Middlesex Company

Probably every corporation that arose in Lowell had a story to tell about its history. All had a tale for the telling but none could match the epoch of the Middlesex Manufacturing Company from its inception to its demise. The topic of this book is underground waterpower but a glimpse of its use in the system, and how it evolved, hopefully will serve to expand the interest of the reader.

This is probably the most overlooked of all the mill complexes and by far the most interesting. Maybe one of the reasons so little attention is paid to it is that it wasn’t a cotton mill at all but a woolen mill, the only one in the system. If you study the history of any of the mills closely, mentions will be made here and there as to forays into manufacturing products with wool. Both the Hamilton and the Appleton Companies were incorporated “for the purpose of manufacturing cotton and woolen goods” as were the Suffolk, Tremont and Lawrence.37 The Lowell Manufacturing Company used wool in its carpet industry.

The Middlesex was the only textile Company that stayed with wool as its primary raw material. That in itself probably made the operation different enough to warrant exclusion from the ol’ boy fraternity. Another oddity was that it was the only mill to draw water from two different sources, drawing from the Merrimack River and during it’s early years utilized a source drawing from the Concord. And last but not least maybe the quirkiness of Thomas Hurd, the gentleman that started businesses at several other locations in the area before ending up eventually on these 37 acres38 through various transactions.

Lets start at the beginning. There is another book in this series titled *The Canals That Powered a Textile Industry* that tells the story of Hurd’s Canal on page 23. Hurd’s first two woolen mills on seven acres# and the two canals he dug to power them was the forerunner of the Middlesex Company. The three sources that powered this mill site at various times were the Concord River and the Hamilton and Lower Pawtucket Canals fed from the Merrimack River and they came into use in that order.

The Middlesex got its ambiguous start with an implied act of skull drudgery. Thomas Hurd was accused of an underhanded act while he only duplicated the acts of the Boston investors who conned the locals when acquiring their land on the cheap to begin their textile empire. Hurd simply got to one prime parcel (Bowers sawmill) on the Merrimack River in 1822 before they did and held them up for what he could. Its location on the Dracut side of the river above the falls was where their proposed dam would be anchored on the northern end.39 With out it, no dam. No dam, no reservoir to pool the water of the Merrimack River needed to run the mills. No mills and this tale would be a work of fiction.

This is one chapter where the telling of the story of the waterpower lays the foundation of the tale, not as an afterthought but the inception.

Hurd already had two mills on the banks of the Concord River, the first bought in 1818 and the second he built in 1821. He also built a small dam above the falls in the River and ran a canal from above it and paralleling the Concord River for a source of power for his second mill. The sketch below illustrates the location of the dam on the Concord River and the two waterways that Hurd built. This area and the waterways within it were to form the basis for the Middlesex Company.
This little sketch contains more information and detail than many pages of text would provide. The circled area is the approximate location of the future Middlesex Company. The partial legend below the sketch accompanied the original drawing but the remainder was of no interest so wasn’t included.

Presented by A. B. Wright. Drawn by Ignatius Tyler.

1. Although the Locks don’t show, this is the Pawtucket Canal entering the Concord River.

16. This is Hurd’s original canal and Nos. 13 and 15 indicate his first mills.

18. The Hamilton Canal from where this second of Hurd’s canals began would be off the sketch at the top center. The canal is shown tying into Hurd’s original canal to provide additional water.

23. The description given of this waterway is “This was a subterranean canal constructed in 1832.” We will return to this waterway later in the text.
Hurd would need more water power than could be supplied by his canal from the Concord River and he held up the Boston investors for more than money with his little scheme. They agreed to allow Hurd to tap off the end of the Hamilton Canal (waterway designated 18 in the sketch). He had purchased one mill power in 1826 as part of the buyout of his mill site at the Pawtucket Falls. He went underground for a good distance from the Hamilton to avoid existing roadways before just digging along the surface and tying into his original canal.

Anyway he went on his merry way, doing whatever you do in a mill. Hurd must have become sick of combing wool and figured there was an easier way to turn a buck. There was and he hocked the whole works to William and Samuel Lawrence along with W. W. Stone in 1827 for $55,000, defaulted on the payments, went bankrupt in 1828 and faded away. At any rate whether or not Hurd’s Canals were canals in the strict sense or penstocks is a play on words. Hurd’s canals were already defined as such by all previous descriptions and we’ll continue to refer them it as canals.

History being history, and with many people reporting on its contents over the years, one can see why it could get distorted with frequent telling. But when two written records by unimpeachable sources cast doubt on gospel, the fact becomes a flip of the coin. Quoting from the Northern Middlesex Registry of Deeds, by August 9, 1830, the Middlesex Company had possession of Hurd’s property, buildings and machinery. That record is pretty cut and dry. Yet an entry from a Directors of the PL&C meeting dated April 6, 1831 dictates that “The Treasurer be authorized to exchange the mill power sold to Mr. Hurd on the Upper Level for one on the Lower & that he be authorized to receive $4000 on the sum to be paid for the same.” (Authors note: Upper is the Hamilton and Lower is the Lower Pawtucket). The dates of these entries, the bankruptcy, the Registry record and the Directors entry are three years apart. Maybe Hurd didn’t go away.

At any rate, by 1830 the epoch of the Middlesex Manufacturing Company had begun. Its expansion through the mid 1800s necessitated the purchase of more mill power from the PL&C until it totaled over five. It occupied seven acres in the beginning but was to expand to cover 37 acres. It seemed to have waterpower coming from every direction and source available. In a written Report signed by James B. Francis in 1857, an estimate was made of The value of the Land and Water Power belonging to the Middlesex Company in Lowell. Under the heading of WATER POWER, 5 23/30 mill powers were held under lease from the PL&C, Concord River Power with no amount and a third source listed as simply Wamesit Mill lot and water power.

As usual though, the Middlesex Company marched to its own drummer. Long after most mills had changed over to turbines, the Middlesex was still using breast wheels into the 1890s. Their use was most likely confined to the older buildings which were still in service all though there is no mention of this.

Our main interest of underground waterways has been overlooked somewhat. To get back in focus the next page has a series of two photographs that represent the headrace leaving the Lower Pawtucket Canal just above the Lower Locks on the top left and its course through the turbines in new mill number one and to eject the spent water into the Concord River from the Granite arches in the photograph on the top right.
And last but not least are the remnants of the only visible vestiges of the final power source that fed the Middlesex Mills.

Blocked headrace leaving the Pawtucket Canal from under the hotel wall.  
Photo by Author

Tailraces emptying into the Concord River through two granite arches.  
Photo by Author

Middlesex Company Mills  1850  Sidney and Neff
Massachusetts/Prescott Manufacturing Companies.

Both of these mill complexes are usually treated as a single entity. The Massachusetts Mills were chartered in 1839 and are regularly carried as being the last of the main mill complexes constructed. In a way this is true even though work on construction of the Prescott buildings was started in 1844. The company was bought by the Massachusetts Corporation in 1847 before it was in full operation and was simply absorbed by the Massachusetts. Geographically all that separates the buildings is East Merrimack Street that runs between the sites. Taken together their combined yards cover about 11 ½ acres and are bordered by the Merrimack and Concord Rivers, the Lower Locks Wasteway, Bridge, Prescott and Central Streets.

But their backgrounds and beginnings were diverse enough to treat the history of the two corporations separately until they merged and for no other reason than to give them their own identity, and their early development certainly allows for that distinction.

The Prescott Mills

The site completely demolished now and occupied by the Middlesex Community College, was the smaller of the two, sitting on about 4 acres. Compared to the larger complexes, even its power need was small, contracting with the PL&C for only 4.6 Mill Power. The five raceways that supplied the water ran from the Eastern Canal and emptied into the Concord River. There is no mention of a waterwheel by any of the early sources. The first reference to a wheel was a turbine installed in 1847 followed by the statement that there were two turbines powering the mills by 1848.

Showing one set of pair of headraces leaving the Eastern Canal with Community College in background. Strangely none of the six headraces that once provided water power to the Prescott Mills shows signs of having been protected by trash racks.

Photo by Author

It is quite possible the Prescott Mills never went through the waterwheel cycle given the date of its inception that bordered on the introduction of the turbine. At the first appearance of the turbine on the power scene many were doubtful if the new machine could out perform the large and well seasoned breast wheels. The trial installation was reported to be made at the Appleton Mills in 1844 and it was successful with no less than the head engineer for the PL&C, James B. Francis attesting to the excellent test results.
If the first mention of a new mill along the banks of the Concord that appeared in the Minutes of the Directors Meeting held on October 7, 1843 is any indication of the eventual size of the first building in the Prescott Yard, it took a lot of courage to go with an untried power system and install turbines and at this date it is possible the Prescott, and not the Appleton was the first. But even the looms installed in the Prescott were innovative. They were the first ever built by the machine shop with iron instead of wooded frames.

But let’s return to the channels that were to carry the water from the Eastern Canal and drop 17 feet into the Concord River. The sketch below shows the first proposed raceways.
These are the five tailraces Leaving the Wheelpits under the Prescott Mills. The water left the Eastern Canal through headraces as shown on page 69 and fell 17 feet to turn the turbines before being returned to the Concord River.

Lowell National Historical Park
LOWE 7937

All of these photographic reproductions were obtained from the collection, www.museum.nps.gov/ These views were take during 1918/1919 either just before or during reconstruction of the raceways. The photos below show the work in progress of installing a draft tube in the Concord River wall during the installation of 3-33” Hercules turbine wheels that will be attached to electric generators.
The Massachusetts Mills

This was the last major corporation chartered in 1839 and its construction on 7 ½ acres brought further expansion of the canal system to a halt. The simple fact was there was no more land with access to the canal waters available and it took the last mill power that could be produced in the canals to turn the machinery and eventually over 24,000 spindles. By 1841 the four mills were in full operation.

Only the Merrimack Manufacturing Company came up to par with the manufacturing capabilities of the Massachusetts. In the use of mill powers they were almost identical. However it took 1116.267 cubic feet per second of water flowing in the raceways of the Massachusetts to accomplish what the Merrimack could do with 616.667 cfps. The difference was in the amount of head the water generated at their respective falls and carried when leaving the respective canal and entering the buckets of the mill wheel. Definition and description of mill powers on page 55 gives a full explanation. The head supplied by the Merrimack Canal feeding the Merrimack Mills was 30 feet while that of the Eastern Canal feeding the Massachusetts was only 17 feet.

Four headraces left the Eastern Canal to supply waterpower to the Massachusetts Mills complex and remains of the two trash racks covering them are quite visible if the water level is down any at all. Here the canal is empty. At one time these raceways were open in the mill courtyard delivering the precious cargo of liquid power to each of the four breast wheels, one under each of the original mill buildings. They were covered over many years ago probably to allow other buildings to be built over them during periods of expansion.

Both Photos by Janet Pohl

The two photos above show the deteriorating racks covering the headraces that fed the mill wheels. Mills nos. 1 and 2 paralleled the Concord River and their tailraces emptied into it, now covered over with concrete. Nos. 3 and 4 mills paralleled the Merrimack and evidence of their tailraces can be seen from the Bridge Street bridge mostly covered over by a recently constructed sewerage conduit that hugs the river bank for most of its way.
This sketch is dated November, 1839. The plan shows the original layout of the Massachusetts mill yard including raceways supplying each of the four mills outlined by the dotted lines.

There never seemed to be a problem with engineering for the mill construction centuries ago. The best use of the land and water was determined and laid out in a sketch as presented at the left. The construction methods were kept simple and then the work began following the straight forward layout and designs of the artificer. Their works are still standing and while not serving the original use maybe, a good many are still functional and occupied.

PL&C Archives, Massachusetts Mills

These raceways were dug to supply the wheel pits for 17 foot wooden water wheels but the headraces, pits and tailraces would serve just as well to service the turbines that were beginning to appear on the horizon. After 1850 turbines were installed in all new additions to the complex and by 1869 the last breast wheel was removed.49

In 1856 a central wheel house was built containing four wheel pits containing two 10 foot 375 hp turbines with two pits left empty for future use.50
The two wheel pits designated for future use have long since been pressed into service with the installations of turbines. Eight tailraces can be counted leaving the powerhouse and this is the only instance uncovered in the research so far that indicates two tailraces leaving each turbine wheelpit.

To the right is a small portion of the sketch on page 76 showing the four turbines in the Massachusetts powerhouse and the double tailraces leaving each wheelpit and emptying into the Concord River.
Water, water, water. This was the power that fueled the mill machinery. As long as it flowed through the canals and was distributed through the raceways to the individual wheel pits, everything was working up to par. But what was the result when a mill within a complex lost one or more turbines for whatever causes.

Most mill sites had several power sources, whether they were breast wheels or turbines. Common sense would dictate that somehow the output of the individual wheels would be available for all. The answer would be through shafting. Any one mill that had multiple turbines coupled them together and through this method achieved a more balanced output. Also if one unit was down for any given reason, power was still supplied to all of the machinery, granted with less horsepower.

So why not tie several mills together using the shafting method between them and achieve the same results. And go a step further and supply power to a mill that was added to the complex. Digging a new canal amongst the existing buildings every time a new mill building was added could be daunting at best. It was possible to weaken the supporting foundations of the existing structures or loosen the fill of the banks containing the raceways that were supplying the current water power.

This was probably the concept behind the process of building separate and free standing wheelhouses with all of the wheels centrally located as mentioned previously, detached from the mill buildings and not installing the individual turbines in the basement as was the previous norm. Once this technique was adopted, provisions could easily be provided for future expansion without digging under and around a hodge-podge of scattered buildings with new raceways every time expansion occurred in the complex.

Centralization of the power producing turbines would also free up a large amount of space for production previously occupied by the great breast wheels and inherited by the turbines. One shaft running throughout the mill yard and tapped off at intervals using gearing was the answer. There are other mentions in the records of mechanical methods to feed individual mill sites but this is the first to show up in the order chosen to present the material.

To be sure the waterpower was still the prime motivator. The shafting was simply one more innovation amongst the many that were adapted to the industry to improve on the power transmission and thus add to the production. But this also allowed the output of the steam engines to be tied into the power train as that source was developed.

The composite sketch on the next page show the whole power layout of each site in its entirety. The parallel dotted lines indicated the underground raceways leaving the Eastern Canal and emptying into either the Merrimack or Concord Rivers. The circles are the location of the turbines and the notes tell the manufacturer and horsepower of the units. It’s quite obvious the solid lines are the shafting and they are noted as such. In the lines of shafting in both the Massachusetts and Prescott Mills will be a solid rectangular line heavier than the others. Look close and they are marked Steam Engine.

So through the use of the shafting all of the power motives at each site have been combined to operate as one.
A small section of the composite sketch has inevitably been eliminated effecting the layout of the Massachusetts Mills powerhouse. This has reduced the size and number of turbines shown. The correct layout of the powerhouse shows in the sketch on page 68 but the mistake does nothing to take away from the purpose of the distorted composite sketch.

Power Layout in 1889 at the Massachusetts Cotton Mills
Lowell National Historical Park

The prime study of water power, the delivery of it through a maze of underground raceways from the canals to the wheelpits and thus the wheels at the mill sites, is still the main objective of this book. But still one can’t be faulted for deviating for a moment to include mention of other power sources and methods of delivery such as steam and shafting if it serves to expand the overall picture.
Pause for a minute while looking at this drawing of the building layout of the Massachusetts Manufacturing Company in 1911. Waterpower was still being employed at this date although possibly as hydro-electric units only but still functional and providing power the complex. While steam power had been introduced in the 1870s, it was done so as a supplemental energy source to the water power.\textsuperscript{51}

While there have been changes to the configuration of buildings in the mill yard, and probably some demolished and some added as the industry demanded, just to envision the force of the water from the Merrimack River as the prime motivator of the power supply is almost unbelievable. And multiply the demands of the other ten complexes and it becomes mind boggling.

1911 Insurance Survey of the Massachusetts Cotton Mills
Chartered on March 27, 1835 by the Massachusetts General Court, the incorporators of the Boott Cotton Mills were Abbott Lawrence, Nathan Appleton and John Lowell. \textsuperscript{52} Talk about the mill owners being a closed society, these same names appear as the controlling interest in many of the corporations. Even the name chosen for the mill complex honored the first agent of the Merrimack Mills who was to pass away in 1837.

But their projected operation would prove to represent more profit for the Proprietors of the Locks and Canals [PL&C]. The outstanding shares of the PL&C had been purchased in 1822 by the Merrimack Manufacturing Company and the company was now effectively controlled by the investors so they were welcome by any name. In 1825 the Merrimack Company realized the scope of building new canals, leasing water power and constructing new mill buildings was proving to be too complex on top of running their own cotton mills so the PL&C was re-organized and all of the excess land in their control, which was effectively all of it, was sold the new PL&C. The object of the game was to sell water and for that the PL&C was more than willing and certainly able, even to the point of digging a new canal to get the water to the chosen site of the Boott Mills, and they wasted no time. In fact the PL&C was one step ahead. At the Directors meeting of September 20, 1834, “the agent informed the board of an application for the purchase of four mill sites & machinery, and at the same time submitted a plan locating nine mills on the lower level & the canal to supply them with water.” In two subsequent votes, a committee was appointed to sell the mill sites applied for and to contract for the machinery and the agent authorized to proceed with construction of the canal.

Winter months were sure to put a cramp in any plans concerning the PL&C and their building operations but on March 16, 1835 the committee reported to the Directors at their meeting that they had contracted with Abbott Lawrence for a total of nine mill powers “for a price not less than Five Dollars pr. Spindle.” Another source quotes the price of the land and mill privileges as over $84,000.\textsuperscript{53} The site would prove to consist of 5.7 acres bounded by the Merrimack River, Bridge, French and Kirk Streets.\textsuperscript{54} An indenture dated November 16, 1835 also records the annual rent for each mill power as “sixteen ounces, seventeen penny weights, twelve grains troy weight of gold or two hundred and sixty ounces troy weight of silver.”\textsuperscript{55} We’ll stick to the dollar figures where possible.

This is the only mention found of the request for locating nine mills to supply them with water. No additional buildings except for the original four proposed for the site appear on the original plan of the Boott Mill yard. It is more possible that this line was meant in reference to nine millpower and was copied into the directors minutes wrong.

At any rate the Eastern Canal was dug from the Lower Pawtucket to the Merrimack Wasteway to provide waterpower in anticipation of the Boott construction. It was recorded as being of rectangular in shape at 2,000 feet in length, eight feet in depth and from 42 to 66 feet wide.\textsuperscript{56} An accounting ledger page presented at the Directors meeting dated July 30, 1836 gives a cost from the PL&C Records under the heading of Eastern Canal as $18,874.16.
This is a copy of the original plan of the Boott Mill yard in 1835 that accompanied the Deed. It can be found in the files of the *Middlesex County Deeds---Southern Registry: Plan Book 36, Plan 17*. The Eastern Canal is bisecting the property horizontally from Bridge Street at the left to the Merrimack Wasteway on the right. At the top of the canal is shown the proposed company boarding houses and to the bottom is depicting the four mill buildings each to be approximately 150 by 45 feet with the raceways to carry the water outlined between the dotted lines and emptying into the Merrimack River.

Nine millpower were contracted for by the Boott Mills in 1835 which gave the mill complex the right to draw 45.5 cubic feet per second from the canal with a head of 17 feet as the water dropped from the canal to the Merrimack River. All four mills were completed by 1839.57 The Massachusetts Mills would also be built along side this canal and tap it for their source of waterpower.

Prior to 1852 when adjustments of the water powers were decided on, the Boott Mills had added one more millpower bringing the total to ten. After the adjustments were finalized on September 20, 1853 the total amount of mill powers contracted for was recorded at 17\(^{26/30}\).58 The underground water distribution system for the canal system is the topic of interest and to plot these particular routes under the Boott Mills we started with the simple plot plan on this page dated 1835. Although the raceways

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Proprietors of Locks and Canals, Draw 155, Drawing 7

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would expand considerably over the years with the expansion of the millyard, the source of the waterpower from the Eastern Canal would remain constant.

By 1896 the layout of the underground raceways at the Boott Mill site had been expanded considerably to accommodate the added mill buildings that had been constructed in the millyard and it remains substantially the same today.

In most cases, only the trash racks covering the entrances to the headraces are visible today. All of the remaining structure of the underground raceways are completely covered and out of sight. However the National Park Service has commissioned a report titled the *Historic Structure Report* that describes the construction of the raceways as “The four mill sites were provided waterpower by four brick barrel-vaulted underground raceways that ran perpendicular to the canal. It is likely that the water turned 17’ diameter wood and iron breast wheels that would have been set into the cellars of each mill.”

Proprietors of the Locks and Canals   Draw 155   Drawing 7
The source of the research for the this description is mute but we have to consider every bit of available information that we come across as being reliable unless proven otherwise and the National Park Service probably feels the same.

View from vehicle bridge that spans the Eastern Canal and runs from foot of John and Amory Streets and enters the Boott mill yard between buildings #6 & 8. Trash racks shown are under building #6.

Photo by Janet Pohl

View from pedestrian bridge over Eastern Canal. It runs from Amory Street and enters building #8 in the Boott Mills. The bridge spans the trash rack.

Photo by Janet Pohl

The trash racks covering the headraces under mills Nos. 6 & 8.
Most photographs of the canals illustrate well the majestic and slightly view of the serene waters flowing between the granite walls but the working parts only appear when they are viewed empty, warts and all. The debris on the empty canal bottom may be unsightly but it is there and it is part of the underwater scenery for better or worse. At one time these canals were drained every Saturday late afternoon and not refilled until late Sunday for that one purpose of cleaning and maintenance but with the demise of the mills that too is a thing of the past.

As mentioned before the trash racks cover most of the headraces leaving the Eastern Canal and entering under buildings Nos. 6 & 8 of the Booth Mills. In the sketch of the underground raceways on page 80, two turbines are shown located between mills Nos. 5 East and 5 West. The two headraces are located under the vehicle bridge that crosses the Eastern Canal at the foot of John Street and provides access to the millyard.
If the reader was to follow the path that leads to the Riverwalk that runs between the Boott Mills and the River from the vehicle bridge straight through the millyard toward the River, and it is accessible between the No. 5 buildings, the turbine pit can be seen to the left under the #5 West building. Also visible are the head and tailrace entering and leaving the turbine pit. It is only a small piece of the extensive underground raceways but it remains an impressive small piece.

Steel guard erected over the turbine pit. There is also a grate that bars even the light from the view and greatly restricts the photographs that can be taken.

The view down into the turbine pit showing the headrace entering the forebay with the turbine housing projecting from the bottom.

This partial view shows the opening allowing the tailrace to enter the River from the wheelpit. A short trip following the directions is recommended.

Photographs by the author
The series of pictures presented above show probably the only raceway that at least complete portions of can be followed, and then only the underground system providing water to power the wheel in building #5 West. The entrance to the headrace leaving the Eastern Canal is depicted in page 83, the turbine pit and its associated raceways on the previous page and just below on this page a pair of tailraces emptying into the Merrimack River. The bank of the Merrimack River under the Boott Mill site is encased in granite block but these tailraces may not be authentic to the described turbine raceway. Never the less the photograph does portray a typical archway framing a typical tailrace.

Proprietors of Locks and Canals - #1405
Center for Lowell History

If the mill sites were anything, they were constantly being changed; rebuilt because of the industry demands, floors added because of space restrictions imposed by other surrounding mill sites and simply geographic boundaries. So any source that enabled expansion that arose was quickly taken advantage of.

The straightening of the banks of the Merrimack River was seized upon as a gift from the gods. The southern bank on which the Boott Mills were constructed on was extended in 1882 by 25 feet and allowed for a four story addition to the #5 East Mill on the newly filled land. The informative Cultural Resources Inventory compiled by Shipley, Bullfinch, Richardson and Abbott quotes the General court of the Commonwealth of Massachusetts when it refers to Chapter 89 of Acts of 1882 which declares that “several manufacturing companies were granted the right to ‘define’ and improve the rivers channel.”
One more point can be illustrated to portray exactly the flow of the water through the underground raceways at the Boott Mill complex. The sketch below shows a cutaway schematic of the chambers that exist beneath one mill building that funnel the waterpower through the system. It is by far the simplest and likewise the most complete presentation imaginable. From the beginning at the headrace (penstock) into the forebay and into the turbine to empty into the tailrace and ultimately a lower canal or the river.

Boott Cotton Mills: Field work and measured drawings/HAER 1983

This sketch is shown in an abbreviated view as it is the only part of the complete original drawing that is of our interest. And many words have been written just to explain the motive process that is before us with a few stokes of a pen.

The romance of the rushing water pouring through the wheels and spinning the great looms of the Boott Mills was approaching obsolescence; first as turbines replaced the breast wheels by 1857 and then it became the turbines to slip into oblivion, heralded by the introduction of steam to supplement the waterpower in 1873 and 1878. Still, both modes of power continued to be used as late as 1932. At this time it was calculated that 5/8 of the power of the Boott Mills was produced by steam, and the remaining 3/8 by water.
Environmentally, waterpower couldn’t be beat in it’s day, or even today for that matter. Lowell’s biggest manufacturing rivals, the mills of Britain, were buried in the smog from burning coal to fire their steam boilers. But waterpower did have its natural disadvantages not seen in steam. Fluctuations in the height of the water in the Merrimack River, too high or too low, all contributed to the problems of the PL&C in providing the millpowers to the manufactories. Too low in the mid-summer hopefully could be controlled by flashboards at the Pawtucket dam and reduced hours of operation by the mills in order to pool the available water above the dam could all help somewhat. This solution was just common sense. But spring freshets generated by the melting snows of the North Country could cause havoc with the resulting flooding of the river. The excessively high water levels didn’t so much overpower the canals and their ability to handle the volumes that poured down the Merrimack River. That was suppose to be controlled for the most part by the upper (Swamp Locks) and lower (Lower Locks) dams and their gates regulating the water level in the canals, and the capacity of river itself.

The major problem was the flooding of the wheelpits at the mills. The major supposition amongst people when the threat of flooding is broached is just let the excess volumes of water pour down the canals. What’s the difference? So the mills gain a little extra power for a time: the PL&C will charge them accordingly and everybody will be satisfied. Yes, as the canals fill up, more water does flow through the headraces at an increased rate and into the wheelpits propelling the waterwheels or turbines with greater power. But the same increased volumes of water also pour down the lower canals or the river into which the tailraces eject the water spent from turning the wheels.

Backwater is the term given to this condition. Instead of the spent water being ejected from the wheelpit and allowing the wheel to turn freely from the weight of the inrushing water in the headrace, the same volume of water is rushing backward into the wheelpit through the tailrace because of the increased water level in the lower level canals or the river effectively chokes the motion of the wheel. The net result is a loss of power, not a gain from all of this excess water. The input and output of the volume of water through the wheels is a delicate balance that has to be maintained to effectively operate the system. This was the reason why the level of water in the canals was regulated so closely at the overall level of 30 feet with a calculated fall of 13 feet at the upper falls and 17 feet at the lower. These are the levels that the system will function at most efficiently.

The ice problem in the Eastern Canal

As already explained in chapter four, the Boott Cotton Mills had a unique problem not experienced by any other mill complex. All experienced a somewhat loss of production because of ice jams in the canals that fed waterpower to their wheels but none to the extreme extent that the Boott did. The Merrimack Mills as well, being at the end of the Merrimack Canal spent many hours and days clearing the ice from their trash racks that blocked the flow of water into the headraces. But at least the workers there could break up the ice and force it over their dam and into the Merrimack Wasteway to allow it to flow into the river.

Take a minute and consult the map on pages 8 and 30 to get a better picture of the locations of these mills and canals and their locations in the system. The reason the Boott Mills ended up with the largest problem with the ice isn’t easy to understand unless one can envision the ice problem as it is explained further into the text. It was simply that a lot of the cause of the excessive ice build-up experienced by that mill complex was primarily the poor selection of that particular location in the system. True, it placed the Boott at the extreme end of several miles of fast flowing waterways but the mill complex was bypassed by most of the volume of water, once again by the location in the system of
the Eastern Canal which supplied it. And the solution to the low water was the Boott Penstock which
was to create an unforeseen problem down the road.

A given was simply that in the winter, the ice on the Upper Pawtucket Canal was no problem.
The ice was forced over the Swamp Locks Dam and became the problem of the Lower Canal. The ice in
the Hamilton Canal was also fed into the Lower Pawtucket Canal through its own wasteway and consequently all of the accumulated ice was pushed by the heavy currents down stream to jam against
the dam of the Lower Locks and accumulate in the Lower Locks basin.

Open the gates at the dam and push the ice over the spillways and into the Concord River; so
what’s the problem? There is no problem to that solution to the method of removing the ice from the
Lower Canal, just in the cost. The cost was to the PL&G if the precious liquid gold had to be squandered
to wash ice out of the canals, especially if it appeared that it wasn’t their responsibility in the first place
but more on this further on.

As mentioned before, the Eastern Canal was about 2000 feet in length feeding waterpower first
to the Massachusetts Mills and then to the Boott Mills before dropping through the underground
raceways and into the Merrimack River. The Boott Dam straddled the end of the canal and then merged
with the Merrimack Wasteway before any surplus waters entered the river. This waterway should have
presented the ideal answer to the question of what to do with the ice, providing a somewhat direct route
from the Lower Locks basin to the river. The swift flowing canal water was going that way anyway so
also no added expense would be incurred with the wasting of water.

This seemingly simple solution was actually no solution at all. This ongoing examination of the
ice problem that plagued the Boott Mill Complex has nothing to do with our interests in the underground
raceways that fed water to the wheelpits in the various mill buildings. And yet it is everything. This
problem could be so severe as to prevent the amount of water to which the Boott Mills were contracted
for from flowing into the wheelpits and thus interfere with the manufacturing process. If the freezing
persisted for a long enough duration, the anchor ice could build up all the way to the bottom of the canal
allowing no water at all to flow in the raceways.

Seeing that we’re bound and determined that this ice problem has to be addressed again, let’s
approach it from a different angle than that presented in chapter four. A quote from a booklet outlining
the operation of the Lowell canals and the experience of the men who worked them titled Working the
Water63 will be included here. A little literary license will be taken with the re-telling to make it more
readable and brief.

The author, Steve Turner, starts with the statement that winter means headaches on the canals
and heavy snows can clog the waterways. And then there is the anchor ice, the oddly named glue like
slush that forms (under proper conditions) on the surface of the flowing canals as a kind of forerunner of
solid ice.” He adds that the proper conditions are bitter cold and a little wind. “It sticks to almost
anything it touches, mounding up quickly.” This description should more that paint the picture for our
purposes.

Why wouldn’t the swift currents of the Eastern Canal simply push the accumulating ice over the
Boott Dam and alleviate the problem from the beginning before the jam grew so massive that it couldn’t
be handled? We have to go back to the penstock that was built between the Merrimack and Eastern
Canals after the completion of the Northern Canal and the Moody Street Feeder in 1848 that connected
those canals together. The purpose of the penstock was to allow the increased volume of water now
pouring into the system from the Northern to supply the Eastern Canal with an added flow from that source to alleviate the chronic shortage in that canal because of its location at the end of the water supply chain. It served the purpose to increase the level to a degree but was also the prime cause of the ice build-up problem that we are discussing.

How? How could the successful introduction of adding water to increase the volume in the Eastern Canal have caused as much, if not a greater problem than it was meant to solve? The fact that the water from the Merrimack Canal that was entering the Eastern Canal through the Boott Penstock was flowing in the opposite direction as the current in the Eastern Canal had much to do with the unanticipated results.

The two water flows collided head on but the turbulence created didn’t affect the quality of the added volume one iota. It added to the level in the canal and so the end result of the Boott penstock was achieved. Boott was happy because the looms were turning full speed and the PL&C was happy to be receiving the extra $6,000. the penstock generated in revenue. All was bliss, that is until winter raised it’s ugly head, or rather it’s ugly ice. The ice was always present in the winter and that was true on every canal, not just the Eastern. But the Eastern was the only canal that had a heavy flow of water pushing against its current with its own forceful current, that which was generated by the flow from the Boott Penstock. This opposite current was what held the ice jam in place and prevented all efforts to freely allow it to flow over the spillway at the Boott Dam and into the Merrimack River.

This very question was addressed by Thomas L. Livermore and a report made to the Boott Cotton Mills. The Directors received a copy and the Minutes of their meeting of March 8, 1889 stated so. The report was printed in the Sundry Papers and titled, *Removal of Ice from Eastern Canal*. We will quote in part from the observations that Mr. Livermore made in his writings concerning which party had the obligation for the removal of the ice. “The question now arises whether the Proprietors of the Locks and Canals are bound by anything in their lease to the Boott Mills of December 1, 1853, to remove the ice. The lease grants to the Boott Mills 17 26/30 ‘mill powers or privileges at the Lower Falls.’ It is to be remarked in the outset that no right is conferred by the lease on the Boott Mills to touch the canals or the weirs of the Lessor, and unless the Lessor is bound to remover the ice, the Boott Mills must submit to its presence (if the Lessor so wills) unless they construct a wasteway through their mill site, and with the ‘mill powers’ to which they are entitled, float the ice over this wasteway.”

He goes on to add that nothing indicated that the Lessee was to use its mill powers from clearing ice from the canals.

Everywhere the Boott Mills turn to alleviate the ice seems to leave them between a rock and a hard place. Mr. Livermore next quotes from the *Form of Lease of Water Power at Lowell, 1853* that the PL&C and all of the manufactories signed and adopted as their contract form. Article III provides that the Proprietors of the Locks and Canals shall “from time to time, as occasion may require...remove from the said canals and water course all obstructions and accumulations that may sensibly interrupt the flow of water therein.”

It appears that the Boot may have won a point in their favor but the PL&C was prepared to argue further for their cause. They claimed that “Article III of the lease referred only to the accumulations and obstructions which sensibly interrupt the flow of water ‘in’ the canal and not the flow ‘out’ of the canal, and that the ice which accumulates in front of the Boott Mills does not sensibly interrupt this flow of water in the canal.”
All of the PL&C’s arguments were based on a court case brought by the Essex Company at Lawrence because of the ice problems they had in their canals with ice but the two cases were apples and oranges. The reader can decide on his own by reading the article that the previous text is quoted from. We have beaten this issue to death but that the flow of water through the underground raceways and into the wheelpits was severely restricted by the ice jam cannot be disputed.

Before leaving Mr. Livermore, at least we know he reached the same conclusion in 1853 as we did with our research of today as to the cause of the huge ice jams at the Boott Mills. We will quote him one more time before we take leave for good and put the entire past ice history behind us.

“But the greater part of the ice which accumulates in the Eastern Canal opposite the Boott Mills is stopped and detained there, not by the inflow to the wheels or the racks, but by the southerly current from the Boott Feeder, which acts like a dam across the canal, and this is in no was the result of any act chargeable to the Boott Mills. Furthermore no amount of attention or care on the part of the Boott Mills could clear away the accumulation of ice because the currents in the canal make it impossible for the Boott Mills to move it one way or another.”

Chapter Four describes in detail the Boott Penstock, its final configuration, and the part it played in raising the water level of the Eastern Canal. The photograph on page 33 illustrates how the waters of the penstock were intermingled with those of the canal through ports in the stone wall separating the penstock and canal. By allowing the penstock waters to enter the canal at a right angle to the trash racks, much of the problems because of the immovable ice packs were solved.

With that last paragraph we’ll tuck the ice problem into its bed as a solved historical question and return to our quest for descriptions and explanations of the construction and operation of the underground raceways that furnished the mill complexes with their contracted for millpower from the PL&C.

The Boott Cotton Mills   Lowell Illustrated   Frank Hill   1884
Tremont and Suffolk Mills and the Lawrence Manufacturing Company

As on any unfamiliar trip, a map always eases the burden of navigating unfamiliar territory and this foray into these three mill complexes is no different. At least a quick glance by the reader of the site layout and becoming somewhat acquainted with the relationship of the three manufactories with each other can’t help but make the following text more comprehensible.

The layout of the buildings and canal in the Lawrence Mill yard is left blank in this drawing but will be presented in full detail in the following pages when its underground operation is described in detail.
Tremont and Suffolk Mills and the Lawrence Manufacturing Company.

Why, the reader is probably asking himself, are these three manufactories lumped together? Are they all under one roof or the same ownership? Or have they all merged such as the Massachusetts and Prescott Mills did as outlined in the previous text. To answer the prior questions, no, somewhat and at least the Tremont and Suffolk were always treated as one entity because of the close ties of the management of the two down through the years.

The inception of the first step toward construction of these three mill complexes appears to be in an entry in the records of the PL&C Directors Meetings dated November 19, 1830. It reports that a committee had already been appointed to consider a contract with the Suffolk Manufacturing Company for two mill seats and power at Lowell.

This seems to indicate that the contracts between the PL&C and the Lawrence brothers for the land, buildings and power to operate the machinery were finalized in late 1830. The Tremont and Suffolk Mill sites were documented as having the construction commencing shortly thereafter even though the proceeding were not actually recorded until 1832, around the time of the completion of the Western Canal.

The three complexes did have several common denominators. The planning for the construction of the mills seems to have been contemplated by the PL&C as early as 1830. On a page from a ledger taken from 1830 is an entry, "Western Canal & Mill Sites," $32,800.40. [The first recorded mention of the Suffolk Manufacturing Company addressing the PL&C to obtain two mill seats with full power and contracting for the buildings, gearing and machinery appears in the record of the Directors Meeting of November 19, 1830]. They were all incorporated in 1831, the Suffolk on January 17, the Tremont on March 19 and the Lawrence June 7, and all three manufactories bore the name of William Appleton as one of the incorporators. Benjamin Nichols was involved in at least two of the manufactories, the Tremont and the Lawrence among the others.

All three corporations were actually organized by wealthy Boston merchants Amos and Abbott Lawrence. Both Lawrence names are listed as incorporators of the Tremont Manufacturing Company and the Lawrence Manufacturing Company was to bear the family name. They were both seasoned businessmen and eventually were to hold tight reigns on the entire textile industry of Lowell through the merchantile outlet they established of A. A. Lawrence that soon became the largest purveyor of the finished product of the mills in the industry.

By November 30, 1830, the PL&C had already let a contract with stonemasons Russell and Barr for the foundation walls of the underground work. All of these doings may seem to have taken on an extremely fast pace for a contract that was only agreed on in the previous weeks but the PL&C was very familiar with the plans for these mill sites. In fact they had been laid out in the early 1820s by the incorporators of the Merrimack Manufacturing Company when they were making plans to develop all of the land and power for their own use.

So it is not surprising that they were referred together as the Western Group when they were constructed alongside the Western Canal by the Proprietors of the Locks and Canals [PL&C].
This is a presentation of the three mill yards as they were conceived at the time of their planning. Nothing is identified in this sketch of the three mill yards. The author maybe overstepping literary allowances by taking the liberty to include descriptive passages indicated by arrows and explained on the next page but here it is almost unavoidable for clarity.

Tremont, Suffolk and Lawrence Yards  Benj. Mather  1832

Arrow #1  This indicates the layout of the Lawrence mill buildings as they were in 1832. The waterway running parallel and below the buildings shows the location of the Lawrence Canal in relationship to the mills.

Arrow #2  Indicating the secondary yard of the Lawrence Mills with the Lawrence Canal supplying the water source.

Arrow #3  the site of the Suffolk Mills yard. The parallel lines running vertically to the left of the indicated buildings is the Western raceway that collected the spent water from the mill tailraces.

Arrow #4  The site of the Tremont Mills yard with its raceway shown vertically to the right of the two mill buildings.
Arrow #5 Indicates the path of the Western Canal. The bulge in the canal in the center of the sketch shows the location of the Hall Street Dam. The canal water dropped 13 feet at this point to supply the head for the motive power for the Suffolk and Tremont mill wheels. A short distance above a single line crosses the canal before it reduces in width to indicate the wasteway before it enters the Merrimack River. Here the water drops another 17 feet to created the necessary head to drive the wheels of the Lawrence Mills.

With this grouping of the mill complexes it’s quite obvious that all received their waterpower directly or indirectly from the Western Canal or that the Tremont and Suffolk when described or written about seem to share the same background as the two did merge in 1871. But from the very inception of the two complexes, Frank Hill records in his Lowell Illustrated “The management of both these corporations was substantially in the same hands, even before they were merged in one company.” The biggest single difference was that they were almost mirror images of each other only because each was built on opposite sides of the same canal directly across from each other.

The Lawrence Mills were constructed at the end of the waterway, the so called Lower Western Canal, and utilized the same water source as the Tremont and Suffolk from their tailraces, admittedly second hand. So the trinity was grouped together and they are treated in this manner in much of the material that was researched.

Our interest is in the underground raceways that fed the waterpower to the mill complexes and regardless of how close the complexes resembled each other in the site layouts, they evolved their individual underground systems quite differently. The completion of the Northern Canal in 1848 also greatly affected the source of the water supply to the Suffolk and Tremont Mills. The direct result was the Tremont Gatehouse built at the same time as the Northern to cut off the flow to the existing waterway below the gatehouse from which the headraces for both these complexes originally drew their waterpower.

This entailed relocating both headraces. The Suffolk was tapped directly from the Northern Canal as it passed in front of the complex for its waterpower and the Tremont would now have its penstocks leaving the canal at the junction of the Northern and Western. This supposedly minor alteration of the raceways was to have major implications on how the underground waterways would evolve.

That difference dictates that for our purposes each manufactory has to be treated entirely separately whether their configurations are closely alike on the surface or completely alien as is the Lawrence. For that matter, so were the canals that fed them. We are getting too far ahead of ourselves now. One step at a time and the first will be an abbreviated description of the topography of the Western Canal itself.
Western Canal

The Western Canal was built on two levels as was the Pawtucket. This gave promise for the canal to be able to support more wheels using two smaller drops along its length of 13 and 17 feet respectively rather than the full 30 foot head at its end before dropping off into the river. Whether or not this was the most efficient use of the fall of the head of water in the system was debated pro and con and several outside sources were highly critical.

The Suffolk and the Tremont Mills were built on the upper level of the Western Canal. The Lawrence Mills were built on the lower level and received their water power from the Lawrence Canal which was an extended raceway of the Western really, accumulating waters from the runoff of the Suffolk and Tremont Mills and utilizing the spent water being ejected from the tailraces of those mills a second time to power the wheels of the Lawrence Mills. If for any reason either or both, the Suffolk or/and the Tremont Mills were not operating and thus no water was flowing from the tailraces to enter the Lawrence Canal, then the normally closed gates at the Tremont Dam would be opened to flood the Tremont Wasteway and thus the basin above the Hall Street Dam. With that dam’s sluice gate open water would pool behind the Lawrence Dam and provide all of the water needed to fill the Lawrence Canal until the Suffolk and Tremont were back in operation. This in fact would bypass the tailraces of the mills on the upper level as a source of the waterpower for the Lawrence wheels temporarily.

At the risk of repeating myself, and I am, one picture can replace a thousand words and do a better job too. The sketch on the following page should need no more explanation than as it presents itself and the brief description of the waterway as presented above. It will help to refer to it often as the text unfolds to describe the genius involved in the design of the Western Group.

An excuse has to be made here in some ways for showing this sketch at all. It in no way presents the actual layout of the waterways at any time in history except in the most remote respect. What it does do is schematically indicate the sources of the various water supplies without making any claim for accuracy. For example the notation in parenthesis under the identifying heading of Tremont Wasteway makes the claim that the wasteway is normally dry. The Tremont Gates actually would have had to been opened regularly just to sustain normal daily operations. It is an impossible situation at any time seeing that the Lawrence Mills drew more waterpower than both the Suffolk and Tremont together could supply when running at their peak. This fact will be discussed more fully in the section on the Lawrence Mills.

The reader should just take the sketch with a grain of salt and understand its intent without letting it confuse the issue as the rest of the chapter unfolds. More will be said on the validity of the information in the sketch further along in the text.

Because this sketch is suppose to indicate an overall explanation of the water flow of the waters of the Western Canal and the way it was used to supply the various mills in the group, the author will take the liberty of superimposing the junction of the Northern Canal with the waterway after 1848. The dotted parallel lines entering from the left will indicate the approximate point of entry that the Northern Canal made into the Western upon its completion. Without this overlay to the sketch, the sketch would be useless for any reference to it after 1848.
Reproduced from “Water Power in Lowell” by Patrick M. Malone.
For all the misgivings the sketch produces, and for want of a better description and allowing for the distortions it presents, the genius of the men who build the system still shines through. They came, they saw and they conquered.

While all the canals were somewhat effected by the completion of the Northern Canal in 1848, primarily do to the increase in water flow and in some cases rebuilding to handle it, it was extreme in the case of the Western. The two following sketches should at least illustrate the topography of the position of the Western in relation to the Northern Canal.

Arrow #1 designates the Hickey-Hall Dam.

Arrow #2 designates the Swamp Locks with its dam.

This is a sketch of the entire canal system as it existed in 1836. The mills the canals fed are indicated by circles drawn at their locations.

Pre – Northern Canal

This is the identical map as the pre-Northern shown above. The addition of the Northern Canal in 1848 was to effect the water levels in all of the canals.

Post - Northern Canal

Both sketches drawn by Mark M. Howland for HAER 1975
Most of the main canals diverged from a common point on the Pawtucket Canal designated the Upper Locks or also known as the Swamp Locks. The water level in the basin at the Swamp Locks was the same height as that of the Merrimack River providing a 30 foot head. The dam that exists here creates a 13 foot drop, the water falling into the Lower Pawtucket Canal. This drop in the water level provided the head that powered the Appleton and Hamilton Mills on the Hamilton Canal. The full 30 foot head continued down the Merrimack and Western Canals.

For all practical purposes with the opening of the Northern Canal, the Western Canal became two different waterways with completely separate roles from each other. With the overpowering volume of water pouring into the Western from the Northern, the current in the Western was reversed so that the waters were now feeding back into the Swamp Locks basin and the canal was effectively cut in half at this point. The Upper section of the canal no longer fed any of the mills in the Western Group and it was now the upper nothing. Instead of being a feeder canal, it was now simply a 3500 foot canal funneling the Northern’s water into the Swamp Locks basin.

In fact the Lower Canal had for all practical purposes ceased to exist. The lower water course was now termed the Tremont Wasteway and the Tremont gatehouse at the head of the Wasteway effectively blocked any water from entering unless by choice. The Northern Canal now fed waterpower directly to both the Suffolk and the Tremont penstocks. The tailraces from both these mill complexes fed the spent waters from their wheels into the Lawrence Canal to power the Lawrence Mills. What was left of that 1000 foot waterway only contained the waters backed up against the Hall Street Dam that overflowed from the Lawrence Canal. This description of the new role of the Western Canal really takes a lot understanding on the part of the reader. You can examine both maps on page 96 showing the pre and the post Northern Canal but in no case does the effect on the Western become evident. Only by reading and re-reading the text, and visualizing the reversal in the motion power does the change fall into place.

No other mills exist on the Upper Western Canal as shown in the two maps on the previous page until the Tremont and Suffolk are reached. This abbreviated description of the Canal just about completes our brief history of the waterway, more a refresher course than a history lesson, before delving into the text describing the underground waterways of the Tremont, Suffolk and Lawrence Mills.

For our purposes, our tale starts at the bottom of the sketch on page 95. It is at this point in the sketch that the waters of the Upper Western Canal are tapped by both, the Suffolk and Tremont Mills. The water has flowed 3500 feet between the canal walls uninterrupted from the Swamp Locks and it is about to be put to work. Keep in mind that this appears to be a composite sketch containing some of the characteristics of both the pre and post Northern Canal eras. As the reader sifts through the sketches of the underground raceways scanned from material uncovered in the research, the presentations may, no will not exactly match.

For example the sketch is described as “adapted from ‘plan of the Suffolk Mill Yard,’ Locks and Canals Drawing, 1941.” Was this drawing executed in 1941? If so, why isn’t the Northern Canal shown which would have entered this area just to the left of the Upper Canal. And the Tremont gatehouse didn’t exist until the Northern was built. And no drawings of the proposed underground raceways that we came across in the research ever showed the original penstocks leaving the upper canal at these points. After 1927, the dam referred to in this sketch as the Hall St. Dam was renamed the Hickey-Hall Dam and even that hasn’t caught up with the producer of this sketch.
So treat this sketch as a stylized drawing that was meant to portray the direction that the water took in order to feed the mill powers into the wheel pits in the two mills, a sort of schematic or blueprint if you will. And that’s the way we will use it. If the reader has no comprehension whatsoever of how the water entered the two mills there is no better presentation than this sketch. Letting your fingers do the walking so to speak and we will follow the course the water took before getting involved too deeply with the actual underground raceways.

At the indicated point of the water entering our picture at the bottom of the page, that is the Upper Western Canal, the head or the level of the water is the same as that of the Merrimack River. When the head of 30 feet is given what is meant is that the water stands at approximately 82+/− feet above sea level at the Pawtucket Dam, and this is the point that the canal system draws its water from. At some point all of the canals empty back into the river below the Pawtucket Falls or the Concord River, either through individual tailraces or over the spillway at the Lower Locks Dam. At this point the water level is approximately 52+/− feet above sea level and that difference in water height is what creates the 30 foot head in the waters in the canals.

Bypassing the stylized sketch that is being criticized so drastically, an individual head gate would have been located where the penstocks left the canals by agreement with the Proprietors of the Locks and Canals [PL&C] written into the lease last updated in 1853. This allowed either the mill or the PL&C to interrupt the water flow for repairs to the machinery or the raceways themselves if necessary. Under normal operating conditions the spent water that had flowed through the headrace, wheelpit, waterwheel or turbine of the Suffolk and Tremont Mills and then through their tailrace and into the Lawrence Canal would have dropped 13 feet leaving a 17 foot head to power the Lawrence Mills.

Keep in mind, the Upper Western Canal is carrying the full 30 foot head of the water level originated from behind the Pawtucket dam. The Suffolk and Tremont were located on the Upper Western Canal. At the point on our sketch on page 90 where the Hall Street Dam in indicated, the water fell 13 feet into the Lower Canal leaving 17 feet to power the Lawrence Mills. These mills ejected their spent water directly into the river below the Pawtucket Falls and just above the Concord River.

Now we have more or less followed the course of the water from above the Pawtucket Falls to the re-entry back into the River and have expended the entire 30 foot of head in doing so. But what part does the Northern Canal play in all of this? Why is it needed? The water flow and the operation of the mills seemed to be running smoothly so what was the need for the added 4100 foot waterway. It left only a few hundred feet further down river from the Pawtucket and its beginning was still behind the dam.
The role of the Northern Canal

The old existing canal system was really too small to do the job. The expansion of the mills as fast as the canals could be built to the extent that they were, beginning with the Merrimack in 1822 through the construction of the Boott in 1835 was unforeseen, never mind the development of each complex using every available inch of property they commanded. The canals simply couldn’t handle the demand of the volume of water now called for.

Besides, physically the mills had built right to the canal edges so widening or the dangers inherent with dredging to deepen the canals with the fear of weakening the walls left the PL&C with no alternative except to find an alternate solution to providing more water into the system. Several plans were proposed; digging another canal paralleling the Upper Pawtucket and emptying into the canal just below the Guard Locks was one of the favorites, but they all entailed adding more water to the existing canals and that was proving impossible. Thus the construction of the Northern became the only alternative. This entailed that the entire volume from that canal would flow into the Western Canal. This flood of water demanded the construction of the Moody Street Feeder between the Western and Merrimack Canals to assure the most effective distribution of this sudden wealth of the liquid gold into the Western. Add to this construction the building of the Boott penstock to funnel the water into the Eastern Canal which had always been water starved because of its location at the end of the waterway and it appears the Northern was needed years ago.

Following the paths of the canals in the map on the bottom of page 96 will greatly simplify the explanation for the need of the Northern Canal outlined in the text above. The one major effect on the canal system because of the construction of the Northern that can’t show on any map was the reversal of the current in the Western Canal. Where as the water always flowed from the Swamp Locks north in the canal toward the Western group of mills, the greater volume from the Northern now forced its waters back up the Western and into the Swamp Locks which was the intended effects from the inception of the canal to add its waters to the volume in the existing waterways.

This is what entailed the necessity for the building of the Tremont gatehouse, the re-routing of the penstocks from the so called Tremont Wasteway to directly feed water from the Western Canal to the Tremont wheels and now providing the waterpower supply to the Suffolk directly from the Northern Canal. At this point all indications of how the mills on the Upper Western on the sketch on page 95 received their water power can be disregarded. Future text will clarify all of the underground right from the canal and through the wheels in each individual mill.

One last gasp at a meaningless history lesson. All three manufactories were incorporated within six months of each other in 1831, the Suffolk in January, the Tremont in March, and the Lawrence in June. In 1871 the Suffolk and the Tremont were consolidated. The strange part of the incorporations in 1831 is that the Western Canal wasn’t even finished until 1832, even though started in 1828. Even stranger is the fact recorded in the minutes of the Directors Meeting of April 20, 1831 that the PL&C had contracted to build the mill buildings and supply the mill power for 20,000 spindles? Foresight? From here on each of the mills and their accompanying underground waterways will be treated as a separate entity. Some repeating will be demanded especially in the case of the Suffolk and Tremont Mill complexes. No matter how much text is provided, the answer to all of the questions pertaining to the waterways will be answered in the sketches that accompany the work.
In the sketch below, the Tremont Mill complex is portrayed in the upper center and it is marked as such. The Suffolk Mills are on the right. In the blank area in the lower portion of the sketch is where the Lawrence Mills would be located.

This photo is of the 1928 Lawrence Manufacturing Company at its zenith. The buildings on this site were jammed on every inch of available space. The Lawrence Dam is in the lower right with the waters of the Western Canal flowing over it.
Suffolk Manufacturing Company

From a ledger page offered by the PL&C and dated July 31, 1831, it appears that the PL&C was paid the sum of $135,000 under the heading of “by Suffolk Mang. Co.” But this up front fee didn’t represent all profit. On the same ledger page is the figure of $16,756.36 expended by the PL&C on the Western Canal.

The first Suffolk Mill buildings followed closely the dimensions and layout of all of the mills that preceded them in Lowell, approximately 150 by 45 feet and four or five stories high. Most were constructed parallel to the canal from which the mill drew its water. This allowed the power canal to be dug in a more or less straight line from the feeder canal to slightly off center in the mill basement to feed the wheel pit that would be located there. This brief paragraph explains the entire complexity of the basic plan for supplying the water to create the power to operate the mill machinery.

A more detailed description of the course of the underground waterways is given in an outline simply titled Suffolk Mills prepared by Cornelia Wyma and Paul Cloyd. “An 18’ wide feeder ran from the Western Canal to the center section of each mill. The feeders continued through the mills and emptied into a race, known as the Western Race that flowed north to the Lawrence Manufacturing Company.”

The plan of the proposed buildings and underground waterways that were to be built to supply the water is what was being described in the text above. The Lawrence Mills are off to the right. Company housing showed above Race Street on the original plan.

Copy of original plan to accompany Deed for the sale of land from PL&C to Suffolk Mfg. Co. Jan. 1, 1832 Courtesy of HAER

The authors added a little more detailed picture of the construction of the waterways with the observation from their source “that the sides of the feeders were stoned, with timbers laid across and planked over the top.”
Before we go any further, as long as the raceway from the Suffolk to the Lawrence is brought up, a little point of interest should be explained here. It’s difficult to separate the operations of the Suffolk, Tremont and Lawrence Mills from each other because all of their operations are so intertwined, and that includes their water usage.

As mentioned on page 101, the tailraces from the Suffolk wheel pits merged with the Western Race and that race then tied into the Lawrence Canal. The water has already dropped 13 feet through the wheels in the Suffolk Mills and was now used for a second time being utilized to power the wheels in the Lawrence Mills. Here it dropped 17 feet through the Lawrence wheels before being discharged into the Merrimack River.

Because of this unique arrangement of the tailraces of the Suffolk and Tremont emptying into their own races, the Western Race in the case of the Suffolk, and what has been referred to as the Eastern Race for the Tremont, and then into the Lawrence Canal, this total volume of water had to be used by the Lawrence mill wheels or risk backwater from the height of any unused portion of this water backing up the raceways and into the wheelpits of the feeder mills.

As a matter of fact the Lawrence mill complex was much larger than either the Suffolk or the Tremont. The Lawrence had contracted for more mill power than the Suffolk and the Tremont combined so using all of the waters emptied into the Lawrence canal by the two upstream mills was certainly no problem. As mentioned before, if not enough water was supplied by the two of them to the Lawrence, the gates at the Tremont Dam would have to be opened to make up the difference. It now appears that even in normal operating conditions the volume of water being ejected from the tailraces of the Suffolk and Tremont Mills combined could not even meet the demand of the Lawrence Mills wheels.

In the 1853 report by the PL&C and titled Statement of the New Adjustment of the Water Power at Lowell, the total “number of powers to which each company is entitled by the new adjustment” is listed in a column under that heading. The Suffolk and Tremont each drew $\frac{15}{30}$ for a total between them of 13 mill powers. The Lawrence Manufacturing Company alone was contracted for 17, $\frac{9}{30}$ $\frac{4}{30}$ mill – power more than the two combined.

Under the title of the afore mentioned chart defining the distribution of the waterpower between the mill complexes an exception is included pertaining to the water usage of the Suffolk and Tremont Mills, “who, by the consent of all parties, are entitled to divide equally between them, the quantity of water to which the Lawrence Manufacturing Company is entitled.” So were the Suffolk and Tremont Mills shortchanging themselves out of water they were entitled to command by the exception outlined in the above statement?

Evidently not. There were 12 columns in the statement and only that one which pertained to the entitled millpowers of the mills was quoted above. Under another, “Maximum Quantity of Water Used by the Measurement of 1852” given in cubic feet per second, the Suffolk and Tremont made up for the discrepancy. Combined they made use of 726.95 cfps against 787.02 cfps for the Lawrence. The amount of water flowing over or through the wheels is what calculates the millpowers which translates into the work of the machinery being done and these figures indicate that the Suffolk and Tremont were playing catch-up, probably through the usage of surplus water.

Most of the previous page may appear to be a trip to the sidebar but when a dispute involving historical figures shows up in the research, better it be handled where it arises than try to pull the facts out of a dim remembrance.
To return to the underground raceways, various dates show up in several different sources declaring assorted specific dates for the incorporation and construction of all three mill complexes. All are probably right and depend on what time frame one wants to assign to what stage of any of the development of each complex but most agree that construction was started in the late 1830s or early 1831\textsuperscript{79} by the PL&C on the Suffolk Manufacturing Company. One outside faction probably should put the cap on any disagreement and help place a date as to when the Suffolk actually existed in terms of the original deed and plans. The 1832 plan below shows the Suffolk, Tremont and Lawrence Yards.

Plan of Lowell by Benjamin Mather
Page 101 in itself well describes the entire procedure that was followed by the Suffolk Mills to create the power necessary to allow them to operate their machinery. Simplicity at its finest. Basically it had worked perfectly to lay the groundwork for the entire textile industry in Lowell at the time. But after the digging of the Northern Canal in 1848 and connecting it into the Western in order to increase the available waterpower from the Merrimack River, all of the original plans became obsolete. The methods for generating the motive power remained the same but what became different was directing the waterpower that now flowed from the Northern Canal instead of the Western to the wheels.

The place to start is at the beginning and the headraces leaving the Northern Canal to feed the wheels of the Suffolk are the prime source. At the Directors meeting of April 19, 1847, it was determined by the appointed committee to go with the construction of the plan to build four wheelpits leaving the Northern Canal. Even though the go ahead was immediate for the ordering of the materials to construct the raceways, there must have been some mix up in plans between the Corporation and the PL&C for the Suffolk was assessed for half of the costs of extra work that it cost the PL&C. 

Photo of Suffolk headraces leaving the Northern Canal by Author
What the revamped direction of the water supply did entail was the digging of four new wheel pits and that entailed all of the connecting raceways as well. The power source from the added waterpower was to be expanded and it was no longer from the Western Canal but from the Northern. The Western was now for all purposes in a new role as a feeder canal, back feeding the Swamp Locks Basin and having nothing to do with the old role as the feeder to the Suffolk Mills.

The new headraces leaving the Northern Canal shown in the photograph only stretched for maybe 30 feet before they entered the forebay that directed the water into the wheel pits. This is what it was all about for the wheelpits, built to contain the waterwheels and/or later the seven turbines. The breast wheels had served the industry well but their end was foretold. The turbine was of a smaller size and still produced more horsepower, plus it wasn’t affected by backwater, the nemesis of high water situations in the canals and river.

The Suffolk Manufacturing Company had experienced some difficulties with the first turbine they installed. It was modeled after the original that had been tested at the Appleton Mills with excellent results but the experience caused the Suffolk to proceed slowly with the changeover. In fact from 1851 to 1855 the Suffolk continued to utilize both water sources, the Northern for their turbines and the Western for the breast wheels. In 1853, the Suffolk was still using two breast wheels with two turbines. In 1854 they were using only one wheel and three turbines but by 1856 all four machines were turbines. The wheels had reached the end of their life in the mid 1850s.
After the water left the tailraces of the Suffolk wheels, except for Mather’s 1832 map of Lowell reproduced on page 103, the visual tale of the courses of the underground raceways comes to an end, covered over to protect from the elements or under buildings that were built during the never ending expansion of the yard. The rest of the story describing the waterpower and its role in operating the mill machinery will continue to be told in the accompanying text.

The trouble with using more than one source in the research is the possibility of contradictions or simply exclusions of the material by the author of the record. The choice is to disregard both because of no way to tell which is more correct, or tell both stories. This is so in the case of the covering over of the original raceways from the Western Canal feeding the turbines of the Suffolk Mills. In this version which appears in a volume of the Cultural Resources Inventory, the construction of the feeders was described as; “The sides of these races were covered over with timbers upon which planks were laid.” The same offering goes on to state, “The foundation of the former Suffolk Manufacturing Company Counting House (the only structure in the yard remaining from the 1830s and 1840s) is still containing stone elements from the arches that spanned the original eighteen foot head race.” This statement appears to be declaring that the headrace was constructed and covered when the raceway was dug as stone archways indicate a permanent part of the structure and built prior to 1831 when the Counting House was erected.

The second source under the sub-heading of Original Feeders and Raceways [check superscript] in the document we examined states “The foundation of the counting house still contains elements of the stone arches which spanned one of the original 18’ feeders that led from the Western Canal and passed under the counting house to Mill #2. These early feeders were evidently left uncovered in the beginning, but within two years they were covered with boards and the Western Race was vaulted (covered) over to prevent freezing.” This statement indicated a two year delay between the construction and the covering over of the raceway.

To illustrate how records being used in research can unwillingly become distorted in the final results, or simply difficult to unravel the original intent to put the meaning in context, a third source is offered here that begins by describing the 18’ feeder from the Western Canal to the Suffolk Mill buildings that continued through the mills and emptied into the Western Race. Describing the possible addition of two more mill buildings and the expansion of the race to handle the expected added volume of water the race will have to carry from the two new additional buildings, Henry Hall, the treasurer of the Suffolk Mills wrote to Kirk Boott, the agent for the PL&C on August 22, 1833 to describe the work he was recommending be done on the Western Race. Hall is discussing in a part of the letter that “taking up the present side walls (on the Lawrence land) and widening the race 3 or 4’.” He goes on to add, referring to the proposed two new mill buildings at the Suffolk although he alludes to four mill seats, “I have supported that if they were ever occupied this course would actually be necessary -- & that the expense would be very small compared with that it would be after the arching was complete.” He emphasizes that the sides of the feeders “were stoned, with timbers laid across and planked over the top.”

Here is a gentleman well versed in the construction and operation of the power system that the mills relied on. He is clearly discussing the Western Race which carry’s the runoff from the tailraces of the Suffolk Mills to feed waterpower to the Lawrence Mills. Yet he himself apparently uses the descriptive wording of feeder for either or both the headrace carrying the water from the canal to the wheelpit or likewise the tailrace that now carry’s the water after it has done its work flowing through the turbine and is being ejected into the Western Race.
This dual usage of the word feeder to describe two entirely different but complementary operations that are close enough in their definition so only the author or speaker can differentiate his meaning because of the singularity of his topic can easily confuse even the most well informed reader.

There most likely was only one great, great, great, great grandfather who uttered or wrote the phrases from which all of recorded history evolved concerning the construction of the canals and was handed down to modern times just as happened in any other topic. The problem is there were many stories told to many people, or different versions of the same event recorded by different interested parties. The covering or not covering of the raceways at the time is very minor, or is it? It leaves the question of what other supposed statements of fact are open to -------discussion?
Proprietors of the Tremont Mills

This company was actually incorporated as the Proprietors of the Tremont Mills on March 19, 1831. The two Lawrence brothers, Amos and Abbott, financiers of the Suffolk, Tremont and Lawrence Mill complexes were included as two of the several incorporators of the Tremont. They were born in Groton and went on to become wealthy Boston businessman with previous ties to the cotton industries.86

The Suffolk and Tremont have been joined at the hip so to speak since the inception of the two manufactories, and a little curious history has been dredged up during the research into the background of the two companies. Both of these mill sites had been first laid out in the early 1820s by the incorporators of the Merrimack Manufacturing Company as part of their early plan. They owned all of the surrounding land and the water rights. When the Merrimack was organized by the Boston Manufacturing Company, the extended vision was for that complex to expand and not only control but occupy all of the land and mill powers generated by the Pawtucket Falls for its own use.

If the sketch of the proposed layout of the Tremont Mills seems a slight bit familiar, it should. As brought out before, it is an exact mirror image of the Suffolk Mills, part of which was reproduced on page 93. In that case the anticipated housing that was projected to accompany the mill’s development has been edited out and all that is shown is the actual mill site.

Flip this sketch upside down and you are looking at the plan of the Suffolk Mills. Notice the dotted headraces leave the top of the Western Canal on the Suffolk Mill site plan on page 101. The Tremont plan is the exact opposite. The housing is shown on the bottom.

Copy of original plan to accompany Deed for the sale of land from PL&C to Tremont Mills. Jan 1, 1832 Courtesy of HAER
The housing for the mill workers was built in both cases just beyond the indicated race above and below the mill structures.

The fact that the Tremont and Suffolk Mills were more or less operated by the same people has already been hashed over in the previous text on the Suffolk Mills so we’ll dispense with any duplication of the past histories and get right into how the underground waterways of the Tremont differed considerably from its sister mill complex on the other side of the Western Canal, and the reason why.

Following the completion of the Northern Canal, the Tremont like the Suffolk were obligated because of the changed location of the new source of waterpower that not only the headraces be relocated but that new wheelpits be dug as well. Because four were determined to be the best plan which would allow for sufficient capacity for the present power needs and future expansion at the Suffolk, the same was adopted at the Tremont without question. It was to be very seldom that one complex would make a move that the other didn’t follow but it was to happen as expansion began to dictate separate routes. Even though they were mirror images at conception outside forces were about take over.

When the Northern Canal was completed, it passed directly in front of the Suffolk and presented a large frontage to the mill site giving the opportunity to the complex to more or less design its access to the waterpower to suit itself. The sketch on page 105 shows the entire Suffolk waterpower system as it was adapted and updated in the later years but from the descriptions of the wheelpits constructed in 1848 given in earlier writings, the locations probably remained the same from day one, right until today.

The Tremont wasn’t afforded the same luxury of picking and choosing the site of the headraces from the Northern. The only contact at which the waters from the Northern brushed the Tremont Mill site was at the point where the two canals came together and the Northern merged with the Western Canal. The movers and shakers of the Tremont Mills simply decided if that was to be the only location where they had access to the waterpower of the Northern Canal, so be it. A site for the wheelhouse was decided on 90 feet inside the Eastern bank of the Western Canal and plans were laid for a wheelhouse with four wheelpits also.

The new raceway layout at the Tremont would encompass nothing of the original and all of the underground would be dug anew. But to begin at the beginning, the following photos show where the headraces feeding the turbines in the new wheelhouse left the Western Canal. They are blocked off now and a wooden barrier has been build where the racks would have been located. The underground raceways left the canal on a slight angle to enter the wheelhouse building.

The remains of the single story wheelhouse still stand but in worse than poor condition. Sections of the floor as well as the roof have collapsed and the future of the site is now under consideration. A clandestine visit to the fenced-in yard by an intruder has produced a few photographs of the building and the ground that has cave in covering the underground raceway in places. If you look close enough in person, some of the stone remains of the raceway walls can be detected under the openings in the ground.
This photo taken of the Tremont Gatehouse in 1915 has the trash racks covering the headraces to the wheelhouse and turbines in the Tremont Mills showing to the right. The only surviving building is the wheelhouse.

The degeneration of the Tremont Wheelhouse is certainly apparent in this photo taken in 2006. This building is under consideration at this time to be rebuild and added to with an exhibition of the original turbines to be offered.

This is the rear entrance into the wheelhouse. It led to an addition that was built to house the electrical equipment installed after generators were mounted on the turbines. Note hole in ground front of door. Tailrace below.

By unknown person
The original wheelhouse was built in 1847 and rebuilt in 1862 with three floors added above but no change to the Picker/Wheelhouse itself.  

The underground feeders must have been satisfactory in its original form because it remained the same throughout the many developments made in the yard and the machinery.

The Tremont mills were one step ahead of the Suffolk as well in changing over from the breast wheel to the turbine. The Suffolk continued to operate with at least some breast wheels for several years after the turbines became available. The Tremont switched over immediately with the completion of the new wheelhouse. The Suffolk was skeptical as to the overall performance of the newly introduced turbine when they determined that the first one they installed didn’t operate up to expectations. It wasn’t until the mid 1850s that the change over from breast wheels to turbines would be completed at the Suffolk.

Even though the Tremont prepared for the installation of four turbines, and with wheelpits constructed for that amount of wheels, it appears from the records that only two were installed initially. In a Report to Directors of the Proprietors of the Lock and Canals under the title, Tremont Mills, dated 1853, the report states that “the water used at these Mills is all drawn through two turbine wheels”. Why only two turbines were installed at that time leaves something of a question after reading the rest of the report. “The Turbines are not sufficiently powerful, to drive all the machinery in the Tremont Mills at the desired speed.” Accompanying this written report was a list of the machinery that was down, “purposely stopped, in order to allow the remainder to run at speed.”

Now the above statement presents another conflict between the supposedly infallible records that the reader has no other choice except to rely on as gospel. As was said before, how many different sources can the historians rely on, and if those differ to extreme, then the researchers are not doing their job. The ultimate tellers are all writing about the one and same incident. In 1857 Henry Hall, in his 25 annual Reports as treasurer of the Tremont Mills, amongst other milestones, reported that “In 1852 the old wooden breast wheels were removed, and four turbines, which, with the Penstocks, are entirely of iron, were substituted.”

The Suffolk Mills delayed an immediate change over from breast wheels to turbines after a poor showing of the efficiency of the first turbine they installed. Yet the Tremont changed over completely. Why this sudden deviation from the past habits of the two mill complexes always following each others decisions as to time tables for buildings, procuring machinery, and even to identical product lines. If the installation of the first turbine didn’t perform at the Suffolk, why did the Tremont assume it would do a better job in their mills. The turbines supplied to both mills were identical machines. They were made from the same designs and patterns at the same time. So alike they were considered to be in their operation that the discharge of the water from one of the Tremont turbines was gauged by James Francis during testing for his future famous Lowell Hydraulic Experiments for the purpose of testing the efficiency of the wheel and the results were applied to all of the wheels in both complexes.

What do these conclusions expressed in the previous discussions tell us about the performance of the turbines supplied to the Suffolk and Tremont Mills? With all of the touting of the superior results at the Appleton Mills where the first turbine built by Boyden was tested, why weren’t the same results obtained at these other two mills. All were built from the design Boyden had developed. In Francis’ report to the Directors mentioned above, “The Suffolk and Tremont wheels were all made at the same time from the same designs and patterns and were considered identical, in all the parts affecting the discharge of water.” Something had to be different; there had to be some variation in the input to the
turbines to obtain results that were so erratic. These dates of the installations in the three mills are so close that it’s doubtful that even any improvements that Francis would make to Boyden’s design wouldn’t have had time to be implemented. Boyden’s first machine was accepted for testing at the Appleton Mills in 1844. The turbines at the Suffolk were installed over several years with all four planned turbines installed by 1856. The Tremont complex removed their breast wheels and replaced them with turbines and iron penstocks in 1852. The results at the Appleton were raved about. The Suffolk and the Tremont would prove to be less than acceptable. Why?

Very dry weather conditions resulting in low water in the river and the canals had been hinted at as an excuse for the poor performance of the Suffolk turbine but if that were so all of the wheels should have suffered the same fate.

No factual explanation that the researcher has come across has ever been offered in the historical records to explain the discrepancy in the performance of the turbines. The Appleton Mills were perfectly satisfied so they went their own way with the turbine installation. The Suffolk Mills held off before a complete change over until the mid 1850s. As mentioned before even for James B. Francis, the chief engineer for the PL&C, to conduct his famous Hydraulic Experiments on the Tremont Turbine, the machines wouldn’t carry the full load of the mill and much of the machinery was either stopped or running at reduced speed.⁹³

If the mill operators who were on top of the entire process, or Francis who was on top of them offered no explanation, how can we, 150 years later, contribute to solving the dilemma? Never at any time were RPMs mentioned as a constant for any wheel, just horsepower. And they were fairly simple machines. There was no fuel involved but water of which the amount that flowed through the runner on the turbine determined that. If it was agreed on that all of the wheels were identical that were installed in the Suffolk and Tremont Mills, then it makes sense that the only variable that could be deduced to vary the speed and power was the amount of fuel. And that translates into water.

The adjustment of the waterpower under the new rules of the available water initiated in 1852 [this after the added volume supplied by the completed Northern canal] was allotted and the figures published in the reported measurements of the Water Power Used by the Manufacturing Companies of Lowell There is a chart that accompanies the Report found inside the back cover titled Statement of the New Adjustment of the Water Power at Lowell, Based Upon the Measurement of 1852. It contains 12 columns that record every conceivable figure that could possibly be taken into account in the computations that would be presented to the PL&C by Francis and Baldwin. Every mill complex is represented and the figures vary with each complex as to amounts before and after the adjustments of 1853. For example the columns list Powers, before and after, number of shares held in the PL&C, balance paid to and received from the PL&C; this type of information was recorded for each Company in the columns.

The Tremont and Suffolk have their place on the list and when their figures are compared with each other, all are identical. All that is except under the column that recorded, “Maximum quantity of water used, by the measurements of 1853, in cubic feet per second.” The Suffolk is recorded as using 423.52 cfps while the Tremont used only 303.43 cfps, a difference of 120.09 cfps. Each Company was contracted for the same amount of Powers, 5 1/3. This allowed them to draw a certain quantity of water and to push it through their wheels. If the Tremont Mill didn’t make use of the amount of water allotted to them, how were the wheels going to provide the required power to the machinery.
Evidently the Suffolk and Tremont Mills were both underpowered from the beginning. Was this the reason the Suffolk was dissatisfied with the performance of the first turbine they installed and they stuck it out with the breast wheels until more waterpower became available after the new adjustment came into effect? Are they inferring that the breast wheel out performed the turbine or were the two wheels just compatible with the waterpower they were drawing? Was this also the reason when Francis conducted his experiments using the Tremont turbine that some of the machinery had to be left off-line because the turbine couldn’t carry the full load? The Tremont utilized much less water than the Suffolk as recorded in the chart. Why? Their operations were identical in every way and manner.

And why was the Appleton Manufacturing Company so enthused by the results of the tests done on the turbine they installed? They were contracted for almost the identical millpowers that the Suffolk and Tremont were, 5 1/2 and they drew almost the same quantity of cfps as the Suffolk at 441.33. Something is amiss.

What are we trying to prove here? Do we know? With the re-distribution of the added volume of water made possible by the completion of the Northern Canal, the PL&C was now able to legally increase the amounts that could be sold to the individual mills, something they were prevented from doing under the old agreements because of a fear amongst the mill owners that there wouldn’t be enough water to go around during times of drought, even to the point of restricting what new businesses could be built along the canal banks.

The topic on the waterpower we just left sort of got carried away before its time but it would have to be brought up somewhere along the line. To return to the underground raceways, there is every reason to believe that the headraces leaving the Western Canal at its junction with the Northern [text and photo above] are the original raceways. The description given in a 1979 archeological study of the site appears to support this conclusion very well.94

The unscrupulous person that prowled the yard of the Tremont Wheelhouse and took the risk to snap a few photos was a little reluctant to venture inside the decaying remnants of that building for safety’s sake [his] so any proof of the underground headrace entering the building is conjecture at this point and relies on secondhand information. Some of the underground channels on the site have been filled in and the threatened development of the wheelhouse site is sure to expedite the destruction of any underground archeological remains that exist.

The forebay and the wheel pits under the Wheelhouse are deemed in the same archeological study to be the original although its commented on that maybe they have been dug a little deeper.

The accompanying sketch showing the original 1847 layout of the raceways and turbines is reproduced below. It is simple and straightforward. The Northern Canal is marked and shown bisecting with the Western Canal. The Tremont Gatehouse controls the water in the Western Wasteway leaving toward the top right the three headraces indicated with dotted lines, leave the Western Canal to the right and feed the forebay and ultimately the four turbines. The water drops 13 feet at this point as it flows through the turbines. This action is what creates the mechanical energy that is the output of the revolving turbine blades and is transferred through gearing and shafts, and at a later date, shafts, pulleys and belting. To transmit this motive power from mill building to mill building, it was common to construct the buildings in a line so the shafting could be continuous95. There are many examples of this method of power transmission between mill buildings, one of the most elaborate we have come across to date being the layout of the Massachusetts Mills. The first mill building in order in this sketch is represented by the rectangular protrusion abutting the wheelhouse at the top.
Peabody Museum’s final report on Tremont Yard.

The four dotted lines forming a right angle as they leave the wheelhouse to the far right indicate the twin tailraces that travel north toward the river for 900 feet before each splits in two as they reach opposite the Hall Street Dam. At this point one section of raceway from each tailrace empties into the basin formed at the end of the Tremont Wasteway just below the Hall Street Dam.
The remaining sections of the two tailraces emptied into the Lawrence Canal, of which this portion is now buried in a landfill along side the Tsongas Arena.

The saga of the Tremont Mills and the part it has played in water usage in the Lower Western Canal has ended. The waters that were ejected from the tailraces of the Tremont have reached the Lawrence Canal and will now be used a second time to fuel the wheels of the Lawrence Mills.
It is a continued oddity that the name of neither Amos nor Abbott Lawrence appears on the incorporation papers. They are credited with being the movers behind the development of all three complexes in the Western group, the Suffolk, the Tremont and the Lawrence sites and yet only the Tremont bears their names on the incorporation papers. Several investors appear as at least part owners of all three manufactories but this it not uncommon or unique among these businessmen.

The Lawrence is different from the Suffolk and the Tremont Mills in design and layout. In fact it is completely different from every other mill complex in the entire canal system. It is also probably the only one not directly effected, or at least to a lesser degree, by the water flow from the Northern Canal when it was completed. Prior to this major and much herald opening, the water supply for the Lawrence simply poured down the Western Canal, all the way down the Western when it was one continuous waterway for there was no Tremont Gatehouse to impede the flow and flooded the Lawrence Canal. After the completion of the Northern Canal and the gatehouse, the Lawrence Mills would rely on the secondary runoff from the tailraces of the Suffolk and the Tremont Mills for their water supply.

The Western Canal was to mimic the Pawtucket Canal in the fact it was constructed on two levels. In both cases a dam at the approximate mid-point in the canals established the fall in the water level that would differentiate the Upper from the Lower Canal by 13 feet. This drop in the water level is
also what developed the head that provided the motive power to the mills on the Upper Levels of the two canals.

The Western Canal achieved this drop in the water level at the Hickey-Hall Dam built along side Suffolk Street at the intersection with Hall Street. From that point the water flowed into the Lawrence Canal which bisected the Western Canal before reaching the Lawrence Dam that straddled the Lower Western Canal. It was at this dam location that the falling water developed the final 17 foot drop and generates the head that would power the machinery of the Lawrence Mills before emptying into the Merrimack River.

Pages of text can be written on the simple process of generating the motive power for the Lawrence Mills as described above but the two photos below of the Lawrence Dam as it was and as it is tell the whole story.

This is the Lawrence Dam as it appeared in 1914 when it was performing as a working dam. Following a common practice the gatehouse built on the top housed the mechanisms to lift or lower the gates and operate the spillway.

PL&C Collection
Center for Lowell History

Today the dam is a mere shell of itself with its glory days left long behind. The wasteway is empty with the only water backing up from the Merrimack River in the background.

Photo by Author
But something is amiss here with the dates offered in other records detailing the building of the Lawrence Mills. In the Directors Minute, March 14, 1833 is an entry that the PL&C will sell as much extra water that the Lawrence wants as long as it doesn’t exceed that is purchased by the Suffolk and Tremont. On September 20, 1834 a proposal is voted on and approved to build an additional nine mills on the Lower Canal and a canal to feed them. If this is the Lawrence Canal that is referred to, and the timing and the usage mentioned would deem it the only possibility, by what method did the Lawrence funnel waterpower to the mills prior to that date? According to the Research Report on the Lawrence Mills found in the Cultural Resources Inventory, production of the first two mills at the Lawrence had begun by May, 1833, 15 months before the canal to supply the water power was even reported to have been started.

Whether the Suffolk or Tremont had their gates open or not appear of no concern. Yet it is constantly stipulated that the very lifeblood of the machines in the Lawrence Mills depended on the ejection of water from the tailraces of the Tremont and Suffolk Mills. The only obstacle to the unimpeded flow of water in the Western Canal was the Hall Street Dam. Its primary object was to provide the 13 foot drop and develop the head of the flow in the Western Canal. After the construction of the Tremont Gatehouse, this dam had no gates, just a spillway. This dam was not designed like the dams at the Upper and Lower Locks on the Pawtucket Canal with a daily function of regulating water flow besides creating the drop in the head of 13 feet. It simply sat there, 13 feet above the continuing water flow in the canal and created a small basin behind itself, probably with a secondary purpose of storing the water for the operation of the two chambered locks that at one time was built along the left hand side of the dam looking downstream to give access to vessels locking through to service the Lawrence Mill yard.

After completion of the Northern Canal and the Tremont gatehouse, the dam was rendered obsolete and the locks removed. Only the remains of what once was the sluice gate still stands as a monument to the large part this small structure played in the Lowell textile empire that now also ceases to exist.

It was after the Tremont Gatehouse was built at the completion of the Northern Canal in 1848 that some interruption in the volume of water necessary for the Lawrence Mills could have hindered operations at the Lawrence. Now if the gates at the Tremont Dam were closed to the canal waters, and the Lawrence had to rely on the output from the tailraces of the Suffolk and Tremont Mills only, big problems could occur. Number one, both complexes running together wide open couldn’t supply the volume that the Lawrence required to operate their spindles at full efficiency; at least not without resorting to the use of Surplus water. The gates at the Tremont Dam would have to be opened, just like in the old days.

Keep in mind that after the completion and the building of the Northern Canal and of the Tremont Dam and Gatehouse, the Lawrence complex was suppose to operate entirely on secondary waters from the Suffolk and Tremont. The chart on the New Adjustment of the Water Power in Lowell that Francis compiled and reported on to the PL&C in 1852 describing water usage to the corporation’s exemptions concerning the amounts of water the Tremont and Suffolk were able to draw on over their allotted quantities. After stipulating contracted limits of all manufactories, the Report to the PL&C, Statement of the New Adjustment of the Water Power at Lowell went on with exclusion the case of the Western Group. “Excepting for the Suffolk Manufacturing Company and the Tremont Mills, who, by the consent of all parties, are entitled to divide equally between them, the quantity of water to which the Lawrence Manufacturing Company is entitled.” Its a cut and dry declaration stating that irregardless
of what the Suffolk and Tremont contracted for between them they were allowed to draw and extra $4^{9/30}$ mill power from the canal to satisfy the exclusion in the report to the PL&C.

The simplistic schematic shown on page 95 has a sub-note that notes that the waterway of the Tremont Wasteway is normally dry (between the Tremont and Hall Street Dams according to the indications on the sketch), presumably in normal, everyday operating conditions. This condition definitely indicates to the reader that the only source of water to the Lawrence Mills be provided through the tailraces of the Suffolk and Tremont Mills.

So here is one condition that existed for the Lawrence that no other manufactory in the system had to deal with. The fact that its mill buildings were located on both sides of the Western Canal didn’t make distributing the motive power exactly an easy task either. The Lawrence Canal had to be kept full at all time to even begin to furnish the mill powers they had contracted for and all references to the fact that the so called Tremont Wasteway was normally dry or that the Suffolk and Tremont raceways could handle the volume required by the Lawrence has to be treated as a historical distortion of plain fact.

Before we go any further lets bring this last statement to a head. Combined, after the new adjustments of 1852, the Suffolk and Tremont mills together had contracted for about 13 millpowers. The Lawrence mills contracted for 17 $9/30$. Only two other complexes needed more power than the Lawrence, the Merrimack and the Massachusetts with the Boott in a tie. The exclusion agreed on in the Directors Report quoted above was meant to correct this discrepancy of $4^{9/30}$ mill power. This added amount of water that the Suffolk and Tremont were being allotted in order to satisfy the demands of the Lawrence Mills could only be acquired by the use of surplus water that supposedly was available only during high water periods experienced by the level of the Merrimack River. What was to happen when water was low or all of the mills were drawing their maximum allowable limits?

Granted that after the completion of the Northern Canal there was no shortage of water in the Western Canal. But if both the Suffolk and Tremont were down for some reason, or even one of the complexes for any given reason, it seems the only alternative was to throw open the gates of the Tremont Dam and flood the wasteway. Now the question arises would, could a waterway with the dimensions of the Tremont Wasteway provide the necessary increased volume that the Lawrence Mills now drew under the adjusted allowances of 1852, to operate the machinery or would some have to be shut down or run at reduced speed. And how much of a barrier to the increased flow would the Hall Street Dam be?

In the official Reports on the Water-Power of the United States, 1880, the dimensions of the canal were given as “8 feet deep and 30 to 80 feet wide.” The 80 feet was actually only possible at the site of the Hickey-Hall Dam. The canal now measures, and appears after extensive rebuilding itself, only about six to eight feet deep and 24 feet wide from below the gatehouse to the dam, reducing possible volume it can carry even more and is renamed the Tremont Wasteway. And the Lower Merrimack River Inventory describing the dam states that in 1845 the dam was rebuilt in the present step configuration but not so to as accommodate the new upper level of the canal. Also “in 1868 the dam was cut down two feet in order to increase the supply of water directly into the Lawrence canal when the Tremont and Suffolk Mills were not in full operation.”

It is evident from these statements that our questions were not presumptuous.
Below is an indentured copy of the drawing of the Lawrence Manufacturing Company, circa 1831.

A brief explanation of the highlights of the drawing is in order to clarify mill layout and make the details easier to follow as it is referred to. This is the proposed site layout that accompanied the Deed.

The dotted lines feeding into the Lawrence Canal from above represent the tailraces from the Suffolk Mills to the right and the Tremont to the left. The dotted lines leaving the Lawrence Canal from the bottom represent the headraces feeding the individual mill buildings. Those leaving the mill buildings are the tailraces from the wheelpits and enter the Merrimack River.

The Lawrence Mill buildings to the left of the Western Canal are located in the secondary mill yard. Those buildings on the right are in the main yard.

Arrow #1 identifies the Western Canal.
Arrow #2 identifies the Hickey-Hall Dam. It is from this point that the water drops 13 feet to create the head at the Suffolk and Tremont Mills.
Arrow #3 is the Lawrence Canal which is fed from the Western in both directions and supplies water to the mills in both yards.
Arrow #4 identifies the Lawrence Dam. Here the water drops 17 feet to create the head for the Lawrence Mills before returning to the River.
After the reader has examined the raceways shown in the sketch on page 120, just keep in mind that this was the original indenture that accompanied the deed. The Lawrence Mill yard developed so rapidly that no matter what representation of the site one relied on as the ultimate of the site development, the layout of the buildings and thus the underground feeders were probably re-arranged by the next photo or sketch observed. And not so much that the development of the yard was constantly being improved as simply the constant adding of buildings as the manufactory expanded to five mills and the dye houses.

In the attempted to photograph the mill yard for his 1884 publication, Lowell Illustrated, Frank Hill resigned his efforts to failure. “We have not been able to present so good a view of this corporation as was hoped for owing to the crowded condition of the yard. Every available spot is so covered with buildings as to make it almost impossible to get a good general view from the inside.”

But the Lawrence Company maintained easy access to its water supply through the Lawrence Canal running parallel to the entire site. They didn’t have to dig under, around or between buildings to service a new building, and risk weakening or otherwise damaging the structures. The canal could be tapped anywhere along it length to feed waterpower to a new mill.

A little history provides the story of the Lawrence brothers, Amos and Abbott and their foray into the textile empire they were to launch. A twenty dollar loan and a rented store front filled with consigned goods in Boston provided the building bricks. Raw ambition, vision and courage the mortar. And Lowell would provide the catalyst. Hard financial times caused by a depression in 1829 effected the textile manufactories also and hit the Merrimack Manufacturing Company as well as the rest. Abbott Lawrence was able to deal to obtain excellent terms for the 20 acres and six mill powers. Not bad when one considers that the Western Canal wasn’t even built yet.

The canal had been begun in 1828 but when the financial picture soured, so did any potential investors and the digging was “slowed or halted.” This lapse in the construction may well be what resulted in the peculiar jug handle that ended up in middle of the canal’s course. It’s as if when the digging resumed it dawned on someone in command that the present tract of the canal would bisect with the middle of the Merrimack Mill Yard. Probably rather that start all over at the Swamp Locks and forfeit the money, time and energy all ready spent in the digging, a slight offset was decided on in the course of the canal. This is quite evident in any view of the canal on either maps or drawings such as on page 96 for example.

The Lawrence Manufacturing Company would expand rapidly once progress began to be made. The original plan called for four buildings to be built and equipped by the PL&C and they had contracted for 20 acres and six mill power as the base for the complex. Even the dates of record seem to follow the turmoil that appears to have preceded the first loom to begin spinning the golden thread. And of course the advancement of the progress of the Lawrence Mills had to proceed in lock step with that of the Suffolk and Tremont as well. All three were incorporated in 1831. From that date on at least the Lawrence progressed more or less on it’s own. They all had some of the same investors and Henry Hall was the treasurer for all three at one time or another starting in 1832.

The Lawrence Manufacturing Company was chartered by the Massachusetts General Court on June 7, 1831, for the purpose of manufacturing cotton and woolen goods in the town of Lowell. Thus its birth was assured even if the goals of the company were to vary and change over the period of time that it was in existence. This date can’t be disputed even if some of the later or even earlier do tend to leave a question mark.
The Western Canal was completed in 1832, jug handle and all. Apparently Abbott Lawrence was not one to sit around waiting for something to happen because of other people's actions. The minutes of the PL&C Directors meeting of April 30, 1831 records that he applied to the PL&C for land and water power for 20,000 spindles and for a print and bleach works. Along with the plans for the enterprise went a request that read in part – “That sufficient land for the above works being something more than 700,000 ft. may be furnished on the lower level of the Western canal & that it is expedient to offer him five millpowers.” Not a bad request of a man who was a tenant haberdasher only a few years before.

The story of the development of the Lawrence Mills is told in several writings, some of which agree and some of which vary in the slightest mode. There are only so many sources no matter how many times the story is told, and that comes down to one. There is correspondence available between the interested parties, the investors, the directors and others involved that chronicle all of the decisions made at the time that determined the direction of the company. It is interesting to follow but our primary interest is in the underground raceways and the power they delivered to the mills so we will simply skirt the heavy stuff and follow the early development in the records of the Directors minutes.

July 31, 1830   Here is an accounting entry over the name of Kirk Boott, Treasurer mentioning moneys expended for “Western Canal and Mill Sites of $32,800.40.” For whatever reason, the purpose isn’t given and it’s immaterial. It’s the mentioning that is. This date is long before the Western Canal was operating but the wheels of progress was already turning.

July 31, 1831.   Another expenditure appears on work at the Western canal for the sum of $16,756.36. July 31 must represent the end of the fiscal year or whatever term that was used back then to organize and report the yearly expenditures for whatever governing body.

July 31, 1832. The sum of $63,000 appears in this financial ledger sheet but apparently under the receiving column as in receiving a payment. This is followed by a report one year later on August 1, 1833 with another entry in the “BY” column for the sum of $218,213.98.

But at about this time something must have gone wrong with the finances of the Boston investors, or at least to the point that it made them hesitate in their grand plans for the Lawrence Company’s mill site. As recorded in the minutes of the Directors meeting of December 28, 1832, the PL&C was approached by the treasurer of the Lawrence Company with a request to suspend all operations pertaining to the construction and equipping of number three and four mills. There was some controversy between the PL&C and the company as both mills had been started and had various degrees of the construction work already finished.

At any rate, the work on the mills must have progressed without a great deal of interruption. On March 14, 1833 an inquiry was received by the PL&C from the treasurer of the Lawrence Manufacturing Company as to the feasibility of the PL&C to “contract to furnish the Lawrence Manufacturing Company as much water as they require for four mills and a bleachery.”

There is something disputable between the historical facts as presented between the so call recorded data by different authors and their sources. From the above entries recorded in the Minutes of the PL&C Directors we can be fairly certain of the source of the information as it is as first person as can be imagined.

Perhaps a step by step chronological sequence of events involved in the establishing, that is in the actual development of the Lawrence Manufacturing Company as recorded by the body governing the
construction of the buildings and providing the machinery, the PL&C, will help clear the haze from the jumble of supposed dates that appear in other writings.

Directors Minutes

1831, April. Prior to this date Lawrence approached the PL&C with his plans.

On the above date, the PL&C granted Lawrence his request for land and power on the Lower Western Canal.

June, 1831, the Lawrence Manufacturing Company received its Charter.

1832, December. The Lawrence Company requested that the PL&C cease all work on buildings number three and four at the mill yard.

At this same Meeting it was voted to complete mill buildings number one and two and fill both with machinery.

1833, March. Discussions by the Directors concerning water usage appear to establish that all four mills were up and running along with the Bleachery.

1834, November. It appears that the four mills mentioned above are running as these discussions are all about water power for those mills. The record does not mention in addition to the existing mills or any other phrasing that would lead us to believe that they are not the original mill buildings with the request for nine other mills sometime in the future.

1835, March 16. Abbott Lawrence requests the PL&C increase the allotted amount of millpowers available for the Lawrence Mills by one for a total of nine.

As the yard expands through development, more mill buildings are added and so is the volume of water needed to power the machinery. By the time the new adjustments are made in 1852 allowing all of the manufactories to increase the water usage, the Lawrence mills are drawing 14 1/2 millpowers. Under the new adjustments, the Lawrence will increase that total to 17 9/30.

Only the Merrimack and Massachusetts Mills drew more millpower from the overburdened canal system than the Lawrence. The Merrimack also had its own secondary canal known as the Inner Canal as the Lawrence did to feed the many mills in its yard. It also had its own feeder canal [tapped only by the Lowell Mills] known as the Merrimack Canal naturally and the advantage of a 30 foot head. The Massachusetts Mills took advantage of a complex internal shafting system to feed power to its many mills and maintain its position as the second largest complex in the system. In their heyday, they both utilized waterpower from the canals to operate the machinery. But little by little as improvements were made in the motive systems, steam began to make inroads but that was at a later date.
A more detailed layout of the underground as it existed after the Lawrence Mill yard was fully developed has not been located in the research. The profusion of buildings that existed at this later date is shown in the presentation below would probably place a strain any underground raceway system if each were supplied separately but what was the alternative. Mechanical shafting between the buildings as at the Massachusetts yard could have been the answer and that would justify why no up to date underground layout has surfaced.

The following is a condensed description culled from an article prepared by David Redding of the Lowell National Historic Park in 1983, titled the Lawrence Powerhouse and the Big Pulley Wheel. It is an excellent job of presenting the operation of the motive power of the Lawrence Mills as it was first proposed; clear, concise, and certainly grasping the very few particulars necessary to propel the mill machinery with the least amount of text and sketches. The accompanying sketch following the text tells the rest.

“When the four original mills of the Lawrence Manufacturing Company were built, they followed the typical pattern of design and set up of the other Lowell Mills. Each mill was supplied water by feeders ['underground'-authors note] running to the center of each mill basement. There the water fell 17 feet over the floats of breast wheels, 17 feet in diameter and about 20 feet in length, three breast wheels per mill. The name breast wheel refers to the iron breast or apron used to hold the water in place against the water wheel as the water wheel turns adding to the efficiency of the wheel.”
Below is basically an abridged copy of the sketch on page 120 that was included with the above text. It effectively eliminates ninety percent of the clutter and offers only the four original mills with their underground races.

Proprietors of the Locks and Canal - 1833

This sketch is a representation of the basic waterwheel that was contained in the basement of every cotton mill and supplied the motive power to the machinery that ran the looms.

Both of these Illustrations from David Redding’s “The Lawrence Powerhouse”

This sketch of a pitchback wheel was the type most commonly used in mills. Water enters high on the wheel at ‘A’, is held in the buckets of wheel by the apron [breast] ‘B’ and discharged at the bottom. ‘C’.

The Lawrence Manufacturing Company was one manufactory that kept up with any new development adopted by any other mill to enhance production. The first Boyden turbine was tested at the Appleton Mills in 1844 and by the mid-1850s the Lawrence was digging new raceways and
wheelpits to take advantage of the reports of success of the trials. The turbine was to prove of less size, could produce more horsepower and was able operate underwater so it was much less vulnerable to the old nemesis of the waterwheel, backwater.

Below is a sketch of the underground raceway system constructed, to service and to house the newly introduced turbines at the Lawrence Mills. Once again, the simplicity of the design and layout are evident as adverse to the complicated mess that would be produced by today’s engineering.

![Diagram of the underground raceway system](image1)

Lawrence Powerhouse by David Redding

This is a sketch of a Francis designed Boyden turbine that was probably chosen to operate the machinery from those newly constructed wheelpits. He was the chief engineer at the PL&C and supervised the testing to the turbine at the Appleton Mills.

![Sketch of a Francis designed Boyden turbine](image2)

Lowell Hydraulic Experiments
This photo taken in 1908 is typical of any wheelpit. The workers are in the process of removing a casing of an old turbine to be replaced. They are standing in one of the raceways.

All that remains now in the story of the hydraulic motive power that powered the textile empire of Lowell is to return the water to the Merrimack River from whence it originated. Regardless of what product the mills were producing, nothing was to interfere with the waterpower flowing through the underground raceways to provide the mill power for the insatiable thirst of the machinery.
Two massive stacks stand in testimony in the mostly demolished mill yard today, testifying to the eventual dependency of the motive power on steam engines. But long before the happening of this event, and for a good time after the introduction of steam power, waterpower was the prime mover. Waterpower had the advantage that it was simpler to operate and much cheaper fuel-wise. The drawback was the erratic functioning of the wheel or turbine, the power chain from the river through the feeder canal to the tailrace to operate the machinery, due to the low supply of water in the dry seasons that vastly effected the production of the manufactories. But this narrative is on waterpower not steam engines, and whether wheels or turbines, the end result was identical and the looms turned.
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List of Photographs/Illustrations

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   Sponsored by – Merrimack Valley Textile Museum.
   National Park Service.
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11. Top   Lowell National Historic Park Museum Collection
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15. Top   From the author’s Photo Journal of the Lowell Canal System.
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30. from Working the Water – Life and Labor on Lowell Canals pp. 11
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31. Slight modification of drawing 7, Drawer 153 of the PL&C.

32. By author.

33. Top – by author.
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40. Top   Taken inside Tremont Mill site [now parking lot]

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41. Both photos from Author's collection.
42. Proprietors Locks and Canals  Shelf 165  Drawer 32.
43. From Water Power in Lowell Massachusetts by Pat Malone.
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49. Section, “Pawtucket & Northern Lock Structure  Illustration #110 pp.263
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62. Top left: photo by author
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63. Prescott Mill Headraces from the Eastern canal by author
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65. Will be photos of Prescott mills tailraces emptying into Concord River
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68. Top -Tailraces of Massachusetts Mills entering the Concord River by author
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81. Top - Taken from Vehicle Bridge over Eastern Canal. From collection.
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82. View from Amory Street. From collection.
83. All three photographs taken by author.
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85. Boott Cotton Mills: Field work and measured drawings / HAER. 1983
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90. Sketch showing buildings of the Tremont and Suffolk Mills. Circa 1926
92. From Peabody Museum of Archaeology Figure 6D No page number
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95. From Center for Lowell History
96. Top From “Canals and Industry” by Pat Malone No page.
100. Top Surveyed 8/26/1915 Factory Insurance Assoc.
    Bottom www.museum.nps.gov/ LOWE 7231 Lawrence Mills
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    Illustration 4 This print should have been dated 1832
104. Entrance to Suffolk Mill turbines in the National Park exhibition. History of Industrial Power
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108. Indenture drawing for the Tremont Mills, July 1, 1832, PL&C
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110. Top -taken from where old Tremont St. intersects with Morrissett Blvd.
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