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The Brooks Aqueduct:
A Technological and Engineering History
1912-79
by David Finch

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The Brooks Aqueduct: A Technological
and Engineering History 1912-79

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Abstract

The Brooks Aqueduct is a unique irrigation water conveyance system located in the Eastern Irrigation District in southeastern Alberta. Originally opened in 1914 by the Canadian Pacific Railway to help with the irrigation of an otherwise uninhabitable area of land, the District was turned over to the farmers in 1935. The Brooks Aqueduct was replaced by an earthen fill canal in 1979 and plans for its demolition were halted while studies of the structure were carried out. Finally, it was decided to retain the structure, largely intact, and interpret it for the public. This study provides background information as to the technological and engineering significance of the Brooks Aqueduct and enables planners and other interested people to understand the significance of this flume to the irrigation of a large part of southeastern Alberta.

Précis

The Brooks Aqueduct is a unique technological and engineering structure and, therefore, worthy of preservation and interpretation for many reasons. This flume is important, if for no other reason, just because it moved water into an area that was dry and allowed farmers to bring parched land into production. Since ancient days, people have successfully put their energies to this task. Although overshadowed during its conception, construction and operation by the Bassano Dam, the Brooks Aqueduct was a reliable structure which consistently delivered water to farmers in a large portion of the Eastern Irrigation District of southeastern Alberta.

Delivering water from the Lake Newell reservoir to the farmers in the north and eastern sections of the District was a considerable feat. Crossing the old river valley, two miles in width, with a flume held as high as sixty feet in the air was an engineering challenge. But the minimal drop in altitude between the reservoir and the eastern side of the river valley allowed only a five foot loss of elevation, or head, in that two mile long crossing. Also, a siphon under the Canadian Pacific Railway tracks line added an additional, if minimal, loss of head. Although this gentle incline caused operations problems, the fact remains that the aqueduct worked for 65 years.

Criticism can be levelled against the construction, operations and maintenance of this giant water conveyance system. Nevertheless, the aqueduct pushed the limits of numerous aspects of technology at the time of its

construction. The Eastern Irrigation District was the first Canadian irrigation district to use reinforced concrete in all its major works although this new material was standard in American projects at the time. The CPR chose to use the hydrostatic catenary curve principle in the shell of the flume as it was theoretically the shape a flexible channel, filled with water, would naturally take if suspended from supports. No one else had attempted to apply this theory in a suspended, reinforced concrete shell. The shell design called for five inches of reinforced concrete, a thickness theoretically adequate to provide enough thickness in the concrete to keep it from cracking and enough tensile strength in the steel to carry the weight of the water when filled to capacity. Also, the construction crews watered down the cement to a wet slush in order to assure a thorough filling of the lower sections of the shell. Although this new technique helped make the pour as perfect as possible, the concrete in the lower section of the flume was probably irreparably harmed by this decision. The CPR engineers also used a new formula when they calculated the maximum flow of water through the flume. Either it was in error or a friction value excessively low was used. Regardless of the actual mistake in calculation, low slope and high friction, compounded by cross-struts that impinged upon the flow of water at the surface, together combined to keep the discharge capacity well below its original 913 cubic feet per second. Only after much study, experimentation and renovation to the structure did it ever exceed a flow of 700 cubic feet per second. Finally, expansion joint technology in cold weather applications of reinforced concrete flumes was also in its infancy and as a result the Brooks Aqueduct was a testing ground for the new, and largely untried, systems.

Operations and maintenance problems at this location posed new questions never before entertained in aqueduct systems. No other reinforced concrete flume operated in

temperatures which ranged as much as 140°F. Although the irrigation system did not operate during the coldest part of the year, by running water through the flume until the end of October, the shell froze and stayed saturated with water throughout the coldest months of the year. The destructive action of frost on concrete was not well understood in the early years of the aqueduct's life. Repair crews used air entrained concrete, which better resists freezing, to replace much of the lower section of the shell in later years. The destructive forces of alkali, which in another site in the Eastern Irrigation District totally demolished a reinforced concrete structure, were warded off at the Brooks Aqueduct by carefully replacing exposed surfaces as the inevitable destruction occurred and waterproofing the rebuilt support systems as protection against further trouble. A system of drainage channels moved water away from the foundations of the aqueduct, thereby reducing contact between alkali saturated water and the pedestals. Maintenance engineers creatively tested and eventually perfected the use of galvanized, and the longer lasting copper, "V" shaped, accordion like expansion joints to replace the flawed original design. And finally, these crews successfully utilized the cement gun and its product, gunnite, to repair damaged concrete wherever encountered in the Brooks Aqueduct and lined the flume with a coating which kept it in service long after the original concrete in the lower part of the flume had deteriorated to powder.

Therefore, the Brooks Aqueduct is best described as an engineering and technological forerunner of reinforced concrete irrigation flumes which, although plagued by various design, construction, operations and maintenance flaws, carried many hundreds of millions of acre feet of water to farmers at an economically viable cost for 65 years without major failure.

Acknowledgements

This report was made possible by the excellent work of Elise A. Corbet in her source survey of materials relevant to the history of the Brooks Aqueduct. The Glenbow Museum Library, Manuscript and Photo Archives were, as always, most helpful in the preparation of this report and special thanks go to Lindsay Moir, Douglas Cass and Bill Leonard. Laurette Doucet at the Eastern Irrigation District provided additional information. R.T. (Bob) White of Brooks, a previous manager of the District, was also most helpful. Keith Stotyn at the Provincial Archives of Alberta provided valuable direction and insight into a recently listed collection of papers which appear to be part of the black hole into which many of the records of the Calgary office of the Department of the Interior disappeared. Archivists at the Public Archives of Canada were most helpful even though the vast collection of records dealing with irrigation in Alberta contained no details of the construction and maintenance of the Brooks Aqueduct. Finally, David Manz and Robert Loov, professors in the Department of Civil Engineering at the University of Calgary, provided criticism and insight into some of the engineering concepts mentioned in this report.

Introduction

The remains of the Brooks Aqueduct stand just south and east of the town of Brooks, in southeastern Alberta. Built during the second decade of the century as a water conveyance system to bring moisture to a parched area of Alberta, it is a unique engineering tribute to the attempt to make arid land bloom with crops. For hundreds of years nomadic animals and people wandered this open prairie. Next, it attracted European hunters and trappers, seeking goods they could export for a profit. Later, ranchers passed its poor grasslands over for more lush range land further to the west.

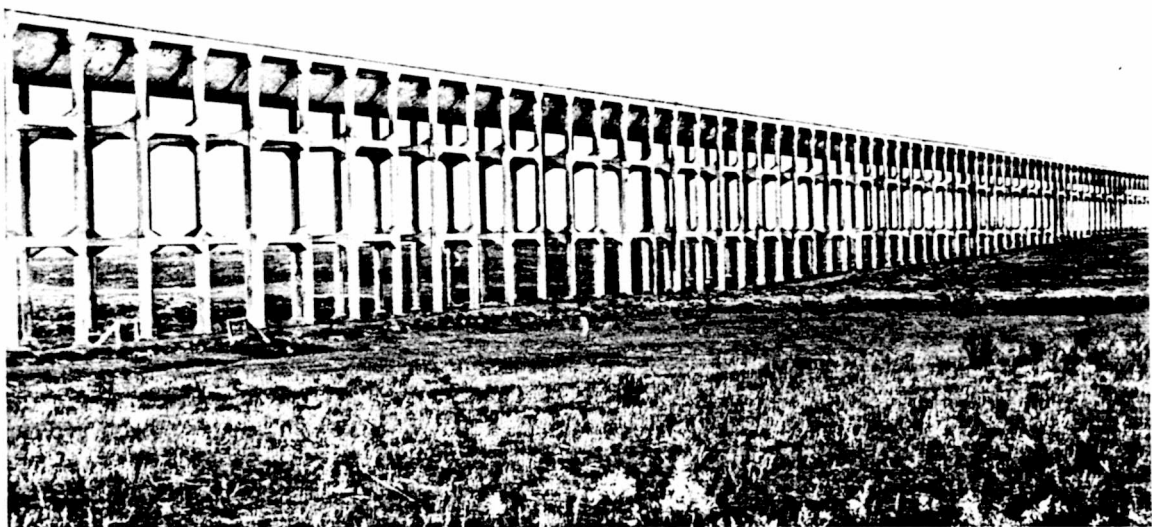


Illustration 1 Brooks Aqueduct, 1926 (Glenbow-Alberta Institute, (GAI) NA-4389-31)



Illustration 2 Siphon outlet, c. 1950 (Provincial Archives of Alberta (PAA) P-820)

Finally, as available agricultural land ran out in more accessible parts of North America, people began to consider the possibility of creating farms in this parched territory.

Alberta Irrigation

Two main obstacles stood in the way of the development of farms in the southeastern part of Alberta. Transportation to and from markets and support facilities was non-existent and water was scarce. The solution to both of these problems came in the form of a transcontinental railway. With a monopoly on western development and transportation for many years, the Canadian Pacific Railway also had a number of

responsibilities. First, as part of its initial inducement to finish the railway which the national government of the day had been unable to complete, the Company was given the right to choose 25 million acres¹ of land along the right-of-way. The land which it chose was then developed by the Company and sold to farmers. This it did throughout the prairies until it encountered the dry area of southern Saskatchewan and Alberta. The CPR balked at the idea of taking land that appeared unable to support agriculture. However, William Pearce of the Department of the Interior, and J.S. Dennis of the government of the Northwest Territories convinced railway authorities that the land could be fruitful. Both later became employees of the Company. The CPR also felt compelled to make a profit for itself and its investors, and consequently, when a way to develop this area was suggested, it took the bait. Besides, as the old local saying goes, there was "not enough revenue to pay for the axle grease from Medicine Hat to Calgary."² By developing the territory in this area, the CPR could not only sell land, it could also increase traffic along its line.

Dry land along the line was also further aggravated by periodic droughts. Officials of the Department of the Interior recorded severe droughts in the seasons of 1910 and 1914.³ By this time, however, the government had granted

¹ The measurements referred to in this study conform to those used during the construction of the Brooks Aqueduct.

² W. Tait White, interviewed by W. L. Jacobson, July 16, 1959, Glenbow-Alberta Institute tape RCT-90-32, side 1.

³ Canada, Department of the Interior, Annual Report, Report of the Superintendent of Forestry in *Sessional Papers* (Ottawa: Queen's Printer, 1912), No. 25, Part vii, pp. 103; Canada, Department of the Interior, Annual Report, Report of the Superintendent of Forestry in *Sessional Papers* (Ottawa:

water rights from the Bow River to four companies. In addition to the Canadian Pacific Railway Company, the Alberta Railway and Irrigation Company, Southern Alberta Land Company and its subsidiary, the Alberta Land Company, received the right to build irrigation systems.⁴

The national government gave the CPR the right to act as an irrigation company in 1902 under the following terms:

The Company may excavate, construct, maintain and operate irrigation ditches or canals upon its lands for supplying water for irrigating any portion of such lands and for supplying water for irrigation, water-power or other purposes to municipalities, cities or towns, and to individuals, corporations or companies holding lands contiguous to the lands of the Company, and, for the purposes aforesaid, generally exercise the powers of an irrigation company.⁵

Attached to its right to act as an irrigation company, the CPR also had the responsibility to complete all its construction on its lands within fifteen years of April 12, 1914. In the meantime the Company used water from the Bow River at a charge of \$.50 per acre/year until the completion

Queen's Printer, 1916), No. 25, Part vii, pp. 3.

⁴ Canada, Department of the Interior, Annual Report, Report of the Superintendent of Forestry in *Sessional Papers* (Ottawa: Queen's Printer, 1913, Sessional Paper No. 25, Part vii, p. 163.

⁵ Public Archives of Canada, RG 15 Vol. 41 f. 19c Royal Commissions re Railways, An Act Respecting the Canadian Pacific Railway Company, Assented to 15 May, 1902, 2 Edward VII, Volume II-4½, Chapter 52, Point 11.

of the works.⁶

Indeed, the Company had its irrigation system up and running by 1915 and showed prospective settlers and interested newspaper reporters around its irrigation areas in grand style. One reporter, taken in by the hospitality, wrote an article entitled "A Pleasant Journey Through Alberta: Some of its Irrigation Features" in a Salt Lake City publication called *Irrigation Age*. Its readers found his description of the CPR irrigation scheme almost as interesting as the description of the tour:

...These gentlemen (officers of the CPR) impressed us as all having been born to fill good positions, and who, having obtained them, are satisfied, but in no sense arrogant, as was evidenced by their meek and lowly looks when gently landing their tenderfoot passengers after a long flight. It may not be out of place to explain that each of the CPR districts furnishes its experts with a car that is used in going over their respective field, the cars are also used in showing visitors over the property. These cars are a sort of a cross between an aeroplane, an hydroplane, and a Ford. They can follow the ground when necessary, leap or sail from hill to hill, follow a ditch bank with deep water on one side and a bed of quicksand on the other. Each new pilot made us feel like going back and apologizing to his predecessor for the things we

⁶ Canada, Department of the Interior, Annual Report, Report of the Superintendent of Forestry in *Sessional Papers* (Ottawa: Queen's Printer, 1908-1909), No. 25, Part vii, p. 14.

had thought but failed to say to him.⁷

The CPR divided the irrigation district into three sections, each of approximately 1,000,000 acres. The Western Irrigation District was the first developed. Immediately adjacent to the eastern side of Calgary, with its dam actually inside the city limits, plans for this first district included some \$5,000,000 in works and include 2900 miles of ditches.⁸ Construction on this district began in 1908 and was completed in 1914. Complaints against the Company began almost immediately. Farmers paid a water fee based on lands that the CPR had surveyed and considered as fit for irrigation. But much of this land was not level enough to allow for irrigation and the farmers called upon their local, provincial and national politicians to save them from the tyranny of the railway.⁹

Farmers in the Eastern Irrigation District also filed complaints once it began operating later in the decade and the Central Irrigation District only escaped the wrath of the farmers because the CPR never attempted to apply water to

⁷ Glenbow-Alberta Institute Archives, W.L. Jacobsen papers, M3761/f.401 "A Pleasant Journey Through Alberta: Some of its Irrigation Features" Summary of an article in *Irrigation Age*, September-October, 1918 XXXIII, No. 7-8, published at 213 Templeton Building, Salt Lake City, Utah.⁵⁰

⁸ Canada, Department of the Interior, Annual Report, Report of the Superintendent of Forestry in *Sessional Papers* (Ottawa: Queen's Printer, 1908-1909), No. 25, Part vii, p. 14.

⁹ Canada, Department of the Interior, Annual Report, Report of the Superintendent of Forestry in *Sessional Papers* (Ottawa: Queen's Printer, 1910), No. 25, Part vii, pp. 10-12, 65-77; Canada, Department of the Interior, Annual Report, Report of the Superintendent of Forestry in *Sessional Papers* (Ottawa: Queen's Printer, 1914), No. 25, Part vii, p. 4.

this portion of its lands. In the end, much of the land in both the Eastern and Western Irrigation Districts was reclassified by survey crews and the farmers and the Company came to an uneasy truce.¹⁰

In the development of its two irrigation districts, the CPR pursued different policies. In the Western District it placed inexpensive and easily erected wooden structures at almost all its water works gates and control structures. Once the water was flowing, the Company crews returned and replaced these temporary works with permanent ones. This program got land into production immediately and allowed the CPR time to work out the design for the permanent concrete structures.¹¹ By way of contrast, when the Eastern District was constructed in subsequent years, the Company decided to follow the example of the government irrigation projects in the United States and build all the works with concrete so as to be permanent from the start.¹²

The largest of these structures was the Bassano Dam. It was so large that it made the Brooks Aqueduct project look small by comparison, and consequently, details of the construction and maintenance of the dam are much easier to find than of the aqueduct. Second only to the Aswan Dam in Egypt for size when built and called "America's Greatest Irrigation Project" by *Scientific American* in 1915, it was described as follows:

The earthen embankment is some 7,000 feet in

¹⁰ Canada, Department of the Interior, Annual Report, Report of the Superintendent of Forestry in *Sessional Papers* (Ottawa: Queen's Printer, 1918), No. 25, Part vii, p. 16.

¹¹ Canada, Department of the Interior, Annual Report, Report of the Superintendent of Forestry in *Sessional Papers* (Ottawa: Queen's Printer, 1915), No. 25, Part vii, p. 4.

¹² Ibid.

length, extending from the south end of the spillway until it meets and merges with the sloping ground running down to the river. At its highest point it is 350 feet wide at the base and contains about 1,000,000 cubic yards of earth. The spillway contains some 40,000 cubic yards of concrete and 2,500,000 pounds of reinforcing steel. Construction on both parts was begun in the summer of 1910... The construction of the dam and canals took almost four years and cost \$17,000,000. In all over 20,000,000 cubic feet of earth were moved in the building of the project.¹³

The Brooks Aqueduct, included at the end of the above quote as part of the canal system, was nonetheless a significant part of the overall project and certainly worthy of study for its own merit. In fact, the aqueduct carried water for as much as a third of the land that was irrigated in the District. However, before investigating the details of this unique structure, a brief review of water conveyance systems will establish the significance of the Brooks Aqueduct in the context of engineering history.

Background to Aqueducts

The word "aqueduct" conjures up the image of any structure that carries large quantities of water from one area to another. In fact, the strict definition of "aqueduct" does not include the Brooks Aqueduct at all since it is open at

¹³ Z.E. Black, "America's Greatest Irrigation Project, The Bassano Dam," *Scientific American*, Vol. 113, No. 12, (September 18, 1915) pp. 252-253.

the top, and therefore more accurately called a "flume."¹⁴ Early water conveyance systems were considered national treasures in Egypt and Mesopotamia and popular objects for destruction by conquerors. The first aqueduct was probably built in this area.

The Assyrian king Sennacherib was the first to build a long-distance water supply (691 B.C.) in order to water the fields and palace gardens north of Nineveh. He constructed a dam in the Khosor River near Bavian and conducted its water through a gently sloping masonry channel to Nineveh, some thirty-five miles to the southeast. This channel, which sometimes bridged valleys on arches, was the earliest aqueduct, and it served as an example to Eupalinos, who built the first Greek aqueduct on the island of Samos (530 B.C.).¹⁵

Water Conveyance Designs

The Romans built aqueducts throughout their empire and one near Tarragona, Spain, built circa 200 B.C. was a covered masonry structure. Built of two tiers of stone arches which make up a total height of 123 feet at highest point, the overall length of the structure is 712 feet. The original length was over 1200 feet. Broken slabs found inside the

¹⁴ R.T. (Bob) White, March 10, 1988 interviewed at his residence in Brooks, Alberta by the author of this report.

¹⁵ Melvin Kranzberg and Carroll W. Pursell Jr. Editors. *Technology in the Twentieth Century. Volume II of Technology in Western Civilization.* (New York: Oxford University Press, 1967), p. 31.

aqueduct probably formed covers for this inverted siphon.¹⁶ Although ravaged by time over the centuries, ancient aqueducts such as these were built to last. An important element in Roman engineering success was the ability to choose appropriate materials, designs and workmen and their skill at organizing these complex forces in such a way as to maximize the results. Engineers since their days have frequently compared their works to those of these ancient masters.¹⁷

Another form of aqueduct is the stave structure. Built of staves or planks of wood held together with steel bands, it is usually semicircular or formed into a pipe although trough shaped flumes were built by the San Diego Flume Company at the turn of the century.¹⁸ In the Canadian west, the CPR built wooden stave pipes at Crossfield, Alberta and at the Lathom and Crawling Valley crossings in the Eastern Irrigation District. At the Crossfield location, built during 1910 and put into service in 1911 at a cost of \$12,000, a 1,680 foot long 53 inch pipe operated with a maximum capacity of 130 c.f.s.(cubic feet per second). Workers backfilled the pipe in order to protect it from the elements, but it rotted through by 1920 and was subsequently

¹⁶ John B. Rippey, "The Roman Aqueduct near Tarragona, Spain," *Engineering News*, Vol. 74, No. 2 (July 8, 1915) p. 51.

¹⁷ Melvin Kranzberg and Carroll W. Pursell Jr. Editors. *Technology in the Twentieth Century. Volume II of Technology in Western Civilization*. (New York: Oxford University Press, 1967.) p. 65.

¹⁸ Herbert M. Wilson, *Irrigation Engineering*, 6th ed., (New York: John Wiley & Sons, Inc., 1912) pp. 275, 291.

brought above grade.¹⁹ The pipes at Lathom and Crawling Valley were both semicircular. (See Illustration 3)

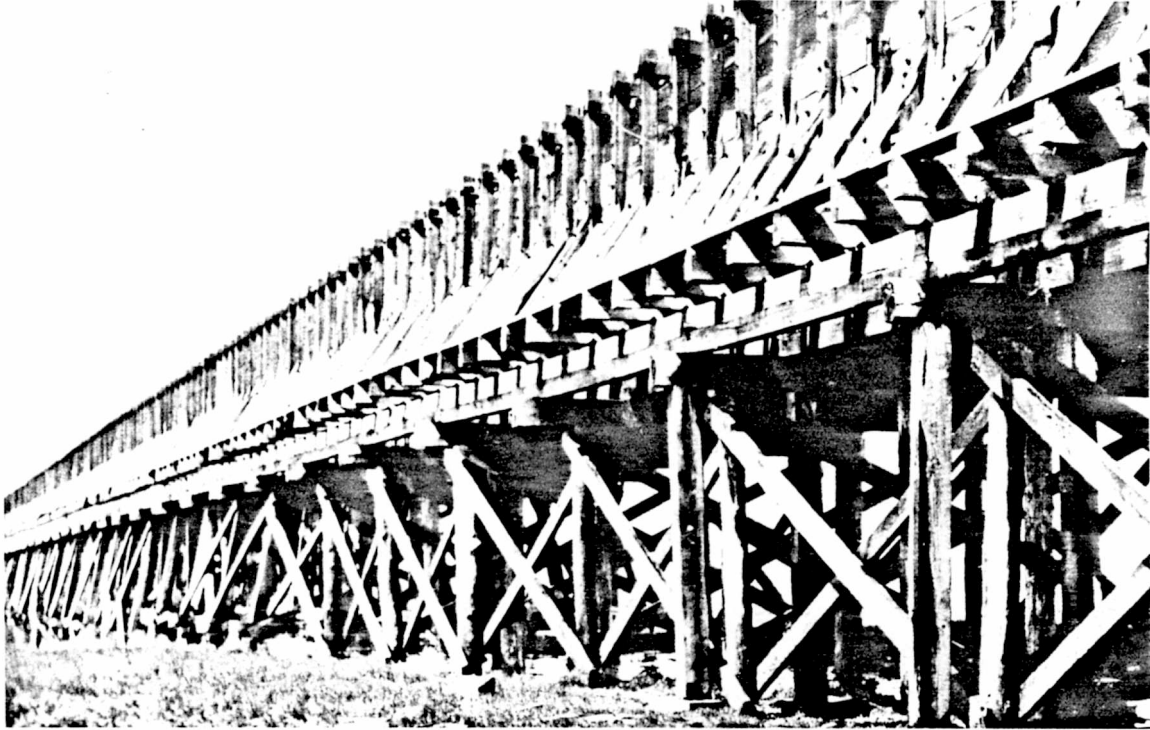


Illustration 3 Lathom Flume, 1926 (GAI NA-4389-28)

Built as part of the Eastern Irrigation District works in the period from 1910 to 1914, they utilized pressure treated wood and sat on pile foundations to keep them above grade. Each was fifteen feet in diameter. The Lathom flume was 2593 feet long and delivered water at a maximum capacity of 978 c.f.s.

¹⁹ Canada. Department of the Interior, Irrigation Branch. *Official Proceedings of the 21st International Irrigation Congress held at Calgary, Alberta, Canada, October 5-9, 1914*, (Ottawa: Government Printing Bureau, 1915). Contains a verbatim report of the address by H. B. Muckleston, Assistant Chief Engineer, Department of Natural Resources, Canadian Pacific Railway Company, entitled "Irrigation Enterprises of the Canadian Pacific Railway Company in Alberta." pp. 261-274.

The Crawling Valley structure was 1388 feet long and delivered 673 c.f.s.²⁰

The Reclamation Service in the United States used concrete flumes in the early part of this century. On the Tieton project in Washington, a system of reinforced concrete trestles supported a thin walled (4 inch) semicircular reinforced concrete flume. Four inch square, ten foot long beams held the top of the flume together. In this case the flume sat on top of the trestle, and did not hang from it as at the Brooks Aqueduct.²¹

However, the most common type of concrete flume used by the American service was a reinforced concrete trough. Used in all its major irrigation systems, the trough was nearly as deep as wide and its walls were thick enough to render cross bracing unnecessary.²²

At the massive Catskills aqueduct project, begun in 1907 by the Board of Water Supply of the City of New York, 105 miles of a variety of structures carried water. One, a reinforced concrete pressure tunnel, was used in 35 miles of application. Sizes varied from 11 feet to 16 feet 7 inches in diameter.²³

Concrete technology also applied to culverts and inverted siphons. Whereas culverts merely transported water underneath a roadbed or similar obstacle, the inverted siphon accomplished the same task while dropping below the grade of

²⁰ Glenbow-Alberta Institute Archives, W.L. Jacobsen papers, M3761/f.182, *Engineering Journal*, June 1937, p. 410.

²¹ Herbert M. Wilson, *Irrigation Engineering*, 6th ed., (New York: John Wiley & Sons, Inc., 1912), p. 283.

²² Ibid.

²³ Alfred D. Flinn, "Forms for Construction of an Aqueduct," *American Concrete Institute, Proceedings*, Vol. II, (1915) pp. 291, 340-345.

the remainder of the structure. In American applications these siphons commonly crossed under rivers and canals.²⁴ In the Eastern Irrigation District an above grade stave pipe replaced a buried concrete inverted siphon at Antelope Creek. Originally a five barrel structure 1740 feet long and 5 feet in diameter, it cost \$117,000 to build. The Antelope Creek siphon went into operation in 1914 and cost \$93,140.00 to replace in 1921. Problems first surfaced in 1917 as the buried siphon suffered severe damage in the alkali soil.²⁵

Superpassages, or canals that carry water under a river, were constructed out of masonry as well as concrete but did not find any application in North America.²⁶

The CPR chose an unusual type of water conveyance design, the hydrostatic catenary, for the Brooks Aqueduct location. Although used elsewhere, it differed from these applications in two significant ways. First, other hydrostatic catenary flumes used steel in their shells but

²⁴ Herbert M. Wilson, *Irrigation Engineering*, 6th ed., (New York: John Wiley & Sons, Inc., 1912), p. 294.

²⁵ Glenbow-Alberta Institute Archives, W.L. Jacobsen papers, M3761/f.56 *History of the Eastern Section, Irrigation Project, Department of Natural Resources, Canadian Pacific Railway*, A.S. Dawson, Chief Engineer, November 23, 1925 compiled by G. Boese, p. 13; Glenbow-Alberta Institute Archives, W.L. Jacobsen papers, M3761/f.89, Provincial Auditors Report of the CPR Co. EID Project, Special Report, February 19, 1935, J.C. Thompson C.A. Provincial Auditor, p. 4.

²⁶ Herbert M. Wilson, *Irrigation Engineering*, 6th ed., (New York: John Wiley & Sons, Inc., 1912), p. 285.

the CPR used concrete in this application.²⁷ Secondly, these other flumes were supported from below and not suspended like the Brooks Aqueduct.²⁸ They were customarily either built into the sides of hills and had banks built up to carry them over depressions or perched atop wooden concrete trestles. Both of these design considerations took on significance as Brooks Aqueduct operations and maintenance problems began to occur.

Aqueduct materials

Until well into the 1800s, most permanent water conveyance systems were built to last forever. Therefore, masonry was the material of choice.²⁹ The largest of these is no doubt in India. The Solani aqueduct on the Ganges canal is 920 feet in length, carries a body of water 750 feet wide and rises to a height of 38 feet above the valley. Its masonry piers rest on 50 foot deep foundations and it boasts a

²⁷ Anonymous, "Canadian Pacific Railway Company's Irrigation Project in Alberta," *Engineering Record*, Vol. 65, No. 12, (March 23, 1912) pp. 332-333.

²⁸ Herbert M. Wilson, *Irrigation Engineering*, 6th ed., (New York: John Wiley & Sons, Inc., 1912), p.283; Douglas Babcock, *The Brooks Aqueduct*, (Edmonton: Alberta Culture-Historic Sites Service, October 31, 1977), p. 3.

²⁹ Charles, E. Singer, J. Holmyard, A. Rupert Hall and Trevor I. Williams. Editors. *A History of Technology. Volume V. The Later 19th Century, 1850-1900*, (Oxford: Clarendon Press, 1958), pp. 558-560.

discharge capacity of 30,000 c.f.s.³⁰

Cast iron and steel aqueducts became common in this industry in the 1800s.³¹ Although very strong, they were usually short because of their high construction cost. Their reputations also suffered because of their inability to expand and contract without damage.³² The CPR operated one such structure in its Western Irrigation District, the Winona flume. It lived up to all the worst predictions for this technology. Built in 1910, it was 210 feet long and 33 feet at the highest point above the gorge. Galvanized 16 gage³³ steel sheets 28 inches wide were riveted with 1½ inch overlaps to cross at this point. The fall across the ravine was 2.33 feet and the maximum capacity was 141 c.f.s. Water ran through the flume for the first time in 1911. Winter temperatures as low as -50°F caused many problems at this location. First the bents, or wooden supports, heaved in the severe cold and were cut many times to keep them from destroying the flume by pushing it above grade. Expansion and contraction factors quickly opened the steel rivet holes and the structure lost its waterproof quality. Annual maintenance involved brushing a mixture of coal-tar pitch and 5 to 10% beef tallow melted to form a coating to brush on inside at 60°F. The recipe also read:

For beef tallow we buy the unrefined tallow from a

³⁰ Herbert M. Wilson, *Irrigation Engineering*, 6th ed., (New York: John Wiley & Sons, Inc., 1912), p. 279.

³¹ Charles, E. Singer, J. Holmyard, A. Rupert Hall and Trevor I. Williams. Editors. *A History of Technology. Volume V. The Later 19th Century, 1850-1900*, (Oxford: Clarendon Press, 1958), pp. 558-560.

³² Herbert M. Wilson, *Irrigation Engineering*, 6th ed., (New York: John Wiley & Sons, Inc., 1912) p. 276.

³³ Gage is the engineering spelling of gauge.

local butcher, just as it comes from the animal. If the tallow is rancid it makes no difference except that it is not so pleasant to work with.

This annual ritual kept the flume in service until 1928 when the lack of expansion joints proved catastrophic. On June 1, 1928, while carrying only 50 c.f.s of water, the rivets gave way at one of the joints in the iron flume. The resulting dump of water washed out one bent and the unsupported end of the structure collapsed. By June, 14 repairs again made the flume viable but the expansion joint problem continued until expansion joints were finally installed.

After this experience, a V-shaped expansion joint was installed near each end of the flume. Each joint was made of two pieces of galvanized sheet iron, riveted and soldered together at the bottom of the "V" and riveted on each side to a section plate of the flume, from which a strip had been cut to accommodate the joint. The "V" is approximately 5 in. deep and at ordinary temperatures about 3 in. wide. These joints have obviated all trouble from expansion and contraction.

This example in the Western Irrigation District shows why even if the Brooks Aqueduct had been built of steel, its expansion problems would have continued.³⁴

Engineers began using wood once they started building structures in North America. Elsewhere timber was scarce but in the new continent it was plentiful and, although not a permanent solution to water conveyance situation, cheap. Wooden flumes, canals, culverts and inverted siphons became

³⁴ R.S. Stockton, "Maintenance of a Canadian Irrigation Flume." *Civil Engineering*, Vol. 4, No. 5, (May, 1934) pp. 238-239.

common in North America.³⁵ However, as plentiful as it was, wood also had its drawbacks. Although wood lasts for many years in some applications, aqueduct usage often meant that untreated wood faced numerous wet and dry cycles. Buried structures were often attacked by salts. Such was the case in the irrigation districts of the CPR. According to one longtime employee, treated structures lasted sometimes for decades when properly maintained but untreated wood was much more prone to decay.³⁶

The most recent arrival in the field of aqueduct materials is concrete. By 1912 the United States Reclamation Service had established concrete as the standard material for all its major structures.³⁷

The discovery of this important construction product dates back many centuries.

The great baths and other Roman construction works were built of stone and cement. By a fortunate accident, the Romans discovered and made use of hydraulic cement (that is, cement that hardens under water and is not dissolved by water). Cement until that time had only a limited use because it could not stand up under the elements, but the

³⁵ Charles, E. Singer, J. Holmyard, A. Rupert Hall and Trevor I. Williams. Editors. *A History of Technology. Volume V. The Later 19th Century, 1850-1900*, (Oxford: Clarendon Press, 1958), pp. 558-560; Herbert M. Wilson, *Irrigation Engineering*, 6th ed., (New York: John Wiley & Sons, Inc., 1912), p. 291.

³⁶ Robert S. Stockton, employee of the Canadian Pacific Railway, interviewed by W. L. Jacobson. June 23-25, 1959. Glenbow tape RCT 90-7,8 Tape 8, Side B counter 200-380.

³⁷ Herbert M. Wilson, *Irrigation Engineering*, 6th ed., (New York: John Wiley & Sons, Inc., 1912), p. 283.

Romans fortunately had a supply of pozzalana sand nearby, which, when mixed with limestone, formed a cement which was impervious to water. The Romans did not know why this particular sand made such a superior cement, but nevertheless they used it in their construction works. After Roman times hydraulic cement disappeared from history, only to be invented in the 19th century. We know it today as Portland cement.³⁸

In Canada the use of cement dates back to its use by French engineers on the lighthouse at Louisbourg in Nova Scotia. Later, engineers in Lower Canada (Quebec), used local limestone to make Portland cement³⁹ in the 1830s. By the 1890s much of industrial Canada relied on local Portland cement plants.

The CPR began using this cement in many of its major projects, including a set of grain elevators in Montreal in 1887. In 1893 the company built a portland cement plant in Vancouver. By 1896 the trade journal *Canadian Engineer* wrote of cement: "Of late monolithic works of great importance have been carried out and every day concrete as building material is creeping to a foremost place." Masonry structures were still being called upon to replace temporary wooden bent bridges across the CPR system well into the twentieth century but cement was seen as the new material. In 1904 the *Canadian Engineer* noted:

³⁸ Melvin Kranzberg and Carroll W. Pursell Jr. Editors. *Technology in the Twentieth Century. Volume II of Technology in Western Civilization*. (New York: Oxford University Press, 1967.), p. 63 .

³⁹ Portland cement, patented by Joseph, James and William Aspdin in 1824, was made with limestone from the island of Portland. See R.J. Barfoot, "The Aspdin Jigsaw" in *Concrete*, (August, 1974), pp. 18-26.

Cement is proving a formidable competitor to stone for uses in which the latter was for long employed almost exclusively. Quarrymen look askance at the new material which is replacing their product in bridge work, foundations and construction work of various kinds, contending that it will prove less durable, and more liable to destruction by frost when exposed to the action of water. Time only will show whether these imputations are warranted, but in the meantime there is little doubt that cement for many uses is pressing hard on stone.⁴⁰

Therefore, when the CPR began using cement in its Eastern Irrigation District structures, some observers reacted with skepticism. As the author of the history of professional engineering in Canada wrote, reinforced concrete was "a material regarded with some suspicion" at the time of the construction of the Brooks Aqueduct.⁴¹

Aqueducts Contemporary with the Brooks Aqueduct

A review of aqueduct construction projects in the early twentieth century in North America will provide background for analysis of the relative significance of design,

⁴⁰ T. Ritchie and the Staff of the Division of Building Research, National Research Council, *Canada Builds, 1867-1967*, (Toronto: University of Toronto Press, 1967), pp. 229-237.

⁴¹ Norman R. Ball, *Mind, Heart and Vision: Professional Engineering in Canada, 1887 to 1987*, (Ottawa: National Museum of Science and Technology, National Museums of Canada in cooperation with the Engineering Centennial Board, 1987), p. 50.

operations and maintenance problems experienced at the Brooks Aqueduct. The following description of the Los Angeles Aqueduct was published in *Engineering Record* in 1912.

A reinforced concrete flume supported on concrete piers forms certain sections of the Los Angeles, California aqueduct, where it was found necessary to span canyons or washes of considerable depth. The section of flume over the Freeman wash, of which the following is a description, has spans of 50 ft. with piers of plain concrete carried to rock foundation. These piers are of rectangular section with a 2 by 10 ft. core of variable depth...The tops of the intermediate piers were left rough in order to insure bonding with the invert of the flume, but the tops of the end piers were smoothly finished and covered with tar paper, when the flume section was poured, to prevent adhesion between the pier top and the flume. This was done to provide for expansion joints which were placed in the structure at these points.

The flume section is a reinforced concrete structure with vertical sides and a flat circular arc for the invert. It has an inside width of 10 ft. 1 in. and a depth from water surface to invert of 9 ft. 4 in. This gives a flow area of about 81 sq. ft. The invert has a minimum thickness of 11 in., increasing to 23 in. at the sides of the flume. It is reinforced transversely with a system of rods tied into the system reinforcing the sides and longitudinally with 3/4 in. square twisted rods spaced at unequal intervals. The sides of the flume are 15 in. thick and are heavily reinforced as through girders...The cover is an 8 in. reinforced concrete slab, continuous except at expansion joints, with the under surface 6 in.

above the water surface. The expansion joints extend across the bottom and up the sides of the flume with an opening of not less than $3/8$ in. Leakage is prevented by use of waterproof paper. At these joints one of the end sections of the flume is made wider and carried outside of the other section about 2 ft...All reinforcing rods are of square twisted steel and vary in size from $3/4$ in. to $1\ 3/8$ in. In the side walls the top rods are lapped 4 ft. and the bottom ones are 5 ft. 4 in., and in both places they are well wrapped with wire at the joints.⁴²

The same publication reviewed another comparable project in 1913. Located in Washington state, it was subject to some of the harsher elements which would later affect the Brooks Aqueduct.

...This structure is the reinforced concrete flume commonly known as the Congdon Ditch, which has its intake in the Naches River about 9 miles above the city of North Yakima, Wash.

The flume, which is about 6 miles long, and conveys water for irrigating land controlled by the Yakima Valley Canal Company, was originally built in 1892 as a timber flume and earth ditch. The route followed, however, is over such rough ground that $5\frac{1}{2}$ of the 6 miles were wooden flume, only about half a mile being stable enough to support an earth ditch...

No expansion joints were used, but provision for contraction was made by the use of longitudinal reinforcing steel, which, it was thought, would

⁴² Anonymous, "Concrete Flumes and Culverts, Los Angeles Aqueduct," *Engineering Record*, Vol. 65, No. 25, (June 22, 1912) pp. 698-699.

also give the structure added strength.

TYPE OF FLUME

When built on a bench excavated in earth the bottom of the flume was made 4 in. thick. The inner wall was also made 4 in. thick and leaned toward the hill on a slope of 1/4 to 1, while the outer wall was 6 in. thick at the bottom and 4 in. thick at the top, the inner face being vertical. The depth of the flume is 3 ft. 1 in., and the width at the bottom ranges from 5 ft. to 5 ft. 6 in., according to the grade, which varies from 0.14 to 0.10 per cent. The capacity is 65 sec.-ft. with a 6-in. freeboard.

Where pier supports were employed the length of the span between piers was 25 ft., and the flume walls were made 7 in. thick. The wall reinforcing in these spans consisted of 3/8-in. vertical rods, spaced 16 in. on centers and about 1 in. in from the inner and outer faces. These vertical rods were continuous through walls and bottom, being bent into proper shape from 12 ft. 6-in. lengths. The longitudinal rods...were placed in 36 ft. lengths, lapping at the points not less than 30 diameters.

At a point where an old slide crosses the flume line it was decided to build a siphon 322 ft. long. A reinforced concrete pipe, 48 in. in diameter, was adopted for this siphon, and was built according to the head, which was 40 ft. at the lowest point. A short section of the pipe was left uncovered at the lowest point and two 12-in. blow-off gate valves were placed here...

CONSTRUCTION FEATURES

Work was started on a 4500-ft. section of the flume late in January, 1912, and after the old

wooden flume had been removed and the line regraded, a 1/2 yd. Smith mixer was brought on the job to be moved from point to point as the work advanced...

The floor of the flume was poured first and after this had set sufficiently the wall forms were set, a runway was laid on the cross ties, and upon this concrete was conveyed along the flume for pouring the walls. Meantime graders, formsetters and steel men were strung out on the preceding sections. The concrete mix used was approximately 1:2½:4. The sand was very clean and coarse; there was a natural, uniform gradation in the sand which ranged from about 30 mesh to grains the size of pea gravel. The gravel was passed through a 1½-in. screen. Both sand and gravel came from the river bed nearby and were screened and delivered by contract. The cement used in the first season was Superior Portland, while Inland Portland was used in the second season. The concrete was mixed wet, well spaded so as to get as dense a product as possible, and finished with a two-coat neat cement wash. The steel was hard grade corrugated bars rolled by the Pacific Coast Steel Company.

The design of the flume was worked out taking into consideration the following stresses: (1) Contraction due to temperature changes; (2) water pressure, including a large factor of safety to cover the landslides and the impact of boulders rolled from above; (3) earth and frost pressure on the inner wall; (4) frost heaving from below, and (5) settling of the foundation.

Considerable difficulty was encountered in placing the concrete on account of cold weather. All the work had to be done outside of the

irrigation season, and in the winter of 1911 concrete was poured until Christmas. At that season the sun does not strike the flume at all, and on several occasions the temperature fell nearly to zero in the night. During the freezing weather the water and gravel were heated as used, and after pouring, sheeting 90 in. wide was spread over the top of the flume. By the use of coal burning salamanders placed 50 ft. apart and kept burning night and day, as much as 1000 ft. of the work was protected at a time. After keeping the concrete warm in this manner for 48 hours it was allowed to freeze. In the following spring it thawed and resumed setting, and these sections are now said to be as strong as those poured in favorable weather. The only frost damage was a slight flaking at the top of the walls most exposed during pouring.

Total cost for 4500 feet of flume, including 1140 barrels of cement at \$2.50, 1,070 yd. sand and gravel at \$1.50 delivered, steel, coal, teaming, hardware, tools etc., form lumber, concrete labor, engineering and supervision, and grading was \$12,366 or \$2.758 per linear foot.⁴³

Utah was the location of another reinforced concrete aqueduct which sheds light on the construction process for the flume at Brooks. Built in 1915 at a cost of \$12.17 per linear foot, its capacity of 312 c.f.s. was one third of the proposed capacity of the Brooks Aqueduct. It was not a catenary curve in design but a trough, built at grade and not elevated. Its trough was eight or nine feet in width depending on location and five feet six inches high. Walls

⁴³ Anonymous, "Concrete Flumes That Did Not Fail." *Engineering Record*, Vol. 68, No. 21, (November 22, 1913) pp. 571-573.

and floor were one foot thick. As part of a canal system, it actually consisted of six flumes over a seventeen mile length of which 5184 feet were concrete flume. Poured in 100 foot sections, the bottom and two feet of the sides were poured first and the walls poured later. The inside was steel troweled to make as smooth a surface as possible. The "n" or friction value of the inside of the trough was 0.012. The concrete mixture was 1:1.8:3.7 cement, sand, gravel. Gravel and sand were carefully screened and graded, then mixed 15 seconds dry and 90 seconds wet. The finishing mortar was 3:1 sand to cement. The expansion joints were of "hub and spigot" construction, a process where the end of one sits inside the next. The joints were 36 inches long, overlapped 18 inches, with the overlap being twelve inches wider than the main body of the flume. The joints were "filled with 'sacro' or mineral rubber" for waterproofing. Instructions for sealing these joints suggested "surface to be filled with warm tar and two thicknesses of burlap soaked in hot asphaltum." By 1918 few cracks had appeared in the shell of the flume.⁴⁴

The final flume sat 3500 feet high in the mountains of Tasmania. Also a trough, its walls were nine feet six feet high, the inside was nine feet wide, the walls were four inches thick at the top increasing to eight inches at the bottom. The floor was also eight inches thick. The well reinforced concrete flume had no need for cross bracing and had a capacity of 450 c.f.s when flowing at a five foot depth.⁴⁵

⁴⁴ D.B. Gumensky, "Reinforced-Concrete Flumes poured in 100 foot lengths," *Engineering News Record*, Vol. 80, No. 12, (March 21, 1918) pp. 567-568.

⁴⁵ W. Nimmo, "A Tasmanian Concrete Flume," *Engineering News Record*, Vol. 89, No. 9, (August 31, 1922) pp. 366-367.

Notable Characteristics of the Brooks Aqueduct

An obsolete, abandoned hulk of concrete and steel which stands thin in comparison to its overpowering replacement may not appear to have much to commend it. But there are many aspects to the design, construction, operation and maintenance of this structure which bear mentioning. Above all, the Brooks Aqueduct is a major testimony to the ability of a group of people to triumph over a natural obstacle and bring tens of thousands of acres of near-desert into irrigation. This is not to say that the irrigation projects in southeastern Alberta were perfect applications of resources and political drive because this is not the case. However, as one engineer wrote almost seventy years after the flume began carrying water to early settlers: the Brooks Aqueduct is "a fine example of pioneer engineering in Western Canada representing an early application of complex structural and hydraulic concepts in a peculiar design." He also credits it with being "the largest steel reinforced concrete aqueduct in North America, possibly in the world."⁴⁶

Although the examples detailed above prove that other aqueducts carried more water over short distances, the Brooks Aqueduct was the longest aqueduct to carry this quantity of water. Therefore, this is the first application of the principle of the hydrostatic catenary curve to the conveyance

⁴⁶ E. Caligiuri, Manager, Alberta Regional Division, Canada, Department of Agriculture, Prairie Farm Rehabilitation Administration, Engineering Branch. *The Brooks Aqueduct. A Historic Landmark* (Calgary: PFRA, June 1983).

of water.⁴⁷

Various sources contemporary to the project described the significance of the Brooks Aqueduct. Shortly after its completion in 1914 the *Brooks Bulletin* praised it as:

the last link in the chain of engineering accomplishments which make possible the irrigation of the eastern section of the Canadian Pacific railway [Eastern] irrigation block.

The same issue of the paper commented that it looked "like a giant centipede" and made the unsubstantiated claim that "It is the largest aqueduct[sic] of its kind in the world."⁴⁸

The *Scientific American* published praise and details of the Bassano Dam, Lake Newell and the Brooks Aqueduct in 1916:

The Brooks Aqueduct is, next to the great dam at Bassano, the most important engineering work in the Eastern Section of the Canadian Pacific's Railway Irrigation Block in Alberta...The main canal leads away in an easterly direction [from the Bassano Dam] for about 5 miles, and is then divided into two branches, going respectively north and east. The east branch, after having several smaller branches taken off, discharges the majority of its volume into an artificial reservoir that has been formed in a depression in the hills, and which is named Lake Newell reservoir. It has a storage capacity of 187,300 acre feet, or over 50,000,000,000 gallons, and is designed to be filled during the non-irrigating season.

A marked feature of the topography of this section is the existence of several deep valleys,

⁴⁷ Douglas Babcock, *The Brooks Aqueduct*, (Edmonton: Alberta Culture - Historic Sites Service, October 31, 1977), 4 pp.

⁴⁸ *Brooks Bulletin*, October 10, 1914, p.1.

one of which is situated just east of the reservoir. It is about 2 miles in width, and to cross it an aqueduct has been constructed; an aqueduct being chosen, after some consideration, in preference to a siphon - a type of structure which has been used elsewhere in the irrigation block.

The aqueduct is supplied by a short canal from the reservoir. It consists of a reinforced concrete flume 10,480 feet in length, having a curved cross section, about 23 feet in width at the top, and nearly 9 feet in width from the top full-flow water level to the center of the curve at the bottom. This will carry water for the irrigation of 125,000 acres of land, and its discharge capacity is 900 cubic feet per second. The eastern end is between 4 and 5 feet lower than the western end, causing a grade for the water flow.⁴⁹

Theories Promoted for use in the Brooks Aqueduct

Although constantly compared and overshadowed with the massive Bassano Dam, the Brooks Aqueduct was the engineering challenge of the Eastern Irrigation District construction project. Each aspect of the giant flume was apparently considered carefully. However, many engineering decisions pushed the cutting edge of the understanding of the capacity of both the design and the materials. These choices, made long before the first hole was dug for the first foundation pier, are reviewed below.

⁴⁹ Anonymous, "The Brooks Aqueduct of Canada," *Scientific American* Vol. 114. (April 8, 1916) pp. 385-386.

Reinforced concrete flume

Constructing the aqueduct out of Manitoba limestone was perhaps considered by the CPR engineers, but not for long. Masons could have created a masterpiece to rival the work of the Romans but they would have still been working on it long after the settlers had given up in frustration and gone on to other lands. Wood was available in plentiful supply along the CPR track in the mountains and used in copious amounts for its temporary bridges, but the Company decided to construct permanent works in the Eastern Irrigation District rather than have to replace them as soon as the water began to flow. Perhaps a steel flume was considered but, as noted above, this material was expensive and did not have a good reputation in locations subject to great temperature variations. An earthen fill, similar to the modern Brooks Aqueduct replacement was inconceivable considering the earth moving capabilities of the day. Although large amounts of earth were moved at the site of the Bassano Dam, the prospect of building a fill sixty feet high with horses and fresnos at the site of the aqueduct would have made a teamster chuckle in 1912. The only other water conveyance systems capable of doing the job were pipes or inverted siphons. As Assistant Chief Engineer for the Department of Natural Resources of the CPR and man in charge of the choice of the flume for the Brooks Aqueduct site, H.B. Muckleston discounts both of these alternatives in his 1915 article in *Engineering News*.

CONTROLLING FACTORS OF DESIGN

The reservoir [at Lake Newell] is a very important factor, not only in the design of the canal system as a whole, but in the design of the aqueduct. By Canadian law the duty of water is fixed at 1 cu.ft. per sec., delivered at the farm boundary, for each 150 acres of irrigable land flowing continuously for 153 days, or, in round

figures, about two acre-feet per acre during the season. To this must be added about 25% for losses in transit through seepage and evaporation, thus requiring the diversion of about $2\frac{1}{2}$ acre-feet for each acre of irrigable land. The legal season is from May 1 to Oct. 1, and during the remainder of the year, under usual conditions, the system would be empty...

Now, the elevations of high water in the reservoir and of the discharge end of the aqueduct were fixed by other considerations and could not be altered. That is to say, the total available fall between high water in the reservoir and the outlet end of the aqueduct was a fixed quantity, of which a certain portion would be required for the slope of the outlet canal and aqueduct and the remainder available as storage...

The probable cost of the aqueduct involves questions of type of structure and material to be used, and can only be solved by a process of cut and try on a number of examples.

For a preliminary estimate it was assumed, first, that a pressure pipe or inverted siphon would be the cheapest type; second, that the cost would be a direct straight-line function of the cross-section area. Approximate designs were worked up for steel, concrete, and wood-stave pipes and estimates made, allowing for maintenance charges in each case. From these estimates the probable extreme values of the lost storage were deduced.

While in many cases, especially where the depth of the valley is great, a siphon is cheaper than a structure on the hydraulic grade with free surface, it is not always so; and even when it is

cheaper, siphons as the solution of such problems are open to many objections from which flumes are free. In the first place, canals do not always run full, whereas the siphon must always do so. This condition has two very disagreeable effects. The low velocity in the siphon causes the hydraulic grade to flatten out, resulting in a drop at the upper end, which, in a large canal at any rate, requires control works; otherwise the effect of the fall will be felt for a long distance above. Another effect is the accumulation in periods of little demand for water of sediment in the bottom of the pipe, which is caused by low velocity at small discharges. The only cure for these effects is to divide the full discharge among several pipes and provide means of cutting one or more pipes as the discharge decreases. This remedy costs money and, if the available head is limited, is not always feasible. Another objection is the necessity in a northern climate of blowing off every fall. In a large pipe under high head, especially if very long, this must be done very slowly; otherwise serious pressure oscillations are liable to set up, giving rise to stresses which are difficult, if not impossible, to estimate with any accuracy.

For these reasons and some others it was decided to investigate the possibilities of a grade structure. Accordingly, a tentative design was worked out and its probable cost compared with that of a pressure pipe, using the same hydraulic slope in each case. The cost of the grade structure proved to be somewhat less than that of a single pipe and very much less than that of a double one. Consequently, subsequent investigation were

confined to the grade structure..."⁵⁰

The CPR decided to use the hydrostatic catenary curve as the principle upon which to design the flume. Although the magazine *Canadian Engineer* in 1915 cited Muckleston as "responsible for the adoption of this unique design,"⁵¹ the task of applying the principle to this specific case apparently fell to H.M. Gibb, Engineer of Structures for the Canadian Pacific Irrigation Department at Brooks. In 1915 he wrote up his explanation of this principle in *Engineering News* as follows:

If a flexible sheet, with no resistance to bending, is hung between two level supports, and the resulting basin filled with water up to the level of the supports, the sheet will hang in the curve of a hydrostatic catenary. The characteristics of this curve are:

1. The tension T in the sheet is a constant because the pressure of the water is normal at all points to the surface of the curve.

2. There is neither shear nor bending moment⁵² induced at any point...

Gibb then included four figures explaining the differences between various curves at different levels of water flow. He

⁵⁰ H.B. Muckleston, "Hydrostatic Catenary Flume on a Concrete Aqueduct," *Engineering News*, Volume 74, No. 2. (July 8, 1915) pp. 58-63.

⁵¹ Anonymous, "The Canadian Pacific Railway Company Irrigation System in Alberta," *Canadian Engineer*, (September 30, 1915), pp. 419-423.

⁵² In lay terms which oversimplify these complex engineering concepts, shear is the tendency of the internal cohesion of a material to give way under stress while moment is a force which bends an object.

concluded with the following statement:

The application of this curve occurs in structures holding fluids, such as metal flumes, and large uncovered water pipes under very low head.⁵³

Therefore, the decision by the CPR to use the hydrostatic catenary curve in a suspended, reinforced concrete shell design was a new combination of principles untried in an aqueduct application.⁵⁴

Design of the shell

The shell, the reinforced concrete sling which would actually support the water as it travelled across the valley, was also a new design application. Muckleston explained the factors which he considered as follows:

The thickness of the shell is determined by two requirements - (1) when the channel is running less than full there exists both moment and shear, and the shell must be designed stiff enough to resist these without cracking; (2) when running full, the concrete shell must not crack in tension.

⁵³ H.M. Gibb, Engineer of Structures, Canadian Pacific Irrigation Department, Brooks, Alberta "Curves for Solving the Hydrostatic Catenary," *Engineering News*, Vol. 73, No. 14, (April 8, 1915) pp. 668-670.

⁵⁴ Anonymous, "Canadian Pacific Railway Company's Irrigation Project in Alberta," *Engineering Record*, Vol. 65, No. 12, (March 23, 1912) pp. 332-333; E. Caligiuri, Manager, Alberta Regional Division, Canada, Department of Agriculture, Prairie Farm Rehabilitation Administration, Engineering Branch. *The Brooks Aqueduct. A Historic Landmark* (Calgary: PFRA, June 1983); Douglas Babcock, *The Brooks Aqueduct*, (Edmonton: Alberta Culture - Historic Sites Service, October 31, 1977), 4 pp.

To meet these requirements, a sufficient area of steel was provided to take all the tension at 10,650 lb. per sq.in. The elastic ratio was assumed at 15, and a sufficient thickness of concrete was added so that, assuming the concrete and steel to share the tension, the stress in the concrete should not exceed 70 lb. per sq.in. The steel was then distributed in two layers, as far apart as the thickness so found would allow, and the shell investigated for deflection, moment and shear under partial loads. The stresses thus calculated were well within the specified limits and the deflections very moderate.⁵⁵

Although the composition of the cement itself also caused problems, this leap into an unknown area of stress and elasticity of a new material, suspended reinforced concrete, was apparently based on untried engineering assumptions. Only the story of 65 years of maintenance which is recounted below fully explains how this pivotal, educated guess affected the financial viability of the Brooks Aqueduct.

Expansion joint design

Expansion joints are necessary in a structure such as the Brooks Aqueduct in order to allow it to move. Movement in a two mile long flume is not enormous but room for natural shrinkage and expansion is necessary. Even in materials as apparently impervious to the elements as steel or concrete, failure to allow for this normal process can have disastrous effects.

For example, the Winona flume, built of steel in 1910 as

⁵⁵ H.B. Muckleston, "Hydrostatic Catenary Flume on a Concrete Aqueduct," *Engineering News*, Volume 74, No. 2. (July 8, 1915) p. 61.

part of the Western Irrigation District, did not include expansion joints. When the movement of the rivets proved inadequate to the demands of expansion and contraction, the flume collapsed. The CPR then installed "V" shaped expansion joints at each end, apparently patterned after the ones finally chosen at the Brooks Aqueduct.⁵⁶

Concurrent with the work at Brooks, a concrete flume at a hydro-electric plant of the Northern Idaho & Montana Power Company at Big Fork, Montana used copper expansion joints. Built in 1911, this flume suffered from many of the environmental factors that faced the Brooks Aqueduct.

This necessity was imposed by two conditions; first, the fact that the flume walls were thin and exposed to the air, and, second, the severity of the winters, which made it certain that ice would form on the water side of the flume walls. It was felt that if water was allowed to freeze in the expansion joints, with temperatures running as low as 30°F., it would spall[crack] off the concrete and probably injure the structure seriously in a short while...

The flume has been in use for a year or more and the expansion joints are giving perfect satisfaction.

The effectiveness of this joint is dependent on the adhesion between copper and concrete, because, if the adhesion between the two is not good, such a joint would be subject to the same ice troubles as the ordinary expansion joint.

A search was made in engineering literature for information on the adhesion of concrete to

⁵⁶ R.S. Stockton, "Maintenance of a Canadian Irrigation Flume." *Civil Engineering*, Vol. 4, No. 5, (May, 1934) pp. 238-239.

copper, but as the search was fruitless some simple and hurried experiments were made to determine the point. The results of these experiments were very gratifying, and, since there seems to be little if any published information on the subject, these experiments may be of interest to others indicating what may be expected, though they are too crude to determine safe working stresses. They show, however, that there may be a very good bond between concrete and copper.⁵⁷

The only other flume with expansion joints which was comparable to the Brooks Aqueduct was in Utah. As detailed above (pages 29-30), the joints in this trough-shaped flume were of the "hub and spigot" variety with one end overlapping the other eighteen inches. A tar and burlap gasket waterproofed the joints and they worked well during their first three years of operation. This flume, however, was neither a hydrostatic catenary, nor suspended in mid air, and did not operate in temperature variations as extreme as those at Brooks.⁵⁸

The CPR decided to use copper expansion joints in the Brooks Aqueduct, a choice which it never explained in any of its construction summaries. According to Muckleston, "Provision is made for variation in length of shell due to change of temperature by expansion joints at every fourth bent [or every 80 feet as bents were 20 feet apart] and at

⁵⁷ J. William Link, "An Effective Type of Expansion Joint for Concrete Flumes," *Engineering Record*, Vol. 65, No. 9, (March 2, 1912), p. 240.

⁵⁸ D.B. Gumensky, "Reinforced-Concrete Flumes poured in 100 foot lengths," *Engineering News Record*, Vol. 80, No. 12, (March 21, 1918) pp. 567-568.

each portal and at each end of the siphon."⁵⁹ (This original design is shown in Illustration 4)

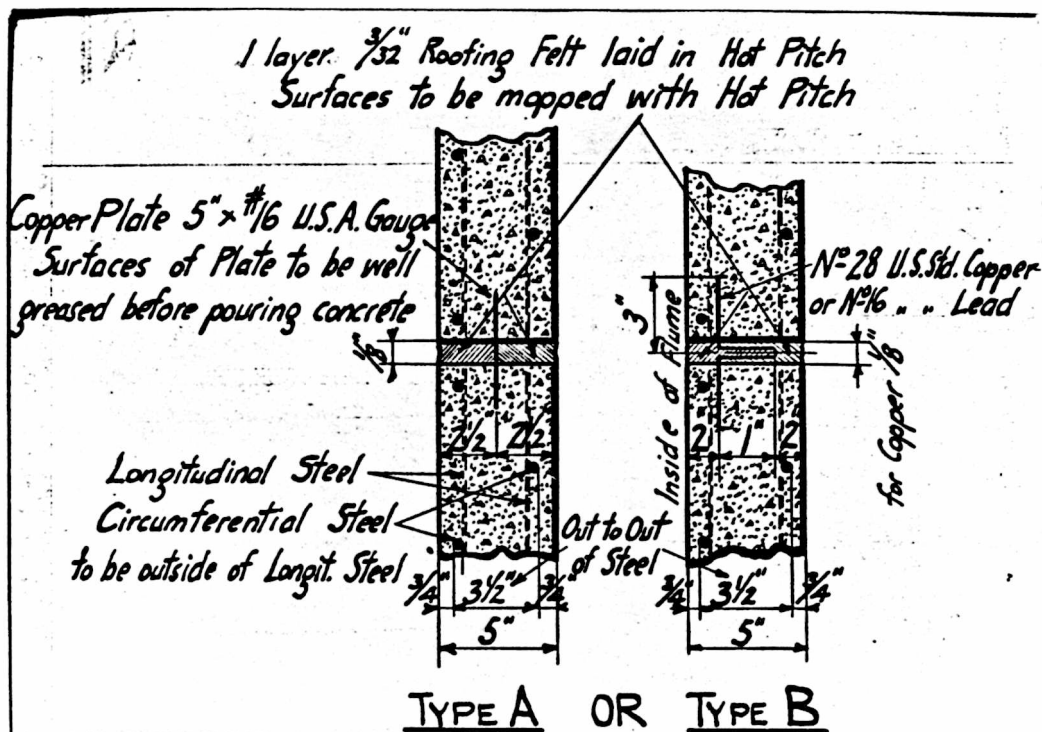


Illustration 4 Expansion joint (EID Plan No. 2005-3-2)

Gibb's explanation of the process read "...Double expansion joints were made every 80 ft. by putting a sheet of tar-paper on the top of the cap, and in girders and shell, making a clean cut clear across the structure with a tongue of sheet-copper 5 in. wide across the 1/8 in. gap..."⁶⁰ Only the record of years of operation and maintenance reports recounted below will reveal whether or not this untried design would work in the unique application at the Brooks Aqueduct.

⁵⁹ H.B. Muckleston, "Hydrostatic Catenary Flume on a Concrete Aqueduct," *Engineering News*, Volume 74, No. 2. (July 8, 1915) p. 62.

⁶⁰ *Brooks Bulletin*, October 3, 1914, p.1; H.M. Gibb, "The Brooks Aqueduct, Alberta," in *Engineering*, Volume 99. (April 23, 1915) p. 452.

Siphon design

As luck would have it, the CPR was forced to contend with its own railway tracks as it crossed the river valley with the aqueduct. One option was to lower the track grade for miles on either side of the flume in order to allow trains to pass under the water course.⁶¹ The only other option was to build a siphon under the tracks. Muckleston's reasons for ordering this option are as follows:

The site of the aqueduct is crossed by the main line of the Canadian Pacific Ry. This track is at such an elevation that sufficient headroom for an over-crossing could not be obtained and a siphon under the track was necessary. In order to save excavation, and more especially for reasons of drainage, the siphon was designed with a reduced section and an increased velocity on the principle of the Venturi tube.⁶²

Gibb further explained the reduced section principle and the minimal loss of head, or water elevation.

...When the water enters the siphon, which we have mentioned as being constructed to carry the water under the main line of the Canadian Pacific Railway, it flows at the same rate as in the flume - 7.14 ft. per second; but as it descends the barrel gradually tapers from 12 ft. 8½ in. to 9 ft. 9 in. in diameter, and the velocity increases to 12.25 ft. per second. After leaving the 9-ft. 9-

⁶¹ R.T. White, *Brief Historical Review of the Brooks Aqueduct*, (Brooks: Eastern Irrigation District, July, 1983), p. 4.

⁶² H.B. Muckleston, "Hydrostatic Catenary Flume on a Concrete Aqueduct," *Engineering News*, Volume 74, No. 2. (July 8, 1915) p. 62.

in. barrel, which is the bottom of the siphon, it rises in a gradually expanding section, similar to the descent on the inlet, and enters the flume again at the same velocity with which it entered; 2/10 ft. has been allowed on the siphon to cover friction losses...⁶³

An elevated canal full of water was probably an intriguing playground to many boys on a hot summer days. Some stories recount that daring young men dove through the siphon as a diversion but an engineer who worked on the aqueduct for many years discounts such tales. According to him, swimming through the siphon would have been dangerous and his only recollection of anyone attempting the passage resulted in death. A man stricken with cancer apparently committed suicide by jumping into the aqueduct at the siphon and his remains surfaced a few days later, with every bone in his body broken.⁶⁴

Trestle design

Muckleston wrote:

In designing the trestle carrying the flume a good deal of preliminary work was done in order to arrive at the most economical type...In order to keep down form costs it was desired to have as little variety in spans as possible, even if quantities were somewhat increased thereby.

The trestle is divided into four typical

⁶³ H.M. Gibb, "The Brooks Aqueduct, Alberta," in *Engineering*, Volume 99. (April 23, 1915) p. 452.

⁶⁴ R.T. (Bob) White, March 10, 1988 interviewed at his residence in Brooks, Alberta by the author of this report, side 3, counter number 50.

constructions, depending on the height of the columns. When the height of the columns changes, the change is invariably by a step of 3 ft. or a multiple of three.⁶⁵

Foundation design

Again the engineer in charge of the project wrote:

The foundations for the aqueduct are carried to a depth of 7 ft. below the original surface, so as to be sure of getting below any possibility of heaving by frost. At this depth the material as exposed in foundation pits is a stiff sandy clay, which might almost be classified as a weak sandstone. In its natural state or when freshly exposed it is quite firm, but it disintegrated rapidly on exposure to the atmosphere. Test loads were applied to surfaces varying from 36 to 324 sq.in. in area and the sinking under various loadings observed. Under 18 tons per sq.ft., on 36 sq.in., the settlement was about 0.20 ft. when dry and 0.31 ft. when wet. As the service load under maximum wind pressure is only about two tons per foot, the foundations were considered satisfactory.⁶⁶

Inlet design

Gibb's description of the challenge of the inlet read:

...The problem presented at this point was to join

⁶⁵ H.B. Muckleston, "Hydrostatic Catenary Flume on a Concrete Aqueduct," *Engineering News*, Volume 74, No. 2. (July 8, 1915) p. 62.

⁶⁶ Ibid.

up the canal, measuring 21 ft. 4½ in. on the water surface, to increase the velocity from 2 ft. per second to 7.146 ft. per second, to reduce the sectional area from 456 sq. ft. to 126 sq. ft., and to increase the depth from 7.7 ft. to 8. ft...⁶⁷

Outlet design

Of the other end of the aqueduct Gibb wrote:

...At the end where the aqueduct discharges into the continuation of the canal no attempt was made to recover any velocity head, and so the outlet structure is just a plain rectangular box shape, equal in width to the bed-width of the canal and 30 ft. long. To prevent the stream of water in the flume driving in a bore along the center of the canal and causing side whirls, which erode the banks, a baffle-wall, 21 in. high and 114 ft. long was placed on the floor of the outlet, 20 ft. back to create a disturbing wave upwards through the whole body of water and cause it to partly deflect to either side. This device has proved satisfactory in operation...⁶⁸

Design stress factors

Muckleston was confident that his aqueduct would not pull apart, blow over, or sink into the parched ground.

The structure was designed for the following unit stresses:

⁶⁷ H.M. Gibb, "The Brooks Aqueduct, Alberta," in *Engineering*, Volume 99. (April 23, 1915) p. 452.

⁶⁸ Ibid.

	Lb. per Sq. In.
Concrete-bearing stress	400
Direct compression - massive work	400
Compression in flexure, reinforced	750
Short columns, not over 18 in. diam.	400
Hooped columns	600
Shear in flexure	60
Bond plain bars	60
Bond deformed bars	120
Steel tension	16,000

The structure was designed to resist wind pressure of 30 lb. per sq.ft. in any direction on all exposed surfaces. The range of atmospheric temperature was assumed from -45° to $+85^{\circ}$ [F], and full allowance was made in the design for all stresses caused thereby.⁶⁹

Design capacity

With an apparently casual engineering decision, Muckleston calculated the capacity of the Brooks Aqueduct to carry water by a new method.

The discharge calculation's were made by an exponential formula instead of by the usual Kutter formula. The latter formula, while very widely used, holds its place in hydraulics largely because of the very extensive collection of tables and diagrams which have accumulated around it. The exponential formulas require no such aid, are as easily handled and are believed more closely to fit observed results than the older and much more

⁶⁹ H.B. Muckleston, "Hydrostatic Catenary Flume on a Concrete Aqueduct," *Engineering News*, Volume 74, No. 2. (July 8, 1915) p. 62.

complicated Kutter formula. The particular formula used is attributed to Prof. T. Claxton Fidler, of St. Andrews University, Dundee, and is as follows:

$$\text{Log } S = X (M + \log V - 2/3 \log R) - 6.00$$

S, V and R have the usual significance,⁷⁰ X is a friction factor depending on surface and M a friction factor depending on shape. For any given relations between area and hydraulic radius the formula is readily transposed to give friction head direct for any required conditions. It is thus simpler than Kutter's formula for channels of fixed shape, such as pipes, flumes and the like.⁷¹

Perhaps it was the use of a new formula or some other mistake, but the original Brooks Aqueduct never came close to meeting its projected water moving capacity.

Construction of the Brooks Aqueduct

The general specifications for the construction of the Brooks Aqueduct are little less than staggering.

The following are statistics on the original design:

Type	[hydrostatic] catenary reinforced concrete
Top width of barrel	22'6"
Depth	8'8"
Length	10,452 feet
Elevation drop (approximately)	5.5 feet
Maximum height	61 feet

⁷⁰ R is hydraulic mean radius, V is velocity and S is grade.

⁷¹ Ibid., p. 61.

Capacity	900 c.f.s.
Perimeter of barrel (approximately)	33 feet
Transverse girders (struts)	13.75" x 12"
Twin columns	516 at 20' spacing
Expansion joint spacing	80'
Footings	spread type top 1'8" x 1'8" bottom 8' x 8' depth 8'6"
Mean velocity	3.5 feet per second ⁷²

In 1912 *Engineering Record* predicted: "The structure as a whole will probably contain about 25,000 cu. yd. of concrete and upward of 2,000,000 lb. of reinforcing steel."⁷³ By 1924 *Canadian Engineer* reported that some 4,000,000 pounds of steel had been necessary to complete the task.⁷⁴ The steel came from Winnipeg.⁷⁵

Construction cost was set at \$700,000 by both CPR Chief Engineer for the Department of Natural Resources, A.S. Dawson

⁷² R.T. White, *Brief Historical Review of the Brooks Aqueduct*, (Brooks: Eastern Irrigation District, July, 1983), p.3.

⁷³ Anonymous, "Canadian Pacific Railway Company's Irrigation Project in Alberta," *Engineering Record*, Vol. 65, No. 12, (March 23, 1912) pp. 332-333.

⁷⁴ Anonymous, "The Canadian Pacific Railway Company Irrigation System in Alberta," *Canadian Engineer*, (September 30, 1915), pp. 419-423.

⁷⁵ Laurette Doucet, *The Brooks Aqueduct*, (Brooks: Eastern Irrigation District, August 15, 1985), 2 pp.

in 1925⁷⁶ and the *Engineering Journal* in 1937.⁷⁷ However, Gibb's account of the project in 1914 estimated "...the total cost was about 650,000 dols."⁷⁸ Later, when Provincial Auditor, J.C. Thompson, filed his Special Report of the CPR Co. Eastern Irrigation District Project in 1935 as a supporting document in the local farmers' bid to take over the District from the railway, he listed the original construction cost for the Brooks Aqueduct from 1912 to 1914 as \$569,287.⁷⁹ Lacking any documents that prove otherwise, it is safe to assume that the auditor's review of the records is the most accurate available.

The firm of Grant, Smith & Co. & McDonnell of Vancouver built the Brooks Aqueduct. Each of the three American principals in this firms had their own construction firms in the United States before they formed this Canadian company.⁸⁰ The corporation has since dissolved and its records have

⁷⁶ Glenbow-Alberta Institute Archives, W.L. Jacobsen papers, M3761/f.56 *History of the Eastern Section, Irrigation Project, Department of Natural Resources, Canadian Pacific Railway*, A.S. Dawson, Chief Engineer, November 23, 1925 compiled by G. Boese.

⁷⁷ Glenbow-Alberta Institute Archives, W.L. Jacobsen papers, M3761/f.182, *Engineering Journal*, June 1937, pp. 410-11.

⁷⁸ H.M. Gibb, "The Brooks Aqueduct, Alberta," in *Engineering*, Volume 99. (April 23, 1915) p. 454.

⁷⁹ Glenbow-Alberta Institute Archives, W.L. Jacobsen papers, M3761/f.89, Provincial Auditors Report of the CPR Co. EID Project, Special Report, February 19, 1935, J.C. Thompson C.A. Provincial Auditor, Schedule "C".

⁸⁰ Elise A. Corbet, *Brooks Aqueduct: Source Assembly Study*, Microfiche 261, (Ottawa: Environment Canada-Parks Canada, September, 1986) p. 7.

disappeared. The local newspaper, the *Brooks Bulletin*, reported engineers named Ross and Engstrom as being responsible for the companies operations at the site. [Another source gives the second engineer's name as R.V. Engstrom and credits him as being the construction company's "Superintendent of construction"⁸¹] At peak summer periods the company employed as many as 300 men on the project.⁸²

CPR officials connected to the project included A.S. Dawson⁸³ and H.B. Muckleston from their offices in Calgary and E. Stephens as the general inspector. "H.M. Gibb, a clever young Scottish engineer, was engineer-in-charge for the railway company" wrote the local newspaper editor.⁸⁴

Camp went up and foundations were dug for some of the foundations or pedestals beginning in June, 1912. During the second summer, many of the columns and part of the flume was put in place, while the summer of 1914 saw the completion of the project.⁸⁵ Since the contractor's reports are missing, articles published by representatives of the CPR provide the only record of the details of the events of these three busy summers. Muckleston wrote, in part:

Railway sidings were built near the crossing, store-houses for cement and other material erected and a concrete-lined reservoir for water was constructed. A double-track, standard-gage

⁸¹ H.B. Muckleston, "Hydrostatic Catenary Flume on a Concrete Aqueduct," *Engineering News*, Volume 74, No. 2. (July 8, 1915) pp. 58-63.

⁸² *Brooks Bulletin*, October 10, 1914, p. 1.

⁸³ H.B. Muckleston, "Hydrostatic Catenary Flume on a Concrete Aqueduct," *Engineering News*, Volume 74, No. 2. (July 8, 1915) pp. 58-63.

⁸⁴ *Brooks Bulletin*, October 10, 1914, p. 1.

⁸⁵ Ibid.

railway, with frequent crossovers, was built along the line of the work on the south side, and a pipe leading from the reservoir to an elevated tank at the west end of the structure laid down, with taps at frequent intervals. Column, girder and brace forms were erected by stiff-leg derricks travelling on skids and working backward as the forms were put up. (See Illustration 5)

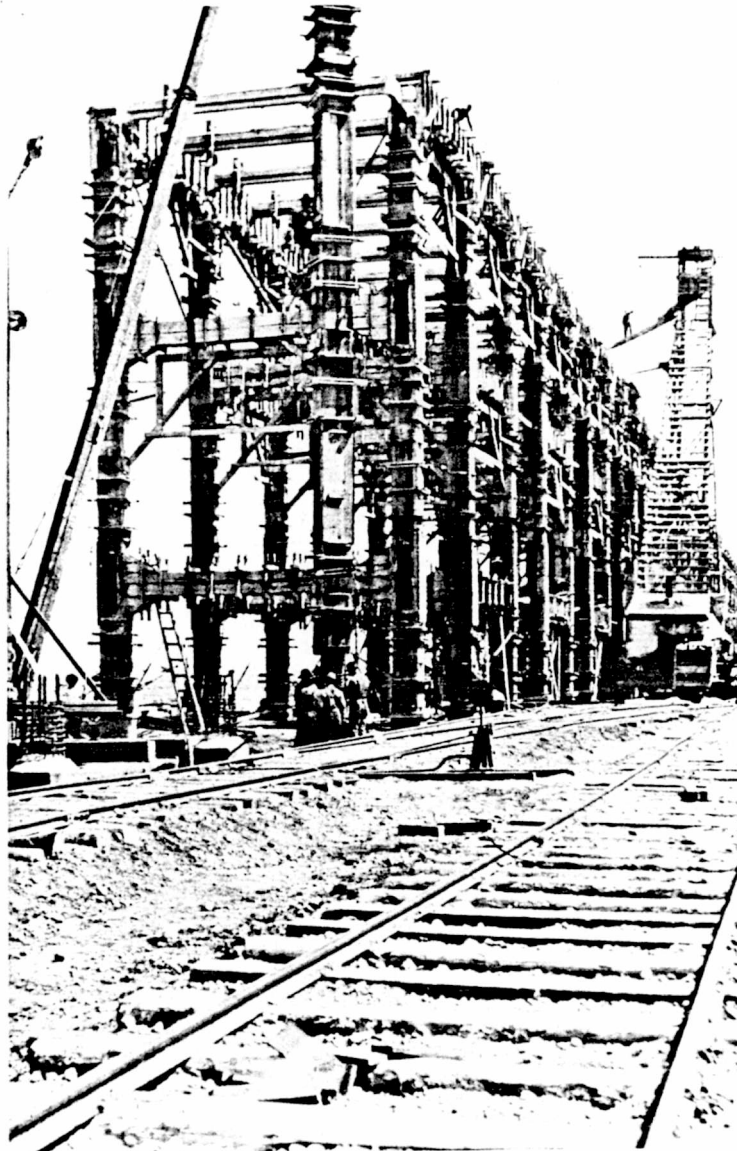


Illustration 5 Superstructure forms, 1914 (GAI NA-2622-65)

Outside shell forms were mounted on a carriage

which traveled on rails carried by the upper cross-struts, the forms being raised into place or lowered by screwjacks. (See Illustration 6) A locomotive crane was used for various purposes and a Shay engine for switching cars and pulling the outside shell forms ahead.

The pedestals were poured by a portable mixing plant with a dwarf hoist and spout, from four to six pedestals being cast from one setting. (See Illustrations 7 and 8) As soon as the concrete had set, the forms were stripped and the pits backfilled. For the construction of everything except the pedestals, the concrete hoisting and mixing plant was mounted on flat cars, which travelled on the track nearest the structure. The gravel for concrete was all shipped in by rail in steel side-dump cars. A small reserve storage was kept, but most of the requirements were filled direct from the cars. A special chute with gate was constructed which could be fitted to the cars and which allowed them to discharge directly into the hopper of the mixer, the cars standing on the second track alongside the mixer car.

All reinforcing steel, except that for the shell, was shipped cut to length. All bending and the assembling of the column reinforcement were done in a central yard. The shell steel, which consisted of No. 0000 galvanized steel wire, was shipped in coils and, after being passed through a wire straightening machine, was cut to length by a power shear. Steel for braces, girders and the shell was assembled in place and wired.

The first step after the pedestals had been stripped and backfilled was to erect the column

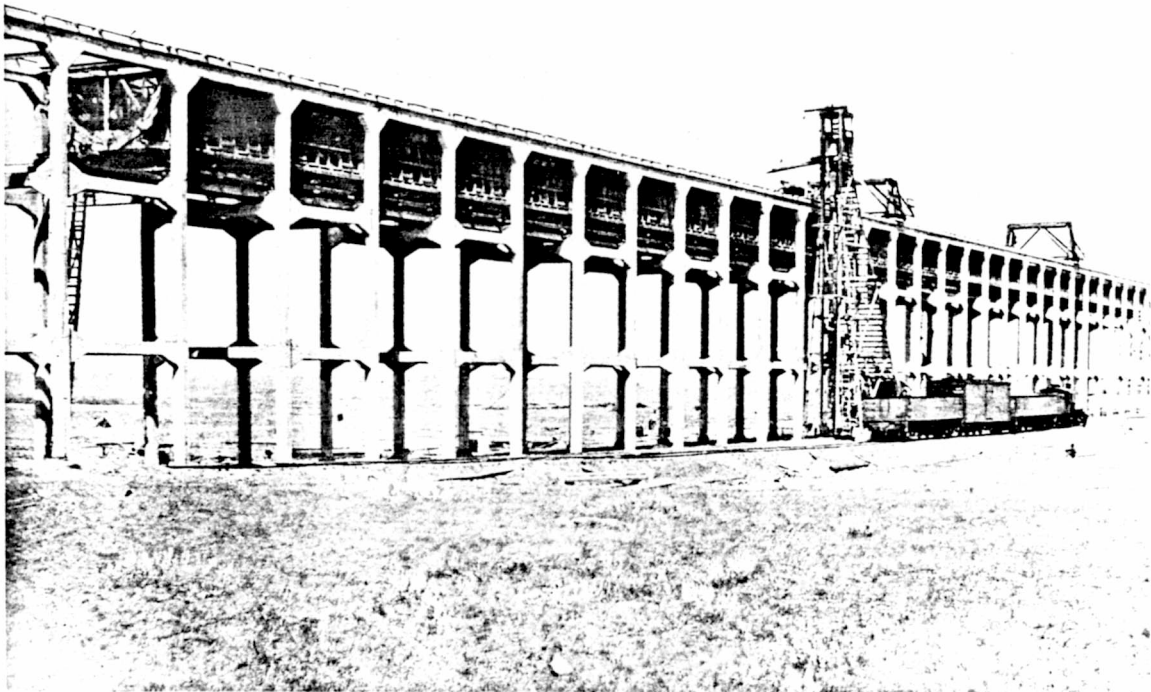


Illustration 6 Shell forms, 1914 (GAI NA-2622-64)



Illustration 7 Cement mixer at siphon, 1914 (GAI NA-2622-63)

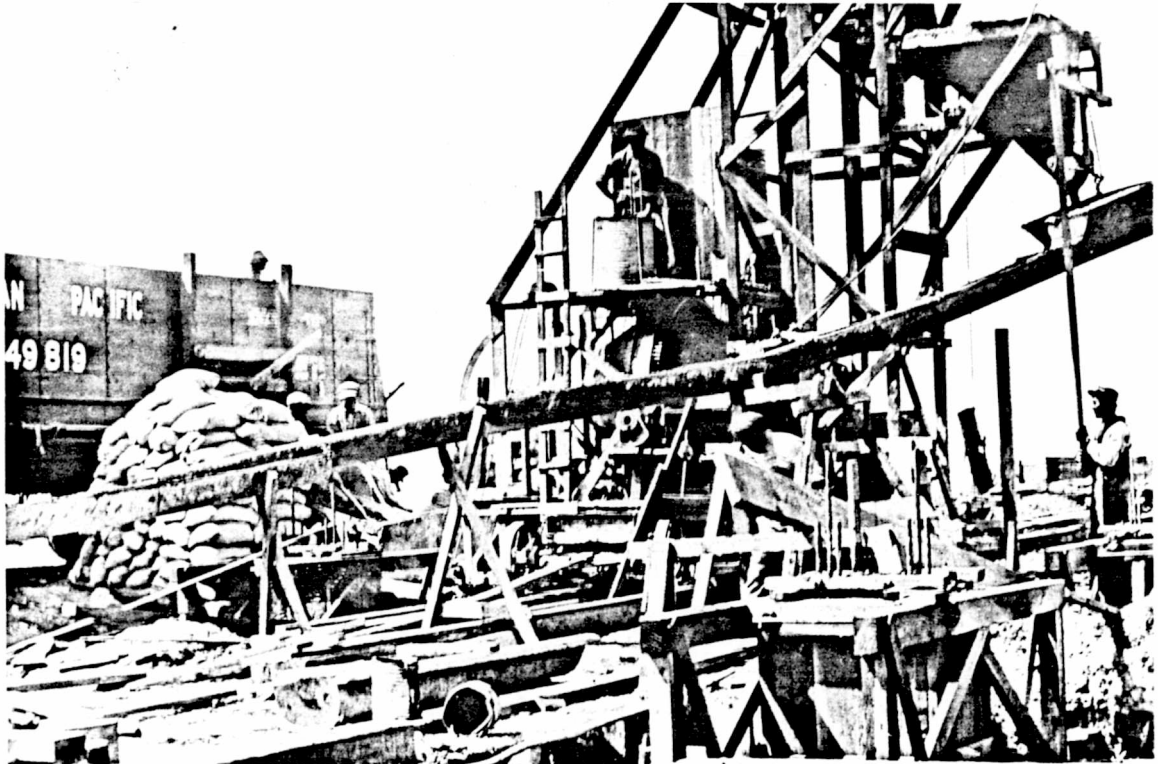


Illustration 8 Cement mixer, 1913 (GAI NA-5200-46)

forms, which were securely guyed and cross-braced. Forms for the braces, if any, and the girders were next set up and the reinforcement placed in them and wired. (See Illustration 9) The girder cross-struts were precast in yards and hoisted and placed by the locomotive crane. The columns and braces were poured in a single lift, followed by the girders after an interval to allow for setting and shrinkage. After the concrete had set sufficiently, the column, brace and girder forms were stripped and the track for the outside shell forms put in place. The outside forms for the shell were then pulled ahead and jacked up to correct elevation, followed by the placing of the shell reinforcement, which was held in position by concrete spacing blocks grooved to hold the wires.

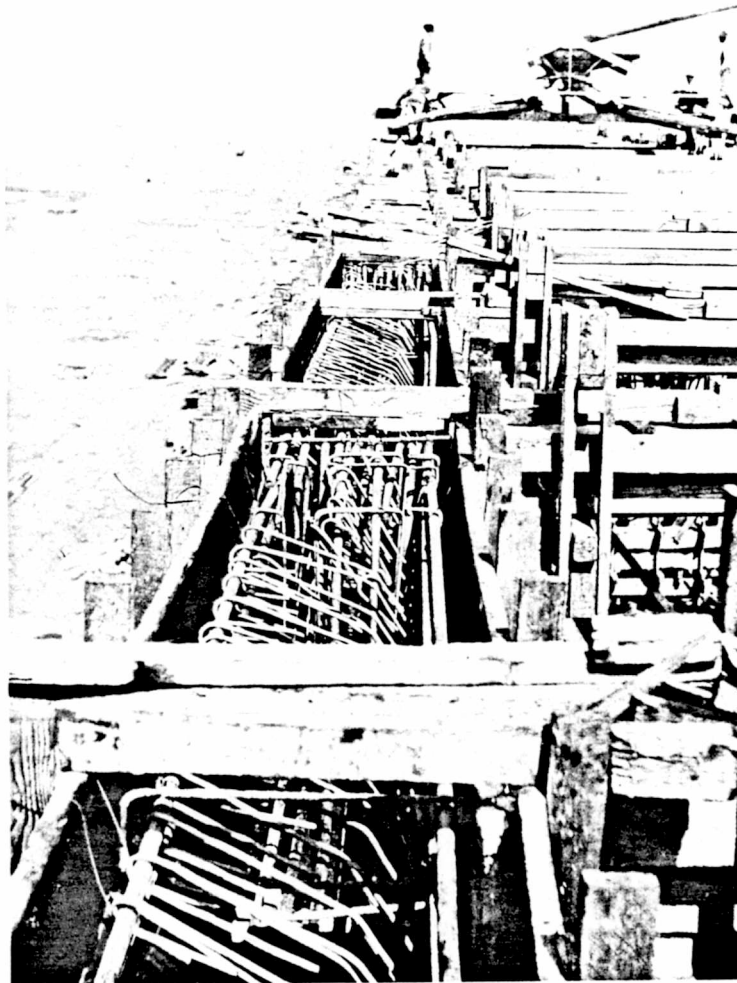


Illustration 9 Top of forms, 1914 (GAI NA-2622-67)

Inside forms for the shell were handled from $\cap$ [shaped] tracks suspended from the cross-struts and were placed as soon as the steel had been put in.

The pouring of the shell was done in alternate 80-foot sections. A good deal of difficulty had been anticipated in making a good job of casting this thin member, and the inside forms first provided had removable panels of doors so that the lower part could be poured from near the bottom.

It was found, however, that if a sufficiently fine aggregate were used and the mixture kept very wet, little or no difficulty was experienced, and the doors were abandoned as unnecessary. The secret of success was found to lie in pouring batches alternately from each side, and in rapid work, thus insuring a constant backward and forward movement of the fluid concrete crossways of the shell until it was full. This method made certain that the reinforcement was well surrounded and that no voids were left unfilled. This was only possible because the running foot quantities were small and a whole section could be cast in a short time before the concrete first poured could take its initial set. (See Illustration 10)

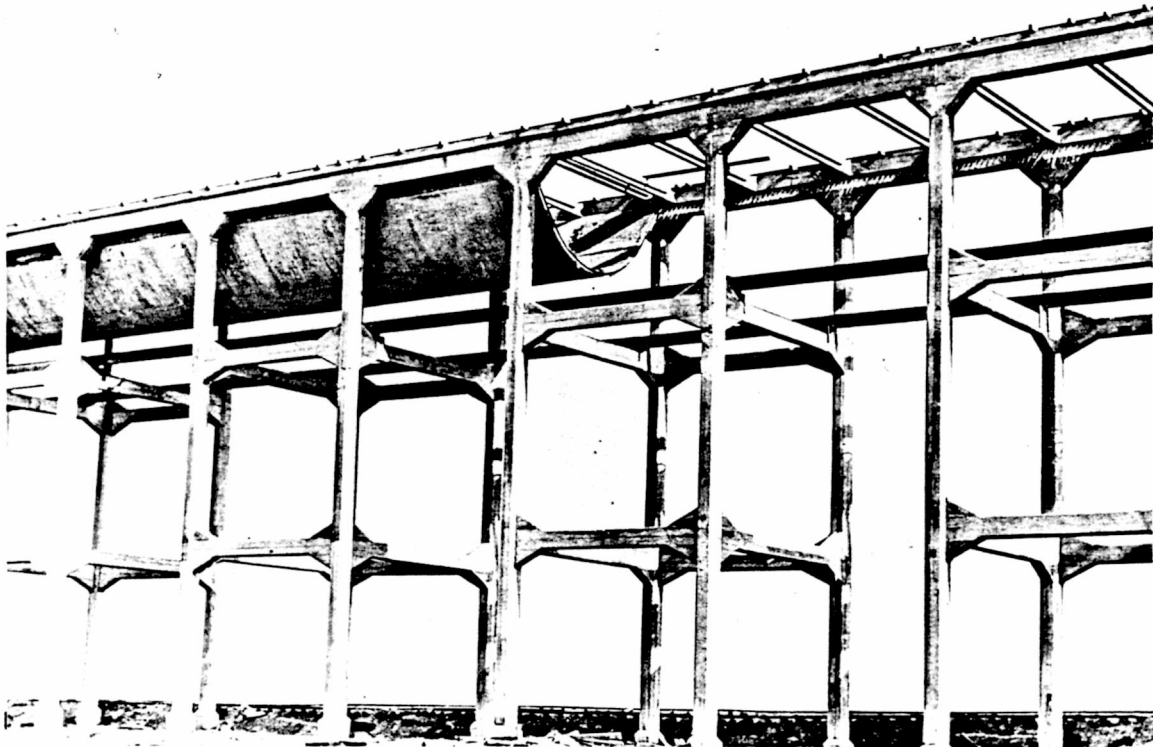


Illustration 10 Flume in progress, 1914 (GAI NA-146-29)

It was found in building the experimental section that the shrinkage in setting lifted the

concrete off the outside forms. This had been expected, and the inside forms had been stripped as soon as the concrete was sufficiently hard to stand alone on the steep side slopes. The same thing was anticipated in building the aqueduct, and to prevent possible cracking from this cause, the inside forms were stripped within a few hours after pouring.

The construction of inlet, outlet and siphon, apart from rather complicated formwork, presented little that was in any way unusual. As they could be used but once, the forms were built up on the spot and wrecked when the concrete had set. (See Illustrations 11 and 12)

During construction of the aqueduct temporary bulkheads were built at several points and the shell filled with water for testing. The object was principally to test the efficiency of expansion joints, and no attempt was made to measure deflections. They must have been very small, however, as the leakage under the bulkheads was almost negligible.⁸⁶

Gibb's account goes into much more detail regarding water supply problems and the specifics of the concrete mix.

...The contract was let in June, 1912, and the remaining summer months were occupied in building the camp, drilling two wells for water, constructing switches to the main line, grading and laying the construction track alongside the aqueduct, and excavating pedestals 384 to 450 inclusive. The railway company built the bridge

⁸⁶ H.B. Muckleston, "Hydrostatic Catenary Flume on a Concrete Aqueduct," *Engineering News*, Volume 74, No. 2. (July 8, 1915) pp. 62-63.

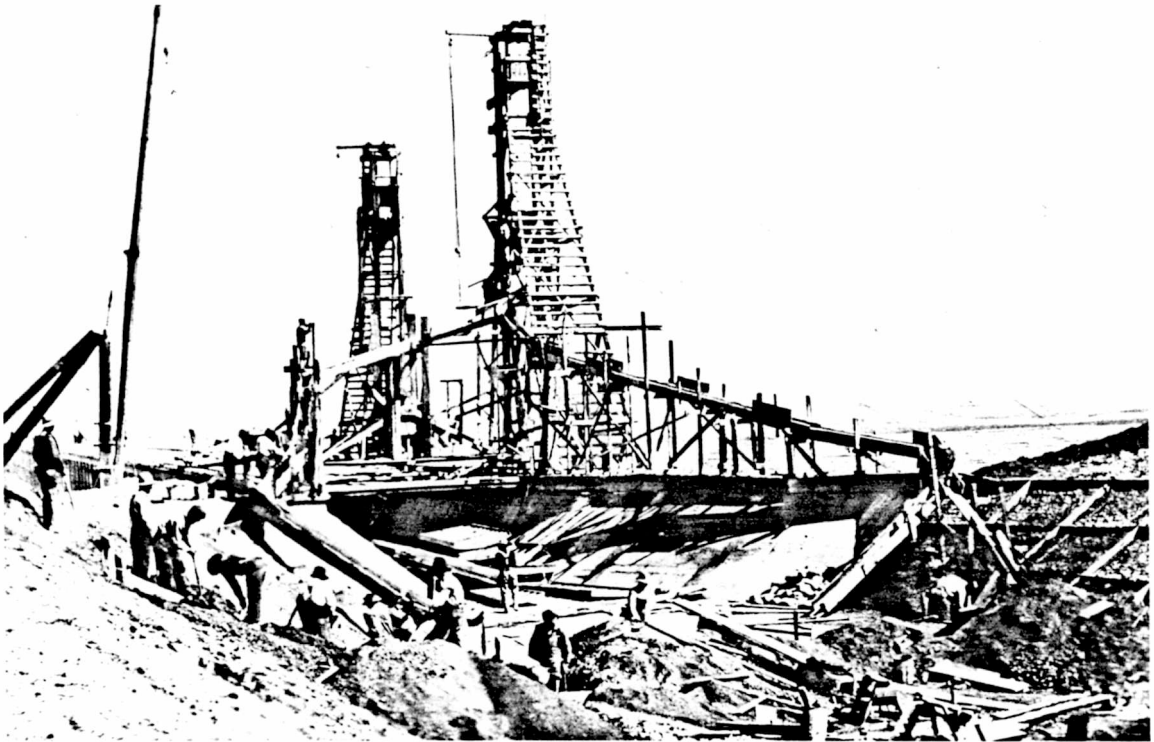


Illustration 11 Inlet paving, 1914 (GAI NA-2622-68)

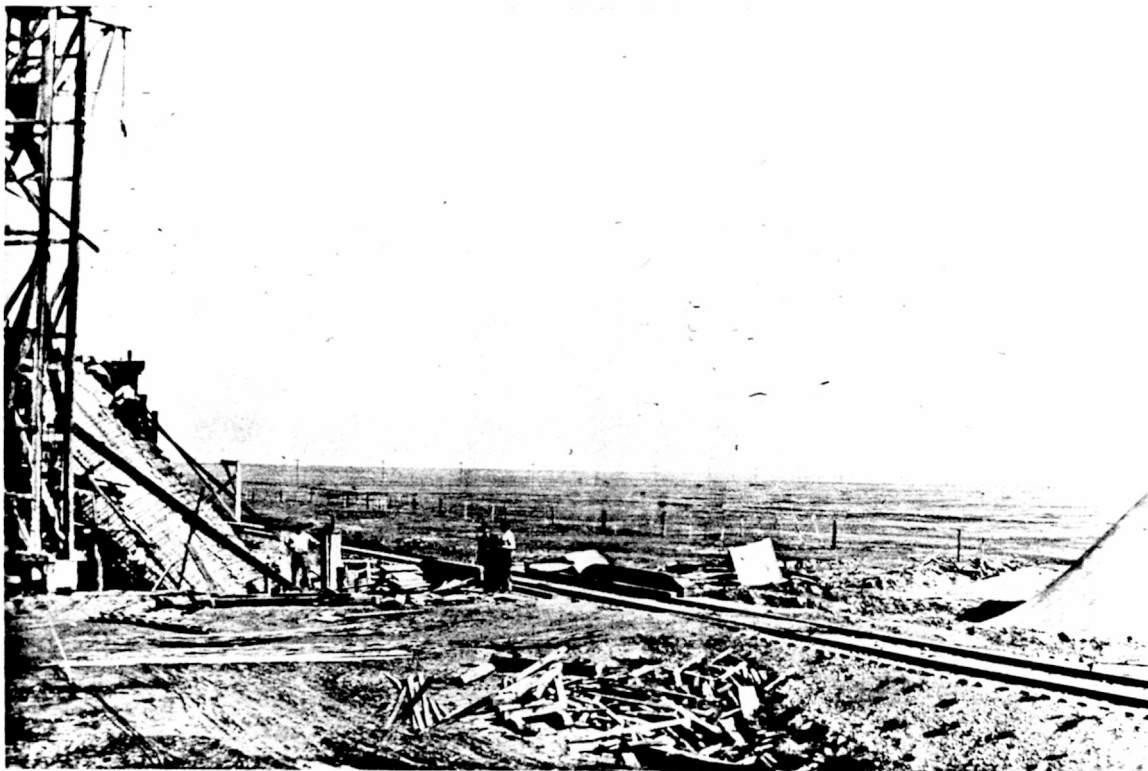


Illustration 12 Pouring siphon, 1914 (GAI NA-2622-69)

crossing over the siphon, and the Government put their telephone line in a conduit under the structure. (For various aspects of camp life see Illustrations 13, 14 and 15)

During 1913 two other wells were drilled, but sufficient water could not be got to supply the work. A reservoir was made alongside the track, about 90 ft. by 40 ft. by 6 ft., to hold 150,000 gallons, and a water-train of six water-cars delivered about 30,000 gallons per day, brought from Suffield, about 40 miles away. From this reservoir it was pumped and piped to the concrete-mixers and the camp. All pedestals west of the track were poured and backfilled, and 480 ft. of columns and girders were constructed. Washed gravel was got from Keith, 140 miles west on the railway, and was shipped in cars. This gravel contained plenty of stone and was graded to have 40



Illustration 13 Aqueduct workers, 1912 (GAI NA-206-21)

to 50 per cent. of sand; the resulting mixture gave 20 to 23 per cent. voids. Samples of gravel were screened and the grading recorded...All cement was tested on the ground and had to pass the specifications of the Canadian Society of Civil Engineers. The concrete mixture in pedestals and foundations was 1:3:6, in columns, girders and shell 1:2:4⁸⁷; the maximum size gravel in the shell was 3/4 in., and in the remainder of the work it was 1½ in.

During 1914 the whole superstructure of columns and girders (except the 480 ft. built in 1913) was built, including the inlet, outlet and siphon, and finished by August 31. Progress was



Illustration 14 Engineers' quarters, 1914 (GAI NA-2622-66)

⁸⁷ A Utah project in 1915 used a mix of 1:1.8:3.7. D.B. Gumensky, "Reinforced-Concrete Flumes poured in 100 foot lengths," *Engineering News Record*, Vol. 80, No. 12, (March 21, 1918) pp. 567-568.

recorded daily on suitable forms by the use of a dating-stamp. Weekly progress photographs were also taken, and progress for the week printed on the negative.⁸⁸

These detailed records and photographs have not survived.

Excerpts from Gibb's article recount, in general chronological order, the construction process for the pedestals or foundations, the columns or uprights, the shell of the flume where the water flowed, and finally, the cross-struts which held the top of the flume apart when empty and together when full.

Pedestals - The tops of the pedestals were first dressed off to grade, and then the splice-bars and "U" bolts, clamps, and hoops all fixed. The erection was done by a derrick with a 60-ft. jib,



Illustration 15 Men in storehouse, c. 1913 (GAI NA-206-20)

⁸⁸ H.M. Gibb, "The Brooks Aqueduct, Alberta," in *Engineering*, Volume 99. (April 23, 1915) p. 453.

travelling backwards on the skids on the centre line of the structure. The mixing plant ran on the track on the south side, and the building and assembling of forms took place on the north side...⁸⁹

Columns - In pouring the columns, it was found that the first batch of concrete usually left all its cement and sand sticking to the steel and forms, and the bottom of each column was apt to be gravelly, with not sufficient grout to fill the voids. To avoid this, the concrete was shot down from a collapsible metal chute from the hopper on top of the structure into the centre of the brace-beams, the excess grout then ran along and down into the columns, and after sufficient grout had run in, the chute was brought right up into the splay and the column filled up. For filling the top lift, the hopper on top of the structure had four chutes - one to each column - and by this means they were filled...⁹⁰

Shell - The construction of the shell followed three to four weeks behind the columns and girder construction, and at a rate of ten sections of 80 ft. per week, equal to 800 ft. In the previous week the 800 ft. of track would be laid ahead on the cross-beams. Starting on Monday, two 80-ft. sections of shell were poured daily up to and including Friday, and in the following order: 1, 3, 2, 5, 4, 7, 6, 9, 8, 10, forms on 1 being successively set on 3, 5, 7, 9, and forms on 2

⁸⁹ Ibid.

⁹⁰ Ibid., p. 454.

successively set on 4, 6, 8, 10...⁹¹

Cross-struts - The cross-struts were made on the ground, fifty-four forms being used, and about twenty poured each afternoon. These beams were cambered by cambering the supports to the forms, and the beams were erected when two weeks old. Some erected, seven days old, gradually sagged about ½ in. to 1 in...⁹²

Thus did the officials of the CPR report on the construction process of the Brooks Aqueduct to the interested public. In the years that followed, however, the aqueduct developed a reputation as a poorly built structure, in need of constant and extensive repair. Whether or not this reputation was warranted, various sources report that work at the construction site was not without its troubles. Some of these reported irregularities may have contributed to the deterioration of the structure. Alternately, the reports may be somewhat biased since the locals routinely referred disparagingly to the railway company as the "Canadian Pathetic."⁹³

One local rumor maintains that condemned cement went into the flume.⁹⁴ F.G. Cross, Assistant Superintendent, CPR Operation and Maintenance at Brooks, confirmed this in his report in 1928. Built in 1906 by the Western Canada Coal and Cement Company and taken over by the Canada Cement Company in 1910, the cement plant at Exshaw, west of Calgary, provided

⁹¹ Ibid.

⁹² Ibid., p. 453-454.

⁹³ R.T. (Bob) White, March 10, 1988 interviewed at his residence in Brooks, Alberta by the author of this report.

⁹⁴ Ibid.

all the cement for the Brooks Aqueduct.⁹⁵ Worked to its limit by the enormous demand for cement for CPR structures throughout the west, it consequently shipped its product to the Brooks Aqueduct project before samples were thoroughly tested. He wrote:

Samples were sent to Winnipeg for test and field tests were made on the ground. Many times Winnipeg wired asking us to hold up certain car numbers for a fresh test, only to find the cement had been used up. In all such cases close observation was given the material in structure and where necessary, the work was replaced.⁹⁶

Poor quality gravel was occasionally blamed for problems at the aqueduct but it is unlikely that the contractor cut corners in this way. CPR employee Robert S. Stockton acknowledged that the company had considerable problems with finding gravel of good quality in the area.⁹⁷ But as noted above by Gibb, gravel was imported from Keith to the west for the aqueduct.⁹⁸ In 1928, Cross pointed out a double standard in the provision of gravel to construction sites. Some received gravel from local pits, material far too sandy and silty for concrete work. He went on to write: "But clean gravel and sand was shipped in for the Aqueduct and I have

⁹⁵ Edna Appleby, *Canmore: A Story of an Era*, (Canmore: Edna Appleby, 1975), p. 23.

⁹⁶ F.G. Cross, *Eastern Section. Concrete Structures. Retrospect*, (Brooks: Eastern Irrigation District, December 15, 1928), p. 7.

⁹⁷ Robert S. Stockton, employee of the Canadian Pacific Railway, interviewed by W. L. Jacobson. June 23-25, 1959. Glenbow tape RCT 90-7,8 Tape 8, Side B counter 200-380.

⁹⁸ H.M. Gibb, "The Brooks Aqueduct, Alberta," in *Engineering*, Volume 99. (April 23, 1915) p. 453.

often wondered as to the reason for making a difference in the two classes of work."⁹⁹ It seems likely that the best gravel available was used in the Brooks Aqueduct.

Water was obviously scarce in territory requiring irrigation. According to Gibb, water from four wells at the site was insufficient to meet the need. Therefore, trains hauled water in daily from Suffield.¹⁰⁰ In his 1928 report, Cross expressed concern about the quality of water used in all concrete structures in the Eastern Irrigation District. "This was a serious matter. Most of the drilled wells at our reservations were alkaline and it was not uncommon for contractors to haul water from 5 to 10 miles at their own expense. Without doubt, unsuitable water was used in spite of all precautions."¹⁰¹ If water in the wells at the aqueduct was alkaline, it would indeed have been "unsuitable" for use in the structure and might have contributed to the early demise of much of the concrete in the Brooks Aqueduct. But, since Suffield was the prime source of water, problems with alkali attacking the cement probably did not affect the aqueduct.

The quality, placement and joining of the steel in the aqueduct was of critical importance. Muckleston claimed that all steel was shipped cut to length and was installed correctly in order to match the plans and ensure maximum

⁹⁹ F.G. Cross, *Eastern Section. Concrete Structures. Retrospect*, (Brooks: Eastern Irrigation District, December 15, 1928), pp. 6-7.

¹⁰⁰ H.M. Gibb, "The Brooks Aqueduct, Alberta," in *Engineering*, Volume 99. (April 23, 1915) p. 453.

¹⁰¹ F.G. Cross, *Eastern Section. Concrete Structures. Retrospect*, (Brooks: Eastern Irrigation District, December 15, 1928), p.8.

strength.¹⁰² But in 1928 Cross reported:

Although the steel rods were ordered in the most suitable lengths for important structures, very often there was either a mix-up in the shipping or loading of tote wagons. This necessitated extra cutting and the use of splice bars at critical points where it would have been more advisable to use a continuous bar.¹⁰³

An engineer who later became the manager of the Eastern Irrigation District recalls at least one example of inadequate reinforcing steel in the aqueduct.

I ran across a case...where the flume goes along and there's an inlet transition and the outlet transition, and there's a bulkhead, a concrete wall on the outlet side, and this thing started falling apart. We had to replace it and, you know, whereas the plans showed rebar [reinforcing bar] up to an inch thick in there, there wasn't one piece.¹⁰⁴

After providing a refreshingly candid review of areas of weakness in the construction of the Brooks Aqueduct and other concrete structures in his report in 1928, Cross listed five factors over which the CPR had virtually no control and then puts the entire maintenance record of these structures into the CPR's economic perspective.

¹⁰² H.B. Muckleston, "Hydrostatic Catenary Flume on a Concrete Aqueduct," *Engineering News*, Volume 74, No. 2. (July 8, 1915), p. 62.

¹⁰³ F.G. Cross, *Eastern Section. Concrete Structures. Retrospect*, (Brooks: Eastern Irrigation District, December 15, 1928), pp. 7-8.

¹⁰⁴ R.T. (Bob) White, March 10, 1988 interviewed at his residence in Brooks, Alberta by the author of this report, Side 3, counter number 170.

Alkali was the first of these five unavoidable problems which contributed to the deterioration of concrete in Eastern Irrigation District works. The problem was so severe in the area that some samples, after surviving perfectly when buried in the soil near Calgary, "broke down completely" after only three weeks in the alkaline soil of the Irrigation District. Frost also contributed to the deterioration of concrete in the district and its effects were unavoidable as water still ran through the structures well into the fall. Moisture trapped therein often cracked these fixtures. In order to understand the charges of "poor workmanship and supervision" Cross wrote that "It is necessary to carry our thoughts back to a period of activity not experienced since 1914." In the context of the frantic work of that year as the final touches were being put on an irrigation system for the entire Eastern Irrigation District, no one should express surprise over occasional errors.

He next cited faulty materials as an additional area over which the Company had little power in a busy season and some of his examples appear above. Finally, design factors of many of the structures created untenable situations where natural forces destroyed every material used in their construction.¹⁰⁵

Cross' economic analysis of the various concrete facilities in the Eastern Irrigation District begins with this statement:

A good concrete structure should be built as cheap as possible and be strong enough to last out its economic life in a presentable state. That some of our structures have failed does not necessarily cast a reflection on the designers.

¹⁰⁵ F.G. Cross, *Eastern Section. Concrete Structures. Retrospect*, (Brooks: Eastern Irrigation District, December 15, 1928), pp. 2-9.

He then proceeds to analyze maintenance cost of various works in the District and arrives at a figure of \$45,129 for the upkeep of the aqueduct for the eight years from January 1, 1921 to December 31, 1928. This he prorates against the CPR's official cost of \$700,000 for the flume and arrives at a maintenance cost of 0.80% of the original construction cost per year or 6.44% for the eight year span. Either figure seems reasonable to him and both fall below the average of 1.36% and 10.9% respectively for irrigation works in the District as a whole. He concludes his report with this rousing summary:

These figures appear excellent. There is nothing "permanent". Our structures work and everything and everybody that works must of necessity be maintained...

How far away is the evil day of heavier expenditure on the maintenance of concrete structures, one cannot say. The careful thought and study given to structures which are failing... is an object lesson in the conservation of funds.

Much brain and sinew was required in the building of the Project [Eastern Irrigation District] and it was necessary to have recourse to expedients in order to meet certain economic conditions.¹⁰⁶

Construction was completed in August of 1914 and Gibb was on hand for the trial in the fall of that year:

...Water was run through the aqueduct last September. Under full head the shell sweated on the outside for a few days, and then dried and remained tight. Slight leakages occurred at the expansion joints until they were caulked with oakum and petrolastic. The siphon remained perfectly

¹⁰⁶ Ibid., pp. 10-12.

water-tight under its full pressure...¹⁰⁷

The *Brooks Bulletin* called the aqueduct "virtually an overhead river" in its account of the completion of the flume. The future looked good for the area and farmers were quick to learn the new ways. It continued:

The completion of the flume enabled the settlers on Sutherland colony to get water, and they are busy as bees preparing for a good crop next year. A party of settlers including... journeyed to Bassano to get information from the methods employed at the Colorado colony north of that town. They returned Thursday night and since then have been diligently irrigating their farms.¹⁰⁸

Although the construction of the Brooks Aqueduct was a positive influence on the economy as a whole in the southeastern area of Alberta, stories of fatal accidents during the construction of the flume mar an otherwise positive series of events. One of these stories claims that a tornado hit the construction project in 1912, knocking down three sections of formwork and killing three or four men.¹⁰⁹ This story seems unfounded since construction in 1912 was confined to building the camp and pouring footings, neither of which involved forms of the size which would injure a man if they were blown over. One manager of the district says there "was no record at all of any deaths" at the Brooks Aqueduct. In fact, he remembers arriving unannounced at the Bassano Dam while a watchman was telling a group of wide-eyed

¹⁰⁷ H.M. Gibb, "The Brooks Aqueduct, Alberta," in *Engineering*, Volume 99. (April 23, 1915) p. 454.

¹⁰⁸ *Brooks Bulletin*, October 3, 1914, p.1.

¹⁰⁹ W. Tait White, interviewed by W. L. Jacobson, July 16, 1959, Glenbow tape RCT-90-32, side 2.

tourists a tale of horror and carnage about all the men that had been killed in the construction of the dam. After the group left, the manager confronted the watchman about the story and he agreed to stay with the facts in the future.¹¹⁰ Also, the local newspaper observed the project closely and reported on any progress at the construction site. In 1913 the *Brooks Bulletin* reported an incident in an article entitled "Accident at the Flume - Wind Blew Down Superstructure - Workman Hurt" which shows how these stories often get started.

A windstorm, which blew up very suddenly on Wednesday afternoon, blew over a portion of the superstructure at the flume and injured a Swede workman. At first it was thought serious loss of life had occurred, because one man had run for the telephone and informed Dr. Anderson that three men were killed, but luckily this was not so. The man who was injured sustained a fracture of one of his ribs. The accident will cause considerable delay to the work.

There was considerable excitement in town when the first report that three men were killed was bruited abroad.¹¹¹

However, in a 1914 summary of the construction process after the Brooks Aqueduct tests, the newspaper reported "A couple of accidents costing the lives of two men occurred during the progress of the work."¹¹² No other details are provided. It is reasonable to assume that accidents occurred on a

¹¹⁰ R.T. (Bob) White, March 10, 1988 interviewed at his residence in Brooks, Alberta by the author of this report, side 3, counter number 95.

¹¹¹ *Brooks Bulletin*, August 9, 1913, p. 1.

¹¹² *Ibid.*, October 10, 1914, p. 1.

construction site of this size but no reliable records exist to indicate the types of injuries or if lives were lost.

Inspection Procedures at the Construction Site

Inspection procedures on the construction of the works in the Eastern Irrigation District in general and the Brooks Aqueduct in particular left something to be desired. In 1928, as Cross reviewed the problems encountered in the construction of these works and the subsequent maintenance headaches, he mentioned the inspection service in his report. The best inspectors were assigned to oversee the work on structures involving concrete and steel while junior men inspected wooden installations. Concrete inspectors were "mostly college graduates" and the maximum staff allotted to the project was eleven concrete and twelve timber inspectors. As a result, with 38 construction crews in the field at any given time, inspectors covered a number of projects.

I myself had to spread supervision over an area of 2500 square miles and efficient results depended entirely on the loyalty of the staff to myself and the Company and the ability to solve emergency problems. The Department's idea of suitable transportation did not keep pace with requirements and for some months it took from two to three weeks to make a round of the camps by team and a goodly portion of the nights were spent on the open prairie. The situation was rectified later on.

Contractors apparently got away with some shoddy work and Cross explained this situation with a review of human nature.

In those hectic days the contractor did not exist who would fail at an opportunity to make an extra dollar and we should probably fail if we

searched for a similar man to-day...No observation was received from my Chief that illegal practice had been discovered...

Hustle was the order of the day and the contractors were urged on to expediency by a penalty clause hanging over their heads in case they failed to fulfil their contract by a stipulated date. In other words - to take a deep long breath was fatal.

Considering the frantic level of activity, Cross stated: "During the three years construction it was necessary to remove only three [inspection] men (1 Concrete and 2 Timber) for conduct prejudicial [damaging] to the work."¹¹³ As far as this CPR official was concerned, the Company did a relatively admirable job keeping track of its inspectors.

Although the CPR showed interest in the quality of the work its contractors were doing in the Eastern Irrigation District, it was decidedly less than forthcoming with details of its work when it came to reporting to the Department of the Interior. This government agency wrote its branch at Calgary in 1914 requesting the plans for the CPR irrigation construction projects only to receive the following reply from its regional officer.

Sir:

I am attaching hereto a copy of a letter which is being sent this day to Mr. Muckleston and which is self-explanatory.

As you are fully aware, the Canadian Pacific Railway Company has been entirely remiss for the past several years in filing plans with this office, as required by the Irrigation Act, and this

¹¹³ F.G. Cross, *Eastern Section. Concrete Structures. Retrospect*, (Brooks: Eastern Irrigation District, December 15, 1928) pp. 4-6.

Department has treated the Company very leniently in this connection, but has from time to time drawn the Company's attention to the fact that their policy with respect to the filing of plans must be changed.¹¹⁴

In this specific case the plans in question were those of the Western Irrigation District weir at Calgary. The Company moved the location of the structure without notifying the Department of the Interior and when challenged on this point the CPR Department of Natural Resources, the railway's responsible department, replied:

...I would also say that unless the decision as to what changes are material and which are not is left with this [CPR Engineering] department, it will be necessary for us to request sanction for every small alteration, which will throw an altogether unnecessary amount of work on your office.¹¹⁵

The change of location of a weir was not a minor alteration and Muckleston's reply was merely an attempt to keep the government's inspectors away from his work. Additional correspondence convinced the CPR to keep up its regular reports to the Department of the Interior. Finally, in 1915

¹¹⁴ Public Archives of Canada, RG 89, Vol. 54, File 29, Vol. 4. CPR irrigation information, 1914-1917, mostly Western Irrigation District in Alberta, F.H. Peters, Commissioner of Irrigation, Department of the Interior, Irrigation Office, Calgary to E.F. Drake, Esq., Superintendent of Irrigation, Department of the Interior, Ottawa, April 15, 1914.

¹¹⁵ Public Archives of Canada, RG 89, Vol. 54, File 29, Vol. 4. CPR irrigation information, 1914-1917, mostly Western Irrigation District in Alberta, H.B. Muckleston, for Chief Engineer, Canadian Pacific Railway, Calgary, to F.H. Peters, Esq., Commissioner of Irrigation, Department of the Interior, Calgary, April 28, 1914.

it sent a full set of plans for the Brooks Aqueduct to the Calgary office, which were then forwarded to headquarters in Ottawa.¹¹⁶ Although these specific plans are not in the records of the Department at the National Archives, copies of these original as-built drawings are in the possession of the current management of the Eastern Irrigation District. Appendix A includes copies of these plans.

Operations

Water flowed through the Brooks Aqueduct annually from 1915 until it was replaced by an earthen canal in 1979. This record of operation is impressive but the details of the operational history prove that the aqueduct never quite measured up to its potential. This shortfall was due to two factors. First, much of the land was not level enough to sustain irrigation and the farmers almost immediately challenged the CPR water bills. Consequently, land reclassification over the first few years gave a more realistic estimate of the irrigable land in the area. Secondly, although the Brooks Aqueduct was theoretically designed to deliver 913 c.f.s. when full, its peak capacity only reached 2/3 of that amount after considerable alteration to the flume.

These limitations to the project were not immediately recognized. In 1917, the review of the Eastern Irrigation District by the Department of the Interior listed 8,000 acres

¹¹⁶ Provincial Archives of Alberta, Department of Environment, PAA 80.168/398, A.S. Dawson, Chief Engineer, Department of Natural Resources, Canadian Pacific Railway, Calgary to F.H. Peters, Commissioner of Irrigation, Department of the Interior, Calgary, March 2, 1915.

of the potential 400,000 under irrigation. The number of water users was 67 and progress seemed assured although "immediate development, however, will probably be retarded by conditions arising from the war."¹¹⁷ By 1920 the same report listed 24,400 acres receiving water.¹¹⁸ The CPR's own report for that year says that the aqueduct carried a maximum head of water of 246 c.f.s. in July and was in operation for a total of 140 days.¹¹⁹ The next year the Company reported 152 days of operation for the flume with a maximum flow of 460 c.f.s. in July.¹²⁰ Whereas the season for the Brooks Aqueduct was originally from May 1 to October 1 each year, in 1929 the Chief Engineer for the CPR Department of Natural Resources was informed:

Referring to your letter of the 28th ultimo [September], I have to advise you that the approval of the Minister has now been given for the use of water in the Eastern Section of the C.P.R. Company's Irrigation Project during the month of

¹¹⁷ Canada, Department of the Interior, Annual Report, Report of the Superintendent of Forestry in *Sessional Papers* (Ottawa: Queen's Printer, 1917), No. 25, Part vii, p. 6.

¹¹⁸ Canada, Department of the Interior, Annual Report, Report of the Superintendent of Reclamation Service in *Sessional Papers* (Ottawa: Queen's Printer, 1920), No. 26, Part iv, pp. 11.

¹¹⁹ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1920), p. 101 [GA M511].

¹²⁰ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1921), p. 91 [GA M511].

October.¹²¹

This approval to push the season for the aqueduct to a maximum of 184 days was apparently at the request of the farmers in the District. The flume was not delivering anywhere near its rated capacity of 913 c.f.s and the farmers needed more water than the system could supply.

A number of factors limited the ability of the Brooks Aqueduct to provide water. First, with a drop of less than five feet in elevation, or head, from one side of the valley to the other, the gradient of 0.01% was very slight and did not promote a high velocity in the flow. Also, according to one study, a slope of anything less than 0.02% allows too much aquatic growth to build up in the channel and further reduces the speed of the water.¹²² By the late 1940s the problem of low volume was a pressing matter. Therefore, in 1949, T. Blench of the Department of Civil Engineering at the University of Alberta analyzed the problem based on a critique of the original formula used to compute the friction of the inside of the flume. According to him:

Inserting the design values of V, R, S (corresponding to 900 cusecs [c.f.s] running with surface at corbel base level) shows that the aqueduct was designed, virtually, in the expectation of n [friction] = 0.0109, an impossibly

¹²¹ Provincial Archives of Alberta, Department of Environment, PAA 80.168/409, J.S. Tempest, Commissioner of Irrigation, Department of the Interior, Calgary to A.S. Dawson Esq., Chief Engineer, Department of Natural Resources, Canadian Pacific Railway, Calgary, October 14, 1929.

¹²² Anonymous, *Storage and Flow Capacity Pertaining to the Bantry Canal System*, (Calgary: Prairie Farm Rehabilitation Administration, n.d.), p. 2.

low value.¹²³

R.T. White, who worked on the analysis with Blench, recalls that this friction value was similar to that of fine porcelain and consequently reduced the capacity of the flume by 28%.¹²⁴ Blench figured that the best friction factor for the existing structure was an "n" value of 0.15 or a maximum of 655 c.f.s. By cleaning and totally polishing the interior of the channel a friction value of 0.13 could be attained and thereby increase the flow to 755 c.f.s. However, (as shown in Illustration 16) the cross-struts at the upper edge of the flume created a backwater which in turn slowed down the movement of the water. Blench recommended that the first



Illustration 16 Flume running full, 1931 (GAI NA-4389-43)

¹²³ T. Blench, Department of Civil Engineering, University of Alberta, *Report on the Aqueduct*, (Brooks: Eastern Irrigation District, January 13, 1949), p.1.

¹²⁴ R.T. (Bob) White, March 10, 1988 interviewed at his residence in Brooks, Alberta by the author of this report.

quarter mile of these be removed and replaced with steel beams mounted above the top of the shell and not inside the upper edge.¹²⁵ Discarded railway ties from the Calgary street car system replaced the concrete cross-struts.¹²⁶ Although attempts were made to keep the flow at a maximum, the Brooks Aqueduct's capacity only exceeded 700 c.f.s. after much alteration to the original flume and never approached the 913 c.f.s. promised by the original engineers.

Finally, one last detail about the operation of the aqueduct may account for, from a humorous angle, part of the loss of water transportation capacity. No one, as far as research to date has revealed, ever considered the other c.f.s. value, that of the cubic fish per second. Floyd Yeats, a long time engineer on the CPR's transcontinental passenger train, the *Canadian*, tells a fish story about the siphon under the CPR tracks. The misuse of certain words in the following transcription of his story is done in an attempt to remain as close to his original testimony as possible.

...Another little antidote as you mentioned about the thing, the aqueduct was that each fall, when they drained the irrigation canal, there was always quite a crowd that would gather at the aqueduct, the place where it went under the railroad. This would trap all the fish that were in the canal, they'd get trapped in the part underneath the railway, when the water was all shut off on both sides, and it quit running, then they'd open two

¹²⁵ T. Blench, Department of Civil Engineering, University of Alberta, *Report on the Aqueduct*, (Brooks: Eastern Irrigation District, January 13, 1949), pp. 2-3.

¹²⁶ R.T. White, *Brief Historical Review of the Brooks Aqueduct*, (Brooks: Eastern Irrigation District, July, 1983), p. 6.

big steel doors and ... the natives around Brooks there would just get sacks of fish out of there, whitefish mostly, that were trapped in here when the water was shut off. So that was always quite an occasion in the fall when the water was shut off, to get the fish out of there.¹²⁷

Fish, friction and cross-strut factors ensured that the Brooks Aqueduct could never deliver 913 c.f.s.

Maintenance of the Brooks Aqueduct by the CPR

"A good concrete structure should be built as cheap as possible and be strong enough to last out its economic life in a presentable state."¹²⁸ Thus wrote CPR employee Cross in 1928 about the Eastern Irrigation District works. His definition of the life of a structure was obviously different from that of the engineers who built ancient water conveyance systems. Nevertheless, this decision to build as close to the economic and practical edge of the tolerances gave the Brooks Aqueduct a reputation as a structure in constant need of repair. No one knows how long the CPR expected the aqueduct to last. Indeed, the Company could not have reasonably expected the farmers to be ready to take over the operations for at least two or three decades. As the records reviewed below indicate, the CPR completed most of the major repairs to the aqueduct by the time the farmers took over the system in 1935. Maintenance and repair records after 1935

¹²⁷ Floyd Yeats tape sent to the author of this report February, 1988.

¹²⁸ F.G. Cross, *Eastern Section. Concrete Structures. Retrospect*, (Brooks: Eastern Irrigation District, December 15, 1928), pp. 10-12.

are not as thorough as when the CPR was making annual reports of the Eastern Irrigation District works and the Department of the Interior was checking up on them. The farmers' organization did minor repairs until the 1950s when it began a program of major reconstruction of the lower part of the shell. Thereafter the manager of the District worked towards a goal of replacing or bringing up to modern standards every one of the major works in his area of responsibility, including the aqueduct. In the end, the Brooks Aqueduct could not be repaired and was replaced by another structure immediately to the south.

R.T. White is a local engineer who later became the manager of the Eastern Irrigation District. He is respected in the community and accurately recollects much of the history of the Brooks Aqueduct. As a boy he used to ride down to the flume on his pony on hot summer days. With water leaking from expansion joints, cracks in the shell itself, and over the edges when forced to its maximum capacity and it spilled over the edge, the boy and his pony cooled off in the shade and the wet under the aqueduct.¹²⁹

Not all observers considered the flaws in the flume entertaining. In 1917, Department of the Interior officials in Calgary reported on "concrete structures where difficulty of one kind or another has been experienced: Antelope Creek Siphon, chute at Lake Newell, Brooks Aqueduct, drop at Springhill canal headgate, drops at Springhill canal north of Southesk, double drop on North Branch Canal and drop on Spillway "E" North Branch Canal to their superiors in Ottawa. In addition to expansion joint and alkali details which follow, the government report warned there was "some danger that a low temperature may come on while the pores of the

¹²⁹ R.T. (Bob) White, March 10, 1988 interviewed at his residence in Brooks, Alberta by the author of this report, side 1, counter number 70.

concrete are filled with moisture and damage may be done by freezing." It also found that the pedestals in the east half of the aqueduct responded with "a dead sound" when struck with hammer. The inspecting engineer suspected that inferior materials were used in construction and, if so, this "account[ed] for their deterioration." He also noted poor quality concrete in the east pedestals generally.¹³⁰ In spite of the expense of repairs to these portions of the aqueduct, CPR inspector Cross still found the maintenance costs very reasonable in his 1928 report.¹³¹

The fate of one of the structures mentioned in the 1917 Department Report above, the Antelope Creek Siphon, compares well with the maintenance problems at the Brooks Aqueduct. Its statistics included an original 1914 capacity of 1200 c.f.s. carried in five reinforced concrete pipes, each five feet in diameter, 1740 feet long. In 1917 it had 850 feet of two of the pipes replaced with wooden stave pipes at the bottom of the valley, due to alkali problems. Four years later, the three remaining pipes were replaced with one wooden stave pipe, ninety inches in diameter on pile foundations.¹³² CPR engineer Muckleston's reported on the

¹³⁰ Provincial Archives of Alberta, Department of Environment, PAA 80.168/401, Sam G. Porter, Assistant Chief Engineer, Department of the Interior, Calgary, to F.H. Peters, Commissioner of Irrigation, Department of the Interior, Calgary, September 12, 1917.

¹³¹ F.G. Cross, *Eastern Section. Concrete Structures. Retrospect*, (Brooks: Eastern Irrigation District, December 15, 1928), pp. 10-11.

¹³² Glenbow-Alberta Institute Archives, W.L. Jacobsen papers, M3761/f.182, *Engineering Journal*, June 1937, pp. 410-11.

siphon:

The original structure consisted of a five barrel reinforced concrete inverted siphon (with common walls) each pipe having an interior diameter of five feet, and a length of 1,739 feet. The estimated discharge of the five pipes was 1,167 c.f.s....

The concrete shell was $4\frac{1}{2}$ inches thick, with half inch circumferential steel placed at five-inch centers, and twenty-eight half-inch longitudinal bars spaced equidistant around the barrel, all joints being lapped thirty diameters. All intersections and joints were lashed with No. 14 gauge wire. The gravel used was local pit-run material; the amount of cement used being ten per cent. in excess of the voids as determined by field tests. An aggregate of sand to pebbles as one is to two was aimed at, and regularly graded from fine to coarse. Sand was considered as material which would pass a one-quarter inch screen...

The structure as a whole included about 3,800 cubic yards of reinforced concrete, and 462,000 lbs. of steel.

Its cost in 1913 was:

\$75,000 for labor.

35,000 for material.

7,000 for engineering and supervision

\$117,000.

The pipes were backfilled to a depth of five feet, but this was found afterwards to have been a mistake in judgement.

No expansion joints were provided at the time of construction, as it was thought that the backfilling and continuous service would make such joints unnecessary.

The following year the backfilling was partially removed, and two expansion joints were installed on each side pipe in the form of concrete collars, four feet four inches wide and two inches thick; reinforced with wire fabric and placed around the inner surfaces of the pipes, the original barrels being cut around the circumference at the center of each collar.

The pipe as a whole terminated at each end in reinforced concrete portals; the change in cross-section being made by tapered ends, elliptical in cross-section. Flashboard control was adopted at each end, and a twelve-inch blow-off was placed at the lowest point on each of the five pipes, the valves all being controlled through one gate house...

The structure was put into operation early in 1914, and within twelve months serious troubles developed. At first these were small leaks, but these soon developed into blow-outs, necessitating the shutting out of the water, and immediate repairs. Most of the trouble occurred on the lower portion of the pipes where the head was the greatest, and drainage inefficient.

Investigation both by engineers and chemists have lead to the conclusion that most of the trouble has been due to the presence of certain alkali salts (probably sodium sulphate, magnesium sulphate, magnesium chloride, and sodium chloride) in the soil on which the pipes were built, and with which they were backfilled, coupled with lack of possible drainage. Some idea of the conditions obtaining may be judged when it is stated that some of the half-inch steel reinforcement in these pipes was completely eaten through, after having been in

the structure less than seven years...

In the fall of 1920 it became evident that the area of irrigable land sold and being put in crop could not be satisfactorily served by this structure as it stood...

A careful study of the conditions obtaining resulted in the following conclusions...

1. It would not be economical or even desirable to make use of any portion of the existing structure as a foundation for any new pipe built.

2. The grade of any new pipe, and at a later date the grade of the existing pipes should be raised if possible, so as to permit of their being properly inspected, repaired and painted, and also to admit of better drainage being provided underneath the structure...

The staves are Douglas fir, six inches in width, average length not less than sixteen feet, with a finished thickness of 3 5/8 inch, with No. 10 gage galvanized tongues, one and a half inches wide at the joints. The bands are three-quarter inch mild steel; guaranteed and tested as having a tensile strength of from 55,000 to 65,000 pounds per square inch...The staves were pressure creosoted at the rate of eight pounds per cubic foot...¹³³ (See Illustration 17)

The final cost of replacing the Antelope Creek Siphon was

¹³³ A.S. Dawson, "Large Inverted Siphons of Reinforced Concrete and Wood Stave Construction," *Irrigation Review*, Vol. 3, No. 8 (March 1922), pp. 114-120.

\$93,140. or almost 80% of the original \$117,000 cost.¹³⁴ Although some of the problem factors reflected in this replacement program of the major siphon in the Eastern Irrigation District are different from the situation at the aqueduct, many are similar. Shells of reinforced concrete

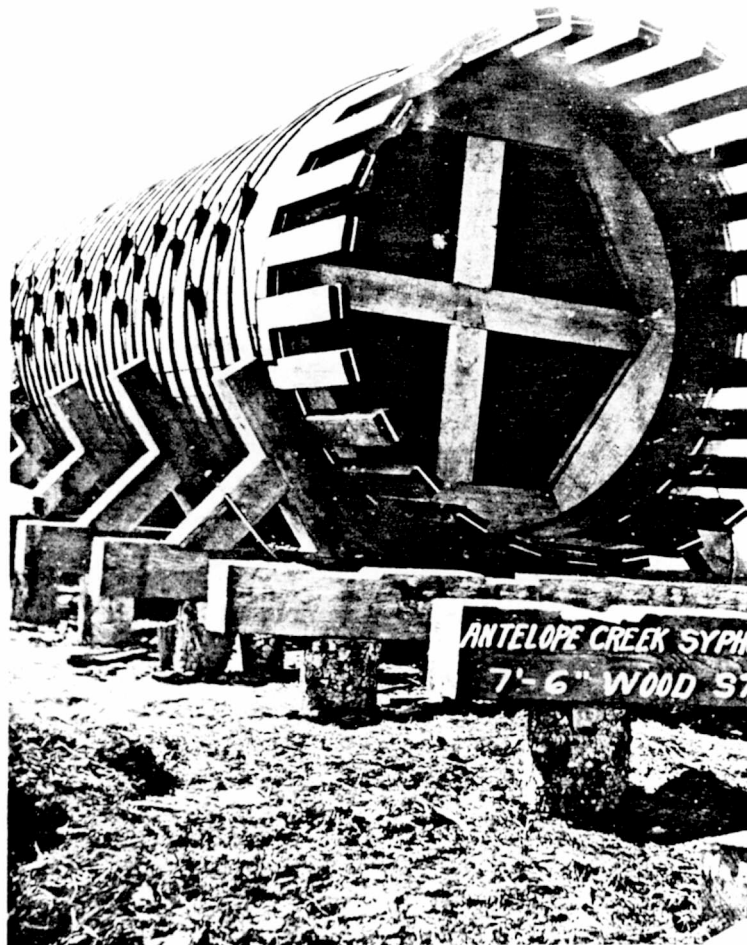


Illustration 17 Antelope Creek siphon, 1921 (GAI NA-4389-16)

¹³⁴ Glenbow-Alberta Institute Archives, W.L. Jacobsen papers, M3761/f.89, Provincial Auditors Report of the CPR Co. EID Project, Special Report, February 19, 1935, J.C. Thompson C.A. Provincial Auditor, p. 4.

made up the walls of each structure and were exposed to similar freezing and expansion forces. Both were backfilled with soil and where these surfaces were not well drained alkali quickly attacked the concrete. Expansion joints were not provided in the siphon but were installed at the aqueduct. However, neither design proved sufficient to meet the contraction and expansion problems. By contrast, although the Antelope Creek Siphon was later raised above grade on wooden supports, the concrete pedestals were not similarly protected from the alkali soil at the Brooks Aqueduct.

Using this background of a similar structure in the vicinity as a comparison, the maintenance review will first highlight the activities of the Brooks Aqueduct crews in the employ of the CPR. During the 1915 season, the first operational year for the aqueduct, the Company reported that the expansion joints were in poor repair and that surface drains had to be installed to keep the soil below the flume from flooding.¹³⁵ (Additional details of the actual work involved for each of these years and the costs associated therewith can be found in the footnoted sources)

The work in 1916 consisted of attempting to make the original expansion joints work as installed. Crews placed timber supports and metal bands on the outside in order to make for a better seal and repacked thirty joints with rubber duck instead of felt in an attempt to get a better fit. Farmers' complaints about the lack of water in mid-September stopped the repairs during the irrigation season. "Small metal bands were placed at three joints of the Aqueduct in order that the expansion and contraction might be

¹³⁵ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1915), [GA M511].

determined."¹³⁶ Details on these tests appeared in the next annual report.

The CPR purchased the house used by the superintendent of Grant, Smith & Co. & McDonell in September of 1917 for \$300.00 and moved it to S.W. 23-18-14, adjacent to the aqueduct. It also installed a telephone at the site and built more drainage ditches to carry water away from the leaking flume. The CPR totally replaced three expansion joints and repacked 57 with waterproofing in addition to repairing 39 pedestals.¹³⁷ The Department of the Interior inspection this year noted that expansion joint repair was made necessary since the original copper plate meant to allow concrete on either side of it to slip was cracking off away from the metal and not sliding along its smooth surface as

¹³⁶ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Monthly Report*, (Calgary: Canadian Pacific Railway, October, 1916), p.5-6 [GA M511]; Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Monthly Reports*, (Calgary: Canadian Pacific Railway, September, 1916), p. 4 [GA M511]; Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Monthly Reports*, (Calgary: Canadian Pacific Railway, September, 1916), p. 4 [GA M511]; Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1916) [GA M511].

¹³⁷ Of human interest in this report was the fact that 4234 meals were served to workmen at the site at an average cost of 42.6¢ per meal. Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1917), pp. 3-65 [GA M511].

originally intended.¹³⁸ Finally, the three expansion joint tests revealed that in December of the previous year, during a period when the temperature had fluctuated 79°F, the joints had moved as much as 1 5/32 inches. One joint showed a 1 inch movement in a four day period.¹³⁹

Leaks were largely stopped and "considerable amount of repair work is still in progress in an attempt to remedy them" wrote Sam G. Porter, Assistant Chief Engineer, Department of the Interior, to his superior the Commissioner of Irrigation in Calgary in 1918.¹⁴⁰ The shell of the flume was replaced in two places where large chunks had fallen out, a first for the aqueduct and only just a glimpse of things to come. Routine maintenance included repairs to 57 expansion joints and 31 pedestals.¹⁴¹

The troubles with the expansion joints escalated and in 1919 the CPR began replacing some of the weakest ones with

¹³⁸ Provincial Archives of Alberta, Department of Environment, PAA 80.168/401, Sam G. Porter, Assistant Chief Engineer, Department of the Interior, Calgary, to F.H. Peters, Commissioner of Irrigation, Department of the Interior, Calgary, September 12, 1917.

¹³⁹ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Monthly Report*, (Calgary: Canadian Pacific Railway, January, 1917), p. 3 [GA M511].

¹⁴⁰ Provincial Archives of Alberta, Department of Environment, PAA 80.168/404, Sam G. Porter, Assistant Chief Engineer, Department of the Interior, Calgary, to F.H. Peters, Commissioner of Irrigation, Department of the Interior, Calgary, June 20, 1918, p. 4.

¹⁴¹ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1918), pp. 40-42 [GA M511].

four different types to see which would last best in the hostile climate. The Callendrite joint, made of fabric, was only temporary as it needed replacing annually. A canvas duck joint was used in emergency situations only and was coated with tar and pitch. Accordion joints of galvanized metal seemed to have promise and a Deegan joint, invented and installed by a Mr. Deegan of Calgary, was placed in four trials joints. The shell situation was deteriorating and this year six patches averaging 20 feet by eight feet were replaced.¹⁴² Wage rates for teamsters and labourers at the aqueduct this year was \$4.00 per 10 hour day. The next year the rate rose to \$4.50 but in 1921 it dropped to \$3.50 and then to \$3.00 for the years from 1922 to 1925.¹⁴³ The final note of interest this year was visit of a new machine to the Brooks headquarters of the Eastern Irrigation District operations.

On September 24, [1919] Captain Fred McCall, D.S.C. accompanied by Captain Brett, visited Brooks with his flying machine. Several members of the staff made flights, observing as they did so, the different canal systems over which they were taken. Some very interesting photographs were taken of Brooks Headquarters, the Company's Demonstration Farm, and the town and vicinity of Brooks.¹⁴⁴

¹⁴² Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1919), pp. 79-81 [GA M511].

¹⁴³ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1925), p. 31 [GA M511].

¹⁴⁴ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1919), pp. 79-81, 103 [GA M511].

The irrigation department employee partially covered his glee to having had a chance to ride in an airplane by proving that the flights were business related.

The report for 1920 detailed an ever growing maintenance program at the aqueduct. Expansion joint repair continued on two levels. Crews applied emergency repairs on 21 joints by the various temporary means described in the previous years' report and installed seven permanent metal "V" joints. These were also the most expensive of the experimental models but were the most reliable as well. The CPR bought a second cement gun this year. This machine sprayed a material called "gunnite" on structures needing cement repairs. No mention is made of the purchase date of the first one but it was probably bought and used primarily at the Bassano Dam and then another one ordered when the work at the Brooks Aqueduct began to mount. A detailed explanation of the technology involved in the cement gun follows this maintenance review. Water for the machine was siphoned from the interior of the aqueduct itself. The gun broke down in August and repairs were done in Calgary using parts from Allentown, Pennsylvania. A two month wait for repairs meant that by October it was too cold to do anything with the gun that winter. The maintenance crew built a new settling basin at the entrance to the aqueduct to trap deposits. It also served as an additional protection against moisture getting inside the flume in the winter as the canal from Lake Newell occasionally leaked and water trickled down to the head of the flume.¹⁴⁵ The Department of the Interior reports for the same year stated that the Brooks Aqueduct was "leaking badly at the expansion joints near the East end and alkali appears

¹⁴⁵ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1920), p. 94-131 [GA M511].

to be attacking some of the pedestals." Also, there were "many large spots on the barrel of the flume where the concrete has flaked off exposing the reinforcing. This does not appear to be the effect of alkali action but is probably due to the reinforcing being placed too near the surface."¹⁴⁶ The canal superintendent for the CPR reported to his Calgary superiors in July about the problems associated with maintenance of the flume.

Work continued on the repairs to the shell and the building of expansion joints. The moving and building of underneath form work made the repairs a slow process. Holding a crew that would build scaffolding and climb the ladders was also found more difficult than on the usual camp work.¹⁴⁷

It is no wonder that the wage rate for labourers on this site went up this year as mentioned above. It probably dropped once the cement gun was in operation and less trapeze work was required of the hired hands.

The 1921 report by the Department of the Interior recorded the usual problems with expansion joints but that the solution of metal "V" shaped joints had now become the norm. The east end pedestals, previously mentioned as dead sounding when struck with a hammer, were all repaired. The process involved chipping off the old material and building up the solid core with layers of gunnite. A firm sound was

¹⁴⁶ Provincial Archives of Alberta, Department of Environment, PAA 80.168/405, G.N. Armstrong, Assistant Chief Engineer, Department of the Interior, Calgary, Report on Inspection of Works, etc. Eastern Section, 1920, September 7, 1920.

¹⁴⁷ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report, Canal Superintendent's Monthly Report (1920)*, (Calgary: Canadian Pacific Railway, 1915-1920), [GA M511], p. 23.

heard when they were struck with a hammer after this treatment.¹⁴⁸ The CPR reported that it had jackhammered over 27000 square feet of rotten concrete out of the shell of the flume, mostly from the interior, and repaired it with gunnite. Construction workers waterproofed more than 8000 square feet of the shell and punched ten drainage pipes through the bottom of the shell in order to speed up its cleanout in the fall. They also installed nine of the permanent "V" shaped expansion joints in addition to 43 temporary ones. The CPR report says its employees repaired 99 pedestals and waterproofed twelve of them.¹⁴⁹

In 1922 the CPR report included reference to buildings at the Brooks Aqueduct site. These included a house built in 1912, 20 feet by 30 feet on a sill foundation and of poor quality, valued at \$500. Sheds and a cistern complete the list of structures at the flume. Workmen repaired the shell in 35 places and added chicken wire when repairing particularly bad holes. They repaired ten expansion joints with the permanent "V" joints and applied temporary remedies at six locations. A Mr. Gallup, of Medicine Hat, brought ten car loads of sand or a total of 400 cubic yards for use in the repairs to the flume.¹⁵⁰ A new inspector for the

¹⁴⁸ Provincial Archives of Alberta, Department of Environment, PAA 80.168/405, P.J. Jennings, Acting Assistant Chief Engineer, Department of the Interior, Calgary to Commissioner, Irrigation Branch, Department of the Interior, Calgary, August 31, 1921.

¹⁴⁹ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1921), pp. 103-106 [GA M511].

¹⁵⁰ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1922), pp. 34, 103 [GA M511].

Department of the Interior made a most peculiar report to the Acting Commissioner in Calgary on November 2, 1922. He wrote:

This structure was found to be in excellent condition and no leaks whatever were observed throughout its entire length. There are one or two places where some disintegration has taken place in the shell of the structure, but steps are being taken to have those attended to during the winter. These places are usually scraped and built up again by the cement gun.¹⁵¹

Although he was correct to notice the extent of the repair to the flume, his observation of a total lack of leaks weeks after the aqueduct was drained indicates that his knowledge of his new job had room to grow.

In 1923 the CPR reported 57 repairs to the shell as well as ten permanent and 21 temporary replacements for expansion joints. Of interest was its loan of the cement gun to a project at another massive western Canadian industrial site, the Connaught Tunnel on the CPR mainline through the Rogers Pass in British Columbia. The summer months were undoubtedly slow months for the cement guns at both the Bassano Dam and the Brooks Aqueduct.

On August 14th [1923] Foreman Hodge was loaned to the Junkins Construction Company at Glacier Tunnel, where they were doing some work for the Operating Department. Foreman Hodge instructed these people in the operations of a cement gun and gave advice as to the best method of carrying out

¹⁵¹ Provincial Archives of Alberta, Department of Environment, PAA 80.168/406, P.J. Jennings, Assistant Acting Commissioner of Irrigation, Department of the Interior, Calgary to Acting Commissioner of Irrigation, Department of the Interior, Calgary, November 2, 1922.

the work on hand. He returned to Brooks on August 23rd.¹⁵²

The CPR reported the repair of another 40 sections in the shell of the flume in 1924. It installed six permanent expansion joints and 28 temporary ones. Sand was also imported, washed and screened.¹⁵³ (Illustration 18 shows the condition of the aqueduct support system and leaching through the shell in 1927)

The 1925 Department of the Interior report on the aqueduct listed the flume "in good condition."¹⁵⁴ For the most part it was but the CPR report showed that extensive and ongoing maintenance was necessary to keep it that way. Shell repairs in fifty places, twelve permanent and 34 temporary repairs to expansion joints, the repair of twenty pedestals, the installation of twenty four-inch drain pipes in the bottom of the flume to bring this total to thirty, and the washing of more sand for the next year's repairs were all

¹⁵² Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1923), pp. 111-13, 182 [GA M511].

¹⁵³ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1924), pp. 16-17, 117-118 [GA M511].

¹⁵⁴ Provincial Archives of Alberta, Department of Environment, PAA 80.168/407, B. Russel, Reclamation Engineer, Department of the Interior, Calgary to Commissioner of Irrigation, Department of the Interior, Calgary, August 1, 1925.

part of this routine maintenance schedule.¹⁵⁵

Major shell reconstruction was once again required in 1926 and the CPR reported gunniting over 12000 square feet on the inside and 112 spots outside the flume. Its crews installed twelve permanent expansion joints in addition to 29

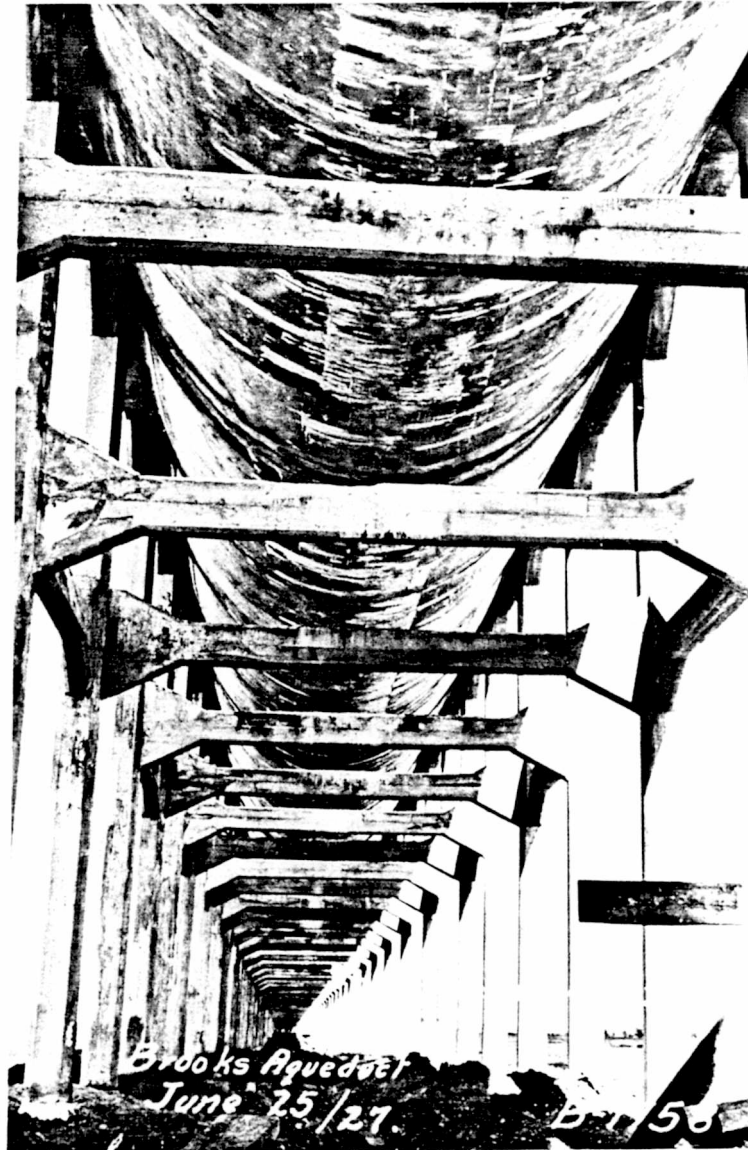


Illustration 18 Underside of flume, 1927 (GAI NA-4389-35)

¹⁵⁵ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1925), pp. 104-108 [GA M511].

of the temporary variety.¹⁵⁶

Only a few hundred feet on the shell received gunnite in 1927. Maintenance crews only installed ten permanent and 23 temporary expansion joints. They were busy, however, repairing 124 pedestals, some of which were totally rebuilt. Waterproofing materials of various types were applied to 192 pedestals.¹⁵⁷ (Illustration 19 shows a pedestal stripped of rotten concrete and prepared for repairs in 1927)

Gunnite and chicken wire was applied to nearly 10000 square feet of the interior of the shell in 1928. Crews worked on ten permanent expansion joints and twelve temporary sites. The big news this year was the first repairs to the siphon which passed under the trackbed of the CPR. The workmen applied a coat of waterproofing.¹⁵⁸

From 1929 to 1934 shell reconstruction gradually decreased as waterproofing efforts took over. Each year also included the repair of eight or ten permanent expansion joints, a few temporary ones and the rebuilding of an

¹⁵⁶ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1926), pp. 85-86 [GA M511].

¹⁵⁷ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1927), p. 92-94 [GA M511].

¹⁵⁸ Provincial Archives of Alberta, Department of Environment, PAA 80.168/409, P.J. Jennings, Reclamation Engineer, Department of the Interior, Calgary to Commissioner of Irrigation, Department of the Interior, Calgary, December 12, 1928; Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1928), p. 13 [GA M511].

occasional pedestal.¹⁵⁹ Finally, in 1933 and 1934 the inside of the siphon was totally refaced with new concrete and glazed tiles. This work was worthwhile as it proved permanent. Part of the outside was excavated, cleaned and coated with tallow and pitch.¹⁶⁰ It was almost as though the construction job was finally finished, twenty years after its official opening. By 1935 the Brooks Aqueduct had worked out most of its problems with bad cement in the shell and support structures, most of the expansion joints had been repaired with the permanent "V" shaped accordion type joints, waterproofing had been applied to the inside of the shell as

¹⁵⁹ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1929), p. 17 [GA M511]; Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1930), p.18 [GA M511]; Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1931), p. 19 [GA M511]; Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1932), p. 18 [GA M511]; Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1933), p. 19 [GA M511]; Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1934), p. 19 [GA M511].

¹⁶⁰ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1933), p. 19 [GA M511]; Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1934), p. 19 [GA M511].



Illustration 19 Pedestal repair, 1927 (GAI NA-4389-36)

well as the foundation surfaces which were likely to come into contact with the alkali soil, and the interior of the siphon had received a smooth coat of tile. The Brooks Aqueduct was now ready to be given away.

In 1935, the farmers' took over the Eastern Irrigation District and all its structures along with some \$300,000 to help with the transition to a farmer run organization. According to a later manager of the system, the CPR had virtually repaired the entire inner surface of the flume with

a two inch coat of gunnite feathered out toward the top.¹⁶¹ A report on the status of the aqueduct was commissioned by the Irrigation Council in 1935 and they chose as their engineer one H.B. Muckleston. By this time a consulting engineer headquartered in Vancouver, Muckleston was hired to inspect and make recommendations regarding the very flume he had designed and seen through construction twenty years earlier. His instructions were to inspect the Bassano Dam and the Brooks Aqueduct for general condition and predict what major repairs would be necessary over the next ten years. His report ended:

I have been surprised at the excellent condition of this structure. About ten of the expansion joints still remain for renewal, of which the cost will be approximately \$1,000.00. The exterior of the trough shows steel in a few places, none of any great area, and its repair should be undertaken as a routine. The inside of the trough is in splendid shape throughout. I am informed that the annual cost of maintenance is not far from \$2,000.00 for the whole aqueduct, which is about one-third of one per cent. of the capital cost new. I do not anticipate any further concentrated expenditure on this structure which has behaved far better than I ever expected it to do.¹⁶²

¹⁶¹ R.T. White, *Brief Historical Review of the Brooks Aqueduct*, (Brooks: Eastern Irrigation District, July, 1983), p. 2.

¹⁶² Provincial Archives of Alberta, Department of Environment, PAA 80.168/415, H.B. Muckleston, Reg. Prof. Eng., Edmonton to L.C. Charlesworth Esq., Irrigation Council, Administration Building, Edmonton, February 9, 1935.

Maintenance of the Brooks Aqueduct by the Farmers

From the farmers' perspective, the irrigation district was quite a good deal. Its manager for many years recalls:

Aside from the aqueduct, for the first fifteen years of the district [EID], it was said that they lived off the cream of what the CPR had left. Because, you see, the CPR had crews everywhere patching and putting in wood instead of crumpled structures and things, tremendous. They had these work camps they called them, I can remember, I was always fascinated by them, they had wooden, like caravans, on wheels pulled with horses, and some of these camps had up to two hundred horses, and these wagon trains, and in there they had their material in one, and their equipment, and they would have their sleeping quarters, and they also had their kitchen. And each one of them had a Chinese cook with a pigtail.¹⁶³

But even the aqueduct was turned over to the farmers in quite good shape due to the gunniting inside and repairs and waterproofing to the questionable parts of the support system for the flume. There were some farmers who adamantly opposed the acquisition of the irrigation system from the CPR. One vocal critic was a Mr. Mortonson. Many farmers suspected that the Brooks Aqueduct was a "White Elephant" and might end up costing them a lot of money. But Mr. Mortonson had helped build the flume and because of his first-hand observation of the construction process, he wanted nothing to do with its

¹⁶³ R.T. (Bob) White, March 10, 1988 interviewed at his residence in Brooks, Alberta by the author of this report, side 3, counter number 325.

maintenance.¹⁶⁴

Bob White first worked for the organization in the summer of 1946. He remembers how patchwork was done to the flume in this era. Cracks in the Brooks Aqueduct were merely fixed with a bit of sand and cement grout, a mixture which constituted little more than a coat of stucco. Pit run gravel, with up to 40% silt, was used for these repairs. Not having been washed or graded, the resulting concrete was very weak.¹⁶⁵ Once hired on by the District as an engineer, White began to campaign for a more thorough analysis of the needs of the aqueduct. Others checked for rotten cement by tapping lightly on the inner surface of the flume but he was convinced that below the thin skin of gunnite lay a major problem. Finally, he convinced Carl Anderson, the current manager of the Eastern Irrigation District, to check it out personally.

That's one of the reasons why when they turned the project over to the farmers they threw in \$300,000 in the pot because there was an awful lot of work to be done on that. And the district [Eastern Irrigation District] until, about in the early 1950s, I got a little fed up with this because I saw our crews would go out and plaster a little crack up and this every year and the next year it would fall off. So one day I got hold of the Carl Anderson, who was the manager and I said, "Listen, this is no good, let's go down there." So we got down there and I said "You know this stuff is rotten. This in the bowl, in the bottom of the thing." He said "Well, I'll see whether it is or not." So he grabbed a hold of a pick, he just kind of lifted it up a bit and then drove it right

¹⁶⁴ Ibid., side 1, counter number 20.

¹⁶⁵ Ibid., side 1, counter numbers 102 and 130.

through, right through the bowl. Well, as the pick went through the bowl his hair stood straight up on end, I can assure you. And, then we started a program of jackhammering all this rotten stuff out and having to form it up from below and bring new concrete in over the top and we continued this until about four years ago [1977], this replacement stuff. We replaced, I guess about, at that time, about 55% of the lower portion of the aqueduct.¹⁶⁶

Whereas the CPR had just lined the flume with a coat of gunnite and fixed the exterior where it was actually falling out, the Eastern Irrigation District took on the expensive and time consuming task of completely replacing lower sections of the shell of the flume. (Special forms built for this repair program are shown in Illustration 20 and a closeup view of the repair job in Illustration 21) Other routine maintenance chores such as repairs to pedestals also fell to the Brooks Aqueduct crew.¹⁶⁷ One year the water was shut off for two weeks in August to allow for maintenance of the flume but farmer's complaints quickly restored water for the full season. Thereafter the maintenance crews had to return to doing their work in the cold of the late fall, winter or early spring.¹⁶⁸

Significant events in the maintenance life of the aqueduct after 1935 included various major projects. In the late 1940s the capacity of the structure was increased by

¹⁶⁶ Robert T. White, engineer and manager of the Eastern Irrigation District. Interviewed by Thomas Kirkham in Brooks. October 23, 1981. Glenbow tape RCT - 383 Side 2.

¹⁶⁷ R.T. White, *Brief Historical Review of the Brooks Aqueduct*, (Brooks: Eastern Irrigation District, July, 1983), p. 8.

¹⁶⁸ Ibid., p. 7.

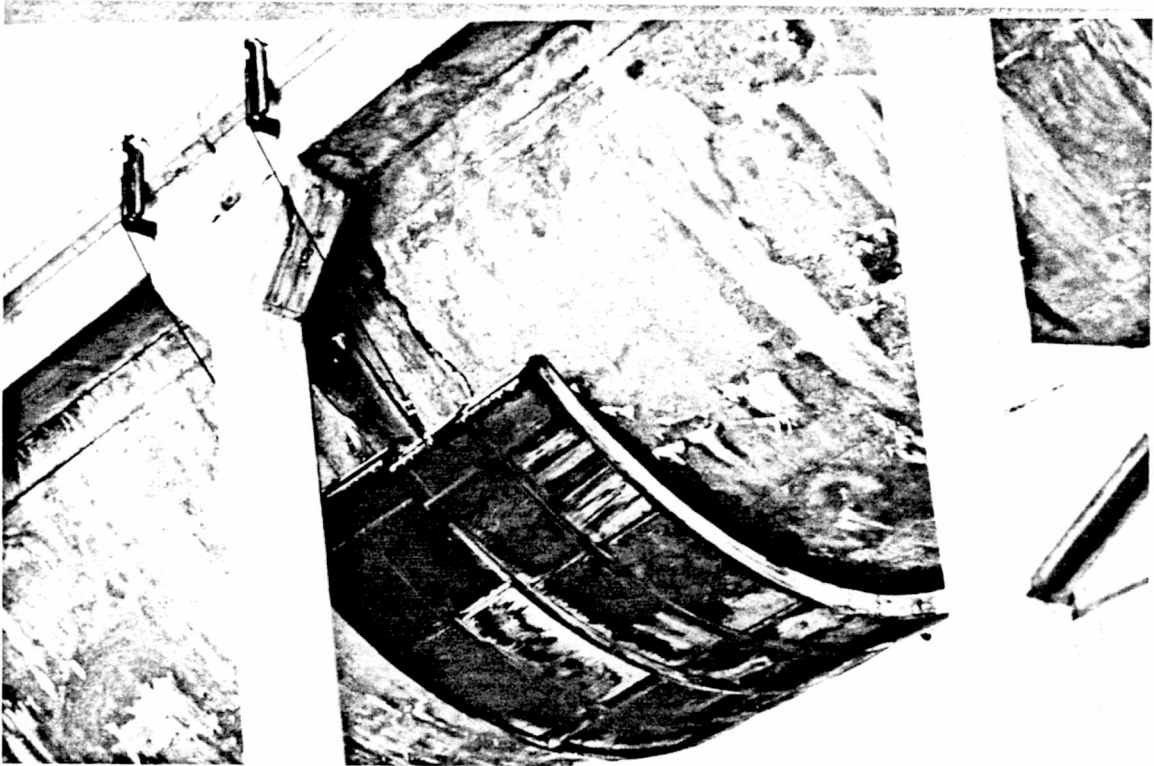


Illustration 20 Repair forms in position, 1988



Illustration 21 Shell showing repaired lower section, 1988

replacing cross-struts in the west end of the flume with steel rails. This special work cost an additional \$9,273.65 than was budgeted for in routine maintenance. In the mid-1950s the Eastern Irrigation District began a program of replacing the rusting galvanized metal "V" joints with copper ones and this process took many years. The process of reconstructing large sections of the bottom of the flume also began in the mid-1950s and permanent forms for this work cost \$6,878.76. Routine maintenance costs for the period 1935 to 1963 totalled \$75,670.24.¹⁶⁹

A thorough review of the structure in 1961 found it in good condition except for the old concrete under the thin skin of gunnite. Sections where deterioration was the worst were replaced with new "high quality air entrained concrete" which resists freezing better than the original material. Core tests of the support systems revealed them to be safe but aging and not up to modern construction standards.¹⁷⁰

A review of two important technological factors involved in the maintenance of the Brooks Aqueduct is in order before discussing its replacement in the 1970s. First, the expansion joints were one of the most critical aspects of maintaining the flume in working order. At no time during the operation of the flume were these all in good working order. The first ones were merely copper plates upon which the adjacent concrete was expected to slide with little or no

¹⁶⁹ Various, *Brooks Aqueduct - Concrete Flume Structure/Summary of Condition Surveys and Records of Repairs* (Calgary: PFRA, 1961 to 1974, W.D. Gray, Regional Engineer, P.F.R.A. Calgary to M.J. Fitzgerald, Director, P.F.R.A., Motherwell Building, Regina, Saskatchewan, July 30, 1964.

¹⁷⁰ Various, *Brooks Aqueduct - Concrete Flume Structure/Summary of Condition Surveys and Records of Repairs* (Calgary: PFRA, 1961 to 1974), 1961 reports.

friction. These were almost immediately recognized to be failures and a search for a better alternative began.¹⁷¹ After the CPR tested various temporary and proposed permanent solutions to this problem, it finally decided on a "V" shaped, galvanized metal joint which moved like an accordion at its fold. About ten of these were then installed each year, until almost all the original copper joints were replaced. The design proved successful but the material was prone to rusting even though it was galvanized and eventually they also needed replacing. For about twenty years these joints, with regular waterproofing, served quite well. Finally, the Eastern Irrigation District replaced the majority of the expansion joint seals with copper "V" joints. This eventual solution married the appropriate design with a reliable material and the outcome was an expansion joint which was able to outlive the Brooks Aqueduct's productive years.¹⁷²

Other than the expansion joints, the main problem with the aqueduct was the concrete. Rather than completely demolishing and rebuilding the entire flume, an expensive proposition, the CPR decided to purchase a cement gun and use it to repair its concrete structures at the Brooks Aqueduct, Bassano Dam and other locations. Invented about the same time as the Bassano Dam was being built, it apparently owes its creation to a taxidermist.

C.F. Akeley, the taxidermist and naturalist
connected with the Field Columbian Museum of

¹⁷¹ Provincial Archives of Alberta, Department of Environment, PAA 80.168/401, Sam G. Porter, Assistant Chief Engineer, Department of the Interior, Calgary, to F.H. Peters, Commissioner of Irrigation, Department of the Interior, Calgary, September 12, 1917.

¹⁷² R.T. (Bob) White, March 10, 1988 interviewed at his residence in Brooks, Alberta by the author of this report.

Chicago, was hunting about for a rapid and economical method of building up forms over which the skins of large mammals, such as elephants and hippopotami, might be stretched, when he hit upon the idea of spraying rough frames with Portland cement. The scheme worked perfectly.¹⁷³

This description of the idea for the invention tells us nothing about the concept or design of the cement gun. A 1912 issue of the *Engineer* offers a more complete description of the process. (See also Illustration 22)

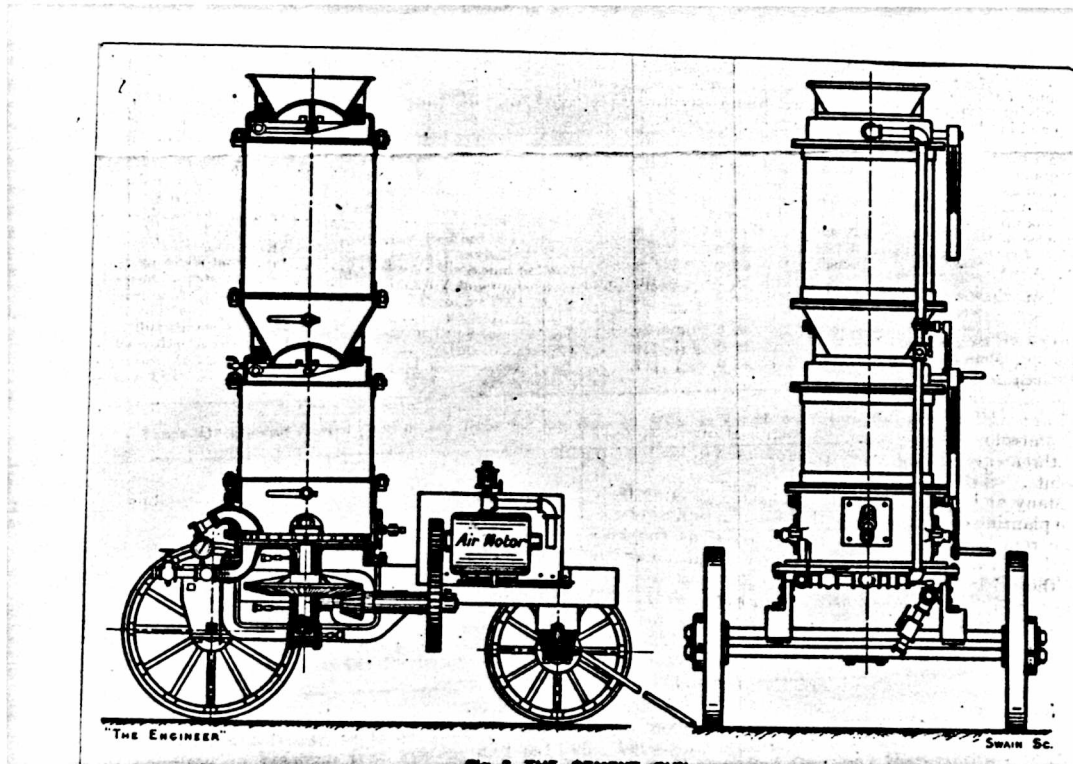


Illustration 22 Drawing of cement gun c. 1912

The apparatus, known by the name, not perhaps too happily chosen, of "cement gun," [is a] new process. Its essential parts are two steel hoppers, or compartments, from the bottoms of which

¹⁷³ Ralph C. Davison, "The Cement Gun," *Scientific American*, Vol. 106, (January 13, 1912) pp. 44-45.

dry cement and sand or other materials, are ejected by compressed air through a hose pipe. At the discharge end of this is a nozzle, to which another and smaller hose supplies water, also under pressure. The hydration thus takes place while all the materials are in motion, and the resulting mixture, leaving the nozzle, is "shot" upon the surface to be coated, or into the interstices of any aggregate. The mortar issues from the nozzle orifice in the form of spray, and at a velocity of about 350 ft. per second, with the result, in the first instance, that the coarser grains of sand rebound from the surface pointed at, leaving a thin film of fine cement mortar to serve as a plastic base in which they finally become embedded. The mixture is then built up upon the film to any thickness desired.¹⁷⁴

So successful was the new applicator for concrete that the CPR purchased two of them for its operations in the Eastern Irrigation District. Although some problems were experienced with the machines when they broke down, it is reasonable to state that the use of gunnite throughout the entire interior surface of the shell and on many of the questionable concrete support systems enabled the Brooks Aqueduct to last as long as it did.¹⁷⁵

¹⁷⁴ Anonymous, "The Cement Gun, Gunite and their Uses," *Engineer* (January 19, 1912), pp. 61-62.

¹⁷⁵ Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1920), pp. 128-130 [GA M511]; Glenbow-Alberta Institute Archives, W.L. Jacobsen papers, M3761/f.56 *History of the Eastern Section, Irrigation Project, Department of Natural Resources, Canadian Pacific*

Brooks Aqueduct Replacement Process

The poorly constructed, patched up and eventually aging Brooks Aqueduct could have experienced a major blowout or leak. According to Bob White, the spectre of just such an accident often loomed in his mind because the effect would have been devastating. A large chunk of the floor giving way when the flume was full of water would have washed out part of the support system which held the flume elevated above the valley floor and, if the washout were extensive, would have toppled part of the aqueduct. Such a disaster was not only possible in the minds of those responsible for the system. The chain of events which could have culminated in disaster actually got started at least once. Two years before it was replaced a section, seven or eight feet across, fell out and began dumping water from the flume to the ground below. A nearby patrolman prevented a catastrophe by quickly shutting off the water supply to the aqueduct.¹⁷⁶

The planning for a replacement to the Brooks Aqueduct began none to soon. For many years before this incident engineers had been at work planning the replacement of the flume. By the end of its life it was costing the Eastern Irrigation District 50¢ per acre per year for maintenance.¹⁷⁷

Railway, A.S. Dawson, Chief Engineer, November 23, 1925 compiled by G. Boese, p. 18; Canadian Pacific Railway, Department of Natural Resources, Department of Irrigation, *Annual Report*, (Calgary: Canadian Pacific Railway, 1923), p. 182 [GA M511].

¹⁷⁶ R.T. (Bob) White, March 10, 1988 interviewed at his residence in Brooks, Alberta by the author of this report, side 3, counter number 800.

¹⁷⁷ Ibid., side 2, counter number 118.

Studies in the mid 1970s investigated a variety of solutions including using the old support system for a new concrete trough or metal flume, as well as totally new steel or concrete flumes or a concrete siphon.¹⁷⁸ Eventually an earthfill canal was agreed on and construction took place between 1974 and 1979.¹⁷⁹ The massive new canal dwarfs the slender-legged original. It is 44 feet wide, carries a body of water six feet deep upon an earthen embankment 600 feet wide at base. Its capacity is 950 c.f.s., just slightly more than the projected 913 c.f.s. for the original Brooks Aqueduct. A siphon, 100 feet long and fourteen feet in diameter runs under the tracks parallel the original siphon which has since been filled with concrete.¹⁸⁰ Turned over to Alberta Environment on January 20, 1981¹⁸¹ and officially opened August 11, 1983, the new canal stands just south of the original Brooks Aqueduct.¹⁸²

¹⁷⁸ Various, *Brooks Aqueduct - Concrete Flume Structure/Summary of Condition Surveys and Records of Repairs* (Calgary: PFRA, 1961 to 1974), 1973 and 1974 reports.

¹⁷⁹ E. Caligiuri, Manager, and R. Powley, Project Engineer, Alberta Regional Division, *The Brooks Aqueduct Replacement Performance Evaluation Report*, (Calgary: Prairie Farm Rehabilitation Administration, March, 1984), p. 1.

¹⁸⁰ Laurette Doucet, *The Brooks Aqueduct*, (Brooks: Eastern Irrigation District, August 15, 1985), p. 2.

¹⁸¹ E. Caligiuri, Manager, and R. Powley, Project Engineer, Alberta Regional Division, *The Brooks Aqueduct Replacement Performance Evaluation Report*, (Calgary: Prairie Farm Rehabilitation Administration, March, 1984), p. 1.

¹⁸² Laurette Doucet, *The Brooks Aqueduct*, (Brooks: Eastern Irrigation District, August 15, 1985), p. 2.

Conclusions

Not everyone wanted to keep the Brooks Aqueduct for future generations to view. Bob White recommended saving just a few sections because, as he sees it, there is little nostalgia surrounding it.

In the course of my walking the coping, not only did I walk that thing even when I was manager, I walked it when it was full of water, looking for something to happen, maybe the coping was crumbling or something, and, that was an exercise, that's where my nostalgia goes right out the window because if you're walking along this thing, and this thing is full of water, and its moving at about three and a half feet per second average velocity, and the wind is blowing from the south, and you're looking down sixty feet...it's no fun.¹⁸³

However, the Brooks Aqueduct is a unique technological and engineering structure and, therefore, worthy of preservation and interpretation for many reasons.

This flume is important, if for no other reason, just because it moved water into an area that was dry and allowed farmers to bring parched land into production. Since ancient days, people have successfully put their energies to this task. Although overshadowed during its conception, construction and operation by the Bassano Dam, the Brooks Aqueduct was a reliable structure which consistently

¹⁸³ R.T. (Bob) White, March 10, 1988 interviewed at his residence in Brooks, Alberta by the author of this report, side 3, counter number 210.

delivered water to farmers in a large portion of the Eastern Irrigation District of southeastern Alberta.

Delivering water from the Lake Newell reservoir to the farmers in the north and eastern sections of the District was a considerable feat. Crossing the old river valley, two miles in width, with a flume held as high as sixty feet in the air was an engineering challenge. But the minimal drop in altitude between the reservoir and the eastern side of the river valley allowed only a five foot loss of elevation, or head, in that two mile long crossing. Also, a siphon under the Canadian Pacific Railway tracks line added an additional, if minimal, loss of head. Although this gentle incline caused operations problems, the fact remains that the aqueduct worked for 65 years.

Some critics may derive pleasure from lampooning the construction, operations and maintenance problems associated with this giant water conveyance system. Nevertheless, the aqueduct pushed the limits of numerous aspects of technology at the time of its construction. The Eastern Irrigation District was the first Canadian irrigation district to use reinforced concrete in all its major works although this new material was standard in American projects at the time. The CPR chose to use the hydrostatic catenary curve principle in the shell of the flume as it was theoretically the shape a flexible channel, filled with water, would naturally take if suspended from supports. No one else had attempted to apply this theory in a suspended, reinforced concrete shell. The shell design called for five inches of reinforced concrete, a thickness theoretically adequate to provide enough thickness in the concrete to keep it from cracking and enough tensile strength in the steel to carry the weight of the water when filled to capacity. Also, the construction crews watered down the cement to a wet slush in order to assure a thorough filling of the lower sections of the shell. Although this new technique helped make the pour as perfect as possible,

the concrete in the lower section of the flume was probably irreparably harmed by this decision. The CPR engineers also used a new formula when they calculated the maximum flow of water through the flume. Either it was in error or a friction value excessively low was used. Regardless of the actual mistake in calculation, low slope and high friction, compounded by cross-struts that impinged upon the flow of water at the surface, together combined to keep the discharge capacity well below its original 913 cubic feet per second. Only after much study, experimentation and renovation to the structure did it ever exceed a flow of 700 cubic feet per second. Finally, expansion joint technology in cold weather applications of reinforced concrete flumes was also in its infancy and as a result the Brooks Aqueduct was a testing ground for the new, and largely untried, systems.

Operations and maintenance problems at this location posed new questions never before entertained in aqueduct systems. No other reinforced concrete flume operated in temperatures which ranged as much as 140°F. Although the irrigation system did not operate during the coldest part of the year, by running water through the flume until the end of October, the shell froze and stayed saturated with water throughout the coldest months of the year. The destructive action of frost on concrete was not well understood in the early years of the aqueduct's life. Repair crews used air entrained concrete, which better resists freezing, to replace much of the lower section of the shell in later years. The destructive forces of alkali, which in another site in the Eastern Irrigation District totally demolished a reinforced concrete structure, were warded off at the Brooks Aqueduct by carefully replacing exposed surfaces as the inevitable destruction occurred and waterproofing the rebuilt support systems as protection against further trouble. A system of drainage channels moved water away from the foundations of the aqueduct, thereby reducing contact between alkali

saturated water and the pedestals. Maintenance engineers creatively tested and eventually perfected the use of galvanized, and the longer lasting copper, "V" shaped, accordion like expansion joints to replace the flawed original design. And finally, these crews successfully utilized the cement gun and its product, gunnite, to repair damaged concrete wherever encountered in the Brooks Aqueduct and lined the flume with a coating which kept it in service long after the original concrete in the lower part of the flume had deteriorated to powder.

Why then has the Brooks Aqueduct acquired a reputation as a "White Elephant" or failed project? In part, this feeling comes from the less than positive relationship between the people of western Canada and what they perceived to be a monopolistic economic machine, the Canadian Pacific Railway. The study of this relationship in general and that of the farmers of this area and the CPR is, by definition, beyond the scope of this report. However, given the lack of close cooperation between these two parties, it is no surprise that critics of the Brooks Aqueduct can find many legitimate as well as contrived faults in the design, construction, operation and maintenance of the flume.

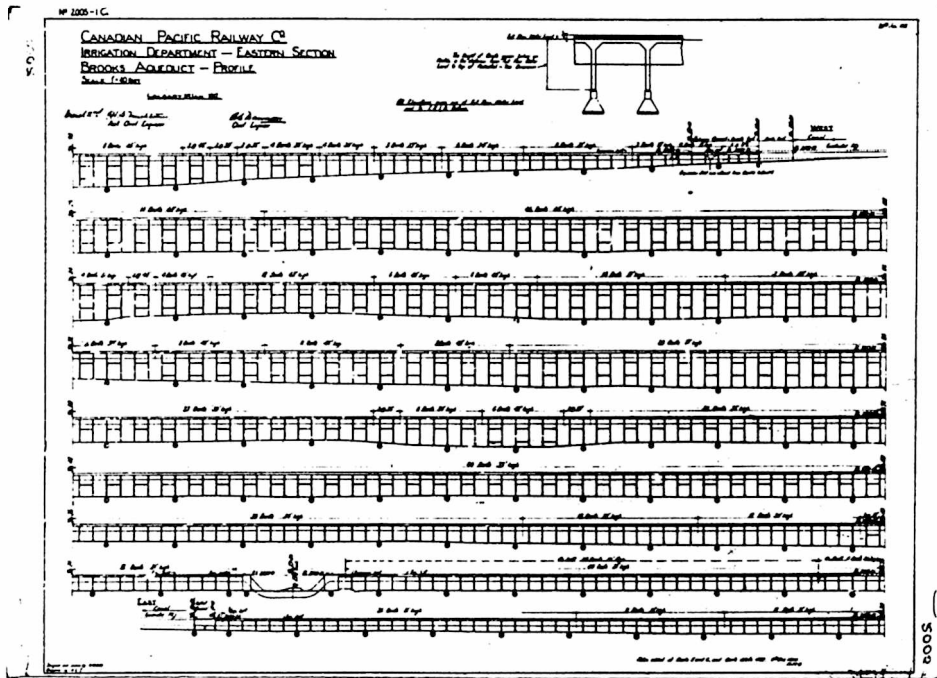
Therefore, the Brooks Aqueduct is best described as an engineering and technological forerunner of reinforced concrete irrigation flumes which, although plagued by various design, construction, operations and maintenance flaws, carried many hundreds of millions of acre feet of water to farmers at an economically viable cost for 65 years without major failure.

Appendix A

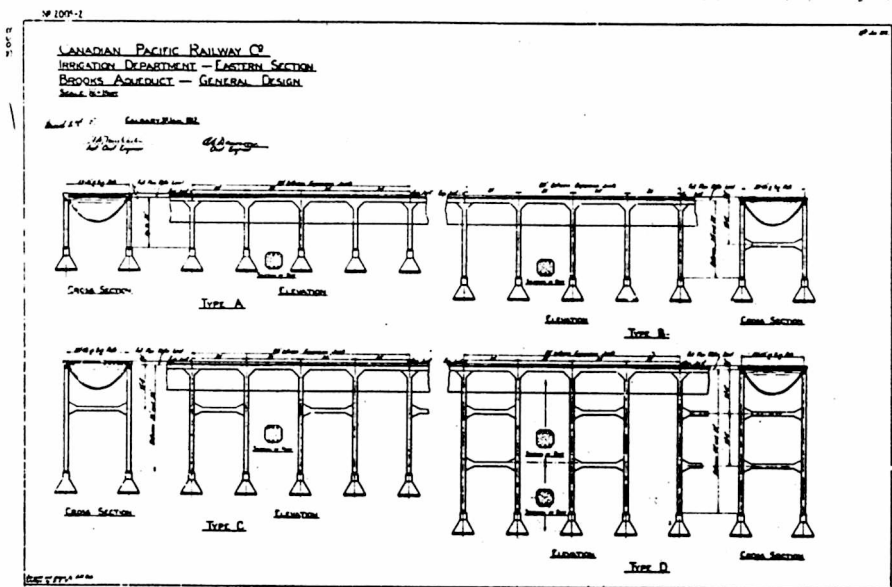
As-built drawings of the Brooks Aqueduct

The as-built drawings are not all microfiched. The ones which follow are available at the Eastern Irrigation District offices as well as at the Glenbow-Alberta Institute Library and Archives. The originals, and more, are at the Irrigation District offices in Brooks.

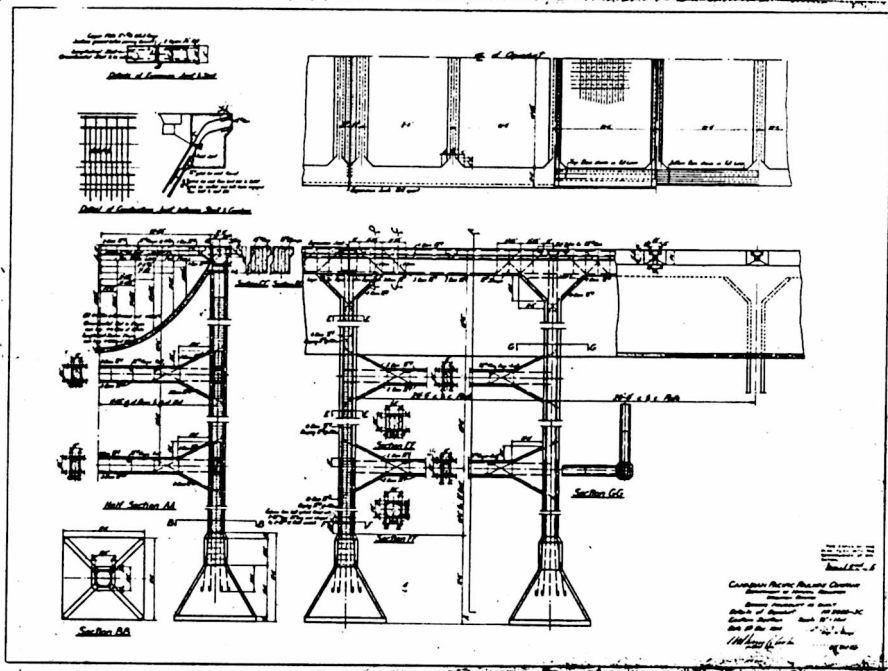
Drawing No.	Title	Date
2005-1C	Profile	31st January, 1912
2005-2	General Design	31st January, 1912
2005-3C	As-built details	5th December, 1914
2005-4C	Plan of Inlet	5th Decemher, 1914
2005-5C	Plan of Inlet	5th December, 1914
2005-6C	Siphon Crossing	5th December, 1914
2005-7	Girder Span over Siphon	31st January, 1912
2005-8C	Plan of Outlet	5th December, 1914
2005-9C	Topography of Site	31st January, 1912
2005-11	Stress Sheet	no date
2204-3	Chute for spillway	5th September, 1918
2204-1	Spillway	5th September, 1918



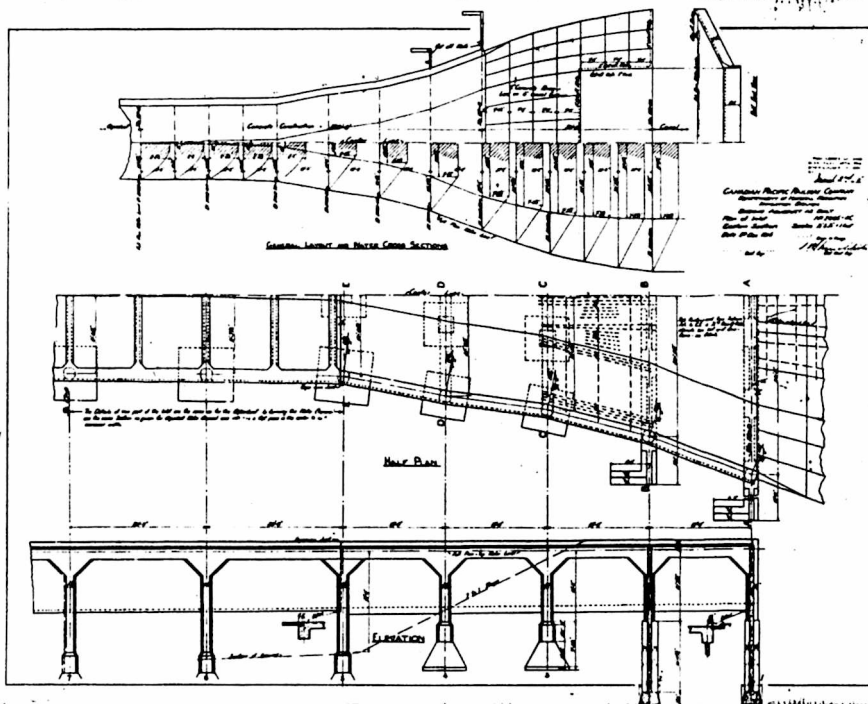
31st January, 1912



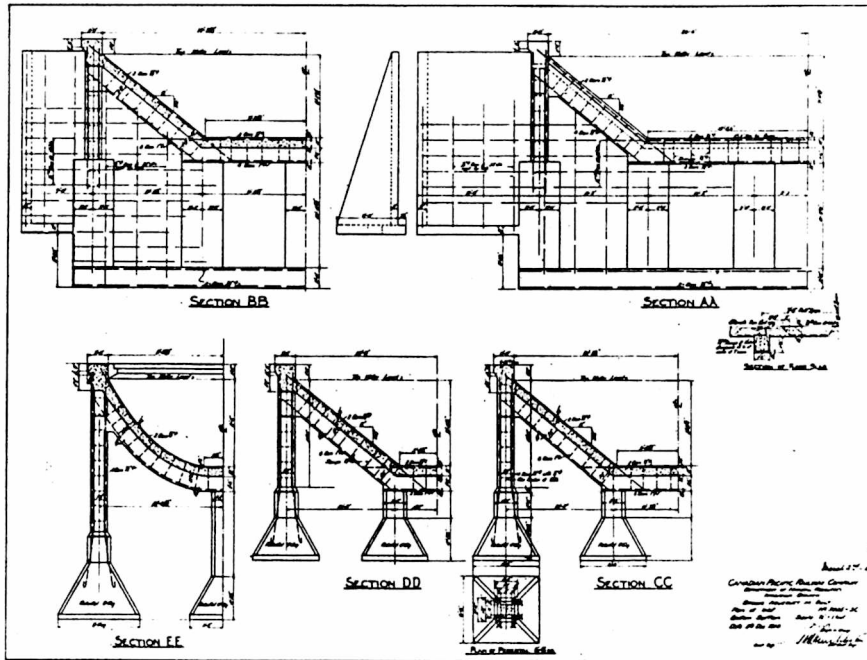
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2005-3C As-built details 5th December, 1914



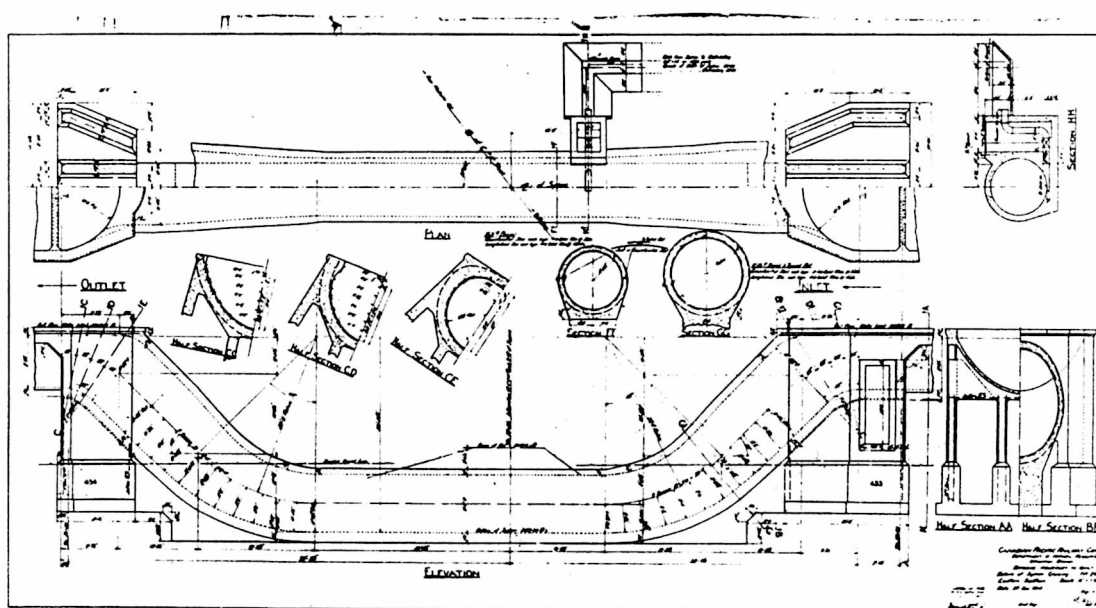
2005-4C Plan of Inlet 5th December, 1914



2005-5C

Plan of Inlet

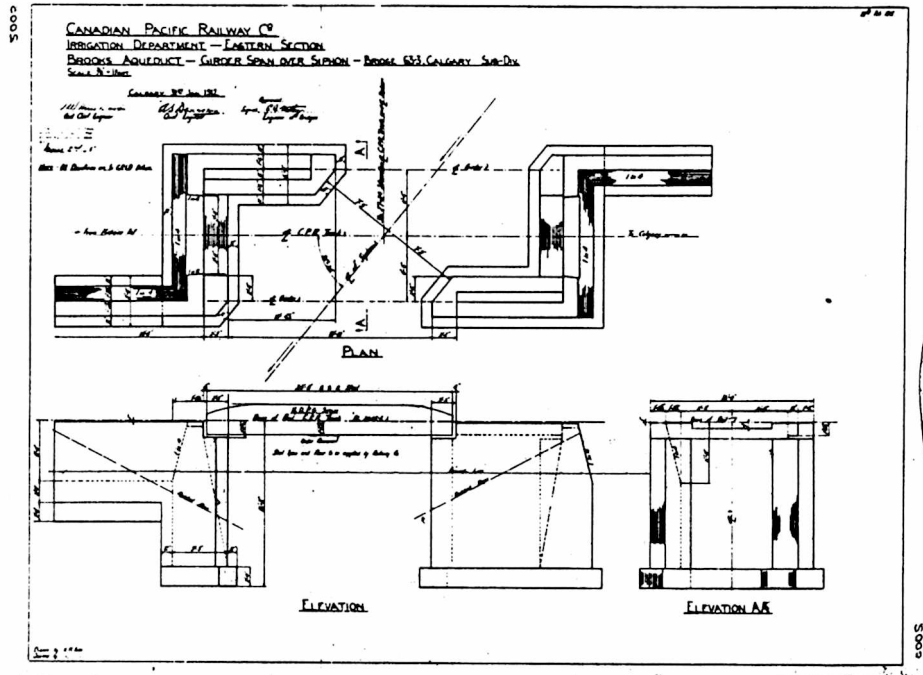
5th December, 1914



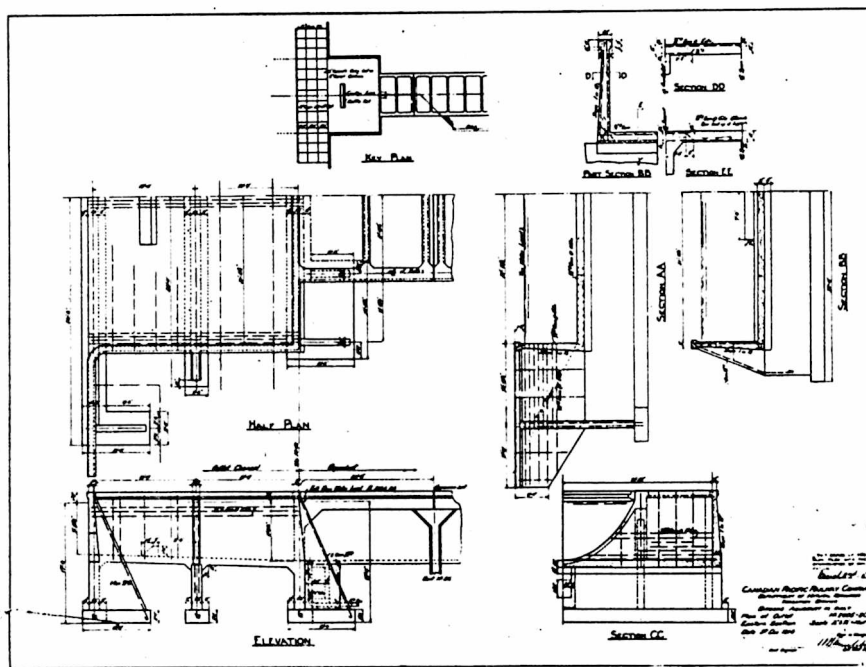
2005-6C

Siphon Crossing

5th December, 1914



2005-7 Girder Span over Siphon 31st January, 1912



2005-8C Plan of Outlet

5th December, 1914

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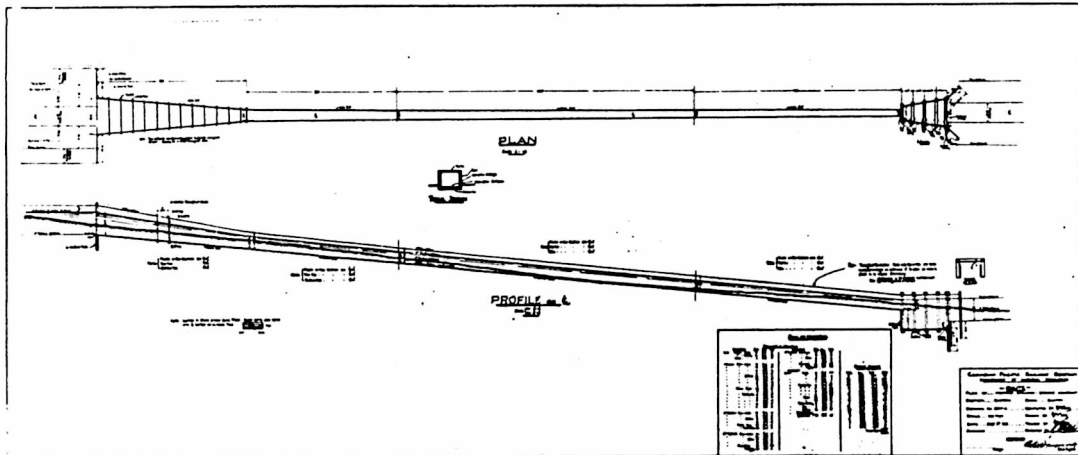
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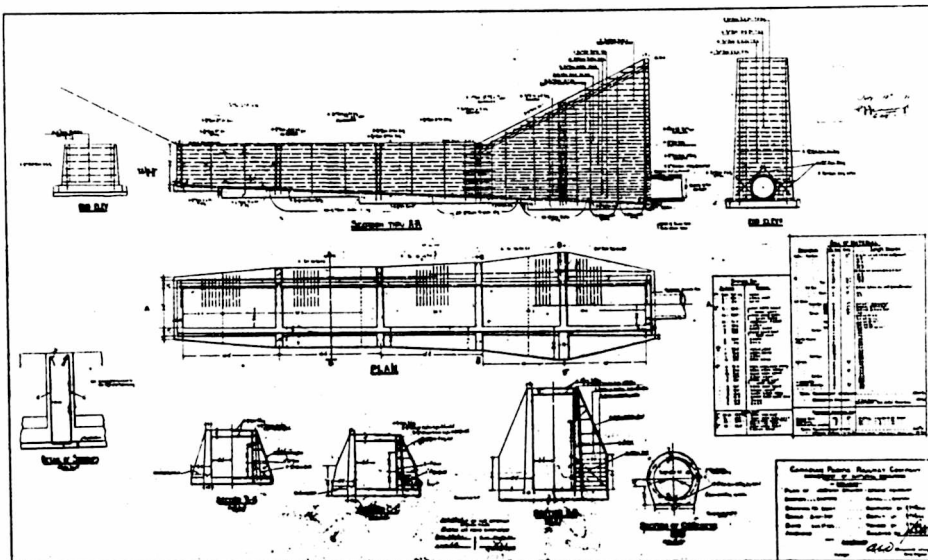
no date



2204-3

Chute for spillway

5th September, 1918



2204-1

Spillway

5th September, 1918

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As this report constitutes the analysis and interpretation of the history of the Brooks Aqueduct in the Eastern Irrigation District of southeastern Alberta, it relied heavily upon the source assembly which was completed by Elise A. Corbet in 1986. A few additional materials were found while researching and writing this document that were not mentioned in the source survey. These include the Department of the Environment papers at the Provincial Archives of Alberta, Records of the Department of the Interior and the Water Resources Branch in the Public Archives of Canada as well as the articles by R.E. Loov and D.H. Manz, et. al. listed below and interviews conducted by the author. Therefore, those interested in pursuing further research into this topic should use the following bibliography in conjunction with the source survey.

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