Fairmount Water Works
East Bank Schuylkill River
Aquarium Drive
Philadelphia
Pennsylvania

HAER No. PA-51

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Historic American Engineering Record
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FAIRMOUNT WATER WORKS

HISTORIC AMERICAN ENGINEERING RECORD

PA-51

Location:	Along the east bank of the Schuylkill river just west of and below the Philadelphia Museum of Art at the south end of Aquarium Drive.
Dates of Construction:	1814-1815; 1821-1822; 1860-1862; Last technical changes made 1867 - 1872.
Present Owner:	City of Philadelphia, Water Department
Present Use:	Discontinued operations 1909. Machinery removed 1911, except for 1851 turbine and pump. An appropriate reuse for the structure is now being planned
Engineers/Builders:	Frederick Graff Sr., Frederick Graff Jr., Henry P.M. Birkenbine
Significance:	The Fairmount Water Works is perhaps the premier example of early 19th century American industrial architecture. It was built to supply Philadelphia with a reliable source of fresh water. During its operational life the Fairmount Water Works employed a wide variety of hydraulic technologies including steam engines, wooden and cast iron breast wheels, and iron water turbines. Known as the "Mecca of hydraulic engineers" the Fairmount Water Works greatly influenced subsequent municipal water works development throughout the United States.
Historian:	Jane Mork Gibson, 1978
Cross-Reference:	Additional photographs catalogued as HABS No. PA-1654
Transmitted by:	Kevin Murphy, Historian HAER, September 1984

ACKNOWLEDGEMENTS

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Jane Mork Gibson

September 1, 1978

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Philadelphia's Water Works, personified by William Rush's allegorical wood carving The Schuylkill Freed, was world renowned in the nineteenth century for its technological feats of hydraulic engineering and for the beauty of its architectural design and its parklike setting.[1] It was ranked "among the most noble public undertakings in the world."[2] It was a pioneer in the field of municipal water works, and much of its engineering was innovative.

The history of the technology at Fairmount Water Works shows the evolution of three systems, each of which met the need for "watering the city" at the time of installation, but which became obsolete with the development of unforeseen events, associated mainly with the phenomenal increase in the population of Philadelphia. Three specific types of prime movers were used to operate the hydraulic machinery--steam engines, breast wheels, and water turbines--and each system had other basic components in the form of storage reservoirs and distribution facilities.

The first system at Fairmount in 1815 employed early stationary steam engines and wooden pipes, as had the earlier Centre Square system, which Fairmount replaced. Fairmount was designed to provide a larger quantity of water in a more reliable way to a rapidly growing city. The shift to water power by 1822, using breast wheels, and the adoption of cast-iron pipes required considerable capital investment, but it economized in the costs of fuel and of supervisory personnel, expanded the works and provided for future growth. Turbine wheels, because they are most efficient in the use of water for power, were introduced at mid-century as the final stage in the technological growth of the Works, and for low operating cost, provided sufficient water except in time of drought. Unfortunately, the quality of the water was deteriorating because the Schuylkill River served as a sewer for the sprawling city and for manufacturers upstream.

The first Philadelphia Water Works, designed by Benjamin Henry Latrobe, was constructed to meet the immediate need for water in 1799, because of the annual yellow fever epidemics that were decimating Philadelphia.[3] Although an example of beautiful architecture and clever design, it was never really successful beyond meeting part of this need. Costs of fuel were exorbitant, the engines and boilers were faulty, and the supply of water was neither reliable nor sufficient. A crucial need and the time factor were instrumental in the adoption of this system, and outweighed an alternate proposal to bring water by aqueduct from a distance.

It was a historic achievement for a municipality to provide water that was pure for drinking and plentiful for cleansing in the hope of alleviating the yellow fever epidemics, and the immediacy of the situation called for quick action. This was accomplished by building a steam-powered system, as opposed to a water-powered system or the construction of an aqueduct to bring water from outside the city.[4]

The man who presented the plan to the City Councils had much to do with the choice of steam power for both the Centre Square and the Fairmount systems. Benjamin Henry Latrobe was an engineer born of American parents in England. Trained in Great Britain, he emigrated to the United States and was in Philadelphia on business in 1798, when the Committee asked him to survey the situation and make recommendations.[5]

In his report, Latrobe analyzed the Schuylkill River as the best local source of pure water, but reported that it could not become useful unless "raised to an elevated level. To do this, in sufficient quantity, very powerful machinery will be required; and I am very certain that human ingenuity has not hitherto invented anything capable of producing the proposed effect with constancy, certainty and adequate force, excepting the steam engine."[6] He advised putting control "at the option of Man" and warned against a water-powered system which placed the safety of the city in the hands of vagaries of a river. He also denounced cranks as "the very worst thing in mechanism."

The drawings Latrobe presented to the Committee are elegant renditions of the Centre Square System, which consisted of one steam-powered pumping station at the Schuylkill River, connected to a similar but more ornamental pumping station containing elevated tanks for reservoirs at Centre Square, from which wooden distribution pipes led to hydrants and some houses.

The system was in operation by 1801 and provided water to the City. New distribution pipes were added each year. However, because steam engines and their boilers were recent inventions there was little relation between the estimated and real costs. Continual breakdowns occurred, fuel expense was high, and there was only a half-hour supply of water in the reservoir when the pumps were not working. In addition, the estimated revenue was well below expectations, and yellow fever returned to the city in 1802, 1803, and 1805.[8]

Although Latrobe did not remain in Philadelphia, he influenced the decision to erect a steam-powered system at Fairmount in 1812. Frederick Graff had been trained by Latrobe and worked as his draftsman for the Centre Square System. Latrobe considered Graff the first of his "eleves."[9] He was made Superintendent of the Works in 1805, when John Davis, another Latrobe protege, left to construct a water works in Baltimore.

By October 24, 1811, when there appeared to be no end to the outlay of funds for the Centre Square system, and the supply of water was dangerously inadequate, the City Councils requested a study and recommendations for solutions. Davis and Graff presented their report, which contained "ample corrobration of the opinion entertained by many of our fellow citizens, that the present plan of watering the City is miserably deficient in the essential requirements of security and economy."[10] On May 2, 1812, the Watering Committee chose a steam-powered system to be built at Fairmount.[11]

CHAPTER TWO

STEAM ENGINE SYSTEM

The land for a new municipal water system, which the City Councils enacted by ordinance, envisioned an Engine house on a water lot of the Schuylkill River near the Upper Ferry Bridge and reservoirs on the Fair Mount, or Morris Hill, directly behind it.[1] Two independently operating steam engines were to be placed side by side in the Engine House. Water was pumped from the river via a channel through an ascending main up to the reservoirs, a height of 92 feet. The reservoirs were large enough to hold 3 million gallons, there were wooden distribution mains, 6 inches inside diameter, leading to the cast-iron distributing chest located at the Centre Square Works, from whence the water would flow through already established distribution pipes to hydrants, pumps and dwellings in Philadelphia.

At this point it is proper to recognize the contribution of Frederick Graff, Esq. to the Fairmount Water Works. From the time of the adoption of his plan, Graff worked long hours in his position as Superintendent, and was active in every phase of the work. He carried on all the business relating to the construction and the operation of the new works, designed the over-all plan, and supervised the old system. On March 3, 1815 Graff resigned when the Committee failed to pay for the extra work. He was rehired at a considerable increase when no one could be found to take his position, and he served until his death in 1847. At that time the City of Philadelphia erected a tribute to him, and the Works itself was recognized as a monument to his genius.

Given the go-ahead by Councils, immediate steps were taken to construct the new works. Construction was delayed because the terrain was mostly solid rock, which was quarried and used in construction. Changes in the original plan were made, the most notable one being the decision to install two different types of steam engine side by side in the Engine House. This is a unique case where some comparison could be made of both low-pressure and high-pressure early stationary steam engines.[2]

A contract was signed on October 3, 1812 with Samuel Richards "to make and furnish all cylinders and castings which may be necessary for the constructing of the steam engine intended to be erected at Fair Mount, and also the cylinders and castings which may be necessary for the pipes of conduit," conforming to patterns, drawings and directions furnished by the Watering Committee. The engine and pump were to be delivered in three months.[3] The price was to be according to the weight of the article, ranging from $4 to $8 per cwt based on the difficulty of the casting. Some of the work was probably done at the Weymouth Forge near May's Landing which Richards operated in New Jersey, for mention is made of transporting material to Philadelphia.

Sometimes under the name of Foxall-Richards, or Weymouth Furnace, Richards had done castings for Centre Square Works, and appears to have become a specialist in cast-iron pipes. He supplied the small cast-iron cylinders used to join the wooden mains in 1802, and the larger pipes installed after 1819. Richards cast the first of the large water mains at his charcoal blast furnace; one of the earliest was displayed at the Centennial Exhibition by the American Society of Civil Engineers.[4] Graff wrote that once a month he rode 40 miles to Weymouth Forge in New Jersey to "prove" pipes.[5]

The South Engine was very impressive, with a beam measuring close to 24 feet, and was known as "the great English Engine."[6] The cost of the South Engine was $54,341, as reported in 1876 by Frederick Graff, Jr., who gave the following account of the engine:

> "The engine and pump first put in at Fairmount, which was started to supply the City September 7, 1815, was almost similar to those at Schuylkill and Centre Square Works, except that the lever beam and fly wheel arms and shafts were made of cast-iron. They were all Bolton and Watt style of that period, with poppet valves worked by handgear and tappets.
>
> The dimensions of this engine were: steam cylinder 43 5/8 inch diameter, and six feet stroke; lever beam, cast in two leaves, was 23 feet 9 inches long, between centres; the pump was double acting, 20 inches diameter and 6 feet stroke; the water was raised 102 feet above low tide; the boiler was cast-iron.
>
> The castings for the engine were made by Samuel Richards, at Weymouth Furnace, and at a foundry then situated within a forth of a mile of Fairmount. The price paid for the cylinder castings $160 per ton; for lever beams $120; for fly wheel and shaft $100, and for the cast iron boiler plates $90 per ton; the weight of the latter was 16 tons 12 hundredweight and 39 pounds.
>
> The founder reported that the castings of the cylinder (which had to be cast with nozzles for the side pipes separate) took all the metal that the "Eagle Works" would hold, viz. thirty-five hundredweight.

> "This engine, with steam 2 1/2 pounds above the atmosphere, raised 2,116,882 United States gallons, with the consumption of seven cords of oak wood; the run was for twenty-four hours, but after the first eight hours it was found difficult to keep the steam up to 2 1/2 pounds pressure, and the engine finally stopped for want of steam; the chimney flue was afterward enlarged, and then steam was carried up to 4 pounds to the square inch..."[7]

With the exception of having a cast-iron shell with a semi-circular top, the boiler was built on the plan of the wooden boiler used at Centre Square, described as being a rectangular chest:

> "made of white pine planks five inches thick; they were nine feet square inside at the ends, and fourteen feet long in the clear, braced upon the sides, top and bottom with oak scantling ten inches square, the whole securely bolted together by one and a quarter inch rods passing through the planks. Inside of this chest was placed a fire box twelve feet six inches long, six feet wide, and one foot ten inches deep, with vertical (wrought iron) flues, six of fifteen inches diameter and two of twelve inches diameter; through these the water circulated, the fire acting around them and passing up into an oval flue situated just above the (wrought iron) fire box, carried from the back of the boiler to near the front, and returned again to the back where it entered the chimney..."[8]

The original timetable could not be adhered to because of delays in construction and setting up machinery. One such difficulty was a faulty casting for the air pump. After Richards made two more unsatisfactory castings, the Watering Committee ordered an air pump from Oliver Evans' Mars Works.

On October 15, 1813 the City took legal action against Richards over the air pump. Richard's workmen were let off, and he stated that he didn't care who they got to do it. The Court found in favor of the Watering Committee and advised it to "hold up payment to cover indemnity."[9] Oliver Evans was paid $215.62 on January 1, 1814 "for air pump."[10]

The South Engine, with its boiler, pump and the ascending main was finished in August and put into regular operation on September 7, 1815. The supply of water from that time on was entirely from the New Works. The boiler and pump were leaky and defective, but repairs could not be made until the second engine was in operation. The low-pressure (south) engine worked about 12 hours at a time and used five cords of oak wood or six bushels of Virginia coal in 13 hours.

It had the capacity to raise 2,100,000 gallons of water to the reservoir in 24 hours, but did not do that because of the defects. Graff reported in 1819 that it never exceeded 1,787,000 gallons in 24 hours.[11] The engine and pump problems evidently continued, for George Escol Sellers remembered that most of the time the North Engine was used.[12]

In 1816, two of the valve seats of the pump of the South Engine gave way, so the engine was stopped while repairs were made. This entailed separating the whole and putting in new seats. Oliver Evans was paid for valve seats and other castings in the amount of $330.84 on October 2, 1816.

The repair work was carried on without intermission day and night, but it was not until September 5, 1816 that the work was finished. The North Engine, although not yet accepted for performance, raised the water to the reservoir during that time.

The North Engine was the largest non-condensing high-pressure Columbian steam engine built up to that time. It produced approximately 100 HP and was designed by Oliver Evans. The North Engine was built at Evan's Mars Works on Vine Street at Ninth Street and Ridge Road, Philadelphia, where his sons-in-law James Rush and Peter Muhlenberg were his able assistants. The original plan had been for the old engine at the Schuylkill Works to be moved to the Fairmount Engine House, but this changed in favor of the newly developed high-pressure Columbian Engine, which promised a saving in fuel as well as having a large capacity guaranteed by Evans, who would remove the engine at no cost if unsatisfactory.

It was at this point that Latrobe's influence at the Water Works was successfully contested. Latrobe had no use for the high-pressure engine and denounced it in 1808.[13] He continued to support the low-pressure design and recommended his associate, James Smallman, whenever possible. From 1813-1815 in Pittsburgh he competed openly with the Evans establishment there.[14] Evans was a sensitive man and was in the process of making his own proposals for the Centre Square System, when Latrobe appeared on the scene in Philadelphia. He indicated that it was Latrobe's fine drawings that captivated the Councils and caused them to adopt his plan.[15] The low-pressure engines that were installed in the Centre Square system were built by Nicholas Roosevelt of New Jersey, who became Latrobe's son-in-law.[16]

In any case, Evans, as representative of the Philadelphia Mechanics Community, was probably not pleased by Latrobe's remark that he could "direct" the smiths of Philadelphia so that they would be capable of proper construction of steam engines.[17] Evans was a practical mechanic who was self-taught, but understood the principles of steam engineering as well as or better than anyone at that time.[18] Graff lived on 6th Street in the heart of the Mechanics Community and had probably seen Evans' engines in operation, and they had mutual friends such as Jacob Perkins, William Sellers and Dr. Robert Patterson.[19]

A contract with Oliver Evans for the North Engine was entered into June 9, 1814, following his response to a letter of inquiry from Graff and the Watering Committee in May.[20] The contract called for:

> "a complete Steam Engine on [Evans'] principles, capable of supplying the reservoir at Fair Mount - 3,500,000 gallons of water of 282 cubic inches to the gallon, in each twenty-four hours,... to be in operation nine months from the date of execution of the articles of agreement. The whole appertaining to said engine (the pumps and lever beam, with their fixtures, wall plates and other materials for setting up the engine and removing the same from Mars Works excepted) will cost including the putting up, twenty-three thousand dollars in full compensation..."[21]

Evans guaranteed to remove the engine (except the pump and beam) if it was not satisfactory, and repay any monies. There was to be additional payment if his engine performed above contract specifications. The engine was delivered by March, 1815 and presumably went under steam at that time, and was used at intervals until it was finally accepted by the Watering Committee on December 15, 1817, a date which is given by many sources as the date of operation.

The Annual Report of 1816 states that when the South Engine's pump broke down, the Evans engine supplied all the water for the city from mid-July 1816 until September 5th, while repairs were made. Even though the Report indicates that this was quite hazardous because of difficulties with the boilers, the date of July 1816 appears to indicate the actual first use of the North Engine.

The North Engine was individually designed for Fairmount and differed from other Columbian engines. It had a 20 inch cylinder with a rotating steam valve, worked by bebel gear wheels, driven from the main shaft. There is a difference of opinion concerning the stroke of the piston and the pumps, whether it was 60" or 48". A possibility exists that adjustments were made after intallation. The Graff drawing of the North Engine differs in some particulars from other records and has not previously been available.[22] The description given by Evans' biographer is based mainly on the scale model of the engine which is in the Franklin Institute:

> "The cylinder of this engine was 20 inches in diameter and 60 inches in stroke, the arrangement of the engine being slightly different from the standard Columbian, for in this case the piston rod was attached to one end of the beam and the suspension links or vibrating arms, to the other. The connecting rod and crank-shaft were placed as near to the cylinder as was convenient for turning over. Two radius arms forming the parallel motion which guided the piston rod were used but it would appear that this engine had also a strong bracket raised above the cylinder to steady the motion of the beam from any side movement."[23]

According to the Annual Report of 1852, the pump was a vertical double-acting force pump with 20" diameter and 48" stroke, attached to the "grasshopper" beam probably close to the upper end of the connecting rod bearing.[24]

To give an idea of the massiveness of this 100 HP engine the following list made by Evans indicates the weights of cast iron parts:[25]

6 segments (fly wheel) 1254 lbs. ea.		7524
6 arms (fly wheel) 620 lbs. ea.		3720
Working cylinder		3252
Valve seat		1602
	lbs.	16,101

The boiler for the North Engine consisted of four cylinders made of wrought iron plates, where pressure was at times carried at two hundred twenty pounds per square inch, although this was not considered safe. There is also some doubt as to the size of the boilers. The Annual Report of 1852 lists them as 30 inch diameter and 24 feet long, while Graff Jr., in his Notes Upon the Water Works states they were 27 inches in diameter and 27 feet long.[26]

The engine's acceptance was delayed because the boilers were constructed of numerous wrought iron plates and it was difficult keeping the laps of the plating water-tight. The rivets worked loose by the constant expansion, contraction and sagging of the long boilers, and the fire beneath was often put out by escaping steam. By the end of 1816 this was solved by applying rust cement.[27]

Because of controversy between Oliver Evans and the Watering Committee over the engine's performance, there are three sets of statistics on its operation from the three contract tests in 1817.[28] The final test by the Watering Committee on November 26 and 27, 1817, which acknowledged that Evans had fulfilled his contract, confirmed that the North Engine's capacity was 3,556,401 gallons in 24 hours, with 100 gallons raised 98 feet at each stroke, and 24 3/4 strokes per minute. The fuel consumption was ten cords of oak wood in 20 hours.[29] However, Graff Sr. indicated in 1819 that only 2,300,000 gallons could be counted on with safe operation of the machinery.[30]

There was good cause for Graff's concern about safety because the boilers exploded twice, on June 20, 1818, and again on October 12, 1821.[31] The explosion was probably caused by an insufficient level of water in the boiler, which was dependent upon the proper action of a small plunger pump. If it failed, the weight of the many-jolted boilers, held together by rivets, caused them to sag and break when overheated.[32] Repairs amounting to $833.33 were promptly made by Evans at the City's expense, and there were no repercussions.

Explosions of steam boilers were not uncommon, but occurred in large part on ships, and caused the City Councils in 1817 to appoint a committee to determine the causes, which in turn recommended such a study to the State legislature. Nothing resulted from this, but from 1830-1835 the Franklin Institute in Philadelphia conducted such an investigation in cooperation with the Federal Government.[33]

Although the two engines were able to keep the reservoirs filled with water, there was no let-up in the cost of operation. In addition there was a need to add a reservoir and increase distribution lines. In 1819 Graff reported that he estimated $30,858 to be the annual cost of operation of either engine raising a load of 2,300,000 gallons in 24 hours:[34]

Six men to work and keep the engine in repair, @ $9.75		$ 3,558.75
For tallow, oil, chandlery, etc.		1,250.00
3,650 cords of wood cordage and hanking @ $7		24,550.00
Wear and tear of machinery		1,500.00
	Total	$30,858.00

If more water was desired, he said an additional main could be constructed from the Engine house to the reservoir, so that both engines could pump at the same time, but then the annual expense would be doubled.

This cost was very far from the estimate made in 1811, when the total cost for Fairmount Works was given as $148,938.54 and the annual operating cost as $17,296.31.[35]

The distribution system which the Fairmount Works inherited from its predecessor consisted of spruce and yellow pine pipes from 3" to 6" inside diameter, and had grown to over 32 miles by 1817. Leakage had been somewhat lessened from the earlier experience by using short sections of iron pipe called "connectors" to join the logs, but it was soon evident that it was not possible to utilize the new system to its fullest unless better distribution could be made.[36]

As early as 1816, investigations were undertaken to overcome the problem of contraction of the metal at the joints if cast-iron pipes were laid, and in 1817 this investigation continued. In a letter to Joseph Lewis requesting that information be obtained from England on cast-iron pipes, Graff described the entire distribution system then in operation:

> "The works which supply Philadelphia with water stand 1 1/4 miles from the center of the City, or what is called Centre Square in a northwest direction from the same. The water raised from the Schuylkill River by means of Steam Engines, and forced into the Reservoir which stands on an eminence called Fair Mount, distant from the river about 400 feet, the average height the water is raised is 98 feet. The Reservoir covers near an acre and a quarter of ground, and contains 3,264,126 gallons beer measure, which is sufficient for the present supply of the City for nearly 4 days. From thence the water is lead to the Centre Square distant one and a quarter miles through 5 mains of 6 inch bore and one of 4 1/2 inches. Those are found scarcely sufficient owing chiefly to the unfavorable ground through which they pass, together with the many turns at right angles, and in the friction in wood pipes of such small diameters. At the centre square the water enters an Iron chest to which the mains that supply the City are attached. As the supply of water through the City is continual, the pipes are generally connected at the intersection of the streets, and an entire distribution of water flows at all times through that part of the City in which the pipes are laid. The parts of the City now improved and supplied are from the Delaware River to the Centre Square, and from Vine to Cedar Streets, begin the boundary lines of the City north and south, on which extent there are now laid upwards of 32 miles of pipes, of 3 inches, 4 1/2 inches, and 6 inches bore. The pipes at the Iron chest at Centre Square are under a head of 56 feet and the the average pressure on the pipes through the city is 65 feet-the greatest head which is in Water and Dock Street is 84 feet. The number of houses and

> manufactories now supplied are about 3,500, together with upwards of 300 cistern pumps placed in the streets for public use. The average quantity of water flowing to the City in each 24 hours is near 900,000 gallons."[37]

There was a water shortage in the City in the summer of 1818, for even though the reservoir was full and the engines at work, it was estimated that only one million gallons in 24 hours was able to be distributed to the city because of the small pipes in the "imperfect plan upon which the pipes were originally laid down." In October 1818, Graff made a detailed report to the Watering Committee in which he recommended the adoption of cast iron pipes, and this was done January 26, 1819 by Councils.[38]

Another difficulty was the bursting of the pipes, described by Graff in a letter to Joseph Lewis on July 14, 1819.[39] Since a major problem had been the small quantity of water that reached the City through the main--a series of five 6 inch pipes and one 4 1/2 pipe--these were replaced by a 20 inch iron main laid from the Reservoir to Broad and Chestnut Sts. At the same time it was decided to abandon use of the distributing chest at Centre Square, marking the end of the building's usefulness to the water works. The spigot and faucet joint which was not standard in cast iron pipes, with curved pipes for going around corners, made the installation a successful solution to the major problems of distribution. The expense was especially high during the years following 1819, but with sufficient water and an increase in the length of distribution lines, there now could be an increase in revenue, which eventually would mean a profit for the City.

The reservoir which was planned for Fair Mount had been completed in 1815, containing 3,264,126 gallons beer measure in 1817, and its capacity was increased in 1818, adding half a million gallons.[40] The water remained in the reservoir for at least a day before distribution, so it operated as a sedimentary basin to some extent. When the 20 inch cast-iron main was installed, a funnel-shaped pipe of 30 inches tapering to 22 inches was placed at the outlet of the reservoir, which added to its efficiency. The main became 20 inches after a distance of 2,661 feet.

The continuing growth of the city was evident and more water would be needed. At the same time as information on iron pipes had been sought in England in 1818, inquiry was made about the purchase of another steam engine, with the idea of adding an ascending main and reservoir so both engines could work at once. It is unknown which engine was to be replaced, but the correspondent strongly favored the Boulton and Watt design.[41]

Yet the system was only as good as its parts—and once again the Watering Committee looked for an end to the continued expense of operating the steam engines, while providing additional water.

There was a limited number of choices. The Committee again investigated the use of water power, which had been one of Graff's proposals in 1811. The Report of the Watering Committee on the River Schuylkill was presented to the Councils on February 5, 1819. They reviewed the fact that Latrobe in 1799 had believed there was insufficient water power within a reasonable distance of the

City, and that in 1811 the estimate of $359,718 necessary to obtain power from the Wissahickon was considered too costly.

There had always been a tension between proponents of different types of power, and the report stated:

> "The constant and great expense attending the Steam Engine, and the vexation occasioned by repeated accidents, have always been present to the Watering Committee, who have ever thought water power should be resorted to if practicable. [The Committee is] gratified that they now have it in their power to say that the object so long desired may be accomplished, and at an expense less than upon any occasion heretofore counted upon."[42]

The element that had changed related to the activity of the Schuylkill Navigation Company, which was incorporated under an act of the General Assembly of the Commonwealth on March 8, 1815, "to make a lock navigation on the river Schuylkill."[43]

Local interest in internal improvements was reflected in the attempt once more to provide a navigable route to the interior of Pennsylvania, this time using the river itself, with canals and locks and dams to by-pass different portions of the river. The rights to build dams and to harness the waterpower for use, leasing or selling was also granted. The company had proceeded downstream from the source of the river near Pottsville, with "improvements" as far as the Falls of the Schuylkill.[44] There Josiah White and Joseph Gillingham had rights to the water power.[45]

The Watering Committee realized it must act immediately if it was ever to utilize water power. "It is concerned, that Councils should not reject a plan so long sought for; hitherto unattainable; and if now suffered to escape from our grasp, never to be reclaimed."[46] The Schuylkill Navigation Company, in need of funds to finish the project and make the whole system operable, was agreeable to the City's building a dam and using the water power at Fair Mount, if a canal and locks were also built for navigation, the tolls to be paid to the Company. White and Gillingham were agreeable to the purchase of their water rights by the City for $150,000.

After the presentation to Councils of a detailed report on March 8, 1819, which contained specific proposals to construct a new water-powered system to provide water for the Fair Mount Reservoir, the Councils voted unanimous approval April 8, 1819.[47]

For the Watering Committee, the use of steam engines had been a noble experiment, but although water was provided as promised, it was always at too great a cost. Now the City reverted to the use of an older power source, but in so doing incorporated what had been learned of hydraulic engineering and benefitted from the distribution system already established.

"The majestic steam engines had made a mighty effort, but they were retired when the new system took over on the 24th of October, 1821, the steam engines were stopped and it is believed will never again be wanted."[48] For a short time the engines were kept in repair in case of an accident to the dam or other equipment. In 1831 they were offered for sale even though in a state of despair:

> "...these articles are daily depreciating; nay they are not now of much more value, beyond that of old iron. In no event could a part of them be at all used, and were the remainder repaired, it would be at much cost..."[49]

The two engines were sold at public sale on May 10, 1832 for $5,523.75. Councils is appropriated the funds to buy some land adjacent to Fairmount and to pave and put curbs on Fairmount Street.

With the removal of the engines, the Engine House was so dilapidated that it was recommended the building be torn down. The Councils, however, with a successful operation by 1833, and having established a parklike setting for the Works, decided to repair the "steam engine building" in a manner "suited to the character of the works, for the convenience of strangers and the public, who visit the place, and for tenements for the workman who have charge of the pump machinery."[50] The change from a utilitarian building was complete by 1835 and the Engine House became known as the Saloon or Hall, and later the Graff Mansion.

The North and the South Engines had been replaced. Oliver Evans and Benjamin Latrobe had died but Frederick Graff carried on.[51]

CHAPTER THREE

BREAST WHEEL SYSTEM

The plan which the City adopted for a water-powered system featured the construction of a dam across the Schuylkill River just above the Engine House at Fairmount, with a canal and locks on the west bank and a mill race and mill house on the east bank. The cost was estimated to be $346,000 and the annual cost estimated to be minimal when the system was operational. Using water power, ten million gallons could be raised in twenty-four hours for half the cost of raising two million gallons under the existing sytem, and the surplus water could be sold to districts outside the city limits.[1]

The height of the dam was governed by the agreement with the Schuylkill Navigation Company permitting the city to raise the water only as high as would have been done at the Falls by White and Gillingham. A dam would back up the river for six miles, forming what came to be known as the Fairmount pool directly above the dam, and the city was responsible for damages to those whose property was affected. Thomas Oakes, who advised on much of the construction, figured the flow of the river to be 70 million gallons in twenty-four hours, with a fall of 5 feet, which provided ample power and pumpage.[2] The figure of 440 million was given at a later date.[3] An additional consideration in planning was the tidal rise and fall in the Schuylkill, which made a difference of 6 feet in the water level below the dam.

A contract was signed with Captain Ariel Cooley of Chicopee, Massachusetts, whose proposal was favored over others submitted, including that of Oakes. Cooley started work on April 18, 1819 to build the dam, canal and locks, head arches and mill race for the sum of $150,000, with $4,250 added when the height of the dam was raised 18 inches in 1820. Most of the river bed was rock, but the depth varied. The dam was designed as an over-fall and was 1,204 feet long, built of cribs of hickory logs filled with stone, which were sunk in the river and fastened to each other and to the rock bed.[4] At the eastern end there was a stone pier joining it to a mound dam 270 feet long and 150 feet at the base, 12 feet at the top, which was 15 feet higher than the over-fall dam and was built on the part of the river bed that had 11 feet of mud above the rock bottom.[5] Beyond this were three head arches 104 feet overall, at the entrance to the mill race which had to be cut out of solid rock.

Cooley's dam crossed the river diagonally, upstream, turned at an angle near the western shore, providing a large over-fall, and joined the head pier of the canal guard locks at a right angle. This design helped protect the dam from injury from ice and freshets, both of which Latrobe had feared. During and after the construction, there were questions about the dam's structure and reliability. It was repaired and rebuilt several times, but was never breached.

During some of these repairs, workmen were amazed that the structure still held.[6] The last crib of the dam was put in place June 25, 1821 and the first water flowed over it Sunday morning, July 23, 1821.[7]

The mill race, running parallel to the river, and the foundation of the mill house were blasted out of solid rock to a total width of 140 feet. The mill race was 419 feet long, 90 feet wide, and from 16 to 60 feet deep, allowing continual passage of 408 square feet of water to the forebays of the wheels.

The lower section of the mill building was divided into "apartments" for 8 forebays and 4 pump chambers, and were heated in winter to prevent icing. Only three wheels were installed initially. Additional space was provided for future growth because the cost of expansion later would have been considerable and would have necessitated stopping the wheels -- and the supply of water to the city -- during construction.

Here again, Frederick Graff's significant contribution to the Fairmount Water Works should be noted. The Watering Committee assigned him to cooperate freely in the building of the new Works. Returning in April, 1819, from purchasing timber for the dam:

> "Graff became concerned that no specific plan or design was adopted with regard to the buildings, or the location or form of any part of the works, excepting the dam and the water wheel, the form of the latter of which was given by Mr. Oaks... [Graff became] uneasy, and fearing the general outline of the works had not been properly digested, commenced drawing plans for the same, and making models..., which when completed were approved of and

> adopted by the Watering Committee, who instructed [him] to enter into agreements for their construction, and to procure materials for the execution of the works. From this period until the works were finished, in December 1822, [he] had the sole charge (under the authority of the Committee) of directing the works under contract, as well as the management of all other parts connected with them. [Graff] gave all the designs and superintended their execution, for the canal and locks on the west side of the river, the forebay, head arches, and their gates, and the reservoir on the east side of the Schuylkill, the mill buildings, the pumps, mains, and all other parts of the works, excepting the wheels, and the mill machinery, and the dam."[8]

The mill house was sectioned off so each wheel had its own forebay from which both the water for power and for pumpage was taken. Each wheel powered a double acting pump, two of which were placed side by side in a pump chamber. A sixteen-inch iron main from each pump was laid on the bottom of the mill race to the foot of the Fair Mount, where it ascended to the reservoir above, with a stop cock at the top so that it could be shut off.

As part of the system, a New Reservoir (No. 2) with a capacity of 3 million gallons was constructed in 1821 at the crest of the hill, west of the Old Reservoir (No. 1) which contained 4 million gallons. The new mains were connected directly to this New Reservoir, from whence the water flowed through two 20-inch pipes into the Old Reservoir for distribution. Later it was noted that because No. 2 was a receiving reservoir, it collected more sediment than the others on top of Fair Mount. The reservoirs were 102 feet above low tide and were 56 feet above the highest ground in the city.[9]

To complete the system, Graff worked out a distribution plan for the city based on his 1818 proposal, replacing all wooden pipes with iron. This was presented to the Councils in a Report dated November 22, 1821. To support the request for a complete change, the Report stated, "Since the iron pipes, upon the present plan, have commenced to be laid, no instance of a leak has occurred."[10] The Annual Report of 1854 commends the distribution arrangement, calling it "very perfect," noting that it was done before any other distribution system in this country.[11]

By 1843 the mill house contained the full complement of eight breast wheels, the original three made of wood and the remaining five of cast iron, and in 1846 the first three wheels were re-built. One of the features of the building, which was opened to the public, was a gallery "extending the length of the building, from which all the wheels may be seen at one view."[12] The year 1822 saw the beginning of the Fairmount system that was to become famous throughout the world for its beauty and efficiency. It rivalled the water systems of the ancients and was considered a pattern for municipal water works. In subsequent years Graff gave detailed information to more than 37 organizations about erecting water works.[13]

The water flowed from the mill race into the forebay of each wheel. Two intake pipes for the pump were located on one side, and the sluiceway was at the end, placed at the angle considered most advantageous for impact on the wheel. The water struck the wheel under a head of one foot and the fall was seven or seven and a half feet, depending on the diameter of the wheel. The bottoms of the wheels were placed two feet below high water, which was lower than was customary, but they were not affected by back water until it reached sixteen inches on the wheels, which caused them to lose only 64 hours in a month. The most efficient operation of wheels, if the water supply is limited, is to work from just before low water to just before high water.

The first three wheels were made mostly of "good white oak," as recorded by Graff.[14] The plans of these wheels are nowhere specifically given, although it is known that Thomas Oakes was the designer, but a Graff study drawing of wheels contains notations in the corner listing the wood used in Wheel No. 1 constructed by Bromley and Oakes, and this is probably also the wheel as constructed, for it is consistent both with an 1827 illustration in the Journal of the Franklin Institute and with the drawings of the re-built wheels in 1846.[15] They were magnificently large with a diameter of fifteen or sixteen feet and their width was fifteen feet. The three wheels were built by Millwright Drury Bromley for $9,721.95 and all three were operational by the end of 1822.[16] The dates when they began to supply the city with water were Wheel No. 1: July 1, 1822; Wheel No. 2: September 14, 1822, and Wheel No. 3: December 24, 1822.

The shafts were of iron weighed five tons each, and Reeve and Lewis were paid $1,970.51 for three mill shafts. The wheels weighed twenty-two tons each. "The great size and weight of the wheel give it a momentum which adds greatly to the regularity of its motion, so necessary to preserve the pumps from injury under so heavy a head as they are required to work, which is a weight of 7900 lbs., the height 92 feet."[17]

The following chart shows the relevant facts about each wheel at the start of operations in 1822 according to the Annual Report of 1822, where it was assumed that Wheel No. 2 could be improved to the standard set by Wheel No. 3.[18]

Each wheel worked a pump by a "crank on the water wheel attached to a pitman connected with the piston at the end of the slides."[19] Although they were fitted for a six foot stroke, experience showed that four and a half or five feet was better.

The pumps were designed by Graff and built by Rush and Muhlenberg, who had taken over the Mars Works of Oliver Evans. Daniel Large, who had worked with Graff repairing the pumps in 1816 in the Engine House, disputed Graff's claim of designing the pumps and Graff had to defend his priority.[20] Graff differed from Thomas Oakes whose plan of the buildings shows perpendicular pumps, similar to those used in the Engine House.[21] Graff placed the pumps in an almost horizontal position which worked so well that this became the standard arrangement at the Works until 1860. Graff also designed the valves and the valve seats.[22] The contract price for the three pumps was $11,000.

The Annual Report for 1823 was exuberant. The new system worked perfectly, costs were down, and there was plenty of water. It took only two men on 12 hour shifts to operate the machinery at a cost of $4 per day, and the efficiency of the wheels was found to be 30 gallons needed to pump one gallon into the reservoir, instead of the estimated 40 gallons, raising the water power by one-third. In July an experiment showed that plenty of water was supplied by two wheels even though four fire plugs were in constant use to wash gutters for 18 days. When the wheels had to be stopped for three days in December because of a freshet, there was sufficient water in the reservoir to supply the city, and the reservoir was quickly replenished after the turbulence had died down. As of December 1823, the whole cost of the works was $432,512.

Wheels No. 4, No. 5 and No. 6 were designed by Graff and made of cast-iron. Instead of the wheel being braced by sets of parallel timbers at right angles, Graff use eight cast-iron "arms" as spokes around the hub of the wheel, and there were forty buckets made of wood.[23] These iron wheels differed from one another mainly in their diameter, with corresponding changes in other parts related to that measurement.[24] The wheels were contracted for and installed individually, as the need became apparent. Wheel No. 4 was built by Rush and Muhlenberg, who also contracted for the pump, to be executed according to the drawings of the Watering Committee.[25] The price of the wheel was $4,500 and the pump, $3,667. The city was to "find" the cast-iron shaft. This was already on hand in case of an accident to a wheel, and was cast in 1825 by William Kemble of the West Point Foundry in Cold Spring, in New York for $633.69. After the wheel was completed, Rush and Muhlenberg discovered their cost would not even be covered, and requested an additional payment from the city of $669.34.[26] There is a notation of $95.50 paid them "for extra work not in the contract." but no other record of payment.[27] Rush and Muhlenberg continued to supply castings and to make repairs on the machinery at Fairmount for many years.

Wheel No. 4 was put in operation November 10, 1827,[28] and measured 18 feet in diameter, 15 feet in length, with a stroke of 6 feet and 11 revolutions per minute, capable of pumping 1,689,000 gallons to the reservoir in 24 hours. Waiting on the Fair Mount, ready to receive the additional supply of water, was the newly-constructed Reservoir No. 3, with a capacity of 2,707,295 gallons.

By 1830 there had been a "constant supply of wholesome water without one day's intermission" since the wheels began turning, and the decision to build Wheel No. 5 was made following the connection of a new main from the reservoir to Chestnut and Broad Streets on December 17, 1829.[29]

A contract for No. 5 was signed with Levi Morris, using Wheel and Pump No. 4 as models, at the price of $4,4300 for the wheel and $3,100 for the pump. The contract specified that the pump's connecting rod was to have an additional bar in the center.[30] Graff handed the working drawing of the wheel to Levi Morris on March 21, 1831.[31]

The wheel was to have been ready in October 1831, but there was some delay in the delivery because it was difficult to obtain materials and some defective castings were condemned. Finally Wheel No. 5 went into operation April 5, 1832, just in time to allow extensive use of water to cleanse the streets during a cholera epidemic that summer.

There was a "hot season" in 1832—a time when larger amounts of water were required--and the Watering Committee in 1833 immediately recommended the addition of Wheel No. 6, especially since Wheels Nos. 1, 2, and 3 were getting old. On March 25, 1834 a contract was signed with Levi Morris and Co. to build Wheel No. 6 and its pump for $7,900.[32] The wheel and pump were to be on the same design as Wheels No. 4 and 5. The wheel, however, was to be 16 feet diameter.[33]

New distribution lines and water storage facilities were also being added to the Fairmount system. By 1834 the Works was supplying the City and four districts with water, which made it a very profitable enterprise. In the following two years a new reservoir was built in three sections adding a total capacity of over 12 million gallons to the existing reservoirs.

On November 5, 1834, Wheel No. 6 went into operation, and its excellence was praised by the Watering Committee for giving "...perfect satisfaction, and it is believed that this work excels any other of the kind that has been executed at Fair Mount."[34]

The process of using the same design for the three wheels over a period of 8 years enabled Graff to work out problems, and Levi Morris to reach the perfection indicated. It was an unusual situation to have space provided at the Works for the extra wheels so that research and development could take place on the spot. Graff took full advantage of the opportunity. There may have also been some advantage from the Franklin Institute's investigation of the efficiency of water power undertaken in 1829, involving members of the Mechanics' Community in Philadelphia. Although initially it had been thought to utilize the facilities at Fairmount for the investigations, experiments were conducted in specially constructed sheds under controlled conditions.[35]

By the end of 1835 the system was working so well that the Watering Committee could not contain itself and uttered a paean of self-praise. Not only was there plentiful water at a low cost, with revenue coming to the city from the districts, but the Works had become a showplace in a parklike setting where the world came to marvel and to pay homage to Philadelphia's greatness. Latrobe still had an influence over the Works, but only in the architectural design which was splendidly Greek Revival. Even the Old Engine House, devoid of its engines since 1832, had taken on a new life as a Public Saloon.

> "The Committee flatter themselves that their expenditures have been judiciously applied, and the work done was actually necessary to insure a constant supply of water, and a gradual addition to the ornamental part of the Works, so as to make them not only important for their utility, but to hold their rank as a master work in hydraulics."[36]

The contract for the final pair of wheels, No. 7 and No. 8, was given in February 1843 to Merrick & Towne for $15,000. The concern of 1832 over whether there was enough water for two more wheels appears to have been forgotten.[37] The wheels were 18 feet in diameter and of the same design as the other cast-iron wheels. However, the working drawing has the notation, "arrangements for wrought iron cast."[38] The pumps had become standard items by this time and are not mentioned. The wheels were speedily prepared and were in operation August 24, 1843.

Financially the Works was in excellent shape. In 1841 the amount of revenue over expense had been $100,839.50. The attempt to negotiate with the Schuylkill Navigation Company to raise the dam by 18 inches had been abandoned in 1841; steps were taken to rebuild the dam from low water mark which was finished by December 1843.

The Annual Reports of the next few years take up the question of the old Wheels No. 1-2-3 and indicate what did <u>not</u> happen: a turbine wheel was not installed, and Wheel No. 1 was not replaced by a cast-iron one similar to Wheel No. 8, as was proposed. Although bids were submitted, because the appropriation was only $5,000 instead of $8,000, the three wooden wheels were temporarily repaired in 1845 and plans were instigated to rebuild them in 1846.[39]

The contract to replace Wheels No. 1, No. 2, and No. 3 and their pumps with wheels of the original design was awarded to I.P. Morris & Co. February 9, 1846, and they were paid $14,545. The woodwork and breastings were done by Edward Heston. There is a working drawing of the re-built wheels in the Graff Collection at the Franklin Institute, and a record drawing at the Philadelphia Museum of Art.[40] Two of the wheels were in operation July 15, 1846. The final one, which was the last breast wheel ever to be installed at Fairmount, went into operation on Frederick Graff's 72nd birthday, August 27, 1846.[41]

All the contracts for wheels were awarded to firms having long established ties with the Mechanics' Community, although there were inquiries and bids from smaller firms, some from men who had worked on earlier installations wishing to go into business themselves.[42] The choice of manufacturers may have been the result of specialization or it may have led to specialization, as in the case of the I.P. Morris Co. Port Richmond Works, which became expert in providing equipment for large hydraulic systems.[43]

The men of the Mechanics' Community and the Franklin Institute were interested in what was happening at Fairmount, where professional and civic interest coincided. This also affected the quality of the men serving on the Watering Committee, who might have self-interest at heart, but were also interested in Philadelphia.[44]

The relationship of the Watering Committee with other groups in the city has not been fully established. However, these were prominent men in positions of authority. For example Joseph S. Lewis, who as chairman from 1817 to 1825 favored the water power development, negotiated hard and successfully with the Schuylkill Navigation Company and in 1825 became President of that company and entered into an adversary relationship with the Works.[45]

The water power system as it had been established in 1822 was able to withstand the onslaughts of nature and was justly considered a pattern for other cities. Conditions had ranged from severe droughts to extreme freshets, but the wheels had continued to turn and provide water to the city. In 1838 water was so low in the river that Graff considered altering the gates to work the wheels undershot.

The ice freshet which occurred January 26, 1839 caused the water to rise ten feet perpendicular over the dam, and "completely inundated all the pumps and machinery," but the "wheels and pumps were in operation less than 24 hours after it subsided."[46]

The attacks of men on the system were equally threatening. The Schuylkill Navigation Company acted to promote trade and its profit, interpreting agreements with the City without due regard to the interests of the citizens who were fully dependent on the water level of the river for their water supply. Manufacturers upstream channeled waste to the river, as did the local citizenry. Campaigns against waste of water were mounted as the dry season of August-September came around.

The forethought which had provided space for eight wheels in the Mill House had been extended to the construction of four reservoirs on Fair Mount and continual extension of the distribution system. From 1826 the Fairmount Water Works supplied water not only to the city, but to neighboring districts outside which were charged at twice the rate of city taxpayers.[47] The reservoirs which served Fairmount had been built as a part of the system, and were interconnected with one another, covering six acres. They contained a total of 22 million gallons and were twelve feet three inches deep, being 96 feet above the dam.

The rise in consumption from 4 million gallons in 24 hours in 1836 to 7 million gallons in June, 1849 indicated that problems were developing regarding supply. With the reservoirs holding only 22 million gallons, there was "scarcely a sufficient surplus to admit of the subsidence of the earthy matter, sometimes contained in the water, after spring freshets, in the Schuylkill."[48] Two large 20-inch mains served the city, but it was evident a new one would be needed.

The financial picture was favorable beyond the fondest hopes of the Watering Committee. Although the installation of new equipment or repair work might cause one year's expense to be heavy, the Works generally operated at a low figure. With the non-accrual type of accounting, revenue exceeded expenses after 1830, this amount being $109, 933 in 1841 and a high of $121,788 in 1844. Chart # 1 shows comparative figures of the revenue and expenditures from 1817 to 1849.

Chart # 1
STATISTICS RELATING TO FAIRMOUNT WATER WORKS 1822-1851
(Source: Annual Report, 1851)

Year	Amount paid into the Treasury	Amount of Expenditures	Number of tenants	Average daily supply of water in ale gallons
1822	$25,485.50	$106,517.82	4,758	- -
1823	26,013.09	69,268.54	4,844	1,616,160
1824	26,574.20	82,208.94	5,061	1,473,200
1825	27,299.18	44,307.37	5,470	1,280,700
1826	29,764.64	73,517.40	5,879	1,400,000
1827	37,558.27	80,749.92	6,204	1,340,000
1828	46,475.61	64,150.64	6,775	1,690,000
1829	52,313.17	81,180.06	9,633	1,800,200
1830	68,918.27	35,660.84	10,143	2,020,100

Chart # 1 (cont.)

Year	Amount paid into the Treasury	Amount of Expenditures	Number of tenants	Average daily supply of water in ale gallons
1831	65,694.62	63,009.57	11,386	2,420,000
1832	3,019.81	65,195.58	11,646	3,000,200
1833	79,437.01	37,354.06	13,472	3,288,100
1834	85,258.15	65,163.36	14,204	3,400,100
1835	92,116.82	73,288.38	18,704	3,364,625
1836	101,266.39	71,706.51	19,674	3,422,664
1837	105,870.92	49,730.10	20,462	3,456,383
1838	109,826.06	50,642.29	21,947	3,850,647
1839	121,099.87	24,742.39	22,636	3,978,357
1840	126,074.51	22,452.44	23,482	4,034,638

Chart # 1 (cont.)

Year	Amount paid into the Treasury	Amount of Expenditures	Number of tenants	Average daily supply of water in ale gallons
1841	134,634.67	24,701.75	24,828	4,445,630
1842	139,682.97	63,911.40	25,816	4,297,480
1843	144,765.74	63,171.84	26,549	4,422,400
1844	151,501.37	29,713.35	28,082	5,330,455
1845	92,226.79	25,891.93	20,165	4,117,559
1846	100,200.26	50,771.29	21,551	3,492,963
1847	110,505.17	34,316.18	22,789	4,075,682
1848	117,976.36	49,580.32	24,230	4,275,552
1849	125,511.41	84,576.74	25,670	4,421,190
1850	132,592.31	131,826.22	27,550	4,785,338
1851	140,313.50	92,380.19	29,014	5,690,774

The Fairmount Water Works had become known throughout the world, and travelers came to observe the machinery and to enjoy the gracious buildings and scenic grounds. Alexis de Toqueville's analysis of the American workmen's attitude was well illustrated: "the will habitually prefers the useful to the beautiful, and they will require that the beautiful should be useful."[49]

Another observer was Thomas Ewbank, a writer on technical subjects, who visited Fairmount in October of 1840, and was most enthusiastic in his description of the Works.

> "Six breast wheels (15 feet long and 16 feet in diameter) were in operational; each, by a crank on one end of the axle, communicating motion to the piston rod of a single pump. (What a contrast with the old works at London bridge, where one wheel worked sixteen small pumps; the friction of the numerous pistons and the apparatus for moving them consuming a great portion of the power employed). The pumps are double acting...They are placed a little below the axles of the wheels and in nearly a horizontal position. The cylinders are 16 inches in diameter; and, that the water may not be pinched in its passage into and escape from them, the induction and education pipes are of the same bore; and all angles or abrupt changes in their direction and those of the mains are avoided. The stroke of two or three of the pumps was four feet, and their wheels made fourteen revolutions per minute; the others had a stroke of five feet ten inches, and the wheels performed eleven revolutions in a minute, consequently the contents of the cylinders of the latter were emptied into the reservoirs twenty-two times in the same period, and those of the former twenty-eight times. The cylinders are fed under a head of water from the forebays and they force it to an elevation of 96 feet, through distance of 2900. An air chamber is adapted to each.

It is impossible to examine these works without paying homage to the science and skill displayed in their design and execution; in these respects no hydraulic works in the Union can compete, nor do we believe they are excelled by any in the world. Not the smallest leak in any of the joints was discovered; and, with the exception of the water rushing in the wheels, the whole operation of forcing up daily millions of gallons into the reservoirs on the mount, and thus furnishing in abundance one of the first necessaries of life to an immense population -- was performed with less noise than is ordinarily made in working a smith's bellows! The picturesque location, the neatness that reigns in the buildings, the walks around the reservoirs and the grounds at large, with the beauty of the surrounding scenery, render the name of this place singularly appropriate."[50]

The year 1847 marked the end of an era at Fairmount, for Frederick Graff, Esq. died on April 13, 1847, at the age of 72, having been Superintendent of the Works since 1805. The City Councils immediately reacted by appropriating $2,000 for a monument to be erected on the Fairmount Grounds, where it remains. The real monument to Graff is the Works itself.

CHAPTER FOUR

TURBINE WHEEL SYSTEM

The Fairmount Water Works in 1851 entered a new era of technology. The aborted attempt to install water turbines was resurrected and the technology of the old breast wheel could not delay the efficiency promised by the newer turbine wheel.

When Frederick Graff, Jr. became Superintendent of the Works in 1847 at the age of thirty, he began to investigate the possibility of installing a water turbine in the Mill House, even though during 1846 Wheels No. 1,2 and 3 had been completely re-built. The earlier plan to place a turbine wheel in the space occupied by Wheel No. 1 as a demonstration wheel was no longer practical. In order to plan for eventual conversion, some alternative had to be developed to convince the Watering Committee of the value of the newer technology.

In the early 1840's there had been a great deal of interest in the "new kind of wheel." It had been developed earlier in France by M. Fourneyron, but was not explained in America until a translation of French journals appeared in the Journal of the Franklin Institute in February 1849.[1] This "turbine wheel" claimed to be more efficient that a water wheel because the water acted simultaneously on several curved blades, or "buckets" instead of on one at a time, and it could work submerged so it did not have to stop because of backwater.

Fourneyron had invented his hydraulic turbine in 1827 but in 1828 Austin and Zebulon Parker of Ohio had developed a "reaction wheel" that was similar in some respects.[2] Ellwood Morris, an engineer active in the Franklin Institute, became interested in reaction wheels in 1833 and later became an advocate of the turbine.[3] In order to overcome general satisfaction with the traditional water wheel and to promote the newer technology he wrote articles for the Journal of the Franklin Institute in the Fall of 1842.[4] First, hc reported the reaction wheel to be superior to the undershot breast wheel in backwater, and he recommended highly the Fourneyron turbine which could perform with uniform effectiveness of 75% with any fall of three feet or more.[5]

The design was especially suited to the conditions at Fairmount, which Morris specifically discussed in his article of November 1842.[6] He illustrated how turbines could elevate 50% more water than the breast wheels, and 87% more if a pit were excavated to make the turbine lower and obtain a greater fall.

> "As the day is not far distant when the amount of water required to feed the breast wheels and their pumps, which now supply the city of Philadelphia with water for use, will equal in quantity the entire summer flow of the Schuylkill River -- clear of the leakage of Fairmount Dam, and of the amount

> necessary for the navigation -- it must be a gratified reflection to the citizens that when that day does come, all they have to do is use the beautiful invention of M. Fourneyron, discard all the breast wheels, and subsitute turbines in their stead, whereby their supply of water will be at once augmented by at least one half."[7]

Morris concluded with a list of twelve advantages promised by the use of turbines.

Following the publication of these articles, Morris conducted experiments on two turbines, built by Merrick & Towne to his plan, and installed at mills on the Brandywine River. He reported the results to the American Philosophical Society on May 30th and in the Journal of the Franklin Institute in December, 1843.[8]

The Watering Committee in 1842 had been authorized by Councils to add two more wheels at Fairmount. However, in January of 1843, there were discussions about installing a turbine. On January 31, Graff wrote a letter to the Watering Committee regarding Merrick & Towne, criticizing the installation of one of their steam engines for the Union Canal Co. He added a notation at the bottom of the letter, "Can they handle a new turbine wheel (with which they are comparatively unacquantied?)"[9]

After explanations by the Canal Company, Graff withdrew his complaint, but it was two breast wheels (No. 7 and No. 8) that were ordered from Merrick & Towne in February 1843, not a turbine.

The debate must have continued, for the "new type of wheel" was recommended in the 1843 Annual Report to replace the original No. 1 Wooden Wheel. A drawing at the Franklin Institute, by Graff, Jr., showing plan and section of a new style wheel, is dated February 1, 1843.[10] Another drawing, dated November 18, 1843, has an erased pencil notation near the tail race, "to be quarried for a turbine, two feet 2 inches deep."[11]

The Fourneyron turbine and the Jonval turbine (which was the design installed at Fairmount) were basically horizontal water-wheels, but they differed in the manner in which the water was released from an upper chamber (or reservoir) to impact upon the buckets of a revolving wheel (or runner) and in the exiting of the water into the tail race. In the former, the water issued horizontally from "channels formed all around the bottom of a cast-iron cylinder...against the concave surface of the passing buckets [moving the wheel and escaping] all around its exterior circumference into the wheel pit."[12] In the latter, (similar to the Fontain turbine), the water was "directed into it from the top side, by means of curved iron plates suitably inclined and fixed in a stationary cylinder, [passing] through channels formed by these plates and [acting on the buckets] of the revolving wheel, which are situated under and exactly concentric with the fixed cylinder..." escaping underneath into the tail race.[13] The special discovery of Jonval was related to the placement of the wheels so that there would be no loss of power if placed less than 28 ft. from the surface of the tail race:

> "the suction occasioned by the pressure of air, removed form the underside of the wheel, he found to be exactly equal to the pressure of a column of

> water whose height was equal to the distance from the bottom of the wheel to the surface of the water in the tail course."[14]

The Jonval turbine's construction permitted repairs to be made easily since it was not submerged and the wheel could be made instantly dry and accessible.[15]

The turbines are called "Jonval turbines," in all the records of the Watering Committee. On its introduction at a paper mill in Pont d' Aspuch in France, the Jonval turbine exceeded 80 percent in effective duty. It was simple in form, had few parts and was well designed, each wheel being individually planned for a specific installation. The mechanical engineer Emile Geyelin, who observed the manufacture of the wheel by its inventor Jonval, introduced this style of wheel into the United States in 1842.[16] One of the first was placed at the powder mills of E.I. duPont de Nemours in Delaware, and "the engineer of the Philadelphia Water Works recommended that one of the Geyelin-Jonval Turbines be substituted for one of the large breast wheels at the Fairmount pumping station," and subsequently replaced all of them with these turbines.[17]

In February of 1844, Graff Sr. wrote to Edward Heston, who later worked on the 1846 installation of re-built Wheels No. 1, 2 and 3, for an opinion about using turbines for pumping. Heston replied that it was his "candid opinion that your pumps cannot be geared to a Turbine so as to make a permanent substantial fixture, and would be also subject to considerable repairs and consequently loss of time," and that the breast wheels were especially well adapted to driving the pumps and were favored over the turbine.[18]

On April 4, 1844, Graff wrote to Merrick & Towne and to I.P. Morris & Co. asking for proposals for a turbine.[19] Merrick & Towne, with whom Ellwood Morris was associated, made a bid of $8,000 on May 7, 1844. However, the Annual Report for 1844 stated that the Committee suspended the building of a turbine wheel "to obtain a more decisive opinion of that kind of power," for although there were good results on two Lehigh River installations, because of "the necessary gearing required to adapt these wheels to pumping, your committee has concluded to abandon the erection of a Turbine..."[20]

The Committee then recommended a new Wheel No. 1 to be built of cast-iron and not to cost over $8,000, having received such a proposal from I.P. Morris & Co. If any difference of opinion still remained, Councils made certain a turbine could not be installed by appropriating only $5,000 in 1845, which was then used to repair all the wooden wheels. Later that year Councils voted funds to completely re-build Wheels No. 1, 2 and 3, and this was accomplished in 1846.

Young Graff was clearly in favor of turbines and in 1847 once again sought a way to erect an experimental one at Fairmount. The "Parker Wheel" had been discussed in Morris' article in the Journal of the Franklin Institute, but experimental results submitted by Z. Parker to the Journal in 1841 and 1844 were not published.[21] Graff considered reaction wheels for use at

Fairmount, and Zebulon Pakrer, around 1848, made suggestions to the Watering Committee about installations in the Mill House.[22]

Graff decided on a turbine and his ingenuity matched that of his father. He cleverly designed a way to alter the waste gate at the end of the mill race so part of it could be used as a forebay for a small turbine. Then he constructed a room below ground level, in the angle between the Mill House and the Engine House, where he placed the turbine, with the pump under the porch of the Engine House, using the ascending main of the early steam engines to carry water to the reservoir. The forebay also supplied water to two intake pipes for the pump. It was a very tight fit, but the installation was successfully accomplished before the end of 1851.[23]

Without any warning in prior reports, the 1851 Annual Report announced the successful operation of the newly installed turbine.

> "The completion of the Turbine wheel and pump was retarded considerably beyond the period expected, principally on account of the confined situation which the wheel occupies, making it difficult and tedious to get such large castings as were required for the work into their porper situations. The wheel and pump have, however, been tried, and their entire applicability to the purpose for which they were erected, fairly exceeded the most sanguine expectations. By this wheel we shall be able to gain some six hours per day in time and about 512,183 ale gallons in quantity, over any heretofore used. The success of this wheel cannot but be considered as very important, inasmuch as similar ones would give the power to increase the efficiency of our works hereafter without erecting additional buildings, or resorting to steam power, for by adapting such wheels to the present pumps in place

> of those now employed, a power to raise at least 4,166,281 gallons more than we are now able to do, could be obtained; and by substituting stronger pumps than those now in use, it is quite probable an addition of 6,000,000 gallons per day could be obtained...The general design for the locus and arrangement of the new wheel and pump, and its gearing and application to the purpose for which it was intended, was furnished by the engineer of the works, Frederick Graff, Esq. The working details of the waste wheel and gearing are from the designs of Emile Geyelin, Esq., the patentee for the Jonval Turbine in this country."[24]

The 1854 Annual Report carried a full description. The standard gallon (or wine gallon) of 231 cu. in. was used in that report in place of the ale gallon (282 cu. in.), although this measurement was not officially changed until 1855.[25]

> "The Turbine was made of cast-iron with wrought iron buckets enclosed in a watertight case. It runs horizontally and is 7 feet in diameter and 10 in. deep [and 13 in. wide] in the buckets. It drives it own pump by mean of two bevel and two spur wheels, and has a head and fall of 6 feet 6 inches when the tide is full and of 10 feet when the tide is low."[26]

The turbine had power greater than the 18-foot breast wheel and ran faster. It was not retarded by ordinary high tides and could raise 1,685,016 standard gallons in 24 hours, having it own (433 foot) ascending main. The pump arrangement was the same as earlier ones, with a 16 in. cylinder and a 6 ft. stroke. The price paid to Emile Geyelin was $8.490.

This small Jonval turbine was a "gem" as far as the Works was concerned. It was in almost constant operation, and needed repairs only as parts wore out. This wheel was the last to be shut down, continuing to supply water to the reservoir, though the original 1815 main, until 1909. It was left <u>in situ</u> according to the Ordinance of March 1911, and can be seen today at the Works. It is no longer possible to operate the turbine because the runner has been cut away and the crank wheel interred in concrete to stop the movement of the gearing as tides rise into the tail race.

Graff Jr. also recognized the need to expand other parts of the system, and in 1850 a 30 inch main was installed across the entire city from the Schuylkill to the Delaware and steps were taken to provide additional storage areas. The expanded summit of Fair Mount was covered with the existing reservoirs. The search for a site for another reservoir resulted in the purchase of 13 acres on Corinthian Avenue, 3,747 feet from the Works. A reservoir was built there at a cost of $46,030.47 (exclusive of land) to contain 16,646,246 ale gallons and water was admitted to it December 22, 1852. The level of the water was higher than at Fair Mount, and it was calculated to utilize this to provide a satisfactory head when an unusual amount of water was used in the City.

Because of the difference in height, a stand pipe was erected at Fair Mount and the ascending mains were attached to it at the base so they could supply either the old or the new reservoirs. The base of the stand pipe was part way up the cliff beyond the mill race.. From the following description, the stand pipe took on the characteristics of the Fairmount Water Works - utilitarian but clothed in acceptable architecture.

> "This stand pipe is of cast-iron 4 feet in diameter in the clear, and fifty feet high from its base; thirty feet above the new reservoir when full. The pipe has been surrounded by an ornamental tower of brick work, to protect it from the frost. The pump mains are connected to a lateral taper pipe, twenty inches in diameter at one end and four feet at the other; the total weight of the stand and this lateral pipe, is twenty-four tons nine hundered weight; from the base of the pipe is carried a thirty inch main to the new reservoir..."[27]

The concept of "load" was introduced in 1852 with an experiment to see at what time of day the most and least water was used. Seasonal changes were always recognized. The greatest supply was required on Saturday and the least on Sunday. During the week, water was used most from nine to twelve in the morning and from two to four in the afternoon, the minimum from twelve to one, "when factories and steam engines are stopped."[28] The new reservoir, with its additional height, permitted the "head of water, formerly deficient on Saturdays in the higher stories of houses in the City [to be] kept up during the summer..."[29] The analysis of the Sunday load might explain why water was drawn from the pumps each Sunday so that the air chambers could be filled with air to last until the following week.[30]

There were adequate reservoirs and distribution systems for the short term. Graff had proved the value of the turbine to the City, in the quantity of water pumped, and as a reliable supplier of water. But the breast wheels and pumps were not designed for the work that had been added to them. The stand pipe, while necessary to raise the water into the higher level of the new reservoir, was just too much for some of the old machinery which had served so well when used within its own system. The great wheels and pumps were showing signs of age. A new generation of hydraulic machinery foreshadowed by the 1851 Jonval turbine was needed to take over the duty.

The shift to turbines was not the only change for the Fairmount system in the 1850s. The greatest change came about as a result of the consolidation of the City of Philadelphia with neighboring districts in February, 1854. This meant an increase in the population and area of the city, and in the problems of water supply.

The realities of political unknowns also became apparent when the functions of the Watering Committee were taken over by the Department for Supplying the City with Water, operating under the Committee on Water. Before this time, even though there had always been political forces in operation, experience and friendships had built up a sense of how to act and react. With the new situation, the path was not clear.

Graff, Jr. became the Chief Engineer of the Department, taking over three steam pumping stations, which the districts had built after 1846 so they would not have to pay the high rate charged by the city for their water. He continued to supervise Fairmount Water Works, and of the 30 million gallons pumped in 24 hours in 1854, Fairmount supplied 14 million and her reservoirs provided storage for 47 million gallons of the total 66 million. Working to unify the system, as had his father before him, Graff Jr. analyzed the distribution system in the former districts and the financial system of payments. He found both to be irregular and began to organize them in a manner similar to the old city system. The Fairmount Works continued to be a marvel of "efficiency, perfect repair, and remarkable cheapness of running expenses...in strong contrast with the far more expensive and troublesome steam works..."[31] But in July 1856, Graff resigned.

For the first time in over fifty years, the water of Philadelphia was not controlled by a Graff. Samuel Ogdin became Chief Engineer for two years. The change could have been a matter of political expediency, for according to some, Graff had "no sympathy with political matters."[32] Ogdin criticized the condition of the Works in 1856 for being run-down, where Graff had reported them in perfect condition in 1855. Graff became associated with I.P. Morris & Co. at the Port Richmond Works.[33]

The next step in the expansion of Fairmount's technology came under the aegis of a controversial figure, Henry P.M. Birkenbine, whose firm, Birkenbine & Trotter, had designed and constructed the 24th Ward Works for the district of West Philadelphia. Neither Graff nor Ogdin thought very highly of this installation. Graff considered the work poorly planned and poorly located. Ogdin concurred in this and found the machinery defective.

Birkenbine took over his duties in 1858 and immediately started to repair the flaws in the system. He commented on the complaints about water deficiency, and on his predecessors, saying, "if the works had been kept in perfect order and managed with care, sufficient water would have been supplied."[34] The answer, as he saw it, lay in more mains, interconnection of reservoirs, and the expansion of the water works' capacity. He recommended using the full flow of water at Fairmount by more efficient machinery and suggested that Wheel No. 4 be replaced by a turbine and two large turbine wheels and four pumps be placed in a New Mill House erected on the Mound Dam.[35] Fairmount supplied so much of the water for Philadelphia, pumping from ten to twelve million gallons a day, that the city could not stop the present wheels in order to remodel the Mill House for large turbines, or to extend the mill race and alter the head arches to allow passage of more water for a wheel which might be installed in the Engine House. The only other way to expand was by the construction in the Mound Dam. Councils approved the plans for an extension of the Works by ordinance April 8, 1859, and work began early in the summer of 1859.

A great deal of controversy appears to have arisen over what type of turbine should be installed. A series of tests was therefore scheduled and Birkenbine built an apparatus for testing the model turbine wheels submitted to the Department. This appears to have been done in some haste. An announcement appeared in Scientific American on June 4, 1859 announcing trials would start June 7th, but they were delayed until the first of August. There were nineteen wheels tested and 122 experiments made. The experiments were "undertaken with great reluctance," because, while they were supposed to be scientific, Birkenbine himself indicated that the necessary time for proper care and deliberation was not possible because construction was beginning. Also the $500 appropriated by Councils to pay for these test was too small.[36] In an unusual statement, Birkenbine denied any inference that the contract would be awarded on the basis of the mathematical results of the testing, claiming the practical experience of the Department was an overriding factor.

The tests continued into the next year, and by mid-April the contest had narrowed to the makers of four of the wheels, who were asked to submit bids; J.E. Stevenson of Paterson, New Jersey, Emile Geyelin of Philadelphia, Andrews and Kallback of Bernville, Pa. and Levi Smith of Reading, Pa. were asked to submit a bid. The low bidder was Geyelin for a Jonval wheel. Stevenson's Jonval wheel gave the best results, but the city's experience with the Geyelin turbine installed in 1851 had been so successful, that this outweighed the rating, especially since the Geyelin's bid was $6,100 less than Stevenson's bid of $30,000.

The results of the experiments were not made available to the public until 1861, while the turbines were being installed, "because of agitation on the subject in the Councils."[37] The Jonval wheel was ideally suited to Fairmount's needs, but the former Chairman of the Committee on Water had recommended the pair of wheels on a horizontal shaft, a modification of the Parker Wheel, presented by Andrews and Kallback. This was not considered the best equipment for Fairmount because of the physical size of the wheels, the small head available, and the complicated gearing required to reduce the velocity of the wheel to the speed of the pumps. It was a difficult situation, and the Committee on Water passed several resolutions directing that the testing be stopped because it delayed construction, but the owners of the models persuaded Councils to continue. By June 7, 1860, the contract was finally awarded to Geyelin for two Jonval turbines. These were built by I.P. Morris at the Port Richmond Works.

There was no appropriation for a third wheel, although by this time the size of the New Mill House had been increased to allow for that possibility and later a contract was awarded for the third set of machinery.

There had been unexpected difficulty in the excavation for the New Mill House. The basic reasoning governing the construction of the Mound Dam by Captain Cooley in 1819, who considered it along with the head arches a true part of the total structure blocking the river, appears to have been forgotten. Also forgotten was the fact that the Mound Dam itself was composed of small stones and earth.

Soundings were taken which indicated a solid foundation, but this was discovered later to consist of loose stone, and the rock that was visible at low tide was only a narrow spur with mud seventeen feet deep on each side. Eventually, piles had to be driven in the mud, the true bed of the river in 1819, and the cost of construction soared. There was also difficulty with water flooding the cofferdams. The Schuylkill Navigation Company tried to stop construction, but the City had legal rights and persisted.

The three turbines were the largest of their kind yet constructed.[38] The Annual Report of 1861 describes their installation in the New Mill House.

> "The wheels are placed near the south front of the wheel house. This was necessary on account of the danger there would have been in excavating further into the dam. The water is conducted...to each wheel by an elliptical wrought iron flume, having a sectional area of seventy feet. It is then delivered into a cast iron case, or reservoir, immediately over the wheel; from this it passes through the guide curves, which direct the water upon the movable wheel under them, giving motion to the wheel. The water, after having acted upon the wheel, passes down through the draft tube, and out at the gate, which is a hollow cylinder, forming a continuation of the draft tube, resting upon the bottom of the wheel-pit and opening from below. These wheels have no essential feature not common to well constructed Jonval turbines. They have been proportioned and constructed with care, with direct reference to the work they are to perform, and the peculiarities of the water-power under which they are to act...The guide wheels are fitted into a conical cylinder, and the number of curves in each wheel is seventeen. The movable wheel is nine feet in diameter, and has fifty buckets.
>
> The gearing by which the power is transmitted from the turbine wheel to the pumps, is composed, first of a pair of bevel wheels, carrying the power from the vertical shaft of the turbine to a horizontal counter shaft, then through a pair of spur wheels to the crank-shaft of the pumps, to which crank

> wheels are attached at either end, giving motion to the pumps. The pinions of both pairs of wheels are of iron, with the cogs accurately dressed, working into mortice wheels with hickory cogs.
>
> Two pumps are worked by each wheel, making six in all. They are placed in pairs horizontally, one on each side. They are eighteen inches in diameter, with six feet stroke of piston. The valves are double beat, working vertically in chambers placed at both ends of the pumps. One air vessel is placed immediately over each set of valves, one on the connecting main, between the chambers, and one on the suction pipe, which takes the water from the flumes supplying the wheels. The packing of the pumps pistons is end wood, which is kept tight by means of a cone forced under the wooden ring. The mean capacity of all six pumps will be 16,000,000 gallons per day, although they can be worked up to 18,000,000 gallons, if necessary."[39]

With the advent of the New Mill House turbines, it was necessary to provide adequate mains for the water to reach the reservoirs. In keeping with Fairmount's scenic design, this was done in a grandiose way by a decorative tower and bridge, forming an archway on the side of the "Fair Mount." The tower enclosed an upright pipe of wrought iron, 60 inches in diameter and 64 ft. high. The top was closed, and 7 feet below the top a branch led off, with the space above acting as an air chamber. The branch was 36 inches in diameter and was contained in the bridge. This 36 inch pipe connected with the stand pipe at its base, and from the stand pipe the water could be discharged to Fairmount reservoirs or to the Corinthian Avenue reservoir. Three 30 inch mains from the turbines crossed the mill race over the old head arches and then branched into one 48 inch main, which connected with the upright pipe of the distribution arch. Another 48 inch pipe could be connected in the opposite direction in the future which would lead directly to the Corinthian Avenue Reservoir.

The wheels did not go into operation until June, 1862, and even then they were used only intermittently until problems were worked out. At first the power of the wheels was only 70% of capacity, because of the fall and the quantity of water used.[40] Operation of the turbines was delayed only partly by changes in Birkenbines original plan. In a stinging denunciation of the contractor, Birkenbine blamed the middle-man who increased the cost of everything. Birkenbine preferred to supervise directly the machinists doing the work, and to be able to make improvements that were suggested as the work progressed.

In order to cover his spiraling costs, Birkenbine had shifted funds from one appropriation to another, and in December 1860, Councils investigated the cost and the reasoning for the New Mill House. They received an explanation which included a comparison with the cost of the original Mill House, the difficulty of the construction and the quality and ultimate value of the New Mill House System to the City.[41]

The political situation may have been hostile. In his report for 1860, Birkenbine pleaded for independence and deplored politics entering department affairs. He commented on patronage, and noted that the cost of pipe varied from 26¢ to 26.9¢ a foot, and was at one time 64¢ a foot. For reasons that may have been political there was a new Chief Engineer in 1862, Isacc S.

Cassin, but Birkenbine returned to serve from 1864 to 1866. During the 1860s serious questions about the quality and quantity of Schuylkill water were raised. One solution was to strictly enforce the laws that had been made as far back as 1828 concerning what could and could not be dumped into the Schuylkill. Birkenbine proposed to alter the basic operation of the dam as an overfall by constructing a sluiceway under the dam, which would allow the impurities which had sunk to the bottom of the river to be discharged and not to collect at the dam. He also indicated in 1858 that the city might obtain water from a distance upstream, and from 1864-66 he made a detailed study of the Perkimen Creek, recommending it as a source.

There had been several petitions from citizens for a better supply of water. One of Birkenbine's actions in 1858 had been to improve the distribution, laying a large main to the First Ward of the City. Even with the New Mill House functioning, part of the answer to supply still lay in distribution, since by connecting the Spring Garden Reservoir with the Fairmount system, it would be possible to use the cheap water power of Fairmount when it was available to fill storage facilities, and steam power of the Schuylkill (Spring Garden) station when there was low water in the Schuylkill. The Fairmount system was no longer autonomous and had to be operated in conjunction with the larger all-Philadelphia system. Also, the river was not exclusively available to the city, because of the navigational rights of the Schuylkill Canal Company.

The distribution system demanded larger mains in order to utilize to the fullest the new equipment at Fairmount. The Distribution Arch which had been built at Fairmount to enclose the ascending mains from the New Mill House was not as functional as it could have been because of the size of the main connecting it with the Corinthian Avenue Reservoir. After yearly prodding, a 48 inch main was laid in 1866. The height of the stand pipe was raised 21 feet in 1859, and by 1862 the height of the Corinthian Avenue Reservoir was raised.

The new turbines had proved a satisfactory addition to the Works, although there were necessary adjustments. At the time of installation, they were the largest turbines to have been built, and it was recognized that there might be problems when they went into operation. In 1865, while reporting the machinery to be in perfect order, Birkenbine commented that the defects left by the contractor had been remedied, but that there was still room for improvement. Now plans were presented to remodel the Old Mill House and substitute five turbines and eight pumps for the old breast wheels. Birkenbine also suggested putting a Cornish engine in the Old Engine House which would taken water from below the dam, in case of low water or an accident to the dam. The Annual Report for 1866, the last one written by Birkenbine, stated that:

> ...at no time since consolidation has the condition of the Department been so satisfactory as at present...The income from the Works has been increased, and the expenses reduced...the supply of water has been more satisfactory in quantity and the distribution and the number of water takers largely increased.[42]

In contrast, he commented on the state of the Department when he took over, but he could not understand why Councils did not now appropriate funds to remodel the Old Mill House, although they had made a large appropriation for other matters.

In February, 1866, Birkenbine presented his report on the Perkiomen Creek project, which recommended the construction of a storage reservoir 26 miles from the city in Montgomery County and an aqueduct to carry the water to Philadelphia. The Annual Report of 1866 again reminded Councils of this possible way to supply 75 million gallons a day, which was more than twice the amount needed for the population of 750,000. The plan was not adopted, and the following year another report was made to Councils, this time by a special committee of the Fairmount Park Commission, established in 1866 to control the municipal park adjacent to the river. Frederick Graff, Jr. was one of the Commissioners. In 1867 the Fairmount Park Commission reported that "the Schuylkill River could be relied upon for many years, if properly guarded from pollution."[43]

Graff took over as Chief Engineer of the Department on March 1, 1867, and remained until 1872. He immediately took up Birkenbine's proposal to remodel the Mill House so that turbines could be installed. In 1851, after placing the experimental turbine, now known as Wheel No. 9, in operation, he had planned to install identical small Jonval turbines in the Mill house and attach them to the existing pumps. This could have been done gradually without endangering the water supply, in the same manner as replacing or repairing a breast wheel, not interfering greatly with the capacity of the Works. Now, fifteen years later, although the demand for water had increased, the machinery of the New Mill House made other actions possible.

On June 20th, Graff presented his plan to Councils and there was an immediate acceptance. He approached the problem cautiously, and the fact that extensive construction work took place in three stages without interrupting the pumping of water in any serious way is a tribute to Graff's ability. Three large Jonval turbines with two pumps each were to replace Breast Wheels Nos. 2 through 7, and the Mill House was altered to accomodate the machinery. This required excavating for the wheel pits and moving the west wall 7 feet towards the river, besides raising the roof. Work began in October, 1867, and Breast Wheels No. 2 and No. 3 were removed to make way for the new wheel, which went into operation February 19, 1869. The dates the other two wheels commenced daily duty were June 20, 1870 and December 14, 1871. Two small turbines intended to replace Wheels No. 1 and No. 8 were never installed, and the breast wheels remained in place, although Wheel No. 8 was useless and was removed in 1873. Wheel No. 1 was in use through 1875 and was removed in 1883.

The planning and arrangement of the work was by Graff, Jr. and the design of the wheel and gearing was by Emile Geyelin. As contractor, Geyelin sub-contracted the pumps to I.P. Morris & Co. and the gearing and shafting to the West Engine Co. of Norristown. His own shop made the wheel and gate-hoist.

In making necessary adjustments to the building, Graff consciously preserved the image of the Fairmount Water Works which was so well known. Some of the niceties had to be removed to make way for the large machinery. Although not beautiful or romantic, the turbines were powerful, and they were the largest constructed to that date, just as the New Mill House turbines had been. Since the forebay and wheels were covered, there was no visible activity as there had been with breast wheels, so the interior of the mill house was not of great interest to anyone but engineers. The exterior was enhanced by the addition of a central Pavillion in 1871 following an original design of Graff Sr. The grounds were improved and Graff in his capacity as a Fairmount Park Commissioner promoted the parklike surroundings.

The turbines were reported by Graff to be "perfectly successful pieces of machinery."[44] They were Jonval turbines, with a diameter of 10 ft. 3 inches, having 49 buckets 17 inches deep and 21 inches wide.[45] Water entered the forebay (wrought iron flume) from the mill race, then flowed into the upper chamber of the turbine, and passed vertically through channels formed by guide vanes in a stationary wheel and impacted at an angle on the buckets of the horizontal revolving wheel (runner) causing the wheel to turn, and finally exited through a draft tube in the tail race.

Each turbine was geared to two double acting force pumps of 22 inch diameter and 6 ft. stroke, which were placed perfectly horizontally, water being taken from the wrought iron flume through two valve chests. There were three 36 inch mains for the six pumps. In Graff's original design, two of the mains formed their own bridge, 77 ft. long across the mill race, 9 ft. above the level of the water of the dam, suspended by wrought iron suspension bars, and then ascended at a 43 degree angle to the reservoir. The third 36 inch main crossed the mill race over the head arch bridge, and went to the base of the distribution arch where the water could be directed to the Fairmount or to the Corinthian reservoirs. The pumps had an expected capacity of 8,631,630 standard gallons in 24 hours as opposed to the capacity of the two breast wheels which had been 2,836,080 gallons. The turbine used less than 10% more water to raise approximately 3 times the quantity of water to the reservoir.

There were problems during the construction, and some delay, but the work appears to have gone much more smoothly than with the building of the New Mill House. Excavation of the rock on the river side proved especially difficult. It was done during the winter and the machinery was late in arriving. After thier initial enthusiasm, Councils delayed the work by withholding appropriations, and following the unprecedented drought of 1869 there was some question about whether the Schuylkill River contained enough water to justify the new wheels. Graff countered with the statement that the cost of water power was so low compared with steam, that even if the wheels only worked half the year, the expense would be worth it.

The general public understood little about the water system. A contemporary newspaper account describes an adamant citizen who sought the reason for the lack of water during the period of drought.[46] The man came to the Fairmount Reservoir and saw that it was low. Graff explained that it was being cleaned.

The man saw that the wheels were not turning in the Mill House. Graff explained that the mill race was being allowed to fill up in order to make the best use of the available water power, which meant that the wheels should be started near low tide and stopped near high tide. But the citizen did not understand this, and returned home convinced that there was no water, because the wheels were not turning -- and he held Graff responsible.

A newspaper reported that for four days during the drought, the volunteer fire companies, unsought and unthanked by Graff, threw streams of water to the reservoir.[47] In a more practical vein, Graff hired the steam fire and wrecking tug John Fuller from New York to pump water from below the dam to the reservoir for $400 a day until he could put some temporary steam auxilliary engines at the foot of the hill. By 1872, Graff had moved a small duplex engine from the Spring Garden Works to an "ornamental" building constructed on the old wharf near Fairmount, and connected a 12 inch main to the stand pipe. Steam power was used only in the hottest months of the summer and increased the supply by 3 million gallons a day.

Following the drought, a sudden freshet greater than ever before materialized on October 4, 1869 and the water rose to a record height of 11 ft. 5 in. above the level of the dam, but there was no damage to the Works. This is especially surprising because when the water was so low in summer, Graff was able to inspect the dam, discovering among other things that the old original dam was made of small timbers and was not secure. Plans were made for a major re-building of the dam, which was accomplished in 1872.

If Graff had thought in 1867 that he could return to the halycon days of his youth at Fairmount, he very soon found he was mistaken, as an item in one newspaper illustrates:

> "HOT WATER VS. COLD
>
> Chief Engineer Graff will soon be as accustomed to hot water as he is to cold, and it is a curious fact, while our citizens not infrequently get out of the latter, he is constantly getting into the former."[48]

In 1868 Graff became involved in the "Worthington Pump Controversy" by his choice of a New York firm to build a Worthington Duplex Engine for the Roxborough works. This was taken as an affront by the local Philadelphia mechanics. The price was also questioned. Graff claimed that his selection was made on the basis of the most appropriate engine, and this engine could only be obtained from the patent holder. Newspapers carried articles about the disgrace inflicted on the city by Graff. An ordinance was even proposed requiring that all equipment for the Water Department be built in Philadelphia. At this point several firms in the Mechanics' Community wrote a letter to the Council <u>against</u> the ordinance, because localism would only provoke reciprocal action from other cities where Philadelphia manufacturers sought to market their products. The controversy continued in the press throughout Graff's term, during which several other Worthington engines were installed.[49]

One contemporary source turned a phrase to praise Graff's aid to the city:

> "Engineer Graff of the Water Department, has not received justice from the press of this city. He proved his ability at a very critical period in the history of the city, and it is but right that he should have the poor reward of 'well done, good and faithful servant.' In the midst of our difficulties, with admirable address and judgment, he procured from New York a powerful floating steam-pump to supply the reservoir at Fairmount with water, taken from the Schuylkill below the dam. He by this means pumps up some five million gallons per day, which, with the assistance of the wheels, furnishes a fair supply of water to the people of the city. This floating steam-pump was built in Philadelphia and sold to New York. 'Honor to whom honor is due.'"[50]

In 1867, soon after Graff's return, there was a dramatic reminder of the fact that Fairmount was part of a system, and that all parts were equally essential. The brick lining of the Corinthian Avenue Reservoir gave way because of the manner in which the water from the 49 inch intake main was released. This happened just at the time the floods had stopped the pumps at Fairmount and storage in the reservoirs was at a minimum. Repairs were hastily made and Graff warned that "the good work must be continued and large storage reservoirs be provided or the city of Philadelphia (the first in the country to provide its citizens with water) will fall into discredit, and lose the reputation it has enjoyed for nearly seventy years, of being one of the best-watered cities in the world."[51] To meet this need, Graff proposed to build the East Park Reservoir, which evolved into a political issue. The reservoir was to cover an extensive area, and was started in 1871, but was abandoned and not finished until 1889. Funds were tied up by an injunction placed on the City Treasurer and the Water Department by the Supreme Court, as well as by the veto of the appropriation bill by the Mayor. Finally, late in

1871, funds were made available and work was started. The Mayor's objection was the large amount of money -- two million dollars -- which would be controlled by one man, Fred Graff.[52] Another cause of dissention may have been the possibility of political patronage in the hiring of 900 men to dig the reservoir.[53]

Between the shortage of water, the Worthington Pump Controversy and the East Park Reservoir, the newspapers were full of comments during this period and Graff was frequently the target. Councils failed to give Graff critical funds when he requested them. In the Annual Report for 1871, Graff evidently felt it expedient to give the reasons why improvements had taken longer than expected, and added, "It has been necessary to advert this matter in order that it may be seen that the unfortunate delay in commencing and finishing the work of vital importance to the city, cannot be chargeable to any failure of duty on the part of the Chief Engineer of the Department."[54]

The water turbine system was complete by the end of Graff's term, except for the East Park Reservoir. The nine wheels in operation were re-numbered in accord with their placement in the buildings:

Wheel No. 1	Experimental Turbine (1851)
Wheel No. 2	Breast Wheel (Old No. 1, 1846)
Wheel No. 3	Remodeled Mill House Turbines
No. 4	(1868-1871)
No. 5	"

Wheel No. 6	Never installed; space provided
Wheel No. 7	New Mill House Turbines
No. 8	(1860-1862)
No. 9	"

The Annual Report of 1872 was almost as glowing as the report of fifty years earlier, which announced the commencement of the breast wheel system. The dam had been safely re-built and strengthened. The re-building of the Mill House was complete, and the entire works presented a "neat, substantial appearance, in strong contrast with the shameful state of dilapidation in which they were found when [Graff] took charge of the Works in March 1867.[55] Operating costs were low, "The cost [expense] in 1871 for raising one million gallons one foot high by water power was one and thirty-eight hundredths of a cent, while to do so by steam power cost from eight and five-tenths of a cent to nineteen and nine-tenths of a cent."[56] The total expense of raising 8,821,728,593 gallons at Fairmount by water power in 1871 was $12,229.96.

With the restoration of the Fairmount Water Works to a dignified stature once again, Frederick Graff declined re-election in February 1873. The last major addition to the technology of the Water Works had been made, and the Graffs once more ceased to control the Works. The Fairmount Water Works in subsequent years was under the supervision of competent engineers, but they were more interested in steam power and tolerated the water power system because it was there and it was inexpensive to operate.

CHAPTER V

DECLINE

The continuing growth of Philadelphia after 1872 increased the quantity needed, and the continuing deterioration of the quality of Schuylkill River water demanded some type of purification before distribution.

The Schuylkill was originally a fast-moving river which could clean itself, but it had been made into a series of lakes when dams were constructed to make it navigable. The discharge from mines in the upper reaches of the river, and the sewage and industrial waste indiscriminately added in the lower portions, made pollution a major problem in the late nineteenth century. The Fairmount system would not survive.

As the population of the city increased, the influx of voters established a new element in the Water Department's troubles. The history of Philadelphia became entangled with political bossism following the Civil War, and this included the Department for Supplying Water to the City.[1] There were many unskilled jobs to be filled and contracts to be awarded for maintaining the distribution system and digging reservoirs, and to the politicians this meant votes. There were rumblings about politics by Birkenbine and there were major clashes when Graff returned. To keep the Fairmount system in good order was not the first priority of those who controlled the purse strings.

The Annual Reports for the ten years following 1873 plead for adequate funds to build a proper system for the city, for "who can tell the misery of impure water?"[2] There was special concern that the Schuylkill River was the major source of water for the entire city, and the Annual Report for 1882 demanded Councils' attention, saying, "One million dollars would not compensate for the loss caused by one day's suspension of water."[3]

At various times the Councils had authorized studies or commissions to make recommendations on the subject of water supply. In 1854 Graff had made a study of filtration installation at the Fairmount Reservoirs, but he had concluded that they were "troublesome, needless and expensive apparatus."[4] Birkenbine had proposed an aqueduct from the Perkiomen in 1866, and although Councils did not adopt his plan, some persons considered the money spent on the Remodeled Mill House would have been better employed in constructing this system for supplying pure and plentiful water.[5] The Fairmount Park Commission's Special Committee in 1867 approved the Schulkill water if it was protected, and recommended that compensating reservoirs in the upper Schuylkill be released in time of drought.[6] This report appears to have negated the urgency expressed by Birkenbine. Finally, in 1899, a Commission recommended filtering and more pumping stations. Steps were taken to establish large filtration plants. This was the death knell for the Fairmount Water Works, for there was no way filters would fit into this system that had its beginnings a century earlier.

The Fairmount Water Works continued to supply a large percentage of the city's water until the day the Torresdale Filtration System entered service. Fairmount's machinery and buildings had begun to grow old together. When it was seen that they would not be useful in the new system, only necessary maintenance was performed. The beautiful woman of The Schuylkill Freed was becoming a shabby old lady.

The end of service came in 1908 when all the wheels but one were stopped.[7] That one continued to supply water to the Reservoir for one large user of water until 1909. Water Department personnel remained on site until May 13, 1912.[8]

By Ordinance, the Fairmount Water Works was turned over to the Mayor on April 10, 1911 for use as an aquarium, and the site of the Fairmount Reservoir for the construction of an art museum. The ordinance stipulated that one set of machinery be retained. Thus, the Jonval Turbine of 1851 remains in place where Fred Graff Jr. managed to fit the "new kind of wheel" in order to show Councils how the new technology worked.

Today the Engine House, now called the Graff Mansion, is empty and does a little to bring to mind the two great steam engines that were once in operation. Only the ascending main the heavy foundations of the building remain to record how once the early high-pressure Columbian Engine of Oliver Evans stood side by side with the low-pressure engine based on a Boulton and Watt design.

The great breast wheels which turned in majestic unison in the Mill House are only a romantic memory recreated by drawings, but a portion of the head arch and the mill race can still be seen and give some idea of the size of the system. The exterior has been altered to meet the needs of the turbine wheels. The interiors of the two mill houses give little hint of the powerful machinery they once contained.

What was learned at Fairmount during its hundred year history was transmitted around the world in journals and trade papers, and it was acknowledged as being in the forefront of technological development. In an address before the American Waterworks Association in 1891, Emile Geyelin said:

> "Many an engineer, now resting on his labors, no doubt, can look back, who, when young, visited this city to study its water works. Philadelphia then held the title of the Mecca of the hydraulic engineer..."[8]

NOTES

CHAPTER ONE

1. Each year since 1798 the organization responsible for providing water to the City of Philadelphia has issued a report on its status, plans and projects. These reports have at various time had different titles and different publishers, but all together they represent the year by year record of what is now the Philadelphia Water Department. They are referred to in the text of this paper by the title "Annual Report" citing the specific year covered by that report. Facts and dates which have not been footnoted in the text have been taken from these Annual Reports. It is important to note that both "Fairmount" and "Fair Mount" have been used to refer to the water works during the past 170 years. Except when referring directly to the reservoirs above the water works or when quoting from historical texts, this report uses the term "Fairmount."

2. "Schuylkill Water Works at Philadelphia 1840," New England Water Works Association. Vol. LXIV June 1845 No. 2, p. 121.

3. The history of the Centre Square System is covered in Nelson M. Blake, Water for the Cities: A History of the Urban Water-Supply Problems in the United States (Syracuse: Syracuse University Press, 1956). Much of the material about Latrobe and Graff is from this source. Blake provided a valuable chronological development for both systems, including external events affecting them.

4. Carroll W. Pursell, Jr., Early Stationary Steam Engines in America: A Study of the Migration of Technology (Washington, D.C.: Smithsonian Institution Press, 1969). p. 31. The first Water Works in 1799 represented the most ambitious use of steam attempted in this country.

5. Information taken from The Columbia Encyclopedia, ed. William Bridgewater and Elizabeth J. Sherwood. (New York: Columbia University Press 1950). Article: Latrobe, Benjamin Henry, p. 1100.

6. Latrobe, Benjamin Henry, View of the Practicability and Means of Supplying the City of Philadelphia with Wholesome Water in a Letter to John Miller, Esq. December 29, 1798. (Philadelphia: Zechariah Poulson, Jr., 1799). p. 5.

7. Latrobe, Practicability, 1798.

8. Blake, Water for the Cities, p. 36.

9. Blake, Water for the Cities, p. 41.

10. John Davis and Frederick Graff, Report, Philadelphia City Archives, 1811, p. 3.

11. Plans presented included the repair and continuance of the Centre Square System, and an Aqueduct for Wissahickon water with a pumping station near the Schuylkill Falls, powered by water or steam. Report of the Watering Committee: Present State of the Works. May 2, 1812, reprinted in Annual Report. Annual Report November 5, 1812 pp. 7-19.

CHAPTER TWO

1. It was hoped that the problems which plagued the Centre Square facility would be corrected by the new Fairmount Water Works. The Centre Square facility was too small, making repairs difficult. Pipes leaked, and the engines did not run smoothly. Frederick Graff attempted to remedy the engine problems by installing an air chamber in the pump. "The air vessel has produced the suspension of the water in the rising main during the action and reaction of the pumping, it steadies the engine and may afford a greater number of strokes by which the reservoirs can be filled in a much shorter time than heretofore." Annual Report 1810, p. 3.

2. Schematic drawings of the two types of engine and good descriptions of how they work can be found in Pursell, Early Stationary Steam Engines, pp. 13-14 and 45-46.

3. Contract, Samuel Richards, October 3, 1812. City Archives.

4. Graff, Frederick Jr., Notes Upon the Water Works of Philadelphia 1801-1815. (Philadelphia: The Franklin Institute, 1876) p. 7.

5. Graff, Frederick Sr., To the Select and Common Councils of Frederick Graff...(Philadelphia: n.p., 1833) p. 6.

6. Eugene S. Ferguson, ed. Early Engineering Reminiscences, 1815-1840, of George Escol Sellers. (Washington, D.C.,: Smithsonian Institution, 1965) p. 12. The South Engine is believed to be the engine in the working-drawing entitled "North Face Section of Engine Building at Fair Mount," which is in the Graff Collection at the Franklin Institute.

7. Graff, Notes Upon the Water Works, p. 6. The figure "102 feet above low tide" is probably a clerical error which has been perpetuated and should read "102 feet above high tide."

8. Graff, Notes Upon the Water Works, pp. 3-4.

9. Case Before Judge Hathaway, City v. Samuel Richards, October 25, 1813., City Archives.

10. Annual Report, 1815.

11. Letter: Graff to Lewis, February 4, 1819.

12. Ferguson, Reminiscenes of George Escol Sellers, p. 12.

13. Benjamin Henry Labrobe, "First Report of Benjamin Henry Latrobe, to the American Philosophical Society, Held at Philadelphia; in Answer to the Enquiry of the Society of Rotterdam, 'Whether Any, and What Improvements Have Been Made in the Construction of Steam-Engines in America?'" Transactions of the American Philosophical Society, vol. 6 (1809) pp. 89-98. Cited in Barbara E. Benson, ed., Henry Latrobe and Moncure Robinson: The Engineer as Agent of Technological Transfer (Wilmington Delaware: Eleutherian Mills-Hagley Foundation, 1975), "The American Career of Benjamin Henry Latrobe," by Edward C. Carter II, p. 29.

14. Pursell, Early Stationary Steam Engines, pp. 44 and 64.

15. See Ferguson, Reminiscences of George Escol Sellers, pp. 37-38.

16. Pursell, Early Stationary Steam Engines, pp. 44 and 64.

17. Pursell, Early Stationary Steam Engines, pp. 31-32.

18. See Oliver Evans, The Abortion of the Young Steam Engineers' Guide, (Philadelphia: Oliver Evans, 1805). The curious title refers to the fact that Evans published the book without finishing it.

19. See Ferguson, Reminiscenes of George Escol Sellers, p. 63. ALSO Greville Bathe and Dorthy Bathe, Oliver Evans: A Chronicle of Early American Engineering (New York: Arno Press, 1972). p. 246.

20. The text of Evans' letter is in Bathe and Bathe, Evans, pp. 211-212.

21. Annual Report, 1814.

22. This drawing is believed to be the North Engine. It was not identified before the HAER Study, and thus was not available to Bathe and Bathe. It shows the lower portion of the installation, which includes the pump cylinder. The drawing is to scale, but no measurements are listed.

23. Bathe and Bathe, Evans. pp. 228-229.

24. Annual Report, 1852. p. 27. See also Bathe and Bathe, Evans. p. 229.

25. Bathe and Bathe, Evans. p. 229.

26. Both sources have had errors; but no more reliable information appears to be available.

27. Bathe and Bathe, Evans, p. 241.

28. March 25, 1817, Bathe and Bathe, Evans, p. 246. May 15, 1817, Graff, Jr. Notes. p. 6. November 26 and 27, 1817, Bathe and Bathe, Evans. p. 247.

29. Bathe and Bathe, Evans, p. 247. Reported in Aurora, December 25, 1817.

30. Letter, Frederick Graff to Joseph Lewis, February 4, 1819.

31. Graff, Jr. Notes Upon the Water Works, p. 6.

32. Bathe and Bathe, Evans, p. 262.

33. See Edwin T. Layton, Jr. ed. Technology and Social Change in America (New York: Harper and Row, 1973), pp. 103-104.

34. Letter from Graff to Joseph Lewis, February 4, 1819.

35. "Report of the Watering Committee Upon the Present State of the Works for Supplying the City with Water, and the Several Other Plans Proposed for the Purpose" dated May 2, 1812. (Philadelphia: Jane Aitken, 1812).

36. These "cast-iron joints" were made by Foxall and Richards @ $80 a ton. Annual Report, 1802, p. 7.

37. Letter from Graff to Joseph Lewis, December 22, 1817. Water Department Archives.

38. Letter from Graff to Lewis, October 18, 1818, included in November 1818 Report; See also Annual Report, 1852.

39. Letter, Graff to Lewis, July 14, 1819, City Archives.

40. The Annual Report for 1855 notes the change from ale gallons (282 cu. in.) in 1854 to wine gallons (231 cu. in.) in 1855. Today's standard gallon is 282 cu. in. Annual Report 1822, p. 11.

41. Letter from J. Walker to Messrs. Glennie and Son, August 2, 1819. Water Department Archives.

42. "Report of the Watering Committee on the Subject of Obtaining Water Power from the River Schuylkill." (Philadelphia: Lydia R. Bailey, 1820).

43. Laws of Pennsylvania, 1814-1815, p. 72. Representing Philadelphia among 37 Commissioners were Samuel Wetherill, Jr.; Jonathan Williams, Samuel Richards, Robert Kennedy and Josiah White.

44. Blake, Water for the Cities, p. 84.

45. "Report of the Watering Committee on Propriety of Raising the Dam at Fair Mount" (1820) p. 4. On August 14, 1816 the Schuylkill Navigation Co. granted the right to Josiah White to erect a dam across Schuylkill Falls, restricting the height.

46. "An Additional Report on Water Power..." (1819), p. 5.

47. This date is given in the Annual Report, 1822 on page 8. It differs from later data, Annual Report, 1858 and from F. Graff's 1876 Notes which appears to a be a clerical error.

48. Annual Report, 1822, p. 8.

49. Annual Report, 1831.

50. Annual Report, 1833, p. 4.

51. Evans died April 15, 1819. Latrobe died September 3, 1820.

CHAPTER THREE

1. Additional Report, 1819, p. 5.

2. These are figures given in Additional Report, 1819. p. 13.

3. Annual Report, 1822, p. 4, states the lowest quantity of water is estimated to be 440 million in 24 hours.

4. According to Annual Report, 1822, p. 3: "The cribs were formed of logs, about fifty feet up and down stream, by seventeen or eighteen feet wide, which were sunk and filled with stone, and securely fastened to each other above low water, having the upstream side planked from the bottom to the topl and the spaces immediately above, filled to some extent, with earth, small stones, and other matter, to prevent leakage."

5. The original height of the mound dam was 7 feet, but this was raised to 15 feet by Graff following the great freshet in February, 1822. See Graff, Memorial, p. 6.

6. The Annual Report, 1852 has a concise description of the structure and the repairs to that date. See also "Notes Upon the Early History of the Employment of Water Power for Supplying the City of Philadelphia with Water and also the Building and Re-Building of the Dam at Fairmount," a paper read before the Engineers' Club of Philadelphia by Frederick Graff, Active Member of the Club, May 1, 1886, Proceedings of the Engineer's Club of Philadelphia, Vol. V, No. 5.

7. See notation on "Plan of the Mill Buildings at Fair Mount, Designed by Fred K. Graff in 1819," Graff Collection, Franklin Institute, Philadelphia.

8. Graff, Memorial, pp. 5-6.

9. See Footnote 7, Chapter II.

10. Report, signed Joseph S. Lewis, Chairman, Watering Committee, dated November 22, 1821. (Printed, no publisher).

11. Annual Report, 1854, pp.9-10. "The distribution of the old city proper, although arranged in 1819, before any other in this country, is very perfect, the system originally laid down have been strictly adhered to. The city is crossed upon the highest streets, running north and south, by two supply mains of twenty inch diameter each; and in the opposite direction, through a centeral street, runs a main of thirty inches diameter; the whole plot is then circumscribed by mains sixteen inches diameter, reducing to twelve and ten inches, and it is crossed north and south at intervals of about twelve hundred feet by mains of ten and twelve inches; these again are crossed east and west by several mains of sixteen, twelve and ten inches diameter, (all connected at proper intervals, and making a complete network of main or feeders), supply the remainder of the distribution, which consists of six four and three inch pipes. The arrangement is quite complete, the only source of regret being that any pipes so small as three inches should have been used; but at the very early date when the distribution was devised and commenced, they were considered more than sufficient...It is proper to mention, that no pipe of three inches diameter is ever extended beyond one square, or say, three hundred and ninety-six feet, without being connected at either or both ends with larger mains."

12. Annual Report, 1822, p. 6.

13. Henry Simpson, The Lives of Eminent Philadelphians, (Philadelphia: William Brotherhead, 1859).

14. Graff, notation on "A Study Drawing of Water Wheels." Graff Collection, Franklin Institute, Philadelphia.

15. Graff, "A Description of the Water Wheel and Forcing Pumps, Used at the Philadelphia Water Works, Constructed under the Direction of Frederick Graff, Esq." Journal of the Franklin Institute, Vol. 3 No. 1, January 1827, p. 65. and "Section of Wheel and Forebay," signed Fred Graff, Jr. November 18, 1843, copy delivered to I.P. Morris & Co. February 5, 1846. Graff Collection, the Franklin Institute, Philadelphia.

16. See notation on "Plan of the Mill Buildings," Graff Collection, the Franklin Institute, Philadelphia.

17. Annual Report, 1822, p. 7.

18. Annual Report, 1822, pp. 6-7.

19. Annual Report, 1822, p. 8.

20. Karin E. Peterson, "The Philadelphia Water Works," unpublished ms., p. 18. This includes also the text of a letter from F. Graff to Samuel Whetherill dated October 19, 1824.

21. "Plan of Thomas Oakes for the Wheels and Pumps at Fair Mount in 1819, with Lever Beams and the Pumps Placed Perpendicular." Graff Drawings, Philadelphia Museum of Art.

22. Detailed drawings are in the Graff Collection, the Franklin Institute, Philadelphia.

23. Graff, "Design for a Cast Iron Wheel for Pump No. 6," Graff Drawings, the Franklin Institute, Philadelphia.

24. City Archives. See Contract with Levi Morris for Water Wheel No. 5, adjusted to Wheel No. 6, dated April 1, 1831.

25. City Archives, 1826, Contract for Water Wheel. The contract proposal was dated August 28, 1826, and it was "agreed" October 3, 1826, to be ready for operation March 1, 1827. "We will make and put up at Fair Mount Water Works a water wheel to be eighteen feet in diameter to the extreme of the buckets, and fifteen feet long, the socets and rims four in number and the arms for which are to be cast iron, then together with all the work to be connected therewith embracing castings of iron, and of brass together with all the wrought iron bolts, railings, partitions, linings, flumes, gates, gearings and every other part of said work necessary to be done in the space comprehended from the north line of the north wall of the wheel pit, to the extreme of the crank wheel and crank pin at the south end of said wheel, and between the walls of the east and west of the building including the enclosure on the west side of the wheel."

26. Rush & Muhlenberg to Watering Committee of Fair Mount Water Works, November 12, 1827, City Archives. "When we contracted for that wheel we were ignorant of the cost of a wheel of that description, we however being desirous to obtain the job (concluding that we at least would not lose by it) agreed to make it for the price specified in the contract.

We do not make this statement with a view that we have a right to claim any renumeration for the cost over and above the amount contracted for but merely to state facts, leaving it with your body to act on it as you think proper.

Very respectively
yr. obedient svt.
Rush & Muhlenberg"

27. Annual Report, 1827.

28. These figures are from Annual Report, 1827, except the stroke, which is given as 6 1/2 feet. The contract for the pump states 48" stroke, but this was probably changed because of the greater diameter of the wheel. Graff gives stroke as 6 feet, in the contract for Wheel No. 5, with Wheel No. 4 as a model. See City Archives.

29. Annual Report, 1830.

30. See City Archives, Letter Levi Morris to F. Graff, March 14, 1831. Contract: Levi Morris, Isaac P. Morris and Joseph P. Morris, April 1, 1831.

31. Graff, "Design for Wheel No. 5 at Fairmount, and section with details of cant and arm wheel." Graff Collection, the Franklin Institute, Philadelphia. This drawing includes large-scale renditions of the detail of the wheel.

32. City Archives, March 25, 1834. Contract dated March 25, 1834, Levi Morris & Co. (Levi Morris & Isaac P. Morris).

33. The working drawing delivered to Levi Morris is in the Graff Collection, Franklin Institute, titled "Design for Cast Iron Wheel for Pump No. 6, delivered to Levi Morris."

34. Annual Report, 1834, p. 4.

35. See Bruce Sinclair, Philadelphia's Philosopher Mechanics: A History of the Franklin Institute 1824-1865. (Baltimore and London: The Johns Hopkins University Press, 1974) pp. 140-149.

36. Annual Report, 1834, p. 4

37. Because of drought in August and September, the Annual Report, 1832 questioned if there was enough water for 8 wheels, and the thought of improving the older wheels was considered. In 1832 bids were requested for the re-building of Wheel No. 1, similar to Wheel No. 5. The bid of Levi Morris was accepted, but there was no further action, and no mention

was made in the Annual Reports. City Archives, Letter to Rush & Muhlenberg and Levi Morris Co. from F. Graff, October 29, 1832. Bids for new Wheel No. 1 to be ready June 1, 1833. Letter from Rush & Muhlenberg dated November 6, 1832.

39. City Archives. Graff wrote a proposal for a new wheel and pump dated 1845, but it was not completed, and on March 4, 1845 another proposal requested bids for a wood wheel.

40. Graff, Jr., "Section of Wheel and Forebay (Front and Side) with Specifications for Wheel and Forebay Breasting." November 18, 1843 "Copy of Above Drawing Delivered to I.P. Morris & Co. February 5, 1846" Graff Collection, the Franklin Institute, Philadelphia. Graff, Jr." [Breast Wheel] Drawn by Fred'k Graff, Jr. February 27, 1847. Graff Drawings, Philadelphia Museum of Art.

41. Dictionary of American Biography, "Graff, Frederick," gives Graff's dates, p. 467.

42. See City Archives, March 12, 1834: Jacob Green to Watering Committee, December 21, 1842: Sutton & Smith to Frederick Graff.

43. See Sinclair, Philosopher Mechanics, p. 293.

44. See Sam Bass Warner, Jr. The Private City: Philadelphia in Three Periods of Its Growth. (Philadelphia: University of Pennsylvania Press, 1968). p. 104.

45. Blake, Water for the Cities, p. 90.

46. Annual Report, 1839, p. 7.

47. In 1844, local rebellion at the rates caused some districts to construct their own water systems. Dates of application and withdrawal vary with the districts.

48. Annual Report, 1849.

49. Quoted in Hugo A. Meier, "Technology and Democracy, 1800-1860" Mississippis Valley Historical Review, No. 43, March 1957, p. 618-640. See also Edwin T. Layton, Jr. ed. Technology & Social Change in America (New York, Evanston, San Francisco, London: Harper & Row, 1973) p. 95.

50. Thomas Ewbank, "A Descriptive and Historical Account of Hydraulic and Other Machines for Raising Water" (2nd ed. New York, Greeley & McElrath; 1847) p. 301.

CHAPTER FOUR

1. J. Griscom, trans., "Notices from the French Journals Translated for the Journal of the Franklin Institute" Journal of the Franklin Institute, Vol. XXIII, No. 2, February 1839, pp. 133-134.

2. These were installed in several places by the Parker Brothers. The material on Fourneyron and the Parker Brothers is from an unpublished manuscript by Edwin T. Layton, Jr. "Millwrights and Engineers, Science, Social Roles, and the Evolution of the Turbine in America," which is to appear as a chapter in the book The Dynamics of Science and Technology, eds. Wolfgang Krohn, Edwin T. Layton, Jr., and Peter Weingart (Dordrecht, Holland: Reidel, 1978).

3. A summary of the story of Ellwood Morris is in Sinclair, Philadelphia's Philosopher Mechanics, pp. 285-322.

4. Ellwood Morris, "Remarks on Reaction Water Wheels Used in the United States; and on the Turbine of M. Fourneyron, and Hydraulic Motor, Recently Used with the Great Success on the Continent of Europe." Journal of the Franklin Institute, Vol. XXXIV, No. 4, October 1842, p. 217-227; and No. 5, November 1842, pp. 289-304.

5. Ellwood Morris, "Reaction Water Wheels," Journal of the Franklin Institute, October 1842, pp. 225-227 & November 1842, pp. 289-299.

6. Ellwood Morris, "Reaction Water Wheels," Journal of the Franklin Institute, November 1842, pp. 301-302.

7. Ellwood Morris, "Reaction Water Wheels," Journal of the Franklin Institute, November 1842, p. 302.

8. Ellwood Morris, "Experiments on the Useful Effect of Turbines in the United States." Journal of the Franklin Institute, Vol. XXIV, No. 6, December 1843, pp. 377-384.

9. Graff to Watering Committee, January 31, 1843. City Archives.

10. Frederick Graff, "Section of Wheel and Pump, with Pencilled Sketch of Turbine," February 1, 1843, Graff Collection, the Franklin Institute, Philadelphia.

11. Frederick Graff, Jr., "Section of Wheel and Forebay," November 18, 1843, Graff Collection, the Franklin Institute, Philadelphia.

12. William Cullen, A Practical Treatise on the Construction of Vertical and Horizontal Water-Wheels. 2nd ed. (London: F.N. Spon, 1871). p. 17. Cullen was an Irish millwright who personally researched the French turbines and wrote an explanation to promote thier use in Ireland.

13. See Cullen, Water Wheels, p. 18.

14. Cullen, Water Wheels, p. 18.

15. Cullen, Water Wheels, p. 18.

16. Peterson, "Philadelphia Water Works," p. 21.

17. This material on Geyelin is from the catalog of 1901, R.D. Wood & Co., Philadelphia, with who Geyelin was associated, "Water and Gas Works Appliances and Pumping Machinery," pp. 103-104, made available by the Smithsonian Institution. No information has been found as to when Geyelin started his association with R.D. Wood.

18. Letter Edward Heston to F. Graff, February 16, 1844. City Archives.

19. Letter F. Graff to Merrick & Towne, and I.P. Morris & Co., April 4, 1844. City Archives. The City Archives also contains an unsigned form of a contract which includes the plan of a turbine placed in the No. 1 Wheel space of the Mill House, operating the existing pump: Watering Committee, 1844 Proposal for Turbine.

20. Annual Report, 1844.

21. Layton, "Millwrights and Engineers," p. 22.

22. Annual Report 1861, p. 89. Also, a Graff drawing at the Philadelphia Museum of Art dated November 20, 1848, is titled "Economical Efficiency of the Wheels at Fairmount Water Works, Calculated from Data Furnished to F. Graff by Z. Parker," and "Estimate of the Effect of Parker's Wheel for Raising Water at Fair Mount," by Z. Parker.

23. The Graff drawings at the Philadelphia Museum of Art include a series of three working drawings by Graff Jr. showing in detail the "Jonval" turbine, the necessary alteration to the waste gate, and a "Design for Hoisting Machine" dated January 4, 1850.

24. Annual Report, 1851, pp. 7-9.

25. Annual Report, 1855.

26. Annual Report, pp. 6-7.

27. Annual Report 1852, p. 39.

28. Annual Report 1852, p. 9.

29. Annual Report 1853, p. 6.

30. Emile Geyelin, Address before the American Water Works Association, 1891. p. iv.

31. Annual Report 1855, p. 3.

32. Obituary, Frederick Graff, Jr., Journal of the Franklin Institute, 1890.

33. Ibid.

34. Annual Report, 1858.

35. Although Birkenbine officially requested only two turbines, he indicated that three turbines and six pumps were desirable. Annual Report, 1858.

36. Annual Report 1860, p. 9.

37. Annual Report 1861, p. 3.

38. See "Turbines at the Philadelphia Water Works," Engineering, April 27, 1866, p. 269. This gives a detailed description of the turbines and was reprinted in Zerah Colburn and William H. Maw, The Waterworks of London, Together with a Series of Articles on Various Other Waterworks. (Philadelphia: Henry Carey Baird, Industrial Publisher, 1868).

39. Annual Report 1861, p. 13.

40. "Turbines at the Philadelphia Waterworks," Engineering, April 27, 1866, p. 269.

41. Annual Report 1861, pp. 79.-92.

42. Annual Report 1866, p. 5.

43. "Description of the Filtration Works and Pumping Stations," also "Brief History of the Water Supply," Department of Public Works, Bureau of Water, City of Philadelphia, 1909., p. 70.

44. Annual Report, 1869.

45. The material on the turbines in the remodeled Mill House is taken from Editorial, "Fair Mount Water Works -- New Wheels and Pumps," Journal of the Franklin Institute, Vol. LVII, No. 3, March 1869, pp. 145-148. See also Engineering September 18, 1868, pp. 267-269 & p. 272.

46. Information on contemporary press coverage has been obtained from newspaper clippings in the Graff Jr. Scrapbook, Water Department Archives.

47. Ibid.

48. Ibid.

49. Dictionary of American Biography, p. 467. "From 1873 to 1877 Graff was associated with Henry R. Worthington of Philadelphia and New York, and for the remainder of his life engaged in practice as a consulting engineer...and established a reputation as one of the leading water-works engineers of his time. His standing in the profession was recognized by his election to the office of president of the American Society of Civil Engineers in 1885...He was also president of the Engineers' Club of Philadelphia and was for three years a vice-president of the Franklin Institute.

50. Graff Jr. Scrapbook, Water Department Archives.

51. Annual Report 1867, p. 2.

52. Graff Jr. Scrapbook, Water Department Archives.

53. "The Water Works of Philadelphia," United States Railroad and Mining Register, November 23, 1872.

54. Annual Report 1871, p. 6.

55. Annual Report 1872, p. 5.

56. Annual Report 1871, p. 6.

CHAPTER FIVE

1. James Bryce, The American Commonwealth, 2nd. ed., Vol. II (New York: The Commonwealth Publishing Co., 1908) p. 420.

2. Annual Report 1874, p. 8.

3. Annual Report, 1882.

4. Frederick Graff, Esq., "Report of the Watering Committee with the Accompanying Reports of Frederick Graff, Esq. Superintendent of Fairmount Water Works, on Filtration; and the Professors Booth and Garrett on Schuylkill Water." (Philadelphia: Crissy & Markley, 1854).

5. Henry P. M. Birkenbine, "Future Water Supply of Philadelphia," Journal of the Franklin Institute, Vol. 105, p. 305, May 1878.

6. Annual Report, 1883. p. 266.

7. This is presumed to be Wheel No. 1, the 1851 turbine, because it operated independently to supply the Fairmount Reservoir and it was completely overhauled in 1906.

8. Notation on a printed copy of Journal of the Common Council, "Aquarium Ordinance" p. 294: "Water Bureau employees withdrawn from Fairmount Works May 13, 1912" Water Department Archives.

9. Emile Geyelin, "Address before the American Water Works Association" 1891.

Addendum to:
Fairmount Water Works
East Bank Schuylkill River
Aquarium Drive
Philadelphia
Pennsylvania

HAER No. PA-51

HAER
PA,
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WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
National Park Service
Department of the Interior
Washington, D.C. 20240

HISTORIC AMERICAN ENGINEERING RECORD

FAIRMOUNT WATER WORKS
HAER

Location:	In Fairmount Park, Philadelphia, Pennsylvania. On Aquarium Drive along the east bank of the Schuylkill River, south of Fairmount Dam, below the Philadelphia Museum of Art. UTM: 18.48400.4423760 Quad: Philadelphia
Date of Construction:	Engine House 1812-15, Mill House 1819-22, Remodelled Engine House 1834-35, New Mill House 1859-62, Remodelled Mill House 1867-72, Aquarium 1911, Kelly Natatorium c.1950.
Present Owner:	Water Department of the City of Philadelphia Municipal Services Building Philadelphia, Pennsylvania
Present Use:	Discontinued providing water in 1909. Became Philadelphia's Aquarium from 1911-62. Kelly Natatorium closed in 1967. Engine House now is a summer luncheon restaurant; all other buildings are currently not used.
Significance:	The Fairmount Water Works (1812-1911) replaced B.H. Latrobe's famous Centre Square Engine House (1801-15), one of two engine houses of the first municipal water distribution system in the United States. The new Works was located along the Schuylkill River below "Faire Mount," the highest point near the city, and pumped water to reservoirs at the top of Fair Mount by steam engines (1815-1822), breast wheels (1822-1876), and water turbines (1851-1909). The picturesque site, enhanced by Greek Revival and Tuscan-inspired buildings, became the nucleus of Fairmount Park.
Historian:	Susan Stein September, 1978

ACKNOWLEDGEMENTS

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This project would not have been realized without the interest and enthusiasm of Mrs. Susan Myers and the Junior League of Philadelphia, Inc.

ABSTRACT

The Fairmount Water Works replaced Benjamin Henry Latrobe's famous Centre Square Engine House (1801-1815), one of two engine houses of the first municipal water distribution system in the United States. The new works was located on the banks of the Schuylkill River below "Faire Mount," the highest point near the city. Water was pumped to reservoirs at the top of Fair Mount by steam engines (1815-1822), breast wheels (1822-1876), and water turbines (1851-1909).

The Engine House, a domestic-looking structure with Federal style details, was erected in 1812-15 and enclosed two steam engines: a low pressure engine of Boulton and Watts design built by Samuel Richards (1814) and a high pressure Columbian engine built by Oliver Evans (1815). Frederick Graff, formerly Latrobe's

chief draftsman at Centre Square, was the architect and engineer.

The high cost of fuel and an explosion in 1818 which killed three men caused the Watering Committee to convert the water works from steam to water power. After construction of a dam across the Schuylkill (1819-21), a mill race and forebays, a large Mill House designed for eight breast wheels was erected. Three wooden breast wheels crafted by millwright Drury Bromley were installed (1822). Additional wheels later were made by Rush and Muhlenberg (1827), Levi Morris and Company (1832 and 1834), and two by Merrick and Towne (1843). The three wooden wheels were replaced by I.P. Morris and Company (1846).

The Fairmount Water Works immediately became an important site for its technology and picturesque beauty. Its immense popularity grew through lithographs, engravings, porcelain, poems and music such as "The Fairmount Quadrilles." A visitor described Fairmount in 1838:

> Almost every body at home and abroad has heard of the beautiful spot called "Fairmount;" at least every travelled person has. It would be considered as the absence of all taste, for a stranger to appear in Philadelphia, and not to devote an hour to visit "The Fairmount Water Works."
>
> The grounds, connected with Fairmount are beautifully laid out in circular grass plots adorned with ornamental trees and shrubbery . . .
>
> In the main edifice, there is a capacious hall arranged with settees for the accommodation of visitors; and no scene can be more cheering than to mingle in the multitudes of all tongues and nations, who come hither in a hot summer's day.
>
> Around the basins, there are gravelled walks, in which vast numbers of people promenade at all hours of the day. A space between these promenades is grass-platted; and recently ornamental trees have been planted upon the crown of the lower plat which will in time form a delightful shade, entirely encircling the hill.

The top of the Tuscan-inspired Mill House served as a promenade along the mill race, flanked by two wings with Doric porticoes facing the river. Two portals were crowned by sculptures by William Rush, The Schuylkill Chained and The Schuylkill Freed. A gazebo (1835) was built at the end of the Mound Dam and a portico (1835) in the prevailing Greek Revival style was added to the saloon, the remodelled Engine House.

Philadelphia's growing population made increasing demands on the water supply. A more efficient method was achieved with the 1851 installation of a Jonval turbine made by E.E. Geyelin and I.P. Morris and Company. This turbine proved so successful that three more were erected in a New Mill House (1860). Six breast wheels were removed from the old Mill House during its alteration (1867-72) to accommodate three additional turbines. The central Doric pavilion and two Entrance Houses were erected at the same time. The last breast wheel was removed in 1883.

Steadily increasing pollution of the Schuylkill River forced the closing of the Fairmount Water Works in 1909. The mill buildings and Engine House were turned over to the City of Philadelphia to establish an aquarium which operated until 1962. The New Mill House was converted for use as the Kelly Natatorium (c. 1950). Fair Mount, the site of the reservoirs, was given to the Commissioner of Fairmount Park for the construction of the Philadelphia Museum of Art.

Water Distribution in Philadelphia, 1799-1815

CHAPTER I

American cities began to flourish following a period of economic crisis after the Revolution. Trade increased and while the cities grew rapidly, local government had not yet begun to provide many public services. The danger of fire was particularly acute in the crowded alleys and streets. Firefighting was left primarily to either volunteer bucket brigades or, in Philadelphia, to privately paid fire companies. At best, the water supply was inadequate. In 1790, 28,522 persons lived within the boundaries of the old city of Philadelphia with 13,998 more in the adjacent sections of Northern Liberties and Southwark. By 1796 about three hundred public pumps and wells provided water.

Undoubtedly the greatest menaces to the city's inhabitants were fire and disease. Plagued by smallpox and yellow fever epidemics, thousands lost their lives. The worst outbreak in

Philadelphia was the great yellow fever epidemic of 1793. More than four thousand deaths, almost ten percent of the population, occurred in three months. The nation's busiest port was virtually closed while everyone who could leave the city fled to nearby towns. Yellow fever returned again in 1794 and 1797, and the fourth epidemic of 1798 caused almost total evacuation of the city. Forty thousand people (about seventy-five percent of the population) were forced to leave; thirty-five hundred perished.

Two factions developed about the cause and treatment of yellow fever; one believed in domestic origin and the other in foreign origin. Neither was correct. Dr. E.H. Smith described the New York epidemic of 1795:

> Clouds of musketoes, incredibly large and distressing . . . continued to afflict us, long after the times when they usually depart . . . The irritation, restlessness, and consequent watchfulness and fatigue, occasioned by these animals, no doubt predisposed the well to be affected by the fever; while they extremely harrassed the sick, and retarded their recovery.[2]

Philadelphia's Dr. Benjamin Rush noted, too, that mosquitos generally accompanied sickness. Of course, the cause was not known until Dr. Walter Reed proved that yellow fever is transmitted by mosquitos carrying the yellow fever virus.

Whatever the disagreements over the cause of yellow fever, all concurred that stagnant pools were a harbinger of disease. The Aurora of May 3, 1799 reported:

> Persons who are disposed to visit the environs of this city, and more particularly on a warm day after a rain, are saluted with a great variety of fetid and disgusting smells, which are exhaled from the dead carcasses of animals, from stagnant waters, and from every species of filth that can be collected from the city, thrown in heaps as if designedly to promote the purposes of death . . . It must be evident that an atmosphere impregnated with putrid exhalations, not only generated pestilential diseases, but tends to render them more contagious.

The Select and Common Councils of Philadelphia decided to combat filth by flushing the streets with water three times per week.

Benjamin Franklin remarked in his will that Philadelphia's wells might become as contaminated as those of Europe.

The close proximity of wells to privies and graveyards generated considerable concern. Every house had a privy which drained into a boghole in the ground. Water for drinking and cooking was drawn from pumps located on each street; seepage certainly occurred between boghole and well. The Aurora's editor wrote:

> Another most preposterous and baneful custom prevails among us, it is that of digging privies twenty or thirty feet deep, whereby magazines of putrefaction are maintained for a hundred years together; as by means of the absorbent powers of the gravel that is generally found at a certain distance beneath the surface of the earth, they must naturally communicate their excrementious qualitites to the waters of the city.[3]

The new interest in municipal cleanliness exemplified by frequent flushing of the streets emphasized the increasing demand for water. Philadelphia was proud particularly of her public pumps. The water quality apparently was quite high. Peter Kalm, a Swedewho visited the city in 1748 wrote, "The good and clear water in Philadelphia is likewise one of its advantages." However, by 1794 water quality had deteriorated noticeably, especially in rainy weather when seepage from cemeteries contaminated wells. A decision would have to be reached soon about how to provide a clean, plentiful water supply. Two alternatives were to be considered: The first alternative was the system of public aqueducts constructed in Roman antiquity, familiar to eighteenth century gentlemen schooled in the classics. The second was private water companies as established in London with the New River Company, the Chelsea Water Company, and the Lambeth Water Works.

The Delaware and Schuylkill Canal Company, incorporated by an act of the Pennsylvania Legislature in 1792, intended to build a canal linking Philadelphia with the Ohio River and Lake Erie. In addition, the Delaware and Schuylkill Canal Company in its charter received the right to supply and sell water to Philadelphia at a profit of not greater than ten percent. Work was begun on a sixteen mile canal between Norristown and Philadelphia: By 1795 only three miles had been finished at either end and it appeared that the project would not be completed. Meanwhile, investors lost faith and the company's assets plummeted, resulting in the suspension of work on the canal. The canal company proposed that the city buy twenty-five percent of the company's stock for 50,000 pounds with the privilege of appointing four out of six directors. The Joint Committee, of course, refused to settle for a minority interest and the issue over public or private control of the water supply developed. Continued yellow fever outbreaks forced the city into action.

In November 1978 the Common Council called for the formation of a Joint Committee on supplying the city with water. In December Select and Common Councils issued a petition to the state legislature calling for action on the water issue:

> In this state of uncertainty, prudence dictates the propriety of guarding in the best possible manner against both sources, and it seems generally agreed (be the origin

> foreign or domestic) that the introduction of good and wholesome water for drinking and culinary purposes, and for the occasional flooding of the streets of this city, will be the best means of promoting the health of its inhabitants, and of correcting the state of our atmosphere so as to render it less recipient of contagion.[4]

Few persons in America were equipped with the abilities and expertise to handle such a complex problem. It was fortunate that Benjamin Henry Latrobe (17 -18), engineer and architect, had located recently in Philadelphia to design the Bank of Pennsylvania, a great circular banking hall covered by a brick dome and illuminated by large windows. While at work on the bank, Latrobe first encountered Frederick Graff, future engineer and architect of the Fairmount Water Works, and hired him to make working drawings of the bank.

Raised in England, Latrobe was the son of the well-known Bishop Benjamin Latrobe, pastor of a Moravian parish, and Ann Margaret Antes, daughter of a Pennsylvania Moravian. Latrobe studied architecture probably with Samuel Pepys Cockerell, an early exponent of the Greek Revival, and engineering with John Smeaton, known for building waterwheels, canals and machines. In England, while three especially important architects were active, Latrobe was familiar with the fanciful, inventive work of John Soane, the more traditional Palladian approach of William Chambers, and the superb planning of the Roman-influenced Adam brothers. Latrobe's own approach was identified with "simplicity, geometric power, and rationalism."[5]

When invited to make recommendations about the future water supply, later published as <u>View of the Practicability and Means of Supplying the City of Philadelphia with Wholesome Water</u>,[6] Latrobe enumerated the requirements for the project: First, the works must be operational by August, 1799; second, they must be constructed for permanent use; and third, the works must be operable yearround, regardless of freshets and ice.[7] Latrobe's proposal was completed while he was at work on the Bank of

Pennsylvania and less than two months after his arrival in Philadelphia, a testimony to his ability to work quickly. The Watering Committee soon elected Latrobe's plan to build a basin on the banks of the Schuylkill from which water could be pumped by steam engine through a channel to Centre Square where a second steam engine would pump the water to a high tank for distribution.

Talbot Hamlin, architectural historian, wrote: "One is amazed at the speed which the working drawings of this important work were made. Latrobe's chief draftsman on the waterworks project was Frederick Graff . . . Latrobe chose well . . ."[8] The master drawings probably were finished by Latrobe, a superb draftsman with remarkable skills in rendering and especially in applying water color. Undoubtedly Graff studied Latrobe's technique which Latrobe in turn had learned from Smeaton's exceptional engineering drafting.

It was not surprising that Latrobe called Graff "the first of my eleves" when recommending him to William Loughton Smith for the position of engineer of the Catawba Canal in South Carolina in 1804.[9]

The Delaware and Schulkill Canal Company, infuriated by their failure to complete the canal and to provide water, criticized the Centre Square project during its construction begun on March 12, 1799. The agreement between Latrobe and the city stipulated that the works were to be operational by October 2, 1799 and finished by July 1, 1800. Impeded by bad weather, Nicholas Roosevelt's delay in manufacturing the steam engines, excavation through stone, outbreaks of yellow fever and financial difficulties, the Centre Square works opened on January 27, 1801. What Latrobe estimated would cost $127,000 and take seven months, ultimately cost over $220,000 and took twenty months to complete. Nelson Blake described Centre Square:

> . . . The pioneer Philadelphia waterworks had its source in a marble-paved basin, eighty-four feet wide and two hundred feet long, extending eastward from the Schuylkill River at the foot of Chestnut Street. This was provided with a set of side-lock gates, so that the turbid waters of high tide could be excluded and the clearer water of ebb tide admitted. From this primary basin the water passed through sluice gates into a second and somewhat smaller basin and then into an oval-shaped tunnel, three hundred feet long, cut through solid rock nearly the whole distance. From this, the water emptied into a well ten feet in diameter and thirty-nine feet deep.
>
> Above this well stood the so-called Lower Engine House, which raised the water into a brick tunnel six feet in diameter and 3,144 feet in length, extending down Chestnut Street to Broad Street and thence to the Centre Square, or Upper Engine House. Here the water was pumped fifty feet from the bed of the tunnel, into two wooden tanks with a total capacity of over twenty thousand gallons. From these reservoirs the water descended into an iron chest on the outside of the building, to which the wooden mains were connected that supplied the city. Two 6-inch mains ran down Market Street: one 4 1/2 inch ran down Arch Street and one 4 1/2 inch down Chestnut; from these the water was distributed in the cross streets through 4-inch and 3-inch logs.[10]

Occupying the present site of City Hall, Centre Square's white marble facade enclosed a raised storage tank within a high circular drum covered by a flat dome. The circular drum was forty feet in diameter and was supported by a lower story sixty feet square housing machinery. The simple geometric composition and dome suggested a Roman source in the Pantheon although at Centre Square the would-be oculus served as a smokestack. "The twin porticoes employed _in antis_, rested on the stereobate, their proportions and execution similar to archaic Greek originals, for example, those found in Paestum and Sicily," wrote David Orr.[11] On the other hand, the Schuylkill or Lower Engine House reflected a more utilitarian approach. Each structure housed machinery, and each structure masked its machinery differently. Three bays on each side and two stories tall, the Schuylkill Engine House was finished with brick and covered by a low pitched gable roof. At Centre Square a dramatic Classical Revival building was achieved while at the Schuylkill Engine House a plain and rather domestic resolution was sought.

The Centre Square Engine House was immediately a source of pride; _Poulson's American Daily Advertiser_ wrote, "This is a joyful circumstance to the citizens at large."[12] _Independence_

Day Celebration in Centre Square, Philadelphia (1812), John Lewis Krimmel's painting, shows William Rush's sculpture Nymph and Bittern, (installed in 1809) and later moved to Fairmount. Rush sent his bill to the Watering Committee, "to carving figure for fountain at Centre Square to collecting stone for fountain and superintending the erection thereof and painting thereof."[13] Nymph and Bittern at once was famous, if not notorious, for the life-like, scantily clad representation of its model, Nancy Vanuxem, daughter of the Chairman of the Watering Committee, James Vanuxem. Certainly Latrobe was successful in creating "an ornament to the city."[14]

Difficulties with Centre Square's operation aggravated City Councils: In 1801 one vote defeated a resolution to thank Latrobe for his efforts. The steam engines of Boulton and Watts design used tremendous amounts of coal and were expensive to maintain. The wooden arms and shafts of the fly wheel and the lever beams broke down constantly. Unfortunately, Latrobe's system depended on two engines operating in tandem so that whenever one engine failed, the entire water supply system ceased operation immediately. Distribution, too, was troublesome because of wooden pipes which often rotted away or burst.

Latrobe's Centre Square Water Works was a significant advance for the city in spite of the system's shortcomings. Centre Square primarily established that one of the responsibilities of city government was the provision of an adequate water supply. In addition, Latrobe trained two capable young engineers at a time when there was no formal education available. John Davis was the second chief engineer at Centre Square who left in 1805 to design the Baltimore waterworks system. Latrobe also employed Frederick Graff to excavate the Schuylkill basin and tunnel. After Graff returned from his first independent project in 1805, the Catawba Canal, Davis selected Graff to succeed him as Chief Engineer, a post Graff held until his death in 1847.

Steam Engines at Fairmount, 1815-1822

CHAPTER II

As early as 1802 John Davis recognized the inadequacy of the present water works and realized that an improved system was needed. He conferred with members of the Watering Committee and especially with Henry Drinker about a site on the east bank of the Schuylkill called Morris' Hill. Morris' Hill, the highest point near the city, had been called "Faire Mount" by William Penn and appears on a 1682 map by Holmes. By 1811 the Centre Square system could not be endured; Graff was forced to spend many nights patching the leaky, temperamental engines. Finally the Watering Committee was ordered by Councils to evaluate the situation. Together Graff and John Davis conducted a survey and on December 18, 1811, Graff and Davis offered four proposals to the Watering Committee: (1) to overhaul the Centre Square works for $7,330 with an annual cost of $18,000; (2) to maintain the Centre Square reservoir and add two steam engines below Morris' Hill; (3) to complete the old Delaware and Schuylkill Canal; and, (4) to use the Wissahickon Creek, as Benjamin Franklin had advised in his will.[15] The plans to utilize the Wissahickon would cost over $359,000 with an annual maintenance cost of about $23,000. The Delaware and Schuylkill Canal could not be considered seriously because the canal height would be three feet lower than the highest levels of the city. Clearly the Fair Mount site was the best choice in terms of cost and feasibility; on May 2, 1812 the Watering Committee made its recommendation to Councils.

Morris' Hill was purchased by the city and construction began on August 1, 1812 with Frederick Graff as Superintendent. Graff also was authorized to make contracts on behalf of the city. Jonas Smith hauled "all the stone wanted for the building of the walls of the Reservoir at Fair Mount from the quarry at the foot of the hill of said place;"[16] approximately three hundred perches of stone were required. The Union Canal Company of Pennsylvania granted the Watering Committee the right to lay pipes of conduit along their towing path. By June 1813, five thousand feet of straight yellow pine logs were delivered to the log pound near the Schuylkill where they were soaked and then bored.

Two steam engines were to be used at Fair Mount: The first to be a low pressure engine of Boulton and Watts design and the second, to be a high pressure Columbian engine of Oliver Evans design. Initially Samuel Richards furnished the castings and an air pump. These proved defective and on October 25, 1813, the Watering Committee summarized the situation:

> Two air pumps have been furnished by Mr. Richards neither of which are fit for use, nor correspond with that contracted for. Mr. Richards refused to cast another air pump, and the time in which he contracted to furnish one having expired; the Watering Committee engaged Mr. Oliver Evans to cast an air

> pump, of which the price to be paid, the Watering Committee informed Mr. Richards.[17]

Oliver Evans later manufactured the high pressure Columbian engine operated in July, 1816.

Before work could begin on the Engine House, it was first necessary to sink a wharf for landing fuel, build a cofferdam to enable carrying the aqueduct from the pump chamber into the river, cut a passage for the ascending main to the reservoir at the top of Fair Mount, and clear rock in front of the future Engine House for storing fuel. In his 1813 report, Graff wrote:

> Owing to the hard nature of the rock through which the pump chamber on Schuylkill is to be formed, little or no progress has been made in the building of the engine house this year: As the masons were too much exposed from the frequent blowing of the rock, it was deemed more prident for their safety, and for the interest of the city, to suspend the work this season, and to complete the pump chamber by the opening of the spring.[18]

By September 1813 the surrounding wall of the reservoir was completed. Divided into two chambers, the reservoir floor was puddle clay and the walls grout with clay. Half of the fifty thousand feet of timber for the leading main was delivered and two ranges of pipe were laid from Centre Square on the east side of Broad to Vine and five ranges to Schuylkill Third Street. Distribution continued along Schuylkill Third Street to the Union Canal tow path.

The 1814 Watering Committee report recorded:

> The engine house and boiler sheds have been erected and slated. To protect that building from receiving damage from the high freshes in the Schuylkill, and particularly against the floating ice, a strong wall upwards of four feet thick, projecting ten feet from the engine house, has been built, carried up to the level of the street and vaulted.
>
> The engine is now putting up, the lever beam and fly wheel are hung, and the boiler placing. The pump chamber, four feet below low water mark, is finished; and the channel which is to be two feet below said mark and conducted several feet in the river, remains to be accomplished. The excavation in the rock for the rising main, from the reservoir to the building, is almost complete.[19]

The foundations remained partly finished until Oliver Evans's engine was put in place in order to regulate the proper height of the walls. The remaining work to be begun the following spring was the installation of the engine, pumps and cylinders, and rising main. To date the costs were:

Leading Main	30,878.97
Buildings	18,885.60
Reservoir	27,959.24
Engine and Pumps	55,708.75
Salaries	3,137.72
	136,570.28

In addition, Alexander and William Adams were paid over $250 for procuring nine hundred thirteen gallons of whiskey and spirits for the workmen. James Flanagan made the sashes and window frames, Samuel Pancoast was ironmonger, and Jacob Babb was the stonemason who cut the fascia. Bennett and Tennant charged $306.47 for marble coping while Richard Smith turned one hundred ninety balusters at fifteen cents each. The roof was slated by John R. Griffiths.[20]

The Boulton and Watt steam engine, boiler, pump and ascending main were finished in August, 1815 and began operation on

September 7, 1815, "and from that time to the present, the supply of water for the City has been derived entirely from the New Works."[21]

> The parts of the Works remaining to be finished are the following: The small pump at the Old Works is to be removed and fixed up for supplying the cold water cistern of the Engine; the plastering, painting, and glazing of the Engine House are to be completed; the pump channel is to be deepened, and an iron balustrade erected upon the platform, fronting the Schuylkill. The wall of the Reservoir is also to be covered with a stone coping, and further quarrying will be needful to enlarge the woodyard, which is by much too confined.[22]

The boiler and pump looked leaky and defective yet could raise two million gallons to the 3,264,126 gallon capacity reservoir per day. The engine worked about twelve hours at a time and used five cords of oak or one hundred six bushels of Virginia coal in thirteen hours.

The Engine House, begun in 1813, erected in 1814, and finally finished in 1815, was designed by Frederick Graff. A complete set of drawings of the Engine House signed by Graff and dated 1813 identifies Graff as the architect. For many years the attribution was questionable, largely because of Talbot Hamlin's supposition about the possible collaboration between Graff and Robert Mills.

> There was one other important work in Philadelphia in the influence of Mills may perhaps be traced--the Waterworks on the Schuylkill River . . . Mills had been in close touch with the entire project and had in 1810 refused the presidency of the company. It is therefore not beyond the bounds of possibility that Mills designed the buildings, or at least had great influence in their creation. Certainly, many of the details of the powerhouse have the closest resemblance to other Mills work of the time, such as the Ninth Street houses; and stylistically the combination of restraint and delicacy would indicate a strong influence from Mills or someone exactly like him.[23]

Hamlin failed to recognize that Graff, like Mills, had trained with Latrobe not only as engineer but as architect. Graff was equally at ease drawing buildings as he was designing machinery.

The numerous Engine House drawings of 1813 demonstrate Graff's sophisticated mastery of Latrobe's technique and architecture. Graff's experience as draftsman on the Bank of Pennsylvania and as chief draftsman at Centre Square produced considerable expertise. These visionary drawings of the

Engine House were rendered in sepia ink with finely applied water color. Most noticeably different from later views is the exterior finish. Evidently Graff preferred finished, coursed blue stone, but the Watering Committee was unwilling to pay the additional expense and stucco was selected instead. The Engine House exterior for the most part has remained unchanged since 1815. The main block on the east and west fronts has three bays, three stories with another story below grade and is flanked by a one-story boiler shed on the north and south façades. Doorways are located at the central bays and in the boiler shed bays on the east and west, and at the southwest and northeast walls of the sheds. The north and south façades have four openings on the first and second floors and two on the third floor. A wood balustrade broken by three equally-spaced medallions tops the sheds' roofs on the north and south; at east and west the balustrade is pictured with finished stone. The four chimneys are shown to be of equal size, although a handwritten note designates two higher east chimneys.

Apparently the earliest published view was the frontispiece of Portfolio in 1819, executed by William Strickland or someone who copied his earlier signed view. Here the Engine House was shown from a vantage point on the west bank of the Schuylkill. The fence around the reservoir was visible as was a steep flight of stairs leading to the reservoir. The original sea wall was pierced by four semi-circular openings and a round-headed door with access to the river bank. A balustrade, probably iron, stretched along the river at the top of the sea wall. The two tall and two short chimneys were depicted correctly; the roof was either slate or wood shingles. The large steam engines were placed on the floor of the lowest level with the lever beams extending just above the second floor. The fly wheels were parallel to the north and south façades. The rising main ascended rapidly from the pumps at about a thirty degree angle.

Graff's stylistic resolution of the Fairmount Water Works was an interesting choice in view of the contemporary architectural scene. Of course Graff was particularly well acquainted with the stylistic differences between Centre Square and the Schuylkill Engine House. Centre Square was a bold, if not avant-garde, design which was one of several harbingers of the Classical Revival in Philadelphia. On the other hand, the Schuylkill Engine House was a more straightforward, vernacular structure. Hampered by the Watering Committee's constraint, financial and otherwise, Graff opted for an approach which would neither cost too much nor further alienate critics of the Fairmount project. Potentially explosive steam engines were encased in a building which looked much like the typical Pennsylvania stuccoed house with Federal details. Hamlin's comment about "the combination of restraint and delicacy"[24] probably stems from the fenestration where arched recessed openings surround rectangular windows. The fenestration of Robert Mills's Ninth Street houses appears somewhat similar. At Fairmount, however, Graff manipulated this fenestration scheme to make the building seem smaller and less imposing.

During 1816 the channel which led from the river to the pump chamber was deepened to increase the water supply to the pumps. The Annual Report for 1816 reported, "An iron balustrade has been erected upon the platform, fronting the river, and the Engine House has been plastered, painted and glazed." The severe winter damaged the upper masonry courses of the reservoir and the Watering Committee decided to finish the wall in a less costly fashion. The Boulton and Watts engine was useless from late July until it was repaired on September 5th. To complicate matters, trouble with the Columbian engine "rendered a continuance of the supply extremely precarious."[25]

Rapidly deteriorating and leaky wood pipes were so problematic in 1817 that Graff suggested the installation of iron pipes, ". . . although the cost in the first instance will be greater, yet the Committee are inclined to believe the ultimate saving will be very considerable by the substitution of Iron pipes . . . ."[26] An experimental four hundred foot long section was laid; cast iron pipes and stopcocks were ordered from England for examination. It was also proposed that Graff go to London to inspect cast iron pipe installations. By this time, the Columbian engine proved successful:

> After a full trial of the Engine constructed by Oliver Evans, it has been found to perform equal to his contract, and the Committee have therefore accepted it, and have paid him the balance of his account.[27]

A post and rail fence was installed by Noble Caldwell around the city's property at the reservoir and D. and C. Landreth improved the landscape by planting twenty-seven trees. One year later in 1818, the Watering Committee proposed to remove part of the stone work on the reservoir in order to cover the reservoirs with three-foot "wharf logs," thus increasing the holding capacity to 500,000 gallons. A lot on Cherry Street between Ninth and Tenth Streets was purchased for workshops.

Although the high-pressure Columbian engine was able to pump more water than the earlier Boulton and Watts engines, the Columbian also consumed much more fuel. It cost over $30,000 to operate the Fairmount Water Works per year while annual receipts averaged only about $20,000. The reservoir could store 3,226,126 gallons and the Columbian could pump 3,000,000 gallons, but the pipes could distribute no more than 1,000,000 gallons daily. The growing population needed twice as much. To make matters worse, one of the boilers exploded in 1818 and killed three men. The Fairmount Water Works would not be successful until a less expensive and a more efficient means could be devised to pump water into the reservoir.

Breast Wheels at Fairmount, 1822-1876

CHAPTER III

The Delaware and Schuylkill and the Schuylkill and Susquehanna Canal Companies persisted in believing the Schuylkill could be made navigable and that they could provide a better supply of water. The two companies were chartered together as the Union Canal Company which was granted the right to supply Philadelphia with water by the Pennsylvania Legislature. The Union Canal never progressed beyond a waterway from Middletown on the Susquehanna to Reading on the Schuylkill. The plan to link the canal to the Delaware was dropped.

At about the same time, the Schuylkill Navigation Company was chartered, in March, 1815, to make the Schuylkill navigable with canals, dams, and locks. The company also was granted rights to harness the Schuylkill's water power. As the Watering Committee grew disenchanted with steam power at Fairmount, the city investigated a possible agreement with the Schuylkill Navigation Company to use water power to pump water into the Fairmount reservoir. Captain Ariel Cooley of Chicopee, Massachusetts was hired to survey the Schuylkill to determine whether a dam could be built. Thomas Oakes filed an additional report in 1818 in which he stated:

> The mode of raising water for a supply of the city, by using the water power of the river Schuylkill by a water fall at Fair Mount, appears to me to be the most effectual and desirable of any within the reach of the city.[28]

Oakes also recommended the installation of water wheels of fifteen feet in diameter and eighteen feet wide, and a head race of eighty feet long and four feet deep to accommodate eight wheels. He estimated costs as well: construction of the dam, $25,000; locks, piers, and head gates, $25,000; mill house, four water wheels, head race, and a raising main to each pump, $46,000.

In 1819 Ariel Cooley, Lewis Wernwag, Thomas Oakes, William Briggs, and William Lehman collaborated on <u>An Additional Report</u>

on Water Power by the Watering Committee with Communications on the Subject. Obviously in favor of the proposal, the Committee stated:

> The committee forbear to display the advantages which would be derived in extreme hot weather, from a constant flow of water in our streets, and the playing of fountains in our public walks, creating an elasticity in the air so necessary to public health; but they cannot forbear alluding to the advantages which would be derived from the surplus water of the river.[29]

An agreement was reached between the Schuylkill Navigation Company and the city; the city would build a dam, canal, and locks. The canal and locks then would be turned over to the Schuylkill Navigation Company for operation. The company retained the right to draw as much water as it needed to operate the canal and locks. Meanwhile, the city also negotiated with Josiah White and Joseph Gillingham, mill owners at the Falls of the Schuylkill, whose water power would be lost after the dam was built. The city agreed to pay $150,000 to compensate White and Gillingham.

Joseph S. Lewis, the shrewd Chairman of the Watering Committee from 1817 to 1825, formally proposed the improvements to Councils after the tentative agreements were reached. In two reports presented to Councils in February and March, 1819, the Committee stated that annual operating costs could be reduced from $30,000 to less than $23,000 with a capital expenditure of about $346,000, not to mention the tremendous increase in water supply:

> The committee are sensible, that the cost of the contemplated work is large; but when it is considered, that a safe and an economical means of obtaining 10,000,000 gallons of water can be had, in lieu of a costly and precarious supply of but little more than 2,000,000, and at the cost of not much more than one half, without calculating on the sale of a gallon to our neighbors in the districts; it is conceived that councils should not reject a plan so long sought for; hitherto unattainable; and if now suffered to escape from our grasp, never to be reclaimed. The committee believe, that their fellow citizens view with anxiety the accomplishment of a measure so important to the health of this great city; already combining so many advantages, and which if this plan be carried into effect, will, at so small an expense, be better watered by artificial means, than any other in the world.[30]

Councils approved the plan on April 8, 1819, after $350,000 had been appropriated.

Construction of the dam began promptly on April 19, 1819, under the supervision of Captain Cooley. In February, 1819, Cooley reported to Councils that the project "cannot be effected and completed in manner and form as it ought to be, so as to render the whole work perfectly safe and secure and so as to fully answer all the purposes intended short of a heap of cash."[31] Cooley's early estimate of $150,000 was accepted and was to be paid in full five years after completion of the dam. He expected the canal to be finished by September, 1820. Although the Schuylkill was not wide (about 900 feet), several complications with the site proved to be problems. First, the river bed was irregular. Near the east bank mud covered underlying rock and near the west bank, the river was extremely shallow. Sudden floods and freshets frequently occurred. Cooley, assisted by Frederick Graff, compensated by designing a diagonally-placed dam rather than one placed straight across the river. A stone, earth, and log barrier 1,204 feet long was erected, thus reducing the chance that a sudden freshet could tear away the dam. The flow of water also was directed away from the future mill buildings.

In 1820 the contract with the Schuylkill Navigation Company was amended to allow the city to increase the height of the dam by eighteen inches; William Briggs was hired for $3,200. When finished in 1821, the dam's overfall was linked on the west to the pier at the head of the Schuylkill Navigation Company's two locks and canal. On the east the dam was joined to a mound dam and then to the head arches of the mill race for the water works.

In February, 1820, "The Committee are now engaged in procuring suitable plans for the Mill houses and Machinery, which they contemplate to have erected in time to work as soon as the Dam is completed."[32] Presumably these plans were made by Frederick Graff. The new works were to be built on a scale to meet future demands. A second reservoir was constructed to increase the storage capacity to 3,500,000 gallons, largely to supply the unincorporated districts of Spring Garden and Northern Liberties. Although only three breast wheels were installed initially, the Mill House was designed to house eight wheels.

The difficulties with poor distribution were aided in 1820 by a new large iron main from the reservoir to Broad and Chestnut Streets. A plan to extend a ten-inch main from Chestnut to Front Streets was presented as well. Thus, "the means of conveying a supply of water will probably be more than equal to the quantity that can be raised by the steam engines and will be in readiness to receive the copious supply anticipated from the new Water Works."[33] The wooden pipes, however, sprung continual leaks. The dam was almost finished with the exception of a 107-foot section in the center. The iron shafts for the breast wheels were cast and ready for delivery in January, 1821;

Drury Bromley, a millwright recommended by Thomas Oakes, began to craft the breast wheels in the early spring of 1821.

Construction of the new Mill House started in the spring of 1821:

> Contracts have been made for the dressed stone for the mill houses, Mill arches, etc., to be delivered by the 10th April, at which period the Committee contemplate commencing the erection of the buildings.[34]

On January 24, 1822, Graff reported substantial progress:

> The dam, the head arches, the race, the locks and the canal, are nearly completed; some little alteration being required in the last, which can be done in a few days in the spring . . . The Mill buildings and reservoir are in a state of considerable progress; the pumps and wheels are nearly ready to be put in their places; and the raising mains are in part laid, and will be completed in full time for the other parts of the work.[35]

Meanwhile, deterioration of the steam engines accelerated, creating an incentive for finishing the new works rapidly.

Upon completion of the great work at Fair Mount, the Watering Committee issued a special detailed account describing the work and its construction. The best description noted that:

> The Mill-buildings are of stone, two hundred and thirty-eight feet long, and fifty-six feet wide. The lower section is divided into twelve apartments, four of which are intended for eight double forcing pumps. The other apartments are for the forbays leading to the water-wheels. The pump and forbay chambers are arched with brick, and are perfectly secure from the inclemency of the Winter. Those now in use are kept warm by means of two large iron stoves, heated to great advantage and economy with Schuylkill and Lehigh coal. A gallery will be erected, extending the whole length of the building, from which all the wheels may be seen at one view. The centre part of the buildings is one hundred and ninety feet by twenty-five feet, with circular doors to the pump chambers, and a range of circular windows over the arch ways of the wheel rooms: on a line with the cornice of the central part is the base course of two pavilions, with Doric porticoes, which terminate the west front. One of these is used for the office of the Committee; and the other is the residence of an old and faithful servant of the Corporation, who has the general care of the property at Fair Mount. On the east front, immediately over the pumps and forebay rooms, is a terrace, two hundred and fifty-three feet long, and twenty-six feet wide, paved with brick, and railed, forming a handsome walk along the race, and leading by steps at the end to the top of the head arches, mound dam, and pier.[36]

John Moore was the mason who exercised considerable skill, "not only for the excellence of the work in appearance, but for its substantial properties; . . . in the whole extent of the foundation along the race, under a six feet head of water, there is no leak."[37] The carpenter, Frederick Erdman, performed his work satisfactorily. The Watering Committee assigned paramount importance to the three wheels and pumps. In their construction, "We are particularly indebted to Mr. Thomas Oakes, a gentleman of science and practical knowledge, now employed as the Engineer of the Schuylkill Navigation Company."[38]

The ingenious engineers Rush and Muhlenberg made the double-acting pumps designed by Frederick Graff. The pumps were fed by a head of water supplied from the forebays. Each pump was connected to a sixteen-inch diameter main which ran along the bottom of the mill race to a rock at the foot of Fair Mount and then into the new reservoir. The pipes to the reservoir could be closed by a stop cock. The new reservoir, linked at the bottom with the old reservoir, measured 139 feet by 316 feet and was twelve feet deep with a 3,500,000 gallon capacity. The water was raised 102 feet above low tide, some fifty-six feet above the highest ground in the city.

The troublesome steam engines were finally halted on

October 24, 1822. The dam, which had received so much adverse criticism during its construction, held during the highest freshet remembered--nine feet above the overflow. The three new wheels began to lift water: Wheel number 1 on July 1, 1822, Wheel number 2 on September 4, 1822, and Wheel number 3 on December 24, 1822. At last the city had a water supply which exceeded demand. The wheels were more efficient than expected:

> It was stated that forty gallons upon the wheel would be required to raise one to the reservoir, but experience has shown that thirty are more than ample . . . increasing the calculation of the water power of the river one-third.[39]

Total cost of the new works was $432,230 while operating expenses amounted to just $4.00 per day:

> Two men are found sufficient to attend the works twelve hours at a time alternately night and day; and the calculation made last year of four dollars per day for wages, fuel, light, tallow, etc. is, upon experience, found to be ample.[40]

Additional machinery could be installed without dramatically increasing operating costs. Eight wheels pumping ten million gallons would elevate operating costs to only ten dollars per day whereas ten million gallons pumped by steam engines would cost in excess of $550 per day.

Regrettably, the Engine House was damaged during the construction of the new works. Twelve thousand pounds of gunpowder were exploded to blast away rock for the mill race, forebays, and mill house. Higher expenditures than anticipated in 1823 were explained:

> The expense of a new roof for the old engine house, the repairs of that building, and putting it in a decent state, after the injuries it had sustained by time, and by the effects of the severe blasting of the rocks for the new works; and furthermore, the alteration of the new pumps, at the commencement of their operation, which was not estimated for.[41]

The balky distribution system was the remaining difficulty to be surmounted. The Watering Committee discussed the idea of using cast iron pipes to avoid the bursting wooden ones that plagued the water system, but the proposal was dropped because the "experiments which had been made were not encouraging . . ."[42]

In 1818, after Graff consulted with Mr. J. Walker, an eminent London engineer, more information was uncovered which at once improved the overall use of cast iron pipes. The large iron main leading from Fair Mount to Broad and Chestnut proved so successful that all of the wooden pipes ultimately would be replaced by iron pipes. Pleased by the achievement of the Fairmount Water Works, the Report of the Watering Committee in 1822 announced:

> The uses and importance of this water, it is impossible sufficiently to value. The additional cleanliness of the City,--the supply of the neighboring Districts, for culinary purposes, as well as for purposes of refreshment,--the great advantages in cases of fire,--the ornament of fountains in the Public Squares so wisely provided by our Great Founder,--the benefit to manufacture, --and the establishment of Water Power in the City for various purposes, may be named among the advantages of this New Work; but above all we are to place its effect upon the health of a great and growing community, which of itself would justify a much greater expenditure.[43]

Immediately Fairmount became one of the most important sites to visit in Philadelphia, if not in America. Upon seeing Fairmount for the first time, Frances Trollope, an English critic of things

American, noted it was "one of the prettiest spots the eyes can look upon."[44] Frederick Graff was rightfully credited:

> The Committee cannot close this Report, without presenting, in the most distinct manner, to the notice of both the Councils and the City, Mr. Frederick Graff, for many years Superintendent of the Water Works, whose taste in the design, and whose judgment in the arrangement of the Works at Fair Mount, with his indefatigable zeal for the public interest, in every department, has attracted the regard and thanks of the Committee, and entitle him to those of the Councils.[44]

The technological ingenuity of the water works captivated Philadelphia's imagination. The excitement of viewing the giant water wheels, about fifteen feet in diameter and sixteen feet wide, generated amazement and enthusiasm. Water from the pond above the dam passed through three head arches into the 419 foot long and 90 foot wide mill race. The stone mill house was situated between the mill race and the river. Flumes adjoined the mill race at right angles and carried water through the mill house. The water passed over the great breast wheels to be released through arches into the river below the dam. Double forcing pumps, cranked by the water wheels, moved the water from the flumes to an iron main which raised the water to the hilltop reservoirs.

The Fairmount Water Works served a dual purpose in an era without a public park. The Water Works' rapid acclaim fostered the Watering Committee's deliberate development of a picturesque, pastoral site. Rather than erect a building with solely an industrial approach, Graff endeavored to symbolize the significance of the Water Works. Fairmount was America's premier municipal achievement and thus deserved a dignified treatment. The Mill house graced the Schuylkill with a Classical Revival façade that "conjured up images of Roman civilization and its famed engineering feats, including the great aqueducts of ancient water systems."[46] A paved terrace extended the length of the eastern front overlooking the mill race and hill to Fair Mount. Two large portals were crowned by sculptures by William Rush, Schuylkill Chained and Schuylkill Freed, representing the superb accomplishments at Fairmount. The portals were entrances to a gallery overlooking the water wheels. Two houses with Doric tetrastyle porticoes on the west flanked the gable roof of the Mill house. On the river side the Tuscan-inspired Mill house was faced with finished Leiperville stone.

Graff experimented with other possible design solutions before he chose a composite of Greek and Tuscan styles. Several drawings in the Graff Collection at the Franklin Institute demonstrate a different plan and treatment. Two elevation drawings show a scheme with a single central entry using a portal similar to the one actually installed. The Tuscan mode, however, is used throughout the structure. The Mill house terminates in two squat Tuscan towers with hip rooves. The openings to the river are almost the same with semi-circular windows placed over arches. The round-headed portals at the river's edge were eliminated.

The tradition of ornamenting civic structures continued with William Rush's carved figures of The Schuylkill Chained and The Schuylkill Freed installed in 1825 to crown the entrances to the Mill house. Graff's later plan (as constructed) placed them rising above the promenade and mill race. An elevation from the Franklin Institute's collection labeled "Doorway to Mill House at Fair Mount" shows what must have been an early version of both the doorway and The Schuylkill Chained. Here the portal is depicted as a large arched opening which echoes the fenestration scheme of the Engine House. The Schuylkill Chained appears as a bearded old man or river god holding a section of a flowing water main. Dorinda Evans stated, " . . . . . Probably inspired by an engraving of an antique sculpture of the River Nile in The Artist's Repository or Encyclopedia of the Fine Arts, published by Charles Taylor in London in 1813 . . . Rush is known to have owned the 1808 edition, and although the resemblance is not exact, the similarity in the legs is unmistakeable."[47] The reclining male figure of <u>Schuylkill Chained</u> supposedly symbolized the freedom of the river in its harnessed state. The seated female figure was in Rush's words "emblematic of the water works." Serenely presiding over the water wheel at her left, <u>Schuylkill Freed</u> is supported by an urn and flowing water main. Rush, assisted by his son John, carved the figures in wood. After they were finished in 1825, the sculptures were painted to simulate stone. The figures remained in place until 1937 when they were removed to the Philadelphia Museum of Art.

Meanwhile, an agreement was reached with the Schuylkill Navigation Company to protect the Fairmount pool from pollution with dye stuffs, noxious, fetid, or injurious substances. The astute Joseph S. Lewis struck his last significant bargain on behalf of the Watering Committee. The Schuylkill Navigation

Company had run out of money and was unable to finish their canal. The Watering Committee and the city stepped in, offering the company $26,000, the cost of finishing the canal, in exchange for "the whole of the water power at Fairmount." The financial position of the Schuylkill Navigation Comoany was so critical that the city took possession of the canal, locks, and toll house on January 23, 1825, during Lewis's last term as Chairman.

The decade following the installation of the breast wheels was a peaceful era for the Watering Committee. At last the growing needs of the city were met comfortably. Graff was justifiably proud of the new works, particularly their efficient production:

> The truest economy will be found in doing the work substantially at first: This is fully exemplified by the New Mills and Works, which have been in operation for upwards of two years, without requiring, or appearing to require for a long time to come any repairs whatever.[48]

In 1825 Graff envisioned a tremendous scheme to enlarge the works and increase profits for the city. He planned to extend the mill race and build three mills to utilize the excess power.[49]

The water works production was augmented by a new cast iron breast wheel made by Rush and Muhlenberg, which "was put into operation on the tenth of November last [1826]; . . . and pumps into the reservoir at the rate of 1,689,000 gallons of water in twenty-four hours."[50] In 1828 the mill buildings were painted and a new stairway was erected to the reservoir. A contemporary lithograph by George Lehman, published by C.G. Childs in 1833, shows a wooden walkway across the mill race and a single wood stair leading to an open-roofed summer house at Fair Mount's crest. William Rush's carving of <u>Mercury</u> for the top of the summer house was also depicted.

Descriptions of the Fairmount Water Works abounded in newspapers and periodicals. For example, C.G. Childs noted in his <u>Views in Philadelphia</u> (1827-30):

> From the earliest times, Philadelphia has not been wanting in the spirit which leads to such enterprises, though it has not always been accompanied either with the knowledge or taste which renders them successful as works of utility, and beautiful as specimens of art. With the present century, however, a new era commenced, and, with few exceptions, our public works have been such as may be viewed without shame, while their benefits can never be too highly estimated.
>
> Among these, the water-works at Fairmount are perhaps the most conspicuous. After several plans had been tried with more or less success, to supply the city with abundance of wholesome water, the scheme of elevating and turning into it the river Schuylkill, by means of an immense dam and water power, was determined in the year 1818 . . . This plan was at once boldly adopted, and has been crowned with complete success.[51]

In 1825, John Sheldon, a Fairmount visitor, wrote:

> I will not attempt to tell you how much I was delighted with the beauty, magnificence, and strength of the works. The scenery in their immediate vicinity is of the most delightful kind. The superb dam--the beautiful though small expanse of water above it, and the fine lively stream below, with its handsome bridges, combined with the delightful gardens, shaded seats, wooded hills rising here and there from the brink of the water by the side of the smooth lawns--present in the *tout ensemble*, a paradise, where the lover of nature could almost delight to dwell, even as a stranger . . .[52]

More abundant and diverse were the picturesque views of Fairmount popular throughout the nineteenth century. One of the best known was Thomas Doughty's painting *View of the Water Works on Schuylkill--Seen from the Top of Fair Mount*. In this 1826 view the two tall chimneys remain on the Engine House. A wooded vista surrounds the water works creating a harmonious composition. Doughty, landscape painter and friend of Thomas Sully and Rembrandt Peale, exhibited View of Fairmount Water Works &tc. Seen from the Opposite Side of Schuylkill at the Pennsylvania Academy of Fine Arts in 1827. This familiar view was engraved by W.E. Tucker and published by C.G. Childs in 1829. Another popular early rendering was Thomas Birch's View of the Dam and Water Works at Fair Mount, Philadelphia engraved by R. Campbell and published in 1829. The viewpoint from below the dam shows the mouth of the canal, the south side of the Engine House, Lemon Hill and the new mill buildings.

Fairmount's renown inspired further improvements by the Watering Committee. Especially before the creation of Fairmount Park in 1867, the pre-eminent site was at once recognized for its pastoral qualities. Several measures were taken in 1832 to enhance and protect the site. First, the wall south of the Engine House for securing the bank of the Schuylkill was finished and coped with stone. Second, the area south of the Engine House was sodded and planted with trees. A fountain was erected and gravel walks were laid. "In the future, the entire property of the City will present uniformity in taste as well as utility."[53] An estimate for the changes amounted to $3,400.

Equally significant in 1832 was the passing of an act intended to protect the purity of the Schuylkill. Preserving clean water was already a problem as the population and number of factories increased yearly. Organic wastes were particularly high; no sewers were installed until the 1880's. The "Purity" Act was presented to the Pennsylvania Legislature on December 20, 1831 and approved on February 7, 1832:

> Be it enacted by the Senate and House of Representatives of the Commonwealth of Pennsylvania in General Assembly met and it is hereby enacted by the authority of the same. That if any persons shall hereafter willfully take lead conduct carry off or throw shall cause to be taken led conducted carried off or thrown into that

> part of the Schuylkill which is between the dam at Flat Rock and the dam at Fair Mount near the city of Philadelphia any carrion or carcass of any dead horse or other animal or any excrement or filth from any slaughterhouse vault well sink culvert privy or necessary or any offal or putrid or noxious matter from any dye-house still-house tan-yard or manufactory or any matter or liquid calculated to render the water of said river impure every such person shall for each and every offence forfeit and pay a sum not less than five dollars nor more than 50 dollars . . .[54]

Regrettably the act was not enforced; the Schuylkill was polluted by chemicals, manufacturing wastes, and organic matter.

After the mill buildings were constructed (1822), the Engine House was no longer used. The old steam engines finally were put up for sale in 1831 and the Watering Committee decided to renovate the Engine House for use as a saloon:

> The engine building, which had stood in a dilapidated state since the erection of the water power works in 1822, have, according to the resolution of Councils, been repaired. At the time the estimate for this object was handed to Councils, it was contemplated only to repair it partially, but after having commenced with taking out the old walls, and timbers formerly applicable to the steam engines, it was found necessary for the support of the floors, to connect them with the framing of the roof; and to go further than was first intended; and finally, it was concluded that unless a perfect repair was made, the estimated sum would be uselessly expended; consequently, the estimate has been exceeded by the additional work done, and by furnishing the saloon.[55]

The steam engines required an expansive interior without a second floor to accommodate the elevated lever beams. Thus, the changes to the Engine House included the addition of a second floor, two stairways to provide access, and tenements for the workmen in charge of the machinery. Twelve settees and stools were furnished by Stuart & Sanderson in September, 1883. It was planned to advertise for a design for a fountain to be placed at Fairmount in order that "the ornamental parts of the whole mound at Fairmount, may be finished in a style that will surpass for beauty and convenience any other work of the kind extant."[56]

The idea for another fountain was dropped in 1835 since Rush's Nymph and Bittern had been moved from Centre Square to Fairmount in 1829. Instead Graff

> applied to erect a portico to the Saloon building . . . to build a new wall 214 feet long on the mound dam, and to curb and pave the same. The above improvements, together with the replacing of railings, the erection of new ones, and other additions, having been deemed more important than the fountain, it is hoped this change in the appropriation will be approved.[57]

Drawings in the Franklin Institute document Graff's designs for the new portico and gazebo, both executed in the prevailing Greek Revival style. The ten-column Doric portico was drawn directly on an 1813 elevation of the Engine House. Another drawing entitled "Design for the Saloon Building at Fair Mount," dated June 11, 1835, illustrates the porch profile with balustrade and basement façade. The exterior is depicted as coursed stone rather than stucco. The twelve-column Doric gazebo has an octagonal plan with bell-shaped roof, originally capped by an eagle carved by William Rush. Metal tie rods were added later. The gazebo was rebuilt after it was damaged by a storm.

Upon his retirement from the chairmanship of the Watering Committee in 1825, Joseph S. Lewis was given one of Thomas Doughty's views of the water works, engraved by C.G. Childs, with the inscription:

> To Joseph S. Lewis Esquire, This view of Fair Mount Works is inscribed by a number of his fellow citizens

> as a tribute of respect and gratitude for the eminent service he rendered to the City of Philadelphia, in originating and by his persevering and disinterested exertions bringing to a completion, the public work here exhibited, which for magnificence of conception, simplicty, and solidity of execution, and unmixed character of beneficence is worthy of being placed among the noblest achievements of enlightened civic enterprise.[58]

Within eight years, however, Lewis was Philadelphia's *persona non grata*. He became the President of the Schuylkill Navigation Company and totally turned against the city. On February 4, 1833, Lewis, a constable, and fifteen to twenty Schuylkill Navigation employees entered the canal toll-house, then operated by the city, evicted the gatekeeper and his family, and demolished the structure. Thus, the company regained control of the canal and created a political brouhaha:

> And what have the City Councils done to vindicate the City's rights to rescue its wounded honor? . . . have they proclaimed to the City, that its most cherished improvement, its most important security against pestilence, its only safeguard against conflagration, its best source of revenue, the object of its honest pride, has been jeopardized,--that the city of Philadelphia may now be deprived of its whole supply of water at the discretion of the Navigation Company . . .[59]

Minor skirmishes flared between the city and the company. Use of the locks lowered the water level in Fairmount pond, consequently jeopardizing the water supply to the city. As canal traffic increased, the water supply was threatened more frequently.

Lewis and the Schuylkill Navigation Company wanted additional locks to accommodate growing river traffic, thereby increasing revenues and profits. The company's interpretation of its charter established that the company was empowered primarily to make the river navigable and secondly to utilize the river's power. In effect, the navigation company viewed the river as a highway while the city viewed the river as a public resource. The company glibly maintained that there was a surplus of water. Graff knew otherwise and grimly wrote:

> In the months of August, September and October last two-thirds of the top surface of the dam was dry, and there was not water enough in the river to drive six wheels and pumps, without drawing down the water below the top

> line of the dam . . . A diminution of water, therefore, occasioned by the increased demand of the Company for their locks, will render the City water works unfit for use.[60]

Litigation dragged on for years; neither the Legislature nor the courts took action to resolve the dispute.

The dispute with the Schuylkill Navigation Company had other repercussions as well. Water service had been extended to the outlying districts after the water wheels began operation: Southwark, June 1, 1826; Northern Liberties, June 6, 1826; Moyamensing, June 6, 1832; and Kensington, October 5, 1833. Before the installation of water meters, the city charged water rents which enabled anyone to receive an unlimited water supply for a flat fee. The districts, however, were charged twice as much water rent as the city. By 1845 Fairmount could not provide water to all parts of all the districts. Spring Garden and Northern Liberties applied in 1843 to build their own distribution systems dependent on the water supply from the pond above the Fairmount dam. The Watering Committee, of course, objected, but in 1844 a pumping station was built on the east bank of the Schuylkill near Girard Avenue to supply Spring Garden, Northern Liberties, Kensington, and Moyamensing; Fairmount continued to supply Southwark. The success of the districts' distribution was interrupted abruptly on November 11, 1848 when the Spring Garden reservoir gave way, ending all water service to the districts. Frederick Graff, Jr., the new Chief Engineer, immediately ordered water to flow again to Spring Garden and Northern Liberties until the reservoir was repaired.

The Consolidation Act of 1854 incorporated the districts into the City of Philadelphia. At this time daily water consumption reached about 5,000,000 gallons and rose above 7,000,000 during the summer. Once again dramatic improvements were required to accommodate the accelerated population growth.

Water Turbines at Fairmount, 1851-1909

CHAPTER IV

The third phase of Fairmount's operation was characterized by its most sophisticated technology. As early as 1843, Frederick Graff, assisted by his son Frederick Graff, Jr., presented a plan to the Watering Committee for an experimental turbine to replace breast wheel number 1. At the same time, however, two additional replacement wheels were manufactured by Merrick and Towne for installation in August, 1843. Connecting iron mains were added and the forebay gates and waste gates were replaced as well. Excessive demands for water forced immediate action and Graff's turbine plan was abandoned until it could be further investigated. Wheel number 1 was replaced by another cast iron breast wheel.

Many general repairs were accomplished in 1846. Three leaky wood breast wheels were replaced by three new cast iron ones made by I.P. Morris and Company. The stairs to the reservoir and gazebo floor were put in good order. Granite platforms with cast iron balusters were placed at the pump chamber windows of the Mill House. In addition, the marble fountain and basin in the garden were rebuilt, the footways repaved, and the river front walls coped with stone.

Fairmount remained a picturesque spot throughout the nineteenth century. An English visitor, N.P. Willis, noted:

> The Water-Works of Philadelphia rank among the most noble public undertakings of the world . . . Fairmount is a beautiful spot; and standing, as it does, just on the skirt of the town, it serves the additional use of a place of pleasant and healthful public resort. The buildings containing the pumprooms have considerable pretensions to architecture; and the façades and galleries extend along the river, forming a showy object from every point of view.
>
> Steppes and terraces conduct to the reservoirs, and thence the view over the ornamented grounds of the country seats opposite, and of a very picturesque and uneven country beyond, is exceedingly attractive. Below, the court of the principal building is laid out with gravel walks, and ornamented with fountains and flowering trees; and within the edifice there is a public drawing-room, of neat design and furniture;

> while in another wing are elegant refreshment rooms--and, in short, all the appliances and means of a place of public amusement.[61]

Moreover, Fairmount became a "model for almost all public improvements of this kind erected in the country."[62] The water works served as a public park before the founding of rural cemeteries, such as Mount Auburn and Philadelphia's Laurel Hill, forerunners of America's public park system.

Fairmount's prominence rightfully is attributed to Frederick Graff who served as Chief Engineer until his death on April 3, 1847. Graff the engineer advanced three technologies at Fairmount: steam engines, water wheels, and water turbines. His genius extended to both architecture and landscape architecture as well. Graff firmly established the Fairmount Water Works not only as a source of water but also as a public resource. He supplied detailed information to more than thirty-seven corporations who erected waterworks. John B. Jervis, engineer of New York City's famed Croton Aqueduct, had consulted with Graff about the use of cast iron pipes. His obituary was a testimony to his professional capabilities: "Mr. Graff's character, in his relations with these works, was marked by an unbending integrity, untiring energy, and ceaseless activity for the best interests of the public."[63] His death was caused by the effects of a bad cold received fourteen years earlier when he was ordered to spike the canal's lockgates shut during a storm. Graff's memorial stone portrait bust encased by a Gothic Revival canopy was executed by John Struthers and put in place in 1848 south of the Engine House.

After Graff died, his son assumed the post of Chief Engineer from 1847-1855 and then from 1867-18

Graff, Jr., knew Fairmount well; he and his father collaborated on drawings of Fairmount's steam engines and water wheels (1843), which explained their functions and arrangement. It was

Frederic Graff, Jr. who carried out the first experimental turbine plan of 1851. As daily water consumption climbed to 4,785,338 gallons, new solutions had to be provided to increase the water supply. The first turbine at Fairmount was a French design by Jonval patented in America in 1842 by Emile E. Geyelin. The Watering Committee first visited Alfred Dupont's mill along the Brandywine Creek to see a Jonval turbine in operation and were impressed with its efficiency, agreeing to give the turbine a try.

The turbine (Wheel No. 9), manufactured in Philadelphia by I.P. Morris and Company, was put into operation on December 16, 1851. The wheel, measuring 7 feet in diameter with a bucket 10 inches deep and 13 inches wide, powered a double-acting pump. The turbine was situated in a niche between the Mill House and Engine House; the pump was placed in a new pump room adjacent to the former outside wall.

The pump room used the the old sea wall as its interior wall and had a new exterior wall. Foundation stone was suplied by G. Leiper. The exterior wall was finished with stucco and perforated by four semi-circular windows with a round-headed transom over the door at the central bay. The roof had a low slope with two skylights. The path of the original 1815 ascending main was used to carry a new pipe to the reservoir. Completion of the turbine wheel and pump was slower than anticipated because of the hard-to-reach location of the wheel. In 1853 Graff reported:

> Turbine wheel continues to give entire satisfaction and has proved itself a most valuable auxiliary to the Works, rendering most important service during the hottest months of the summer.[64]

Minor repairs were made to the water works once again in 1853. Fences and all the woodwork on the mill buildings were repainted. The Watering Committee was pleased to announce that Fairmount was in first rate condition because of "the indefatigable exertions and attentions of our efficient superintendent, Mr. Frederic Graff."[65] Difficulties ensued, however, following the 1854 Act of Consolidation which united the City of Philadelphia with the County of Philadelphia, thus incorporating the surrounding districts complete with their distribution systems and problems.

Luckily, a new reservoir at Corinthian Avenue between Poplar and Parish Streets in Spring Garden, was opened on December 22, 1852. The reservoir was 16 feet higher than the Fairmount reservoir, forcing the Fairmount engines to work harder. A 50 foot high cast iron standpipe, four feet in diameter, was erected (1852) at Fairmount to direct water to reservoirs at either Corinthian Avenue or Fairmount. The stand pipe, demolished in 1926, was protected from freezing by ornamental brickwork. Its Italianate tower design was deceptive. Segmented into five stories, each story had blind windows forming a decorative rather than functional scheme.

The distribution system was expanded in 1855 with the opening of the Twenty-Fourth Ward Works. Graff resigned in 1855 and Samuel Ogdin was appointed Chief Engineer for the years 1856 and 1857. Ogdin soon was replaced by Henry P.M. Birkinbine, a far-thinking engineer who directed the construction of the New Mill House. Reports of an inadequate water supply were common, especially in the summer months. Birkinbine's first report as Chief Engineer stressed the potentially dangerous situation:

> . . . Machinery generally was found to be out of order, and numerous leaks and other imperfections were discovered, causing a loss amounting to about 20% of all water pumped.[66]

Although few objections were voiced about Schuylkill water, quality had deteriorated. Above Reading, Pennsylvania, drainage from the mines was dumped straight into the Schuylkill, killing fish and making the water undrinkable in Reading. Burgeoning factories in Manayunk turned waste directly into the Schuylkill, imperiling Philadelphia's future water supply. Birkinbine suggested that an alternative water supply be considered in addition to the enlargement of the present works. Two proposed turbines were to be placed in a New Mill House north of the present one. Worn-out Wheel No. 4 was unable to pump except into the old reservoirs and needed replacement. These three new turbines could push output to as much as 16,000,000 gallons per day, a one-third increase.

Construction of the New Mill House began in 1859 prior to the completion of experiments (1859-60) testing the efficiency of various turbines. The experiments, monitored by the Franklin Institute, were published in 1861. Jonval's turbine again was selected for use at Fairmount; three turbines were installed in 1862.

The New Mill House echoed the Tuscan-inspired design of the old Mill House with large quoins and similarly finished

Leiperville stone. The foundations were difficult to secure because of water which leaked through the cofferdam at its conjunction with the mound dam. Additional machinery was required to keep the work area free of water. The foundations consisted of 300 piles driven 23 feet into rock. The ground was excavated 18 inches around the head of the piles and then filled in with broken stone. Timbers measuring 12 inches thick were laid to make a platform which was then covered by two layers of three-inch plank. The structure of the New Mill House, 90 feet on the north and 108 feet on the south, was finished by the summer of 1861.

During Birkinbine's term as Chief Engineer, the character of the Watering Committee changed. First, the Watering Committee became the Water Department of the City of Philadelphia, managed by a Committee on Water Works and also by Select and Common Councils. At this point, dealings with the Chief Engineer became more formal than in the past. For example, the first official inquiry was conducted on January 30, 1861 about the New Mill House. Birkinbine had promised, "Not a dollar will be required for repairs in the next fifty years," but actual cost was $123,000 which did yield a substantial structure.[67] Birkinbine carefully explained why the old Mill House could not be converted from breast wheels to turbines without interrupting the supply of water. The turbines required a floor 11 feet below the current level which would damage the building and render the wheels inoperable. Birkinbine concluded, " . . . it would still be necessary to construct a new turbine house, if the City wished to enjoy the whole of the water power of the river which it purchased at so great a price."[68]

The Schuylkill Navigation Company, of course, objected to the New Mill House, maintaining that it would damage the mound dam and jeopardize their canal. The objections were withdrawn after the company examined the plans, but the company claimed that their consent must be obtained before construction could begin. Consequently,

> . . . The department refused to ask this consent, believing as it does, that the structure of the dam is the sole property of the city, they having purchased the water power, and erected the dam at their own expense, the Navigation Company possessing no right, save that of using the pool created by the dam, for the purpose of navigation . . . Councils taking the same view of the matter as the department, refused to enter into any contract with the company.[69]

Fortunately, the courts agreed to allow construction to begin without the company's consent.

Concern about the contamination of the water mounted. The rapid accumulation of detritus (rocky fragments) and mud were severe enough to impede navigation. Mud sometimes was pumped into the forebays and reservoirs. Factories polluted the river as well with thousands of tons of impurities. Even the Philadelphia Gas Works dumped their wash water and refuse tar into the Schuylkill. According to Birkinbine, "The character of this discharge and the repulsive appearance of the scum floating upon the surface, are such to call imperatively for your [Councils] intervention."[70] The Purity Act of 1832 remained unenforced, yet no action was considered to alleviate the pollution.

The need to protect the river from pollution encouraged the Commissioners of Fairmount Park in 1867 to acquire 104 acres of land along the Schuylkill. Both sides of the river were cluttered with hotels, breweries, oil refineries, dwellings and mills. The state assembly had to pass an act of eminent domain in 1867 to enable acquisition of the land. The park had grown sizeably since its founding in 1855 when Lemon Hill was incorporated for use as a park. Lemon Hill, an eighteenth century country estate owned by Robert Morris, was adjacent to the Fairmount Water Works, the nucleus of the park. With the acquisition of Lemon Hill, a precedent for expanding Fairmount Park was established. By 1868 the park reached from the reservoirs at Fair Mount to Northwestern Avenue (now City Line), the city's western boundary. An 1851 drawing, "Plan of Lemon Hill and Sedgely Park, Fairmount and Adjoining Property" by Frederic Graff, Jr., demonstrates that he envisioned the park's founding and eastern expansion.

Fairmount's popularity never diminished. In 1861 Birkinbine commented, "So many thousands resort to this place during the year, that the whole should be kept in most thorough repairs and never allowed to present the dilapidated appearance they now do."[71] The over-worked water wheels demanded attention as well. A frame stop-house for the ascending mains rotted and was demolished in 1859, replaced by a corbelled stone arch in the Italian mode. A path led over the arch connecting the summer house at the top of the first flight of stairs with the standpipe terrace.

After a two-year hiatus when Isaac Cassin served as Chief Engineer, H.P.M. Birkinbine returned to the post in 1864. The outspoken Birkinbine was distressed with the obsolete breast wheels which simply were not powerful enough to pump sufficient water. Moreover, the condition of the Schuylkill had deteriorated:

> Its salubrity is however threatened and partially impaired by refuse from factories, mill, etc., and other impurities allowed to flow into it, and by the large amount of mine water pumped from the coal workings, in the country drained by the head water of the Schuylkill.
>
> A large amount of objectionable water is constantly flowing into Fairmount Dam--drainage from breweries, distilleries, gas, chemical and dye works . . .[72]

The water wheels were in such poor condition that two millwrights worked at nothing except their repairs. Birkinbine argued that either new works had to be constructed soon or the present machinery had to be rebuilt entirely. As a result of constant moisture, steam and heat, the old Mill House decayed severely.

Chief Engineer Birkinbine presented his Perkiomen proposal in 1866 to the Committee on Water Works and Councils. Fully realizing the scope of the Schuylkill's pollution, Birkinbine proposed to collect clean water from the Spack Creek, Conshohofpen Run, Perkiomen Creek, Indian Creek and Macoby Creek. A large stone lake or reservoir would be constructed between Zieglers-ville and Schwenksville in northern Montgomery County, Pennsylvania. The water was to be conveyed by aqueduct from the reservoir to a distributing reservoir on high ground north of the city. Supply mains would then carry the water to the present distribution lines.

Although water consumption rose to 30,281,019 gallons in 1865 as the population reached 738,856, Councils were not easily moved to action. A one million dollar loan was appropriated without any provision for implementing it. The annual revenues were $670,223 in 1866; the Water Department showed a $396,106 profit. Some of these funds were allocated to embellish the grounds with 62 settees and three rustic summer houses located on the second terrace, the top of the reservoir at Spring Garden Street and near the lower fountain north of the reservoir. In addition, water inspectors in 1866 checked for illegal use of water; many connected lines to the city's system without reporting it to avoid paying the water rent.

Birkinbine's strongest appeal to clean up the Schuylkill was presented to the Committee on Water Works and Councils in 1867. He stated that the amount of impurities had increased at an alarming rate during the last year. Factories, especially in Manayunk, continued to deposit their waste in the river. While water at the Flat Rock Dam was bright and clear, water between the Falls and the Columbia Bridge was discolored: the water turned brown as soon as it passed the paper mills. At Manayunk refuse from dye works, factories and all raw sewage was released into the Schuylkill. The final assault was delivered by the Gas Works which dumped tar and chemicals into the river. Birkinbine warned:

> . . . Constant deterioration in quality is going on, which if not arrested, will ultimately force the City to abandon the Schuylkill, as a source of supply, if the time to do so has not already arrived.
>
> Shall our industry only tend to make the most beautiful and necessary of objects laothsome, or shall we, by the strong arm of law, protect the purity of the water, and force manufacturers to find some other means of carrying away refuse?[73]

The forthright Birkinbine was relieved of his responsibilities in 1867; he went on to water distribution projects in Harrisburg; Mount Joy, Pennsylvania; Lebanon, Pennsylvania; and Long Branch, New Jersey. Frederic Graff took over as Chief Engineer in March, 1867, apparently to carry out the conversion of the Mill House to accommodate three turbines. The massive renovation began in October, 1867, just after the summer water demands abated. Unfortunately, the project should have been begun long before the limit was reached. Because of the heavy demands for water, the renovation had to be accomplished in sections. Old photographs and prints indicate that the work was done in three major phases corresponding with location: South Entrance House (1868), Pavilion (1871), and North Entrance House (1871).

Graff's design attempted to be compatible with the existing structures. The Doric temple-like Pavilion recalled the Doric porticoes of the Committee Room, Caretaker's House and Engine House:

> The mill-house at Fairmount is made familiar throughout the country by its age and the numerous published pictures; it was therefore thought desirable, in remodelling the works, not to alter the style of architecture. Its general appearance will not be materially altered.[74]

The large portals capped by The Schuylkill Chained and The Schuylkill Freed were used as monumental doors to the new wood Entrance Houses; the Italianate Entrance Houses also were ornamented by small brackets at the cornice and pilasters. The river front of cut stone was extended seven feet. The pitch roof was removed to substitute a flat terrace, raised several feet on the north. The designs of the buildings, pumps, flumes, suspended main and head-gates were executed by Graff.

The new turbine, replacing Wheels Numbers 2 and 3, pumped water through a 36-inch main suspended nine feet above the water level at the dam. The turbine took longer to complete than expected (October, 1867 to February 17, 1869), because of the extensive quarrying which was needed. A drop gate, similar to a canal lock, was located at the wheel pit outlet. When the drop gate was closed, the wheel pit could be pumped out. The interior of the remodelled Mill House was finished with cut stone walls. Wrought iron Phoenix columns supported a roof of wrought iron girders alternated with brick arches. Mains 2 and 3 were connected to the Fairmount reservoir; one main was attached to the standpipe to go to either the Corinthian Avenue or Fairmount reservoirs. Main No. 3 for the New Mill House turbines (Numbers 10, 11, and 12) was carried across the north end of the forebay and attached to the standpipe.

The renovation progressed substantially in 1870. The second turbine wheel and pump began to operate on June 20, 1870. Most of the foundations were completed and the stone for the façade was ready to be applied at the beginning of 1871. The new cast iron head gates and north wall were finished as well. The last turbine was put in place in 1872; the total renovation cost was $360,000.

When the turbines were completed, Fairmount was able to pump a maximum of 34,000,000 gallons per day, four times the daily average in 1854. William H. McFadden, the new Chief Engineer, called it "our former boast and present pride."[75] Water consumption increased at a higher rate than population because ". . . the appliances necessary for modern convenience have multiplied in the past twenty years . . . It is quite usual for houses to have three or four baths and water-closets, wash-basins in every chamber, stationary wash-tubs in the kitchens, and the universal wash-pave." As a result, Graff called for the implementation of water meters in 1869, but meters still had not been approved in 1873. Water rents made no provision for the amount of water actually used. Breweries were known to report a single kitchen pump assessed at $4.50 per year, yet draw thousands of gallons of water.

Improvements were made at Fairmount in 1873 and 1874 under the direction of Chief Engineer McFadden. Breast wheel No. 6, no longer used, was removed. A small Worthington engine was installed and pumped for 82 hours during an extended drought in 1873. The roof of the New Mill House leaked during rain storms and required repairs; large skylights were put in at the same time to ease the raising and lowering of machinery. The pump room housing the 1851 turbine was roofed with iron girders alternated with brick arches, similar to the fireproof roof of the remodelled Mill House. In 1874 the flagging was removed from the Mill House roof and vulcanite pavement was substituted. The walks from the Mill House to the Mound Dam were raised and paved with flagging. A stairway was built to the level of the pier at the eastern end of the dam. A painted cast iron balustrade was erected along the river wall. The Saloon (Engine House) was repainted on the interior and exterior. The pump room roof was razed to extend the piazza to the riverfront, but new Phoenix columns were not installed in 1881. The outside wall was built from a solid foundation twelve feet below low tide. Water closets for ladies were installed off the main hall and men's facilities were built under the piazza.

In 1875, Mayor William S. Stokely appointed a Commission of Engineers to conduct a long-overdue investigation of the water supply. The experts, W. Milnor Roberts of New York City, William J. McAlpine of Albany, Julius W. Adams of Brooklyn, and William E. Morris and Solomon W. Roberts of Philadelphia, concluded that the Schuylkill's purity had deteriorated: "The contamination of this stream is not alarming, yet it is believed that unless a remedy be applied it will ultimately be rendered unfit for domestic uses."[77] The principal causes of contamination were, as Birkinbine had recognized fifteen years earlier, sulfuric acid from coal mines, refuse and sewage from the population, and factory wastes. It was obvious that the only way of furnishing clean water was to maintain a pure source of supply. McFadden thought it ridiculous "to pour all manner of filth into our water supply and then attempt to get rid of it by costly and seldom efficient processes."[78] Yet a year later the Commissioners of Fairmount Park recommended constructing a sewer to dump directly into Fairmount Pool, making the Schuylkill little more than an open sewer.

The Fairmount Water Works' declining importance was manifested in two areas: the deterioration of water quality and the construction of pumping stations at Belmont, Roxborough, Frankford and Germantown. The death knoll for Fairmount was sounded in 1876 when McFadden reported that, "In summer the demand for water is greatest when the power at Fairmount is least, which proves that Fairmount is not the main stay of the Department."[79] Consequently, only minimal physical changes were undertaken between 1876 and 1909, the year of Fairmount's closing. In 1886 new bathrooms for workers were installed in the Mill House and new platforms and steps were placed over the flumes. The entire length of the New Mill House gallery was repaired and iron railings were placed on each side. The Saloon, then called the Mansion House, was cleaned and repainted in 1889. An electric power plant, supplied by the Edison Electric Company in

1883, consisted of an engine and dynamo to light sixty lamps throughout Fairmount.

The case for compulsory water meters was renewed during the 1890's. Chief Engineer John C. Trautwine stated in 1893:

> Meters prevent waste, detect leaks, and equalize the charge for water to all consumers . . . The city is not interested in placing meters where a loss of results therefrom, but as a matter of justice for the consumer.[80]

Water meters were approved for use at the discretion of the consumer in 1873, but most users opted to stick with water rents. A hotel which paid $300 water rent annually should have paid $1,549. The Water Department, now included with the Department of Public Works, viewed itself as "a socialistic or communistic organization, by means of which the entire community seeks to obtain certain results to the best advantage and at a reasonable expense."[81]

Trautwine was concerned too, with providing clean and plentiful water:

> The foul condition of the Schuylkill River below Fairmount Dam, mentioned in my report of 1895, continued during last summer, not only unabated, but if anything, aggravated by the natural increase in the quantities of filth discharged into the river.[82]

Trautwine reviewed the major studies for the future water supply previously undertaken by the Water Department: H.P.M. Birkinbine's 1864 Perkiomen plan, the Fairmount Park Commission's 1867 plan to build an intercepting sewer from Manayunk to below Fairmount Dam, the 1875 Commission of Engineers plan to build reservoirs farther north on the Schuylkill, and Rudolf Hering's 1883-86 survey of the watersheds of the Neshaminy, Tohickon and Delaware Rivers. This last study influenced the eventual outcome of combining a water filtration and pumping station using water from the Delaware watershed, eliminating the dependency on the Schuylkill and thus on Fairmount.

After completion of the Delaware system for supplying filtered water from Lardner's Point, the Fairmount Water Works was closed in 1909 (except to keep one reservoir full to supply a large factory). The battle against pollution was lost, in spite of warnings dating back to 1865. Since the Fairmount Water Works had once been the showplace of the nation, "a model for almost all public improvements of this kind in the country,"[83] the closing of the water works was a solemn warning for the future:

> Unless some measures are adopted to protect our natural waterways from pollution; with the increase in population dependent on them for drainage, all will become, as many are now, a source of danger to the health of the communities . . .[84]

Unable to prevent contaminating the Schuylkill's water, filtration and chemical treatment became the only solutions.

The Fairmount Water Works was turned over to the Department of the Mayor by an ordinance of City Councils on March 16, 1911. A public aquarium and museum were established for the study of aquatic animals. Mounted specimens of fish were donated by the Department of Fisheries of the State of Pennsylvania from the St Louis World's Fair of 1904. The ordinance mandated that:

> It is desirable that the beautiful buildings, together with the standpipe or water tower, be preserved for all time as a fine example of the earlier architecture and methods of supplying water to the City of Philadelphia.[85]

The mill buildings were occupied with tanks and pools for fish while the Engine House, erroneously called the Greaves Mansion, served as a biological laboratory. It was also specified in the ordinance that one turbine remain, the 1851 Jonval turbine. Local history has it that concrete was poured over the wheel to silence the groans of Frederic Graff's ghost.

The Mill House has been abandoned since the closing of the aquarium in 1962.

The Kelly Natatorium, constructed c. 1950, in the New Mill House, closed in 1967.

The site of the reservoirs, Fair Mount, was given to the Commissioners of Fairmount Park for the construction of the Philadelphia Museum of Art.

The Junior League of Philadelphia, Inc., operates a summer luncheon restaurant on the porch of the Engine House, now known as the Graff Mansion.

NOTES

[1]This account of the history of the Centre Square distribution system is largely drawn from Nelson Blake, Water for the Cities (Syracuse: Syracuse University Press, 1956), and the Reports of the Watering Committee.

[2]Noah Webster, A Collection of Papers on the Subject of Billious Fevers (New York: Hopkins, Webb and Company, 1796), p. 76.

[3]Aurora, May 3, 1799.

[4]Aurora, December 13, 1798.

[5]Talbot Hamlin, Benjamin Henry Latrobe (New York: Oxford University Press, 1955), p. 39.

[6]Benjamin Henry Latrobe, View of the Practicability and Means of Supplying the City of Philadelphia with Wholesome Water, in a Letter to John Miller, Esq. (Philadelphia: Zachariah Foulson, Jr., 1799).

[7]A freshet is an overflowing stream of water.

[8]Hamlin, Latrobe, p. 161.

[9]Hamlin, Latrobe, p. 161.

[10]Blake, p. 35.

[11]David Orr, "Centre Square Pump House," Three Centuries of American Art (Philadelphia: Philadelphia Museum of Art, 1976), p. 189.

[12]Poulson's American Daily Advertiser, January 29, 1801.

[13]Philadelphia Water Department, City Archives, Bill from William Rush, 1809.

[14]Latrobe, View of the Practicability, n.p.

[15]Blake, p. 79.

[16]Philadelphia Water Department, City Archives, Articles of Agreement between Frederick Graff and Jonas Smith, 1812.

[17]Philadelphia Water Department, City Archives, Opinion of the Solicitor, Opinion for the Watering Committee, October 25, 1813.

[18]Report of the Watering Committee, Read November 11, 1813, n.p.

[19]Report of the Watering Committee, Read January 11, 1815, n.p.

[20]Report, Read January 11, 1815, n.p.

[21]Report, Read January 25, 1816, n.p.

[22]Report, Read January 25, 1816, n.p.

[23]Talbot Hamlin, "Some Greek Revival Architecture in Philadelphia," Pennsylvania Magazine of History and Biography 65 (April 1941), pp. 125-126.

[24]Hamlin, "Some Greek Revival Architecture in Philadelphia," pp. 125-126.

[25]Report of the Watering Committee, Read January 23, 1817, n.p.

[26]Report of the Watering Committee, Read January 22, 1818, n.p.

[27]Report of the Watering Committee, Read January 22, 1818, n.p.

[28]Thomas Oakes, *Additional Report to the Watering Committee*, Read January 22, 1818, p. 10.

[29]Oakes, p. 5.

[30]*An Additional Report on Water Power by the Watering Committee with Communications on the Subject from Messrs. Ariel Cooley, Lewis Wernwag, Thomas Oakes, William Briggs, and William Lehman* (Philadelphia: William Fry, 1819).

[31]*An Additional Report on Water Power by the Watering Committee*, p. 5.

[32]*Report of the Watering Committee*, Read February 10, 1820, p. 4.

[33]*Annual Report of the Watering Committee*, Read January 18, 1821, p. 3.

[34]*Annual Report of the Watering Committee*, Read January 18, 1821, pp. 4-5.

[35]*Annual Report of the Watering Committee*, Read January 1, 1822, p. 6.

[36]*Annual Report of the Watering Committee*, Read January 6, 1823, pp. 5-6.

[37]*Annual Report*, Read January 6, 1823, p. 6.

[38]*Annual Report*, p. 7.

[39]*Annual Report of the Watering Committee*, Read January 8, 1824.

[40]*Annual Report*, Read January 8, 1824.

[41]*Annual Report*, Read January 8, 1824.

[42]Annual Report of the Watering Committee, Read January 6, 1823, p. 11.

[43]Annual Report, Read January 6, 1823, pp. 10-12.

[44]Frances Trollope, Domestic Manners of the Americans, 1832, ed. Donald Smalley (New York, 1949), p. 261.

[45]Annual Report, Read January 6, 1823, pp. 11-12.

[46]Richard Webster, "Fairmount Water Works," Three Centuries of American Art (Philadelphia: Philadelphia Museum of Art, 1976), pp. 223-224.

[47]Dorinda Evans, "The Schuylkill Chained and The Schuylkill Freed," Three Centuries of American Art (Philadelphia: Philadelphia Museum of Art, 1976), p. 263.

[48]Annual Report of the Watering Committee, Read January 13, 1815, p. 4.

[49]"Opinion of Frederick Graff," Annual Report of the Watering Committee, May 19, 1825.

[50]Annual Report of the Watering Committee, Read January 6, 1827, p. 5.

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[52]John P. Sheldon to James Watson Webb, Letter dated December 14, 1825, "Notes and Queries," Pennsylvania Magazine of History and Biography, 18 (1894), p. 124.

[53]Annual Report of the Watering Committee, Read January 12, 1832.

[54]Philadelphia Water Department, City Archives, Senate File, No. 31.

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[80] Annual Report of the Chief Engineer of the Water Works for 1893, p. 110.

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[82] Annual Report of the Chief Engineer of the Water Works for 1898, p. 98.

[83] Smith, Philadelphia, p. 51.

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