

## Water-distribution efforts in Madras: from sailor George Baker (1750s) to engineers John Jones, Hormusji Nowroji and James Madeley (1870s–1920s)

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*Madras (now Chennai) has been, and is, an acutely water-scarce city. Today the city's landscape has undergone substantial changes losing many of its reservoirs. In this context, here we highlight the efforts made in distributing water to Madras residents from the late 17th to the early 20th centuries. In the 1770s, George Baker, a sailor, dug large wells in the 'Seven Wells Street'. In the late 1860s, James Fraser (Madras Engineers Corps?) proposed to the Government at Fort St. George that the Kôsastalai river should be accessed for water for Madras and the water be stored in the now near-extinct Spur Tank. Kilpauk – about a kilometre away from the Spur Tank – was chosen, instead, because of cost. The Madras-Municipal Water Works (MMWW) at Kilpauk was formally launched in 1872. Although the Government of Madras owned the MMWW, the Corporation of Madras (CoM) retained the responsibility of day-to-day water distribution. In the 1880s, John Alfred Jones, executive engineer, CoM, improved the open channel that delivered water from the Red-Hills reservoir to Kilpauk. He proposed construction of filter beds in MMWW. In 1903, an Indian engineer Hormusji Nowroji from the Government service was seconded to CoM. During his stay with CoM until 1912, Nowroji worked on improving water distribution. He submitted a report to the Government, the Nowroji Report, untraceable today. James Madeley from Manchester, UK, was appointed as the Special Engineer to CoM, in-charge of drainage works. Because his position was equal to that of the Chief Engineer, Madeley is today credited for developing water distribution in Madras. This note refers to the scientific water-works of Jones, Nowroji and Madeley. It also brings to light a controversy, not been spoken about previously. Nowroji has written in a British civil-engineering journal, *The Surveyor* (1915), challenging Madeley's report published earlier in the same journal. From the early 1970s, the Government of Tamil Nadu (Government of Madras) has been making efforts to the improve water situation in Chennai bending over backwards. One effort was to bring water from the Veerānam lake in Cuddalore district across c. 250 km. At present water from this reservoir meets most of Chennai's requirements.*

### Water in Madras

Madras (now Chennai; 13°5'N, 80°16'E) has always been a water-scarce city<sup>1</sup>. With an annual rainfall of 100–120 cm during the northeast monsoon – mostly as cyclonic showers spread over a week in October–November and with a population of 8.2 million – this megalopolis (c. 420 km<sup>2</sup>) continues to experience acute water shortage. According to the Centre for Water Resources, Anna University, Chennai, the groundwater recharge of the city has declined sharply in the last five decades because of rapid urbanization, with the natural and artificial water bodies being the principal victims. Retraction of natural rejuvenation of aquifers (<https://www.annauniv.edu/Water-Resource/research.php>, accessed on 10 May 2020) is another reason. Further, the geomorphology of Chennai permits limited subsoil-water percolation<sup>2</sup>.

Alexander Hamilton<sup>3</sup>, an English merchant, while travelling in Madras in the 1690s, remarked (p. 358):

'Fort St. George or Maderass (Madras), or as the natives call it, China Patam (Chennai-p-pattinam), is a Colony and City (note 1) belonging to the English East-India Company, situated in one of the most incommodious Places I ever saw. ...The Foundation is in Sand, with a Salt-water River on its back side, which obstructs all Springs of Fresh-water from coming near the Town, so that they have no drinkable Water within a Mile (1.6 km) of them, the Sea often threatening Destruction on one Side, and the River in the rainy Season Inundations on the other, the Sun from April to September scorching hot;...'

Before the English traders Francis Day (1605–1673) and Andrew Cogan (c. 1600–1660) arrived from Machilipatnam (16°17'N, 81°13'E) in 1640 in this area, which later grew as Madras, no reference to this terrain occurs in the ancient and medieval Tamil literature, except for oc-

casional mention of Mylāpōre and Firūalli-k-kēni (presently suburbs of Chennai) in the compositions of Nāyanār-s and Āzhwār-s (6th–10th centuries). This contrasts strongly with the abundantly cited Madurai (9°9'N, 78°1'E) and Fanjāvūr (10°47'N, 79°8'E) in Tamil literature, because of their prosperity, enhanced by the rivers Vaigai and Kāvēri respectively. In 1644, the English East-India Company (EEIC) built the Fort St George (hereafter, the Fort)<sup>4</sup> for weird reasons such as low cost of cotton fabric<sup>5</sup>. Water scarcity in Madras has been formally recorded as early as 1779. Dialogues among prominent EEIC staff on the need to survey the landscape between Madras and the Krishna–Godavari rivers took place to bring water from those rivers and to facilitate irrigation and trade in the landscape inbetween<sup>6</sup>.

Long before the British arrived in the Madras landscape, the SE segment of peninsular India included several large and small lakes, many interconnected by flood canals. For example, the

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Madurāntakam lake (c. 1900 acres) in the Pālār catchment, built by Uṭṭama Çolā (r. 970–985 AD, a. k. a. Madurāntakā Çolā)<sup>7</sup>, enabled and continues to enable irrigation of farmland in the vicinity. The Çembarambākkam lake (13°0'N, 80°3'E), 30.5 km SW of the Fort, holds about 100 M m<sup>3</sup> of water. For more details of the extant and extinct lakes of Madras city and the Presidency, see Amirthalingam<sup>8</sup>.

In the ancient and medieval Tamil country, agricultural lands were irrigated by channels (vāi-k-kāl, Tamizh). A Middle-Eastern water-lifting technology (shaduf<sup>9</sup>, counterpoise lift, water crane) got introduced into the Tamil country in medieval times, which later acquired the name 'étram' (Tamil). 'Kavalai' (self-emptying bucket hoist) is similar to étram in function, but pulled by a pair of bullocks to draw water from the well. These devices were common in the rural Tamil country until the late 1960s (ref. 10).

In Madras city (hereafter, Madras), the Cooum (Kūvam, Chintādaripét, Triplicane rivers) and the Adayāru are extant. The Cooum is an embarrassing eyesore today, because of its poor management in the last two centuries<sup>11</sup>. The biological-oxygen demand (BOD) value of Cooum water (measured near the Napier Bridge, 13°06'88"N, 80°28'45"E) was 36 mg/l in 2008 – an alarming indeed (<https://economictimes.indiatimes.com/news/environment/pollution/tns-cooum-river-80-dirtier-than-sewage/article-show/33826-89.cms?from=mdr>; accessed on 29 April 2020). Politicians and administrators in the past half century have been talking of restoring Cooum to its historical pristineness, but nothing has been achieved. Realistically, this effort is difficult, considering the high BOD level and anaerobic-microbial density. The Cooum starts from the namesake village in Tirūvallūr District (45 km NW) (<http://casmbenvis.nic.in/Database/Cooum-estuary10562.aspx?format=Print-Mary>; accessed on 16 April 2020) and falls into the Bay of Bengal at Chepauk (13°06'17"N, 80°28'04"E). The Adayāru commences from Malaipattū in Kānchipūram district (45 km SW), flows through Kānchipūram, Tirūvallūr and Chennai before falling into the Bay of Bengal at the Adyār estuary (13°00'63"N, 80°25'74"E), south Chennai. The extinct Élambōre river flowed from the north.

A 9.5 mile (15 km) long Cochrane's Canal, built by Basil Cochrane, running

along the Madras–Ennore coastline (13°21'N, 80°32'E) was dug in 1803 for trade and water transport. In 1878, this was extended to Kākināda (16°57'N, 82°15'E, 670 km) and renamed the Buckingham Canal after Richard Chandos (the third Duke of Buckingham, Governor of Madras). Details of commercial navigation in this Canal in the 19th century are available<sup>12</sup>.

Madras underwent many changes, principally at the cost of its reservoirs even 100 years ago (Figure 1 a and b). Another major change that occurred was the degradation of the Cooum because of massive volumes of non-degradable-waste dumped into it. According to a 19th century Government of Madras report (ref. 13, p. 105):

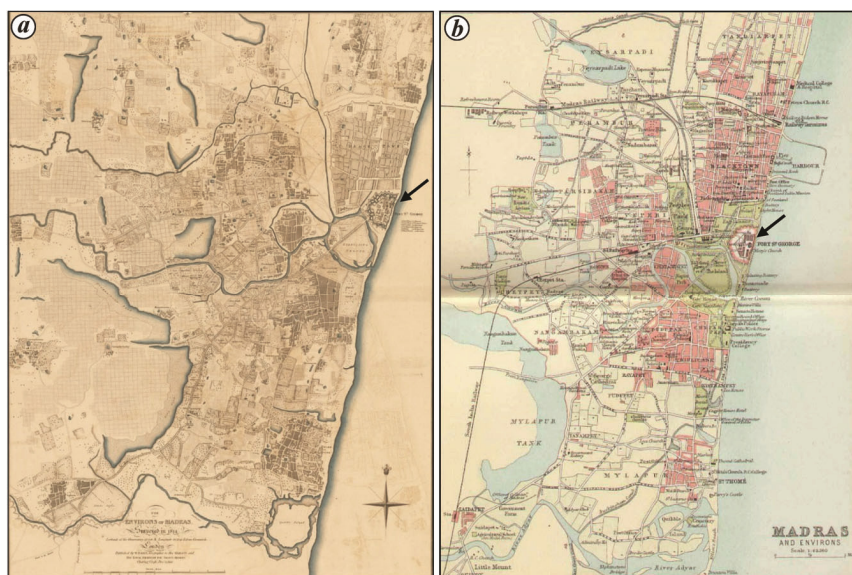
'The Cooum: This river still continues to be in the same insanitary and unsatisfactory condition as in former years. ... The river Cooum, which ought to be an ornament and a blessing to Madras, is now only a source of disease, and the receptacle for the sewage of about a third of the population.'

Water is a commodity of despair in Chennai. The present note records various efforts made to procure water and

supply piped water to Madras residents from the late 17th century to the early 20th century. By 1915, a well-designed water-supply project was established.

### Supply efforts, 1690–1750

Nathaniel Higginson (1652–1702), President of the Council of Directors at the Fort (≈ Governor), organized digging a channel connecting the Çembarambākkam lake with the Fort (40 km), bringing water to irrigate the paddy fields owned by EEIC along the outer western edge of the Fort (note 2) in the 1690s. The Europeans living within the Fort and elsewhere in the Presidency obtained water from wells, rivers and tanks, as did the Indians. In the early 1700s, large timber–mud cisterns were used to store water within the Fort. Paul Benfield (1741–1840; note 3), a building contractor, filled these cisterns with water transported in bullock carts from the lakes and wells outside the Fort<sup>14</sup>. In 1726, Stephen Newcombe, Surveyor of Works erected a wind-powered water lift in Fort St David, Cuddalore (11°75'N, 79°75'E)<sup>15</sup>. Possibly, Newcombe used the Dutch windmill technology to irrigate the betel-leaf and tobacco farms around Cuddalore (note 4).



**Figure 1.** Madras maps, about a century apart. **a**, Madras in 1814. Possibly surveyed by the cadets training at the Military Institution (ref. 54, p. 191) in Madras in 1805–1810. A few named and unnamed water bodies and the rivers Cooum and Adayaru are shown with blue and black margins (source: Faden<sup>55</sup>). **b**, Madras (1890s) (source: Bartholomew<sup>56</sup>). A comparison of Figures **a** and **b** reveals urbanization in Madras, over a century. Most importantly, both maps are nearly of the same scale. Arrow: Fort St George.

**Supply efforts, 1750–1850**

George Baker arrived in Madras commanding the *Cuddalore*, a single-mast battle ship in the 1760s (ref. 16). Arthur Thomas de Lally–Tollendal (Governor-General, French India, Pondichéry), besieging Madras, intercepted water cartage to the Fort. After the Anglo-French battle of 1758, the EEIC Directors prioritized the safety of water cartage to the Fort. From 1771 Baker, now settled in Madras, contracted carting water to the Fort. He maintained the water cisterns within the Fort, guaranteeing water for 6000 people for four months<sup>17</sup>.

Baker’s proposal of a water-supply scheme by digging massive wells at a location about 2 miles (3.21 km) NW of the Fort at 7–8 m amsl was approved in 1770–1775 (ref. 1). Ten wells, seven initially and three later, each 16’ (c. 5 m) wide and 30’ (9–10 m) deep, were dug. The name Seven-Wells Street (Ézhû Kinarû Feru, 13°7’N, 80°17’E) exists today. These wells supplied good-quality water. George Pearse (Secretary, Madras Medical Board; a physician) remarks on the quality of water from these wells in 1842 (ref. 18, p. 4):

‘The water obtained from the wells in a certain enclosure near the north wall, known by the name of the “seven wells”, is especially valued for its purity, which it is said by sea-faring people to preserve for a length of time at sea.’

In July 1773, Baker established a pipe network to transport water to the cisterns within the Fort, by forging pipes with metal recovered from discarded iron drums (an early ‘recycling’ effort)<sup>19</sup>. This is the earliest ‘pipe’ water supply of significant scale in the whole of India<sup>20</sup>. The Europeans living within the Fort received carted-water supply. The Black Town, just outside the Fort, was ignored. The Indians living here drew water from shallow wells, often contaminated by the liquid sewage that flowed in open drains along street verges.

Francis Whyte Ellis (1777–1819), collector of Madras (1810–1819), dug 27 wells (dimensions not known) in different locations outside the Fort, enabling the Indians to face the acute water scarcity in Madras in 1818 (<http://www.varalaaru.com/design/article.aspx?ArticleID=539>; accessed on 19 April 2020).

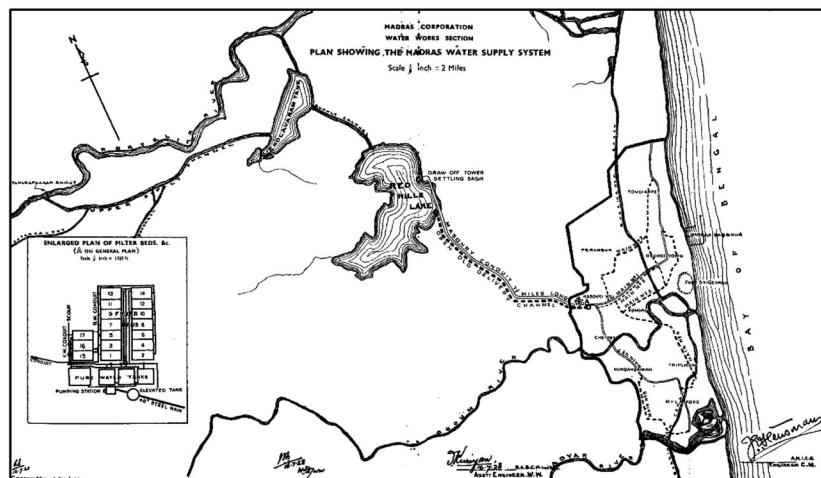
**Piped-water supply to Madras and selection of Kilpauk site, 1850–70**

Charles Trevelyan (1807–86), Governor of Madras (1859–60), enthusiastically worked on improving the needs of the residents of Madras, both within and outside the Fort<sup>21</sup>. One was to improve the sanitary conditions and provide piped-water supply in 1859–60. Between 1855 and 1866, a piped-water supply scheme to entire Madras was discussed among the Aldermen (Councillors) of the Corporation of Madras (CoM, note 5). Similar to the report of the Public-Sanitation Commission of Bengal that included piped-water supply in Calcutta (1870), a report appeared in Madras in 1866 (ref. 22), which was ignored. Water-borne infectious diseases, e.g. cholera, have been ravaging Madras for long, although formal recording of such diseases occurs only after the 1820s (refs 23, 24).

In the late 1860s, James Fraser (note 6) proposed to the Government at the Fort to access the Kôsastalai River (note 7) and distribute its waters in Madras. Based on Fraser’s proposal, a weir was constructed at Fâmarai-p-pâkkam (c. 30 km NW of Madras, 12°76’N, 79°30’E) diverting Kôsastalai waters to the Çôlavaram reservoir (Tirûvallûr district, 13°22’N, 80°15’E) via the upper channel and from Çôlavaram to the Red-Hills reservoir [RHR] (Pûzhal éri, 13°10’N, 80°10’E, 16.8 km NW) via the lower channel. The RHR waters were to be delivered to the Spur Tank (Figure 1 b) and from there to be stored in a covered ‘basin’ assuring a four-day supply.

Only a small portion of the tank exists today in Spurtank Road, Chetpet (13°07’41”N, 80°24’24”E). This water was to go through a pump-well to an elevated cistern before distribution (ref. 25, p. 38). The CoM rejected Fraser’s proposal of bringing water to the Spur Tank, considering the cost of pumping from there, although the rest of Fraser’s suggestions was accepted. The CoM considered storing of water at an elevated location was better because that would help water distribution by gravitation (ref. 25, p. 39).

The project, hence moved to Kilpauk, located at a slightly higher elevation than the Spur Tank. A tank capable of storing a large volume of water was built in Kilpauk. Water delivery from RHR to the Kilpauk tank was achieved gravitationally via an open channel: 7½’ deep (2.3 m) and 6’ wide (1.83 m) at the bottom, 6½ miles (10.5 km) long with a 3” (7.6 cm) gradient for every mile (1.61 km) (ref. 25, p. 35) (Figure 2). Water from the RHR was delivered into a circular 22 ft [6.7 m] wide masonry terminal shaft (MTS), built like a well at Médavâkkam (Mâdam-pâkkam, 13.4 m amsl; note 8). From the MTS, equipped with self-regulating flood gates, water distribution occurred through the town utilizing its elevation. Use of gravitation for water supply reduced pumping cost appreciably (ref. 25, pp. 38–39). A specially constructed masonry work – the ‘inclined spill-water’ shaft – in Kilpauk in 1872 enabled pressure acceleration of water (Figure 3). From the RHR, about 9,330,000 cubic feet (264,300 m<sup>3</sup>) of water



**Figure 2.** Madras water-supply system plan. Authorized by J. E. Hensman, Engineer, CoM. (Source: Ganapati<sup>53</sup>.)

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per year was delivered to the MTS. About 5,000,000 cubic ft (1,415,800 m<sup>3</sup>) of water was discharged per year via open channels for local irrigation<sup>4</sup>. This project completed between 1866 and 1870 was the earliest piped-water distribution in the whole of southern India.

The Government made simultaneous efforts to explore groundwater within the town limits. William King (1834–1900; Director, Geological Survey of India, Calcutta, 1887–1894), commencing his professional life as an assistant of Henry Francis Blanford in Madras, dug an artesian well at People's Park (13°07'34"N, 80°27'32"E) in 1870. He hit hard granite at a short depth<sup>1</sup> and the effort was abandoned.

### The Madras Municipal Water Works, Kilpauk, 1870–1920

#### Plans by John Jones

The Madras-Municipal Waterworks (MMWW) was formally launched in May 1872 by Francis Napier (Governor, 1866–92) in Kilpauk. The Government of Madras owned MMWW, whereas its day-to-day responsibility of bringing water from RHR to the town (Figure 4), maintenance of supply conduits, and distribution remained with the CoM, which paid a rate of Re 1/1000 yd<sup>3</sup> (about 765 m<sup>3</sup>) to the Government (ref. 26). MMWW carried out a scheme improving water supply to Madras from the Red Hills in 1872 at a cost of about Rs 130,000 towards the diversion of Kôsastalai waters to Çôlavaram and RHR (note 9). This work included building a new valve house and a gravity-aided earthen-supply channel from RHR and was completed by the Public-Works Department (PWD), Government of Madras. Cast-iron pipes delivered water from the Kilpauk tank to the residents in different suburbs of the town<sup>4</sup> (note 10).

John Alfred Jones was the executive engineer at CoM, in the 1880s (note 11). Because the open channel connecting RHR and Kilpauk was occluded by aquatic weeds, silt and microbes, it required improvement. Jones executed this work in 1889 (ref. 27). To Jones, a 36' (11 m) water column in RHR was essential for clean-water supply to town residents. The column between 36' and 31' (11 and 9.4 m) was reasonable, but that less than 31' (9.4 m) was not, because of infective

microbes. Jones therefore saw the need for filter beds. He proposed establishing filter beds either at Kilpauk – the final destination – or in Kônñür (note 12), 4 km NW of Kilpauk. He favoured Kilpauk location considering expenditure. For building filter beds, he acquired land in Kilpauk from James Henry Spring Branson (note 13). Because Kilpauk was at 17' (5.16 m) amsl, building of settling tanks became a necessity: either the settling tanks of about 23' (7 m) height and 10' (3.04 m) depth besides the filter beds at 3' (0.90 m) had to be built, or both settling tanks and filter beds were to remain subterranean. He preferred the latter because of safety and less-space requirement. However, this decision necessitated water to be raised by 35' (10.7 m) to maintain pressure. Consequently a stand-pipe tower was erected (note 14). On the proposed filter beds, Jones remarks (ref. 27, p. 10):

'The filter beds are designed to show 3' (0.91 m) of water above the filtering media, which are: 2' (0.61 m) of fine sand (sourced from Kortalayar [Kôsastalai]), 1' (0.30 m) of sand size shot (sourced from the Red Hills), 1' (0.30 m) of walnut-size gravel, and 1' (0.30 m) of large gravel (the latter two sourced from Kortalayar).'

Six settling tanks, five filter beds and one service reservoir were planned and built. Each settling tank was 45,000 square feet (4,180 m<sup>2</sup>) in area and 9' (2.75 m) deep. The filter beds were to draw water only up to 8' (2.43 m), allowing 1' (0.3 m) for the settling particulate impurities. The six settling tanks were to store 13,500,000 gallons (51,103,059 L) of water at a time. Jones built a two-floor brick-work – the 'sand-washing' box (see figure 13.1, ref. 28); the upper floor was formed using perforated cast-iron



Figure 3. Inclined masonry shaft at Kilpauk, 1872 (photo: N. Meenakshisundaram).

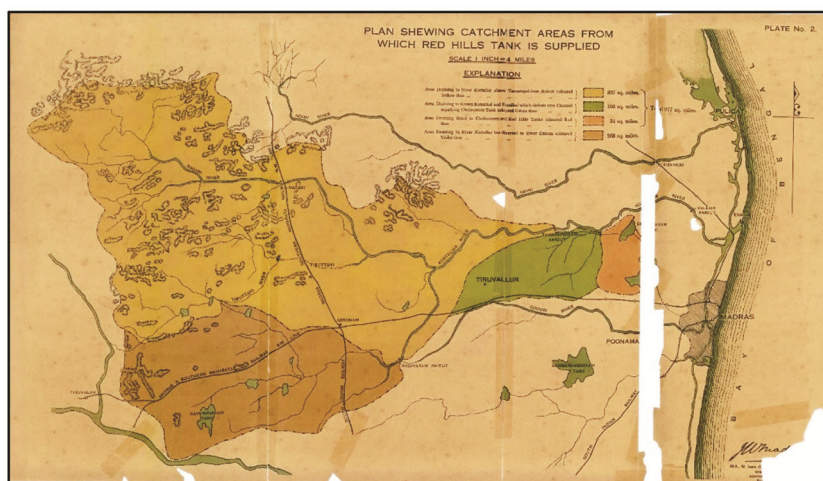


Figure 4. Madras water-supply catchment. Source: Madeley<sup>38</sup>.

plates on which sand was laid. When pressurized water was passed through the sand, the water was stirred manually.

The required water for Madras was 6,000,000 gallons (22,712,471 l) a day. However, while planning the supply pipe from RHR, Jones anticipated the demand will double in the next two decades (12,000,000 gallons; 45,424,941 l per day). Based on John Neville's<sup>29</sup> formula, Jones decided that the main-pipe diameter was to be 36" (0.91 m) to discharge 22.2 ft<sup>3</sup> (0.63 m<sup>3</sup>) of water per second to meet the needs of Madras. He rationalized the 36" diameter pipe by comparing with the calculation of pipe dimensions calculated in Calcutta in the 1840s (ref. 30). Jones's remark (ref. 27, p. 10), 'Red Hills water is not so foul as Thames water' is curious. In 1881, an intake tower at RHR was constructed to assess and measure water depth named the 'Jones Tower' (Figure 5).

John Pennycuik (1841–1911, Chief Engineer, Government of Madras, 1890–96; Chairman, Sanitary Board, Madras) is a venerated name (note 15) in Tamil Nadu<sup>31</sup>. In 1899, Pennycuik spoke at the Institution of Civil Engineers (ICE), London, UK, on the practical problems of conserving water in Madras and the struggles faced by MMWW. The text of his speech, published in the proceedings of ICE, also includes remarks by Jones on MMWW. This text impresses as an invaluable document in the context of Madras water<sup>32</sup>. It, importantly, includes

data and comments on water loss in Madras storage due to evaporation and leakage.

### The untraceable Nowroji Report

Hormusji Nowroji (Portrait 1, note 16), born in Madras in 1860, graduated from the College of Engineering, Guindy (note 17) with a bachelor's degree in Civil and Survey Engineering. Nowroji joined the Government of Madras as an Assistant Sanitary Engineer in the 1880s. He was temporarily transferred to CoM by the Government in 1903, when its engineer Samuel Joshua Loane (note 18) proceeded on furlough (ref. 33). A government report<sup>34</sup> clarifies the extension of his secondment to CoM from October 1908. The same report refers to Nowroji's completion of the water-works plan for Madras town (ref. 34, p. 42):

'The services of Mr. H. Nowroji were placed at the disposal of the Corporation for the purpose of carrying out a special investigation regarding the improvement and extension of the distributary system of the water-supply to the city. This officer, who was subsequently appointed Assistant on the water-works side to the Special Engineer, had nearly completed his investigation at the end of the year. ...'

In 1903, Nowroji was asked to plan and redesign the water-works. Planning an

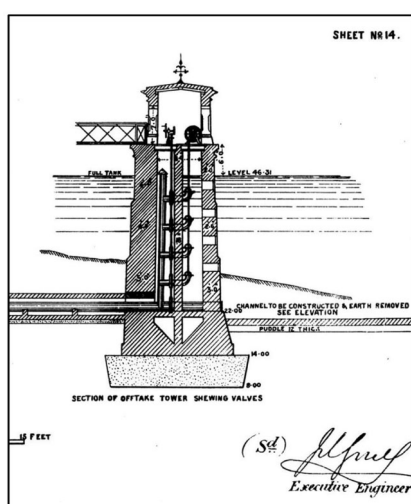
extensive network of pipe-water supply for Madras town on a relatively flat terrain was difficult, because moving of water utilizing gravity was difficult. Complex calculations of required pressures in different suburbs of Madras were a challenge. Additionally, the Government had instructed Nowroji to develop his plan on the 'Fourth Annual Report of the Sanitary Board 1899' published by the Madras Sanitary Board, chaired by Pennycuik. Other contributors to this report were John A. Jones and Surgeon Walter Gaven King (Sanitary Commissioner, Madras)<sup>35</sup>. In 1907, Nowroji submitted his plan – the 'Nowroji Report' – to the Government. That the Nowroji Report is not traceable today is distressing, although we know of its existence because of the citations in subsequent reports<sup>34,36</sup>.

From the reports<sup>34,36</sup> that refer to the Nowroji Report, we can construe that Nowroji suggested plans on the collection of water from different catchments around Madras town, its direction and storage in the RHR, movement to Kilpauk, and distribution throughout Madras via underground pipes, keeping the water supply safe, adhering to the Madras Sanitary Report (1899). The Nowroji Report included cost estimates for the water-distribution project. The Government of Madras accepted the Nowroji Report for implementation soon after<sup>34</sup>.

### New water-works and James Madeley

In the 1900s, the Government of Madras decided to employ a 'Special Engineer' in the rank of a Chief Engineer to lead the Sanitary Engineering Division of CoM in the 1900s. The Secretary of State for India, Henry Percy, appointed James Welby Madeley (Portrait 2, note 19). Madeley (read, 'Made'-'ley') assumed charge in Madras in December 1907. Since he participated in the Indian Science Congress (ISC) in Madras in 1922, and also since he led the ISC attendees on a tour of the Kilpauk Water Works (KWW), he must have been in service in 1922–23 (ref. 37).

In reforming MMWW, Madeley<sup>38</sup> followed the plans and designs proposed by Nowroji. Nowroji worked as a deputy to Madeley, supervising the pipe-network and related construction work from 1907 to 1912. Engineers F. A. Adlard (water



**Figure 5.** Engineering drawing of the intake tower at RHR (later, the 'Jones Tower') prepared by J. A. Jones in the 1870s (signature at the right bottom). (Source: Jones<sup>27</sup>.)



**Portrait 1.** Hormusji Nowroji (Source: *The Hindu*, 14 October 2019).

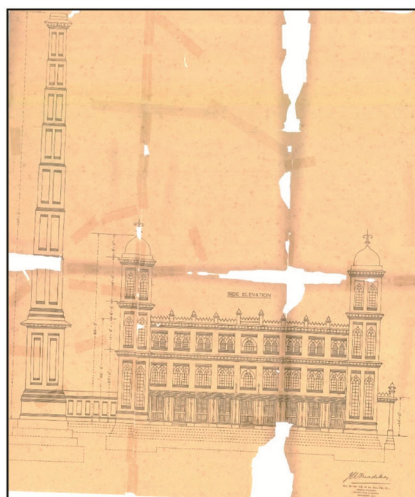
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distribution, until 1914), J. E. Hensman (from 1914), F. T. Newland (design and erection of engines in pumping plants, filter-outlet regulators and other mechanical machinery), and T. A. Pereira (filters and settling beds) were the other members of the Madeley team<sup>39</sup>.

The deliverable water situation in Madras in 1907 was as follows: holding capacities of RHR and the Çolāvaram reservoir were 2162 M cubic feet (61,221,000 m<sup>3</sup>) and 579 M cubic feet (16,395,450 m<sup>3</sup>) respectively; the MMWW aimed at distributing water to a projected



**Portrait 2.** James W. Madeley (source: N. Meenakshisundaram).

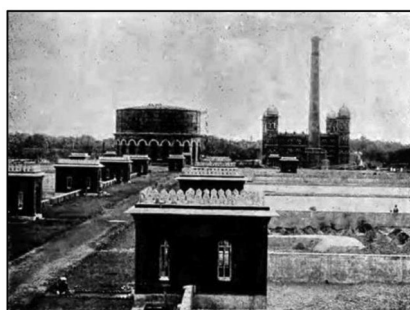


**Figure 6.** Pumping station side-elevation plan, New Water Works, Kilpauk (1907–1908). The final structure differs slightly from this plan, see Figure 7. Authorized by J. W. Madeley (right bottom) (source: Madeley<sup>38</sup>).

population of 660,000 at the rate of 25 gallons (about 95 L) per person per day. In 1907, a new building to accommodate the pumping station was planned at KWW (Figure 6).

Wastage of piped water was a matter of concern<sup>38</sup>. Madeley, therefore, arranged frequent inspections of rusted and leaking pipes in the houses, since they not only lost water, but also sucked surface impurities and infective microbes. Madeley (ref. 40, p. 44) remarks: ‘Several cases of serious illness have been traced to this cause.’ Consequently, he restricted the number of pipe connections, metered every water outlet, arranged house-to-house inspections, and measured wasted water. He metered water use and levied a fee – a step to minimize wastage<sup>40</sup>. Those who could afford, secured direct-pipe connections to their residences, receiving up to a maximum of 100 gallons (378 L) per day. Those who could not, collected water from municipal taps (‘fountains’) fixed at street junctions. Others were supplied limited volume of water via a half-inch (1.27 cm) tap. By 1920, the per-capita water supply had increased from 15 (57 L) to 25 gallons (95 l) and with the number of people in Madras being 666,000 and with 25 gallons per head, the total volume of water released was 16.5 million gallons (62,459,295 L) per day.

Madeley introduced many reforms to improve water supply. In 1914, The Governor of Madras, John Sinclair (1912–19) inaugurated the ‘new’ water works (Figure 7). Out of an annual budget of Rs 4,208,960, nearly 30% was spent on installation of pipes, valves and meters. Given the large volume of water needed to cover a much wider area than



**Figure 7.** Water Works, Kilpauk, 1914. The filter-outlet in the foreground, the elevated-steel tank and the pumping station with a tall turret in the distant background (source: Madeley<sup>40</sup>).

perceived in the 1880s and with more people to be supplied Madeley installed pumps enabled with high-power engines. He raised the height of the steel tank in Kilpauk to enhance the flow pressure. The inclined-masonry shaft in Kilpauk was improved and enabled with new valves. He prioritized the supply of clean water. For public distribution, water was drawn from the middle layers of the column at RHR and not from either the top or the bottom layers, because of surface impurities and sediments. This practice contrasts strongly with that of Jones made 2–3 decades earlier.

Before launching major changes to the MMWW, in 1907, Madeley studied the rainfall pattern in the previous 25 years and evaluated per-day water requirement of Madras residents. He arrived at 3 million gallons (11,356,240 l) per day as nominal. Based on this, Madeley fixed gauges at the mouths of creeks and streams supplying the Tirûvallûr catchment and the delivery channels. Based on trials previously made in London and Zürich<sup>41</sup>, he ran trials of slow-sand filtration to minimize surface contamination during water storage (Figure 8). He also strengthened the already existing slow-sand filtration, enabling it to build a gelatinous layer (‘biofilm’ today; note 20) at the top. However, the gelatinous layer thickened frequently obstructing water movement, and required manual cleaning. In spite of the best efforts the slow-sand filtration in KWW proved unsatisfactory because in three months, the filter stands were generating H<sub>2</sub>S due to dissolved sulphates. Madeley, therefore, proposed that the slow-sand filters be changed to sedimentation tanks and rapid filters (note 21). He followed Alexander Houston (Lincoln, England) to chlorinate water for improving safety and quality<sup>42</sup> (note 22). A chlorine-delivering Chloronome™ administered the desired levels of liquified chlorine at the KWW<sup>43</sup>. Double-filtration was attempted at KWW, supplemented with the treatment of water with measured quantities of alum (Al<sub>2</sub>[SO<sub>4</sub>]<sub>3</sub>) added to precipitate the unwanted HCO<sub>3</sub>-s.

In 1914, Madeley<sup>37</sup> provided technical details of the improved machinery installed at KWW. After passing through the filter tanks, water gravitated into the pumping-station culvert from where it was pumped to the main pipes via an elevated, balancing tank between the pumps and distribution pipes. The

pumping plant included three direct-acting, then popular Worthington™ pumps<sup>44</sup>, each capable of delivering 12,000 gallons (42,400 l) of water per minute, against a head of 80 ft (24 m), including suction. Three Babcock & Wilcox (B&W) utility boilers supplied steam, thus energizing the Worthingtons. Each B&W unit was able to run any two engines at the same time. A Venturi meter (note 23) connected the 48" (1.22 m) main-supply pipe registering water movement up to 18,00,000 gallons (c. 68,13,700 L) per hour. This meter was supplemented by a combined water-level and pump-pressure recorder. The Venturi measurement device was useful, since it measured the efficiency of water distribution.

The elevated steel tank maintained a balance between the pumped water and day-to-day variable water needs. This massive flat-bottomed tank (104' [32 m] wide, 28' [8.50 m] deep) held 1.5 million gallons (56,78,100 l) of water at one time. It stood on a steel tower (58 feet, 18 m tall) with the tank 28' (8.53 m) deep, meeting the pressure required to flow through entire Madras that is located on a landscape varying from 8 to 20 ft (2.5–6.1 m) amsl. The smart design of this tank included a 36" (0.90 m) wide overflow pipe running along the centre – incidentally supporting the tank roof. A small proportion of the tank-held water met the supply, with one pipe operating both as the inlet and outlet source. Madeley organized radial-zonal water distribution system that involved the whole of Madras divided into many manageable sub-areas (Figure 9) enabled by gravity distribution (Figure 10). Each sub-area was equipped with a centrally located, raised distribution tank from where the pipes ran radially towards the peripheries. This system was not only rapid, but the calculation of pipe size also became simple<sup>38</sup>. The choice of radial-zonal distribution by Madeley in the early decades

of the 20th century was good, since this practice is followed even today as an efficient, environmental-friendly and sustainable distribution mechanism<sup>45</sup>. The radial-zonal system supplied 25 gallons of water per person per day, accelerated by a pressure at 50 ft (15.24 m) amsl at the ends of principal mains. As a water-saving measure, the valves on the principal mains were maintained partly open. Full pressure was never maintained through the day. The New Water Works was made foolproof in resisting subsoil contamination, bringing down the number of human deaths due to water contamination (ref. 46, p. 1583):

‘Since the new waterworks was opened, the number of deaths had decreased by 4000 per year as compared with the average of the last 10 years.’

Thus it contributed notably to improved general health of Madras residents.

In 1918, the New Water Works had the many capacities (p. 46, p. 1583) (Box 1).

**A controversy in 1915**

A two-page letter to the editor of the British journal *The Surveyor and Municipal and County Engineer (SMCE)* titled ‘Design of the Madras city water works’ by Nowroji dated 31 March 1915 has been published in the 30 April 1915 issue of the journal<sup>46</sup>. Nowroji<sup>47</sup> challenges Madeley’s report published in an earlier issue of the same journal on many a points with reference to MMWW (46, p. 572):

‘The claim made therein that Mr. J. W. Madeley, special engineer to the Corporation of Madras, was responsible for the entire design and construction of the works is absolutely

unwarranted. The entire scheme for the improvement of the water supply of Madras, including its distribution in the city was prepared by me, and the vitally important portion of the scheme – namely that relating to the conveyance of the supply from its source to the city, its filtration and elevation – was prepared by me, and was accepted by the corporation and sanctioned by the Government of Madras sometime before Mr. Madeley set his foot on Indian soil.’

Nowroji argues that he developed the first part of the Madras water-supply scheme: building of roughing filter, 7-miles (11.3 km) of the conduit and filters covering an area of 7 acres, three large, covered reservoirs for storing filtered water, the suction well, and foundations to the engine-house up to the basement level<sup>46</sup>. He, however, indicates that certain modifications were necessary and expected them to be made. Thus, he concurs with Madeley’s redesigning of the engine room and elevated tank. However, he adds that such redesigns by Madeley indeed incorporated the suggestions available in his report. The saddest element here is that the Nowroji Report is untraceable. Referring to his 1907 report, Nowroji quotes William Hutton, the

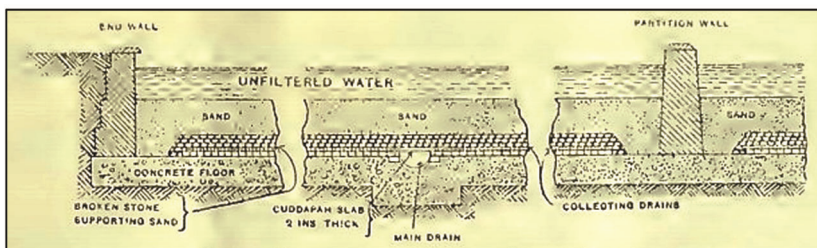


Figure 8. Slow-sand filter (sectional view) (source: Madeley<sup>48</sup>).

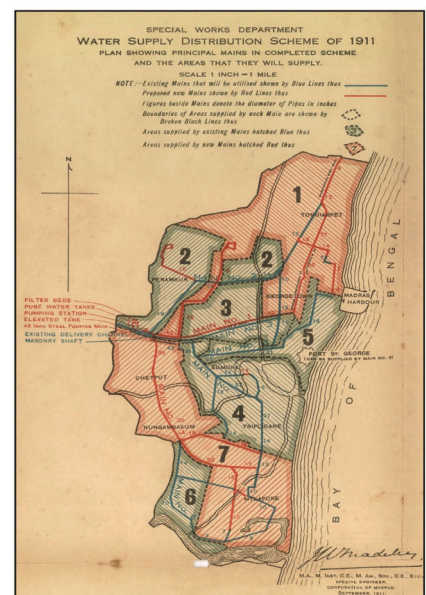


Figure 9. Plan showing the principal mains in the completed scheme and the areas with details of the radial-zonal water distribution supply (source: Madeley<sup>38</sup>).

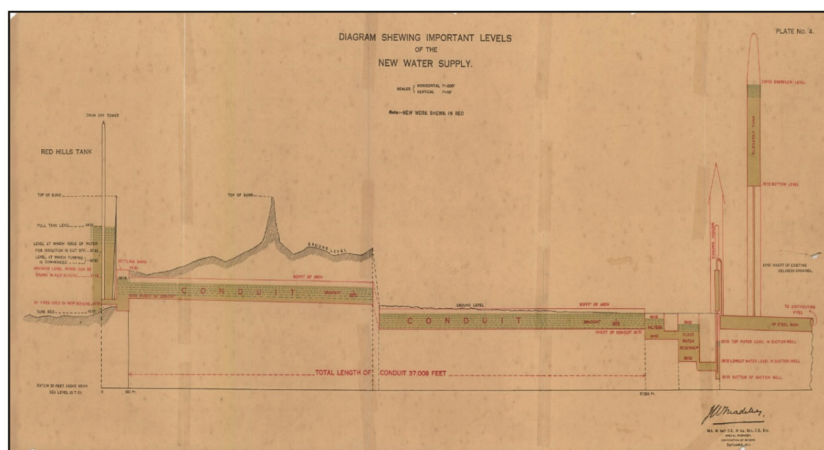


Figure 10. Important Levels of the new water supply (source: Madeley<sup>38</sup>).

**Box 1. Enhanced capabilities of the New Water Works, 1918**

- Catchment area: 977 miles<sup>2</sup> (2530 km<sup>2</sup>)
- Storage capacity at the Red Hills and Çolāvaram reservoirs: 18,000 million gallons (68,137,412 l)
- Masonry conduit: 7 miles (11.26 km)
- Number of filters: 14
- Total filtering area: 6.43 acres
- Total for complete scheme: 9.65 acres
- Capacity for pure water tanks: 4,200,000 gallons (15,898,730 l)
- Pumping capacity of each of the three pumps: 12,000 gallons (45,425 l) per min
- Quantity of water that could be supplied: 16,300,000 gallons (61,702,212 l)
- Quantity then supplied: 14,000,000 gallons (52,995,765 l)
- Pressure that can be supplied at the ends of principal mains: 50' (15.2 m) above ground level.

Sanitary Engineer, Government of Madras (ref. 46, p. 572):

‘I think Mr. Nowroji is to be congratulated on the careful manner in which the work has been done, and the exhaustive character of this report describing the work. The scheme has been drawn out on sound principles, which, if carried out in Madras, will give the city what is of first importance to the town – viz., a pure and wholesome water – delivered into houses uncontaminated and at a sufficient pressure.’

The editor of *SMCE* had included a note at the end of this published letter (ref. 46, p. 573), a part of which is:

‘The article referred to in the above letter was prepared from the official description of the works, a copy of

which was presented to Lord Pentand (John Sinclair) on the occasion of the opening. The statement which Mr Nowroji complains is that Mr, Madeley “was responsible for” the entire design and construction. It appears from Mr Nowroji’s letter that this “responsibility” was that of a special engineer or consultant, and we regret having used words which may have been open to another construction.’

In short, the editor of *SMCE* justifies Madeley’s<sup>48</sup> report and indicates that Madeley in his report, as the Special Engineer, had appropriately acknowledged the contribution of Nowroji. Nevertheless, the claim made by Nowroji<sup>47</sup> remains unresolved. What is appreciable, however, is that the editor of *SMCE* published Nowroji’s<sup>47</sup> letter as such, following it with his explanatory note. Nowroji quit the Madras-Government Service in

1912 and joined the Government of Mysore as a Senior Engineer (Sriram, V., <https://sriramv.wordpress.com/2014/12/20/the-indian-in-the-water-works/>, accessed on 31 May 2020).

A summary of the MMWW (Madras Municipal Water Works, which in the 1990s became the Madras City Water Works) between 1900 and 1916 is available in Krishnaswami<sup>36</sup> (pp. 148–151). The present note chronicles the efforts made by many British engineers and one Indian engineer to distribute piped water to Madras residents, to address its perpetual water scarcity.

**What is happening presently?**

The water-supply mechanism previously managed by the CoM was transferred to the new Madras Metropolitan Water Supply and Sewerage Board (presently, Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB)) in August 1978. The PWD (Irrigation) currently manages the supply sources, viz. Red Hills, Çolavaram and Poondi reservoirs. The groundwater cell, formerly with the PWD and now with CMWSSB, holds responsibility for groundwater exploration to improve water distribution to the swelling population of Chennai. The PWD and CMWSSB are exploring groundwater options at Poondi, Kannigaipair (13°27’N, 80°09’E), Panjéttý (13°27’N, 80°15’E), Tāmarai-p-pākkam and Minjûr (13°27’N, 80°26’E). That much of the explored groundwater is contaminated because of industrial effluents and sea-water intrusion is depressing. The Veerānam Water Supply Project for drawing water from the Veeranārāyanapûram lake (41,484,180 m<sup>3</sup>) was launched in 2004 to supplement the water needs of Chennai, supplying about 180 ML of water per day. The Veeranārāyanapûram lake receives water from the Kāvéri and its tributaries. Pumped water from Veeranām gets treated at Vadakûthû Water Plant (11°62’N, 79°56’E, 20 km of Veerānam lake). The treated water is moved over to Kadampûliyûr (8 km, 11°70’N, 79°55’E), and then to the Pôrûr Water Station (13°04’N, 80°16’E) close to Chennai by gravity. From the Pôrûr Station, water is distributed to Chennai residents.

Today, the Veerānam Project, originally intended to deliver water to Chennai, is struggling because of repeated monsoon



failures. The CMWSSB has recently dug 45 deep borewells along the upper edges of the Veerānam lake, which has stirred the hornet's nest, since agriculturists in the area are resisting this action.

The late C. S. Kuppuraj (ex-Chief Engineer, PWD, Government of Tamil Nadu) mentioned (<https://frontline.thehindu.com/other/article30222555.ece>; accessed on 1 June 2020):

'... the exploitation of groundwater on such a scale would result in severe damage to the aquifer and lead to the intrusion of sea water because the sea shore is 20–25 km away from the bore wells.'

The CMWSSB is hopeful and positive. In a recently aired 'Elets webinar' the Executive Director of CMWSSB Prabhushankar T. Gunalan explained the projects CMWSSB is currently undertaking to address and mitigate Chennai's water problem (<https://egov.eletsonline.com/2020/04/improvement-in-progress-chennai-gearing-to-overcome-water-woes/>, accessed on 9 June 2020). Gunalan indicated that CMWSSB has the capacity to reuse at least 10% of wastewater. Effective rainwater harvesting is another strategy that CMWSSB is working on. Presently, 90% of households in Chennai have functional rainwater-harvesting systems. As for a foreseeable future, the CMWSSB is developing an 'ultrafiltration' reuse of wastewater, which will successfully utilize the tertiary-treated water (note 24) for specific uses. CMWSSB is also working on practices ensuring judicious future water use. It is also contemplating utilizing abandoned mine quarries (AMQs) for water, since AMQs are not only a reliable source of groundwater, but they store water as well. Tests of AMQ water samples indicate that the water quality is good. Complementing the efforts of CMWSSB, the Greater Chennai Corporation (formerly CoM) is working on desilting and cleaning the extant reservoirs in and around Chennai. With the Krishna Water Supply Scheme launched in 1996, water delivery by the State of Andhra Pradesh to Chennai presently occurs at an annual allocation of 15 TMC (= 424,752,698,880 L) of flood waters of the Krishna. However, due to frequent monsoon failures in recent years, Krishna water supply to Chennai has been irregular.

The latest developments in CMWSSB in the context of water management in Madras (Jaishankar, M. R., Executive Engineer, CMWSSB, pers. commun., e-mail 19 June 2020) include determination of new water sources, after intense field explorations. From the Çikkarāyapūram (13°02'N, 80°10'E) quarries, about 30 ML per day of water is delivered to Pōrūr storage. Other identified sources are the Āyanam-pākkam (13°6'21"N, 80°8'20"E), Rēttai Ēri (13°11'70"N, 80°21'14"E), and Pérūmpākkam (12°90'53"N, 80°19'86"E) reservoirs, each with about 10 ML per day capacity. The stark reality, however, is that these sources are rain-dependent, necessitating an immediate need to determine sustainable water-supply sources for Chennai's long-term water management. In terms of wastewater recycling, CMWSSB is planning establishment of sewage-treatment plants at Kōdūngaiyūr (13°14'09"N, 80°24'81"E), Kōyambédū (13°06'93"N, 80°19'74"E), Nésapākkam (13°04'00"N, 80°19'92"E), and Pérūnkūdi (12°97'N, 80°25'E), to provide clean water at the rate of 100, 40, 60 and 60 million litres per day respectively. CMWSSB is also working on desalination plants since 2017.

Water-starved Chennai residents are patient, positive and hopeful, just as CMWSSB, that one day the city will be water self-sufficient.

## Notes

- Alexander Hamilton indicates Madras as a 'city' in 1727.
- See 'prairie' in the Madras map by Jacques-Nicholas Bellin, 1764 (ref. 49).
- Benfield was 'notorious'; <https://www.oxforddnb.com/view/10.1093/odnb/> (accessed on 18 April 2020).
- Newcombe was a clerk of the Madras Market in 1724. He annexed 'Egmore', 'Persiawalk' (Pūrasawālkam), and 'Tōndiarwood' (Tōndiarpet) villages to the Fort administration<sup>5</sup>. The Cuddalore windmill was the first windmill in the whole of India.
- The oldest municipal institution in India. Became operational on 29 September 1688, decreed by the Royal Charter issued by King James II on 30 December 1687.
- 'John Fraser' of the Madras Engineer Corps; possibly 'James Fraser'. Not clear.
- The Kōsastalai-Ārū – anglicized as Kōtralayār – is a c. 140 km long river originat-

ing in Tirūvallūr district (13°8'N, 79°54'E). The Nagari, starting in Chittoor (14°28'N, 78°49'E, Andhra Pradesh), joins the Kōsastalai close to the Poondi reservoir (13°12'N, 79°51'E), where the Kōsastalai waters are presently stored. From Poondi, the Kōsastalai flows through Madras and falls into the Bay of Bengal near Ennore (13°21'N, 80°32'E).

- Identified presently by the 'Médavākkam Tank Road', 3 km NW of Kilpauk; a part of Kilpauk revenue division.
- John A. Jones uses 'Madras Municipal Water Works' (MMWW) in his reports, although others refer variously. Here we use MMWW, following Jones.
- Use of galvanized-iron (GI) pipes in water supply started in the 1960s, although galvanization (coating Fe pipe with Zn) to improve the performance efficiency of Fe pipes was known before. Stanislaus Sorel, a French civil engineer, patented galvanization in 1836.
- 'Jones Road', Saidapet, celebrates J. A. Jones. The Red-Hills Reservoir intake tower is named the 'Jones Tower'.
- Also spelt 'Coonoor'. Kōnnūr is presently incorporated into the Villivākkam revenue division. Kōnnūr exists presently only in 'Kōnnūr High Road', Ayanāvaram (13°6'E, 80°14'N).
- James Branson was a barrister; relieving Advocate-General, Madras Presidency, 1887–97. He owned a vast property in Kilpauk (the Branson's Garden). Presently represented by 'Branson Garden Street'.
- A tower that includes 'stand-pipes' through which water is raised to maintain pressure (ref. 50, pp. 19–27).
- Farmers in Thēni–Cumbum area (9°73'N, 77°3'E) visit the Pennycuick memorial (Lower Camp, Thēni) as a pilgrimage (*Times of India*, 16 January 2013; <https://timesofindia.indiatimes.com/city/madurai/Pennycuick-memorial-a-temple-for-us-say-farmers/articleshow/18041254.cms>; accessed on 26 April 2020).
- Nowroji contributed much to the sanitary and water-distribution engineering of Madras. Remembered by 'Nowroji Road', Chetpet. He built the Clubwālā Dār-é-Méher – fire temple in Royapūram, North Madras, consecrated in 1910.
- College of Engineering Guindy (CEG), Madras, is the oldest teaching engineering institution in India, started as a Survey School located in Fort St. George by the Michael Topping in 1794. It transformed into the School of Civil Engineering in 1858. In 1859, the institution was affiliated to the University of Madras (established 1857). Until this time, it trained students in civil and survey engineering only. From 1859, this institution began offering mechanical engineering degree. It relocated to Guindy in 1920.

18. Loane supervised the construction of the once famous, but now extinct, Moore Market of Madras in 1900–01. Loane Square (presently the Loane-Square Park) in Broadway, Madras celebrates his name.
19. After acquiring the membership of the Institution of Civil Engineers (London), James Madeley worked as the resident engineer with the Elan Valley Waterworks, Birmingham, then with the Distribution Works, Birmingham, and subsequently with the Stockport Waterworks. In 1907, he was appointed in the Corporation of Madras.
20. The gelatinous layer (GL) as a useful mechanism in water filtration was established by John Gibbs from Scotland in 1804 (ref. 51). GL forms within the first few days and will include various aquatic microorganisms providing an effective filtration in obtaining potable water. As water passes through GL, particulate foreign material gets trapped in the mucilage and concurrently gets adsorbed. With time, the trapped contaminants are metabolized by the microorganisms. The water released via an efficient slow-sand filter is generally known to result in 95% bacterial cell-count reduction<sup>52</sup>.
21. Rapid filters were introduced in Kilpauk Water Works only in 1955. Ganapati<sup>53</sup>.
22. Bleaching powder [CaCl(OCl) · 4H<sub>2</sub>O], an oxidizing agent, readily releases about 35% of active chlorine on contacting moisture.
23. Clemens Herschel (1842–1930), American hydraulic engineer, worked with the Holyoke Water-Power Company in Massachusetts, USA, in the 1880s. He developed the Venturi meter in 1886–1888, naming it after Giovanni Venturi, the Italian physicist. The Venturi meter worked on the principle of differential pressure in a U-tube partly filled with water. It enabled measuring water movement through the tube.
24. The final cleaning process that improves wastewater quality before it is reused, recycled and/or discharged into the environment. Tertiary-treated water is also referred as ‘recycled water’.
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ACKNOWLEDGEMENTS. We thank R. Bhaskarendra Rao (Madanapaltee) for alerting us to the report on Madras Water Works in the *Asylum Press Almanack* (1918). We also thank M. R. Jaishankar (CMWSSB, Chennai) for helpful comments.

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