Keldgate WTW
nitrates removal scheme

by
Peter Corrigan (BSc. CEng. MICE) and Ian Farmery (BSc Hons)

Keldgate WTW is owned and operated by Yorkshire Water Services Ltd (YWS) and is located at Cottingham in the East Riding of Yorkshire. The works was commissioned in 1999 and has a capacity of 90 Ml/d. It is a vital component in ensuring the supply of potable water to the city of Hull, located approximately 5km to the south east of the site. Raw water for the works is supplied from 4 separate borehole sites, namely Keldgate, Dunswell, Cottingham and Springhead.

Aerial View of the Site with Civils Works Nearing Completion *Courtesy of Peter Smith Aerial Photography*

The main elements of existing treatment at the Keldgate works comprise:

- Blending of the raw water sources;
- Chlorination (to inhibit biological growth on downstream membranes);
- Ultrafiltration membranes (primarily as a barrier for turbidity and cryptosporidium);
- Disinfection (with Sodium Hypochlorite);
- Plumbosolvency control (with MSP);
- Treated water contact tank and storage.

The Problem

Over recent years nitrate levels in the borehole waters have been increasing and in the near future are likely to exceed the statutory Prescribed Concentration or Value (PCV) of 50 mg/l. Detailed feasibility was undertaken by Arup, the YWS framework technical consultants, who by modelling future trends based upon historical data, were able to confirm linear and cyclical trends and identify appropriate algorithms for calculation of the 95 and 99 percentile confidence limits for future nitrate levels. This resulted in a peak prediction of 63 mg/l at the design horizon of 2025.

Having identified the nitrate problem YWS agreed an undertaking with the Drinking Water Inspectorate (DWI) to provide a solution by the regulatory compliance date of 31st March 2010.

The Proposed Solution

During feasibility it was determined that options involving discontinued usage of high nitrate level boreholes would not leave the works with sufficient yield of raw water. Similarly, importing water for blending from low nitrate sites was discounted as further treatment would still have been required. A preferred option was therefore identified to construct a new nitrate removal plant at Keldgate WTW.

Initially several technologies were considered including:

- Reverse osmosis – An established treatment technology utilising pressure to force water through a membrane leaving concentrated contaminant on one side and treated water on the other;
- Electrodialysis reversal – Another established membrane treatment process, but utilising electrical charge as the driving force rather than pressure;

- Ion exchange – A physical-chemical process utilising suitably selective resins to replace undesirable ions (e.g. nitrate) with more passive ions in the treated water.

After extensive evaluation, ion exchange technologies were shown to offer the most cost effective solutions in terms of both CAPEX and OPEX. They also offered the added benefit of a much reduced waste stream in comparison with other technologies. This was a significant factor in the decision making process due to limited capacity in the local sewer network.

The preferred solution identified comprised an ion exchange plant capable of treating sufficient flow to reduce nitrate levels in blended treated water to a target level of 42 mg/l at peak nitrate levels and peak flow. This required treatment of approximately 35 Ml/d at full works throughput of 90 Ml/d and would result in the construction of the largest plant of its type in the UK.

The solution also included the capacity to store all waste flows for a minimum of 12 hours in the event of the receiving public sewer surcharging (An automated system inhibits discharge from the site when levels in the downstream sewer exceed agreed levels).

Procurement

The scheme was competitively tendered under the YWS AMP4 Large Scheme programme with documents based on NEC Option C (Target Cost). Arup ensured the transfer of information collected during the feasibility stage by arranging presentations from suppliers and the distribution of a contractor's information pack including the feasibility report and extensive supporting information. However, although several different ion exchange technologies had been evaluated and developed to preliminary design during feasibility (including the final chosen technology) the choice of ion exchange supplier was left to the discretion of the tenderers.

In July 2008 the contract was awarded to MMB, a joint venture between consultants Mott MacDonald and contractor JN Bentley Ltd. The chosen ion exchange technology was NITREAT by ACWA Services Ltd.

Design Issues

Ion exchange resin is extremely vulnerable to chlorine attack and therefore options available included:

- Location of the ion exchange plant upstream of the pre-membrane chlorination point;
- Location of the ion exchange plant downstream of the membranes with de-chlorination upstream and re-chlorination downstream.

With a fixed bed Ion exchange process there were concerns that periodic high concentrations of fine chalk particles in the raw water would lead to fouling of the resin. This might suggest that the most appropriate location for the ion exchange plant was downstream of the existing membrane plant. However, the chosen ion exchange technology includes an innovative fluidised bed process which was considered to significantly reduce the risk of fouling of the resin, thereby allowing the ion exchange plant to be located upstream of the membrane plant. This negated the need for de-chlorination and re-chlorination resulting in significant CAPEX and OPEX savings to the scheme.

Planning Constraints

The works is located in a visually sensitive area and is sited approximately 500 metres to the east of the Grade II listed Skidby Windmill, the last remaining working windmill in Yorkshire. When

Feed Pumps & Bollfilters with Ion Ex Resin Vessels in Background *Courtesy of MMB*

New Building with Saturators being Installed *Courtesy of MMB*

the original WTW was built there was a requirement to finish the buildings externally to a very high standard for a plant of this type. The buildings were arranged around a central courtyard and constructed incorporating architectural features into brickwork and roofs were clad in ceramic pantiles. Liaison with the planning authority during feasibility had confirmed that similar architectural appearance would be required for the new plant and that building heights could not exceed existing.

As a borehole site the proposed nitrate plant would necessarily be situated immediately over a major aquifer located within the Inner Source Protection Zone (SPZ I), as designated by the Environment Agency (EA). Clay cover to the chalk aquifer was as little 3 metres in places and when combined with height limitations on the building meant that necessary excavations for the building footprint would come very close to the chalk surface. A full hydrogeological risk assessment was undertaken and approved by the EA, leading to specific construction methodologies, such as impermeable liners to vulnerable excavations, sealed pipe systems and continuous ground water monitoring, being employed in order to minimise risk to the aquifer.

Construction and Programme

All necessary planning conditions were discharged by January 2009 with MMB taking possession of site from 5th January. Construction required few intrusive works to the existing plant (only two under pressure connections to the existing raw water main and power connection to the existing MCC). However, in order to minimise costs, YWS agreed that access to the site could be via the existing works with site cabins located in the existing courtyard. Good cooperation and communication between all contract parties (MMB, YWS and Arup) ensured that construction proceeded smoothly and the main civils work, including the new process building, was completed by July 2009. This allowed ACWA relatively undisturbed access for the installation of the ion exchange plant.

Mechanical and electrical installation also proceeded smoothly with wet commissioning beginning in November 2009 followed by commissioning into supply in December 2009. After resolution of some minor issues, particularly regarding systems integration and control systems, the 28-day reliability test period began in February 2010 and was successfully completed in March 2010. This resulted in project completion and takeover in advance of both the contract date and the regulatory compliance date. Completion was also achieved within the scheme budget.

Conclusions

Although delivering the largest plant of its type in the UK in an environmentally sensitive location did not happen without overcoming some obstacles, there was good organisation throughout and an excellent collaborative approach from YWS, MMB and Arup. The result is clean and modern plant housed in a building which blends in well with the surroundings and constitutes a high quality asset for Yorkshire Water. The scheme is considered to be a success by all parties.

Note: ***The Editor & Publishers thank Peter Corrigan, Capital Solutions Manager with Yorkshire Water Services Ltd and Ian Farmery, Project Manager with Arup, for providing the above article for publication.***■