

**HISTORY OF THE
CITY OF ALTOONA RESERVOIR SYSTEM**



**ALTOONA WATER AUTHORITY - CITY OF ALTOONA
BLAIR COUNTY, PA**

BY:

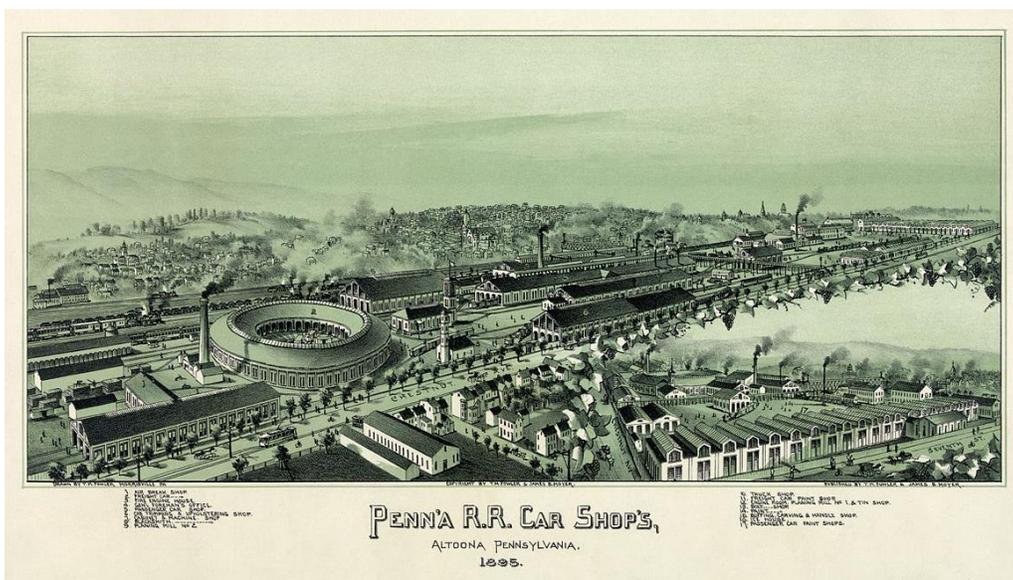
**MARK GLENN, P.E., PRESIDENT
GWIN, DOBSON & FOREMAN, INC.
ENGINEERS**

JANUARY 2017

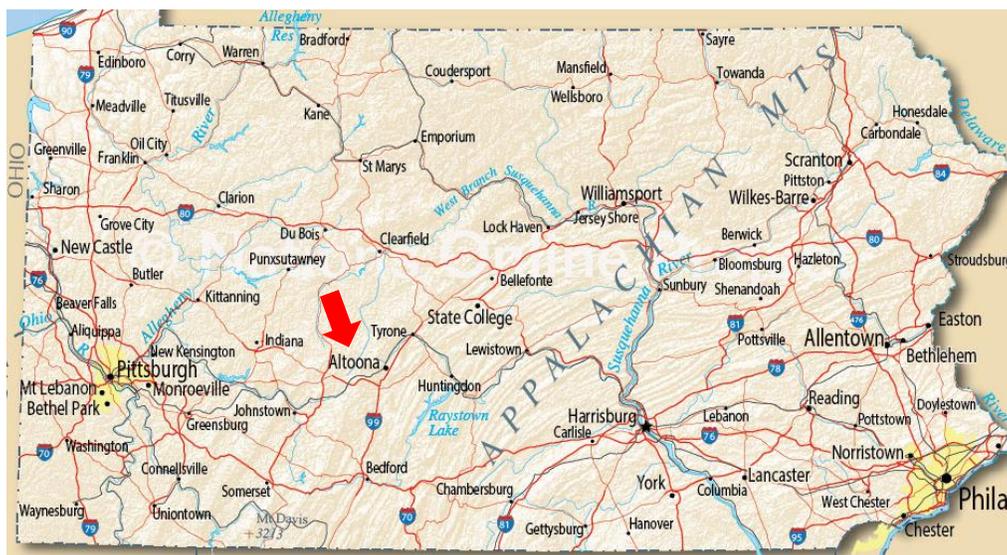
HISTORICAL NARRATIVE

Introduction - The City of Altoona (PA) Reservoir System has provided the water supply needs of the area for over 135 years. It is an integrated system of dams, diversions, channels, tunnels, and weirs designed to provide not only capacity but enhanced water quality. Located at the famous Horseshoe Curve rail site, the reservoir system is an outstanding example of 19th century hydraulic engineering.

Background - Altoona was founded by the Pennsylvania Railroad (PRR) in the mid-19th century as the site for a shop and maintenance complex. It later became one of the largest railroad manufacturing and repair centers in the world. The Altoona area experienced significant growth during this time and a reliable water supply system was a necessity. Built over 25 years, the Altoona reservoir system was designed with ever increasing capacity and technical sophistication. The evolution of the system and its unique design features are discussed along with photos and maps.



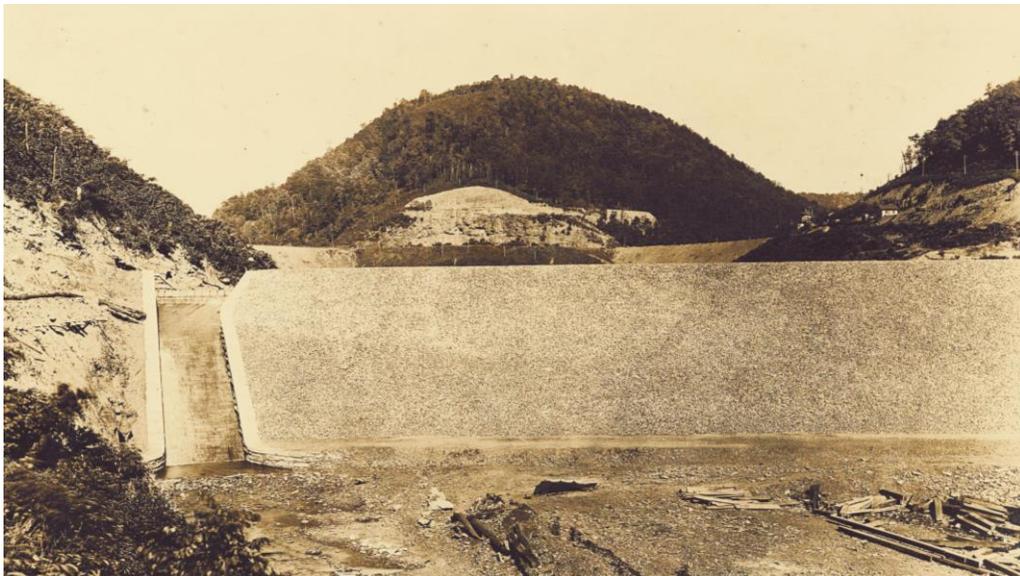
1895 LITHOGRAPH OF ALTOONA WORKS



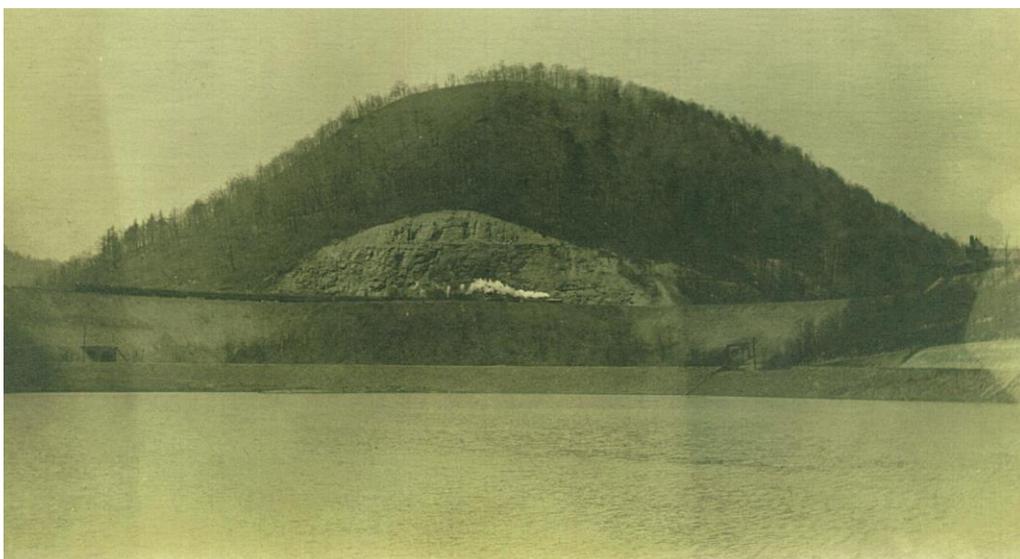
LOCATION MAP – ALTOONA, PA

Location – Altoona is located near the base of the Allegheny Mountains and at the headwaters of the Juniata River. No major rivers existed to provide the water needs of the railroad shops and community – rare for a 19th century industrial enterprise. Instead, efforts focused on collecting mountain streams in water reservoirs for conveyance to the City and its railroad complex. One prospective location was near the PRR Horseshoe Curve where the railroad embankment spans to two ravines formed by Kittanning Run and Glen White Run. This site offered storage potential and gravity delivery of water to the City.

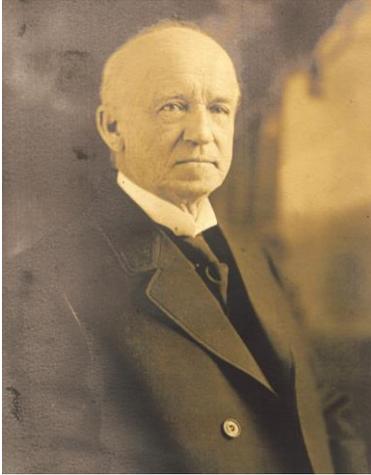
Kittanning Pont Reservoir - In 1872, the Pennsylvania Railroad, under the direction of Thomas Seabrook, provided the resources to build a small intake near the apex of the PRR Horseshoe Curve. The basin quickly proved to be inadequate and a larger impoundment, known as Kittanning Point Reservoir, was built by the City in 1888. At a storage capacity of 65 million gallons, the earth dam was 45 feet high and 550 feet long with a masonry overflow spillway at the right abutment. Campbell Bros. of Altoona was the construction contractor for the project.



1. KITTANNING POINT DAM & SPILLWAY, 1887



2. KITTANNING POINT RESERVOIR & PRR HORSESHOE CURVE, 1899



C.W. KNIGHT, CIVIL ENGINEER

This project marked the appearance of Charles W. Knight, a civil engineer from Rome, New York, who was to be the design engineer for this and subsequent improvements to the Altoona water supply system. Mr. Knight (1845-1923) designed over 60 waterworks projects including systems in Rome and Schenectady in New York and DuBois, Uniontown, Altoona and Greensburg in Pennsylvania.

Like many 19th century engineers, Knight had no formal technical education, but attained proficiency through practical experience and self-study. Through his efforts, Knight became proficient as a hydraulic engineer and gained notoriety for his innovative water projects with the Altoona reservoirs considered his master work.

Pollution Problems – Although heavily forested today, the watershed then was an active timber and coal mining district. Coal was mined for the large furnaces and steam plants at the PRR Altoona Works. However, coal waste and debris accumulated and heavy timbering practically denuded the watershed. An extensive amount of sediment, mine debris, driftwood and vegetative matter washed into Kittanning Point Reservoir during severe storms. A storm in 1894 deposited 20,000 cubic yards of debris in one day alone. The net affect was dwindling reservoir capacity and impaired water quality. Kittanning Point Reservoir also proved to be inadequate for the water supply needs of a rapidly growing community. Action was demanded of the City and it turned to Engineer Knight for a solution.



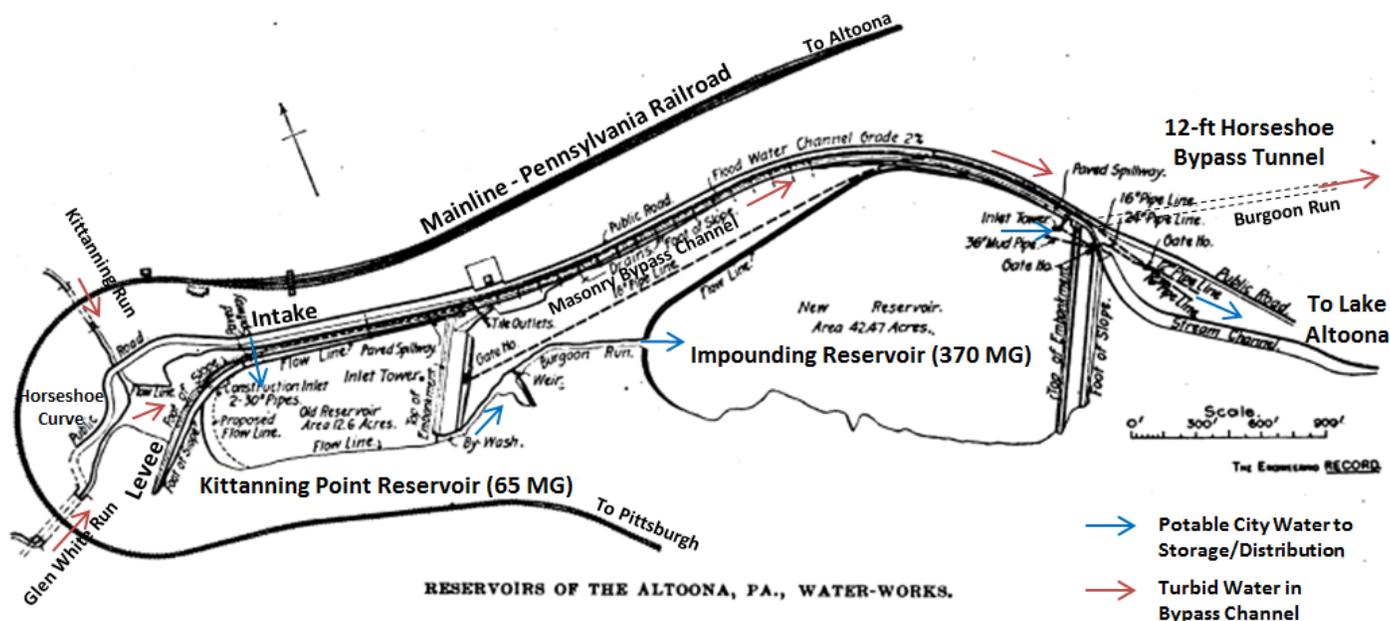
3. FLOOD DEBRIS ACCUMULATION



4. DEBRIS REMOVAL FROM RESERVOIR

Solutions – C.W. Knight recommended that in conjunction with a new reservoir, a bypass channel be constructed to divert highly turbid water around the reservoirs with stream intakes used to admit normal flow to the basin. In this manner, the reservoirs were isolated from the main streams during storm events but able to receive higher water quality for system usage. This plan was adopted by the City and design work commenced in 1892.

A new 350 million gallon reservoir and a mile-long levee and flood water channel were constructed from 1893 to 1897. In 1899, The Engineering Record (now Engineering News-Record) published a map of the upper reservoirs and bypass system which is shown on the next page (several features added for clarity).



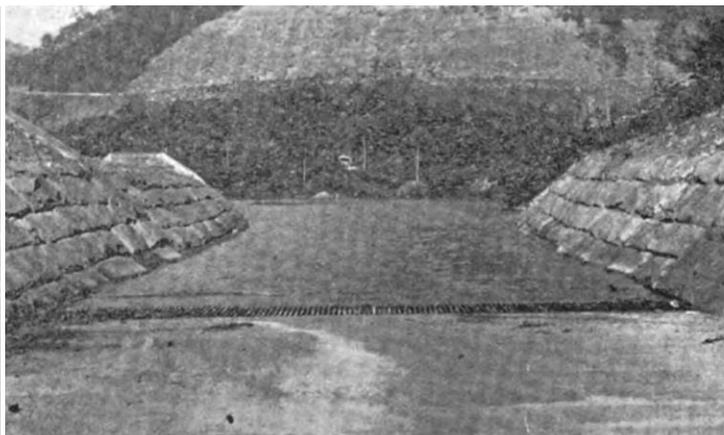
Design of Upper Flood Water Channel & Levee – Engineer Knight had to devise a method of directing flood water around the reservoirs at an alignment and grade such that normal stream flow could be admitted to the impoundments by gravity. This was accomplished by the construction of a levee and stone masonry bypass channel with an intake chamber installed in the channel bottom.

Knight designed a 900-foot earth levee across the valley at the upper reservoir to direct all stream flow to the head of an intake on Burgoon Run (juncture of Glen White and Kittanning Runs). A sunken masonry chamber with iron grates was built across the channel bottom and a 24-inch cast iron pipe (with valve) was extended to admit water into the reservoir. This structure forms the inlet for all the water entering the reservoirs, as the supply for the lower basin passes first through the upper reservoir.

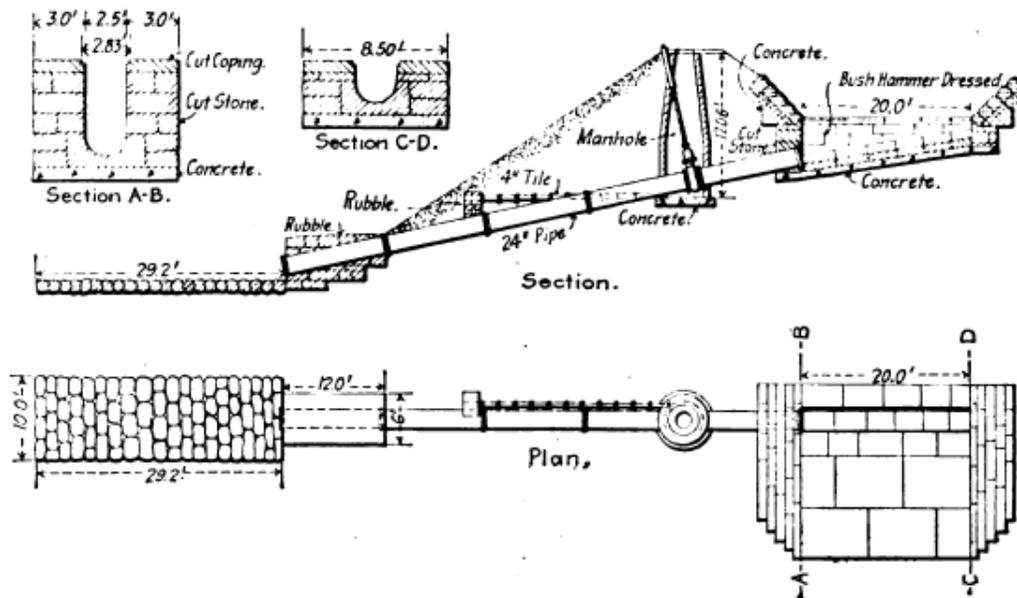
In addition, a 100-foot wide emergency masonry spillway placed 6-feet above the channel bottom was constructed to divert excessive flood flows into Kittinging Point Reservoir. An original drawing of this arrangement and photos of the intakes and emergency spillway are shown below:



5. KITTANNING RESERVOIR INTAKE, 1897



6. BYPASS CHANNEL KITTANNING INTAKE, 1897

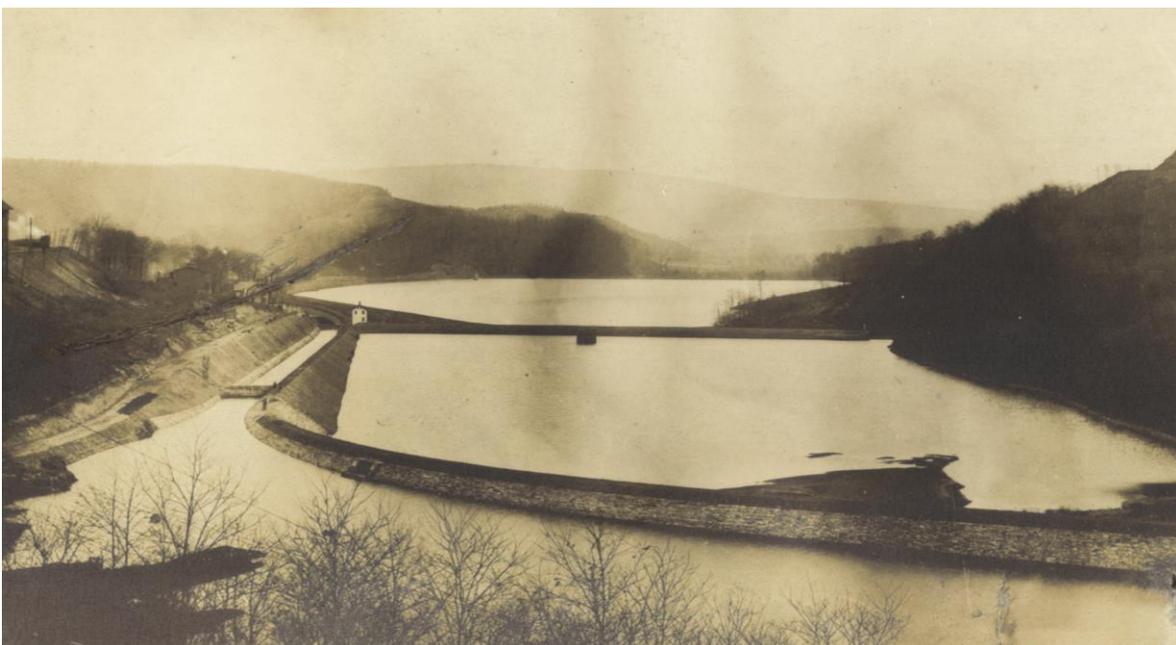


DETAILS OF INLET OF UPPER RESERVOIR.

ORIGINAL DRAWING OF KITTANNING POINT DAM INTAKE STRUCTURE

The final bypass component was the construction of a 4,500 foot long masonry channel extending from the Kittanning Point intake to the Impounding Dam spillway. A 20-wide trapezoidal channel made of cut sandstone paving blocks was laid at a constant 2% grade. Over 110 stone cutters and masons were employed in this work, some coming as far away as Massachusetts and Indiana. All work was completed from August to November 1897 including quarrying, cutting and laying of the masonry. The contractors were Jutte & Foley, Pittsburgh (levee/intake) and W.G. Stahl & Sons, Altoona (stone masonry).

The upper bypass channel system, including flood water channel and levee, was constructed from 1895 to 1897. This remarkable example of 19th century workmanship has stood the test of time showing no signs of deterioration over the intervening 120 years. Period photos of the completed work are below:



7. LEVEE, INTAKE AND FLOODWATER CHANNEL FROM HORSESHOE CURVE, 1897



8. MASONRY FLOOD WATER CHANNEL ALONG IMPOUNDING DAM, 1897



9. MASONRY FLOOD WATER CHANNEL AT IMPOUNDING DAM, 1897

Impounding Reservoir - Built in 1896 with a capacity of 356 million gallons, the Impounding Reservoir, received water from the overflow at Kittanning Point Dam. Impounding Dam was an earth dam, 60-feet high with a crest length of 1,000 feet. A masonry spillway at the left abutment received flood-water from the bypass channel and reservoir overflow from a 25-foot wide cut-stone spillway. An emergency reservoir spillway, 100-foot wide, was built adjacent to the principal spillway. Water was piped to the City through an intake tower and 16/24-inch mains. Collins & Martin, Altoona, was the contractor.



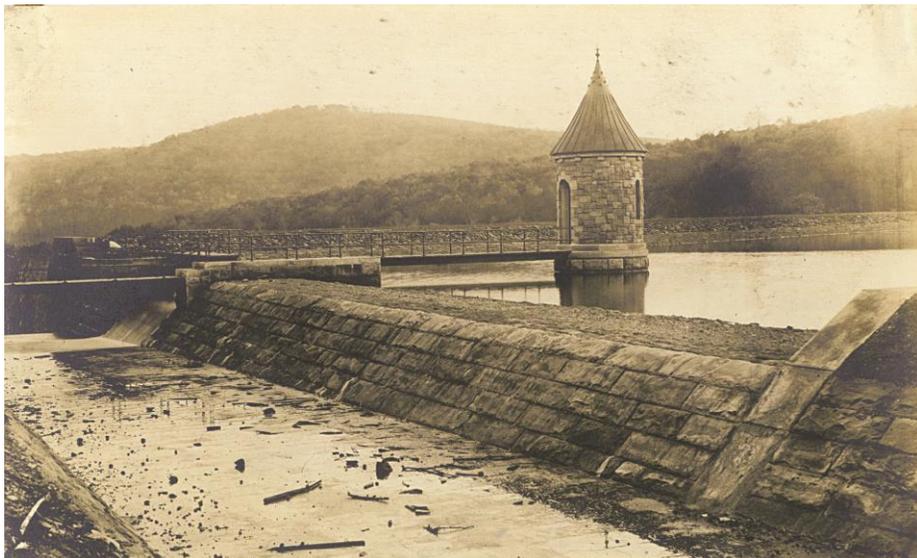
10. IMPOUNDING DAM, 1897



11. IMPOUNDING RESERVOIR, 1897 (HORSESHOE CURVE BEYOND)



12. PRINCIPAL OVERFLOW SPILLWAY - IMPOUNDING RESERVOIR, 1897



13. EMERGENCY SPILLWAY - IMPOUNDING RESERVOIR, 1897



14. IMPOUNDING DAM SPILLWAY CHANNEL, 1897



15. SPILLWAY CHANNEL DISCHARGE, 1897

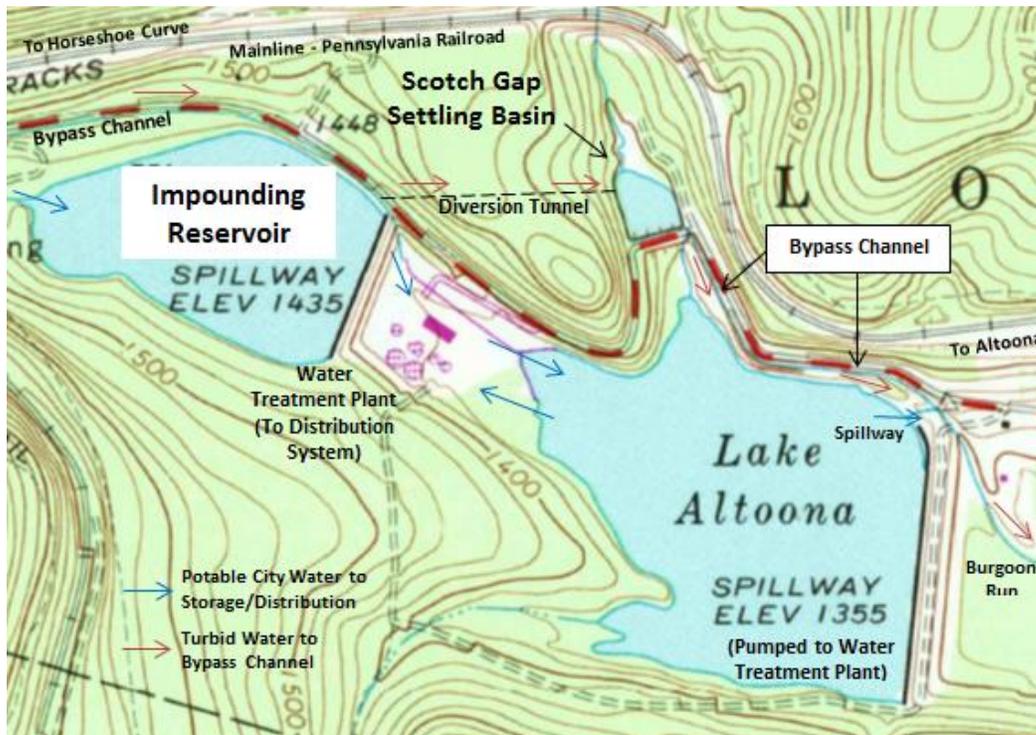
Additional Capacity Needed - Within a period of ten years, the City reservoir system was again insufficient for the area's water demands because of the rapid expansion of Altoona and the occurrence of extreme droughts in the early 1900's. Drought conditions also restricted operation of the PRR shops whose water demand reached 10 million gallons per day. Hence, the City and PRR independently pursued additional supplies but often clashed on the issue of water rights on individual streams.

In 1904, the City again turned to Engineer Knight to make recommendations for a permanent water supply solution. After examining several watersheds, he concluded that these interfered with the needs of the railroad. The only solution was to build another reservoir on Burgoon Run. How this was to be done presented an engineering challenge but one that Knight met with an innovative solution.

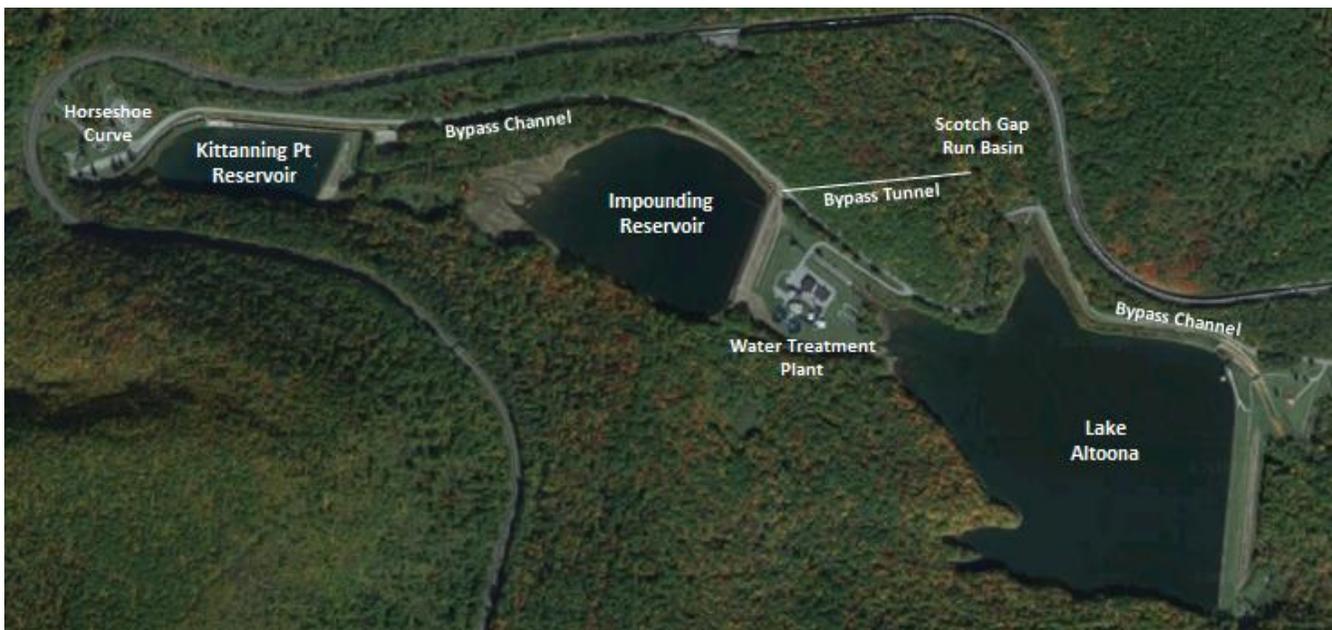
Lake Altoona Dam and Bypass System – Surveys and test borings were favorable for a dam site just downstream of the Impounding Dam. The new reservoir, called Lake Altoona, was designed to impound up to 800 million gallons and be sufficient for a population of 100,000. The basic problem was how to divert debris-laden flood water around this massive reservoir. The current discharge below the Impounding Dam would quickly diminish the capacity of the new reservoir. In addition, a major intervening tributary, Scotch Gap Run, prevented the continuation of the bypass channel.

Scotch Gap Run Diversion Design – Scotch Gap Run proved to be a major physical impediment. Years earlier, Knight designed a gravity water tunnel through the Continental Divide to the City of DuBois (PA) to the west. For Altoona, he proposed a similar solution by driving a gravity tunnel from the Impounding Dam bypass channel to the Scotch Gap Run watershed. Instead of building a high-level aqueduct above the stream bed, Knight proposed to build a small dam to be filled with water from the tunnel outlet. The overflow spillway for this dam would then form the head of a new floodwater channel around Lake Altoona. This bypass would then discharge all flood waters below the dam into Burgoon Run.

The Scotch Gap Run diversion system is one of the most unique hydraulic structures in central Pennsylvania. By the means of a diversion tunnel, storage basin and bypass channel, the continuation of the gravity bypass system was preserved while protecting reservoir capacity and water quality. A map of the lower bypass system and Lake Altoona reservoir along with a satellite image of the entire system are shown on the following maps. A narrative of each facility component of the lower reservoir system is provided.



LAKE ALTOONA RESERVOIR AND BYPASS CHANNEL SYSTEM

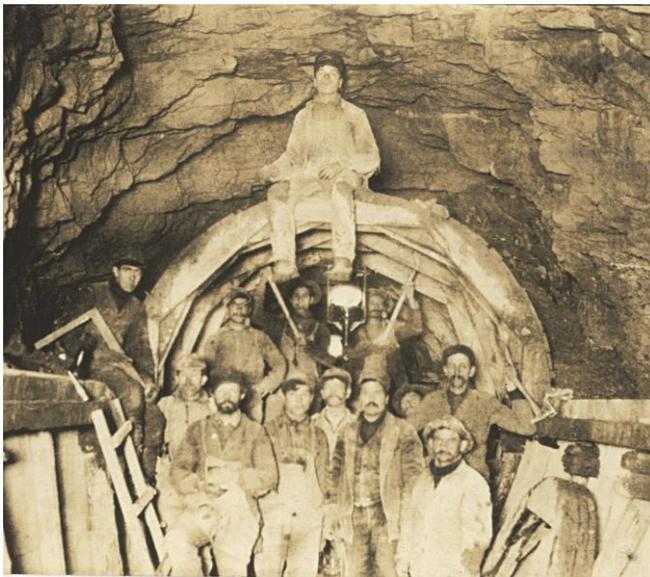


SATELLITE IMAGE – ALTOONA RESERVOIRS AND BYPASS CHANNEL SYSTEM

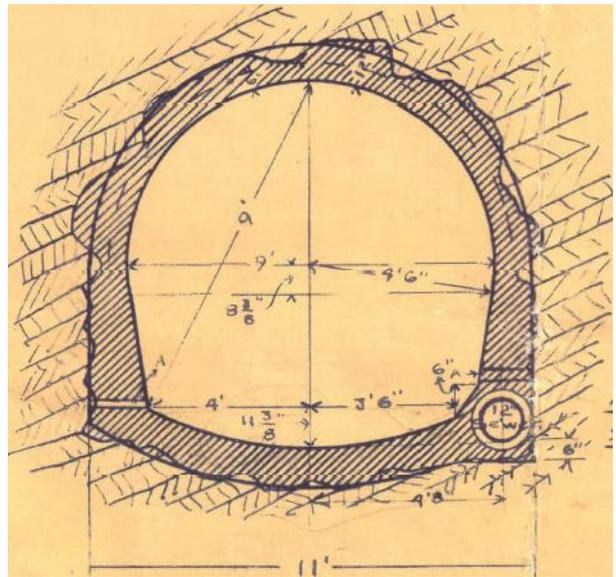
Diversion Tunnel – The diversion tunnel was completed in 1908 and consisted of a 9-ft diameter horseshoe-shape conduit, 1,275 ft. long and laid at a grade of 1.29%. Compressed air jackhammers were used to remove rock and the entire section was formed and lined with concrete. A 12-inch sewer was offset from the pipe invert for conveyance of sewage and mine drainage around the reservoir system. A large concrete outlet structure was constructed about 10 feet above the level of Scotch Gap Run Dam. Total tunnel rock excavation was 5,400 CY while 3,500 CY of concrete was poured for the tunnel lining and inlet and outlet structures. Photos of the tunnel construction are shown below.



16. INLET TO DIVERSION TUNNEL AT IMPOUNDING DAM, 1907



17. WORKERS FORMING TUNNEL LINING, 1907



18. ORIGINAL DRAWING OF TUNNEL



19. TUNNEL OUTLET AT SCOTCH GAP RUN SETTLING BASIN, 1908

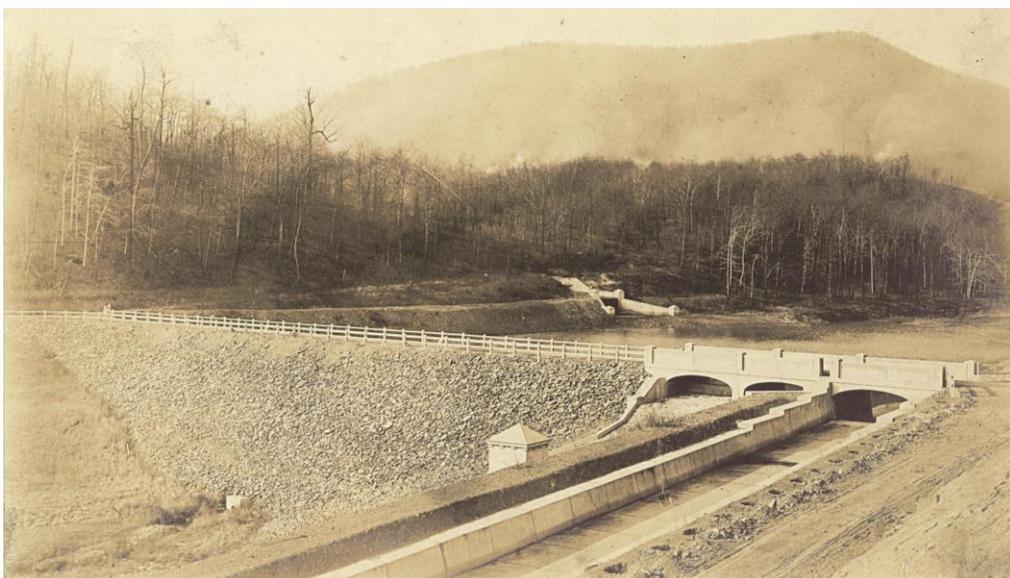
Scotch Gap Run Dam and Settling Basin – Scotch Gap Run Dam performed several important functions which were incorporated into a unique hydraulic design by Engineer Knight including:

1. Economically connect the diversion tunnel to the head of the Lake Altoona bypass channel
2. Impound debris laden flow which, after a period of years, would fully silt the reservoir and allow for future construction of a bypass channel across the basin
3. Provide potable water storage during the intervening period
4. Incorporate a bridge into the spillway to allow highway traffic on Kittanning Point Road

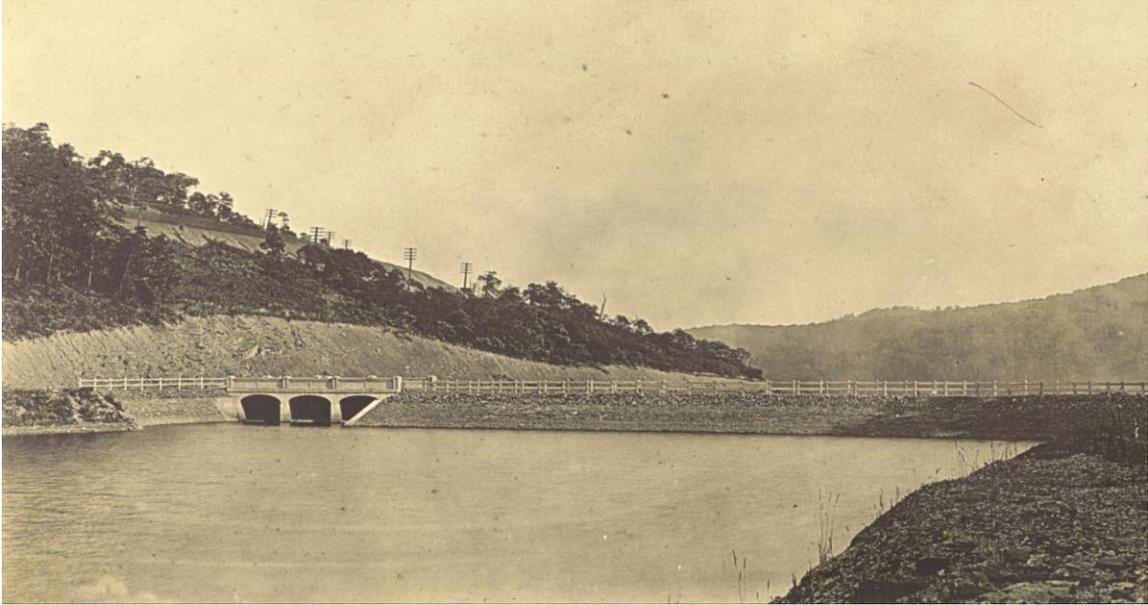
Scotch Gap Dam was built in 1908 as an earthen structure with a storage capacity of 17 million gallons. The dam was 35-feet high with a crest length of 300 feet. A unique spillway structure was designed with three openings, two of which flowed to an overflow spillway while the other opening (with a lower weir elevation) discharged to the Lake Altoona bypass channel. Photos of this unique construction are shown below. The earthwork and concrete quantities were 50,000 CY and 500 CY, respectfully.



20. EARTHWORK CONSTRUCTION, SCOTCH RUN GAP DAM, 1907



21. OVERVIEW OF SCOTCH GAP RUN DAM & TUNNEL OUTLET, 1908

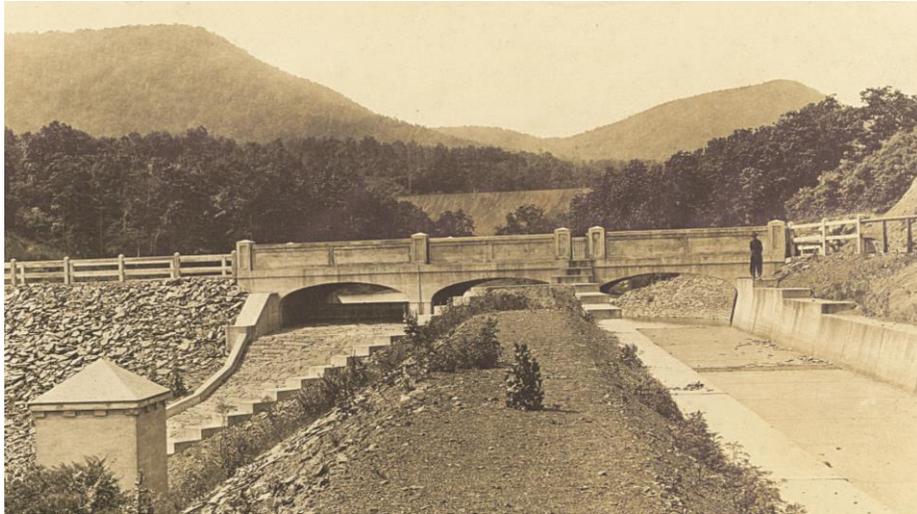


22. OVERVIEW OF SCOTCH GAP RUN RESERVOIR FROM TUNNEL, 1908

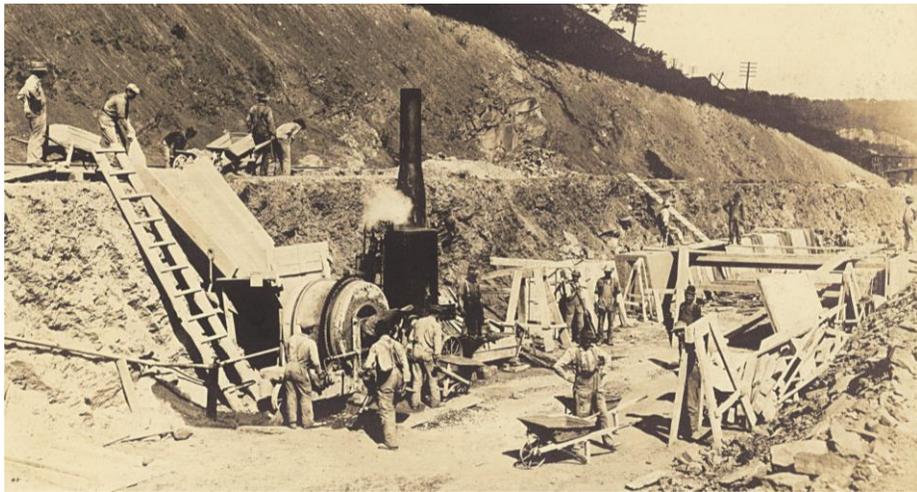


23. PORTABLE CONCRETE BATCHING & MIXING PLANT - SCOTCH GAP RUN DAM, 1907

Lake Altoona Bypass Channel – A 16-ft. wide concrete bypass channel was constructed around Lake Altoona from the Scotch Gap Run Dam spillway to the Burgoon Run stream channel below dam. The channel is 2,200 feet long and was directed past Lake Altoona Dam by means of a chute that discharges to a baffle block apron. The reservoir overflow spillway discharged to the chute using a broad-crested weir. A total of 5,500 CY of concrete was involved in this work.



24. HEAD OF LAKE ALTOONA BYPASS CHANNEL AT SCOTCH GAP RUN DAM, 1908



25. POURING CONCRETE AT LAKE ALTOONA BYPASS CHANNEL, 1907



26. LAKE ALTOONA BYPASS CHANNEL, 1908



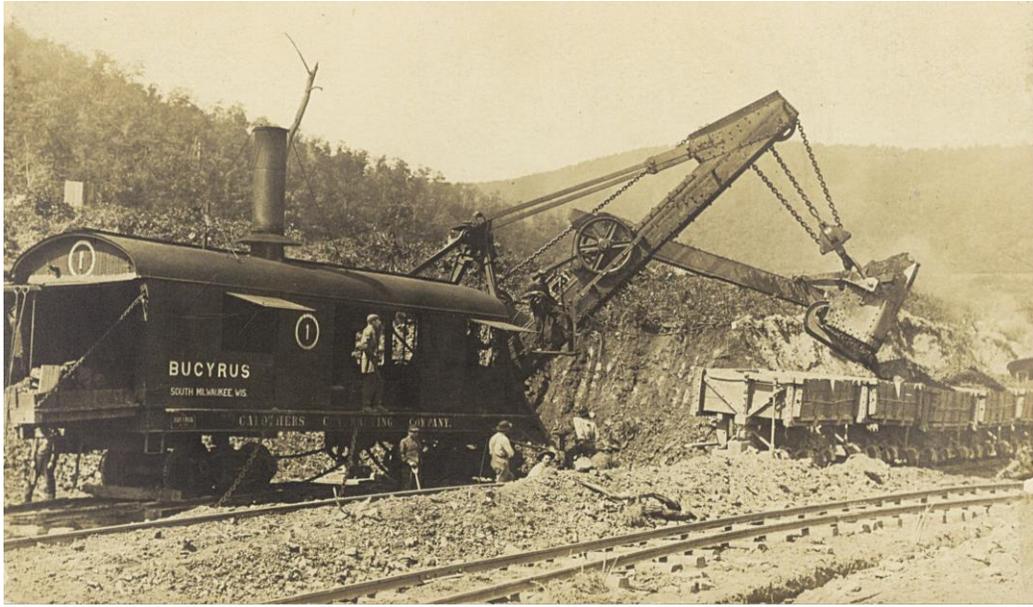
27. BYPASS CHANNEL DISCHARGE TO BURGOON RUN AT LAKE ALTOONA DAM, 1908

Lake Altoona Dam & Reservoir - Lake Altoona Dam was a large undertaking in its own right involving considerable earthmoving and structural concrete work. This dam was completed in two phases from 1906 to 1913. It was 1,650 feet long and 66 feet high with a storage capacity of 500 million gallons. The dam was not constructed to its full design height of 90 feet since funds obligated by a City bond issue were exhausted at a dam height of 66 feet. The dam was raised to its present height (73 ft.) in 1929.

The first phase was the construction of the bypass system including the diversion tunnel, Scotch Gap Run Dam, Lake Altoona Bypass Channel, partial intake structure, reservoir drain and intake pipes and dam foundation work (cutoff trench excavation, grouting, concrete core wall and puddle core material). This work was performed from 1906 to 1909 by Daniel F. O'Rourke, Altoona. Phase II included placement of earth embankment material, reservoir clearing, completion of the full depth concrete core wall, spillway, intake tower and mechanical piping, slope protection and access bridges. This work was performed from 1909 to 1913 by Carothers Construction Co., Greensburg, PA. The total amount of earth embankment placed was 560,000 cubic yards along with 33,000 CY of structural concrete for the intake tower and core wall.



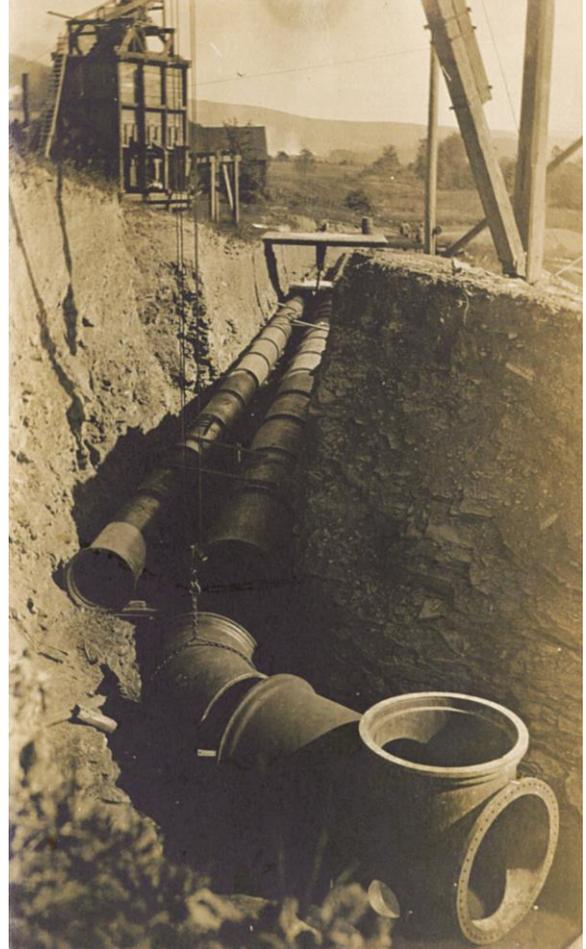
28. LAKE ALTOONA CUTOFF TRENCH EXCAVATION & COFFERDAM, 1908



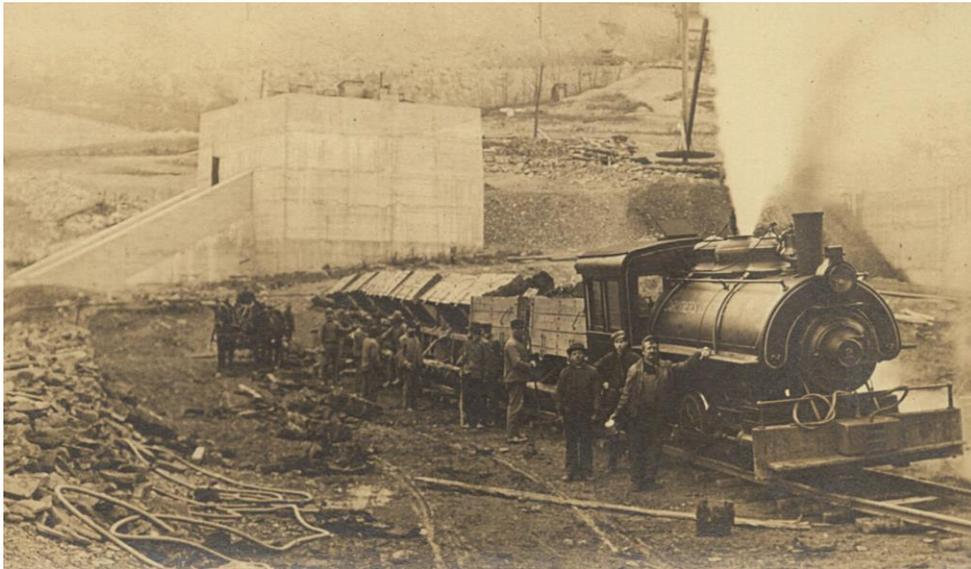
29. STEAM SHOVEL LOADING EMBANKMENT MATERIAL INTO DIRT CAR TRAM, 1910



30. CUTOFF EXCAVATION & CONCRETE CORE WALL WITH STEAM DERRICK HOIST, 1910



31. 60" & 36" CAST IRON DRAIN & INTAKE



32. STEAM LOCOMOTIVE HAULING DIRT CAR TRAM; INTAKE STRUCTURE AT REAR, 1911



33. OVERVIEW OF LAKE ALTOONA DAM CONSTRUCTION, 1911



34. OVERVIEW OF LAKE ALTOONA DAM CONSTRUCTION, 1911

Construction Cost – The total construction cost of the water supply works including dams, appurtenances, bypass channels and diversion tunnels was \$850,000 (Current value - \$85 million). The work was financed by the issuance of water revenue bonds by the City of Altoona.

Historical Significance – The importance of the Altoona Reservoirs as a unique waterworks system was recognized immediately by the engineering community. C.W. Knight was asked to present a paper to the New England Water Works Association (NEWWA) on September 13, 1899. The treatise, entitled “*Flood-Water Channel of the Altoona, PA Reservoirs,*” was later reproduced in the NEWWA Journal and Engineering News-Record. It gave a description of the upper reservoirs and bypass system. Famous civil engineers have evaluated the system through the years and commented on its importance.



Allen Hazen



George W. Fuller



Francis S. Friel



Elio D'Appolonia

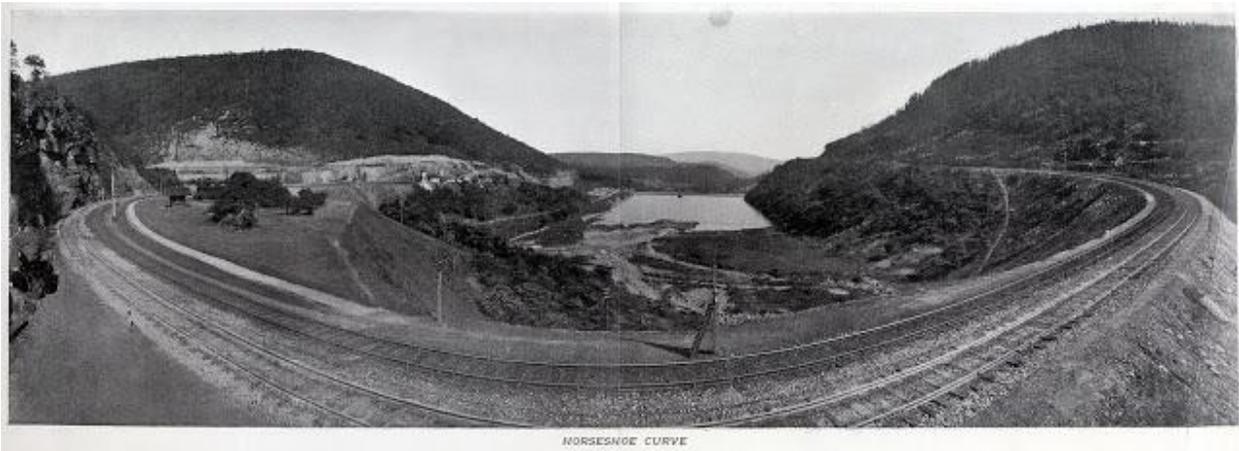
Allen Hazen, the famous Boston waterworks engineer and Panama Canal consultant, evaluated reservoir system capacity for the City of Altoona in 1921. His report notes, “...of the substantial character of the works...were fully up to the engineering practice of the times... the spillways and flood channels are of ample proportions...this reflects credit on Mr. Knight as engineer of the works...”

George W. Fuller, a renowned hydraulic engineer, reviewed the system in a 1929 City water supply report as part of Fuller & McClintock, Philadelphia.

Another prominent Philadelphia engineer, **Francis Friel** of Albright & Friel Engineers and former vice president of the American Society of Civil Engineers, examined the system in 1955 as part of a water system improvement project.

Elio D'Appolonia, of Pittsburgh and one of the nation's foremost geotechnical engineers, performed detailed dam inspections in 1979.

Finally, no mention of these reservoirs can be made without a reference to the World Famous Horseshoe Curve, itself a National Park Service Historic Site and ASCE Civil Engineering Landmark. Constructed in 1854 using only draft animals and manual labor, the Horseshoe Curve made possible the surmounting of the Appalachian Mountain barrier for train travel. This mammoth earthwork totally encloses the reservoirs and makes for a most picturesque setting. A National Park Service Visitors Center provides information on its significance including references to the Altoona Reservoir System.



By virtue of their high visibility on the New York-to-Chicago mainline, the reservoirs have been a feature of train travel for over a century including travelers such as Abraham Lincoln and Dwight Eisenhower.

Changes to the Reservoir System – After 1913, the only additions were increasing the capacity of Lake Altoona Dam (800 million gallons) and channelizing the streams above the Kittanning Point intake in 1929. Although many of the abandoned mine sites were restored and the watershed became reforested, the effects of acid mine drainage took a toll on drinking water quality. A water treatment plant was constructed below the Impounding Dam in 1970. Ironically, although more recent concrete work was deteriorating, the native stone masonry channels have been unaffected by mine drainage.

The passage of the National Dam Inspection Safety Act of 1972 refocused attention on the Altoona Reservoirs which were found to be hydraulically deficient based on new “probable maximum flood” hydrology criteria. The resulting \$20 million dam safety upgrades were constructed from 1984 to 1999 involving new spillways, floodwalls, stability improvements and channel rehabilitation. Remarkably, the dam rehabilitations were the first such projects since their original construction. The improvements are shown in the following photos.



KITTANNING POINT RESERVOIR AT HORSESHOE CURVE (COURTESY, ASCE MAGAZINE, JANUARY 2015)



KITTANNING POINT RESERVOIR UPSTREAM SPILLWAY AT STREAM INTAKE, 1986



KITTANNING POINT RESERVOIR FLOODWALL ALONG BYPASS CHANNEL, 1986



KITTANNING POINT RESERVOIR DOWNSTREAM SPILLWAY ALONG BYPASS CHANNEL, 1986



IMPOUNDING DAM SPILLWAY & WATER TREATMENT PLANT, 2000



IMPOUNDING DAM STABILITY AND SEEPAGE IMPROVEMENTS WITH INTAKE TOWER, 1988



ENTRANCE TO DIVERSION TUNNEL AT IMPOUNDING DAM, 1988



IMPOUNDING DAM PRINCIPAL SPILLWAY, 1988



IMPOUNDING DAM EMERGENCY SPILLWAY WITH INFLATABLE RUBBER DAM, 1988



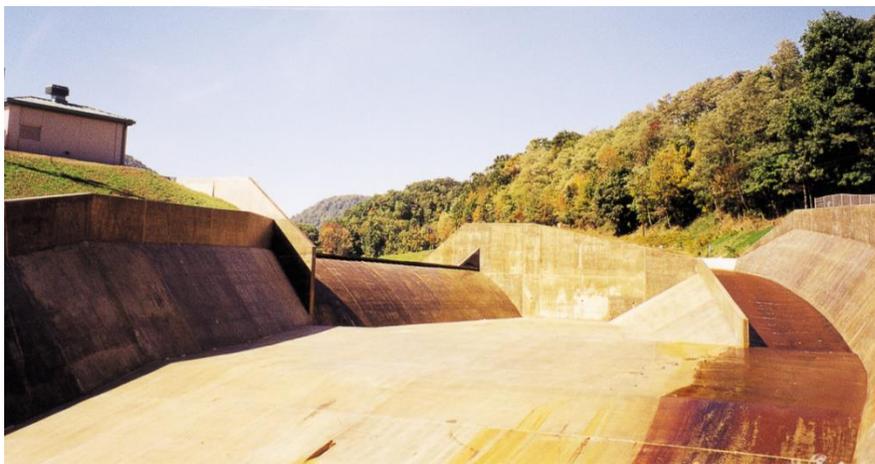
LAKE ALTOONA DAM SPILLWAY & FLOODWALL, 1999



LAKE ALTOONA BYPASS CHANNEL REHABILITATION, 1998



LAKE ALTOONA DAM SIDE CHANNEL SPILLWAY, 1998



LAKE ALTOONA DAM SIDE CHANNEL SPILLWAY & BYPASS CHANNEL, 1999



LAKE ALTOONA SPILLWAY, INTAKE STRUCTURE & FLOODWALL

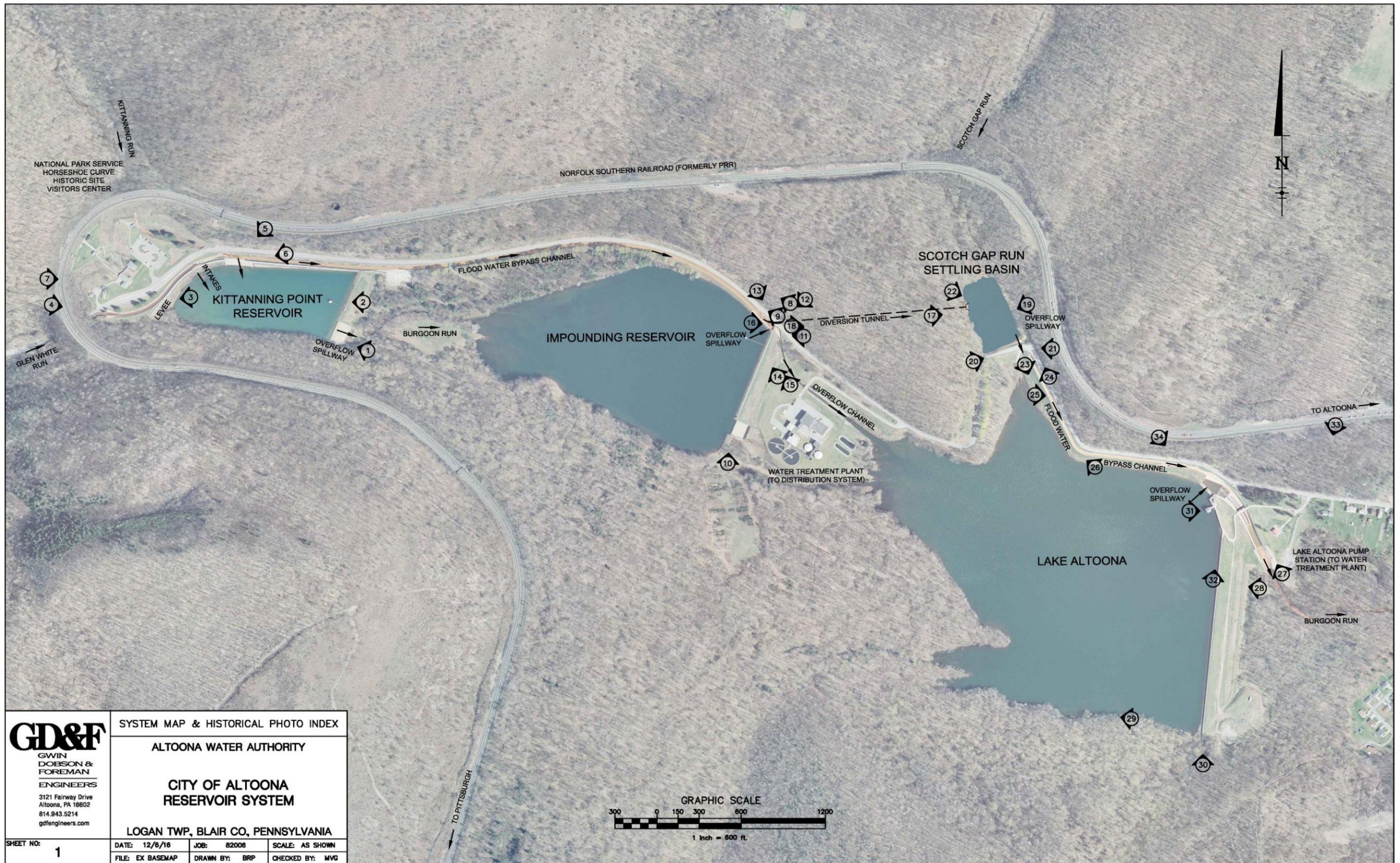
Photography - The period photographs in this report depicting the construction and completion of the reservoir system are part of a larger folio commissioned by Mr. Knight. They are remarkable for not only depicting physical features but also the workers who built the system and the equipment used in their construction.

The period from 1885-1915 was marked by a great transition in construction technology - from manual labor and draft animals to steam-powered mechanical equipment. Some photos show a team of horses towing a roller alongside steam shovels and gasoline-driven tamping equipment. These photos are a remarkable record of the men and machines who built the Altoona Reservoir System.

Original Drawings – The drawings of the Altoona Reservoir System are on-file at the offices of the Altoona City Engineer and Gwin, Dobson & Foreman, consulting engineers to the Altoona Water Authority. They represent a historical record of the engineering capabilities of the design engineer, C.W. Knight.

Altoona Reservoir System Today – Operated by the Altoona Water Authority, the Altoona Reservoir System is now an integral part of a regional supply system serving the needs of 75,000 residents. The reservoir system has a capacity of 1.2 billion gallons and a safe yield of 6.3 million gallons per day.

Summary – The Altoona Reservoir System is considered an outstanding example of 19th century hydraulic engineering. Their innovative design features have been recognized by renowned engineers for over a century. The remarkable masonry workmanship has stood the test of time showing no signs of deterioration over the intervening years. Most importantly, the system continues to operate in the manner originally conceived by its design engineer and is a testimony to the skill utilized in its construction.



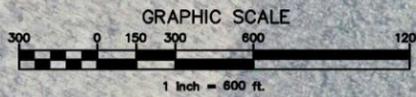
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SYSTEM MAP & HISTORICAL PHOTO INDEX

ALTOONA WATER AUTHORITY

**CITY OF ALTOONA
 RESERVOIR SYSTEM**

LOGAN TWP, BLAIR CO, PENNSYLVANIA



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