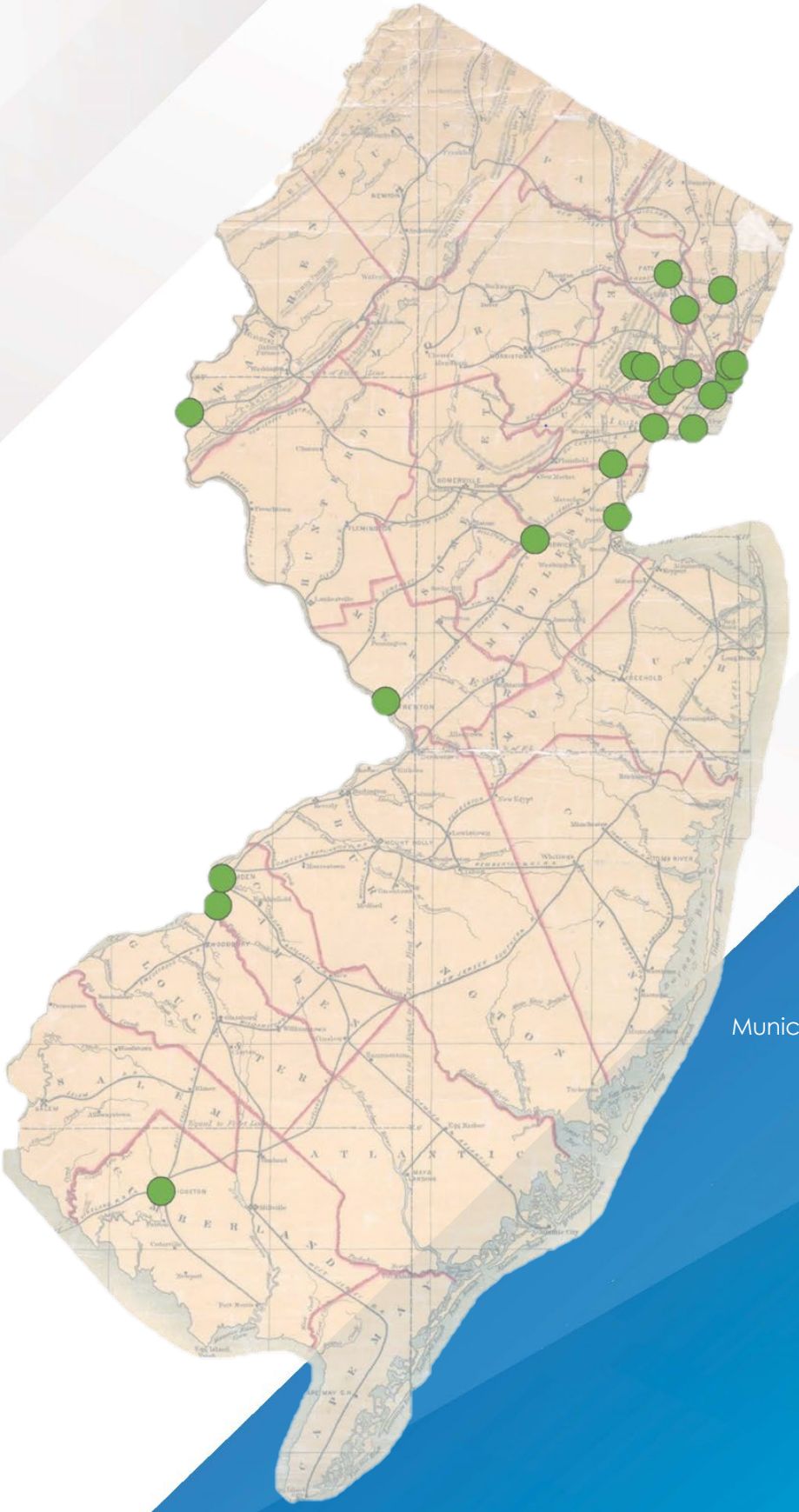
Brick Sewer Cities: A Public Health History of New Jersey's Sewer Infrastructure



Anu Khandal
Christina Servetnick
T. Cregg Madrigal
Elizabeth Davis

Municipal Finance and Construction Element
Division of Water Quality
2023

Brick Sewer Cities

A Public Health History of New Jersey's Sewer Infrastructure

Anu Khandal

Christina Servetnick

T. Cregg Madrigal

Elizabeth Davis

Municipal Finance and Construction Element

Division of Water Quality

New Jersey Department of Environmental Protection

2023

Front cover image: Map of the twenty-two brick sewer cities. Source: Map created by Christina Servetnick using Ellis A. Apgar's *Outline Map of New Jersey for Schools* (1872). http://mapmaker.rutgers.edu/NJ_1872.jpg

Copies of this report are available at the New Jersey State Library; Municipal Finance and Construction Element, Division of Water Quality, New Jersey Department of Environmental Protection; and the Historic Preservation Office, New Jersey Department of Environmental Protection.

Acknowledgements

Since the 1970s, the Cultural Resource Unit in the Municipal Finance and Construction Element (MF&CE) of the New Jersey Department of Environmental Protection (DEP) has reviewed water infrastructure projects funded under the federal State Revolving Fund program for their potential to affect historic properties. At first, projects mainly involved construction of new facilities but, as the program matured, more projects for the rehabilitation of older facilities were submitted. A historic context was needed to better inform our management recommendations for New Jersey's oldest sanitation utilities. Two years ago, the MF&CE released the first volume of research on the historic brick sewers of Camden, New Jersey. The research concluded by identifying future areas of study; in particular, it recommended investigating the list of brick sewer cities that was generated from the *Report of the State Sewerage Commission to the Legislature, Session of 1900*, and the *Twenty-Sixth Annual Report of the Board of Health of the State of New Jersey* (1902). The present volume is the result of that investigation.

The Cultural Resources Unit has managers who understand the importance of context in evaluating the effect of projects on historic properties. Assistant Director Charles Jenkins and Section Chief Karen Cole continue to support this research and recognize the added value it brings to our project reviews. Alexandra Tarantino generously provided thorough and inspired editing suggestions and advice, which have greatly improved this context. Linda DiCicco and Tonia Wu at the DEP Environmental Research Library have been generous with their time and helped facilitate our research. Bonny Beth Elwell, librarian at the Camden County Historical Society, helped us access historical images, including photographs of Aaron Ward on site at the Line Ditch Sewer. Berry N. Bennett, Preservation Program Manager, at the Iowa State Historic Preservation Office kindly shared many historic context reports of sewers that had been submitted to the Iowa State Historic Preservation Office. These context reports were invaluable to our discussion of eligible and listed sanitary infrastructure. We are also indebted to Matt Tomaso for his work on Newark's sewers, and many other cultural resources consultants who have done their own research in the course of compliance work for this and other programs. It has developed into quite a body of work that is, in large part, the basis for this research.

Abstract

In the seventeenth and eighteenth centuries in the United States, public sanitation was limited to the proper disposal of food waste and other garbage. Private citizens constructed open drains, or sewers, to carry off stagnant water from populous areas often without much, if any, municipal oversight or planning. Unplanned, piecemeal sewer construction continued into the nineteenth century with municipal sewer construction.

New Jersey cities began to construct sewers as early as 1838, usually piecemeal and without a larger plan. Wood and brick were the earliest materials used, though the durability of brick meant it quickly became the preferred material. Today, across New Jersey, many original sewers are still in service, most of which are in need of repairs or replacement. Because of its association with improving public health and fostering the growth of cities, sewer infrastructure in Newark, Trenton, and around the world has been recognized as historically significant. The Municipal Finance & Construction Element is required to consider impacts to cultural and historical resources during construction and is therefore addressing questions about the history and status of New Jersey's historic sewer infrastructure while also developing a framework to streamline the review of sewer repair projects in these cities.

This context includes a history of sanitation in the United States, as well as sewage conveyance technologies, materials and construction methods, a history of the brick sewer cities, and their sewerage infrastructure, and recent archaeological research on these early sewer systems. A summary of other sewers and sanitary infrastructure listed on or eligible for the National and/or New Jersey Registers of Historic Places and

the specific criteria for significance and eligibility are used to develop questions for further research when evaluating the sewers' historical significance.

Brick Sewer Cities builds upon previous reports, which have considered the eligibility of specific segments of sewers in individual municipalities, to provide a synthesis of brick sewer systems throughout the State of New Jersey. This context report will provide guidance on evaluating the eligibility of historic sewer infrastructure and streamline the review of sewer-related projects.

Contents

Illustrations

List of Figures

List of Tables

List of Acronyms

ASTM	American Society for Testing and Materials
CIPP	Cured in Place Pipe
CSO	Combined Sewer Outfall
CWA	Clean Water Act
DEP	[New Jersey] Department of Environmental Protection
EPA	[United States] Environmental Protection Agency
HLIC	Hoboken Land and Improvement Company
MF&CE	Municipal Finance & Construction Element
NJBOH	New Jersey Board of Health
NRHP	National Register of Historic Places
PVSC	Passaic Valley Sewerage Commission
SHPO	[New Jersey] State Historic Preservation Office
SRF	State Revolving Fund
SUM	Society for Establishing Useful Manufactures
USSC	United States Sanitary Commission
VCP	Vitrified Clay Pipe

1. Introduction

The sewer is the conscience of the city – Victor Hugo, Les Misérables

Wastewater infrastructure was vital to the development of cities and public health in the United States. Early cities had no systematic plans for dealing with sewage and stormwater. Human waste was deposited in privies or cesspits while rudimentary, uncoordinated, and often ineffectual drainage systems were built by property owners to reduce flooding from rainstorms. By the mid-nineteenth century, American cities were overcrowded and polluted, largely without clean water or adequate waste removal, and subject to repeated epidemics of deadly diseases like cholera.

The Sanitation Movement arose in response to the devastating epidemics and the growing awareness that disease and filth were linked. Water works projects, such as the Croton Aqueduct system for New York City and the Fairmount Water Works in Philadelphia, provided clean drinking water. By increasing the amount of water being brought into homes and businesses, the amount of wastewater that had to be discarded also increased. The reform movement gradually resulted in local and state governments taking responsibility for sanitary infrastructure by regulating and financing comprehensive city-wide sanitary sewer systems, which permitted cities to capitalize on economies of scale, reducing per linear foot cost for sewer construction. Some of the earliest municipal sewer systems in the United States were built in the 1850s in Brooklyn, Chicago, Jersey City, and Newark resulting in marked improvements in health and mortality rates. The mortality rate dropped from 20.03 per 1,000 people in 1879 to

12.16 per 1,000 people by 1929; deaths from typhoid fever dropped from 3.17% to 0.14% during this fifty-year period.[1]

During the latter half of the nineteenth century, shifts in perspective transitioned health to a public responsibility. Court cases determined that public health was "supreme law," and the duty of the state. Other cases determined that drainage for public health trumped private ownership of land. This is not a uniquely New Jersey sentiment. Frederick Law Olmsted, a landscape architect, was hired by the City of Boston to make sanitary improvements to the Back Bay Fens. As sewers and sanitary improvements became the accepted response to public health epidemics and miasma theory gave way to germ theory, public health expanded to encompass public waterways. These conditions better contextualize the emergence of brick sewers.

Statement of Purpose

We recently completed a context report on the sewer system of the City of Camden, in Camden County, New Jersey, titled *Sewers Invincible: A Historic Context for Camden's Sewer Infrastructure*. Construction on this municipal sewer system began in the 1860s as a combined system, which carried both sanitary waste and stormwater. The early components were primarily constructed of brick. We had data that there are at least another twenty-one cities in New Jersey which, like Camden, have brick sewer systems that are also in need of repair or replacement. We foresaw a need for future research to enrich our understanding "of bricks as a material, ad hoc and planned sewer

[1] David L. Cowen, *Medicine and Health in New Jersey: A History* vol. 16 (Princeton: D. Van Norstrand Company, 1964), 82; Richardson Dilworth, *The Urban Origins of Suburban Autonomy* (Cambridge: Harvard University Press, 2005), 17; New Jersey, Department of Health, *Fifty-Third Annual Report of the Department of Health of the State of New Jersey, 1930* (Trenton, New Jersey: MacCrellish & Quigley Co Printers, 1931), 155.

construction, and the many motivations that pushed New Jersey residents, lawmakers, and politicians to ensure more and more New Jersey residents had access to sanitary infrastructure."[2]

To address the problems of an aging sewer system, cities and municipal utilities authorities have applied to the New Jersey State Revolving Fund (SRF) program for loans to repair and replace existing pipes. Federal and state regulations require consideration of potential impacts on cultural and historical resources. The Municipal Finance & Construction Element (MF&CE) of the New Jersey Department of Environmental Protection (DEP), through a delegation agreement with Region II of the United States Environmental Protection Agency (EPA), is responsible for the administration of the SRF program, including implementation of aspects of Section 106 of the National Historic Preservation Act of 1966.

Due to the importance of early sewer systems in improving public health and fostering the growth of cities, sewer-related infrastructure in several states has been listed on the National Register of Historic Places (NRHP). In New Jersey, the City of Newark sewers, the Jersey City brick sewer system, the Passaic Valley Sewerage Commission (PVSC) Newark Bay Outfall Sewerage Works Historic District, the Trumbull Street Sewer in Elizabeth, and the Lamberton Street Interceptor in Trenton have all been determined eligible for the NRHP. This historic context report provides guidance to the MF&CE for evaluating the potential historical significance of New Jersey's sewer infrastructure and streamlining the review of projects. It provides a

[2] Anu Khandal et al., *Sewers Invincible: A historic context for Camden's sewer infrastructure* (Trenton, N.J.: New Jersey Department of Environmental Protection. Division of Water Quality. Municipal Finance and Construction Element, 2021), 125.

history of sewer infrastructure, describes types of sewers that may be present, begins to evaluate the potential eligibility of sewer infrastructure for the National and New Jersey Registers of Historic Places (NJRHP), and identifies areas where additional research is necessary.

Parameters

This context discusses brick sewer systems built to convey sewage and stormwater away from buildings and ground surfaces within the State of New Jersey between approximately 1838 and 1898. This timeframe begins with the first known construction of a sewer in 1838, in Jersey City, and includes the period when brick was the preferred material for large sewers. With the close of the nineteenth century, approximately 70% of New Jersey's population lived in municipalities with sewers. Though brick was used into the twentieth century, other materials, including cast iron, concrete, and vitrified clay began to eclipse brick sewers after the turn of the twentieth century. By the time the country entered World War II at the end of 1941, municipal sewer systems were a common and well-established fixture of most American cities.

Methods

A major source of information was the New Jersey Board of Health (NJBOH) reports, which were issued every year starting with its founding in 1877 until 1938, and the State Sewerage Commission reports, issued yearly from 1899 until 1908. The *Report of the State Sewerage Commission to the Legislature, Session of 1900* and the *Twenty-Sixth Annual Report of the Board of Health Report to the State of New Jersey* were most helpful in determining which cities had brick sewers. This information was used to create a database of sewers in New Jersey municipalities, including their material type,

system type, date of construction, and other information. Rutgers University's New Jersey Session Laws Online provided access to the language of sanitary acts passed by the State Legislature. Historic and contemporary maps, as well as early city, county, and state histories from the late nineteenth and early twentieth centuries provided contemporary perspectives.

We conducted further research into cultural resource management reports, government documents, contemporary and historical engineering articles and texts, historical and social overviews of sanitation history, and National Register documents. The Iowa Department of Cultural Affairs maintains a Historic Architectural Database, which contains a list of context reports conducted in the state, including those covering sewers. This was a resource for comparison with other determinations of eligibility carried out across New Jersey. Online resources, including archive.org, sewerhistory.online (previously sewerhistory.org), and waterhistoryphl.org (previously phillyH2o.org), were useful for finding additional sources and historic images.

Building on this body of primary and secondary resources, this context report will delve into historic sanitary solutions, sewers, construction materials, sanitary commissions and legislation, followed by a brief history of New Jersey. This background will better contextualize the twenty-two cities with brick sewers and a discussion of their significance.

2. Sewerage Systems

Early sanitation was intended to ensure that people had access to clean air and water and that natural habitats were not polluted in order to promote health.[3] As cities increased access to water, sanitary solutions evolved to address the outflow of water. Despite these efforts, by the close of the nineteenth century, eminent sanitary engineers wrote "[t]he earth upon which many of our cities stand is literally saturated with sewage."[4]

Sewage Conveyance Technologies

One of the earliest methods to manage household waste was the dry carriage system, which retained solid waste in a centralized location and released liquid waste into the soil, as seen in privies and cesspits (or cesspools).[5]

Privies, Cesspits, and Septic Systems

A privy or outhouse is a small structure, usually constructed in the backyard of a property, with a vault or a pail underneath for collecting human waste. A privy vault could be an unlined hole dug into the earth, a buried wooden barrel, or a pit lined with brick, concrete, stone, or wood (Figure 1).[6]

---

[3] Commerce was a noticeably absent reason for sanitary solutions in many New Jersey towns. In contrast, coastal towns in the Netherlands were concerned that releasing waste into the waterways would cause eventual blockages. Waterways were the main transportation routes, and blockages directly hampered the local economy. In New Jersey, similar concerns were not raised for commerce or waterways. For more information on the role of commerce as it pertains to sanitation, see Roos van Oosten's "The Dutch Great Stink: The End of the Cesspit Era in the Pre-Industrial Towns of Leiden and Haarlem."

[4] Cady Staley and George S. Pierson, *The Separate System of Sewerage: Its Theory and Construction* (New York: D. Van Nostrand, 1886), 17, 26.

[5] A. Prescott Folwell, *Sewerage, The Designing, Construction, and Maintenance of Sewerage Systems,* 6th ed. (New York: John Wiley & Sons, 1910), 2.

[6] Jean Howson and Leonard G. Bianchi, *Covert Larch: Archaeology of a Jersey City Neighborhood. Data Recovery for the Route 1 & 9T (25) St. Paul's Viaduct Replacement Project Jersey City, Hudson County, NJ* (Parsippany, NJ: The RBA Group, 2014), i-iv.

Figure 1. Excavated privies with a variety of linings.
Source: Jean Howson and Leonard G. Bianchi, *Covert Larch: Archaeology of a Jersey City Neighborhood. Data Recovery for the Route 1 & 9T (25) St. Paul's Viaduct Replacement Project Jersey City, Hudson County, New Jersey* (Parsippany, NJ: The RBA Group, 2014), 352.

A cesspit differs from a privy vault in that pipes transport waste from the house into the cesspit. This may include both kitchen waste as well as human waste from water closets. Some cesspits were unlined and allowed waste to percolate into the surrounding soils, but others were water-tight, sometimes only at the bottom, and sometimes entirely. Privy vaults could be converted into cesspits by connecting a pipe to the vault. A single large cesspit could be linked to two or more buildings.[7]

These early privies were unregulated, but as populations increased in urban areas, sanitation problems, including the contamination of drinking water sources, led to government regulation (Figure 2). As early as 1863, some cities required that privy vaults be at least 8 feet deep, lined with brick or stone, and at least 10 feet from any public street. However, cities often had a limited ability to ensure residents followed the law.[8]

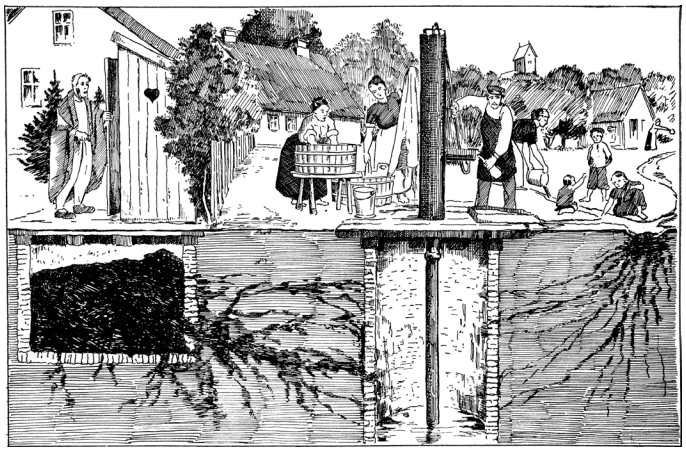


Figure 2. Infiltration of a water well with typhoid.
Source: Anonymous, Forskelige Veje ad hvilken Brønd kan inficeres med Tyfusbaciller*, 1939.*
https://upload.wikimedia.org/wikipedia/commons/6/63/ForskeligeVeje_ad_hvilkenBroen_kan_inficeres_medTyfusbaciller.png

[7] Folwell, *Sewerage,* 3; Anson Marston, *Sewers and Drains* (Chicago: American School of Correspondence, 1908); Giusy Lofrano and Jeanette Brown, "Wastewater management through the ages: A history of mankind," *Science of the Total Environment* 408, no. 22 (2010): 5256.
[8] Stephen W. Yost and Glenn R. Modica, *Stage IA Cultural Resources Survey, Remsen Avenue Storm Sewer Improvements, City of New Brunswick, Middlesex County, New Jersey* (Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2003), 4-5.

Privies and cesspits had to be emptied regularly. This might be done nightly for privies with pails or smaller vaults, or as infrequently as a few times each year for larger ones. Dry loam was used as a deodorizer and absorbent in the pails, and any liquid wastewater was scattered on the ground. Cities regulated this process, including times worked and tools used, and contracted the job to people called scavengers. They used a long handle dipper and shovel to manually remove the waste, euphemistically called night soil, however, by the late nineteenth century, as technologies evolved, wagon-mounted pumps were sometimes used to suction the waste out. Irrespective of how the privy was emptied, the night soil was then put in airtight containers and either dumped elsewhere or sold as fertilizer (Figure 3). In some cities, the waste could not be carried through any public markets or other public spaces, and the scavenger's horse was not allowed to travel faster than a walk.[9]

Figure 3. Men carrying a night soil barrel.
Source: Charles V. Chapin, Municipal Sanitation in the United States *(Providence, R.I.: The Providence Press: Snow & Farnham, 1901), 745.*

[9] Stuart Galishoff, *Newark: The Nation's Unhealthiest City, 1832-1895* (New Brunswick: Rutgers University Press, 1988), 109; Marston, *Sewers and Drains*; Glenn R. Modica and Jesse O. Walker, *Stage IA Cultural Resources Survey, North Hudson Sewerage Authority, System-Wide Combined Sewer Overflow Improvements Program, Cities of Hoboken and Union City and Township of Weehawken, Hudson County, New Jersey* (Richard Grubb & Associates, Inc., 2004), 4-12; George W. Rafter and Moses Nelson Baker, *Sewage Disposal in the United States* (New York: D. Van Nostrand Company, 1894), 352-353; Charles V. Chapin, *Municipal Sanitation in the United States* (Providence: The Providence Press: Snow & Farnham, 1900), 746; Howson and Bianchi, *Covert Larch*, 351.

Circumventing the issue of frequent emptying done for privies and cesspits, septic systems also separated out and treated the more harmful components of wastewater. Though septic systems were first patented in France in 1881 and introduced to the United States in 1883, they were not widely used until after World War II. Septic systems did not gain much traction in New Jersey's municipalities, though there are a scant number of municipalities that use septic systems today. Generally, privies and cesspits suited New Jersey's urban areas; however, eventually privies and cesspits would not suffice.[10]

In response, the centralized water carriage sewer system would be developed to use a combination of gravity and water to move waste through a conduit system. Though privies often remained in use at this time, in some cases, pipes were added to cesspits and privies to drain them into the sewerage system.[11]

Pneumatic and Water-Carriage Systems

Many factors influenced the transition away from the dry carriage system. When water was available in limited quantities, usually from a hand pump, the ground was able to absorb excess water, but as the water supply increased and more of the streetscape was paved, ground absorption decreased, necessitating sewers. Technological developments in sewage removal methods in the nineteenth century effectuated pneumatic and water-carriage systems.[12]

---

[10] Martin V. Melosi, *The Sanitary City: Urban Infrastructure in America from Colonial Times to the Present* (Baltimore: Johns Hopkins University Press, 2001), 170-171, 193.
[11] Folwell, *Sewerage,* 8; Galishoff, *Newark*, 109; Marston, *Sewers and Drains*; Modica and Walker, *Stage IA Cultural Resources Survey, North Hudson Sewerage Authority*, 4-12; Rafter and Baker, *Sewage Disposal in the United States*, 352-353; Chapin, *Municipal Sanitation in the United States*, 746; Howson and Bianchi, *Covert Larch*, 351.
[12] Rudolph Hering, *Report on a Sewerage System for the City of Trenton, N.J.* (Trenton, N.J.: Naar, Day & Naar, Printers, 1885), 7.

The pneumatic system is a catch-all term for systems that use a vacuum to move sewage through pipes. Sanitary waste is removed separately from the rest of the house drainage, surface, and subsurface water.[13] Engineering innovations during the latter half of the nineteenth century led to uniquely named systems that built upon the same concept, including the Berlier, Liernur, and Shone systems. Following studies of these pneumatic systems, American engineers Colonel George E. Waring, Jr., and Rudolph Hering wrote that the pneumatic system was not viable for American cities. They determined that the pneumatic system had high installation and operational expenses and required specific conditions to work well.[14] It is unclear if any New Jersey cities adopted, or experimented with, the pneumatic system.[15]

The water-carriage system, in contrast, relied on water to flush the pipes and convey waste to an outfall point or a treatment plant, and became the most common system by the end of the nineteenth century. Early land drainage systems were a type of water-carriage system.[16]

Combined and Separate Systems

Both combined and separate sewers use the water-carriage system. Oftentimes, combined sewer systems were built in industrial cities. They could receive domestic sewage, industrial wastewater, and stormwater into one set of pipes. When the system is at maximum capacity, untreated sewage and stormwater is discharged into bodies of

[13] A modern equivalent to the pneumatic system would separate grey water for reuse.
[14] For example, pressure reduced as the system scaled up. Liernur circumvented this issue at larger scales by dividing municipalities into districts, each having its own centralized treatment plant, which most likely contributed to the increased installation expense.
[15] Folwell, *Sewerage*, 7; Rudolph Hering, "Sewerage Systems," *Transactions of the American Society of Civil Engineers* 230, no. 10 (November 1881): 367; George E. Waring, Jr., *The Sanitary Drainage of Houses and Towns,* 11th ed. (Boston and New York: Houghton, Mifflin and Company, 1876), 298.
[16] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900* (Trenton, N.J.: MacCrellish & Quigley, State Printers, Opposite the Post Office, 1900), 7.

water from outfall points known as combined sewer outfalls (CSO) (Figure 4).[17] This system, particularly during wet weather conditions, results in the pollution of water bodies and is detrimental to health. Many texts on sewerage systems construction during the late nineteenth and early twentieth centuries believed draining untreated sewage into waterways was safe and called it "disposal by dilution." This approach moved the waste management responsibility to waterways, which were tasked with carrying waste out of populous areas. Following testing of water bodies, early twentieth century sanitary engineers determined that disposal by dilution does technically work at a specific threshold; however, this threshold is often easily surpassed and does not account for all living conditions. And because these water bodies also supplied drinking water, it created a public health nuisance. Even today, CSO overflows are a major problem in many communities.[18]

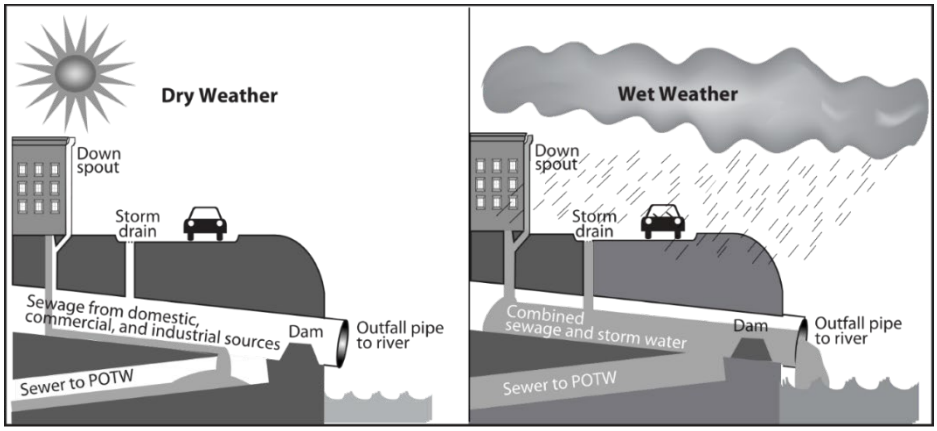


Figure 4. Comparison of dry and wet weather conditions in cities with a CSO.
Source: U.S. Department of the Interior, Environmental Protection Agency, Report to Congress: Impacts and Control of CSOs and SSOs *(Washington, D.C., 2004), 2-2.*
https://www.epa.gov/sites/production/files/2015-10/documents/csossortc2004_full.pdf

[17] NJDEP has a record of extant CSOs across the state at: https://www.nj.gov/dep/dwq/cso-sewer-maps.htm
[18] Leonard Metcalf and Harrison P. Eddy, *Sewerage and Sewage Disposal, a Textbook* (New York: McGraw-Hill Book Company, Inc., 1922), 18; Ellen H. Richards, *Conservation by Sanitation, Air and Water Supple, Disposal of Waste [Including a Laboratory Guide for Sanitary Engineers]* (New York: John Wiley & Sons, 1911), 174.

In a separate system, the sanitary and stormwater pipes are separate. Sewage is conveyed to a treatment plant, and stormwater is released into nearby bodies of water. Separate systems cause less pollution, especially when stormwater outfalls are fitted with nets to catch trash and separators to remove road oil and grease.

By the close of the nineteenth century, some separate systems attempted to treat their sanitary waste through intermittent filtration.[19] Sanitary sewer pipes transported the waste to a plot of land that was prepared to filter the waste using either a biological, chemical, or mechanical filter (Figure 5). Waste would be added to the filtration bed intermittently, thus the term intermittent filtration. Pipes that were located below the filtering beds received the now-filtered liquid waste, which was then transported to a water body. In some historical texts, intermittent filtration has also been referred to intermittent downward filtration.[20]

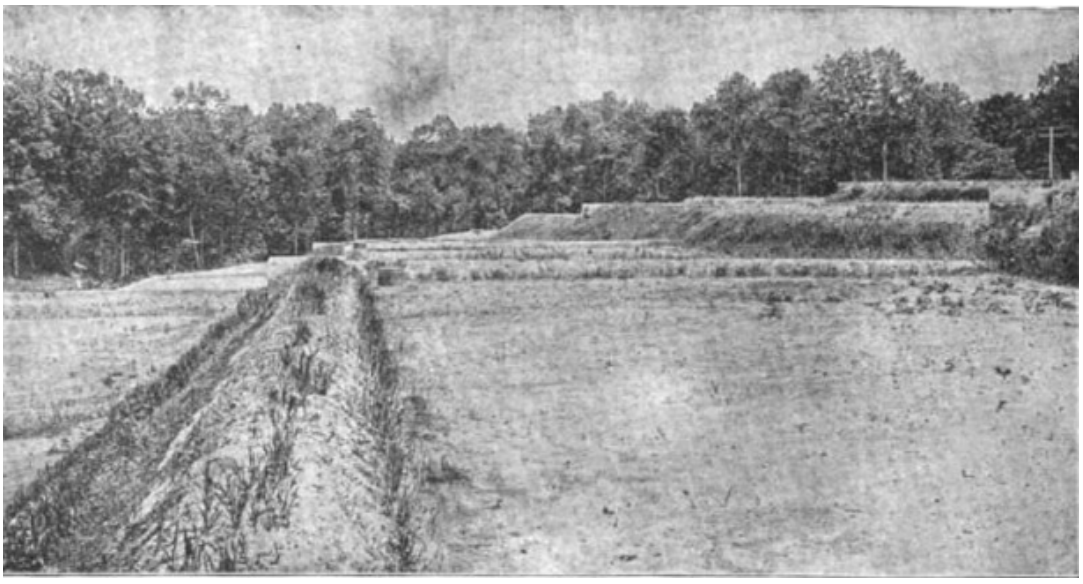


Figure 5. Filtration bed, in Summit, New Jersey, designed Carroll Phillips Bassett and constructed in 1892. Source: George W. Rafter and W.N. Baker, Sewage Disposal in the United States, *2nd ed. (New York: D. Van Nostrand Company, 1894), 524.*

[19] Early intermittent filtration systems can be found in other New Jersey cities during the nineteenth century, including Burlington, Freehold, Orange, and Summit.
[20] Rafter and Baker, *Sewage Disposal in the United States*, 262.

Both systems were multi-leveled. Lateral sewers connected home sewer lines to a branch or main sewer. The branch sewers collected waste from the lateral sewers and conveyed it to a main or trunk sewer, which then conveyed sewage to an outfall point, typically a river or ocean. Interceptor sewers were later installed in combined systems to transport sewage to a wastewater treatment plant before eventual release into waterways (Figure 6). Weirs, or dams, installed within the trunk sewer directed flow to the interceptor pipe most of the time but permitted overflow directly to an outfall during wet weather conditions (Figure 4). Weirs prevented the treatment plant from becoming overwhelmed, which could lead to sewage backups and flooding.

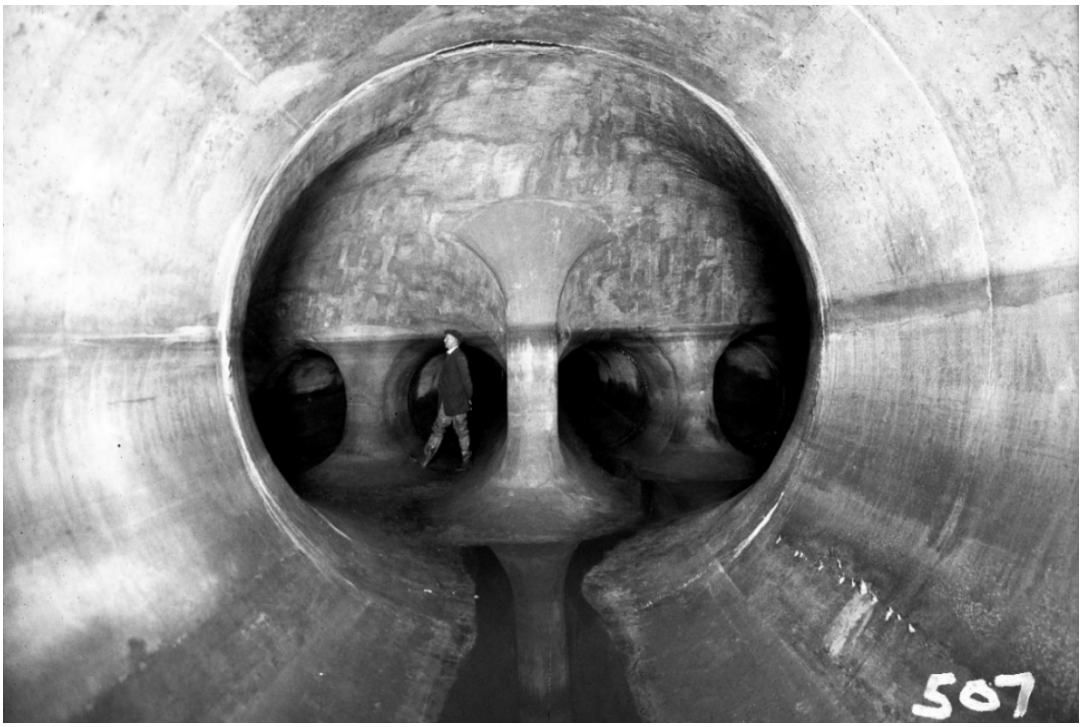


Figure 6. Passaic Valley Sewerage Commission interceptor.
Source: Passaic Valley Sewerage Commission, Construction of Interceptors, for PVSC, 1920s.
https://www.nj.gov/pvsc/who/history/photos/images/plant/img023.jpg

American systems were influenced by and paralleled European sewer systems, and engineers on both continents debated the best way to design sewers. Some cities, like Paris, which improved and enlarged its sewers in 1857, constructed separate

systems. London, in contrast, following the "Great Stink" of 1858, undertook the construction of a combined sewer system between 1859 and 1865. While Hamburg built a sewer system in 1842 as part of the reconstruction of the city after a major fire, it was not until after another deadly outbreak of cholera in the 1860s that many other European cities constructed sewer systems: Frankfurt in 1867, Berlin in 1873, and Munich in 1881.[21]

Waring and Hering: Opposing Sewer Ideologies

In the United States, Waring and Hering promulgated opposing ideologies on the type of system cities should use. In 1880, Hering, a Philadelphia-born engineer educated in Germany who had begun working on sewer systems in 1875, was sent by the National Board of Health to Europe to study their sanitation systems, which resulted in an influential monograph on sewerage and drainage practice. Hering's monograph opened with, and emphasized, the significance professional bias had on the debate: "[e]ach person judges matters from his own sphere of working, and it seems that, by considering this unconscious bias and its tendency to exaggerate insignificant facts, both *pro* and *con*, and, on the other hand, by fully realizing the most essential feature, we may advance a step towards truer conclusions."[22]

Hering advocated decision-making based on "sanitary value" and cost, noting that solutions that could work in European villages and towns would be impossible to

[21] Ellis S. Chesbrough, *Chicago Sewerage: Report of the Results of Examinations Made in Relation to Sewerage in Several European Cities, in the Winter of 1856-7* (Chicago, Ill.: Printed by the Board, 1858); Rudolph Hering, *Report on a System of Sewerage for the City of Binghamton, N.Y.* (Binghamton: Daily Leader, 1882); Javier Abellán, "Water supply and sanitation services in modern Europe: developments in 19th-20th centuries," *XII International Congress of the Spanish Association of Economic History – University of Salamanca* (Salamanca: Universidad de Salamanca, 2017), 1-17.
[22] Hering, "Sewerage Systems," 362.

carry out in the United States.[23] For large cities in the eastern United States, he generally recommended a combined sewer system. This part of the country had enough stormwater to flush sewers, as well as numerous streams and rivers in which to dilute wastewater, which made sewage treatment a distant concern. Smaller cities and cities with less rainfall could build systems meant solely for waste disposal and rely on surface-level drainage of stormwater. Hering also wrote that the generally unsatisfactory conditions of sewers across the United States, when compared to European sewers, could be attributed to the lack of maintenance.[24]

Comparatively, Waring wrote about the ill effects of sewer gas and the function of the separate system in transporting the sewer gas out of both the house and the city. It is likely that Waring's separate system proposals were built because they were less expensive than a combined system. The separate system tended to use smaller pipes, usually vitrified clay pipe (VCP), which required less labor to construct than a combined system that required larger pipes and on-site construction.[25]

In 1876, Waring constructed his first separate system with a disposal plant in Lenox, Massachusetts. However, Waring's most renowned separate system was constructed in 1880 in Memphis, Tennessee, and contributed to the end of repeated epidemics of cholera and yellow fever, though funding limitations in Memphis meant

[23] Hering went on to design or consult on water and sewer systems in many cities throughout the United States, including Montgomery, Alabama; Los Angeles, California; San Francisco, California; Atlanta, Georgia; Chicago, Illinois; Indianapolis, Indiana; New Orleans, Louisiana; Baltimore, Maryland; Trenton, New Jersey; Binghamton, New York; Cleveland, Ohio; Columbus, Ohio; and Washington, D.C.
[24] Hering, "Sewerage Systems," 363, 380; Hering, *Report on a System of Sewerage for the City of Binghamton, N.Y.*; Leonard Metcalf and Harrison P. Eddy, *American Sewerage Practice* (New York: McGraw-Hill, 1914), 1:28; Joel A. Tarr, *The Search for the Urban Sink, Urban Pollution in Historical Perspective* (Akron: The University of Akron Press, 1996).
[25] Tarr, *The Search for the Urban Sink,* 137-138.

that poorer communities did not immediately get access to sewers (Figure 7).[26] Public health was further improved when an aquifer of clean water was discovered, which meant that the city could turn to a non-contaminated source of drinking water.[27]

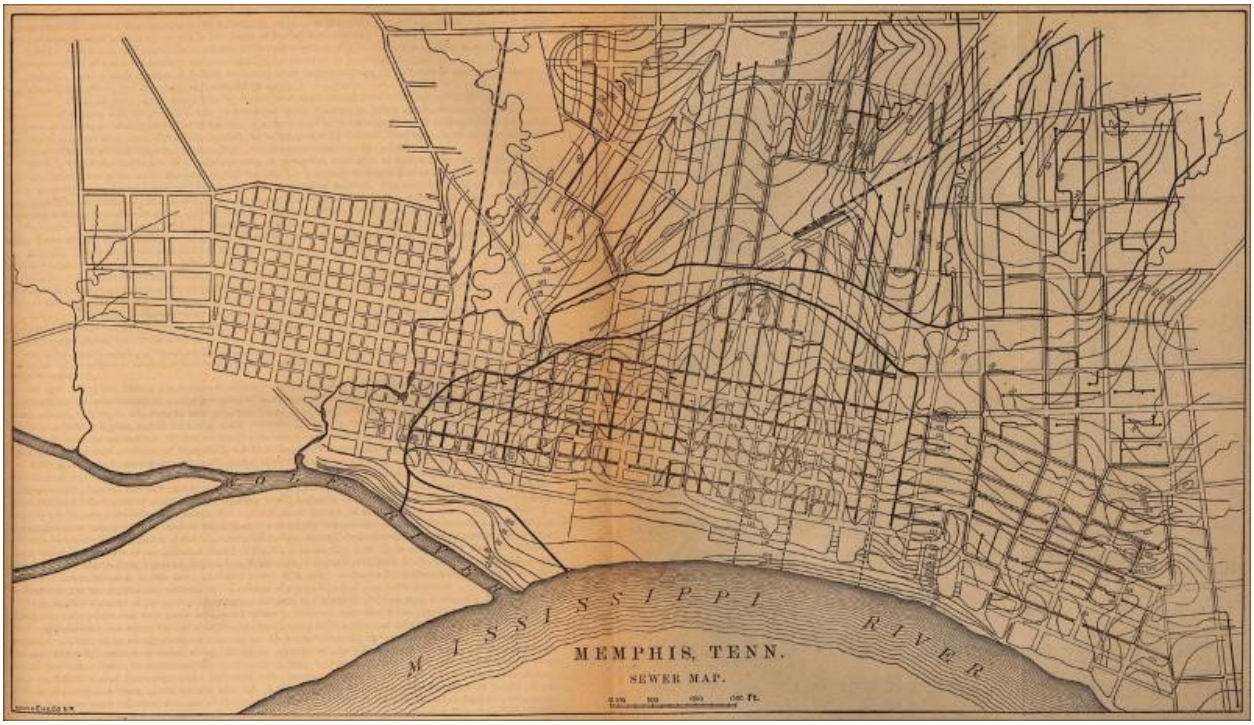


Figure 7. Waring's sewerage system map for Memphis, Tennessee.
Source: George E. Waring, Jr., Report on the Social Statistics of Cities, Part II, The Southern and the Western States *(Washington: Government Printing Office, 1887).*

In 1881, Waring patented his design of the separate system, likely to endorse the system's legitimacy.[28] He further endeared himself to municipal governments who

[26] Memphis was frequently discussed during the 1880s. Often, pro-Waring engineers presented papers, which were followed by discussions, or wrote articles. An early discussion of Memphis can be seen in Frederick S. Odell's *The Sewerage of Memphis* presented in 1880 at the Annual Meeting of the American Society of Civil Engineers. Waring was present at this meeting and refuted the criticisms launched at him. Waring's comments on the system's design are available at: https://memphislibrary.contentdm.oclc.org/digital/collection/p13039coll5/id/2080/rec/69
[27] Tarr, *The Search for the Urban Sink*, 118-119, 138; Molly Caldwell Crosby, *The American Plague, The Untold Story of Yellow Fever, The Epidemic That Shaped Our History* (New York: Berkley Books, 2006), 88-89; George E. Waring, Jr., *Concerning Mr. Rudolph Hering's Project for the Sewerage of Binghamton, N.Y.* (Newport, R.I.: Marshall & Flynn, Printers, 1883), 4; Center for Applied Earth Science and Engineering Research, *How Memphis Found its Water* (Memphis: University of Memphis, 2021).
[28] Waring's patented separate system was also constructed in Birmingham, Alabama; Little Rock, Arkansas; Pittsfield, Massachusetts; Kalamazoo, Michigan; Omaha, Nebraska; Keene, New Hampshire; Wilkes-Barre, Pennsylvania; and Norfolk, Virginia. The patent can be accessed at: https://patentimages.storage.googleapis.com/dd/04/fd/b5f9f6542375d9/US236740.pdf

wanted sewer systems by keeping construction costs low. It was not just the pipe and labor costs that were economical; Waring's design excluded manholes. If Waring's patented design was selected, he would financially benefit. Thus, it is not surprising that Waring heavily advocated for the separate system, which prompted his contemporaries' skepticism of him.[29]

Their first concern was Waring's lack of discernment for a city's unique needs, including topography. While reviewing the Memphis system after it had been in use for six years, Hering criticized Waring's impractical use of flush tanks in areas with sloping topography, which describes most of the city. Hering wrote that sewers aligning with the sloping topography would have been at a sufficient angle to move waste through the system. City engineers eventually stopped constructing flush tanks in sloped areas. Hering theorized that if Waring had not excluded all storm water from the system at the outset, the flush tanks would not have been a requirement.[30]

Waring also excluded manholes in their entirety, citing inspection and maintenance as a non-essential component of sewer design.[31] Some of Waring's contemporaries supported this method, praising his ability to push the limits of sanitary engineering. Manholes were ultimately proven essential. By 1887, Memphis' city engineers had constructed at least seventy manholes with more planned to correspond

[29] Dilworth, *The Urban Origins of Suburban Autonomy*, 17.
[30] Rudolph Hering, "Results of Six Years' Experience with the Memphis Sewers," *The Engineering & Building Record and the Sanitary Engineer* 16, no. 26 (1887): 739.
[31] Maintenance considerations included the grease that collected in pipes. In Frederick S. Odell's *The Sewerage of Memphis*, the discussion following Odell's presentation considered the build-up of grease from soaps as contributing to blockages that could only be resolved through maintenance.

to the system's expansion. Prior to constructing the manholes, segments of the sewer system were torn up to conduct maintenance and repair blockages.[32]

Waring's and Hering's approaches to sanitation demonstrate that the engineers influenced the sewerage system installed in a municipality. The topography and financial considerations, which encompassed material choices and the requisite construction techniques, were equally significant.

[32] "Six Years' Experience with the Memphis Sewers," *The Engineering & Building Record and the Sanitary Engineer* 16, no. 26 (1887): 737; Hering, "Results of Six Years' Experience with the Memphis Sewers," 739.

3. Sewer Pipe Materials and Construction

Material knowledge, influenced by financial limitations, growing populations, and technological developments, determined the materials used in sewer construction. Prior to the development of brick sewers, box sewers made of wood planks notched together were sometimes used in wet conditions, such as with submerged outfalls. These wooden stormwater outfalls were often used in conjunction with sewer systems made of brick or other materials, as seen in New York City. Selection of the type of wood used directly corresponded to its functionality in wet conditions; a yellow pine board storm sewer from 1830 was reported in the Camden & Amboy Railroad yard in South Amboy, New Jersey. Wooden pipes were also used for laterals until around the middle of the nineteenth century, when iron or vitrified clay laterals became more common. Wood, however, continued to be used in brick and concrete sewer construction for foundations, piling, and shoring. Sometimes, if the sewer needed extra protection, the timber shoring and piling may have been left in place after construction was completed.[33]

[33] Charles R. Pennington and Paul S. Schopp, *Stage IA Cultural Resources Survey, Combined Sewer Overflow Planning Study, City of Camden and Gloucester City, Camden County, New Jersey* (Cranbury, New Jersey: Richard Grubb & Associates, Inc., 1998); Martin Reinbold et al., *Phase IB Archaeological Investigation of the Combined Sewer Overflow (CSO) Site C10 for the Camden County Municipal Utilities Authority's Combined Sewer Overflow Replacement Project, Kaighns Avenue and Front Street, City of Camden, Camden County, New Jersey* (Metuchen, New Jersey: ARCH^2, Inc., 2009); Martin Reinbold et al., *Phase IB Archaeological Investigation Addendum, Combined Sewer Overflow (CSO) Site C05/10 for the Camden County Municipal Utilities Authority's Combined Sewer Overflow Replacement Project, Kaighns Avenue and Front Street, City of Camden, Camden County, New Jersey* (Metuchen, New Jersey: ARCH^2, Inc., 2010), 11; Nancy Zerbe, "Monitoring report for the Combined Sewer Overflow Project, CSO Site C05/10. ARCH2, Letter submitted to Elizabeth Davis, NJDEP," August 24, 2009; Nancy Zerbe, "Monitoring report for the Combined Sewer Overflow Project, CSO Site C10/15. ARCH2. Letter submitted to Elizabeth Davis, NJDEP," January 29, 2010; Folwell, *Sewerage*, 142; Joanne Abel Goldman, *Building New York's Sewers: Developing Mechanisms of Urban Management* (West Lafayette, Indiana: Purdue University Press, 1997), 86; Baldwin Latham, *Sanitary Engineering, A Guide to the Construction of Works of Sewerage and House Drainage* (London: E. & F.N. Spon, 48, Charing Cross, 1873), 142-143.

Brick Sewers

Brick sewers were widely used in the United States by the 1850s. The earliest brick sewers had flat bottoms, or bottoms that curved with the natural base of the trench. Engineers experimented with multiple sewer cross sections, including horseshoe, basket-handle, catenary, semi-elliptical, gothic, parabolic (delta), U-shape, semi-circular, and rectangular shapes (Figure 8). English engineer John Phillips designed the oval or egg-shaped brick sewer in 1846 (although a slightly different egg-shaped design had been constructed by John Roe by 1842), and they were built in the United States soon after. Phillips' design, slightly modified in 1847 and 1874 to make it stronger and better at self-cleaning in low-flow situations, was soon recognized as the best design for sewers with an intermittent flow, such as in a combined system. The egg-shaped pipes allowed for higher flow velocities in dry conditions than circular pipes, while maintaining a large capacity for wet-weather events (Figure 9). Egg-shaped sewers were not without weaknesses; they required more labor, were liable to crack, and if constructed poorly, were often less stable. A circular section permitted the highest velocity of flow and was the most efficient option for pipes that would remain at least half full. They were also stronger and less expensive to construct than egg-shaped sewers. In situations where a uniform flow was expected, such as in separate systems, circular brick sewers were more likely to be built (Figure 10).[34]

[34] Jon A. Peterson, "The Impact of Sanitary Reform upon American Urban Planning, 1840 – 1890," in *Introduction to Planning History in the United States*, ed. Donald A. Krueckeberg (New Brunswick: Center for Urban Policy Research, Rutgers University, 1983); Metcalf and Eddy, *Sewerage and Sewage Disposal*, 258; Latham, *Sanitary Engineering*; Marston, *Sewers and Drains*, 39; John Phillips, *On the Drainage and Sewerage of Towns* (London: E & F.N. Spon, 48 Charing Cross, 1872); Christopher Hamlin, "Edwin Chadwick and the Engineers, 1842-1854: Systems and Antisystems in the Pipe-and-Brick Sewers War," *Society for the History of Technology* (1992): 680-709; Glenn R. Modica, *The History of the Newark Sewer System* (Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2001), 6.

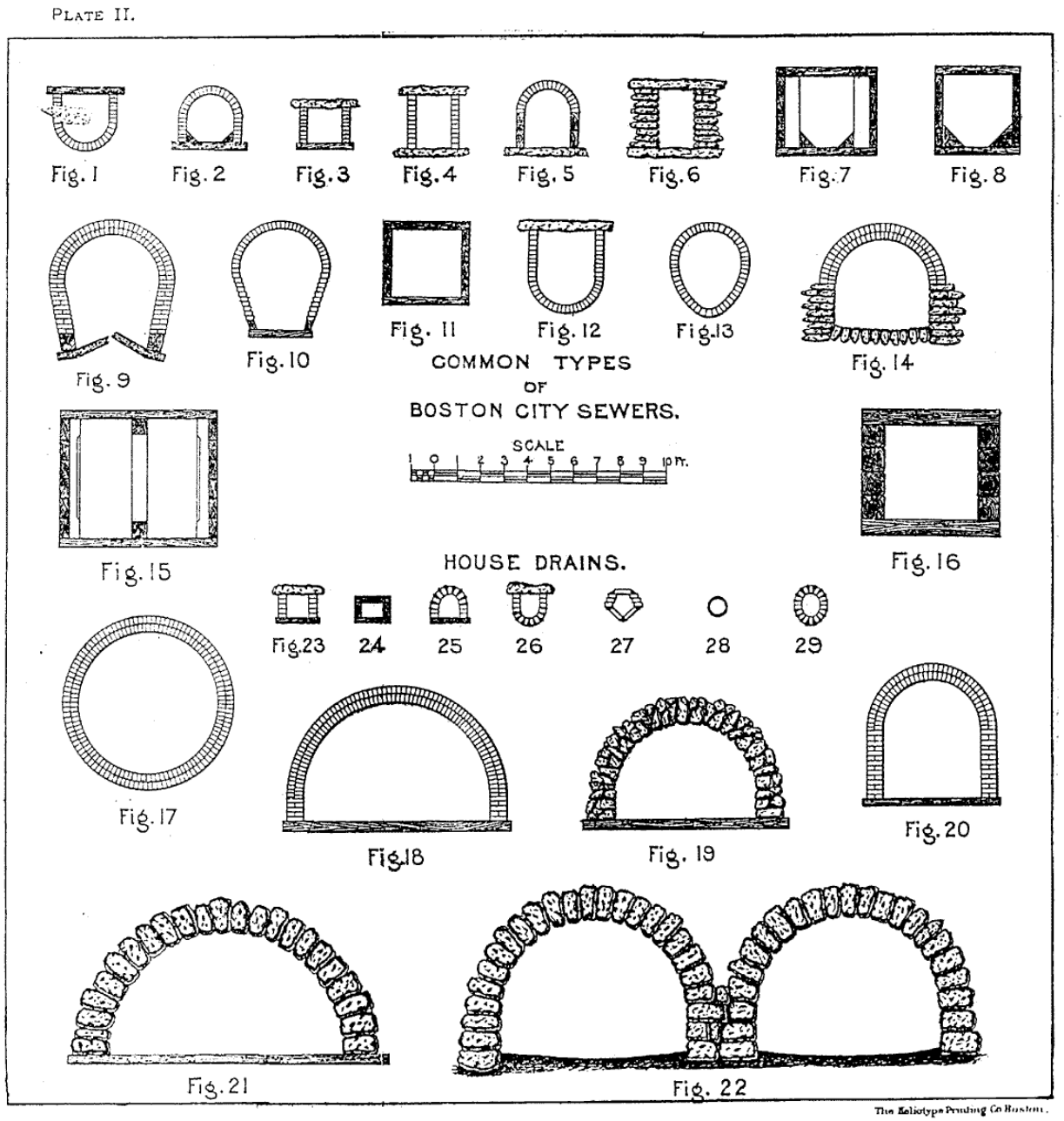


Figure 8. Cross-sections of sewers of varying shapes.
Source: Eliot C. Clarke, Main Drainage Works of the City of Boston, *2nd ed. (Boston: Rockwell and Churchill, City Printers, 1885), Plate II.*

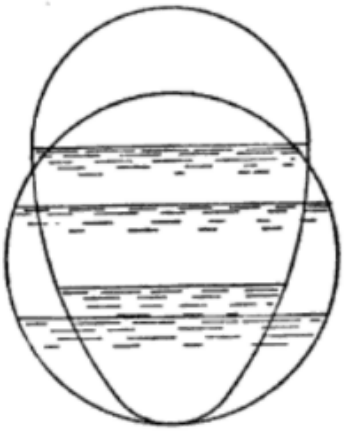


Figure 9. Differing flows in a circular sewer versus an egg-shaped sewer.
Source: Hugh S. Watson, Sewerage Systems, Their Design and Construction *(New York: McGraw-Hill Book Company, 1911), 35.*

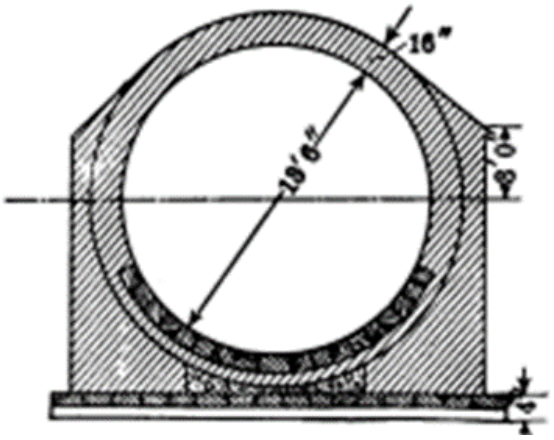


Figure 10. Cross section of circular sewer.
Source: Henry N. Ogden, Sewer Construction *(New York: John Wiley & Sons, 1908), 30.*

Brick was generally favored for larger conduits, while vitrified clay or cast iron was preferred for smaller pipes. Initially, brick was reserved for larger dimension pipes, approximately at least 24 inches, and unique shapes, whereas clay pipes were recommended for sewers with an interior diameter less than 18 inches. However, by the early twentieth century, responding to evolving technologies in clay and concrete pipe production, brick pipes were recommended for sewers with diameters greater than 36 inches. Though oval or egg-shaped brick sewers had advantages of flow and strength, the same could not be said for earthenware pipes, which were prone to distortion and had a greater margin of error when assembling the ends.[35]

Several types of brick were used for sewer construction; generally, the bricks needed to be able to withstand temperature changes and resist chemical and physical degradation from liquid and solid wastes.[36] Paving bricks, which were smooth and

[35] Latham, *Sanitary Engineering*, 102-103; Henry N. Ogden, *Sewer Construction* (New York: John Wiley & Sons, 1911), 29.
[36] In the early nineteenth century, bricks were produced on an as-needed basis, but by the mid-nineteenth century, brickyards had popped up across the New Jersey to meet the rising demand for brick. There was a huge brickyard in Sayreville, amongst others.

impervious, were used for the bottoms of sewers, while regular building bricks, which were cheaper, were sufficient for the rest of the structure. Vitrified brick, which had a hard, glassy consistency, was preferred over common brick because of its hardness, high strength, and low porosity. Since the waste passing through the sewers could be corrosive, vitrified brick was thought to have greater longevity. The importance of the invert material is evidenced by the 1909 excavation of an egg-shaped sewer in Newark, which was 46 inches by 69 inches with a slope of 1.6% and built in 1886. The excavation turned up severely deteriorated brick samples from the invert, which demonstrated that significant deterioration occurred at steep grades in pipes that carried large amounts of street wash, which was offensive and could include hooves and horns (Figure 11).[37]

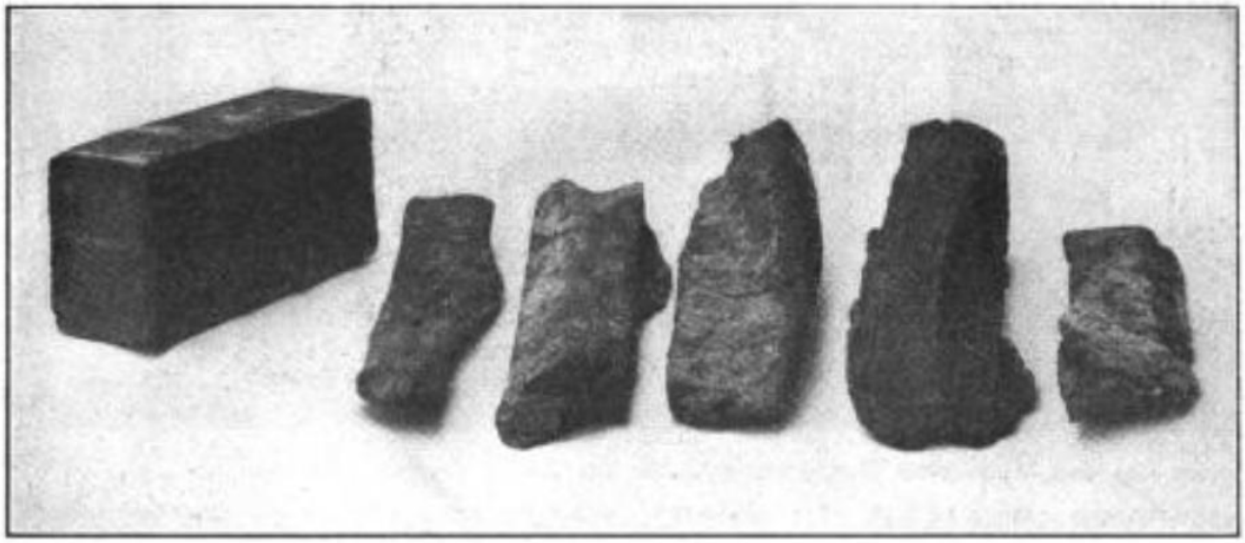


Figure 11. Samples of bricks from sewer inverts.
Source: Edward Rankin, "Materials for Sewer Inverts," The Engineering Record, Building Record and Sanitary Engineer *60 (1909): 629.*

[37] Latham, *Sanitary Engineering*, 120; Edward McM. Larrabee, "New Jersey's Cultural Resources: A.D. 1800-1865," in *New Jersey's Archeological Resources, A Review of Research Problems and Survey Priorities: The Paleo-Indian Period to Present*, ed. Olga Chesler (Trenton: New Jersey Historic Preservation Office, 1982), 231; H. A Wheeler, *Vitrified Paving Brick, A Review of Present Practice in the Manufacture, Testing and Uses of Vitrified Paving Brick* (Indianapolis, Ind.: T. A. Randall & Co., Publishers, 1910), 63; Edward Rankin, "Materials for Sewer Inverts," *The Engineering Record, Building Record and Sanitary Engineer* 60 (1909): 629; Richards, *Conservation by Sanitation,* 170.

The quality of the clay and the equipment used to produce the bricks played a significant role in the kind of brick produced. The temperature of the kiln in which the brick was produced affected the porosity of the brick. Higher kiln temperatures, around 1,500◦F to 1,800◦F, resulted in vitrification and low porosity. Latham proposed methods of testing a brick's durability for sewers, including soaking the brick in water and then exposing it to frost or weighing the brick, soaking it in a strong solution of sulfuric acid for a week, then weighing it after it was dry to measure damage. He determined that a good brick was one that did not lose weight from being soaked in sulfuric acid and its general appearance did not demonstrate any major damage. Latham also suggested a crushing test for bricks that passed the durability test, to test the bricks against external pressures. It was recommended that bricks used in the invert have a smooth surface since they were acted upon by waste that often included gravel and other sediments.[38]

Bricks suited to sewer construction were usually soaked in water for twenty-four hours to decrease sewage absorption. The soaked bricks improved adhesion to and curing of the mortar. The bottom half of the sewer was constructed first and allowed to settle before construction began on the top half. In some cases, the invert of the sewer was made with solid or hollow shaped blocks made of terra cotta or vitrified clay instead of regular bricks. The hollow blocks also reduced the structural weakness caused by the excessive thickness of the invert joints (Figure 12). The hollow blocks purportedly drained groundwater, though the effectiveness was questioned. Some late nineteenth century engineers also recommended filling in the blocks with concrete, which some builders did before installation. Other engineers, like Ogden and Latham, advised

[38] Wheeler, *Vitrified Paving Brick,* 9; Latham, *Sanitary Engineering*, 121.

against the use of hollow blocks, which in Latham's experience could drain wastewater into the subsoil. Instead, they recommended grooved blocks, which created a better seal. In some situations, a separate, smaller pipe was installed under the brick sewer to drain ground water. When the ground underneath the sewer was soft, a concrete or timber base or cradle could be placed to prevent shifting or settling of the sewer. When sewer trenches were excavated into bedrock, concrete was used to fill the area in between the sewer and the bedrock, and cement was used as mortar (Figure 13). It is unclear if grooved or hollow blocks were used in nineteenth century brick sewer construction in New Jersey and further research is needed.[39]

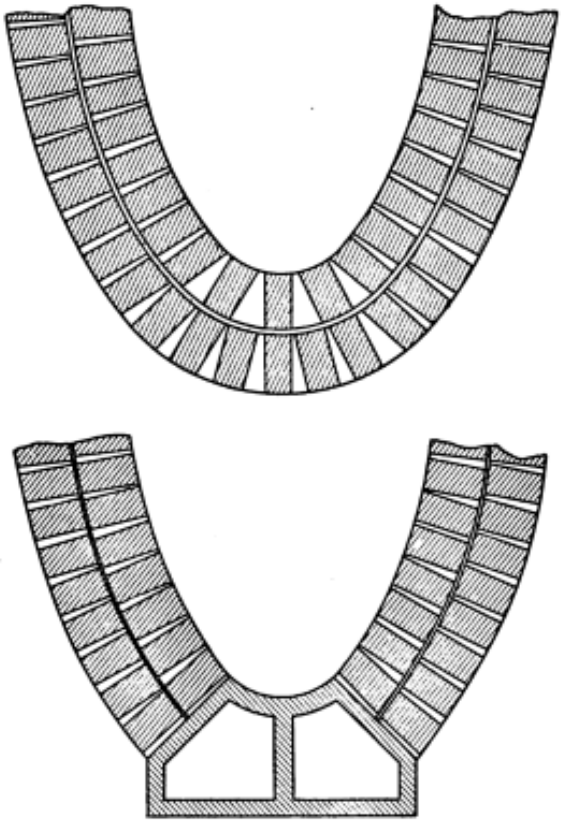


Figure 12. Diagram of invert block in an egg-shaped sewer.
Source: Henry N. Ogden, Sewer Construction *(New York: John Wiley & Sons, 1908), 31.*

[39] Ogden, *Sewer Construction*, 31-34, 51; Latham, *Sanitary Engineering*; "Impervious Sewer Pipes," *The Manufacturer and Builder* 12, no. 3 (March 1880): 54; Folwell, *Sewerage*, 182.

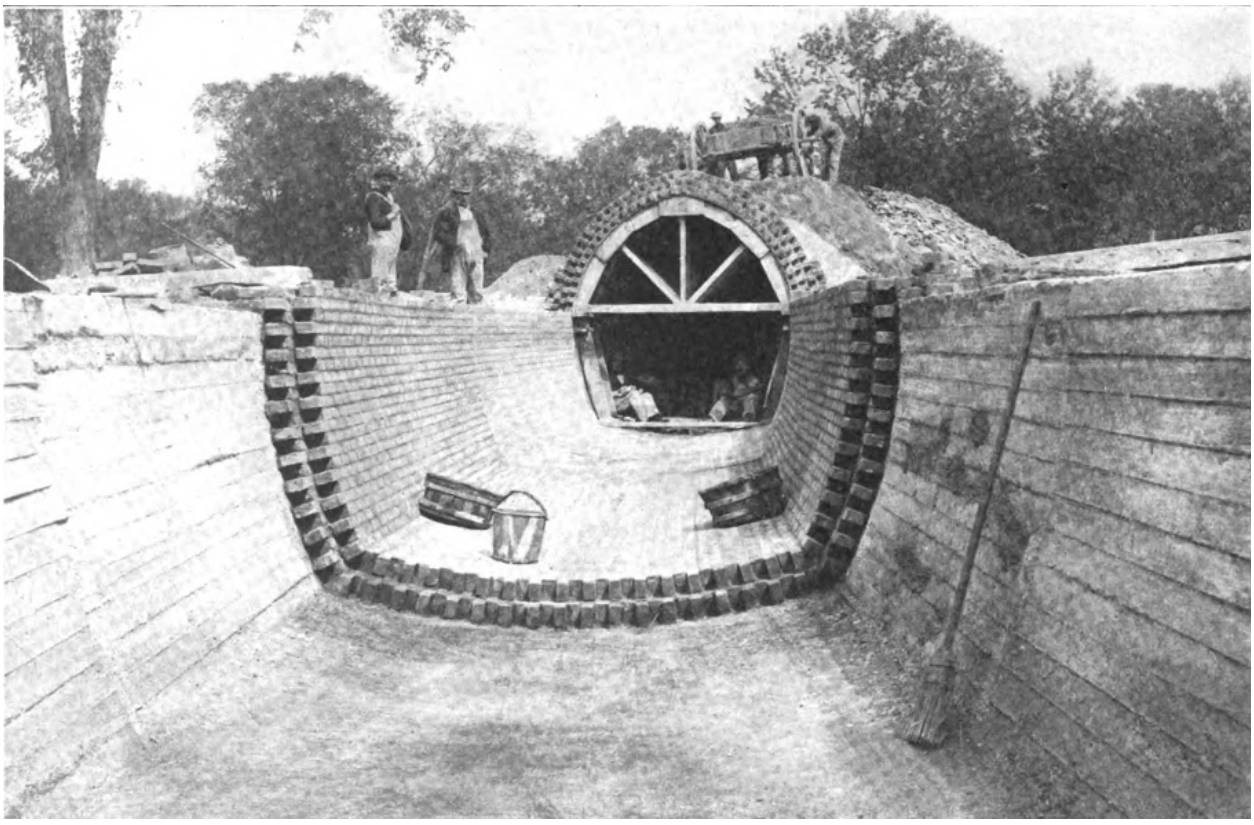


Figure 13. Combined use of brick and concrete in sewer construction.
Source: Anson Marston, Sewers and Drains *(Chicago: American School of Correspondence, 1908), cover.*

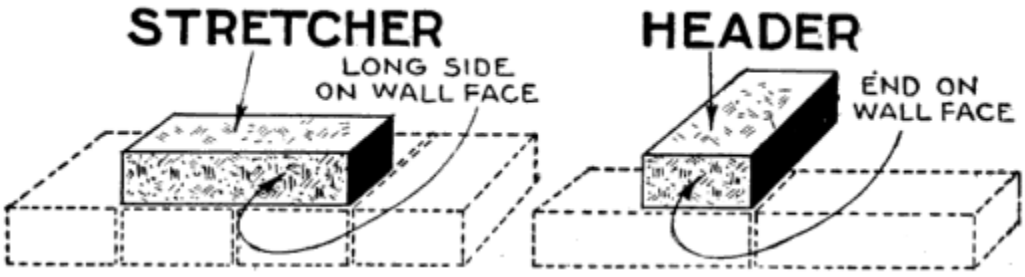


Figure 14. Stretcher and header orientation of a brick.
Source: Frank D. Graham and Thomas J. Emery, Audels Masons and Builders Guide #1 (New York: Theo. Audel & Co., Publishers, 1924), *169.*

Bricks could be laid in different bond patterns, defined by the masonry units, commonly stretchers and headers. Stretchers are oriented with the long edge facing outward, whereas headers are oriented with the short edge facing outward (Figure 14). There are two relevant types of bonds: all the bricks are laid as stretchers (running

bond); and a mix in which the bricks are laid as a combination of stretchers and headers (common or American bond, Flemish bond, English bond, or Dutch bond). Non-running bonds could be used to better distribute the pressures on the sewer (Figure 15). Once the brick was laid on the mortar, the joint would be made flush with the brick to ensure that the interior surface of the pipe was smooth, a process known as pointing. Brick sewer joints were to be no more than ½-inch thick, and usually between ¼-inch to ⅜-inch. Variations were seen in the way the brick has been laid into a mortar bed to adhere it.[40]

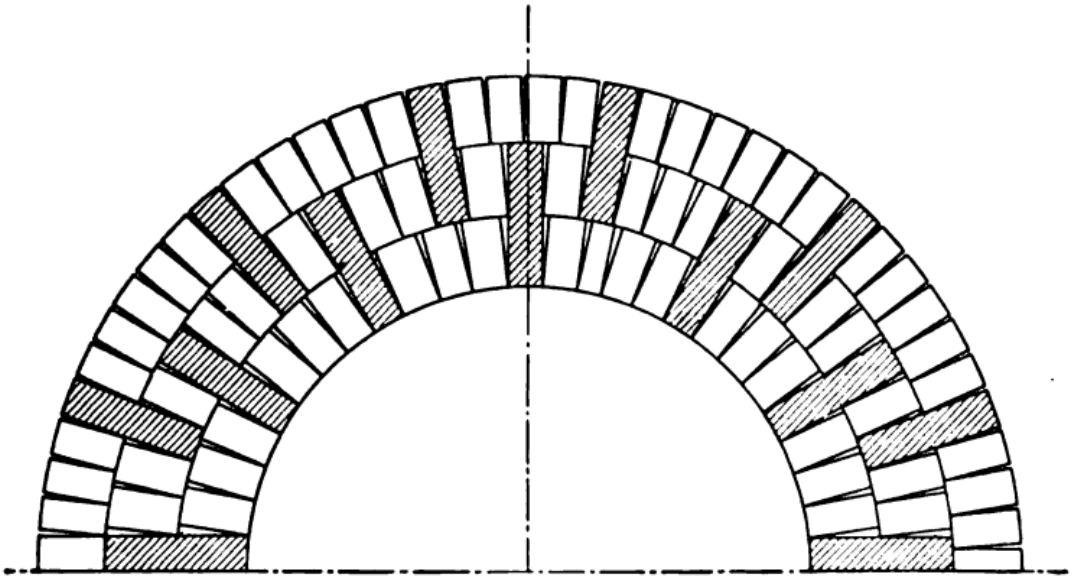


Figure 15. Cross-section of a brick sewer constructed using non-running bond.
Source: Henry N. Ogden, Sewer Construction *(New York: John Wiley & Sons, 1911), 49.*

Sewer dimensions were generally formulaic and corresponded to factors such as depth; one formula to find the optimal pipe thickness was based on the expected depth of excavation and external radius. However, this formula did not consider the soil that the sewer was constructed in. The pipe's thickness determined the number of wythes that would be needed. Wythes in a sewer are equivalent to layers in an onion; the sewer

[40] Folwell, *Sewerage*, 264; Metcalf and Eddy, *Sewerage and Sewage Disposal*, 266.

in figure 14 has three wythes. Another dimension is courses, which are the number of rows of bricks. The sewer in figure 14 has twenty-six courses on its inner wythe.[41]

It is likely that further research can be undertaken into brick sewer construction, including where bricks were sourced from, the specific mortar used, and the role of construction firms in the employment of specific construction techniques and other material nuances.

Other Material Choices and the Eventual Successor to Brick

As casting technologies evolved, the dimensions that could be achieved in clay and concrete sewers began to supersede brick. This meant that material choices were influenced by a variety of factors, including the shape and size of the pipe, slope and soil quality at the site, and the affordability of the materials for construction, and were continuously evolving in response to available technologies.

Vitrified Clay Pipe Sewers[42]

While the use of clay for pipes dates back thousands of years, one of the earliest commercial producers in the United States was Hill, Merrill and Company, near Akron, Ohio (Figure 16). They began production in 1849, with many other companies following suit. Hill, Merrill and Company first produced a hexagonal water pipe, though they would go on to produce circular pipes. Most VCP were circular, although a small number of egg-shaped vitrified clay sewers were installed in the United States. At least

[41] Latham, *Sanitary Engineering*, 128.
[42] Early twentieth century texts on sewer construction appear to use the terms "vitrified clay pipe" and "terra cotta pipe" interchangeably, most notably Ogden's 1908 text *Sewer Construction*. Modern usage differentiates between the two. Some historical references used clay tile instead of clay pipe.

one manufacturer in England designed a clay pipe that was circular on the outside but had an elliptical interior cross section.[43]

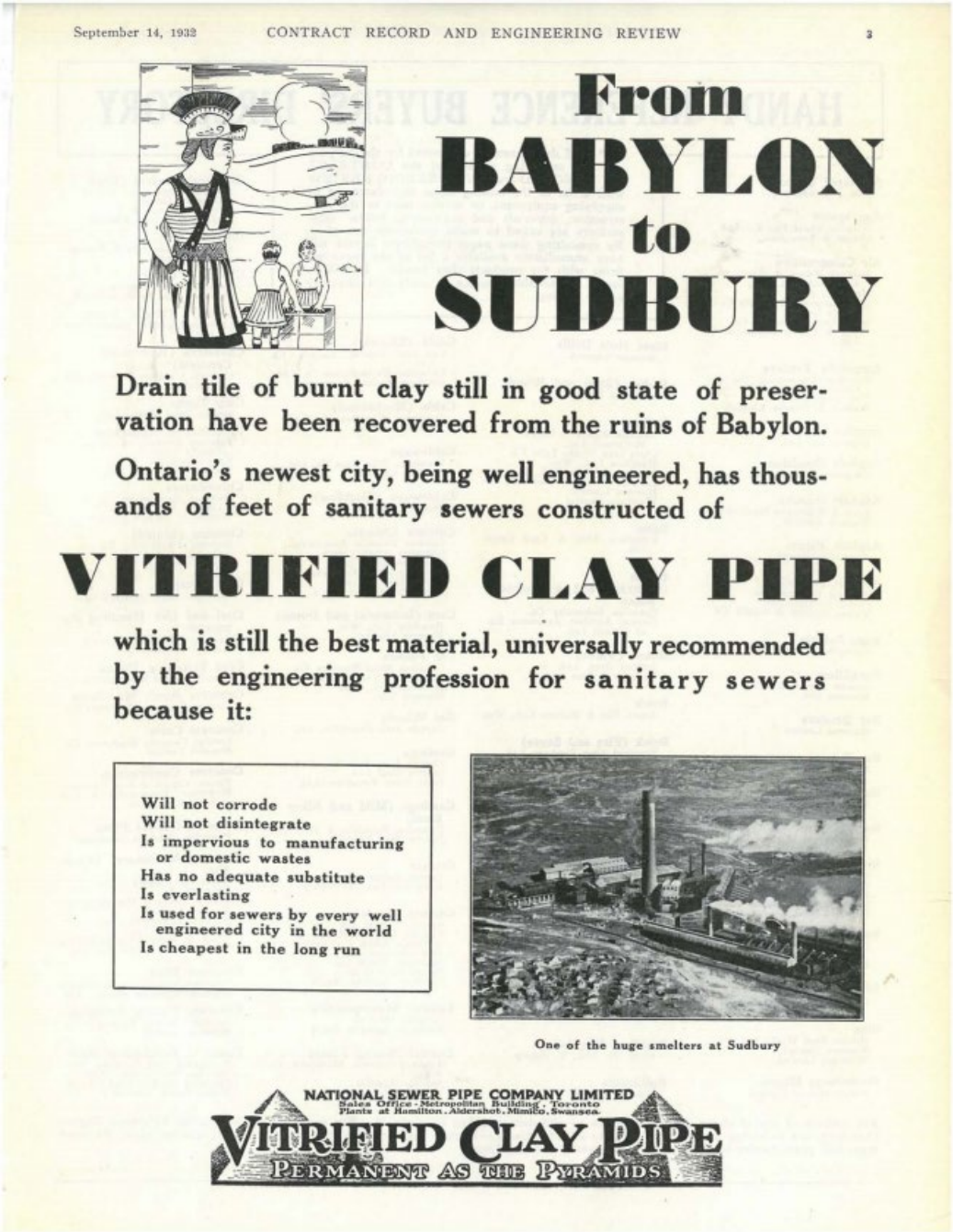


Figure 16. Advertisement by the National Sewer Pipe Company Limited for VCP.
Source: Contract Record and Engineering Review*, September 1932, 3.*

[43] Heinrich Ries and Henry Leighton, *History of the Clay-Working Industry in the United States* (New York: John Wiley & Sons, 1909), 31; Edward J. Sikora, "ASTM and the National Clay Pipes Institute: 100 Years of Teamwork and Achievement," *ASTM Standardization News* (2004); Ogden, *Sewer Construction*, 9.

By the end of the nineteenth century, VCP was widely used for small diameters, usually less than 24 inches. In 1908, the standardized diameters were 4, 5, 6, 8, 9, 10, 12, 15, 18, 20, and 24 inches; odd sized diameters were 7, 14, 16, 21, and 22 inches, and could be made on special order. The segment of pipe produced was 2 feet in length, but by 1908, improved manufacturing techniques saw the advent of pipes 2.5 feet and 3 feet long. In the early twentieth century, the American Society for Testing and Materials (ASTM) standardized pipe length according to the diameter of the pipe. Longer segments of pipe decreased overall leakage, as there were fewer joints. By 1908, larger diameter pipes of 30 and 36 inches were produced to replace brick sewers.[44]

Pipe wall thickness eventually became standardized into single strength ("Ohio Standard") or double strength forms, wherein pipes that were 12 inches or larger in diameter had to have a thickness equal to 1/12th of the internal diameter of the pipe. Double strength pipes were intended for use under railroads, closer to the street surface, or deep below roadways.[45]

Clays were typically sourced throughout the country, according to the specific needs of the factory producing the pipe. Every factory had its own standardized formula for production. A plant in Portland, Maine, used clay that was mined in New Jersey, transported to Maine by boat, and then combined with locally sourced clay and finely ground, burnt pipe. A factory in St. Louis used 40% fire clay, 40% surface soil, 15% yellow clay, and 5% burnt pipes. Most formulas for sewer pipes required greater quantities of silica and aluminum oxides alongside other chemical compounds. The

[44] Metcalf and Eddy, *Sewerage and Sewage Disposal*, 244; Folwell, *Sewerage*, 177; Ogden, *Sewer Construction*, 10.
[45] Monmouth Mining & Manufacturing Company, "Sewer and Culvert Pipe, Drain Tile, Well Tubing, Paving Brick, &c, &c. Monmouth Illinois (catalog)," (1890); Ogden, *Sewer Construction*, 11.

formula was mixed and then shaped into pipes. Before firing, many companies allowed the water to evaporate naturally. This process reduced the volume of water in the pipe, to prevent cracking during firing.[46] For sewers, companies produced vitrified pipes with a salt-glaze. Slip-glaze was another early production method, using clay that was not suitable for vitrification; since it was not as long lasting or resistive to acids and frost as salt-glazed pipe, it was not recommended for sewers.[47]

Salt-glazed pipe required clay that could be vitrified, which meant that the clay had to have more silica than aluminum. If the amount of silica was too low or too high, the clay would not vitrify. The pipes would be fired at a high temperature, approximately 2,400◦F, to achieve vitrification, where it would solidify into a hard, nonporous glass. To make salt-glazed pipe, small quantities of coarse salt were thrown in the kiln during firing. This process would release sodium vapors which would combine with the silica in the pipe to create a salt-glaze, which is resistant to acids and frost. Vitrified pipes are hard, water-tight, and durable, and the salt-glazing added to its impermeability. The impervious surface of the interior of the pipe enhanced its durability by preventing corrosion from acids, silts, and steam.[48]

Vitrified clay has many ideal qualities for sewer pipe – hardness, impermeability, smoothness, and resistance to acid, steam, and silt abrasion – but it is brittle and prone to cracks or breaking, especially if not installed correctly. Clay pipes were usually placed

[46] Clay that is still wet inside will explode during firing, ruining not just that piece but surrounding pieces too.
[47] Ogden, *Sewer Construction*, 2; Metcalf and Eddy, *Sewerage and Sewage Disposal*, 242; Austin Thomas Byrne, *Inspection of the Materials and Workmanship Employed in Construction. A Reference Book for the Use of Inspectors, Superintendents, and Others Engaged in the Construction of Public and Private Works* (New York: John Wiley & Sons, 1898), 366.
[48] Byrne, *Inspection of the Materials and Workmanship Employed in Construction*, 366; Tony Hansen, "Vitrification," 2015; Ogden, *Sewer Construction*, 2.

in a concrete cradle to ensure proper installation. Each pipe would have an enlarged "bell" at one end, so that the other end of the adjacent pipe would fit into it to create a bell-and-spigot joint (Figure 17). This socket could be sealed with cement mortar or other materials to make the joints water-tight and reduce unwanted infiltration or exfiltration of liquids. In 1891, the Portland Stoneware Company introduced the deep-and-wide socket in addition to the standard socket. Laboratory experiments demonstrated that the deep-and-wide socket allowed for greater leakage (Figure 18).[49]

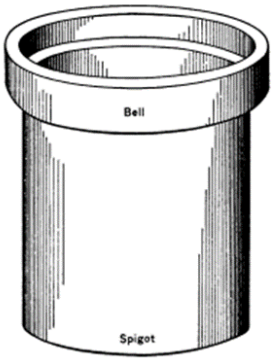


Figure 17. Bell and spigot design. Source: Henry N. Ogden, Sewer Construction *(New York: John Wiley & Sons, 1908), 12.*

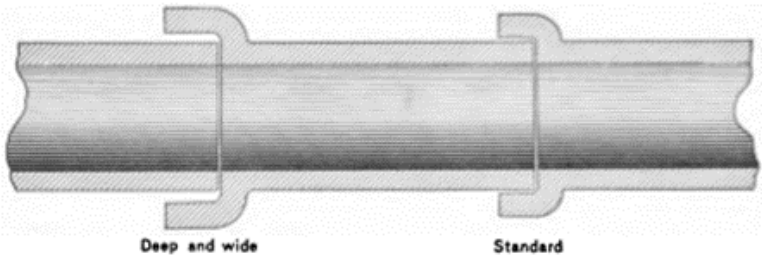


Figure 18. Standard versus deep and wide joints. Source: Henry N. Ogden, Sewer Construction *(New York: John Wiley & Sons, 1908), 12.*

Folwell noted that glazing on the pipe reduced the quality of cement adherence; however, he thought it likely that waste flowing through the pipe would collect at joints and increase its watertightness. It was common to wrap joints with jute or oakum that had been soaked in cement grout to improve its impermeability.[50]

[49] Ogden, *Sewer Construction*, 1-2, 8-11, 22; Metcalf and Eddy, *American Sewerage Practice,* 1:245.
[50] Folwell, *Sewerage*, 169; J.F. Springer, "Construction of Vitrified Pipe Lines," *Municipal Engineering* 52 (January-June 1917): 238.

Concrete Sewers

The earliest use of concrete pipe in the United States is thought to be a 6-inch pipe in Mohawk, New York, that transported domestic sewage from the Francis E. Spinner House to the Erie Canal in 1842. Concrete pipes continued to be installed in cities over the course of the latter half of the nineteenth century, including Brooklyn's municipal system by 1861, as an extension of a brick sewer in Hoboken in 1867, and by D.E. McComb for large sewers in Washington, D.C., beginning in 1883. Several cities, including Duluth, Minnesota; Milwaukee, Wisconsin; Pawtucket, Rhode Island; and St. Paul, Minnesota, used concrete for at least some of their sewers in the late nineteenth and early twentieth centuries. As concrete technology improved and became less expensive by the twentieth century, concrete sewers like the De la Brea sewer in Los Angeles, which was 153 inches by 108 inches, and the San Francisco egg-shaped concrete sewer, with a slab top instead of an arch as was typically seen, were constructed.[51]

Concrete is made of aggregate (i.e., stone, sand, and gravel), cement, and water. If the aggregate isn't thoroughly saturated with water before being mixed with cement, it can hinder the curing of the pipe. Concrete sewers can be either poured-in-place (monolithic) or precast. The individual precast sections could be constructed at a

[51] Susan R. Perkins and Caryl A. Hopson, *German Flatts* (Charleston: Arcadia Publishing, 2010), 47; *Concrete Sewers* (Portland Cement Association, 1918), 4; Laura Cushman et al., *Archaeological Monitoring, North Hudson Sewerage Authority, Grand Street Combined Sewer Rehabilitation, City of Hoboken, Hudson County, New Jersey* (Cranbury, New Jersey: RGA, Inc., 2015), 3-1; A. Grant Lee, "Century Concrete Pipe Does Exist," *Canadian Concrete Pipe Association* (n.d.); G.M. Wood, "The Future and the Present of Concrete Pipe," *Cement and Engineering News* 28, no. 11 (1916): 231-233; Stephen Israel, *Report on the Identification of the Historic and Prehistoric Cultural Resources Along Lamberton Street Southerly of Cass Street, Trenton, Mercer County New Jersey: An Assessment Study for the Plan of Action* (1976), 8; Ogden, *Sewer Construction*, 68; J.F. Springer, "Methods of Concrete Sewer Construction," *Municipal Engineering* 51, no. 2 (1916): 47; H.W. Shimer, "Equipment and Methods Employed in Building Sewers in San Francisco, Calif.," *Municipal and County Engineering* 56, no. 4 (1919): 137.

company factory, or, especially for larger diameter pipes, cast near where the pipes were to be installed. Pipes typically needed time to cure. For poured-in-place pipes, a trench would be excavated, larger than the desired size of the pipe to provide space for a cradle, usually concrete, on which the form would rest. In wet environments, a vitrified clay underdrain pipe was installed underneath the concrete pipe. The forms, or casting molds, were initially made of wood, but later a combination of wood and steel, or only steel was used. For sewers 24 to 48 inches in diameter, the form would be placed on the cradle and concrete would be poured in one constant flow, ensuring a smooth interior surface. For larger diameters, the invert would be cast first and allowed to partly cure, before the sides and the arch were poured. In order to ensure a smooth interior surface, the pipe would be shaped using a mold that was covered in a zinc sheet that was coated with grease.[52] Once the concrete had set, the form could be removed.[53]

Precast sections would be joined together using a bell-and-spigot connection or other, sometimes proprietary, methods. Similar to VCP construction, a gasket made of jute or oakum soaked in cement grout was placed around the end of the spigot to prevent any mortar from squeezing out of the joint. Sometimes, if a gasket was not used, cheese cloth was wrapped around the exterior of the joint to prevent the mortar from moving out of place or collecting at the bottom.[54]

Concrete was also used as a reinforcement or base for other types of sewers. During the mid to late nineteenth century, concrete and brick were sometimes used

[52] This process was modified once the pipes were prefabricated; however, the goal was the same: produce a smooth interior surface.
[53] Metcalf and Eddy, *American Sewerage Practice,* 1:273; Folwell, *Sewerage*, 305; Latham, *Sanitary Engineering*, 130, 133; Springer, "Methods of Concrete Sewer Construction," 47, 49, 51; Shimer, "Equipment and Methods Employed in Building Sewers in San Francisco, Calif."
[54] *"Lock Joint" Reinforced Concrete Pipe* (New York: Lock Joint Pipe Company, 1918); Metcalf and Eddy, *American Sewerage Practice,* 1:248-1:249.

together, with one material used for the invert and the other for the arch of a sewer pipe. Sometimes the interior of a concrete pipe would be completely lined with brick. Like brick sewers, both precast and poured-in-place concrete sewers could have circular, egg, or other cross section shapes, to meet specific construction requirements (Figure 19).[55]

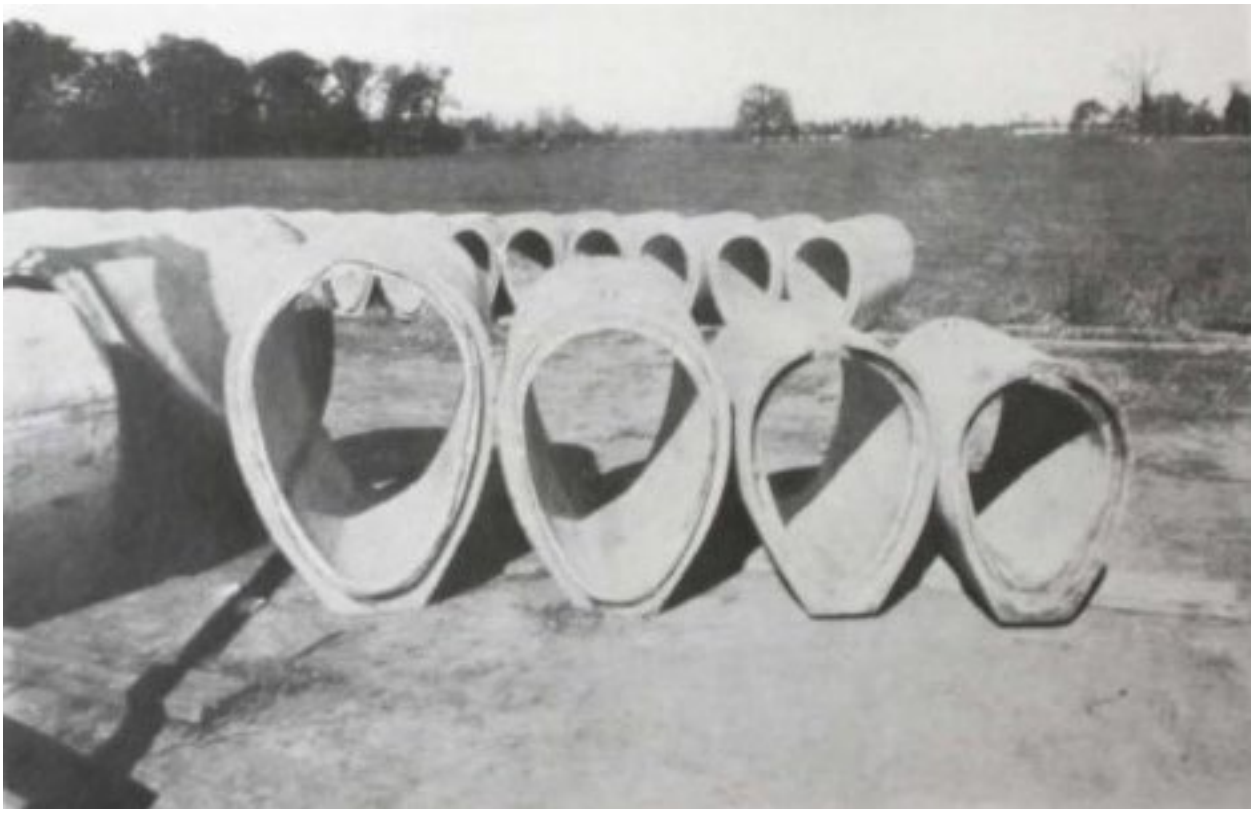


Figure 19. Egg-shaped reinforced concrete pipe sections.
Source: "Lock Joint" Reinforced Concrete Pipe *(New York: Lock Joint Pipe Company, 1918), 62.*

According to Metcalf and Eddy, there are two key factors in the production of a reliable, long-lasting concrete pipe. First, the forms needed to connect properly to ensure joints are water-tight, requiring accuracy in their construction. Second, the concrete used in the pipe and as mortar for the joints should be of a proper consistency.[56]

[55] Metcalf and Eddy, *American Sewerage Practice,* 1:16; Ogden, *Sewer Construction*; Shimer, "Equipment and Methods Employed in Building Sewers in San Francisco, Calif.," 136-140.
[56] Metcalf and Eddy, *American Sewerage Practice,* 1:271; Ogden, *Sewer Construction*, 55.


56 Market—ENGINEERING NEWS-RECORD—Place Vol.99, No.17

Laying 99-inch INDEPENDENT Reinforced Concrete Sewer Pipe at South Bend, Ind.
Carl D. Frazier, Contractor.

Better Sewers—Laid Faster

USING two machines, one for excavating and one for pipe-laying, the contractor made quick time in building this INDEPENDENT Concrete Pipe Sewer in South Bend, Indiana.

Only a very short length of trench was kept open—just as quickly as a section of trench was dug and prepared, pipe units were laid and joined, and the trench back-filled. No waiting for the joints to set—once sealed, INDEPENDENT Pipe Joints *hold* their alignment.

Speedy, efficient work like this is possible on every sewer job where INDEPENDENT Concrete Pipe is used. The "Recessed Joint" enables the contractor to save time, labor and material—build a better sewer at lower cost. This joint is simplicity itself. It facilitates fitting the pipe, and simplifies the sealing of each joint—the UPPER half of the recess is sealed OUTSIDE the sewer; the LOWER half is filled INSIDE the pipe. Cave-ins, wet or muddy trenches do not interfere with sealing the joints. The entire joint is visible for inspection.

There are many other time and money-saving features you should know about INDEPENDENT Concrete Sewer Pipe.

Let us send you information and estimates on your concrete pipe sewer projects.

INDEPENDENT CONCRETE PIPE CO., 202 N. West St., Indianapolis, Ind.

INDEPENDENT
Reinforced Concrete Pipe

Figure 20. Advertisement for reinforced concrete pipe.
Source: Engineering News-Record *99, No. 17, 56.*

Concrete sewers were favored because they were cost effective, even when steel was added for reinforcement (Figure 20). Reinforced concrete, in which steel or other materials were included as mesh or rods in the concrete, was invented in 1854 (Figure 21). It is likely that the flexibility and affordability offered by concrete pipes led them to succeeding brick sewers by the late nineteenth and early twentieth century.[57]

[57] *Cassell's Reinforced Concrete: A Complete Treatise on the Practice and Theory of Modern Construction in Concrete-Steel*, ed. Bernard E. Jones and Albert Lakeman (London, New York, Toronto and Melbourne: Cassell and Company, Limited, 1913), 6; "Methods of Constructing a High-Pressure Concrete Pipe Water Main at Swansea, England," *Engineering-Contracting* 28, no. 12 (September 18, 1907): 168-169.

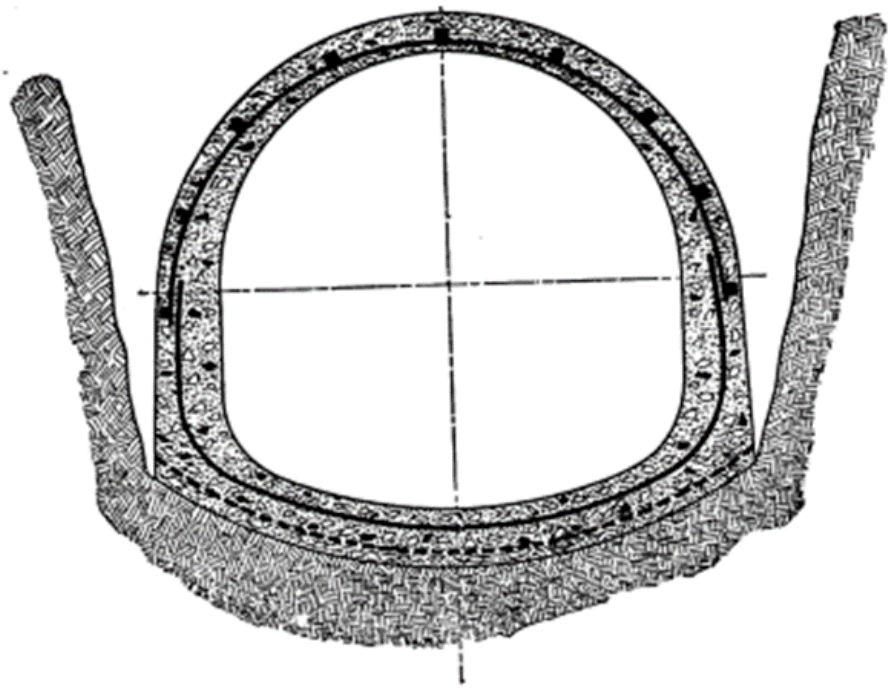


Figure 21. Cross-section of concrete water pipe by the Jersey City Water Supply Company. Source: Henry N. Ogden, Sewer Construction *(New York: John Wiley & Sons, 1908), 81.*

Cast-Iron Pipe Sewers

After first being used at Versailles, France, in the mid-seventeenth century, cast-iron pipes were used for water distribution in some cities in the mid-eighteenth century. In the first half of the nineteenth century, the City of Philadelphia switched its drinking water system from wood to cast iron, and other cities soon followed (Figure 22). Widespread use of cast iron in sewer systems came later. In the nineteenth century, it was used for smaller pipes in areas of high pressure and in shifting environments like sand or under water. In situations along a sewer line in which a siphon was required, wrought-iron or cast-iron pipes, which could be made airtight, were recommended even if a different material was used for the rest of the sewer line. The diameter of cast-iron pipes ranged from 4 inches to 60 inches in the United States (Figure 23). They were almost always circular and were joined together by a bell and spigot joint, bolted

together with internal flanges at the joints, or held together by poured hot lead. If required, the pipes could be curved by resting straight pipes on bent railroad lines, heating the pipes, and then letting them settle into shape under their own weight. Cast-iron pipes could be lined with tar or cement to protect them from corrosion.[58]

Figure 22. Advertisement for cast-iron pipe.
Source: Cast Iron Pipe Research Association, Sewage Works Journal *16, no. 4 (July 1944): 20.*

[58] Jane Mork Gibson and Robert Wolterstorff, "The Fairmount Water Works," *Philadelphia Museum of Art Bulletin* 84, no. 360, 361 (Summer, 1988): 15; Folwell, *Sewerage*, 141; Jay N. Meegoda, Thomas M. Juliano, and Chi Tang, *Culvert Information Management System – Demonstration Project. New Jersey Institute of Technology,* Report No. FHWA-NJ-2009-017, (2009), 5; Ogden, *Sewer Construction*, 133; J.F. Springer, "Iron and Steel Sewer Pipe," *Municipal Engineering* 51, no. 3 (1916): 87; Rafter and Baker, *Sewage Disposal in the United States*, 359.

Figure 23. Cast- iron pipes with a 60-inch diameter.
Source: J.F. Springer, "Iron and Steel Sewer Pipe," Municipal Engineering *51, no. 3 (1916): 89.*

Cast-iron pipes could be constructed without the need for concrete cradles. Engineers determined that the longer length and quick-setting joints meant that cast-iron pipes would not settle as much as vitrified clay pipes, which had more joints that were sealed with cement mortar. The cement mortar took at least twenty-four to forty-eight hours to set and up to twenty-eight days to reach full strength. The cast-iron pipe could be laid directly on firm ground, which was prepped with extra depth at the points where the joint would be bolted together.[59]

Material Choices and Sewer Longevity

Ultimately the ability to produce and construct a cost-effective pipe that was long lasting with a consistently smooth interior surface led to circular concrete and vitrified clay pipes succeeding the brick and concrete sewers in unique shapes. Late nineteenth and early twentieth century engineers highlighted the importance of smooth pipe interiors, measured as roughness. The rougher the pipe's interior, the greater the likelihood of waste accumulation and putrefaction, as well as blockages. Producing brick pipes with smooth interiors required skilled labor and quality workmanship, including the production of bricks through to the construction of the interior surface of the pipes. Materials, like prefabricated concrete and vitrified clay, had lower roughness in comparison to brick pipes. A smooth interior promoted the movement of waste and could be achieved at a lower slope. The lower slope meant less excavation for the same distance, which further reduced costs.[60]

[59] Hugh Sexton Watson, *Sewerage Systems, Their Design and Construction* (New York: McGraw-Hill Book Company, 1911), 241.
[60] Ogden, *Sewer Construction*, 29.

Long lasting brick pipes were difficult to produce. For example, arch construction required careful consideration. Because a mathematical understanding of the loads and stresses on the arch would come later, early brick sewers were produced from practical, rather than technical, expertise. Loads acted evenly upon circular pipes, whereas they varied on egg and oval-shaped pipes, meaning that a well-constructed circular pipe was stronger. Eventually, brick arches proved to be disadvantageous. By the early 1900s, engineers understood that the elasticity of unreinforced concrete arches responded better to changing stresses than brick arches.[61]

Reinforced concrete sewers have a slightly higher probability of survival over brick sewers of the same age, likely because off-site production of concrete pipes in a controlled factory environment resulted in a pipe that typically aged better than brick sewers, which were constructed in situ. Slope, however, had a significantly lower impact on survival probability than age. Historical records from Camden, New Jersey, demonstrate that the size and shape of brick sewers appears to affect their durability. For example, brick sewers with a diameter between 24 and 36 inches were repaired or replaced at a much higher rate than any other size range, even accounting for the frequency of each size. Proportionally, within this size range, more circular sewers needed to be repaired or replaced than elliptical. It is not clear why this should be the case, and further research is needed. In some industrial New Jersey cities, the quantity of manufacturing wastes in the sewer pipes was greater than domestic waste, and these "objectionable trade wastes" damaged the interior of the pipes, increased blockages, and

[61] Ogden, *Sewer Construction*, 255- 265.

increased flow beyond projected amounts. Further research into the impact of industrial waste on brick sewers would be advantageous in informing risk management.[62]

After construction, the backfill around the pipe likely impacted its longevity. For example, an 84-inch single wythe circular brick sewer of "doubtful construction" lasted fourteen years most likely due to the stability provided by the clay in which it was constructed. Metcalf and Eddy agreed that packing down the surrounding soil was vital, although they stated that it would be "practically impossible" to press the soil so firmly that the pipe would not shift. According to their analysis, if the horizontal diameter of the pipe lengthened by 0.04 inches under vertical loading, the pipe would crack or break. Metcalf and Eddy stated that the main cause for cracks was loose and improper filling around the pipe and trench. If the ground was unable to provide support, damage to the pipe was likely. However, VCP was not infallible; it could crack if stones or frozen earth were thrown as part of the backfilling. If the backfill was well tamped down around the pipe, the VCP would not collapse, though it would leak, even if it reached the break point.[63]

Concrete and vitrified clay pipes cost less, were easier to clean and flush, while being as impervious as brick sewers. Construction costs for brick sewers could be reduced by constructing circular sewers rather than elliptical sewers. However, the larger the dimensions of the sewer, the more expensive it was because the pipe also had

[62] Eliseo Ana et al., "Investigating the effects of specific sewer attributes on sewer ageing - a Belgian case study," *11th International Conference on Urban Drainage* (2008): 5; Division of Capital Improvements and Project Management, "Camden Sewer Notebooks" (Camden: Department of Planning and Development, n.d.); George C. Whipple, "Appendix I. Composition of Paterson Sewage," in *Report of the Joint Committee and of the Consulting Engineer on the Subject of Sewage Disposal on the Sewage Disposal of Paterson, NJ* (Paterson, N.J.: Chronicle Print, 1906), 8.
[63] Ogden, *Sewer Construction*, 36, 267; Metcalf and Eddy, *Sewerage and Sewage Disposal*, 237; J.P. Davies et al., "Factors influencing the structural deterioration and collapse of rigid sewer pipes," *Urban Water* 3, no.1-2 (2001): 75; Folwell, *Sewerage,* 167.

to be thicker to prevent failure, which meant that more bricks were required to construct a stronger pipe. Unfortunately, public perception generally favored large brick sewers and presented an opposition to municipal officials and engineers. In Newark, the City Surveyor noted that costs for brick sewers ranged from $60 to $70 per lot whereas it ranged from $25 to $35 for other types of sewers. Even lot owners objected to paying for brick sewers. In certain parts of Newark, "elongated cesspools" formed in the interior of large brick sewers as a result of the low volume of sewage that would flow in from the laterals. Engineers like Hering supported quality production and construction techniques, writing that "[i]f good material is used, and if they are properly laid, there can be no doubt of their making the best sewer. The best vitrified or even slip-glazed pipes are as durable, if not more so than brick." Gradually, pipe sewers were more frequently constructed (Figure 24).[64]

List of Comparative Number of Feet of Brick and Pipe Sewers Built in Different Cities.

Names of Cities.	Brick Sewers.			Pipe Sewers.			Remarks.
	Size.	Length in feet.	Length in miles.	Size.	Length in feet.	Length in miles.	
St. Louis, Mo.	2' to 3'	10,002	1.89	15" / 12"	10,471 / 9,787	1.98 / 1.85	Built in 1882.....Brick 1; Pipe, 2
St. Louis, Mo.	.....	11,490	2.18	12" to 18"	55,230	10.46	Were to be built in 1885. " 1; " 4.8
Chicago, Ill.	2' to 4' 6"	1,106,048	209.51	12" to 15"	740,606	140.18	Built up to 1879..... " 1; " 0.70
Brooklyn, N. Y.	24" to 30"	122,178	23.14	12" to 24"	1,298,667	245.96	From 1858 to 1880..... " 1; " 10.6
New Haven, Conn.	24"	501	0.09½	15" to 12"	3,066	0.58	Built in 1878..... " 1; " 6
Buffalo, N. Y.	20" to 40"	4,176	0.80	12" to 18"	26,038	4.93	Built in 1883..... " 1; " 6
Rochester, N. Y.	.....	3,432	0.65	6" to 24"	183,532	34.76	Report of 1882..... " 1; " 53
Erie, Penn.	12" to 51"	49,522	9.40	12" to 15"	42,303	8.01	Report of 1881..... " 1; " 0.85
Newark, N. J.	2' to 9'	270,917	51.31	10" to 24"	230,947	43.74	Total at 1891..... " 1; " 0.85

Figure 24. Comparison of brick and pipe sewers in 1891.
Source: Report of the City Surveyor of the City of Newark, N.J., for the Years 1888, 1889 and 1890 *(Newark, N.J.: Advertiser Printing House, 1891).*

[64] New Jersey, Board of Health, *Seventeenth Annual Report of the Board of Health of the State of New Jersey and Report of the Bureau of Vital Statistics, 1893* (Trenton, N.J.: MacCrellish & Quigley, Book and Job Printers, 1893), 148; Metcalf and Eddy, *Sewerage and Sewage Disposal*, 255; Ogden, *Sewer Construction*, 35; *Report of the City Surveyor of the City of Newark, N.J., for the Years 1888, 1889 and 1890* (Newark, N.J.: Advertiser Printing House, 1891), 18-19.

4. Drainage and Disease

Disease Theory

The theory of humoral concepts emerged during the fifth century BCE with Hippocrates who believed that there were four basic humors (bodily substances): black bile, blood, phlegm, and yellow bile. An imbalance, or corruption, of one or more of these humors resulted in illness. Unfortunately, this did not explain why and how epidemic diseases appeared, and so the theory of epidemic constitutions was developed. Seventeenth century English physician Thomas Sydenham theorized that the climate and environment had a significant role in causing illness. Sydenham believed that miasmas arising from "the bowels of the earth" were responsible for changes in atmospheric conditions, which led to epidemic diseases (Figure 25).[65] Miasmas could not be seen but could be smelled, and it was soon connected to putrefying substances releasing noxious gases. This supported the notion that sickness and filth, typically found in poorer parts of town, were interconnected. Additionally, because miasmas were thought to be responsible for the spread of disease, public health often correlated to land drainage and paving. For example, following the arrival of the bubonic plague in England, the interest in land drainage increased because it was thought that stagnant waters and waste in sewers and ditches caused the spread of disease. Other sanitary engineers during the mid-nineteenth century promoted paving, because exposed soils in

[65] There is an interesting, but disproven, myth, which was shared in house museums. It was suggested that historic beds were shorter because people slept upright to avoid the heaver bad air (miasma) and breathe in the lighter fresh air. See: https://historymyths.wordpress.com/tag/sleeping-sitting-up/

unpaved roads released greater amounts of disease-causing miasmas. Following rainfall, which saturated the soils with water, miasmas were released as the soil dried out.[66]

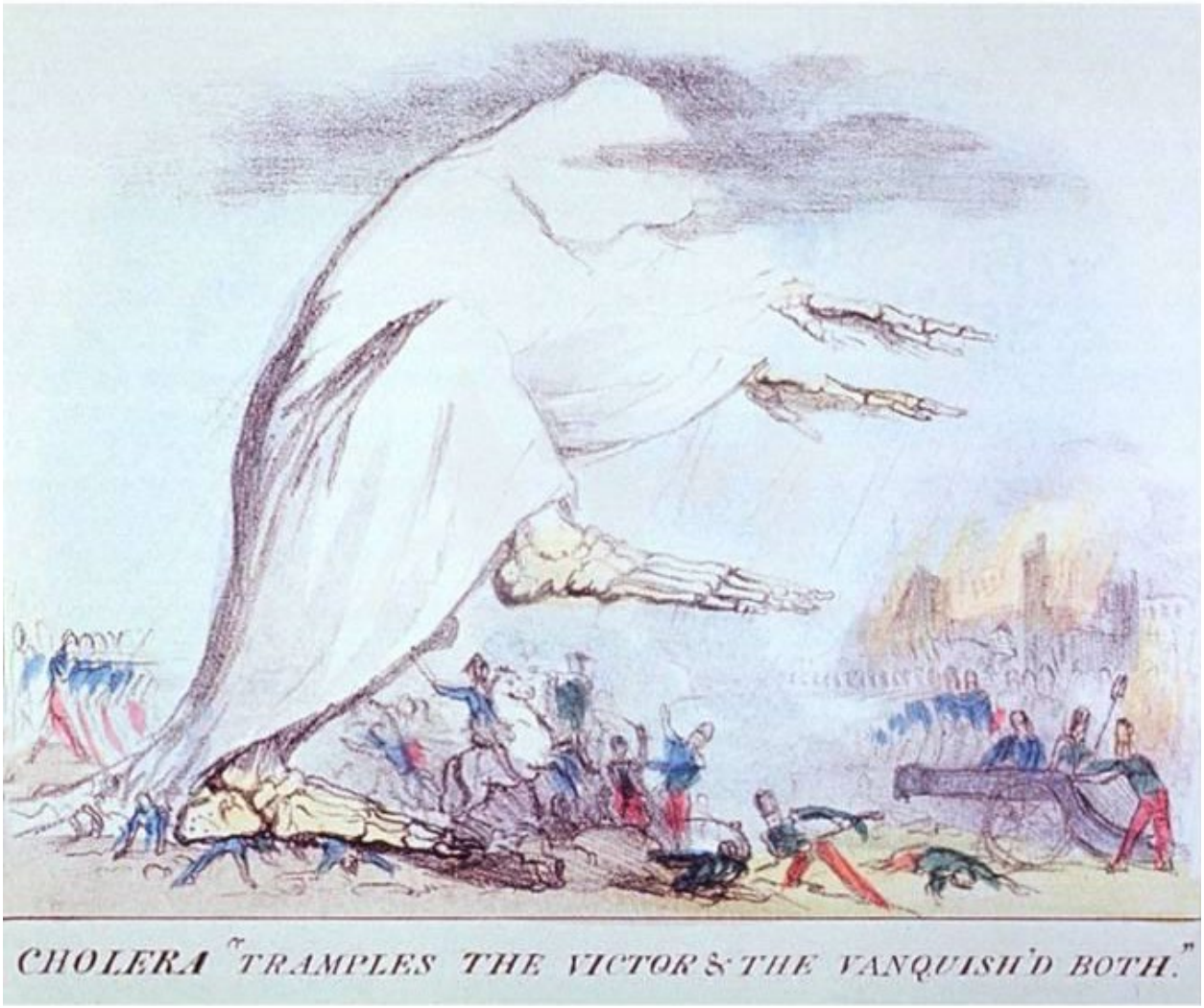


Figure 25. Depiction of a cholera specter indiscriminately killing soldiers.
Source: Robert Seymour, Cholera "Tramples the Victor & the Vanquish'd Both," 1831.
http://resource.nlm.nih.gov/101393375

In 1720, Cadwallader Colden, a Scottish physician working in New York City, postulated that the recurring yellow fever epidemics were correlated to the city's poor

[66] John Duffy, *The Sanitarians, A History of American Public Health* (Urbana: University of Chicago, 1990), 20-21; H.G. Richardson, "The Early History of Commissions of Sewers," in *The English Historical Review*, ed. Reginald L. Poole, (Oxford: Frederick Hall, 1919), 24:386; Egbert L. Viele, *Report on Civic Cleanliness, and the Economical Disposition of the Refuse of Cities* (New York: Edmund Jones & Co., Printers, 1860), 11.

water supply. Twenty years later, Colden furthered his theory to state that filthy water and the putrefying substances found within the water were producing unique miasmas, each responsible for a specific disease (Figure 26). Accordingly, Colden suggested that the only way to prevent epidemic diseases was to clean the city, which would result in the removal of the disease-causing miasmas. Unlike Sydenham, who suggested that miasmas were indirectly responsible for the spread of disease, Colden held miasmas directly responsible.[67]

Figure 26. Depiction of malaria, smallpox, and leprosy as skeletal miasmas.
Source: George Frederick Keller, San Francisco's Three Graces, 1882, Cover Image of The Wasp*, vol.8, 304. The Ohio State University, Billy Ireland Cartoon Library and Museum. https://hdl.handle.net/1811/baac0cf8-7dff-410c-8fc0-722cd1f21afa*

[67] Duffy, *The Sanitarians*, 21-22.

Miasma theory was also seen in Dr. John Jones' war-time surgical field manual, published prior to the outbreak of the Revolutionary War.[68] He recommended that soldiers use privies set up downwind of the camp site, rather than relieve themselves near the camp site. He reasoned that the prevailing winds would carry the odors away, thus preventing the spread of sickness.[69]

Miasma theory judged water for scent, taste, and clarity, none of which are definitive indicators that the water was safe to consume. As early as the sixteenth century, it had been postulated that microorganisms caused disease; however, it was not until the invention of the achromatic microscope in the 1830s and the identification of fungi and parasites in the 1840s that this theory was proven (Figure 27). Over the course of the latter half of the nineteenth century, germ theory, as this theory came to be known, emerged from the work of Louis Pasteur, a French chemist and microbiologist, Joseph Lister, an English surgeon, and Robert Koch, a German physician.[70] Though he might not have known it as germ theory, English physician John Snow provided further evidence for it. In 1849, while studying the rapid spread of cholera, Snow postulated that the excrement of cholera patients contained "some material," which was somehow ingested by other people and subsequently infected them with cholera. Snow studied the work of physicians from the last few decades and epidemics of cholera in other towns to trace the disease's spread to local water supplies, which might be contaminated with

[68] To read the manual, see: https://collections.nlm.nih.gov/catalog/nlm:nlmuid-2751026R-bk
[69] Duffy, *The Sanitarians*, 22.
[70] When Paris was revamping its sewer system in the mid-nineteenth century, there was debate about whether or not human waste should be allowed to drain into the system, which was released into the Seine. Louis Pasteur and other microbiologists at the time advocated against draining human waste into the Seine because of concerns with cholera and typhoid contamination, at a time when "fanatics of Seine water" wanted to continue to use the river as a source of drinking water.

sewage.[71] In 1854, he made his most significant contribution by confirming his theory. He mapped the proximity of deaths from cholera to water pumps in Soho and concluded that a water pump at Broad Street was contaminated with sewage and the likely source of a localized outbreak.[72]

Figure 27. Recreation of microscopic bacteria of the Thames.
Source: William Heath, A Woman Dropping Her Tea-cup in Horror upon Discovering the Monstrous Contents of a Magnified Drop of Thames Water Revealing the Impurity of London Drinking Water, 1828.
https://hdl.loc.gov/loc.wdl/wdl.3956

Germ theory allowed for the identification of specific organisms that were responsible for disease; however, even as late as 1880 it was not widely accepted.

[71] John Snow's map is available at: https://www.ph.ucla.edu/epi/snow/snowmap1.pdf
[72] Alice Outwater, *Water, A Natural History* (New York: Basic Books, 1996), 141; Duffy, *The Sanitarians*, 193; Matthew Gandy, "The Paris Sewers and the Rationalization of Urban Space," *Transactions of the Institute of British Geographers* 24, no. 1 (1999): 31; John Snow, *On the Mode of Communication of Cholera* (London: John Churchill, Princes Street, Soho, 1849), 8, 11; John Snow, *On the Mode of Communication of Cholera*, 2nd ed. (London: John Churchill, New Burlington Street, 1855), 40.

Scholars have theorized that this could be attributed to the belief in sewer gas causing disease. Refuse in sewers contained disease causing microbes, including typhoid, cholera, etc., thus, it was interpreted that odorous sewage caused disease. In response, anti-sewer gas companies emerged "to do everything practically possible to secure our patrons against the dangers of living in unsanitary houses." The Manhattan Anti Sewer Gas Company recommended that houses be visited by an expert who can inspect the sanitary system, because both disagreeable and odorless gases can cause disease. The company's services included identifying defects, cleansing pipes to ensure good flow, burning sulfur to fumigate pipes, remedying areas with bad ventilation, and fumigating rooms and clothing that were exposed to illness-causing miasmas.[73]

Doctors also dismissed germ theory. Dr. Edgar Holden conducted a survey of health and mortality in Newark, New Jersey, from 1860 to 1880. He hypothesized that an exact amalgamation of living conditions resulted in the spread of a specific disease; for example, the spread of malaria could be attributed to grading, excavations, sewer construction, or sewer defects, though as we know today malaria is spread by mosquitos. He also hypothesized that mortality in infants and young children due to diarrheal causes could be attributed to impure air, defective sanitary surroundings, bad water, filth, overcrowding, and neglect. Holden's data demonstrated that sewers were not a source of disease and, ultimately, had positive effects on health. Holden attributed Newark's poor sanitary conditions to the absence of a sanitary solution that responded to updating technologies or population growth and the lack of expenditure, of both time

[73] James Whorton, "'The insidious foe'-sewer gas," *Western Journal of Medicine* 175, no. 6 (December 2001): 427-428; *A Plain Exposition of the Only Practical and Sure System for the Prevention of Disease Ever Offered to the Public, Prospectus of The Manhattan Anti Sewer Gas Company, No. 41 Union Square, New York, Everything Pertaining to House Sanitation* (New York: Printed by P.F. McBreen, 16 Beekman Steet, 1883), 3-4.

and money. Though Holden looked to causes other than germ theory for the spread of disease, he correctly emphasized the importance of clean drinking water and acknowledged that most of the residents of the city probably believed the water supply from the aqueduct and city wells was impure.[74]

The Search for "Wholesome Drinking Water"

Figure 28. Public perception of the Thames River water as a source of disease.
Source: George Cruikshank, Salus Populi Suprema Lex: Source of the Southwark Water Works, 1832.
http://resource.nlm.nih.gov/101394171

Contaminated water was a major vector of disease, which made safe drinking water essential to community health (Figure 28). Drinking water was obtained from

[74] Edgar Holden, *Mortality and Sanitary Record of Newark, N.J.* (1880), 5, 19-24.

wells, springs, rivers, or streams.[75] As both populations and industrial activity increased in urban areas across the United States, these water sources became contaminated or insufficient to meet the needs of their population. Initially private companies, incorporated by the state legislature, constructed water systems to introduce an unpolluted water supply and, ultimately, pipe water to houses. Though municipalities were interested in supplying water, this responsibility was frequently entrusted to private companies who could afford the cost of construction.[76]

The New Jersey State Legislature incorporated the earliest privately-owned water companies. The first was in Morristown in 1799, created as a response to drought that left wells in the town dry. The state legislature established the Proprietors of the Morris Aqueduct, later known as the Morris Aqueduct Company. Initially, it installed 2 miles of manually augured wooden pipes to connect Morristown with an aquifer on Mount Kemble. The design of the system relied on gravity to transport the water to a wood and clay reservoir in town, which distributed water to subscribers. At this time, treatment was not seen as necessary.[77]

The Newark Aqueduct Company, chartered in 1800, was the next water company established in the state. Wooden water pipes were laid to transport water from the aqueduct to residences; by 1828, the wooden pipes were replaced by iron pipes. It was later taken over by the City of Newark in 1860, who completed construction of the

[75] For a look at some early springs in New York City, check out: https://www.urbanarchive.org/stories/6nKUHq6Wk35 and https://www.nyhistory.org/blogs/james-reuel-smiths-new-york-city-springs
[76] Nelson Manfred Blake, *Water for the Cities: A History of the Urban Water Supply Problem in the United States* (Syracuse: Syracuse University Press, 1956), 63.
[77] Arthur Mierisch, *The Morris Aqueduct Company: New Jersey's First Water Company, Part 1: 1798-1869*, GSL18 (Garden State Legacy, 2012); Arthur Mierisch, *The Morris Aqueduct Company: New Jersey's First Water Company, Part 2: 1860-1923,* GSL21 (Garden State Legacy, 2013), 2.

municipal water works in 1870. Subsequent efforts by the Newark Board of Health in 1884 to transition residents from contaminated well water to piped-in water was met with resistance. The reasons were twofold. First, residents were upset that their municipal Board of Health was attempting to guide their private decision on their drinking water supply. Second, residents were skeptical of transitioning to water piped in from the Passaic River, especially because they felt that it was inconceivable for communicable diseases to be spread by drinking water.[78]

Water companies continued to be chartered over the course of the nineteenth century. The privately owned Trenton Water Works was chartered in 1804. The Passaic Valley Water Commission was incorporated in 1849 as the Passaic Water Company to distribute water to Paterson and surrounding towns. The Camden Water Works Company was incorporated in 1845 and relied on river water, not fully switching to artesian wells until 1899. Hoboken began laying water mains as early as 1857.[79]

By the mid-nineteenth century, half of United States' cities had a water works, but this resulted in a new problem. Access to running water in houses led to a dramatic increase in the amount of water used, which was then discharged to privies and cesspits,

[78] Frank John Urquhart, *A History of the City of Newark, New Jersey, Embracing Practically Two and a Half Centuries, 1666-1913* (New York: The Lewis Historical Publishing Company, 1913), 2:850; M.H.C Vail, *Essex County, N.J., Illustrated* (Newark, N.J.: Press of L.J. Hardham, 1897), 20-21; Galishoff, *Newark*, 111.
[79] Francis Bazley Lee, *History of Trenton, New Jersey, The Record of Its Early Settlement and Corporate Progress* (Trenton, N.J.: John L. Murphy, Printer, 1895), 87; Passaic Valley Water Commission, "Historical Development of PVWC: An Overview," (2021); Charles S. Boyer, *Annals of Camden No. 2, The Public Utilities in Camden, New Jersey* (Privately printed, 1921), 4-6; Laura Cushman and Paul J. McEachen, *Northwest Resiliency Park, Block 103, Lots 7-26, Block 107, Lot 1, and Block 113, Lot 1, City of Hoboken, Hudson County, New Jersey* (Cranbury, New Jersey: RGA, Inc., 2015), 3-7.

causing them to overflow and contaminate the surrounding soil. Most municipalities prioritized access to "wholesome drinking water" over the construction of sewers.[80]

Like with sanitation, experimentation on best practices for treating drinking water first took place in England. Under engineer James Simpson, the Chelsea Water Company installed a slow sand filtration system in 1829. The filtration process reduced the visible cloudiness, or turbidity, of the water. At the time, low turbidity water was believed to be cleaner and safer. Separate discoveries by James Alfred Wanklyn and Edward Frankland, in the 1870s, demonstrated that filtration did not remove as much organic matter as it was thought to, which meant that it was important for cities to rely on water supplies that were as unpolluted as possible.[81] In the late nineteenth century, Newark residents who drank well water judged the water by its smell and turbidity; however, testing by the Newark Board of Health in 1894 determined that of the 425 open wells 57% were definitely contaminated and an additional 27% likely contaminated, which demonstrated that turbidity should not be a metric for safety. As late as 1896, turbidity continued to be the measure of cleanliness of London's drinking water supply. However, by this time, advancements had been made in drinking water testing, due to the development of germ theory and of methods to test for disease-causing bacteria. The safety of the drinking water supply was only as good as the

[80] Passaic Valley Sewerage Commission, *Report of the Passaic Valley Sewerage Commission upon the General System of Sewage Disposal for the Valley of the Passaic River, and Prevention of the Pollution Thereof* (Newark, N.J.: John E. Rowe & Son, Printers, 1897), 65.
[81] Wanklyn and Frankland were contemporaries working on water analysis. Wanklyn was critical of Frankland, which according to *A Science of Impurity*, "revenge on Frankland became a *raison d'être*" for Wanklyn as he continued his work. To learn more about their history, see: https://publishing.cdlib.org/ucpressebooks/view?docId=ft667nb43t&chunk.id=d0e3139&toc.id=&brand=ucpress

technology that existed to test the water. In 1899, treatment, though valuable, was considered prohibitively expensive.[82]

New Jersey's first water treatment plant, the Little Falls Water Treatment Plant, was constructed in 1901 for the East Jersey Water Company (Figure 29). The large rapid sand filter system gave the treatment plant a net capacity of 32 million gallons daily, and 40 million gallons daily for periods of heavy consumption. The plant received water from the Passaic River and purified it to remove vegetable dyes, a waste byproduct from nearby factories, before supplying Bayonne, Franklin, Glen Ridge, Harrison, Kearny, Montclair, Nutley, Passaic, Paterson, and West Orange.[83]

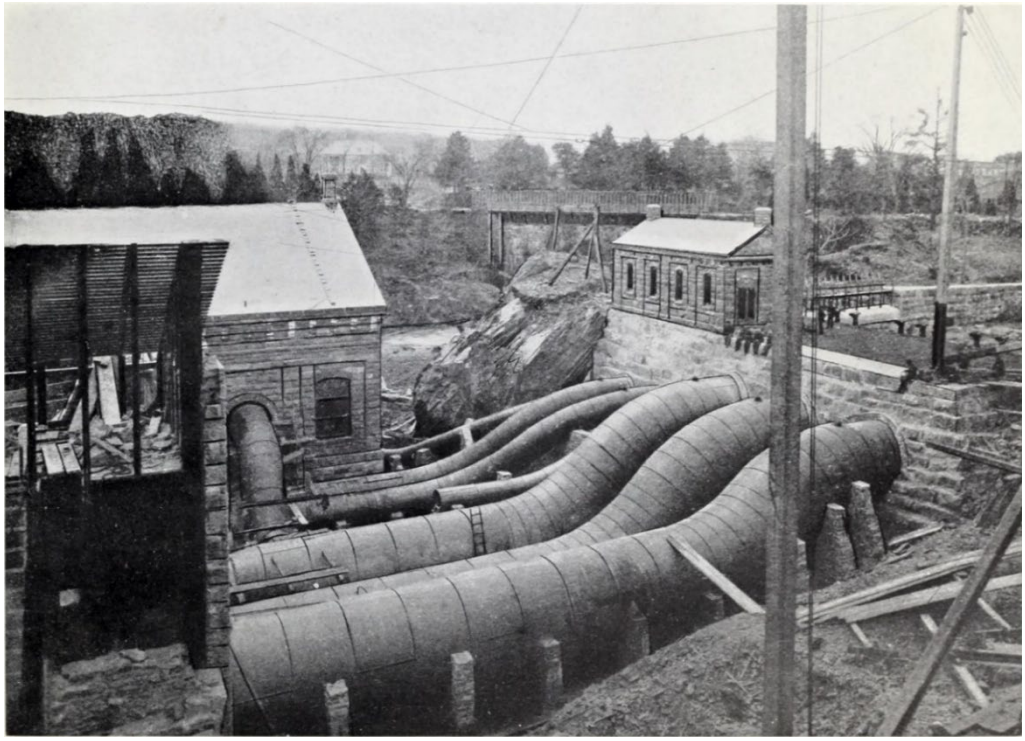


Figure 29. The Little Falls Water Treatment Plant.
Source: The T.A. Gillespie Company, Engineers and Contractors, Water Works and Pipe Lines, Railroads and Tunnel Construction, Hydro Electric Plants *(New York City: T.A. Gillespie Company, 1912), 69.*

[82] Allen Hazen, *The Filtration of Public Water-Supplies*, 2nd ed. (New York: John Wiley & Sons, 1896), 79; United States, Environmental Protection Agency, *The History of Drinking Water* (Office of Water: February 2000), 2; Galishoff, *Newark,* 112.
[83] George W. Fuller, "The Water Purification Works of the East Jersey Water Company at Little Falls, New Jersey," *The Engineering Record* 43, no. 19 (1901): 442.

Allen Hazen, a chemist and engineer, wrote that though the initial expense for treatment was considerable, it only added an average 10% to the cost of water supplied. In 1903, Hazen pioneered the Hazen Theorem, which formulated a correlation between the purity of drinking water and mortality rates.[84]

Dr. John L. Leal pioneered the use of chlorine to disinfect water, known as a sterilization process. By hiring Hering and Fuller to design a plant at the Boonton reservoir, which supplied the Jersey City Water Company, Leal made Jersey City the first American city to have a chlorinated water supply in 1908 (Figure 30). Chlorination, when combined with filtration, provided safe drinking water.[85]

Figure 30. The Boonton Dam, Upper and Lower Gate Houses, and Sterilization Plants.
Source: George W. Fuller, "Description of the Process and Plant of the Jersey City Water Supply Company for the Sterilization of the Water of the Boonton Reservoir," in Proceedings of the Twenty-Ninth Annual Convention of the American Water Works held at Milwaukee, Wis., Jun 7-12-1909 *(Published by the Secretary: 1909), 117.*

[84] Hazen, *The Filtration of Public Water-Supplies*, 4.
[85] George W. Fuller, "Description of the Process and Plant of the Jersey City Water Supply Company for the Sterilization of the Water of the Boonton Reservoir," in *Proceedings of the Twenty-Ninth Annual Convention of the American Water Works held at Milwaukee, Wis., Jun 7-12-1909* (Published by the Secretary: 1909), 110; Melosi, *The Sanitary City*, 164; Rafter and Baker, *Sewage Disposal in the United States,* v-vi; Outwater, *Water*, 144; United States, Environmental Protection Agency, *The History of Drinking Water*, 2.

The 1908 Conference of State and Provincial Boards of Health included a Committee on the Pollution of Streams, which argued against using waterways as both sources of potable water and receptacles of outfalls. They recommended cities purify their sewage and filter their drinking water, as a two-part public health approach. Public health would be safeguarded from the threat of disease and the waterways' health could be safeguarded, ensuring continued use for recreational purposes.[86]

Shortly after, in 1910, the State of New Jersey created the Board of Public Utility Commissioners (originally established as the Board of Railroad Commissioners in 1907), whose duties included overseeing "railroad, express, street railway, traction, canal, subway, pipe line, gas, electric light, heat and power, water, sewer, telephone, [and] telegraph." A survey conducted by the Board showed that many New Jersey municipalities had running water by 1910, though fewer had access to sewers.[87] However, living in a city with a water supply did not mean that all the residents had access to it. Providing residents with clean drinking water and access to sewers while encouraging industrial development was a difficult balance for many cities to strike. Broader access to safe drinking water meant that more wastewater was generated, which entered the sewers, then public water ways, which in turn were the drinking water supply for many towns. This created a cycle wherein the public water supply was significantly polluted, and wastewater treatment became increasingly important.[88]

[86] Tarr, *The Search for the Urban Sink,* 167.
[87] *The Manual of American Water Works*, first published in 1889, has a summary of construction of water works; by 1888, there were forty-eight water works in the state of New Jersey, with a steady growth in construction. Thirty-five new water works were constructed between 1880 and 1888.
[88] New Jersey, Legislature, *Acts of the One Hundred and Thirty-Fourth Legislature of the State of New Jersey and Sixty-Sixth Under the New Constitution* (Trenton, N.J.: MacCrellish & Quigley, State Printers, 1910), 56-57.

5. Sanitary Commissions and Conventions

Disposing of the "most dangerous material"

Human waste has historically been judged as the "most dangerous material," thought to putrefy faster than kitchen wastes. The resulting odor from putrefaction at a time when miasma theory abounded might explain why cities initially, explicitly forbade the disposal of human waste into sewers. These laws were frequently ignored or unenforceable and eventually cities began to change their regulations. Boston did so in 1833; Greenwich Village in 1845; and Philadelphia in 1850. In cities both large and small, existing sewer systems, which were constructed piecemeal and often with little or no municipal oversight, could not handle the increased load. They were often poorly designed, ineffective, and did little to prevent the contamination of water supplies.[89]

Beginning in the 1850s, the inadequacy of existing systems, combined with a growing awareness of the role of water systems in spreading cholera and other deadly diseases, spurred municipal governments to plan and build comprehensive sewer systems to address the needs of the city. However, the safe disposal of human waste became increasingly difficult as cities grew more densely populated. Even though early sanitarians did not correctly understand how disease spread and blamed miasmas, cities and countries learned from each other, fostering the growth of the sanitation movement and an understanding of best practices.

---

[89] George E. Waring, Jr., *Sewerage and Land Drainage*, 3rd ed. (New York: D. Van Nostrand Company, 1891), 295; Jean E. Howson, "The Archaeology of 19th-Century Health and Hygiene at the Sullivan Street Site, New York City," *Northeast Historical Archaeology* 22, no. 22 (1993): 140-142; Rudolph Hering, "Sewerage Work; a Twenty-Five Years' Review," *The Engineering Record Building Record and Sanitary Engineer* 47, no. 1 (1903): 21; Benjamin D. Maygarden et al., "National Register Evaluation of New Orleans Drainage System, Orleans Parish, Louisiana," (New Orleans, LA: Earth Search, Inc., 1999), 5; Steven J. Burian et al., "Urban Wastewater Management in the United States: Past, Present, and Future," *Journal of Urban Technology* 7, no. 3 (2000): 36-37; Goldman, *Building New York's Sewers*.

Health Boards and Sanitary Commissions

Cities like Boston, New Orleans, and New York City in the nineteenth century were home to physicians and medical societies, statisticians and insurance companies, city boards of health, and numerous societies who studied public health and sanitary conditions to determine the factors that encouraged the spread of disease. Across the country, officials concluded that the morality of the poor and their typically unsanitary living conditions encouraged miasmas and were to blame for the greater spread of disease within these communities (Figure 31).[90]

Figure 31. An open drain located between two-family dwellings in Pittsburgh in 1907.
Source: F. Elisabeth Croswell, "Painter's Row, The Company House," in The Pittsburgh District, Civic Frontage, *ed. Paul Underwood Kellogg (New York: Survey Associates, Inc., 1914).*
https://www.russellsage.org/sites/all/files/Kellogg_The%20Pittsburgh%20District_0.pdf

[90] Duffy, *The Sanitarians,* 93-97.

In 1857, Dr. Wilson Jewell, a Philadelphia physician, organized the first sanitary convention. Hosted by the Philadelphia Board of Health, the meeting brought together seventy-four delegates representing boards of health, boards of trades, city councils, and medical societies from across the country interested in standardizing national sanitary practices and procedures.[91]

The 1858 Quarantine and Sanitary Convention was focused on determining how diseases spread and how to prevent them from becoming epidemics. Eighty-six delegates, composed of forty-two doctors and forty-four businessmen, lawyers, and politicians, from twelve states met in Baltimore, Maryland, to develop a quarantine and sanitary code, which was flexible enough to work across the many unique climatic conditions across the country. To develop the code, the delegates debated two conflicting theories, contagion theory and miasma, or anticontagion, theory. Proponents of contagion theory held that disease was spread by touch, thus quarantine was the best preventive measure, whereas proponents of miasma theory held that increased sanitary regulation was the best preventive measure. The discussions concluded that existing quarantine measures needed to be improved, although a few delegates favored their complete abolishment. Many of the arguments were made without substantive science, relying instead on observed patterns.[92]

These discussion topics were repeated at the 1859 National Quarantine and Sanitary Convention, with an emphasis on yellow fever. In April 1859, ninety-one delegates gathered in New York City. Dr. Guthrie, a delegate from Memphis, Tennessee,

[91] Duffy, *The Sanitarians,* 102-103.
[92] Duffy, *The Sanitarians,* 104; *Minutes of the Proceedings of the Second Annual Meeting of the Quarantine and Sanitary Convention, Convened in the City of Baltimore, April 29, 1858* (Baltimore: Printed by John D. Toy, 1858), 7-10.

questioned if yellow fever spread by contagions or atmospheric conditions. Guthrie and his fellow convention attendees affirmed that quarantine of people infected with yellow fever should be discontinued, since it was not effective at containing the spread. Dr. John H. Griscom, of New York, proposed that a lower degree of dryness found in neighborhoods in Brooklyn and New Orleans was a factor of yellow fever epidemics. He compared those conditions to Manhattan at the same time of the year and found the city to have a higher degree of dryness, which he hypothesized was a result of moisture evaporation prompted by brick and stone paved streets. The convention proceedings included a report on disinfectants, which concluded that disinfectants corresponded to specific diseases. For example, it was thought that the disinfectant for yellow fever was ventilation, which would disperse the contagion and prevent adherence to surfaces, including coffee, cotton, and wool. The discussions concluded that existing quarantine measures were insufficient and sanitary measures were needed to prevent the spread of disease. Accordingly, many attendees of the 1859 National Quarantine and Sanitary Convention felt that it was necessary to enact legislation at the state level, especially in states in which a health act did not already exist. They published a draft Public Health Act, adopted from Great Britain's 1848 Public Health Act, in which each state would establish its own Board of Health to oversee public health. They also drafted a Sanitary Code for Cities that codified sanitary measures (including sewer construction, street cleaning, vaccination, and ventilation), recommended annual sanitary surveys, and permitted each town to have its own local Board of Health. These legislative recommendations were not immediately carried out at either the municipal or state levels. Though the majority of the convention discussed quarantine, sanitary issues were an equivalent concern. Thus, four committees were appointed to report on tangential

issues associated with personal and public hygiene, including food, civic cleanliness, poisons and drugs, and the role of architecture.[93]

The last National Quarantine and Sanitary Convention was held in Boston in 1860. The 191 delegates (of which 118 were physicians) focused on "internal sanitation," which included sewage, street cleaning, ventilation, and other topics connected to disease. The Committee on Civic Cleanliness, led by Egbert Ludovicus Viele, presented their finding that municipalities are responsible for ensuring drainage, paving, water supplies, and sewage (and in that order) after which health is overseen by individuals. The committee made a particularly astute observation, it was difficult to convince private individuals to construct sewers at their cost for their health and the health of future generations. Because a system's success was determined by its outset comprehensiveness, the upfront expense was a significant deterrent to private investment in sewers. The convention delegates recommended the establishment of a national sanitary organization, public education on health and sanitation, sanitary reforms, and further research on sanitary science.[94]

Ultimately, due to the looming Civil War, the convention delegates were unable to ensure the implementation of a national sanitary organization for the next twelve years. Broader discussions to improve sanitary conditions shifted from cities to army campsites through the efforts of the United States Sanitary Commission (USSC).[95]

---

[93] *Minutes of the Proceedings of the Second Annual Meeting*, 16; Duffy, *The Sanitarians,* 104-106; *Proceedings and Debates of the Third National Quarantine and Sanitary Convention, Held in the City of New York, April 27th, 28th, 29th, and 30th, 1859* (New York: Edmund Jones & Co., Printers to the Board of Councilmen, 1859), 21, 26, 76, 210-211, 645, 647-672.
[94] Duffy, *The Sanitarians,* 106; Viele, *Report on Civic Cleanliness*, 6, 16.
[95] According to Duffy, women on both sides of the Civil War were inspired by the efforts of Florence Nightingale. After the opening shots of the Civil War were fired, prominent New York women met the New York Infirmary for Women to find a way to establish a national body that would support the federal

Initially, there was resistance to creating the commission, which would be volunteer run and financially supported by donations; however, President Abraham Lincoln signed them into existence on June 18, 1861, to ensure that those living in the Union Army camps had sanitary living conditions. Volunteers for the USSC staffed field hospitals, raised funds through fairs in northern cities to provide supplies, and educated soldiers, officers, and government officials on health and sanitation (Figure 32).[96]

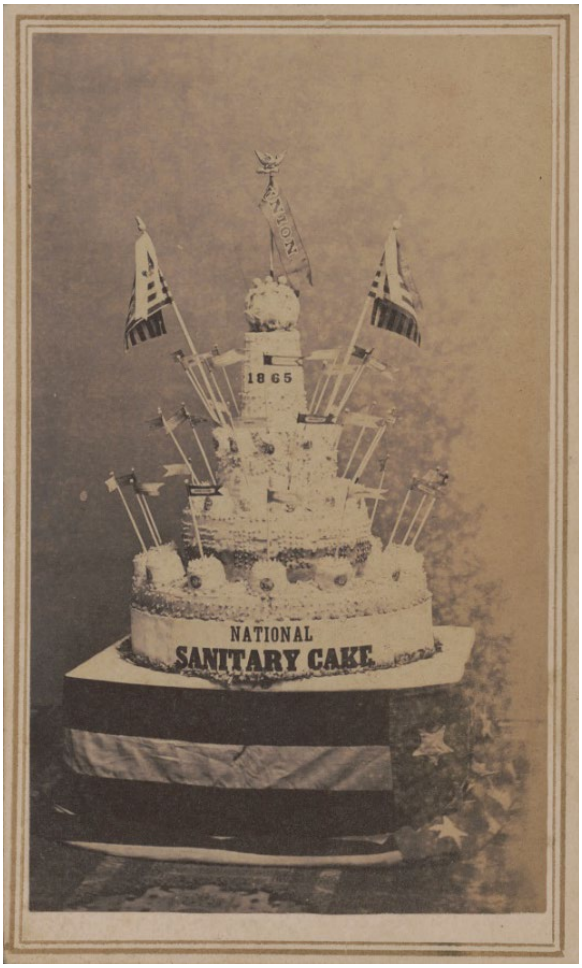


Figure 32. An example of a cake sold to raise money for the USSC.
Source: Hugh S. Anderson, National Sanitary Cake, sold at a fair in Arcata, California, to raise money for the U.S. Sanitary Commission, 1865. https://www.loc.gov/item/2019630432/

government by coordinating volunteer activities. This meeting would be the catalyst for establishment of the USSC. In addition to fundraising for the USSC, many women also volunteered as nurses.

[96] Duffy, *The Sanitarians,* 107, 112; *Metropolitan Fair in aid of the United States Sanitary Commission* (New York: Charles O. Jones, Stationer and Printer, 1864).

Earlier nineteenth century efforts to promote sanitary conditions at wartime can be seen in Florence Nightingale's studies of conditions at hospitals in the 1850s. Nightingale concluded that there were four major deficiencies in hospitals: too many sick individuals under one roof, not enough space allotted to each hospital bed, poor ventilation, and not enough sunlight. Nightingale's observations and other studies conducted during the Crimean War were taken into consideration by the USSC, who also believed wartime deaths from disease and sickness could be greatly reduced by prevention. The USSC continued the work of the sanitary conventions and tested different techniques to reduce the death toll, including the drainage at the camp sites, location of the camps, sanitary conditions in the camps, and ventilation of the living quarters and tents. Following the end of the Civil War in 1865, the USSC was disbanded.[97]

Though the USSC could not improve sanitary conditions in Confederate camps, their publication *The Sanitary Commission Bulletin* shared accounts of their usually appalling conditions. In 1864, Prescott Tracy, an ex-prisoner of war held at Camp Sumter, a Confederate prisoner-of-war camp in Andersonville, Georgia, detailed the living conditions, meals, and mental conditions of his fellow prisoners, as well as causes of death. He described the drinking water at Camp Sumter as a "stream, or more properly sewer," which received waste from the "sink," a Civil War-era term for the

[97] Florence Nightingale, *Notes on Hospitals, Being Two Papers Read Before the National Association for the Promotion of Social Science at Liverpool, in October, 1858, with Evidence Given to the Royal Commissioners on the State of the Army in 1857* (London: John W. Parker and Son, West Strand, 1859), 11, 13, 15, 18; United States, Sanitary Commission, *The Sanitary Commission of the United States Army, A Succinct Narrative of its Works and Purposes* (New York: Published for the Benefit for the United States Sanitary Commission, 1864), v; United States, Sanitary Commission, *The United States Sanitary Commission, A Sketch of Its Purposes and Its Work, Compiled from Documents and Private Papers* (Boston: Little, Brown and Company, 1863), 31.

latrine, and revealed that he and other prisoners attempted to filter the water using their blouses, haversacks, and shirts (Figure 33).[98]

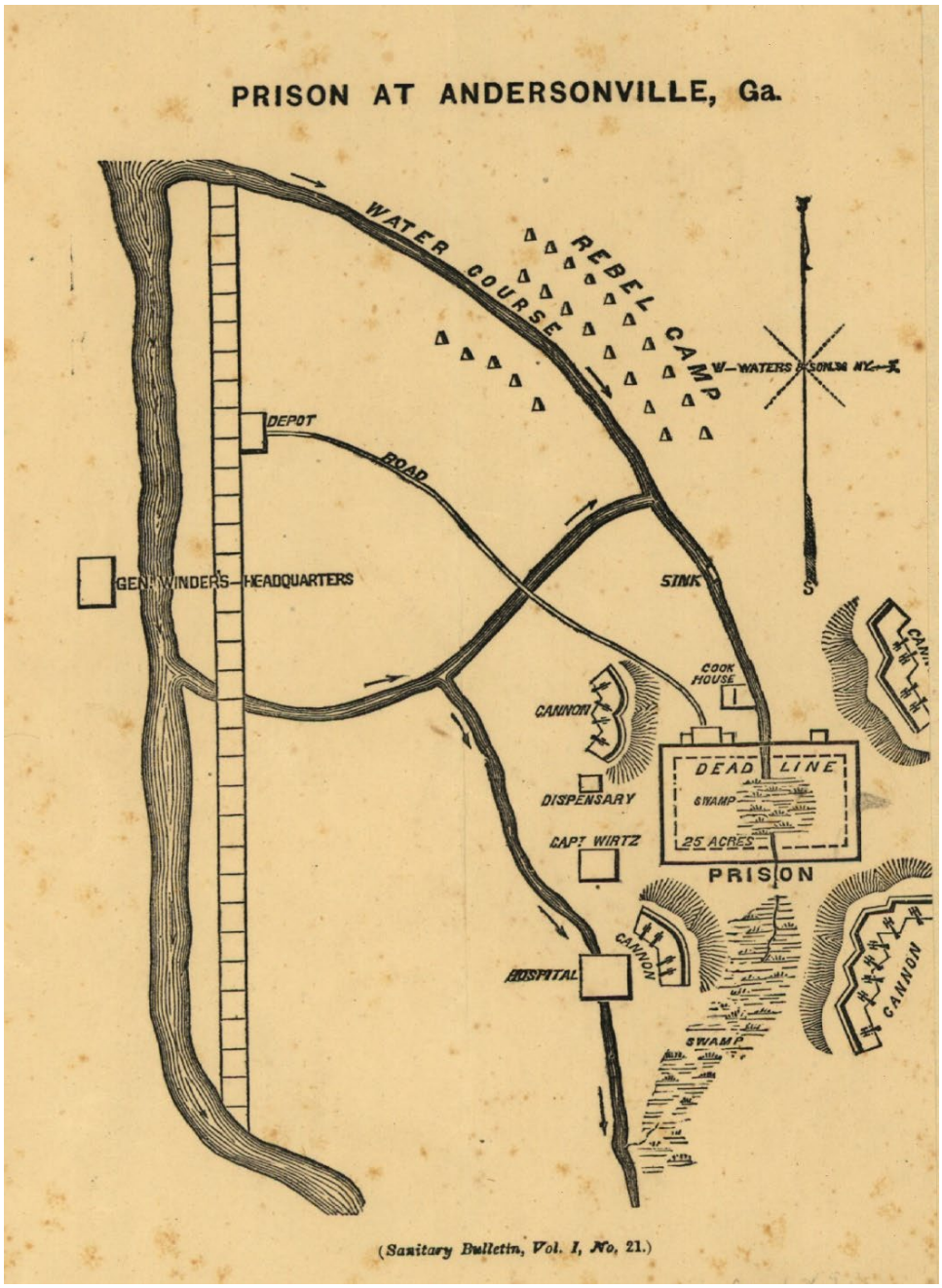


Figure 33. Map of Andersonville POW prison, with arrows noting directions of drainage. Scale not given. Source: Prescott Tracy, "Prison at Andersonville, GA., Camp Sumter," The Sanitary Commission Bulletin *1, no. 21 (1864). https://www.loc.gov/resource/g3924a.cw0134000/*

[98] Prescott Tracy, "Prison at Andersonville, GA., Camp Sumter," *The Sanitary Commission Bulletin* 1, no. 21 (1864): 652.

New Jersey: State Sanitary Commission and Board of Health

In addition to the efforts of sanitarians during the nineteenth century, the New Jersey Legislature passed sanitary laws with the goal of improving public health and reducing pollution in the state. To facilitate infrastructural development in municipalities, early acts of incorporation for cities passed by the State Legislature typically included a provision for sewer construction. For example, Section 14 of Newark's incorporation act of 1836 included the provision "for causing common sewers, drains or vaults to be made in part thereof."[99] Section 18 authorized the mayor and Common Council to sell bonds to fundraise for all actions authorized by the incorporation act. The bonds could later be repaid by raising taxes. Over the next few decades, these laws and incorporation charters were amended, and new laws were passed to fill gaps in sanitary measures. Accordingly, the following overview of sanitary law does not cover all the sanitary laws that were passed in the state; rather, it is a look at significant measures.[100]

The United States was plagued by epidemics of cholera in 1832, 1849, 1854, and 1866. In 1866, the New Jersey Medical Board argued that only governmental authorities would be able to take necessary measures, specifically sanitary laws and actions at both the city and the state levels, to prevent future epidemics. Thus, the Sanitary Commission was created through the passage of "[a]n act relative to the appointment of a Sanitary

[99] During the eighteenth century, the term common sewers was often stylized as "common shores," "Common Shewer," and "Comon Shore." It is unclear how common this stylization was, and what insights can be gleaned from further research into these terms.
[100] Dilworth, *The Urban Origins of Suburban Autonomy*, 37; New Jersey, Legislature, *Acts of the Sixtieth General Assembly of the State of New Jersey, at a Session Begun at Trenton, on the Twenty-Seventh Day on October, Eighteen Hundred and Thirty-Five. Being the First Sitting* (Trenton: William Boswell, Printer, 1836), 191-194; Carl Bridenbaugh, *Cities in the Wilderness, The First Century of Urban Life in America 1625 – 1742*, 2nd ed. (New York: Alfred A. Knopf, 1955), 159; Carl Bridenbaugh, *Cities in Revolt, Urban Life in America, 1743-1776* (New York: Alfred A. Knopf, 1955), 29.

Commission" (1866 Sanitary Commission Act) on April 5, 1866, six years before a national commission would be introduced. The Sanitary Commission consisted of five physicians to study the "general sanitary condition of the state, the causes, prevention and curative treatment of epidemic and contagious diseases, the vaccination of the indigent" with the goal of preventing, mitigating, and treating cholera. The Sanitary Commission studied the broader trends in the spread of cholera in both New Jersey and New York to accurately determine preventive methods. They also investigated the physical, natural, and built environments of cities to better understand their impact on public health.[101]

Having begun the study of public health, the state turned its attention to funding mechanisms, particularly since, following the conclusion of the Civil War and the Panic of 1873, many cities found it difficult to raise funds through the sale of municipal bonds, which discouraged public capital investment in cities. Also, during the 1870s, attitudes began to shift, and more people began to look to the government, both state and local, to oversee health measures. In 1876 the state passed "[a]n act for the construction, maintenance and operation of water works for the purpose of supplying cities, towns and villages of this state with water" (1876 Water Act; supplemented March 5, 1884). This act permitted the establishment of water companies by private individuals without requiring the state legislature to pass an incorporation act for every company. Around

[101] New Jersey, Sanitary Commission, *Report of the State Sanitary Commission, to the Governor of New Jersey for the Year 1866* (Trenton, N.J.: Printed at the Office of the State Gazette, 1867), 5-6; New Jersey, Legislature, *Acts of the Ninetieth Legislature of the State of New Jersey and Twenty-Second Under the New Constitution* (Paterson, N.J.: Printed by Chiswell & Wurts, Daily "Press" Office, 1866), 982-983.

this time, there was a clear consensus that water and sewers were necessary for public health.[102]

With the passage of "[a]n Act to establish a state board of health" (1877 Board of Health Act), the NJBOH was created out of the Sanitary Commission, although its powers were restricted at first. Its purpose was to conduct "sanitary investigations and inquiries in respect to the people, the causes of disease, and especially of epidemics and the sources of mortality, and the effects of localities, employments, conditions and circumstances on the public health."[103]

In 1880, at the direction of the National Board of Health and supervised by the NJBOH, J. Mortimer Brush and William E. Eddy demonstrated that the Bayonne Board of Health was limited by their inability to construct segments of their sewerage plan that passed through private property. Because of this, the city built temporary outlets that traversed salt meadows before the sewage was released into an open ditch.[104] Brush and Eddy recommended that the powers of local Boards of Health be expanded to permit them access to land on private property. The same year, "[a]n Act concerning the protection of the public health and the record of vital facts and statistics relating thereto" required every New Jersey municipality to have its own board of health, which

[102] Dilworth, *The Urban Origins of Suburban Autonomy*, 42, 66; New Jersey, Legislature, *Acts of the One Hundredth Legislature, of the State of New Jersey* (Paterson, N.J.: Chiswell & Wurts, Book and Job Printers, 1876), 318.
[103] New Jersey, Legislature, *Acts of the One Hundred and First Legislature of the State of New Jersey, and Thirty-Third Under the New Constitution* (Mount Holly, N.J.: William B. Wills, Printer, 1877), 220-221.
[104] A sanitary survey of Hudson County was also completed around this time, available at: https://maps.princeton.edu/catalog/princeton-k0698c21j

were later given the power to pass ordinances to impose penalties in areas of hygiene and sanitation.[105]

Cases undertaking public health issues were reported upon in the 1880 Report of the NJBOH. In Elizabeth, the distillation of kerosene oil created a sludge that diffused sulfuric acid and other noxious gases into the air as a byproduct of the processing, resulting in harm to public health. The issue was escalated into the court system, which required the owners to abate the nuisance to prevent further injury. The case illustrated that the law would lean towards protecting public health, especially when it could be demonstrated that unrestricted action had a negative impact. The case also established that ensuring public health was the duty of the State and "supreme law." In Bound Brook, Dr. Field reported on the prevalence of malaria in his town, with nearly everyone falling ill. Dr. Hunt and his fellow Bound Brook Board of Health members determined that the town's marsh was "a 'macerating reservoir of vegetable substances, causing those pestiferous exhalations…' [w]hile no doubt other evils exist, this marsh and its tributaries were the chief cause" of the spread of malaria in town. The Bound Brook Board of Health ordered the owner of an adjacent mill-dam to remove the marsh. The owners refused, and the issue was escalated to the Somerset County court. The court decided that drainage for public health was more important than private ownership of real estate, with the NJBOH writing that the Bound Brook case demonstrated that the "law must in such flagrant cases protect the protect the health of the citizen, and that even ownership in real estate is not so precious as the lives of the people… Surely the

[105] New Jersey, Board of Health, *Fourth Annual Report of the Board of Health of the State of New Jersey, 1880* (Camden, N.J.: Printed by Sinnickson Chew., 1881), 52-54; New Jersey, Legislature, *Acts of the One Hundred and Fourth Legislature of the State of New Jersey, and Thirty-Sixth Under the New Constitution* (Morristown, N.J.: Vance & Stiles, Printers, 1880), 206.

public interest requires that whole communities should not be prostrated as a result of such artificial marshes as that which fully suspended the prosperity of this growing town."[106]

In Hoboken, even though half of the city had been sewered, it was determined that a proper drainage system was needed to reclaim meadows and swamp land, reduce pollution, and keep the city clean. It remained to be seen who would pay for the completion of a comprehensive sewer system. The earliest sewers were built by individuals to address issues that affected them directly; there were not many of them, and the systems were not cohesive. It was only after municipal authorities began to plan and fund construction that comprehensive, effective sewer systems were built.[107]

In 1882, the state legislature passed "[a]n Act to authorize cities to construct sewers and drains, and to provide for the payment of the cost thereof" (1882 Sewer Act) on March 8, 1882, and gave cities the responsibility to construct, provide, maintain, and alter a sewerage system.[108] The act was intended to encourage the construction of city-wide systems at the cost of the municipality (Figure 34). Section V states that "in case the costs and expenses of such work shall exceed the amount of said benefits, the excess thereof shall be paid by the city at large, and raised by general tax; in no case shall any property or owner thereof be assessed beyond the amount of benefit actually derived from the construction of such sewer or drain." It is unclear if this stipulation could have prompted the transition away from brick sewers, which were more expensive to

[106] New Jersey, Board of Health, *Fourth Annual Report,* 17-22.
[107] Ibid.*,* 48.
[108] For more information on Newark's role in the passage of this act and the circumstances that led to the passage of this act see Stuart Galishoff's *Newark, the Nation's Unhealthiest City, 1832-1895*.

construct, or if the greater availability of concrete sewers was the catalyst. Further research is needed into the transition away from brick sewers.[109]

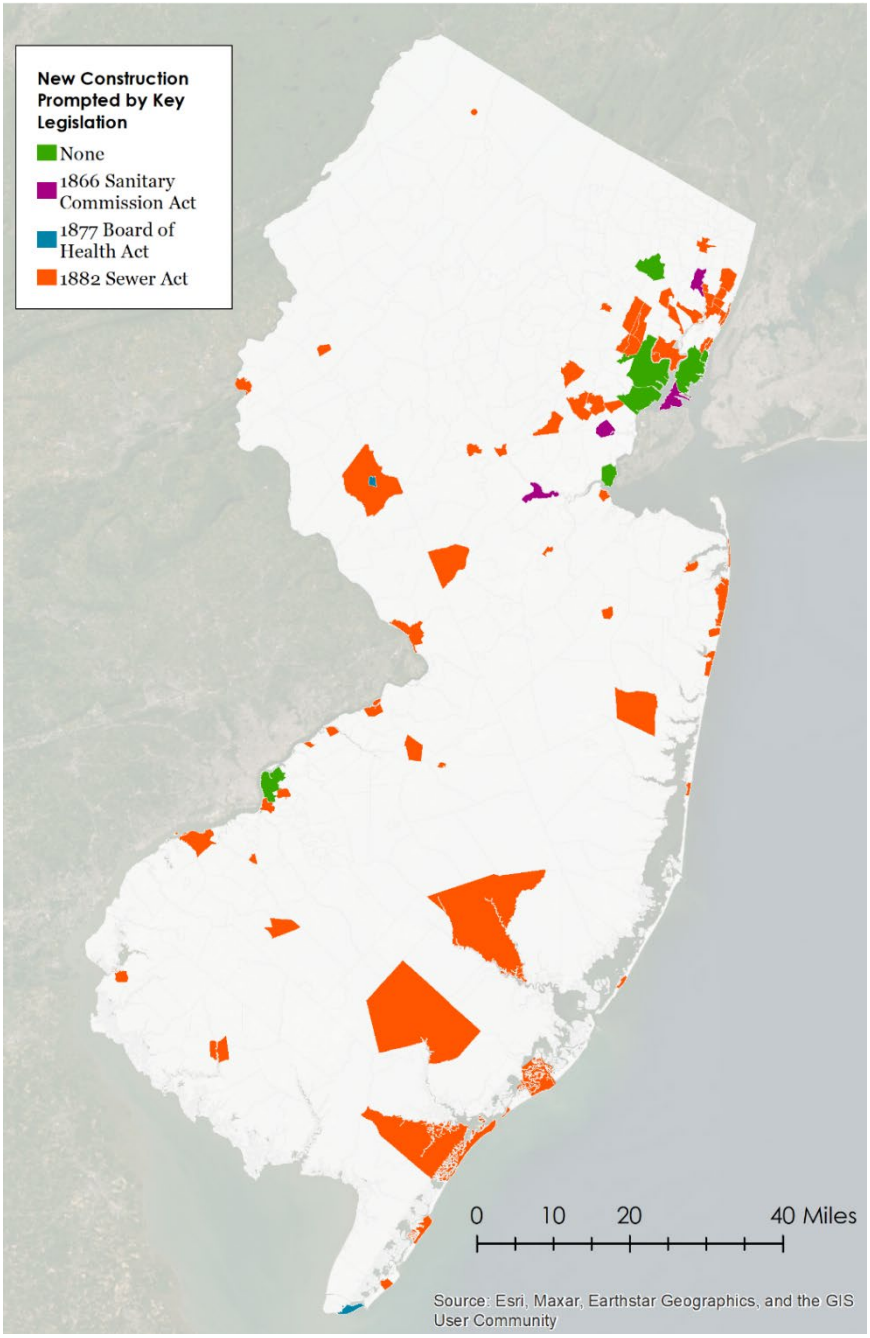


Figure 34. Sewer construction in New Jersey, by 1900.
Source: Map by Christina Servetnick.

[109] New Jersey, Legislature, *Acts of the One Hundred and Sixth Legislature of the State of New Jersey and Thirty-Eighth Under the New Constitution* (Paterson, N.J.: Carleton M. Herrick, 1882), 60-62; Galishoff, *Newark,* 251.

A second act was passed on March 27, 1882, titled "[a]n Act relating to the improvement of streets and the construction of sewers in cities of this state," which used the population of cities to establish the maximum allowable amount to be raised for the construction of sewers. For cities with populations less than 25,000, the capital sum to be raised was not to be greater than $5,000; for cities with populations between 25,000 and 50,000, the capital sum to be raised was not to be greater than $10,000; and not greater than $75,000 for cities with populations of 100,000 or greater. A few days later on March 31, 1882, "[a]n Act to provide for the payment of indebtedness incurred in excess of appropriation made to any city board having control of the improvements and reconstruction of streets and sewers" passed, which permitted an additional $3,5000 allotment for cities to improve or reconstruct sewers and streets. This was a borrowable sum that would be passed on as a tax to residents.[110]

The New Jersey Legislature continued to pass acts that created a system for broader sanitary management. In 1899, "[a]n Act to authorize two or more municipalities in this state to jointly construct and maintain outlet or trunk sewers" permitted cities to construct a joint sewer that connected municipal sewer lines into a broader system. "An Act to prevent the pollution of the waters of this state by the establishment of a state sewerage commission, and authorizing the creation of sewerage districts and district sewerage boards, and prescribing, defining and regulating the powers and duties of such commission and such boards" also passed in 1899. In the first Report of the State Sewerage Commission, the commission wrote that they would veto new sewerage systems that had potential to cause harm by way of further pollution of

[110] New Jersey, Legislature, *Acts of the One Hundred and Sixth Legislature*, 190, 235.

streams. "An Act to secure the purity of the public supplies of potable waters in this state" also passed in 1899 and prohibited the pollution of any water bodies used as a public water supply. Inspections were slow to start as money was not set aside for the purpose, but by 1905 regular testing of the water supplies of twenty-two towns was conducted. Deaths from typhoid fever, already in decline, fell further over the next two decades.[111]

On March 27, 1902, "[a]n Act to create a sewerage district to be called Passaic Valley Sewerage District" passed, which created an authority to oversee sewerage in Bergen, Essex, Hudson, and Passaic counties. A few days later, on April 3, "[a]n Act to authorize incorporated towns to construct, operate and maintain a system of sewers, or a system of sewers and drains, and to provide for the payment of the costs of the construction, operation and maintenance thereof" passed, which permitted the construction of sewers beyond municipal boundaries and connections to outlet or trunk sewers. This act also addressed other parts of a comprehensive sewer system, including filtration beds, pumping stations, etc.[112]

Passaic Valley Sewerage Commission

The Passaic River and its tributaries were the site of significant pollution during the nineteenth century; many industrial cities lined its banks and dumped factory waste into the river. Concerned by the pollution, the State Legislature passed "[a]n Act for the

[111] New Jersey, Legislature, *Acts of the One Hundred and Twenty-Third Legislature of the State of New Jersey, and Fifty-Fifth Under the New Constitution* (Trenton, N.J.: MacCrellish & Quigley, State Printers, 1899), 48, 73, 536; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission, to the Legislature, Session of 1900*, 4-5; New Jersey, Board of Health, *Twenty-Ninth Annual Report of the Board of Health of the State of New Jersey, 1905* (Trenton, N.J.: The John L. Murphy Publishing, Printers), 55-57; New Jersey, Department of Health, *Fifty-Third Annual Report,* 164.
[112] New Jersey, Legislature, *Acts of the One Hundred and Twenty-Sixth Legislature of the State of New Jersey, and Fifty-Eighth Under the New Constitution* (Trenton, N.J.: The J.L. Murphy Publishing Co., Printers, 1902), 190, 371.

consideration of a general system of sewage disposal for the valley of the Passaic river and the prevention of pollution thereof" and established the Passaic Valley Sewerage Commission (PVSC) in 1896. The condition of the Passaic River, which received 70 million gallons of untreated, raw sewage every day in 1897, was described by the PVSC as "growing bad up to 1893 had become worse in 1894, and reached a climax in 1895. The Summer of 1896 saw considerable relief, extraordinary rainfalls having increased the usual flow of the river and diluting the sewage, so as to relieve the nuisance materially."[113]

The PVSC studied the causes of the pollution and recommended sewage be chemically treated by all cities across the state. However, it was difficult to convince some engineers. For example, Ernest Adam, the Engineer of Street and Sewer Departments in Newark, reported his preference for constructing a main intercepting sewer alongside the Passaic River instead of chemically treating the sewage before releasing it into the Newark Bay, as recommended by the PVSC in 1897. Adams referred to the lack of success in chemical treatment of sewage and intermittent filtration as seen in East Orange and Summit, which used filtering beds.[114]

PVSC further recommended that the state set standards for the condition of the sewage before it enters waterways and forestall human waste from entering the water.[115] In 1897, the "[a]ct to prevent the willful pollution of the waters of the Passaic river, and

[113] New Jersey, Legislature, *Acts of the One Hundred and Twentieth Legislature of the State of New Jersey, and Fifty-Second Under the New Constitution* (Trenton, N.J.: MacCrellish & Quigley, Current Printers, 1896), 20; Passaic Valley Sewerage Commission, *Report of the Passaic Valley Sewerage Commission*, 11-14.
[114] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 56.
[115] The original facilities constructed by the end of 1924 provided primary treatment for approximately 150 million gallons per day, twice as much as the daily sewage amount entering the Passaic River in 1897.

of the tributaries thereof, above the great falls of the Passaic river at Paterson" was passed, followed by the passage of the 1899 "[a]ct to authorize two or more municipalities in this state to jointly construct and maintain outlet or trunk sewers" (Figure 35).[116] The purpose of the trunk sewer was to collect the sewage from the cities lining the Passaic River and move the outfall point from the Passaic River to the Newark Bay (Figure 36).[117]

Figure 35. Concrete outfall pipes of the PVSC system.
Source: Passaic Valley Sewerage Commission, Construction of outfall pipe, 1920s.
https://nj.gov/pvsc/who/history/photos/images/plant/img020.jpg

[116] The PVSC engineers planned the system to construct a sewer outlet with a shaft house in the New York Bay, which required permission from Congress, who did ultimately grant the power to construct in 1910. Even before Congress permitted the construction to proceed, the State of New York was not keen to allow wastewater to be released into waters adjacent to the state through a trunk sewer, as per the 1906 *Documents of the Senate of the State of New York*. The State of New Jersey did not immediately rectify this, which led to lawsuits, which were decided in the United States Supreme Court. See George Warren Fuller's *Sewage Disposal* for a comprehensive overview of the lawsuits.
[117] New Jersey, Legislature, *Acts of the One Hundred and Twenty-First Legislature of the State of New Jersey, and Fifty-Third Under the New Constitution* (Trenton, N.J.: MacCrellish & Quigley, Current Printers, 1897), 99; New Jersey, Legislature, *Acts of the One Hundred and Twenty-Third Legislature,* 48; Passaic Valley Sewerage Commission, *Report of the Passaic Valley Sewerage Commission*, 23-24.

Figure 36. Wooden frame for the construction of a PVSC outfall pipe.
Source: Passaic Valley Sewerage Commission, Construction of outfall pipe, 1920s.
https://nj.gov/pvsc/who/history/photos/images/plant/img148.jpg

The PVSC also recommended the creation of additional drainage districts throughout the state, each overseen by a commission, to reduce pollution. This was enacted in the 1902 "[a]ct authorizing the appointment and defining the powers and duties of commissioners in sewage and drainage districts created for the purpose of relieving the streams and rivers therein from pollution, and to provide a plan for the prevention thereof, and providing for the raising, expenditure and payment of moneys necessary for this purpose." From the original recommendation in 1897 to service four counties, encompassing twenty-seven municipalities and hamlets, with a trunk sewer, today PVSC serves five counties and forty-eight municipalities (Figure 37). Sanitary law transitioned from municipal level action to manage public health outbreaks into cooperation between multiple municipalities to manage pollution.[118]

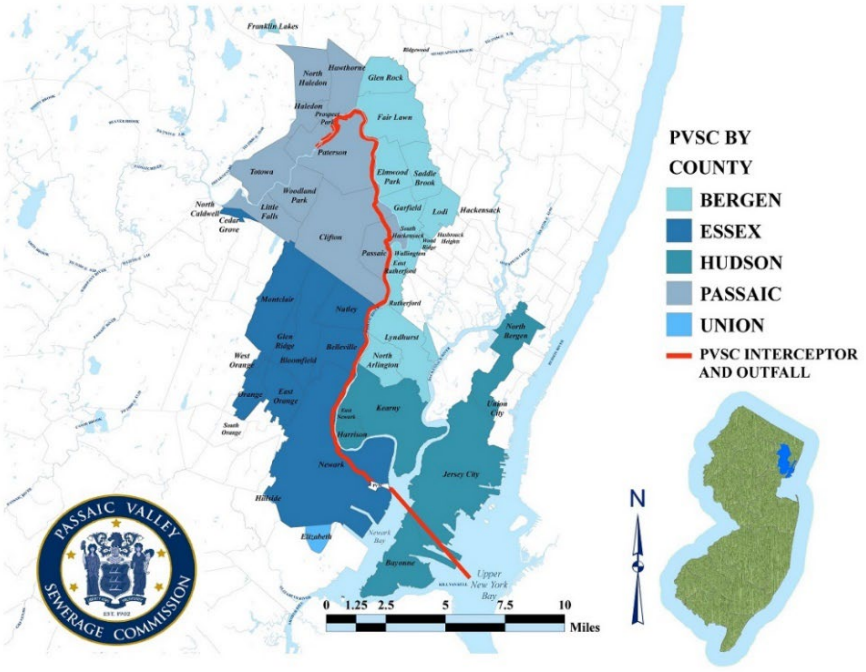


Figure 37. PVSC's current service area.
Source: Passaic Valley Sewerage Commission, 2022.
https://nj.gov/pvsc/library/secondary/service_area_map_smnew.jpg

[118] Passaic Valley Sewerage Commission, *Report of the Passaic Valley Sewerage Commission*, 20-21; New Jersey, Legislature, *Acts of the One Hundred and Twenty-Sixth Legislature,* 195.

"Disposal by Dilution"

By the end of the nineteenth century, both the Passaic Valley Sewerage Commission and the State Sewerage Commission frowned upon the practice of dilution, citing the pollution of the Passaic River, where 70 million gallons of untreated raw sewage was dumped every day. An 1896 study found *Escherichia coli*, which marked the presence of feces in the water, and *Salmonella enterica* subsp. *enterica*, which causes Typhoid Fever, in the Passaic River. The water samples, after being left to stand for six hours, produced a range of odors from "disgusting" to "offensive" to "very offensive" to "decidedly offensive" to "extremely offensive" to "an odor of putrefaction" to "a very disagreeable odor of putrefaction."[119]

The State Sewerage Commission, in 1900, observed that adequate treatment of sewage was onerous and expensive in a combined system. However, the Commission also acknowledged that it would be difficult to split existing combined systems into separate systems. Twentieth century sanitary engineers also began to promote separate storm water and sanitary sewers, citing the pollution of water bodies. Since many cities relied on freshwater bodies for their water supply, downstream communities were especially affected. Accordingly, the Sewerage Commission broadly recommended state-level oversight to ensure that municipalities were not endangering each other, accomplished by mandating better methods of sewage disposal.[120]

---

[119] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 4; Richard M. Connolly, "Bacteriologist's Reports," in *Report of the Passaic Valley Sewerage Commission, Upon the general system of sewage disposal for the valley of the Passaic River, and prevention of the pollution there*, ed. Passaic Valley Sewerage Commission, (Newark, N.J.: John E. Rowe & Son, Printers, 1897), 71-82.

[120] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 4, 7; Outwater, *Water*, 142.

In 1909, "[a]n Act to empower municipalities to establish and maintain plants for the treatment, disposal or rendering of sewage" passed. Similar to the 1882 Sewer Act, this act allowed cities to issue bonds to pay for construction and other associated costs; however, it did not specify the expected level of treatment which should occur at these plants. It is likely that standards were set by the Board of Health, which was given the authority to approve plans. It appears that existing treatment plants were insufficient as a second act was passed in 1912, "[a]n Act to empower towns having plants for the treatment, disposal or rendering of sewage to reconstruct and enlarge such plants, and to issue bonds to pay the cost thereof." As the government pushed for treatment plants, some sanitary engineers noted their reluctance to disavow disposal by dilution because it was a useful tool. Their perspective considered the fact that disposal by dilution was the predominant method in places where the water body was not yet overburdened by sewage; however, it was often litigation that pushed municipalities to consider sewage treatment.[121]

Financial Woes: Sewer Construction and Judicial Relief

During the latter half of the nineteenth century a complex aggregation of factors likely culminated in key legislative actions (and later amendments and additive laws). The rapidly growing cities were faced with a multitude of difficulties. First, they were much more densely populated than the farms and small towns of early settlers; an individual's sanitation and health affected many others in a city. On the other hand, they

[121] New Jersey, Legislature, *Acts of the One Hundred and Thirty-Third Legislature of the State of New Jersey, and Sixty-Fifth Under the New Constitution* (Paterson, N.J.: The News Printing Co., State Printers, 1909), 138-139, 142; New Jersey, Legislature, *Acts of the One Hundred and Thirty-Sixth Legislature of the State of New Jersey, and Sixty-Eighth Under the New Constitution* (Trenton, N.J.: MacCrellish & Quigley. State Printers. Opposite Post Office, 1912), 93-94; George W. Fuller, *Sewage Disposal* (New York: McGraw-Hill Book Company, 1912), 204.

were easier to be overseen by the government in a city. However, because municipalities backed the initial investment in sanitary structures and relied on the sale of municipal bonds to raise collateral, they were hindered by the Panic of 1873. Second, some cities like Elizabeth, Jersey City, and Rahway reached the brink of bankruptcy; some, like Elizabeth and Newark, were sued by their residents. In response to its bankruptcy, Jersey City spent less on infrastructure improvements and created a bureau of civil engineering and surveying, which would be tasked with carrying out future improvements. Though the breadth of these lawsuits and a comprehensive survey of cities that filed for bankruptcy is outside the scope of our work, a brief overview provides insight into legislation.[122]

Multiple cases were filed over the course of the nineteenth century; however, it is likely that the Panic of 1873 prompted an influx of cases into the Court of Chancery and the Court of Errors and Appeals, precursors to the New Jersey Superior Court and the New Jersey Supreme Court, respectively.[123] Generally, the cases followed a pattern: the municipality would assess a property owner for the costs of improvements, there would be a disagreement over repayment, the city would attempt to, or would, repossess private property, and the dispute would make its way into the court system. One of the cases that exemplified this was *Dusenbury and others v. The Mayor and Common Council of the City of Newark* decided October 1874. In 1869, the landowners along

[122] Paul Israel, "The Garden State Becomes an Industrial Power: New Jersey in the Late Nineteenth Century," in *New Jersey: A History of the Garden State*, ed. Maxine N. Lurie and Richard Veit (New Brunswick: Rutgers University Press, 2012), 195.
[123] The Court of Errors and Appeals was the highest court in the state until it was abolished in 1947 and replaced by the New Jersey Supreme Court. Other cases include but are not limited to *The State, The Hoboken Land and Improvement Company, Relator v. Oliver L. Marvin, Treasurer and Collector of the Bulls Ferry Road Sewer Assessment, in the Township of Weehawken*, 51 N.J.L. 285 (New Jersey Supreme Court 1889). One case in which the assessor sued the municipality was *Wilmon W. C. Sites v. Inhabitants of the Township of West Hoboken,* 45 N.J.L. 428 (New Jersey Supreme Court 1883).

Fairmount Avenue agreed to improvements, including curbing and flagging the sidewalks. Though work should have been completed in one year, it took the contractor nearly three years, and they used materials inferior to those agreed upon in the initial assessment. According to the landowners, inferior materials should have meant a lower repayment. However, according to the charter of the City of Newark, the city was empowered to repossess the properties along Fairmount Avenue to pay off the assessments. Three key arguments were used in the judgement, which dismissed the claim, and were seen in later, similar cases.[124]

The first argument given was that the complainant(s), either a single or group of property owner(s), had not filed their lawsuit before the statute of limitations expired. It is unclear what the statute of limitations was for filing a lawsuit for municipal assessments to property owners. In *Dusenbury and others v. The Mayor and Common Council of the City of Newark*, the assessment to the landowners was made in 1869, the work was completed in 1872, at which point the City of Newark had finished paying the contractor; however, the complainants waited until 1874 to file a case even though they were aware that inferior materials were used.[125]

A second, closely related argument was that the claimant had not pursued relief by *certiorari*, wherein a decision could be reviewed by someone with greater authority. For example, *George W. Smith v. The Mayor and Common Council of the City of Newark* was dismissed in February 1880 because the complainant did not approach circuit or supreme courts for relief, especially since the Court of Chancery felt it was not

[124] *Dusenbury and others v. The Mayor and Common Council of the City of Newark*, 25 N.J. Eq. 295, 296 (Court of Chancery 1874).
[125] Ibid.

empowered to make decisions on equity. It appears that relief by *certiorari* also had a statute of limitations. For example, *Lewis v. The City of Elizabeth and Aitkin, Comptroller*, decided in October 1874, was dismissed because the claimant's lawsuit was filed more than one year after the assessment was approved.[126]

The third reason was that misrepresentation of the assessment did not permit the court to overturn the tax. For example, in *Dusenbury v. Mayor and Common Council of Newark*, the judgement stated that the court could not "restrain the collection of a tax which is illegal or void, merely because of its illegality, but there must be some special circumstances attending the injury threatened, to bring the case within some recognized head of equity jurisprudence." Essentially, the court needed a different reason to terminate the repayment or provide judicial relief to the complainant other than the inaccuracy of the assessment due to the use of inferior materials, particularly since the landowners saw the construction occur with inferior materials and the municipality already paid against the original assessment. Amongst the cities that were sued by private residents, the City of Elizabeth presented an interesting case study where the funding mechanism failed and led the city to default on a loan.[127]

Case Study of Elizabeth

The 1858 supplement to its incorporation act empowered the City of Elizabeth to assess the whole amount of costs, damages, and expenses for sewer construction and present a "just and equitable assessment thereof, either in whole or in part, upon the

[126] *George W. Smith v. The Mayor and Common Council of the City of Newark,* 32 N.J. Eq. 1, 5 (Court of Chancery 1880); *Lewis v. The City of Elizabeth and Aitkin, Comptroller*, 25 N.J. Eq. 298, 301 (Court of Chancery 1874).
[127] *Dusenbury and others v. The Mayor and Common Council of the City of Newark*, 25 N.J. Eq. 295, 297 (Court of Chancery 1874).

owners of all the lands and real estate benefited thereby, in proportion, as nearly as may be, to the advantage each shall be deemed to acquire." Other improvement expenses were either imparted in whole to property owners or divided, with property owners paying for two-thirds of the total expense and the City of Elizabeth paying the remaining one-third. This is reflected in the 1863 revised and amended charter for the city. To determine the loan amount, the city council was responsible for calculating the full cost of construction, which would be divided proportionally between property owners. If property owners did not repay the assessment made to them, the city council could give a two weeks' notice, followed by a sixty-day waiting period for repayment. If repayment did not occur, the city council could either bring legal action or collect the assessment through public sale of the property. According to the 1863 charter, the property would be a lien "from the time when said improvement shall have been made." Though it did not specifically include sewers, this stipulation was "for the payment of the costs, damages and expenses of laying out and opening, altering, widening or straightening any street, road, highway or alley."[128]

Following the Civil War, this mechanism was used to make improvements when speculators and contractors purchased acreages of farmland, forests, and meadows at the rate of a few dollars per acre. Between 1865 and 1874, the purchased acreages were divided into lots, more than 200 new streets were opened, and the land value increased to thousands of dollars for a single lot. It is likely that the city paid the higher rate when they purchased land to make improvements, which was partly the reason the city's debt

[128] New Jersey, Legislature, *Acts of the Eighty-Second Legislature of the State of New Jersey, and Fourteenth Under the New Constitution* (Morristown, N.J.: Printed by Louis C. Vogt, 1858), 344-350; New Jersey, Legislature, *Acts of the Eighty-Seventh Legislature of the State of New Jersey, and Nineteenth Under the New Constitution* (Newark: Printed by E.N. Fuller, Daily Journal Office, 1863), 148.

grew. The debt grew more as the city took out contracts and bonds to make improvements in these newly laid out areas. They planned to bill homeowners after houses were constructed on the empty lots. By 1868, the city's debt was up to $976,952, mostly made up of street improvements, including lighting, paving, and sewering. The Panic of 1873 resulted in the devaluation of land and ended construction of homes in the newly developing areas but did not reduce the city's debt.[129]

Under these economic conditions, people were disinclined to pay their assessment for sewer construction, but the city needed to recoup its money to avoid bankruptcy. A litigatory environment emerged, with landowners filing lawsuits against the municipality, like *Bogert v. The City of Elizabeth*. Bogert's case was dismissed in 1874; he then appealed his case to the Court of Errors and Appeals, who in June 1876 determined that there was no statute of limitations on *certiorari*. The court also determined that the Common Council could not assess property owners for construction, which voided any pending payments from property owners. Additionally, the Common Council could not execute this proportional division of benefits received by the owners, stating

> [t]he direction is perfectly clear; the entire burthen [sic] is to be borne by the land along the line of the improvement, and the ratio of distribution among the respective lots is left to the judgement of the common council. Such a power, according to legal rules now at rest in this state, cannot be executed. The whole clause is nugatory and void, and all proceedings under it are not mere irregularities, but are nullities.

By voiding the clause, the court voided the lien placed on the property, which meant that municipalities could not repossess property in order to recoup the debt. Following this

[129] *The City of Elizabeth, New Jersey, Illustrated, Showing its Leading Characteristics: its Attractions as a Place of Residence, and its Unsurpassed Advantages as a Location for Manufacturing Industries* (Elizabeth, N.J.: Printed by The Elizabeth Daily Journal), 24-26; Jean-Rae Turner and Richard T. Koles, *Elizabeth, The First Capital of New Jersey* (Charleston: Arcadia Publishing, 2003), 96.

ruling, the city repaid any payments received from property owners with 7% interest. This worsened the city's financial plight. The city's cache of funds was depleted and covering expenses and loan repayments would have required increasing the tax rate by at least 5 to 6%, which was exorbitant for its residents. By February 1879, the debt was $5.6 million, and the city ultimately defaulted on its loan.[130]

The litigations against municipalities nearing bankruptcy in pursuit of infrastructural improvements appeared to have an impact on sewer construction laws, including the 1882 Sewer Act. First, the litigatory environment following the Panic of 1873 might have prompted Section VII, which stated that after thirty days of the assessment of costs, landowners could not apply for relief by *certiorari*. Second, likely intending to prevent bankruptcy, the 1882 Sewer Act required an annual tax levy that would raise more than the assessed amounts for the upcoming fiscal year. Third, the term "benefits" was clarified. In Elizabeth, it was unclear if "benefits" was the proportion of the sewer laid in front of your house or the increase in property value from sewer construction. However, historic evidence suggested that benefits referred to property value, because the lawsuits following the Panic of 1873 were prompted by the devaluation of property. Thus, in the 1882 Sewer Act, if the Board of Alderman determined that "the construction of such sewer or drain is likely to benefit and increase the value of any lands and real estate in the vicinity thereof," there was the potential to reassess the property value and therefore increase the property tax. According to Section V, of the 1882 Sewer Act, benefits assessments should be proportional to the property

[130] *The City of Elizabeth,* 24-29; *Bogert v. The City of Elizabeth*, 27 N.J. Eq. 568, 569, 570 (Court of Errors and Appeal 1876); "City of Elizabeth," in *History of Union County, New Jersey, 1664 -1923*, ed. A. Van Doren Honeyman, (New York: Lewis Historical Publishing Company, Inc., 1923), 323.

and should be less than the total construction costs assigned to the property, which were proportionally divided from the total construction costs. Additionally, if construction costs exceeded the benefits assessed, the difference would be paid for by the city, with funds raised from taxes. Section V stated that

> lots or parcels of land and real estate peculiarly benefited by such sewer or drain…which assessment shall in each case be in proportion, as near as may be, to the advantage which each of such owners shall be deemed to have acquired by the construction of such sewer or drain; in case the costs and expenses of such work shall exceed the amount of said benefits, the excess thereof shall be paid by the city at large, and raised by general tax; in no case shall any property or owner thereof be assessed beyond the amount of benefit actually derived from the construction of such sewer or drain.

In Elizabeth, the stipulation to implement a city-wide tax was not seen favorably by residents who had already paid for their own municipal improvements. Attempts to resolve this resentment can be seen in "[a]n Act to authorize cities to commute and adjust for a fixed sum the payment by abutting land owners of special sewer taxes," passed in 1886. This payment considered the amount previously paid by the landowner in determining the fixed amount the property owner would pay to be absolved of future special sewer taxes.[131]

In addition to the legislative and judicial background, New Jersey's geography and history further contextualize the emergence of brick sewers in the state.

[131] New Jersey, Legislature, *Acts of the One Hundred and Sixth Legislature*, 61-64; New Jersey, Legislature, *Acts of the Eighty-Second Legislature*, 344; *The City of Elizabeth,* 30; New Jersey, Legislature, *Acts of the One Hundred and Tenth Legislature of the State of New Jersey, and Forty-Second Under the New Constitution* (Trenton, N.J.: MacCrellish & Quigley, Printers, 1886), 78.

6. Contextualizing New Jersey

Geography

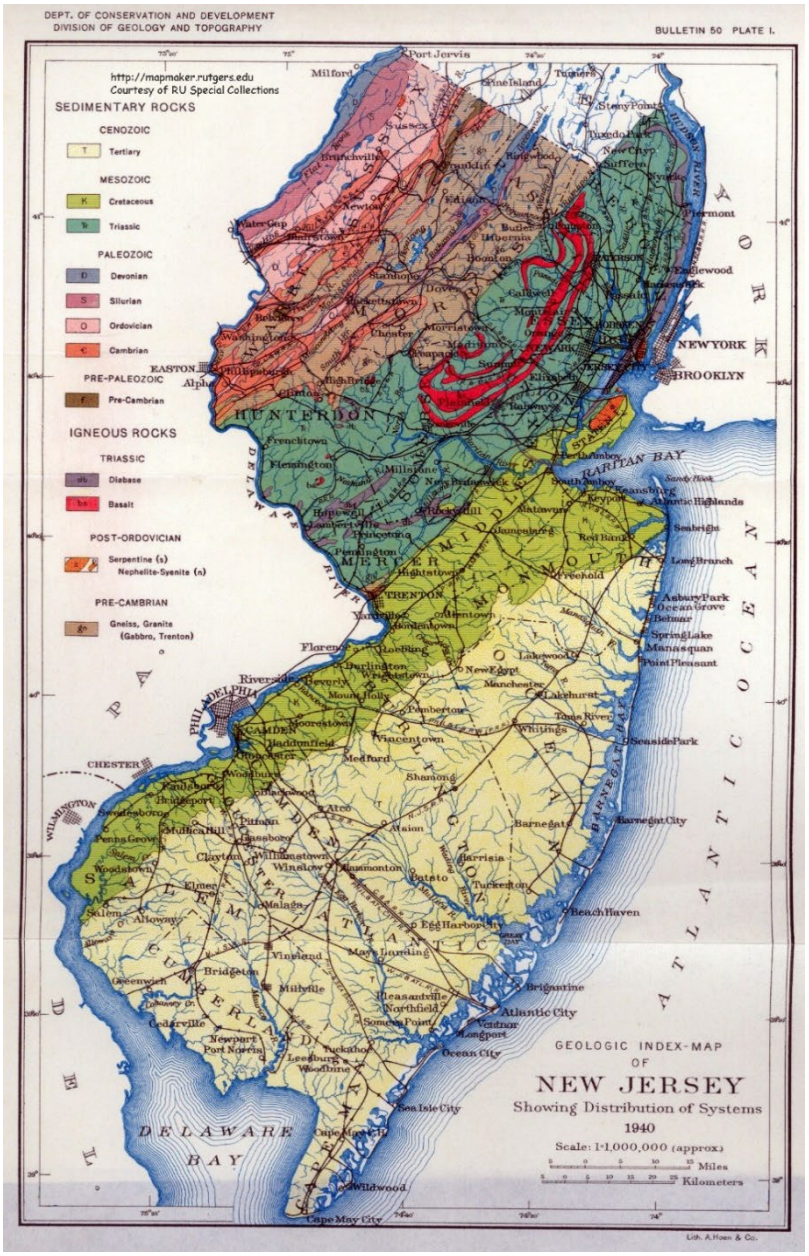


Figure 38. Geologic map of New Jersey.
Source: A. Hoen & Co., Geologic Index Map of New Jersey, Showing Distribution Systems, 1940.
http://mapmaker.rutgers.edu/HISTORICALMAPS/NJ_Geology_1940.jpg

The State of New Jersey is bordered by the Atlantic Ocean on its eastern coastline and the Delaware River on the west (Figure 38). Historically, the state's many rivers,

including the Delaware, Hackensack, Hudson, Passaic, and Raritan, transported goods and people. In addition to settlements at port cities, the rivers provided an opportunity for inland settlements at the furthest navigable point of the river to become commercial hubs. New Jersey's location between the cities of New York City and Philadelphia also influenced the growth of the state.[132]

Historic Context

European Exploration and Settlement

Native Americans had lived in what is now the State of New Jersey for thousands of years before European explorer Henry Hudson made the first recorded landing in 1609. He and his crew dropped anchor near Sandy Hook and met the Native American population before continuing north up what is now known as the Hudson River.[133]

Early seventeenth century Dutch, English, and Swedish settlements along the Delaware and Hudson Rivers provided an opportunity for settlers to lay claim to the land and compete for trade, particularly fur. The next few decades were a tumultuous period; the power struggle culminated in 1664, when the British crown replaced Dutch colonial rule and established a proprietorship to govern the colony.[134]

---

[132] David Listokin, Dorothea Berkhout, and James W. Hughes, *New Brunswick, New Jersey, The Decline and Revitalization of Urban America* (New Brunswick, New Jersey: Rutgers University Press, 2016), 4.
[133] Herbert C. Kraft and R. Alan Mounier, "The Late Woodland Period in New Jersey (ca. 1000 – 1600 AD)," in *New Jersey's Archeological Resources, A Review of Research Problems and Survey Priorities: The Paleo-Indian Period to Present*, ed. Olga Chesler (Trenton: New Jersey Historic Preservation Office, 1982), 139; Richard Veit, "Setting the Stage, Archaeology and the Delaware Indians, a 12,000-Year Odyssey," in *New Jersey: A History of the Garden State*, ed. Maxine N. Lurie and Richard Veit (New Brunswick: Rutgers University Press, 2012), 6; John P. Snyder, *The Story of New Jersey's Civil Boundaries, 1606-1968* (Trenton, N.J.: Bureau of Geology and Topography, 1969), 1.
[134] Veit, "Setting the Stage," 19-21; Peter O. Wacker, "New Jersey's Cultural Resources: A.D. 1660-1810," in *New Jersey's Archeological Resources, A Review of Research Problems and Survey Priorities: The Paleo-Indian Period to Present*, ed. Olga Chesler (Trenton: New Jersey Historic Preservation Office, 1982), 199; Maxine N. Lurie, "Colonial Period: The Complex and Contradictory Beginnings of a Mid-Atlantic Province," in *New Jersey: A History of the Garden State*, ed. Maxine N. Lurie and Richard Veit (New Brunswick: Rutgers University Press, 2012), 35.

The proprietors promised religious freedom to encourage settlement in the state. However, slavery, which began with the earliest settlements, persisted throughout English colonial rule. In 1674, political machinations divided the colony into West Jersey and East Jersey. Settlers in New England moved to present-day Essex, Middlesex, Monmouth, and Union counties; Dutch farmers previously living on Long Island moved to northern Monmouth and Somerset counties; and Swedes, Finns, and English Quakers settled the southern and southwestern areas of the state.[135]

The proprietors planned for Burlington, the capital of West Jersey, and Perth Amboy, the capital of East Jersey, to become administrative and port centers, and for Elizabeth, Newark, and Piscataway to be religious and social centers. Some cities like Morristown and Newton grew because the proprietors had established court houses there; others, including New Brunswick and Trenton, grew along preexisting Lenape trails, which facilitated trade. In 1702 West and East Jersey were reunited into a single New Jersey and the system of proprietorship was replaced with a royal governor.[136]

Industrial Development

Though the colony's economy was primarily agricultural throughout the eighteenth century, industries also developed in colonial New Jersey due to the availability of abundant natural resources and lower-cost water transportation routes. Mills processed lumber, grain, and other products. Atlantic White Cedar, sourced from the Pine Barrens, was used to make barrel staves and shingles for shipments to New York City, Philadelphia, and as far as the Caribbean.[137] Before it was the Garden State,

[135] Lurie, "Colonial Period," 33, 38; Wacker, "New Jersey's Cultural Resources: A.D. 1660-1810,"199-200.
[136] Lurie, "Colonial Period," 40, 54; Wacker, "New Jersey's Cultural Resources: A.D. 1660-1810," 204-205.
[137] Atlantic White Cedar is now the focus of restoration efforts by the DEP.

New Jersey was one of the "Bread Colonies," so nicknamed for its export of ground wheat flour. The iron industry drove the growth of the Highlands of northern New Jersey and the Pine Barrens in southern New Jersey, and early ceramic, glass, and other industries were established. The colony was well situated to participate in a world outside its borders through immigration and trade.[138]

Following the Revolutionary War, the newly established United States of America experienced more turmoil before the close of the eighteenth century, including a countrywide depression, reduced demand for agricultural goods, and insufficient printed currency. Efforts were made to promote industrial activity in the state. In 1792, the Society for Establishing Useful Manufactures (SUM) established Paterson along the Passaic River, where the Great Falls provided power for mills.[139]

Initially, handcrafted goods were valued more than factory-produced ones, however, manufacturing evolved as the country exited the Civil War. Huge factories were employing hundreds of people, which created a concentrated work force in cities like Camden, Elizabeth, Jersey City, Newark, Paterson, and Trenton who produced textiles, consumer products, and numerous other goods. Other smaller cities located close to rail or water transportation grew their fortunes through industry. Expansions of the telegraph and railroad system nationwide, faster trans-Atlantic shipping, and

[138] Wacker, "New Jersey's Cultural Resources: A.D. 1660-1810," 209-210; Lurie, "Colonial Period," 40-41, 55.
[139] John Fea, "Revolution and Confederation Period: New Jersey at the Crossroads," in *New Jersey: A History of the Garden State*, ed. Maxine N. Lurie and Richard Veit, (New Brunswick: Rutgers University Press, 2012), 84; Graham Russell Gao Hodges, "New Jersey in the Early Republic," in *New Jersey: A History of the Garden State*, ed. Maxine N. Lurie and Richard Veit, (New Brunswick: Rutgers University Press, 2012), 90- 106; Wacker, "New Jersey's Cultural Resources: A.D. 1660-1810," 214-215; Michael Birkner, "New Jersey in the Jacksonian Era, 1820-1850," in *New Jersey: A History of the Garden State*, ed. Maxine N. Lurie and Richard Veit, (New Brunswick: Rutgers University Press, 2012), 123.

telegraph cables that permitted communications with a European market kept New Jersey's industrially produced goods in demand with a wider reach.[140]

Population

New Jersey, like most of the United States at the start of the nineteenth century, was overwhelmingly rural. While the state's population was 226,861 in 1810, less than 6,000 lived in urban areas. Much of the state's landscape was agrarian; however, improvements in farming technologies led to the introduction of mechanized processes that reduced the need for farm labor. This catalyzed the movement of people from farmland to cities in search of work by the mid-nineteenth century. Between 1790 and 1830, the population doubled.[141]

Neither the Civil War nor an economic depression in the 1870s could slow New Jersey's growth. In 1830, only 6% of the state's 320,000 residents lived in cities, whereas by 1870, 50% of the state's 906,096 residents lived in cities. The nineteenth century witnessed the transformation of the urban landscape of New Jersey.[142]

Transportation

The movement of people along pre-existing Native American routes provided a blueprint for the early transportation network across the state.[143] The Manunkachunk branch of the Great Minisink Trail formed part of modern Route 22. The Assanpink Trail ran from present-day Elizabeth to New Brunswick and onto the Delaware River,

[140] Larrabee, "New Jersey's Cultural Resources: A.D. 1800-1865," 224; Israel, "The Garden State Becomes an Industrial Power," 179.
[141] Hodges, "New Jersey in the Early Republic," 90-91; Larrabee, "New Jersey's Cultural Resources: A.D. 1800-1865," 221-223.
[142] Jone Johnson Lewis, "Sanitary Commission (USSC)," *ThoughtCo* (February 19, 2019); Melosi, *The Sanitary City*, 315-316.
[143] Some contemporary examples of Native American routes and their adoption into the modern road network can be found in John P. Snyder's *The Story of New Jersey's Civil Boundaries, 1606-1968*.

near present-day Trenton, and formed the intercolonial post road, King's Highway, which is now modern-day Route 27. It was later expanded to connect to New York City and Philadelphia. These routes were not only important for commerce, but also communication. Improvements to, and innovations in, steam power technology and its use in ferry boats, as well as the development of a transportation network comprised of turnpikes, canals, and railroads were significant to the movement of goods and people across the state. By the time steam power technology was refined for use in ferry boats, ferries using man- and horsepower had already been in use for over a century. Cities like Camden and New Brunswick, located along the Delaware and Raritan Rivers, respectively, established ferry services in the late seventeenth and early eighteenth centuries.[144]

Turnpikes were planned and constructed in the first half of the eighteenth century and helped the growth of certain towns into major population centers. Some of these roads are not part of the modern turnpike network but are generally still major corridors across the state. For example, the 1804 Straight Line Turnpike from Trenton to New Brunswick has since been integrated into the modern U.S. 1. New Brunswick was a terminal port for other turnpikes, including the Essex and Middlesex Turnpike (present-day Route 27 North from New Brunswick), which connected New Brunswick and Newark, and the Georgetown and Franklin Turnpike (present-day Route 27 South from Kendall Park to County Route 518 to Lambertville), which connected Lambertville and New Brunswick.[145]

---

[144] Snyder, *The Story of New Jersey's Civil Boundaries, 1606-1968*, 1; Listokin, Berkhout, and Hughes, *New Brunswick*, 4.
[145] Larrabee, "New Jersey's Cultural Resources: A.D. 1800-1865," 225; Listokin, Berkhout, and Hughes, *New Brunswick,* 5.

The canal and railroad networks were constructed in the early 1820s, though the railroads proved to be more successful long-term.[146] The canals moved ships and barges across the state and connected major industrial cities. The Delaware and Raritan Canal and the Morris Canal were two of the state's most important canals. The Morris Canal was chartered in 1824 and opened in 1831, ran from Phillipsburg to Jersey City, and predominantly carried coal, fertilizer, and lime. The canal was obsolete by 1900 and was eventually closed by 1924. The Delaware and Raritan Canal was chartered in 1830, opened in 1834, and operated until 1933. Most of the boats that passed through the Delaware and Raritan Canal carried coal, though personal conveyances also used it. The canal connected Bordentown and New Brunswick.[147]

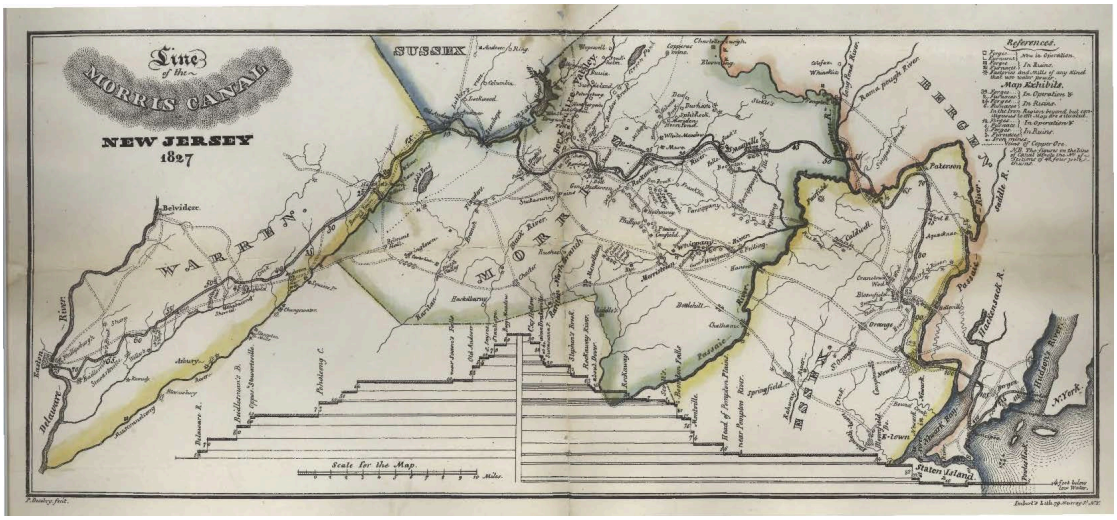


Figure 39. The Morris Canal.
Source: Prosper Desobry, Line of the Morris Canal, New Jersey, 1827. http://hdl.handle.net/10929/41793

To get into the Morris Canal at Phillipsburg from Easton, Pennsylvania, boats relied on a cable ferry (Figure 39). With the construction of the Lehigh Valley Railroad,

[146] Turner and Koles proposed that early railroad construction was completed piecemeal to avoid the high cost of the railroad right of way. For example, the Somerville and Easton Railroad Company and the Elizabethtown-Somerville Railroad Company merged in 1947, fully connecting Easton, Pennsylvania to Elizabeth, New Jersey.
[147] Larrabee, "New Jersey's Cultural Resources: A.D. 1800-1865," 227; Birkner, "New Jersey in the Jacksonian Era," 118.

the cable ferry was no longer necessary, and as the company expanded, connections could be made to cities farther east; a railroad switch at Metuchen connected the line to Perth Amboy and Jersey City. The Philadelphia and New York Railroad, which ran nearly parallel to the Delaware and Raritan Canal, connected Philadelphia to South Amboy and New York. Chartered in 1830, the Camden and Amboy Railroad connected Camden to South Amboy when construction was completed in 1834 (Figure 40).[148] Camden's extensive ferry system transported passengers on to Philadelphia. The railroads created junction towns, like Hampton Junction, Monmouth Junction, and Princeton Junction, which became important centers for industry and underwent population growth over the next century. By the early twentieth century, there was a comprehensive railroad network across the state (Figure 41).[149]

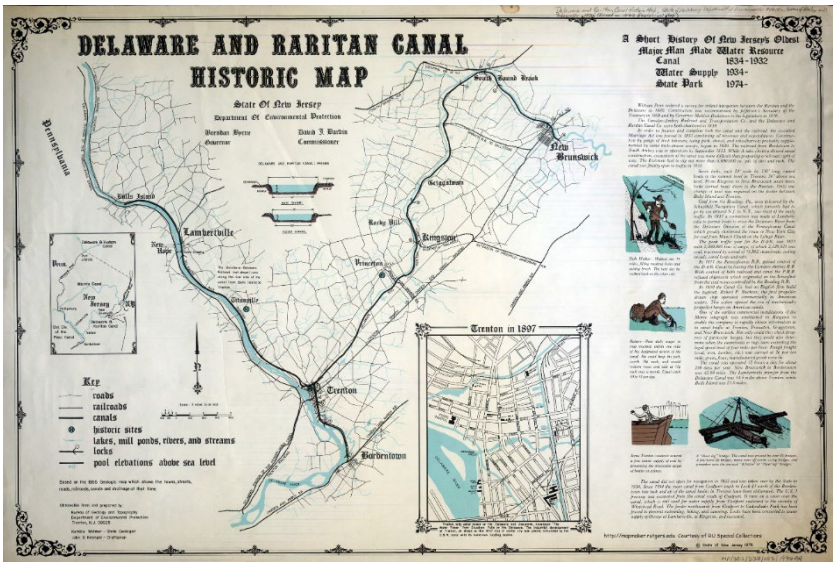


Figure 40. The Delaware and Raritan Canal.
Source: New Jersey Department of Environmental Protection, Delaware and Raritan Canal Historic Map, 1976. http://mapmaker.rutgers.edu/HISTORICALMAPS/DandR_canal_1976.jpg

[148] Over time railroads and canal operators consolidated and transformed into transportation monopolies across the state. For example, the Pennsylvania Railroad Company leased canal lines, railroad lines, and surrounding land from individual operators. Their transportation monopoly would include the Camden and Amboy Railroad and the Delaware and Raritan Canal Companies.
[149] George R. Prowell, *The History of Camden County, New Jersey* (Philadelphia: L.J. Richards & Co., 1886), 349-351; Larrabee, "New Jersey's Cultural Resources: A.D. 1800-1865," 230.

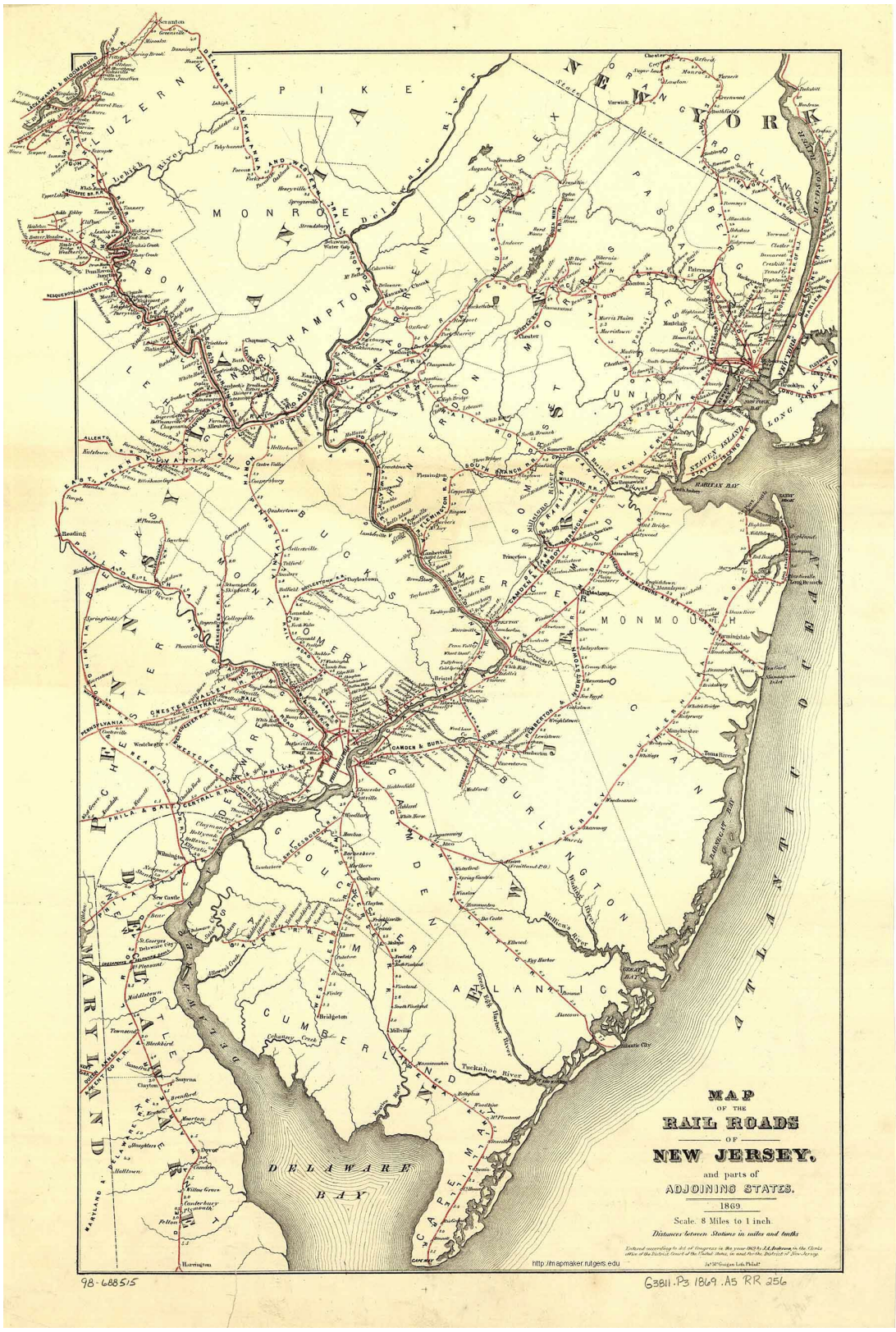


Figure 41. Railroad lines in New Jersey and adjacent states in 1869.
Source: James McGuigan, Map of the Rail Roads of New Jersey, and parts of Adjoining States, 1869.
http://mapmaker.rutgers.edu/HISTORICALMAPS/RAILROADS/rr_NJ_PA_NY.jpg

These infrastructure improvements promoted the further growth of cities and surrounding areas. Because of the wide-spread transportation network, non-industrial towns, including resort towns and suburbs, emerged. Atlantic City benefited from the railroads and presented itself as an accessible resort town for the urban masses. Suburbanization was prominent in northeastern New Jersey, where the commuter population to New York City had nearly tripled between 1869 and 1897, growing from 48,000 to 175,000. The influx of immigrants further contributed to the growth of the state.[150]

The state's agriculture benefited too. The ability to transport goods at speed meant that agricultural areas were now significant and primed for growth. Reportedly, it was difficult to find tomatoes in mid-1830s New York City, but by 1851 it was easy to find fresh tomatoes alongside other produce. Some farmers did not profit from canal and railroad construction, particularly since many farms were destroyed in their construction.[151]

It is within this context of the transformation of New Jersey's urban fabric through immigration, industrialization, and transportation infrastructure, that cities, citing a need and availing contemporary technological developments, lay brick sewers.

[150] Birkner, "New Jersey in the Jacksonian Era," 120-128; Israel, "The Garden State Becomes an Industrial Power," 191; A.G. Lichtenstein & Associates, Inc., *The New Jersey Historic Bridge Survey* (1994), 35; Edward S. Rutsch, "New Jersey's Cultural Resources: A.D. 1865 to the Present," in *New Jersey's Archeological Resources, A Review of Research Problems and Survey Priorities: The Paleo-Indian Period to Present*, ed. Olga Chesler (Trenton: New Jersey Historic Preservation Office, 1982), 246.
[151] Birkner, "New Jersey in the Jacksonian Era," 120-130.

7. Brick Sewer Cities

As the state transformed, so did the sanitary system, which responded to evolving needs and technologies. Unfortunately, often infrastructure could not keep up with the growth of New Jersey's and the nation's industry and population, even as demand for adequate sanitation increased.[152] Between 1850 and 1920, the population across the United States quadrupled; simultaneously, urban areas, which were once home to one-eighth the population, were now home to nearly half the population. The need for water and sewer infrastructure was evident as cities experienced rapid population growth.

The 1900 *Report of the State Sewerage Commission*

To track the status of New Jersey's sanitary infrastructure, the State Sewerage Commission, in 1899, requested municipalities submit a Sewerage Report, which included demographics of the city and details on the sewerage system. City reports were either scant or demonstrated contradictory details, likely because of poor record keeping or lack of financial resources to retain a knowledgeable engineering advisor.[153] By 1900, not all cities and towns had submitted a report or had a sewer system to report upon; it appears that the 1882 Sewer Act did not spur sewer construction state-wide. Even in cities that had sewer systems, privies remained in use through the end of the nineteenth and into the twentieth century, whereas other municipalities continue to rely on septic systems today. There were scarcely any cities with sewage treatment. The only cities to

[152] Municipalities were frequently being annexed in the nineteenth century. As a result of this, municipal boundaries have evolved. Often, smaller cities were looking to benefit from infrastructural development in the larger cities. By the time of annexation, many larger cities had both knowledge and technological experience in sewer construction. For a broader discussion on annexation as it pertains to infrastructural development, see Richard Dilworth's *The Urban Origins of Suburban Autonomy*.
[153] Burian et al., "Urban Wastewater Management in the United States: Past, Present, and Future," 47; Dilworth, *The Urban Origins of Suburban Autonomy*, 76; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 7.

self-report the treatment of sewage were the City of Plainfield, which used intermittent filtration through sand, and the Town of Freehold, which disposed of the waste on a sewage-disposal field.[154] Fuller reported that the City of Plainfield used septic tanks within the city-wide system, though it is unclear how treatment and tanks were structured.[155]

Storage tanks were self-reported in five cities and one joint outlet, all of whom used the separate system and did not treat the waste.[156] It is unclear if only separate systems used storage tanks. A more contemporary term for storage tanks might be holding chamber. Storage tanks, which connected to outfall pipes, held the waste until it could be released into the water. Waste was often released at low tide to ensure that it would be carried away. Some tanks might have been equivalent to large septic tanks, well-suited to areas without a connection to tidewater. The system in the Borough of Wildwood, in Cape May County, emptied into a vault, which connected to an overflow outlet, which released waste into tidewater. The Township of Raritan, in Hunterdon County, had a storage tank that was 40 feet square and 4 feet deep. The Town of Freehold, in Monmouth County, had one storage tank, which they referred to as a receiving tank. The Borough of North Spring Lake, which has since been absorbed into

[154] Fuller, having visited the Plainfield plant where the septic tanks were located, noted that though he never experienced the odors from a distance over 100 yards, the septic tanks had the "reputation of behaving badly."
[155] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 119; Fuller, *Sewage Disposal*, 477.
[156] The term "storage tank" has been used interchangeably with wet well and diversion chamber, though they more properly refer to different components. However, each of these components allow water or waste to be hold water or wastewater, to release it at low tides, to prevent overflows due to capacity issues, or just to keep underwater equipment in water. The sewerage tank, sometimes also referred to as a tidal tank, tank sewer, or storage reservoir, is not to be confused with a septic tank. Storage tanks are valuable today for sewer systems that are easily overwhelmed during storm events. For example, with the redesign of Hoboken's sanitary sewers, storage tanks were recommended. For more information, see: https://www.nj.gov/dep/floodresilience/docs/rbdh-eis/execsummary.pdf

Spring Lake, in Monmouth County, had one storage tank, which was located at Ocean Avenue and emptied directly into the Atlantic Ocean. The Township of Westfield in Union County only reported that they used storage tanks. The Orange outlet sewer, which was a joint sewer with Bloomfield, Glenridge, Montclair, and Orange, had a storage tank in Newark. Within the next decade, storage tanks fell out of favor because the waste could putrefy and create a larger nuisance when released later.[157] It is unclear if these storage tanks can still be found below ground or if they were used into the twentieth century.[158]

The Sewerage Report also included details about discharge points, the number, their locations, and the receiving body of water. A few municipalities reported that disposal of waste in the body of water that supplied the town's drinking water might be endangering health.[159] The City of Beverly supplied water by pumping from the Delaware River, and private drains in the city emptied their waste into the Delaware River near the pumping station.[160]

The report connected system type to paving data, specifically from cities with combined systems, including length paved, length unpaved, and length of sewers. Unpaved or permeable ground was able to absorb storm water; however, paved streets reduced the creation of mud. Interestingly, the report did not ask for paved lengths for

[157] In the *Report of the State Sewerage Commission to the Legislature of 1908*, tidal tanks, like the one in the City of Woodbury, were proposed to be converted into a septic tank because the tank disposed of solid waste into the Woodbury Creek. This waste had putrefied while held in the tank, creating a nuisance each time the tidal tank was emptied.
[158] Watson, *Sewerage Systems*, 154-157; Fuller, *Sewage Disposal*, 474-475; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 44-48, 93-95, 122.
[159] A turn of phrase that was quite amusing amongst these reports can be found in the Borough of Spring Lake's general remarks to supplement their survey response. The borough noted that the sewerage is "emptied 680 feet in the ocean, where it is never heard from and comparatively inexpensive."
[160] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900,* 23, 36.

cities with separate sewers, this was likely because street wash was as "objectionable" as house sewage and contained debris from the streets. Thus, combined sewers received significantly more abrasive wastes than separate sewers, which could damage the interior surface of the sewer, create blockages, or further pollute water bodies.[161]

The Sewerage Commission acknowledged that sanitary engineering was an emergent field; accordingly, solutions for the problems of sewage disposal had not yet been perfected. They recognized that the condition of rivers was such that the water could never again be considered potable, but that it was possible to prevent it from being "a source of injury or offence to the inhabitants either in their health, comfort or property." Thus, the Sewerage Commission recommended that future sewer construction should be on the separate system, because it was more expensive and complex to treat waste from the combined system. Multiple publications in the early twentieth century reported that cities were dissuaded from constructing wastewater and sewage treatment plants because of the greater upfront cost, so they emphasized treating drinking water instead. As late as 1914, sanitary engineers were unable to come to a consensus about the best and most effective treatment technologies for wastewater.[162]

The Twenty-Two Brick Sewer Cities

While several industrial cities across the state had built sewers prior to the passage of the 1882 Sewer Act, many other municipalities only began to construct sewers after this act went into effect. By 1900, eighty New Jersey municipalities

[161] Frederick S. Odell, "The Sewerage of Memphis," *Transactions of the American Society of Civil Engineers* 10 (1881): 33.
[162] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 4-10; Metcalf and Eddy, *American Sewerage Practice*, 1:30.

reported sewer systems under construction or in service and nearly 70% of the state's population lived in a town or city with a sewer system (Figure 42). Both combined and separate systems were built. Some cities used both types of systems. At least three municipalities classified their system as surface drainage, without providing details (Figure 43). Twenty-two cities reported brick sewers to the Sewerage Commission (Figure 44). This list is extensive but not exhaustive, since many cities did not submit reports and some of those that did respond to the survey did not specify the type of material they used. The term "pipe" could refer to cast iron, concrete, terracotta, or vitrified clay. In the remainder of this chapter, we summarize each of New Jersey's twenty-two brick sewer cities (Table 1).

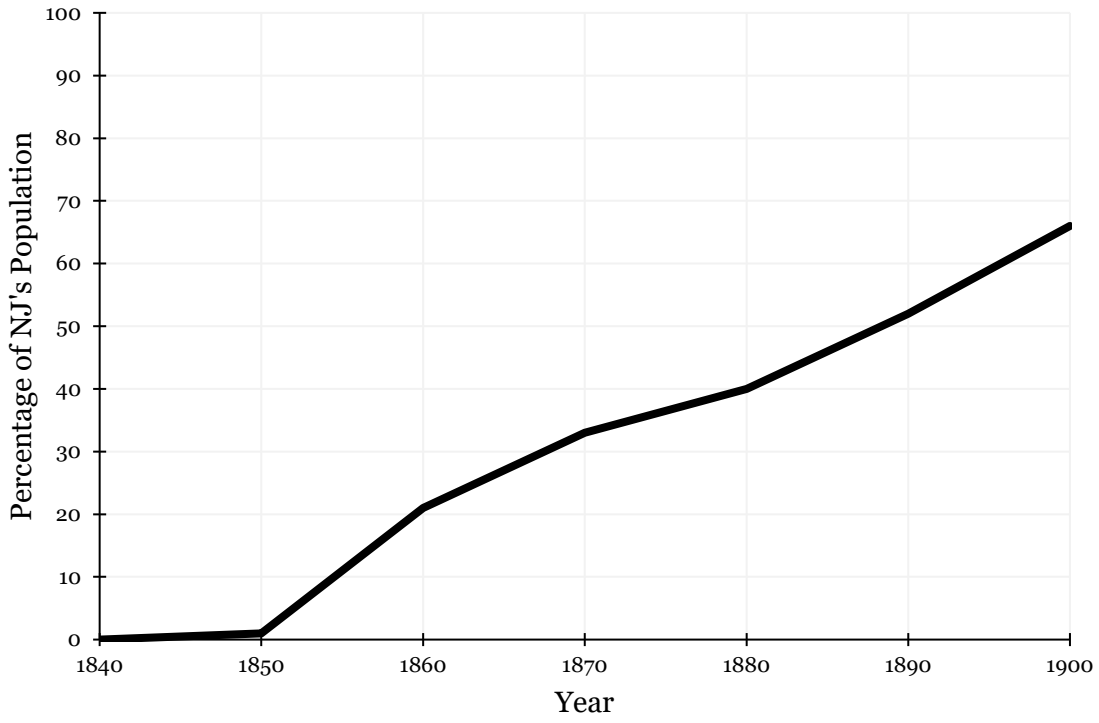


Figure 42. Percentage of New Jersey's population living in municipalities with sewers.

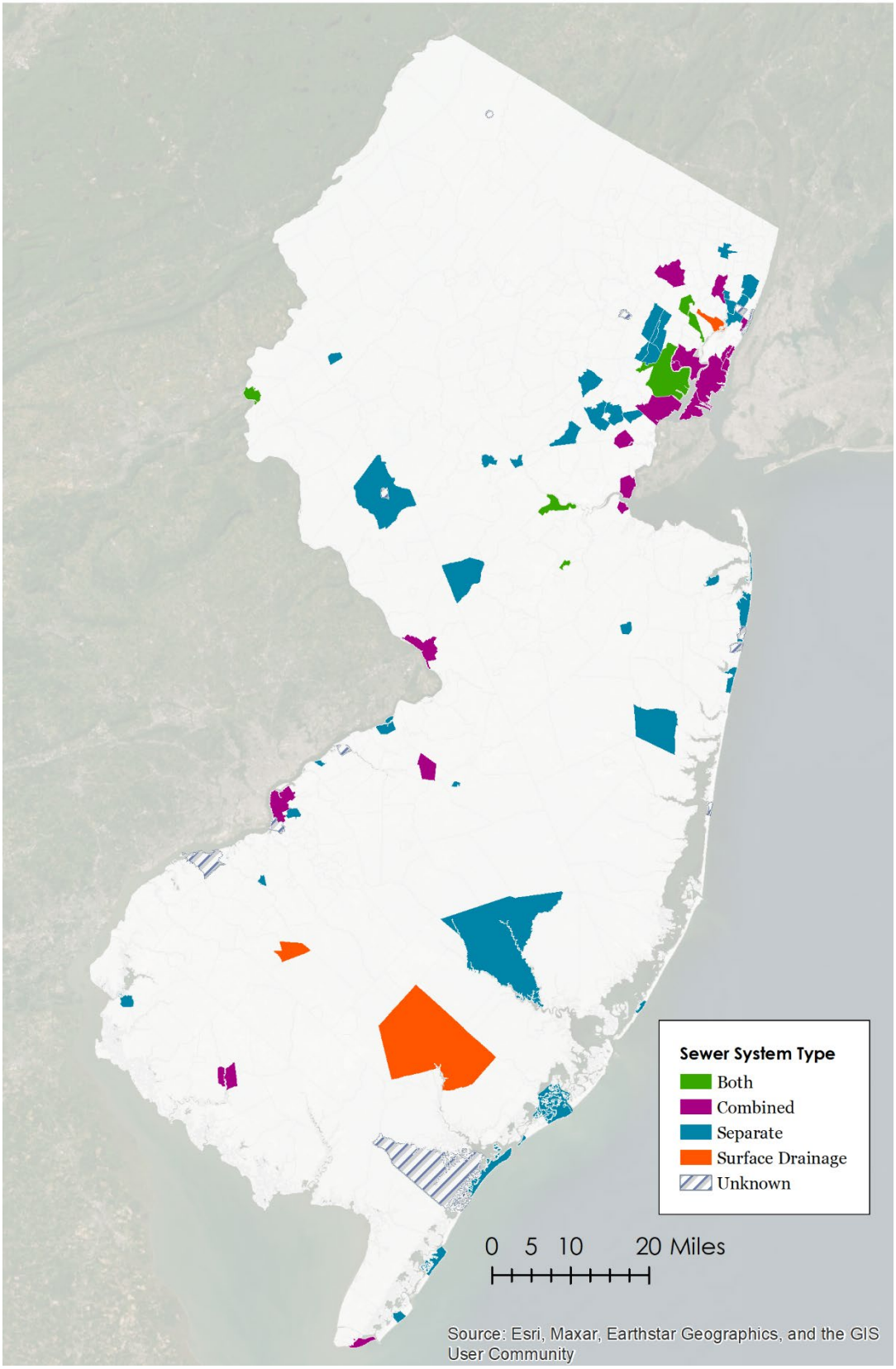


Figure 43. Sewer system type for all reported sewer construction, as of 1900.
Source: Map by Christina Servetnick.

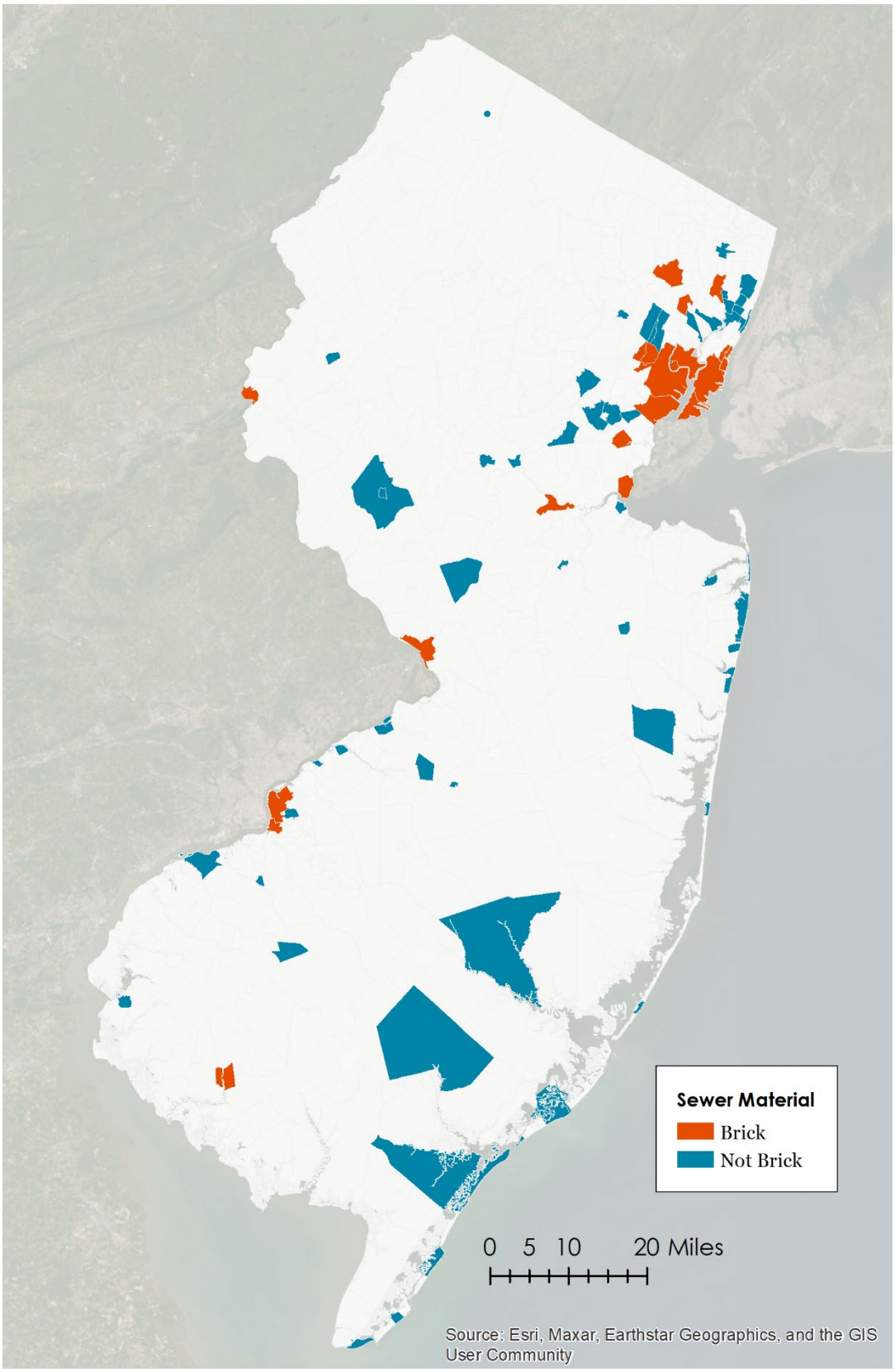


Figure 44. Comparison of sewer material type for all reported sewer construction, as of 1900. "Not brick" refers to sewers reported as pipe sewers. Source: Map by Christina Servetnick.

Table 1. Cities known to have brick sewer lines and the earliest sewer constructed, irrespective of material.

County	***City***	***Year of First Construction***	***Type of System***
Bergen	Hackensack	1870	Combined
Camden	Camden	1860	Combined
Camden	Gloucester City	1885	Combined
Cumberland	Bridgeton	1898	Separate
Essex	East Orange	1887	Separate
Essex	Newark	1852	Both
Essex	Orange	1885	Separate
Hudson	Bayonne	1870	Combined
Hudson	Harrison	1872	Combined
Hudson	Hoboken	1858	Combined
Hudson	Jersey City	1838	Combined
Hudson	Kearny	1891	Combined
Hudson	Union City	1874	Combined
Hudson	Weehawken	1874	Combined
Mercer	Trenton	1860	Combined
Middlesex	New Brunswick	1871	Both
Middlesex	Perth Amboy	1859	Combined
Passaic	Passaic	1887	Separate
Passaic	Paterson	1852	Combined
Union	Elizabeth	1852	Combined
Union	Rahway	1867	Combined
Warren	Phillipsburg	1889	Both

City of Hackensack, Bergen County

Prior to its incorporation in 1925, Hackensack was a village in the township of New Barbadoes. In 1868, the Hackensack Improvement Commission was incorporated to oversee the governance of the village of Hackensack and New Barbadoes township

(Figure 45). The Commission oversaw public services, including the board of health, police and fire departments, streets and sidewalks, and the water company.[163]

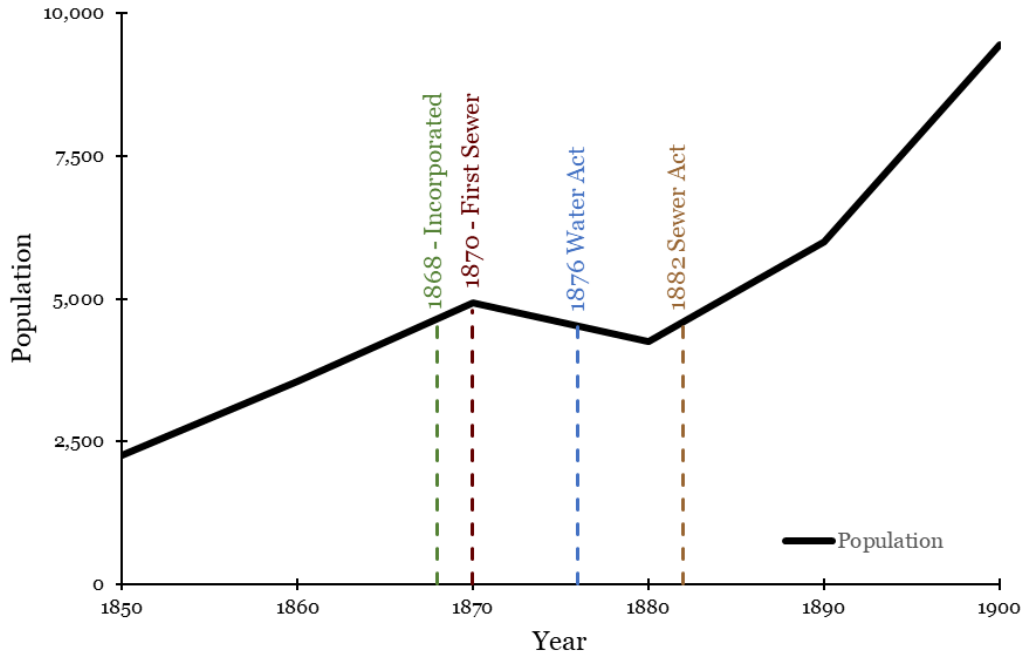


Figure 45. Population data for Hackensack alongside key historical markers.

Hackensack was a freight depot for the Northern New Jersey – Hackensack Turnpike. The introduction of a railroad in 1868 brought with it a residential community, many of whom commuted to New York. The settlement started along the river, with newer and wealthier areas settling to the north and west. Brickyards, oil tanks, stone crusher plants, and warehouses were primarily located close to the river, making for easy transportation of goods. Other manufacturing ventures included cement, clothing, haberdashery, and slipper manufacturing. The population grew in the

[163] Federal Writers' Project of the Works Progress Administration for the State of New Jersey, *New Jersey, a Guide to its Present and Past, Compiled and written by the Federal Writers' Project of the Works Progress Administration for the State of New Jersey; Sponsored by the Public Library of Newark and the New Jersey Guild Associates* (New York: Viking Press, 1939), 259; Barbara J. Gooding et al., *Hackensack* (Charleston: Arcadia Publishing, 2009), 12.

1890s with arrivals from both western and eastern Europe and African Americans from the south.[164]

Sewer History

Shortly after the incorporation of the Commission, a combined sewer system was introduced in 1870. It was reportedly planned by Mr. Bacot. Not much else was reported about the designer other than his last name; however, it can be inferred that Mr. Bacot is most likely Robert Cochran Bacot. Bacot had previously served as the superintendent of the Jersey City Water Works, designed the street and sewerage system of the Van Vorst section of Jersey City, and was most likely serving as the Secretary and Engineer of the Riparian Commission at the time.[165] The main sewers on Bridge and Anderson Streets had 72-inch diameters, and the Main and State Streets lateral sewers had 36-inch diameters.[166]

Early Sewers and Corresponding Outfalls

Hackensack Creek Sewer

Hackensack Creek was located south of Central Avenue and was a tributary of the Hackensack River (Figure 46). Like in many other cities, Hackensack residents living adjacent to the creek used it as an open sewer. The deteriorating conditions of the waterway prompted the State Legislature to pass "[a]n Act to authorize the Cleaning out, Opening, Widening and Straightening of Hackensack Creek, in the Village of

[164] Maureen Dillon, "Hackensack," in *Encyclopedia of New Jersey,* ed. Maxine N. Lurie and Marc Mappen (New Brunswick: Rutgers University Press, 2005), 341; Federal Writers' Project, *New Jersey,* 256-258.
[165] To see a map by Bacot: http://mapmaker.rutgers.edu/HUDSON_COUNTY/JerseyCity_1848.jpg
[166] New Jersey, Board of Health, *Twenty-Sixth Annual Report of the Board of Health of the State of New Jersey, 1902* (Trenton, N.J.: The J. L. Murphy Publishing Co., Printers, 1903), 347; Metcalf and Eddy, *American Sewerage Practice,* 1:17; "Personal," *The Engineering Record* 36, no. 6 (1897): 113; A. Clark Hunt, "The Sewer Systems of New Jersey," in *Thirteenth Annual Report of the Board of Health of the State of New Jersey, and Report of the Bureau of Vital Statistics, 1889* (Camden, N.J.: F.F. Patterson, Printer, 1890), 90.

Hackensack, in the County of Bergen, within the limits therein named" in 1873 to clear the creek of all debris and create a mechanism for fining property owners who stymied the free flow of water. The act must not have been successful or people must have continued to affect the water quality because, in 1890, Dr. A. Clark Hunt recommended shifting the 119 sewage connections that discharged to the creek to an existing sewer. The city began to raise $56,000 for construction costs in 1898 and it is likely that the creek was covered over in the early twentieth century.[167]

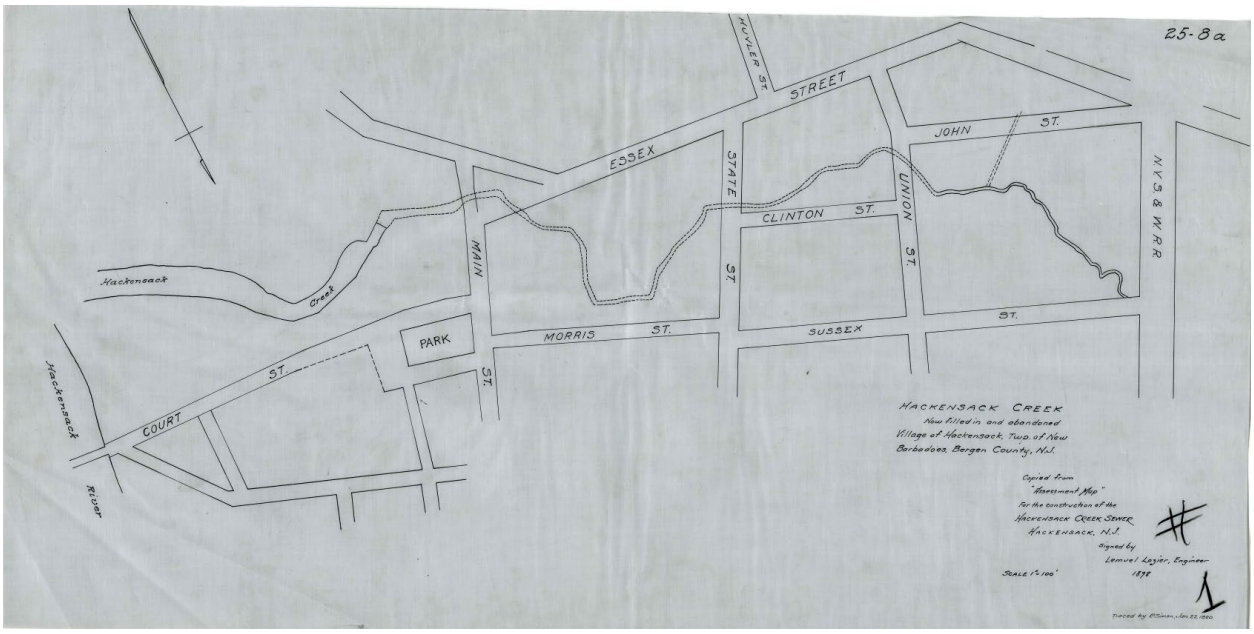


Figure 46. Map of the path of Hackensack Creek.
Source: Lemuel Lozier, Traced by R. Simon Copied from "Assessment Map" for the construction of the Hackensack Creek Sewer, Hackensack, N.J., Original from 1898, Trace from 1920. https://rucore.libraries.rutgers.edu/rutgers-lib/56198/PDF/1/play/

The Hackensack Creek sewer outfall was south of Court Street. It was a reinforced concrete sewer with dimensions of 36 inches by 108 inches. The sewer was part of a separate system, with a stormwater outlet into the creek and a second pipe to release dry weather flow into the Hackensack River. Approximately 0.25 miles south of the creek

[167] Hunt, "The Sewer Systems of New Jersey," 90; New Jersey, Legislature, *Acts of the Ninety-Seventh Legislature of the State of New Jersey, and Twenty-Ninth Under the New Constitution* (Morristown, N.J.: Vance & Stiles, Steam Power Book and Job Printers, 1873), 751-753.

sewer is a 36-inch brick sewer, which discharges into the estuary of the Hackensack River.[168]

Anderson Street Sewer and Outlet

The Anderson Street sewer is a 60-inch diameter circular brick sewer, built in 1875 and discharging into the Hackensack River. In order to underdrain the sewer, a wooden cradle was constructed below the invert. A 1-mile-long northern branch sewer, under Fairmount Avenue, and a 0.75-mile-long southern branch sewer, under Main Street then through Maywood to Paterson and Ridgewood, connected to the Anderson Street sewer. As the elevation of the branch sewer increased, the diameter of the interior decreased.[169]

Main-Bridge Street Sewer

The Main-Bridge Street sewer is located north of the U.S.M.C. First Lieutenant William C. Ryan Jr. Memorial Bridge. The outfall sewer has a dimension of 60 inches though not much else is known about its shape or construction. Its tributary sewers serviced Main Street and its parallel streets, parts of the city south of the Anderson Street sewer outfall.[170]

By 1900, there were five outfalls which discharged into the Hackensack River, though only the outfalls at Anderson and Court Streets are still active today. Aside from the Hackensack Creek sewer, which was partly separate, the rest of the city was on the combined system. In 1900, the system was 13 miles long, included 5 miles of brick

[168] New York, Metropolitan Sewerage Commission, *Sewerage and Sewage Disposal in the Metropolitan District of New York and New Jersey* (New York: Martin B. Brown, Press, 1910), 342-343.
[169] New York, Metropolitan Sewerage Commission, *Sewerage and Sewage Disposal,* 342.
[170] Ibid., 342.

sewers, which ranged in dimensions from 24 inches to 78 inches. Pipe sewers of unspecified materials, 8 miles in length, were 24 inches by 8 inches.[171]

City of Camden, Camden County

Like many other cities in this report, Camden was first settled in the late seventeenth century.[172] Settlement along the Delaware River encouraged the introduction of a ferry service, which transported people to Philadelphia and back. Originally a village in Newton Township, Camden was incorporated as a township in Gloucester County in 1828 to encourage the city's growth (Figure 47).[173]

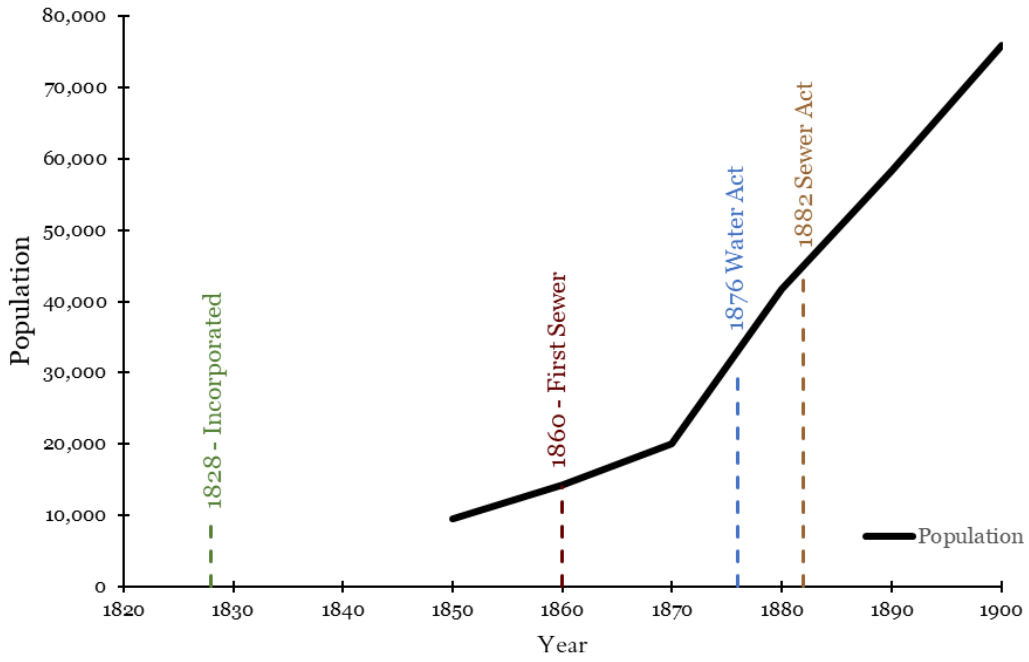


Figure 47. Population data for Camden alongside key historical markers.

[171] Daniel J. Van Abs et al., *Water Infrastructure in New Jersey's CSO Cities: Elevating the Importance of Upgrading New Jersey's Urban Water Systems* (New Brunswick: Rutgers University, 2014), 40; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 30-31.
[172] For a much more in-depth look at Camden, please see our previous report *Sewers Invincible: A Historic Context for Camden's Sewer Infrastructure,* available at https://hdl.handle.net/10929/107508
[173] Howard Gillette, Jr., "Camden," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen (New Brunswick: Rutgers University Press, 2005), 112.

The township became the terminus for the Camden and Amboy Railroad, introduced in 1834. Following the Civil War, the city transformed into an industrial and manufacturing hub and attracted a growing population of workers. Some of its many famous businesses included Campbell Soup, Esterbrook Pen Company, and RCA Victor. Camden's character stayed predominantly industrial into the twentieth century.[174]

Sewer History

A private corporation in 1845 provided clean drinking water to Camden residents before the introduction of sewers. In 1850, Camden was reincorporated as a city. This incorporation act included a provision for the city council to construct common sewers and drains. While some drainage systems had been built by the 1850s, the earliest municipally owned sewer, likely meant for flood control, was built beneath Federal Street in 1860. In 1861, a supplement to the incorporation act required that landowners who benefited from sewer construction pay for their share of the total expense, as billed by the city. After this, sewer construction increased rapidly.[175]

Cooper Street Sewers

Cooper Street between 3rd and 4th Streets had a sewer by 1863. Wood-lined box privies, barrel privies, and a brick-lined shaft privy were discovered during archaeological excavation in the 300-block of Cooper Street. Three wooden privies were associated with a dwelling at 318 Cooper Street constructed around 1810 and in use

[174] Gillette, Jr., "Camden," 112.
[175] New Jersey, Legislature, *Acts of the Seventy-Fourth Legislature of the State of New Jersey, and Sixth Under the New Constitution* (Trenton: Printed by Phillips & Boswell, 1850), 218; Ann Marie T. Cammarota, *Changing Pattern: The Suburbanization of Southern New Jersey Adjacent to the City of Philadelphia* (Philadelphia: Temple University, 1996), 111; New Jersey, Board of Health, *Twenty-Third Annual Report of the Board of Health of the State of New Jersey, 1899* (Trenton, N.J.: MacCrellish & Quigley, State Printers, 1900), 86; New Jersey, Legislature, *Acts of the Eighty-Fifth Legislature of the State of New Jersey, and Seventeenth Under the New Constitution* (Freehold, N.J.: Printed by James S. Yard, 1861), 468-469.

during the early nineteenth century. A 10-foot by 10-foot brick shaft privy was likely built in the mid-nineteenth century and may have been shared with the adjacent dwelling at 312 Cooper Street. A second brick shaft feature had a metal drainage pipe in its northwest quadrant, oriented towards a corner of the building at 312 Cooper Street, and may have served to drain household wastewater after the advent of indoor water service but before the sanitary sewer system was established.[176]

Also, on Cooper Street, west of Delaware Avenue, a 72-inch diameter brick sewer was recorded by archaeologists in 2018. The original sewer at this location was built in 1881, and later repaired, and possibly extended, in 1925. The top of the sewer had been truncated and covered with a flat concrete slab. In one section, wooden beams had been placed across the bottom of the sewer with the ends inserted into holes in the sewer wall.[177] The concrete slab is probably related to this repair work. The purpose of the beams is unknown; possibly they were used as support for scaffolding or the sewer itself during repairs and mistakenly left in place.[178]

Kaighn Avenue Sewer

The earliest sewers in Camden were not all made of brick. Records indicate that a wooden box sewer, constructed in 1870 by John Ambruster on Kaighn Avenue between Front Street and the Delaware River, was replaced by a brick sewer built by Aaron Ward in 1915. Archaeological monitoring at this location revealed additional details not recorded in the documents. At the western end of the brick sewer was a wooden box

[176] Richard Affleck et al., *"A Bright Pattern of Domestic Virtue and Economy," Phase II/Data-Recovery Archaeological Excavations of the Smith-Maskell Site Cooper Street Development, Camden, New Jersey* (Burlington, New Jersey: URS Corporation, 2012), 4-48.
[177] Since they were blocking the flow of the sewer, the beams were removed during this project.
[178] Camden County Municipal Utilities Authority, Upgrades to Camden City's Combined Sewer Overflow System Sewer Photos, Project No. 340640-22, (2018); Khandal et al., *Sewers Invincible*, 95.

sewer of unknown length that appears to have been constructed in two parts. The point where the wooden box sewer and the brick sewer meet is approximately 200 feet from the current shoreline, and the original wooden sewer is approximately 60 feet long. The second section is interpreted as an addition constructed when a new ferry terminal extended into the river around 50 feet from the original shoreline. Based on this interpretation, the extension was likely built in 1880, well before the brick sewer was rebuilt. The wooden sewers had evidently undergone repairs at some point, possibly at the same time as the sewer replacement in 1915.[179]

By 1900, Camden reported a 52-mile-long combined system.[180] The system was primarily brick and included both circular sewers, with diameters ranging from 24 inches to 72 inches, and egg-shaped sewers, with dimensions ranging from 16 inches by 24 inches to 24 inches by 36 inches. Sewerage Commission reports in 1890 and 1900 differed in their reporting of Camden sewers. Whereas the largest brick sewer in the 1900 report was 24 inches by 36 inches, in 1890, the largest reported sewer was 40 inches by 66 inches. The 1890 report included smaller pipes of unspecified materials, with diameters ranging from 4 inches to 12 inches. In the 1900 report, the depth of the sewers ranged from 5 feet to 9 feet, with a reported average depth of 8 feet. The City of Camden reported that these sewers discharged into public water bodies at eleven points

[179] Nancy Zerbe, "Monitoring report for the Combined Sewer Overflow Project, CSO Site C05/10. ARCH2. Letter submitted to Elizabeth Davis, NJDEP," (August 24, 2009); Reinbold et al., *Phase IB Archaeological Investigation Addendum*.

[180] We suspect that the data on brick sewer lengths as provided is accurate in the Report of the State Sewerage Commission; however, it is likely that there is an extra zero in one of the figures where the sizes and their respective lengths are listed.

on the Delaware River, one point on Little Newton Creek, and three points on Cooper's Creek by the end of the nineteenth century.[181]

Little Newton Creek, also known as Line Ditch, was eventually enclosed in a sewer by Aaron Ward in 1907. The Line Ditch sewer used stone for its walls, the floor was concrete poured onto a timber base built on wooden pilings, and the top consisted of a brick arch (Figure 48). Prior to constructing the Line Ditch sewer, in 1885, Aaron Ward applied for patent for a machine to press bricks. It is unclear if the patented brick press was used in the construction of the Line Ditch sewer or in any brick sewers constructed by Aaron Ward.[182]

Figure 48. Construction of Newton Creek Line Ditch, with Aaron Ward at center, wearing a bowtie, hat, and suit. Source: Camden County Historical Society, No. 5017.

[181] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 39-40; Hunt, "The Sewer Systems of New Jersey," 87; George E. Waring, Jr., *Report on the Social Statistics of Cities, Part 1, the New England and the Middle States* (Washington: Government Printing Office, 1886), 681.
[182] "Passing of Line Ditch in South Camden Means Much to that City," *Philadelphia Inquirer* (November 1, 1906); Aaron Ward, Patent # US328552A, (Camden: 1885).

Gloucester City, Camden County

Settled in 1682, Gloucester City was incorporated in 1868 (Figure 49). The city is located south of Camden along the Delaware River. Gloucester City was a predominantly industrial city, including ironworking, paper and textile manufacturing, shad fishing, and shipbuilding. Following the Civil War and compounded by the lack of a well-connected transportation network, industry declined. However, the efforts of a local businessman brought investment; a bank, gas lighting company, gingham mill, terra-cotta works, and textile printing company were established in the city.[183]

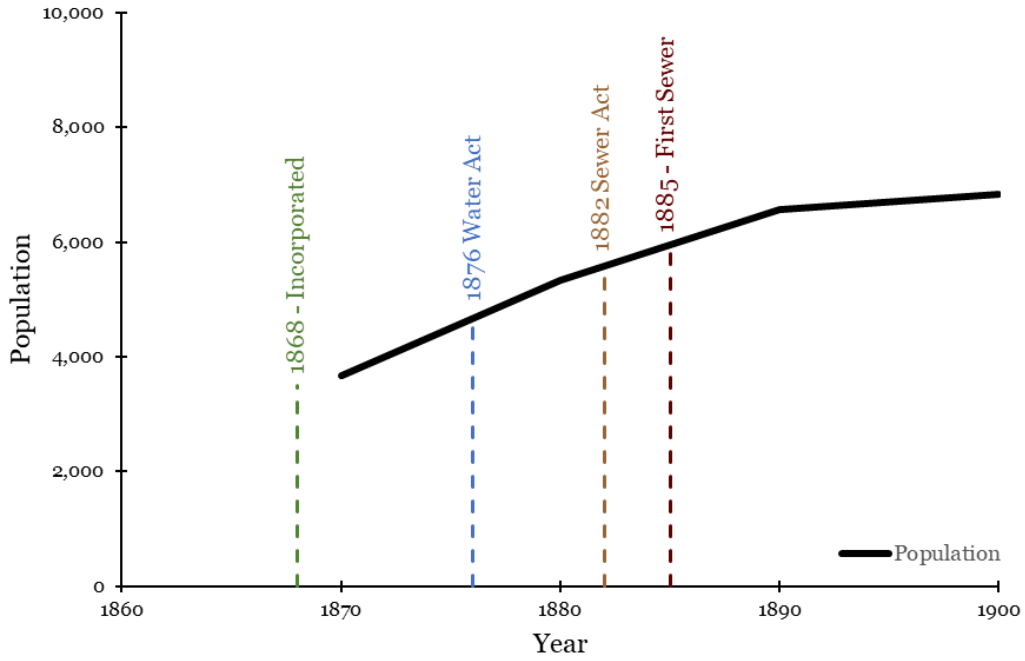


Figure 49. Population data for Gloucester City alongside key historical markers.

Sewer History

Gloucester City introduced a piped-in water supply as early as 1883. Two years later in 1885, sewer construction was undertaken by Rapp and Son, but within a year,

[183] Gail Greenberg, "Gloucester City," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen (New Brunswick: Rutgers University Press, 2005), 320.

the new sewers beneath Market Street were reported to be overflowing. In 1889, the firm Fowler & Loomis, of Philadelphia, was engaged by Gloucester City to design a combined system and a new contractor replaced Rapp and Son. By the close of 1889, there were a total of 5 miles of sewers.[184]

Market and Hunter Streets Sewers[185]

Writing about the sewers in Hudson, Market, and Mercer Streets in 1889, Hunt reported egg-shaped sewers, with a 48-inch diameter and an unmortared bottom. There are some key discrepancies between what Hunt reported and what has been found during archaeological monitoring in 1996. Egg-shaped sewers are described in two dimensions, so there is likely some discrepancy in the dimension or shape reported by Hunt. Archaeological monitoring in 1996 determined that some of the exposed sewers were egg- and circular-shaped; a segment of sewer beneath Market Street was described as eye-shaped and was most likely a circular sewer that shifted due to stress (Figure 50).[186]

[184] Paul W. Schopp, *National Register of Historic Places Nomination: Gloucester City Water Works Engine House*, (Haddonfield: Remington & Vernick, Engineers, 1997), 7-2; Hunt, "The Sewer Systems of New Jersey," 89-90; Jean Howson, *Cultural Resource Inspection of Market and Hunter Street Sewer Reconstruction, Gloucester City, Camden County, New Jersey* (New Brunswick: Rutgers University Center for Public Archaeology, 1996), 10.
[185] These sewers were monitored during construction, between December 1994 and January 1995, during which time they were rebuilt.
[186] Hunt, "The Sewer Systems of New Jersey," 89-90.

Figure 50. Photograph of the Market Street brick sewer.
Source: Jean Howson, Cultural Resource Inspection of Market and Hunter Street Sewer Reconstruction, Gloucester City, Camden County, New Jersey *(New Brunswick: Rutgers University Center for Public Archaeology, 1996), 23.*

Hunt reported that most of the system was 6 feet below grade, however, archaeological monitoring in 1996 found the sewers were located between 1-foot to 6 feet below grade. Considering the discrepancy between the 1889 reporting and the 1996 archaeological monitoring, the archaeological monitoring should be considered the most accurate record of what was built. The sewers on Market and Hunter Streets were constructed of standard-sized bricks, with stretcher bonds. There was no brick or concrete buttressing, and the walls were one wythe. The lateral sewers were made of cement pipe and ranged in diameter from 12 to 24 inches.[187]

In 1890, three outfall points drained into the Delaware River; by 1908, there were six. The outfall on Monmouth Street was a 12-inch pipe. Another outfall discharged into Newton Creek, at 0.5 miles below the intake point for the city's water works. An oval

[187] Hunt, "The Sewer Systems of New Jersey," 89-90; Howson, *Cultural Resource Inspection of Market and Hunter Street*, 30.

trunk sewer, 16 inches by 22 inches and 0.72 miles long, connected to this outfall. The material and year of construction of this sewer is unknown.[188]

City of Bridgeton, Cumberland County

Straddling the Cohansey River, Bridgeton was founded by Quakers in 1686. The Town of Bridgeton was incorporated in 1845, and later as a city in 1865 (Figure 51). The Cohansey River is a tributary of the Delaware River and served as a water transportation route for steamboats to and from Philadelphia. By 1861, the West Jersey Railroad connected the city to Camden.[189]

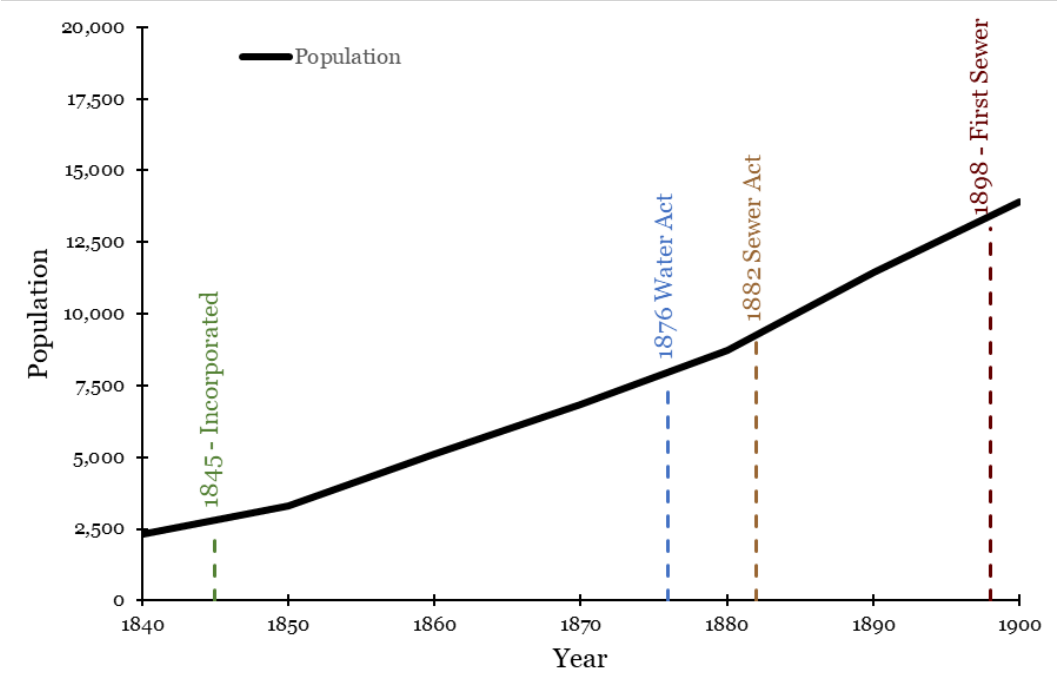


Figure 51. Population data for Bridgeton alongside key historical markers.

Prior to its incorporation, the city's industrial character emerged with iron forges and glass furnaces. By the end of the twentieth century and following competition from

[188] Hunt, "The Sewer Systems of New Jersey," 89; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature of 1908* (Sommerville, N.J.: The Unionist-Gazette Association, State Printers, 1908), 171.
[189] Federal Writers' Project, *New Jersey,* 635; H. Roger Grant, "Bridgeton," in *Encyclopedia of New Jersey*, ed. by Maxine N. Lurie and Marc Mappen (New Brunswick: Rutgers University Press, 2005), 99.

western states and the introduction of automatic machinery, approximately twenty smaller glass factories were consolidated into one large factory. Canning was another major industry; since the city was not agrarian, vegetables and fruits were transported into the city. Other industries included woolen mills, machine shops, and other smaller trades.[190]

Sewer History

Bridgeton's Board of Trade advocated for both a water works and sewers because it fit with their purpose to ensure Bridgeton had "a high degree of healthfulness" and an "[e]xcellent system of waterworks." The City Council approved the construction of a water works in March 1877 and hired civil engineer Isaac S. Cassin to design it. The water works opened in December 1877 with 7.5 miles of water mains laid in the city. A sewer system would not be constructed for many years, however. This is surprising because Edward M. Fithian and other members of the Board of Trade had completed studies for a sewerage plan and the City Council had, in 1891, engaged engineers (Waring, individually, and Rudolph Hering and Howard Murphy, jointly) to report on the conditions of the city for sewers. Charles McMillan (sometimes spelled McMillen) was also engaged in 1891 to design the sewerage system.[191] For undisclosed reasons, the city did not retain any of these engineers and instead hired Alexander Potter in 1897 to prepare a new report and plans for a sewerage system.[192]

---

[190] Grant, "Bridgeton," 99; Federal Writers' Project, *New Jersey,* 635; William B. Kirby, *A Souvenir of Bridgeton, N.J., "The Metropolis of Southern Jersey," Its Religious and Educational Advantages, Public Government, Business Importance, Attractive Surroundings, Enterprising Citizens and Pleasant* Homes (Bridgeton, New Jersey, U.S.A.: News Job Printing House 74 Commerce Street, 1895), 8.
[191] McMillan was known as the first Professor of Engineering at Princeton University and served as the Borough Engineer, reportedly designing Princeton's first sewerage system.
[192] Kirby, *A Souvenir of Bridgeton,* 61-62, 77; "Bridgeton, N.J.," *The Engineering Record* 24, no. 7 (1891): 113; Alexander Potter, *Report of a System of Sewerage and Sewage Disposal for the City of Bridgeton, New Jersey* (Bridgeton, N.J.: George W. McCowan, Printer, 1898), 6.

By 1897, 1.4 miles of sewers had already been privately constructed; information on these is limited. Potter recommended a separate system since Bridgeton is surrounded by creeks, lakes, and rivers, which could receive storm water, and sanitary waste could be disposed elsewhere.[193] Potter considered three methods of sewage disposal: chemical precipitation, disposal by dilution, and intermittent filtration; he determined intermittent filtration to be best suited to Bridgeton. Potter also recommended pipes ranging in diameter from 8 to 15 inches; in 1900 the city had 3.75 miles of 8-inch and 10-inch diameter pipes. Potter recommended the construction of a storm sewer along East Commerce Street, which flooded during storms. An additional 0.81 miles of 24-inch diameter brick sewers was recommended for stormwater drainage, though it is unclear if this was constructed on East Commerce Street. The system had ten outfalls, which discharged into the Cohansey River. Though Potter designed a 25-mile sewer system to service upwards of 40,000 people, construction progressed slowly, and, by 1900, only 4.56 miles were built. And, as late as 1917, approximately 29% of city residents were connected to the sewer system, 21% used cesspools, and 50% used privies.[194]

Though Potter proposed a separate system, there are some historical discrepancies about the type of system that was constructed in the nineteenth century. Timothy Woodruff, the Superintendent of Sewers in 1900, reported a combined system. Whereas in 1906, Mayor A.R. Fithian reported a separate system. Ultimately, it is

[193] To demonstrate the disadvantages of cesspools to broader public health and bolster the need for sewer construction, Potter's report included a case study on the spread of typhoid fever in Lausen, Switzerland, that demonstrated that water filtered through the ground still carried disease and infections, and turbidity could not be used to measure purity.
[194] Potter, *Report of a System of Sewerage and Sewage Disposal for the City of Bridgeton,* 16-17, 20-30, 46; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 45-46.

unclear what was constructed, but the data suggests that Bridgeton has both combined sewers alongside storm sewers.[195]

In 1907, the State Sewerage Commission sent a notice to the city asking them to cease polluting the river, as it harmed the oyster industry. Bridgeton disputed the harm, but bacteriological testing of oysters from the Cohansey Creek and water between Bridgeton and Greenwich demonstrated that the river was significantly polluted. Ultimately, Bridgeton complied with the State Sewerage Commission's notice and constructed a sewage purification plant in 1927.[196]

City of East Orange, Essex County

Today, East Orange is sandwiched between Newark and Orange. Historically, it was a part of Newark until 1806, when it split off and became a part of Orange. East Orange later split from Orange in 1863 when it was incorporated as a town and later as a city in 1899 (Figure 52).[197]

[195] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 45; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission, to the Legislature of 1906* (Trenton, N.J.: MacCrellish & Quigley, State Printers, 1906), 170; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission, to the Legislature, Session of 1902* (Trenton, N.J.: The John L. Murphy Publishing Co., Printers, 1902), 170.
[196] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission, to the Legislature of 1907* (Trenton, N.J.: MacCrellish & Quigley, State Printers, 1907), 87-88.
[197] William Hart, "East Orange," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen (New Brunswick: Rutgers University Press, 2005), 231.

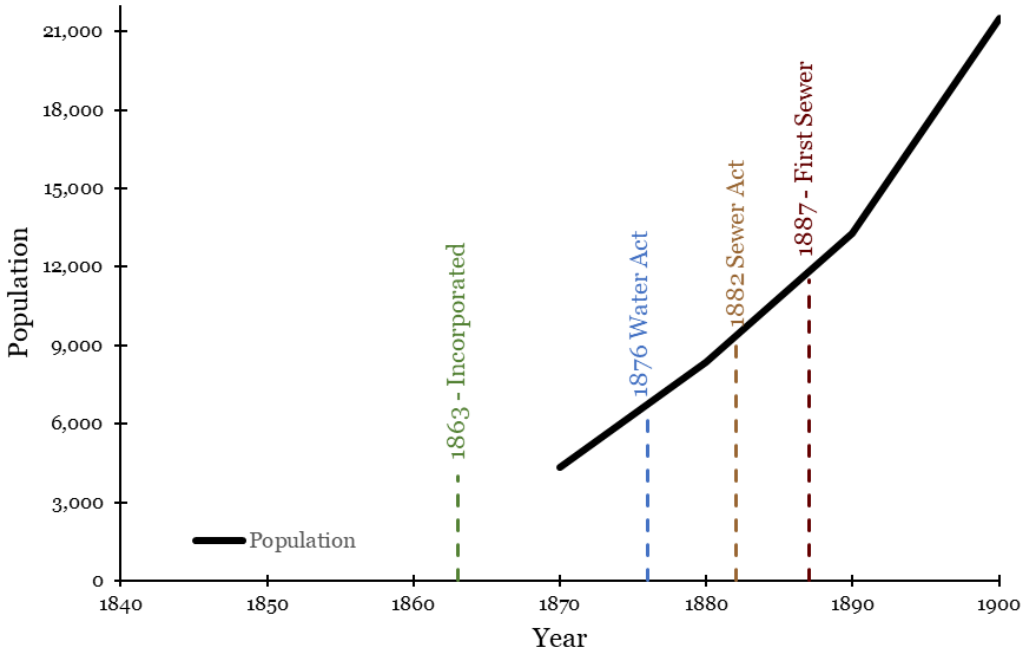


Figure 52. Population data for East Orange alongside key historical markers

East Orange started as a farming community and its proximity to Newark and New York City encouraged its development as a residential and suburban town. However, the 1720 discovery of copper on John Dod's land brought capital and people to labor in the mines. The town's location adjacent to streams encouraged the growth of mills. Around the same time, Dod established a gristmill alongside Second River that outlasted the copper mining, which ended around 1760. Later industries in East Orange included hat-making (the first Stetson hat factory was established in the 1830s), with additional production centered on electric motors, generators, and miscellaneous machinery.[198]

[198] Hart, "East Orange," 231; Bill Hart, *East Orange* (Charleston: Arcadia Publishing, 2006), 11, 18; Federal Writers' Project, *New Jersey,* 341.

Sewer History

In 1882, the Orange Water Company introduced a water supply to the Township of East Orange. The following year, the Town Improvement Society engaged John James Robertson Croes to examine the topography of the town, prepare a drainage map, propose methods for sewage disposal, and estimate the costs. Croes's report, dated September 28, 1883, recommended a 40-mile-long separate system which he expected would expand to 60 miles to mirror the town's growth. He argued that a combined system resulted in a greater volume of waste to treat, which equaled greater costs. Croes recommended sewers ranging in shape and size from circular pipes of iron and earthenware with 6-inch diameters to larger elliptical brick pipes sized 28 inches by 42 inches. To flush the system, cisterns connected to every house received rainwater runoff from roofs, which would be released into the sewer system without overwhelming it.[199]

Sewage disposal was a complex problem for East Orange because it was not adjacent to any water bodies and was surrounded by populous cities. East Orange had considered multiple options: connect to the Newark sewer system and release waste into the Passaic River; construct an independent outlet below Newark; or treat and dispose of the waste without an outlet. Croes favored a treatment plant that would release waste into a tributary of the Second River, which emptied into the Passaic River on the

[199] New Jersey, Board of Health, *Twenty-Fourth Annual Report of the Board of Health of the State of New Jersey, and Report of the Bureau of Vital Statistics, 1900* (Trenton, N.J.: The John L. Murphy Publishing Co., Printers, 1901), 259; Carroll Phillips Bassett, "The East Orange Sewage Disposal Works as Compared with Other Methods. Abstract of Paper read before New Jersey Sanitary Association, Trenton, November 22, 1889," in *Thirteenth Annual Report of the Board of Health of the State of New Jersey, and Report of the Bureau of Vital Statistics, 1889* (Camden, N.J.: F.F. Patterson, Printer, 1890), 73; New Jersey, Board of Health, *Twenty-Sixth Annual Report*, 347; W.H. Baldwin, "A General Consideration of the Sewerage Problem in East Orange, Embodying the Report of Mr. J.J. Croes, C.E." in *The Sewerage of East Orange, N.J.*, 9; John James Robertson Croes, "Report on a Plan of Sewerage for the Township of East Orange, New Jersey," in *The Sewerage of East Orange, N.J.*, 13-19; Waring, *Sewerage and Land Drainage*, 45.

northern boundary of Newark, whereas East Orange favored coordination with Newark to construct an outfall into the Newark Bay.[200] Because Newark refused to cooperate with East Orange, on April 3, 1884, Croes's proposal for a sewage treatment plant was unanimously adopted. By September 1884, East Orange asked Croes to revise his proposal to include an in-town disposal solution and an East Orange-operated outfall into the Newark Bay. For unspecified reasons, the city did not proceed with Croes's plan and paused sanitary development until the spring of 1886, when Carroll Phillips Bassett was hired to design a sewage purification works.[201]

Under Bassett's direction, with advisement from Rudolph Hering, construction on 26 miles of the system started in 1887.[202] Because ground water penetrated the pipes during construction, Bassett recommended under-draining the sewer pipes; reportedly, the town did not authorize this extra expense. Once the system was put into operation in 1888, Bassett was no longer involved in the design or construction of sewers or sewage purification works. By 1900, the constructed system consisted of 40 miles of vitrified, salt-glazed separate sewers ranging in diameter from 8 inches to 15 inches; 1.5 miles of

[200] East Orange was able to pursue coordination with Newark due to legislation passed on March 4, 1884. This legislation granted power to cities and towns with a public water supply and a density equal to, greater than, or expected to reach, 2,000 people per square mile, to construct sewers in other cities and towns in order to connect to tide waters, if the adjoining town agreed to cooperate.
[201] Baldwin, "A General Consideration of the Sewerage Problem in East Orange," 1, 9; Rafter and Baker, *Sewage Disposal in the United States*, 385; "The East Orange, N.J., Sewerage System," *Engineering News* (January 19, 1889), 42; New Jersey, Legislature, *Acts of the One Hundred and Eighth Legislature of the State of New Jersey, and Fortieth Under the New Constitution* (Camden, N.J.: Printed by Sinnickson Chew, 1884), 32-33; Niart Rogers, "Report on Sewage Disposal," in *Twentieth Annual Report of the Board of Health of the State of New Jersey, and Report of the Bureau of Vital Statistics, 1896* (Trenton, N.J.: MacCrellish & Quigley, State Printers, Opposite Post Office, 1897), 301.
[202] There was some controversy with B. J. Coyle, who constructed the first 5 miles of sewers. *Engineering News* reported that Coyle quit the contract because "the material to be passed through proved exceptionally difficult." Shortly after Coyle wrote to the editor of *Engineering News* that the issue was a matter for the courts and he did not find *Engineering News'* statement to be correct.

brick storm sewers with a diameter of 54 inches; and some pipe sewers of unspecified materials.[203]

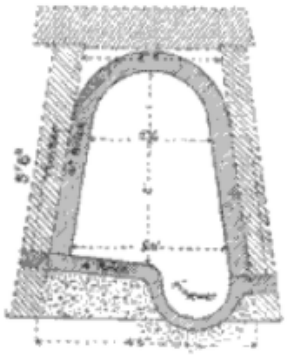


Fig 2.—Sketch Showing Section of Brick Sewer.

Figure 53. A brick sewer of Bassett's design in East Orange.
Source: "The East Orange, N.J., Sewerage System," Engineering News (*January 19, 1889): 43.*

Not reported by the City of East Orange in 1900 but reported by Bassett in 1889 was a segment of egg-shaped brick sewer 24 inches by 36 inches beneath Arlington Avenue, near the commercial and business parts of town. The sewer was 31.5 feet deep and passed through a conduit tunnel for 0.32 miles (Figure 53). This segment also included a storm sewer to provide relief against flooding in the Arlington Avenue area of town. It appears that later ad hoc storm sewers were constructed sometime in the early twentieth century. Though stormwater was excluded from the sewer system, it did get into the sewers and often overwhelmed the joint outlet sewer. It is likely that the 1.5-mile segment of storm sewers and natural streams eventually proved to be an insufficient receptacle. Thus, in 1922, city planners proposed a comprehensive city-wide storm sewer system, which was completed in 1939.[204]

---

[203] "The East Orange, N.J., Sewerage System," 42; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 49-50.
[204] Bassett, "The East Orange Sewage Disposal Works," 73; New Jersey, Board of Health, *Twenty-Sixth Annual Report,* 347; Rogers, "Report on Sewage Disposal," 302; Rafter and Baker, *Sewage Disposal in the United States*, 386; Carroll Phillips Bassett, "Inland Sewage Disposal, With Special Reference to the East Orange, N.J. Works," *Transactions of the American Society of Civil Engineers* 25 (August 1891),

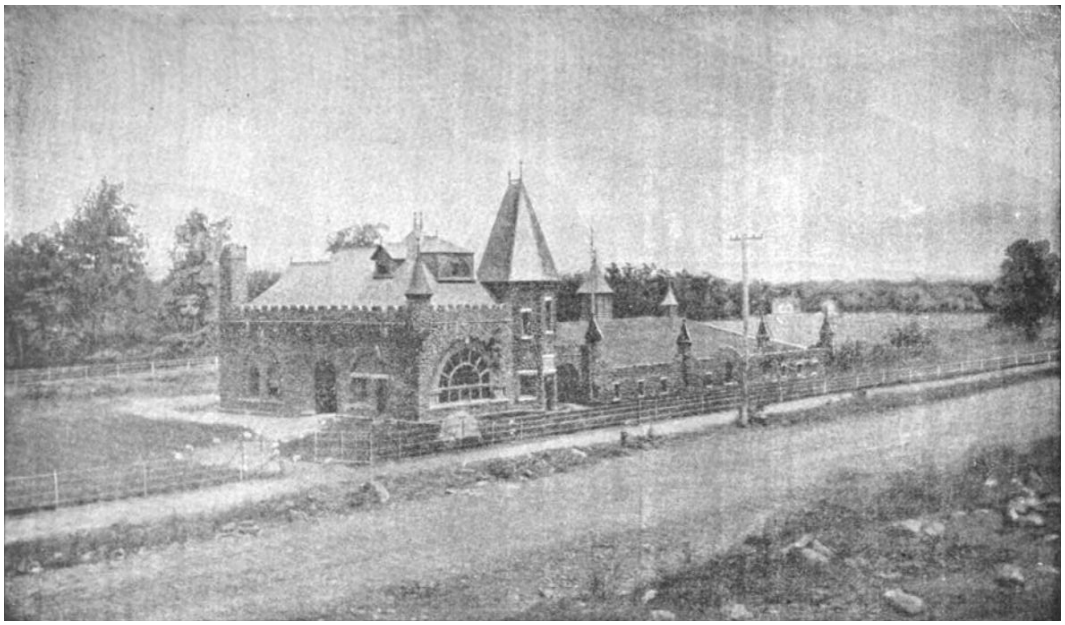


Figure 54. East Orange Sewage Purification Works, designed by Carroll Phillips Bassett. Source: George W. Rafter and W.N. Baker, Sewage Disposal in the United States, *2nd ed. (New York: D. Van Nostrand Company, 1894), 387.*

Bassett also designed a sewage purification works, which used a combination of intermittent filtration and chemical treatment (Figure 54). Unfortunately, by the mid-1890s, the purification works was deemed "impracticable" and East Orange was sued by the Town of Bloomfield. Ultimately, with no way to dispose of their sewage, East Orange contracted with the City of Newark. Reportedly, by 1900, there was a tie in at the 6th Avenue sewer and an outlet sewer that drained into the Mill Brook sewer.[205]

156-157; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 49; "The East Orange, N.J., Sewerage System," 43; New York, Metropolitan Sewerage Commission, *Sewerage and Sewage Disposal*, 324-325; Allison A. Gall et al., *Stage IA and Stage II Cultural Resources Survey, The Crossings at Brick Church Station* (Cranbury, New Jersey: Richard Grubb & Associates, Inc. 2021), 4-26.

[205] Rafter and Baker, *Sewage Disposal in the United States*, 386-388; New York, Metropolitan Sewerage Commission, *Sewerage and Sewage Disposal*, 307; New Jersey, Board of Health, *Seventeenth Annual Report,* 141; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 49; City of Newark, Board of Street and Water Commissioners, *Annual Report of the Board of Street and Water Commissioners of the City of Newark, New Jersey, for the Year ended December 31, 1896* (Newark, N.J.: Madison & Co., Stationers and Printers, 1897), 113.

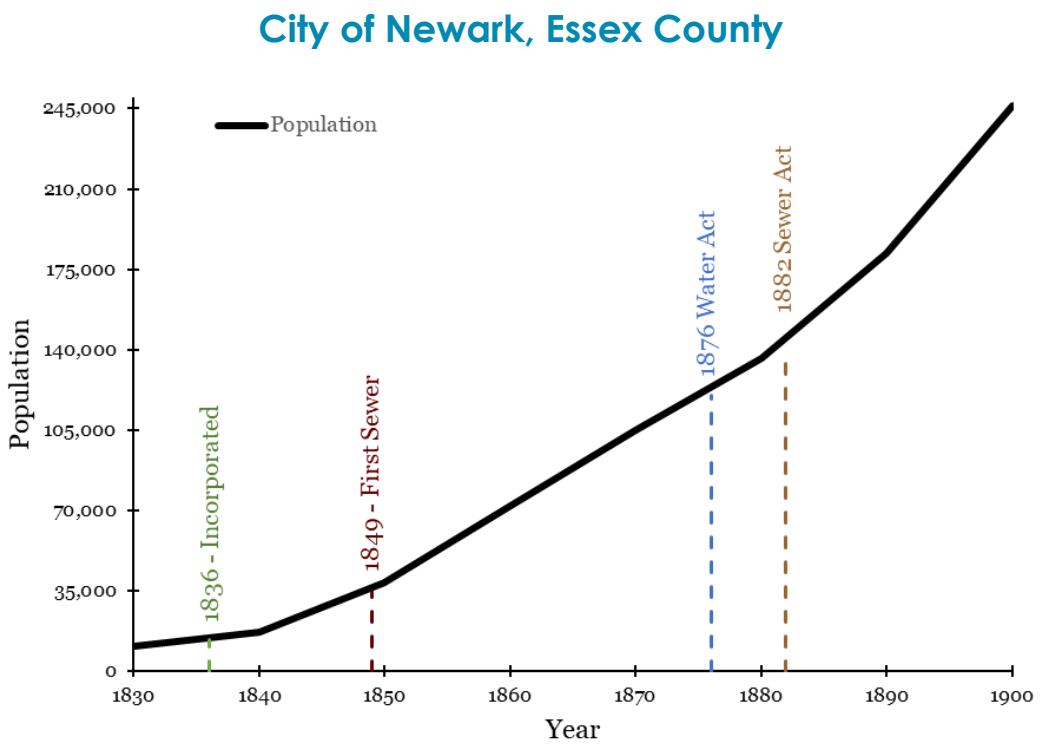


Figure 55. Population data for Newark alongside key historical markers.

Puritan settlers from New Haven moved to Newark in 1666. The city was later incorporated in 1836 (Figure 55). The city is partly surrounded by water bodies, with the Second River on the north, the Passaic River on the northeast, and the Newark Bay on the east. Marshland fronted Newark Bay until the twentieth century. From its early history, land and sea routes converged in Newark and propelled its growth. In the nineteenth century, railroad lines connected Newark to central and south Jersey and drawbridges over the Hackensack and Passaic Rivers improved connectivity to New York City. Even into the twentieth century, transportation routes continued to respond to the needs of the city. Work started on a deep-water port in the early twentieth century, when it became clear that the lack of one hampered economic expansion.[206]

[206] G. Kurt Piehler, "Newark," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen (New Brunswick: Rutgers University Press, 2005), 560-561; Federal Writers' Project, *New Jersey*, 313.

Newark's industries were established during the eighteenth century, and by the nineteenth century were more diverse than its contemporaries, seen in its hat making, jewelry, leather, including patent leather, and other artisanal goods. The city continued to be a leading manufacturing center and "every kind of product sold in the United States is manufactured in Newark." In addition to industry, the city was home to innovators and was the fourth largest insurance center in the country and second largest life insurance city in the country. The growth of industry in the city encouraged immigration, with Irish immigrants arriving in the 1830s, German immigrants in the 1850s, Italian immigrants in the 1880s, Chinese immigrants in the 1890s, and Polish immigrants in the 1900s. The burgeoning population made Newark "the largest industrial city in the United States."[207]

Sewer History

Newark's 1836 incorporation act empowered the Common Council to pass ordinances "causing common sewers, drains or vaults to be made in any part thereof," as needed for the public good. Though the act specified how other municipal expenses could be defrayed through taxation, it did not specify the same for sewers. In 1838, a newly revised incorporation charter sanctioned borrowing and fund raising by the Common Council for all sewer construction and requisitioned property needed for sewer construction. The frequently supplemented incorporation act must have been either ineffective or insufficient as local business owners urged a revision to the city charter. The 1849 addendum empowered the Common Council to "order and cause sewers or drains to be made and kept in repair, in such part of the city as the common council

[207] Piehler, "Newark," 561; Federal Writers' Project, *New Jersey*, 316-328; Israel, "The Garden State Becomes an Industrial Power," 178.

shall think necessary," with property owners who benefited from sewer construction required to pay either partial or full cost of the construction.[208]

Common Council Sewers

The earliest sewers constructed in Newark following the 1849 amended charter were analogous to open ditches, often dug in the middle of unpaved streets. These sewers overflowed and disgorged household garbage, human waste, and decaying animals whenever it rained. Seeing that the open sewers were a public nuisance, Newark residents urged the Common Council on Sewerage and Drainage to provide a permanent solution and construct enclosed, subterranean, sewers. The Common Council consulted the engineers who had worked on the New York City sewer system, studied the sewer advancements out of Europe, and by 1852, began construction on the first sewer, which was completed in 1854. The 60-inch diameter circular brick sewer was constructed 23 feet below Broad Street, ran east below Park Place and Rector Street, and ended in an outfall to the Passaic River. Later in 1854, the Market Street sewer was completed in three separate segments, running between Washington Street and New Jersey Railroad Avenue, with the longest segment over 1-mile long. The sewer also had an outfall to the Passaic River. The first three sewers cost $11,000, of which the city paid one-third and property owners paid the rest. This high cost of construction dissuaded property owners from advocating for further sewer construction.[209]

---

[208] New Jersey, Legislature, *Acts of the Sixtieth General Assembly*, 191-198; New Jersey, Legislature, *Acts of the Sixty-Second General Assembly of the State of New Jersey, at a Session Begun at Trenton on the Twenty-Fourth Day of October, Eighteen Hundred and Thirty-Seven. Being the First Sitting* (Trenton: Printed by James Adams, 1838), 218-219; Modica, *The History of the Newark Sewer System*, 4; New Jersey, Legislature, *Acts of the Seventy-Third Legislature of the State of New Jersey, and Fifth Session Under the New Constitution* (Trenton: Printed by Phillips & Boswell, 1849), 207-208.
[209] Modica, *The History of the Newark Sewer System*, 4-5; Galishoff, *Newark,* 36-41.

Newark's early sewer inverts were constructed with several courses of brick laid without cement mortar, to underdrain the sewer; unfortunately, there is no further information on the streets where this technique was employed. These sewers would have been constructed on a 1-inch-thick cradle of hemlock wood, with the bottom five or six courses laid without mortar. Not long after, public health concerns emerged. Newark physician, Dr. Lott Southard, hypothesized that under drained sewers contaminated groundwater, which infiltrated local wells and spread disease.[210] It is unclear if public health concerns or modifications to construction techniques resulted in the transition to the use of cement mortar by 1900. Into the twentieth century and under the leadership of Edward S. Rankin, Engineer of Sewers and Drainage in Newark, these early unmortared sewers were discovered, and it was reported that sewer construction was completed with mortared bases. In addition to changing the construction technique for the invert, vitrified paving brick replaced building brick in the late nineteenth and early twentieth century.[211]

Newark reported in 1886 that the main sewers were "nearly all constructed" and local sewers were added to the system as needed and "according to regular plans" (Figure 56). The same year, major watercourses throughout the city were covered. The 10th Ward ditch, approximately 0.38 miles long, was enclosed in a sewer which ranged in diameter from 45 to 53 inches. Mill Brook (sometimes referred to as First River) was

[210] Though he correctly hypothesized the role of contaminated drinking water in spreading disease, like his contemporaries Dr. Southard was also a proponent of miasma theory.
[211] Edward S. Rankin "Rebuilding an Old Brick Sewer in Newark, N.J." *Municipal Engineering* 41, no. 3 (September 1911): 284; Lott Southard, "Essex Water Supply. Drainage and Sewerage of the City of Newark, and their Relation to the Causation of Disease – The President's Annual Address to the Essex District Medical Society," *Transactions of the Medical Society of New Jersey* (1877): 194; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 54; Edward Rankin, "Materials for Sewer Inverts," 629.

fully enclosed by 1890 in the Clay Street and Mill Brook sewer, which was approximately 0.38 miles long and ranged in diameter from 108 to 144 inches (Figure 57). The Mill Brook outlet was a twin-horseshoe shape, with an outlet size of 81 inches by 111 inches. Other watercourses that eventually became a part of the early sewerage system included Hayes Brook and Wheelers Creek.[212]

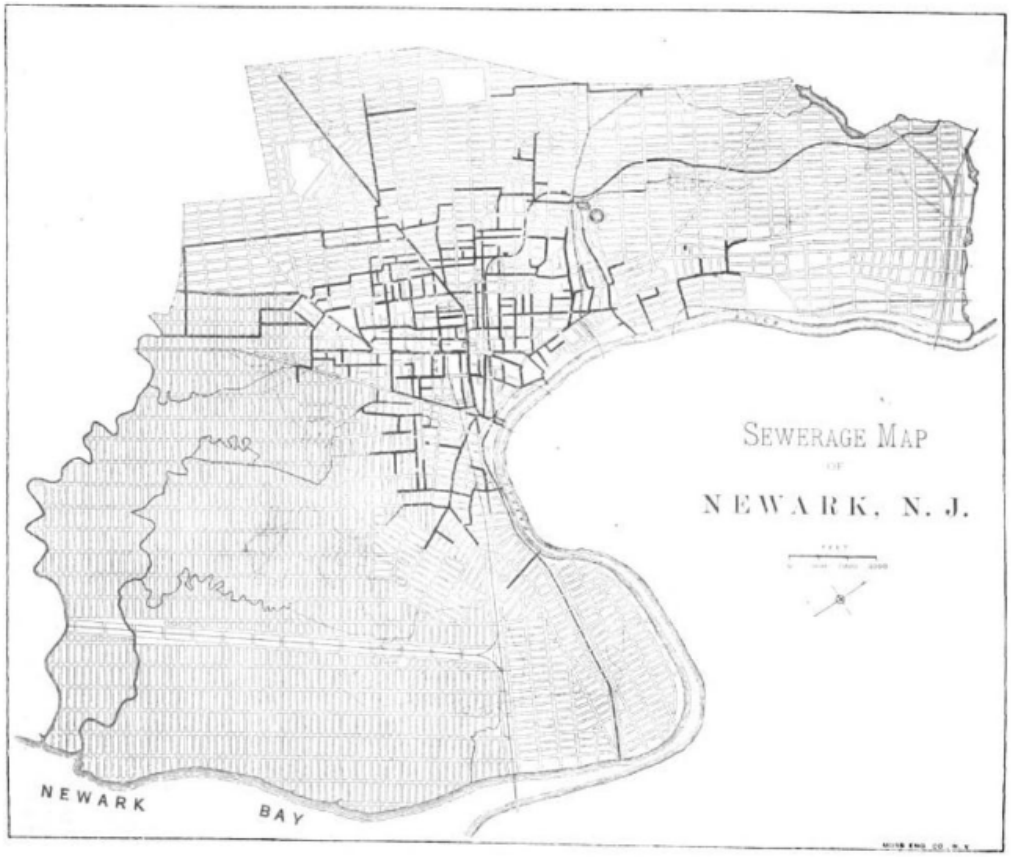


Figure 56. Sewerage map of Newark, New Jersey, in 1886.
Source: George E. Waring, Jr., Report on the Social Statistics of Cities, Part 1, the New England and the Middle States *(Washington: Government Printing Office, 1886).*

[212] Waring, *Report on the Social Statistics of Cities*, 710; Modica, *The History of the Newark Sewer System*, 6; New York, Metropolitan Sewerage Commission, *Sewerage and Sewage Disposal*, 311; Paul McEachen, Glenn Modica, and John W. Lawrence, *Cultural Resources Investigation, City of Newark, New Jersey, Department of Engineering, Phase III/IV Brick Sewer Evaluation and Environmental Assessment, Appendix A to Volume 3* (Cranbury, New Jersey: Richard Grubb and Associates, Inc., 2000), 7-16.

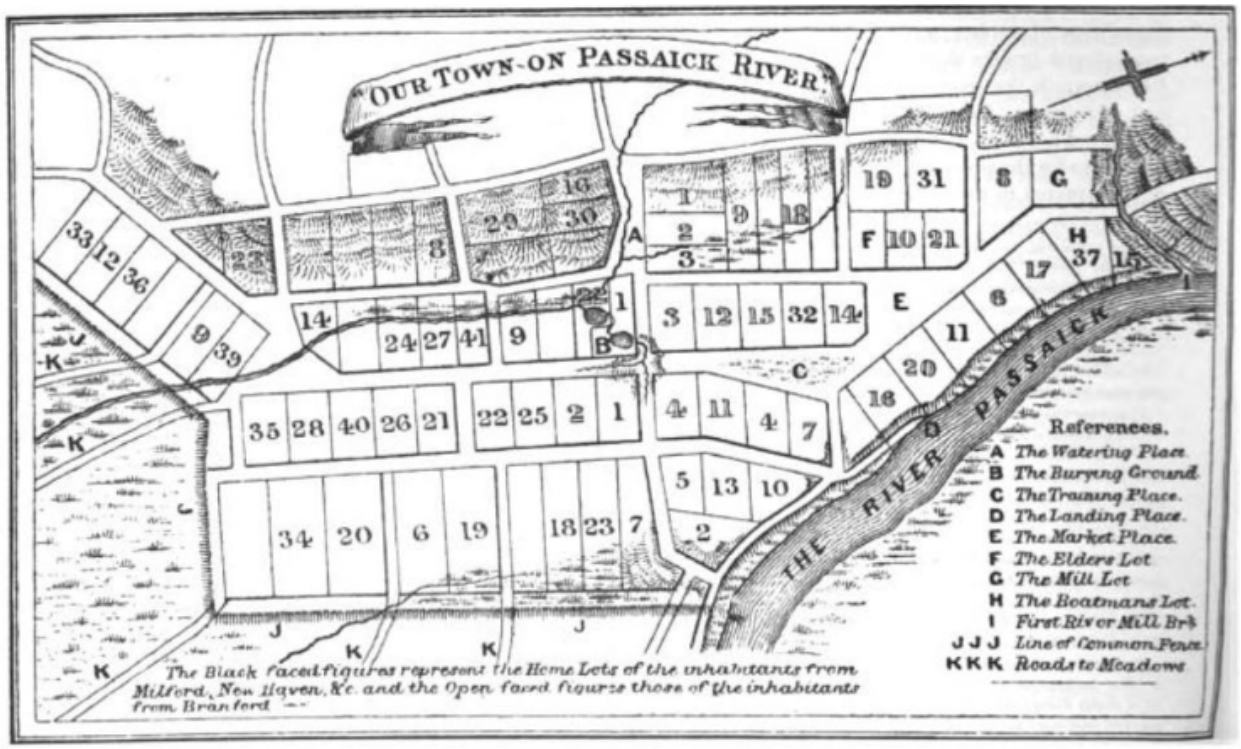


Figure 57. Historic map of Newark depicting Mill Brook, seen in the upper right. Scale not given. Source: William H. Shaw, History of Essex and Hudson Counties, New Jersey *(Philadelphia: Everts & Peck, 1884), 1:380.*

Common Council Guided Private Sewers

Irrespective of the powers granted to the Common Council by the city's incorporation act, some sewers were privately constructed by individuals. After the Civil War, real estate promoters advantageously acquired pasture lands located on the outskirts of the city. In order to attract new residents, they installed sewers, often haphazardly and in ungraded streets. The Common Council tried to systematize private sewer construction through an ordinance passed in 1885, which required construction to be directed and supervised by the City Surveyor. Sewer dimensions were regulated to ensure they could meet future capacity requirements; the spacing of manholes was standardized to enable future cleaning. Nevertheless, private sewer construction alongside municipal construction led to a fragmented system. In 1896, 0.5 miles of

private sewers were constructed, predominantly by factories, whereas the municipality constructed 5.3 miles of sewers. It is unknown what materials were used in the construction of private sewers.[213]

Often municipal officials promoted private sewer construction. The City Surveyor reported in 1891 that private lateral sewer construction saved the municipality money as it bypassed expenses associated with advertising, securing bids, etc., and was completed in less time because advertising and legal proceedings were not a prerequisite to the process. By 1910, almost 12% of all sewers had been privately constructed.[214]

Dissatisfied with the conditions of the city and believing that municipal improvements attracted economic growth, the Board of Trade, established in 1868, was often involved in improving sanitary conditions in the city. They had previously paid for a survey on methods of garbage disposal used in large cities; in 1884, they hired Julius W. Adams, Alphonse Fteley, and Rudolph Hering to survey the existing sewer system. The engineers observed that the lack of a comprehensive system, with new segments added for immediate but not comprehensive relief, was a major issue and also recommended the replacement of the Peddie Street Ditch with a trunk sewer, which would discharge into the Newark Bay.[215]

Even into the late nineteenth century as sewer construction was slowly taking off, repairs and modifications to the existing system steadily became a priority. Additions to the system included intercepting sewers and a pump station as early as 1884. By 1887,

---

[213] Modica, *The History of the Newark Sewer System*, 6-7; *Report of the City Surveyor of the City of Newark, N.J.*, 9; City of Newark, Board of Street and Water Commissioners, *Annual Report*, 111-112.
[214] *Report of the City Surveyor of the City of Newark, N.J.*, 10.
[215] Modica, *The History of the Newark Sewer System*, 12-13; Galishoff, *Newark*, 64; Paul J. McEachen and Glenn R. Modica, *Cultural Resources Investigation, City of Newark, New Jersey, Department of Water and Sewer Utilities, Phase V Brick Sewer Rehabilitation Program, Sewer Evaluation and Design Phase, Environmental Assessment* (Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2003), 7-2.

some separate sewers were constructed. In order to flush the sewer system, storm water was supplemented by tanks of water. In some areas, the sewers were considered for enlargement as they were not satisfactory for storm service. By 1897, with the intention of preventing extensive defects by addressing early stages of damage, repair work was discussed for a majority of the 55 miles of brick sewers since they were thirty to forty years old at the time. Most manufacturing wastes entered the sewers at this time as well.[216]

Simultaneously, half of Newark's homes had privy vaults and the other half had water-closets, which drained into the sewers. Many privies were still lined with wood as late as 1885. By 1888, Newark required that homeowners abandon their cesspools and privy vaults once sewer connections were available, with the Board of Health authorized to enforce this by 1890. The exception to enforcement were politically influential landlords, who often did not tap into the sewers because of the added expense.[217]

By 1900, 138 miles of Newark's sewers were on the combined system and 6 miles were on the separate system. There were 58 miles of brick sewers ranging in diameter from 30 inches to 108 inches as well as 86 miles of pipe sewers of unspecified material ranging in diameter from 8 inches to 36 inches. Most of the brick sewers were egg-shaped, with others classified as oval and circular shaped. The separate system only used pipe sewers of unspecified material ranging in diameter from 8 inches to 15 inches.

---

[216] *Report of the City Surveyor of the City of Newark, N.J.*, 17; New York, Metropolitan Sewerage Commission, *Sewerage and Sewage Disposal*, 309; Hunt, "The Sewer Systems of New Jersey," 95; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 54; City of Newark, Board of Street and Water Commissioners, *Annual Report*, 115; Waring, "Report on the Social Statistics of Cities," 712.
[217] Waring, *Report on the Social Statistics of Cities*, 712; Yost and Modica, *Stage IA Cultural Resources*, 4-5; Galishoff, *Newark*, 108-110, 128-129.

Initially, small ceramic laterals were used; however, by the early 1900s, cast-iron laterals were more common.[218]

By 1900, the sewers discharged waste at nine outfall points, composed of eight main sewers discharging into the Passaic River, and one intercepting sewer, receiving waste from six sewers and discharging into the Newark Bay. Though almost all the sewers flowed by gravity, the Newark Bay intercepting sewer had a lift. A lift is a type of pumping station that collects waste and lifts it to a higher elevation. By 1910, there were a total of seventeen outfalls, draining most of Newark. The outlets for these sewers ranged in size from 15 inches to 84 inches by 96 inches, with shapes such as horseshoe, circular, twin horseshoe, and "ellipse on its side." Materials included brick and concrete, as well as other materials.[219]

By 1905, the Board of Street and Water Commissioners oversaw all public works in the city; however, it was the Department of Sewers, comprised of a Chief Engineer and a team of eight engineers and three helpers, who were tasked with design. However, they may have consulted private engineers on specific projects as they did with Fteley and Hering, who were consulted on the intercepting sewer.[220]

Between 1894 and 1910, nearly 200 miles of sewers were constructed, in addition to the already 100-mile system. By 1910, it was reported that the sewer system covered most of Newark. At the same time, the city decided it would lay sewers and all below

[218] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 53-54; McEachen, Modica, and Lawrence, *Cultural Resources Investigation … Appendix A to Volume 3*, 7-14, 7-25.
[219] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 54; New York, Metropolitan Sewerage Commission, *Sewerage and Sewage Disposal*, 311.
[220] New York, Metropolitan Sewerage Commission, *Sewerage and Sewage Disposal,* 309.

ground infrastructure before paving the road, which suggests streets had been frequently ripped up to lay sewers.[221]

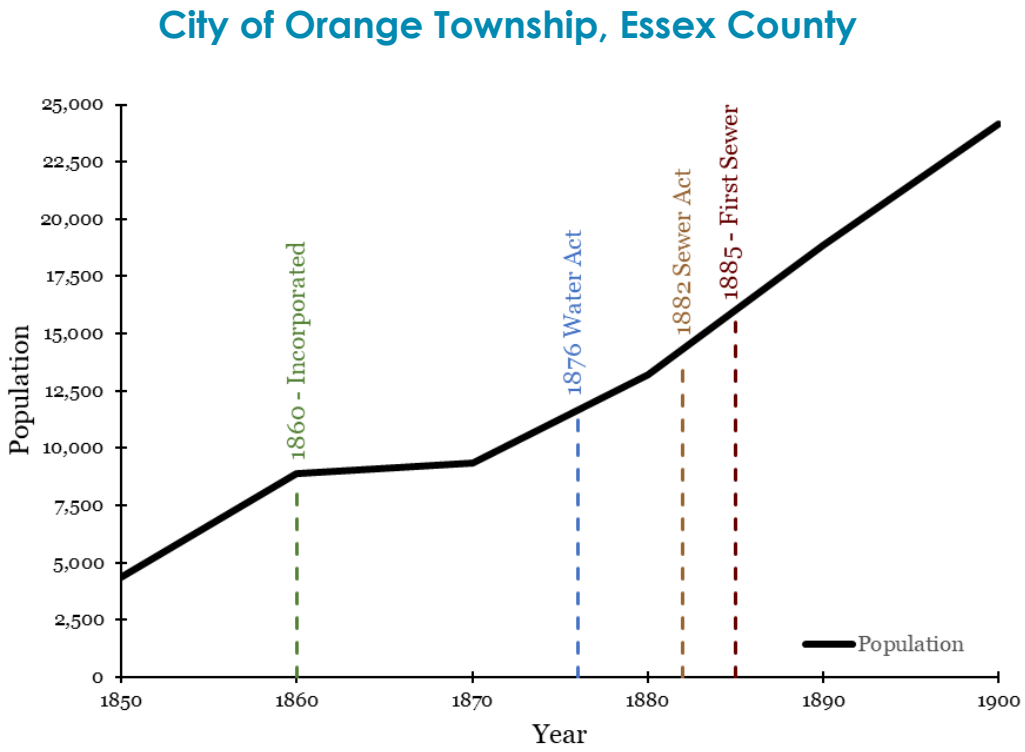


Figure 58. Population data for Orange alongside key historical markers.

Following its settlement in 1678, Orange was a farming community. Originally known as Western Newark, it came to be known as Orange as early as 1780. Orange went on to be incorporated as a town in 1860 and later as a city in 1872 (Figure 58). Historically identified waterways that ran through the city included the Parrow Brook, which ran south, and the Watchung Brook. The Nishuane and Wigwam Brooks, which were tributaries of the Second River, and the East Branch of the Rahway River, are today partially enclosed.[222]

[221] Galishoff, *Newark*, 128; New York, Metropolitan Sewerage Commission, *Sewerage and Sewage Disposal,* 314-315.
[222] Federal Writers' Project, *New Jersey*, 342; Peter J. Wosh, "Orange," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen (New Brunswick: Rutgers University Press, 2005), 605.

The industrial revolution prompted the growth of the city's shoemaking industry in the early nineteenth century. By the 1850s, hatting emerged as the dominant industry in the city, including the Stetsons. The hatting industry grew until it was crippled by labor disputes in the 1890s. This gave way to a focus on boxes, calculating machines, electrical supplies, pharmaceuticals, and radium watch dials.[223]

Sewer History

Before municipal sewers were constructed, Orange, like most cities, had an informal disposal mechanism in place. Liquid household wastes were disposed of in either cesspools or privy vaults. Laundry and kitchen wastes were sent through drains that connected to brooks, or, in select instances, street gutters. The cesspools were reportedly "unquestionably bad," though downward filtration was said to be "working well." Factories and houses (including those with cesspools or privy vaults) that abutted the Parrow and Watchung Brooks discharged waste directly into the waterways, a practice that was frowned upon by authorities.[224]

The growth of industrial activity and population in the city lent support to the construction of a sewerage system. In 1869, with the revised and amended charter for the Town of Orange, the Common Council was permitted to order sewer or drain construction. It is unclear if any sewers were constructed under this provision. As concerns mounted about the contamination of the current water supply, the drinking water system was built first. However, it would not be until 1881, when the city's water

[223] Wosh, "Orange," 605.
[224] Waring, *Report on the Social Statistics of Cities*, 718-719.

supply sources, including Bull Spring, Wigwam Brook, and Rope's Swamp, began to dry up, that the city considered the construction of a city owned water works.[225]

In August 1882, the City of Orange purchased the water rights to the West Branch of the Rahway River, which would feed a reservoir. The following month, the City of Rahway intervened, concerned with the detriment to their commercial establishments, including the mills lining the river, and public health if the City of Orange introduced an outfall below their intake point. Responding to these concerns, on October 20, 1882, Mayor George H. Hartford, of Orange, told the City of Rahway that his city had no sewerage system, was not planning to introduce one, and if it did, it would not construct an outfall into the Rahway River. With Rahway persuaded that their commerce and health would not be endangered, construction began by November 1882. On February 22, 1884, the Orange Water Company began supplying water. It is likely that the early commitment to not construct an outlet into the Rahway River influenced the eventual construction of the sewerage system.[226]

In 1885, Bassett & Nute (the firm of Carrol Phillips Bassett and John W. Nute) with Rudolph Hering, who lent support as a consulting engineer, were engaged to design a sewerage and drainage system.[227] Bassett & Nute recommended a separate system comprised of circular 6-, 8-, 9-, and 10-inch diameter circular pipes of cement or

[225] Nancy Zerbe, Marianne Walsh, and Angela Materna, *Historic American Buildings Survey, Chestnut Street Pumping Station* (Metuchen, New Jersey: ARCH^2, Inc., 2008), 6-8.
[226] Zerbe, Walsh, and Materna, *Historic American Buildings Survey*, 7; Henry Whittemore, *The Founders and Builders of the Oranges, Comprising a History of the Outlying District of Newark, Subsequently known as Orange, and of the Later Internal Divisions, viz.: South Orange, West Orange, and East Orange; Also, a History of the Early Settles or Founders, and of Those Who Have Been Identified with its Growth and Prosperity, known as the Builders, 1666-1896* (Newark, N.J.: L.J. Hardham, Printer and Bookbinder, 1896), 206.
[227] Bassett & Nute proposed ideas uncommon to other plans, including the construction of wet wells for areas of Orange that were not yet built up. These wet wells would collect the sewage and pump it through a force main, into an intercepting sewer, and then to an outlet.

vitrified stoneware and egg-shaped 12-, 15-, and 18-inch cement pipes with a flat exterior base. The only brick sewer in the design was the proposed channelization and enclosure of the 9,900 feet long Parrow Brook and its 5,500 feet long west branch.[228] The brick sewer dimensions they recommended ranged in size from 30 inches to 96 inches, with smaller pipes of egg-shaped cross-sections and larger pipes with circular cross-sections (Figure 59).[229]

COST OF PARROW BROOK DRAINS (Main Brook).

SIZE.	FROM.	TO.	GRADE.	DISTANCE.	PRICE PER FOOT.	COST.
30-inch...	Harrison st.....	Point on a new st.....	.3 ft. per 100 ft.	200 feet.....	$4 00.....	$800 00
33-inch...	1st point on a new st...	2nd point on a new st...	1.67 ft. per 100 ft.	1,000 feet.....	4 50.....	4,500 00
40-inch...	2nd point on a new st...	Oxford and Hickory sts.	.4 ft. per 100 ft.	800 feet.....	5 00.....	4,000 00
54-inch...	Oxford st.....	Reynolds st.....	.4 ft. per 100 ft.	580 feet.....	8 00.....	4,640 00
60-inch...	Reynolds st.....	Central ave.....	.2 ft. per 100 ft.	700 feet.....	9 00.....	6,300 00
60 inch...	Central ave.....	South st.....	.2 ft. per 100 ft.	1,460 feet.....	9 00.....	13,140 00
66-inch...	Hickory and South sts..	D., L. & W. R. R.....	.2 ft. per 100 ft.	830 feet.....	10 00.....	8,300 00
80 inch...	D. L.&W.RR & Comm'ce	Canfield and Main sts..	.2 ft. per 100 ft.	860 feet.....	13 00.....	11,180 00
80-inch...	Canfield and Main sts...	N. Centre & William sts	.2 ft. per 100 ft.	870 feet.....	13 00.....	11,310 00
80-inch...	N. Centre and William..	Wallace st.....	.2 ft. per 100 ft.	600 feet.....	13 00.....	7,800 00
75-inch...	Wallace st.....	Park ave.....	.8 ft. per 100 ft.	700 feet.....	11 00.....	7,700 00
75-inch...	Park ave.....	Washington & River sts.	.8 ft. per 100 ft.	1,450 feet.....	11 00.....	15,950 00
96-inch...	Washington & River sts.	East Orange line.....	.1 ft. per 100 ft.	640 feet.....	14 50.....	9,280 00
	Total.....					$104,900 00

COST OF PARROW BROOK DRAINS (West Branch to Commerce Street).

SIZE.	FROM.	TO.	GRADE.	DISTANCE.	PRICE PER FOOT.	COST.
22-inch...	Highland ave.....	Essex ave.....	1.5 ft. per 100 ft.	1,200 feet.....	$2 50.....	$3,000 00
33-inch...	Reynolds Terrace.....	Brook crossing.....	.8 ft. per 100 ft.	500 feet.....	4 50.....	2,250 00
48-inch...	Brook crossing.....	Henry st.....	.2 ft. per 100 ft.	1,000 feet.....	6 50.....	6,500 00
54-inch...	Henry st.....	Mechanic st.....	.2 ft. per 100 ft.	250 feet.....	8 00.....	2,000 00
60-inch...	Mechanic st.....	D., L. & W. R. R.....	.2 ft. per 100 ft.	1,100 feet.....	9 00.....	9,900 00
60-inch...	Lumber st.....	Commerce st.....	.2 ft. per 100 ft.	1,600 feet.....	9 00.....	14,400 00
		(West Branch) Total.....				$38,050 00
		(Main Brook) Total.....				104,900 00
		(Complete Book) Total.....				$142,950 00
		Contingencies, engineering, &c. (10 per cent.....				14,295 00
		Grand Total.....				$157,245 00

Figure 59. Proposed lengths and locations of the Parrow Brook brick sewers.
Source: Bassett & Nute and Rudolph Hering, Report with Plans and Estimates for the Sewerage and Drainage of Orange, N.J. *(Orange, N.J.: Press of the Orange Journal, 1885), 24.*

Bassett and Nute's primary concern was the purification of the city's streams, "owing to the large quantity of excreta, which find their way into them, little else than

[228] As late as 1890, the City of Orange recommended Parrow Brook be deepened, straightened, and widened to accommodate higher flows during rain events. It is likely that the unlabeled brook seen flowing through Orange and East Orange in an 1889 historical map is Parrow Brook: http://mapmaker.rutgers.edu/ESSEX_COUNTY/The_Oranges_1889.jpg
[229] Bassett & Nute and Rudolph Hering, *Report with Plans and Estimates for the Sewerage and Drainage of Orange, N.J.* (Orange, N.J.: Press of the Orange Journal, 1885), 21-23.

elongated and winding cesspools, oozing through the city." They were distressed with the condition of Parrow Brook, which they stated could not technically be classified as a sewer, only because it was not straightened and graded. To emphasize their point, they noted that if the same flow passed through a sewer and entered neighboring watercourses, the brook would have provoked governmental intervention.[230]

The construction specifications focused on ensuring that the drain was able to gather water from the sodden soil around the brook without discharging it into dry soil. Construction techniques that made this possible included constructing a brick sewer on a cement base, with inlet blocks at frequent intervals to connect laterals into the main drain, and small pipes in the trench alongside the larger brick sewer to underdrain the main sewer. By slowly adding water into the system, the system would not be inundated with water and would be able to carry it off to an outfall point.[231]

The design ran the brook through a drain and transformed it into a subterranean river enclosed in a culvert. Since Parrow Brook traversed privately owned lots, thus preventing construction, Bassett & Nute proposed channelizing the brook on public land. Laterals connected the main drain to factories that the brook supplied with water, with pumps where necessary. The factories would then release their wastewater into the municipal sewers. Bassett & Nute stated that this intervention prevented the wet soils associated with the brook from releasing illness causing miasmas, increased available land for building, cleaned the brook of future pollution by reversing its transformation from a sewer, and continued to provide clean water to the manufactories.[232]

---

[230] Bassett & Nute and Hering, *Report with Plans and Estimates for the Sewerage and Drainage of Orange,* 22.
[231] Ibid., 25.
[232] Ibid., 23.

Construction on the city-wide system started in 1891 and it was operational by 1894. By 1900, the separate system included 2.83 miles of brick sewers and 33.34 miles of vitrified clay sewers, of which 3.60 miles were storm sewers and 32.57 miles were sanitary sewers. Over 90% of the 35.5-mile sanitary sewer system that Basset & Nute had proposed, had been constructed by this time. There was an outlet on the Second River, near the northern boundary of the city along East Orange. The brick sewers, as constructed, included a 132-inch by 60-inch egg-shaped brick sewer 0.10 miles in length, with the remaining circular brick sewers ranging in diameter from 31 inches up to 84 inches. The VCP storm sewers ranged in diameter from 12 inches to 30 inches for a length of 0.77 miles, and the VCP house sewers ranged in diameter from 8 inches to 24 inches for a length of 32.57 miles. Only fourteen factories connected to the Orange sewer system. Other factories constructed their own private sewers, which continued to discharge into local waterways.[233]

Bassett & Nute also recommended sewage disposal alternatives in their proposal; however, it is unclear if any suggested was implemented. Ultimately, with the passage of the 1899 act, which permitted the construction of a joint sewer between multiple municipalities, the City of Orange participated in a joint sewer with Bloomfield, Glen Ridge, and Montclair. The joint sewer consisted of 24-inch vitrified clay pipes and egg-shaped brick sewers, 28 inches by 46 inches, along the Second River valley to a storage

[233] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 57-59; Bassett & Nute and Hering, *Report with Plans and Estimates for the Sewerage and Drainage of Orange,* 16; New York, Metropolitan Sewerage Commission, *Sewerage and Sewage Disposal*, 360.

tank located at Summer Avenue and Washington Avenue in Newark, which released waste into the Passaic River.[234]

City of Bayonne, Hudson County

Bayonne was settled by 1646 as a trading post. Residents prospered in oystering and shad fishing since the city is a peninsula surrounded by the Newark Bay on the west, the Kill Van Kull on the south, and the New York Bay on the east. Bayonne went on to be incorporated as a township in 1861 (Figure 60).[235]

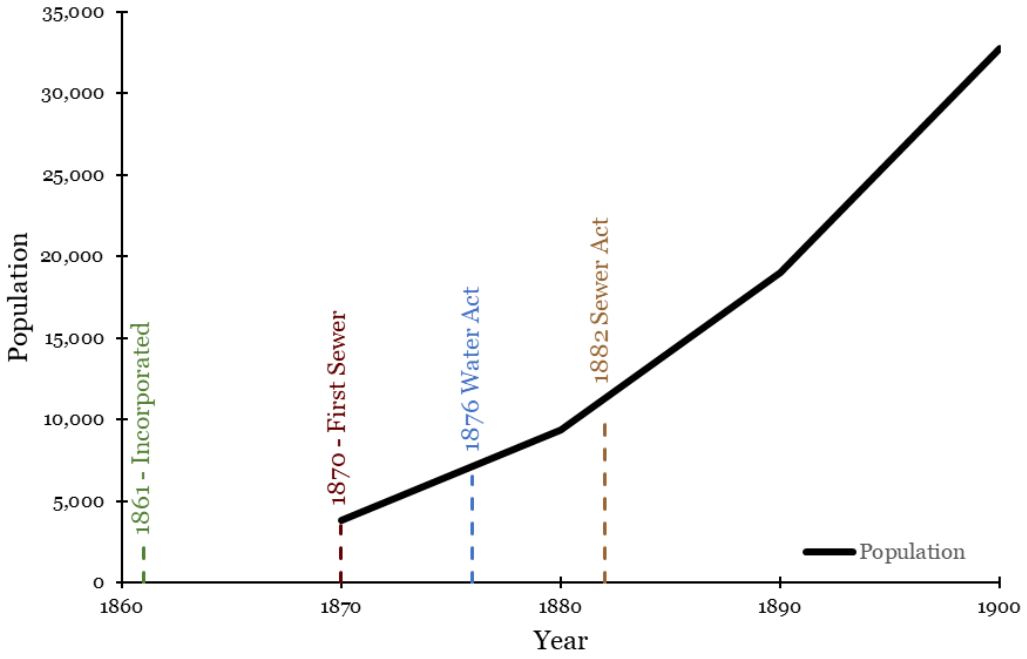


Figure 60. Population data for Bayonne alongside key historical markers.

The first industrial establishment was formed after the War of 1812; known as the Hazard Powder House, it produced gunpowder for military use. Located in the Constable Hook area and established in 1875, Prentice Refinery, the first refinery in the

[234] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 48, 57.
[235] Carmela Ascolese Karnoutsos, "Bayonne," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen (New Brunswick: Rutgers University Press, 2005), 63.

city, led the city to be known as the "oil-refining center of the State." By the late nineteenth century, a pipeline connected Constable Hook to oil fields outside the state. Other smaller industries in town lined the waterfront and produced cables, chemicals, cork, garments, metal and food products, and yachts.[236]

Sewer History

With the incorporation of Bayonne in 1869 as a city, the board of councilmen was empowered to "make and adopt a general plan of sewerage and drainage." The incorporation act suggested that sewers might have been built prior to 1869, as it stated that privately constructed sewers or drains could be absorbed into the municipal system, though no archaeological or historical research has confirmed this. The first brick sewer main was constructed on Cottage Street between 1870 and 1871. The sewer was reportedly circular in shape. In 1880, Bayonne had a design for the sewerage system, but further research is needed to determine if the system was constructed as planned.[237]

By 1900, Bayonne's combined sewer system included 9.5 miles of brick sewers with diameters ranging from 30 inches to 54 inches, 0.15 miles of cast-iron pipe, and 11.5 miles of 12-inch to 24-inch diameter pipe of unspecified material. Private sewers were still in use, though not much is known about them. The system discharged at five outfalls into the Newark Bay, at two outfalls into the New York Bay, and at two outfalls into the Kill Van Kull. Later sewers constructed in the heavily industrial areas on the eastern part of the city, including Constable Hook, were on the separate system. As of

[236] Federal Writers' Project, *New Jersey*, 201-203; Karnoutsos, "Bayonne," 63.
[237] New Jersey, Legislature, *Acts of the Ninety-Third Legislature of the State of New Jersey, and Twenty-Fifth Under the New Constitution* (New Brunswick, N.J.: Printed by A.R. Speer, 1869), 386, 399; Royden Page Whitcomb, *First History of Bayonne, New Jersey* (Bayonne, N.J.: Published by R.P. Whitcomb, 1904), 75; United States, Board of Health, *Annual Report of the National Board of Health* (Washington: Government Printing Office, 1879), 217.

1997, multiple sizes and shapes of brick sewers were still in use. The largest elliptical brick sewer was 56 inches by 80 inches and the largest circular brick sewer had a diameter of 54 inches. Some unique shapes in the system include a brick arch sewer sized 68 inches by 48 inches on Ingham Avenue by East 2nd Street and a brick horseshoe sewer sized 70 inches by 60 inches on Ingham Avenue by West 5th Street.[238]

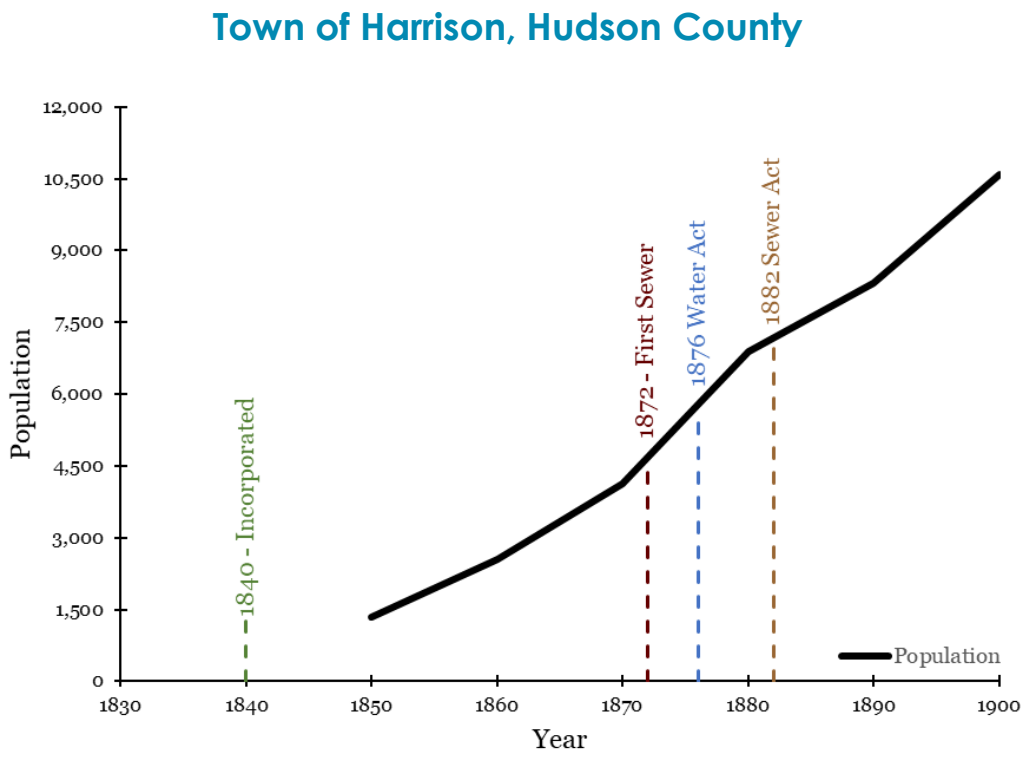


Figure 61. Population data for Harrison alongside key historical markers.

Founded by British settlers as early as 1668, Harrison was originally part of the township of Lodi and was incorporated as an independent township in 1840 (Figure 61). Separated from the City of Newark by the Passaic River, Harrison was described as a "Hive of Industry" by President William Howard Taft. Alongside the Crucible Steel

[238] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 62-63; Van Abs et al., *Water Infrastructure in New Jersey's CSO Cities*, 78; John S. Rolak, *City of Bayonne Combined Sewer System, Annual Inspection and Assessment Report, NJPDES Permit No. 0105023 and Individual Authorization No. 0109240, dated October 1997* (Whitehouse: Killam Associates, 1997), 29-30; Rolak, *City of Bayonne Combined Sewer System,* 63-64, 103, 118.

Company, the largest plant in the town, other manufacturing plants included those of Otis Elevator, Public Service Electric and Gas Companies, R.C.A Radiotron, and Worthington Pump. While the town's plants employed upwards of 90,000 people during World War II, the residential population was 14,171 people in 1940, indicative of a significant commuter population.[239]

Sewer History

When the incorporation charter for the Town of Harrison was revised and amended in 1872, a provision was included for the Common Council to "order and cause sewers and drains to be constructed in any part of said town." Construction began that same year. A piped-in public water supply was introduced afterwards, in 1886, by the Jersey City Water Company, which sourced water from the Passaic River.[240]

By 1900, Harrison had a combined system comprised of 1-mile of 30-inch brick sewers and 3 miles of 20- and 30-inch sewers of other unspecified materials. Wastewater was not treated before entering the Passaic River at any of the three outfalls. Though the system was inadequate for storm water, enlargement of the system was not considered.[241]

---

[239] Ray Floriani and Karen A. Floriani, *Harrison* (Portsmouth, New Hampshire: Arcadia Publishing, 2003), 7; Federal Writers' Project, *New Jersey*, 544; Daniel R. Campbell, "Harrison," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen (New Brunswick: Rutgers University Press, 2005), 351.

[240] New Jersey, Legislature, *Acts of the Ninety-Sixth Legislature of the State of New Jersey, and Twenty-Eighth Under the New Constitution* (Trenton, N.J.: Naar, Day & Naar, "True American" Office, Printers, 1872), 1336; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 66; New Jersey, Legislature, *Documents of the One Hundred and Twenty-Fifth Legislature of the State of New Jersey and the Fifty-Sixth Under the New Constitution* (Trenton, N.J.: The John L. Murphy Publishing Co., Printers: 1901), 3:262.

[241] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 66-67.

City of Hoboken, Hudson County

Hoboken was first settled by the Dutch around 1630. It is bordered on the east by the Hudson River and by Jersey City on the south. One of Hoboken's most influential residents was John Stevens, who purchased the land in 1784 for $90,000 and established the village of Hoboken; however, this would be as part of Bergen Township, and later North Bergen Township. He was responsible for introducing a ferry service to and from New York City.[242]

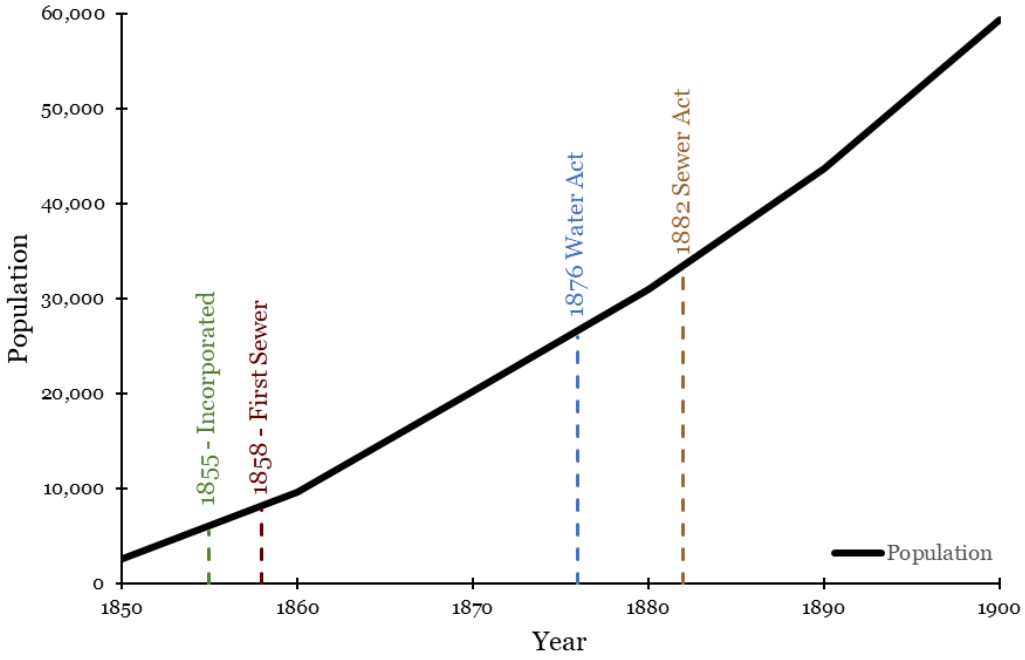


Figure 62. Population data for Hoboken alongside key historical markers.

During the first half of the nineteenth century, the city was a leisure destination for New Yorkers, who travelled to the city via ferry for the city's offerings of beer gardens, fireworks, and walking paths. Hoboken separated from North Bergen and incorporated as city in 1855, which gave way to the city's transformation into an industrial center with a major seaport (Figure 62). The location of the city also made it a

[242] Leonard Luizzi, "Hoboken," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen, (New Brunswick: Rutgers University Press, 2005), 378.

transportation center, with ten steamship and five railroad lines converging in the city.[243]

Factories were primarily located in the northern end of the city, and manufactured chemicals, food, foundry products, furniture, leather, metal, and technical equipment. Much of the city's immigrant population worked in the docks, factories, or railroads.[244]

Sewer History

Founded in 1838, the privately owned Hoboken Land and Improvement Company (HLIC) was one of the largest landowners in Hoboken. Prior to the incorporation of the city in 1855, the HLIC was averse to public works construction because it would not increase their bottom line, and unlike incorporated municipalities, the HLIC was not empowered to bill residents. At this juncture when the need for infrastructural development was gaining traction, a political movement to incorporate Hoboken as a municipality galvanized and succeeded. Even in the newly incorporated municipality, the HLIC held enough sway to discourage public works construction because they wanted a low tax burden for prospective residents.[245]

As the city's population grew, there was a growing desire to drain marshland for land reclamation. Sewer construction was slow and did not adhere to a plan. It is likely that city engineers oversaw the design of segments of the system as and when required. Tidal sewers were proposed as early as 1858. Early tidal brick sewers were installed in the uplands on Bloomfield Street (south from 8th Street), Newark Street, and

[243] Luizzi, "Hoboken," 378; Federal Writers' Project, *New Jersey*, 264.
[244] Federal Writers' Project, *New Jersey*, 263-264.
[245] Dilworth, *The Urban Origins of Suburban Autonomy*, 110, 122.

Washington Street (south from 6th Street) in 1860. The Bloomfield and Washington Street sewers drained into the trunk sewer on Newark Street, which had an outfall on the Hudson River. In 1866, additional brick sewers were being constructed in the uplands. At the same time, the city constructed a system of wooden tidal box sewers and open ditches in the meadows. The wooden tidal box sewer system was generally ineffective; it was out of service during heavy storms and sewage could only escape through evaporation.[246]

Brick sewers constructed between 1866 and 1868 ranged from circular to ovular, and diameters ranged from 30 to 60 inches. There was a brick lateral sewer on a segment of Garden Street; a trunk sewer on 3rd Street, between Adams Street and the Hudson River; and brick sewers on segments of Meadow and Willow Streets. A cement pipe of unspecified size was installed in 1867 on Garden Street between 9th and 11th Streets. Between 1869 and 1871, city residents petitioned the City Council to construct additional tidal box sewers.[247]

By 1880, it was reported that nearly all houses had connections with sewers, though house connections in the lowlands were considered "little more than worthless," likely due to the ineffective wooden tidal box sewers that were part of the lowlands landscape. Of Hoboken's homes, 75% had water closets, of which 90% drained into the

[246] *History of the Municipalities of Hudson County, New Jersey, 1630- 1923,* ed. Daniel van Winkle (New York: Lewis Historical Publishing Company, Inc., 1924), 1:293-1:295; United States, Board of Health, *Annual Report of the National Board of Health*, 181; New Jersey, Board of Health, *Twenty-Sixth Annual Report*, 347; Dewberry, *Rebuild by Design Hudson River, Resist, Delay, Store, Discharge* (2016), 1:58; Cushman et al., *Archaeological Monitoring, North Hudson Sewerage Authority,* 3-10, 5-1; New Jersey, Legislature, *Acts of the Ninetieth Legislature*, 942; Kathleen Abplanalp and Megan E. Springate, *Stage 1A Cultural Resources Survey, North Hudson Sewerage Authority, Collections System, Combined Sewer Rehabilitation, Wood Sewers, City of Hoboken, Hudson County, New Jersey* (Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2006), 3-14-3-15.

[247] Dewberry, *Rebuild by Design Hudson River,* 1:58-1:59.

sewers. Though nearly all houses were connected to sewers, approximately half of the city was not sewered most likely because it was unoccupied marsh land.[248]

Grand Street Sewer

Figure 63. Photograph of the interior of the Grand Street wood sewer.
Source: Laura Cushman, Michael Tompkins, Amy Raes, and Paul McEachen, Archaeological Monitoring, North Hudson Sewerage Authority, Grand Street Combined Sewer Rehabilitation, City of Hoboken, Hudson County, New Jersey *(Cranbury, New Jersey: Richard Grubb & Associates, 2015), Appendix E.*

Wooden sewers were constructed on Grand Street between 1869 and 1871 (Figure 63, Figure 64). Some of these 5 feet by 2 feet rectangular wooden sewers are still extant (Table 2). The wooden sewers generally consisted of vertical beams spaced about 4 feet apart that supported horizontal wooden planks, topped by a wood plank cover. The bottom of the sewer could not be observed during a 2015 archaeological monitoring project. Analysis of wood samples identified the species as pine (*Pinus* sp.). Little to no

[248] United States, Board of Health, *Annual Report of the National Board of Health*, 182-187; Thomas H. McCann and Alphonse Fteley, *Reports of Thomas H. McCann, City Surveyor, and Alphonse Fteley, Consulting Engineer, on a General Sewerage Plan, for the City of Hoboken, N.J.* (Hoboken, N.J.: The Evening News Print, 1890), 3.

hardware was used in the original construction of the wooden sewers; while there were a few metal spikes in boards, most boards had notches on the ends to fit together instead (Figure 65).[249]

Figure 64. Photograph of the exterior of the Grand Street wood sewer.
Source: Laura Cushman, Michael Tompkins, Amy Raes, and Paul McEachen, Archaeological Monitoring, North Hudson Sewerage Authority, Grand Street Combined Sewer Rehabilitation, City of Hoboken, Hudson County, New Jersey (*Cranbury, New Jersey: Richard Grubb & Associates, 2015), 4-17.*

Table 2. Extant Hoboken Wood Sewers Locations

Street Name	***Bounding Streets***
Jackson Street	Newark Avenue and Fifth Street
Grand Street	Newark avenue and Seventh Street
Madison Street	Sixth Street to Eighth Street
First Street	Marshall Street to Jackson Street
Newark Avenue/Street	Adams Street to Madison Street

Source: Laura Cushman, Michael Tompkins, Amy Raes, and Paul McEachen, Archaeological Monitoring, North Hudson Sewerage Authority, Grand Street Combined Sewer Rehabilitation, City of Hoboken, Hudson County, New Jersey *(Cranbury, New Jersey: Richard Grubb & Associates, 2015), 3-10.*

[249] Cushman et al., *Archaeological Monitoring, North Hudson Sewerage Authority*, 4-1, 4-19.

Figure 65. Metal spikes used in the construction of the Grand Street wood sewer, though notched ends were more common.
Source: Laura Cushman, Michael Tompkins, Amy Raes, and Paul McEachen, Archaeological Monitoring, North Hudson Sewerage Authority, Grand Street Combined Sewer Rehabilitation, City of Hoboken, Hudson County, New Jersey (*Cranbury, New Jersey: Richard Grubb & Associates, 2015), 4-20*

14th Street Sewer

The 14th Street sewer was monitored as part of a construction project between August 10, 2005, and February 24, 2006. The brick sewer is 54 inches wide by 72 inches high and built between 1880 and 1908. The interior of the sewer is egg-shaped (Figure 66). The upper arch of the sewer is two wythes and has a thin layer of plaster covering its exterior surface. The lower part of the sewer has straight exterior sides consisting of at least five or six courses of brick. The bottom of the sewer was not completely excavated, but there were wooden planks, 1.1 feet thick, underlying and running parallel to the sewer.[250]

[250] Joseph V. Moore et al., *Archaeological Monitoring/Stage IB Archaeological Survey, North Hudson Sewerage Authority, Solids/Floatables Removal Project, Package 1 (h-6/H-7 and Consolidation Conduit) City of Hoboken, Hudson County, New Jersey* (Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2006).

Figure 66. Photograph of the 14th Street egg-shaped sewer.
Source: Joseph V. Moore et al., Archaeological Monitoring/Stage IB Archaeological Survey, North Hudson Sewerage Authority, Solids/ Floatables Removal Project, Package 1 (h-6/H-7 and Consolidation Conduit) City of Hoboken, Hudson County, New Jersey *(Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2006), 6-34.*

Thomas H. McCann and Alphonse Fteley Plan

In 1890 the City Council engaged Thomas H. McCann and Alphonse Fteley to report on a sewerage system for the city. Of the existing tidal box sewers, half were wood, and the other half were brick on piling. While the tidal sewers were "nothing more or less than elongated cesspools," the sewers in the Hoboken uplands were in good condition and of ample size.[251] McCann recommended a combined system, as a separate system would be insufficient to accommodate any future construction of factories and tenements. The design included a pump station in areas where gravity could not convey the waste. It is unlikely that McCann and Fteley's designs were adopted, as the City of Hoboken faced push back from residents of the uplands, who would be taxed to pay for

[251] The term "elongated cesspools" has also been used by English sanitarians, in the 1840s, to condemn early sewers, which frequently clogged.

construction. A later 1910 report confirms this: "no definite action has been taken with respect to further improvements in sewerage."[252]

Ferry Street (Observer Highway) Sewer

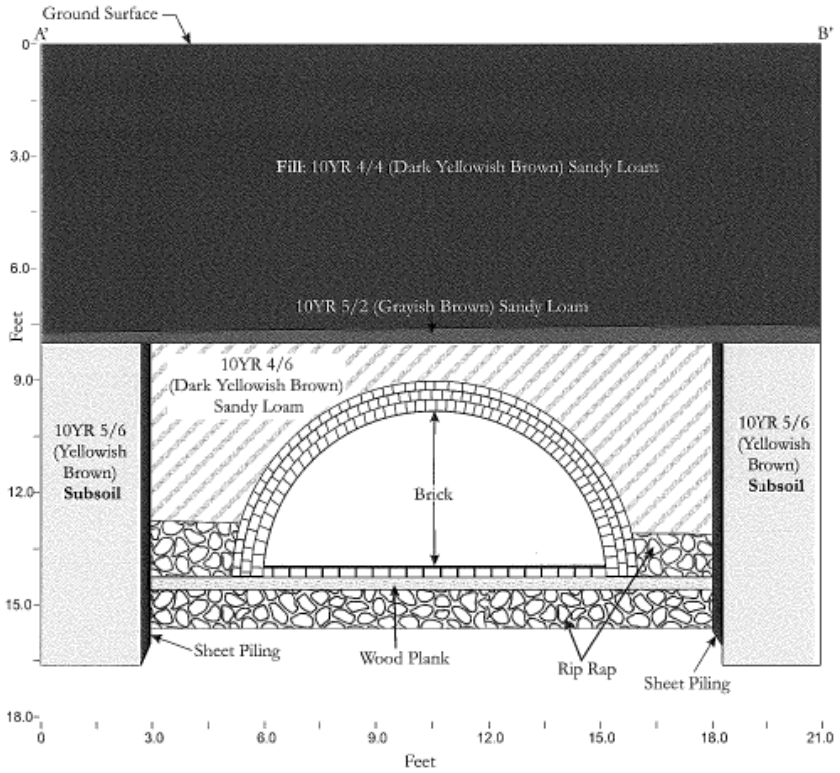


Figure 67. Cross-section drawing of the Observer Highway.
Source: Scott Wieczorek and Michael Tomkins, Archaeological Monitoring North Hudson Sewerage Authority, H1 Screening and Wet Weather Pump Station, City of Hoboken, Hudson County, New Jersey *(Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2012), 4-18.*

A 48-inch by 96-inch brick outfall sewer was constructed below Ferry Street (now Observer Highway) (Figure 67). The sewer was planned as early 1870 but was not built until 1895. It started near Jefferson Street and Ferry Street and continued onto Hudson Street. From there, it turned to pass below the rail yard of the Delaware, Lackawanna & Western Railroad and continued below the railroad pier. The aboveground conditions influenced the materials used in construction. The segment along Ferry Street was

[252] McCann and Fteley, *Reports*, 3-6, 12; *History of the Municipalities of Hudson County,* 295; New York, Metropolitan Sewerage Commission, *Sewerage and Sewage Disposal*, 357.

constructed of brick, the segment below the rail yard was a 48-inch cast-iron pipe, and the segment below the railroad pier was a wooden box sewer. A tidal gate was also constructed as part of the Ferry Street sewer.[253] It consisted of three courses of brick with cast-iron mechanisms (Figure 68).[254]

Figure 68. Brick tidal gate with iron mechanisms in the Observer Highway sewer.
Source: Scott Wieczorek and Michael Tomkins, Archaeological Monitoring, North Hudson Sewerage Authority, H1 Screening and Wet Weather Pump Station, City of Hoboken, Hudson County, New Jersey *(Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2012), 4-7.*

In 1900, Hoboken reported that the sewer system was not perfect but it was adequate for storm service, though enlargement was not being considered. The combined system was 14 miles long and composed of brick and other unspecified materials. The average dimension of the brick sewers was 30 inches by 45 inches, and

[253] The tidal gate was documented before removal.
[254] Scott Wieczorek and Michael Tomkins, *Archaeological Monitoring, North Hudson Sewerage Authority, H1 Screening and Wet Weather Pump Station, City of Hoboken, Hudson County, New Jersey* (Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2012), i, 3-1, 3-3.

the average diameter of the other sewers was 12 inches. All the sewers had outlets into the Hudson River.[255]

City of Jersey City, Hudson County

Jersey City was established as a Dutch colonial town by 1621. The city is located between the Hackensack and Hudson Rivers, and the City of Bayonne to the south. The early focus was on farming, but industries were also established during the late seventeenth century, starting with the Lorillard Tobacco Company. With the motto "Everything for Industry," the city's factories produced consumer goods, ranging from food items, household goods, personal care products, to industrial goods. Some well-known brands include Colgate and Dixon.[256]

Jersey City was first incorporated in 1838 and then, in 1873, it was again incorporated as a consolidated city composed of the original settlement around Paulus Hook, Bergen Township, and Van Vorst, Hudson, and Greenville villages (Figure 69). Like other towns adjacent to waterways, a ferry service was established in the late seventeenth century. In 1834, a horse-car service to Newark was introduced, and the Morris Canal opened in 1836. The city's proximity to New York City encouraged railroad construction in the late nineteenth century, including the Erie, Jersey Central, and Pennsylvania Railroads. The Lackawanna Railroad was introduced to the city later. Construction efforts needed laborers, which attracted primarily Irish Catholic and

[255] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 64-65.
[256] Federal Writers' Project, *New Jersey*, 270-271, 274-275.

German immigrants in the 1840s. Immigration into the city continued even after railroad construction was complete, as factory jobs were abundant.[257]

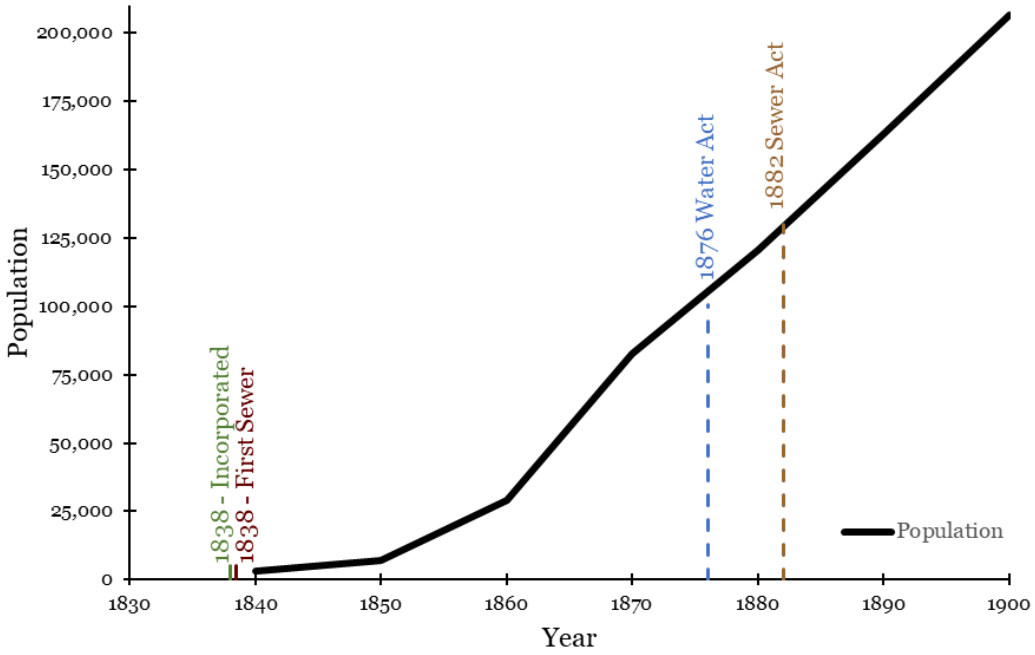


Figure 69. Population data for Jersey City alongside key historical markers.

Sewer History

In 1838, the State Legislature passed "[a]n act to incorporate Jersey City," which repealed the original incorporation act of 1820. The new incorporation act empowered the Common Council to permit the construction of common sewers and drains, as well as privy vaults, which would be paid for by raising taxes in the city. One of the earliest private sewers was constructed in 1837, by residents living along Essex Street. Another early sewer was constructed in 1838 under Grand Street, between Greene Street and Hudson Street, for an approximate length of 0.09 miles. This sewer would have drained directly into the Hudson River. At the time of construction, Hudson Street abutted the Hudson River; however, between 1841 and 1855, the coastline was filled in. When Grand

[257] Barbara Petrick, "Jersey City," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen (New Brunswick: Rutgers University Press, 2005), 423; Federal Writers' Project, *New Jersey*, 270-274.

Street was later extended one block further, so too was the sewer. By 1853, the Grand Street sewer was reported to be 0.17 miles long, running between Washington Street and the Hudson River, sized 36 inches by 30 inches. Later sewers, most likely constructed between 1848 and 1855, included 2.97 miles of brick sewers ranging in size from 20 inches by 15 inches up to 48 inches by 36 inches.[258]

When the city entered the latter half of the nineteenth century, city officials were able to prioritize sewer construction and drinking water through the passage of two key acts in 1851, and their later supplements. "[A]n act to incorporate Jersey City," gave the Common Council the powers to construct sewers and charge property owners their share of construction. "[A]n act for the appointment of commissioners in relation to supplying the townships of Hoboken, Van Vorst, and the city of Jersey City with pure and wholesome water," (Jersey City Board of Water Commissioners Act), in its later 1852 supplement, considered sewers an equally important infrastructural investment. City officials, swayed by the experiences of the Croton Aqueduct Board in New York, considered drainage and sewerage conjointly. The Jersey City Board of Water Commissioners engaged William Scollay Whitwell to design the drinking water system, which he started on August 26, 1851. Before the year was over, construction on the city-owned water works started and was completed in 1854.[259]

---

[258] New Jersey, Legislature, *Acts of the Sixty-Second General Assembly*, 110, 116, 119, 123; Alexander McLean, *History of Jersey City, N.J., A Record of Its Early Settlement and Corporate Progress* (Jersey City: Press of the Jersey City Printing Company, 1895), 40; Dilworth, *The Urban Origins of Suburban Autonomy*, 114; William Scollay Whitwell, *Report Made to the Water Commissioners of Jersey City, April 11th, 1853, upon a Plan of City Sewerage* (New York: Van Norden & King, Stationers, 1853), 22, 30-31.
[259] Teresa D. Bulger et al., *Stage II Cultural Resources Survey, Jersey City Municipal Utilities Authority, Sewer Phases 1-2 Sewer Rehabilitation, City of Jersey City, Hudson County, New Jersey*, (Cranbury: RGA, Inc., 2019), 3-17-3-18; New Jersey, Legislature, *Acts of the Seventy-Fifth Legislature of the State of New Jersey, and Seventh Session Under the New Constitution* (Trenton: Printed by Phillips & Boswell, 1851), 406; New Jersey, Legislature, *Acts of the Seventy-Sixth Legislature of the State of New Jersey and Eighth Under the New Constitution* (Somerville: Printed by Donaldson & Brokaw, 1852), 428; Charles H.

One year prior, in 1853, Whitwell was engaged to design a comprehensive sewer system for the city. Whitwell's plan expanded on the existing sewer components, of which 1.17 miles were out of commission (Figure 70, Figure 71). He also took inspiration from London, which shared similar geographical and topographical conditions, low-lying and difficult to drain, and customized a solution that was specific to Jersey City. Whitwell's proposal included combined brick sewer mains on alternating streets, running west to east. Because there was no mechanism to flush the system, he recommended a canal for flushing the sewers, which was approved by the State Legislature, though it was ultimately deemed unfeasible and not built. Whitwell recommended a combination of circular and egg-shaped pipes. Like many sanitary engineers who reported on sewer systems, Whitwell, too, considered construction economy. He proposed the use of common brick, which would permit the construction of smaller dimension sewers, over hollow radiated brick. Though Whitwell acknowledged that hollow radiated brick was a denser material with greater strength and impermeability, it is unclear which brick was used in construction and its impact on the longevity and survivability of the sewer pipe.[260]

Winfield, *History of the County of Hudson, New Jersey, from its earliest settlement to the present time* (New York: Kennard & Hay Stationery M'fg and Printing Co., 1874), 292.

[260] Waring, *Report on the Social Statistics of Cities*, 698; Whitwell, *Report Made to the Water Commissioners of Jersey City,* 12, 22; Lauren Lembo and Elizabeth Diker, *Stage IA Cultural Resource Survey, Jersey City Municipal Utilities Authority Sewer Phases 1-2 Sewer Rehabilitation, City of Jersey City, Hudson County, New Jersey (JCMUA Project No. S340928-24)* (Cranbury: RGA, Inc., 2018), 4-39; Teresa D. Bulger et al., *Stage II Cultural Resources Survey, Jersey City Municipal Utilities Authority,* 3-19-3-20; Jean Howson, *Cultural Resources Survey of the Jersey City Water Works Pipeline, 1851-1873, U.S. Route 1&9 Truck Interim Improvements Project, Charlotte Circle, Jersey City, NJ* (The RBA Group, Inc., 2001), 21; New Jersey, Legislature, *Acts of the Seventy-Eighth Legislature of the State of New Jersey and Tenth Under the New Constitution* (Mount Holly: Printed by Moreton A. Stille, 1854), 403.

TABULAR VIEW OF EXISTING SEWERS IN JERSEY CITY.

NAME OF STREET.	Size Sewer. Height.	Width.	Inclination per 100 feet.	Length of Sewer.	Length to be taken up.	Discharges into.	Condition of Sewer, March 15, 1853.	Cost per foot. Inst.	Culverts.
Morris, from Greene to Hudson River,	4 ft.	3 ft.	15 in.	460 ft.		Hudson River.	About an inch of mud, easily removed by a constant run of water.	3	64
Sussex, from Green to River,	1 ft. 8	1 ft. 3	36 in.	470 ft.		Hudson River.			
" " " Wash'n,	3 ft.	2 ft. 6	5 in.	430 ft.		Washington-st.			
York, between Washington and Hudson River,	3 ft. 4	2 ft. 6	15 in.	700 ft.		Hudson River.			
Grand, between Washington and River,	3 ft.	2 ft. 6	16 in.	900 ft.		Hudson River.			
Montgom'ry, between Washington and River,	3 ft. 6	2 ft. 9	10 in. 12 in.	490 ft. 300 ft.	790 ft.	Hudson River.			
Montgomery, between Washington and Warren,	4 ft.	3 ft.	3 in.	430 ft.	430 ft.	Washington-st.	3 inches of mud.		
Montgomery, from Van Vorst to Henderson,	2 ft. 9	3 ft. 3	3 in.	410 ft.	410 ft.	Henderson-st.	From 16 to 20 inches of thick black mud.		
Montgomery, from Grove to Barrow,	3 ft. 8	3 ft.	3 in.	230 ft.	230 ft.	Grove-st.			
Mercer, from Grove to Barrow,	3 ft. 8	3 ft.	3 in.	480 ft.		Grove-st.			
Wayne, from Washington to River,	4 ft.	3 ft.	2½ in.	600 ft.	600 ft.	Hudson River.	4 inches of deposit; quite hard at cor. Greene and Wayne. The tide has free access.		
Wayne, from Henderson to Grove,	3 ft.	2 ft. 6	3 in.	340 ft.	340 ft.	Henderson-st.		2	60
Wayne, from Barrow to Grove,	3 ft. 8	3 ft.	3 in.	300 ft.	300 ft.	Grove-st.	3 inches mud and sand.		

Figure 70. Part 1 of Whitwell's 1853 survey of existing sewers in Jersey City.
Source: William Scollay Whitwell, Report Made to the Water Commissioners of Jersey City, April 11th, 1853, upon a Plan of City Sewerage *(New York: Van Norden & King, Stationers, 1853), 30.*

Gregory, from York to Henderson,	3 ft. 4	2 ft. 8	8½ in. 1¾ in.	350 ft. 540 ft.	540 ft.	Henderson-st.	Greatest deposit at Henderson-st. From 5 to 18 inches thick black mud.		
Newark Av. east of Henderson,	3 ft.	2 ft. 4	3 in.	270 ft.	270 ft.	Henderson-st.	" 4 to 6 " "		
R. R. Av., from Grove to Henderson,	3 ft. 9	3 ft. 6	3½ in.	490 ft.		Henderson-st.	4 inches mud and sand,	2	36
Washington, from Grand to Bergen,	4 ft.	3 ft.	12 in.	980 ft.		Morris Canal.			
" " " Wayne.	4 ft.	3 ft.	24 in. 3 in.	390 ft. 520 ft.		Dock, foot of Wayne. " "	Very clean at upper end. Lower end was not opened.		
Henderson-street, from Newark Av. to Communipaw Bay,	3 ft. 9	3 ft.	1¾ in.	1,370 ft.	1,370 ft.	Under Morris Canal to tide water.	From York-street to Canal, this sewer is quite clear. From York-st. north, from 8 to 18 inches of mud and sand. This sewer has settled; and its appearance indicates that none of the solid matter passes beyond York-st. The syphon is clear.		
Grove, from Newark Av. to Montgomery-st.,	4 ft.	3 ft.	6½ in. 2½ in.	340 ft. 520 ft.		Under Morris Canal to tide water.	In some parts, 2 or 3 inches of deposit; but generally the sewer is very clear. The syphon is entirely filled.	2	57
Grove, from Montgomery to Communipaw Bay. Wooden sewer,	3 ft.	1 ft. 8	2½ in.	840 ft.					
York, from Washington to Henderson,	3 ft. 4	2 ft. 6	20 in. 4½ in. 4 in.	340 ft. 460 ft. 460 ft.	460 ft.	Henderson-st.	From 4 to 16 inches of thick black mud. The greatest depth at Henderson-street.		
Grand, from Washington to Henderson,	3 ft. 9	3 ft. 4	9½ in.	800 ft.		Henderson-st.	In some parts 5 or 6 inches of sand washed in from street,	2	11
	" "	" "	6½ in.	460 ft.					
				15,670 ft.	6,200 ft.				

2,756 feet of sewers in Grove, Wayne, Mercer and Montgomery-streets, cost $2.70 per foot, including Culverts, Receiving Basins, &c.

Figure 71. Part 2 of Whitwell's 1853 survey of existing sewers in Jersey City.
Source: William Scollay Whitwell, Report Made to the Water Commissioners of Jersey City, April 11th, 1853, upon a Plan of City Sewerage *(New York: Van Norden & King, Stationers, 1853), 31.*

Whitwell left Jersey City before construction on the sewer system began; one likely theory attributes the departure to conflicts between Whitwell and the Board of

Water Commissioners. George H. Bailey, Whitwell's assistant, replaced him and oversaw construction, which ran from 1855 to 1864 and was confined to a small part of contemporary Jersey City, between the Morris Canal Basin and 12th Street, and to the east of Interstate 78. The first operational segment was a 36-inch circular brick sewer, with 8-inch-thick walls, constructed on Essex Street, between Van Vorst and Hudson Streets; this segment likely replaced an earlier segment constructed in 1837. A segment of this sewer can still be found below Essex Street, between Washington Street and Greene Street. The circular brick sewer, 36 inches in diameter, carried both wastewater and stormwater (Figure 72).[261] Diversions from Whitwell's plan included the use of brick sewers for lateral sewers, whereas he had proposed narrow vitrified clay pipes. Extensive construction during the nineteenth century took place across Paulus Hook and near the Hudson Riverfront.[262]

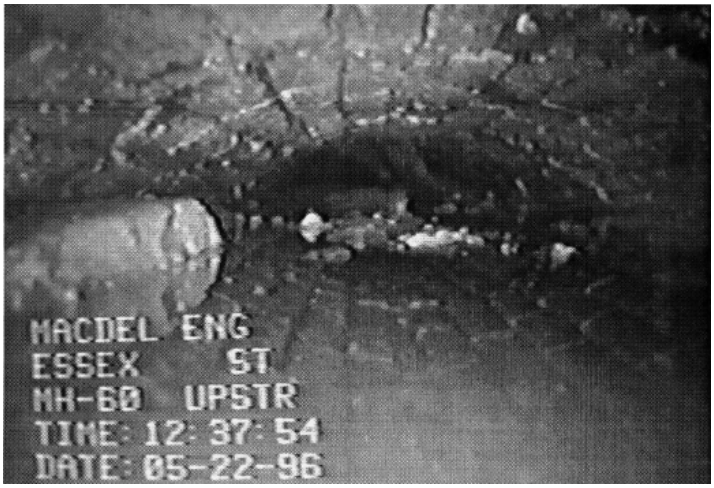


Figure 72. The Essex Street sewer, taken from CCTV footage from 1996.
Source: Joan H. Geismar, HBLR MOS-1: Jersey City Report on Monitoring, April 7, 1998 to September 6, 2000 *(2002), 29.*

[261] The sewer has since been filled with sand, left in place, and is no longer operative.
[262] Teresa D. Bulger et al., *Stage II Cultural Resources Survey, Jersey City Municipal Utilities Authority,* 3-12, 3-23-3-24; Dilworth, *The Urban Origins of Suburban Autonomy*, 117; Lembo and Diker, *Stage IA Cultural Resource Survey, Jersey City Municipal Utilities Authority Sewer Phases 1-2 Sewer Rehabilitation,* 4-40, 4-51; Joan H. Geismar, *HBLR MOS-1: Jersey City Report on Monitoring, April 7, 1998 to September 6, 2000* (2002), 6, 26.

As the city grew, additional brick sewers were constructed that were not part of the original plan. A sewer construction boom took place in the late nineteenth century, as a response to public health concerns. Historical research determined that the circular sewers had diameters ranging between 18 to 60 inches, and the oval sewers were sized 30 inches by 24 inches, 52 inches by 35 inches, and 53 inches by 34 inches. Some sewers were described as having "incorporated an arched design," though no pictures are available.[263]

By 1900, Jersey City reported that the sewer system was composed of multiple materials and pipe sizes. Circular vitrified clay pipes ranged in diameter from 12 inches to 24 inches, circular iron pipes ranged in diameter from 16 inches to 48 inches, circular steel pipes ranged in diameter from 36 inches to 66 inches, and circular brick sewers ranged in diameter from 18 inches to 60 inches, and one length of egg-shaped brick sewer was sized 48 inches by 96 inches, though it is likely that the brick sewers were significantly underreported at this time. Two of the most common pipes were 18-inch vitrified clay pipe, totaling a length of 19.8 miles, and 24-inch brick pipe, totaling a length of 20.1 miles. The sewers were located at a depth of 8 to 12 feet. Jersey City's sewerage plan continued to be modified well into the twentieth century as the city grew. By 1900, four of the city's storm sewers located on Eighth, Grand, and Montgomery Streets and Fairmount Avenue were considered inadequate.[264]

---

[263] Ilene Grossman-Bailey, *Stage IA Cultural Resources Survey, JCMUA Sewerage Facilities Improvements, Brown Place, Princeton Avenue, and Linden Avenue, City of Jersey City, Hudson County, New Jersey* (Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2011), 1-1; Lembo and Diker, *Stage IA Cultural Resource Survey, Jersey City Municipal Utilities Authority Sewer Phases 1-2 Sewer Rehabilitation,* 4-42.

[264] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 67-69; Hunt, "The Sewer Systems of New Jersey," 91.

Though the city had a planned system to adhere to, construction of both water and sewer lines was an ongoing process. In the Covert Larch Historic District, now demolished, drinking water lines were laid as early as 1872, but sewer lines were not laid until 1891-1903. Some privies remained in use until the 1920s. There was variation in how households dealt with their sewage, but the process became more standardized as municipal regulations and sewers were imposed. Houses dating to the 1880s and early twentieth century were found to have unlined privies; wood-lined, stone and wood lined, or brick-lined privies were also found. Some privies and cisterns appeared to have been converted into cesspits. There were leach fields, drywells, and cisterns as well. The types of privies these families had were likely related to differences in their economic status, and whether they were tenants or homeowners.[265]

Town of Kearny, Hudson County

Kearny was formerly known as New Barbadoes Neck, undergoing multiple name and boundary changes until 1867, when it was incorporated (Figure 73). It was named after Maj. Gen. Phillip Kearny, who was killed in the Civil War fighting for the Union Army. The city is surrounded by the Passaic River to its west and the Hackensack River to its east, with East Newark and Harrison on its southern border. The town's thread and knitting mills brought a Scottish immigrant population. There was also a significant shipbuilding industry.[266]

[265] Howson and Bianchi, *Covert Larch*, 1-4, 350-354.
[266] Daniel R. Campbell, "Kearny," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen (New Brunswick: Rutgers University Press, 2005), 437; Federal Writers' Project, *New Jersey*, 543.

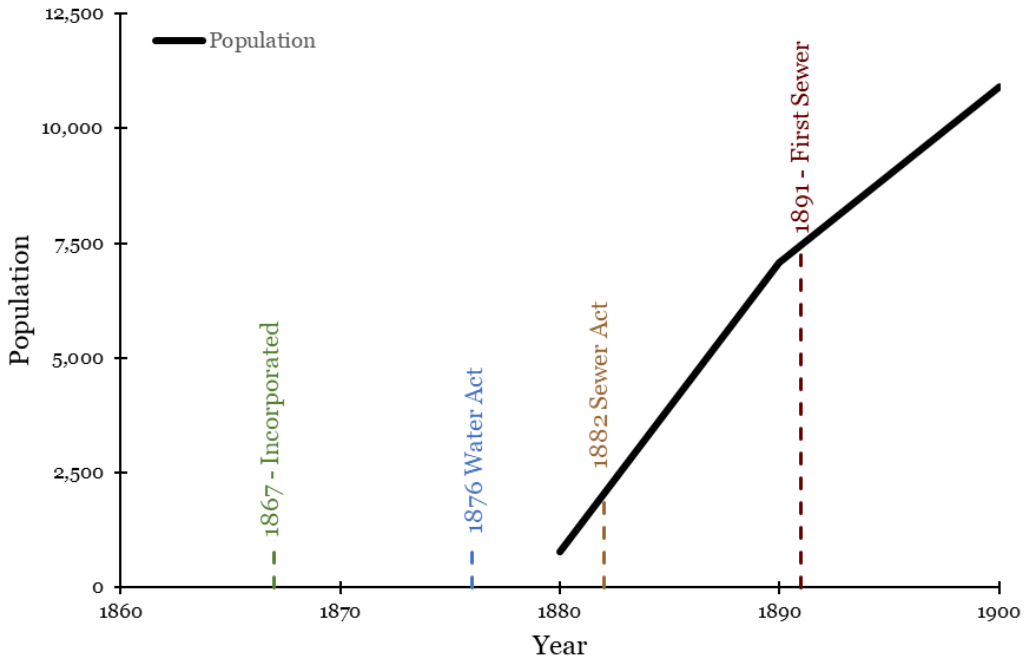


Figure 73. Population data for Kearny alongside key historical markers.

Sewer History

At the time of its incorporation in 1867, there was no provision for a municipal water supply or sewer construction. Kearny's water and sewer infrastructure, 1887 and 1891, respectively, was not constructed until after the passage of the 1876 Water and the 1882 Sewer Acts. It is possible that a private sewer might have been constructed earlier, as the 1895 Board of Health report mentioned "one private sewer running from Kearny into the [Passaic] river." Kearny's health ordinances required that houses with running water on streets with sewer lines, connect to the sewer system.[267]

There is a lack of clarity about the brick sewers themselves; in 1893, the town reported 4 miles of brick sewers with the largest reported dimension 72 inches by 60

[267] New Jersey, Board of Health, *Nineteenth Annual Report of the Board of Health of the State of New Jersey, and Report of the Bureau of Vital Statistics, 1895* (Trenton, N.J.: The John L. Murphy Publishing Company, Printers, 1895), 15; New Jersey, Board of Health, *Seventeenth Annual Report,* 171. These health ordinances are referenced in an 1893 NJBOH report however it is unclear when they were first enacted.

inches, but these were not mentioned in a later 1900 report on the sewer system. In 1900, Kearny reported a 21.15-mile combined sewer system composed of 2.83 miles of brick sewers and 18.32 miles of other unspecified materials. The brick sewers ranged in size from 36 inches to 72 inches and the other pipes ranged in diameter from 10 inches to 30 inches.[268]

Sewage was not treated before it was released at the five outfall points in the city, three on the Passaic River and two on Frank Creek. The presence of standing water in catch-basins, cesspools, other receptacles of water, and release of waste into Frank Creek quickly devolved into a severe mosquito problem, to the extent that the city was labeled as having "the distinction by all odds the worst mosquito breeding area for its size."[269]

City of Union City, Hudson County

Dutch settlers arrived in what is now Union City in the mid-seventeenth century. Union City would be created much later in 1925 by the consolidation of West Hoboken and Union Hill, which were incorporated as municipalities in 1861 and 1851, respectively (Figure 74).[270] During the mid-nineteenth century, present-day Union City was home to German Americans and was a sparsely settled rural area. Development began in 1890, when the primary property owner in West Hoboken, the HLIC, subdivided the lots and sold them to builders. When compared to New York City, it is

[268] New Jersey, Board of Health, *Seventeenth Annual Report,* 172; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 70.
[269] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 70; John B. Smith, "Report on the Mosquito Work for 1911," in *Report of the Entomological Department of the New Jersey Agricultural College Experiment Station, New Brunswick, NJ, for the Year 1911* (Trenton, N.J.: State Gazette Publishing Co., Printers, 1912), 516.
[270] A 1900 report only noted the presence of sewers in West Hoboken.

likely that the relatively less urban environment attracted migration of Dutch, German, Irish, and Italian immigrants living in New York City and across Western Europe. It slowly developed into an industrial area during the early twentieth century, with the construction of factory buildings and tenement housing for workers. Union City was known countrywide for its embroidery industry and was the home of multiple garment and lace manufacturers. Secaucus sits on the western border. Hoboken and Weehawken are on the eastern border.[271]

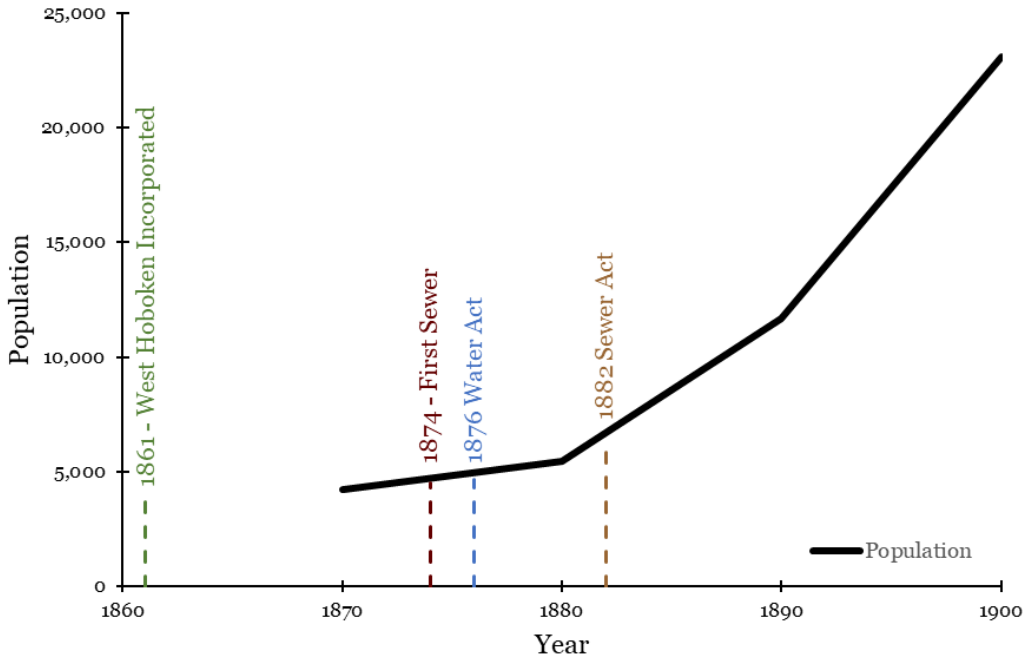


Figure 74. Population data for West Hoboken alongside key historical markers.

Sewer History

Prior to constructing sewers, the watercourses located on 17th Street (then Malone Street) and 13th Street (then Hill Street) were used to remove waste. These early open sewers remained open as late as 1919. In 1874, the Bull's Ferry Sewer was

[271] Daniel R. Campbell, "Union City," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen, (New Brunswick: Rutgers University Press, 2005), 823; Modica and Walker, *Stage 1A Cultural Resources Survey, North Hudson Sewerage Authority,* 4-4, 4-13.

constructed through Weehawken, West Hoboken, and Union to the Hudson River. It became one of the earliest sewers in West Hoboken. Only the western portion of the city drained into it.[272]

West Hoboken's system was constructed piecemeal as funding was acquired. By 1900, the 14-mile-long combined system included 4 miles of brick sewers, with egg-shaped sewers at 20 inches by 30 inches and circular sewers up to 48 inches; and 10 miles of pipe sewers of unspecified materials with diameters of 12, 15, 18, and 20 inches. The system had two outlet sewers. The first outlet received the drainage of the northern half of the city and discharged into the Hudson River. The southern outlet discharged into Penhorn Creek, a tributary of the Hackensack River located in Secaucus.[273]

Kerrigan Avenue Sewer

As part of a 2005-2006 sewer replacement project, the Kerrigan Avenue Sewer was monitored, documented, and later removed. The sewers on Kerrigan, Summit, and Central Avenues, between 20th and 27th Streets, were made of brick. It appears that at the time of construction, the natural bedrock was "channelized" to create a cradle for the sewer. Because the depth of the natural bedrock varied, so too did the depth of the sewers. These sewers were most likely constructed between 1912 and 1920.[274]

The cross sections of these sewers have been described as circular, egg-shaped, and oval; the archaeologist clarified that sections identified as oval might have been egg-shaped, considering the possibility of visual distortion as they were looking down at the

[272] Modica and Walker, *Stage 1A Cultural Resources Survey, North Hudson Sewerage Authority*, 4-13-4-14.
[273] Gerry Scharfenberger, *Archaeological Monitoring, Kerrigan Avenue Sewerage Replacement Project, City of Union City, Hudson County, New Jersey* (Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2006), 8-3; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 74.
[274] Scharfenberger, *Archaeological Monitoring, Kerrigan Avenue Sewerage Replacement Project,* 8-1.

sewer from street level. The sewers were predominantly two wythes. Construction anomalies were also discovered during monitoring. The segment between Central Avenue and 27th Street had a 1-inch-thick wood sheet below the sewer invert, though it is unclear why.[275]

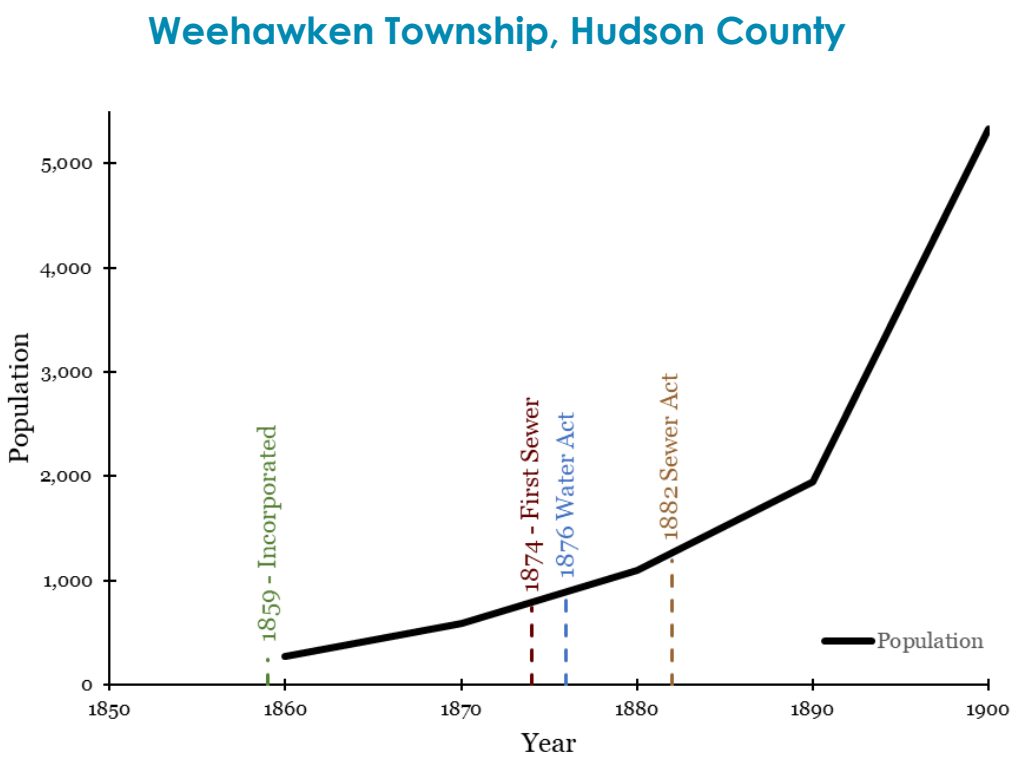


Figure 75. Population data for Weehawken alongside key historical markers.

The Hudson River borders Weehawken on the east, with New York City across the river. This proximity encouraged the establishment of the first ferry services to connect to New York City, sometime before the close of the eighteenth century. Weehawken was originally part of Hoboken until 1859, when it was incorporated (Figure 75). Since most of the city was split into eight large lots, development did not occur before 1894 when real estate agents subdivided the lots, opened streets, laid

[275] Scharfenberger, *Archaeological Monitoring, Kerrigan Avenue Sewerage Replacement Project,* 7-1-7-2, 8-2.

sewers, and sold the newly subdivided smaller lots. The Hudson Palisades bisect Weehawken into a lower, eastern section along the Hudson River, and a western, upper section. Summer resorts, followed by suburban homes, were situated in the upper section, while industry and transportation hubs were located along the Hudson River.[276]

Sewer History

Even after its incorporation, Weehawken, because of its proximity to Hoboken, cooperated with the larger city for sewer construction as early as 1866, with the passage of "[a]n act to provide for the drainage of certain low lands lying in the city of Hoboken and the township of Weehawken." This act was an early intervention in land and water management. "An Act to provide for the construction of a Main Sewer in the City of Hoboken, and Township of Weehawken" passed in 1873, well after Hoboken had begun sewer construction in 1858. This act did not explicitly list streets in Weehawken to be included in construction. The act was amended, in 1874, to extend construction to "embrace two drainage districts, and providing for the construction of main and lateral sewers," thus encompassing more of Hoboken and including parts of Weehawken as a second drainage district.[277]

By 1900, the city reported that there were both brick and other unspecified material sewers in its combined system. George W. Bond, engineer for the Town of

[276] Daniel R. Campbell, "Weehawken," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen, (New Brunswick: Rutgers University Press, 2005), 858-859; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 72.
[277] New Jersey, Legislature, *Acts of the Ninetieth Legislature*, 941; New Jersey, Legislature, *Acts of the Ninety-Seventh Legislature*, 799; New Jersey, Legislature, *Acts of the Ninety-Eighth Legislature, of the State of New Jersey, and Thirtieth Under the New Constitution* (Paterson, N.J.: Chiswell & Wurts, Book and Job Printers, 269 Main Street, 1874), 559.

Weehawken, reported to the State Sewerage Commission that sewer data for areas of the town were unavailable, since many segments were privately built prior to 1894.[278]

City of Trenton, Mercer County

Trenton was established in 1679 at the convergence of the Assunpink Creek and the Delaware River. Another important waterway in the city was Petty's Run, which tanneries used in the 1730s for both fresh water and waste disposal. Eighteenth century Trenton used the Delaware River to float lumber and farm goods downriver, which were often transferred onto a sloop for further transport. Trenton was selected as the state capital in 1790 and incorporated as a city in 1792 (Figure 76).[279]

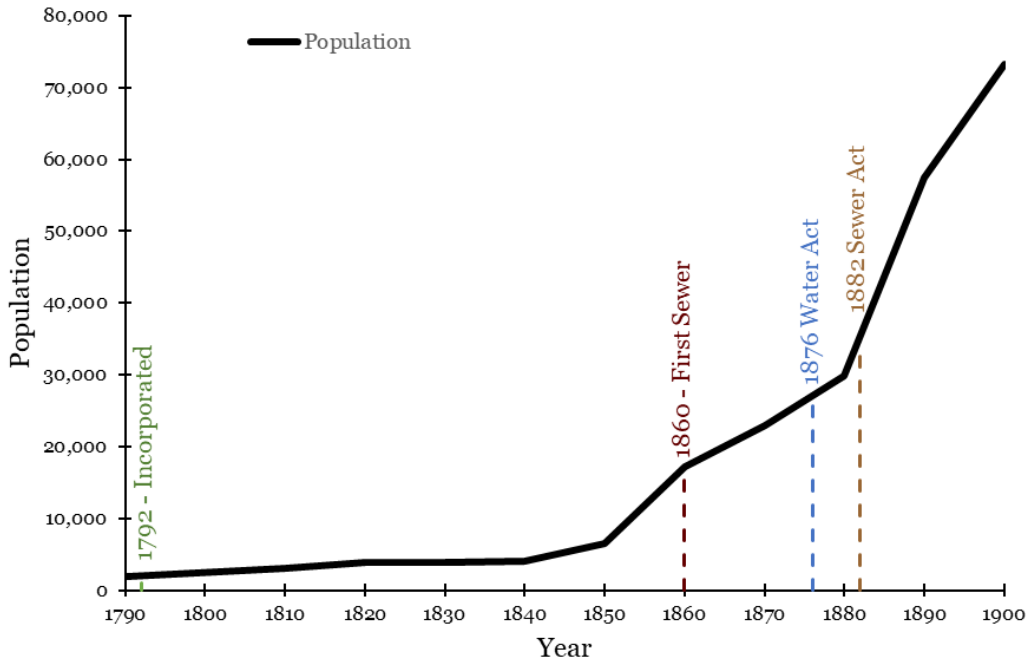


Figure 76. Population data for Trenton alongside key historical markers.

[278] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 72.
[279] Jon Blackwell, "Trenton," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen (New Brunswick: Rutgers University Press, 2005), 813; Richard W. Hunter and Ian C. Burrow, *Petty's Run Archaeological Site, Iron, Steel, Cotton and Paper in Historic Trenton* (Trenton, New Jersey: Hunter Research, Inc., 2014), 1:5-1.

The city's transportation links to New York City and Philadelphia were pivotal to its growth. In 1726 a ferry service to Philadelphia was introduced, and by 1788 John Fitch had launched a steamboat connecting the two cities. As early as the 1750s stagecoaches connected Trenton to New Brunswick, New York City, and Perth Amboy. The Delaware and Raritan Canal in 1834 and the Camden and Amboy Railroad in 1832 connected Trenton and New York City.[280]

Most of Trenton's industry was located in the southern and eastern areas of the city, with the business and residential areas to the north and west, following redevelopment across the city. For example, the Trenton Delaware Falls Company completed construction of its power canal, the Trenton Water Power, in 1834, which engendered large-scale industry. The canal was later known as Sanhican Creek in the 1910s. The Trenton Iron Company, which manufactured wrought-iron beams used in the construction of the U.S. Capitol dome, was established in 1847, followed by the John A. Roebling's Sons Company, which produced wire ropes used in bridge construction. Nationwide, the city was known for its porcelain and sanitary ware industries, which thrived after the 1850s. Other important manufactories in the city produced automobiles, cigars, linoleum, pottery, rubber, watches, and wire ropes and cables, which led to the introduction of the slogan "Trenton Makes, the World Takes." The city's industry, which needed laborers, resulted in a population surge and the annexation of boroughs between 1880 and 1920.[281]

[280] Blackwell, "Trenton," 813.
[281] Federal Writers' Project, *New Jersey*, 399; Hunter and Burrow, *Petty's Run Archaeological Site,* 1:3-26; Richard W. Hunter, *Power to the City, The Trenton Water Power* (Trenton, New Jersey: Hunter Research, Inc., 2005), 2, 18; Blackwell, "Trenton," 813.

Sewer History

As in most cities, residents and industries discharged water and waste directly into the rivers and streams that ran through Trenton. Some parts of these watercourses were channelized by businesses and landowners along the banks to increase flow and reduce flooding. Ultimately, channelizing did not mitigate pollution, and by the mid-nineteenth century, the watercourses were public nuisances.

With the passage of the "act to revise and amend the charter of the city of Trenton" in 1866, the Common Council was granted the power to construct sewers or drains in any part of the city. The initial cost would be paid by the Common Council, who would then request the city clerk to bill the landowners who benefited from the improvements.[282]

Early Wooden Sewers

Wooden trunk sewers were some of the earliest drainage interventions in the city. One wooden sewer ran from Stockton Street to Montgomery Street to Greene Street (now Broad Street) to Warren Street (now Route 206); these segments turned onto Bank Street and then discharged into Petty's Run. These sewers ranged in size from 12 to 60 inches square. Irrespective of the dimensions, the slopes of these sewers were not conducive to drainage and created elongated cesspools. The situation was exacerbated because the sewers received both liquid and solid wastes and lacked catch-basins, which meant that the sewers were frequently blocked. The sewers' frequent failures due to

[282] New Jersey, Legislature, *Acts of the Ninetieth Legislature*, 364, 397-399.

decay and blockages discouraged Trentonians from supporting further municipal sewer construction.[283]

Other early sewers were constructed by the New Jersey State Lunatic Asylum and the New Jersey State Prison. In 1848, when the New Jersey State Lunatic Asylum at Trenton was constructed, a 10-inch cast-iron pipe was laid to remove waste from the building and discharge it into a reservoir approximately 0.15 miles from the main building. The stone-lined reservoir, likely a cesspit, was 40 feet by 50 feet and 5 feet deep. The collected waste was used as compost in the farm and garden. Later *Annual Reports of the Officers of the New Jersey State Lunatic Asylum at Trenton* mentioned this sewer pipe being ventilated through various means. Another early sewer was constructed in 1860 by the New Jersey State Prison. This stone drainpipe, 12 inches in diameter, replaced an earlier drainage culvert that connected the prison and the Delaware and Raritan Canal. The pipe was 0.76 miles long and discharged the prison's waste into the Delaware River.[284]

In 1875 another sewer was constructed beneath Warren Street from the Delaware and Raritan Canal to the Assunpink Creek, followed by the 1876 construction of a sewer on Clinton Avenue, from Model Avenue to the Assunpink Creek. Around this time, the city also authorized the construction of sewers on Fountain Avenue, Pennington

[283] C.C. Haven, *Report on Petty's Run, made to the Common Council of the City of Trenton* (Trenton, N.J.: John L. Murphy, Steam Power Book and Job Printer, 1879), 3-7; Lee, *History of Trenton*, 91.
[284] H.A. Buttolph and Jasper S. Scudder, *Annual Report of the Officers of the New Jersey State Lunatic Asylum, at Trenton, for the year 1848* (Trenton: Printed by Phillips & Boswell, 1849), 34; Lee, *History of Trenton,* 91; New Jersey, State Prison, *Annual Report of the Condition of the New Jersey State Prison, Embracing the Reports of the Joint Committee, Commissioners, Inspectors, Keeper and Physician,* (Trenton: Printed at the "True American" Office, 1861), 14.

Avenue, Spring Street, West Hanover Street, and Willow Street that would drain into Petty's Run.[285]

In 1876, the American House Hotel built an individual, private sewer which drained into Petty's Run, a natural stream. This sewer went on to be the subject of a court case that, perhaps, illustrated a more general sewerage problem in the city. The hotel served between 45 to 150 people at a time, and its sewer discharged water closet effluent, kitchen waste, and laundry water directly into Petty's Run, where, especially during dry weather, it stagnated. The City Board of Health successfully filed an injunction seeking to compel the hotel to pay for the cost of cleaning up the nuisance.[286]

Petty's Run Drain

Petty's Run was used in the 1730s by tanneries for fresh water and for waste disposal. As the city grew, residents of properties along the Run used it to dispose of human and animal wastes and general rubbish. Originally, three tributaries met near Bank Street and then flowed southwest and over the bluff edge onto the floodplain, turning southwards before emptying into the Delaware River near the Assunpink Creek (Figure 77).[287]

[285] Lee, *History of Trenton,* 90-91.
[286] Hunter and Burrow, *Petty's Run Archaeological Site*, 1:5-7-1:5-8.
[287] Ibid., 1:5-1-1:5-8.

Figure 77. Map depicting the original path of Petty's Run.
Source: Richard W. Hunter and Ian C. Burrow, Petty's Run Archaeological Site: Iron, Steel, Cotton and Paper in Historic Trenton *(Trenton, New Jersey: Hunter Research, Inc., 2014), 1:5-13.*

Stone side walls were installed along parts of Petty's Run by 1814 (and possibly much earlier), likely for the primary purpose of improving the waterpower system for mills along the river.[288] The construction of the Delaware and Raritan Feeder Canal in the early 1830s most likely prompted the progressive channelization of Petty's Run. The Petty's Run culvert is 60 inches wide and 54 to 78 inches high (one section, which carries the culvert over the bluff edge, is 180 inches high), with 36-inch-high stone side

[288] Channelization only ensured a contained flow; an 1848 newspaper clipping speaks to a young boy who fell into the stream and was carried off. He was eventually able to escape.

walls, possibly dating to the eighteenth century, all still in place. A natural schist bedrock floor and an arched mortared brick roof were thought to have been constructed between 1860-1880 (Figure 78). The northern portion of the culvert has both a stone arch and walls. Ceramic and cast-iron feeder pipes protrude into the culvert in several locations. There is also evidence of cut bedrock and built-in timber features, which suggests that there were modifications for waterpower that were either contemporaneous with or predated the construction of Petty's Run Drain.[289]

Figure 78. Photograph of the interior of Petty's Run Drain.
Source: Richard W. Hunter and Ian C. Burrow, Petty's Run Archaeological Site: Iron, Steel, Cotton and Paper in Historic Trenton *(Trenton, New Jersey: Hunter Research, Inc., 2014), 1:5-21.*

Enclosure of a segment of Petty's Run from West State Street to the Delaware River was completed by 1870, though this did not prevent the rest of it from becoming a noxious open sewer. By the early 1880s, the Board of Health of the City of Trenton determined that draining into Petty's Run had negatively impacted the water quality and created a public health concern. When the stream ran dry, a foul smell emerged and caused a nuisance. In 1880, an ordinance to convert Petty's Run into a closed sewer

[289] Hunter and Burrow, *Petty's Run Archaeological Site,* 1:5-2, 1:5-16.

passed, though it would be another few years until construction would begin under a plan provided by Rudolph Hering.[290]

Rudolph Hering's Plan for Sewerage

With the passage of the 1882 Sewer Act, the Sanitary Committee of the Common Council of the City of Trenton hired Rudolph Hering to mitigate the pollution nuisance of Petty's Run, resolve the flooding of basements and cellars due to rising subsurface water, mitigate heavy flooding following major rainstorms, and design a comprehensive sewerage system for the city. At the time the city's basements and cellars were located 5 to 8 feet below ground and were often used for both occupancy and storage. The threat to human life by flooding was a significant concern for city officials. The Hering plan, approved in 1885, consisted of a separate system for most of the city and a combined system for parts of the Chambersburg neighborhood. Hering generally emphasized reducing the length of laterals and suggested constructing sewers in rear alleyways rather than the street. While he typically recommended laying two sewer pipes on wider streets, on Greene Street he determined that a single brick sewer at a greater depth would be more cost effective.[291]

The first constructed component of the plan was an enclosed culvert on Petty's Run (known as Petty's Run Drain #1), operational by 1888. More of the stream was covered or diverted in the mid-1890s when Petty's Run Drain No. 3, an oval shaped brick sewer, was installed, and portions of the original run were realigned and rebuilt in 1911-1914 using concrete (Figure 79).[292]

---

[290] Hunter and Burrow, *Petty's Run Archaeological Site,* 1:5-7-1:5-8, 1:8-3; Lee, *History of Trenton,* 91.
[291] Hering, *Report on a Sewerage System for the City of Trenton*, 6, 26.
[292] Hering, *Report on a Sewerage System for the City of Trenton*, 18; Hunter and Burrow, *Petty's Run Archaeological Site*, 1:5-7-1:5-8, 1:5-16, 1:5-22, 1:5-41.

Figure 79. Photograph of the interior of Petty's Run Drain No. 3.
Source: Richard W. Hunter and Ian C. Burrow, Petty's Run Archaeological Site: Iron, Steel, Cotton and Paper in Historic Trenton *(Trenton, New Jersey: Hunter Research, Inc., 2014), 1:5-45.*

Because Hering's planned system mitigated pollution and noxious smells, the intervention reportedly swayed local opinion to favor sewers. So, construction of the rest of the sewer system followed between 1888 and 1897, with the North Assunpink Interceptor built between 1888 and 1891, the South Assunpink, or Lamberton, Interceptor, between 1891 and 1892, and the two eventually connected in 1894.

Hering designed the Lamberton Interceptor to be the main intercepting sewer.[293] It is over 1.5 miles long and includes both egg-shaped and circular brick sections. It originally discharged into the Delaware River through twin 18-inch diameter cast-iron pipes, but a concrete pipe was constructed in 1926 to connect the interceptor to a new

[293] The Lamberton Interceptor, designed by Rudolph Hering and constructed by Thomas Craig, was determined to be National Register-eligible because of its association with Trenton's early sewerage efforts.

sewage treatment plant. Every brick sewer since 1894 in Trenton was lined with vitrified brick for a third of the height. The Lamberton Interceptor was one of three sewers lined in this way before 1894. The brick sewers were constructed with a double layer of bricks in a stretcher bond and had a total thickness of 8 inches. Vitrified brick was used for the lower fourteen courses, or about one-third of the height of the sewer, and a hollow tile base was present in some sections. The section of the interceptor that passed beneath the Cass Street Lateral was constructed with fifteen courses of granite block on the lower part, instead of brick. Granite drainage holes allowed sewage to flow from the lateral to the interceptor.[294]

By 1900, the total length of sewers in the city was 9.75 miles of combined sewers and 22.7 miles of separate sewers, of which 11 miles were brick and 21 miles of unspecified pipe. The combined sewers were mostly brick, for an approximate length of 9 miles, while the separate system used brick for less than 2 miles of its total length. These would have been placed at an average depth of 9 feet.[295]

In addition to this, there were 6.2 miles of sewers used exclusively for flood drainage and stormwater. The circular stormwater pipes ranged in size from 8 inches to 24 inches, and the "oval" brick pipes ranged in size from 24 inches by 36 inches to 48 by 60 inches. By 1900, egg-shape was a common term so the use of the term oval to describe some pipes is interesting. Lengths for each material type were not given for the storm sewers. The sole sewerage outfall was on the Delaware River; the storm sewers

[294] Israel, *Report*, 10, 26; Richard W. Hunter, *Archaeological Monitoring of the Lamberton Interceptor, Lamberton Street, City of Trenton, New Jersey* (Hopewell: Richard W. Hunter, 1982).
[295] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 82; Hering, *Report on a Sewerage System for the City of Trenton,* 32.

discharged in six locations, with three on the Assunpink Creek and three on the Delaware River.[296]

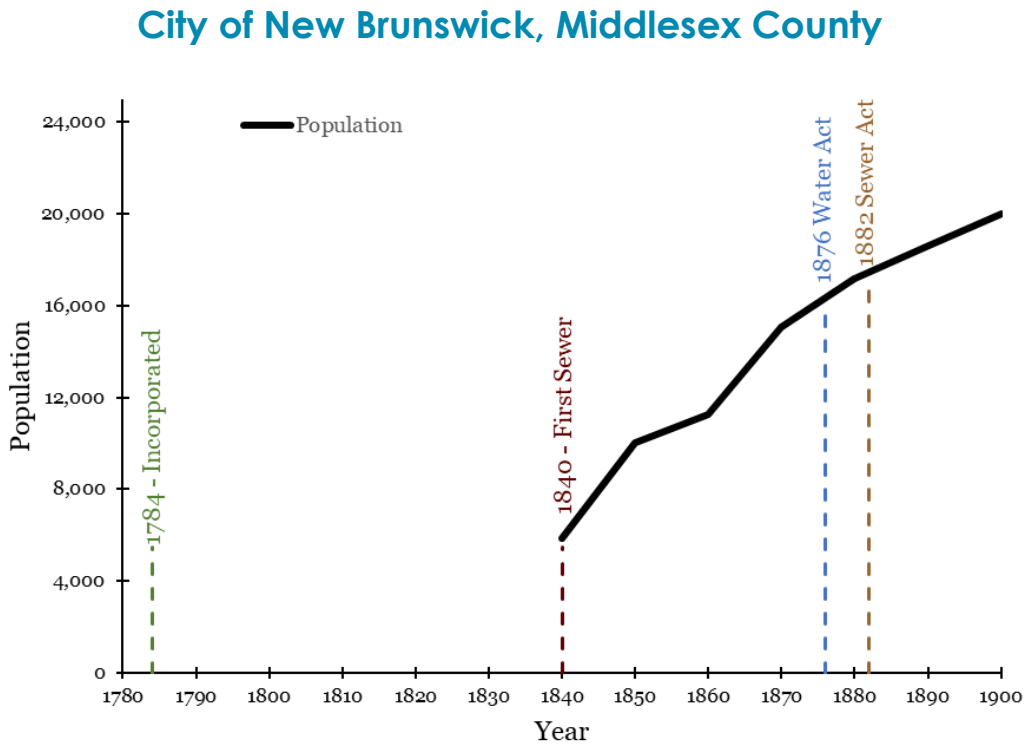


Figure 80. Population data for New Brunswick alongside key historical markers.

New Brunswick was established in 1681 and was later incorporated in 1784 (Figure 80). The city is bordered on the north by the Raritan River, the Mile Run on the west, and Lawrence Brook and Westons Mill Pond on the east. Tributaries within the city include the Barrack Spring Brook and the East and West branches of Lyle Brook.

The city was mainly a farming community during the seventeenth and into the eighteenth century. The waterways in town were bordered by mills, which helped make the city an agricultural depot. A ferry service was introduced in 1686 to carry passengers across the Raritan River. Though eighteenth-century New Brunswick was a shipping

[296] Hering, *Report on a Sewerage System for the City of Trenton*, 13; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 82-83.

port and settlement, nineteenth-century New Brunswick became the northern terminus of the Delaware and Raritan Canal in 1834, which positively and negatively impacted New Brunswick over the course of the nineteenth century. Because the canal was a source of waterpower, commerce and industry spurred the city's development. However, canal boats did not stop at New Brunswick, which curtailed the city's role as a trading settlement. The nineteenth century industries included factories for boatbuilding, carriages, hosiery, machinery, rubber products, shoes, and wallpaper, as well as a cotton mill. One of the most famous companies was Johnson & Johnson, which was established in 1886.[297] Like many other manufacturers, Johnson & Johnson built subsidized row housing for its workers. The city was also a manufacturing center for cigars and cigar boxes. During the twentieth century, the city transformed into a manufacturing center.[298]

New Brunswick's population grew during the nineteenth and into the early twentieth centuries, with Hungarian and southern and eastern European immigrants moving to New Brunswick to work in the factories. Many Irish immigrants living in New Brunswick worked on infrastructure projects in the city, including construction of the

[297] James Wood Johnson, one of the founding brothers of Johnson & Johnson, was traveling by train from New York City to Philadelphia. At the time, Johnson was in search of a home for sterile surgical dressing facility. En route, his train stopped in New Brunswick, and from the tracks, Johnson saw an empty manufacturing building, previously occupied by Janeway & Carpender. He hopped off the train and rented the fourth floor. By 1894, Johnson & Johnson had grown from a single floor to fourteen buildings, encompassing both manufacturing and office spaces.
[298] George Dawson, "New Brunswick," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen (New Brunswick: Rutgers University Press, 2005), 567; Federal Writers' Project, *New Jersey*, 299-301; Listokin, Berkhout, and Hughes, *New Brunswick*, 3, 19; John P. Wall, *The Chronicles of New Brunswick, New Jersey, 1667-1931* (New Brunswick, N.J.: Thatcher-Anderson Company, Publishers and Printers, 1931), 67.

city's sewer system in 1877, the railroad bridge across the Raritan River, and the digging of the Delaware and Raritan Canal, amongst others.[299]

Sewer History

Barrack Spring Brook's Transformation into a Sewer

Barrack Spring Brook, sometimes called Nathan Haviland's spring, started above George Street, near the intersection of Church Street and Spring Alley, ran between Albany Street and Church Street, and into the Raritan River. During the late eighteenth century and early nineteenth century the brook was used as a water supply, initially for a tannery located on the brook and later for the townspeople. In 1801, with the incorporation of the Fountain Company, bored wooden logs were connected to the spring, installed on Albany Street, and used to distribute water. No major alterations were made until 1839, when the City of New Brunswick passed "[a]n Ordinance for Cleansing the Water Course from the Barrack Spring to the River." The ordinance tasked property owners with coordinating with the city surveyor to channelize Barrack Spring Brook and ensuring that the sewer could drain their cellars. The ordinance set the requirement that the width of the channel be no less than 3 feet.[300]

Unlike many modern sewers, which are in road, the Barrack Spring Brook sewer was located along property lines, 85 feet from Albany Street and 115 feet from Church Street. A 32-foot section of the sewer was exposed in 1980 as part of an archaeological salvage project; parallel stone walls, 4 feet apart, were revealed. The stone walls were about 4 feet high and rested on natural subsoil, although bedrock was only about 1-foot

[299] Dawson, "New Brunswick," 567; Listokin, Berkhout, and Hughes, *New Brunswick*, 45.
[300] Betty J. Cosans, *Archeological Investigations of a Proposed Urban Redevelopment Site, New Brunswick, New Jersey* (West Chester, PA: John Milner Associates, Inc., 1983), 96; William H. Benedict, *New Brunswick in History* (New Brunswick, N.J.: Published by the author, 1925), 41, 158.

beneath the base of the stone walls. Several lateral drains from Albany and Church Streets were also excavated. They included two terra cotta pipes, one which pierced the stone wall and emptied directly into the channel, and one which butted up against the outside of the stone wall. Liquid from the latter pipe was expected to percolate through the unmortared stone wall into the channel. There was also an iron pipe as well as a box drain made of wood planks on the bottom, bricks for the side walls, and bricks and stones on the top that entered the sewer through a brick opening. Initially, the Barrack Spring Brook sewer did not convey sanitary waste as adjacent properties continued to use privies.[301]

Extensive grading and filling were done in conjunction with the channelization of Barrack Spring Brook, which created more usable, drier land for development during the mid-nineteenth century. Neither the archaeological evidence nor the historical sources could definitively determine if the sewer was initially open to the air or closed. It was inferred that it must have been closed in segments where a building was constructed above the sewer but open in other places. The sewer would later be closed in its entirety at some point between 1886 and 1904.[302]

[301] Cosans, *Archeological Investigations of a Proposed Urban Redevelopment Site*, 50, 87.
[302] Ibid., 58, 95, 112.

Lyle Brook Sewer

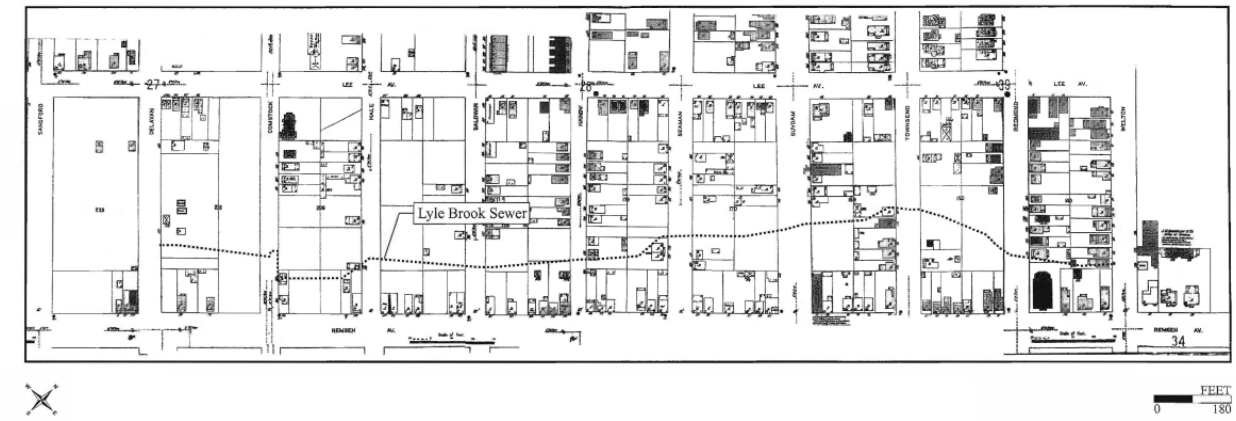


Figure 81. Path of the Lyle Brook sewer.
Source: Stephen W. Yost and Glenn R. Modica, Stage IA Cultural Resources Survey, Remsen Avenue Storm Sewer Improvements, City of New Brunswick, Middlesex County, New Jersey (*Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2003), 4-18.*

Roughly parallel to Remsen Avenue, Lyle Brook and its branches were transformed into a covered sewer in a piecemeal fashion starting in the 1870s and through to the 1920s (Figure 81). The sewer was made of slate conduits, brick arches, concrete boxes, and reinforced concrete pipe. Much of the area around Lyle Brook was relatively unoccupied until the late nineteenth century, and so drinking water lines were not installed nearby until 1873. The earliest components of the sewer were culverts under streets that crossed the brook; these are still present in the modern sewer, and each segment's length is equal to the width of the street it ran under, "varying from 29-50 feet. All are circular shaped, except for the horse-shaped [sic] segment beneath Redmond Street." Connecting segments were built over the next several decades and include circular, horseshoe-shaped, and egg-shaped brick sewers, as well as circular vitrified clay and concrete pipes. Most of Lyle Brook remained uncovered in 1910, and the East Branch section was not completely covered until the 1930s.[303]

[303] Yost and Modica, *Stage IA Cultural Resources Survey*, 3-16, 4-13-4-16.

Individual Sewers

Other examples of sewers likely constructed by property owners rather than as part of a municipal sewer system include a 30-inch wide drainage trench lined with 2-inch thick wooden planks associated with the Buttler & Johnson's Sash, Door and Blind Factory on John Street and a functioning ceramic pipe carrying raw sewage from a house to a brick manhole near Drift Street, where a 6-inch wide trench conveyed it to a stormwater culvert. Both examples are undated but were likely built in the mid to late nineteenth century.[304]

Municipal Sewers

Like many other municipalities whose incorporation charter included a provision empowering the Common Council to construct sewers, the same applied to New Brunswick with its 1863 revised and amended charter. However, the city did not consider sewer construction until the organization of its Board of Sewerage by an act of the State Legislature in 1870. The New Brunswick Board of Sewerage did not immediately pursue sewer construction, citing insufficiencies in the act. In 1871, the State Legislature passed "[a]n Act appointing Commissioners of Streets and Sewers in the City of New Brunswick," which repealed the 1870 act and any inconsistencies that could be found in the charter and its later supplements. Municipal sewer construction began in 1871.[305]

---

[304] Marilyn R. Frasier and John W. Lawrence, *Stage I Cultural Resources Survey, Lyle Brook Culvert Rehabilitation, City of New Brunswick, Middlesex County, New Jersey* (Cranbury, New Jersey: Richard Grubb & Associates, Inc., 1997); Michael J. Gall, *Archaeological Monitoring, Sanitary Sewer Improvements at Drift Street and Abundant Life Church, City of New Brunswick, Middlesex County, New Jersey* (Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2013), 5-19.
[305] New Jersey, Legislature, *Acts of the Ninety-Fourth Legislature of the State of New Jersey and Twenty-Sixth Under the New Constitution* (Newark, N.J.: Printed by E.N. Fuller, 1870), 879; New Jersey, Legislature, *Acts of the Ninety-Fifth Legislature, of the State of New Jersey, and Twenty-Seventh Under*

New Brunswick's sewer system relied on both combined and separate sewers, as they were not part of a cohesively designed system. The combined sewers were predominantly constructed in the older section of New Brunswick, then known as District No. 1, which was industrialized and developed (Figure 82). This area included Bayard, Burnett, Canal, French, Hamilton, Hardenburgh, Hiram, Nelson, Prospect, and Somerset Streets. This portion of the system was designed by a Mr. Ryan.[306]

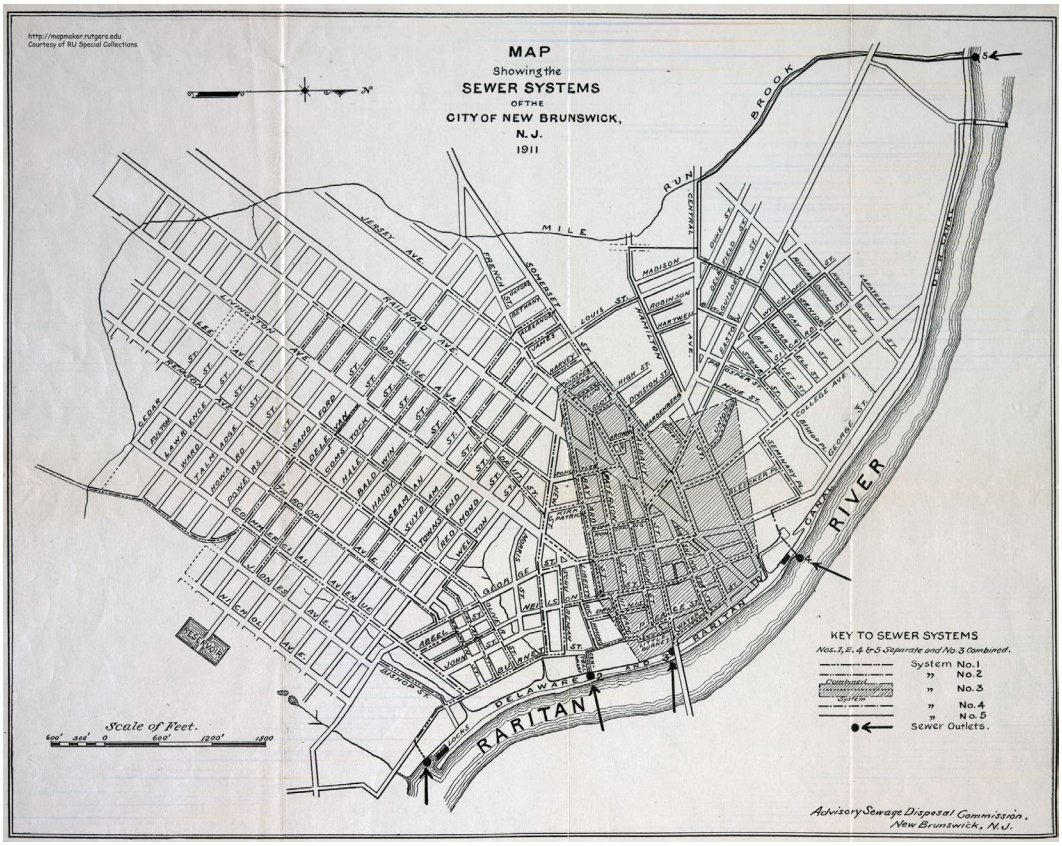


Figure 82. Map showing the sewer system of the City of New Brunswick in 1911.
Source: Advisory Sewage Disposal Commission, Map Showing the Sewer Systems of the City of New Brunswick, 1911. http://oldnewbrunswick.rutgers.edu/HISTORICALMAPS/NewBrunsSewerSystems1911.gif

By the end of the nineteenth century, the city had not yet been completely sewered. At this time, 5.17 miles of combined sewers and 3.44 miles of separate sewers

the New Constitution (Morristown, N.J.: Vance & Stiles, Book and Job Printers, 1871), 805; New Jersey, Board of Health, *Twenty-Sixth Annual Report*, 348.
[306] Yost and Modica, *Stage IA Cultural Resources Survey*, 4-10-4-13; Hunt, "The Sewer Systems of New Jersey," 89-93.

had been built. Of the combined sewers, 4.22 miles used 12-inch to 18-inch pipe, and 0.95 miles used 30-inch to 60-inch brick sewers. It is likely that the 0.95 miles of brick sewers were circular in shape because only one dimension is listed. The 3.44 miles of separate system used pipes ranging in size from 8 inches to 24 inches. The sewers emptied into the Raritan River through two outfalls, located north and south of the city. In addition to the municipally owned sewers, another 3 miles of separate sewers were constructed privately. By the close of 1900, another 3 miles of sewers were under contract and approaching completion. Asher Atkinson, the engineer for the City of New Brunswick, noted that the city expected to complete sewer construction in all developed areas by the end of 1902.[307]

City of Perth Amboy, Middlesex County

Dutch traders settled in Perth Amboy as early as 1651.[308] The city is surrounded by water on three sides, with the Raritan Bay on the southeast which meets the Arthur Kill on the east, and the Raritan River on the south. The city originally had four smaller waterways, including Eagleswood Brook and Sonmans Brook, that drained into the

[307] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 84-86.

[308] While conducting research into the history of Perth Amboy, we came across this description of the city: "The early settlement of Perth Amboy, the hopes of its progenitors and the way in which the prospects of the carefully planned settlement at the mouth of the Raritan river were not realized, suggest the life of the average human being. Born to fond parents, what dreams there are of future greatness and of wonderful accomplishments, and how seldom do subsequent developments agree with the plans and predictions of those who were interested in our advent into the world." John P. Wall and Harold E. Pickersgill, *History of Middlesex County, New Jersey, 1664-1920, under the associate directorship of John P. Wall and Harold E. Pickersgill assisted by an Able Corps of Local Historians, Historical-Biographical* (New York and Chicago: Lewis Historical Publishing Company, Inc., 1921), 2:361.

Raritan River, but all of them were eventually covered as the city grew. The topography of the city was further modified as areas of the coastline were filled in.[309]

Following the Revolutionary War, Perth Amboy became a summer resort town and continued to be one until the Civil War. By 1815, shell fishing along the bay helped the town prosper. During the nineteenth century, the town was home to abolitionists, artists, and innovators. The city continued to prosper with the introduction of industry, the most prominent of which was the production of ceramic wares, which included bricks, porcelain, terra cotta, and tiles created from local deposits of clay. The first of these companies, the J.R. Watson Fire Brick Company, was introduced in 1836. Not long after, Perth Amboy was incorporated in 1844 (Figure 83).[310]

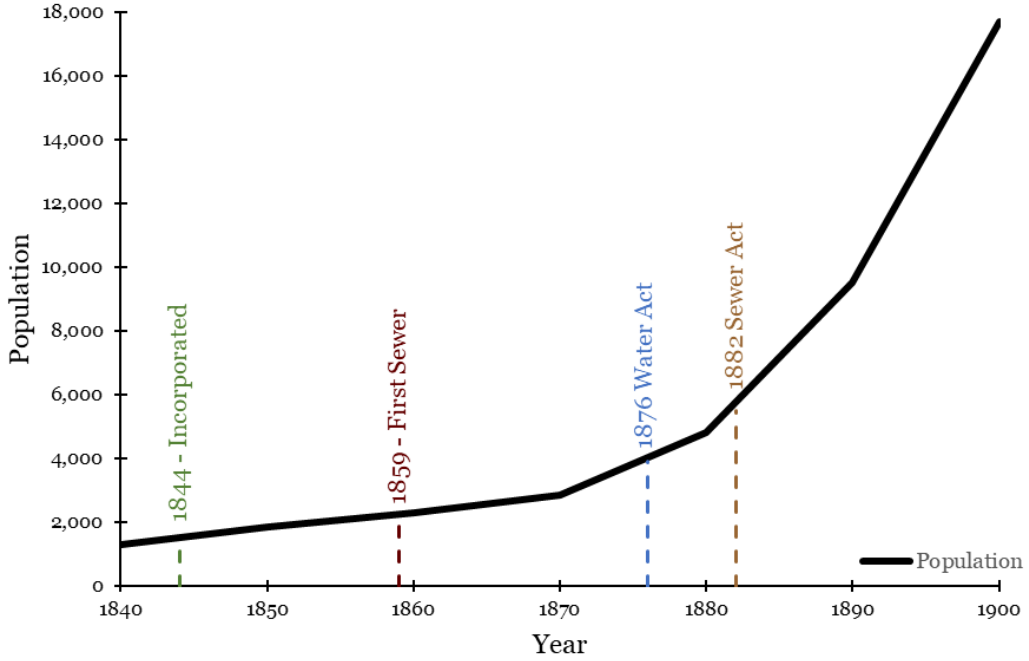


Figure 83. Population data for Perth Amboy alongside key historical markers.

[309] Federal Writers' Project, *New Jersey*, 361; Susan Kardas and Edward Larrabee, *Cultural Resource Survey of the Proposed Route for Sanitary Sewer Connection to the Middlesex County Sewerage Authority for the City of Perth Amboy* (Robert A. Brooks Associated & Historic Sites Research, 1980), 5.
[310] Anton J. Massopust, *Cultural Resource Survey: City of Perth Amboy* (1976), 3-4; Federal Writers' Project, *New Jersey*, 362-363.

During this period of industrialization, the Lehigh Valley Railroad was the first rail line in the city, introduced in 1859. Major companies include American Smelting and Refining, Anaconda Copper Works, M. Guggenheim and Sons, and National Lead. Immigrants came from Austria, Czechoslovakia, Hungary, Italy, Poland, and Russia to work in the factories.[311]

Unlike other cities discussed in this report, Perth Amboy's piped-in water supply was built after the sanitary sewer system. Perth Amboy's drinking water supply came from artesian wells and springs within the municipal boundaries. The wells lowered the water table, which caused salt water from the Arthur Kill to infiltrate the aquifer. Leveraging the 1876 Water Act, the Perth Amboy Water Works Company was organized in 1880.[312]

Sewer History

Private Sewers

With the passage of the revised and amended charter of the City of Perth Amboy in 1859, landowners were required to pay for sewers that would connect to their properties, although the city would arrange for the construction. By 1871, an amendment to the charter empowered the city council to adopt privately constructed sewers into the broader sewerage system.[313]

---

[311] Federal Writers' Project, *New Jersey*, 364; Peter J. Wosh, "Perth Amboy," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen (New Brunswick: Rutgers University Press, 2005), 629.
[312] G. William Page, "Perth Amboy, New Jersey, Case Studies," in *Planning for Groundwater Protection*, ed. G. William Page (Orlando: Academic Press, Inc., 1987), 289; Richard Edwards, *Industries of New Jersey, Middlesex, Somerset and Union Counties*, Part 4 (New York, Newark and Philadelphia: Historical Publishing Company, Publishers, 1882), 518.
[313] New Jersey, Legislature, *Acts of the Eighty-Second Legislature*, 124-125; *Charter of the City of Perth Amboy, in the County of Middlesex and State of New Jersey, as Revised by an Act of the Legislature, Approved March 17, 1870, and Amended by a Supplement, Approved April 5, 1871,* (Perth Amboy, N.J.: Perth Amboy Publishing Company Print, 1905), 42.

The earliest municipal sewer in Perth Amboy was most likely the Smith Street sewer, located between State Street and the Arthur Kill, and attributed to the administration of Dr. Solomon Andrews, who was mayor in 1849, 1853, and 1855. Historical records refer to street improvements completed during all three terms and Andrews' experience as a physician treating those afflicted by cholera and yellow fever likely informed his understanding of the need to construct sewers. An 1882 publication, however, attributed the first sewer to Ephraim Martin, Edward J. Hall, and Charles Keen during the 1859 mayoral term of William Paterson. Their design was reportedly constructed at a cost of $2,795.[314]

Around the same time, a second sewer was reportedly constructed on State Street that ran to the Raritan River.[315] Additional sewers were later constructed on Jefferson Street in 1877, Fayette Street in 1879, Rector Street in 1880, Washington Street in 1883, and Commerce Street in 1886. In 1900, C.C. Hanmann, the City Surveyor, reported that more sewers were constructed between 1886 and 1889. The Fayette, Smith, and Washington Streets sewers connected to an outfall on the Arthur Kill. By 1900, another four sewer outfalls into the Arthur Kill and four into the Raritan River were added.[316]

---

[314] "City of Perth Amboy," in *History of Union and Middlesex Counties, New Jersey, with Biographical Sketches of Many of Their Pioneers and Prominent Men*, ed. W. Woodford Clayton, (Philadelphia: Everts & Peck, 1882), 615-616; Scott A. Sandage, *Born Losers: A History of Failure in America* (Cambridge: Harvard University Press, 2005), 140; John P. Wall and Harold E. Pickersgill, *History of Middlesex County, New Jersey, 1664-1920, under the associate directorship of John P. Wall and Harold E. Pickersgill assisted by an Able Corps of Local Historians, Historical-Biographical* (New York and Chicago: Lewis Historical Publishing Company, Inc., 1921), 2:381.

[315] The State Street Sewer prompted a New Jersey Supreme Court case in 1861 because municipality officials did not give property-owners the opportunity to make their objections known. This then led to an 1862 supplement to the city charter, because the city failed to collect on the assessments. To read the decision: https://cite.case.law/njl/29/259/

[316] Hunt, "The Sewer Systems of New Jersey," 99; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 88.

In 1900, the system was composed of 10 miles of combined sewers. Approximately half were made of brick. The brick sewers ranged in size from 20 inches by 28 inches to 42 inches by 54 inches. They were likely elliptical or egg-shaped, as two dimensions were recorded. The sewer pipes of unspecified materials ranged in size from 8 to 24 inches, and the most common size was 12 inches.[317]

At this time, Hanmann reported that the combined system had reached its limits, and any future extensions or construction should use the separate system. This was echoed by George W. Fuller, who was engaged by the State Sewerage Commission in 1907 to help the city with a sewerage plan for the Sheridan Street. Even though two sanitary engineers recommended the city construct sewers on the separate system, ultimately, the Sheridan Street sewer was constructed on the combined system in 1908.[318]

City of Passaic, Passaic County

Passaic was originally settled by Dutch traders in 1678. Originally Acquackanonk Landing, a village in Acquackanonk Township, it acquired its current name in 1854 from the Passaic River, which forms its eastern border. The City of Clifton borders the city inland and across the Passaic River is the City of Wallington.[319] Passaic was first incorporated as a village in 1869, and later as a city in 1873 (Figure 84). Weasel Brook

[317] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 87.
[318] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 89; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature of 1908*, 251-254.
[319] According to the Federal Writers' Project of the Works Progress Administration for the State of New Jersey's text *New Jersey,* during Prohibition, a pipeline below the Passaic River conveyed molasses from Wallington, which bootleggers in Passaic would manufacture into alcohol, and then send back to Wallington. This made Passaic critical to bootleggers and hijackers.

and McDonald Brook flowed through the city and into the Passaic River, though they were later partly covered. Passaic was primarily an agrarian community, but the city's location adjacent to the water led to an early shipping industry as well.[320]

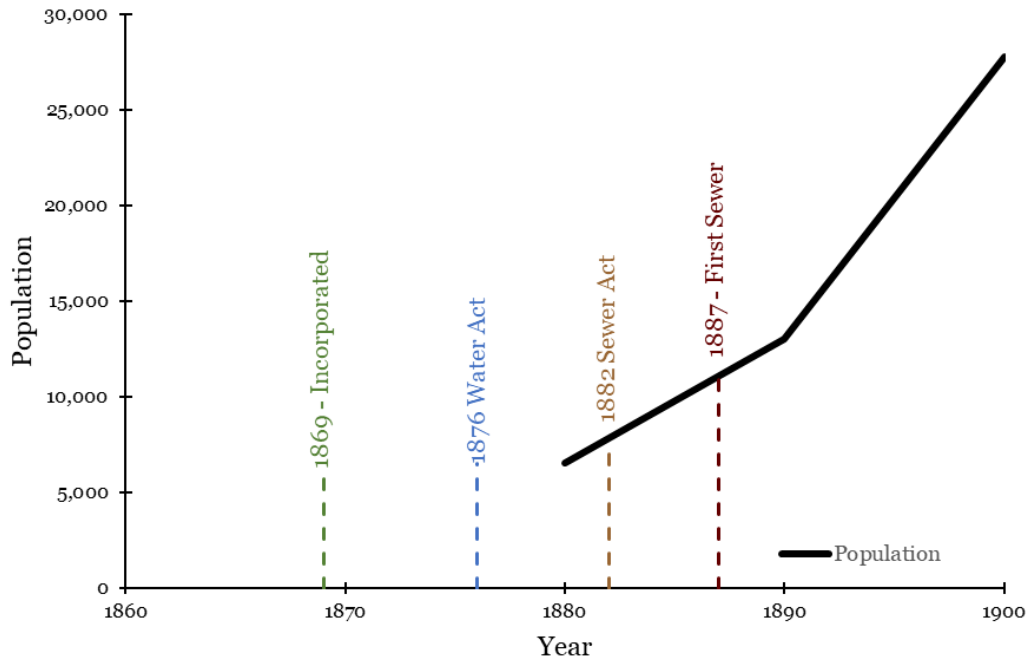


Figure 84. Population data for Passaic alongside key historical markers.

The railroad was introduced to Passaic in the 1830s and transitioned the city away from its agrarian character into a more industrial one. The Passaic River provided waterpower, which encouraged Passaic's industrial growth during the 1860s. The major industry in the city would be worsted wool, particularly after the Botany Mills textile plant opened in 1890. Other significant industries include garment making, handkerchiefs, and rubber manufacturing. The slowly industrializing city attracted immigration, which took place in phases.[321]

[320] Federal Writers' Project, *New Jersey*, 346; Evelyn Gonzalez, "Passaic," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen (New Brunswick: Rutgers University Press, 2005), 615.
[321] Federal Writers' Project, *New Jersey*, 346-347; Gonzalez, "Passaic," 615.

Sewer History

The 1869 charter granted the board of councilmen the power to "build and open sewers, drains and receiving basins in and upon any street, road or avenue in said village, or any part thereof" at the request of landowners who would pay for the work. Like other incorporation charters, it delineated how costs would be divided. All main sewers and main open drains were assessed to the inhabitants of the village, whereas other sewers would be assessed to the property owners who benefited from the construction.[322]

Drinking water was introduced in 1872 by the privately owned Acquackanonk Water Company. The following year when Passaic was reincorporated as a city, the revised incorporation act empowered the City Council to "order and cause sewers or drains to be constructed in any part of said city," if they felt it would benefit public health, with costs assessed to the property owners who benefited from the sewer construction.[323]

Municipal Sewers

It appears that sewers were not constructed under the provision of the 1869 charter, since sewer construction efforts were spearheaded by the municipal government in 1883. They hired Colonel George E. Waring, Jr., who completed a survey of the city on March 25, 1884, and recommended a separate system composed of small pipes. Construction of Waring's designed system began in 1887. Outside the scope of Waring's plan, a 72-inch diameter storm sewer was constructed in 1890 on Main

[322] New Jersey, Legislature, *Acts of the Ninety-Third Legislature*, 328, 331.
[323] William W. Scott, *History of Passaic and Its Environs, Historical – Biographical,* (New York and Chicago: Lewis Historical Publishing Company, Inc., 1922), 1:319; New Jersey, Legislature, *Acts of the Ninety-Seventh Legislature*, 507-510.

Avenue, from Jefferson Street to Park Place, at a cost of $10,000. This sewer connected with a preexisting storm sewer and outfall on Park Place. The Main Avenue sewer would most likely have been constructed of brick, as it was the most common material for large sewers before 1890.[324]

In 1900, the system had 28.42 miles of sanitary sewers, 2.24 miles of storm sewers, and 0.25 miles combined sewers. The sanitary sewers were constructed of vitrified clay pipe ranging in diameter from 6 inches to 15 inches and cast-iron pipe ranging in diameter from 18 inches to 30 inches. The most common pipe size and material was 8-inch vitrified clay pipe, which made up nearly 20.76 miles of the system. The storm sewers were composed of circular vitrified pipe ranging in diameter from 12 inches to 20 inches, egg-shaped brick pipe ranging in size from 32 inches by 48 inches to 39 inches by 58.5 inches, and egg-shaped cement pipes that were 26 inches by 34 inches.[325] These are the only egg-shaped cement pipes we have come across in New Jersey. The brick sewers were laid 13 feet below the street, whereas sewers constructed from other materials were placed 7 feet below the street.[326]

The waste was not treated before being discharged into the Passaic River, at one of nine outfalls located at Mercer Street, Lodi Street, Passaic Street, Park Place, Essex Street, Washington Place, Lafayette Avenue, Ayerigg Avenue, and Van Houten Avenue.[327]

---

[324] Scott, *History of Passaic*, 1:444-1:445.
[325] We posit that the concrete pipes were misreported as cement, since cement pipes have not been found to be widely reported in the historical record.
[326] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 105-106; Hunt, "The Sewer Systems of New Jersey," 96.
[327] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 106.

City of Paterson, Passaic County

The Passaic River passes through the City of Paterson and makes up the northern and eastern border. Molly Ann Brook and Slippery Rock Brook flow into the Passaic River on the western side of the city. Paterson was first settled in 1678 by European, primarily Dutch, settlers. There was no significant development in the city until SUM, established in 1791 at the urging of Alexander Hamilton, purchased land along the Passaic River to harness the waterpower of the Great Falls and foster industry in the city. At the time of purchase, there were only ten houses in the city. The efforts of SUM were successful, and Paterson became one of the earliest manufacturing centers in the country. By 1825, Paterson was known as the "Cotton Town of the United States." Paterson was incorporated as a city in 1831, which brought with it new means of transportation to Jersey City, with the Morris Canal in 1831 and the Paterson and Hudson River Railroad in 1832 (Figure 85). The connection to Jersey City helped Paterson bring its goods to the rest of the world.[328]

[328] Maxine N. Lurie, "Paterson," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen (New Brunswick: Rutgers University Press, 2005), 618; Federal Writers' Project, *New Jersey*, 352-353.

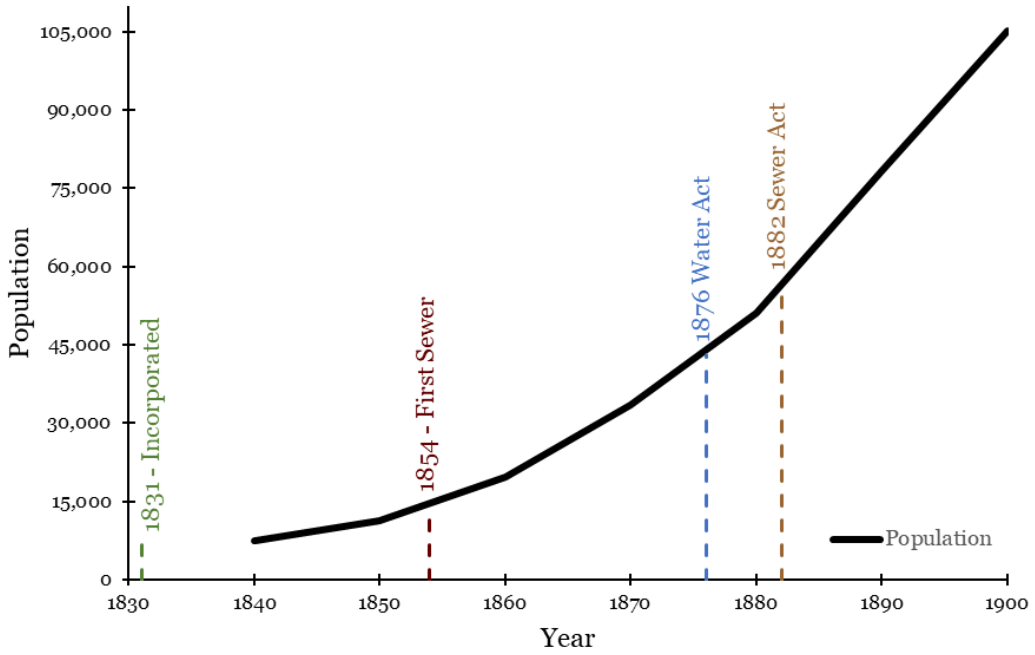


Figure 85. Population data for Paterson alongside key historical markers.

In 1840, John Ryle established a silk manufacturing plant in the city; by 1850, silk production surpassed cotton production and Paterson came to be known as the "Silk City." By 1870, 50% of the silk woven in the country was produced in the city's mills. Other manufacturing establishments produced guns, locomotives, and many other products. All this industry encouraged migration from Germany, Ireland, Italy, and Russia to labor in the manufactories. These workers faced unpleasant working conditions, including long workdays extending to upwards of sixteen hours. The earliest recorded strike was in 1794 and beginning in the 1880s Paterson saw over 137 strikes over the next twenty years, making it the "most strike-ridden city." Since strikes often shut down manufacturing, manufacturers quickly sought out alternate locations in search of laborers who would work irrespective of the conditions. The city's troubles were exacerbated in the twentieth century when fires and natural disasters struck, but

the Great Fire of 1902 had the severest impact. Nearly $10 million of property was damaged, including City Hall and other government buildings.[329]

Sewer History

Paterson's 1851 incorporation act included provisions "for causing drains to be made in any part thereof" and "for supplying the said city with water, for the extinguishment of fires and for other purposes." The next year "[a]n act to authorize the construction of works to supply the city of Paterson with water" passed and in 1854, the incorporation act was supplemented to require the city council to pass an ordinance for sewer construction. In addition to using money raised from taxes to pay for construction expenses, as was written in the 1851 act, the supplement added the option for the City of Paterson to sell bonds to raise capital.[330]

The earliest known sewer construction in Paterson took place in the 1850s, though it is difficult to determine the exact year, due to inconsistencies in the historical documents. John T. Hilton, the city surveyor in 1880, reported that approximately 0.13 miles of egg-shaped sewers were built in either 1852 or 1853. A later 1890 text connected the first sewers to Mayor John J. Brown's year-long tenure in 1854 as Paterson's first mayor. Considering the technology available and the shape of the sewer, it is likely that this sewer would have been constructed of brick.[331]

---

[329] Federal Writers' Project, *New Jersey*, 351-353; Lurie, "Paterson," 618-619; New Jersey, Legislature, *Acts of the Seventy-Fifth Legislature,* 450-451.
[330] New Jersey, Legislature, *Acts of the Seventy-Fifth Legislature,* 450-454; New Jersey, Legislature, *Acts of the Seventy-Sixth Legislature*, 501; New Jersey, Legislature, *Acts of the Seventy-Eighth Legislature,* 326.
[331] Waring, *Report on the Social Statistics of Cities*, 723; Charles A. Shriner, *Paterson, New Jersey. Its Advantages for Manufacturing and Residence: its Industries, Prominent Men, Banks, Schools, Churches, etc.* (Paterson: The Press Printing and Publishing Company, Paterson, N.J., 1890), 306.

General Egbert Ludovicus Viele's Design for a Sewer System

City-wide sewer construction started in 1868 with the adoption of General Egbert Ludovicus Viele's comprehensive design for a sewer system.[332] Viele was a proponent of leveraging the topography in planning rather than imposing a grid system. Though Viele was disinclined to permit industrial waste to enter the public sewer system, ultimately, Paterson's sewer system in the early twentieth century received substantial manufacturing wastes. He recommended brick sewers in a combination of both egg and circular shapes and ranging in diameter from 24 to 96 inches. Smaller pipes with diameters ranging from 12 to 30 inches were made of either concrete or vitrified clay.[333]

There are at least two construction indicators that can help date either brick or concrete pipes. Prior to 1874, concrete pipes were formed in the trench. After 1874, city engineer H.J. Harder supervised the prefabrication of precast concrete pipes; these pipes were manually formed off site and after curing could be brought to the site for assembly. City surveyor John T. Hilton reported that stoneware invert blocks were first used in the brick sewers in 1877 and he "would not like to build a brick sewer without them now" as they helped with drainage.[334]

---

[332] Viele's map for Paterson's sewer system was lost following the Great Fire of 1902, which resulted in a new illustration and survey of sewers and streets.

[333] Waring, *Report on the Social Statistics of Cities*, 723; Peterson, "The Impact of Sanitary Reform upon American Urban Planning," 27; Viele, *Report on Civic Cleanliness*, 16; Whipple, "Appendix I. Composition of Paterson Sewage," 6; Jo Ann Cotz, *Phase II Historical Research Survey of the Proposed Sanitary Sewer Replacement System, City of Paterson, Passaic County, New Jersey* (Wayne, NJ: Pandullo Quirk Associates, 1977), 19; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 107.

[334] Cotz, *Phase II Historical Research Survey*, 21; Waring, *Report on the Social Statistics of Cities*, 723; Shriner, *Paterson,* 310. Hilton was known to be particular about materials used in sewer construction; however, many contractors wanted to use lower cost materials. Late 1970s surveys have shown that some sewers were constructed of pale brick instead of hard burned brick. For the most part, the Committee on Streets and Sewers supported Hilton, but by 1884, the Committee on Streets and Sewers supported the contractors, thus he was ousted.

Approximately 50% of Viele's sewers were constructed as proposed, while the remaining were constructed in different locations or with smaller pipe sizes at the behest of the Sewer Commissioners of the City of Paterson.[335] The result was insufficient sewer capacity in the planned system. The second issue that reportedly plagued Paterson's sewer system was poor workmanship and materials. It is likely that political favoritism in contractor selection and political appointments for the Commissioners of Sewers led to these construction issues being overlooked.[336]

Though construction on Viele's system was completed by 1880, it had long been considered "imperfect" by city surveyors and engineers, who felt they had to "rectify" the design of the system. Prior to 1880, it is most likely that A.A. Fonda, the City Surveyor, as well as John T. Hilton and Leslie S. Menger, both of whom worked together under Fonda, were tasked with amending the system. By 1880, the City of Paterson hired an engineer to continue to improve the system.[337]

Many sewers continued to be modified into the twentieth century. The Arch Street brick sewer was built in 1874 to discharge sewage into the Passaic River (Figure 86). After 1911, a trunk sewer was constructed to convey the Arch Street sewage farther away and in 1921, the brick sewer was tied into the new trunk line to serve as an overflow sewer. The Arch Street sewer was two wythes of bricks laid in running bond and arranged in an egg-shaped design (Figure 87).[338]

---

[335] For further information on specificities of annual sewer construction refer to the Annual Report of the City Officers of the City of Paterson, NJ.
[336] Cotz, *Phase II Historical Research Survey*, 8-9.
[337] Cotz, *Phase II Historical Research Survey*, 19; Waring, *Report on the Social Statistics of Cities*, 723; Shriner, *Paterson,* 309, 310, 314.
[338] Robert J. Lore and Michael Tomkins, *Archaeological Monitoring CSO Solids/Floatables Control Facility 005 Brick Sewer Documentation, City of Paterson, Passaic County, New Jersey* (Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2008). The report states "The sewer's profile was egg-shaped

Figure 86. Exterior of the Arch Street brick sewer.
Source: Robert J. Lore and Michael Tomkins, Archaeological Monitoring CSO Solids/Floatables Control Facility 005 Brick Sewer Documentation City of Paterson, Passaic County, New Jersey *(Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2008), 18.*

Name of sewer.	Length.	Size.	Material.	Price per foot.	PRICE OF MATERIALS USED.							Nature of cut.	Total cost.	Cost per foot, including every thing.
					Manholes, each.	Catch-basins, each.	Receiving-basins, each.	Hard-rock excavation, per cubic yard.	Soft-rock excavation, per cubic yard.	Timber, per 1,000 feet.	Concrete, per cubic yard.			
	Feet.	*Inches.*												
Arch Street	867.0	30	Brick, egg-shaped	$3 40	$30 00	$20 00	.....	$2 00	$1 00	$17 00	$3 50	Sand and clay	$3,730 34	$4 30
Smith Street	393.0	12	Cement pipe	1 10	30 00	20 00	.....	7 00	4 00	35 00	5 00	Sand and clay	821 48	2 09
Straight Street	140.0	48	Brick, egg-shaped	7 95	28 00	33 00	$85 00	5 00	3 00	18 00	5 00	Sand, clay, and gravel		
Straight Street	1,023.0	36	Brick, egg-shaped	4 35	28 00	33 00	85 00	5 00	3 00	18 00	5 00	Sand, clay, and gravel	15,346 95	5 00
Straight Street	533.0	30	Brick, egg-shaped	3 45	28 00	33 00	85 00	5 00	3 00	18 00	5 00	Sand, clay, and gravel		
Straight Street	1,044.0	24	Brick, egg-shaped	2 33	28 00	33 00	85 00	5 00	3 00	18 00	5 00	Sand, clay, and gravel		
Mechanic Street	1,205.0	18	Cement pipe	1 61	30 00	30 00	100 00	7 00	4 00	35 00	5 00	Gravel, sand, and clay		
Mechanic Street	821.0	15	Cement pipe	1 33	30 00	30 00	100 00	7 00	4 00	35 00	5 00	Gravel, sand, and clay	4,537 07	2 24
Willis Street	582.0	12	Vitrified pipe	69	30 00	30 00	.....	6 00	5 00	18 00	6 00	Very fine sand	772 08	1 33
Cedar Street	243.0	12	Vitrified pipe	68	30 00	29 00	.....	6 00	5 00	18 00	6 00	Sandstone, gravel, and clay	406 78	1 67
Van Houten Street	1,037.5	18	Cement pipe	1 71	32 00	30 00	.....	7 00	4 00	35 00	5 00	Sand and gravel		
Van Houten Street	771.0	15	Cement pipe	1 43	32 00	30 00	.....	7 00	4 00	35 00	5 00	Sand and gravel	4,352 32	2 41
Lawrence Street	425.5	12	Cement pipe	1 15	33 00	33 00	85 00	5 00	3 00	18 00	5 00	Clay, gravel, and sand	870 99	2 05

Figure 87. Table of sewers constructed in Paterson by 1880, as compiled by George E. Waring, Jr.
Source: George E. Waring, Jr., Report on the Social Statistics of Cities, Part 1, the New England and the Middle States *(Washington: Government Printing Office, 1886), 724.*

and contained two courses of horizontally laid bricks joined with cement," however, studying the images from the monitoring depicts a sewer that is two wythes.

By 1900, the combined sewer system was 71.72 miles long, with 20.45 miles of brick sewers and 51.27 miles of concrete or vitrified clay sewers. The system had twenty-two outfalls into the Passaic River.[339]

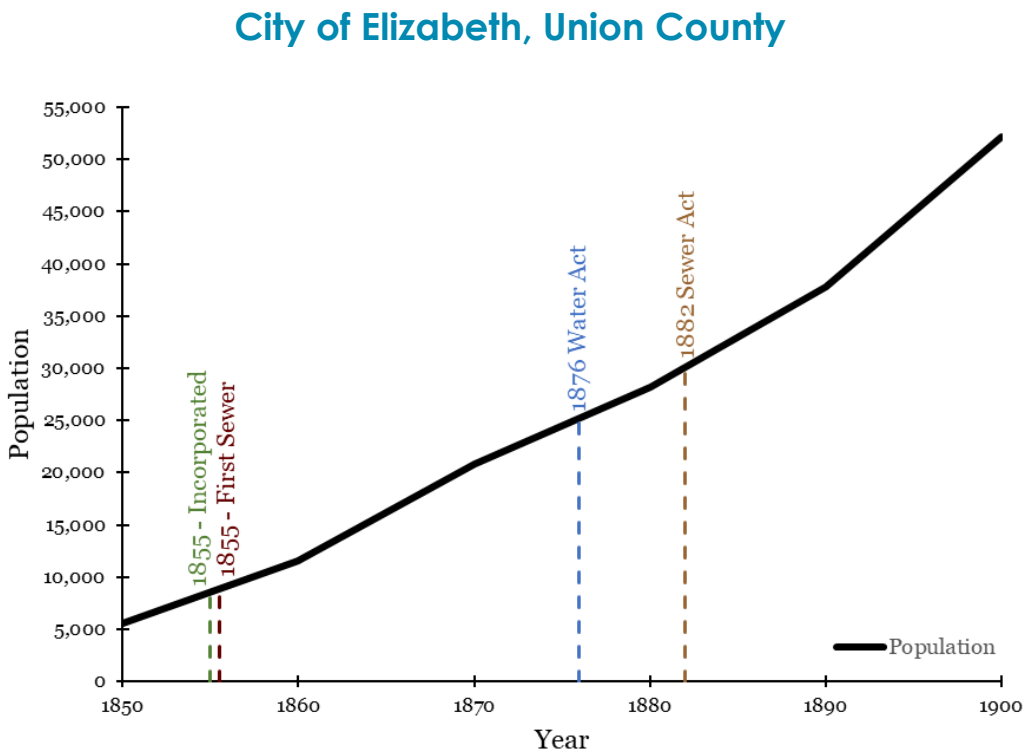


Figure 88. Population data for Elizabeth alongside key historical markers.

Elizabeth was founded as Elizabethtown by English settlers in 1664 as an agrarian community. It would be incorporated as a city in 1855 (Figure 88). The City of Elizabeth is bordered on the south by the Elizabeth River, which drains into the Arthur Kill. The eastern border of Elizabeth fronts the Arthur Kill and Newark Bay, which connects Elizabeth to the Atlantic Ocean. The city was a terminal for highways and railroads.[340]

---

[339] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 107.
[340] Harry Glazer, "Elizabeth," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen (New Brunswick: Rutgers University Press, 2005), 246; Federal Writers' Project, *New Jersey*, 238-239;

The city's early industry started with tanning, and by 1687 the city was shipping leather across the colonies. Another early industry was whaling, whales were then abundant along the New Jersey coastline. Industrialization was spurred by the establishment of "The New Manufacturing Town of Elizabeth Port" by New York businessmen in 1835. The Singer Sewing Machine Company set up in this area in 1873 and employed close to 7,000 people by the end of the nineteenth century. Railroads, which connected Elizabeth to other major industrial cities, stimulated industrial development that attracted immigrant populations from Germany and Ireland to work in the manufactories. In addition to sewing machines, other products produced in Elizabeth included beds, chemicals, clothing, iron and steel machinery, printing press machines, refined petroleum, soap, and other commodities.[341]

Sewer History

In 1855, the Elizabethtown Water Company laid cast-iron pipes and began water operations to service the population of 8,978 people. Prior to that year, only private drains had been constructed in the city, but a new charter permitted the construction of "sewers and drains in and from the public streets and squares." The 1858 supplement to the "act to establish the city of Elizabeth" permitted the city council to make a "just and equitable assessment" of the cost of sewer construction and transfer the proportionally divided expense in its entirety to the property owners who benefited from construction.[342]

New Jersey, Legislature, *Acts of the Seventy-Ninth Legislature of the State of New Jersey and Eleventh Under the New Constitution* (Trenton: Printed by Phillips & Boswell, 1855), 217.

[341] Federal Writers' Project, *New Jersey*, 240-242; Glazer, "Elizabeth," 246.

[342] Glazer, "Elizabeth," 246; Robert D. B. Carlisle, *Water Ways: A History of the Elizabethtown Water Company* (Elizabeth: Elizabethtown Water Company, 1982), 54; Waring, *Report on the Social Statistics of Cities*, 687; New Jersey, Legislature, *Acts of the Seventy-Ninth Legislature*, 230; New Jersey, Legislature, *Acts of the Eighty-Second Legislature*, 343.

Ernest Ludolph Meyer, the civil engineer and surveyor for Elizabeth between 1852 and 1875, is credited with introducing the combined sewer system in 1855 and making improvements to the city's street and sidewalk alignment. The combined system was composed of brick and other unspecified materials. The system expanded to over 30 miles of sewers by 1880, 41.5 miles by 1900, and 56 miles by 1902. This included 12.2 miles of brick sewers ranging in size from 24 inches by 36 inches to 60 inches by 90 inches. The system used gravity to move wastewater to thirteen discharge locations in the Arthur Kill and the Elizabeth River.[343]

Trumbull Street Sewer[344]

The Trumbull Street Sewer was a main trunk line in the Elizabeth system. The segment of the sewer closest to the Arthur Kill was reportedly constructed by the Singer Manufacturing Company. Exposed sections of the Trumbull Street Sewer between Bond Street and East 6th Street revealed a two wythe, egg-shaped brick sewer, 48 inches by 66 inches, located at an approximate depth of 4.25 feet. The bricks were 8 inches long, 3.5 inches wide, and 2.25 inches thick. It is likely that the bricks were hand-molded, which resulted in inconsistencies. Some bricks had slightly irregular corners; cracks, most likely from over-firing; and signs of warping from firing.[345]

---

[343] Turner and Koles, *Elizabeth*, 68; Waring, *Report on the Social Statistics of Cities*, 687; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 116-117.

[344] Archaeological monitoring was conducted on the Trumbull Street Sewer in 2018, as part of a flood control project. A segment of the Trumbull Street Sewer, from Division Street to the Arthur Kill, was determined eligible for listing on the NRHP under Criteria A and C in 1999.

[345] Dorothy Guzzo, "SHPO Opinion, Trumbull Street Sewer, Elizabeth, New Jersey. NJ State Historic Preservation Office. Letter submitted to Edward Hummel, US EDA, 10 September," (1999); New York, Metropolitan Sewerage Commission, *Sewerage and Sewage Disposal*, 341; Grossman-Bailey and Cushman, *Trumbull Street Flood Control Project,* i, 2-18.

Figure 89. Cross-section of the Trumbull Street sewer, with wooden planks in the invert.
Source: Ilene Grossman-Bailey and Laura D. Cushman, Trumbull Street Flood Control Project, Trumbull Street, East Sixth, Street and Bond Street, Block 7, Lot 1227, City of Elizabeth, Union County, New Jersey *(Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2019), 2-21.*

The sewer was constructed on a semi-circular wooden cradle formed by six wooden planks, possibly made of pine (Figure 89). Prior to the archaeological monitoring, parts of the sewer had been rehabilitated with gunite, a mixture of sand, cement, and water, which is applied by spray onto a wire mesh screen. A 1.5-inch thick

gunite layer was found on top of the wire mesh screen (Figure 90). Gunite has also been used in the rehabilitation of Hoboken's wooden sewer and Newark's brick sewers.[346]

Figure 90. Wire mesh used in the gunite rehabilitation of the Trumbull Street brick sewer.
Source: Ilene Grossman-Bailey and Laura D. Cushman, Trumbull Street Flood Control Project, Trumbull Street, East Sixth, Street and Bond Street, Block 7, Lot 1227, City of Elizabeth, Union County, New Jersey *(Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2019), 2-17.*

City of Rahway, Union County

Rahway was settled as early as 1664. The Rahway River flows south then east through Rahway. The Robinsons Branch and South Branch are the two main tributaries of the river within the city, and Orchard Creek is a smaller tributary. Initially, people were attracted to the city for its fertile soil, and they established farms and plantations. After its incorporation in 1858, Rahway transformed into an industrial city, with major industries including books, cereals, chemicals, dehydrated foods, drugs, furniture,

[346] Grossman-Bailey and Cushman, *Trumbull Street Flood Control Project,* i, 2-18.

lubricating oils, metal products, rubber goods, and vacuum cleaners (Figure 91). One of the most famous chemical and drug manufacturers in the city is Merck Co.[347]

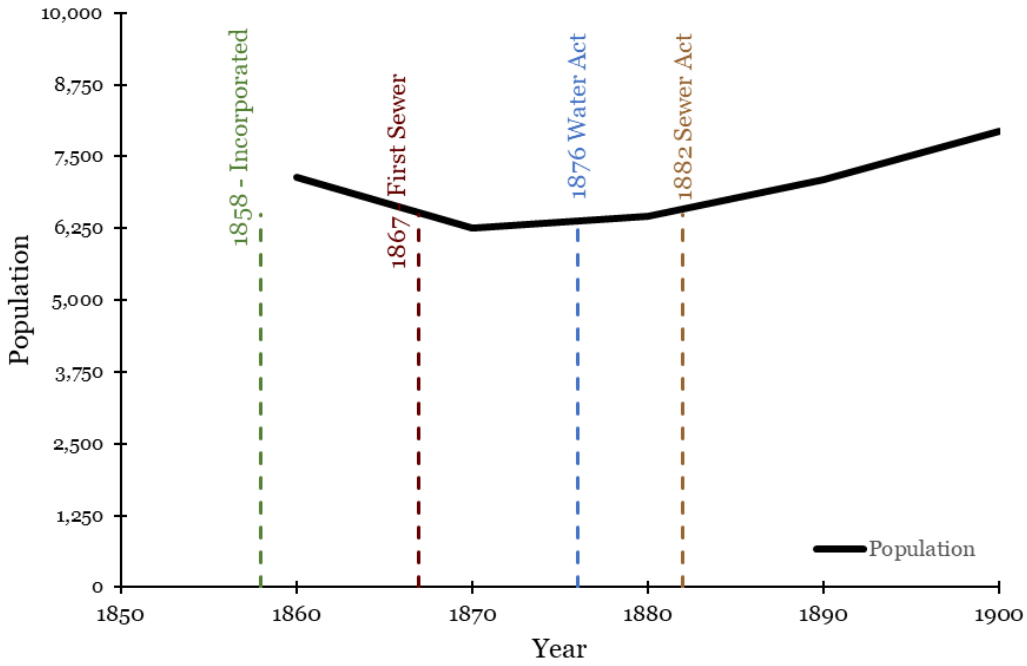


Figure 91. Population data for Rahway and key historical markers.

Sewer History

A combined sewer system was constructed in Rahway between 1867 and 1874, under the supervision of city engineers. The main sewers were constructed of brick with a diameter of 66 inches. Even though a single dimension was provided, the report described their shape as oval, and smaller main sewers as egg-shaped. The brick sewers were laid with dry courses at the bottom to encourage sub soil drainage. There were seven outfalls into the Rahway River.[348]

[347] Patricia M. McGuire, "Rahway," in *Encyclopedia of New Jersey*, ed. Maxine N. Lurie and Marc Mappen (New Brunswick: Rutgers University Press, 2005), 674; Federal Writers' Project, *New Jersey*, 485.
[348] Hunt, "The Sewer Systems of New Jersey," 100.

Town of Phillipsburg, Warren County

Phillipsburg was settled in the early eighteenth century. Bordered on the west by the Delaware River, and across the river from Easton, Pennsylvania, Phillipsburg was a farming village initially. The Lopatcong Creek flows through the southern part of Phillipsburg into the Delaware River. In 1811, there were only fifteen families in the town. The introduction of the Morris Canal in 1831 resulted in the town's growth to fifty dwellings in 1847. Phillipsburg's adjacency to the Delaware River meant that the town's industry had a reliable source of waterpower. The town's first major industry was a brass and iron foundry established in 1848, the J.R. Templin & Co. The same year, the Cooper Iron Works built a blast furnace in the southern part of town; the company grew, added two additional furnaces, and was later sold off. Other major industries in town included agricultural implements, cast-iron pipes and columns, cement, drills, silk, and steel casings. The arrival of the New Jersey Central Railroad in 1852 encouraged growth. The following year, the Phillipsburg Land Company formed and began to sell land lots to people. Eventually, Phillipsburg went on to be incorporated in 1861 (Figure 92).[349]

[349] George Wyckoff Cummins, *History of Warren County, New Jersey* (New York: Lewis Historical Publishing Company, 1911), 226-238; Winton C. Garrison, *The Industrial Directory of New Jersey* (Camden, N.J.: S. Chew & Sons Co., Printers, 1909), 357.

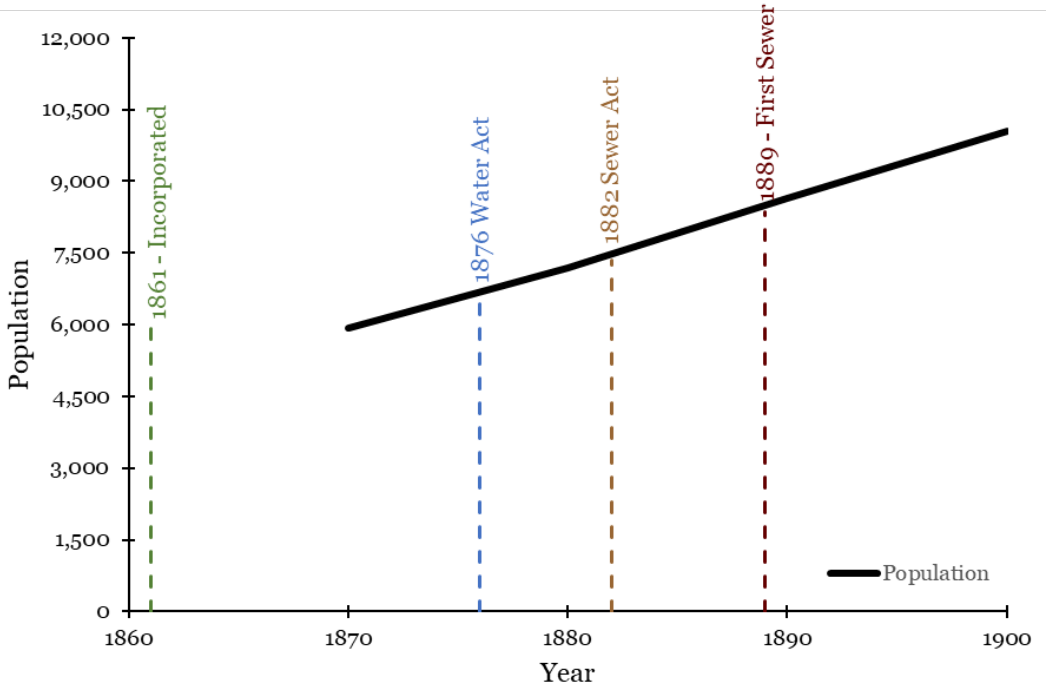


Figure 92. Population data for Phillipsburg and key historical markers.

Sewer History

Piped-in water was introduced in 1861 by Easton's Lehigh Water Company; later in 1886, the People's Water Company of Phillipsburg supplied well water to residents. The increased water supply prompted the city to consider sanitary waste. The city had already attempted to carry off storm water using culverts, but it did not resolve the issue of unsanitary conditions emerging from cesspit use in populated parts of the city.[350]

Thus, Carroll Phillips Bassett was hired in 1888 to design a sewerage system, though as seen in many other towns, the system was not built as it was proposed. Broadly, Bassett's design proposed both combined sewers made of brick, with a split pipe invert embedded in concrete, and separate sewers for stormwater (Figure 93). By 1900, 3.76 miles of the proposed 3.80 miles of combined sewers were built, but only

[350] Cummins, *History of Warren County*, 236; "Phillipsburg, N.J.," *Engineering News and American Railway Journal* (November 17, 1888): 397.

0.53 miles of the proposed 8.84 miles of separate sewers were built. Of these lengths, 1.06 miles were brick. Bassett recommended egg-shaped brick sewers sized 48 inches by 60 inches, 40 inches by 60 inches, and 36 inches by 42 inches, however, the smallest-sized brick sewers had not been constructed by 1900. Instead, the city constructed some sewers outside of Bassett's proposal, including egg-shaped brick sewers measuring 36 inches by 54 inches, and likely circular sewers with diameters of 30 inches or 45 inches. For smaller pipes, Bassett proposed 18-inch iron pipe and 12-, 15-, 18-, and 20-inch vitrified clay pipe. He specifically stated the 1882 Sewer Act would be used to fund construction; however, it appears that property owners were not assessed any construction costs. Rather the town used its general funds to construct sewers and charged a $25 fee to homeowners for sewer connections. Early sewer connections, approximately 425 in 1908, were made by well-off families and businesses.[351]

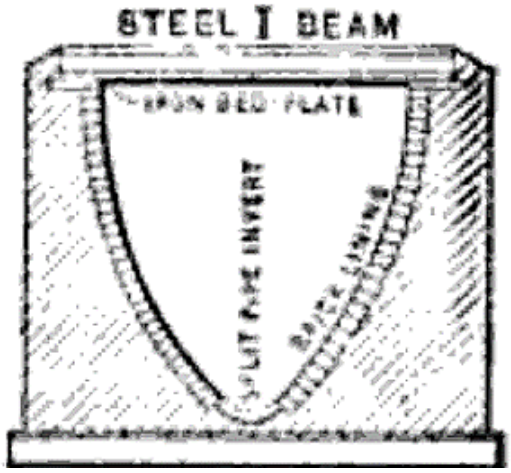


Figure 93. Example of a split pipe invert in a brick sewer.
Source: A. Prescott Folwell, Sewerage, The Designing, Construction, and Maintenance of Sewerage Systems, *6th ed. (New York: John Wiley & Sons, 1910), 148.*

[351] "Phillipsburg, N.J.," 397; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature, Session of 1900*, 124-125; New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature of 1908*, 256.

In 1900, there were three outfalls, all of which released waste into the Delaware River without any treatment. However, by 1908, the town reported six public outfalls and two privately-owned sewer outfalls. Three combined sewers, including dimensions of 84 inches, 36 inches by 48 inches, and 16 inches, discharged into the Delaware River. The storm water outfalls included a 36-inch by 54-inch sewer, which discharged into the Delaware River, a 48-inch sewer, which also received factory wastes and discharged into the Morris Canal, and an 18-inch sewer, which discharged into the Morris Canal. The two privately owned sewer outfalls were 8 inches and 14 inches and received waste from the Pennsylvania and Central Railroad of New Jersey's stations and workshops. In 1908, it was also reported that the system was not built in its entirety, and the built segments were constructed with "a number of departures from the original plan."[352]

Construction steadily continued over the next few decades and brought legal troubles for the inhabitants. The waste was not treated before entering the Delaware River, and the New Jersey Sewerage Commission designated Phillipsburg a pollutant town. On October 8, 1906, the State Sewerage Commission notified the Town of Phillipsburg to stop polluting the Delaware River within a year's time. The town failed to meet this deadline, so George W. Fuller was hired to report on a potential sewage disposal works for Phillipsburg. Of the total daily discharge on a day with no rain, less than 10% was domestic sewage, with the rest being industrial waste. Multiple reasons were given by the town for why no corrective action was taken; the financial challenge of rearranging the sewer system and pumping the waste to a disposal site was the most likely reason. The issue was not immediately resolved, as the Board of Health filed a

[352] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature of 1908*, 256-257.

case against Phillipsburg in 1909 for not discontinuing the pollution of the Delaware River.[353]

While the common thread amongst these twenty-two cities is the construction of brick sewers systems, because they were constructed over a period of time spanning most of the nineteenth century, each city's needs, strategies, and engineering techniques changed over time in response to available knowledge, resources, and technology. Some systems began as responses to public health crises, whereas others were the result of the need to dispose of excess water. Though almost all were industrial cities, geography and population varied, so each city's system represents a unique solution to a universal problem. Particularly interesting is how most city sewer systems are a combination of localized, ad hoc segments, often built by private individuals or companies, and large-scale systems, designed by sanitary engineers (not all of whom had been formally trained in sanitary engineering) and funded by government. The evaluation of historic sanitary infrastructure in these twenty-two brick sewer cities for National and New Jersey Registers of Historic Places eligibility must be an exercise in nuanced thinking.

[353] New Jersey, Sewerage Commission, *Report of the State Sewerage Commission to the Legislature of 1908*, 256-258.

8. Sanitary Sewers and National Register Eligibility

Across the country, historic sanitary infrastructure has been determined eligible for listing or has been listed on the NRHP, as seen in the extensive but not exhaustive lists below (Table 3 and Table 4). A historic resource is evaluated within the context of both area of significance (e.g., agriculture, engineering, or transportation) and level of significance (i.e., local, state, or national). Previous studies have primarily evaluated sanitary infrastructure within the areas of community planning and development, engineering, health/medicine, and social history, and at all three levels of significance.

To be determined eligible, a resource must meet at least one of the four National Register Criteria (A, B, C, and D, detailed below), and retain enough integrity to convey that significance. There are seven aspects of integrity: location, design, setting, materials, workmanship, feeling, and association. In this chapter, we consider how the four criteria of significance and seven aspects of integrity have been applied in prior determinations of eligibility, and we raise questions for consideration in future evaluations of brick sewer infrastructure.

Table 3. Sanitary infrastructure sites listed on the NRHP.

Type of Sewer Infrastructure	***Resource Listed on the NRHP***	***Criteria***	***NRHP #***
Intercepting Sewer	River Walls, in the Civic Center Historic District, within The City Beautiful Movement and City Planning in Des Moines, Iowa, 1892-1938 Multiple Property Submission (Des Moines, Iowa)	C	88001168
Pump Station	Return Sludge Pumping Station, in the Public Works and Utilities - Sewage Treatment Facilities in Providence, 1895- 1935 Thematic	A	88003105

Type of Sewer Infrastructure	***Resource Listed on the NRHP***	***Criteria***	***NRHP #***
	Resource (Providence, Rhode Island)		
Pump Station	Washington Park Sewage Pumping Station, in the Public Works and Utilities - Sewage Treatment Facilities in Providence, 1895- 1935 Thematic Resource (Providence, Rhode Island)	A	88003107
Pump Station	Reservoir Avenue Sewage Pumping Station, in the Public Works and Utilities - Sewage Treatment Facilities in Providence, 1895- 1935 Thematic Resource (Providence, Rhode Island)	A	88003108
Pump Station	Ernest Street Sewage Pumping Station, in the Public Works and Utilities - Sewage Treatment Facilities in Providence, 1895-1935 Thematic Resource (Providence, Rhode Island)	A	88003103
Pump Station	Willow Street Pumping Station, in the Willow Street Pump Station Historic District (Houston, Texas)	A	04000547
Pump Station	Main Sewerage Pumping Station, District of Columbia, also known as the DC Water Main Pumping Station (Washington, D.C.)	A, C	12000297
Pump Station	Kakaako Pumping Station (Honolulu, Hawaii)	A, C	78001022
Sewage Treatment Plant	Chemical Building / Blower Building, in the Public Works and Utilities - Sewage Treatment Facilities in Providence, 1895-1935 Thematic Resource (Providence, Rhode Island)	A	88003106
Sewage Treatment Plant	Sludge Press House (Demolished) / Filter Building, in the Public Works and Utilities - Sewage Treatment Facilities in Providence, 1895- 1935 Thematic	A	88003104

Type of Sewer Infrastructure	***Resource Listed on the NRHP***	***Criteria***	***NRHP #***
	Resource (Providence, Rhode Island)		
Sewage Treatment Plant	Water Disposal Plant (H.S.-2), also known as Water Reclaim Plant[354] (Grand Canyon, Arizona)		74000348
Sewage Treatment Plant	Hibbing Disposal Plant (Demolished), also known as Hibbing Waste Treatment Plant (Hibbing, Minnesota)	A, C	91001022
Sewer	Alcantarilla Pluvial sobre la Quebrada Manzanares, also known as Los Tuneles de San Germán; Vaulted Brick Tunnel Storm Sewer System (San Germán, Puerto Rico)	A, C	90000552
Sewer Trestle	Arboretum Sewer Trestle, in the Bridges, Trestles and Aqueducts, in the Historic Bridges and Tunnels in Washington State Thematic Resource (Seattle, Washington)	C	82004229
Storm Sewer	Methodist Hollow Storm Sewer, in the McGregor Commercial Historic District, within Iowa's Main Street Commercial Architecture Multiple Property Submission (McGregor, Iowa)	A, C	100006174

[354] For images from the Historic American Engineering Record survey, see https://www.loc.gov/pictures/collection/hh/item/az0199/

Table 4. Sanitary infrastructure sites eligible for listing on the NRHP.[355]

Type of Sewer Infrastructure	***Resource Determined Eligible for Listing***	***Criteria***	***Source***
Pump Station	Sewage Pump Station #669, also known as Harris Place Sewage Pumping Plant (Los Angeles, California)	A, C	Murray et al., 2011
Sewage Treatment Plant	Tarrytown Sewage Treatment Plant (Tarrytown, New York)	A, C	Jennings, 2011
Sewage Treatment Plant	Passaic Valley Sewerage Commission Newark Bay Outfall Sewerage Works Historic District[356] (Newark, New Jersey)	A, C	Bzdak et al., 1996 and Tomaso, 2013
Sewage Treatment Plant	Tallman Island Water Pollution Control Plant (Queens, New York)	A, C	Blasland, Bouck & Lee, Inc., and Tams Consultants, Inc., 2006
Sewer	The Lake Union Sewer Tunnel (Seattle, Washington)	A, C	Sheridan, 2012
Sewer	Delgany Street Sewer Extension (Denver, Colorado)	D	Mead & Hunt, 2017
Sewer	Central City Tunnel System (Minneapolis, Minnesota)	A, C	Miller and Foss, 2017
Sewer	The City of Newark Sewers (Newark, New Jersey)	A, C	McEachen et al., 2000
Sewer	Lamberton Interceptor (Trenton, New Jersey)	A, C	Israel, 1976
Sewer	Trumbull Street Sewer (Elizabeth, New Jersey)	C	Guzzo, 1999

[355] The Kerrigan Avenue sewers in Union City, which were determined "technologically and historically significant," were not considered eligible without further evaluation within a broader brick sewer context. Paterson's sewers were also evaluated and were determined not eligible because they "likely used representative technology that was not innovative," even though the evaluation did not consider issues related to the development of infrastructure or public health nor contextualize the sewers in a comparative study with other historic sewers. Later historic contexts have determined sewer eligibility by considering localized engineering ingenuity and representative construction techniques.

[356] The PVSC Newark Bay Treatment Plant was evaluated in 1975 for its cultural significance. It was considered significant in the context of twentieth century industrial archaeology and several components of the facility received State Historic Preservation Office (SHPO) Opinions of Eligibility. More recent research has defined the Passaic Valley Sewerage Commission Newark Bay Outfall Sewerage Works Historic District and industrial archaeological site 28-EX-136, as having a period of significance of 1908-1957 and consisting of the Newark Shaft, Passaic Valley Interceptor Sewer, Historic Main Conduits, Outfall Tunnel, Sedimentation Basins, Robbins Reef Diffusor Structure, Unit 2 Sedimentation Basins, and Unit 3 Sedimentation Basins.

Type of Sewer Infrastructure	*Resource Determined Eligible for Listing*	*Criteria*	*Source*
Sewer	Early Jersey City Brick Sewers (Jersey City, New Jersey)	A, C, D	Bulger et al., 2019
Sewer	Cedar Rapids Sanitary Sewer System (Cedar Rapids, Iowa)	A, C	Deiber and Yengling, 2010
Sewer	Des Moines Sewer System (Des Moines, Iowa)	A, C	Rogers, 2009
Sewer	Keokuk Sewer System (Keokuk, Iowa)	A, C	Rogers and Price, 2012
Sewer	New Orleans Drainage System (New Orleans, Louisiana)	A, C	Maygarden et al., 1999

Criterion A

Criterion A defines eligibility as association "with events that have made a significant contribution to the broad patterns of our history." The two areas of significance that sewer systems have been associated with are community planning and development, and public health.[357]

The Alcantarilla Pluvial sobre la Quebrada Manzanares (trans. Storm Sewer over the Manzanares Creek), in San Germán, Puerto Rico, was listed under Criterion A because the ad hoc sewer system was significant to the development of the community. As the town developed and animal and human wastes entered the Quebrada Manzanares, it became necessary to mitigate the emergent public health threat. The situation would be exacerbated during heavy rainstorms, when the Quebrada Manzanares would flood Calle Javilla (trans. Javilla Street). Covering over the Quebrada Manzanares allowed land to be reclaimed, which expanded the boundaries of the city, accommodated the growing population, and eliminated the flood threat. Since the San Germán government eschewed responsibility, construction of the system between 1835

[357] National Park Service, *How to Apply the National Register Criteria for Evaluation, National Register Bulletin 15* (Washington, D.C.: U.S. Department of the Interior, National Park Service, 1997), 12.

and 1918 was representative of the private property owners' response to health and public safety issues presented by the Quebrada Manzanares.[358]

Brick sewers in Newark, New Jersey, were determined eligible for their "association with the vast improvement of public health and sanitation in late nineteenth century Newark, and stand today as a successful nineteenth century development in infrastructure that was integral to the growth of New Jersey's largest city" and "industrial growth and modernization." Between 1870 and 1890, Newark had one of the highest mortality rates in the country. Sewer construction, done in segments over many years, resulted in a marked improvement in public health and the corresponding transformation of the city.[359]

Likewise, the Early Jersey City Brick Sewers were determined eligible under Criterion A "in the area of Health and Medicine for their association with the urban public health reform movement of the mid-nineteenth century" and Trenton's Lamberton Interceptor was determined eligible for its association with community planning and development and health. The physical structure of the interceptor sewer evinced "the accomplishments of Trenton's City Officials and the early pioneering endeavors in the planning and developing Trenton's municipal services beginning in the 1880's," particularly since the municipality initiated the construction and design of the interceptor to "improve the city's environment, livelihood, and life style [sic]."[360]

---

[358] Héctor Santiago and Luis Pumarada, *National Register of Historic Places Nomination: Alcantarilla Pluvial sobre la Quebrada Manzanares* (San Juan, Puerto Rico: Puerto Rico Historic Preservation Office, 1990), Section 8.
[359] McEachen, Modica, and Lawrence, *Cultural Resources Investigation…Appendix A to Volume 3*, 7-33, 9-2; McEachen and Modica, *Cultural Resources Investigation, City of Newark*, 7-2-7-3.
[360] Bulger et al., *Stage II Cultural Resources Survey, Jersey City Municipal Utilities Authority,* 5-5-5-8; Israel, *Report,* 19.

In several cities in Iowa, specific sewer segments have been determined eligible under Criterion A. In Cedar Rapids, an interceptor sewer constructed in 1930 was determined eligible because it was the first step in addressing the public health of waterways. The construction of a sewage disposal and treatment facility followed in short succession. In Des Moines, despite financial and political constraints, an early sewer system was constructed that served both poor and wealthy neighborhoods. This system represented the evolution of ideas about sanitation, disease, and public health. In Keokuk, the Rand Park sewers were determined eligible for their association with the development of the city, and the Soap Creek/Bloody Run sewer was significance for its role in addressing major health and quality of life issues that residents faced. The Methodist Hollow Storm Sewer was determined significant because it addressed the flooding that had plagued McGregor, Iowa, since the city was settled.[361]

Significance can be determined at the local, state, or national level. For example, the Early Jersey City Brick Sewers were determined nationally significant because Jersey City was "the first municipality to undertake the initial planning stage of the water supply and sewerage system concurrently." Whereas Keokuk's trunk sewer and submains are significant at the state level as an example of an early, public storm water system constructed by an Iowa municipality.[362]

---

[361] Camilla R. Deiber and Michael C. Yengling, *Historic Context for the Sanitary Sewer System, of Cedar Rapids, Linn County, Iowa* (Marion, Iowa: The Louis Berger Group, Inc., 2010), 44; Leah D. Rogers, *Historic Context for the Des Moines Sewer System, City of Des Moines, Polk County, Iowa* (Iowa City, IA: Tallgrass Historians L.C., 2009), 90; Leah D. Rogers and Jennifer A. Price, *Historic Context for the Keokuk Sewer System, City of Keokuk, Lee County, Iowa* (Iowa City, IA: Tallgrass Historians, L.C., 2012), 76-77; David C. Anderson, *Intensive-Level Survey and Architectural Evaluation, Methodist Hollow Storm Sewer, Site #22-00676, Historical Architectural Database #22-003* (Waukon, Iowa: 1998), 2.
[362] National Park Service, *How to Apply the National Register Criteria for Evaluation*, 12; Rogers and Price, *Historic Context for the Keokuk Sewer System*, 75; Bulger et al., *Stage II Cultural Resources Survey, Jersey City Municipal Utilities Authority,* 5-5.

Not all sewers made of brick will be eligible under Criterion A. By the late nineteenth century, the construction of municipal sewers, whether a combined or separate system, was the accepted response to public health and sanitation needs. Brick sewer construction had also become relatively standardized by this time, even as newer technologies, such as concrete, began to be adopted. A demonstrable relationship between the sewer, either ad hoc or planned, and its impact on the development of the city and the health of its citizens, or waterways, must be present when applying Criterion A. For example, sewer segments that were part of rebuilding efforts following the Great Fire of Seattle did not demonstrate a significant association, whereas the Lake Union Sewer Tunnel was considered eligible because it was a wholly new system that was "a better representation of this early period of infrastructure development." For each city, it is likely that site-specific research will need to be undertaken to provide justification.[363]

Criterion B

Criterion B applies to properties that are "associated with the lives of persons significant in our past;" for example, a person's home, business, office, laboratory, or studio that are associated with the person's "productive life." Many brick sewer cities identified in this context were associated with engineers who proposed cohesive systems for cities to implement. However, these engineers frequently did not see the project through to completion and their designs were altered by municipal officials, city engineers, or contractors to suit their budget or for other reasons. To our knowledge, no

[363] Seattle Department of Transportation, *Cultural Resources Technical Report for the First Avenue Sewer Rehabilitation. In Seattle Center City Connector Environmental Assessment, Appendix A-6* (Seattle: Seattle Department of Transportation, 2017), 7-1.

brick sewer system has previously been determined eligible under this criterion. For example, both the Central City Tunnel System in Minneapolis and the First Avenue and First Avenue S sewers in Seattle were specifically determined not eligible under Criterion B because they could not be directly associated with a specific individual's historic contributions. For these reasons, Criterion B is unlikely to apply to brick sewer systems.[364]

Criterion C

Criterion C defines eligible properties as those that "embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic value, or that represent a significant and distinguishable entity whose components may lack individual distinction." Because sewers are not "the expressions of aesthetic ideals or preferences," they do not fulfill the requirement to "possess high artistic value."[365]

Previous studies have reached diametrically different conclusions about whether mid to late nineteenth century brick sewer construction embodies "the distinctive characteristics of a type, period, or method of construction." The Alcantarilla Pluvial was determined significant in the field of engineering because it demonstrated the "gamut of popular construction techniques utilized during the approximately eighty-three-year period of construction, ranging from rubble, to brick, to concrete construction and from

[364] National Park Service, *How to Apply the National Register Criteria for Evaluation, National Register Bulletin 15,* 14-15; Saleh Miller and Nicole Foss, "The Minneapolis Central City Tunnel System Context Report, Minneapolis, Hennepin County, Minnesota," in *Attachment F, Preliminary Design Report, Central City Tunnel System*, Appendix E (Saint Paul: The 106 Group Ltd., 2017), 27; Seattle Department of Transportation, *Cultural Resources Technical Report for the First Avenue Sewer*, 7-2.
[365] National Park Service, *How to Apply the National Register Criteria for Evaluation, National Register Bulletin 15,* 17.

vaults to slabs; all working together to create a functional flood-control channel as a whole." In Keokuk, both the distinctive characteristics of brick, reinforced concrete, segmental block, stone, and stone and brick sewers, and the skilled masonry work required to construct them, represented significant engineering achievements, whereas prefabricated segments, including those constructed of clay, concrete, and VCP, were ineligible for listing because they did not demonstrate design and workmanship skills. The Lamberton Interceptor "represents a significant and distinguishable entity" and was "representative of engineering structures, being well design and constructed of brick, and…reflects an important accomplishment of American historical engineering and industrial contributions to Trenton's 19th Century industrial development."[366]

Likewise, the Lake Union Sewer Tunnel was determined eligible under Criterion C as the first recorded example of a brick-lined sewer in Seattle (prior to the Great Fire, sewers were constructed of wood and ironstone). In contrast, sewer segments in downtown Seattle, while representative of late nineteenth and early twentieth century sewer construction, were not eligible under Criterion C since they "include multiple sections that are characterized by various materials, shapes, and sizes… [and] do not embody distinctive characteristics of a type, period, or method of construction."[367]

While Paterson's brick sewers were determined to be not eligible since "[t]he technology utilized in all of these sewers is representative of the types of sewers being constructed in many other cities during this period of time, and the construction

[366] National Park Service, *How to Apply the National Register Criteria for Evaluation, National Register Bulletin 15,* 17; Santiago and Pumarada, *National Register of Historic Places Nomination: Alcantarilla Pluvial sobre la Quebrada Manzanares*, 8-4; Rogers and Price, *Historic Context for the Keokuk Sewer System*, 75-77; Israel, *Report*, 26.
[367] Seattle Department of Transportation, *Cultural Resources Technical Report for the First Avenue Sewer*, 6-1-6-2, 7-2.

methods of each of these is available today," it was recommended that early sewers be documented before removal to capture technological variation in their construction, since historical records had been destroyed.[368]

In both Cedar Rapids and Keokuk, lateral lines were not eligible for listing because they were made of clay, concrete, or VCP, and did not carry the same significance as the mains and submains, which required more "complex engineering principles of flow and capacity." In New Jersey, as in other states, brick sewers were succeeded by concrete and VCP sewers, which were easily prefabricated and are still in use today. It is unlikely that most of the sewer mains and lateral lines made from these materials and mass-produced in factories would be determined eligible in New Jersey.[369]

Early sewers associated with significant engineers may potentially "represent the work of a master." Many of the engineers who designed and built sewers in New Jersey had studied or trained in other disciplines, ultimately making meaningful contributions to the field of sanitary engineering. Colonel George E. Waring, Jr. (Passaic) and Rudolph Hering (Trenton), probably the most prolific, designed systems and consulted on projects nationwide. Carroll Phillips Bassett (East Orange, Englewood, Orange, Phillipsburg, and Roselle) trained as a civil engineer, and designed and constructed sewage treatment plants, sewerage systems, and water works in Connecticut, Delaware, New York, New Jersey, and Pennsylvania. He was also involved in the design of electric power plants. Alexander Potter (Bridgeton) worked on systems throughout the country

[368] Cotz, *Phase II Historical Research Survey*, 27-28.
[369] Rogers and Price, *Historic Context for the Keokuk Sewer System*, 75; Deiber and Yengling, *Historic Context for the Sanitary Sewer System, of Cedar Rapids*, 44

and returned to New Jersey to consult on a joint sewer that traversed Essex and Union counties. General Egbert Ludovicus Viele (Paterson) was the State Engineer of New Jersey in 1855, an active member of the Quarantine and Sanitary Conventions, and conducted a sanitary and topographical survey of Manhattan in 1865, which is still used for new construction.[370] William Scollay Whitwell (Jersey City) had experience on water systems, which included his time at the Boston Cochihuate Aqueduct, where he was the Chief Engineer of the Eastern Division from 1846 to 1849.[371]

Other men worked primarily within New Jersey, including Robert Cochran Bacot (Hackensack), Ernest Ludolph Meyer (Elizabeth), and Aaron Ward (Camden). Bacot started his career as a cartographer, transitioned to planning street, sewerage, and drinking water systems. He later served as the superintendent of the Jersey City Water Works, designed the street and sewerage system of the Van Vorst section of Jersey City, and was the Secretary and Engineer of the Riparian Commission. Meyer started his career surveying and designing a cemetery in Elizabeth. Aaron Ward was a local contractor and innovator, who held a patent for a brick press.[372]

Previous studies have tended to emphasize engineering and government over the role of the individual. The 2012 Keokuk study did specifically contextualize Waring's role in the design. However, segments of the system were eligible because they were "representatives of the type, period, and method of construction utilized in nineteenth century sewer construction in this city and in the nation," not because they were the

[370] Viele's map can be found at: https://digitalcollections.nypl.org/items/82566ae0-084f-0131-9e8d-58d385a7b928
[371] William Nelson, *Nelson's Biographical Cyclopedia of New Jersey* (New York: Eastern Historical Publishing Society, 1913), 2:724; Bulger et al., *Stage II Cultural Resources Survey, Jersey City Municipal Utilities Authority,* 3-18.
[372] National Park Service, *How to Apply the National Register Criteria for Evaluation, National Register Bulletin 15,* 17.

"work of a master." Waring's proposed design not only incorporated an older, existing system, but it also was modified by city engineers while under construction in response to evolving technologies and information.[373]

Yet, it is possible that future research may identify a system that does reach this standard. Bridges, another important type of infrastructure, are a good point of reference for understanding how "the work of a master" may be identified. The Brooklyn Bridge, a wire rope suspension bridge designed by John A. Roebling and completed by Washington Roebling and Emily Warren Roebling, "stands as the ultimate expression of the art practiced by the Roeblings." Structures can qualify as the "work of a master" even when designs are produced through a collaborative process. The role of the prolific architecture firm McKim, Mead & White in the design of the Arlington Memorial Bridge in Washington, D.C., was included in the statement of significance.[374]

Brick sewers "represent a significant and distinguishable entity whose components may lack individual distinction." The Early Jersey City Brick Sewers were determined eligible under Criterion C "in the area of Engineering for its innovative combination of existing sewer engineering used to address the unique topographical challenges within the original Jersey City." The emphasis on cohesive entities is seen in the reasoning for the Newark Sewer System's eligibility as "the implementation of an integrated sanitation system supplied Newarkers with the amenities and health benefits that residents of other American cities of comparable size and industry had long taken

[373] Rogers and Price, *Historic Context for the Keokuk Sewer System*, 20, 72-77.
[374] S. Sydney Bradford and James B. Armstrong, *National Register of Historic Places Nomination: The Brooklyn Bridge* (Washington, D.C.: Historic American Engineering Record, Department of the Interior, National Park Service, 1975), 8-1-8-2; Betty Bird, *National Register of Historic Places Nomination: Connecticut Avenue Bridge* (Washington, D.C.: Betty Bird Associates, 1991, updated 2003), 8-1.

for granted." Sewer segments in these systems lack individual distinction, unlike the Lamberton Interceptor or Line Ditch.[375]

Brick sewers may be significant at the local, state, or national level under Criterion C. In New Jersey, the Lamberton Interceptor was argued to have national significance as "both a symbol of America's former engineers, engineering, urban life and planning, and a time and place which are irreversible and irretrievable." The Jersey City system is also significant at the national level. Future determinations of eligibility will need to make a strong case for national significance, whereas local and state significance is more easily demonstrated.[376]

Criterion D

Properties are eligible under Criterion D if they "have yielded, or may be likely to yield, information important in prehistory or history." For Criterion D to apply, "the property must have, or have had, information to contribute to our understanding of human history or prehistory," and "the information must be considered important." Criterion D can apply to structures only if they are "the principal source of the important information." Historic documents, including blueprints and as-built plans, can provide abundant information, but are not always available. The brick sewers themselves are the as-built record of construction, but the information obtained by archaeological

[375] National Park Service, *How to Apply the National Register Criteria for Evaluation, National Register Bulletin 15,* 17; Bulger et al., *Stage II Cultural Resources Survey, Jersey City Municipal Utilities Authority,* 5-8; McEachen and Modica, *Cultural Resources Investigation, City of Newark,* 7-3.
[376] Israel, *Report*, 19; Bird, *National Register of Historic Places Nomination: Connecticut Avenue Bridge*, 8-1.

excavation (or monitoring during construction) may not provide significant data not already available.[377]

The Delgany Street Sewer Extension was determined eligible only under Colorado State Criterion E, which mirrors NRHP Criterion D and states that the "[p]roperty contains the possibility of important discoveries related to prehistory or history." The structure is a source of information on some of the first engineered elements of the then newly-established City of Denver, specifically brick sewer construction and design techniques.[378]

The Early Jersey City Brick Sewers were determined eligible under Criterion D. Research has shown that Whitwell's original plan was modified by later engineers. Therefore, the examination of surviving sewer components can yield information on how his 1853 plan was implemented and altered over time. Additionally, construction and design specifications, including but not limited to the brick type, diameter, grade, shape, sub-base footing support, and wall thickness can be better understood through archaeological research.[379]

Historical documents have referenced some unique construction techniques that were proposed, adopted, and abandoned; fieldwork would confirm the existence of these techniques. Data obtained for engineering/evaluation purposes, such as video recording of sewer interiors, and photo documentation of sewer repairs, may provide enough information to exhaust the research potential of a given sewer segment. For this

[377] National Park Service, *How to Apply the National Register Criteria for Evaluation, National Register Bulletin 15,* 21; Cotz, *Phase II Historical Research Survey*, 27.
[378] Mead and Hunt, *Historic Resources Inventory Report: National Western Center Redevelopment* (Mead & Hunt, 2017), 576-577.
[379] Bulger et al., *Stage II Cultural Resources Survey, Jersey City Municipal Utilities Authority,* 5-8.

criterion to fit, the information should not be available in any way besides examining the sewers themselves, because records are incomplete or non-existent, are inaccurate, or do not contain necessary information. Each historic sewer system must be evaluated individually.[380]

Integrity

A historic resource's integrity is composed of seven aspects: location, design, setting, materials, workmanship, feeling, and association. Historic properties vary in which aspects are most important to their integrity. Both the criteria under which a resource is eligible as well as the individual characteristics of the structure affect which aspects are most important. For sewers eligible under Criterion A, the most significant aspects of integrity are association, design, location, and materials. For properties eligible under Criterion C, it is often some combination of location, design, materials, workmanship, and/or association.[381]

Location

Location is defined as "the place where the historic property was constructed or the place where the historic event occurred." The original linear sewer alignment is the "historic path." Locational integrity is diminished if segments on the historic path are altered or destroyed.[382]

[380] Waring, *Report on the Social Statistics of Cities*, 723; Shriner, *Paterson,* 310; New York, Metropolitan Sewerage Commission, *Sewerage and Sewage Disposal*, 342.
[381] National Park Service, *How to Apply the National Register Criteria for Evaluation, National Register Bulletin 15,* 44; Deiber and Yengling, *Historic Context for the Sanitary Sewer System, of Cedar Rapids,* 44; Miller and Foss, "The Minneapolis Central City Tunnel System Context Report," 27.
[382] National Park Service, *How to Apply the National Register Criteria for Evaluation, National Register Bulletin 15,* 44.

Design

Design is defined as "the combination of elements that create the form, plan, space, structure, and style of a property," which is reflected in the sewers themselves. If segments are changed through repair or expansion, design integrity is impacted.[383]

Setting

Setting is "the physical environment of a historic property" and "refers to the *character* of the place in which the property played its historic role." Because sewers are a largely underground resource, setting is not a vital aspect of integrity. Like the integrity of location, sewers retain integrity of setting as long as they are not moved or destroyed.[384]

Materials

Materials are defined as "the physical elements that were combined or deposited during a particular period of time and in a particular pattern or configuration to form a historic property." Retaining the original materials used in construction ensures the sewer retains integrity, as it is reflective of its early construction, design, and engineering techniques. Repair and rehabilitation, by introducing new materials (such as replacing brick with concrete), will generally reduce material integrity. However, modifications made within the period of significance, even if they include the use of different materials, may not affect integrity.[385]

---

[383] National Park Service, *How to Apply the National Register Criteria for Evaluation, National Register Bulletin 15,* 44.
[384] Ibid., 45.
[385] National Park Service, *How to Apply the National Register Criteria for Evaluation, National Register Bulletin 15,* 45; Mead and Hunt, *Historic Resources Inventory Report: National Western Center Redevelopment*, 577.

Workmanship

Workmanship is "the physical evidence of the crafts of a particular culture or people during any given period in history or prehistory." For brick sewers, workmanship is reflected in the skilled labor that handcrafted the sewer on site, rather than assembling and sealing a prefabricated pipe. Larger pipe sizes, required in the mains and interceptors, were commonly made of brick, whereas smaller pipes, often laterals, were likely to be prefabricated. Later repairs or replacements may not have the same level of workmanship as the original segment.[386]

Feeling

Feeling, defined as "a property's expression of the aesthetic or historic sense of a particular period of time," is unlikely to be an important aspect of integrity for sewers as they are not meant to be seen. Note, however, that feeling may be an important characteristic for above-ground sanitary infrastructure.[387]

Association

Association is defined as "the direct link between an important historic event or person and a historic property. A property retains association if it is the place where the event or activity occurred and is sufficiently intact to convey that relationship to an observer." The brick sewers are associated with mid to late nineteenth century public health initiatives. Similar to location, integrity may be diminished if segments on the historic path are altered or destroyed.[388]

---

[386] National Park Service, *How to Apply the National Register Criteria for Evaluation, National Register Bulletin 15,* 45.
[387] Ibid., 45.
[388] Ibid., 45.

Assessing Integrity

Integrity is defined by a property's significance; does the property retain the elements that made it significant? First, the "essential physical features that must be present" must be established. For brick sewers, these can include the historic path, the original materials, or its function within a larger system. How is integrity affected when you lose segments along the historic path, for example? The National Register Bulletin also states that essential features must also be visible enough to convey significance. However, sewers are a unique resource in that they were never meant to be viewed. We have argued that, for instance, as relining a failing sewer allows it to continue operating in its original place and with its original materials, this rehabilitation technique does not affect the overall integrity of a brick sewer.[389]

Integrity is further assessed by comparing the sewer in question with its peers, either within its own system or with sewers in other cities. In this instance, engineering ingenuity can be a metric for workmanship since a unique sewer may be one with exceptional workmanship. In order to properly assess the integrity of a sewer or sewer system, it must first be determined which aspects of integrity are most relevant and whether they are present. However, the rarity of a sewer's workmanship or engineering may supersede reduced integrity in determining its significance.

The Historic Path

The historic path is the original linear alignment of the sewers as constructed during the period of significance. For example, the significant historic path of the Jersey City system includes not only sewers constructed as part of Whitwell's original plan

[389] National Park Service, *How to Apply the National Register Criteria for Evaluation, National Register Bulletin 15,* 45.

between 1853 to 1869, but also older sewers built before 1853 that were incorporated into his design, and other brick sewers constructed outside of Whitwell's plan, but still within the period of significance.[390]

With regard to integrity, it is, as Deiber and Yengling posit, the "sufficiently intact" phrasing of the definition of association that is most relevant to the evaluation of the historic path, wherein a sewer retains the "materials, and design, to convey such association with the time period in which they were constructed." They argue that at least half of the original sewer segment should remain intact as a minimum requirement to represent the historic path. The complete lengths of trunk sewer lines often represented the extent of the development of the city within the period of significance. Therefore, if an egg-shaped brick sewer segment that was four blocks long when first constructed was later replaced outside the period of significance for a length of three blocks with circular concrete sewers, the integrity of the historic path has been destroyed and that sewer segment is not eligible. On the other hand, in New Orleans, researchers argued that locational integrity of the drainage canals overrode any modifications that were made as a response to the growing city. By maintaining the original locations, the canals contextualized the other components of the system. Improvements, redesigns, and repairs were a functional necessity and appropriate response to the changing demands of the city of New Orleans since construction of the system began in 1897.[391]

[390] Bulger et al., *Stage II Cultural Resources Survey, Jersey City Municipal Utilities Authority*, 5-7-5-8.
[391] Deiber and Yengling, *Historic Context for the Sanitary Sewer System, of Cedar Rapids*, 43-44; Maygarden et al., "National Register Evaluation of New Orleans Drainage System," 90.

Material reconstruction of segments on the historic path, even if they are not completely replaced, may reduce integrity. For the city of Newark, sewers reconstructed using brick retained eligibility, but later reconstructions that used concrete or other contemporary materials were excluded. In contrast, stone sewer mains in Keokuk constructed during the 1850s were rehabilitated during the late 1890s and early 1900s by replacing the stone inverts with concrete floors. These repairs did not reduce integrity as the modifications were part of Waring's original sewer plan and were made during the period of significance.[392]

Rehabilitation and Relining

Rehabilitation is "the act or process of making possible a compatible use for a property through repair, alterations, and additions while preserving those portions or features which convey its historical, cultural, or architectural values." Previous studies have been divided on how rehabilitation interventions like cured-in-place pipe (CIPP), gunite, and shotcrete affect integrity. CIPP lining is a resin that is applied to the interior of a pipe, which has been cleaned and the gaps were filled with grout to create a smooth interior surface. Once the CIPP lining has cured, the lining is tightly fitted to the interior and is a self-supporting structure. By comparison, to apply a gunite/shotcrete lining, a steel mesh or steel bar structure must be installed within the sewer, after which concrete is sprayed on to it. Together, the two provide structural support to the sewer. Though these rehabilitation methods provide structural soundness to the pipe by reinforcing the interior, the degree to which they affect the integrity of the pipe has been questioned.

[392] Mead and Hunt, *Historic Resources Inventory Report: National Western Center Redevelopment*, 577; McEachen and Modica, *Cultural Resources Investigation, City of Newark,* Appendix C; Rogers and Price, *Historic Context for the Keokuk Sewer System*, 77.

The *Standards* recommend identifying, preserving, and retaining the structural systems and the character defining features of historic structures. For load-bearing masonry walls, the *Standards* recommended augmenting the structural system, rather than replacing it. We posit that this argument can be extended to brick sewers.[393]

It is generally accepted that sewers that are severely deteriorated and are beyond repair lack integrity and need to be replaced; however, extensively deteriorated sewers can still be repaired through rehabilitation interventions while retaining integrity. CIPP lining has previously been used in NRHP-eligible sewer systems in Jersey City and Newark; cultural resource surveys for both interventions produced some debate about the reversibility of CIPP. During the late twentieth century, when Newark's sewers were nearly 150 years old, they were "intact and in an excellent state of preservation" and the workmanship was commended; however, to avoid failure, they were considered for rehabilitation. Because the selected intervention had to fit multiple parameters, including not damaging the interior of the sewer, CIPP was selected as the appropriate intervention. The CIPP liner adhered to the sewer wall but could be removed without damaging the interior surface. When CIPP was considered for rehabilitation in the Early Jersey City Brick Sewers, however, it was reported that the liner permanently adheres to the sewer wall and cannot be removed without damaging the sewer wall. In both cities, for sewers that were not suited to CIPP lining, gunite/shotcrete were the alternative considered. Despite its potential irreversibility, CIPP was the recommended

[393] Anne E. Grimmer, *The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring, & Reconstructing Historic Buildings* (Washington, D.C.: U.S. Department of the Interior, National Park Service, Technical Preservation Services, 2017), 75, 121; Bulger et al., *Stage II Cultural Resources Survey, Jersey City Municipal Utilities Authority,* 5-20; McEachen et al., *Cultural Resources Investigation…Appendix A to Volume 3*, 9-3.

rehabilitation method because it minimized the impact to integrity, including design, location, materials, and setting, while being rehabilitative.[394]

Concrete lining has been used in a sewer that is contributing to a NRHP historic district. In McGregor, Iowa, the Main Line Storm Sewer, a stone-lined sewer, was lined with concrete as part of stabilization efforts. The irreversible concrete lining did not reduce the significance of the pipe and its ability to contribute to the "historic appearance and overall integrity and significance of the historic district." Seattle's sewers that were already in poor condition or were structurally deficient were determined to lack integrity, thus relining and repairs had no impact on integrity.[395]

Regardless of the reversibility of the process, rehabilitation ensures that the sewers are able to retain integrity of the design, location, materials, setting, and workmanship. Rehabilitation is key, as the Secretary of the Interior's Standards for Rehabilitation encourages continued use of the property while protecting and maintaining the character defining features. Any intervention that rehabilitates the sewer rather than replaces it with a more modern material takes precedence because it ensures that some aspects of integrity are still retained. Additionally, sewers that demonstrate a high level of workmanship only benefit from rehabilitation.

---

394 McEachen et al., *Cultural Resources Investigation…Appendix A to Volume 3,* 9-2; Brett Hansen, "Newark's Brick Sewers Reinforced with Cured-in-Place Pipe," *Civil Engineering News* (June 2005): 27; McEachen and Modica, *Cultural Resources Investigation, City of Newark*, 7-4; Bulger et al., *Stage II Cultural Resources Survey, Jersey City Municipal Utilities Authority,* 5-20.
395 Leah D. Rogers and Lori Vermaas, *National Register of Historic Places Nomination: McGregor Commercial Historic District* (Iowa City, IA: Tallgrass Historian L.C., 2002), 7-24; Seattle Department of Transportation, *Cultural Resources Technical Report for the First Avenue Sewer*, 7-2.

Engineering Ingenuity

Engineering ingenuity in this context is the ability to successfully apply engineering knowledge and creativity to solve local or novel problems with sewer design in a way that addresses public health needs.

In Cedar Rapids, it was determined that the design and construction, regardless of shape, were representative of the "first significant attempt at a permanent sanitary sewer system from 1887 to 1892, which was crucial to the early development of the city." The design required ingenuity as there was no existing sewer system to build off. This evaluation excludes prior ineffective or temporary interventions to improve sanitary conditions, an argument which is potentially applicable to other systems.[396]

Engineering ingenuity extends to individual sections of a larger system. Sewer systems are multi-level; their design encompasses interceptors, laterals, mains, and trunk sewer lines, whose scale often correlates to the type of material used in construction and the corresponding degree of workmanship. Deiber and Yengling advanced the importance of the trunk and interceptor sewer lines since smaller, lateral lines did not require the same complex engineering. More complex engineering also required higher-level funding mechanisms; for example, trunk lines in Cedar Rapids were constructed following a municipal vote, whereas lateral lines were constructed at the expense of the property owners who directly benefited.[397]

This was echoed in Newark, whose sewers were both representative of "localized engineering ingenuity" and "a distinctive style of brick sewers installed in the northeast from the mid-to-late 19th century and early 20th century." Other intact brick sewers, like

[396] Deiber and Yengling, *Historic Context for the Sanitary Sewer System, of Cedar Rapids,* 43-44.
[397] Ibid., 43-44.

the Kerrigan Avenue brick sewer, have been determined to be "technological and historically significant resource in the context of Union City's…first-generation brick sewer system." In some unique cases, like Camden's Line Ditch sewer, brick was used alongside other materials to construct a sewer that would overcome the challenge of building in quicksand.[398]

As seen in many of the New Jersey brick sewer cities, localized design decisions were reflective of the evolving responses to developing issues and new sewer technologies and construction methodologies. Pipe sizes were frequently designed to be larger than the needs of the city at the time of design in anticipation of population growth. In some cities, like Paterson, there was often an incongruity between what was designed and what was built, with local city engineers and politically influential people driving the decision making. In Des Moines, another city with differences between the planned and built systems, it was determined that "the sewers themselves constitute the only record that fully documents the system as it was actually built." The brick sewers of New Jersey are representative of the nineteenth century construction techniques modified to meet the ground conditions specific to the city.[399]

Rarity

Over time, many brick sewer segments have been replaced. Brick sewers are becoming increasingly rare due to this. Rarity and integrity must both be assessed when evaluating a resource for eligibility. Studies of historic transportation infrastructure have established that, for example, bridges that are "unique, rare, or infrequent

[398] McEachen et al., *Cultural Resources Investigation…Appendix A to Volume 3*, 9-2; McEachen and Modica, *Cultural Resources Investigation, City of Newark*, 7-2-7-3; Modica and Walker, *Stage IA Cultural Resources Survey, North Hudson Sewerage Authority,* 5-1.
[399] Rogers, *Historic Context for the Des Moines Sewer System*, 90.

survivors of a type of construction detail" can still have engineering significance, even if they have reduced integrity. The same argument can be made for sanitary infrastructure.[400]

Brick sewers have been replaced due to engineering failure or insufficient capacity, reducing the number of surviving examples of nineteenth century infrastructure. Another reason that a historic resource might be rare is that few like it were built. Some bridges with "unusual construction details" are significant because they are central to a period of experimentation. The presence of unusual construction details in a sewer may be due to similar experimentation before construction became standardized. Such a sewer may be a rare survivor because that technique was not widely adopted. Losing one or two examples of the rare survivor would result in loss of representation. In these situations, a resource, if determined significant under one of the four criteria, may retain eligibility even integrity is negatively impacted. However, to determine if a structure is a rare survivor, it is necessary to have some knowledge of how common that type of construction was in the past. Historical and archaeological research can provide that context.[401]

[400] A.G. Lichtenstein & Associates, Inc., *The New Jersey Historic Bridge Survey*, 21.
[401] Ibid., 21.

9. Summary and Conclusion

Even though we know that sewer construction is vital to public health, getting here has not been a linear process. Municipal officials had to consider the financial hardships and the public perception of sewers, which was continually revised to reflect the evolving understanding of disease. The early, experimental, era of sewer construction from the mid to late nineteenth century was demonstrative of a broader movement to improve public health; it shifted the tide of public opinion towards increased sewer construction, emphasized public health as encompassing both people and water, and provided an opportunity for early experimentation which led to standards of construction.

Early Drainage (and Sewers)

Early drainage interventions to reduce flooding from rainstorms were precursors to the modern sewer. As privies and cesspools became inadequate, sewers took on the additional role of removing human waste. Even as germ theory began to supplant miasma theory, sewers were discussed in the context of miasmas, an unseen but mephitic odor, which was believed to cause disease and recurring epidemics. Ultimately, the evidence showed that areas with sewers had lower rates of disease because sewers generally had a positive effect on health.

Early sewer construction was also marked by experimentation to find ideal shapes, configurations, slopes, etc. Excluding standardized materials, like VCP and reinforced concrete pipe, which were often prefabricated off-site, constructing a brick sewer in ground custom to the conditions of the site was an innovative process. Primary

documents often referenced unique approaches to design, reevaluations of accepted construction techniques, and modifications to planned sewerage systems.[402]

Local Perspectives on Public Health

One consensus remained: the efficacy of sewers at improving public health within municipalities was irrefragable. "Disposal by dilution," however, was misguided. Water from public waterways, often receptacles of waste from outfalls, and wells or aquifers, contaminated by sanitary waste that leaked from privies or cesspits, gradually became unusable so public health was expanded to encompass water health. This was reflected in perspectives on sewer system type in the late nineteenth and early twentieth centuries; sewerage commissions and sanitary engineers encouraged municipalities to transition away from combined systems to separate systems, citing concerns for the health of water bodies and people.[403]

Responses to Public Health

The earliest codification of funding mechanisms for sewer construction was included as a provision in city charters. Residents needed to petition the Common Council to construct sewers on public land and demonstrate their ability to be able to afford the repayment of construction costs, as they would be billed by the municipality. And construction costs were high. Excavation was performed manually. Brick was an expensive material to produce and required skilled masons for construction. Often this meant that wealthy neighborhoods who could lobby for construction and repay the municipality were the only ones who could benefit. To build municipality-wide systems

[402] Hering, "Sewerage Systems," 373.
[403] Southard, "Essex Water Supply," 194.

under this provision, cities would have to tax residents, which they were reluctant to do. To attract manufacturers and laborers, Common Councils had to be able to advertise low municipal taxes and exiguous public debt. Funding public health responses without a cohesive, state-wide, governmental mechanism often meant that early drainage and sewerage pipes were spread out across a city.[404]

Though the acts of incorporation had proved sufficient for sewer construction for many decades, a likely amalgamation of factors that prompted the New Jersey State Legislature to pass the 1882 Sewer Act includes court cases by private property owners against municipalities and municipalities nearing, or declaring, bankruptcy following the Panic of 1873. It appears that the passage of the 1882 Sewer Act prompted construction state-wide and standardized a financial mechanism that permitted municipalities to use taxes to fund sewer construction. Unfortunately, this did not guarantee that the entire city was sewered nor did it guarantee that everyone was connected to the system, which meant that development and health proceeded differently in each municipality.[405]

Evaluation of New Jersey's Brick Sewers

Sewer infrastructure is historically significant for contributions to community planning and development, and for contributions to public health. Some brick sewer segments in Elizabeth, Jersey City, Newark, and Trenton have already been determined eligible for listing on the NRHP under Criteria A, C, and D. In order to evaluate the

[404] Modica and Walker, *Stage IA Cultural Resources Survey, North Hudson Sewerage Authority,* 4-7.
[405] Galishoff, *Newark*, 129-130; Hugh S. Cumming, *Investigation of the Pollution of Certain Tidal Waters of New Jersey, New York, and Delaware, with Special Reference to Bathing Beaches and Shellfish-Bearing Areas. Public Health Bulletin No. 86, August 1917* (Washington: Government Printing Office, 1917), 76; Dilworth, *The Urban Origins of Suburban Autonomy*, 136.

state's other nineteenth century brick sewers, they too must be contextualized within an area of significance, meet at least one of four National Register Criteria, and demonstrate integrity.[406]

Prior determinations of eligibility concur that some combination of Criteria A, C, and D apply. No demonstrable research has emerged connecting segments of brick sewers to specific, notable, individuals, and so Criterion B is not relevant. As defined under Criterion A, though sewers contribute to the broad patterns of history and encourage development, further research is needed to provide justification to the relationship between the sewer, either ad hoc or planned, and its impact on the development of the city and the health of its citizens or waterways. Criterion C is most relevant as nineteenth century brick sewers "embody the distinctive characteristics of a type, period, or method of construction." Brick sewers are unlikely to be significant on their own, but their material and craftmanship combined with other criteria or other aspects of Criterion C may allow them to achieve significance. Sewers can meet the requirement to "represent the work of a master;" however, because contractors and city engineers modified systems by the time they were constructed, further research is needed to establish the relationship between a system and its engineer. The requirement to "possess high artistic value" does not apply to brick sewers. Since sewers are composed of segments that make up a system, brick sewers can "represent a significant and distinguishable entity whose components may lack individual distinction." A period of significance for these segments will need to be established before it can be

[406] National Park Service, *How to Apply the National Register Criteria for Evaluation, National Register Bulletin 15*, 7.

determined if the segments, cumulatively, have historical significance and sufficiently represent "a significant and distinguishable entity."[407]

Few sewers have been determined eligible to "have yielded, or … likely to yield, information important in prehistory or history." For Criterion D to apply, "the property must have, or have had, information to contribute to our understanding of human history or prehistory," "the information must be considered important," and the structures "themselves must be, or must have been, the principal source of the important information." Many systems and facilities are well-documented and can be considered eligible under Criterion D, for the information they yield in their areas of significance.[408]

Next, the sewers must be considered within an area of significance as well as level of significance, either local, state, or federal. Sanitary infrastructure is often evaluated within community planning and development, engineering, health/medicine, and social history contexts at both the local and state level. Neither Galishoff nor the evaluators of Seattle's First Avenue sewers considered the significance of early sewers on legislation. The financial responsibility was initially on the homeowners and transitioned to the municipality, and it is likely that local brick sewer construction, which was at the center of municipal incorporation charters, cases filed in the New Jersey Court of Chancery, and other legalese provided precedence for the passage of the 1882 Sewer Act, and its later amendments.[409]

---

[407] National Park Service, *How to Apply the National Register Criteria for Evaluation, National Register Bulletin 15,* 17.
[408] Ibid., 21.
[409] National Park Service, *How to Apply the National Register Criteria for Evaluation, National Register Bulletin 15,* 7; Galishoff, *Newark,* 8-9.

Finally, there are seven aspects of integrity that must be considered: location, design, setting, materials, workmanship, feeling, and association. Because the brick sewers are so varied, their integrity will also vary. Additionally, engineering significance, rareness or uniqueness of design can supersede reduced integrity.[410]

Locational integrity is not only about the immobility of the sewers, but also their placement within the system. Prior sewer evaluations have emphasized the built segments rather than the whole system, particularly in instances when the system was not planned. It will be important to determine the locations of the nineteenth century brick sewers within the cities. In instances where a segment was eventually replaced, Deiber and Yengling's proposition that retention of at least 50% of the original sewer line was sufficiently representative of the historic sewer path can be a guideline.[411]

Design integrity is a combination of what is planned and what is built. Half of the brick sewer cities hired designers to report on a sewerage system; however, at the behest of city engineers and politicians, designs were modified, pipes were scaled down, and other segments or major components were not constructed. Material integrity is closely related to design integrity, since sanitary engineers made conscious decisions about material choice that affected the overall structure that could be built. Brick sewers quickly replaced wood sewers, which were ineffective and unenduring. Construction required master masons, representative of the integrity of workmanship since the pipes were manually constructed on site unlike prefabricated concrete or VCP. The requisite expense, labor, materials, and time associated with brick sewers led to the eventual

[410] A.G. Lichtenstein & Associates, Inc., *The New Jersey Historic Bridge Survey*, 21.
[411] Deiber and Yengling, *Historic Context for the Sanitary Sewer System, of Cedar Rapids*, 43-44.

success of concrete and VCP sewers. Additionally, larger pipes, including the sewer mains and outfalls, were most likely to be made of brick, whereas laterals were often made of other materials.[412]

As an underground, unseen resource, setting and feeling cannot be considered significant aspects of integrity. Rather it is the sewers' association with public health movements that is significant. Previous determinations of eligibility have concluded that all sewers are associated with public health, but that this does not guarantee that all sewers are eligible. Variation in a city's financial resources, location, and size made construction city-specific; however, sewers were the solution to public health and sanitary concerns everywhere.[413]

Considerations for the preservation of sewers are pertinent. The Secretary of the Interior defines the act of rehabilitation as "the act or process of making possible a compatible use for a property through repair, alterations, and additions while preserving those portions or features which convey its historical, cultural, or architectural values." For historically significant bridges in New Jersey, higher degrees of alteration do not detract from significance, particularly in bridges that are "very old or very rare." Some sewer rehabilitation techniques, including CIPP and shotcrete, ensure the continued use of the sewer while retaining aspects of integrity. The Secretary of the Interior's Standards for Rehabilitation encourages continued use of the property while protecting and maintaining the character defining features.[414]

---

[412] Galishoff, *Newark*, 94.
[413] Seattle Department of Transportation, *Cultural Resources Technical Report for the First Avenue Sewer*; Galishoff, *Newark*, 8-9.
[414] Grimmer, *The Secretary of the Interior's Standards*, 75; A.G. Lichtenstein & Associates, Inc., *The New Jersey Historic Bridge Survey*, 22.

Further Research

This research is already being used, and will continue to be used, by the Cultural Resources Team of the MF&CE as we evaluate projects with historic resources. We hope that other interested parties also find it to be a valuable planning and preservation tool.

Research into the nineteenth century brick sewers of New Jersey has raised additional questions. First, unique techniques were employed across the state's municipalities over the course of sewer construction, which impacted longevity, ground water quality, etc. Because the sewer is the historical record, without documentation of physical evidence, information will be lost. Further research is needed to understand the eventual impact of historic methods on twentieth century wastewater infrastructure construction and if there is any the correlation between early techniques and long-term survivability of sewers.

Second, both the nineteenth century sewerage reports and the contemporary sewer studies have considered the impacts of different types of waste, such as factory wastes, street wash and other non-point source pollution, and oils and grease, on sewer longevity. Further research specifically into New Jersey's sewers and the various conditions that have led to their failure or longevity may provide a historical perspective on sewer durability.

Third, it is clear that financing mechanisms, legislation, and sewer construction had an impact on each other and on New Jersey's public health and sanitary history. From the 1882 Sewer Act that first addressed the financial impact and needs of water sanitation, to the Bipartisan Infrastructure Law of 2023, innovative financing has always been at the heart of the movement to improve water infrastructure. Though we

undertook an extensive (but not exhaustive) survey of this background, would a more comprehensive overview of legislation provide further insight into New Jersey's public health and sanitary history? These questions are outside the scope of our work but, if answered, can bring further nuance and a greater understanding of sewer construction to better contextualize the nineteenth century.

Finally, the universe of wastewater resources in New Jersey that remain to be evaluated is hardly exhausted. Since sanitary infrastructure continued with the construction of treatment plants, buildings associated with those facilities should be assessed. Many have already been determined eligible for or are already listed on the NRHP. The Federal Water Pollution Act of 1942 was amended in 1972 and has since become known as the Clean Water Act (CWA) of 1972. These amendments provided for funding of sewerage facilities under the Construction Grants program, replaced in 1987 by the State Revolving Fund program. The CWA was enormously significant as the start of a national movement to increase public awareness and clean up water pollution, and it just recently turned 50 years old. The connection to the CWA may in itself impart significance to water infrastructure buildings, and this is an area of research with great potential.

Conclusion

Sanitary infrastructure is all around us: in the sewers below our feet, the pump stations we do not even recognize as pump stations (nevertheless, we drive past these innocuous structures on the way home), and the occasional whiff of a functioning sewage treatment plant along the highway. This infrastructure, generally unappreciated unless something goes wrong, has been recognized as historically significant for its

contributions to community planning and development, and for contributions to public health. Our research has demonstrated that its significance lies in the details that led to the development of wastewater infrastructure in each individual town and lays a foundation for assessing the earliest brick sewers and placing them in historical context in New Jersey. There is more to water infrastructure, however, than just brick sewers. Wastewater treatment systems undergo constant change and improvement to meet public health requirements and increasingly stringent laws, mostly while remaining in continuous service performing their original functions. As we continue to provide financial assistance to wastewater systems throughout New Jersey, we will continue to evaluate each project for its potential to affect historic infrastructure and expand the contextual research so that we may truly understand the role these facilities have played in our lives, past and present. In the nineteenth century, municipalities balanced development and public health. Today, we strike a balance between preservation and public health.

Bibliography

A.G. Lichtenstein & Associates, Inc. *The New Jersey Historic Bridge Survey*. 1994. Prepared for the New Jersey Department of Transportation, Bureau of Environmental Analysis and the Federal Highway Administration, New Jersey Division. https://www.state.nj.us/transportation/works/environment/pdf/Survey_Doc.pdf (accessed July 21, 2023)

Abellán, Javier. "Water supply and sanitation services in modern Europe: developments in 19th-20th centuries." *XII International Congress of the Spanish Association of Economic History – University of Salamanca*. Salamanca: Universidad de Salamanca, 2017.

Abplanalp, Kathleen, and Megan E. Springate. *Stage 1A Cultural Resources Survey, North Hudson Sewerage Authority, Collections System, Combined Sewer Rehabilitation, Wood Sewers, City of Hoboken, Hudson County, New Jersey*. Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2006. Cultural Resources Survey, Prepared for CH2M Hill. Copies available from the New Jersey Historic Preservation Office, Trenton.

Affleck, Richard, George Cress, Ingrid Wuebber, Rebecca White, Kimberley Morrell, and Thomas Kutys. *"A Bright Pattern of Domestic Virtue and Economy," Phase II/Data-Recovery Archaeological Excavations of the Smith-Maskell Site Cooper Street Development, Camden, New Jersey*. Burlington, New Jersey: URS Corporation, 2012. Cultural Resources Survey, Prepared for Camden County Improvement Authority and Michaels Development Company. Copies available from the New Jersey Historic Preservation Office, Trenton.

Ana, Eliseo, Willy Bauwens, Mieke Pessemier, Chris Thoeye, S. Smolders, I. Boonen, and Greet De Gueldre. "Investigating the effects of specific sewer attributes on sewer ageing - a Belgian case study." *11th International Conference on Urban Drainage* (2008): 1-10.

Anderson, David C. *Intensive-Level Survey and Architectural Evaluation, Methodist Hollow Storm Sewer, Site #22-00676, Historical Architectural Database #22-003*. Waukon, Iowa: 1998. Intensive-Level Survey and Architectural Evaluation, Submitted to the City of McGregor, Clayton County, Iowa. Copies available from the State Historical Society of Iowa.

Baldwin, W. H. "A General Consideration of the Sewerage Problem in East Orange, Embodying the Report of Mr. J.J. Croes, C.E." In *The Sewerage of East Orange, N.J.*, 1 – 12. https://hdl.handle.net/2027/uiug.30112069024054 (accessed July 21, 2023)

Bassett, Carroll Phillips. “The East Orange Sewage Disposal Works as Compared with Other Methods. Abstract of Paper read before New Jersey Sanitary Association, Trenton, November 22, 1889.” In *Thirteenth Annual Report of the Board of Health of the State of New Jersey, and Report of the Bureau of Vital Statistics, 1889*, 73 - 82. Camden, N.J.: F.F. Patterson, Printer, 1890.

Bassett, Carroll Phillips. “Inland Sewage Disposal, With Special Reference to the East Orange, N.J. Works.” *Transactions of the American Society of Civil Engineers* 25 (August 1891): 125 – 160.

Bassett & Nute, and Rudolph Hering. *Report with Plans and Estimates for the Sewerage and Drainage of Orange, N.J.* Orange, N.J.: Press of the Orange Journal, 1885. https://rucore.libraries.rutgers.edu/rutgers-lib/67254/PDF/1/play/ (accessed July 21, 2023)

Benedict, William H. *New Brunswick in History*. New Brunswick, N.J.: Published by the author, 1925.

Bird, Betty. *National Register of Historic Places Nomination: Connecticut Avenue Bridge*. Washington, D.C.: Betty Bird Associates, 1991, updated 2003.

Birkner, Michael. “New Jersey in the Jacksonian Era, 1820-1850.” In *New Jersey: A History of the Garden State*, edited by Maxine N. Lurie and Richard Veit, 115-144. New Brunswick: Rutgers University Press, 2012.

Blackwell, Jon. “Trenton.” In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 813-814. New Brunswick: Rutgers University Press, 2005.

Blake, Nelson Manfred. *Water for the Cities: A History of the Urban Water Supply Problem in the United States*. Syracuse: Syracuse University Press, 1956. https://hdl.handle.net/2027/mdp.39015031951216 (accessed July 21, 2023)

Blasland, Bouck & Lee, Inc., and Tams Consultants, Inc. *Environmental Assessment Statement, Tallman Island TI-2/TI-3 Water Pollution Control Plant Plant Upgrade*. New York City: New York City Department of Environmental Protection, 2006. https://www1.nyc.gov/assets/dep/downloads/pdf/environmental-reviews/tallman-island-water-pollution-control-plant-upgrade-program/attachment1.pdf (accessed August 21, 2023)

Boyer, Charles S. *Annals of Camden No. 2, The Public Utilities in Camden, New Jersey*. Privately printed, 1921.

Bradford, S. Sydney, and James B. Armstrong. *National Register of Historic Places Nomination: The Brooklyn Bridge*. Washington, D.C.: Historic American Engineering Record, Department of the Interior, National Park Service, 1975.

Bridenbaugh, Carl. *Cities in Revolt, Urban Life in America, 1743-1776*. New York: Alfred A. Knopf, 1955.

—. *Cities in the Wilderness, The First Century of Urban Life in America 1625 – 1742*. 2nd ed. New York: Alfred A. Knopf, 1955.

"Bridgeton, N.J." *The Engineering Record* 24, no. 7 (1891): 113.

Brown, William M., and Francis Bazley Lee. *Biographical, Genealogical, and Descriptive History of the State of New Jersey*. New Jersey Historical Publishing Company, 1900. https://hdl.handle.net/2027/yale.39002004700150 (accessed July 21, 2023)

Bulger, Teresa D., Philip A. Hayden, Michael J. Gall, and Lauren Lembo. *Stage II Cultural Resources Survey, Jersey City Municipal Utilities Authority, Sewer Phases 1-2 Sewer Rehabilitation, City of Jersey City, Hudson County, New Jersey*. Cranbury: RGA, Inc., 2019. Stage II Cultural Resources Survey, Prepared for Mott MacDonald. Copies available from the New Jersey Historic Preservation Office, Trenton.

Burian, Steven J., Stephan J. Nix, Robert E. Pitt, and Rocky S. Durrans. "Urban Wastewater Management in the United States: Past, Present, and Future." *Journal of Urban Technology* 7, no. 3 (2000): 33-62.

Buttolph, H.A., and Jasper S. Scudder. *Annual Report of the Officers of the New Jersey State Lunatic Asylum, at Trenton, for the year 1848*. Trenton: Printed by Phillips & Boswell, 1849.

Byrne, Austin Thomas. *Inspection of the Materials and Workmanship Employed in Construction. A Reference Book for the Use of Inspectors, Superintendents, and Others Engaged in the Construction of Public and Private Works*. New York: John Wiley & Sons, 1898.

Bzdak, Meredith A., Jean Howson, and Richard L. Porter. *Archaeological Assessment and Intensive Level Historic Architectural Survey: Doremus Avenue Reconstruction Project*. Trenton: RBA Group, 1996. Prepared for Parsons Brinkerhoff. Copies available from the New Jersey Historic Preservation Office, Trenton.

Camden County Municipal Utilities Authority. Upgrades to Camden City's Combined Sewer Overflow System Sewer Photos, Project No. 340640-22. 2018.

Cammarota, Ann Marie T. C*hanging Pattern: The Suburbanization of Southern New Jersey Adjacent to the City of Philadelphia*. Philadelphia: Temple University, 1996.

Campbell, Daniel R. “Harrison.” In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 350-351. New Brunswick: Rutgers University Press, 2005.

—. “Kearny.” In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 437. New Brunswick: Rutgers University Press, 2005.

—. “Union City.” In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 823. New Brunswick: Rutgers University Press, 2005.

—. “Weehawken.” In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 858-859. New Brunswick: Rutgers University Press, 2005.

Carlisle, Robert D.B. *Water Ways: A History of the Elizabethtown Water Company*. Elizabeth: Elizabethtown Water Company, 1982.

Cassell’s Reinforced Concrete: A Complete Treatise on the Practice and Theory of Modern Construction in Concrete-Steel. Edited by Bernard E. Jones and Albert Lakeman. London, New York, Toronto and Melbourne: Cassell and Company, Limited, 1913.

Center for Applied Earth Science and Engineering Research. *How Memphis Found its Water*. Memphis: University of Memphis, 2021. https://storymaps.arcgis.com/stories/c123a2dbd7ff440d8832068c90796202 (accessed July 21, 2023)

Chapin, Charles V. *The Evolution of Preventive Medicine*. Chicago: American Medical Association, 1921. https://hdl.handle.net/2027/osu.32435002498210 (accessed July 21, 2023)

—. *Municipal Sanitation in the United States*. Providence, R.I.: The Providence Press: Snow & Farnham, 1901.

Charter of the City of Perth Amboy, in the County of Middlesex and State of New Jersey, as Revised by an Act of the Legislature, Approved March 17, 1870, and Amended by a Supplement, Approved April 5, 1871. Perth Amboy, N.J.: Perth Amboy Publishing Company Print, 1905. https://hdl.handle.net/2027/njp.32101067713543 (accessed July 21, 2023)

Chesbrough, Ellis S. *Chicago Sewerage: Report of the Results of Examinations Made in Relation to Sewerage in Several European Cities, in the Winter of 1856-7*. Chicago, Ill.: Printed by the Board, 1858.

“City of Elizabeth.” In *History of Union County, New Jersey, 1664 -1923*, edited by A. Van Doren Honeyman, 321-368. New York: Lewis Historical Publishing Company, Inc., 1923.

The City of Elizabeth, New Jersey, Illustrated, Showing its Leading Characteristics: its Attractions as a Place of Residence, and its Unsurpassed Advantages as a Location for Manufacturing Industries. Elizabeth, N.J.: Printed by The Elizabeth Daily Journal, 1889.

City of Newark. Board of Street and Water Commissioners. *Annual Report of the Board of Street and Water Commissioners of the City of Newark, New Jersey, for the Year ended December 31, 1896*. Newark, N.J.: Madison & Co., Stationers and Printers, 1897.

"City of Perth Amboy." In *History of Union and Middlesex Counties, New Jersey, with Biographical Sketches of Many of Their Pioneers and Prominent Men*, edited by W. Woodford Clayton, 602-640. Philadelphia: Everts & Peck, 1882.

Clarke, Eliot C. *Main Drainage Works of the City of Boston*. 2nd ed. Boston: Rockwell and Churchill, City Printers, 1885. https://hdl.handle.net/2027/mdp.39015067087216 (accessed July 21, 2023)

Concrete Sewers. Portland Cement Association, 1918.

Connolly, Richard M. "Bacteriologist's Reports." In *Report of the Passaic Valley Sewerage Commission, Upon the general system of sewage disposal for the valley of the Passaic River, and prevention of the pollution there*, edited by Passaic Valley Sewerage Commision, 71-82. Newark, N.J.: John E. Rowe & Son, Printers, 1897.

Cosans, Betty J. *Archeological Investigations of a Proposed Urban Redevelopment Site, New Brunswick, New Jersey*. West Chester, PA: John Milner Associates, Inc., 1983. Cultural Resources Survey, Prepared for New Brunswick Development Corporation. Copies available from the New Jersey Historic Preservation Office, Trenton.

Cotz, Jo Ann. *Phase II Historical Research Survey of the Proposed Sanitary Sewer Replacement System, City of Paterson, Passaic County, New Jersey*. Wayne, NJ: Pandullo Quirk Associates, 1977. Phase II Survey. Copies available from the New Jersey Historic Preservation Office, Trenton.

Cowen, David L. *Medicine and Health in New Jersey: A History*. Vol. 16. Princeton: D. Van Norstrand Company, 1964.

Croes, John James Robertson. "Report on a Plan of Sewerage for the Township of East Orange, New Jersey." In *The Sewerage of East Orange, N.J.*, 13-19. https://hdl.handle.net/2027/uiug.30112069024054 (accessed July 21, 2023)

Crosby, Molly Caldwell. *The American Plague, The Untold Story of Yellow Fever, The Epidemic That Shaped Our History*. New York: Berkley Books, 2006.

Cumming, Hugh S. *Investigation of the Pollution of Certain Tidal Waters of New Jersey, New York, and Delaware, with Special Reference to Bathing Beaches and Shellfish-Bearing Areas. Public Health Bulletin No. 86, August 1917.* Washington: Government Printing Office, 1917.

Cummins, George Wyckoff. *History of Warren County, New Jersey*. New York: Lewis Historical Publishing Company, 1911.

Cushman, Laura, and Paul J. McEachen. *Northwest Resiliency Park, Block 103, Lots 7-26, Block 107, Lot 1, and Block 113, Lot 1, City of Hoboken, Hudson County, New Jersey*. Cranbury, New Jersey: RGA, Inc., 2015. Stage 1A Cultural Resources Survey, Submitted to Excel Environmental Resources, Inc. Copies available from the New Jersey Historic Preservation Office, Trenton.

Cushman, Laura, Michael Tomkins, Amy Raes, and Paul McEachen. *Archaeological Monitoring, North Hudson Sewerage Authority, Grand Street Combined Sewer Rehabilitation, City of Hoboken, Hudson County, New Jersey*. Cranbury, New Jersey: RGA, Inc., 2015. Archaeological Monitoring, Submitted to Hatch Mott MacDonald. Copies available from the New Jersey Historic Preservation Office, Trenton.

Davies, J.P., B.A. Clarke, J.T. Whiter, and R.J. Cunningham. "Factors influencing the structural deterioration and collapse of rigid sewer pipes." *Urban Water* 3, no. 1-2 (2001): 73-89.

Dawson, George. "New Brunswick." In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 567-568. New Brunswick: Rutgers University Press, 2005.

Deiber, Camilla R., and Michael C. Yengling. *Historic Context for the Sanitary Sewer System, of Cedar Rapids, Linn County, Iowa*. Marion, Iowa: The Louis Berger Group, Inc., 2010. Historic Context, Prepared for the City of Cedar Rapids. Copies available from the State Historical Society of Iowa.

Dewberry. *Rebuild by Design Hudson River, Resist, Delay, Store, Discharge*. Vol. 1. 2016. Cultural Resources Technical Environmental Study. Copies available from the New Jersey Historic Preservation Office, Trenton.

Dillon, Maureen. "Hackensack." In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 341. New Brunswick: Rutgers University Press, 2005.

Dilworth, Richardson. *The Urban Origins of Suburban Autonomy*. Cambridge: Harvard University Press, 2005.

Division of Capital Improvements and Project Management. "Camden Sewer Notebooks." Camden: Department of Planning and Development, n.d. Available with the Division of Capital Improvements and Project Management, in the Department of Planning and Development, in the City of Camden.

Duffy, John. *The Sanitarians, A History of American Public Health*. Urbana: University of Chicago, 1990.

"The East Orange, N.J., Sewerage System." *Engineering News* (January 19, 1889): 42-45.

Edwards, Richard. *Industries of New Jersey, Middlesex, Somerset and Union Counties*. Part 4. New York, Newark and Philadelphia: Historical Publishing Company, Publishers, 1882.

Fea, John. "Revolution and Confederation Period: New Jersey at the Crossroads." In *New Jersey: A History of the Garden State*, edited by Maxine N. Lurie and Richard Veit, 64-89. New Brunswick: Rutgers University Press, 2012.

Federal Writers' Project of the Works Progress Administration for the State of New Jersey. *New Jersey, a Guide to its Present and Past, Compiled and written by the Federal Writers' Project of the Works Progress Administration for the State of New Jersey; Sponsored by the Public Library of Newark and the New Jersey Guild Associates*. New York: Viking Press, 1939. http://hdl.handle.net/10929/32537 (accessed July 21, 2023)

Floriani, Ray and Karen A Floriani. *Harrison*. Portsmouth, New Hampshire: Arcadia Publishing, 2003.

Folwell, A. Prescott. *Sewerage, The Designing, Construction, and Maintenance of Sewerage Systems*. 6th ed. New York: John Wiley & Sons, 1910.

Frasier, Marilyn R, and John W. Lawrence. *Stage I Cultural Resources Survey, Lyle Brook Culvert Rehabilitation, City of New Brunswick, Middlesex County, New Jersey*. Cranbury, New Jersey: Richard Grubb & Associates, Inc., 1997. Cultural Resources Survey, Prepared for CME Associates. Copies available from the New Jersey Historic Preservation Office, Trenton.

Fuller, George W. "Description of the Process and Plant of the Jersey City Water Supply Company for the Sterilization of the Water of the Boonton Reservoir." In *Proceedings of the Twenty-Ninth Annual Convention of the American Water Works held at Milwaukee, Wis., Jun 7-12-1909,* 110 – 134. Published by the Secretary: 1909. http://www.waterworkshistory.us/NJ/Jersey_City/1909AWWAFuller.pdf (accessed July 21, 2023)

—. *Sewage Disposal*. New York: McGraw-Hill Book Company, 1912.

—. "The Water Purification Works of the East Jersey Water Company at Little Falls, New Jersey." *The Engineering Record* 43, no. 19 (1901): 442-444.

Gall, Allison A., Lauren Dunkle, Teresa Bulger, and Michael J. Gall. *Stage IA and Stage II Cultural Resources Survey, The Crossings at Brick Church Station*. Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2021. Stage 1A and Stage II Cultural Resources Survey, Prepared for Bohler Engineering. Copies available from the New Jersey Historic Preservation Office, Trenton.

Gall, Michael J. *Archaeological Monitoring, Sanitary Sewer Improvements at Drift Street and Abundant Life Church, City of New Brunswick, Middlesex County, New Jersey*. Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2013. Archaeological Monitoring, Prepared for Black Rock Enterprises, LLC. Copies available from the New Jersey Historic Preservation Office, Trenton.

Galishoff, Stuart. *Newark: The Nation's Unhealthiest City, 1832-1895*. New Brunswick: Rutgers University Press, 1988.

Gandy, Matthew. "The Paris Sewers and the Rationalization of Urban Space." *Transactions of the Institute of British Geographers* 24, no. 1 (1999): 23–44.

Garrison, Winton C. *The Industrial Directory of New Jersey*. Camden, N.J.: S. Chew & Sons Co., Printers, 1909.

Geismar, Joan H. *HBLR MOS-1: Jersey City Report on Monitoring, April 7, 1998 to September 6, 2000*. 2002. Archaeological Monitoring, Prepared for Parsons Brinckerhoff Quade & Douglas, Inc. and 21st Century Rail Corporation. Copies available from the New Jersey Historic Preservation Office, Trenton.

Glazer, Harry. "Elizabeth." In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 246-247. New Brunswick: Rutgers University Press, 2005.

Gibson, Jane Mork, and Robert Wolterstorff. "The Fairmount Water Works." *Philadelphia Museum of Art Bulletin* 84, no. 360, 361 (Summer, 1988): 1, 4-46.

Gillette, Jr., Howard. "Camden." In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 112-113. New Brunswick: Rutgers University Press, 2005.

Goldman, Joanne Abel. *Building New York's Sewers: Developing Mechanisms of Urban Management*. West Lafayette, Indiana: Purdue University Press, 1997.

Gonzalez, Evelyn. "Passaic." In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 615. New Brunswick: Rutgers University Press, 2005.

Gooding, Barbara J., Terry E. Sellarole, Allan Petretti, and Theresa E. Jones. *Hackensack*. Charleston: Arcadia Publishing, 2009.

Grant, H. Roger. "Bridgeton." In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 99. New Brunswick: Rutgers University Press, 2005.

Greenberg, Gail. "Gloucester City." In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 320. New Brunswick: Rutgers University Press, 2005.

Grimmer, Anne E. *The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring, & Reconstructing Historic Buildings*. Washington, D.C.: U.S. Department of the Interior, National Park Service, Technical Preservation Services, 2017.

Grossman-Bailey, Ilene. *Stage IA Cultural Resources Survey, JCMUA Sewerage Facilities Improvements, Brown Place, Princeton Avenue, and Linden Avenue, City of Jersey City, Hudson County, New Jersey*. Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2011. Cultural Resources Survey, Prepared for Mayo, Lynch & Associates, Inc., and Jersey City Municipal Utilities Authority. Copies available from the New Jersey Historic Preservation Office, Trenton.

Grossman-Bailey, Ilene, and Laura D. Cushman. *Trumbull Street Flood Control Project, Trumbull Street, East Sixth, Street and Bond Street, Block 7, Lot 1227, City of Elizabeth, Union County, New Jersey*. Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2019. Archaeological Monitoring, Prepared for P.M. Construction Corp. Copies available from the New Jersey Historic Preservation Office, Trenton.

Guzzo, Dorothy. "SHPO Opinion, Trumbull Street Sewer, Elizabeth, New Jersey. NJ State Historic Preservation Office. Letter submitted to Edward Hummel, US EDA, 10 September." 1999. Copies available from the New Jersey Historic Preservation Office, Trenton.

Hamlin, Christopher. "Edwin Chadwick and the Engineers, 1842-1854: Systems and Antisystems in the Pipe-and-Brick Sewers War." *Society for the History of Technology* (1992): 680-709.

Hansen, Brett. "Newark's Brick Sewers Reinforced with Cured-in-Place Pipe." *Civil Engineering News* (June 2005): 27-28.

Hansen, Tony. "Vitrification." 2015. https://digitalfire.com/glossary/vitrification (accessed March 03, 2023)

Hart, Bill. *East Orange*. Charleston: Arcadia Publishing, 2006.

Hart, William. "East Orange." In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 231-232. New Brunswick: Rutgers University Press, 2005.

Haven, C.C. *Report on Petty's Run, made to the Common Council of the City of Trenton*. Trenton, N.J.: John L. Murphy, Steam Power Book and Job Printer, 1879.

Hazen, Allen. *The Filtration of Public Water-Supplies*. 2nd ed. New York: John Wiley & Sons, 1896.

Hering, Rudolph. *Report on a Sewerage System for the City of Trenton, N.J.* Trenton, N.J.: Naar, Day & Naar, Printers, 1885. https://hdl.handle.net/2027/nnc1.cu50589946 (accessed July 21, 2023)

—. *Report on a System of Sewerage for the City of Binghamton, N.Y.* Binghamton: Daily Leader, 1882. http://resource.nlm.nih.gov/101186031 (accessed July 21, 2023)

—. "Results of Six Years' Experience with the Memphis Sewers." *The Engineering & Building Record and the Sanitary Engineer* 16, no. 26 (1887): 739.

—. "Sewerage Work; a Twenty-Five Years' Review." *The Engineering Record Building Record and Sanitary Engineer* 47, no. 1 (1903): 21-22.

—. "Sewerage Systems." With Discussions, read at the 13th Annual Convention, June 15th, 1881. *Transactions of the American Society of Civil Engineers* 230, no. 10 (November 1881): 361-386.

History of the Municipalities of Hudson County, New Jersey, 1630- 1923. Edited by Daniel van Winkle. 2 vols. New York: Lewis Historical Publishing Company, Inc., 1924.

Hodges, Graham Russell Gao. "New Jersey in the Early Republic." In *New Jersey: A History of the Garden State*, edited by Maxine N. Lurie and Richard Veit, 90-114. New Brunswick: Rutgers University Press, 2012.

Holden, Edgar. *Mortality and Sanitary Record of Newark, N.J.* 1880. https://rucore.libraries.rutgers.edu/rutgers-lib/47899/JPEG/read/#page/1/mode/2up (accessed July 21, 2023)

Howson, Jean E. "The Archaeology of 19th-Century Health and Hygiene at the Sullivan Street Site, New York City." *Northeast Historical Archaeology* 22, no. 22 (1993): 137-160.

Howson, Jean. *Cultural Resource Inspection of Market and Hunter Street Sewer Reconstruction, Gloucester City, Camden County, New Jersey*. New Brunswick: Rutgers University Center for Public Archaeology, 1996. Cultural Resources Survey, Prepared for The City of Gloucester City. Copies available from New Jersey Historic Preservation Office, Trenton.

—. *Cultural Resources Survey of the Jersey City Water Works Pipeline, 1851-1873, U.S. Route 1&9 Truck Interim Improvements Project, Charlotte Circle, Jersey City, NJ*. The RBA Group, Inc., 2001. Cultural Resources Survey, Submitted to the New Jersey Department of Transportation. https://www.state.nj.us/transportation/commuter/roads/rt1_9t/pdf/wwreport.pdf (accessed July 21, 2023)

Howson, Jean, and Leonard G. Bianchi. *Covert Larch: Archaeology of a Jersey City Neighborhood. Data Recovery for the Route 1 & 9T (25) St. Paul's Viaduct Replacement Project Jersey City, Hudson County, NJ*. Parsippany, NJ: The RBA Group, 2014. Cultural Resource Survey, Submitted to the New Jersey Department of Transportation. Copies available from New Jersey Historic Preservation Office, Trenton.

Hunt, A. Clark. "The Sewer Systems of New Jersey." In *Thirteenth Annual Report of the Board of Health of the State of New Jersey, and Report of the Bureau of Vital Statistics, 1889*, 83-101. Camden, N.J.: F.F. Patterson, Printer, 1890.

Hunter, Richard W. *Archaeological Monitoring of the Lamberton Interceptor, Lamberton Street, City of Trenton, New Jersey*. Hopewell: Richard W. Hunter, 1982. Archaeological Monitoring, Prepared for Clinton Bogert Associates. Copies available from New Jersey Historic Preservation Office, Trenton.

—. *Power to the City, The Trenton Water Power*. Trenton, New Jersey: Hunter Research, Inc., 2005. https://www.mercercounty.org/home/showpublisheddocument/900/636056702754270000 (accessed July 21, 2023)

Hunter, Richard W., and Ian C. Burrow. *Petty's Run Archaeological Site, Iron, Steel, Cotton and Paper in Historic Trenton*. 3 vols. Trenton, New Jersey: Hunter Research, Inc., 2014. Prepared for Wallace Roberts & Todd. Copies available from New Jersey Historic Preservation Office, Trenton.

"Impervious Sewer Pipes." *The Manufacturer and Builder* 12, no. 3 (March 1880): 54-55.

Israel, Paul. "The Garden State Becomes an Industrial Power: New Jersey in the Late Nineteenth Century." In *New Jersey: A History of the Garden State*, edited by Maxine N. Lurie and Richard Veit, 175-201. New Brunswick: Rutgers University Press, 2012.

Israel, Stephen. *Report on the Identification of the Historic and Prehistoric Cultural Resources Along Lamberton Street Southerly of Cass Street, Trenton, Mercer County New Jersey: An Assessment Study for the Plan of Action*. 1976. Environmental Assessment Statement, Submitted to Clinton Bogert Associates, Inc., for the U.S. Environmental Protection Agency. Copies available at the New Jersey Historic Preservation Office, Trenton.

Jennings, Anne. *Historic Resource Inventory Form for Tarrytown Sewage Treatment Plant*. New York: AECOM, 2011 [2010]. https://newnybridge.com/documents/study-documents/section106/c16.pdf (accessed August 21, 2023)

Kardas, Susan, and Edward Larrabee. *Cultural Resource Survey of the Proposed Route for Sanitary Sewer Connection to the Middlesex County Sewerage Authority for the City of Perth Amboy*. Robert A. Brooks Associated & Historic Sites Research, 1980. Stage 1B Cultural Resource Survey. Copies available at the New Jersey Historic Preservation Office, Trenton.

Karnoutsos, Carmela Ascolese. "Bayonne." In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 63. New Brunswick: Rutgers University Press, 2005.

Khandal, Anu, Elizabeth Shikrallah, Christina Servetnick, T. Cregg Madrigal, and Elizabeth Davis. *Sewers Invincible: A historic context for Camden's sewer infrastructure*. Trenton, N.J.: New Jersey Department of Environmental Protection. Division of Water Quality. Municipal Finance and Construction Element, 2021. https://hdl.handle.net/10929/107508 (accessed July 21, 2023)

Kirby, William B. *A Souvenir of Bridgeton, N.J., "The Metropolis of Southern Jersey," Its Religious and Educational Advantages, Public Government, Business Importance, Attractive Surroundings, Enterprising Citizens and Pleasant Homes*. Bridgeton, New Jersey, U.S.A.: News Job Printing House 74 Commerce Street, 1895. https://hdl.handle.net/2027/njp.32101071980633 (accessed July 21, 2023)

Kraft, Herbert C., and Jo Ann Cotz. *Archaeological and Historical Survey of the Proposed Sanitary Sewer Replacement System, City of Paterson, Passaic County, New Jersey*. South Orange: Archaeological Research Center, Seton Hall University Museum, 1976. Phase I Survey, Submitted to Pandullo Quirk Associates. Copies available at New Jersey Historic Preservation Office, Trenton.

Kraft, Herbert C., and R. Alan Mounier. "The Late Woodland Period in New Jersey (ca. 1000 – 1600 AD)." In *New Jersey's Archeological Resources, A Review of Research Problems and Survey Priorities: The Paleo-Indian Period to Present*, edited by Olga Chesler, 139-184. Trenton: New Jersey Historic Preservation Office, 1982. https://www.nj.gov/dep/hpo/1identify/pg_139_LateWdlndPeriodNJKraft_Mounier.pdf (accessed July 21, 2023)

Larrabee, Edward McM. "New Jersey's Cultural Resources: A.D. 1800-1865." In *New Jersey's Archeological Resources, A Review of Research Problems and Survey Priorities: The Paleo-Indian Period to Present*, edited by Olga Chesler, 220 – 240. Trenton: New Jersey Historic Preservation Office, 1982. https://www.nj.gov/dep/hpo/1identify/pg_220_NJCulturalResourc1800_1865Larrabee.pdf (accessed July 21, 2023)

Latham, Baldwin. *Sanitary Engineering, A Guide to the Construction of Works of Sewerage and House Drainage*. London: E. & F.N. Spon, 48, Charing Cross, 1873.

Lee, A. Grant. “Century Concrete Pipe Does Exist.” *Canadian Concrete Pipe Association*. n.d. https://studylib.net/doc/8261655/century-concrete-pipe-does-exist (accessed July 21, 2023)

Lee, Francis Bazley. *History of Trenton, New Jersey, The Record of Its Early Settlement and Corporate Progress*. Trenton, N.J.: John L. Murphy, Printer, 1895. https://hdl.handle.net/2027/chi.102817551 (accessed July 21, 2023)

Lembo, Lauren, and Elizabeth Diker. *Stage IA Cultural Resource Survey, Jersey City Municipal Utilities Authority Sewer Phases 1-2 Sewer Rehabilitation, City of Jersey City, Hudson County, New Jersey (JCMUA Project No. S340928-24)*. Cranbury: RGA, Inc., 2018. Stage 1A Survey, Prepared for Mott MacDonald. Copies available from the New Jersey Historic Preservation Office.

Lewis, Jone Johnson. “Sanitary Commission (USSC).” *ThoughtCo*. February 19, 2019. https://www.thoughtco.com/sanitary-commission-ussc-3528670 (accessed July 21, 2023)

Listokin, David, Dorothea Berkhout, and James W. Hughes. *New Brunswick, New Jersey, The Decline and Revitalization of Urban America*. New Brunswick, New Jersey: Rutgers University Press, 2016.

“*Lock Joint” Reinforced Concrete Pipe*. New York: Lock Joint Pipe Company, 1918. https://archive.org/details/lockJointReinforcedConcretePipePressureSewerCulvertAndSubaqueous/page/n63/mode/2up (accessed July 21, 2023)

Lofrano, Giusy, and Jeanette Brown. “Wastewater management through the ages: A history of mankind.” *Science of the Total Environment* 408, no. 22 (2010): 5254-5264.

Lore, Robert J., and Michael Tomkins. *Archaeological Monitoring CSO Solids/Floatables Control Facility 005, Brick Sewer Documentation, City of Paterson, Passaic County, New Jersey*. Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2008. Archaeological Monitoring, Prepared for Hutton Construction. Copies available from the New Jersey Historic Preservation Office.

Luizzi, Leonard. “Hoboken.” In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 378. New Brunswick: Rutgers University Press, 2005.

Lurie, Maxine N. “Colonial Period: The Complex and Contradictory Beginnings of a Mid-Atlantic Province.” In *New Jersey: A History of the Garden State*, edited by Maxine N. Lurie and Richard Veit, 33-63. New Brunswick: Rutgers University Press, 2012.

—. “Paterson.” In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 618-619. New Brunswick: Rutgers University Press, 2005.

Marston, Anson. *Sewers and Drains*. Chicago: American School of Correspondence, 1908.

Massopust, Anton J. *Cultural Resource Survey: City of Perth Amboy*. 1976. Copies available from the New Jersey Historic Preservation Office, Trenton.

Maygarden, Benjamin D., Jill-Karen Yakubik, Ellen Weiss, Chester Peyronnin, and Kenneth R. Jones. "National Register Evaluation of New Orleans Drainage System, Orleans Parish, Louisiana." New Orleans, LA: Earth Search, Inc., 1999. Submitted to U.S. Army Corps of Engineers.

McCann, Thomas H., and Alphonse Fteley. *Reports of Thomas H. McCann, City Surveyor, and Alphonse Fteley, Consulting Engineer, on a General Sewerage Plan, for the City of Hoboken, N.J.* Hoboken, N.J.: The Evening News Print, 1890. https://hdl.handle.net/2027/nnc1.cu55751890 (accessed July 21, 2023)

McEachen, Paul J., Glenn Modica, and John W. Lawrence. *Cultural Resources Investigation, City of Newark, New Jersey, Department of Engineering, Phase III/IV Brick Sewer Evaluation and Environmental Assessment, Appendix A to Volume 3*. Cranbury: Richard Grubb and Associates, Inc., 2000. Cultural Resources Investigation, Submitted to Camp Dresser & McKee. Copies available from the New Jersey Historic Preservation Office, Trenton.

McEachen, Paul J., and Glenn R. Modica. *Cultural Resources Investigation, City of Newark, New Jersey, Department of Water and Sewer Utilities, Phase V Brick Sewer Rehabilitation Program, Sewer Evaluation and Design Phase, Environmental Assessment*. Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2003. Cultural Resources Investigation, Submitted to Camp Dress & McKee, Inc. Copies available from the New Jersey Historic Preservation Office, Trenton.

McGuire, Patricia M. "Rahway." In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 674. New Brunswick: Rutgers University Press, 2005.

McLean, Alexander. *History of Jersey City, N.J., A Record of Its Early Settlement and Corporate Progress*. Jersey City: Press of the Jersey City Printing Company, 1895.

Mead and Hunt. *Historic Resources Inventory Report: National Western Center Redevelopment*. Mead & Hunt, 2017. Prepared for Mayor's Office of the National Western Center. https://nationalwesterncenter.com/wp-content/uploads/2019/06/Cultural-Plan-Appendix-A_Historic_Resource_InvReport_Reduced2.pdf (accessed July 21, 2023)

Meegoda, Jay N., Thomas M. Juliano, and Chi Tang. *Culvert Information Management System – Demonstration Project. New Jersey Institute of Technology*. Report No. FHWA-NJ-2009-017, 2009. Submitted to the New Jersey Department of Transportation and U.S. Department of Transportation. Copies available from the New Jersey Department of Transportation.

Melosi, Martin V. *The Sanitary City: Urban Infrastructure in America from Colonial Times to the Present*. Baltimore: Johns Hopkins University Press, 2001.

Metcalf, Leonard, and Harrison P. Eddy. *American Sewerage Practice*. 3 vols. New York: McGraw-Hill, 1914.

—. *Sewerage and Sewage Disposal, a Textbook*. New York: McGraw-Hill Book Company, Inc., 1922.

"Methods of Constructing a High-Pressure Concrete Pipe Water Main at Swansea, England." *Engineering-Contracting* 28, no. 12 (September 18, 1907): 168-169.

Metropolitan Fair in aid of the United States Sanitary Commission. New York: Charles O. Jones, Stationer and Printer, 1864. https://hdl.handle.net/2027/loc.ark:/13960/t9h424739 (accessed July 21, 2023)

Mierisch, Arthur. *The Morris Aqueduct Company: New Jersey's First Water Company, Part 1: 1798-1869*. GSL18. Garden State Legacy, 2012. https://gardenstatelegacy.com/files/The_Morris_Aqueduct_Company_Mierisch_GSL18.pdf (accessed July 21, 2023)

Mierisch, Arthur. *The Morris Aqueduct Company: New Jersey's First Water Company, Part 2: 1860-1923*. GSL21. Garden State Legacy, 2013. https://www.gardenstatelegacy.com/files/The_Morris_Aqueduct_Company_Mierisch_GSL21.pdf (accessed July 21, 2023)

Miller, Saleh, and Nicole Foss. "The Minneapolis Central City Tunnel System Context Report, Minneapolis, Hennepin County, Minnesota." In *Attachment F, Preliminary Design Report, Central City Tunnel System*, Appendix E. Saint Paul: The 106 Group Ltd., 2017. Historic Context, Submitted to CDM Smith. https://www.minneapolismn.gov/media/-www-content-assets/documents/wcmsp-214802.pdf (accessed July 21, 2023)

Minutes of the Proceedings of the Second Annual Meeting of the Quarantine and Sanitary Convention, Convened in the City of Baltimore, April 29, 1858. Baltimore: Printed by John D. Toy, 1858.

Modica, Glenn R. *The History of the Newark Sewer System*. Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2001. Cultural Resources Survey.

Modica, Glenn R., and Jesse O. Walker. *Stage IA Cultural Resources Survey, North Hudson Sewerage Authority, System-Wide Combined Sewer Overflow Improvements Program, Cities of Hoboken and Union City and Township of Weehawken, Hudson County, New Jersey*. Cranbury: Richard Grubb & Associates, Inc., 2004. Cultural Resources Survey, Submitted to CH2M Hill. Copies available from the New Jersey Historic Preservation Office, Trenton.

Monmouth Mining & Manufacturing Company. “Sewer and Culvert Pipe, Drain Tile, Well Tubing, Paving Brick, &c, &c. Monmouth Illinois (catalog).” 1890. https://archive.org/details/SewerAndCulvertPipeDrainTileWellTubingPavingBrick (accessed July 21, 2023)

Moore, Joseph V., Allison Savarese, Lauren J. Cook, and Paul McEachen. *Archaeological Monitoring/Stage IB Archaeological Survey, North Hudson Sewerage Authority, Solids/Floatables Removal Project, Package 1 (h-6/H-7 and Consolidation Conduit) City of Hoboken, Hudson County, New Jersey*. Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2006. Archaeological Monitoring and Stage 1B Archaeological Survey, Prepared for CH2M Hill. Copies available from the New Jersey Historic Preservation Office, Trenton.

Murray, Samantha, Steven Treffers, Mary Ringhoff, and Jan Ostashay. *Built Environment Evaluation Report for Properties on Terminal Island, Port of Los Angeles, City and County of Los Angeles, California*. San Pedro: SWCA Environmental Consultants. Submitted to CDM, 2011. https://kentico.portoflosangeles.org/getmedia/8f43c95f-cd03-4f72-bdeb-6c42eee76f79/11912_regagenda_item_5_transmittal_4 (accessed August 21, 2023)

National Park Service. *How to Apply the National Register Criteria for Evaluation. National Register Bulletin 15*. Washington, D.C.: U.S. Department of the Interior, National Park Service, 1997.

Nelson, William. *Nelson’s Biographical Cyclopedia of New Jersey*. 2 vols. New York: Eastern Historical Publishing Society, 1913.

New Jersey. Board of Health. *Fourth Annual Report of the Board of Health of the State of New Jersey, 1880*. Camden, N.J.: Printed by Sinnickson Chew., 1881.

—. *Nineteenth Annual Report of the Board of Health of the State of New Jersey, and Report of the Bureau of Vital Statistics, 1895*. Trenton, N.J.: The John L. Murphy Publishing Company, Printers, 1895.

—. *Seventeenth Annual Report of the Board of Health of the State of New Jersey and Report of the Bureau of Vital Statistics, 1893*. Trenton, N.J.: MacCrellish & Quigley, Book and Job Printers, 1893.

—. *Twenty-Fourth Annual Report of the Board of Health of the State of New Jersey, and Report of the Bureau of Vital Statistics, 1900*. Trenton, N.J.: The John L. Murphy Publishing Co., Printers, 1901.

—. *Twenty-Ninth Annual Report of the Board of Health of the State of New Jersey, 1905*. Trenton, N.J.: The John L. Murphy Publishing, Printers, 1906.

—. *Twenty-Sixth Annual Report of the Board of Health of the State of New Jersey, 1902*. Trenton, N.J.: The J. L. Murphy Publishing Co., Printers, 1903.

—. *Twenty-Third Annual Report of the Board of Health of the State of New Jersey, 1899*. Trenton, N.J.: MacCrellish & Quigley, State Printers, 1900.

New Jersey. Department of Health. *Fifty-Third Annual Report of the Department of Health of the State of New Jersey, 1930*. Trenton, New Jersey: MacCrellish & Quigley Co Printers, 1931. https://hdl.handle.net/2027/mdp.39015068410086 (accessed July 21, 2023)

New Jersey. Legislature. *Acts of the Eighty-Fifth Legislature of the State of New Jersey, and Seventeenth Under the New Constitution*. Freehold, N.J.: Printed by James S. Yard, 1861.

—. *Acts of the Eighty-Second Legislature of the State of New Jersey, and Fourteenth Under the New Constitution*. Morristown, N.J.: Printed by Louis C. Vogt, 1858.

—. *Acts of the Eighty-Seventh Legislature of the State of New Jersey, and Nineteenth Under the New Constitution*. Newark: Printed by E.N. Fuller, Daily Journal Office, 1863.

—. *Acts of the Ninetieth Legislature of the State of New Jersey and Twenty-Second Under the New Constitution*. Paterson, N.J.: Printed by Chiswell & Wurts, Daily "Press" Office, 1866.

—. *Acts of the Ninety-Eighth Legislature, of the State of New Jersey, and Thirtieth Under the New Constitution*. Paterson, N.J.: Chiswell & Wurts, Book and Job Printers, 269 Main Street, 1874.

—. *Acts of the Ninety-Fifth Legislature, of the State of New Jersey, and Twenty-Seventh Under the New Constitution*. Morristown, N.J.: Vance & Stiles, Book and Job Printers, 1871.

—. *Acts of the Ninety-Fourth Legislature of the State of New Jersey and Twenty-Sixth Under the New Constitution*. Newark, N.J.: Printed by E.N. Fuller, 1870.

—. *Acts of the Ninety-Seventh Legislature of the State of New Jersey, and Twenty-Ninth Under the New Constitution*. Morristown, N.J.: Vance & Stiles, Steam Power Book and Job Printers, 1873.

—. *Acts of the Ninety-Sixth Legislature of the State of New Jersey, and Twenty-Eighth Under the New Constitution*. Trenton, N.J.: Naar, Day & Naar, "True American" Office, Printers, 1872.

—. *Acts of the Ninety-Third Legislature of the State of New Jersey, and Twenty-Fifth Under the New Constitution*. New Brunswick, N.J.: Printed by A.R. Speer, 1869.

—. *Acts of the One Hundred and Eighth Legislature of the State of New Jersey, and Fortieth Under the New Constitution*. Camden, N.J.: Printed by Sinnickson Chew, 1884.

—. *Acts of the One Hundred and First Legislature of the State of New Jersey, and Thirty-Third Under the New Constitution*. Mount Holly, N.J.: William B. Wills, Printer, 1877.

—. *Acts of the One Hundred and Fourth Legislature of the State of New Jersey, and Thirty-Sixth Under the New Constitution*. Morristown, N.J.: Vance & Stiles, Printers, 1880.

—. *Acts of the One Hundred and Sixth Legislature of the State of New Jersey and Thirty-Eighth Under the New Constitution*. Paterson, N.J.: Carleton M. Herrick, 1882.

—. *Acts of the One Hundred and Tenth Legislature of the State of New Jersey and Forty-Second Under the New Constitution*. Trenton, N.J.: MacCrellish & Quigley, Printers, 1886.

—. *Acts of the One Hundred and Thirty-Fourth Legislature of the State of New Jersey and Sixty-Sixth Under the New Constitution*. Trenton, N.J.: MacCrellish & Quigley, State Printers, 1910.

—. *Acts of the One Hundred and Thirty-Sixth Legislature of the State of New Jersey, and Sixty-Eighth Under the New Constitution*. Trenton, N.J.: MacCrellish & Quigley. State Printers. Opposite Post Office, 1912.

—. *Acts of the One Hundred and Thirty-Third Legislature of the State of New Jersey, and Sixty-Fifth Under the New Constitution*. Paterson, N.J.: The News Printing Co., State Printers, 1909.

—. *Acts of the One Hundred and Twentieth Legislature of the State of New Jersey, and Fifty-Second Under the New Constitution*. Trenton, N.J.: MacCrellish & Quigley, Current Printers, 1896.

—. *Acts of the One Hundred and Twenty-First Legislature of the State of New Jersey, and Fifty-Third Under the New Constitution*. Trenton, N.J.: MacCrellish & Quigley, Current Printers, 1897.

—. *Acts of the One Hundred and Twenty-Sixth Legislature of the State of New Jersey, and Fifty-Eighth Under the New Constitution*. Trenton, N.J.: The J.L. Murphy Publishing Co., Printers, 1902.

—. *Acts of the One Hundred and Twenty-Third Legislature of the State of New Jersey, and Fifty-Fifth Under the New Constitution*. Trenton, N.J.: MacCrellish & Quigley, State Printers, 1899.

—. *Acts of the One Hundredth Legislature, of the State of New Jersey*. Paterson, N.J.: Chiswell & Wurts, Book and Job Printers, 1876.

—. *Acts of the Seventy-Eighth Legislature of the State of New Jersey and Tenth Under the New Constitution*. Mount Holly: Printed by Moreton A. Stille, 1854.

—. *Acts of the Seventy-Fifth Legislature of the State of New Jersey, and Seventh Session Under the New Constitution*. Trenton: Printed by Phillips & Boswell, 1851.

—. *Acts of the Seventy-Fourth Legislature of the State of New Jersey, and Sixth Under the New Constitution*. Trenton: Printed by Phillips & Boswell, 1850.

—. *Acts of the Seventy-Ninth Legislature of the State of New Jersey and Eleventh Under the New Constitution*. Trenton: Printed by Phillips & Boswell, 1855.

—. *Acts of the Seventy-Sixth Legislature of the State of New Jersey and Eighth Under the New Constitution*. Somerville: Printed by Donaldson & Brokaw, 1852.

—. *Acts of the Seventy-Third Legislature of the State of New Jersey, and Fifth Session Under the New Constitution*. Trenton: Printed by Phillips & Boswell, 1849.

—. *Acts of the Sixtieth General Assembly of the State of New Jersey, at a Session Begun at Trenton, on the Twenty-Seventh Day on October, Eighteen Hundred and Thirty-Five. Being the First Sitting*. Trenton: William Boswell, Printer, 1836.

—. *Acts of the Sixty-Second General Assembly of the State of New Jersey, at a Session Begun at Trenton on the Twenty-Fourth Day of October, Eighteen Hundred and Thirty-Seven. Being the First Sitting*. Trenton: Printed by James Adams, 1838.

—. *Documents of the One Hundred and Twenty-Fifth Legislature of the State of New Jersey and the Fifty-Sixth Under the New Constitution*. 3 vols. Trenton, N.J.: The John L. Murphy Publishing Co., Printers: 1901.

New Jersey. Sanitary Commission. *Report of the State Sanitary Commission, to the Governor of New Jersey for the Year 1866*. Trenton, N.J.: Printed at the Office of the State Gazette, 1867.

New Jersey. Sewerage Commission. *Report of the State Sewerage Commission, to the Legislature, Session of 1900*. Trenton, N.J.: MacCrellish & Quigley, State Printers, Opposite the Post Office, 1900.

—. *Report of the State Sewerage Commission, to the Legislature, Session of 1902*. Trenton, N.J.: The John L. Murphy Publishing Co., Printers, 1902.

—. *Report of the State Sewerage Commission, to the Legislature of 1906*. Trenton, N.J.: MacCrellish & Quigley, State Printers, 1906.

—. *Report of the State Sewerage Commission, to the Legislature of 1907*. Trenton, N.J.: MacCrellish & Quigley, State Printers, 1907.

—. *Report of the State Sewerage Commission to the Legislature of 1908*. Sommerville, N.J.: The Unionist-Gazette Association, State Printers, 1908.

New Jersey. State Prison. *Annual Report of the Condition of the New Jersey State Prison, Embracing the Reports of the Joint Committee, Commissioners, Inspectors, Keeper and Physician*. Trenton: Printed at the "True American" Office, 1861.

New York. Metropolitan Sewerage Commission. *Sewerage and Sewage Disposal in the Metropolitan District of New York and New Jersey*. New York: Martin B. Brown, Press, 1910. https://hdl.handle.net/2027/uc1.c2640886 (accessed July 21, 2023)

Nightingale, Florence. *Notes on Hospitals: Being Two Papers Read Before the National Association for the Promotion of Social Science at Liverpool, in October, 1858, with Evidence Given to the Royal Commissioners on the State of the Army in 1857*. London: John W. Parker and Son, West Strand, 1859.

Odell, Frederick S. "The Sewerage of Memphis." With Discussions. *Transactions of the American Society of Civil Engineers* 10 (1881): 23-52.

Ogden, Henry N. *Sewer Construction*. New York: John Wiley & Sons, 1911.

Outwater, Alice. *Water, A Natural History*. New York: Basic Books, 1996.

Page, G. William. "Perth Amboy, New Jersey, Case Studies." In *Planning for Groundwater Protection*, edited by G. William Page, 289-281. Orlando: Academic Press, Inc., 1987.

—. *Report of the Passaic Valley Sewerage Commission upon the General System of Sewage Disposal for the Valley of the Passaic River, and Prevention of the Pollution Thereof*. Newark, N.J.: John E. Rowe & Son, Printers, 1897.

Passaic Valley Water Commission. "Historical Development of PVWC: An Overview." 2021. https://pvwc.com/about-us/historical-development-of-pvwc/ (accessed July 21, 2023)

"Passing of Line Ditch in South Camden Means Much to that City." *Philadelphia Inquirer*. November 1, 1906.

Pennington, Charles R., and Paul S. Schopp. *Stage IA Cultural Resources Survey, Combined Sewer Overflow Planning Study, City of Camden and Gloucester City, Camden County, New Jersey*. Cranbury, New Jersey: Richard Grubb & Associates, Inc., 1998. Stage 1A Cultural Resources Survey, Submitted to CH2M Hill. Copies available from the New Jersey Historic Preservation Office, Trenton.

Perkins, Susan R., and Caryl A. Hopson. *German Flatts*. Charleston: Arcadia Publishing, 2010.

"Personal." *The Engineering Record* 36, no. 6 (1897): 113.

Peterson, Jon A. "The Impact of Sanitary Reform upon American Urban Planning, 1840 – 1890." In *Introduction to Planning History in the United States*, edited by Donald A. Krueckeberg, 13-39. New Brunswick: Center for Urban Policy Research, Rutgers University, 1983.

Petrick, Barbara. "Jersey City." In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 423. New Brunswick: Rutgers University Press, 2005.

Phillips, John. *On the Drainage and Sewerage of Towns*. London: E & F.N. Spon, 48 Charing Cross, 1872.

"Phillipsburg, N.J." *Engineering News and American Railway Journal*. (November 17, 1888): 397.

Piehler, G. Kurt. "Newark." In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 560-562. New Brunswick: Rutgers University Press, 2005.

A Plain Exposition of the Only Practical and Sure System for the Prevention of Disease Ever Offered to the Public. Prospectus of The Manhattan Anti Sewer Gas Company, No. 41 Union Square, New York. Everything Pertaining to House Sanitation. New York: Printed by P.F. McBreen, 16 Beekman Steet, 1883. https://wellcomecollection.org/works/q78xtjbn (accessed July 21, 2023)

Porter, Richard L., Carolyn L. Hartwick, T. Cregg Madrigal, Ian C. Burrow, and William Liebeknecht. *Archaeological Data Recovery, N.J. Route 18 Extension Interim Improvements, N.J. Route 18 (River Road) Between Landing and Metlars Lanes, Piscataway Township, Middlesex County, New Jersey, Volume 1*. New Brunswick: Rutgers University, Center for Public Archaeology, 1995.

Potter, Alexander. *Report of a System of Sewerage and Sewage Disposal for the City of Bridgeton, New Jersey*. Bridgeton, N.J.: George W. McCowan, Printer, 1898.

Proceedings and Debates of the Third National Quarantine and Sanitary Convention, Held in the City of New York, April 27th, 28th, 29th, and 30th, 1859. New York: Edmund Jones & Co., Printers to the Board of Councilmen, 1859.

Prowell, George R. *The History of Camden County, New Jersey*. Philadelphia: L.J. Richards & Co., 1886.

Rafter, George W., and Moses Nelson Baker. *Sewage Disposal in the United States*. New York: D. Van Nostrand Company, 1894.

Rankin, Edward S. “Materials for Sewer Inverts.” Paper presented at American Society of Municipal Improvements meeting. *The Engineering Record, Building Record and Sanitary Engineer* 60 (1909): 629.

—. “Rebuilding an Old Brick Sewer in Newark, N.J.” *Municipal Engineering* 41, no. 3 (September 1911): 284.

Reinbold, Martin B., John M. Stiteler, Valerie B. Perazio, Nancy L. Zerbe, Angela A. Materna, and Christine M. Morton. *Phase IB Archaeological Investigation of the Combined Sewer Overflow (CSO) Site C10 for the Camden County Municipal Utilities Authority’s Combined Sewer Overflow Replacement Project, Kaighns Avenue and Front Street, City of Camden, Camden County, New Jersey*. Metuchen, New Jersey: ARCH², Inc., 2009. Cultural Resources Survey, Submitted to D&B/Guarino Engineers. Copies available from the New Jersey Historic Preservation Office, Trenton.

Reinbold, Martin B., Nancy L. Zerbe, Sean McHugh, and Angela Materna. *Phase IB Archaeological Investigation Addendum, Combined Sewer Overflow (CSO) Site C05/10 for the Camden County Municipal Utilities Authority’s Combined Sewer Overflow Replacement Project, Kaighns Avenue and Front Street, City of Camden, Camden County, New Jersey*. Metuchen, New Jersey: ARCH², Inc., 2010. Cultural Resources Survey, Submitted to D&B/Guarino Engineers. Copies available from the New Jersey Historic Preservation Office, Trenton.

Report of the City Surveyor of the City of Newark, N.J., for the Years 1888, 1889 and 1890. Newark, N.J.: Advertiser Printing House, 1891.

Richards, Ellen H. *Conservation by Sanitation, Air and Water Supple, Disposal of Waste [Including a Laboratory Guide for Sanitary Engineers]* New York: John Wiley & Sons, 1911.

Richardson, H.G. “The Early History of Commissions of Sewers.” In *The English Historical Review*, edited by Reginald L. Poole, Volume 24, 385-393. Oxford: Frederick Hall, 1919. https://archive.org/embed/englishhistorica34londuoft (accessed July 21, 2023)

Ries, Heinrich, and Henry Leighton. *History of the Clay-Working Industry in the United States*. New York: John Wiley & Sons, 1909.

Rogers, Leah D. *Historic Context for the Des Moines Sewer System, City of Des Moines, Polk County, Iowa*. Iowa City, IA: Tallgrass Historians L.C., 2009. Historic Context, Submitted to City of Des Moines, Engineering Department. Copies available from the State Historical Society of Iowa.

Rogers, Leah D., and Jennifer A. Price. *Historic Context for the Keokuk Sewer System, City of Keokuk, Lee County, Iowa*. Iowa City, IA: Tallgrass Historians, L.C., 2012. Historic Context, Submitted to City of Keokuk, Public Works Department. Copies available from the State Historical Society of Iowa.

Rogers, Lead D., and Lori Vermaas. *National Register of Historic Places Nomination: McGregor Commercial Historic District*. Iowa City, IA: Tallgrass Historian L.C., 2002.

Rogers, Niart. "Report on Sewage Disposal." In *Twentieth Annual Report of the Board of Health of the State of New Jersey, and Report of the Bureau of Vital Statistics, 1896,* 270-306. Trenton, N.J.: MacCrellish & Quigley, State Printers, Opposite Post Office, 1897.

Rolak, John S. *City of Bayonne Combined Sewer System, Annual Inspection and Assessment Report, NJPDES Permit No. 0105023 and Individual Authorization No. 0109240, dated October 1997*. Whitehouse: Killam Associates, 1997. https://www.nj.gov/dep/passaicdocs/docs/3rd-PartyComplaintNexusPackages/3rd-PartyComplaintANexus/BayonneSystem.pdf (accessed July 21, 2023)

Rutsch, Edward S. "New Jersey's Cultural Resources: A.D. 1865 to the Present." In *New Jersey's Archeological Resources, A Review of Research Problems and Survey Priorities: The Paleo-Indian Period to Present*, edited by Olga Chesler, 241-255. Trenton: New Jersey Historic Preservation Office, 1982. https://www.nj.gov/dep/hpo/1identify/pg_241_NJCulturalResourc1865_nowRutsch.pdf (accessed July 21, 2023)

Sandage, Scott A. *Born Losers: A History of Failure in America*. Cambridge: Harvard University Press, 2005.

Santiago, Héctor and Luis Pumarada. *National Register of Historic Places Nomination: Alcantarilla Pluvial sobre la Quebrada Manzanares*. San Juan, Puerto Rico: Puerto Rico Historic Preservation Office, 1990.

Scharfenberger, Gerry. *Archaeological Monitoring, Kerrigan Avenue Sewerage Replacement Project, City of Union City, Hudson County, New Jersey*. Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2006. Cultural Resources Survey, Prepared for CH2M Hill. Copies available from the New Jersey Historic Preservation Office, Trenton.

Schladweiler, Jon C. "Design Choices and Philosophies." *Sewer History*. 2022. https://sewerhistory.online/time-lines/tracking-down-the-roots-of-our-sanitary-sewers/part-5-design-choices-and-philosophies/ (accessed October 13, 2022)

—. "Early American Sewerage Engineers." *Sewer History*. 2022. https://sewerhistory.online/time-lines/tracking-down-the-roots-of-our-sanitary-sewers/part-4-early-american-sewerage-engineers/ (accessed October 13, 2022)

—. "Early Sewage Conveyance Systems." *Sewer History*. 2022. https://sewerhistory.online/time-lines/tracking-down-the-roots-of-our-sanitary-sewers/part-6-early-sewage-conveyance-systems/ (accessed October 13, 2022)

—. "The New American "Roots"." *Sewer History*. 2022. https://sewerhistory.online/time-lines/tracking-down-the-roots-of-our-sanitary-sewers/part-3-the-new-american-roots/ (accessed October 13, 2022)

—. "Pipes – ancient/early types (1)." *Sewer History*. 2022. https://sewerhistory.online/photosgraphics/pipes-ancientearly-types-1/ (October 13, 2022)

Schopp, Paul W. *National Register of Historic Places Nomination: Gloucester City Water Works Engine House*. Haddonfield: Remington & Vernick, Engineers, 1997.

Scott, William W. *History of Passaic and Its Environs, Historical - Biographical*. 3 vols. New York and Chicago: Lewis Historical Publishing Company, Inc., 1922. https://hdl.handle.net/2027/wu.89066012410 (accessed July 21, 2023)

Seattle Department of Transportation. *Cultural Resources Technical Report for the First Avenue Sewer Rehabilitation. In Seattle Center City Connector Environmental Assessment, Appendix A-6*. Seattle: Seattle Department of Transportation, 2017. https://web.archive.org/web/20181024195908/https://seattlestreetcar.org/wp-content/uploads/2017/06/SEPA_AppendixA6_SewerCulturalResReport.pdf (accessed July 21, 2023)

Shaw, William H. *History of Essex and Hudson Counties, New Jersey*. 2 vols. Philadelphia: Everts & Peck, 1884.

Sheridan, Mimi. *Lake Union Sewer Tunnel. National Register of Historic Places Registration Form*. Sheridan Consulting Group. United States Department of the Interior, National Park Service, 2012.

Shimer, H.W. "Equipment and Methods Employed in Building Sewers in San Francisco, Calif." *Municipal and County Engineering* 56, no. 4 (1919): 136-140.

Shriner, Charles A. *Paterson, New Jersey. Its Advantages for Manufacturing and Residence: its Industries, Prominent Men, Banks, Schools, Churches, etc.* Paterson: The Press Printing and Publishing Company, Paterson, N.J., 1890. https://hdl.handle.net/2027/hvd.hb5ivq (accessed July 21, 2023)

Sikora, Edward J. "ASTM and the National Clay Pipes Institute: 100 Years of Teamwork and Achievement." *ASTM Standardization News* (2004). https://web.archive.org/web/20200807184300/https://www.astm.org/SNEWS/AUGUST_2004/sikora_aug04.html (accessed July 211, 2023)

"Six Years' Experience with the Memphis Sewers." *The Engineering & Building Record and the Sanitary Engineer* 16, no. 26 (1887): 738.

Smith, John B. “Report on the Mosquito Work for 1911.” In *Report of the Entomological Department of the New Jersey Agricultural College Experiment Station, New Brunswick, NJ, for the Year 1911,* 505 – 582. Trenton, N.J.: State Gazette Publishing Co., Printers, 1912.

Snow, John. *On the Mode of Communication of Cholera.* London: John Churchill, Princes Street, Soho, 1849.

—. *On the Mode of Communication of Cholera.* 2nd ed. London: John Churchill, New Burlington Street, 1855.

Snyder, John P. *The Story of New Jersey’s Civil Boundaries, 1606-1968*. Trenton, N.J.: Bureau of Geology and Topography, 1969. https://www.state.nj.us/dep/njgs/enviroed/oldpubs/bulletin67.pdf (accessed July21, 2023)

Southard, Lott. “Essex Water Supply. Drainage and Sewerage of the City of Newark, and their Relation to the Causation of Disease – The President’s Annual Address to the Essex District Medical Society.” *Transactions of the Medical Society of New Jersey* (1877): 192-200.

Springer, J.F. “Construction of Vitrified Pipe Lines.” *Municipal Engineering* 52 (January-June 1917): 236-240.

—. “Iron and Steel Sewer Pipe.” *Municipal Engineering* 51, no. 3 (1916): 87-91.

—. “Methods of Concrete Sewer Construction.” *Municipal Engineering* 51, no. 2 (1916): 47-52.

Staley, Cady and George S. Pierson. *The Separate System of Sewerage: Its Theory and Construction.* New York: D. Van Nostrand, 1886.

Tarr, Joel A. *The Search for the Urban Sink, Urban Pollution in Historical Perspective.* Akron: The University of Akron Press, 1996.

Tracy, Prescott “Prison at Andersonville, GA., Camp Sumter.” *The Sanitary Commission Bulletin* 1, no. 21 (1864): 652-654.

Turner, Jean-Rae, and Richard T. Koles. *Elizabeth, The First Capital of New Jersey*. Charleston: Arcadia Publishing, 2003.

Tomaso, Matthew S. *Phase IA Cultural Resource Reconnaisance, Passaic Valley Sewerage Commission, Newark Bay Outfall Sewerage Works, City of Newark, Essex County, New Jersey*. Warren, NJ: PS&S, 2013. Copies available from the New Jersey Historic Preservation Office.

United States. Board of Health. *Annual Report of the National Board of Health.* Washington: Government Printing Office, 1879. https://hdl.handle.net/2027/mdp.39015028132390 (accessed July 21, 2023)

United States. Environmental Protection Agency. *The History of Drinking Water*. Office of Water: February 2000. https://archive.epa.gov/water/archive/web/pdf/2001_11_15_consumer_hist.pdf (accessed July 21, 2023)

United States. Sanitary Commission. *The Sanitary Commission of the United States Army, A Succinct Narrative of its Works and Purposes*. New York: Published for the Benefit for the United States Sanitary Commission, 1864. https://hdl.handle.net/2027/hvd.32044011756921 (accessed July 21, 2023)

—. *The United States Sanitary Commission, A Sketch of Its Purposes and Its Work, Compiled from Documents and Private Papers*. Boston: Little, Brown and Company, 1863.

Urquhart, Frank John. *A History of the City of Newark, New Jersey, Embracing Practically Two and a Half Centuries, 1666-1913*. 3 vols. New York: The Lewis Historical Publishing Company, 1913.

Vail, M.H.C. *Essex County, N.J., Illustrated*. Newark, N.J.: Press of L.J. Hardham, 1897.

Van Abs, Daniel J., Alexander McClean, Ioanna Tsolous, Yuling Gao, and Tim Evans. *Water Infrastructure in New Jersey's CSO Cities: Elevating the Importance of Upgrading New Jersey's Urban Water Systems*. New Brunswick: Rutgers University, 2014.

Van Oosten, Roos. "The Dutch Great Stink: The End of the Cesspit Era in the Pre-Industrial Towns of Leiden and Haarlem." *European Journal of Archaeology* 19, no. 4 (2016): 704-727. https://www.cambridge.org/core/services/aop-cambridge-core/content/view/C2FBEA4E864D8618606E275214FC3615/S146195710001323 1a.pdf/dutch_great_stink_the_end_of_the_cesspit_era_in_the_preindustrial_towns_of_leiden_and_haarlem.pdf (accessed July 21, 2023)

Veit, Richard. "Setting the Stage, Archaeology and the Delaware Indians, a 12,000-Year Odyssey." In *New Jersey: A History of the Garden State*, edited by Maxine N. Lurie and Richard Veit, 6-32. New Brunswick: Rutgers University Press, 2012.

Viele, Egbert L. *Report on Civic Cleanliness, and the Economical Disposition of the Refuse of Cities*. New York: Edmund Jones & Co., Printers, 1860.

Wacker, Peter O. "New Jersey's Cultural Resources: A.D. 1660-1810." In *New Jersey's Archeological Resources, A Review of Research Problems and Survey Priorities: The Paleo-Indian Period to Present*, edited by Olga Chesler, 199 – 219. Trenton: New Jersey Historic Preservation Office, 1982. https://www.nj.gov/dep/hpo/1identify/pg_199_NJCulturalResourc1660_1810Wacker.pdf (accessed July 21, 2023)

Wall, John P., and Harold E. Pickersgill. *History of Middlesex County, New Jersey, 1664-1920, under the associate directorship of John P. Wall and Harold E. Pickersgill assisted by an Able Corps of Local Historians, Historical-Biographical*. 2 vols. New York and Chicago: Lewis Historical Publishing Company, Inc., 1921.

Ward, Aaron. Patent # US328552A. Camden: 1885. https://patents.google.com/patent/US328552A/en?oq=US328552 (accessed July 21, 2023)

Waring, George E., Jr. *Concerning Mr. Rudolph Hering's Project for the Sewerage of Binghamton, N.Y.* Newport, R.I.: Marshall & Flynn, Printers, 1883.

—. *The Sanitary Drainage of Houses and Towns*. 11th ed. Boston and New York: Houghton, Mifflin and Company, 1876.

—. *Sewerage and Land Drainage*. 3rd ed. New York: D. Van Nostrand Company, 1891.

—. *Report on the Social Statistics of Cities, Part 1, the New England and the Middle States*. Washington: Government Printing Office, 1886.

Watson, Hugh Sexton. *Sewerage Systems, Their Design and Construction*. New York: McGraw-Hill Book Company, 1911.

Wheeler, H.A. *Vitrified Paving Brick, A Review of Present Practice in the Manufacture, Testing and Uses of Vitrified Paving Brick*. Indianapolis, Ind.: T. A. Randall & Co., Publishers, 1910.

Whipple, George C. "Appendix I. Composition of Paterson Sewage." In *Report of the Joint Committee and of the Consulting Engineer on the Subject of Sewage Disposal on the Sewage Disposal of Paterson, NJ*. Paterson, N.J.: Chronicle Print, 1906.

Whitcomb, Royden Page. *First History of Bayonne, New Jersey*. Bayonne, N.J.: Published by R.P. Whitcomb, 1904. https://hdl.handle.net/2027/coo1.ark:/13960/t2f76xp63 (accessed July 21, 2023)

Whittemore, Henry. *The Founders and Builders of the Oranges, Comprising a History of the Outlying District of Newark, Subsequently known as Orange, and of the Later Internal Divisions, viz.: South Orange, West Orange, and East Orange; Also, a History of the Early Settles or Founders, and of Those Who Have Been Identified with its Growth and Prosperity, known as the Builders, 1666-1896*. Newark, N.J.: L.J. Hardham, Printer and Bookbinder, 1896.

Whitwell, William Scollay. *Report Made to the Water Commissioners of Jersey City, April 11th, 1853, upon a Plan of City Sewerage*. New York: Van Norden & King, Stationers, 1853.

Whorton, James. "'The insidious foe'-sewer gas." *Western Journal of Medicine* 175, no. 6 (December 2001): 427-428. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1275984/ (accessed July 21, 2023)

Wieczorek, Scott, and Michael Tomkins. *Archaeological Monitoring, North Hudson Sewerage Authority, H1 Screening and Wet Weather Pump Station, City of Hoboken, Hudson County, New Jersey*. Cranbury, New Jersey: Richard Grubb & Associates, Inc., 2012. Archaeological Monitoring, Prepared for CH2M Hill. Copies available from the New Jersey Historic Preservation Office.

Winfield, Charles H. *History of the County of Hudson, New Jersey, from its earliest settlement to the present time*. New York: Kennard & Hay Stationery M'fg and Printing Co., 1874. https://hdl.handle.net/2027/hvd.hnzahb (accessed July 21, 2023)

Wood, G.M. "The Future and the Present of Concrete Pipe." *Cement and Engineering News* 28, no. 11(1916): 231-233.

Wosh, Peter J. "Orange." In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 605. New Brunswick: Rutgers University Press, 2005.

Wosh, Peter J. "Perth Amboy." In *Encyclopedia of New Jersey*, edited by Maxine N. Lurie and Marc Mappen, 629. New Brunswick: Rutgers University Press, 2005.

Yost, Stephen W., and Glenn R. Modica. *Stage IA Cultural Resources Survey, Remsen Avenue Storm Sewer Improvements, City of New Brunswick, Middlesex County, New Jersey*. Cranbury, New Jersey: Richard Grubb & Associates, Inc. 2003. Cultural Resources Survey, Submitted to CME Associates, Inc. Copies available from the New Jersey Historic Preservation Office, Trenton.

Zerbe, Nancy. "Monitoring report for the Combined Sewer Overflow Project, CSO Site C05/10. ARCH2. Letter submitted to Elizabeth Davis, NJDEP." August 24, 2009. Copies available from the New Jersey Historic Preservation Office, Trenton.

—. "Monitoring report for the Combined Sewer Overflow Project, CSO Site C10/15. ARCH2. Letter submitted to Elizabeth Davis, NJDEP." January 29, 2010. Copies available from the New Jersey Historic Preservation Office, Trenton.

Zerbe, Nancy, Marianne Walsh, and Angela Materna. *Historic American Buildings Survey, Chestnut Street Pumping Station*. Metuchen, New Jersey: ARCH^2, Inc., 2008.