, a relief sewer had to be constructed, and the Memphis system was conclusively a comparative failure. Municipal authorities prevented this fact from being widely publicized for some time, but sanitary engineers were aware of the Memphis failure. The separate system designed by Sir Robert Rawlinson, with larger pipes laid without vertical or horizontal bends between successive manholes, was shown to be a superior model for separate systems (Metcalf and Eddy 1914:24-25).

Beside its design shortcomings, the Waring system in Memphis did little to improve conditions in areas inhabited by those of lower socioeconomic status. However, the Memphis effort was an important beginning for publicly funded sanitation efforts in the urban South. In fact, the building of the Memphis sewerage system appears to have stimulated a national boom in sewer construction (Ellis 1969b:352-353; Glaab and Brown 1983:172-173; Larsen 1985:124).

George Waring was a man of great charisma, and the prestige of the Memphis project was such that he impressed his views on small-pipe sewers on a number of other cities, contracting with them for the use of his patent system. However, not only was the Memphis system severely flawed, but the use of his patents by Waring was regarded by many engineers as unprofessional. The National Board of Health had doubts about the Waring system from the earliest date, and in 1880 sent Rudolph Hering to Europe on a tour of investigation of sewerage and drainage systems (see Chapter 5). Based upon the findings of his tour, Hering issued an elaborate report on sewerage and drainage practice in 1881. Hering's monograph retained its value for over 25 years, an unusual longevity for an engineering work, and did much to set American sanitary engineering on a sound and scientific basis. Hering's consideration of separate systems specifically emphasized local requirements for removal of rainwater and house sewage (Metcalf and Eddy 1914:25-26), which was of great importance to the eventual design of the New Orleans drainage system.

Atlanta's efforts to deal with the problems of drainage and sewage had actually begun slightly earlier than those of Memphis. The main trunks of Atlanta's system were constructed by the postwar Reconstruction government. However, by 1880, there were only seven miles of sewers, which followed no systemic plan. They were intended primarily as conduits for storm water. When yellow fever broke out in Jacksonville in 1888, Atlanta was stimulated to expand the system. By 1894, there were 54 miles of trunk, branch, and lateral mains, and many public buildings and residences were connected to the system (Ellis 1969a:210, 1969b:358-359). Other southern cities lagged behind Atlanta and Memphis. By 1880, Lexington, Kentucky, had only a few stone sewers that emptied into a creek. Augusta, Georgia, had drainage sewers that also were used for sewage disposal. Macon, Georgia, had only a few sewers, and these discharged into a swamp just outside the city limits. Montgomery, Alabama, had only inefficient brick and wooden mains. In 1880, Baltimore, Maryland, had only 12 miles of storm sewers to serve the entire city and lacked any plan for sewage disposal (Larsen 1985:122). In that year, Baltimore's mayor stated that:

> The city of Baltimore requires a system of sewerage. The continuance of the plan of digging the cesspools now honeycombing the surface of the ground upon which the city is built - these being on an average about one to each of its eighty thousand houses - must be discontinued if the health of the community is to be considered… [Mayor F.C. Latrobe, quoted in Larsen 1985:122].

Baltimore, like New Orleans (as detailed in Chapter 4), adopted a separate plan of drainage and sewerage, and both cities represented rare opportunities for engineers to design a complete sewerage system for a large city without any necessity for utilizing existing sewerage structures. Drainage arrangements at Baltimore involved discharge of storm water into the nearest watercourses adapted to receiving it, which was considered at the time of design to be an unobjectionable practice (Metcalf and Eddy 1930:17).

In the 1880s, the ultimate disposal of sewage received less attention in the United States than it did in Europe. The disposal of sewage in most cities prior to about 1910 was carried out in the easiest way practicable, "without much regard to unpleasant conditions produced at the place of disposal" (Metcalf and Eddy 1914:27). The major methods of disposal of sewage in Europe included discharge into rivers, irrigation or sewage farming, filtration, septic tanks, and contact beds. Because of the small size of British rivers, discharge of sewage directly into them had been regulated by Parliament after 1855, although industrial sewage treatment was not made compulsory until after 1876. In the United States, disposal of sewage was not at this time considered a pressing problem, unlike the situation in more densely populated Europe. Water discharge and disposal by dilution were not viewed as acute nuisances in the United States. Also, a greater area of land was available in America for other disposal practices. These methods included broad irrigation or intermittent filtration on beds graded *in situ*, and relatively cheap materials suitable for the construction of artificial disposal beds were available. The first extensive sewage treatment plant utilizing chemical precipitation was built at Worcester, Massachusetts, in 1889-1890, and it furnished a large amount of data for experimental work (Metcalf and Eddy 1914:29).

Disposal of sewage by dilution in bodies of water remained in favor in the United States longer than in Britain because of the larger bodies of water available for receiving the sewage. The first comprehensive American study of the subject was begun in 1887 by Rudolph Hering for the City of Chicago and resulted in his recommendation of a drainage canal to dilute the sewage with water from Lake Michigan and deliver it to the Desplaines River, flowing into the Illinois River, a tributary of the Mississippi. Many subsequent studies demonstrated satisfactorily to the engineers of the 1890s and 1900s that disposal by dilution was the most economical option for disposing of sewage. However, by World War I, dilution came under greater criticism, largely on the basis of the potential contamination of rivers or lakes furnishing water for potable purposes. Legal factors influenced the course of regulation on this issue (Metcalf and Eddy 1914:30). In the early years of the twentieth century, concern over the polluting potential of drainage flow largely resulted from the presence of organic wastes, such as animal excrement, washed from streets by rain. Of course, the potential for pollution complications caused by petroleum wastes, detergents, and other chemicals became much more acute in the twentieth century. In the case of New Orleans, the decision was made to construct separate systems of drainage and sewerage, and to discharge daily drainage flow into Lake Borgne. Only stormwater flow was to be discharged into Lake Pontchartrain. This decision was based on concern about pollution of Lake Pontchartrain and the volume of precipitation and high level of ground water with which the drainage system was required to handle. The history of how these issues affected the eventual drainage system design in New Orleans is discussed in greater detail in Chapter 4.