Introduction

Cities, Sprawl, and Climate Change

The *Entrepôt* City

Chicago is a city built on water. Its *raison d'état* as a place of Euro-American settlement was a river, which linked the Great Lakes to the Mississippi River. Among the earliest explorers of the water routes into the interior of the mid-continent were Father Jacques Marquette and Louis Jolliet. In 1673, Native Americans guided their canoes along the western shore of Lake Michigan to the Green Bay peninsula, the Fox and Wisconsin Rivers, and down the Mississippi to within 450 miles/724 kilometers (km) of the Gulf Coast. Turning back and paddling upstream, they took a shortcut into the Illinois and Des Plaines Rivers and then crossed a marshy portage into the Chicago River. Returning in the winter of 1674, Marquette became too sick to continue a second trip farther downstream. He kept a journal while encamped about 6 miles/9.7 km from the lake, near the site of the portage where the south branch of the Chicago River petered out. He spent four months there, waiting for his health to return and the water highway's ice to melt.

The following spring, the Jesuit priest recorded the first account of a flood. "On the 29th [of March]," he writes, "the waters rose so high that we had barely time to decamp as fast as possible, putting our goods in the trees, and trying to sleep on a hillock. The water gained on us nearly all-night, but there was a slight freeze, and the water fell a little, while we were near our packages." Two days later, he resumed his mission but could no longer find the portage—later called Mud Lake—to the Des Plaines River. On the contrary, he observes in his journal, "the very high lands alone are not flooded. At the place where we are, the water has risen more than 12 feet [3.7 meters]. This is where we began our portage eighteen months ago." After a few more days' delay to let

the "dangerous rapids" subside, he was able to proceed across the temporary lake without having to carry his heavily loaded canoe overland.[1]

Looking closer at Marquette's account reveals the fundamental relationship between Chicagoans and their flood-prone environment. The explorer was taken by surprise, because the water rose without the usual forewarning of a rainstorm. Instead, a spring thaw was enough to cause a surge of surface runoff. Marquette did not need a geologist to inform him that the source of the "dangerous rapids" had to be the Des Plaines River. The terrain was so flat that runoff could flow in any direction. He could see that the water was flowing in the opposite direction from its normal course from east to west. What he could not see was the impermeable layer of clay just below the surface soils. The melting snow quickly saturated this ground, forming innumerable tiny rivulets that fed small brooks and streams, leading into slightly larger creeks that poured into the river, which overflowed its banks and turned the portage into a lake. Encompassing the entire Chicago area, this topography is what I call a prairie wetland (see Figure I.1).[2]

The priest's journey also sheds light on humans' dependence on the waterways as an essential economic asset. Before the coming of the railroad 175 years later, moving people and goods on water was cheaper, faster, and more efficient than any alternative means of travel on land. Although Marquette's primary mission was saving the souls of the Indians, a related goal was establishing trade with them. During his layover in Chicago, he exchanged tobacco for beaver and ox skins, corn, and pumpkins. As he learned, even floods could be beneficial when they submerged overland routes and eased transportation across them. At the same time, they could result in lost property and lives as a consequence of human failure. In his case, building a cabin on low-lying ground near the river put his material possessions at risk. In other words, floods are natural; flood *damages* are caused by humans.[3]

Another piece of vital information about the site of Chicago can be extracted from Father Marquette's journal: it was a land of plenty. He describes not only the Indians' willingness to trade their surplus of food supplies but also an abundance of wildlife to supplement his diet, including deer, partridges, and pigeons. He was at the center of what William Cronon has aptly called *Nature's Metropolis*. In this milestone study of environmental history, he reunites the urban and the rural in symbiotic relationship. Cronon shows how the city and the surrounding hinterland grew in tandem, each shaping the development of the other. To harvest nature's bounty, Chicago remained a frontier outpost until 1825, when the completion of the Erie Canal opened a water route between New York City and the Great Lakes. Then, the Euro-Americans poured in, pushing out the Native Americans. A new landscape of farms, city homes, grain warehouses, factories, and shipping docks was erected on this prairie wetland. Chicago became an *entrepôt*, the place where the water stopped and the Great West began.[4]

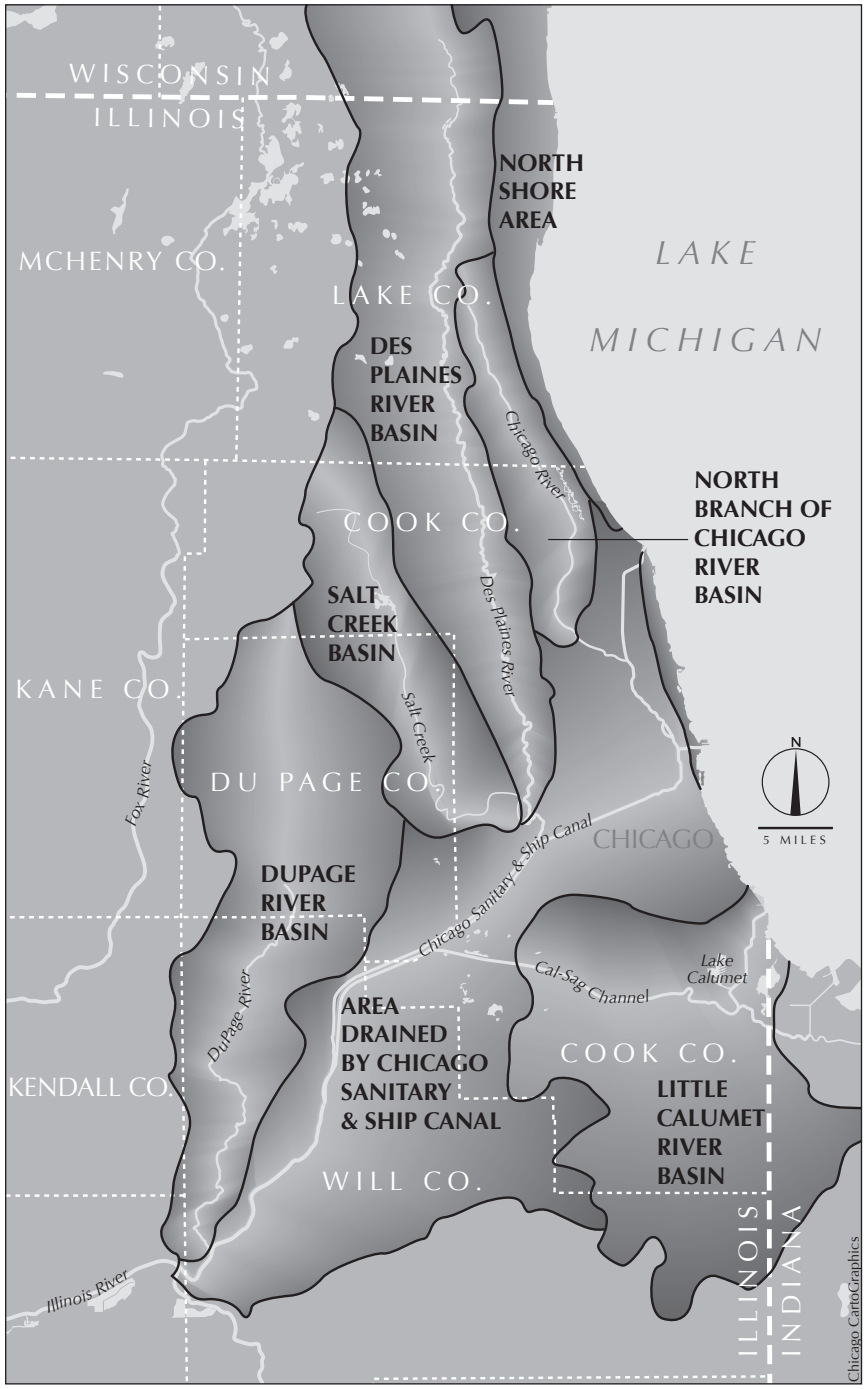

Figure I.1. Chicago's Six Watersheds (Chicago CartoGraphics)

In contrast to Cronon's book, the aim of this environmental history of Chicago is to reunite the water and the land. This book is the first study of the effects of long-term climate change on an American city. *Sinking Chicago* is based on 130 years of weather records, which show a pattern of dry years from 1885 to 1945, followed by a still ongoing wet period of more-frequent and more-severe rainstorms.[5] Chicago is flood-prone because it was built on flat land with poor drainage and an impervious layer of clay just below the surface. This book examines how residents, politicians, and policy makers have grappled with the dual problem of flood control and water quality. In building a city on top of a prairie wetland, people forgot the environmental connection between land use and water management. As they paved over the land, they turned the rain into ever-more-damaging runoff surges of storm water that sank their city and contaminated their drinking supplies with raw sewage.

The Exploding City

The Great Chicago Fire of 1871 is the place to begin this story about the ways in which climate change taught a city how to adapt to living in a flood-prone environment. Costing at least three hundred lives, this disaster was the price paid for losing sight of the links between water and land. Without water, a small accidental fire ended up burning down an entire city built of wood. Starting on the near West Side, flickering embers soon blew across the river, torching the main water-pumping station in the central business district. The conflagration consumed eighteen thousand buildings and made a hundred thousand people, or one-third of the population, homeless. Ironically, a new water tower and pumping station on the North Side were among the few surviving structures. Despite the expensive construction of this public utility, the firemen were left defenseless against the spreading flames. They were completely overwhelmed by another regular weather pattern of the midwestern prairie that makes Chicago known as the "Windy City." From spring to winter, currents of hot air from the southwest prevail, sometimes with gusts of more than 30 miles/48 km per hour. On that October 8, the winds were especially strong, following a three-month drought that left the built environment tinder dry. The fire ultimately burned itself out two days later, as it reached the outer edges of the city.[6]

This human-made disaster exposed the shortcomings of building an urban environment under a regime in which "property ruled."[7] A political culture of privatism adhered to the Jeffersonian ideal that the best government was the least government. In contemporary terms, Chicago's civic leaders were advocates of public policies that delegated most city-building functions to the private sector. Paving streets and sidewalks; supplying water; laying roads to the suburbs; providing streetlights, gas service, and public transit; and even protecting against fires were all consigned to it. Although

the waterworks was the one significant exception, it, too, was run like a private business by a city council devoted to maximizing the profits of the municipal corporation. Their siphoning of most of the utility's revenue to pay for other things kept its expansion lagging far behind the explosive growth of the city. Since the coming of the railroad in the late 1840s, Chicago had become the fastest growing urban center in the Western world, roughly doubling in population every decade to the end of the nineteenth century.[8]

This surge of newcomers caused another human-made disaster: a cholera epidemic from contaminated supplies of drinking water. Chicagoans were forced to take collective charge of the quality of drinking supplies and the removal of disease-breeding effluents. Beginning in the 1850s, the separation between land use and water management became increasingly institutionalized in private associations of real-estate brokers and government departments of public health and public works. As urban growth paved over a flood-prone environment on a metropolitan scale during the Gilded Age, the ability of individuals to protect their property against the effects of climate change diminished, while the power of government increased at each level of the federal system. Landowners and other residents looked to their policy makers to solve Chicago's dual problem of water quality and flood control.[9]

The low-lying peninsula of marshland formed by the lake and the river had become the geographical center of the city. The main street, appropriately named Market Street, paralleled the Main Branch of the river, just behind the docks and warehouses lining it and stretching along its South and North Branches. As the aspiring metropolis swelled with newcomers, the river became its greatest economic asset and a physical barrier to growth. For ships, it was a safe haven from the dangerous storms that swept across the lake. But for people, the river blocked movement, because every bridge thrown across it impeded the crucial flow of traffic in and out of this harbor. For the remainder of the nineteenth century, Chicago expanded mostly to the south, while development of the North and the West Sides was stunted in comparison.[10]

The river at flood stage also played a dual role of natural advantage and human-made disaster. The spring thaw recorded by Marquette that submerged the portage and created a wave sweeping down the South Branch had the effect of flushing the sedimentation on the riverbed into the lake. Local sanitary officials considered these "freshets" a blessing that saved the city the cost of dredging the river's bottom. When this annual event coincided with heavy rains, however, an ice-chunk-laden wave could barrel down the river with destructive force. On March 12, 1849, just such an extreme weather event tore through the downtown area, smashing all the bridges and piling the ships in the harbor on the riverbanks like a stack of cordwood.[11]

Thus, Chicago was forced to confront its first civic crisis: water management. Following the flood, a cholera epidemic from contaminated drinking

supplies turned Chicago into the unhealthiest city in the country. Its citizens had to figure out a way to bring good water in and move the bad out. The problems of water supply and wastewater removal are inseparable. People recognized that they would have to follow the lead of other urban centers, such as Philadelphia and Boston. In 1850, they decided to construct a waterworks that pumped fresh water from the lake through a distribution network of mains and pipes. At the same time, bringing more water into a flood-prone environment compounded all the problems of draining the city's muddy, vermin-infested streets and alleys. As the growth of Chicago was on the verge of turning an imagined metropolis into a real one, the city's future depended on establishing a new relationship with water.[12]

In the wake of the great fire, questions of land-use regulation paralleled public debate on restoring the water supply and the fire hydrants. Massive protests erupted when the city council attempted to enact a building code requiring a "fire-proof" city of bricks, which would have significantly raised the cost of housing compared to wood construction. Chicago entered a general state of class warfare that lasted a quarter of a century. Punctuating the relentless struggle between capital and labor were major pitched battles, including the first national (railroad) strike of 1877, the eight-hour-work-day movement leading to the Haymarket riots of 1886, and the Pullman strike of 1894, when the army occupied the city. The extent to which the environmental conditions of the working class contributed to these events cannot be considered separately from other causes of discontent.[13]

In part, human capacities to build decent housing and public utilities were simply overwhelmed in this exploding city. Yet, a political culture of privatism and a regime of corrupt ward bosses helped widen the gap of environmental inequality between the rich and the poor. The betrayal of the working class on behalf of the slumlords contributed to horrendous rates of infant mortality as well as disproportionate levels of sickness and death among the masses of the city's inhabitants. By the time Jane Addams and Ellen Gates Starr moved into Hull-House in one of the notorious river wards in 1889, for example, reformers estimated that the city had forty thousand illegal outhouses. In plain sight and smell of the health inspectors, they could exist only with the tacit approval of city hall. By then, new waves of water-borne diseases had again reached epidemic levels. This public-health crisis would force the political establishment to undertake another round of heroic public-works projects to regain control of nature.[14]

The Metropolitan City

Chicago always had suburbs, but the Great Fire of 1871 gave them an instant infusion of inhabitants and money. While many of these refuges became residents of shantytowns on burnt-over land, others were absorbed into the city's

spokelike strings of railroad suburbs. A brief look at three different outlying communities linked with a river watershed serves to introduce the history of the metropolitan idea in Chicago.[15]

About 12 miles/19 km north of the city center, a narrow ridge of high land between the North Branch of the Chicago River and the lakefront was a privileged patch of dry, tree-shaded land. One of the first suburbs on this "North Shore" was Evanston, a religious community formed in the 1850s around its school, Northwestern University. An equal distance west of downtown on the Des Plaines River—a thirty-minute train ride—was another high point, Riverside. Just after the Civil War, speculators hired New York City's famous landscape architects Frederick Law Olmsted and Calvert Vaux to turn it into a residential enclave for the well-to-do.[16] To the southeast the same distance along the lakefront was the working-class settlement of Ainsworth, sited at the mouth of the Grand Calumet River and the bottleneck of rail lines coming around the bottom of the lake. Already a thriving, second *entrepôt*, it would be renamed South Chicago after the fire, when it became a favorite site of heavy industry looking to relocate a safe distance from the river congestion and pollution problems in the city's center.

From frontier days, the settlement of the Chicago area can be characterized as villages arising on islands of high land surrounded by a treacherous "sea of mud." What is called "urban sprawl" has never been a one-way flow from the core to the periphery: it is more complicated, because people have always been moving into and within the center at the same time. Consider that each household deserting the city for the suburbs leaves behind a vacant dwelling for another to occupy. Since the coming of the railroad and the telegraph in the late 1840s, Chicago has been going through a simultaneous process of centralization and decentralization. Its earliest suburban settlements served as outposts of future development. "Many were near area rivers and lakes," historian Ann Durkin Keating observes. "Camp meetings, golf courses, picnic groves, beer gardens, amusement parks, cemeteries, and religious and public institutions served as the centers of these settlements."[17]

Before the laying of iron rails on raised embankments, overland travel by horse-drawn, wheeled vehicles across Chicago's prairie wetland impeded the growth of residential, commuter suburbs. The situation of wagons getting inescapably stuck was so common that it earned a special term, "being 'slewed' [sloughed] on the prairie," and gave birth to a local hero, the "mud pilot." These young men learned that the best way to navigate across such wet, featureless landscapes was to strike out across them where no one had previously laid any tracks. "Their beaten paths are deceptive," a veteran of these times remembered, "for once broken through, this sea of mud will prove bottomless. Your wagon will go down to the axles, and you will soon see the way strewn with such wreaks."[18]

In searching for a protected place for their settlement, the decisive factor for the Methodist founders of Evanston was a suburban location with railroad access to the city. In selecting a 379-acre/153-hectare (ha) farm on the North Shore's lakefront in 1853, they purchased a soggy, albeit beautiful site on which to build an oasis of religious values and moral order. The key to their creation of a self-image as a sanctified village was the "4-mile/6 km limit," which banned the sale of alcohol within this island community. The sudden influx of refugees from the great conflagration only strengthened the resolve of its leaders to enforce prohibition and to maintain an identity separate from the city. During the next two decades, Evanston became the national headquarters of the Woman's Christian Temperance Union and the neighborhood center of twenty-two churches.[19]

Already the richest suburb, with three thousand residents listed in the 1870 census, Evanston underwent a 50 percent growth spurt following the Chicago fire. One of the children born there because of his parents' being burned out of their home on the North Side was Maurice Webster. His mother told him that she and his father had been able to load up a wagon and get the family to her brother's house. They lived there for several months while a new house and barn were being built nearby. The "strangers," the local newspaper boasted, "are learning, now, how much cleaner and more quiet and pleasant is our village than the city, and how much better it is for their children." Apparently, the Websters, with six boys to raise, were convinced.[20]

However, the vast majority of Chicagoans were reluctant to abandon their urban amenities for the country life. Besides all the modern conveniences of indoor plumbing, affluent city dwellers could enjoy artificial gas lighting in their homes and an array of street improvements, including pavement, lighting, drainage, and, perhaps, public transit services. In contrast, suburbanites depended on backyard wells and privies, kerosene lamps, jerry-built "plank roads," and, perhaps, a staff of servants to do the endless chores of house cleaning. Only a few prosperous railroad suburbs, including Evanston, could afford urban infrastructure, such as a waterworks or a sewer system; most had to suffer annual damaging floods and perennial seas of mud. To overcome the shortcomings of life in the country, real-estate developers after the Civil War promoted a plan to create an exclusive residential nature park with all the urban amenities included.[21]

The speculators selected a patch of exceptionally high land called Riverside Park that had recently been crossed by a railroad heading west from the center. Now that the rigors of overland travel had been replaced by a half-hour ride in comfort, the destination point of the mud pilots was ripe for redevelopment from a seasonal racetrack and picnic grounds into a pastoral retreat for the city's best men. Reflecting the counterintuitive nature of Chicago's topography, this heavily wooded 1,900-acre/769 ha piece of land surrounds the Des Plaines River as it snakes back and forth across the prairie. To the

southeast lay Mud Lake (present-day Lyons and Stickney), but here the river stayed in its banks most of the time. Gaining control of the farmland in exchange for improvement company stock, the company directors hired the designers of New York's Central Park, Olmsted and Vaux, to draw a master plan of homes nestled in a picturesque setting of the river and the woods. Using credit secured by the land, they built an impressive waterworks tower, an arcade building, a first-class hotel near the train station, a coal-gas manufacturing plant, lighted streets and sidewalks paved with concrete and stones, and designer houses with a $5,000-minimum price tag.[22]

Initial enthusiasm for the success of Riverside was overwhelming. Like the planners, more and more city dwellers believed that "'the most attractive, the most refined and the most soundly wholesome forms of domestic life' were to be found in residential suburbs."[23] Beginning in 1868, its developers sponsored weekend excursions for elite members of society to showcase their property to these potential buyers. Journalists along for the (free) ride aboard luxury Pullman club cars outdid themselves describing the modern technology and the natural beauty of this residential suburb-in-the-making. On one such junket in May 1869, the guests were greeted by Olmsted and Vaux, who became their tour guides. Making the hard sell, Olmsted "claimed that Riverside presented advantages over any park ever laid out in the United States. The land was both fertile and high; the Des Plaines River was unsurpassed for its general beauty; the forest was abundant; and there was no good reason why Riverside Park should not be made the most attractive place on the continent."[24]

In fact, good reasons shattered the suburban vision of its designers and developers. Bad timing undermined the financial house of cards holding up the improvement company. The great fire drained off its construction workers, who suffered no loss of commuter fares or work time in choosing to accept jobs close at hand. In 1873, a national depression halted home sales, while the company's unpaid bills for its infrastructure projects piled up. In a desperate attempt to stay financially afloat, its directors issued more and more stocks and bonds until the unbearable load of this paper debt collapsed. In July 1874, investors sued them for fraud, building a four-year case in equity court that set a new record with 12,000 pages of documents, including the 103-page decision of the trial judge. Although the bursting of this land bubble did not diminish the natural beauty of a riverine landscape, it had the effect of lowering the suburb's rate of growth, land values, and social status.[25]

If the timing of the Chicago fire helped cause the crash of Riverside, it sparked a sustained boom in Ainsworth/South Chicago. The city's second port was well prepared to meet the needs of industry and trade, the result of a public-private partnership. Before the fire destroyed a large proportion of the piers, lumberyards, and factories on the Chicago River, the U.S. Army

Corps of Engineers had begun dredging the entrance and mouth of the Grand Calumet River as an alternative safe harbor at the bottom of Lake Michigan. A private company had installed docks, shipyards, and railroad sidings and was selling riverfront sites for storage facilities, including grain, lumber, coal, and iron ore. These warehouses, in turn, fed heavy industries, such as steel mills, machine shops, oil refineries, fertilizer plants, and breweries, that generated lots of toxic wastewater.[26]

The growth of the population of South Chicago is a good case study of the simultaneous process of decentralization and centralization in a metropolitan region. When industry moved to the suburbs, the construction of housing for its workers followed close behind. These people had to walk to work, because they could not afford to take streetcars or commuter trains. After the fire of 1871, workers followed their jobs from the core to the periphery. At the same time, newcomers were moving to Chicago in expectation of finding jobs in its expanding metropolitan economy. Thousands of these immigrants and transplanted residents alike would land in a South Chicago neighborhood called "Bush." Choked by smoke and crammed with wood-frame two-flat apartment buildings and cottages, it was totally lacking in urban infrastructure and utility services. "Bush," local historians Dominic A. Pacyga and Ellen Skerrett say, "was a typical Victorian industrial slum." In spite of a suburban location, it was not unlike equally disease-ridden counterparts within the city limits along the Chicago River and in Packingtown, the back-of-the-[stock]yards residential district. Bush was one of several ethnic/racial/religious working-class neighborhoods of South Chicago and other mill-gate communities being erected around the southeastern side of the lake.[27]

While manufacturing districts in the periphery, like South Chicago, were being built into environments that were more industrial than residential, plenty of wild places remained in the Chicago area. Just to the west of this industrial suburb arising on the lakefront was some of the best duck hunting in the entire country. Within earshot of the factory whistles of what was known as the Calumet District, the gunshots of hunters rang out thousands of times during the birds' semiannual migrations. Dating to before the Civil War, elite society had established men's clubs in this vast expanse of shallow lakes, swampy marshes, and interconnected rivers. One sportsman in an 1884 issue of *American Field* magazine asks rhetorically, "Who has not been to Calumet hunting?" He recounts "how the blood fairly races through one's veins as just at daybreak the first flocks are seen skimming along the river! How your gun flies to your shoulder, and the bang! bang! followed by the swash, swash of from 2 to 6 of the little beauties." Anyone could "bag" at least fifty birds without effort, he testifies, and a full day's shootout could bring down five or six times as many.[28]

Five years later, a reporter for *Forest and Stream* would take note of his outing at the Grand Calumet Heights [Shooting] Club. Emerson Hough's de-

scription of the marshland along the river explains why the migrating water birds sought out this environment in which to rest and feed. "The Grand Calumet," he writes,

> is a necessarily slow, deliberate, tortuous and torturingly crooked stream. . . . It just strolls off among the sandhills and pine barrens toward the foot of the lake . . . and then chang[es] its mind and takes a while over in the opposite direction. Its general appearance is that of a long crooked valley of rice and cane, running between low wooded banks and stretching out from half a mile to three-quarters of a mile [0.8 to 1.2 km] or more in width. Somewhere in this winding marsh, hidden by what a poet would call the lush and dank sedges of the marsh, creeps the deliberate Grand, ten to fifteen feet deep in much of its channel, a lake creek rather than a river, and a darling for ducks.

Naturalists would pay similar homages well into the twentieth century to patches of beauty within the five other rivers' watersheds, the lake's sand dunes, and the prairie's wetlands of the metropolitan region.[29]

In the postfire era of the Gilded Age, the mutual interdependence of urban, suburban, and rural areas became more tightly woven by the railroad and the telegraph. In 1874, real-estate speculator Everett C. Chamberlin published a four-hundred-plus-page volume titled *Chicago and Its Suburbs*. This boosterish travel guide includes a map that marks the birth of a metropolitan idea of Chicago on a regional scale. As Elaine Lewinnek underscores, "Maps helped people imagine their burgeoning metropolis by making implicit projections about urban growth." Drawn by Rufus Blanchard, half of the map has a series of concentric circles superimposed over a territory radiating from downtown to embrace Cook and DuPage Counties as well as pieces of three other collar counties. Each of the twenty-two rings is 1 mile/1.6 km farther from the center, reaching nearly twice as far as Evanston, Riverside, and South Chicago (see Figure I.2).[30]

The map also highlights the twelve railroad lines fanning in all directions that had "transformed Chicagoland," according to suburban historian Ann Durkin Keating. She attributes the suburban origins of thirty-one farm centers, seventy industrial towns, thirty-five bedroom communities, and thirty-two recreational and institutional retreats as being linked to these iron rails. Like pearls on a string, the railroad suburbs and farming communities in between grew in tandem with the expanding, outer edges of the core. Together, this centralizing and decentralizing process of sprawl began to bring into focus a coherent image of the region as a single economy and society.[31]

A second wellspring of a metropolitan idea of Chicago came from the downside of this success: damaging floods over ever-more-widespread areas.

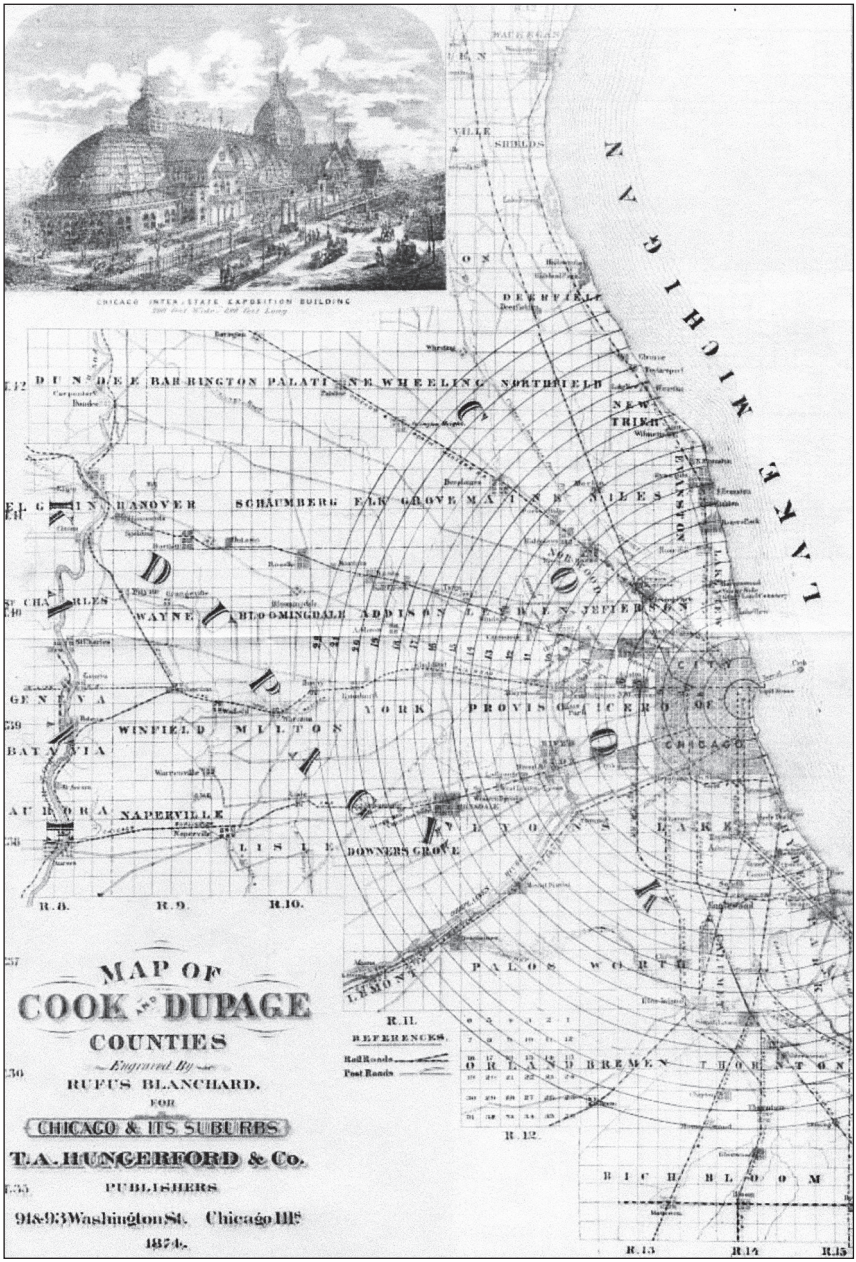

Figure I.2. Blanchard's Map of Chicago and Its Suburbs, 1874

In addition to the region's crazy quilt of overlapping governmental jurisdictions, rainwater has no respect for political boundaries. Outward extensions of the center combined with suburbanization to pave over and drain the land in a piecemeal fashion by public and private actors. Engineering a prairie wetland was producing greater volumes of surface runoff, which was being diverted from one property and watershed to another.

The most troublesome of these drainage projects was the Ogden-Wentworth Ditch, which regularly caused a repeat of Marquette's flood. Others paid the costs of draining their land near Mud Lake when its damlike embankment caused the Des Plaines River to overflow backward into the South Branch of the Chicago River. Bridgeport and other riverfront neighborhoods in the city suffered extensive inundations in February 1871, November 1872, May 1874, March 1875, April 1877, July 1878, June 1879, February and April 1881, February and November 1883, March 1884, and June 1885. Five years before the greatest rainfall yet of August 1885, the burgeoning suburbs on the banks of the 643-square-mile/1,665 square km watershed of the Des Plaines above Riverside began reporting flood damages. During this wet period, punctuated by 3-inch-plus/7 centimeter (cm) plus downpours, thousands of residents in the 450-square-mile/1,165 square km catchment of the Calumet District also witnessed their neighborhoods' seas of mud become lakes of sewage with increasing predictability.[32]

The Second City

By the time of the great flood of 1885, the explosive growth of Chicago and the interrelated, environmental problems of flood control and pollution control had brought into focus an idea of the city as a regional-scale metropolis. Adding a half million people during the 1880s, Chicago became the second-biggest city in the nation. Its built-up areas sprawled into and merged with its bordering communities, such as Edgewater, Jefferson, Cicero, Englewood, and Hyde Park. Extensions of the street railways and telegraph networks also knit the social and spatial fabrics of the urban and the suburban more tightly together.

Nonetheless, the gap between them in terms of modern infrastructure and utility services threatened to widen in coming years. An array of promising new technologies was coming online in the city center, including electric light and power, rapid (electric) transit, telephones, and an advanced generation of gas lighting and heating equipment. But with a few wealthy exceptions, such as Evanston, most outlying communities remained literally and figuratively stuck in a sea of mud. The public blamed the politicians for the chronic failure of government to manage storm runoff surges and safe drinking supplies.[33]

The real flooding on August 2–3, 1885, and the imagined threat of an

epidemic outbreak in its wake led Chicago to undertake systemic reforms of its governmental institutions to regain control of nature. The city's best men were stirred into action against city hall by fear that the gigantic freshet of heavily contaminated water from the historic, 6.2 inches (in.)/15.7 cm of rain in a twenty-four-hour period was reaching the 2-mile/3.2 km water supply intake crib. Like the game-changing electric technologies, germ theories of disease were establishing new standards for measuring the public health of the urban environment. Armed with petri dishes and microscopes, sanitary experts could now identify previously invisible bacterium in the drinking water as well as test the efficacy of various ways to filter and purify it. Over the next four years of civic debate and political contestation, the reformers gained approval for an annexation plan that would burst the city limits from 40 to 190 square miles/64 to 306 square km. Adding 220,000 people during this period, Chicago recorded more than a million inhabitants in the 1890 census. In addition, its civic elites created an independent agency, the Sanitary District of Chicago (SDC), which would soon embrace the 385 square miles/971 square km of the expanded city and its surrounding suburbs.[34]

In some respects, the reformers followed the plan laid out thirty years earlier by the city's first great public-works engineer, Ellis S. Chesbrough, albeit on a much larger, metropolitan scale. The SDC would dig a deep channel to permanently reverse the flow of the Chicago River, install interceptor sewers along the lakefront, and dilute the sewage emptying into the river with fresh water from Lake Michigan. But in other respects, they were influenced by many other novel ideas in addition to germ theories of disease. They embraced modern theories about urban society and healthy bodies, homeownership and gender roles, family life and child rearing, and organized sports and outdoor recreation.

This mix of old plans and new ideas was the result of what engineers call a "path dependency," or a technical system that severely limits alternative options in the future. Thirty years earlier, the city had put the manager of its waterworks in charge of investigating options for solving the drainage problem. At the beginning of his report, Chesbrough states in bold type that "the main object of the sewers is to improve and preserve the health of the city." But by the end, the bottom line of lowest cost became the decisive factor in choosing among the alternative plans. The engineer had done his homework, paying particular attention to London's sophisticated system of wastewater removal and treatment. In the biggest city in the Western world, large interceptor pipes under the embankments of the Thames River carried the effluents to "sewage farms," where the manure became fertilizer. This option and two others were rejected in favor of combined sewer and drain pipes that would empty into the river and the lake. Its advantage of being the cheapest to build and maintain overweighed objections "that it would endanger the health of the city, especially during the warm, dry portions of the year."[35]

This plan became the single-most-important decision in the city's history of its relationship with water and land for four reasons. The first was the path dependency created by building a combined versus separate system of sewerage and drainage, because pollution control and flood control became inseparable. Chesbrough acknowledged that the experts recommended a two-pipe solution, but with few such systems in operation, it could be dismissed as theoretical. To keep costs down, the pipes were designed to handle a maximum of 1 in./2.5 cm of rainfall in a twenty-four-hour period. For a city build on a prairie wetland, this would result in chronic flood damages from storm runoff contaminated with raw sewage.[36]

Second, the decision set the precedent of the subservience of technical expertise to political expediency. One does not have to read between the lines to gain a sense that Chesbrough felt ill at ease with the report's convoluted conclusions. His anxiety is expressed in several sidebars that list possible add-ons to the plan in the future, including building interceptor sewers parallel to the river and deepening the Illinois and Michigan Canal or installing pumps at its Bridgeport entrance to reverse the flow of the river away from the lake. The following year, his lack of confidence in the choice of the city's commercial-civic elite led him to travel to London and other cities in Europe to see for himself how their systems worked.

Upon returning, he wrote a supplementary report to reemphasize the goal of protecting the health of the city. "Public sentiment in favor of sanitary reform has been so thoroughly aroused," he claims, "that a problem so important as this will not be suffered to rest till a satisfactory solution is obtained. The feeling is becoming very general, that wherever practicable, sewage should not be allowed to pollute water courses of any kind." Pleading for a second look, he reiterates his recommendation for interceptor sewers and pins his hopes on the enlargement of the canal to cleanse the river with a steady flow of lake water. Some half measures along these lines were adopted in the coming, postfire years, but Chesbrough and his successors understood that their jobs depended on the subordination of their advice to the demands of politics. Engineers like Chesbrough became semantic experts in dismissing their own technical recommendations as "impracticable."[37]

Another enduring legacy of the city's sanitary strategy was an obsession with heroic, big technology projects to engineer the environment. Although the plan required a minimum of public expenditure, it extracted a tremendous cost of money and inconvenience from the city's residents. It depended on raising the grade several feet, high enough to let gravity empty the sewers. Following this bold scheme to lift the city out of the mud, Chesbrough proposed an even-more-audacious plan to protect the water supply from the human and animal wastes pouring into the lake. Underwritten by the huge profits being generated by the waterworks, the city built a tunnel under the lakebed through the clay to an intake crib 2 miles/3.2 km out from shore.

Begun in 1863, during the Civil War, the project was completed four years later to national fanfare and civic celebration at the new water tower and pumping station on the North Side.[38]

Finally, the decision sealed the fate of the river as an open sewer and the lake as the ultimate sink of the city's effluents. Earning the apocryphal euphemism of a "working river," the waterway served not only as a shipping lane but also as the dumping ground for industries lining its banks. Perhaps the best known of these sources of pollution was the Union Stockyards, which had opened for business on Christmas Day, 1865. They were located on the South Branch to take advantage of a free way to dispose of the tons of organic wastes produced daily in the slaughterhouses. The stench arising from the river became permanent; this degradation of the environment created a social geography of class that divided the city into the lakefront and the riverfront districts. The rebuilding of the city after the Great Fire of 1871 had reinforced this spatial separation between those who could afford to live at a distance from the river and those forced by poverty to make their homes next to it.

In contrast to the first approach to water management, what became a self-proclaimed "Progressive Era" took pride in distinguishing itself from the past by its reliance on scientific experts in the formation of public policy. In the case of flood control, the establishment of a weather bureau in 1872 provided reformers with a consistent set of precipitation and temperature records. Moreover, other professionals had been mapping the underground geography and the surface topography of Chicago's prairie wetlands with much greater precision. Together with the medical practitioners of the new public health, they calculated the design specifications of a heroic public-works project to engineer the environment.

Starting with the crisis of the great flood of 1885, this book follows the policy debate over remaking the city's flood-prone environment during an extended, 125-year period of climate change and geographic deconcentration. Its two subperiods are defined by an equally important combination of dramatic swings in rainfall patterns and evolutionary shifts in society's attitudes toward the environment. From roughly 1885 to 1945, Chicago went through a dry period of rainfall compared to a wet period since then of more-frequent and more-severe storms. This change in its climate is documented in more than 140 years of daily weather records.[39] The causes of change are not at issue here, only the impact on a city built in a flood-prone environment.

The weather bureau's database can be turned into two charts that illustrate long-term patterns of rainfall on a regional area undergoing explosive urban sprawl. Figure I.3 simply plots Chicago's annual precipitation from 1871 to 2014 on a line representing the average amount of 34.5 in./87.6 cm. It clearly shows an above-the-line spike in the decade before the great flood of

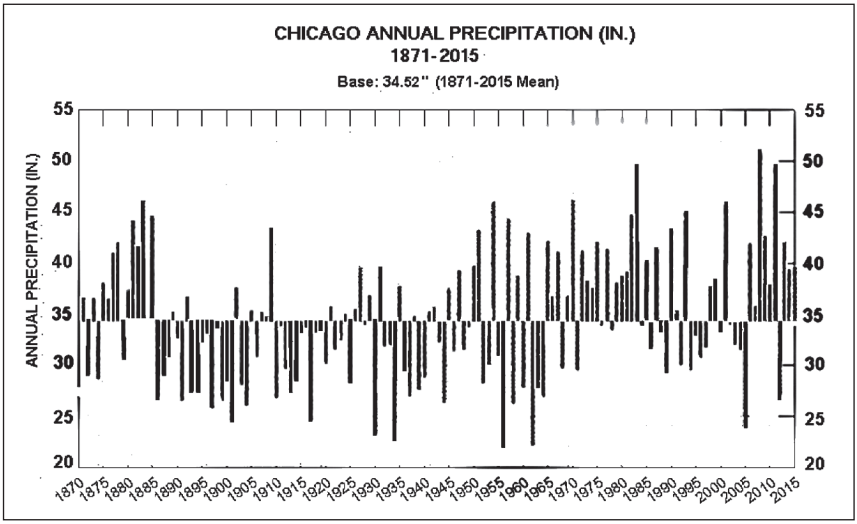

Figure I.3. Annual Precipitation, 1871–2015 (Climate Stations, available at https://www.climatestations.com/wp-content/uploads/2016/01/CHIPRCP.gif)

1885, followed by a sustained, sixty-year period of below-average rainfall. Then, since 1945, Chicago has experienced an equally long period of above-average amounts of rainfall. It has also endured years of record-breaking heat and drought, contributing to this period's pattern of more-frequent and more-extreme weather events.

Yearly totals, however, do not indicate the frequency or severity of downpours that can cause flooding. In the case of Chicago, a 1 in./2.5 cm. rainfall in a twenty-four-hour period can be taken as the benchmark for potential flood damages. On a 1-square-mile/2.6 square km area, it will drop 17,500,000 gallons (gal.)/66,245,000 liters (L) of water. The city's combined sewer system reaches capacity, backflows into basements, and overflows into the rivers and the lake. Historically, a deluge of this amount was considered to be a proverbial "Act of God," or a "hundred-year rainfall," because it would have been enough to sink the city. A true "hundred-year rainfall" is an event with a 1 percent chance of happening in any given year. Figure I.4 marks out a 50 percent increase since the mid-century in the number of rainfalls of 1 in./2.5 cm or more. From 1900 to 1950, the average number of times the metropolitan region's flood-control system was overwhelmed remained flat, at six times per year, but since then, the number has increased to nine. From 1958 to 2007, the number of "heavy rainfall events," or the top 1 percent, increased by a third.[40]

Adding to the risk of damaging floods, more-imperious surfaces have resulted in proportionate increases in storm-surge runoff. Since the 1960s, as little as one-half to two-thirds of an inch of rain has been sufficient to defeat the city's flood-control system.

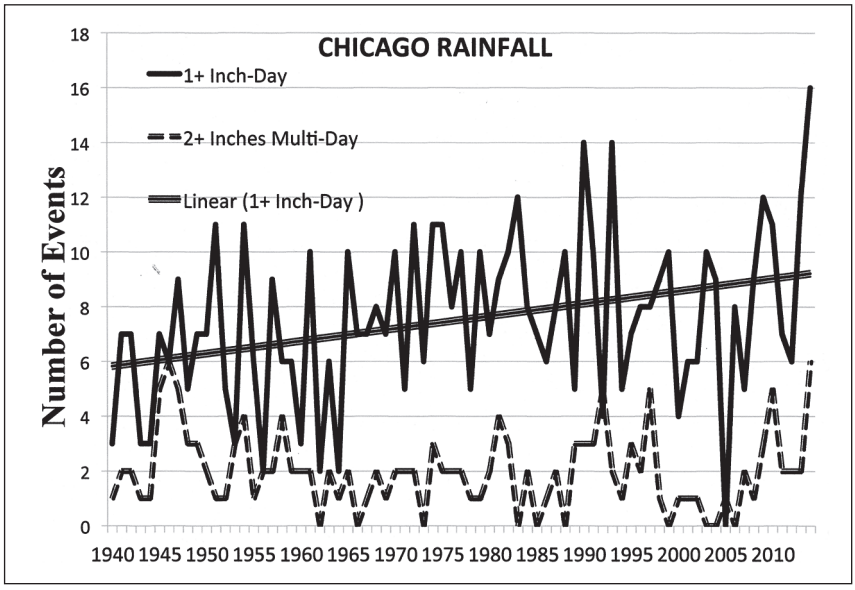

Figure I.4. One-Inch-Plus Rainfalls, 1940–2010 (Data from U.S. National Oceanic and Atmospheric Administration, National Climatic Data Center, *Record of Climatological Observations, 2014*, available at http://www.ncdc.noaa.gov/)

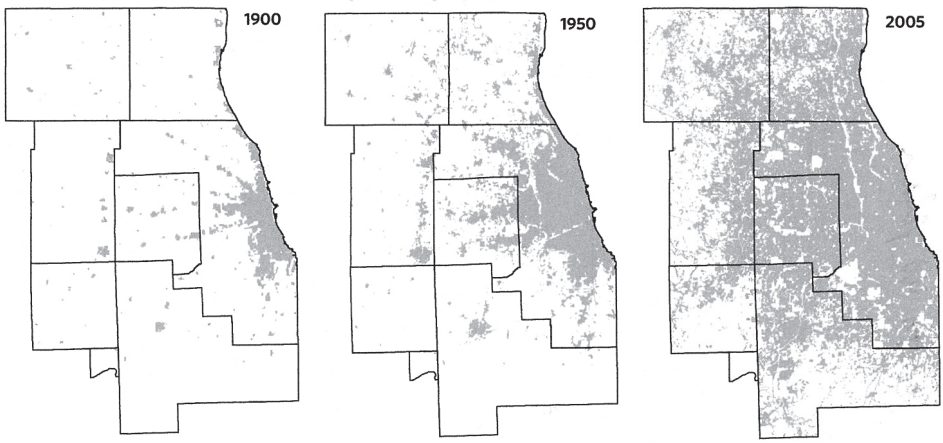

Figure I.5. Regional Sprawl, 1900, 1950, 2005 (City of Chicago and Chicago Metropolitan Agency for Planning, *2040—Comprehensive Regional Plan* [Chicago: Chicago Metropolitan Agency for Planning, October 2010], fig. 10, available at http://www.cmap.illinois.gov/documents/10180/17842/long_plan_FINAL_100610_web.pdf/1e1ff482-7013-4f5f-90d5-90d395087a53)

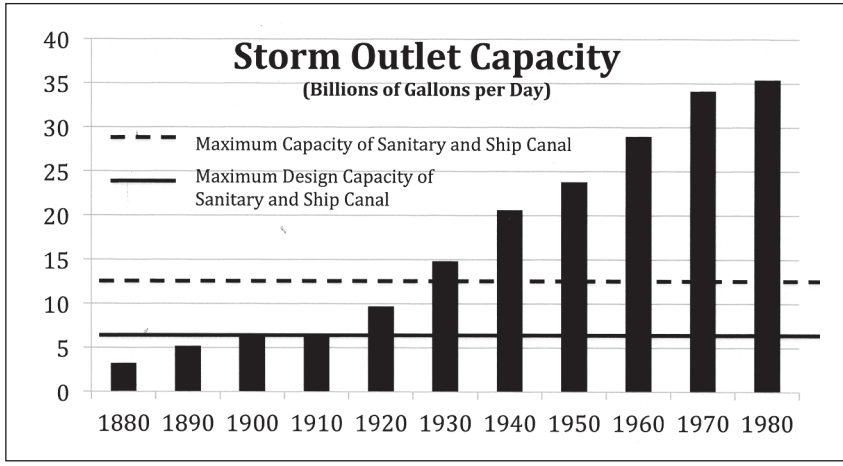

Figure I.6. Storm Outlet Capacity, 1880–1980 (Data from Frank E. Dalton, Victor Koelzer, and William J. Bauer, "The Chicago Area Deep Tunnel Project: A Use of the Underground Storage Resource," *Journal of the Water Pollution Control Federation 41* [April 1969], fig. 9)

Two additional illustrations show how the rate of sprawl—paving over a prairie wetland—has outpaced Chicagoans' efforts to gain control over nature, especially during the wet period of climate change. Figure I.5 maps the built-up area of the metropolitan region at half-century intervals, beginning at 1900.

Figure I.6 traces the growth of the sewer system's storage capacity, crossing a line representing the maximum amount of storm-surge overflow the Sanitary and Ship Canal can release at the Lockport Dam before forcing the sanitary authorities to release polluted storm water into the lake. As early as 1910, the river-in-reverse had already reached its design specifications, and it was at three times the maximum amount by the end of World War II.

An explosive quarter century of suburban homebuilding enlarged the underground network of sewer pipes to five times the limit of the drainage canal to get rid of storm surges. As the property and the human costs from flood damages mounted, policy makers responded in the mid-1970s with a big technology, the Tunnel and Reservoir Plan (TARP). Combined with climate change, the sanitary authorities have needed to discharge a continuing series of record-breaking amounts of effluents into the city's ultimate sink, Lake Michigan, closing its beaches and facilitating the invasion of alien species back and forth between the Great Lakes and Mississippi River basins.

A final illustration, Figure I.7, graphically presents the frequency and amount of sewage-laden wastewater that has been released into Lake Michi-

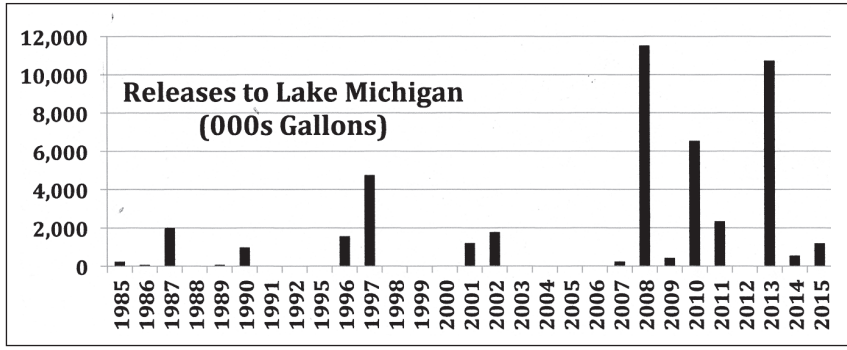

Figure I.7. Storm-Water Releases into Lake Michigan, 1985–2015 (Data from City of Chicago, Metropolitan Water Reclamation District, "Reversals to Lake Michigan [1985–Present]," 2015, available at https://www.mwrd.org/irj/go/km/docs/documents/MWRD/internet/protecting_the_environment/Combined_Sewer_Overflows/pdfs/Reversals.pdf)

gan since the 1985 opening of this never-ending, multi-billion-dollar public-works project.

Despite its heroic imagery as the technological sublime, TARP was built at one-half of the scale and capacity needed to prevent flood damages. Its original designers badly underestimated the amount of storm-surge runoff in the built-up areas.[41] A 2007 study found that 42 percent of Cook County's 925 square miles/2,400 square km of land had been paved over on average, which would amount to 6.8 billion gal./25.7 billion L of runoff, without counting the amount from the other 58 percent of the land. Another recent study calculated that 820 square miles/207.2 square km of the metropolitan region had impervious surfaces, or a runoff of more than 14 billion gal./53 billion L from 1 in./2.5 cm of rainfall. With new, record-breaking storms in 2013 and 2015, the wet period of climate change and the outward thrust of the region's settlement patterns continue, promising more record-breaking flood damages.[42]

The two subperiods of this book correspond not only to climate change but also to a shift from natural resource conservation to ecosystem restoration in popular thought about the environment. In Part I, Chapter 1 traces how Chicago's architects became its nature conservation experts during the Progressive Age. As Daniel Burnham, Dwight Perkins, and Jens Jensen transformed themselves into city planners, they took a leading role in bringing lakefront beaches, neighborhood parks, and riverine forest preserves to the masses of city dwellers. At same time, they engaged in the larger civic debate over how to build the proper mix of the city efficient, the city beautiful, and the city humane. Chapters 2 and 3 take up the post-Progressive, interwar years, when the rainfall continued to be below average. From the 1910s to

1930, Chicagoans engaged in a love affair with homeownership and outdoor living. Subdivisions were built over the city's remaining open spaces, while a ring of county forest preserves opened around this bungalow belt to protect the six watersheds. The New Deal supported a vast expansion of recreational facilities in public open spaces.

Part II examines the growing conflict between the grassroots, politicians, and policy makers over the remaking of Chicago's paved-over prairie wetland from the perspectives of modern ecological thought. By 1945, scientists had accumulated a half century of intense investigations of how engineering the environment changed the aquatic ecology of inland waterways from studying Chicago's six rivers and their downstream impacts on the Illinois River. Chapter 4 examines a twenty-year period when the continuing growth of enthusiasm for the outdoors would turn city dwellers and suburbanites alike from nature conservationists into proto-environmentalists. The postwar period of an unprecedented baby boom would underwrite a building boom of single-family homes in the suburbs. Gaining an ecological understanding of the interconnectedness of all living things from Rachel Carson's book *Silent Spring*, they organized grassroots movements to save the lake from pollution and the rivers from being turned by the sanitary district into sewage and drainage canals.

From 1965 to 1985, city engineers built an alternative big technology system, the Deep Tunnel. Chapter 5 covers this period of infrastructure construction, suburban white flight, and increasing flood damages from more-frequent and more-severe storm-surge runoffs. The failures of local government to prevent flooded basements and polluted waters gave birth to a modern environmental movement that linked the ecology of the lake and the rivers. Record-breaking rainfalls forced the engineers to divert billions of gallons of contaminated storm water into Lake Michigan, closing the beaches and threatening epidemic outbreaks. Adding to this old problem of using the lake as Chicago's ultimate sink were new ones caused by the movement of disruptive, invasive species between the St. Lawrence River/Great Lakes and the Illinois/Mississippi Rivers systems. As the crises of widespread flood and environmental damages grew worse, the grassroots mobilized to oppose the plans of city hall. They formed the Friends of the River and the Open Land Project to save nature in the metropolitan area.

Chapter 6 and the Conclusion take a look at the successes and failures of TARP during a period of mounting political demands for higher standards of environmental quality. From the opening of the deep tunnel in 1986 until the retirement of Mayor Richard M. Daley in 2011, Chicago became the country's last big-city holdout against coming into compliance with the landmark Clean Water Act of 1972. Nonetheless, the return of aquatic and wildlife to the Chicago River produced a self-reinforcing process of restoring urban nature and growing political support for its continued reclamation. The im-

provement of the waterway added to the renaissance of an expanding city center, transforming the "working river's" image from the city's back alley to its centerpiece, a scenic boulevard of light, air, and flowing water.

The goal of *Sinking Chicago* is to shed light on how people respond over an extended period to climate change. Chicago's flood-prone environment furnishes a good case study of a community's attempts to grapple with long-term swings in rainfall. Like those of other American cities, its citizens, politicians, and policy makers lost sight of the connections between land use and water management. Driven by urban rivalries for economic hegemony and their faith in progress, they attempted to conquer nature rather than adapt to its forces, which are beyond human control. Chicagoans became exceptionally obsessed with heroic, big-technology solutions to its dual problem of water quality and flood control. But in the post–World War II period of explosive suburban growth, this approach failed to keep up with the size of storm-water runoff surges caused by sprawl during an increasingly wet period of more-frequent and more-severe rainfalls. Searching for alternative solutions, environmental reform activists have been finding ways to adjust to climate change by reconnecting land and water in holistic ways.