Hidden Waterways of the Lowell Canal System
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Al Lorenzo

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By now we have reached six years of research and writing in an effort to bring the history of the Lowell Canal system to interested readers. This is the fourth book and it promises to be the most difficult because no one actually addressed this aspect of the system fully in print to date, at least that has been uncovered.

Photographs and illustrations will be scarce for the simple reason there are not many in the files. The Proprietors of the Locks and Canals on Merrimack River (from here on PL&C) kept records of much of their own work for the Company and many photographs when the camera became available, When James B. Francis became the head engineer for the PL&C in 1837, his daily work books make many mentions of work done for the mill corporations under the blanket of the PL&C.

The fact is the PL&C built many of the mills and produced the mill machinery in their machine shops and records of the work appear in those workbooks as in earlier records from newspapers and other sources. So does mention of construction of the wheelpits that contained the water wheels and turbines. Of the waterways that made it all work? It seems they were treated as a sideline. Within the research, enough text and sketches can be provided to give some substance to the story to create an interest and provide a background of history for the reader. It is quite possible this small volume will perk up the reader’s interest enough so they’ll want to see what they missed in the other three books. It takes them all to complete the story and well worth reading.

This work was made possible by the generous efforts of several people who were of the greatest help in putting the finished product together. The order of the listings takes away nothing for my appreciation to all.

The National Park Library was a prime source for much of the research material and Jack Herlihy did his best to help out. Dan Walsh was more than willing and able to contribute his expertise and he did to his utmost.

The Center for Lowell History, UML, as usual was a great source of information and Martha Mayo is an exceptional editor. The support of Janet Pohl is one of the main reasons why the finish work exists.

Bud Paquin was instrumental in producing the finished product that you are reading and his workmanship added greatly to the author’s endeavors, and in fact made it possible.

Thank you all.
Chapter One

Introduction to the Subterranean

The entire Lowell Canal System is certainly an object of beauty when full to the brim and the waters serenely flowing between granite stone banks on its journey from the Merrimack River through the canals and returning to the river when its job was done. This observation by any viewer would send him on his way perfectly content that he had experienced all that there was to experience. He had come; seen and understood all there was to understand.

In reality he was as the blind men describing the elephant they had touched or the person who appreciates the classical lines of the cruise ship from the beach as it steams by in the distance. Neither has any real comprehension of what they are feeling or looking at except for the picture their senses are providing. The blind men come away with impressions of the trunk, ears, belly, tail, etc. and are satisfied that each knows the true shape. The observer from the beach is satisfied with the beauty of the ship’s form sailing majestically on the sea, never giving a thought to the enormous engines in its bowel that propel it and turn the electric generators that supply the power to every commodity needed for the good life aboard.

Likewise, the water viewed in the canals in all its serenity is deceptive. The pleasant view of its calm surface a contradiction. The power contained between these walls of the canal banks is unbelievable to all except those who were exposed to the results of the work done day after day without letup at the mill complexes that tapped this power to run the cotton looms inside.

Even if the reader has toured and examined the entire five and one half miles of canals that comprise the Lowell Canal System, at least another several thousand feet of waterways exist underground and out of sight. These can be designated as penstocks, raceways, head and tail races, and at least in one instance as a feeder and all will be more fully described as they are introduced in the text. Except for the feeder, all serve the same purposes, supplying water to the wheelpits from the canals or providing a path from the wheelpits for the water to return to the canal system to be reused, or to the Merrimack and Concord Rivers. As the reader will in no way understand any of what he reads without at least some idea what the terms above are describing, a short description will be given here.

Feeder is referring to a waterway of a design to move a large amount of water from point ‘A’ where it is to point ‘B’ where it is needed. There is only one discussed here and that is the Moody Street Feeder that runs from the Western Canal to the Merrimack.

Penstock parallels the feeder in operation but on a smaller scale as far as volume and usually supplies water to a specific destination.

Flume is a channel usually inclined somewhat to carry water for power.

Wheelpit is the underground chamber constructed for the exclusive purpose of containing the water wheel or turbine on its mounts.

Raceway is usually the term applied to any waterway involved in the supply or exit chain of the water without a specific purpose designated.
Headrace is the term given to the channel designed to supply the wheel or turbine with waterpower.

Tailrace provides an exit path to remove the water from the wheelpit.

Forebay is simply an enlarged area in the channel where the water could collect before entering the wheelpit.

Millpower (sometimes referred to as mill privilege) is the measurement of the waterpower that the individual mill complexes purchased from the PL&C.

Backwater is the term used to describe high water in the tailraces that impeded the operation of the waterwheel by flooding the wheel pit.

It is doubtful if this book would be of any interest unless some knowledge of the canal system and its operation were experienced by the reader. It could be said that it would be like starting in the middle but this is what the system is all about. Providing the waterpower to the mills and the looms. It is the only reason that the power canals were built in the first place. And hopefully this book will provide if not a working knowledge of the operation, at least a fairly comprehensive overlay of these waterways that furnished the waterpower that was the lifeblood of the industrial empire called Lowell.

For the sake of understanding, best we start at the beginning in case this is the reader’s first foray into the world of working canals. Presumably the reader has at least viewed a canal somewhere along the line but let’s start with a layout of the canal system and the mill complexes that they feed waterpower with this map.
The Role of the PL&C and the Corporations

It was the obligation of the owners of the canals, the Proprietors of the Locks and Canals on Merrimack River (from hereon the PL&C), to supply the necessary waterpower in the canal system and to keep the canals free of any debris that would impede the mill operations.\(^1\) Moving the water from the canals and into the mills was the responsibility of the individual mill corporations but these waterways were usually built and maintained by the PL&C under contract as well. The corporations didn’t have the expertise and the waterways would still have to be built to specifications drawn up by the PL&C to maintain continuous integrity of the system. The work force and material already existed at the beck and call of the PL&C so why look any further.

The PL&C also wrote the rules and regulations for the construction and operation of these underground raceways. Where they left the canal proper, a set of gates had to be installed and maintained at the top of the headrace in order to control the volume (millpowers) and to enable PL&C to shut off the flow of water for necessary repairs.\(^2\) They even maintained the right to be able to hold back the flow by shutting these gates if for any reason the corporation fell into arrears. It was fairly difficult to measure the amount of water flowing into any single headrace but the PL&C retained the right to measure the volume as it exited the tailrace after leaving the wheelpit. Only so much water was contracted for and it was only good business practice to check what each corporation’s actual use was.

Usage probably balanced out pretty well in the long run. At times of low water in the river, the mills always complained about the decreased amounts of water flowing through the wheels or turbines, and thus the mills were running slow so they would open the head gates all the way to feed maximum water into the headraces. They only paid for the mill powers contracted. When the river was running high, it was pay back time and if the PL&C didn’t have some control on usage, they might just as well been giving the millpowers away.

The entire story of the Lowell Canal System is told in the second book in this series, *The Canals That Powered a Textile Empire*. To rewrite the entire book here would serve no purpose but it should be read in conjunction with this book. The tale of what the corporations had a right to expect in the way of a water supply from the PL&C deserves retelling before we continue.

The head of the water in the upper Pawtucket Canal, and later the Northern Canal too, was supposed to be maintained at 30 feet. If the Merrimack River was higher, the height in the canals was supposed to be controlled by the various gates at the dams at the Swamp Locks, Lower Locks and the Hickey Hall Dam on the Western Canal. The entire canal system was designed with these levels serving as the gospel and the water wheels in each mill were constructed to run the most efficient at these levels of water. Too little head and the looms ran at slower speeds limiting production. Too much head and the wheelpits would flood through the tailraces because the water used in the wheelpits couldn’t discharge back into a lower level achieving the same disastrous results. When turbines were introduced in the late 1840, the machines proved much more tolerant to fluctuations in the water levels and especially the backwater in the wheelpits.

Remember that the Pawtucket and Western Canals that were the feeder canals for the Western and Eastern Groups of mill complexes were constructed on two different levels to achieve the drop in the water level, and thus the difference in the head that developed the waterpower. The drop in the upper level was 13 feet and the drop in the lower was 17 feet accounting for the full 30 foot drop. If the
reader is confused because this book alone was read or read first it is understandable. But read on and give the big picture a chance to expand.

Consulting the map on page eight and following the description of the individual mill complexes and their location on the canals in the system will greatly help to define the difference between Upper and Lower Canals and the purpose of the drop in the head (water level) as it passes over the falls.

The Eastern Group is comprised of the Appleton and Hamilton Mills on the Upper level of the Pawtucket Canal, and the Middlesex, Prescott, Massachusetts and Boott Mills being fed from the Eastern Canal on the lower level. The water fell 13 feet over the Swamp Locks Dam (also called upper or middle) and so created a difference of 13 feet in the head or water level between the Hamilton Canal which fed the Appleton and Hamilton mills and the Lower Pawtucket that received the discharge from the two mill’s wheelpits. This difference in the falling water levels is what turned the water wheels or turbines.

The lower level mill complexes utilized the 17 foot difference in the levels between the Eastern Canal and the Merrimack and Concord Rivers to create the power to turn those wheels, the canal waters falling from the canal and through the wheelpits into either of the two rivers. This example holds just as true for the Western Group fed from the Western Canal, the Suffolk and Tremont Mills comprising the upper level and the Lawrence Mills the lower. The Lawrence Mills are actually fed from the Lawrence Canal which is no more that a raceway into which the waters from the lower Western Canal flowed.

The Merrimack Mills were left to constitute their own group fed from the Merrimack Canal. The canal waters were supplied directly from the Upper Pawtucket. It was the only mill complex that used the entire canal head of 30 feet in its operation. It was fed from the Upper Pawtucket Canal and its wheelpits emptied directly into the Merrimack River. But along the route of the Merrimack Canal, the Lowell Canal branched off to feed the Lowell Manufacturing Company. This secondary canal traveled 500 feet and dropped 13 feet into the Lower Pawtucket to turn that company’s water wheel in its cotton mill.

A fair question to arise right about here is the apparent inequity in the amount of power being dealt out to the various mills. Certainly the 30 foot drop in head is going to provide more power that the 17 or 13 foot drop. All the mills purchased the same mill powers so how was this discrepancy corrected. The best explanation is probably to quote the formula for mill powers from the Form of Lease of Water Power at Lowell. This was the contract between the PL&C and the Corporations and this was what the mills expected.

**Article 1** –“Each mill-power or privilege at the respective Falls (ed. note – Swamp Locks or Lower) is declared to be the right to draw from the nearest canal or water course of the said Proprietors so much water as, during fifteen hours in every day of twenty-four hours, shall give a power equal to twenty-five cubic feet per second at the Great Fall (Pawtucket Falls), when the head and fall there is thirty feet”- (This is establishing the designed water height of 30 feet) It goes on, “-to forty-five and a half cubic feet per second at the Lower Fall, ( Lower Locks) when the head and fall there is seventeen feet – and to sixty and one half cubic feet per second at the Middle Fall (Swamp Locks) when the head and fall there is thirteen feet.” So what the PL&C is doing to make for the difference in the fall of the water in the upper and lower canal is to increase the volume passing through the respected falls. There is more to the quoted article but let’s leave well enough alone if this much can be understood.

If this is the reader’s first foray into the canal system, a canal full of water is just that, a lot of water. What’s the big deal? And even if there is an interest in the purpose of the building of the canal
system it would be hard to perceive any real features of the workings. Much easier to understand if viewed when the canals are drained of water. Seems self-defeating but the water blocks the view of the working parts. It does no good to describe in a text the underground raceways if no indication of their existence can be offered. For sure, they are all covered and some even buried during more recent developments but there are enough signs of their presence, and accompanied with photos, sketches and illustrations from past records, the ultimate goal of the building of the system can be appreciated.

Here is a prime example of the Hamilton Canal full of water. Not much can be seen except water. The scene belays tremendous Force of its power the water is Pouring through the headrace and into the wheelpits to turn the water wheels and turbines.

Lowell National Historical Park Collection

This is the same view from a later date that accounts for the slight variations. In the top photo you see water. In the scene on the left you see the racks covering the head-races to the waterwheels and turbines, what it’s all about.

Photo by Author
The Hidden Waterways

Describing the locations of the surface canals in Lowell is fairly easy. The photographs used to show them may have lost something over the years as many of the mill buildings that framed the photos of the canals were torn down. This took away much of the identification of the location of the canals to the present day viewer, and even some of the streets in the area had changed names but for the most part the streets were still there that showed in the old maps.

The underground waterways have been exposed to a different fate. In many cases there are no landmarks to associate with clearly to establish their one time location. There may be no remnants of their one time existence left at all. The entire past may be locked up in just a few lines drawn on an old illustration, or maybe only a sketch of their one time route indicated that explained all that had to be known back when. An interested party may be able to follow some of the few archways and openings in granite stone walls and reap a great reward in a history lesson.

So the goal here will be to compile what records are available in text, photos, maps and sketches to hi-light the footprints of the underground waterways. They were the tie between canals and canals; or canals and the mills and steered the lifeblood of the water power from where it was to where it had to be. Many of the sketches used to illustrate the paths that the raceways wove in their underground course will be pre-Northern and some after the construction of the Northern Canal (in the case of the Western Canal).

That leaves the question of where to start. And that presents more questions. The primary object is to inform the reader and perk his interest in the history of the canal system, what and how it achieved its goal serving transportation and then industry. The reading of this book probably should have followed the reading of the Canals that Powered a Textile Empire” as it is almost a supplement to it, but then again, any place the reader starts is the right place.

Here, we will start with a description of the largest and longest of the underground waterways, outline two that were planned and never built and then get into the raceways that serviced the individual mills. If the reader finds himself getting bored from lack of interest, a walk taken to view any of the openings that defined the raceways first hand, at least their existence might become a reality and not just described by text.

Another problem confronting the reader is not, really knowing what purpose the water power serves when it reaches its destination at the mill sight. So it turns water wheels and turbines. Can a mental picture actually be developed of this procedure if neither has ever been experienced by the reader? Most likely not. The only way to fully explain this motive action is to compile a separate book that will outline the series of developing steps from the gates at which point the penstock leaves the canal or at least from the forebay supplying the water to the wheelpit beginning at the water wheel and follow each step through the mill machinery.
Chapter Two

The Moody Street Feeder

The grand daddy of all the covered waterways, bar none, is the Moody Street Feeder shown as a dotted line in the center of the map on page eight. Approximately 1,400 feet in length and averaging 30 feet in width the depth of the feeder was given as approximately ten feet in the middle. It probably deserved to be cataloged as a canal but that’s not the title it was given at conception and who are we to second guess the builders.

The Moody Street Feeder originates from the eastern bank of Western Canal between Morrisette and Moody Streets. This location places it only a few hundred feet from where the Northern Canal enters the Western at the opposite bank. The goal of the feeder was to intercept the waters from the Northern Canal and funnel it into the raceways of the ever water hungry Merrimack Mills via the Merrimack Canal.

This is the entrance to the Moody Street Feeder leaving the Western Canal. It was constructed as three single parallel channels covered over by Moody Street for its entire length. The canal is somewhat drained down so the archways are clearly visible and the stonework can be readily appreciated.

Photo by Author

This photo show the Moody Street Feeder as it exits from under the street and enters the Merrimack Canal. The gatehouse on top served just that purpose. It housed the machinery that enabled the operator to control the water flow between the two canals.

Photo by Janet Pohl
The map on page eight does indicate the position of the Moody Street Feeder in relation to the other canals and mill complexes which was the object but why that name, simple, Moody Street was dug up and the feeder built in the excavation. On completion of the underground channel, it was backfilled and the street rebuilt. The map below will outline the location of the Moody Street Feeder in relation to the streets in the vicinity along with two other feeders proposed in 1855 and deemed necessary at the time but never built and all identified by the numbered arrows.

Reproduced from ‘Sundry Papers’ by James B. Francis, 1855

Arrow #1 identifies the Moody Street Feeder with the angled entrance from the Western Canal and the angled exit into the Merrimack Canal.

Arrow #2 indicates the proposed location of the never built Mechanic Street Feeder. It was designed to flood the Swamp Locks Basin with water from the new Northern Canal via the Western Canal.

Arrow #3 indicates the Merrimack Feeder that was to connect to the Inner Canal and distributed the water from the newly completed Northern canal to the Merrimack Manufacturing complex. This feeder was also never built.
The photograph on the bottom of page 15 depicts the exit of the Moody Street feeder into the Merrimack Canal. The gatehouse on top has been photographed and written about many times but for some reason the feeder is treated only to a mention if at all. Being buried it’s out of sight and certainly out of mind. The building of the feeder is often described as completed in 1848 along with the Northern Canal but an article from the newspaper, Lowell Courier seem to rebut that statement. The January 1, 1848 edition states “Materials are now in readiness for bringing the water in a subterranean aqueduct underneath Moody Street into the Merrimack Canal. This aqueduct will be completed next summer.”

No mention of any digging. Only the fact that preparations for the construction of the feeder were in place. Even though it’s only a single observation its hard to dispute an eye witness as to the exclusion of all others, especially if the ‘others’ are based on modern day interpretations of past records. But the Cultural Resources Inventory, a work commissioned to catalog the historic structures in the City of Lowell in 1979 states that “the feeder was build during the second year of the Northern Canal project.” It goes on to add “completed by 1848 and opened in 1849.”

Too many discrepancies have been found in some recent texts of the past history of the canal system and one seems to beget the next and soon it becomes documented as fact. It’s only a small singular mistake at first but add up enough inconsistencies and they tend to get to be big mistakes and its enough to distort the overall historical picture.

To continue on, at the PL&C Directors meeting of September 15, 1846, it was decided to enlarge the Western Canal and run a flume or watercourse from the New Canal (Northern) to the Merrimack Canal. This was to be the Moody Street Feeder. But for some reason it took until December, 1847 to obtain the necessary permits from the City of Lowell and April, 1848 to settle on a width of thirty feet with regulating gates at the eastern end of the feeder (Merrimack Canal end). These entries in the Directors Minutes seem to support the dates in the preceding paragraphs as to the construction and completion of the feeder regardless of the conclusions of any other sources.

In one way the Moody Street feeder was unique, different from any other in the fact that it was constructed entirely from brick excepting the granite archways that herald the beginning and end. The bottom was covered with wooden planking to reduce the friction of the water as some of the canals were.

The feeder was comprised of three separate aqueducts over the entire length. Each of the three channels had brick laid for the walls rising to an arched overhead and together supported the road. Quite possibly a single 30 foot span would have resulted in to much strain from the weight of the load above and so it was divided into three separate ten foot chambers. The aqueducts were constructed in a straight line from the Western to the Merrimack Canal under Moody Street. At the beginning as the channels left the Western they were angled at 45 degrees allow the rapidly flowing water to enter at a fairly smooth rate without backing it up into the canal because of friction. Again it was angled at 45 Degrees as it intersected with the Merrimack to avoid the turbulenc that would have been created by a head on collision with the two fast flowing currents. The Merrimack Canal was widened from where the feeder connected to the canal down to the Inner Canal, the wasteway and the Boott Penstock.

A drawing or photograph is worth a thousand words so let’s take a minute to examine the construction of the Moody Street feeder illustrated by what is believed to be two undated photos of the subterranean raceway. In any case the brick domed chambers and walls are unbelievable as are the fact that three of them over 1400 feet long each were excavated, built, backfilled and the street above them rebuilt in less than two years.
This view depicts the ten foot wide tunnel with five workers staring back. The bottom appears to be covered with debris and some sort of square bucket to remove it.

Both Photos from PL&C Collection  Center for Lowell History

Canal workers with their numbers stretching into the background. The brickwork in both photos stands out. The arched overhead is visible in all its grandeur.

Both pictures are quite evidently posed and these unnamed faces will always remain anonymous. The results of their work outlasted them by decades and will probably outlast us by at least the same amount of time if not much more.

What remains a mystery is the source of illumination. It actually appears to be reflecting off the walls in both photos. Being undated there’s no way of telling if electricity was available but in the lower picture there could be a gas fixture with a petcock to control it projecting from the lighted patch on the left wall.

With a little perception the wood planking can be made out on the canal bottom in the lower photograph.

The whole purpose of the feeder was to add to the water level of the Merrimack Canal. This would greatly alleviate the seasonal water shortage to the Merrimack Mill Complex but the secondary function of the waterway was to raise the level in the water starved Eastern Canal. A wasteway controlled by a dam ran from the end of the Merrimack Canal to the river and from this wasteway the Boott penstock was constructed to funnel water into the Eastern.
The Northern Canal ran directly from the Merrimack River to the Western Canal as is obvious from the drawing on page eight. This meant that the water had the same head as the river that was two feet higher than that from the Pawtucket Canal. The lower level of the water in the Pawtucket resulted because of the longer semi-circular course and the resulting loss in head because of the narrowness of the Pawtucket and the friction caused by the water flowing through the irregular shape of the banks and the bottom. Consequently the torrent of fresh water reaching the Western Canal from the Merrimack River through the Northern reversed the current in the Western (fed from the Pawtucket through the Swamp Locks basin) and poured water back into the Swamp Locks.

This additional volume assured that the Suffolk, Tremont and Lawrence Mills also would be well supplied and supposedly the Merrimack as well through the Moody Street feeder. We are primarily discussing the feeder but as the saying goes, all ships rise and fall on the same tide. In other words, everyone ultimately benefited from the building of the feeder.

The map on eight should be consulted from time to time as all of these canals and mills are mentioned to establish at least a familiarity with the relevance of the location with each other. The preceding explanation of the new waters from the Northern Canal and its distribution through the canal system was fragmentary at best as each step was outlined individually as they occurred in the bigger picture. Let’s repeat the actions of the Northern Canal waters as it flowed through the system and the ensuing results as one large picture for a better understanding and consulting the maps as we go.

The Pawtucket and Northern Canals left the Merrimack River within a few hundred feet of each other. Whatever the level in the river was, that was the head of the water at the beginning of both canals. Because of the topography of the land and the fact that the Pawtucket Canal followed the course of the existing Speen’s Brook, the Upper Pawtucket followed a somewhat meandering course until it emptied into the Swamp Locks Basin from where all of the power canals except for the Eastern originated. This also meant that the Pawtucket had already traveled almost 2400 feet longer than the entire length of the Northern over a very irregular course. Here is where the friction and resulting loss of head begins to enter the picture.

The complexes being fed from the upper canal were still in comparatively good shape water wise. This included the Appleton and Hamilton Mills fed from the Hamilton Canal, the Machine Shop and the Merrimack Mills fed from the Merrimack Canal, and the Lowell Manufacturing Company that alone was supplied from the Lowell Canal. The Western Canal was its own entity serving the Tremont, Suffolk and indirectly the Lawrence Canal and mills. The map on page eight illustrates the locations of these mills and the canals that served them very clearly.

The mill complexes fed from the Eastern Canal and supplied from the Lower Pawtucket Canal were a different story. This whole Eastern Group comprising the Prescott, Massachusetts and Boott Mills were isolated from the rest of the system (shaded on map). While the Moody Street Feeder performed as was expected by increasing the level in the Merrimack Canal, the effect on the Eastern Group was minimal until the Boot Penstock was constructed tying the wasteway of the Merrimack Canal into the lower end of the Eastern Canal. That didn’t solve all of the problems by a long shot. It did succeed in siphoning some water for the Eastern from the Merrimack causing the Merrimack Mills once again to complain of low water.

It seemed that there was no happy medium and stealing from Peter to pay Paul was a losing proposition. The fact remains that the Moody Street Feeder was a success but because of the separation of the canal system feeders, the Pawtucket and the Western, only so much could be accomplished. The
water was there in the river. The problem remained how to move it from where it was to where it was needed. The solutions offered ranged from digging another canal paralleling the Pawtucket from the river to below the Guard Gates to widening and/or dredging several of the feeder canals.

These schemes were abandoned partly because the further along the canal one traveled the closer to the canal banks the buildings were built, some right to the edge. This also eliminated another option, dredging the canals. Such extensive shoring would be required that it made that plan cost prohibitive. It was agreed any plans to further increase the volume of flow in the Pawtucket was beating a dead horse and hence the building of the Northern Canal. But even this endeavor was not the cure all as far as the distribution of the new water. The Northern deadheaded into the Western. For sure the water flowed to the right and left and all of the upper canals received more water aided greatly through the Moody Street Feeder. But the water starved portion of the Eastern Group fed from the Eastern Canal was still water starved even given the added volume from the Boott penstock.

But all still wasn’t well with the Merrimack Mill complex at the foot of the Merrimack Canal. The canal actually terminated into a smaller power raceway known as the Inner Canal and is represented as a jug-handle within the circle outlining the Merrimack Mills in the map on page eight. This Inner Canal dispersed the water to the individual waterwheels in the mill complex and it took a lot of water to turn the huge 30 foot breast wheels that ran the mills. When the Moody Street Feeder was completed and the canal widened from the feeder to the mill, there appeared to be an abundance of the liquid gold. But when the Boot Penstock was constructed to serve as a second source for water to the Eastern Canal and the Eastern Group of mills, the water from the Northern Canal was shared between them and consequently there still wasn’t enough for both.

The PL&C hadn’t given up on solving the problem, at least not yet. James Francis and his engineering crew still had a few tricks up their sleeves to solve the seemingly perpetual water problems.
Chapter Three

Two Other Underground Schemes that were abandon constituted two of several of James B. Francis’ ideas for increasing the water flow evenly between the Mills, but it was part of the Eastern Group made up of the Booth and Massachusetts Companies that were in the most trouble because of low water. Each of the Mill Companies contributed an amount equal to the shares they held in the Locks and Canal Corporation to build the Northern Canal and it was only fair they received their equal share of the Water Power now available upon the completion of the construction of the New Canal.

The Chapter offered here is only presented to show how far the Locks and Canal Corporation was willing to go to supply the mills with the waterpower necessary for maximum production. Still, only so much investment could be justified. In many cases the mill complexes had reached the limits of possible expansion on their acreage and had added floors to cram in more looms. But there was a limit.

The construction of the Northern Canal and other works involved had cost $650,000.00. Every means possible to fully utilize the advantages of the New Canal certainly had to be investigated. The canal system was awash in new water, a great over abundance for the first time.

The necessary improvements were first contemplated in 1854 at the Directors meeting of July 18. It was voted “that the agent (Francis) be requested to examine the present canals and suggest any improvements therein which he may think necessary or desirable for a more convenient use and just distribution of the water to the several parties entitled thereto.” Francis, also the head engineer, was prepared having already foresaw the necessity of canal expansion and his conclusions were presented to the Directors Committee on the improvements of the Canals in September, 1855 outlining the necessary work and the costs involved.

The Proprietors of the Locks and Canals on Merrimack River were businessmen with large investments and figures in red were to be avoided. When any new construction on the canals was contemplated, Francis produced alternatives, the cost of each, the return on each, the gain to the mills, etc. Everybody knew exactly where they were headed every step of the way. Not one of the proposed improvements was implemented so certainly the figures didn’t jive with the anticipated results.

The map on page 16 comes into full play in this chapter, indicating the location of the two raceways being discussed in this chapter but never built. The Merrimack and Mechanic Street Feeders were very much a part of the master plan drafted by Francis for the Proprietors of the PL&C. The following description of the proposed works have been condensed from Francis’ original text from the Committee report outlining the construction and a sketch of the layout of the routes open to the paths of the proposed feeder reproduced on the next page.
SKETCH OF THE PROPOSED FEEDER
FROM THE NORTHERN CANAL
IN THE YARD OF THE MERRIMACK MANUFACTURING COMPANY
WITH Sections of the several modes of construction for which estimates have been made
Sept. 1855.

Reproduced from a sketch of a plan that accompanied James B. Francis' 1855 report on the "IMPROVEMENTS THAT MAY BE MADE IN THE MEANS OF DISTRIBUTING THE WATER to the SEVERAL COMPANIES AT LOWELL (sic)"
The Merrimack Feeder

The first question to answer, why the added construction of the feeders; what added purpose would they serve? What ultimate benefit to the PL&C and the mills?

The perennial water shortage in the system had been hashed and rehashed over and over between the PL&C and the Corporations almost to the point of resignation. There was now more than enough water available since the completion of the Northern Canal. The challenge was to get it into the wheelpits of the Mills where it was needed. The reader should at this point be well aware of the problem that existed. Francis’ plans were to overcome this problem.

First of all, take a good look at the map on page eight to familiarize yourself with the general layout of the canals and mills. Now turn to the map on page 16 showing the locations of each of the proposed Feeders in relation to the Canals and keep flipping between them until they are familiar enough to remember.

The Merrimack Feeder is designated by the arrow marked number three. Take a minute and compare the route of the Feeder on the map with the sketch of the proposed construction that accompanies this chapter on page 22. Now you are as familiar as Francis was when he submitted the plan, Improvements that may be made in the Means of Distributing the Water to the Several Companies in Lowell to the Directors Committee. You are ready to tackle somewhat of an understanding of the text that will be more enjoyable if you picture yourself involved in the work.

This feeder would be no more that an extension of the Northern Canal. The fact that eventually the proposed route was change to accommodate construction going on at the Merrimack Mills has nothing to do with the original plan to build it. The map on page 16 shows the original proposed path of the construction through the buildings of the Merrimack Mills to tie into the Inner Canal that fed water to the Mills in the complex. The sketch shows both routes along with the various schemes offered for the actual building of the underground raceway.

Francis’ plan on the opposite page describing the route as presented to the Committee was “Starting from the Northern Canal, the first 200 feet in length to be an open canal, 40 feet wide, 12 feet deep, with walled sides; then a gatehouse occupying about 20 feet.” Alternate building methods were offered according to price and several plans submitted but this section of the proposed feeder never varied and if the sketch of the work is consulted it will be come apparent why. The room available for the construction was limited with the existing Tremont Gatehouse and Picker Building that housed the Waterwheels to be skirted. Then the Merrimack Manufacturing Company’s Print Works was standing in the way and those building would have had to be tunneled under as on the original sketch. This is the dotted path as shown on the sketch and meeting the Inner Canal at the lower right hand corner of the drawing.

The revised route in order to avoid the buildings and excavating under them was to go around, following the indicated street as was done in the building of the Moody Street Feeder. The three solid lines indicate the alternative route and would directly enter the Merrimack Canal instead of the previous designated point that was the Inner Canal that tied in directly to the Merrimack Mills. This path was only offered as an alternative and will be discussed a little further on.

It was difficult to leave the description of the maps and sketch while the readers attention was so focused, but after all, it’s Francis that has the stage.
Francis’ text goes on to state, “By this scheme it is propose to supply the Merrimack Manufacturing Company’s Mills by a Feeder 1150 feet in length, directly from the Northern Canal.”

He now delves into different materials to be used in the actual building of the Feeder and the varying costs of each of three schemes as he outlines the path of the feeder and the methods to be followed in each of the three phases of construction which are easily discernible on the drawing.

In all three schemes the first 200 feet of the feeder would be an open canal leaving the Western Canal where joined by the Northern and terminating at a Gatehouse. Leaving the Gatehouse the feeder was originally suppose to follow the path of the dotted lines and connect to the Inner Canal that distributed the water inside the Merrimack Mills yards, shown connecting at the lower right hand corner of the plan. After the Feeder left the Gatehouse, the plan varied in the construction of the remaining 950 feet, the design and materials to be chosen from one of the three schemes appearing as inserts superimposed on the plan.

The deciding feature would probably have been the cost against the projected life of the type of materials used. The density of the buildings or lack of same on the land to be traversed certainly would enter the picture. Was the channel passing under streets? Were there mill buildings to be tunnelled under? The plan indicates both.

Scheme ‘A’ was comprised of mostly wood about 800 feet of it with only 150 feet to be constructed of masonry and that was in the vicinity if large buildings and hence the cheapest way to go at $139,000.

The diagram of the proposed path of the Merrimack Feeder is reproduced on page 16. As most of the canal work in the 19th century, it was simple, straightforward and efficiently engineered.

Scheme ‘B’ was planned with 950 feet of the feeder constructed from masonry, the entire length from the gatehouse to the Merrimack Mills. The building would follow the plan in the upper section shown in the Scheme A drawing and came in at $192,000.

Scheme ‘C’ detailed in the lower left hand corner of the plan was the most elaborate, would last the longest under the constant use of the waterway and thus was the most expensive. It would consist of 950 feet of cast-iron pipe in three lines each ten and one half feet in diameter. $207,000.

Then almost as an after thought to define the reason behind the building of the feeder, he adds the advantages of the waterway.

“Another important advantage that may be derived from this Feeder is, that the Merrimack Company may, in the ordinary state of the river, have one and a half to two feet more fall (head) than they now use, provided they should see fit to put their yards and buildings in a condition to receive the water at a greater height,” as the original plan went, now that the Merrimack Mills would be receiving their own water supply separate from any other source of the other complexes, the entire flow from the Moody Street Feeder would be utilized to raise the head in the Eastern Canal via the Boott Penstock. The Boott Penstock was just that, a penstock or waterway that tied the Merrimack to the Eastern Canal and described a little further on in Chapter four. Therefore the lower Eastern Group of Mills, the Boott, Massachusetts and Prescott would benefit tremendously.
What would the alternate route of the Feeder achieve?

The last paragraph describes the object of building the Northern Canal, and really the prime reason. The goal was to assure that all Companies would benefit from the flow of water from the new canal but not necessarily from that Canal’s waters as such. As long as the low water problem was solved it was to the advantage of all and that’s all that mattered in the end. Keep the Wheels turning was the byword.

Let’s get back to the change in the route of the Feeder. No reason ever showed up in the minutes of the Directors Meetings as to why the project wasn’t followed through with but the fault could be in the following scenario.

The main purpose of the Feeder was to supplement the water of the Merrimack Canal feeding the Merrimack Mills. That’s why the original route of the Feeder tied directly into the Inner Canal that supplied the individual Mills in the complex. In no way the Feeder could replace the entire volume from the Canal but it would greatly limit the draw from the Canal that was necessary for the mill operation.

This would also allow large amounts of water to be directed into the Wasteway from the Canal, and thus into the Penstock that was angled off the Wasteway and then funneled the water into the Eastern Canal, Huzza...mission accomplished.

But now the alternate route raises its ugly head. As the revised plan would dictate the proposed Feeder would now empty into the Merrimack Canal just as the Moody Street Feeder does, instead of the Inner Canal as the original route was designed to do. The Merrimack Feeder would no longer supply the Merrimack Mills and only the Merrimack Mills but would now be sharing its waters with the Boott, Massachusetts and Prescott Mills by way of the Penstock and the Eastern Canal.

Under the alternate plan it seems quite doubtful either Canal would achieve the desired results that were planed for and fueled the original concept for the project. There’s no way of knowing if this assumption on the researcher’s part is what killed the project, or if it just wasn’t deemed financially viable, or a million other reasons. The one positive was that the Mills wanted to be able to purchase all of the Water Power that they could, and the PL&C wanted to sell all of the Water Power that they could. Why the project was consigned into limbo will probably never be known for sure, just almost educated guesses.
Mechanic Street Feeder

One more plan that flunked the finals but it’s worth examining what information we have about its proposal and why it was considered necessary at the time. The next page has a reproduction of the proposed route of this Feeder plus the suggested widening of a section of the Western Canal to make the scheme workable. The Canal had only been rebuilt and widened from the Northern Canal to the Moody Street Feeder to increase the water flow from the Northern to the Merrimack Canal. The rest of the Western was no more than a glorified ditch and it still is if you want to take the time to view it without water. The construction of this Feeder was part of the master plan right along with the Merrimack Feeder that was just presented. Again, before the reader continues with the text, get familiar with the map on page sixteen that outlines the general location in the Canal system and is indicated by the arrow marked two.

Arrow number three on the map is showing the original proposed route of the previously discussed Merrimack Feeder. The alternate route for this Feeder would have entered the Merrimack Canal about half way between the Moody Street Feeder (arrow No. 1) and the end of the canal. And as explained in the previous chapter outlining the construction of that proposed Canal, this change in the proposed route could be very well what doomed both proposals.

Even in the text of the Report offered to the Committee that was appointed by the Directors of the PL&C to oversee the planning of the Canal Improvements, not much ink was given to the proposal for this Feeder. Francis himself favored this proposal only marginally over several others, apparently scuttling those other plans too. One was paralleling the Upper Pawtucket Canal with a new Canal from the Merrimack River to just below the Guard Locks but that plan was abandoned because of irregularities in the contours of the remaining part of the Canal would have greatly impeded the expanded flow of water. The dredging of the Lower Pawtucket created another problem because of the Mills built right on top of the Canal banks and the added cost of pilings to add support and keep the banks (and Mills) from crumbling into the Canal during the dredging was deemed prohibitive. Likewise the widening of a part of the Eastern Canal would have been a waste if the proposed Feeders were built making it possible for the Boott Penstock to supply the Boott and Massachusetts Mills with all of the Water Power they could use.

In Francis’ presentation to the Committee he only allotted one short paragraph in favor of building the Mechanic Street Feeder and even he didn’t sound too convincing. “Another scheme, also represented on Plan No. 4 and intended as a substitute for the preceding, over which it has some advantages, is to widen the Western Canal from Moody Street to Mechanic Street (now Broadway) and to make an arched Feeder through Mechanic Street, from the Western Canal to the Merrimack Canal.” That’s it. That’s all he had to say in behalf of the Feeder’s selling point and he never mentioned it again. It could very well be, again just an educated guess, that Francis was well aware that if the route of the proposed Merrimack Feeder was realigned to enter the Canal instead of the Mill yard, it was probably a dead issue. And so would follow the rest of the proposed improvements.

All this talk of canals and feeders going this way and that way can get confusing enough to simply flip to the next page with a “to heck with it.” The map on page sixteen coupled with the sketches is the easiest way to go to understand the text, because that’s what it’s all about anyway.
SKETCH OF THE WESTERN CANAL
WIDENED TO 50 FEET AS SUGGESTED
TOGETHER WITH THE
FEEDER SUGGESTED
IN
MECHANICS STREET
Sept. 1855

Sketch of the widening suggested for the Western Canal.

SCALE OF FEET.

Lowell Machine Shop.
Francis continued to expound his remaining recommendations for the improvements but his convictions appear to be wavering. “According to my view, the improvement next in order of importance is: “Deepening part of the Lower Pawtucket Canal, and widening part of the Eastern Canal (sic).”

Wrapping a mantle of unimpeachable credentials around the rest of his opinions, Francis announces that from an engineering point of view, the Canals are too small to carry the amount of water that would have to pass through them. “That is to say, if they were to be constructed anew to carry the water now passing, they would under ordinary circumstances, be made of much larger dimensions.” And he adds that if the cost is not too great that they should be made much larger right now than even he is proposing.

True to Francis’ exacting ways he goes on to offer calculations of the end cost of those proposed improvements. Keep in mind that now all of the Corporations share in whatever costs are incurred by the PL&C for whatever reasons. All Water Power that operates the Mills is based on the formula for Mill Powers. Each Corporation contracted with the PL&C for so many Mill Powers according to their individual needs. How many shares the Corporation owns is what determines the percentage of the cost each is responsible for. The total amount of Mill Powers a corporation contracted for was based on the number of spindles in its Mills. The more spindles, the more Mill Power was necessary to operate the Mills. The average cost of the Mill Power worked out to be about three dollars in the 1830s. If these proposed improvements were implemented, the cost would work out to be very nearly $14. per spindle. We’ll pause a moment to allow the echo of the past gagging to cease.

Francis closes his presentation of Improvements That May be Made in the Means of Distributing Water to the Several Companies at Lowell after this little revelation of the cost with some parting words.

“Judged by this standard alone, the proposed improvement would appear to cost more than it was worth.” There’s more but the rest is just as negative.

So died the Mechanic Street Feeder, and all the digging and all the dredging and all the widening of the rest of the Canal improvement along with it. The Mills would have to suffer through the low water of the hot, dry summer months just as they always had and the backwater of the freshets in the wet seasons and the icing problems that would appear in the winter months because of the lack of surplus water to push the ice over the Dams and away from the trash racks protecting the turbine headraces.
Chapter Four

The Boott Penstock

The Boott Penstock – such a small waterway and yet it played such a big part amongst such large Corporations. But without it, the Boott and Massachusetts Mills (and the Prescott that was a part of the Massachusetts Corporation) that depended on the Eastern Canal for Water Power would have been in big trouble. By the time the water from the Merrimack River reached the Eastern via the Upper and Lower Pawtucket Canal, there really wasn’t too much Water Power left. Between the friction of the flowing water created between the walls of the Pawtucket Canal and the irregularities in the shape of the waterways left after the reconstruction of the Canal in 1823, both greatly impeded the flow. Add to that the debris from the granite work scattered along the bottom of the Canals where it was just left to lay where it fell, and the passage through the obstruction of the Upper Falls, the head could be reduced by a couple of feet. A portion of the water had already flowed into the Hamilton Canal powering the Appleton and Hamilton Mills from the Upper Level of the Pawtucket before being returned to the Lower Canal through the tailraces of the Mills which took away a little more of the head. As this water was ejected back into the Lower Canal in a perpendicular stream from each tailrace, it formed a water barrier to the natural flow of the Canal reducing the head even more and compounding an already bad situation.

The Boott and Massachusetts Mills certainly ended up with on short end of the stick in the Water Power lottery due to their location as the last Mills in the pecking order so to speak. The formula that would equalize the amount of water flow to each Mill irregardless of their site in the system, the cubic feet per minute they were allowed to draw to create the contracted for Mill Powers, was fair enough but if the water wasn’t there in the Eastern Canal, all of the Mill Power calculations in the world weren’t going to help matters.

This was the problem. And the Eastern Canal, and so the Boott and Massachusetts Mills, suffered greatly from low water. The problem was magnified in the drier summer months and really it really compounded matters by allowing ice buildup in the winter because there wasn’t enough water to push the ice over the Boott Dam at the end of the Canal. We’ll return to the icing problem a little further along in the text.

The Merrimack Canal was the first canal to draw from the Upper Pawtucket and it drew the full 30 foot head to feed the huge 30 foot Breast Wheels of the Merrimack Mills. It was from the Wasteway at the end of this Canal that the Penstock was tapped as shown in the map and the sketch, and fed into the Eastern Canal. It seems simple enough; just dig a trench from one Canal to the other and they were in business. Next to the thousands of feet of Canals the PL&C had blasted and dug this should have been a cakewalk, right? Well, not quite, but we’ll take it one step at a time and the Penstock will eventually evolve to be a viable waterway in its own right and do the job as Francis had envisioned it doing originally, and that was to alleviate the low water condition in the Eastern Canal.

First of all the two Canals were not on the same levels. The Merrimack was fed from the Upper Level of the Pawtucket Canal and the Eastern from the Lower. That little difference was 13 feet, the lower being the latter Canal. Judging by the current configuration, a gated spillway of some sort would have had to be built at the higher end of the Penstock to control the water flow between the two levels. No problem; it was all downhill from there so to speak.
First the old ‘one picture worth a thousand words’ act. Where is it situated in relation to the Merrimack and Eastern Canals? It’s easy to say the Penstock does this job and describe how it does that job but if you can’t visualize where it physically is in relation to the Canals its all a waste of breath.

The dotted lines outlining the Penstock are a little hard to make out on the map so a circle has been drawn around it to pinpoint its location.

From the map of the Canal System the reader should have a pretty good overall idea of at least what the design of the penstock was trying to achieve. To funnel water from the Merrimack Canal into the Eastern Canal and elevate the level of the water in the Eastern was the goal.
Here we can reproduce a sketch of a 1896 site plan of the Boott Mills showing the Eastern Canal and the Boott Penstock. The arrows and the description of what they are indicating should add greatly to the text. At least this raceway and the Canals can be viewed without much trouble. Even with the Canal full of water the outline of the Penstock wall traversing it can be seen. With the Canal empty, every detail of its construction stands out in all its detail.


Arrow #1 Location of Spillway where Boott Penstock begins at the Merrimack Wasteway drawing water from the Merrimack Canal.

Arrow #2 Underground portion of Penstock, originally a wooden raceway, now a steel pipe, from the Spillway to the open section of the Penstock.

Arrow #3. Open section of the Penstock paralleling the Eastern Canal and separated by a granite block wall. There are 15 rectangular openings underwater between the Penstock and Canal that allow the waters of the Penstock to mix with those of the Eastern Canal.
All of these photos show the Penstock as it looks today. There are none of its past and to date not even a sketch has been found even though sketches are mentioned in the records. But if the route of the waterway is viewed, a little imagination can complete the picture of yesteryear.

To begin with, these are photos of the beginning and end of the underground section of the Boott Penstock. There is rusting machinery perched on the top at one time raised and lowered a gate that regulated the water flow from the Merrimack to the Eastern Canal.

The steel pipe that constitutes the beginning of the Penstock is concealed behind a barrier of wooden planks that now cover the opening. Notice the angle to the entrance of the Penstock in order to facilitate the flow of water from the Merrimack Wasteway into it and to avoid creating a large turbulence at the opening.

Both photographs by Author

At the end of the underground section of the Penstock that began in the photo above, it empties into the main water-way of the Eastern Canal. To the right is the granite block wall that separates the Penstock from the Canal. The overall Length of the underground section was about 128 feet.

All of the photos presented here and on the next page were taken when the Canals were empty of water. However if you chose to view the Canal and Penstock when it is full, the capstones on the granite block wall of the Penstock will be visible.
Two more photographs will complete the visual tour of the Boott Penstock. The only way more can be seen, and it’s really worth it, is to walk the Canal when it’s empty as every Canal should be to be appreciated.

But to continue, the next two photos are of the Penstock and the granite block wall that separated it from the Canal to the left. This section of the wall was the last piece in the Penstock puzzle to be completed in 1888 and ends opposite the middle of the two trash racks that protect the headraces to the Mill turbines under building number Six. The Canal wall is to the right.

This is a good view of the wall taken from the end of the pipe comprising the underground portion of the Penstock. The capstone is always visible even when the Canal is full of water. The openings in the wall between the Penstock and Canal are out of view here.

This photo is from the vehicle bridge that spans the Eastern Canal. It shows the rectangular openings in the granite wall separating the penstock raceway from the canal itself that allows the two waters to merge with the least amount of turbulence.

One advantage in the telling of this tale is that the Penstock exists. Maybe not in its original form but at least we have a visual imprint of the beginning and end and with a peek at the records through the text, photographs and a site plan as we are doing can bring it somewhat to life.

From here on the records can spin the tale of the construction of the Penstock.
Chronology of the Penstock

Two sources have the initial construction of the Boott Penstock in 1846. A report titled Changes in the Boott Mills by Donna Richardson in which she describes it as “a tunnel which sent additional water from the Merrimack Canal to the end of the Eastern Canal” and a second in a HAER Inventory. The first mention of the Penstock in the Records of the meetings of the Directors of the PL&C shows up on April 14, 1848. “Voted; That the Agent be authorized to construct a wooden penstock leading from the Merrimack Canal Wasteway to the Eastern Canal, for the purpose of supplying the mills on the lower level with an additional supply of water, when they are impeded by backwater.”

One way or another, something had to be done and its construction evidently was a stop-gap effort to do something to try to improve the water flow to the Eastern Canal and the Mills located there but it couldn’t have been large enough to do much good. Understandable though, because it was drawing from the same source as the Merrimack Canal that fed the Merrimack Mills. How many ways can you split the same hair?

At any rate upon completion of the Northern Canal project with the accompanying Moody Street Feeder and the widening of the Merrimack Canal, the Boott Penstock was completed in 1849 to aid in the distributing of the additional volumes of water to the Eastern Canal.

It was turning out that the ‘let’s just dig a ditch and be done with it’ rule wasn’t the final solution though; far from it. There was still not enough capacity in the waterway but PL&C would keep at it until they had it right.

They worked at it for over forty years rebuilding and enlarging it again in 1873, 1889 and 1906 and by the time it was really done to the satisfaction of all, so was the life of Water Power. Steam Power had over run the Lowell Canal System and made obsolete the 5 1/2 half mile network that had fostered the Industrial Revolution. Just as the railroad had signaled the demise of the Middlesex Canal, the steam engine was about to play grim reaper to the Canal System.

But in no way can you knock the perseverance of the PL&C in trying to handle the problem of the low water being experienced by the Boott and Massachusetts Mills. The low water reduced the Mill Powers that the Corporations had contracted for. If the Wheels didn’t run at full speed, the machinery didn’t run at full speed and the end result was lost production. And in the eyes of the investors, this was to be avoided at all costs.

Everybody can appreciate how the loss of head could effect the Mills operations; easy to understand with just a simple explanation. But there was a second effect of the low water that was even more disastrous and that was in the winter months. This was the forming of ice in the Eastern Canal. It would form starting at the end of the Canal in front of the Booth Dam and the water would progressively freeze up, backing further and further in the Canal until it would block the trash racks and consequently the headraces leading to the Boott Mills Wheelpits. There was not enough force in the water flowing in the Canal to overcome the heavy current of the water pouring in through the higher Penstock to push the ice over the Dam and being at the end of the Canal the Boott Mills suffered the heaviest. The Eastern was the Canal to feel the results of the ice affect the most of all the Canals, and they all had the problem to one degree or another. The ice from the other Canals had a tendency to accumulate in the Eastern because it was the last in the system. But the Boott Penstock is our only interest at present so we’ll overlook the rest and continue on centered on the Penstock.
The first Penstock as constructed did offer some relief as far as increasing the water level in the eastern Canal. This was what the Penstock was designed to do. But the waterway stopped abruptly where it intersected with the Canal. Remember that the source of the water fed into the Eastern from the Penstock was coming from the Merrimack Canal which was 13 feet higher in elevation. This meant that the new water had to be pouring into the Eastern at a tremendous flow rate as it dropped through the Penstock and clashed head on with the current in the Canal. At this early date, the granite block wall that now separates the Penstock from the Canal didn’t exist. But that was no problem in itself as long it was just water to water; the Canal would even out the levels over its length and the average head at the Boott headraces would be raised enough to justify the building of the waterway.

But the new high water scenario in the Eastern and thus at the headraces of the Boott Mills was not the final hoped for total solution. The amount of new water it added in fact worsened the ice problem in the winter by counteracting the current in the Eastern and holding back any ice that had formed in place, not allowing it to be pushed through the Boott Dam and into the Merrimack wasteway and the River. Also by pumping more water onto the top of the already frozen ice in the Canal it was probably adding to the thickness and certainly making worse the resulting backup of the anchor ice that could thicken until it actually clogged the Canal from top to bottom.

The PL&C must have felt it was living with one long headache. It would no sooner solve one problem, and because of the solution, another would arise. But true to form they pressed on. From time to time, several times during the day if necessary, they would close the Gate at the head of the Penstock to stop the flow of water from that direction. Then the gates in the Boott Dam at the end of the Canal would be hoisted to give the ice a path to return to the River through the Wasteway without combating the adverse current pushing against it from the Penstock.

These two actions together would accomplish exactly nothing without a heavy flow of water introduced into the Eastern Canal from its beginning at the Lower Pawtucket Canal. To achieve this volume of water the Gates at the Middle Dam (Swamp Locks) would have to be opened in order to flood the Lower Pawtucket and add to the water flow into the Eastern to provide the force to push the ice over the Boott Dam and into the River. That wasted water represented wasted money to the investors and another way had to be found to handle the low water.

Keep in mind almost all of the problems with the low head at the Boott were caused simply by the unique location of the Mills at the far end of the system of canals. The reader is probably sick of reading about canals and penstocks and gates and ice and probably gave up trying to sort out one from the other. Maybe the page has already been turned.

It is to be supposed that this ice problem was an ongoing occurrence year after year on a regular basis involving the Boott Mills. Yet the records are strangely silent much of the time. Why it took 25 years to approach the PL&C is anybody’s guess but a communication from the Boott was finally read at the Meeting of the Directors on January 2, 1873 on the subject of “ice in their Canal.” It was voted “that this communication be referred to a committee to confer with the Agent (Francis) as to what shall be done, how it shall be done and what will be the probable cost, to report at a future meeting.”

Pretty good results for a committee as we find an answer from them on May 1. The report states that they examined the premises that is the entire situation of the ice problem, and agreed that it was partly because of the peculiar location of the Mills at the end of the system. They also concluded that the problem was increased by the construction of wasteways by the PL&C “for the discharge of ice from the Upper to the Lower Canal at the Mills of the Hamilton and Lowell Companies.” In other words because
of this action the ice formed there was also floating downstream and into the Eastern Canal and adding to an already bad situation. They also added “we are doubtful as to the liability of the Locks and Canals.” That appeared to have ended that. There was no mention as to the effects of the water flow from the Penstock compounding the problem

But something was accomplished at that same meeting after more or less seeming to abandoning the ice problem. The Agent (Francis) informed the committee that the existing Boott Penstock was in bad shape and must either be repaired or replaced. It was recommended to the Agent that the Penstock be rebuilt as soon as possible out of wood again, “in an improved form.”

For 15 more years the Boott Mills must have continued to fight the ice battle alone. The records and the Minutes of the PL&C Directors Meetings are silent on the issue, until an entry in the Minutes of March 14, 1888. The date alone would suspect that the matter referred to was once again the ice problem from the previous winter. At any rate. It was voted to “refer the matter of extending the penstocks through which water is discharged into the lower end of the Eastern canal.” The referral was given to another committee.

What probably sparked the sudden interest in the Boott Mills situation with the ice most likely had nothing to do with a sudden change of heart in the part of the PL&C as much as the continual complaints from the Hamilton and Appleton Mills about their wheel pits flooding every time the Lower Canals were flooded with water to push the ice over the Dam at the end of the Eastern canal.12

As mentioned before, the success of the Penstock also compounded the ice problem and it still remained for a solution to be found. It would make sense that the issue is what resulted in the vote on March 14 to extend the Penstock again.

At any rate, it was dumped in Francis lap. He had already prepared a report after the meeting of March 14 and as usual had all the facts at hand. He presented his proposal in a report titled, The Proposed Extension of the Penstock for Discharging Water into the Lower End of the Eastern Canal. He suggested that extending the Penstock further into the Eastern Canal instead of deadheading it abruptly when it entered the Canal would facilitate the discharging of the ice over the Boott Dam.

Francis outline two schemes for the proposed extension complete with the costs and he states that sketches are included with the proposals; alas, they seem to be lost to time. A brief summary of both proposals will be offered, and only brief. When Amory Street is mentioned in the descriptions, that is the roadway that paralleled the Canal when the proposals were written in 1888 and still does today.

**Scheme 1** would have a covered conduit in Amory Street 326 feet in length with two outlet conduits, each 20 feet long (Leading into the Canal.)

**Scheme 2** would have a covered conduit in Amory Street for a distance of about 128 feet, thence by an open conduit along the southerly side of the Eastern Canal, about 198 feet with openings into the Canal.

In both cases the overall length is given as 326 feet and this is the figure we will go with for our own reference. In any case, just viewing the end result, Scheme 2 was the selected preference.

Francis’ presentation must have been persuasive to the Directors of the PL&C.
At their meeting of August 30, 1888, they voted that “the Agent be authorized to extend the Penstock by which water is discharged into the lower part of the Eastern Canal in accordance with the plan submitted by him.” What wasn’t mentioned in the vote, but was included in the report was Francis’ recommendation that the PL&C construct the proposed waterway and “the expense of carrying out this plan should be borne by the Locks and Canals.” This more or less overrode the official consensus that the Company had no liability in the situation as they had alluded to at the meeting on May 1.

The final OK for the building of the Penstock was given by the Directors on April 20, 1889 after referring to a report given to the Board by the Consulting Engineer dated March 18. James B. Francis retired in 1885 and the position was filled by his son. The mention of the Consulting Engineer is referring to Francis Senior.

But even after all of the building and rebuilding of the Penstock over the previous years to correct the water and ice problems in the Eastern canal, and the seemingly “dammed if you do and dammed if you don’t” consequences of the decisions the PL&C made thrown their way by the Mills on the upper level of the Canals, they still hadn’t heard the last of that waterway yet.

The underground section of the Penstock was evidently reconstructed of wood during every improvement made to the waterway, and all of the negative features of that type of construction followed it. Finally it was voted by the Directors on July 27, 1909, to eliminate at least one final headache, and probably with great hopes the last, by reconstructing that portion of the Penstock of steel.

All has been quiet ever since. One section of the granite block wall that makes up the Penstock paralleling the Canal wall at about the halfway point has been removed for some reason but there doesn’t seem to be an answer as to why. If it had collapsed the remnants would be evident on the Canal bottom when it was empty which they aren’t. This damage defeats the original intent of the openings in the wall to eliminate the turbulence where the waters meet but it really doesn’t matter anymore. The silence of the Mill operations is deafening.
Chapter Five

The Subterranean Powerhouses

If the reader can appreciate the endeavors of the Canal builders in the four preceding chapters, he should be mesmerized by the tale of the underground raceways that is about to unfold in the following pages. The mighty Merrimack River that raged over the Pawtucket Falls, and the elaborate canal system that tapped into it to harness the power of the water that coursed between the banks, would all be for naught if were not for the little known and sight unseen labyrinth of underground raceways that funneled the flowing horsepower to the machinery in the Mills. Liquid gold it was, in the raw.

Long after the digging and stone laying was completed, the Morning Mail newspaper paid the only tribute it could by the way of a quote from one on the men most involved in the edition of Thursday, August 8, 1889.

“We think it was Kirk Boott who once said that he had spent more money below the surface of the earth than above it in this city, and this remark could be appreciated if one could see the mighty labor and subterranean water courses to utilize the waters of the Merrimack in turning our wheels of industries.”

Enough said as way of introduction.

A walk along the banks of any canal can certainly instill a sense of awe for the backbreaking energy that went into their building with the most primitive of tools. The pick and shovel and later blasting powder, and none of the spoils were moved without the wheelbarrow. Gaze up at the Mill buildings running one after the other in seemingly endless rows, and if one were around back then, to hear the deafening clatter of the looms weaving the miles of cotton goods.

The canal waters rush past all this in its journey from beginning to end without nary a pause and yet the mills machinery turns. But turns from what force? What motive power is working its magic, and how.

This time a walk along the empty canals will provide if not all the answers, at least afford a clue as to what process is taking place beneath the surface of the rushing canal waters. Those wood or steel grates placed seemingly at random along the canal walls in close proximity to mill buildings do more than decorate the waterways. They filter the trash laden water before it enters the headrace openings leading to the wheelpits and turbines behind them, and herein begins the story of turning rushing water to Millpowers.

The Proprietors of the Locks and Canals (PL&C) may have owned the Canals and claimed title to the water that coursed through them but that was the extent of their responsibility to the Corporations. As far as getting the waterpower from the Canals to the wheelpits and power the wheels to turn the machinery, that was up to the individual Mills. But it was the PL&C that had the expertise and organization to do the actual work of engineering and building in order to maintain the integrity of the system. The Mills were probably more than willing to turn over the responsibility to the PL&C for the building of the raceways. No matter how many Mill Powers they contracted for, it was only of use flowing trough the wheelpits.
It follows that seeing the scant information we have about this vital aspect of the power system that was developed to provide the access to the water power between the Canals and the wheels in the mills, we will have to make due. We will start with the first mill complex built, the Merrimack and progress from there in more or less the order that the succeeding mills were built.

Some of the lines that were drawn on the original sketches indicating the underground raceways have faded over time and some lines may have had to be traced over to better define them. But none were created where none showed on the original.

With so little to go on, the reader’s grasp of the overall picture may be vague to begin with but as an understanding of the system develops with familiarity and what the engineering was trying to accomplish, the larger picture should begin to emerge. An overall picture of each canal’s location in the system is reproduced on page eight but a more local sketch will accompany each presentation.

All of the basic construction of the underground raceways was primarily of the same design. Whether termed penstocks, or headraces that moved the waterpower from the canals into the wheelpits, or tail races that allowed the spent water to return from the wheelpits into the lower canal or rivers, the shapes were more or less the same. All we have had contact with were built with a curved granite archway covering a stone lined ditch of varying dimensions, at least at their beginnings and ends. That’s the extent of what can be observed.

The exception to the materials used in the construction of the underground courses is in the few later instances where steel pipe was used. This seemed to have come into vogue after the 1890s. One example is the final configuration of the Boott Penstock shown on page 32. Another is in three very large cylindrical shapes about nine feet in diameter shown below and utilized to move the water into turbines at the Tremont Mills and installed about 1896.17

There are three pipes in all and you are viewing the ends before they would have entered what was known as the forebay. They are prettied up with woodwork and a stone patio in front greets the visitor. Their overall length has been covered over and landscaped but the evidence of their existence can be followed back to behind the Tsongas Arena.

Photo by Corey Sciuto   2006
But the more typical underground waterway still remained the arch covered ditch, usually framed in granite block. The following photographs will serve to illustrate the configuration of them, some smaller, some larger and some much larger. Most headraces leaving the canals will be hidden by the height of the water and even if viewed when the canal is empty, will be covered with trash racks. As the waterways at each mill complex are examined, any visible openings leading to or from headraces or tailraces will be included. That way their existence will become more pertinent to the subject at hand and not become simply another picture with no meaning.

Here is one of the few remaining examples of a raceway that entered underground into a long gone building at the past location of the Tremont Manufacturing Company with its classic configuration.

Photo by the Author

Most evidence of tailraces from the any one of the mills wheelpits that emptied into the Merrimack River has been obliterated by work along the bank of the River. Again if one has the patience to walk along the dry canals, some of the remaining covered headraces leading to the underground chambers can be observed.

These two arched over opening are seen leaving the Hamilton Canal under the Appleton Mills. It is odd that they are not covered by trash racks but they appear to have fallen into disrepair over the years and simply been swept away by the Canal current.

Photo by Janet Pohl
Again a mystery surrounds the lack of any protection from the canal debris entering the head-races. This is the wall of the Eastern Canal. The two openings are under the Middlesex Community College and led to the wheelpits of the long ago demolished Prescott Mills.

Photo by the Author

These are two very large tailraces on the Concord River and came from the now demolished Middlesex Woolen Mills and can be viewed from the Davison Street Parking lot. This Mill complex was unique in the fact that it drew waterpower from both the Pawtucket Canal and the Concord River.

Photo by the Author

Now that we have made an abbreviated tour and surveyed as an example some of the entrances and exits that outlined the routes of the water into and out of the wheelpits beneath the mills, it is time to examine the actual courses that the waterways followed underground. Each Mill complex will be treated as an individual entity to make things as simple as possible, hopefully, and this will entail going back to their earliest days.

But on the next page will be presented a master plan of all of the underground waterways as they existed in 1933. Each Mill complex is identified for easy following when reading the text.
Merrimack Manufacturing Company

The primary use of the sketch below is to magnify not only the location of the mills in reference to the Merrimack Canal but also to bring attention to the all important Inner Canal, the distributor of all the canal waters in the mill complex.

Water Power in Lowell Massachusetts  Fig.2

This was the first of all the mill complexes, began in 1822 and saw water flowing over its huge Breast Wheels by 1823. These mills used the entire 30 foot head available in the Upper Pawtucket Canal via the newly dug Merrimack Canal that was built just for their own use. Instead of drawing water separately from the main Canal for each mill, a smaller canal was extended from the end of the Merrimack into the property in the shape of a ‘U’ as shown in the sketch above and all of the mills were tapped from it.

Known as the Inner Canal it defied the traditional arched shape in its building. It was square and protected with a trash rack in the Canal to prevent the floating debris from entering the waterway.
Here is a view of the end of the Merrimack Canal as it turns to the right and flows over the small Dam housed under the wooden structure. To the left in the photo is the trash rack covering the entrance to the Inner Canal.

Lowell National Historical Park   LOWE 8479

This is the solitary photo of the interior of the Inner Canal. Trash racks are strewn about and some are mounted over headraces on the right hand wall. The top is open and one mill building can be seen. This waterway probably remained open throughout its use.

Lowell National Historical Park   LOWE 9359

All remnants of the Inner Canal have been obliterated. The Canal itself has been filled in and no trace remains today. The entrance from the end of the Merrimack Canal has been blocked with a concrete wall and that is the only evidence of the waterway that exists. While this Canal in itself probably doesn’t qualify to wear a label as being an underground waterway because it was in all likelihood never covered, it fed many thousands of feet of raceways that did. There is not a trace left of the complex except for the Merrimack Canal and the Wasteway that course from the Dam to the River.

The only footprint left of the underground maze of water power raceways that provided the power for the machinery, and to signify the passing of this once large manufacturing giant, and the underground raceways that powered the machinery in its bowels is the 1866 sketch reproduced on the following page. At least we have this much to help etch the past in our history books.
Copy of a plan made from actual survey by G. W. Stevens, 1866

Arrow #1 – Merrimack Canal that Inner Canal is connected to just under the position of the arrow. (There is a gap between two canals in this sketch that didn’t exist.)

Arrow #2 – Inner Canal looping in a big “U.”

Arrow #3 – The dotted lines represent either headraces leaving the Inner Canal and entering the wheelpits under the Mills, or tailraces leaving the Wheelpits and emptying into the River. This particular raceway has three channels.
These Mills used the entire 30 foot drop in the head that fell from the Dam above the Pawtucket Falls to the Merrimack River. This meant that the difference in the height of the water between the Inner Canal and the River was 30 feet. This 30 foot drop over the wheels or turbines in the wheelpits created the power to turn the machinery in the Mills.

If upon comparison of the two sketches on pages 42 and 45 it appears that the raceway layout isn’t quite the same, neither is the time frame. More than 60 years separate them and during that period the Corporations would simply relocated the raceways to where they relocated whatever Mill building which happened regularly.

But what you read here is the only testimony left as to the Mills one time existence. When the wrecking ball had finished its job, not one brick stood on another.

Merrimack Manufacturing Company
From the Record of a City by Kenngott 1912
Lowell Machine Shop

First a glimpse of the background to familiarize the reader with a little history of the company.

It has had several names over the years but the Lowell Machine Shop was the name it was known as in the heyday of the canal and mill expansion so we’ll go with that throughout this brief endeavor.

This machine shop began as a branch of the Merrimack Manufacturing Company about 1824. Most of the early cotton mill’s had a machine shop attached as a necessity and not a convenience. There simply was no other available source to acquire the machinery except to build it themselves in house.

The machinery for the first Merrimack Mill building was fabricated in the machine shop of the Boston Manufacturing Company of Waltham. A cotton mill was a cotton mill and the machinery was the same to be used in both mills. As the Merrimack Manufacturing Company began to expand though, the machine shop in Lowell became a foregone conclusion. More so when Paul Moody relocated from Waltham under his new contract with the Merrimack. It didn’t take long before he and his crew of trained machinists began to improve on the earlier models, and the Merrimack Manufacturing Company began to expand with more mill buildings that had to be equipped,

What was different was the shop being located at such a distance and not as a part of the first mill building itself. The norm was to install the machine shop in the completed ground floor of the first mill building while still under construction and the fabrication of the machines could commence undeterred by the turmoil of the work going on around the site. An added feature was a shorter time delay in furnishing the mill, much being ready when the building was completed.

But just in case there was a change in plans, the building housing the machine shop was constructed along the lines of a standard mill building so it could be changed over to manufacturing at a given moment.

Anyway, that was the beginning of a storied career for the machine shop, being sold to the Locks and Canals in 1824 and then reorganized as the Lowell Machine Shop in 1845 and eventually ending up as part of the Saco-Lowell in a merger in 1912. Of the machine shop itself, our interests do not entail the physical building or its product; just the waterpower that operated it.

It seems odd to tell someone that our only concern is what’s under the ground it sits on. Our interest is in the waterpower that drove the machinery.

The master layout of the entire system in relation to the location of the various mills and indication of their separate underground raceways on page 42 pays scant attention to the machine shop, far belaying its importance in the development of the textile industry in Lowell by eventually furnishing the machinery for most of the mills. Even though it indicates that the shop has the fewest waterways in all the mill yards, it was because the machine shop needed nowhere the amount of mill powers that the mills did but the operation was still a giant presence in the industry. The maps on page 8, or page 42 indicates the location of the shop at the head of the line of mills and it truly was.

There really is nothing left to see of the once thriving site that was in the past crowded with foundries and machine shops. As for remnants of the bygone days, nothing remains except for parking...
lots. And this is one of the few times a walk along the Pawtucket or Merrimack Canals that border the property and once furnished all of the waterpower will produce absolutely nothing for one’s efforts.

The sketch of the outline of all of the underground waterways that existed in the mill development in 1933 [none is known from earlier] is on page 42. The headraces and tailraces are shown entering and leaving the canals respectively with the wheelpits indicated within the single line outline of the mill buildings. As described before, the wheelpits contained the wheels or turbines that the water powered, in effect revolving the shafts and belts that they were attached to and producing the motive power for the mill machinery.

However in some close ups of the individual penstock layouts that are shown in following sketches, the wheels might be accompanied with a kilowatt rating as if identifying with an electric generator, which is exactly the reasoning. The water power still was the driving force turning the wheels of the turbines but now at this date instead of being engaged to the machinery by cumbersome shafts and belt and pulleys, the motive action was transmitted from generators to motors.

The generator and raceways indicated by the designation of No. 6 in the position where all three canals, the Pawtucket, Hamilton and Merrimack diverge from the Swamp Locks on page 51, is an oddity in the Eastern Group of Mills. This was once the site of the foundries at the machine shop. If the reader isn’t familiar with the topography of the site, he would assume from this sketch that the head and tailrace is starting and finishing from the same canal, the Pawtucket, which would get you nothing but wet feet. But it is, and it identified as generating 60 kw of electricity. The sketch is very vague in not better identifying the Dam at the Swamp Locks which is separating the Upper and Lower Canal causing the water in the canal to drop 13 feet between the Upper and Lower Pawtucket Canals. Thus between the headrace and tailrace the water is pouring over the dam creating the necessary drop in the level of the water of 13 feet to generate the waterpower as it fell. First over the water wheel and now through the turbine, turning the generator that it appears in the 1933 sketch and now long gone.

The three headraces leaving the Merrimack Canal and entering the Machine Shop property and marked No. 1 through 5 have had their one time existence pretty well obliterated. There are slight indents in the canal bank, filled with granite blocks or concrete that with a little imagination, can attest to the fact that there once could have been some sort of a waterway that left the canal. When the Merrimack Canal is drained of water, these so called indents become much more pronounced and actually project into the property. They look like they probably could have been entrances to a waterway, and that’s exactly what they were in the past.

Even the tailraces from generators No. 3, 4, and 5 that show emptying into the Lower Pawtucket Canal are hidden in that canal under an overhang that juts out over the canal from the property, outlined by a dotted line, paralleling the Lower Pawtucket. But if you follow the outline from that point on the canal to the left you will run into two solid parallel lines leaving No. 1 & 2 wheels and entering the canal, the one and only waterway that still at least partially exists and can be viewed. This is the tailrace of the waterway that once powered a sawmill first owned by the Merrimack Company, and the remnants can be seen from where it turns on an angle after leaving the wheelpits of the sawmill itself as shown on the sketch offered on page 42 and ends at the Lower Pawtucket Canal. It runs along side an old mill building now converted to condos at the end of the empty lot that used to house the buildings of the Pellon Corporation, [later Freudenburg] and now completely demolished.
The photo below on this page is all that remains of the waterways at the Lowell Machine Shop not buried under acres of asphalt in the parking lots.

The water is backup from the canal. No water runs in the Saw Mill waterway.

The mill building converted to condos is on the left. The site of the demolished Pellon Corp. buildings is in the right. In the distance is the junction of the Saw Mill tailrace with the Lower Pawtucket Canal.

Photo by Author

The question would not be out of hand as to why are we chasing the tale of a ratty old long turned to dust sawmill. Because it’s all we have is a good answer. And it is documented. On the Map of the City of Lowell published in 1841 by Beard and Hoar, it was identified as a bobbin and shuttle factory. Another source put its origin as around 1824-25.

Maybe the purists will complain that this raceway doesn’t meet the definition for an underground feeder, not covered with an arched overhead and leading from the canals to the mills. Maybe that statement is true but the sketch on the next page places the sawmill as being for real on the very edge of the machine shop property where it abutted to the Lowell Manufacturing Company and supplied waterpower to the sawmill.

There are many who classify the Lowell Canal as a penstock for the simple reason that it only furnished waterpower to one building. It’s just a matter of personal interpretation in the long run.
Merrimack Canal designated at top left. Lower Pawtucket Canal is on bottom marked Main Canal. Saw Mill is laid out by rectangle in center of raceway running between canals. Large square at top of raceway and abutting Merrimack Canal is probably an enlarged section of the raceway where the logs were held until needed. Machine Shop land is area to left of raceway.

Plan of Land Near Saw Mill  
*Deeded to Lowell Man'g Comp'y Mar 15, 1828 (sic)*

All of the other generator sites numbered No. 3 to 6 inclusive at one time most likely were the location of wheelpits and turbine sites that supplied the motive power for the buildings they were situated in or close to. Apparently no generators were ever contained at site of Wheels No. 1 & 2 although the wheelpits and raceways still had to exist in 1933 to be present in this sketch. This was the approximate site of the Saw Mill described above and at least the original purpose of this raceway was exactly that, to power the Saw Mill as it produced bobbins for the cotton mills, and probably many more wooden products.

The sketch on page 42 really doesn’t do justice to the Machine Shop Mill Yard. The presentation below brings out the wheelpits and waterways much clearer. The Machine Shop, as vast and crowded with the foundry and various machine shops as it was, required nowhere the amount of Mill Powers to run their operation that a cotton mill complex did. If the reader just compares the amount of raceways at each site in the sketches, this will become evident.
A lot of words have been covered for such a small presentation of material to interest the reader in the past grandeur of the Lowell Machine Shop. Continually harping on the Saw Mill site gets a little old but the evidence of the existence of the Saw Mill centers around only the few sketches, a small bit of documented text and one partial view of the tailrace. What little evidence we have has to be has to be expounded on.

Many pictures of the Machine Shop exist. Outside, inside and being torn down. Our only interest at this time is the raceways providing a channel for the waterpower from the canals to the mills. However least the reader labor under the impression that the Lowell Machine Shop was some penny-ante operation surviving in the shadows and on the fringes of the cotton mills, the picture on the next page should dispel that line of thinking.
This drawing was made of the Lowell Machine Shop when it had just about reached its zenith and before the merger into the Saco-Lowell.

The water indicated by the ink wash in the lower right hand corner is the Swamp Locks basin. Running from the basin diagonally across the drawing to the upper left center is the Lower Pawtucket Canal bisecting the Machine Shop; the foundry buildings are to the right and the machine shops to the left.

At the point where the Canal leaves the Swamp Locks is a low building that straddles the canal with a dam under it; a set of locks is on the right alongside. The head of the canal water drops 13 feet over this dam and the building houses the gates that control the flow. This drop in the water level is what supplies the force for the waterpower.
Hamilton Manufacturing Company

This was the first mill built after the Merrimack Manufacturing Company had shuffled itself around and re-organized the Proprietors of the Locks and Canals (PL&C). The Merrimack had had visions of developing the entire power canal system themselves which also entailed building all of the mills. It didn’t take long to realize this was almost an impossible task they were taking on. The Merrimack owned all of the stock in the now dormant PL&C and the charter was still valid. The best thing to do was to transfer the water and land rights to the PL&C and let that Corporation manage the sale and lease of the water and land.23

And so sprang the Hamilton Manufacturing Company in 1826 on a spit of land on a new canal called the Hamilton that was dug paralleling the old transportation canal, the Pawtucket. What made the location not only feasible, but prime really, was that it copied perfectly the ideal situation for a mill utilizing water power. Two canals on different levels separated by just enough distance to construct a mill between.

The best scenario was to have a source canal say flowing from a river. We’ll call it “A” just to identify it. It gets to a point when you want to build a mill. Now a dam is thrown across the canal and the water backs up into a basin. A new waterway, “B” is dug from the basin paralleling the original course of the canal that has been deepened, says by 13 feet but separated by a given distance of land. Now the water, “A” is allowed to flow over the dam and drop into the newly dredged lower level and go on its merry way, except that it is now 13 feet lower.

The spit of land between the two canals is where you build your mill. The water in the new canal “B” is channeled through a headrace, into the wheelpit and through the wheel or turbine. The channel continues on through the tailrace and empties into the lower canal “A.” This drop in the water level is what is termed the head. The difference in elevation is the force that causes the wheel to rotate and turn the shaft that turns the pulley that spins the belts and away goes the looms weaving and the cotton cloth spits out on the mill floor. So came the Hamilton Mills into existence.

This illustration tells it all. Hamilton Canal on one side feeding into the wheelpits and the turbines, and exiting into the Lower Pawtucket on the other with the water dropping 13 feet from the former to the latter.
This is the first ever plan proposing the development of land belonging to the Merrimack Manufacturing Company laid out in 1824. The canal angled in the top left hand corner is the Merrimack and feeding those Mills. The canal running horizontally straight across the upper center of the sketch is the Pawtucket and it is marked so in small letters. The wavy outline superimposed on the Pawtucket Canal was the course of the canal before it was straightened and filled in.

The lowest of the three canals is what is referred to as the Proposed Canal on many drawings. This will become the Hamilton. The “T” shaped structures are in reality the site of projected future mill buildings atop their headraces. Although the arrangement will be different, this is the location where the Hamilton and Appleton Mills will rise.

The classic canals built parallel on two different levels is really brought out in this drawing of the projected scheme of the mill development. All of the rectangular shapes indicated under the canal layout are occupying the area where the boarding houses for the mill workers would be constructed.

“A plan of the land on the south side of the Pawtucket Canal belonging to the Merrimack Manufacturing Company Chelmsford Jan’y 1824”
Center for History of Lowell, Shelf 106, No. 599
The first two buildings at the Hamilton Mills were not only constructed by the Merrimack Mills, their machine shop produced all of the machinery (under the guise of the PL&C after 1825). But the ownership of the two original Mills was under outside interests, although some of the interests of the stockholders overlapped both Companies, after fully realizing that developing the entire tract of land of 400 acres24 (700 to 800 according to some records25) was unrealistic.

The land was no problem. There it sat. If it was thought to be a good choice, the Corporation would bargain with the PL&C for a price to buy, or to lease.26 But the water was a whole different ball game and the Mill Power was introduced with the building of the Hamilton Mills as a measurement to control its sale and use. Sooner or later the mill power has to be defined and this is an appropriate place. It is the same for each mill. The only variation in the formula is the height of the head of the water and that depends on the location of the mills in the canal system and that never changes.

The mill power established was long termed the “Lowell Standard” at 62.5 horsepower. It was defined as when powering a wheel and the PL&C engineer James B. Francis figured it increased to 68 horsepower when the water powered a turbine.27

The amount of Mill Power was contracted for with the purchase or lease of the land but the determining factor that governed the amount of Mill Power needed was the number of spindles that the mill would run. One mill power was sufficient to drive 3,584 spindles.28

Definition of Mill Power.29

Article I. “Each mill-power or privilege at the respective Falls is declared to be the right to draw from the nearest canal or water course of the said Proprietors so much water as, during 15 hours of every day of 24 hours, shall give a power equal to 25 cubic feet per second at the Great falls, when the head and fall there is 30 feet___to 45 and 1/2 half cubic feet per second at the Lower Falls, when the head and fall there is 17 feet___and to 60 ½ cubic feet per second at the Middle Fall, when the head and fall there is 13 feet.”

The Article continues on giving examples if the water is lower at each falls but best to stop here rather than complicate an already confusing explanation if the reader has no prior knowledge of the nature of a mill power. Even the terms to describe the falls used in the above definition should be clarified. The Great Falls refers to the Pawtucket Falls. The Middle Fall is the Swamp Locks and the Lower Falls is the last falls before the Pawtucket Canal pours into the Concord River.

Louis Hunter in his Water Power defines the mill power nicely describing it as “twenty five cubic feet of water per second falling 30 feet, but with the amount of water varying according to the actual distance of the fall, whether more or less than 30 feet.”

Simple enough and we’ll leave it at that. It’s common sense that water falling thirty feet generates more power than water falling thirteen feet. The only way to compensate and equalize the power of the lesser with the greater of the water fall is to increase the volume of the lesser, and that’s all that the formula does.

Maybe another help to understanding the complexities of the explanation of the mill power calculation is the inclusion of the chart below. While the raw figures were recorded at the Hamilton, the results could be, and are, typical for any mill. The interesting aspect of the figures is the heading they fall under. The first column records the quantity of water used in cubic feet per second and the fourth the
correlating fall of the water from the Upper to the Lower Canal which is another way of expressing the fall of the water through the raceway and turbines.

<table>
<thead>
<tr>
<th>Date of the measurement 1852.</th>
<th>Time.</th>
<th>Quantity of water used, in cubic feet, per second.</th>
<th>Height in the Upper Canal near the Mills.</th>
<th>Height in the Lower Canal near the Mills.</th>
<th>Fall from the Upper to the Lower Canal, in feet.</th>
<th>Machinery in the Mills, reported as not in operation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug. 2. 2h 28' to 4h 32' P.M.</td>
<td>839.21</td>
<td>31.65</td>
<td>17.69</td>
<td>13.96</td>
<td></td>
<td>13 Warp Throstles, 6 Males, 206 Looms, 6 Dressers, 3 Winders, 1 Spooler.</td>
</tr>
<tr>
<td>Aug. 3. 9h 0' to 10h 55' A.M.</td>
<td>873.55</td>
<td>31.83</td>
<td>17.74</td>
<td>14.09</td>
<td></td>
<td>9 Warp Throstles, 8 Males, 239 Looms, 4 Dressers, 4 Warpers, 1 Spooler.</td>
</tr>
<tr>
<td>Oct. 14. 9h 33' to 11h 47' A.M.</td>
<td>984.54</td>
<td>31.82</td>
<td>17.67</td>
<td>14.15</td>
<td></td>
<td>6 Warp Throstles, 4 McCulley ring filling Frames, 1 Loom, 1 Dresser, 3 Winders, 1 Warper, 5 Reels.</td>
</tr>
<tr>
<td>Oct. 14. 2h 4' to 3h 52' P.M.</td>
<td>901.57</td>
<td>31.78</td>
<td>17.65</td>
<td>14.13</td>
<td></td>
<td>6 Warp Throstles, 4 McCulley filling Frames, 5 Looms, 3 Dressers, 3 Winders, 1 Warper, 5 Reels.</td>
</tr>
<tr>
<td>Oct. 28. 10h 15' to 11h 52' A.M.</td>
<td>919.79</td>
<td>31.78</td>
<td>17.63</td>
<td>14.15</td>
<td>No return.</td>
<td>No return.</td>
</tr>
<tr>
<td>Oct. 28. 2h 42' to 4h 46' P.M.</td>
<td>917.97</td>
<td>31.28</td>
<td>17.63</td>
<td>13.65</td>
<td></td>
<td>14 ring filling Frames, 3 Dressers, 2 Winders, 6 Warpers, 2 Reels, 1 Picker, 1 Willow, 3 Stretcher, 1 Speeder</td>
</tr>
<tr>
<td>Nov. 16. 10h 5' to 11h 23' A.M.</td>
<td>942.74</td>
<td>31.85</td>
<td>17.67</td>
<td>14.18</td>
<td></td>
<td>4 warp, 14 filling Frames, 2 Winders, 6 Warpers, 2 Reels, 3 Dressers, 1 Picker, 1 Willow, 1 Stretcher.</td>
</tr>
<tr>
<td>Nov. 16. 2h 9' to 3h 25' P.M.</td>
<td>918.35</td>
<td>31.90</td>
<td>17.65</td>
<td>14.25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The relevant part of offering the chart is so the reader can compare the figures with what he has read in the mill power formula on the previous page, to understand how the fall of the water enters the overall picture.
Seeing at this point the mill power has appeared, the next logical question to follow should be how did they measure the water flow through the wheels or turbines to establish the mill power? There were two methods that were popular for measuring water flow. The first was simply a hollow pipe weighted on one end and its travel over a measured distance was timed. From that test, the amount of flow could be calculated.

In the case of the water wheel, or turbine, the flume (or weir) was the measuring device of choice. In the beginning it was simply a wooden chute of known dimensions installed in the tailrace so the amount of water passing through the wheel could be measured with some degree of accuracy. It was cumbersome and wasn’t a piece of equipment to be left in the tailrace permanently. It was only utilized when there was a doubt as to how much water the mill was actually using verses what they were being charged for. The mill contracted and paid for X mill power and that’s all they were entitled to.

After the advent of the turbine, the measuring end got a little easier with the adoption of the speed gate. Even though the gate that controlled the flow of water through the turbine traveled in feet, the indicating arm only traveled in inches. It was graduated and once the amount of water passing through the turbine for any given indication on the scale was known, by measuring the flow through a flume, or weir, there was no reason for the reading to ever vary. The exact flow could be calculated simply by comparing the scale to as prepared chart.
About all of the scant material that research has produced has been gone over in the previous text. And all of the material is adaptable to every single mill complex in the system, and every wheel and turbine. No matter what part of this book contains a reference to mill power, it will refer to this section and chapter.

This closing will be accompanied by a representation of the Hamilton Mill complex. One thing all of the cotton mills had in common was the use of every square inch of land that they sat on, and the Hamilton was no exception.

Hamilton Manufacturing Company    1882
From Lowell Illustrated by Frank Hill
Incorporated in 1828 to be built to the west of and abutting the Hamilton Mills, the water to power the wheels was drawn from the Hamilton Canal and discharged 13 feet below into the Lower Pawtucket Canal. And like the Hamilton Mills, the buildings were contracted for by the PL&C and the machinery built by the Lowell Machine Shop now fully incorporated into the PL&C. The Hamilton and Appleton Corporations had much in common, including many of the same directors and shareholders active in the Merrimack and Locks and Canals Companies.

The constructions of the Mill buildings have no bearing at all on the water power that flowed through their underground raceways. Still, it doesn’t hurt to acknowledge the existence of the end user of the mill power. To expand on the statement that the PL&C constructed the buildings for the Appleton Corporation, we have to back off a little. When they were scheduled to build and equip the first two buildings, the Merrimack Mills suffered a disastrous fire in 1829. All was put on hold while the Merrimack was reconstructed and refurbished by the PL&C.

Into the picture enters one Capt. John Bassett, a well known builder of the time. It appears, or at least he is given credit for erecting the first two buildings for the Appleton Company. The record of the Directors meeting of July 11, 1829 states “The agent having exhibited a statement of the cost of the Machinery Mills Houses etc. (sic) built for the Appleton Manufacturing Company by the Proprietors of the Locks and Canals on contract-“The fact that the work was done by contract lends some credence to the notion that in fact the buildings were erected by an outside contractor and not by the PL&C themselves. An entry from the Lowell Historical Records found in a volume of Contributions also supports Bassett as being the builder.

But like any well told tale of history, this one also seems a little distorted by a teller somewhere down the line. The fact is on February 4, 1828, a charter incorporating the Appleton Company was awarded to T.H. Perkins, E. Francis and S. Appleton. The fiction seems to be in the statement made by Joshua Merrill that “During the summer of 1828, the Appleton Mills were put into operation” and the statement attributed to Samuel Batchelder that ”By the end of 1828, the Appleton Company had commenced operations.”

It’s difficult to disbelieve these statements considering the stature of both the speakers. Joshua Merrill was a leading educator and Batchelder was an original investor in the Hamilton Mills. And yet in the Director’s Record of the Meeting of September 7, 1830, it appears the Directors are still debating over building and equipping two mills for the Appleton Company. It’s doubtful that they are a third and fourth mill building because according to Frank Hill in his book Lowell Illustrated, 1884; those additions were built in 1846 and 1861 respectively.

Also it is stated elsewhere that a mill building could not be put up and machinery installed in one season. If the charter for the Appleton Company was granted in 1828, no way could two mill buildings be up and running by the end of the year no matter who built them or how esteemed the person who described the happenings.

The Appleton was conceived by two long time associates, P.T. Jackson who was one of the founders of the PL&C and Paul Moody who was the top machinist in the system and came from the Boston Manufacturing Company in Waltham when the Lowell Mills were proposed. Along the way Moody had perfected the mill machinery used in the industry that gave it a higher rate of speed and promised great savings and his anticipations were justified. Jackson was an interested investor and it was
he that established the company known as the Appleton Company to utilize Moody’s improved machinery.

Like all other Lowell mills, the Appleton started out with breast wheels providing the motive power. The diameters of the wheels were usually the same as the fall of the head of water which in the case of the Appleton would have been 13 feet. Wood was the standard construction material of both the wheel and shafting back then, and when the change over to iron began it was slow and caused many problems because of the poor quality of the metal.

One thing the Locks and Canals had no shortage of was talent. When reading the history of this company and the feats that were achieved by the workmen using the most rudimentary tools and basic education, it is just short of amazing. How did we evolve into the cluck headed excuses for engineers today still working on $400 toilet seats and having trouble digging a ditch?

Uriah A. Boyden had been a surveyor with the Locks and Canals until moving on in 1834. Where he moved on to was learning all he could about waterpower which was the liquid gold of the day. Boyden’s main interests lie in turbines.

In 1844 Boyden convinced the agent of the Appleton to allow him to construct and test a turbine for a new mill building that he had been experimenting with. The chief engineer for PL&C, James B. Francis aided in the testing and verified the increase in power of the machine while at the same time occupying less space. The bells were sounding the death knoll for the breast wheels, muted at first but getting steadily louder.

It didn’t take the PL&C long to buy up the Boyden patents on the turbine, especially with Francis verifying the results of the tests. And it didn’t take much longer for the PL&C to convince the manufactories to switch over from the breast wheel to the turbine for the savings offered in the use of the water with the same results in horsepower. Still a fairly large expense was involved on the part of the Companies and there is evidence that breast wheels were still supplying 20% of the power to the mills in 1876.36

Finally we are returning to the subject of the waterpower and again to a very light agenda of information available. One thing all of the waterwheels or turbines had in common was the need for water, a lot of water for as said, that was their fuel. The Hamilton Canal had a great excess and seemingly no end but it was useless as a power source for the Appleton Mills without the underground raceways that would funnel the water from the canal to the wheelpits and then provide a return path to another but lower water course in the Pawtucket.

And in the case of the Appleton Mills, it is in the most perfect location that a mill could be built, on a spit of land flanked by two flowing canals, the Hamilton 13 feet higher than the Pawtucket as they rush by on either side.
This photo by Janet Pohl is of the Hamilton Canal taken from the street crossing the bridge from the Appleton Mill on the left to Jackson Street on the right.

This photo is by the author of the Lower Pawtucket Canal taken from an extension of the same street with the Appleton Mill site on the right.
This photograph appears to be the entrance of a headrace leaving the Hamilton Canal and entering a wheelpit under the Appleton Mills. Strangely enough it is not covered by a trash rack.

This may indicate that the raceway is not a headrace feeding water to a turbine but instead serving some other purpose. Its location matches perfectly the feeder supplying turbine #3 on the schematic.

Photo by Janet Pohl

This is a photo opposite the raceway entrance above. The water in the Lower Pawtucket Canal is extremely high obscuring most of the opening.

The square shape would give more credence to the object of the channel as being a wasteway rather than a penstock to feed water to a wheelpit and thus a turbine. But no such waterway shows in the schematic of the underground on the next page.

Photo by the Author

Simply dig a ditch, a headrace from the Hamilton Canal to the wheelpits containing the waterwheels under the mill and eject the wasted water from the wheelpits into the Lower Pawtucket Canal through another ditch, the tailrace. In the middle of it all, the waterwheel is turning and the machinery is turning and the cloth is turning the profit for the investors.
In the underground sketch of the raceways and turbines under the Appleton Mills below, three different groupings of penstocks are noted.

All three turbine locations are shown as outlined inside of a schematic of what would indicate a building. Some presentations of the underground show the raceways as simply a solid line. This sketch indicates two turbines to the far left, three in the center location and one to the right.

Historic Structure Report, prepared by Anne Booth
Lowell National Historical Park

So far any diagrams of the actual underground raceways and turbine locations within the mills have been sparse at best. These were the earliest mill sites and the builders evidently didn’t think it was of any importance. They knew where the channels went from and to. Who else would even want to know, or care, was probably their thinking at the time.

The advent of the turbine began with its installation in the Appleton Mills and the era of the waterwheel was destined to become history. But it was more than just that cumbersome power device that was disappearing. Any good millwright could fashion a waterwheel. The casting methods and fine machining used in making the turbines removed a skill from his hands forever.
Every mill in Lowell looked just like every other mill, height, width and length and the brick count must have came close also. When one thinks of the untold hours of labor that were expanded inside those walls, the whole scene becomes mind boggling. Entire lives marching to the incessant beat and vibration of the demanding pulse of the machines, only the reaching smoke stacks appeared to have a shot at liberty from the shackles of the daily grind.

The Appleton Company from Lowell Illustrated