New York State Barge Canal, Lockport Locks
(Erie Canal, Combined Locks 67-71)
East of Richmond Avenue
Lockport
Niagara County
New York

HAER No. NY-61

HAER
NY,
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14A-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
National Park Service
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Washington, D.C. 20240

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HISTORIC AMERICAN ENGINEERING RECORD

NY-61

NEW YORK STATE BARGE CANAL, LOCKPORT LOCKS

ERIE CANAL, COMBINED LOCKS 67-71

Date:	Original Locks, 1817-1825 Canal Enlargments, 1836-1862 Electric Lift Locks, 1909-1918
Location:	East side of Richmond Ave. Lockport, Erie County, New York.
Designer:	Nathan S. Roberts, Engineer (original stepped locks).
Owner:	Originally; Holland Land Company. Presently; New York State Department of Public Works
Significance:	The stepped locks at Lockport are significant examples of canal engineering overcoming steep terrain. This site also provides historians a rare opportunity to compare 19th century and early 20th century canal technology.
Transmitted by:	Dan CLement, 1983.

The 60' rise in the Niagara Escarpment presented a major engineering problem during the construction of the original Erie Canal (1817-25). It was solved by Nathan S. Roberts, who designed a double set of five combined locks; one for ascending traffic heading east and another for descending traffic heading west. Each lock was 90' X 15' and had a lift of 12' (an original drawing can be found at the Lockport Library). These locks helped to create the focal point for the development ofthe future city of Lockport.

The first enlargement of the Erie Canal took place between the years 1836 and 1862. The engineer in charge was Thomas Evershed. At this time the canal prism was extended ad the locks at Lockport were increased from their original size to 110' X 18'. This allowed an increase in the tonnage of canal boats from seventy-five to two-hundred-forty.

From the years 1909 to 1918 the Erie Canal was modified to become the New York State Barge Canal. The southern tier of the locks at Lockport were removed and in their place was constructed a set of two electric lift locks. These concrete locks with steel gates were 310' X 45' X 12' and had a combined lift of 49'. The miter gates of the northern tier of locks were removed so the locks could be used for the passage of surplus water.

Researchers wishing more information are asked to refer to:

Noble E. Whitford, History of the Canal System of the State of New York (1906); I, 363, 797, 960, & Passim.

ADDENDUM TO:
NEW YORK STATE BARGE CANAL, LOCKPORT LOCKS
(Erie Canal, Combined Locks 67-71)
Richmond Avenue
Lockport
Niagara County
New York

HAER NY-61
NY,32-LOCK,14A-

PHOTOGRAPHS

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HISTORIC AMERICAN ENGINEERING RECORD

ERIE CANAL, LOCKPORT LOCKS
(New York State Barge Canal Lockport Locks)
HAER No. NY-61

THIS IS AN ADDENDUM TO A 2 PAGE REPORT PREVIOUSLY SENT TO THE LIBRARY OF CONGRESS

Location:	Lockport, Niagara County, NY
Date of Construction (Extant structures):	Locks 67-71 (north flight), 1838-1842 Locks 34-35, 1910-1918
Lead Engineers:	Nathan S. Roberts (1776-1852) Original Thomas Evershed (1817-1890) Enlarged Edward A. Bond (1849-Unk.) Modern Frank Williams (1873-1930) Modern
Present Owner:	New York State Canal Corporation, New York State Thruway Authority
Present Use:	Locks 34 and 35 are in service on the canal. Locks 67-71 (north flight) serve as a by-pass flume for Locks 34 and 35, as well as being an in-situ outdoor museum displaying early-nineteenth-century canal design.
Significance:	Locks 67-71 (north flight) comprise a rare 19th-century example of multiple locks directly connected into a flight and an in-situ example of once-common cut-stone lock construction. This flight is the most complete surviving artifact from the enlarged Erie Canal, the second version of the first major transportation artery between the East Coast and the Great Lakes. Locks 34 and 35 form an excellent example of early-20th-century concrete, electrically powered lock design, and they pioneered methods also used on the Panama Canal. The site is unique in having these two designs together.
Historian:	J. Lawrence Lee, Ph.D., P.E.
Project Information:	In fall 2005, the Historic American Engineering Record began a project to record the extant lock structures at Lockport, using high-definition laser scans of Locks 67-71 by a team from Texas Tech University, supplemented with on-site measurements, photographs, and historical research.

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INTRODUCTION

The Historic American Engineering Record's documentation of the extant Erie Canal locks at Lockport, New York, offers a unique opportunity to examine multiple generations of waterway structures designed and built to overcome a major natural impediment to navigation between the Hudson River in Eastern New York and Lake Erie at the state's western tip. A canal linking these two bodies of water, separated by 353 miles and 565 feet in elevation,[1] was an audacious endeavor when it was first proposed to the New York Legislature in 1808, but no element of the project formed a greater challenge than surmounting the Niagara Escarpment. Several possible routes were surveyed, but the canal's engineers[2] ultimately selected a route that took advantage of a relatively level plain west of Rochester, even though it would have to confront the escarpment head-on at what became the city of Lockport.

The earliest canal proposals called for the use of inclined planes to carry canal boats up and down hills, but hydraulic locks soon came to be seen as a more practical alternative. Locks would not have the potential problems with power that could haunt inclined planes, and they were more compact, which allowed greater latitude in selecting the locations for elevation changes and, thus, more flexibility in choosing the canal's route.

At the location destined to become Lockport, the Niagara Escarpment, which quickly came to be called the "Mountain Ridge," presented engineers with the challenge of ascending

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1 "Map and Profile of the Erie Canal," *Laws of the State of New York, in Relation to the Erie and Champlain Canals* (Albany: E. and E. Hosford, 1825).

2 The term "engineers" needs a little explanation. There were virtually no formally educated civil engineers in the United States when the original Erie Canal was planned and built, and not many more during the canal's enlargement period. Several of the men involved had some surveying experience, but most of them evidently possessed analytical minds and a good working knowledge of the natural world, simple machines, and basic scientific principles. They clearly did engineering design work, however, so the appellation seems justified. By the

what amounted to a 75-foot-high rock cliff. No single lock had been built that could begin to handle that much of a lift. Builders did not understand how to build lock walls or gates that could reliably withstand the cycles of hydraulic pressure that repeated lifts of that magnitude would impose. Additionally, large amounts of time and water would be required for each lift, and it would be very difficult, if not impossible, for one man to open and close the massive gates needed at each end. The solution to both problems was to divide the lift into manageable segments. Five essentially identical locks could be arranged end-to-end, forming a staircase, or "flight," to accomplish the task. Locks this size were practical to build, and each lock could use water discharged from the one above, though there remained some question about how well the flight would operate without pools to store water between the locks. Cutting a channel through the top of the ridge would lower the total lift to 60 feet and put the top level slightly lower than the elevation of Lake Erie, thus assuring an ample supply of water.

Lockport was not the greatest total change in elevation required for a single group of locks—that was on the eastern end of the canal in the vicinity of Cohoes, where eighteen locks were needed to change the elevation almost 160 feet in about 5 miles—but it was the most compact group and the most difficult to construct because of the escarpment's geology. Not surprisingly, the Lockport Locks and the channel through the ridge were the final elements of the original Erie Canal to be completed prior to its grand opening on October 26, 1825.

Similar techniques were employed to build the enlarged locks, numbers 67 – 71—the north flight of which still survives—some two decades later, but entirely different materials and construction methods, not to mention electric power, had come into use when the two large locks, numbers 34 and 35, for the New York State Barge Canal were erected early in the

---

time of the Barge Canal, engineering had become a learned profession that college graduates were coming to dominate, so there should be little confusion over the term after 1900.

twentieth century. Still in service with most of their original machinery, these locks and their sisters throughout the canal were pioneering achievements in modern lock design.

The installation at Lockport thus consists of two flights of locks. The surviving elements of Locks 67 – 71 of the enlarged canal occupy their original position along the north bank. Two identical flights were originally constructed parallel to each other, separated by a terraced walk approximately 30' wide, but only the north flight normally used for westbound boats survives. Each of the five lock chambers nominally measures 110' long by 18'-6" wide by 18' high along most of its length, although many of the walls now exhibit some displacement along portions of their length. Varying amounts of sediment from their years of use as a by-pass channel for the Barge Canal Locks 34 – 35 now cover the floors and make accurate height measurements impractical. Locks 67 – 71, including the central walk and stairs, were constructed of cut stone quarried from the Lockport vicinity. The original lock gates and valves, which no longer exist, were built of wood with wrought-iron hardware. Portions of this hardware that were set into the stone survive, as do some handrails. Three arched concrete foot bridges crossing the lower ends of Locks 67, 69, and 70 are original to those locks, but three other flat steel bridges have been added since Locks 34 – 35 opened.

After Locks 34 – 35 went into service, Locks 67 – 71, north flight, were converted in several steps to the overflow channel configuration now visible. Their lock gates were removed, and concrete weirs were installed at their breast walls to moderate the flow and trap debris and sediment. The upstream weir at the upper end of Lock 71 includes a trash screen and two adjustable gate valves for trimming the flow as necessary to maintain sufficient water in the lower portion of the canal from Lockport to Rochester.

Barge Canal Locks 34 and 34 remain in service in largely original condition. They occupy the space where the eastbound flight of Locks 67 – 71 were located, plus additional width and length. Each of these two lock chambers measures approximately 310' long by 45' wide with a wall height of 39'. They consist of poured-in-place concrete monolithic segments with tongue-and-groove interlocks. The original monoliths have no steel reinforcing bars, but the few replacement sections installed to replace damaged monoliths do. Being the uppermost lock on the canal, Lock 35 includes a second gate at its upper end. This serves as a safety measure to prevent flooding of the lower canal in the event of any failure of the primary gate.

The current Barge Canal lock gates, although similar in design to the original ones, are not original. The primary difference is welded instead of riveted construction, reflecting more recent practice. The same is true for the valves that control water flow into and out of the lock chambers. The electrically powered gear drives that move the gates and valves are original, excepting the replacement of certain routine-maintenance items, as are the electrical controls. The drives are enclosed in steel cabinets painted in the canal Corporation's standard colors of blue and gold.

The installation of Locks 34 – 35 included three buildings in the median that survive. The two-story lock-keeper's office sits between old Lock 71 and new Lock 35, and a two-story machine shop is located between Locks 68 and 34. Both are masonry structures with gray-shingled hip roofs, and they are painted white with blue trim. At the foot of the median between Lock 67 and the downstream approach to Lock 34 is a powerhouse building of similar style and construction that originally housed a pair of hydraulic turbine-generator units that generated electrical power for the new lock complex. This equipment was removed after commercial power became available, and the building now houses a canal museum.

Except where new foundations, stairs, and walks were needed for the machine shop and powerhouse buildings, the mid-nineteenth-century stone walk and stairs adjacent to Locks 67 – 70 survive, though modern, welded-pipe handrails now predominate. Between Locks 69 – 70 and 34, the northwest lock walls of the eastbound flight' Locks 69 – 70 are largely visible. They now serve as a retaining wall between the old walk and a grassed area occupying the remaining space between Locks 69 – 70 and 34. The center walk between Locks 71 and 35, which extends approximately 250' upstream (southwest) from Lock 71, is all concrete and spans the full 51'-9" between the old and new locks. An inclined, partially paved access road along the north side of the old locks occupies what was essentially the tow path used by the mules that pulled boats through the enlarged canal.

Numerous social, economic, and political histories of the Erie Canal have been written since its triumphant opening, some of which are included in the bibliography, but that is not the intent of this report. While no technology can be accurately understood apart from its social context, the intent here is to focus primarily on the unique aspects of surmounting the Niagara Escarpment at Lockport, with an emphasis on the technologies employed to accomplish this feat in different eras. The geological situation at Lockport was unique, but the lock technologies used there in two different eras were similar to those used throughout the Erie, as well as other American, canals. An awareness of the technologies available to accomplish the visions of planners and policy makers described in the comprehensive canal histories can only lead to greater understanding of these outstanding civil engineering achievements and their dramatic influence on both the region and nation.

THE NIAGARA ESCARPMENT

The story of the flight of locks at Lockport, New York, actually began almost 500 million years ago (mya), when the geological structure making them necessary began to form. During this period of the earth's development, known to geologists as the Ordovician Period (490 – 443 mya),[3] what is now most of North America was part of a continent known as Laurentia and located south of the Equator. Under tectonic forces generated by movement of the Earth's molten interior, an earlier super continent, Rodinia, had split into four main masses, or plates, and numerous fragments. Laurentia, second in size to Gondwana (today's Southern Hemisphere continents), began to migrate north, while Gondwana moved toward the South Pole. Sea levels were high during this period, and almost half of the Laurentia plate was submerged. By the beginning of the Silurian Period (443 – 417 mya), Laurentia straddled the Equator and began to interact with two other plates, Siberia and Baltica, to form Euramerica (also called Laurussia). Euramerica would eventually merge with Gondwana to form the second super continent, Pangaea, about 290 mya, and then break apart again into the plates that would move into place as today's seven continents by about 2 mya. These planet-wide actions also drove localized events in Laurentia to produce the rock strata that would become the Niagara Escarpment.

Through the Ordovician, Silurian, and Devonian (417 – 354 mya) periods, much of the area that became Michigan, Ohio, western New York, southwestern Ontario, and portions of the middle Great Lakes was the floor of a vast, shallow body of water now referred to as the Michigan Sea. Since these periods were after the "Cambrian Explosion," a relatively brief era

[3] Geological dating is imprecise, and variations will be found in different sources. The dates used here are from the University of California, Berkeley, Museum of Paleontology., http://www.ucmp.berkeley.edu/ help/timeform.html, accessed Sept. 19, 2006.

during the Cambrian Period (543 – 490 mya) that saw a wide variety of life forms appear, the Michigan Sea teemed with invertebrate marine life. Trilobites and brachiopods flourished, as did coral, mollusks, and bryozoa, small colonial animals that built stony exoskeletons of calcium carbonate (calcite). As untold billions of these creatures died, their shells and skeletons accumulated on the bottom as a thick layer of sediment. During periods with a lot of rain, eroded sand and clay was washed from the surrounding land into the sea, where it, too, settled to the bottom in layers. Over time, the weight of this accumulating material compacted everything beneath, and the pressure caused a recrystallization that turned the sediment into stone. Not surprisingly, geologists term such stone "sedimentary rock." Depending on the material that makes it up, the sedimentary rock in each layer has different properties.[4]

Layers consisting of animal shells and exoskeletons became relatively hard, strong rock, such as dolostone and limestone. Where limestone is composed almost entirely of calcium carbonate, the addition of some magnesium creates dolostone, the harder of the two. Layers with high sand (quartz) content formed into sandstone. While fairly strong, sandstone is not as hard as limestone or dolomite, and it erodes more rapidly than the harder rocks. Weaker and softer still is shale, created when the sediment layer was largely clay. All three of these sedimentary rock types formed in layers on the bottom of the Michigan Sea, where they formed a bowl with a raised rim at the shoreline. How the layers, or strata, were stacked made what we see today as the Niagara Escarpment possible. The lower strata of sand and clay were deposited before the Cambrian Explosion of life, so these layers, the result of early erosion of land around the sea,

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[4] This chapter is informed by a variety of on-line and print sources, particularly Walter M. Tovell, *Guide to the Geology of the Niagara Escarpment* (Georgetown, Ont., Canada: The Niagara Escarpment Commission, 1992); "The Lockport Cyber Museum of Rocks, Minerals, & Fossils" http://www.lockport-ny.com/Museum/rocks.htm, , accessed May 30, 2006; and "The Niagara Escarpment" http://spartan.ac.brocku.ca/~ffueten/niagara/niagara.html, , accessed May 30, 2006.

lacked calcium carbonate. The abundance of life in the Michigan Sea during the Ordovician Period furnished that mineral. Following a mass extinction at the end of the Ordovician Period, most Silurian and Devonian sediments again lacked calcium carbonate.

As the super continent Pangaea began to break apart into the modern continents during the Cretaceous Period (144 – 65 mya), the sea level fell, largely due to falling temperatures and the concurrent buildup of ice sheets on Antarctica. By about 100 mya, this had caused the Michigan Sea to disappear, exposing the inclined strata at the rim to the eroding forces of wind, rain, and ice. These actions of weather wore away the softer stone quicker than the harder stone. Along a broad arc from the west coast of modern Lake Michigan, through the middle of Lake Huron, and into western New York, the old shoreline of the Michigan Sea that was then exposed had layers of hard dolostone and limestone on top of softer layers of shale and sandstone. Rather than the layers weathering from the top down, the softer, lower strata eroded first, leaving an overhanging ledge of hard rock. Increasingly unsupported, it would eventually break and fall after the supporting strata eroded far enough back. The process has continued to repeat until this day, and it generated the abrupt, cliff-like formation known as the Niagara Escarpment. The ice ages of the Pleistocene Period (1.8 mya – 10,000 years ago) enhanced the process by scouring away much of the softer rock and broken talus from the base of the escarpment. The present geological character of western New York was essentially set when the last ice sheets retreated about 10,000 years ago.

The nature and results of this erosion process are perhaps best seen at Niagara Falls, where flowing water and seasonal cycles continue the process of carving Niagara Gorge back toward Lake Erie, but they occur to some degree along the entire exposed length of the escarpment. While the process is the same throughout, the escarpment's height varies considerably at different locations. Where the Niagara Falls plunge as much as 176 feet, the drop is less dramatic at Lockport—about 75 feet—but all of the major strata are present in both locations. Figures 1 and 2 show the arrangement of these strata in western New York.

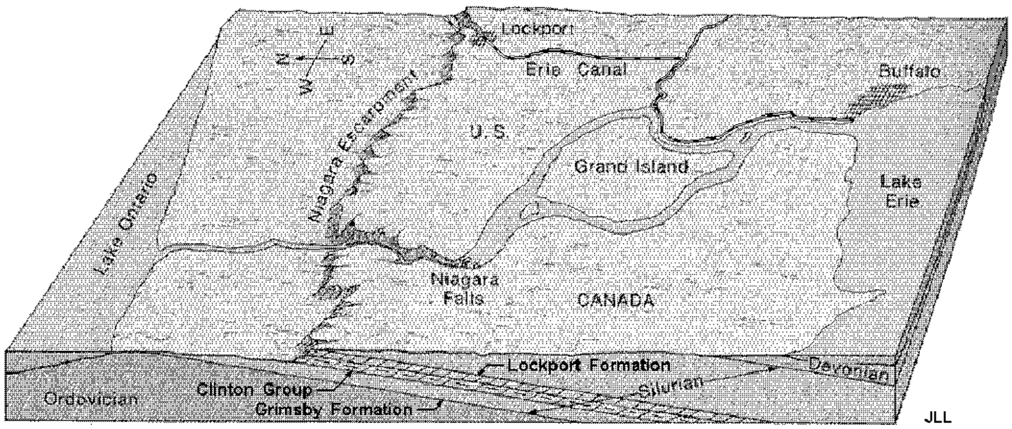

Figure 1. Cross section between Lake Ontario and Lake Erie showing the Niagara Escarpment and major strata by geological periods. Elevation is exaggerated.

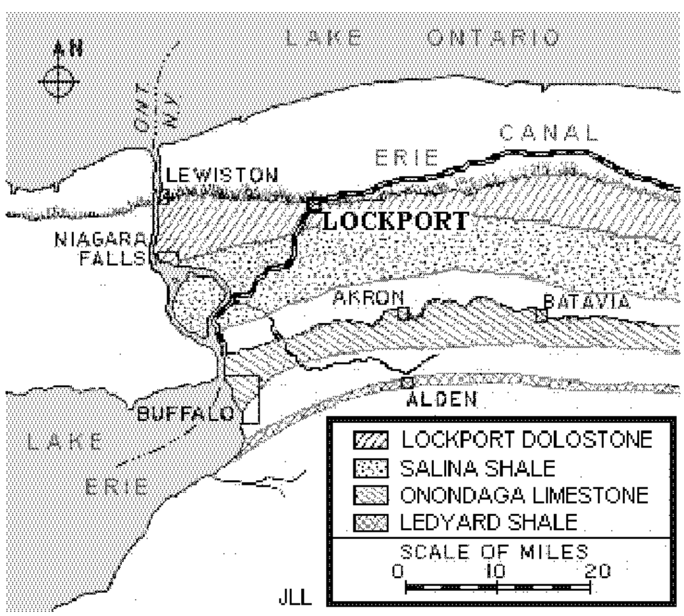

Figure 2. Map showing surface exposure of major strata adjacent to the Niagara Escarpment in western New York.

Geologists named most of these strata and sub-strata for local features. At the escarpment, the hard dolostone[5] upper layer is the Lockport Formation, and it includes sub-strata such as Lockport, Gasport, and Decew dolostones. Rochester Shale sits below the Lockport Formation, and that rests upon the Irondequoit Limestone and Rockway Dolostone layers collectively known as the Clinton Group. Below this is the Grimsby Formation, which is primarily sandstone that extends across the plain northward to Lake Ontario. Excavation into all of these strata was required for lock foundations at Lockport. South of town, the inclined Lockport Formation descends beneath the surface, covered by a softer layer of Salina Shale. The excavated portion of the canal through the Mountain Ridge southwest of Lockport had to be dug through both this shale and the hard Lockport Dolostone.

[5] Nomenclature was less precise in the early nineteenth century, and limestone was frequently the term used for both limestone and dolostone. Stone commonly known as gray or blue Lockport limestone is actually dolostone in modern parlance.

VISIONS OF A CANAL

During the years immediately following the ratification of the United States Constitution in1789, the desirability of government spending on "internal improvements" was far from a settled issue on both the federal and state levels. Thus, even though the need for improved communication with the growing lands west of the Appalachian Mountains was well recognized, the means to achieve it was a matter of great debate. Coastal cities like New York, Philadelphia, Baltimore, and Washington all saw wonderful opportunities if inland trade could be funneled through their respective ports, but financing and building a 300-400-mile road or canal, the only practical technologies available in the late 1700s and early 1800s, to facilitate that trade presented a daunting challenge.

New York State had a possible advantage over its southerly competitors. Where Philadelphia, Baltimore, and Washington were faced with crossing the heart of the Appalachian Mountains, New York's east-flowing Mohawk River negotiated a valley between the state's Adirondack (north) and Catskill (south) mountains. Along with several interior lakes and certain large creeks, the Mohawk had been useful for small boats, but none of these watercourses were completely free of obstacles that required cumbersome portages to get around. The Mohawk joined the south-flowing Hudson River a few miles north of Albany, but only after it plunged over the 75-foot Great Falls at Cohoes. The Hudson was navigable as far north as the Mohawk, but the Catskill Escarpment, over which the Great Falls flowed, formed its western shore and presented a formidable barrier all the way south to New York City. There were hurdles to be sure, but the Mohawk Valley offered an easier path to the west than any other, *if* the state chose to pursue it.

Thanks to a vigorous fur trade with the Five Nations of Native-American tribes in the region, various proposals to improve navigation by connecting natural waterways with short canals appeared as early as America's Colonial Period. As early as 1724, Cadwallader Colden, surveyor general (later colonial governor) of the Province of New York, prepared a report for the governor describing the natural "water courses and carrying places" (portages) between Albany and Montreal, Canada, and between Albany and Cataraqui Lake, now known as Lake Ontario.[6] While Colden proposed no structures to aid navigation at that time, these two routes formed the basis for what ultimately became portions of the Champlain and Erie canals. English restrictions on the colonies did not encourage internal improvements, but nevertheless, Colonial Governor Henry Moore—no doubt encouraged by Colden—recommended construction of ". . . sluices, upon the plan of those on the great canal of Languedoc, in France . . ." between Schenectady and Fort Stanwix (Rome) to the General Assembly in December 1768. The proposal floundered amidst assembly discussions of whether or not it had the authority to act on such matters. Additional proposals came and went over the next two decades, including one by Jeffrey Smith in 1786 that was the first to mention Lake Erie as a possible destination for an inland canal. Like Moore's proposal, Smith's failed due to assembly inaction.[7]

After decades of inaction, the New York legislature (which had replaced the general assembly in 1789) finally looked with favor upon a proposal by Elkannah Watson in 1791. Watson, a native of Massachusetts who was keenly aware of George Washington's involvement with what would become the Chesapeake and Ohio Canal parallel to the Potomac River, offered a comparison of existing and proposed canal routes, and he recommended that the state fund a

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[6] Noble E. Whitford, *History of the Canal System of the State of New York: Supplement to the Annual Report of the State Engineer and Surveyor of the State of New York for the Fiscal Year Ending September 30, 1905, Vol. 1* (Albany: Brandow Printing Co., 1906), 16-17. Hereafter noted as Whitford, *History of the Canal System.*

survey for a canal connecting the upper Mohawk River with Wood Creek, which flowed into Oneida Lake and on to Lake Ontario via the Oneida and Onondaga rivers. "An act concerning roads and inland navigation," passed on March 24, 1791, stands as New York's first statute concerning canals.[8]

Favorable survey results led to "An act for establishing and opening lock navigations within this State" on March 24, 1792. After ratification by an appointed review commission, this act incorporated two companies, the Western Inland Lock Navigation Company and its similarly named Northern counterpart. Canals these companies built were to allow passage of boats 40' long, 20' wide, and with a maximum loaded draft of 2'.[9]

In spite of inadequate funding and interrupted work, an all-too-common scenario for projects of the time, the 0.9-mile canal, with five locks to negotiate the 45-foot difference in elevation between the Mohawk River and Wood Creek, went into service late in 1794. While functional, its size was inadequate, and a $1^3/_4$-mile, two-lock canal able to take boats drawing $3^1/_2$ feet of water replaced it three years later. Unfortunately, this and the other canals built by the Western and Northern companies experienced numerous technical and financial difficulties, and the two companies ultimately failed. The initial under funding has already been noted, and technical problems included poor route selections that required the construction of otherwise unnecessary structures; the use of brick or wood to build locks, both of which deteriorated

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7 *Ibid*, 18-20, 25.

8 *Journal of the Votes and Proceedings of the General Assembly of the State of New York* (Albany: State of New York, 1791), 84. Hereafter noted as *Assembly Journal,* year.

9 *Assembly Journal,* 1792. Also Whitford, *History of the Canal System*, 33-34.

rapidly; and inadequate water supplies. These were coupled with an operating scheme that allowed for easy fraud regarding tolls.[10]

These early canal projects provided some improvement in navigation, but, more importantly, they taught engineers and planners some important lessons about canals: natural streams proved very difficult to maintain compared to man-made channels, stone was the preferred material for lock construction, water supply had to be carefully considered, and good management of the construction and operation was crucial to financial success. All of these lessons would prove to be immensely valuable when the state's most ambitious canal plan, a through canal linking Lake Erie with the Hudson River, finally emerged.

A number of well- and lesser-known people envisioned canals as the key to prosperity during America's early years, and they were the strongest advocates for both public and private investment in canal ventures. Some have already been mentioned, but other notable proponents included George Washington, Philip Schuyler, George and De Witt Clinton, and Gouverneur Morris. Despite Smith's earlier suggestion of Lake Erie as a canal destination, Morris, a prominent figure in the American Revolution and national politics from New York, is usually credited with the original concept of what became the Erie Canal. Following a rigorous cross-state trip, Morris envisioned a canal that, ". . . would enable ships to sail from London through Hudson's River into Lake Erie," in an 1800 letter to a friend.[11] He continued to champion the idea, proposing what he termed an "artificial river" with inclined planes for elevation changes. Morris's vision of a canal suitable for ships extended far beyond his technical understanding of what might be practical, or even possible—he never attempted to identify a particular route or

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10 Whitford, *History of the Canal System*, 36-43.

11 Gouverneur Morris to John Parish, Dec. 20, 1800, noted in Whitford, *History of the Canal System*, 53.

any design details—but his *avant garde* idea of direct communication across the state gradually caught on.

The honor of first developing the route and a realistic conceptual design for an overland canal belongs to Jesse Hawley, a Geneva, New York, flour merchant who struggled to do business over the region's primitive roads. Hawley first suggested a canal in 1805, and he continued to write essays supporting one, even while he spent almost two years in debtor's prison during 1807-08, thanks largely to transportation difficulties and costs.[12]

While Hawley's proposal met with considerable ridicule, a few legislators, Joshua Forman and Benjamin Wright chief among them, began to press their colleagues to at least investigate its feasibility. The legislature directed Surveyor General Simeon De Witt to examine possible routes between the Hudson River and Lake Erie. De Witt wisely chose James Geddes, a well-known surveyor and engineer from Onondaga County, New York, to perform the task. Although De Witt preferred a route utilizing Lake Ontario to minimize the length and expense of construction required, such a route left the difficult problem of ascending the Niagara Escarpment to someone else.[13] Geddes, however, understood the necessity of overcoming the escarpment at some point and the likelihood that eastbound traffic reaching Lake Ontario would continue to travel to Montreal rather than endure the additional transloading needed to take a canal to New York, so he also surveyed an inland route that proved to be remarkably level for some distance across the middle of the state. His final report of January 20, 1809, called

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[12] Whitford, *History of the Canal System*, 54-55. Also "Jesse Hawley (merchant)" Wikipedia, http://en.wikipedia.org/wiki/Jesse_hawley_%28merchant%29, accessed Nov. 8, 2006.

[13] At the time of Geddes' survey, considerable business was portaged around the falls and reshipped via Lake Ontario and Montreal. Canadians ultimately realized that the Erie Canal would siphon off much of that traffic and the Welland Canal Company was formed in 1824 to build a canal between lakes Erie and Ontario west of the Niagara River. The first Welland Canal opened on November 30, 1829, but it failed to have an appreciable impact on the Erie Canal's traffic, which was by then firmly established.

attention to this, and to the possibility of reaching Lake Erie via the Tonnewanta (Tonawanda) and Black creeks at the western end.[14]

No immediate action was taken, but committees continued to study and debate the merits of a variety of canal proposals on both state and national levels. Not surprisingly, the most rancorous debates had centered on how any such project would be funded. For its part, the New York Legislature created a board of canal commissioners in 1811, formalizing a resolution it had passed the year before, and charged the board with all matters concerning inland navigation. The commissioners filed their first report to the legislature in March 1812, recommending initiation of work on a canal immediately. Unfortunately, this was just when the United States again went to war with Great Britain, an emergency that postponed any action on a canal.

The War of 1812 eventually turned out to be something of a blessing in disguise for the canal. The young nation incurred significant debt that became a high priority for revenue allocation, but it was clear that this debt was greater than it would have been had it not cost so much in time and money to transport troops and materiel to the Northwest frontier. Clearly, a canal from the coast to the interior would be not only a state asset, but a national one as well. Two years of distraction also gave Benjamin Wright time to survey two other suggested routes and prove both to be impractical compared to the so-called northern route Geddes found through the Irondequoit Valley in mid-state.

With the cessation of hostilities in early 1815, canal supporters, led by the canal commissioners, renewed their efforts, but they faced an uphill battle against political, technical, and financial skeptics. Even though the national benefits were evident, the federal government refused to offer any financial support. Any canal would have to be a totally state-sponsored

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14 Whitford, *History of the Canal System*, 59-61.

project, but most legislators did not feel their constituents would look favorably on such a massive expenditure.

In a brilliant move to garner public support, the commissioners prevailed upon New York City Mayor De Witt Clinton to write what came to be known as the "New York Memorial," a document that formally championed the northern route and discredited all earlier ideas for inclined planes or routes using Lake Ontario. Hydraulic locks would be used exclusively to change elevations, including the ascent west out of the Hudson Valley along the Mohawk River. The commissioners then enticed Judge Jonas Platt of New York to host a meeting of about 100 prominent New Yorkers, where speeches by Platt, Clinton, and others introduced the grand plan. Most of those present endorsed it, as did many others when copies were sent around the state, and the legislature soon received over one hundred thousand petitions urging an immediate start of construction. Of course, this campaign also reawakened canal opponents, who again pressed their case vigorously as well.[15]

Faced with lobbying from both sides, the legislature once again avoided taking any action, including continued support for the canal board. Deprived of funds for two years, the canal commissioners submitted their final report on March 8, 1816. While presenting no new information, they still strongly recommended construction of canals to both lakes Erie and Champlain.

> From the number and respectability of the applications now before the legislature in favor of an immediate commencement and vigorous prosecution of this great national work, it is evident that the immense advantages that would result from its completion are duly appreciated by our fellow citizens; and it only remains for the legislature to sanction by their approval an undertaking which combines in one object the honor, interest, and political eminence of the state.[16]

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[15] *Ibid*, 72-73

[16] *Assembly Journal*, 1816, 269.

Whether the legislators were inspired by the promised "honor, interest, and political eminence," or by a realization that canal support was indeed broad, is not clear, but they finally began to take positive action, even if initially tentative. Still, debate was fierce, and only on the last day of the session did they vote to authorize a new canal commission, charging it with obtaining surveys, cost estimates, and possible support sources for canals from the Hudson River and lakes Erie and Champlain. Even though no actual construction was approved, canal historian Noble Whitford identifies this act as "the beginning of active canal policy."[17]

The commission, which had selected De Witt Clinton as its president, eagerly pursued its charge and presented its findings on the Erie Canal to the legislature on February 17, 1817. Its salient points were as follows:

- The canal should accommodate boats capable of carrying 100 tons.
- The canal should be 40' wide on the surface, 4' deep, and 28' wide at its bottom.
- Locks should be 90'long by 12' wide.
- By the 353-mile northern route, the canal would have an aggregate rise and fall of 661.35' and require seventy-seven locks.[18]
- The estimated construction cost would be $4,881,738 [1817 dollars], equal to just over $13,800 per mile on average.

Because one of the commissioners, Joseph Ellicott, strongly preferred a southern route—a route that just happened to pass through land owned by a company for which he served as agent—an estimate was prepared for it as well. That estimate was almost $310,000 (6.3 percent) less than the one for the northern route, even though the southern route would require twelve more locks. The northern route's estimate was higher primarily because the engineers as yet had

[17] Whitford, *History of the Canal System*, 75.

[18] The survey found Lake Erie to be 564.85 feet higher than the Hudson River, but this aggregate includes ascending and descending the high ground around Rome.

no idea what it would take to cut through the hard rock to build locks and a channel at Lockport, so they included additional funds for those tasks.[19]

Armed with these figures, Clinton approached Congress for assistance, based on a pending plan by John C. Calhoun of South Carolina to apportion road and canal construction costs among the states that would benefit. Calhoun's bill passed both houses of Congress early in 1817, but President James Madison, previously a supporter of such actions, surprisingly vetoed it. Once again, the burden of building the canal was thrust solely on the backs of New Yorkers, but if anything, the indignation they felt only reinforced their determination to take on the job alone. The collected tolls could ultimately pay for it.

On April 15, 1817, only six weeks after Madison's veto, the New York Legislature authorized construction of the first portion of the "Grand Canal," as the Erie was originally known, along with the shorter Champlain Canal. The first portion of the Erie Canal would be the 86 miles between Rome and the Seneca River. This would test whether the cost estimates were accurate, and in any case, such a canal would be a clear benefit to the area, even if nothing further was built.[20]

The political fights were by no means over with the passage of this bill. Arguments over financing, the location of the Lake Erie terminal, and how the project would be administered continued, but construction of the canal could finally begin.

During America's early decades, the most popular date for the initiation of any major endeavor was Independence Day. The Erie Canal was just such an endeavor, so July 4, 1817, the first Independence Day following the legislature's authorization, was the date of choice for

19 *Assembly Journal*, 1817, 353-354.

20 Whitford, *History of the Canal System*, 81.

commencement of work. Groundbreaking would be at a spot near Fort Stanwix, just west of the village of Rome. Fortunately, the first canal contract was signed just one week before the celebratory day, and the first contractor, John Richardson, could be present to participate in the festivities. Following brief speeches by Village President Joshua Hathaway and Canal Commissioner Samuel Young, Richardson offered his remarks before turning the first spade of earth, an act saluted by a volley from artillery furnished by the nearby fort.[21]

Richardson had been awarded his contract by Benjamin Wright, the project's chief engineer. His selection was one of the commissioners' first actions. As the engineer who had done most of the survey work, Wright was the commissioners' best choice. In addition to his own expertise, Wright benefited from the assistance of his son Benjamin H. Wright as well. The Wrights sought to manage the overall effort and control costs by dividing the work into short segments and contracting each one separately. Other contracts soon followed Richardson's, and a total of 58 miles of canal had been contracted by year's end.[22]

The work progressed rather slowly at first, partly because methods had to be developed to perform certain tasks, such as pulling stumps, at an unprecedented rate, but the work rate increased as appropriate methods, such as an innovative, ox-powered stump puller, were found.

The project received additional aid in April 1819, when the legislature included a provision that exempted canal workers from militia service in a bill authorizing canal construction from the ends toward the middle. By the time the first section was completed, a boat named CHIEF ENGINEER had been built at Rome and set in the excavated channel. When water was first admitted, the CHIEF ENGINEER floated free and became the first boat to sail on

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[21] Whitford, *History of the Canal System*, 88.

[22] *Ibid*, 86-89.

the canal, traversing the 16 miles from Rome east to Utica on October 22, 1819, and returning with the canal commissioners and their guests on board the next day.[23]

In their February 1820 report to the legislature, the commissioners happily reported completion of the canal's entire middle section, from Utica to the Seneca River. The Wrights' management plan had worked well, too. In spite of the many unknown conditions, inexperienced workers, and start-up difficulties, the final cost tallied up to $1,125,983, just over 10 percent above the initial estimate. This averaged out to $11,792 per mile.[24]

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23 *Ibid*, 91-92.

24 *Assembly Journal*, 1820, 516.

THE ORIGINAL LOCKS

With the myriad organizational and technical details that had to be worked out during the first two years of canal construction, neither Benjamin Wright nor anyone on his staff could afford to devote any significant time or effort to figuring out how to surmount the Niagara Escarpment at Lockport, even though Wright saw clearly that this would be the best route for the canal to take, once the legislature authorized that portion of the project. The problem had not, however, gone away, and serious consideration became necessary after the authorization to proceed came through in April 1819.

During his survey, Wright had determined that the level of the canal would have to rise by 60 feet at the head of a short gorge located at what would become the city of Lockport. Five locks, each lifting boats 12 feet, could do the job. Though this would be approximately half again the lift of most Erie Canal locks, the basic design of each lock would likely be the same as those already built or under construction elsewhere, but two unique problems had to be solved before construction could commence: how to be sure there would always be adequate water to operate the locks, and how to excavate the lock's foundations in such a variety of rock strata.

Although no one knew what the actual traffic density on the canal would be, a few people foresaw a third problem; a flight of five locks could present a serious bottleneck during periods of simultaneous traffic in both directions. Once a boat began an ascent, no other boat could descend until the ascending boat had cleared the top lock, or vice versa. This was not a problem for one lock, or even a combination of two, but extrapolating the time required to a transit a flight of five made very long delays conceivable.

Yet a fourth problem had arisen with some of the first locks constructed elsewhere on the canal, and it threatened the entire endeavor. The lock walls were constructed from cut stone that masons quarried and carefully shaped. This stone appeared to withstand the weather and usage cycles quite well, but it could not be cut so precisely that no sealant was required in between the individual stones. The standard technique of the time involved the use of "quicklime," technically calcium oxide (CaO), but also known as burnt lime or calcined lime, to fill and seal masonry joints. Quicklime was produced by heating limestone ($CaCO_3$) in a kiln to around 1,500 Fahrenheit to drive off carbon dioxide (CO_2). A dry, white powder, quicklime was inexpensive and easy to use, but it had some serious drawbacks. Once it had cooled, the highly reactive quicklime began to reabsorb carbon dioxide from the atmosphere and slowly revert to its original limestone. The reformed limestone lost much of the quicklime's powdery consistency and flexibility, but it did not form a dense, non-porous rock either. When wet, on the other hand, quicklime rapidly reacted with the water to form a paste called hydrated lime or slaked lime (Ca(OH)2). Although it was a good binder, slaked lime had little structural strength by itself and, thus, eroded easily. Either case resulted in a poor seal that could leak significant amounts of water through a lock wall. Expansion and contractions due to seasonal temperature cycles tended to exacerbate the problem. Maintenance and repair expenses exceeded expectations. Something better was sorely needed.

This was anything but a new or unknown problem. Masonry construction was one of the oldest technologies in existence, and it was well known that several ancient civilizations had developed various types of mortar for joints. One of the most successful of these was Roman concrete but, unfortunately, the recipe for Roman concrete had been lost for fourteen centuries, ever since the Goths conquered Rome in A.D. 410.[25]

Cement would be rediscovered in England and America during the late 1700s and early 1800s. John Smeaton began the process in 1756, when he added some clay (powdered brick) to a mix of quicklime and pebble aggregates. Though he did not understand the chemistry involved, he knew he had developed a strong, useful building material similar to Roman concrete. It and a similar mortar, made with sand instead of pebbles, found increasing use in England.

Canvass White, one of Wright's most trusted engineers, inspected a number of British canals and associated structures during a several-month visit in 1817. He evidently observed this mortar performing well in England, and he returned to America with considerable knowledge about the material and its use. Seeing the problems resulting from the use of quicklime in American canal construction, White began to investigate to see if a similar mortar could be concocted using local materials, since importing English cement would have been prohibitively expensive, so much so that the Canal Commission had gambled—incorrectly—that quicklime would be sufficient.

White was ultimately successful in his quest to find a substitute. Mason Harris and Thomas Livingston of Madison County were contracted to furnish quicklime for the middle section of the canal during 1818. Although they kilned the local limestone in the standard manner, masons found they could not hydrate, or slake, it at the jobsite. Canvass White took particular interest in the substance, and he engaged "Dr. [Andrew] Barto, a scientific gentleman

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[25] Roman concrete, now known as pozzolanic concrete, consisted of a unique volcanic ash mixed with slaked lime in a 2 : 1 ratio. As it cured—in either air or water—the lime bound the ash particles together into a stable material. A similar compound could be made using sand, though it was not as strong, since sand would not chemically bond

from Herkimer County,"[26] to experiment with it. Barto burned some of the raw mineral, pulverized it, mixed it with sand into a ball, and placed the ball in a bucket of water. The next morning, the party found that the ball was solid enough to be rolled across the floor. Barto compared it to Roman cement. White continued to experiment and develop a practical material that could be repeatedly produced and obtained a patent on "Water Lime Cement" in 1820. What he patented became known as natural cement (later Rosedale cement, for the town that most fully exploited it). White furnished an estimated 500,000 bushels of what he marketed as "water-proof cement" to the canal and, assisted by his younger brother Hugh, established a cement works at Chittenango to produce White's Water-Proof Cement for a wide market.[27]

Unknown at the time, what differentiated this Madison County limestone (argillaceous limestone) from other limestone was its high clay content. In time, similar rock was found in Cayuga, Onondaga, and Ulster counties, a supply originally believed to be inexhaustible.[28] The clay content made natural cement roughly similar to modern Portland cement, which is manufactured by adding clay and other ingredients to ordinary lime.[29] While no Portland cement was used on the original Erie Canal, several thousand tons would be employed on the Barge Canal almost a century later.

All of this forms a vital preamble to the primary focus of this report, the Lockport Locks. Canvass White's natural cement proved to be a Godsend to the canal. The first quicklime-sealed

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to the lime the way pozzolanic ash did. See Benjamin Herring, "The Secrets of Roman Concrete," *Constructor* (Sept. 2002), 13-16.

[26] Harley J. McKee, "Canvass White and Natural Cement, 1818-1834," *Journal of the Society of Architectural Historians*, vol. 20, no. 4 (Dec. 1961), 196.

[27] *Ibid*, 194-197.

[28] "Rosendale Natural Cement Chemistry," www.rosendalecement.net/html/rosendale_cement_chemistry.html, , accessed Nov. 6, 2006, 1.

locks had already begun to leak, and it is doubtful the flight of locks at Lockport could have been successful without it.

With a major construction and maintenance problem solved, and the canal rapidly pushing west, Wright and his team turned their attentions to the escarpment problem. In an enlightened move to find the best possible solution, Wright challenged each of his staff engineers, Charles Broadhead, James Geddes, Nathan Roberts, and Canvass White, along with their assistants, to develop feasible conceptual designs. The winning design would have to deal with the water-management problem and come to grips with whatever construction challenges the site presented.

Available records are few, but it appears that all of the engineers making submittals proposed a series of locks—then referred to as "combined locks," but now usually termed a "flight." Nathan S. Roberts presented the commission with a bold design that was far superior to the other submittals. While his "double-combined" locks, two parallel flights of five locks each, would be expensive to construct, the design clearly addressed the construction *and* operation challenges presented by the escarpment more thoroughly than any of its competitors, and the commission readily selected it. The commission also appointed Roberts to take charge of the actual construction.

Roberts' plan necessarily went beyond design of the locks themselves. Although there had been considerable political and technical debate over the selection of the canal's route through Lockport versus an alternate route further south, the Lockport route had been selected largely because of water supply. The crest of the escarpment was some thirty feet higher than the level of Lake Erie, but both Wright and Roberts realized that the best long-term operational solution was to dig far enough down into it to put the upper lock at the lake's elevation. This

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[29] Englishman Joseph Aspdin is credited with making the first modern Portland cement in 1824.

way, the lake could provide a virtually unlimited water supply, not only for the operation of the Lockport Locks, but also for the canal below them all the way to Rochester, a distance of almost 65 miles.

Digging this channel, known as the Deep Cut, 7 miles southwest to Pendleton may not have been the design challenge that the locks were, but the effort needed to accomplish it was prodigious. More than a third of the distance required excavation of a trench between 25' and 30' deep on average through the escarpment's hard Lockport dolostone layer. The remainder involved cutting into the softer stratum of Salina Shale, but this still required the removal of thousands of cubic yards of material. Not surprisingly, this was the last portion of the original Erie Canal to be completed.[30]

Roberts impressed the commission with the thoroughness of his evaluation and design. Not only was his proposal quite detailed, but his idea to construct two parallel flights of locks promised to eliminate, or at least minimize, a potential bottleneck that might severely impede traffic on the entire canal. The dual flight accomplished this in two ways. First, each flight would normally handle traffic in only one direction. This way, each flight could act something like a modern escalator when traffic was heavy, and no boat would be delayed by one going the opposite direction. By using each lock as the supply "pond" for the one below it, boats could be simultaneously raised or lowered in every other lock. See Appendices A and B for diagrams that illustrate the ascent and descent sequences. Lockage could be done in both directions on a

[30] While an impressive feat, construction of the Deep Cut is beyond the scope of this study. For further descriptions, see Peter L. Bernstein, *Wedding of the Waters:The Erie Canal and the Making of a Great Nation* (New York: W. W. Norton, 2005), 281-283, Hereinafter noted as Bernstein, *Wedding of the Waters*; Whitford, *History of the Canal System*, 104-105; and Paul Bartczak and Craig Williams, *Field Trip Guide: The Erie Canal, Tonawanda to Medina* (Canal Society of New York State, May 5, 2001), 20-21, 48.

continuous basis, with one boat entering each flight just as another one left it, minimizing the total time any boat spent negotiating the flight.

The second advantage of the parallel flights was in their economy of water usage. As the diagrams in Appendices I and II show, each boat required the net equivalent of only one lock's volume of water to make the complete ascent or descent. Having only a single flight would have resulted in many cases where one or more locks would have to be drained without raising or lowering a boat just to change direction. This was not a problem for single locks. In fact, single locks often raised and lowered boats alternately to make the most efficient use of water, but the situation was more complex for a multi-lock flight such as Lockport, and Roberts appears to be the only one who thought it through so thoroughly.

For such a complex installation, the dual flights also furnished a margin of safety. In the event any one lock's gate or valve failed to operate properly, the lock tender had the option of closing just that flight long enough to make repairs. While using only the remaining flight for traffic in both directions significantly reduced throughput and efficiency, the canal could remain open.

Throughout the length of the canal, the commissioners issued relatively small contracts for specific excavations or structures to people who lived in those areas, believing that such individuals best knew the local physical features and where to obtain both supplies and workers. While most of the initial canal workers were men from the area, they ultimately proved too few to accomplish the massive task. The additional work force needed came largely from the ranks of immigrants to the young United States, with a large percentage of them coming from Ireland. A good many were in the area by the time the Lockport project began, and Irish workers seem to have worked on it from the start. Attracted by wages of $12 per month, plus food and a bed of sorts, these hard-working, hard-drinking characters brought with them a colorful heritage and culture that ultimately became an important ingredient in the culture of Lockport and, indeed, the entire canal region.[31]

On May 21, 1821, the commission contracted with Claudius Boughton, Joseph Comstock, Oliver Culver, and John Maynard to build the Lockport Locks, including a portion of the Deep Cut at the head of the locks.[32] No detailed drawings, what are known today as working drawings, or formal specifications appear to have been used. If any existed, they did not survive, nor did any presentation drawings by Roberts (which may have served as the primary construction drawings as well). But many structures of the period were built without drawings, and since a good number of masons existed who had gained experience in building the other Erie Canal locks, they would have needed few, if any, detailed drawings. Roberts' innovations were in the overall concept, not the details.[33]

The primary difference between any of the Lockport lock chambers was the substrate upon which they rested. As noted earlier, the escarpment's strata varied from soft dirt and sandstone at the bottom (Lock 67) to hard dolostone near the top (Lock 71), so the excavation techniques employed ranged from pick-and-shovel to black-powder explosives. Material removal, or "mucking out," was primarily done manually by scores of workers, though innovative, horse-powered derricks were built and employed in the Deep Cut and, possibly, the upper end of the lock excavation.

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[31] Bernstein, *Wedding of the Waters*, 207.

[32] Canal Contracts, Series A1125, Box 5A, Folder 4, New York State Archives, Albany, New York.

[33] *Flight of Five Historic Structures Report* (Buffalo: Flynn Battaglia Architects, 2003), 7. Hereinafter noted as *Historic Structures Report.*

The use of explosives was still a young construction technique, and numerous stories survive of incidents that would be considered horrendous and unacceptable today. Typical is one description by an unidentified visitor in January 1823:

> Excavations for the canal through the Mountain Ridge had progressed in some places to the depth of three or four feet, and in many places not yet begun. Hundreds of drillers were every day click-clicking powder holes into the rock mountain, and blasting out showers of stone, which, in descending, scared the women, wounded or killed the men, and riddled the roofs of the surrounding erections called houses. It was not uncommon to see mangled men, with eyes or limbs destroyed or skulls broken in.[34]

This description may have been of canal excavation through the top of the ridge, but the same method, with all attendant hazards, was employed to excavate the upper lock foundations, and they were closer to most of the houses mentioned. In any event, lock-wall construction on these foundations was just beginning in early 1823, since the same newspaper account noted, "Before leaving Lockport, we were present at the laying of the first foundation stone for the locks."

There is some uncertainty about the composition of the floors of these first locks. The common design of the era laid wooden timbers approximately one foot square in section perpendicular to the lock's long dimension to form a floor. This furnished a smooth bottom for the chamber as well as a flat foundation surface for the stone lock walls. The floor also distributed the weight of the stone walls over a greater footprint area, a valuable feature that helped prevent settling in soft soils. Most of the Lockport flight, however, was cut into solid rock, and debate has continued over whether or not the wooden floor was omitted here. The only known drawing of the original Lockport Locks suggests that both beliefs are partly correct. While Locks 68 – 71 were built on excavations cut into hard rock of several strata, Lock 67, the

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[34] Copy of a clipping from an unidentified newspaper, probably the *Lockport Democrat,* in the files of local historian Margaret Truax. Though it is undated, the writing style and appearance are those of the period rather than of a modern publication.

lowest lock, rested on the upper soil layer of the Grimsby Formation. An undated drawing of what clearly are the original locks shows a wooden floor in Lock 67, but none whatsoever in the remaining locks, a strong indication that these four were erected directly upon excavated bedrock.[35]

The heart of this flight of locks was its stonework. Although it appears that some of the stone used in the original locks may have been re-used in building the enlarged locks, no surviving stones can be definitively identified as being from the original construction, so the specific quarry, or quarries, furnishing this stone can only be presumed at best. Existing specifications from the 1848 enlargement furnish the only clues, noting, "In excavating and removing the present locks, care shall be taken to preserve the cut stone . . . of value in the present locks [that may be] allowed in the new works," and, "The masonry shall be of gray or blue limestone."[36] All of this implies that stone for both the original and enlarged locks was quarried close by from the upper stratum of the escarpment.[37]

All of the canal's lock chambers were built to the same length and width, 90' by 15' (3' wider than the first estimate), and each had a minimum depth of four feet to comfortably accommodate the 3½' foot maximum draft specified for the boats. To allow two feet of freeboard at the top with a lock full, the walls of each chamber at Lockport were 18' high from the floor to the top rim. The lock gates were the same height, except for the upstream gate of

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[35] Entitled "Plan of the Locks at Lockport," the drawing contains both a plan and sections of the flight. The undated drawing appears to be a record drawing made sometime after completion. No dimensions are indicated, but a comparison with its graphic scale yields close correlations to known dimensions of the 1825 locks, and various details closely match other contemporary illustrations. Prints of this drawing are maintained at the New York State Canal Corporation (New York State Thruway Authority) Western (Buffalo) Division Office, Cheektowaga, New York, and at the New York State Archives, Albany, New York.

[36] *SPECIFICATIONS of the manner of building the Combined Locks at Lockport, and Race around the Locks, for the Enlargement of the Erie Canal.* New York State Archives, Albany, NY. Reproduced in "Documentation Report on the Erie Canal 'Flight of Five,'" Foit-Albert Associates, 1999. Hereinafter noted as *Enlargement Specifications.*

Lock 71, which needed to be no taller than 7' since it opened into the upper canal channel. A 12' wide stone walk separated the two flights, a distance quickly found to be inadequate as the balance beams for the parallel lock gates overlapped the same area, making simultaneous operation difficult at best, with two operators needing the same space. Stone steps were built into the lock walls for operators to use when moving from one lock to the next. Two foot bridges were also erected, one at each end of the flight, to enable them to cross the flight. The edges of the lock chambers, stairs, and bridges were lined with wrought-iron railings, except where they would interfere with gate operation.[38] While the available drawing does not show a path for mules up the escarpment, surviving sketches made in the 1830s show a dirt path along the north side of the flight. Such sketches must be viewed with skepticism to account for artistic license, but, interestingly, these depictions all show additional foot bridges across the locks, one at each level, to facilitate easier movement around the complex and an absence of railings along the tops of the lock chambers, which would ease the handling of boats. The oldest available sketch, which first appeared in Colden's *Memoir*, shows only the two bridges indicated on the drawing, so the modifications shown in the sketches likely did occur during the flight's early years.[39]

Lock hardware was similar to that on other locks of the period. The gates were made from wood and assembled with wrought iron hardware. Each gate consisted of two leaves rotating about vertical hinge posts. They met in the center when closed to form a "V" facing upstream, a design known as a mitre gate. Thus, water pressure from the higher upstream level

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[37] Additional evidence of this will be discussed in the next chapter.

[38] "Plan of the Locks at Lockport," drawing.

[39] For an 1825 sketch, see Cadwallader Colden, *Memoir at the Celebration for the Completion of the New York Canals* (New York: W. A. Davis, 1825). The modified arrangement is visible in surviving lithographs, including "View of the Upper Village of Lockport, Niagara Co., N. Y., 1836," by J. H. Buford.

tended to force the leaves together and minimize leakage. A triangular, wooden mitre sill on the floor served as a stop for the closed position. Extending out to the side from the top of each leaf was a balance beam, a long, heavy timber that operators pushed against to open or close the leaf, something that could be done only when the water level was the same on both sides. When open, each leaf fit into a recess in the lock wall so that it would not present any restriction in lock clearance.

Valves of some type were necessary to control the water flow between adjacent lock chambers, but at this remove it is not possible to know exactly what kind of valves the original locks utilized. No surviving documentation mentions them, and contemporary illustrations offer no solid clues. Many early canals featured wooden gate (sliding) or wicket (rotating) valves mounted in the lock gates that were operated by levers or handles mounted on the balance beams. A few used iron for these valve components. A more-advanced arrangement that was starting to become popular replaced the gate or wicket valves with culverts inside the lock walls. These had iron valves, usually gate valves, at their upstream entrances operated by iron winches mounted on top of the lock walls. These valves sealed better and lasted longer than gate-mounted valves, but they required more elaborate stonework to form the culverts inside the walls. The one surviving drawing of the original locks details the stonework quite well, and it has some lines that appear to be just such culverts in the lock walls. But neither this drawing, nor any of the contemporary renderings of the Lockport Flight show anything that could be an operating lever or winch for a valve of any kind, and none of the original construction survives intact. Thus, we are left with something of a conundrum, and it does not appear possible to determine what type valves were installed with any degree of certainty. [40]

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[40] Rotary valves, or gates—the two terms have been used interchangeably for water-control devices—were also known as sluice gates or paddle gates. To further confuse matters, sliding valves, now generally called gate valves,

Another aspect of water management that applied to any lock offered a unique opportunity at Lockport. The water passing through any lock, or flight of locks, necessarily varied with the traffic, but the water supply into the higher level of the canal remained relatively constant, or varied seasonally, irrespective of traffic. Similarly, the flow out of the lower canal level varied because of leakage, downstream lockage and other non-traffic-related reasons. Accordingly, lock installations were built with adjacent by-pass channels parallel to the locks. By using either a weir or movable gate at the by-pass channel's entrance, the upper level could be controlled by allowing any volume of water above that needed by the lock to flow around it. At most locations the 8½' differential pressure head was considered too small to be useful for water power, but the 60' head at Lockport, coupled with the large volume of water available directly from Lake Erie, made the location ideal for extracting a considerable amount of power to run machinery in mills and factories.

This resource was a key to the rapid development of Lockport as a manufacturing center, but it also generated its fair share of conflict and controversy over how rights to any economic gain from this power source should be allocated and who should control them. In fact, the controversy continues to this day, even though direct water powering of mills and factories has long since faded from the scene. The overriding question was, and is, a complex one involving ownership of the land through which any power/by-pass channel is built; the channel structure; and, fundamentally, the water itself and its pressure head. As might be expected, those who invested in purchasing the land and building structures and devices to harness the energy emphasized the ownership rights of rear property, while others claimed that the water and its pressure, caused by a natural geological phenomenon, should be owned by the public. The

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were sometimes called paddle gates as well. Since drawings or illustrations of the original Lockport Locks are inconclusive, the actual type of any valve in the original locks is impossible to determine.

common link, and the one that made the disagreement more than moot, was the Erie Canal with its Lockport Locks, since this man-made structure made use of the water for power practical and provided economical transportation for power-produced products as well. It was a publicly funded structure in an era of *laissez-faire* private enterprise in America, two very different economic concepts no one quite knew how to combine, and for which virtually no regulations or precedents existed.

The canal commission recognized an opportunity and decided to sell the right to use this water to the highest bidder. Messrs. Hatch and Kennedy won the bid and executed the necessary lease with the commissioners in 1825.[41] Their power raceway was to be on the south side of the locks, where it would serve as both a power source and lock by-pass.

There was, however, one wrinkle in this plan. When the water rights lease was issued, the land through which the by-pass channel and raceway would pass was owned not by the canal commissioners, but by one Darius Comstock. Whether Hatch and Kennedy knew Comstock, or had worked out any arrangement with him concerning the raceway before bidding on the lease is not clear, but it soon did not matter. Comstock sold his property to Lockport entrepreneur Lyman A. Spalding, who soon purchased the land on the north side of the locks as well. Like Hatch and Kennedy, Spalding well knew the value of this water for power, and since it went through *his* property, he intended to exploit it exclusively regardless of any agreement made by others. By 1828, Spalding had constructed a flour mill over the race and a diversion dam to route the remaining water through an extended race system to other malls and factories owned by

[41] Hatch and Kennedy's winning bid offered the state $200 per year for use of the surplus water. For reasons now unknown, the lease agreement was written in a way that fixed that amount in perpetuity. Numerous attempts to change this clause have been made in the years since, none of them successful.

others. Spalding, of course, sold what he considered his water to them, completely depriving Hatch and Kennedy of their asset.

Considering Spalding's actions an infringement upon their property rights, Hatch and Kennedy asked the commissioners to intervene. While the commissioners, who had entered into the agreement in good faith, agreed in principle with the plaintiffs, they were on uncertain legal ground. They had leased the water, which they controlled, but they had no authority over the land across which it flowed. Realizing their legal conundrum and eager to reach an amicable settlement that would keep the mills operating and still satisfy the plaintiffs, not to mention start their lease payments, the canal board—through a mediator to avoid a direct confrontation—asked Spalding to reach a compromise with Hatch and Kennedy, possibly by purchasing their lease. Confident in his own position, Spalding refused and continued to use the water free of charge.

Unfortunately, Kennedy died not long after, and Hatch, lacking any firm resolve to pursue the matter from Kennedy's heirs, ultimately sold his lease to a syndicate who had determined the water was worth forcing the issue with the canal board. They immediately pressed their case with the board. Though issued a summons, Spalding failed to appear before the commissioners, who finally realized that no amicable settlement could be reached. Accordingly, they directed the lock superintendent to pass all water through the locks, thereby cutting off flow through the raceway. Deprived of power, Spalding was forced to close his mill and grant the legitimate lessees rights to build and operate power raceways across his land. The new lessees built a second raceway on the south side in 1833, and it furnished power to several additional businesses.[42] The south-side raceway system would be obliterated by construction of the Barge Canal locks between 1910 and 1918, although a tunnel would be built to serve a commercial hydro-electric power station. By then, electricity was rapidly replacing water power in individual mills and factories, making complete restoration of the race unnecessary.

The Lockport Flight was completed with suitable ceremony when its capstone was laid on June 24, 1825, several months before the last portion of the Deep Cut at the crest of the mountain ridge. This last portion was not completed without incident. As completion of the canal neared, merchants and boatmen grew ever more eager to reap their expected rewards. They had established a portage between Buffalo and Lockport until the last section could be finished. As soon as the canal between Buffalo and Tonawanda Creek was finished in August 1825, they persuaded canal operators in Buffalo to fill it and, thus, shorten the portage. Unfortunately, filling this portion of the canal also flooded most of the Deep Cut, delaying work until a drain could be dug to dry out the channel enough for the excavation work to be completed.[43]

As opening day approached, the commission finally chose people to operate the Lockport Locks. William C. Houck, commissioner in charge of the Niagara County section, selected Zenas P. Thrall to be the first lock tender, assisted by an individual identified only as Mr. Land. Thrall, a 24-year-old native of Windsor, Connecticut, who had come to Lockport for canal work in 1821, apparently earned the job by successfully managing the first passage by a boat (the

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[42] "Report, &c. To the Legislature of the State of New York." 1831. New York State Archives, Albany, NY. Hereinafter noted as "Canal Commissioners Annual Report," year. *Historic Structures Report*, Appendix, "Time Line," i.

[43] Whitford, *History of the Canal System*, 123.

WILLIAM C. HOUCK, no less) through the flight. His appointment letter was written a mere three days before the canal's official opening.[44]

In spite of the last-minute difficulties, work on the canal was finally completed in October 1825, and a grand celebration began on October 26th, when a flotilla of boats headed by the SENECA CHIEF carrying Governor DeWitt Clinton began an eight-day journey through the canal and down the Hudson River to New York City. A cannon shot rang out as the boats cast off from the Buffalo dock. Cannons arrayed along the canal's entire length relayed the signal all the way to New York and back, a process that lasted over two hours. When the returning signal was heard, the entourage set off for Lockport and, ultimately the Atlantic Ocean, into which Clinton poured a keg of Lake Erie water to symbolize the "wedding of the waters."[45]

The Erie Canal, "Clinton's Ditch," was open for business.

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[44] "Z. P. Thrall First Lock Tender," [Lockport] *Union-Sun and Journal,* Aug. 21, 1975, 19. This article includes a reproduction of Houck's Oct. 23, 1825 letter to Thrall.

[45] *Ibid*, 123-130. Bernstein, *Wedding of the Waters*, 308-321.

THE ENLARGED LOCKS

The Erie Canal was an immediate success. During 1826, the first full year of operation, some 7,000 boats used it, and they paid over $500,000 in tolls, about five times the amount needed to pay the bond interest due. The traffic and toll revenue continued to exceed anticipated levels, so much so that the commissioners were able to report that the canal's entire construction debt had been paid in full in 1837, years ahead of the most optimistic projections.[46]

While it proved to be a great success and an engineering achievement considered at the time to be one of the wonders of the world, Clinton's Ditch was far from perfect. To stay serviceable, it needed constant attention to repair normal wear and tear on everything from lock gates to the towpath, and natural occurrences wreaked havoc all too often. Heavy rainfall could dump more water into the ditch than overflow spillways could handle, causing the canal to overflow its banks. This usually meant damage to the banks and towpath that stopped navigation until it could be repaired. The entire canal froze in the winter, curtailing both navigation and maintenance for months. Under-ice currents and the action of snow and ice on the earthen banks damaged significant stretches every winter, but the damage could not be seen or corrected until the spring thaw. Miles of banks and towpaths needed reshaping each year, and the first boats through usually ran aground on shallow spots that had formed during the winter. These, of course, had to be dredged out as quickly as possible.

The stone lock and aqueduct structures generally fared better than the channels, but they were certainly not immune from weather damage. In spite of Canvass White's cement, water still found cracks where it could seep into or between stones, and its freezing and thawing

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[46] Bernstein, *Wedding of the Waters*, 325.

actions gradually produced additional cracking or heaving in weak spots. Moving ice could also damage lock gates. Damage that prevented proper operation or distorted the shape and size of a lock could result in opening delays of days, or occasionally weeks, pending repair.

Given the limited technological knowledge and experience at the time, the canal's vulnerability to weather is not surprising. Since nothing of this scale had been built before, little was known about the effects of weather and environment on such a structure, or about how to design for them. In all fairness, however, it must be noted that canals built a century and more after the original Erie, including the present day New York State Barge Canal, still share many of the same weather-related problems in spite of improved materials and methods. In retrospect, the original design and construction appear to be as sound as materials and practices of the day allowed.

Clinton's Ditch has been credited many times as the first field school for engineers in the United States. Much of the foundational work for establishing civil engineering as a respected profession was a by-product of designing and building the original canal, and many of America's best early engineers—men like Benjamin Wright, James Geddes, Nathan Roberts, John Jervis, and Canvass White, all of whom enjoyed distinguished careers—got their start on it.

But the lessons were not over as soon as the canal opened for service. As noted above, its day-to-day operations revealed a number of shortcomings. But the biggest problem the Erie experienced was its popularity. No one foresaw the tremendous growth in traffic that began almost immediately upon its opening. Its success spurred the construction of six more canals over the next decade in New York alone, and some of these connected to the Erie and fed even more boats into it. This density and the intense competition between "canawlers," as the boatmen came to be known, soon began to cause unanticipated maintenance troubles for the canal.

Two types of boats navigated the Erie Canal, packets, which primarily carried passengers, and freighters of varying sizes. Of these, the greatest competition existed between the packets, and speed was a primary means of attracting passengers. The smaller freighters tended to handle more valuable items than the larger bulk carriers, and speed was of interest to them, too. Speed is relative, of course, when the power source is a mule walking along the bank, but a higher speed causes any boat to generate a larger wake. All wakes splashed against the canal prism's banks, and those from speeds greater than about four miles per hour were strong enough to cause noticeable bank erosion. The displaced dirt slid straight to the bottom of the prism and created shallow spots that grounded larger boats. As early as 1819, only three years after the first canal section opened, the commissioners enacted a speed limit of four miles per hour to minimize this erosion. Lock masters could impose fines on boat captains who took too little time coming from the last lock, but many pushed the limit as far as possible anyway.

Packet boats posed other problems as well. They had the right of way through locks, something freight captains greatly resented, and this led to unsuccessful efforts at limiting the number of packets allowed each day. There was also a revenue issue. Canal tolls were based on each boat's net weight, which was determined by measuring their displacement at strategically located weighlocks and subtracting the boat's known tare, or empty, weight (measured each season at a weighlock). After a study revealed that these lightweight packets paid a fraction of the tolls paid by most freighters, the commissioners wanted to limit their numbers, too, but the demand by passengers was strong enough in this era of few travel options that no serious limit could be imposed. As for "speeding tickets," captains tended to consider them merely a cost of doing business and figured them into the fares they charged. Relatively ineffective at controlling erosion with speed limits, the canal maintainers began repairing the most vulnerable prism walls with stone or wood, an effective, but expensive solution. The cost averaged about $1,600 per mile, but almost 250 miles of the canal had been modified this way by 1828. Fortunately, the revenue needed to pay for it—most of it coming from the larger, slower freighters that did little damage—continued to pour in.[47]

More expensive still were major repairs needed to some locks, aqueducts, weirs, and bridges, but some of these offered opportunities to improve the facilities rather than simply repair them in kind. For example, the soft stone used to build at least one aqueduct had not withstood weather cycles well and had to be partially rebuilt. In the process, it was widened to allow two boats to pass. Some locks built in relatively soft or wet ground had settled to the point that they could no longer lift the heaviest boats to the higher channel. Boats having a full draft would run aground trying to enter or exit the upper gate, causing serious delays while some of their cargo was offloaded, portaged around the lock, and reloaded. There was no alternative to replacing such locks, but closing a lock would cost more in lost traffic and revenue than the cost of a new lock, so the best solution was to build a second, new lock beside the old one. Once it was finished, the old one could be dismantled, its foundation raised, and the lock rebuilt to end up with a double set that would expedite lockage in both directions. The Lockport Flight of Locks, having been built mostly on solid rock, did not have noticeable settling problems, but Roberts' wisdom in proposing a double flight was proving to be equally applicable to single-lock sites as well.[48]

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[47] Whitford, *History of the Canal System*, 131-132.

[48] *Ibid*, 132-133.

The collective effect of all these problems combined with the high traffic levels was a growing movement to enlarge the canal. It would, like the original project, be an expensive affair, but the original debt had been repaid quickly, and even with the repair and improvement expenses, the commissioners had been able to lower the tolls about 28 percent in 1833, so confidence was high that an enlargement project would yield similar results.

The canal commissioners submitted a report to the legislature the following year that described overcrowding, especially on the eastern portion of the Erie Canal, and suggested a likely need to double a number of locks in the near future. Though not specifically detailed in this report, the commissioners evidently had canal enlargement in mind, since they did recommend that any new locks be 10' longer than the existing ones. In his 1834 annual address to the legislature, Governor William L. Marcy agreed with the commissioners and began to lay the political groundwork for enlargement as well, noting, "If our canals are to be what a wide management cannot fail to make them—the principal channels for [western] trade—we must calculate its extent, and make them adequate to this object."[49]

As might be expected, this official mention of possible canal enlargement initiated much debate among legislators and other interested parties over the best dimensions for any enlargement, how best to progress any project without hindering navigation, how to fund it, and, of course, whether it was actually needed at all. The last consideration was more than just nay-saying by uninvolved persons who feared greater taxation or public debt, for what would ultimately prove to be formidable competition to all canals was looming on the horizon. Not having a practical canal route to the Ohio River, Baltimore, Maryland, businessmen had gambled on a new technology, the steam railroad, in 1827 to put Baltimore back in the running as a major

49 *Ibid*, 134. Whitford quoted the *Governor's Annual Message* of 1834.

port for traffic to and from the growing West. While the Baltimore and Ohio Railroad would not reach its goal until 1852, the technology was already demonstrating its potential in several locations, including the 16-mile-long Mohawk and Hudson Rail Road, which began ferrying passengers around the twenty-seven Erie Canal locks between Albany and Schenectady in 1831, pulled by a steam locomotive ironically named DE WITT CLINTON. The following year, the New York Legislature issued a charter for the New York and Erie Rail Road, which began building a line that essentially paralleled the Erie Canal, a line it finally completed in 1851. In 1842, a collection of several railroads (that would be consolidated into the New York Central System a decade later) began offering service between Albany and Buffalo. If rail competition was not enough, proponents of a new canal large enough for ships between Lake Erie or Ontario and the Hudson River renewed their push for public support and funding of that venture. All of these efforts argued against additional expenditures on the Erie Canal.

To rebut this potential competition, yet use the threat it posed to help justify an enlargement, the canal commissioners engaged John B. Jervis, Holmes Hutchinson, and Frederick C. Mills to perform a canal-railroad comparative study. Their report, submitted to the legislature in March 1835, suggested, but offered no conclusive evidence, that canals have, and apparently would continue to, "… cost less than rail-roads, both in their construction and repairs."[50]

Though a wide-spread economic recession began to take hold in 1834, support for enlarging the canal in the heavily Democratic legislature remained strong, however, and it ultimately decided in favor of enlargement in 1835, even though the canal board had not yet received its final engineering reports or decided on all of the changes that would be needed to

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50 *Assembly Journal,* 1835, 42.

accomplish the goal. Even the lock size remained in doubt, and the cost estimate of some $15 million was rough at best. In the final analysis, the commissioners decided on a canal 70' wide and 7' deep, with locks 110' long by 18' wide. Some minor changes in the canal's route were made to improve the alignment and eliminate a few locks, especially on the eastern end, but most of the canal would follow the original route, with new locks and aqueducts built more or less beside the old ones. Double locks were specified for locations with the highest traffic density, including Lockport. All of these changes would allow more boats to pass, each of which would be able to carry more than three times the cargo of their predecessors. Figure 3 provides a comparison between the original and enlarged boats and locks.[51]

For Lockport, the enlargement meant that a new flight of double-combined locks would have to be built, since it was not possible to simply enlarge the existing ones, which were in poor condition anyway. Fortunately, better documentation exists for this flight than for the original one. This documentation includes specifications and drawings that provide a good indication of the design and of how the work progressed, and it matches up well with what can be observed of the surviving structure. In many respects, including stone construction and wooden, manually operated gates, the new locks appeared to be simply larger versions of the original locks, but they actually contained a number of subtle, but important improvements.

Though the canal enlargement project was authorized in 1836, construction work at Lockport began two years later, after the funding was in place. Unlike the original Erie, this expansion was substantially engineered before construction began, and that took some time. The canal commissioners had selected Thomas Evershed, a 19-year-old immigrant from England, to serve as engineer in charge. Though young, Evershed brought unexpected experience and

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[51] For a thorough discussion of the enlargement debate and the development of the enlarged canal's specifications and early construction, see Chapter III of Whitford, *History of the Canal System*, especially pp 131-159.

knowledge to the project, and he had the self-confidence needed to take charge of the massive project. Quickly familiarizing himself with the situation, he realized that he had two basic tasks to accomplish before a shovel could break any ground.

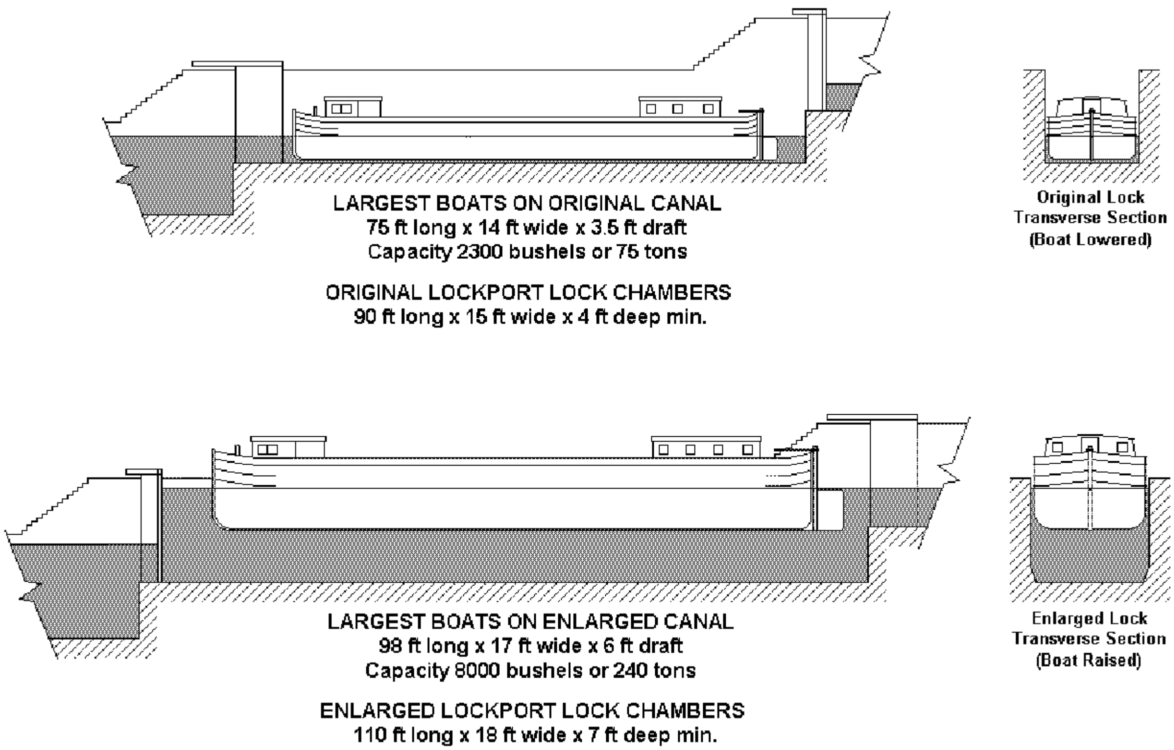

Figure 3. These drawings, all to the same scale, illustrate the capacity increase achieved with the first enlargement. Only one of the lock chambers is fully shown. (Drawing by author)

First, the commissioners insisted that navigation on the canal continue with a minimum of inconvenience during construction, which was initially expected to take about four years. While clearly understandable, this meant that the new Lockport Flight would have to be built alongside the original locks while they remained in service, and that meant a major new excavation into the escarpment wall, since the original locks had been put in the most optimum location. This excavation was, however, primarily a construction and time problem, not an engineering one.

Evershed's second concern did involve engineering, specifically, how to learn from the experience gained from operating and maintaining the original canal and then incorporate those lessons into the new designs. Because of its rock foundation, the Lockport Flight had less subsidence and fewer distortion problems than some other locks had experienced, but there were still opportunities for improvement, and the locks had worn out faster than anticipated. Additionally, the greater volume of the new locks meant that more water had to be handled during each lockage. While the same basic design, a pair of five-lock flights, would be used, Evershed did not want the greater volume to lengthen the time needed to negotiate the flight, which meant a higher rate of water transfer between locks. Water flow had to be controlled so that it did not jostle boats around within a lock, as this could cause damage to a boat, or even binding between the boat and the lock walls.

The design for a project of this magnitude could not be expeditiously accomplished by a single individual, and the Canal Commission had charged Evershed as much with managing the western end of the enlargement project as with engineering any portion of it. Accordingly, Evershed hired additional engineers to do most of the detailed design and drawings. Chief among these were Alfred Barrett, John D. Fay, Stephen F. Goodling, and Davis Hurd. While Evershed retained the ultimate design responsibility and personally signed the drawings, Barrett appears to have written most, or all, of the specifications and directed the design and drafting work.[52]

Where the original locks seem to have been built without much, if any, design documentation, depending instead on the knowledge and skills of stone masons, carpenters, and blacksmiths, Evershed's engineers prepared a detailed set of specifications that covered all facets

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[52] H. S. McCollum, "The Ten Combined Locks," *Niagara Democrat*, April 26, 1849.

of the projects scope, materials and methods to be used, and even the color of paint for the lamp posts.[53] These specifications included most of the material and dimensional information for component parts, as well as a number of construction dimensions that were repeated on Evershed's drawings.[54]

Beyond their larger size, the specifications and drawings reveal several significant differences between the enlarged locks and those completed in 1825, with the most important ones being:

- Timber foundations and floors at the bottom of all locks, not just Lock 67. The specifications and drawings contain considerable detail about these, as well as the stone rubble and hydraulic concrete beneath and between them.
- Filets at the bottom of lock walls, apparently to distribute the weight of the walls over a greater area of foundation.
- The certain use of culverts, channels within the walls, to route water from one lock to the adjacent one below. (Even if the original locks did have culverts with a single opening on each side of the lock, the new locks had larger ones with three inlets and outlets on each side that were able to handle much more water in a given time.)
- A wider apron between the parallel flights to give operators more room and eliminate any overlap of the gate balance beams.
- Longer approaches to the head and foot of the flight to improve boat handling.
- Improved iron snubbing posts to control boats during ascent and descent.
- Initial inclusion of a sufficient foot bridges.

Since the original double flight occupied the optimum location, it would have been ideal from a construction standpoint to demolish it entirely, and then erect the new double flight in essentially the same location, but the canal had to remain open. To maintain operation during

[53] *Enlargement Specifications.*

construction, but still minimize the project's cost, Evershed recommended, and the commissioners agreed,

> . . . to excavate sufficient width on the north side of the canal for one flight of locks, and construct them before the old ones are removed. After this set of new locks is completed, the navigation can be passed through them, and then the old locks may be taken up with safety and the new ones [the second flight] constructed upon their sites.[55]

With the construction plan and design established, the commission signed contracts with individuals identified as "P. Smith" and "Solomon and Horace Parmalee" in October 1838. The total contract price was $558,468.04, with the completion date for the northern flight, or tier, set as April 1, 1841. The southern flight was to be completed by the first of March 1843. The northern edge of the new flight would be 47' north of the existing north flight. Upon its completion, both original flights would be demolished to provide room for the second new flight and the widened center apron. Because of changes elsewhere on the canal, the total lift would decrease slightly.[56]

The drawings show rather ornate arched foot bridges with wrought-iron railings and lamp posts at the head of each lock (except across the foot of Lock 67), with a single stone arch approximately 6½' above each lock chamber. A drawing entitled "Lockport Locks"[57] also shows the bridge at the head of Lock 71, the top of the flight, to be a grander, four-arch span with a continuous deck across the tow path, both locks, center island, and by-pass race. Surviving photographs, however, show none of these elaborate

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[54] Evidenced by a comparison of *Enlargement Specifications* to numerous working drawings of the flight and its components by Thomas Evershed, all at the New York State Archives, Albany, New York.
[55] "Canal Commissioners Annual Report," 1839, 19.

[56] *Ibid*, 18, and "Canal Commissioners Annual Report," 1840, 63-64.

[57] This undated drawing contains both a plan and sections of the flight. Prints of this drawing are maintained at the New York State Canal Corporation (New York State Thruway Authority) Western (Buffalo) Division Office, Cheektowaga, NY, and at the New York State Archives, Albany, NY.

structures. Instead of decorative bridges faced with cut gray or blue limestone, five simple, thin stone arches with wrought-iron reinforcement rods and railings sufficed. These were placed at the foot of each lock, just east of the gates.[58] The decorative bridges no doubt were a casualty of budget constraints and delays that beset the entire canal enlargement project after 1842.

The 1830s and 1840s were difficult economic times for New York, and this caused the enlargement project to come under increasing opposition. Since a recession had begun in 1834, two years before the project even began, it was under something of a cloud from the outset. Many felt the massive debt and expenditure unwise and even extravagant given the conditions, and the pressure on elected officials to curtail the work continued to grow. Finally, with the state's finances in a critical condition and large loan payments—largely loans for canal construction—due, the legislature passed the Stop and Tax Act in March 1842. Governor William H. Seward quickly signed what became popularly known as the "stop law of 1842," or simply the "stop law," and it took effect in April. In addition to adding a property tax to increase revenue, it required that all existing public construction cease immediately, excepting only work absolutely necessary to maintain navigation or preserve work already done. Erie Canal enlargement stopped almost as quickly as a canal boat that had run aground.[59]

At Lockport, the contractors had fortunately remained fairly close to their schedule for building the north flight of locks. While it was not completed in time for the 1841 navigation season, the flight was ready when the 1842 season opened, just before

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[58] Three of these bridges across the north flight survive, but the other two were removed sometime after the Barge Canal locks were opened.

[59] Whitford, *History of the Canal System*, 167-169.

the stop law went into effect. Obviously upset over the stop law, the canal commissioners were nevertheless pleased in the quality of the workmanship at Lockport, reporting that, " . . . this tier of locks is constructed in the most substantial and perfect manner."[60]

While the hardy citizens of Lockport suffered through the same poor economic times as other New Yorkers, times made worse due to the loss of canal work, they had some other hurdles to overcome, or at least go around, after lock construction came to its abrupt halt. The stop law meant stop *now*, in the middle of whatever was going on. For Lockportians, that meant dealing with a maze of stone blocks and other construction materials that were scattered through much of the town, mostly in vacant lots. Within a mile of the locks rested 8,675 cubic yards of dressed and undressed stone, 9,000 feet of timber, and 40,000 feet of sawn planks headed for the southern flight.[61] These had amounted to a profitable inconvenience so long as work was in progress, as the stone more or less continually moved from the quarries to the job site, but stagnant stacks of stone and wood, especially stacks that partially blocked Canal Street, became increasingly annoying, to the point where citizens held public protest meetings. But no remedies were apparent, and the materials remained in place.

Canal operations suffered as well. With the new, larger flight ready for service, the original locks were permanently closed at the end of the 1841 season, and demolition of them began immediately to prepare the site for commencement of foundation construction of the new south flight. Even with the state's economic problems, traffic on

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60 "Canal Commissioners Annual Report," 1842, 49.

61 "Canal Commissioners Annual Report," 1843, 51.

the canal had continued to increase—lockages had increased some 12 percent during the previous year alone—and the commissioners realized that having only one flight in service at Lockport soon, ". . . would be oppressive to those engaged in the navigation, and injurious to the business of the canal."[62] Nevertheless, closing the old flights was a necessary step, and the commissioners had encouraged the contractors to work as fast as possible consistent with quality. They were still on schedule for a fall 1843 completion.

With the old locks partially demolished, the stop law could not have come at a worse time. The old locks could not be rebuilt, and the second new flight could not be progressed, leaving the new northern flight to handle all business in both directions, which continued to increase. Even with the enhanced capacity built into the new locks, negotiating a flight of five locks still took a good bit of time, so substantial delays were inevitable anytime boats arrived simultaneously from both directions. The exact time required to negotiate the complete flight is difficult to assess, as a number of variables could affect it. An optimistic estimate appears in an article concerning the debate over the need for two flights at Lockport that states, "The Locks in perfect order, and no break or other hindrance occurring, the Lockings [*sic*] can be made at the rate of one every EIGHTEEN MINUTES, including the delays in the change of water."[63] Thus, the quickest possible passage through the flight required at least an hour and a half.

To help reduce delays, the 1843 navigation season opened with a policy of operating the flight in one direction only for two hours, then reversing the direction for

[62] "Canal Commissioners Annual Report," 1842, 50.

[63] "The Lockport Locks—Mr. Hoffman," *Niagara Democrat*, Sept. 30, 1846.

the same length of time.[64] Since this was approximately the time required for a routine transit of the flight, it seems likely that up to three, possibly four, boats could be locked through during each two-hour period. (See appendices A and B for the multi-boat ascent and descent sequences.)

With such intense use, any problem, even a minor one, could rapidly become critical. For instance, one news report noted that the failure of a lock gate in 1846 had forced the entire flight to be closed until repairs were made. By that time, over 100 boats had stacked up awaiting lockage. The article did not say how long it took to get traffic back to normal.[65]

This was not an isolated case. Operating experience quickly showed the locks' construction to be something less than "most substantial and perfect," as the commissioners originally reported. In particular, the mortar between the stones proved to be "of inferior quality," in spite of the detailed specifications. Its rapid and unexpected deterioration allowed water to penetrate behind the face stones of lock walls. This trapped water exerted pressure on the back sides of the walls when locks were emptied, and repeated cycles further weakened the walls, so much so that several inches of movement could be seen in some spots. The only repair was to remove and relay the stone using, hopefully, better mortar and new iron anchors into the back walls. Some of the "paddle gates" failed, too, and even the by-pass race needed unspecified "large repairs." Such repairs took the flight out of service for anywhere from several hours to several days at a time. Some of this work was roughly equivalent to new construction,

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[64] "Canal Commissioners Annual Report," 1843, 51.

[65] "Heavy Traffic Resulted in Enlargement of Canal," [Lockport] *Union-Sun & Journal*, Aug. 5, 1964, 20+.

but considered to be maintenance, it was allowable under the Stop and Tax Act. Had it not been possible, the Lockport Locks, and with them the western end of the canal, likely would have closed before many more months had passed.[66]

The stop law may have averted a virtual collapse of New York State finances, but commercial and public pressures for and against completing the canal enlargement program did not diminish after 1842. Particular pressure against canal funding came from the rapidly expanding railroads, but those benefiting from the canals, especially the Erie, campaigned heavily for renewed public support of transportation infrastructure. Other measures taken by the legislature to reduce spending only served to deepen a divide between it and the governor's office, which was trying to eek out every dollar it could for canal "maintenance" to placate canal users. This rift, coupled with a state judiciary system seen to be failing, led to a public petition for a constitutional convention in 1845. This convention met the following year and drafted a new document that became effective on January 1, 1847. So important was the canal question that its Article 7 specifically dealt with canal funding. This article reaffirmed the policy of state support for canal construction and maintenance, but its provisions set limits on expenditures, established a sinking fund to repay canal debt, and defined how canal toll revenues could be used. With annual tolls from all canals by then totaling almost $3 million and expected to increase, a good portion would go to the state's general operating fund.[67]

After five long years of stagnation under the stop law, the canal enlargement, including construction of Lockport's southern flight, could begin again. Work on it re-

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66 "Canal Commissioners Annual Report," 1842, 72, 80. Also "Canal Commissioners Annual Report," 1845, 52.

67 Whitford, *History of the Canal System*, 177-180.

commenced at the end of the navigation season in fall 1842. As with the first flight, work began with Lock 67 at the bottom and progressed upward. In general, the sequence for each lock chamber was to do the necessary excavation; lay the foundation timbers and flooring planks; erect the masonry walls, complete with culverts, breast walls, and quoins; and finally trim it out with wooden gates and iron fittings. Typically, foundation work was being done for one chamber while the one just below it was being erected and fitted out, but most excavation was done between navigation seasons to avoid damage or delays to boats from blasting.

During this second phase of construction, the commissioners reported that "ordinary repairs have been made to the combined locks [northern flight] at Lockport," and noted certain improvements as well, including the addition of iron strips on the coping for protection against tow-line wear. Though not mentioned, presumably similar strips were added to the southern flight as it was being built. Lock gate repairs and replacements appear frequently in the canal commissioners' annual reports, and spare gates were kept available.[68] At mid-century, each set of gates cost approximately $170.[69] The commissioners did not comment on the reasons for such repairs, but these were large, wooden components that saw frequent movement, so normal wear and tear would take some toll. Constantly exposed to water, decay was inevitable. They were also very exposed to impacts from the boats, which were handled entirely by men and mules. Minor collisions with no damage likely were a common occurrence, especially during busy periods, but even though the gates were solidly built, the force from a boat being

68 "Canal Commissioners Annual Report," 1848, 93.

69 "Canal Commissioners Annual Report," 1853, 113.

moved a bit too fast from one lock to the next could be substantial. Damage to a gate severe enough to cause its immediate failure was no doubt rare, if it ever occurred, but serious damage to any structural member could allow the water pressure to distort the gate, causing leaks or making it difficult for the lock tenders to open and close.

The enlarged lock gates were also more complex structures than their predecessors, in that each leaf contained a small gate valve known as a paddle gate that was operated by a long, horizontal lever mounted on top of the balance beam. Unlike early canal locks, this was not to control the water flow between chambers, but rather to ease the lock tender's effort a bit. Even with the same water level on both sides of a closed gate, a large force against the balance beam was needed to start a gate leaf moving, because the water in the upper lock had no place to go until the lock was actually open enough for it to flow around the leaf. By first pressing down on the lever, the lock tender opened the paddle gate in the leaf to give the water a route into the lower lock, thus easing the initial leaf movement. Once the leaf was opened a foot or so, he could release the lever and close the paddle gate if he wished, since the water could then flow between and around the opening leaves.[70]

April 1849 brought completion of the southern flight, and with it a resumption of normal, two-way traffic through Lockport. The construction lull caused by the stop law had more than doubled the anticipated construction time. The stop law had also added to the contractual complexity of the whole project. While the original contract had been

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[70] One paddle gate is shown on a sketch entitled "Lock – Old Erie Canal" made by D. Lacy in 1952, available at the Niagara County Archives, Lockport, NY. Paddle gates are also visible in a photograph taken during construction of the Barge Canal locks in 1911. This photograph shows a portion of one wall of the enlarged locks south flight that remained in place before its gate leaves were removed. See *Annual Report of the State Engineer and Surveyor of the State of New York for the fiscal year ended September 30, 1911* (Albany: Argus Co., printers, 1912), facing 202.

awarded to S. Parmelee & Company in September 1838, Parmelee sold out to William Buell and Asa Douglass a little more than a year later. Buell and Douglass worked to complete the north flight, demolish at least some of both old flights, and begin excavation for the new south flight before the stop law went into effect in spring 1842. When work began again, a contract was awarded to William Buell, Jr. in July 1847. The younger Buell, who evidently worked for his father, held the contract for only six months before transferring it to his father in January 1848. The reason for the son's brief involvement in this is not now known, but the elder Buell went on to complete the job.

With both flights of locks finally in service, the inconveniences caused by the stop law faded into the background as the final product was hailed. Editor H. S. McCollum of Lockport's *Niagara Democrat* was positively effusive in his praise,

> There are few public structures that have a more imposing appearance; none, of the kind, in the world, of greater magnitude; and none, that have been executed with greater skill, or that are more substantial and durable … The whole structure, in reference to exactness and neatness, of mechanical execution, as a specimen of architecture, will compare favorably with the best public edifices in Washington. [71]

In the same article, McCollum listed a number of specifications for the project, and its major designers, contractors, and suppliers:

Lock chamber dimensions:	110' long x 18' wide x 20' 7" high
Lift of each lock:	11' 7"
Total lift (5 locks):	58'
Cut stone used:	23,059 cu. yd.
Rubble & concrete used:	31, 020 cu. yd.
Supervising engineers:	Thomas Evershed Stephen Goodling

[71] H. S. McCollum, "The Ten Combined Locks," *Niagara Democrat*, April 26, 1849.

Engineers:	Alfred Barrett John D. Fay Davis Hurd
Prime contractors:	S. Parmelee & Co. (1838-39) William Buell & Asa Douglass (1839-42) William Buell (1847-49)
General superintendent:	Samuel Buell
Masonry superintendent:	Amasa Drake
Woodwork supervisor:	George Anthony
Lock gate supplier:	G. W. Hildreth
Iron work supplier:	F. Weed & Co.

(Note that, for clarity, modern terminology has been used for some of these titles.)[72]

Unlike the construction of Clinton's Ditch, the Lockport Flight was not one of the last elements of the enlargement project to be completed. Work continued elsewhere for more than a decade, with completion finally declared in 1862. As with the original Erie, the enlarged canal initially proved to be popular, and its traffic gradually increased through most of the 1850s and 1860s, even if it was at a slower rate than before. Thus, it is not surprising that calls for further enlargement began to be heard, with some advocating a canal as large as 150 feet wide and 8 feet deep. In numerous public meetings, citizen groups passed resolutions imploring the state legislature to pass the various "canal bills" that came before it. Owing its very existence to the Erie Canal, Lockport pressed the issue as hard as any area of the state, and the local *Niagara Democrat* minced no words in making its support clear. In a series of articles during 1851, the paper derided the "whigs" in state government who had called the constitutionality of public canal funding into question and defeated one such canal bill.

[72] *Ibid.*

The author, likely Editor McCollum, rebutted their objections in detail, listing no less than six specific precedents to justify the additional public investment.[73]

These "whigs"—both those who actually were members of the Whig Party and those who merely sided with them—were not really as anti-canal as the *Niagara Democrat* made them out to be. They well knew how much the canals had done for New York's economy, and they clearly wished to maintain the state's dominance over trade with the West. They were, however, equally enthused with another emerging technology, the railroad, which they were beginning to see as having even greater potential than the canals. There was public support to be sure, but most of New York's railroads were being built with private capital and, by the 1850s, financiers like Cornelius Vanderbilt and Jay Gould were acquiring many small lines and assembling them into large companies, such as the New York Central (1853), or building completely new ones like the Erie Railroad (completed in 1851). Both of these lines essentially paralleled and directly competed with the Erie Canal.

Not surprisingly, the politicians tried to please both sides. Considering the railroads' potential, the legislature began to shy away from massive enlargement projects. On the other hand, under pressure from canal operators and constituents concerned about this competition and the continued viability of the canal, it enacted various protective measures starting as early as 1833. The legislature chartered the state's earliest railroads to carry passengers only. This was soon amended to allow freight carriage, but only by paying a tax equal to the canal toll. Later acts limited freight business to the winter when the canal was closed and imposed a variety of restrictions and exceptions regarding tolls

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[73] "The Canal Meeting at Lockport," *Niagara Democrat*, May 1, 1851, "The Canal Meeting," *Niagara Democrat*, May 8, 1851, and "The True Friends of the Canals—Who are they?" *Niagara Democrat*, Oct. 16, 1851, are typical.

on such cargoes as passenger baggage and livestock. The complex, continually changing requirements were, however, relatively easy to skirt and difficult to enforce, and they had virtually no effect on the growth of railroad traffic. The total tonnage carried by the New York Central and the Erie, just two of the six railroads competing with the Erie Canal, exceeded that moving over the canal for the first time in 1869. By 1874, *each* of these roads hauled more tons than the canal. Freight on the canal had peaked at 6,673,370 tons two years earlier.[74]

While the debate droned on, the Lockport Locks continued to convey boats across the mountain ridge. Within a few years of the lock-enlargement project's 1849 completion, problems with poor materials or construction methods had mostly been worked out, especially those involving stone and other masonry. The vulnerable wooden lock gates continued to need repairs and periodic replacement, but the repairs do not appear to have been excessive, even with their heavy use. Perhaps the best evidence of this is the fact that the locks remained in service in the same configuration for seven decades.

Certain upgrades were made over the years, including an exchange of the original oil lamps for gas lights and a new pier for waiting boats at the head of the flight in 1853,[75] and the removal of stone arches and installation of iron bars under the foot bridges to increase vertical clearance in 1861.[76] (The latter modification resulted in the thin configuration still visible in the three remaining foot bridges.) The Canal

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74 Whitford, *History of the Canal System*, Table No. 10, 911.

75 "Canal Commissioners Annual Report," 1853, 113.

76 "Canal Commissioners Annual Report," 1861, 100.

Commissioners Annual Reports frequently mention changes to ancillary structures, such as waste-water weirs, races, docks, towpaths, bridges, and banks over the years, often in attempts to deal with flooding. Since Lockport was at the mercy of what happened upstream, particularly at the Tonawanda Creek dam and guard lock, these efforts were actually more repair than improvement.

The arguments for again enlarging the canal to counter railroad competition with larger boats, including steam tugboats, finally resulted in what was known as the "Nine-Million-Dollar Improvement," begun in 1895.[77] It was based on a report by State Engineer Campbell W. Adams a year earlier that recommended:

- deepening the canal to 9'
- lengthening all locks to 220'
- installing "high lifts" where necessary
- installing an electric towage system to replace animals
- modifications to reduce maintenance costs[78]

The second and third items on this list would have a tremendous effect on Lockport. It was not practical to double the length of the two five-lock flights. The total disruption of canal operations and the amount of excavation into the rocky escarpment required made such a design impractical, but an alternative concept known as a lift lock—termed a "high lift" in the Adams Report—appeared to offer a reasonable answer. To assess the practical application of the lift-lock concept at both Lockport and Cohoes, the two points having the greatest elevation changes, the state engineer established an

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[77] Numerous canal improvement experiments and projects were instituted between completion of the enlargement program in 1862 and the start of the Nine-Million-Dollar Improvement in 1892. Since these did not involve the Lockport Locks, they are not included herein. For details, see Whitford, *History of the Canal System*, chapter IV, 258-353.

[78] Whitford, *History of the Canal System*, 355.

advisory board chaired by ex-State Engineer Elnathan Sweet. The advisory board, in turn, looked to consulting civil engineers for a detailed design proposal and estimate. For Lockport, Chauncey N. Dutton and William R. Davis developed a design for a large, two-chamber lift lock that would be pneumatically actuated.[79] For reasons now obscure, they chose compressed air for its working fluid instead of an incompressible liquid like water, but it may have been that this was to be the first pneumatic lift lock ever built.

A lift lock operates very differently from the hydraulic locks usually used in canals. Instead of changing the water levels in one or more fixed lock chambers to raise and lower boats, a lift lock employs two moving chambers with relatively constant water levels. Supported by a large, fixed structure and guided by vertical rails, the chambers traverse the entire lift in one motion. Actuation is by a large piston and cylinder under each chamber, with the two cylinders connected by a valved pipe. The pipe and lower portions of the cylinders are filled with a fluid, usually water, but compressed air in this case. As one chamber rises, the other descends. Their weights almost counter-balance each other, but about a foot more water is admitted to the upper chamber so that this additional weight furnishes the motivating force to lift the lower chamber. When the valve is opened, the greater weight of the descending chamber pushes air from its cylinder into the other chamber's cylinder, forcing it up, along with its water and floating boat(s). Each chamber has drop-down gates at both ends to allow boats to move in and out. As Archimedes first observed in ancient Greece, floating bodies displace an amount of water equal to their weight, so the number or size of boats in the chambers makes no difference; only the depth of the water need be controlled to cause movement. For each

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[79] *Ibid*, 59-50.

lockage, only the foot or so of additional water in the descending chamber is passed from the upper to lower level.

Mechanically, a lift lock is a fairly simple device, but most of the machine is above grade level, requiring a large, complex structure to both support the chambers and maintain their precise alignment. Such a structure is expensive to build, but it can offer a significant performance advantage. Each lockage could be made in a few minutes, compared to almost two hours for the five-lock flight. Another advantage for Lockport was that such a structure could fit in approximately the same space as the existing flights.

Aesthetically elegant lift locks have been built, notably one at Peterborough, Ontario, Canada, but the structure proposed for Lockport could hardly be termed anything but a visual monstrosity! The town's *Union School Courier* printed a pictorial drawing of the anticipated addition to the skyline that is reproduced as Figure 4.[80]

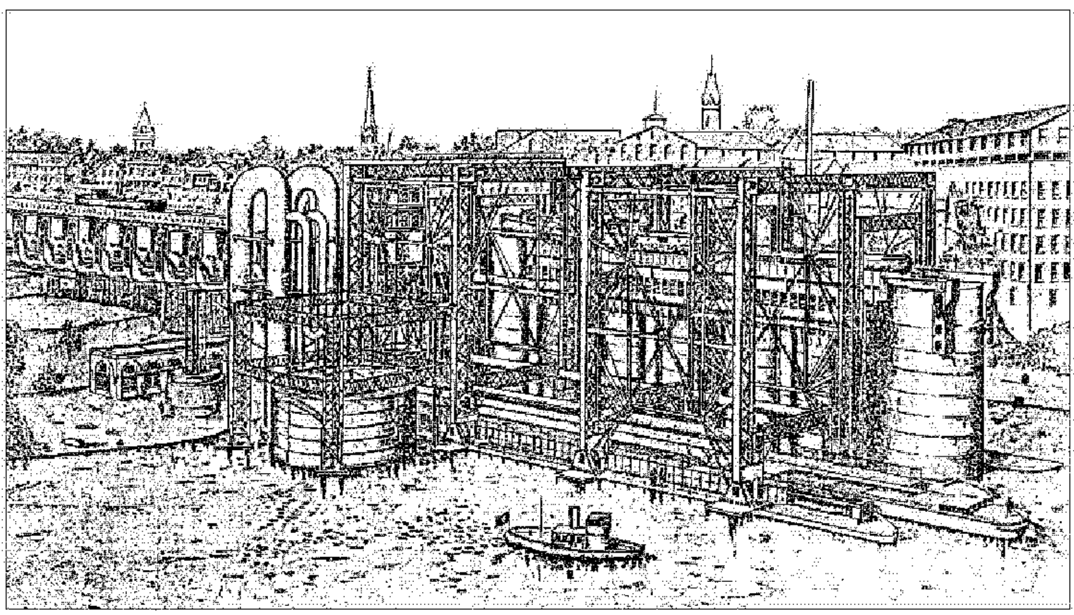

Figure 4. The pneumatic lift lock proposed for Lockport.

[80] "The new Pneumatic Lift Locks to be built in our city," [Lockport] *Union School Courier*, Dec. 1897.

Instead of using concrete for most of the fixed structure, this one was to be entirely fabricated out of steel, so its riveted, lattice columns and beams would have been totally exposed. To say that it would have substantially altered the face of Lockport is an understatement indeed.

Regardless of its aesthetics, this pneumatic lift lock would have been a major engineering achievement, much as the first flight of locks was in 1825, but it was never to be built. By the time Dutton and Davis finished their design in 1897, the whole Nine-Million-Dollar Improvement project had come under intensive review. When it became apparent that the $9 million had been spent and the total cost would actually be more like $15-16 million, allegations of fraud and mismanagement began to surface. While investigations did expose some dishonesty, the main problem was that nowhere near enough money had been authorized to begin with. Proponents wanted to get the enlargement under way, so they submitted the $9 million figure knowing that it was inadequate, but believing it was the maximum amount the legislators were likely to approve. As with the earlier projects, they assumed that supplemental appropriations could be obtained as needed to complete the work. But the gambit failed when the legislature passed no additional appropriations, and the work came to a halt with more than one third of the needed construction, including the pneumatic lift lock at Lockport, undone.[81]

Both the state and federal governments had interest in an improved Erie Canal, and both made efforts to define one, but they began with very different premises about

[81] Noble E. Whitford, *History of the Barge Canal of New York State: Supplement to the Annual Report of the State Engineer and Surveyor for the State of New York for the Year Ended June 30, 1921* (Albany: J. B. Lyon Co., 1922), 25-26. Hereinafter noted as Whitford, *History of the Barge Canal.*

what it should be and do. Congress and the U. S. Army Corps of Engineers entertained the idea of building a canal for ships as large as 30 feet deep and 250 feet wide. Its locks would be 600-740 feet long by 60-80 feet wide, depending on the final depth selected. The Corps estimated the total cost for such a canal would be a staggering $200 million.[82]

Even before the fiasco of the Nine-Million-Dollar Improvement project, New York had begun to re-assess its canal policies. A succession of canal and trade commissions had come and gone without much in the way of meaningful action, but that began to change when Governor Theodore Roosevelt appointed a state Committee on Canals in March 1899 and charged it with developing a state canal policy. Tackling its task with gusto, the commission submitted its report on January 15, 1900. In contrast to the Federal concept, it came to the conclusion that the economics of a larger barge canal substantially outweighed those of a ship canal. Accordingly, it recommended that the Erie, Oswego, and Champlain canals be enlarged, with the Erie made large enough to accommodate barges and boats up to 150' long, 25' wide, 10' in draft, and capable of carrying 1,000 tons of cargo. The committee estimated this Erie project would cost just under $59 million—still not cheap, but less than a third of the Corp's estimate for a ship canal.[83]

[82] *Ibid*, 27-38.

[83] *Ibid*, 40-46.

THE BARGE CANAL LOCKS

The 1900 report of the Committee on Canals outlined what would become the New York State Barge Canal System, but it was by no means certain that it would be built at all. The committee had considered alternatives to such an extensive enlargement and modernization, including the aforementioned ship canal and the complete abandonment of state-run canals. The latter case would rely on railroads to improve their efficiency and thus reduce costs to shippers, something that the committee would have no ability to influence. Alternatively, Great Lakes commerce might be lost to the St. Lawrence River route if Canada chose to invest in the needed improvements.

The committee analyzed each of these alternatives in considerable detail, looking at vessel and operating costs as well as those for construction. It concluded that water transportation would remain cheaper than rail for an indefinite time, and that a large barge would cost about one-tenth as much to build per ton of cargo capacity as an ocean steamer and be much cheaper to operate on inland waters as well. The committee was not alone in its support for a better canal. Perhaps the strongest advocate, in both opinion and personality, was Governor Theodore Roosevelt, who soon would be equally supportive of another canal venture in Panama. While Roosevelt would serve only a single two-year term, his successor, Benjamin B. Odell, Jr., favored the idea as well. Also lining up in support was the New York Commerce Commission, which had been appointed to investigate the causes of a decline in the state's commerce by Roosevelt's predecessor, Frank S. Black. It submitted its report favoring canal improvements just ten days after the Committee on Canals made its recommendation.

In spite of these reports, canals still had powerful opposition in the state legislature, and it took three more years for supporters to get the project authorized and funded by the legislature. As with the earlier canal projects, the legislature authorized Barge Canal funding in piecemeal fashion.[84] After contentious political maneuvering, the legislature directed State Engineer Edward A. Bond to make the necessary surveys and estimates to build what the committee had recommended in April 1900, with instructions to complete the work before the 1901 session convened the following February. By hiring consulting engineers who specialized in various aspects of the project, such as high-lift locks, dams, surveying, and grading, Bond completed the study, now known as the Preliminary Barge Canal Report, on time.

The report was an exhaustive evaluation of four possible alternatives estimated to cost between 46.8 and 81.6 million dollars, and it included several innovative design concepts for locks and other structures that would be utilized in any of these alternatives. Chief among these was the extensive use of concrete as the primary structural ingredient in locks and fixed dams. Additionally, steel would replace wrought iron for metallic components, and electric motors would replace human power for operating gates and valves. Controversially, three of the four alternatives involved the canalization of natural watercourses, particularly the Mohawk River, for portions of the new canal. While many familiar with canal operations considered reliance on unpredictable, natural streams to be more risky than totally man-made ditches, Bond and his consultants believed they had a

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[84] While "Barge Canal" is used herein to identify the modern Erie Canal, the Barge Canal System recommendations and legislation involved three canals, Erie, Champlain, and Oswego (the Cayuga-Seneca Canal was added in 1909). All received improvements, but those for the Erie were far more extensive in scope, and they required approximately 90 percent of the total funds authorized for the Barge Canal System in 1903.

plan that would be both safe and considerably less expensive than a fully man-made canal.[85]

Even with Bond's report in hand, the political process continued at a snail's pace. Re-elected in part on a pro-canal platform, Governor Odell finally brought the matter to a head shortly after his inauguration. Not surprisingly, his January 1903 annual message to the legislature strongly recommended adoption of a constitutional amendment and funding for the large canal, but he also proposed a reimposition of "limited tolls," as he phrased it, to at least pay for its maintenance. (All canal tolls had been abolished in 1882, so, even though the construction debt had been paid, maintenance was an on-going state expense that canal opponents continually brought up.) The necessary bills were quickly written and submitted. Odell's toll comment may well have been a *non sequitur*, but it did help open a door for discussion. Following two months of intensive debate, the legislature passed a canal referendum measure, one that did not include tolls, in March 1903. The act specified the major details for the three canals to enable them to handle 1,000-ton boats. The total cost was not to exceed $101 million. After another hard-fought campaign, New York voters approved what had come to be known as the Barge Canal Law the following November.[86]

With the project finally authorized, attention turned to engineering and construction. In the century since Clinton's Ditch, just about every facet of canal design and construction had changed. Some of the innovations, like concrete and steel, have

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85 Whitford, *History of the Barge Canal*, 57-65

86 *Ibid*, 84-136. Though most details are omitted herein, Whitford devotes two full chapters to the political maneuverings during 1903 that ultimately led to public passage of the Barge Canal Law. For a briefer account, see Michele A. McFee, *A Long Haul: The Story of the New York State Barge Canal* (Fleischmanns, NY: Purple Mountain Press, 1998,) 45-51. Hereinafter noted as McFee, *A Long Haul*.

already been noted, but construction methods changed as well. Trusting State Engineer Bond's recommendations, the legislature took the risk to select his preferred route that included natural courses and bodies of water for about a third of the Erie's total length. This alone was enough to put the Erie Barge Canal on the cutting edge of canal technology, but the waterway's structures, especially its locks, ensured it. Compared to their predecessors, these locks would be enormous, 310' long by 45' wide and capable of holding some 2.7 million gallons of water each. The Barge Canal would accommodate boats with capacities as large as 3,000 tons, ten times that of the enlarged canal. Additionally, mechanical power would replace animals. No tow paths were included.[87]

Before any dirt could be moved, Bond's concept had to be engineered in detail, and all of the project management apparatus put into place. No longer was it sufficient to give craftsmen general drawings and specifications and then let them use their best judgment to fashion the final product. These structures were much larger and more complex, with a variety of parts and systems that would come from different sources, but have to fit and function together precisely. This required many more engineering calculations and drawings than the Barge Canal's predecessors and hundreds of design decisions to obtain the best overall result. While some engineers developed the design specifications and drawings, others worked on the project's construction process and schedule. None of this could be left to chance without risking major conflicts between contractors, an inadequate supply and distribution of workers, vital materials or components not arriving in time, and serious cost overruns. All of this took almost two years to accomplish, so construction did not begin until 1905. The first shovel full of dirt

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[87] McFee, *A Long Haul*, 18-19.

was moved for the Champlain Canal on April 24th, and for the Erie Canal at Waterford on June 7th.[88]

One aspect the Barge Canal project had in common with the state's earlier canal projects was the use of numerous construction contractors. While this may have made overall management of the project more complicated in some ways, it freed the state engineer's office from having to deal with a myriad of day-to-day details. Contractors, not the state, would hire the needed workers and be responsible for their housing and board. They would also be responsible for procuring, maintaining, and operating any needed construction machinery, as well as dealing with others who might be affected by the construction activity. Not only did this system allow the state's engineers to concentrate their efforts on serious design and construction issues, but it was politically popular as well, because the plan enabled a sizeable number of contractors to compete for the business and, hopefully, earn a fair profit from their efforts. Additionally, it kept any one contract from being so large that it could not be effectively managed, thus keeping quality, schedule, and cost under control. Over the duration of the project, the state awarded some 210 separate contracts for everything from channel dredging to lock machinery. Since a number of these contracts were for large canal segments or structures requiring substantial resources, it is not surprising to find that a few well-established firms succeeded in winning several contracts each.[89]

All Barge Canal construction contracts were not awarded at the same time. Partly because of the engineering time required, Contract No. 67, "Construction of the canal

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88 Whitford, *History of the Barge Canal*, 211.

89 *Ibid*, 557-566. Also McFee, *A Long Haul*, 53.

prism, with two locks and all other structures at Lockport," was one of the later major ones to be awarded. At $1,027,137, not including over $90,000 added for supplemental work on bridges and various minor modifications to adjacent structures, it also was one of the largest, because Lockport would be the only combined lock on the Erie Canal.[90]

The city of Lockport had a problem of its own that stood in the way of an early start of lock construction there. The city had tapped into the canal as its source of fresh water from Lake Erie decades earlier, and draining the upper prism would cut off this supply. Accordingly, the city reached an agreement with State Engineer Henry A. Van Alstyne in 1904, well before construction began, to delay work in Lockport for two years, giving the city time to secure another source of water.[91] In actuality, prism excavation around Lockport did not begin until 1908, and lock construction started two years after that.

While project management may have been similar to that of the earlier canals, the actual construction was anything but. The operative word for nineteenth-century construction was "muscle," but by the early twentieth century it had become "steam." Human and animal labor dug rock and dirt, cut stone and wood, and moved everything to build the first two versions of the Erie, but the power of steam had been applied to machines of all kinds by 1900, and these machines were what made it practical to build the Barge Canal at all. Chief among them were steam shovels, steam hoists, steam dredges, and steam locomotives pulling trains of side-dump cars to haul away the

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[90] Copies of Contract No. 67 and other contracts noted herein are available at the New York State Archives, Albany, NY. Contract performance details are noted in various issues of the *Barge Canal Bulletin*, a periodical published by the Canal Commission that is also available at the archives. A similar, two-lock set was built for the Cayuga-Seneca Canal at Seneca Falls after that canal was added to the system in 1909. Seneca Falls and Lockport are the only two locations on the New York State Canal System with combined locks. Both have a total lift of approximately 49'.

[91] "Canal Board Here: Advisory Engineers Met City Officials," *Lockport Journal*, June 10, 1904.

excavated dirt and rock. These massive—at least for the time—machines moved more material than armies of men could have, and they were used for excavating lock foundations as well as canal channels. This is not to say that no manual work was required. Pick, shovel, and axe work remained plentiful, as did the hand work of preparing and setting explosive charges to break up rock. Carpenters also hand built wooden forms for concrete pours, and other men worked animal-pulled scrappers to perform most of the final smoothing operations in the canal prisms. But the awesome material handling tasks were primarily done by machines.

As a point of reference, it is worth noting that the United States built the Panama Canal across that isthmus during essentially the same period that New York constructed its Barge Canal System—1904-1914 versus 1903-1918. It is no accident that the two canals share numerous design similarities in such areas as the extensive use of concrete in locks and dams, the incorporation of natural watercourses, major excavations using steam-powered machinery and railroads, and the use of elaborate measures to control flooding and maintain an adequate water supply. Both projects employed top-notch engineers who used the best available technology. Certainly the health problems experienced in the tropics presented problems in Panama that Barge Canal managers and engineers did not face, and the need to handle ships instead of barges made for larger locks and cuts, but beyond those distinctions, the Erie portion alone compares favorably with, or even dwarfs, the Panama Canal.

Each of the Panama Canal's locks has a lift of approximately 27 feet, similar to many locks on the Barge Canal, which operates seven locks with that lift or greater—up to 40.5' at Little Falls. But Panama has a total of twelve locks (six pairs) compared to thirty-four on the Erie—it has no Lock No. 1—and Panama's total lift of 160 feet is less than one-fourth of the Erie's 675 feet. As at Lockport, two of the Panama Canal's three sets of locks are combined locks. The 50-mile-long Panama Canal's $366,650,000 price tag was more than three times that of the Erie, which was about six times longer. The Panama Canal has deservedly received the highest accolades since its opening in 1914, but engineers and historians familiar with the New York State Canal System, especially the Erie Canal, consistently rank it as at least an equivalent achievement in engineering and construction.

Because of the amount and variety of work needed on the canal's western end, several contractors had crews working in and around Lockport. By 1909, prism excavations were underway in both directions from the town. The Canal Commission awarded Contract No. 40 to the United Engineering and Contracting Company[92] to enlarge the prism southwest to Tonawanda Creek at Pendleton, some of which it subcontracted to the Bellew & Merritt Company and the Rochester Construction Company. The Empire Engineering Company[93] won Contract No. 66 for enlarging the level from the foot of the Lockport Locks east to Gasport. These excavation contracts also called for the erection or modification of bridges across the canal in those areas. When Contract No. 67 for the locks was awarded in 1910, it went to the Larkin & Sangster Co. All of these companies based their local operations in Lockport.

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92 Various sources, particularly Lockport newspapers, also refer to this company as the United Engineering Co. and, simply, the United Co. Part of the confusion may result from the company's bankruptcy and reorganization in 1912.

93 Also known as the Empire Engineering & Construction Co. and the Empire Co.

The canal contracts specified that these companies were responsible for recruiting their own labor forces. A small percentage of these were skilled in specialized areas, such as engineers, timekeepers, mechanics, machine operators, and carpenters, but unskilled laborers made up the bulk of the work crews. To allow them to concentrate on the job at hand instead of labor issues, the larger companies engaged labor agents, known as *padrones*, to secure their unskilled laborers. These *padrones* frequently competed with one another for the available men, and then employed all manner of schemes to extract as much of their hard-earned pay from these laborers as possible. Skilled personnel generally stayed in boarding houses or private homes, where they were generally treated with fairness and respect. The laborers, however, were not as fortunate. Most of them lived in camps of hastily built, one-room shanties lined with crude berths. These shanties, as well as the camp stores, were owned by the *padrones*, making it possible for them to collect the bulk of the men's pay in berth rent and store sales. Rents and prices were often excessive, but the legions of men rarely had any other options.[94]

Wages varied widely depending on the type of job and skills needed. Skilled craftsmen, such as stone masons, steam shovel operators, and the like earned around $4 per day, while laborers typically garnered about $1.50 a day. Waterboys, at the bottom of the pay scale, made less than $1 a day. The engineers, foremen, and boat captains earned $5 per day or more. Daily rates for semi-skilled workers like carpenters and deckhands generally ran around $2. All of these rates were reasonable for the time, but, as noted

[94] McFee, *A Long Haul*, 54-55.

above, the higher-paid men typically retained a greater portion of their pay than did those further down the ladder.[95]

While the money was reasonably good, much of the work could only be done during the winter months, roughly November through April. This was because the canal remained open for navigation from early May through late October. With water in the prism, no bottom excavation work was possible, though some bank work could be performed. This resulted in as many as two-thirds of those workers being laid off each summer.[96] The Lockport Locks were less affected by the navigation season than the channel enlargements. With cofferdams separating them from the operating canal and the enlarged "Flight of Five" handling traffic over the escarpment, construction work on Locks 34 and 35 continued with little interruption.

As with the earlier Erie Canal projects, many of the workers were immigrants from Europe. Irish men, some first-generation immigrants, and others from area families who had moved to Western New York to work on the previous editions of the canal, plus others from such Old World nations as Austria, Hungary, and Italy, made up almost half of the work force.[97] Nationality made no difference to the companies or *padrones,* both of whom considered laborers to be a commodity. The attitude of the time is reflected in a newspaper article about the first accident on the project. "Two foreigners were the victims of a premature explosion of dynamite on the barge canal work …," the article began, and it continued, "The foreigners who worked by number and whose names are

95 *Ibid*, 55. Also J. Rolland Gould to Clarence O. Lewis, Niagara County Historian, July 11 and 20, 1964. Gould's letters, available at the Niagara County Archives, describe his experiences working for the United Engineering & Contracting Co.

96 "Hundreds of Men Laid Off," *Union-Sun*, May 2, 1910.

97 McFee, *A Long Haul*, 55.

not known by the Rochester Construction Co., sub-contractors, were packing holes for blasts."[98] Fortunately, neither man died, though one had serious injuries to both arms and lost several fingers. Hiring and recording by number instead of name was probably the most convenient way around language barriers when English-speaking managers and time keepers could not understand, or even correctly spell, unfamiliar names. Other articles reporting on accidents involving men with English-sounding names identified them by name, indicating that personnel recording practices varied considerably.[99]

As these articles make clear, accidents, some of them very serious, happened throughout the work's duration. Not surprisingly, most accidents happened to workers who were most closely exposed to hazards, but, as the article on John J. Burke's death makes clear, supervisors were not immune. Foreman Burke received his fatal injuries from a dynamite blast after successfully leading several exposed workers away from the danger. That Burke left a place of safety to protect them says much about how the foremen directly involved with the work felt about their men, regardless of whether the company knew them by name or number.[100]

One accident was unusually spectacular, even though it, fortunately, injured no one. It occurred about 3:00 in the morning of August 11, 1910, roughly three miles southwest of Lockport, when a massive cantilever dredge known as a "grab machine," used to enlarge the channel through the mountain ridge, inexplicably collapsed into a twisted mass in the canal. The 300-foot-long machine built by the Brown Hoisting

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98 "First Accident on Canal Work," [Lockport] *Union-Sun,* Oct. 28, 1909.

99 As examples, see "Canal Worker Fatally Hurt," *Union-Sun*, Oct. 30, 1909, and "John J. Burke Meets Death on Barge Canal Work," *Union-Sun*, Feb. 12, 1912.

100 *Ibid.*

Engine Co. of Cleveland, Ohio, had been in service around the clock, so it is remarkable that none of those working on it at the time sustained injuries. United went on with its work, but there was nothing to do with this $50,000 machine except scrap it.[101]

While their function may have been the same, the design of the new locks differed radically from their predecessors. Instead of cut stone laid on a timber foundation, Locks 34 and 35 were constructed out of concrete. It was not then possible to make continuous pours of concrete as is commonly done today. Floors and walls were poured in sections. Carpenters built wooden forms to contain the wet concrete, some of which could be dismantled and re-erected several times when many identical slabs were needed. Some laborers mixed concrete for others to pour into the forms. Though cement mixers were used, they mixed the concrete in relatively small batches, so several were operating continuously when any pour was being made. Photographs taken during construction show two distinct, vertical slots cast into the ends of wall sections. When forms were built for the adjacent section, this slotted end was left exposed so that the wet concrete for the next section would fill the slots and form keys to lock the sections together. No sealant was used in the joints.[102]

Unlike most current concrete construction, no steel reinforcing bars or mesh, generically known as "rebar," were included. Engineers intended each section of floor or wall to be a concrete monolith. Later replacement of some wall sections and their subsequent breaking up for disposal revealed that a wide variety of scrap wood and detritus found its way into the mix. None of this was specified, of course, and it is not

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101 "Huge Cantilever Collapses in Canal," *Union-Sun*, Aug. 11, 1910.

102 A photograph from the New York State Archives showing these slots was reproduced in McFee, *A Long Haul*, 52.

now known if anyone in Larkin & Sangster's management agreed to, or even knew about, including this junk in the pours. It may well have been an easy way to dispose of some trash and reduce the amount of concrete needed by individuals who were ignorant of any deleterious effects it might have. Whether this "disposal" has actually caused any problems is difficult to assess. A number of lock wall sections have been replaced over the years after they cracked or lost chunks of material, but still more original sections remain intact and in service. Do the remaining original sections contain the same kind of foreign material? That will not be known unless they are replaced at some point, but those who operate and maintain the canal assume that they probably do.[103]

The lock gates are steel fabrications weighing roughly 50 or 100 tons. The lighter ones, with leaves that measure 24'-4" wide (not including end seals) by 20' high by 2'-6" thick, are only at the upper end of Lock 35. The heavier gates at both ends of Lock 34 are 44'-6" high, but otherwise similar. The original gates featured riveted construction, the standard for the time, but subsequent replacements have been modern weldments. Their basic structural design has otherwise changed very little. Like their wooden predecessors, every closed gate forms a "V" pointing upstream to ensure that the higher upstream water level tends to force it closed, and each gate opens into a recess in the lock wall to present a full-width opening for passing boats. Each gate leaf does, however, contain some wood. Treated white oak still provides the most practical seal where the leaves meet, at the base mitre, and around the hinge posts. The upper end of Lock 35 has two gates. Since this is now the last lock in the canal, the upper channel is open all the

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[103] Author's conversations with David Kumpf, an engineer with the New York State Canal Corp., Western (Buffalo) Div., in Cheektowaga, NY, and Duncan Hay, a National Park Service historian at the Erie Canalway National Heritage Corridor in Waterford, NY.

way to Lake Erie, and this redundancy ensures that no gate failure could subject the downstream canal to uncontrolled flooding. (There is a guard gate farther west at Pendleton, but it is closed to drain the canal for the winter, not for normal operation.)[104]

Each lock gate leaf is opened and closed by a 7-horsepower direct-current (DC) electric motor through a four-stage gear reduction system. Where many modern gear drives have all moving parts except the input and output shafts fully enclosed in a casing, these drives represent the norm for early twentieth-century drives in that their gears, shafts, and frames are fully exposed. The last link in the drive is an arm attached to the gate. This arm is actually a toothed rack that meshes with the last pinion gear in the drive train. Figure 5 is a diagram of one of these drives, showing the speed reductions at each stage. Reducing the speed increases the force on the gate arm proportionately, allowing a small motor to easily open or close the heavy gate leaf in 45 seconds. Note that the switch and solenoid brake to stop the drive at the fully open or fully closed position is mounted on the electric motor. It works by counting the number of revolutions the motor makes. This allows the single switch to control motion in both directions, and it locates the switch inside the cabinet where it is protected from weather and damage. Since this is an outdoor installation, each drive is housed in a steel cabinet for weather and personnel protection. One side opens for maintenance, which consists mainly of keeping the gears and bearings lubricated, and they are now painted the Canal Corporation's standard blue and gold colors. Those at the ends of each lock display the lock number.

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[104] The description of lock details herein is based on several sources, including the author's on-site inspection and conversations with David Kumpf and Joel Beyer, Chief Lock Operator at Lockport; Whitford, *History of the Barge Canal*, 471, 494-497; McFee, *A Long Haul*, 18, 81-83; and drawings of the locks maintained by the New York State Canal Corp., Western (Buffalo) Div., at its office in Cheektowaga, NY, particularly those for Contract Nos. 67, TAB-96-27C, and TAB-99-43C.

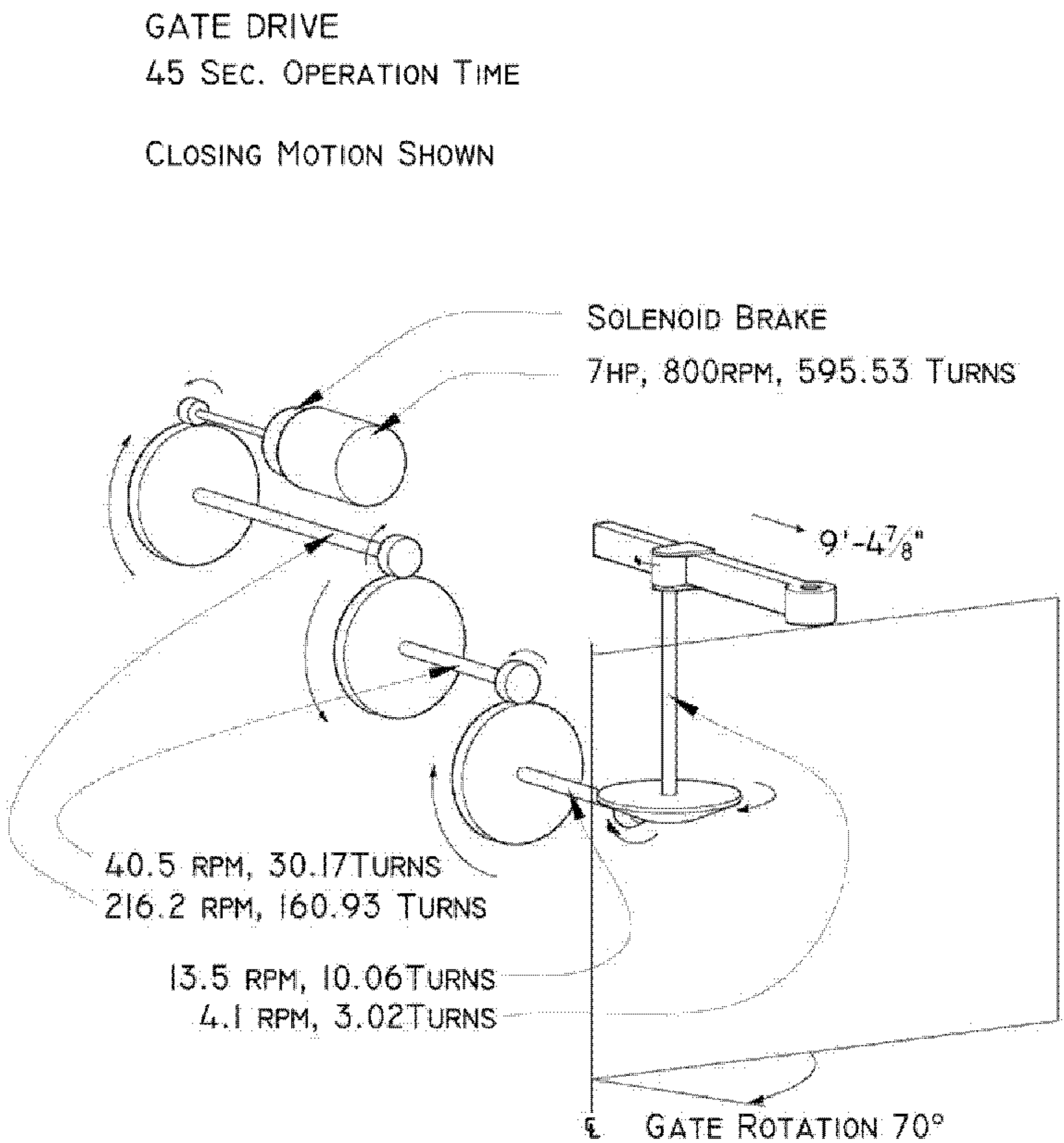

Figure 5. Schematic drawing of the gear drive used for each lock gate. Each gate utilizes two such drives, one for each leaf. (Drawing by Thomas Behrens, Historic American Engineering Record)

A similar 7-horsepower DC motor and gear train opens and closes each 7'-by-9' gate valve that controls the water level in each lock. As with the gate drives, two valve drives are needed at each end of each lock, one on each side. These, too, are four-stage gear drives that utilize exposed spur gears, but instead of stroking an arm, each of these drives turns a hoist shaft. Two wire ropes wrap around this shaft, and a vertically moving gate valve hangs from one end of them, balanced by a counterweight on the other. Originally, large chains were used instead of wire rope, and they will likely return as future maintenance is performed because the wire rope, coated to resist corrosion, has proved very difficult to inspect. Four flanged wheels on each valve roll on a vertical track. They keep the valve aligned to its port and reduce operating friction during the 82-second, 10-foot opening or closing movement. Without these wheels, a much-larger motor and drive would have been needed to overcome the resistance imposed by the water head on a sliding valve. Figure 6 diagrams one of these drives. Like the gate drives, each is enclosed in its own blue-and-gold steel cabinet.

The water passes through 7'- by-9' culverts molded into the lock walls. Twenty openings into each lock chamber, ten per side, were evenly spaced near the bottom of each lock wall, where the horizontal currents of incoming water would cause the least motion and disturbance to boats in the lock, motion that could damage both boats and lock walls if not checked. A single culvert runs within each lock wall, interrupted by a vertical well for the valve near each gate. Portions of these culverts, particularly where they bend, were lined with cast-iron plates to minimize erosion. The openings to admit water from the canal's upper level were fitted with bar grates to catch trash and debris that could damage the locks or boats. The north wall included a second culvert that conveyed water the length of both locks to a small powerhouse at the foot of Lock 34.

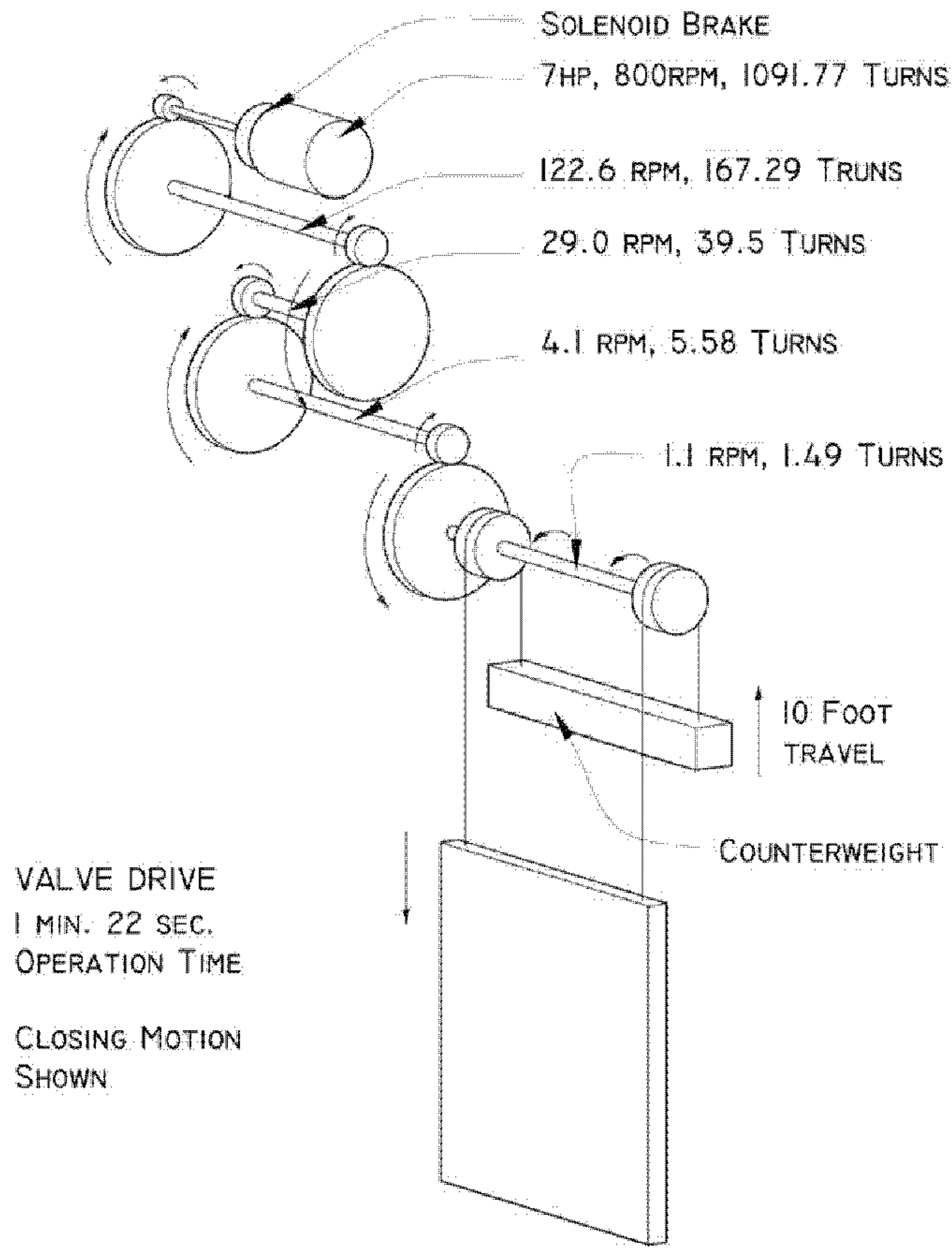

Figure 6. Schematic drawing of the gear drive used for each lock valve. Six of these drives are used, two at each set of lock gates. (Drawing by Thomas Behrens, Historic American Engineering Record)

Electric power also eased the handling of the larger boats through the locks. A 20-horsepower capstan was installed in a wall recess near each end of each lock. Capable of exerting an 8,000-pound pull, these capstans could move a boat at up to 60 feet per minute. A foot-treadle gave the lock operator complete control of the operation while freeing his hands to handle lines. Use of these capstans has been rare since the demise of large commercial craft on the canal more than a decade ago.[105]

Electricity was still relatively new and non-existent in rural areas when the Barge Canal was built, so most lock installations, including Lockport, would have to generate their own power. Since locks involved changes in water elevation, some water could be passed through hydraulic turbines to turn generators. The concrete building at the lower end of Lock 34 that now serves as a canal museum was built to house two 250 volt, 75 kilowatt, DC turbine-generators. With economical, commercial electric power available by the 1950s, motor-generator sets were installed to convert the commercial alternating current (AC) to DC for the drive motors, and the generators were taken out of service. At Lockport, as at most other locations, the generating machinery was removed and sold.

Where operating the original and enlarged locks involved a lot of strenuous manual effort by many men, the Barge Canal locks only require an operator—sometimes two, mainly to minimize the time needed to walk the length of the locks—to turn a few electrical switches and monitor the process. Mounted on a stand inside each of three small, windowed enclosures is a cast brass panel with five rotary switches, one for each gate leaf (right and left), one for each valve (right and left), and one for the buffer beam, a bar that protects the gate from boat impacts. One control station is at the lower end of Lock 34, the second at the gate between Locks 34 and 35, and the third at the upper end of Lock 35. (This station's panel includes two additional switches to control the extra set of gate leaves, but it does not have a buffer beam switch.)

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[105] Whitford, *History of the Barge Canal*, 497.

Larkin & Sangster completed the excavation, concrete, and steel work by fall 1913, long before the electrical machinery arrived from the manufacturers. This made it possible to pass boats through the new locks, albeit with great difficulty, before they and this section of canal were officially opened for business. Normal traffic continued to use the Flight of Five, but two boats, Empire Dredge and Derrick Co. No. 6 and an accompanying derrick boat, locked through Locks 34 and 35 on November 26, 1913. Without machinery to do the heavy work, manpower performed every phase of the procedure, which included pulling the boats, winching the valves open and closed, and moving the gates. The process was long and arduous, to say the least, but the locks performed as intended. The local paper reported it as "an event of some interest … witnessed by hundreds of people."[106]

Sections of the Barge Canal typically went into service for larger boats at the start of the next navigation season following completion, so there was no "grand opening," as occurred in 1825, and few section start-up dates are readily available. The Lockport locks were serviceable by 1915, as was the channel east to Rochester, but considerable work remained to be done on several sections, including between Tonawanda and Buffalo, so the number of large boats wanting to go west of Lockport would have been a fraction of those locking through once the big canal finally reached Lake Erie. While there was no "official" completion date, May 15, 1918, has been noted as the first day that full-sized boats and barges could travel the entire length of the Barge Canal.[107]

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[106] *Union-Sun*, Nov, 26, 1913.

[107] Whitford, *History of the Barge Canal*, 381.

The initial traffic level was disappointing, and canal officials found themselves having to explain that and defend the massive expenditure of state funds. There were, however, some valid, even predictable, reasons for the slow gains. There was little incentive for boat operators to invest in expensive new vessels until there was a canal for them to effectively use, so few large boats were in service by 1918. The captains could get a few more years out of their existing boats until the canal was finished. World War I had also intervened, raising the price of new boats along with most items. Even before the United States entered the conflict in 1917, the country was supplying its allies with large amounts of war materiel. Entering the war added a severe manpower shortage to the high cost of materials. If these economic factors were not enough, the Federal government, fearing that independent, private control of competing transportation companies would lead to uncoordinated chaos, decided to take direct control of most transportation resources early in 1918. The takeover of railroads by the United States Railroad Administration has been well documented, but the Federal action affected canals as well, including the Barge Canal. The return to pre-war ownership and control finally happened for the railroads in 1920 (with vastly increased Federal regulation of service and rates), but the government, which had built a number of concrete boats during the war, continued to operate them and control the Barge Canal for another year, in spite of intensive state lobbying for the return of its property. Even though peace had returned three years earlier, investors had little interest in transportation as long as the Federal government retained total control. The demands of heavy war traffic, coupled with fixed rates and minimal investment in maintenance and new construction, left the nation's transportation infrastructure in poor shape when it was returned to its rightful owners.[108]

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[108] The period of Federal control is thoroughly covered in Chapter 15 of Whitford, *History of the Barge Canal*,

Railroads had matured by the time of the Barge Canal's completion, and they had begun to siphon off a considerable portion of canal traffic. Boat operators with small boats found it very difficult to achieve the economies of scale railroads were by then offering, and the difficult business environment made it hard to get the funding to build the big new boats they needed to compete effectively. These new boats had not only to be much larger and steam powered, but they were starting to be built out of steel instead of wood, all of which made them several times more expensive than their simple wooden predecessors. Additionally, a post-war recession reduced the activity of all businesses, including those that shipped by canal, making prospective lenders even more cautious.

Once operators could acquire new boats, however, they proved to be very productive investments, and they could again compete favorably with the parallel railroads. Both they and the canal officials looked for advantages they could market. Everyone "knew" that trains ran faster, but freight cars spent a lot of time sitting still in yards. One analysis showed the average time for a freight car to go from New York to Buffalo was eleven days, compared to as little as five days on the canal. But, in truth, such analyses did little to persuade shippers either way.

Gradually, business began to improve. The war traffic and final completion of the Barge Canal had brought about the reversal of a decade-long decline in canal traffic in 1919, and it continued to increase in 1920. One year later, a new class of diesel-powered boats designed to operate on both the canal and the Great Lakes marked the beginning of combined service. Thanks to the increasing prosperity of the 1920s and its corresponding growth in personal consumption, a number of large corporations began to locate new plants along the canal and build fleets of their own boats to haul their products. Detailed

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339-358. He also describes much of the post-war challenge and recovery in Chapter 18, especially pp 381-388.

accounts of traffic on the canal system need not be repeated here, but annual traffic increased from a low of 1,159,290 tons in 1918 to over 3 million tons in 1928. It remained at least that high for all but five years through 1969. Agricultural products, especially grain, accounted for as much as 75 percent of all tonnage through the 1920s, but oil and refined petroleum products assumed the dominant position for the next three decades. Commercial traffic began a steady decline after 1969. Ten years later, it was less than 40 percent of the 1969 total, and only 9 percent another decade after that.[109]

The entire canal system might have disappeared by 1980 had commercial traffic, the very reason for each expansion project, been its only use. As early as the mid-1950s, various people promoted giving the canals to the federal government with the idea that the Army Corps of Engineers could then enlarge it to match the dimensions of the Western Rivers (primarily the Mississippi River) System, with wider, straighter channels and locks some 600' long. New Yorkers approved the necessary amendments to the state's constitution, but the Corps' studies could not justify it, and the federal government declined the offer.

What saved the canal system was pleasure boating and tourism. A few pleasure craft had cruised the canal from its early days, but their numbers were fairly insignificant until after World War II, when a growing amount of disposable income resulted in an explosion in the number of pleasure boats. Where fewer than 1,000 non-commercial boats per year were seen on the canals before the war, that number almost tripled by 1955, and doubled again by 1958. Boat ownership and canal use has continued to increase ever since, albeit at a slower rate, but pleasure-boat permits topped 12,000 in the

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[109] A concise discussion of business on the canal system, including a table of annual tonnage, can be found in Chapter 8 of McFee, *A Long Haul*, 173-201.

mid-1990s. Additionally, numerous sight-seeing boats carry tourists on several portions of the waterway, including operations through the Lockport Locks.

State transportation officials began to think about pleasure boating and other recreational uses of the canals as a supplemental justification for their retention at least as early as 1966, but the continuing drop in commercial traffic over the next 25 years changed recreation into the prime justification. Accordingly, the state transferred operation of the canal system from its Department of Transportation to the New York State Thruway Authority, an agency established in 1950 to build and operate the toll highway that roughly parallels the Erie Canal between Albany and Buffalo, in 1992. As part of the transfer, the legislature established the Canal Corporation, an organization within the Thruway Authority, to maintain and promote the canals. The Canal Corporation has held that responsibility ever since, but its budget is controlled by, and subordinate to, that of the Thruway Authority. Since highway traffic and maintenance needs (and costs) vastly overshadow those of the Barge Canal System, funding for the canals in most years covers normal operating expenses and mandatory inspection and maintenance activities. The Canal Corporation shares the Thruway Authority's various offices, with the Cheektowaga office responsible for the Erie's western section, including Lockport.[110]

The available maintenance funds are rarely sufficient to perform all of the preventive maintenance the engineers and lockmasters would like, but major rehabilitation programs are occasionally funded, and fixes for problems that might otherwise result from deferred maintenance can usually be incorporated into the

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110 *Ibid*, 199. Also author's conversations with David Kumpf.

programs' improvements. One such example is when original lock wall monoliths must be replaced because of cracking, spalling, or damage. Monoliths installed since the 1960s have included steel rebar, making them stronger and less susceptible to stress and temperature-induced cracking. Additionally, grout is added to the previously unsealed joints between monoliths to reduce leakage and soil deterioration behind the walls. The Lockport locks have been the recipients of several new monoliths, which are clearly distinguishable from the old ones. Welded lock gates are stronger, leak less, and last longer than their riveted predecessors, and electrical upgrades have made the gate and valve drive systems safer and more reliable. The two most-recent major rehabilitation projects at Lockport occurred in 1996 (Contract No. TAB-96-27C) and 1999 (Contract No. TAB-99-43C). Both of these projects included mechanical and electrical rehabilitation of machinery and concrete work on both locks. Such projects are done during the winter season with the canal drained to simplify the work and minimize any impact on boaters.[111]

The installation and operation of Erie Barge Canal Locks 34 and 35 have had some significant effects on the structures surrounding them as well. As has been noted, water power remained a vital part of Lockport infrastructure for more than a century. With power races on both sides of the canal, water was, without question, a primary factor in the growth of the town into a major manufacturing center. The installation of the Barge Canal locks, however, required a major change to the south race. Here the open race, whose space was taken by the new locks, was completely replaced with a tunnel, including a new inlet southwest of Lock 35. This tunnel and an accompanying

[111] Author's conversations with David Kumpf. Also see drawings for Contract Nos. TAB-96-27C, and TAB-99-43C, maintained by the New York State Canal Corp., Western (Buffalo) Div., at its office in Cheektowaga, NY.

discharge flume served the Lockport Electric Light Co. generating plant, but it also provided a bypass route for water around the locks when necessary. Its outlet flume was designed with a downward discharge to minimize effects from its flow on the lower canal.[112] Prism enlargement west of the locks required a concrete retaining wall along several blocks of Buffalo Street.[113]

Since the old north locks and adjacent north side of the upper and lower prisms remained in place as they were, Contract No. 67 included no alterations to those structures. The tow path remained intact, as did the inlet for the Hydraulic Power Co.'s tunnel, although its later abandonment as a power tunnel and other modifications having nothing to do with the canal or locks have altered the appearance of both over the years.

Probably the most obvious of these ancillary constructions in Lockport were the two new bridges across the canal at Main Street and Transit Street. The Transit Street Bridge (Canal Bridge No. 163) was a deck-plate-girder design with steel girders running parallel to the street.[114] Years later, adjacent railroad and streetcar tracks and related buildings on the north side were removed, and the town extended Genesee Street across the canal. This required a second bridge, very similar in design to the first one, except that the intersection of Transit and Genesee streets fell on the south end of the bridge, necessitating an unusual structural interconnection of the two bridges.

Similarly, the Main Street Bridge (Canal Bridge No. 162), originally built for Main Street alone, received an addition that ultimately allowed it to convey three

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[112] See drawings for Contract No. 67, maintained by the New York State Canal Corp., Western (Buffalo) Div., at its office in Cheektowaga, NY, specifically sheets 28-30.

[113] *Ibid*, sheet 35.

[114] *Ibid*, sheet 47.

intersecting streets across the canal. Main Street was skewed approximately 60 degrees to the canal, so the engineers designed a steel-plate, deck-arch bridge with its arches perpendicular to the canal. This allowed the shortest possible span, but it made for an unusually wide bridge with the street running diagonally across it. Rather than a continuous arch like the recently built Pine Street Bridge (not part of the Barge Canal project), the Main Street Bridge used three-point arches pinned at their centers. Since the vertical clearance under this bridge was about half of that under the Pine Street Bridge, there was insufficient room for a continuous-arch design. In 1912, the decision was made to extend Saxton Street across the canal, and an addendum to Contract No. 67 extended the bridge westward for it. This resulted in a bridge, now usually called the "Big Bridge," having the unusual distinction of being about three times wider than it was long, and the world's widest bridge at the time.[115] Sometime later, Cottage Street, which had crossed the canal at an angle on existing Bridge No. 161, was realigned to cross at a right angle, using the eastern edge of the Main Street Bridge. Since both Cottage and Saxton streets then crossed the canal at right angles, they intersected Main Street at the diagonal corners of the bridge. Portions of the bridge between the streets now serve as parking areas for the adjacent city hall, with the whole area now named "Locks Plaza." No record of Bridge No. 161's demolition has been located, and no trace of it is visible today.

While beyond the scope of this study of the locks, the area known as Lower Lockport, where the canal emerges from the gorge east of the locks, includes several structures directly associated with the canal. These include two vertical lift bridges conveying Exchange and Adam streets across the canal. Erected as part of the Barge

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[115] *Ibid*, sheets 37 and 66.

Canal project (Contract Nos. 106 and 98, respectively), these pony Warren truss bridges are similar to about a dozen others over the western portion of the canal. Each now features a sidewalk that can be accessed by stairs when the bridge is in its raised position. The stairs appear to have been added sometime after initial construction, as they are absent in early photographs of the Exchange Street Bridge.[116]

Just west of the Exchange Street Bridge is a culvert that permits Eighteen Mile Creek to pass under the canal prism on its way north toward Lake Ontario. One of the canal's overflow weirs empties into the creek at the culvert's south bank portal. Across the canal and about 1,000' west of the weir is a gate that is used to help drain the prism when needed. Drainage water flows into Eighteen Mile Creek.

As early as 1855, Henry F. Cady began construction of docks, a boat yard with a drydock, and a saw mill to support canal boat construction and repair. Cady's yard occupied much of the level area next to the drainage gate noted above. To further encourage Barge Canal traffic, the state established a Terminal Commission to build and operate terminals at regular intervals along the canal, including "upper" and "lower" terminals at Lockport. The lower terminal, built adjacent to the drydock, opened late in 1913. This terminal, like its counterparts elsewhere, saw little traffic. The state decided to expand its maintenance capabilities at Lockport in the late 1920s, so it acquired the property and rebuilt the drydock. This yard now serves as a Barge Canal Section Shops facility.[117]

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[116] McFee, *A Long Haul*, 120-122. Also Paul Bartczak and Craig Williams, *Field Trip Guide: The Erie Canal, Tonawanda to Medina* (Canal Society of New York State, May 5, 2001), 30, 71-72.

[117] Bartczak and Williams, *Field Trip Guide*, 29.

A number of surviving photographs and postcards from past years reveal a Lockport that looks quite different than it does today. Many of the downtown buildings around the canal and near the locks have been abandoned or demolished since the Barge Canal's peak traffic year more than fifty years ago, primarily because of continual changes in the overall economy in general, and manufacturing in particular. The causes of these changes go well beyond the scope of this study, except to note that they occurred in spite of, not because of, services the canal could provide. Some of Lockport's products became obsolete, and others became less costly to produce and market elsewhere. In some cases, such as the city hall, new buildings have taken the place of derelict structures, and others are planned as the changing character of structures continues to mirror Lockport's changing economy.

EPILOGUE

Unlike much that surrounds them, Erie Barge Canal Locks 34 and 35 remain in active service, and they remain very much as originally built. While some modifications have been made over the years, these have been more to improve the execution of the original design using modern methods than to change that design, and the locks continue to operate as they have since their completion. Indeed, such items as the welded gates now form part of the locks' historic fabric, since they are evidence of an adaptation to keep the locks viable almost a century after they first opened—far longer than either of their predecessor flights. Other key elements, such as the gate and valve drives, still look and function as they always have, even though they, too, have benefited from the rehabilitation of critical components. Thus, they, along with their rotary electrical switches and brass control panels, offer a rare glimpse of industrial electrification from a pre-pushbutton age.

If the older Flight of Five alongside gets more attention from historians and lay people than the Barge Canal locks, that is unfortunate, because there is a curious irony between the two generations of locks. The enlarged canal, like Clinton's Ditch before it, had the greater effect on the social and political history of the region and nation, but the enlarged locks introduced no technological innovations. They were simply bigger versions of the previous structures. The Barge Canal, on the other hand, has had less sociological and political influence, but Locks 34 and 35, along with their counterparts elsewhere on the system, are among the earliest surviving examples of modern lock design, making them far more important artifacts for the study of engineering, technology, and construction-methods evolution.

This irony is not competitive, but rather complimentary, because the sociological and technological stories are likewise complimentary. They are, in fact, inseparable. Throughout the history of the Erie Canal the physical structures have been intimately intertwined with every aspect of the region's sociological history, a history that has, in turn, had a dynamic effect on much of America's history, particularly its westward expansion. Each generation of the canal resulted from the dreams and desires of strong-willed, visionary individuals, and each became an important element of social change affecting everyone directly and indirectly associated with it. Today, each generation of locks vividly reflects the political, social, and technological aspirations and knowledge of its time, and only at Lockport can two generations be seen and considered side by side.

APPENDIX A

WATER MANAGEMENT – ASCENDING FLIGHT OF FIVE

Since canal locks are filled and emptied by the force of gravity, water from the canal's upper level must be passed through the locks, to the lower level. For a combined set, or flight, of locks, such as the Lockport Flight of Five, managing the water used was crucial. While the water supply in the upper level was directly from Lake Erie and essentially unlimited, the water passed through these locks maintained the level of the lower canal as far east as Rochester. (Ideally, this volume would be equal to the water drained through locks at Rochester plus leakage and evaporation out of this section of the canal. Any excess water was drained off as necessary through weirs installed for that purpose.) Proper water management also maximized the number of boats handled per day, a vital consideration during peak traffic periods.

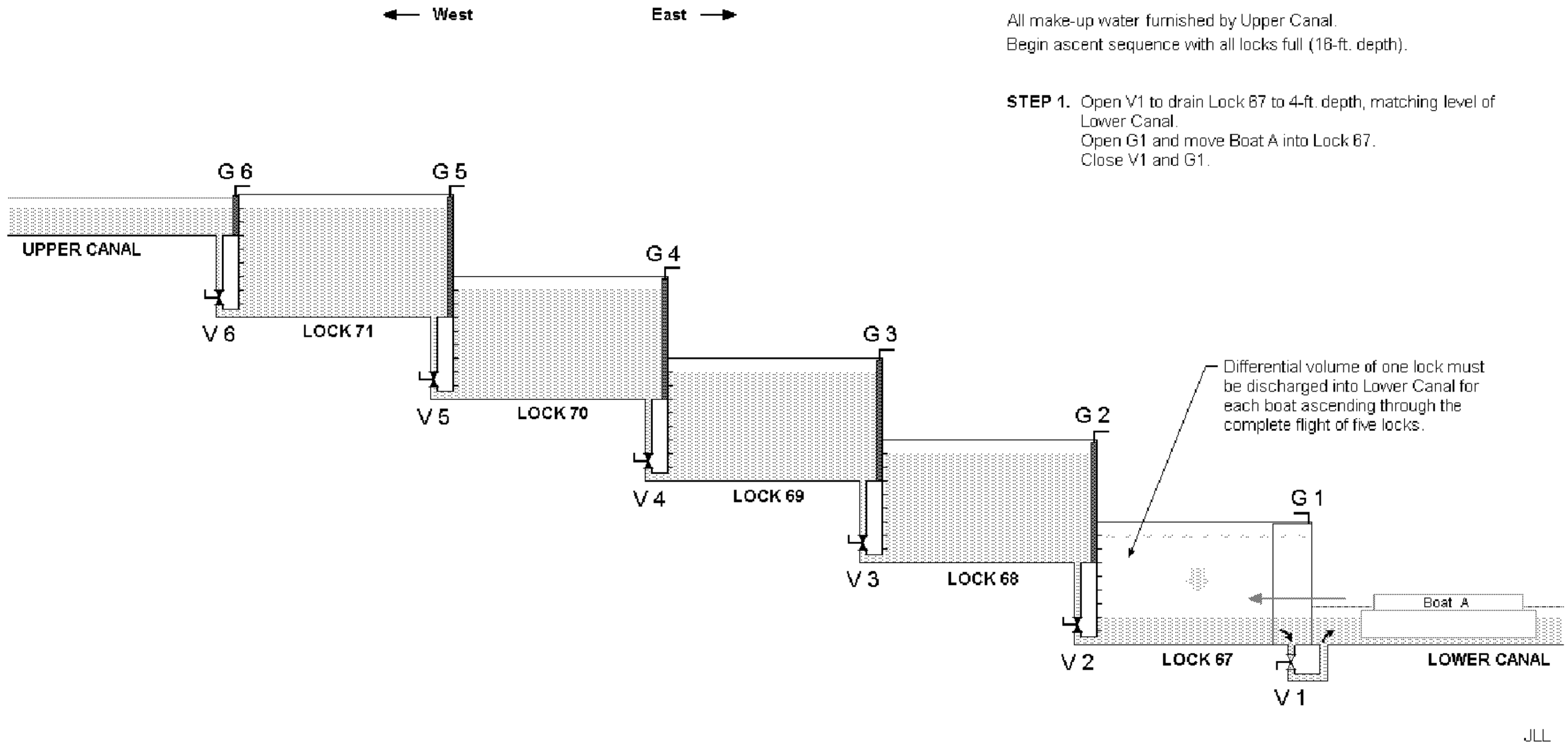
The diagrams in this appendix illustrate the most efficient procedure for locking a series of *westbound* boats through the *ascending* flight. As can be seen, except for Lock 71, each lock chamber's only water source was the lock above it, so one lock had to be drained to fill another. Thus, when a series of boats was properly handled, each boat required the equivalent of one lock chamber's water to make the complete ascent, and boats were lifted simultaneously in every other lock. This sequence could continue indefinitely. When the last boat of a series exited Lock 71, all five locks of the flight were left full, so the flight was ready for the next series. A single boat ascending the flight would require the same volume of water, and it, too, would leave all five locks full when it exited Lock 71.

LOCKPORT LOCKS
ORIGINAL (1825) & ENLARGED (1848)
WATER MANAGEMENT – ASCENDING FLIGHT

Lock depth marked at 2-ft. intervals.

All make-up water furnished by Upper Canal.
Begin ascent sequence with all locks full (16-ft. depth).

STEP 1. Open V1 to drain Lock 67 to 4-ft. depth, matching level of Lower Canal.
Open G1 and move Boat A into Lock 67.
Close V1 and G1.

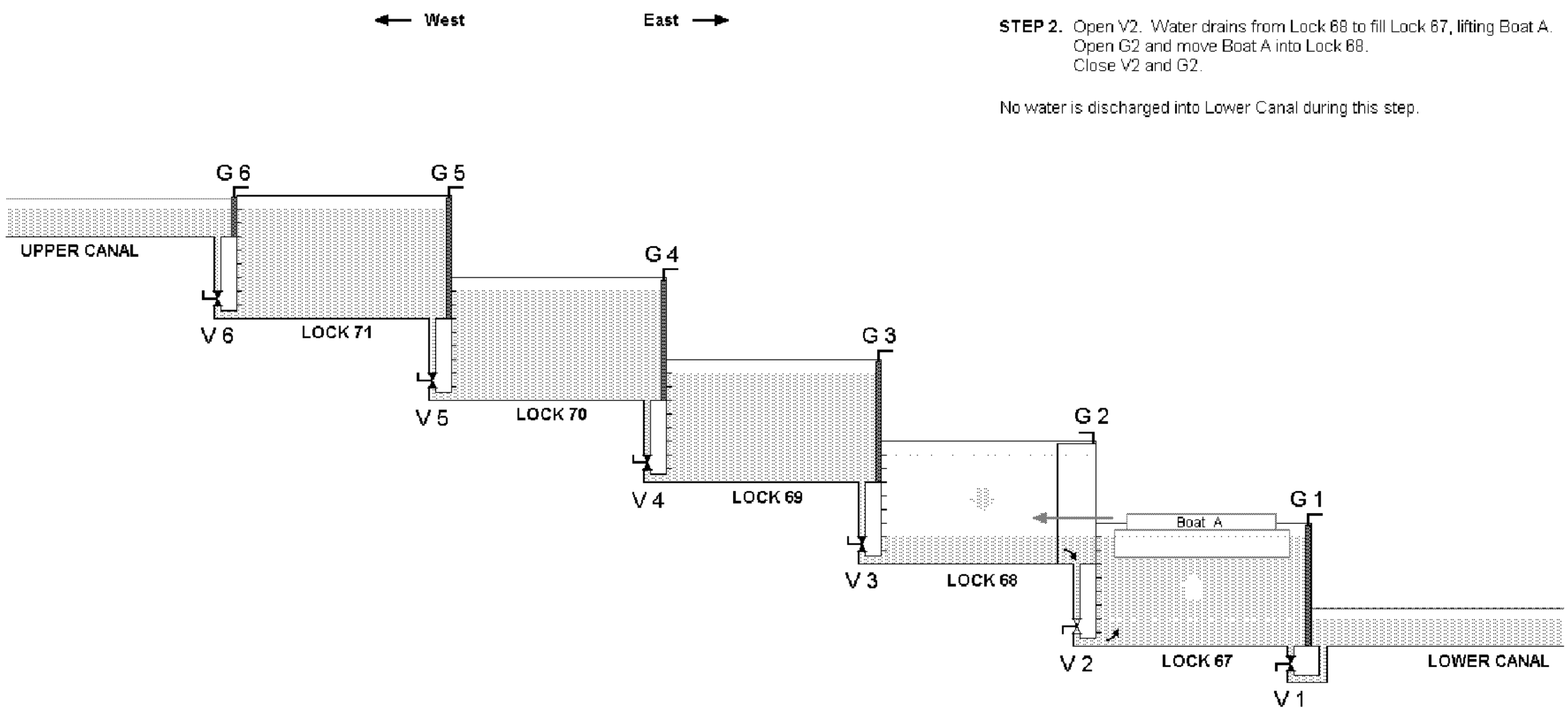


LOCKPORT LOCKS
ORIGINAL (1825) & ENLARGED (1848)
WATER MANAGEMENT – ASCENDING FLIGHT

Lock depth marked at 2-ft. intervals.

STEP 2. Open V2. Water drains from Lock 68 to fill Lock 67, lifting Boat A.
Open G2 and move Boat A into Lock 68.
Close V2 and G2.

No water is discharged into Lower Canal during this step.



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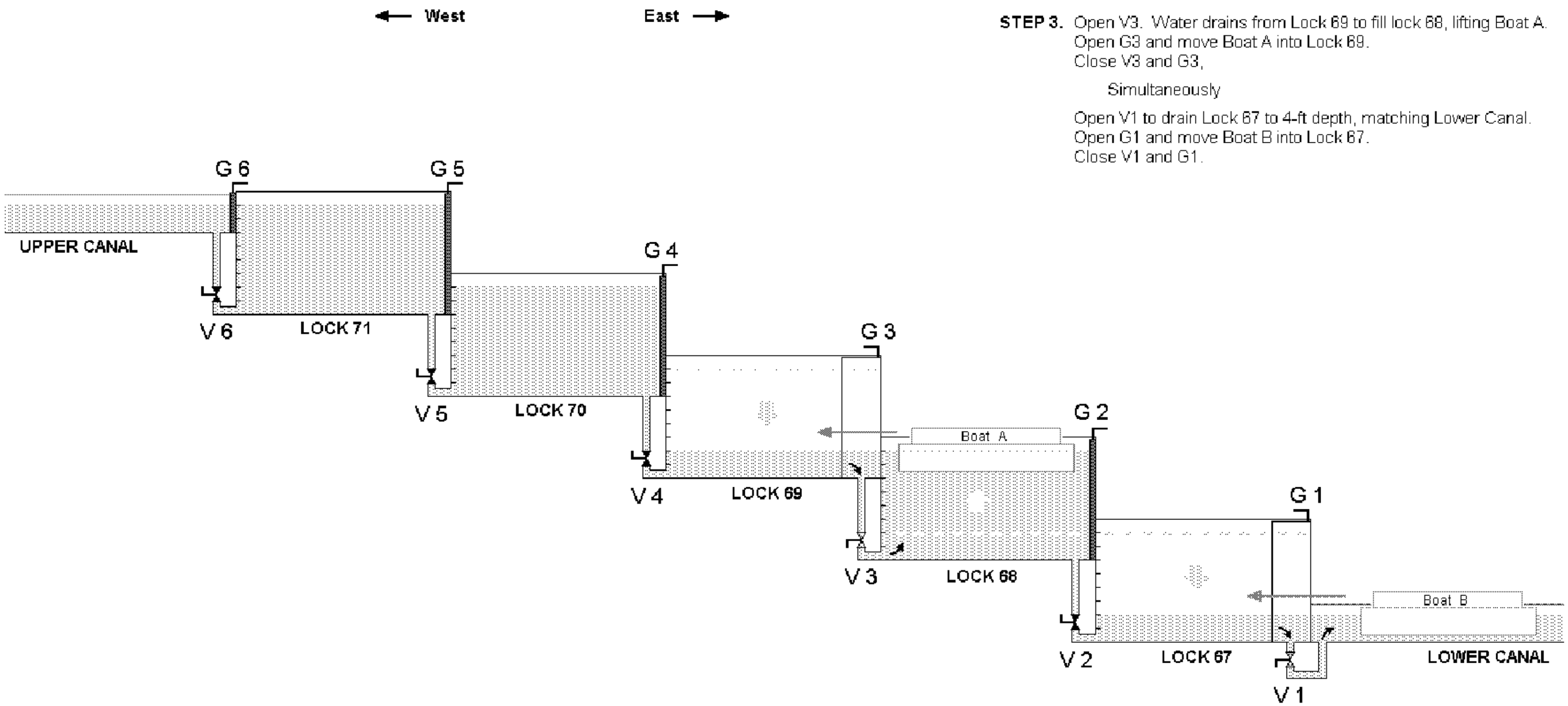
LOCKPORT LOCKS
ORIGINAL (1825) & ENLARGED (1848)
WATER MANAGEMENT – ASCENDING FLIGHT

Lock depth marked at 2-ft. intervals.

STEP 3. Open V3. Water drains from Lock 69 to fill lock 68, lifting Boat A.
Open G3 and move Boat A into Lock 69.
Close V3 and G3,

Simultaneously

Open V1 to drain Lock 67 to 4-ft depth, matching Lower Canal.
Open G1 and move Boat B into Lock 67.
Close V1 and G1.



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LOCKPORT LOCKS
ORIGINAL (1825) & ENLARGED (1848)
WATER MANAGEMENT – ASCENDING FLIGHT

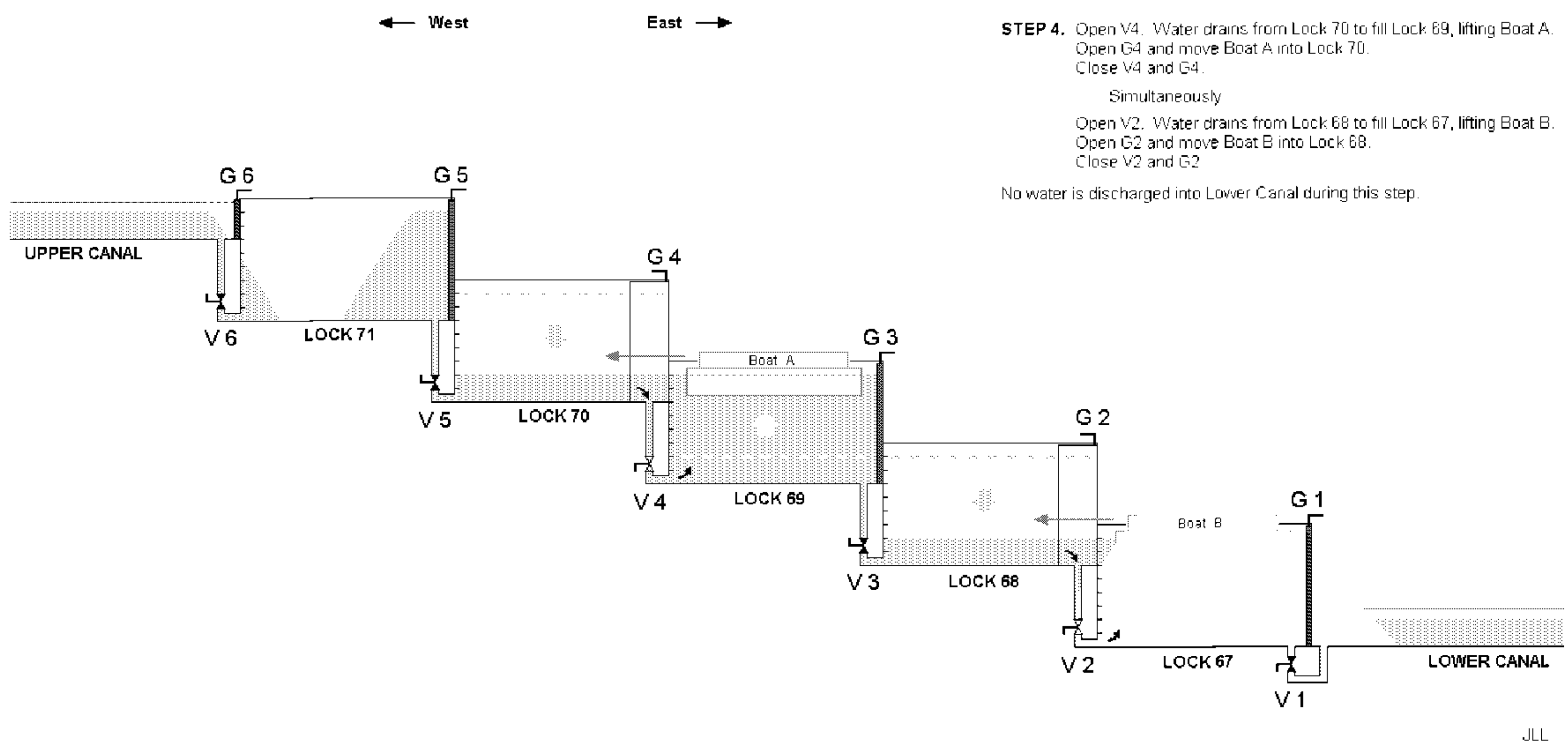
Lock depth marked at 2-ft intervals.

STEP 4. Open V4. Water drains from Lock 70 to fill Lock 69, lifting Boat A.
Open G4 and move Boat A into Lock 70.
Close V4 and G4.

Simultaneously

Open V2. Water drains from Lock 68 to fill Lock 67, lifting Boat B.
Open G2 and move Boat B into Lock 68.
Close V2 and G2

No water is discharged into Lower Canal during this step.



LOCKPORT LOCKS
ORIGINAL (1825) & ENLARGED (1848)
WATER MANAGEMENT – ASCENDING FLIGHT

Lock depth marked at 2-ft. intervals.

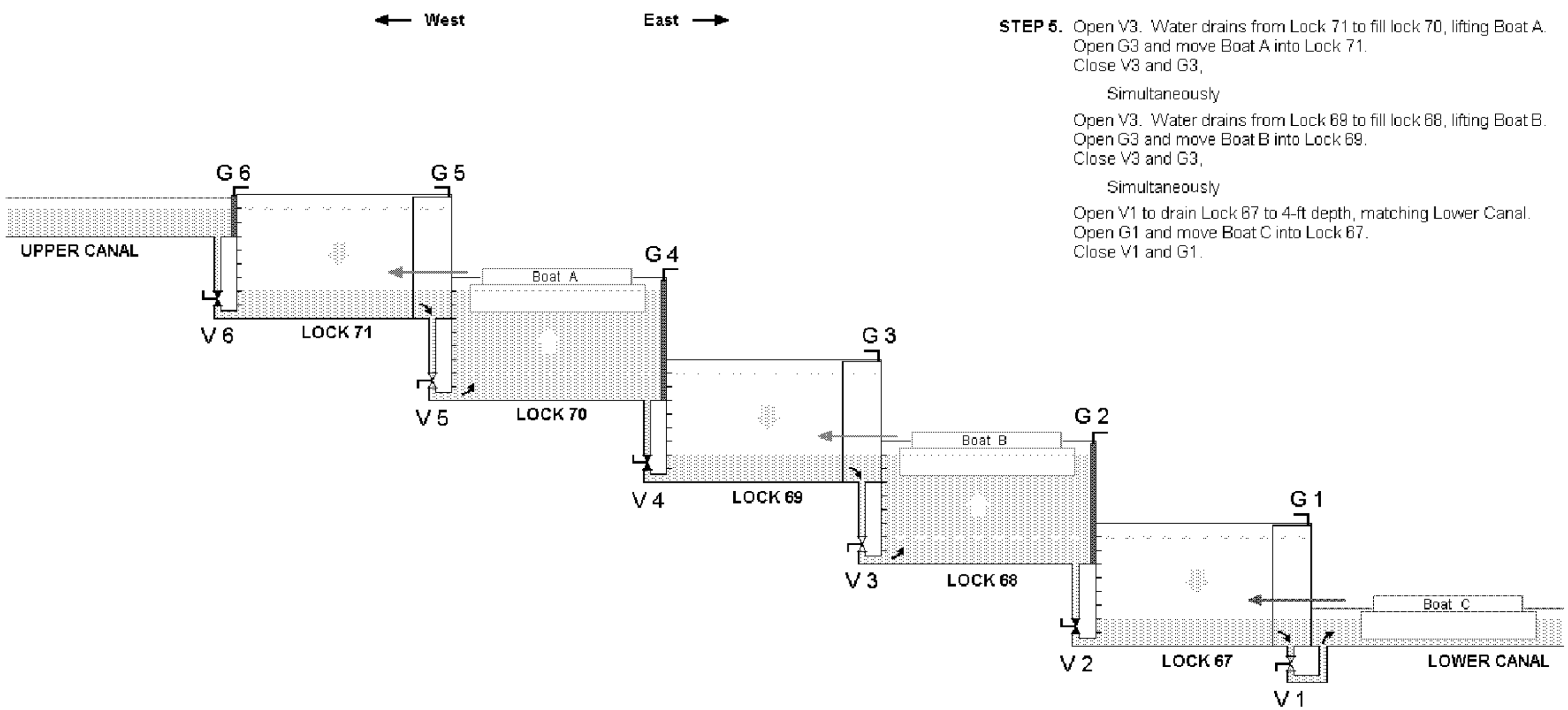
STEP 5. Open V3. Water drains from Lock 71 to fill lock 70, lifting Boat A.
Open G3 and move Boat A into Lock 71.
Close V3 and G3,

Simultaneously

Open V3. Water drains from Lock 69 to fill lock 68, lifting Boat B.
Open G3 and move Boat B into Lock 69.
Close V3 and G3,

Simultaneously

Open V1 to drain Lock 67 to 4-ft depth, matching Lower Canal.
Open G1 and move Boat C into Lock 67.
Close V1 and G1.



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LOCKPORT LOCKS
ORIGINAL (1825) & ENLARGED (1848)
WATER MANAGEMENT – ASCENDING FLIGHT

Lock depth marked at 2-ft. intervals.

STEP 6. Open V6. Water from Upper Canal fills Lock 71, lifting Boat A.
Open G6 and move Boat A into Upper Canal.
Close V6 and G6.

Simultaneously

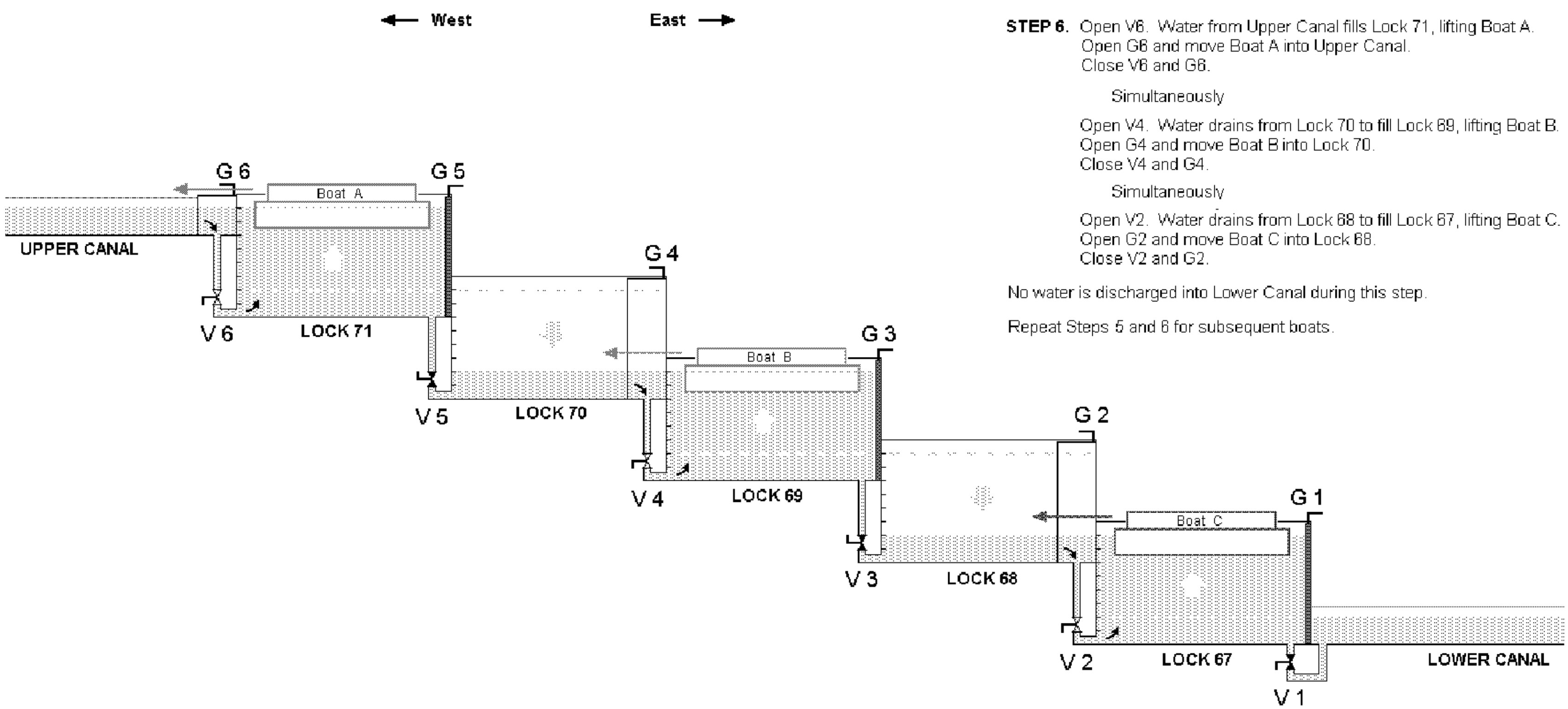
Open V4. Water drains from Lock 70 to fill Lock 69, lifting Boat B.
Open G4 and move Boat B into Lock 70.
Close V4 and G4.

Simultaneously

Open V2. Water drains from Lock 68 to fill Lock 67, lifting Boat C.
Open G2 and move Boat C into Lock 68.
Close V2 and G2.

No water is discharged into Lower Canal during this step.

Repeat Steps 5 and 6 for subsequent boats.



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APPENDIX B

WATER MANAGEMENT – DESCENDING FLIGHT OF FIVE

Since canal locks are filled and emptied by the force of gravity, water from the canal's upper level must be passed through the locks, to the lower level. For a combined set, or flight, of locks, such as the Lockport Flight of Five, managing the water used was crucial. While the water supply in the upper level was directly from Lake Erie and essentially unlimited, the water passed through these locks maintained the level of the lower canal as far east as Rochester. (Ideally, this volume would be equal to the water drained through locks at Rochester plus leakage and evaporation out of this section of the canal. Any excess water was drained off as necessary through weirs installed for that purpose.) Proper water management also maximized the number of boats handled per day, a vital consideration during peak traffic periods.

The diagrams in this appendix illustrate the most efficient procedure for locking a series of *eastbound* boats through the *descending* flight. As can be seen, except for Lock 71, each lock chamber's only water source was the lock above it, so one lock had to be drained to fill another. Thus, when a series of boats was properly handled, each boat required the equivalent of one lock chamber's water to make the complete descent, and boats were lowered simultaneously in every other lock. This sequence could continue indefinitely. When the last boat of a series exited Lock 67, all five locks of the flight were left empty, so Lock 71 would have to be filled before the next series could be handled. A single boat descending the flight would require the same volume of water, and it, too, would leave all five locks empty when it exited Lock 67.

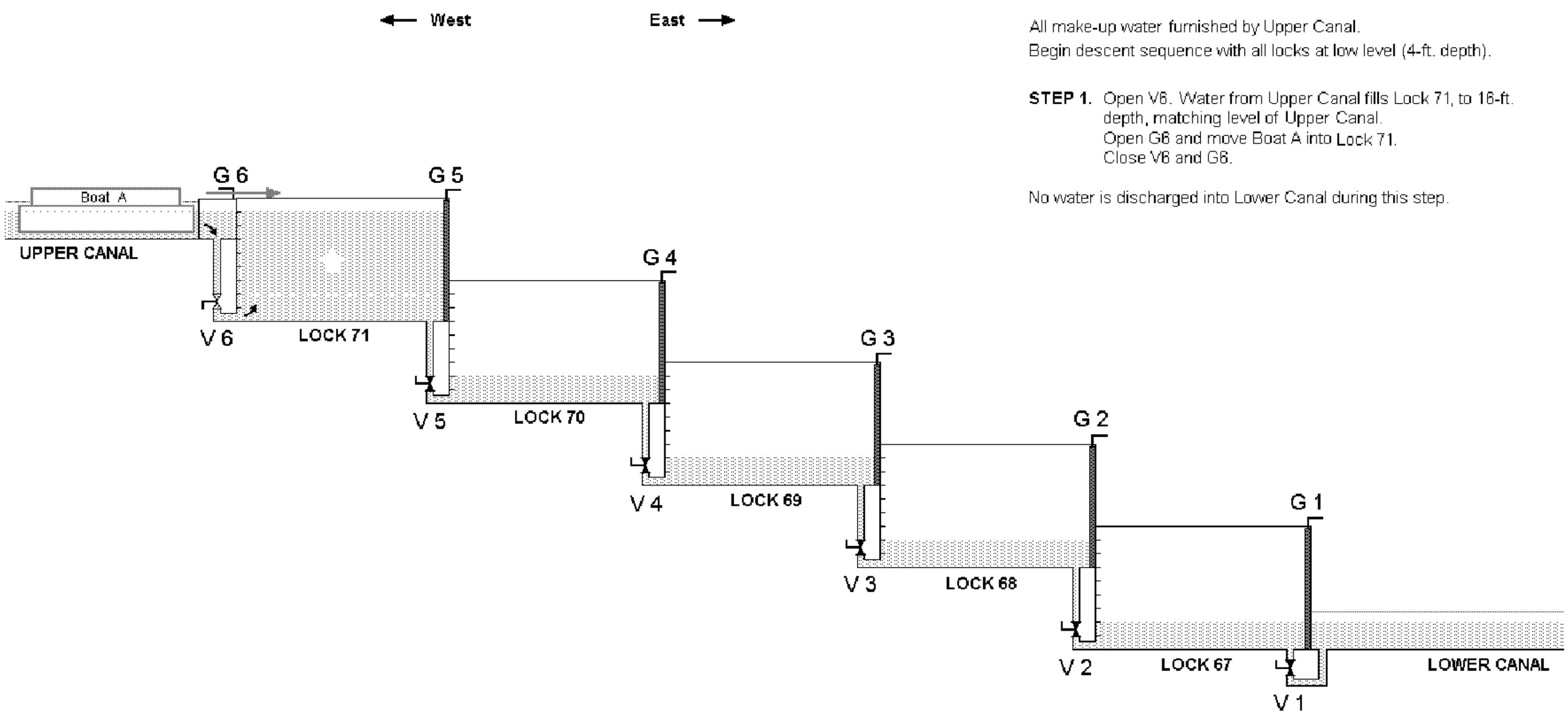
LOCKPORT LOCKS
ORIGINAL (1825) & ENLARGED (1848)
WATER MANAGEMENT – DESCENDING FLIGHT

Lock depth marked at 2-ft. intervals.

All make-up water furnished by Upper Canal.
Begin descent sequence with all locks at low level (4-ft. depth).

STEP 1. Open V6. Water from Upper Canal fills Lock 71, to 16-ft. depth, matching level of Upper Canal.
Open G6 and move Boat A into Lock 71.
Close V6 and G6.

No water is discharged into Lower Canal during this step.



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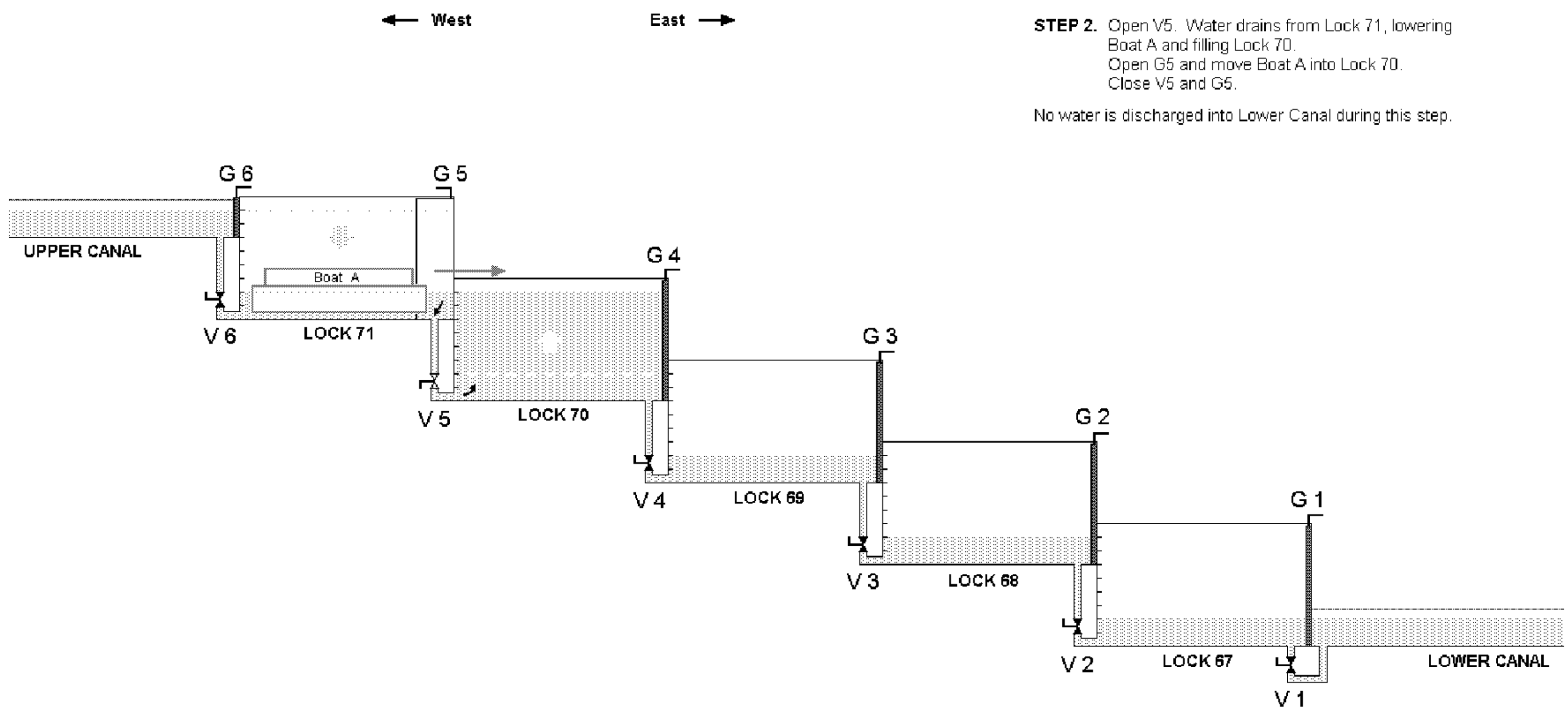
LOCKPORT LOCKS
ORIGINAL (1825) & ENLARGED (1848)
WATER MANAGEMENT – DESCENDING FLIGHT
Lock depth marked at 2-ft. intervals.

STEP 2. Open V5. Water drains from Lock 71, lowering Boat A and filling Lock 70.
Open G5 and move Boat A into Lock 70.
Close V5 and G5.

No water is discharged into Lower Canal during this step.



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LOCKPORT LOCKS
ORIGINAL (1825) & ENLARGED (1848)
WATER MANAGEMENT – DESCENDING FLIGHT

Lock depth marked at 2-ft. intervals.

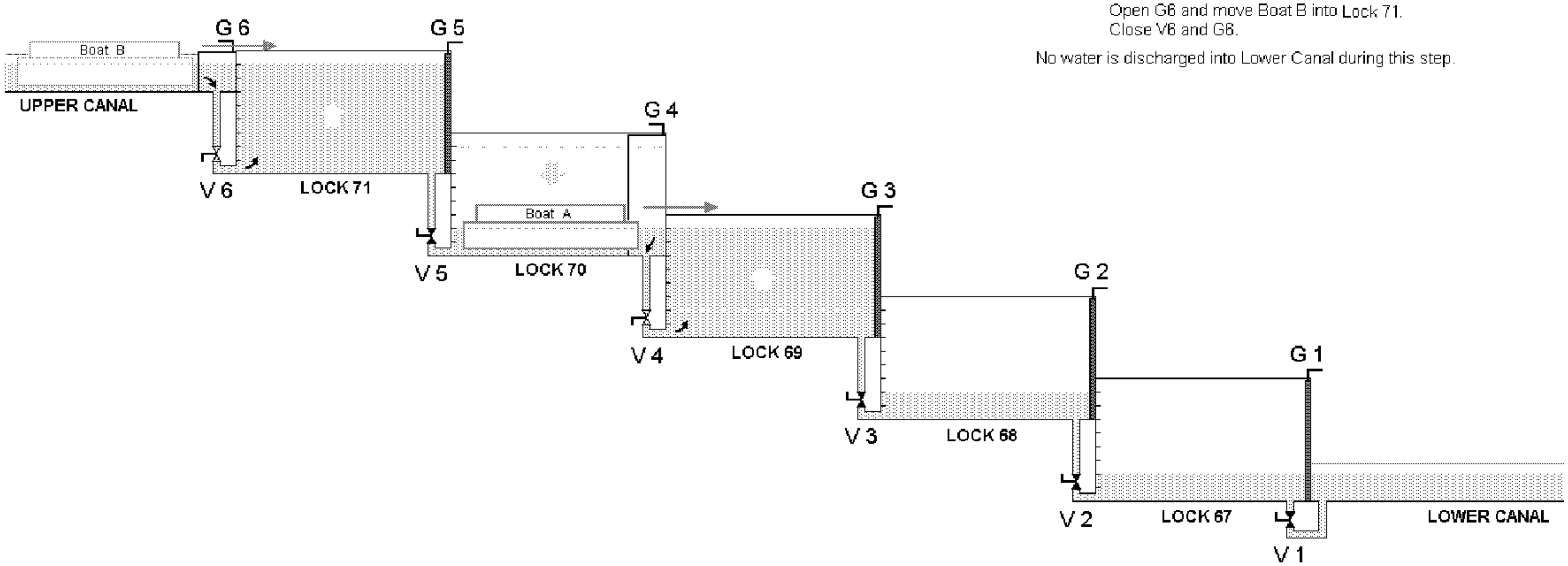
STEP 3. Open V4. Water drains from Lock 70, lowering Boat A and filling Lock 69.
Open G4 and move Boat A into Lock 69.
Close V4 and G4.

Simultaneously

Open V6. Water from Upper Canal fills Lock 71.
Open G6 and move Boat B into Lock 71.
Close V6 and G6.

No water is discharged into Lower Canal during this step.

← West East →



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LOCKPORT LOCKS
ORIGINAL (1825) & ENLARGED (1848)
WATER MANAGEMENT – DESCENDING FLIGHT

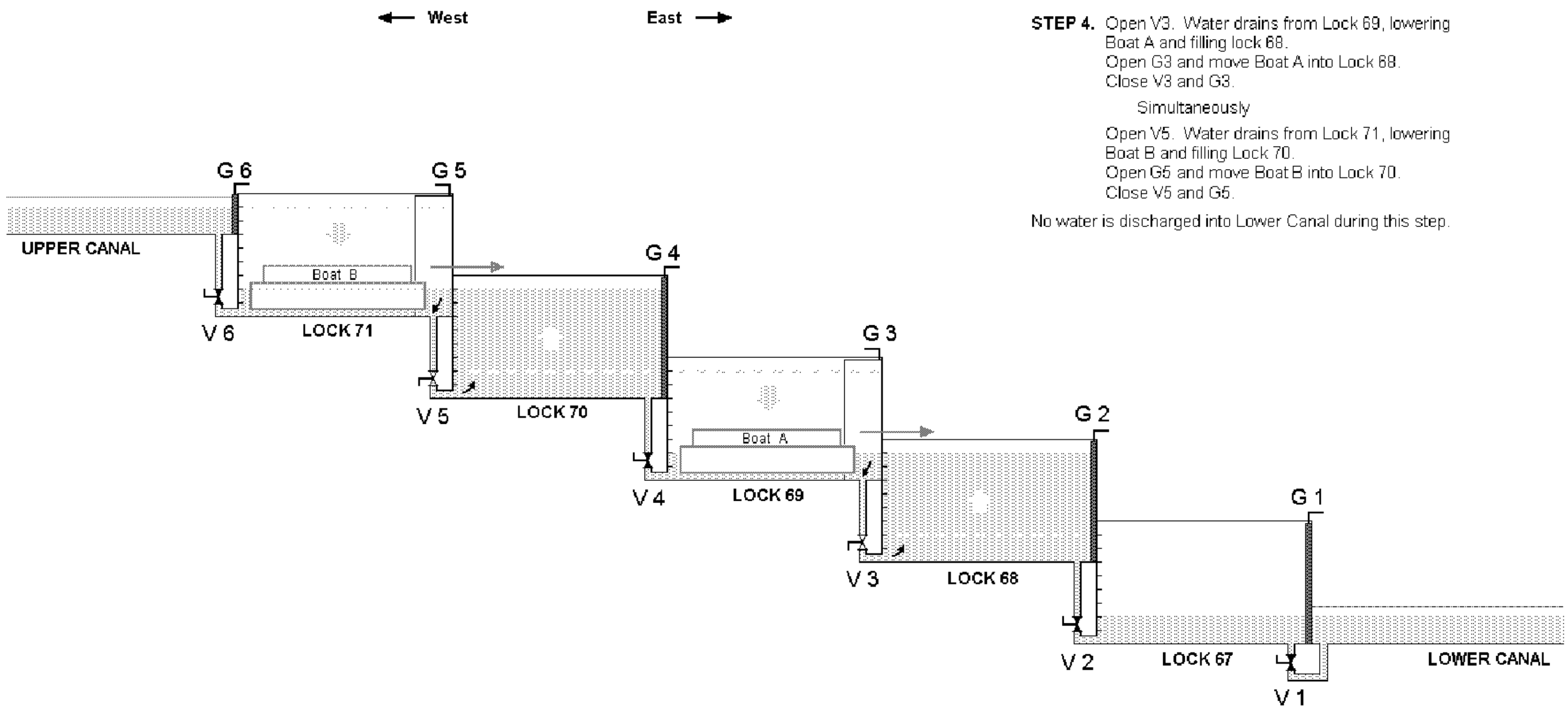
Lock depth marked at 2-ft. intervals.

STEP 4. Open V3. Water drains from Lock 69, lowering Boat A and filling lock 68.
Open G3 and move Boat A into Lock 68.
Close V3 and G3.

Simultaneously

Open V5. Water drains from Lock 71, lowering Boat B and filling Lock 70.
Open G5 and move Boat B into Lock 70.
Close V5 and G5.

No water is discharged into Lower Canal during this step.



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LOCKPORT LOCKS
ORIGINAL (1825) & ENLARGED (1848)
WATER MANAGEMENT – DESCENDING FLIGHT

Lock depth marked at 2-ft. intervals.

STEP 5. Open V2. Water drains from Lock 68, lowering Boat A and filling lock 67.
Open G2 and move Boat A into Lock 67.
Close V2 and G2.

Simultaneously

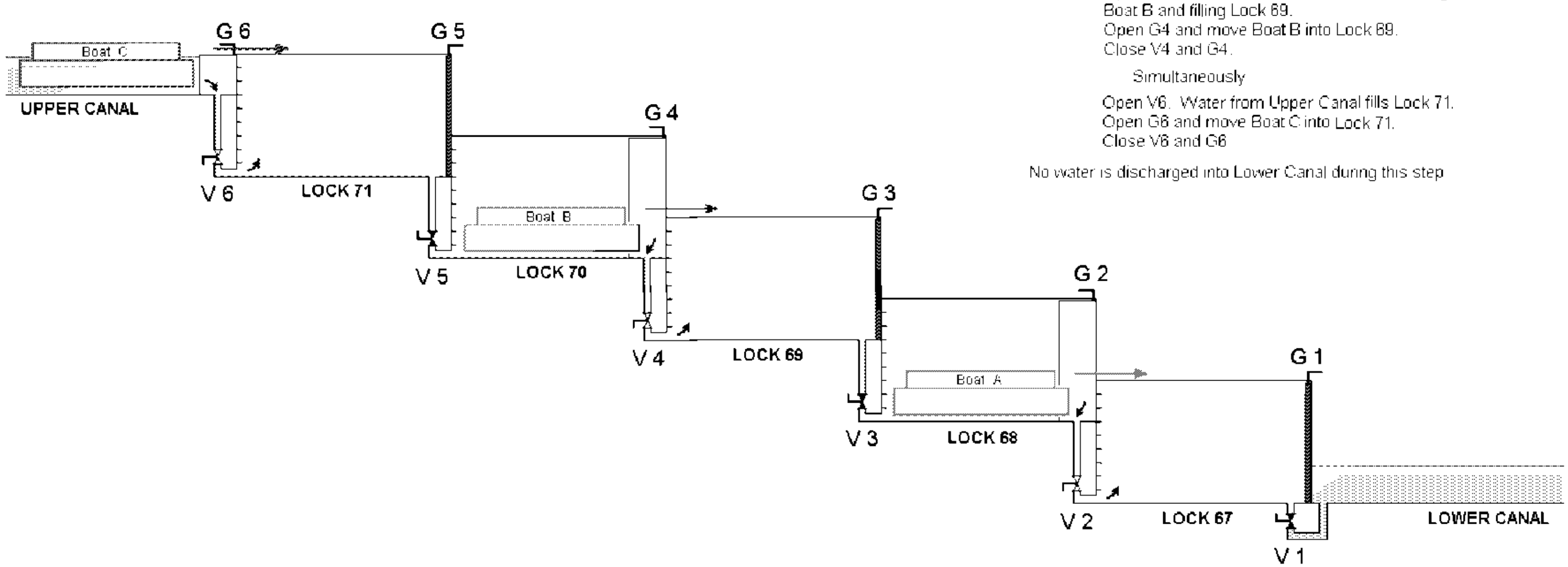
Open V4. Water drains from Lock 70, lowering Boat B and filling Lock 69.
Open G4 and move Boat B into Lock 69.
Close V4 and G4.

Simultaneously

Open V6. Water from Upper Canal fills Lock 71.
Open G6 and move Boat C into Lock 71.
Close V6 and G6

No water is discharged into Lower Canal during this step

← West East →



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LOCKPORT LOCKS
ORIGINAL (1825) & ENLARGED (1848)
WATER MANAGEMENT – DESCENDING FLIGHT

Lock depth marked at 2-ft. intervals.

STEP 6. Open V1. Water drains from Lock 67 into Lower Canal, lowering Boat A to level of Lower Canal. Open G1 and move Boat A into Lower Canal. Close V1 and G1.

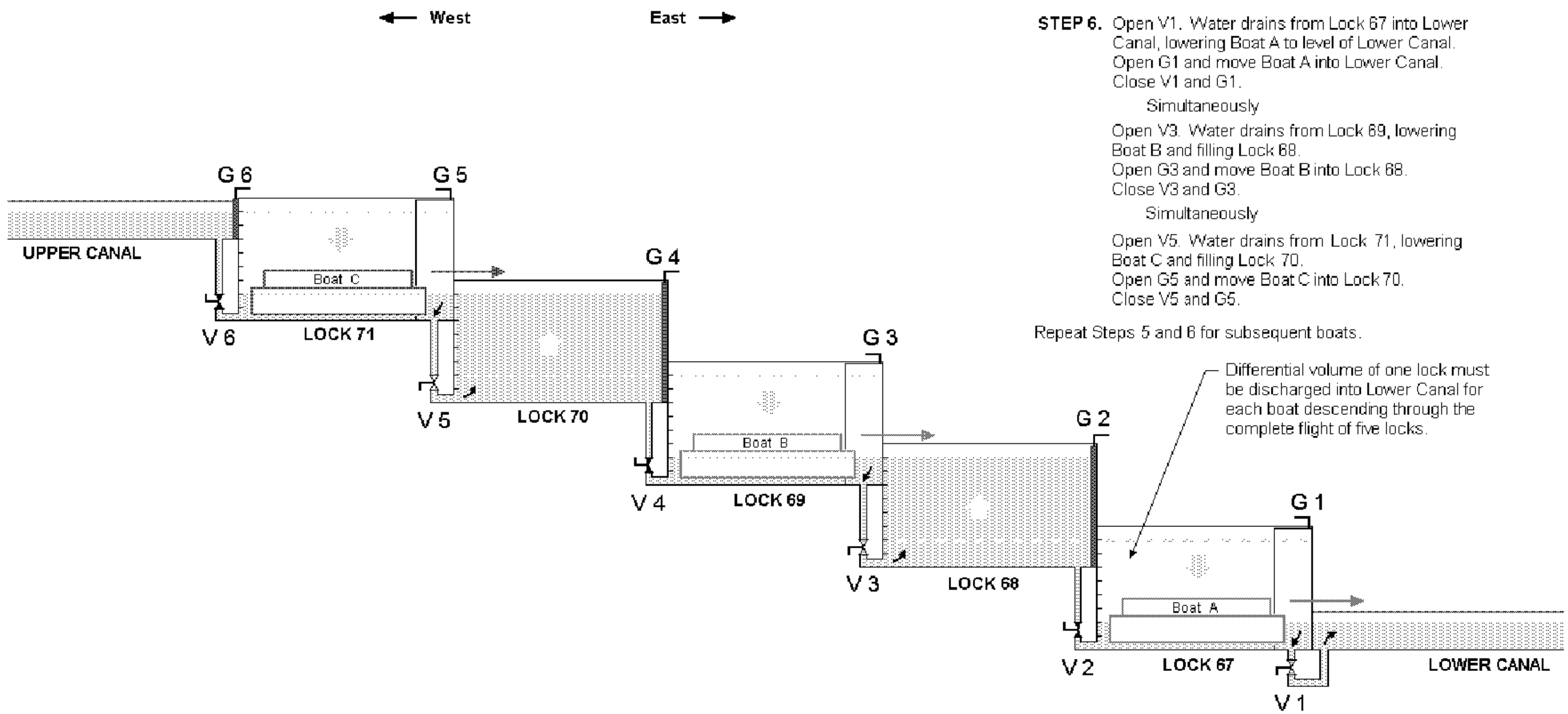
Simultaneously

Open V3. Water drains from Lock 69, lowering Boat B and filling Lock 68. Open G3 and move Boat B into Lock 68. Close V3 and G3.

Simultaneously

Open V5. Water drains from Lock 71, lowering Boat C and filling Lock 70. Open G5 and move Boat C into Lock 70. Close V5 and G5.

Repeat Steps 5 and 6 for subsequent boats.



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BIBLIOGRAPHY

BOOKS AND ARTICLES

Annual Report of the State Engineer and Surveyor of the State of New York for the fiscal year ended September 30, 1911. Albany: Argus Co., 1912.

Bartczak, Paul and Craig Williams. *Field Trip Guide: The Erie Canal, Tonawanda to Medina.* Marcellus, NY: Canal Society of New York State, May 5, 2001.

Bernstein, Peter L. *Wedding of the Waters: The Erie Canal and the Making of a Great Nation.* New York: W. W. Norton, 2005.

Colden, Cadwallader. *Memoir at the Celebration for the Completion of the New York Canals.* New York: W. A. Davis, 1825.

Flight of Five Historic Structures Report. Buffalo: Flynn Battaglia Architects, 2003.

Herring, Benjamin. "The Secrets of Roman Concrete." *Constructor* (Sept. 2002): 13-16.

Journal of the Votes and Proceedings of the General Assembly of the State of New York. Albany: State of New York, 1791, 1792, 1816, 1817, 1820, and 1835.

Laws of the State of New York, in Relation to the Erie and Champlain Canals. Albany: E. and E. Hosford, 1825.

McFee, Michele A. *A Long Haul: The Story of the New York State Barge Canal.* Fleischmanns, NY: Purple Mountain Press, 1998.

McKee, Harley J. "Canvass White and Natural Cement, 1818-1834." *Journal of the Society of Architectural Historians* vol. 20, no. 4 (Dec. 1961): 196.

Tovell, Walter M. *Guide to the Geology of the Niagara Escarpment.* Georgetown, Ont., Canada: The Niagara Escarpment Commission, 1992.

Whitford, Noble E. *History of the Canal System of the State of New York: Supplement to the Annual Report of the State Engineer and Surveyor of the State of New York for the Fiscal Year Ending September 30, 1905, Vol. 1.* Albany: Brandow Printing Co., 1906.

________. *History of the Barge Canal of New York State: Supplement to the Annual Report of the State Engineer and Surveyor for the State of New York for the Year Ended June 30, 1921,* Albany: J. B. Lyon Co., 1922.

NEWSPAPERS

"Canal Board Here: Advisory Engineers Met City Officials." *Lockport Journal*, June 10, 1904.

"The Canal Meeting." *Niagara Democrat*, May 8, 1851.

"The Canal Meeting at Lockport." *Niagara Democrat*, May 1, 1851.

"Canal Worker Fatally Hurt." [Lockport] *Union-Sun*, Oct. 30, 1909.

"First Accident on Canal Work," [Lockport] *Union-Sun* ,Oct. 28, 1909.

"Heavy Traffic Resulted in Enlargement of Canal." [Lockport] *Union-Sun & Journal*, Aug. 5, 1964, 20+.

"Huge Cantilever Collapses in Canal." [Lockport] *Union-Sun*, Aug. 11, 1910.

"Hundreds of Men Laid Off." [Lockport] *Union-Sun*, May 2, 1910.

"John J. Burke Meets Death on Barge Canal Work." [Lockport] *Union-Sun*, Feb. 12, 1912.

"The Lockport Locks—Mr. Hoffman." *Niagara Democrat*, Sept. 30, 1846.

McCollum, H. S. "The Ten Combined Locks." *Niagara Democrat*, April 26, 1849.

"The new Pneumatic Lift Locks to be built in our city." [Lockport] *Union School Courier*, Dec. 1897, 1.

"The True Friends of the Canals—Who are they?" *Niagara Democrat*, Oct. 16, 1851.

"Z. P. Thrall First Lock Tender." [Lockport] *Union-Sun and Journal*, Aug. 21, 1975, 19.

INTERNET MATERIALS

University of California, Berkeley, Museum of Paleontology. http://www.ucmp.berkeley.edu/ help/timeform.html (Sept. 19, 2006).

The Lockport Cyber Museum of Rocks, Minerals, & Fossils. http://www.lockport-ny.com/Museum/rocks.htm (May 30, 2006).

The Niagara Escarpment. http://spartan.ac.brocku.ca/~ffueten/niagara/niagara.html (May 30, 2006).

"Jesse Hawley (merchant)." Wikipedia. http://en.wikipedia.org/wiki/Jesse_hawley_%28merchant%29 (Nov. 8, 2006).

Rosendale Natural Cement Chemistry. www.rosendalecement.net/html/rosendale_cement_chemistry.html (Nov. 6, 2006).

ARCHIVAL MATERIALS

Canal Contracts. New York State Archives. Albany, NY.

Contract Drawings. New York State Canal Corporation (New York State Thruway Authority) Western (Buffalo) Division Office. Cheektowaga, NY.

Erie Canal Collection. Niagara County Archives. Lockport, NY.

"Report, &c. To the Legislature of the State of New York." 1831, 1839, 1840, 1842, 1843, 1848, 1853, and 1861. New York State Archives. Albany, NY.

SPECIFICATIONS of the manner of building the Combined Locks at Lockport, and Race around the Locks, for the Enlargement of the Erie Canal. New York State Archives. Albany, NY.