Edward Bell and the Technology of Sydney's Third Water Supply Scheme

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Abstract

Sydney was declared a city in 1842 and The Sydney City Council was formed. The Council became responsible for the construction of much of the city's infrastructure and one of the biggest problems that they faced was that of water supply. The condition of the old tank stream was putrid and it had been abandoned in 1826. Lachlan swamps and Busby's bore could not supply sufficient water for the growing city. A third water supply scheme was needed.

In 1856 the City Commissioners appointed an Englishman, Edward Bell, as the City Engineer and he was charged with the task of making a flawed concept work. Sydney's third water supply scheme involved the creation of dams, pipes and pumping engines but it also necessitated the construction of buildings; a pumping station and two reservoirs. These buildings were the first of their types in Australia and they saw the importation of English technologies and their adaption to the local sites and circumstances.

Drawing on the archives of the City of Sydney and Sydney Water, newspapers from the period, reports of the various water enquiries and elements of the remaining structures, this paper investigates the work of Edward Bell and some of the innovations and technologies that he implemented in the design and construction of Sydney's third water supply.

Introduction

The Third water Supply Scheme for Sydney was surrounded by controversy and mired in politics and was seemingly constantly discussed in the media of the day. What was often not appreciated at the time and even less so now, was the extent of the technological achievement that created a city wide water supply scheme that was no longer completely at the mercy of weather and climate. Whilst the expanding city meant that the scheme was finally superseded by the more extensive Nepean Scheme, the third water supply scheme, also known as the Botany Swamps Scheme introduced technology from Britain

that had never been used before in Australia, indeed several elements of it were still relatively new in Britain. The scheme also engaged local engineers, manufacturers and contractors who contributed to the project through the manufacture of the pipeline, the construction of the buildings, the installation of the machinery and equipment and through the production of ancillary items, particularly for repairs and maintenance. In several instances Australian materials, particularly timber and stone, were used adjusting the British design and technology to suit.

This paper will focus on the period from 1856 to the close of 1870 when, despite the enquiries, previous designs and false starts the final scheme was designed and realised by Edward Bell, Sydney's city engineer. Edward Bell is a fascinating and arguably much undervalued figure in the history of Victorian Sydney. His training was broad, his skill significant, his knowledge extensive and his perseverance is evidenced by the fifteen years that he worked for the City Of Sydney. Despite being a "eminent engineer" and a "professional gentleman"[1], he also seems a somewhat irascible character and a study of this man is long overdue but this paper will resist the temptation to examine the life of Edward Bell in detail and rather focus only on his role in the Third Water Supply Scheme for Sydney and the technology it introduced into Australia.

Sydney's First and Second Water Supply

When Captain Arthur Phillip made the decision to settle the first fleet in the cove known as *War-ran* by the indigenous population and later named Sydney Cove, the most significant driving factor was the "finest spring of water."[2] This became known as the tank stream and was the first water supply for the settlement. Despite numerous efforts to keep the tank stream clean, the combination of drought, rising population and misuse of the water meant that the Tank Stream supply soon became insufficient in both quality and quantity.

In 1826 John Busby, a mineral surveyor for the Government, was asked by the Governor Sir Thomas Brisbane to find an alternative source of fresh water. Busby recommended drawing a supply from the Lachlan swamps in the area of what is now Centennial Park by a pipe that was to lead to a reservoir at Hyde Park, then known as the Racecourse. The pipe was undertaken but the reservoir was not, instead the pipe was supported on trestles once it reached Hyde Park so that water carts could be easily filled before they distributed the water throughout the city.

With an ever increasing population and droughts regularly affecting the supply, dams were constructed at several points to conserve water. A severe drought in 1849 brought the topic of a reliable water supply to the fore again and a steam pump, the first in New South Wales was installed in 1854 at the lower end of the Lachlan swamp to boost supply but it was never going to be a long term solution.[3]

Sydney's Third water Supply Scheme

Sydney had been plagued by droughts on a frequent but unpredictable basis since the first days of the colony. In 1849 a severe drought with less than a quarter of the annual average rainfall, brought the problem of a reliable and consistent supply of water for Sydney to prominence once again. Sydney had become a city in 1842 and by 1849 the population had reached forty thousand. Two investigations were conducted into possible water supply options; firstly, in 1849 by the then City Surveyor Francis Clark and between 1850 and 1852 by a Special Committee of the Council. Perhaps in frustration at the lack of action to resolve the water supply problem, in January 1852 the Governor, Sir Charles Fitzroy, appointed a board with five members to look at how the Botany Swamps could be used to provide the water supply for Sydney. The recommendations of this board established the main features of what became the Botany Swamps Water Supply Scheme.[4] These included the establishment of a pumping station on the Botany swamps with water pumped to mid and high level reservoirs that would then feed water by gravity to the population of the city.

The Sydney City Council was sacked by the New South Wales government in 1853 and replaced by three commissioners. William Rider who had been the City Engineer under the former council was asked to prepare a design for the Botany Swamp water supply scheme based on the recommendations of the board. The scheme was centred on two existing ponds on land owned by Simeon Lord, Mill pond and what became known as Engine pond.[5]

Rider prepared designs for the scheme to pump from the dams on Lords land which had been acquired by the council, to a mid-level reservoir in Crown Street Surry Hills with a high level reservoir planned for an as yet unidentified site in the vicinity of Victoria barracks at Paddington. Rider's plans were elaborate, expensive and had serious design flaws. The manufacturers of the engines that were to pump the water Thomas Perry and Son of Bilston, Staffordshire in England, found the design and documentation so poor that it was "impracticable to execute the designs"[6]. However they had a contract to supply and in order to avoid being in breach of that contract consulted "one of the highest

authorities upon hydraulic engineering in England"[7]. It seems likely that this was Thomas Hawksley, an English civil engineer who had a significant role in many of the major water supply schemes in Britain.
Hawk(e)sley wrote in a letter to the manufacturers;

> "the design is exceedingly defective and obscure, and the drawing and specification so imperfect and contradictory on many important particulars, and so physically impossible on others, as, in the entire absence of other information, to render it necessary for you to depart in some important particulars from the express direction of the engineer in order to produce a working machine, and in other respects to supply the deficiency of instruction by the best inferences that can be drawn from the general contract and intention of the documents rendered for your guidance."[8]

Part of the problem was "the distance of the parties" and "the impossibility of obtaining specific information in due time" but Hawksley also noted "the obvious inability of the engineer…to design in detail a work of the character of the one upon which you are engaged."[9]

There were also site specific issues. Rider had located the engine house on a foundation of deep sand.[10] This would have made it almost impossible and certainly extremely expensive to construct the necessary footings for a pumping station sufficient to support the heavy machinery required. There was also concern over the manner in which Rider had been appointed and in December 1855 it was recommended that Rider and his assistant be dismissed for fraud and corruption. Rider and the City Commissioners had disagreed over the designs for both the water supply scheme and the city's sewerage system. Rider was dismissed with no workable design for the Botany Swamps Scheme in place.

Edward Bell arrived in Sydney from England on the ship *Joshua* with his wife Mary and eleven children on 25 January 1856.[11] On The 21st of January a notice had appeared in the *Sydney Morning Herald* calling for applications for the position of City Engineer with a closing date of 4th February. On the 1st of February the closing date was extended to the 11th and on the 13th a notice in the newspapers announced that Edward Bell had been appointed to the position by the City Commissioners.[12] Bell had been born and educated in England serving "his articles working on the drainage of fens and on municipal water

supplies in Britain and Holland" and his career had "a particular focus on drainage, water provision and sewerage works" in several countries.[13]

At the same time as the manufacturers were seeking advice from Hawksley, Edward Bell had reviewed Riders documents, come to the conclusion that they were "absurd and impractical" and had with the agreement of the City Commissioners sent word to England to stop the manufacture of the engines as instructed by Rider.[14]

Working on the basic principles established by the Governors board of 1852, where water was pumped from the Botany swamps to mid-level and high level reservoirs, Bell developed a new design. It was a traditionally English design and much of the machinery and components for the various constructions were imported from Britain.

Bell established an agent and inspecting engineer in England and advised them of the requirements of the pumping system, that each "engine and pump was to deliver 1.5 million gallons per day against a head of 210 feet.[15]

The heart of the scheme was the Botany Pumping Station which included an engine house, boiler house, chimney, workshop, pipeline and reservoirs as well as a new wharf constructed nearby to facilitate the delivery of the coal which fired the boilers.

Figure 1. Botany Pumping Station
SRC2907, City of Sydney Archives

The Botany Pumping Station

Bell's design located the pumping station on the northern side of Cook's River, at its junction with Botany Bay on the site of Simeon Lord's former flour Mill where the bedrock was accessible for the foundations required to support the heavy beam engines.[16]

Whilst it has been claimed, "all of the machinery and equipment for the implementation of the Botany Scheme was imported from England and Scotland", this is not strictly accurate[17]. The tendering and ordering of materials had begun in 1854, with P. N. Russell & co. of Sydney, winning the tender for the thirty inch cast iron rising main that was to deliver the water from the pumping station to the mid and high level reservoirs. [18] The pipe had walls two inches thick and the joints in the pipe sections were "turned and bored interference fits".[19] The pipe ran in an almost direct line from the pumping station to a new mid-level reservoir at Crown Street in Surry Hills. The pumping station's foundation stone was laid in December 1857 and the station was operational within two years.[20]

The principle buildings erected at Botany were the boiler house and engine house and a 142 foot high chimney. The engine house was built of stone from George's River and measured fifty feet by forty feet. It was two storeys high with ironbark beams but despite the use of native stone and timber it "was representative of English practise of the day."[21]

Figure 2. Steam Engine Cylinder with Fairbairn drop Valves, 1856. Museum of Applied Arts and Sciences.

The machinery in the buildings and their expected performance were summarised in the *Illustrated Sydney News in 1872;*

> In this building there are three steam engines of 100 horse-power each, six boilers 36 feet in length by 74 feet in diameter, and three large lifting or

> forcing pumps, by which the water for the supply of Sydney is impelled through the 30-inch cast iron main pipes which extend from the Botany engine-house to the reservoirs in Sydney, a distance in a straight line of about four and a half miles. Each pump is capable of sending into Sydney one hundred and forty-four gallons of water every rise and fall of the engine-beam, or two and a half millions of gallons every twenty-four hours; so the three engines combined are able to send in seven and a half millions of gallons daily, or about forty gallons per head for a population of 188,000.[22]

The public showed significant interest in the technical specifications of the pumping station machinery and the newspapers supplied the information. Further details were provided in the Sydney Morning Herald;

> To give some further idea of the size of the engine we may state that the beams are 24 feet in length, which is also the diameter of the fly wheel; the ring of the lathe, without the arms, weighs 19 tons 16 cwt; its entire weight is 36 tons…The width of the cylinder is 42 inches."[23]

The three massive single cylinder vertical steam engines by Thomas Perry and Son were shipped to Australia and installed at the pumping station in 1858. The engines were unique in the colony and were representative of the last generation of beam engines, typically large rotative engines that powered water and sewerage pumping stations. The steam engine cylinder of one of these engines is held in the collection of the Museum of Applied Arts and Sciences in Sydney.[24] [Figure 2].

The engine has Fairbairn drop valves and the visible part of the valve gear includes the means to select the point in the engine cycle at which the steam supply is stopped. This feature improved the energy efficiency by making use of the continued expansion of the steam after it had been cut off. [25] To prevent the condensing of cool air on the outside of the cylinder it was first covered with a course woollen fabric called drugget and then encased in polished cedar slats.[26]

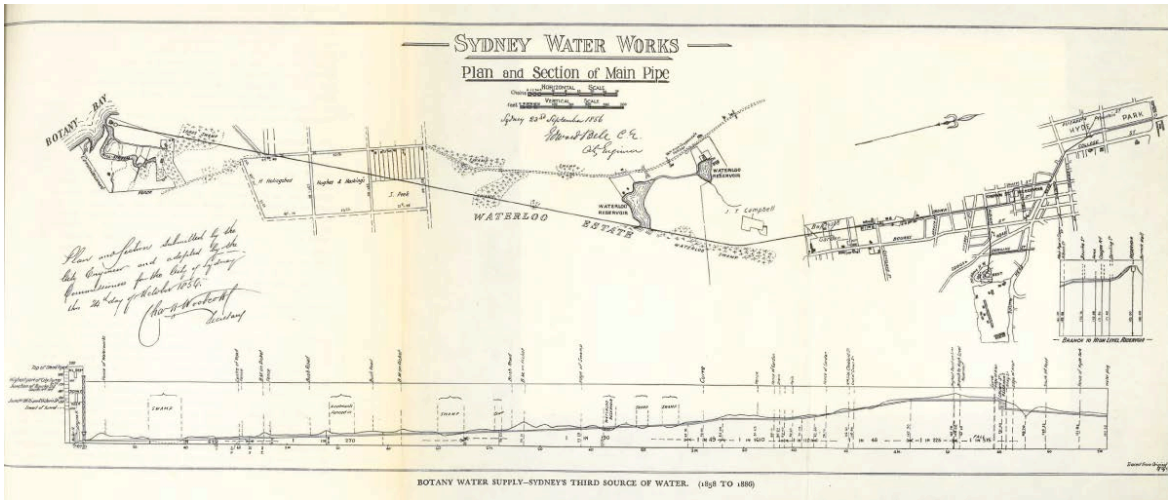

Figure 3. Sydney Water Works Plan and Section of Main Pipe. Edward Bell.
From F. J. J. Henry *The water Supply and Sewerage of Sydney,* opposite page 48

The traditional English method for balancing the pressure of each pump up until the 1850s was the use of a standpipe – in this case 220 foot high. It appeared in Bell's early designs and can be seen on his drawing of the scheme dated 23rd September 1856, [figure 3] but he subsequently replaced the standpipe in the design by pressure vessels for balancing the head for each pump.[27] This was one of Bell's technological improvements over previous schemes. Pressure vessels had only recently been used in England and Bell, clearly aware of the latest English technology and in communication with engineers there, modified his design to utilise pressure vessels.

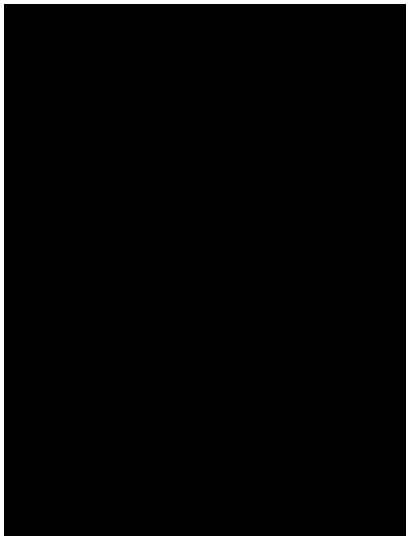

Figure 4. Section through the Engine House showing pressure vessels
Botany Wetlands Heritage Study.

The boiler house was also of stone, a single storey high and measured seventy six feet by fifty feet. It contained six coal fired boilers, each seven feet in diameter and thirty six feet long with each containing two fireplaces.

The pumping station was operational by the end of 1859 and replacement parts were manufactured in Australia from the earliest years of its operation. James Moores, George Allwood and Nicholas Gifford supplied three pumps in 1866, Chapman Brothers supplied a cylinder cover that same year and P N Russell manufactured two cast iron pump barrels.[28] The Dry Dock Engineering Company in Balmain provided two pistons for steam cylinders of the pumping engines at Botany Water Works in 1871.

The application of science and industry at the Botany Pumping Station was a hugely significant undertaking in technological and economic terms for mid-nineteenth century Sydney but the pumping station was only part of the scheme that also involved reservoirs and dams.

Figure 5. Engines at the Botany Pumping Station.
SRC2906, City of Sydney Archives.

Crown Street and Paddington Reservoirs

The pumping station was connected to the mid-level reservoir at Crown Street in Surry Hills by the thirty inch main by P. N. Russell & co. The Crown Street reservoir still exists and is still in full operational use although the three and a half million gallons of water it contains today comes from the Nepean rather than from Botany. The reservoir is located 139 feet (42.367m) above sea level and the original design by Bell was also a typically English design in most respects.[29] Construction commenced in 1857 and the structure

was built partly in excavated rock which was sealed with bitumen and partly on fill with the floor in brick. It was divided into two equal parts and constructed with brick walls that were faced with approximately 300,000 impervious glazed bricks imported from England.[30]

The roof structure comprised cast iron fish-belly girders supported on 170 ironbark columns, each twelve inches square. The column capitals were also imported from Engl`and, manufactured by Rabne Feez and Co. The arches cast iron cross stays followed the shape of the brick jack-arches.[31]

The jack-arch was developed in England towards the end of the eighteenth century, primarily as a means of fireproofing mill construction. In an article about the origin and use of the jack-arch in New South Wales, the conservation architects Sean Johnson and Ian Stapleton claim that “its first use in Australia was at the Old Treasury Building, Melbourne” which was constructed between 1858 and 1862. The Crown street reservoir was complete with its roof sealed with tar and covered in puddle clay in 1858. It was then covered in soil and sown with grass.[32] The reservoir was in service by 1859. It is therefore almost certain that the Crown Street reservoir was the first use of the jack-arch in Australia.

Another ‘first’ for the Crown Street Reservoir was the load testing of its beams. The cast-iron beams were individually load tested to 50% greater than the expected load prior to construction, a new practise in Australia at the time. The practise was first used in England only six years earlier for the construction of the Crystal palace in London in 1851. Not all the construction technology was English. English practise of the time would have supported the beams on cast-iron columns. In the Crown Street Reservoir and the later Paddington reservoir, Australian hardwood ironbark columns were used.[33] Some of these are still in existence at both reservoirs.

Figure 6. Crown Street Reservoir
Sydney Water, 2009.

To further increase the storage of water and to supply the parts of the city and suburbs at higher elevation, a second reservoir was constructed at Paddington with the initial section beginning in 1864 and completed in 1866. A further section was designed to expand the capacity of the reservoir and was built between 1875 and 1878. The combination of technologies used in the Crown Street and Paddington Reservoirs proved to be unique as later reservoirs at Woollahra, Waverley and Petersham used brick columns to support their brick jack-arched rooves.

Initially the Crown Street Reservoir fed water via gravity to properties at lower levels of the city and suburbs but in 1879 a pumping station was completed at Crown Street to pump water up to the Paddington Reservoir. This was the first water pumping system to use Australian made equipment, the pumps being manufactured by *Mort's Dock and Engineering* at Balmain with water valves produced by P. N. Russell and Co.[34]

The Botany Dams

Although the water supply had not failed during the early years of the Botany pumping stations operation, the inadequacy of water storage at the lower end of the scheme that relied principally on Engine Pond made it necessary to turn of the water supply at night. In 1866 a reliable water supply was a regularly discussed topic again in the newspapers and between 1866 and 1867 Bell prepared plans and specifications for six additional ponds between Mill Pond and Gardeners Road, along the line of Mill Creek and work began in 1867.

The dam walls were constructed of a framework of timber beams that were bolted together with iron bolts and closely fitted vertical planks were fixed to both sides of the frame. Two of these frames were then sloped outwards in opposite directions and the space between filled with fine silt mud or bog and sand.[35] The dams were built between high natural sand banks that bordered the stream. The dams were covered in couch grass, and were raised 14 feet above the swamp level. A weir of eight feet above swamp level was inserted to accommodate flood overflow. A sluice was centred along the watercourse in each dam.[36] Bell also erected a puddle wall to protect the Engine Pond dam better from salt ingress.[37]

The 'bog' was applied to the surface of the dam with the intention that it would seep into the body of the work through capillary action of the water. Once there it would consolidate within, filling voids and providing an additional cement to stabilise the earthen structure [38]
In October 1867 during *the Commission appointed to inquire into the supply of water to Sydney and suburbs* Bell was asked about the dam's design because severe damage had occurred during construction due to storms. Despite doubts by some of the commissioners, Bell insisted that the design was sound and was adamant that they would perform adequately.
In February 1868, with the inquiry continuing, heavy rains severely damaged some of the completed dams. Bell was recalled to testify again and asked if the fact that three of the dams had been partially destroyed by the floods had shaken his confidence in the principles of their construction. Bell replied that "the principle of their construction is correct. The partial destruction of the three lower dams is attributed to the stupidity or negligence, if nothing worse, of the man who was charged with them who had not opened any of the weirs or sluices to relieve the water pressure, contrary to his instructions".[39]

Further dams were planned but never constructed although after Bell left Sydney in 1872, several further additions were made to the scheme including in 1879 a pumping plant at Crown Street reservoir to lift water up to Paddington Reservoir and in 1881 a supplemental plant was installed to raise the water up to Woollahra Reservoir, which had been completed in 1880.[40]

In 1884-5 a severe drought dried up the ponds at Botany with only Engine Pond holding water. Hudson's temporary scheme was initiated to bring water from the Upper Nepean into the Botany Supply Scheme and this was achieved in 1886 but this was effectively the end of the Botany scheme although it continued as a backup supply until 1893.[41]

Throughout the life of the pumping station it was added to, repaired and modified until its closure in 1996 when the machinery and equipment was sold, the chimney reused to vent the sewer and later truncated to accommodate the flight paths of aeroplanes to the Kingsford Smith Airport. The workshop, the wharf, the boiler house and some parts of the Engine House were demolished but part of the Engine House and Chimney remain.[42]

The third water supply scheme for Sydney contained some of the latest technological advances in Britain at the time for water supply schemes even though it was half a world away. Innovations such as the Fairbairn drop valves and pressure vessels meant that the Botany Pumping Station was what we would today call "World Class". The innovative use of the jack-arch in the Crown Street reservoir was arguably its first use in Australia. The individually load testing of beams was progressive practise that was to become commonplace after its debut on the construction of the Crown Street Reservoir. The construction of the reservoirs at Crown Street and Paddington used local hardwood for the column supports, an innovation that proved sound, many of these posts still functioning today. The third water supply scheme for Sydney was the largest technological project of its time in the country and the fledgling local manufacturing companies such as P. N. Russell & co. and Morts Engineering works at Balmain played their part contributing to both its creation and its maintenance. For Edward Bell, the irascible but persistent and highly skilled engineer, this was undoubtedly his most technologically complex achievement in Australia. He dealt with the issues of the previous flawed concept, delays in construction, political interference, repeated governmental inquiries, criticism in the press, failed contractors, poor maintenance and possibly incompetent workman and yet despite it all brought to fruition a constant and reliable water supply for Sydney.

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