Shap WwTW

new wastewater treatment works using a Membrane Biological Reactor improves River Eden Special Area of Conservation

by Peter Ratcliffe BSc C Eng MICE

Shap WwTW in the Cumbrian Fells serves a population of 1,200. The WwTW and an upstream CSO both outfall to Shap Beck, a tributary of the River Leith. The Environmental Agency's '*Habitats Directive Review of Consents (May 2007) for the River Eden Special Area Conservation*' raised concerns about the water quality of the River Leith, and modelling and analysis showed that to meet long term water quality targets Shap WwTW would require a revised consent. While phosphorous reduction is the main habitat driver, the BOD and Ammonia also needed to be addressed. The revised consent is 7 : 25 : 2 : 1 (BOD : SS : Ammonia : Phosphorus.). There was also a requirement to reduce spills from the CSO from 138 spills a year to a maximum of 25, and an aesthetic driver requiring 6mm screens on the CSO outfall. Earlier in the project lifecycle United Utilities, the Environment Agency and Natural England had discounted other options, such as piping the flows to discharge to less sensitive watercourses or transferring the sewage to another wastewater treatment works.

Sludge consolidation tank and supernatant storage tank - Courtesy of United Utilities

Existing works

The existing Shap WwTW consisted of an inlet works, primary tank, trickling filters and humus tanks. Sludge was held in a tank, thickened and tankered off site. Supernatant was returned to the head of the works for treatment.

The existing works had a design flow to full treatment (FTFT) of 1.1Ml/d. The team considered two possible FTFT; 1.3Ml/d and 2.0Ml/d. The process and hydraulic assessment of the existing works confirmed that the FTFT could not be increased to 1.3Ml/d. Given that the existing works was 50 years old, and in need of structural and mechanical refurbishment, it was decided to construct a new WwTW rather than refurbish the existing and add additional process units.

Team approach to delivery

The project team was made up of staff from all alliance partners, namely United Utilities, MWH, and KMI plus (Keir, Murphy, Interserve and Mouchel) with the object of delivering the best solution, safely, on time and at the lowest whole life cost. The team manage design & construct projects through the concept, definition, implementation and handover stages.


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Reversible permeate pumps in main plant building
Courtesy of United Utilities

April 2012 - Aeration tanks, 1mm screens and membrane lifting gantry
Courtesy of United Utilities

GRP Switch room kiosk and Adams inlet band screens
Courtesy of United Utilities

Process selection

The following processes were considered for the new works:

- Membrane biological reactor (MBR).
- Biological filters followed by SAF.
- Two stage SAF.
- SAF followed by BAFF.

At initial analysis it was considered that only the MBR and the SAF-BAFF option could be guaranteed to achieve the required 7mg/l BOD. Outline designs were completed for both these options and a whole life cost estimate prepared, which considers capital costs and operational and maintenance cost over the life of the asset. There was little difference between the two options, the MBR being slightly more economic. The MBR also has a smaller footprint, a significantly lower visual impact, and a lower carbon footprint.

The MBR option was selected though this took some time as the business was aware of the environmental impact of the high power consumption of the MBR process, and wanted to be completely certain that this level of investment was needed. A number of review panels all confirmed that the MBR was the right process.

The requirement to reduce the spill frequency of the upstream CSO from 138 spills a year to 25 was achieved by intercepting the spill pipe between the CSO and Shap Beck and constructing a 600m^3 detention tank with a pumped return. The overflow from the tank was to be screened to 6mm by using a static screen.

The selected process

The recommendation of the project team was a 1.3Ml/d MBR treatment works with a 600m^3 detention tank. However, at a meeting of United Utilities Habitats Group it was decided to use the higher FTFT of 2Ml/d for the WwTW, with the CSO detention tank reduced from 600 to 300m^3. With a smaller detention tank and a higher FTFT it was more likely the detention tank would be emptied and cleaned between storms.

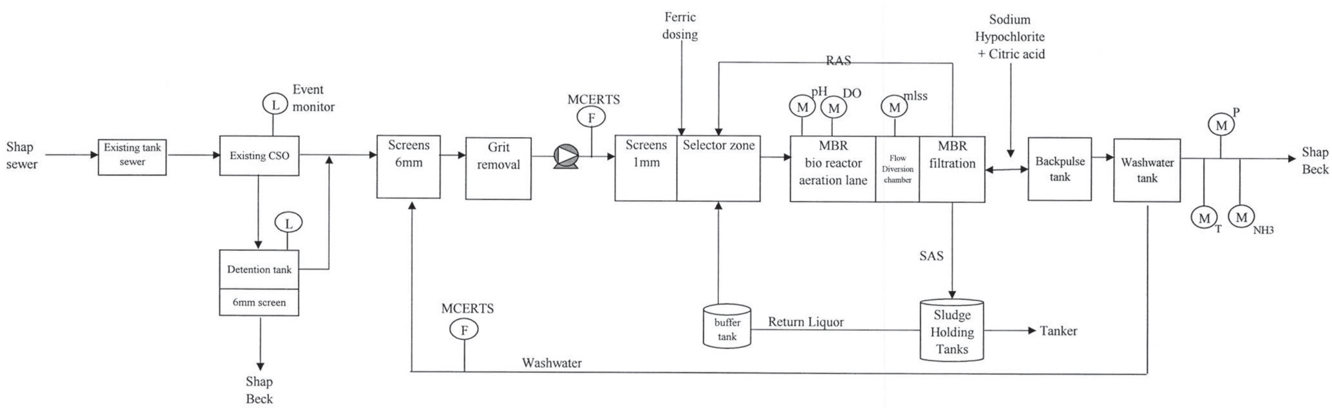
The finally selected scope was an MBR plant rated at 2Ml/d with a 300m^3 detention tank on the CSO outfall.

Site selection

The preferred site was alongside the existing WwTW, however the land owner preferred to sell land in the next field, slightly further away from his farmhouse. United Utilities agreed to purchase this land and also arranged to rent additional land for use during construction. On completion the existing WwTW was demolished and the land returned to agricultural grassland.

Geotechnical

Once the site was selected boreholes were taken. The ground was found to be 3m of drift , comprising very soft clays, with peat



Shap WwTW - Process Flow Design - Courtesy of United Utilities and gravel on a limestone bedrock. The limestone is an aquifer with artesian groundwater, under sufficient pressure to rise in piezometers to about 4m above ground level. In places on the site there were springs. This groundwater was to cause some difficulties during construction.

Design

United Utilities already operated two MBRs, at Nether Kellet WwTW and Over Kellet WwTW, near Lancaster. The design team visited these MBR sites and met with the operator who was very happy with the performance of the works, but had learned many lessons which were incorporated into the design and layout of Shap WwTW.

The main lesson was that the pneumatically actuated valves were problematic in cold weather due to freezing. This was overcome at Shap by using electrically actuated valves wherever possible, and locating valves that had to be pneumatic, inside a heated kiosk.

Another lesson was to omit a bypass on the inlet screens. MBRs are particularly sensitive to screenings. Two stage screening was selected; a 6mm Adams band screen followed by 1mm drum screens. All screens are duty/standby, each able to take the full FTFT.

The layout at Kellet was cramped, and United Utilities field service engineers advised that better maintenance access should be incorporated into the design of Shap WwTW. The project team also visited a plate membrane plant but United Utilities process operations preferred the hollow fibre membranes that they have experience of at Kellet.

A building was required to house RAS pumps, membrane filtration pumps, chemical storage and dosing rigs, MCCs and welfare facilities. It was initially thought that a stone clad slate roofed building would be required, however Cumbria County Council accepted a barn type of building, a blockwork structure clad in timber to match a nearby barn received planning consent in June 2010. The planning authority also required the boundary to the new works to be a lakeland dry stone wall.

The process design determined to use two aeration lanes, and two membrane filtration lanes. The aeration lanes were large enough so that in summer each could handle FTFT and average load. This would allow maintenance of the aeration system in the future. Each membrane filtration lane could filter FTFT by temporarily increasing the membrane flux rate. This would be required during chemical cleaning of the membranes when one membrane stream is off line for cleaning.

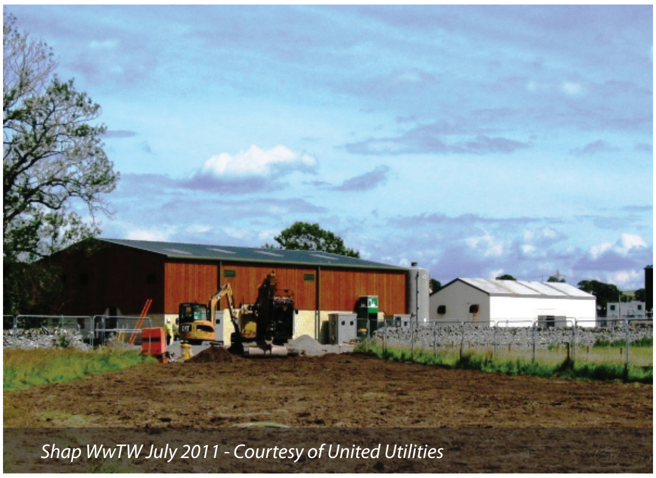
To meet the phosphate consent, ferric sulphate is dosed immediately upstream of the aeration lanes. Other chemicals required were sodium hypochlorite and citric acid, which are used to clean the membranes, and sodium hydroxide for pH correction. Chemical cleaning of one train of membranes at a time is achieved by pumping chemically dosed treated effluent backwards through membranes. The ferric dosing attracted a final effluent iron consent of 1mg/l.

Surplus activated sludge is pumped to two new sludge tanks, designed with decant manifolds to allow supernatant to be decanted to a supernatant tank, from where supernatant is pumped at a trickle (1l/s) to the head of the aeration tanks for treatment. These sludge tanks were sized so that a single sludge tank could hold the volume of a membrane filtration tank. When a full membrane chemical cleaning is scheduled, (expected to be no more than every 6 months or so) a sludge tank will be emptied, and following the chemical cleaning the chemicals in the MBR tank will be pumped into the sludge tank to await disposal or neutralisation.

Blowers were housed in a very large GRP kiosk, two sets of blowers are required; one to supply air to the aeration lanes, and one to air scour the membranes, to keep them free of sludge. The aeration


March 20 11 - The main plant building - Courtesy of United Utilities


March 2011 - Construction of MBR tanks - Courtesy of United Utilities


Shap WwTW July 2011 - Courtesy of United Utilities


Winter 2011 - Flooded excavations following torrential rain
Courtesy of United Utilities

blowers were controlled by DO probes, this would help save energy and also reduce the risk of foam production, which had been a problem at United Utilities Kellet WwTW. This GRP blower kiosk, and other kiosks on site, had the appearance of white roughcast walls and grey slate roof, a requirement of the Planning Authority.

Detail design

KMI led the detail design. The civil, structural and architectural design was carried out by Mouchel, and the process, mechanical, electrical design by Interserve. GE Water who supplied the membranes carried out the process design. Detail design commenced in July 2010, about a month ahead of the start on site date.

The site construction team input to the detail design to ensure constructability. In particular they influenced the foundation design. Initially short piles were preferred for carrying building loads through the glacial tills to the rock, however this was changed to bulk excavation and backfill with stone from a nearby local quarry. This saved weeks on the construction programme as excavation and stone fill could commence without the need for significant design input for the piles, or procuring specialist piling contractors.

The project team was challenged during the detail design to reduce the project costs. A value engineer exercise relocated the welfare facilities into an unused space above the proposed MCC room, concrete roads were changed to bitmac and it was decided to remove the caustic dosing from the scope, but to leave space for caustic tanks and dosing rigs it in the unlikely event that pH correction was proven to be required.

Construction

Construction commenced in August 2010. The first site task was an archaeological survey, carried out because the site was near to Shap Abbey, however no artefacts were found. The winter of 2010/11 was particularly cold and wet, and much time was lost due to poor weather, in particular there was a period of very heavy rain when the site excavations flooded, no doubt aided by the artesian groundwater. The weather continued to delay progress during the construction period. Time was lost when snow prevented access to the site, and many more days were lost when cranes could not operate due to high winds. The site team had to reschedule a number of times, but the mechanical and electrical installation was carried out very quickly, which helped to recover much of the time lost to bad weather during the civil works.

Commissioning

The delayed construction put pressure on the commissioning team. Commissioning commenced in July and had to be accelerated to meet the regulatory date of 30 September 2011. Acceleration is difficult when using biological processes but biomass was imported from other UU sites and with hard work, long hours and a little luck, the commissioning team were able to claim the works in use on 29th September 2011, one day ahead of the regulatory date.

The UID output for the CSO had a regulatory date of 13 September 2012. With the new WwTW in use demolition of the old works could commence which allowed pipework to be constructed to connect up the existing CSO to the new detention tank. The UID output was achieved in December 2011, well ahead of regulatory date.

Landscaping and completion of roads and paving continued into March 2012. In April 2012, United Utilities CEO, Steve Mogford, who had been taking a close interest in the project, opened the new works. The opening was attended by local councillors who praised the efforts of the site team in reducing the impact on Shap village during construction.

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