Water history

Molteno – 'Old boy' of Cape Town still in service despite chequered start

Despite its shaky start, the Molteno Reservoir remains a key part of the City of Cape Town's water supply more than 130 years after its initial construction. Arne Singels traces the history of the reservoir and lifts lessons from its construction for today's water engineers.

Wikipedia

"There's a tank as you might say at the back o' that big hotel up the hill – what do they call it? 'The Molteno Reservoir', I suggested and Hooper nodded," wrote Rudyard Kipling.

It is the year 1870 and Cape Town Municipality is one of nine independent municipalities at the foot of Table Mountain. Up to now the town's growing demand for water has been dependent on water available from numerous springs emanating on the lower slopes of Table Mountain as well as from a few streams.

Two reservoirs have recently been built to store enough water to meet the demand during the dry summer months. These reservoirs are rather limited in size, namely 11.4 Ml (1852) and 54.6 Ml (1860). Both are situated at a level of 56.6 m above sea level, being too low to supply the required pressure for the growing reticulation system. They are rather aptly termed the Lower Service Reservoirs.

John Gamble was appointed by the Colonial Government as the first Hydraulic Engineer in the Colony. He was instructed to advise the city on water matters and advocated the construction of a large reservoir on Van Breda's field, at that time situated high above the town. The town decided to build a substantial storage reservoir at a higher level of adequate size to store water from the existing water resources, namely the Stadsfontein, Lammetjie, Vineyard, House, Klein Tuin, Scholtz Klip, Beltz Klip and Verlatenbosch Springs in order to supply the demand in summer. There were also two streams that would supply the new reservoir, i.e. Platteklip and Silwerstroom.

The new storage reservoir would be sited near the De Waal Park, Gardens well above the current City Centre.

Construction and initial failure

The town was experiencing rapid growth and water demand continuously exceeded the supply.

Severe water restrictions were the order of the day. In 1877, several Bills were passed by Parliament empowering the city to acquire the necessary land, a portion of the *Oranjezicht* Farm, from Mr Van Breda to build a reservoir at the top water level of 92.5 m above sea level. The new reservoir was designed under the supervision of James Tennant, the Town Engineer at the time. A contract for £98 000 was awarded to William James

in 1877 for the construction thereof. The reservoir dimensions were 300 m long, 92 m wide and 15 m deep, with an approximate capacity of 227 Ml.

The sandy soil found on site was not ideal for such a water retaining structure. The reservoir was constructed by a cut-to-fill process, with embankments on three sides. The structure was completed by March 1881 and the first water was impounded on 4 May 1881. Whilst filling to about 500 mm a wing wall to the valve shaft fell over. The Town Engineer, J Stuart Swallow, proposed the abandonment of the revetment walls and constructing a culvert from the valve shaft to a fore bay in the reservoir. Despite not being filled, the official opening of the new reservoir by Sir John Molteno, the first Premier of the Colony after whom the reservoir was named, took place on 21 July 1881.

Filling then proceeded slowly and at about 3 m depth a leak appeared in the tunnel and the water level was reduced in response. A portion of the clay puddle behind the valve tower was removed and a man-sized gap was found running along the top of the outlet culvert. This was filled with puddle clay, which had to be compacted horizontally in very limited space – a very unsatisfactory process according to a Charles John Wood, who was subsequently appointed by the City.

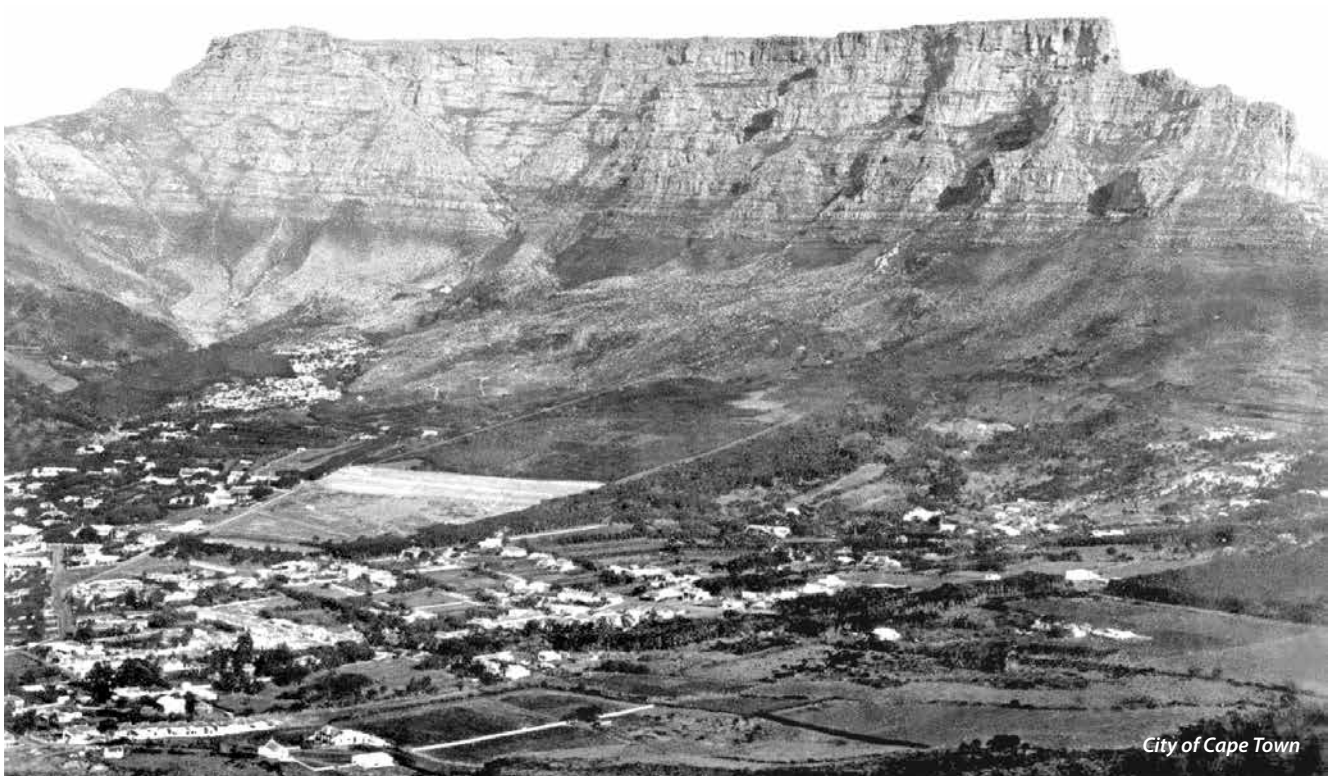
Behind the shaft concrete was placed and the puddle relaid to the top of the embankment. Filling commenced again on 21 September 1881 up to a level of about 3.8 m. Further filling proceeded on 2 April 1882 i.e. the following year, but on the 26th of the month when a depth of 4.3 m was reached a new leak was found.

An inspection hole was sunk over the culvert near the puddle-core and a 40 mm crack through the puddle was found as well as a space through the clay-core above the culvert of up to 450 mm. These were filled and water was again introduced to the reservoir to a depth of 8.2 m, when yet another leak commenced. It was found that the brickwork of the tunnel had been laid so badly that streams of water poured through the pointing disintegrating the puddle. After repair the reservoir was filled up to 10.7 m, which was later reduced to 9.5 m where it remained for three weeks and all seemed well.

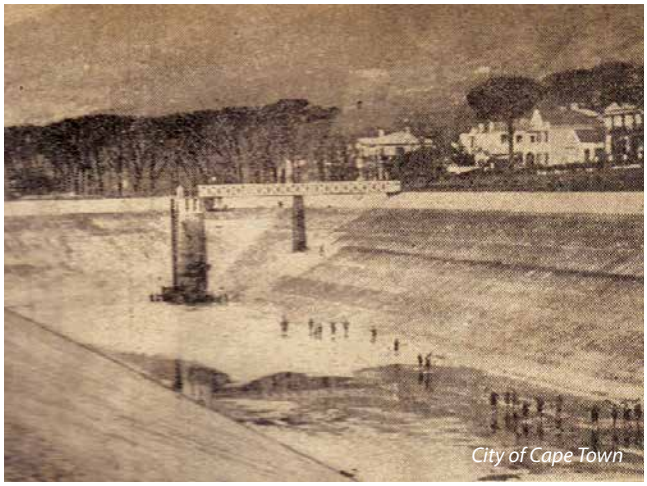
At midnight on Thursday, 23 August, a night watch reported a serious leak, but this stopped almost immediately. Precautionary measures were taken by keeping bags of clay near the valve-shaft to effect quick repairs and the water level was once again reduced and the filling stopped. Men were put in constant attendance. All went well whilst the reservoir was dropping steadily, until the morning of Sunday, 27 August 1882.

The leak broke into the culvert and carried away the filling-in around the culvert, with a resulting flood into the City streets. As the leak had commenced at the side of the shaft at a high elevation the flow was checked fairly rapidly using bags of clay that were at the ready, due to the first alarm. The flood was stopped with difficulty but relatively quickly with 6.1 m of water still remaining, preventing more extensive damage.

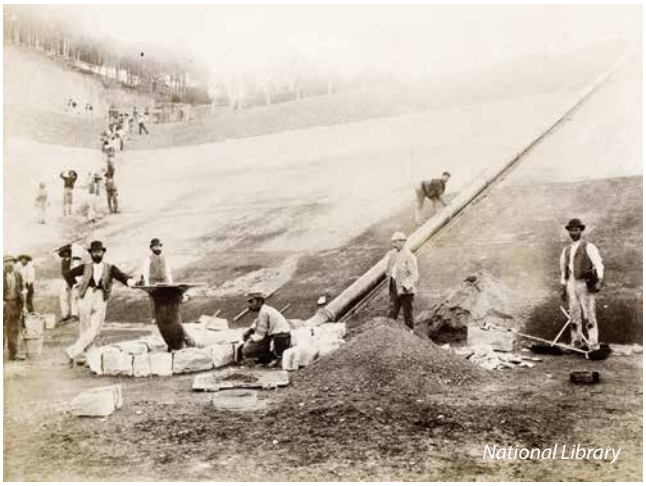
No lives were lost, but Oranje Street was turned red and the flooding impacted the city while church goers were making their way back to their houses. A garden



The Molteno reservoir under construction in 1877.



This sketch of the reconstruction of Molteno Reservoir appeared in the press in 1885.



The Molteno Reservoir being repaired following its failure in 1882.

wall collapsed, a light cart overturned and furniture in houses below the reservoir was damaged. It was further reported in the newspapers that certain roadways had deep ruts in them due to the flood water and that pipe bursts caused by undermined pipework were being repaired by municipal staff.

The reservoir where the leak had occurred was visited by many inquisitive citizens. By 10 July 1883 the reservoir was emptied through controlled consumption. The loss of water was not the only complaint about the reservoir. Residents in the neighbourhood complained about the general leakage doing damage to their properties situated below the reservoir and were very much against the City attempting any further repairs or filling of the reservoir and it remained empty for over a year.

The City then approached the Institution of Civil Engineers (United Kingdom) to select an engineer to advise on the causes of the failure and a method of repair. The task was offered to Charles John Wood, who subsequently arrived in Cape Town from Britain on 21 January 1884, was appointed by the city to report on the failure and to propose remedial work to render the reservoir serviceable. He reported to Council by March the same year.

Analysis of failure

In his report to the City, Charles J. Wood states quite correctly that it is more difficult to repair a reservoir which, for whatever reason is not watertight, than to do the work ab initio. Regarding the water tightness of the reservoir he states that he is convinced that most of the leakage occurred through the floor and was due to unsuitable material for a pressure of about 14 m of water. The 610 mm puddle that was used in the floor was inferior, half-worked and could hardly be distinguished from the floor material.

Similarly, the 300 mm puddle on the slopes was hardly discernible. Furthermore, the ends of the embankments had not been tied into the hillside and the puddle trench should have extended 6.1 m deeper than was constructed. The clay was found to be unreliable and not well worked and, in fact, no suitable clay could be found in the area.

Wood also found that the bursting of the reservoir along the culvert was caused by the over-excavation through the undisturbed ground under the embankment for the culvert. After the construction of the tunnel, the surrounding space had been filled in by labourers who worked without proper supervision and executed the work poorly. This caused the settling of the puddle-core and the occurrence of cracks which resulted in the leakage.

He recommended that 610 mm-thick Portland cement concrete be used to line the floor of the reservoir and the slopes to a level of 2.44 m above the floor. For the next 6.7 m, 460 mm-thick concrete was to be placed on the slopes up to 4.5 m below Top Water Level. Above this the embankment slopes had to be cut back by about 910 mm, the original puddle had to be reworked and replaced, a 300 mm layer of gravel placed and stone pitching added. This was then to be blinded with gravel.

A cut-off wall was to be built around the culvert and a second cut-off 1.22 m thick at the existing puddle trench backed up by a reworked puddle.

Regarding the Eastern culvert and embankment, he proposed that the whole culvert be excavated to invert level and a new one be constructed, founded and surrounded by concrete. The old valve shaft was to be demolished and a new one erected with brickwork and cement mortar further into the reservoir.

Access was to be provided by means of a Warren girder bridge, the one visible today. He also suggested a stone wall at the top of the embankment (North & West sides) to prevent the South-Easter storm winds from blowing water over the embankment and damaging it.

Wood also concluded that the embankment of the Molteno Reservoir was of "enormous strength and proportions," and thus inherently stable. His repair works therefore focussed on making the reservoir waterproof.

During the reconstruction work required, Wood emphasised the need for a competent Inspector of Works and a dedicated Resident Engineer to oversee the works – an element sadly lacking in the original construction of the reservoir. The reservoir was to be filled incrementally after completion of the works. The initial filling would be to 9.1 m in the first year and then 1.5 m for each successive year, with continuous thorough inspection of the structure.

Reconstruction

After a year's delay due to uncertainty, the recommendations of Charles John Wood were accepted and a contract was awarded in 1884 to a local firm, Messrs Ball & Smart, to repair the structure for £35 000. The repairs took 18 months, the cost of the contract was £37 346 7s 2d and final completion was in 1886.

At the beginning of June 1888 the reservoir was thoroughly cleaned during which concrete lining was found to be faulty in places. Three concrete experts were called in to report on this and 19 test holes were made in the lining, although the City Engineer found this inadvisable as he felt that any breach could not be restored to its original state.

The experts concluded from the test holes that the concrete was not strictly in accordance with the requirements of the contract. The reservoir was, however, refilled to about 125 Ml with no sign of leakage. In the Mayor's Minute of the year ending September 1889 it was mentioned that, after the construction and completion of the reservoir, a small stream of water had been noticed at the side of the reservoir.

Wood was of the opinion that this was drainage water from the mountain being impeded by the reservoir. Others thought that this was a more serious leak from the reservoir itself. When the reservoir was empty, the stream was measured at 196 kl per day and with the reservoir full it remained the same, supporting Wood's theory.

Further work was done on the embankments. The City Engineer's Annual reports of 1907 and 1910 state that the embankments of the Molteno reservoir were repaired in places. The pitching of the internal surfaces was grouted to about 150 mm above the high water mark and further grouting was to be executed on the slopes three years later.

Modern status

When the Molteno Reservoir was emptied in 1976 the slopes of the reservoir were lined with a concrete layer about 45 mm thick. This layer extended to above the Full Supply Level, over the original concrete slab(s) and the stone pitching above them.

The first dam safety inspection was conducted in August 1989. When a geotechnical investigation was undertaken in 1983 as part of a proposal to construct a roof over the reservoir, a number of trial holes were excavated through the concrete lining. These generally showed the lining to consist of a 500 to 600 mm layer of cement stabilised gravel covered by a 75 mm-thick concrete layer.

The question of roofing the open (now treated) water reservoir has been an ongoing debate which was started by the Medical Officer of Health in 1904 when he recommended that the reservoir should be covered. He commented that the township above the reservoir was "not a source of comfort".

Covering the reservoir was considered at the time by the City Engineer, RO Wynne-Roberts, but it was found to be too expensive and was deferred. For many years, every junior engineer joining the Waterworks Branch of the City of Cape Town was given the task of designing a roof structure for the Molteno Reservoir.

The last effort was in 1983, when Peter Roux under the guidance of JG Welsh undertook an in-depth investigation, which included an option to accommodate sports fields on the roof for a nearby school. Apart from being very expensive, the main engineering problem was the lack of loading capacity of the in-situ material for the column foundations. The covering of the reservoir would be a controversial option if it had to be done today and would attract considerable resistance from the property owners in the immediate vicinity. For now, this option is still being deferred.

Lessons learnt

The shape of the Molteno Reservoir and the cut-and-fill method has been repeatedly used for a large number of the City of Cape Town's more modern service reservoirs. The obvious difference in these reservoirs is the fact that roofs are provided to protect the water quality. Another improvement is the use of underdrainage systems enabling reservoir floor leakage to be measured and floor integrity monitored.

This was probably the first lesson learned from the Molteno failure. For the construction of any large bulk water infrastructure executed under contractual arrangement (the Waterworks Department constructed a number of significant structures internally) the Bulk Water Branch has consistently assigned a full-time dedicated Resident Engineer and Assistant Resident Engineer from its own staff. This has ensured the quality of workmanship and has no doubt prevented potential disasters such as were experienced with the original Molteno contract. This is a most valuable lesson to learn and an approach not to be deviated from in future.

This article was extracted from a paper presented at the SANCOLD Annual Conference 2015.

The Molteno Reservoir with the De Graaf Electric Lighting Works in the background.