

# Clay Mills STW

## innovative approach to design and construction of the new Bio-P activated sludge plant

by Adrian Bancroft & Richard Thomson

Clay Mills STW is Severn Trent Water's largest filter works serving a domestic population of around 100,000 in Burton-on-Trent, Staffordshire. The works receives a very significant trade load, predominantly breweries and associated industry, resulting in a population equivalent (PE) of 421,879 with FFT 112,665m<sup>3</sup>/d and DWF 47,000m<sup>3</sup>/d. As part of AMP5, Clay Mills has been given a revised and more stringent quality obligation under the UWWTD P removal legislation. The new limit is 1mg/l or 80% removal of phosphorous and this consent level is the principal driver for the upgrade of the plant. As well as the new activated sludge plant the scheme also includes a new sludge thickening plant, acid phase digester and CHP to improve the performance of the digestion plant and increase the green energy generated from biogas. The £45m scheme is being delivered by MWH Treatment as part of the £200 million e5 programme of large projects for Severn Trent Water.



### Collaborative approach unlocks design

The feasibility and solution development phase was complicated due to the unusually high number of site constraints. These include a main line level crossing at the site entrance and limited land availability due to flood plain restrictions.

A collaborative team of Severn Trent Water and MWH Engineers was therefore set up to review the options in terms of process optimisation, environmental impact, outline design and constructability. This early contractor involvement was fundamental in unlocking the outline design, and value engineering the scheme down from £60m to £45m.

The innovative preferred solution was selected as a Carbonaceous Bio-P ASP utilising 40% of the existing filters which would be refurbished and converted to tertiary nitrifying beds for ammonia removal. The principle scope includes:

- Interstage pumping with cross-site 1,200mm diameter flow and return HDPE Weholite pipelines.
- Bio-P ASP with 6 (No.) final settlement tanks.
- Filter conversion to include sealing of baseslab joints, new filter floors, and 12 (No.) new cantilever distributor arms. The dimensions of the filter bed are 160m long x 122m wide x 1.8m deep.
- Primary and SAS sludge ABCT belt thickening plant with poly dosing and odour control.
- Acid phase digestion APD with associated sludge heat exchanger plant.
- 1MW Jenbacher containerised CHP unit.
- PST de-sludging Ram pumps, primary sludge screen and transfer pumps.
- New intelligent motor control centres (iMCCs) with SCADA and fibre optic comms.
- HV power supply upgrade to 4.5MVA.

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Tel: 0870 493 1408  
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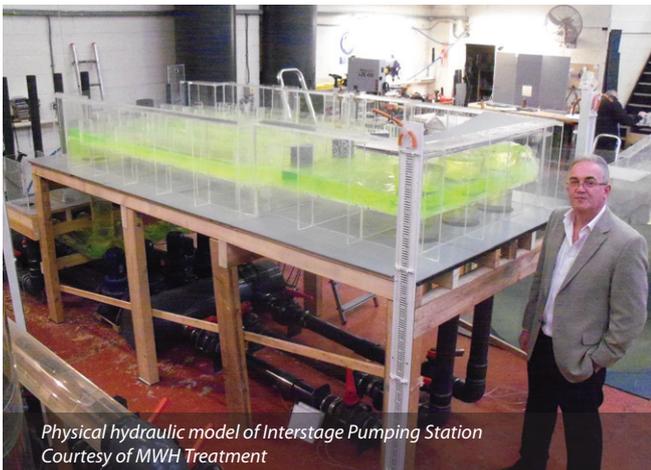


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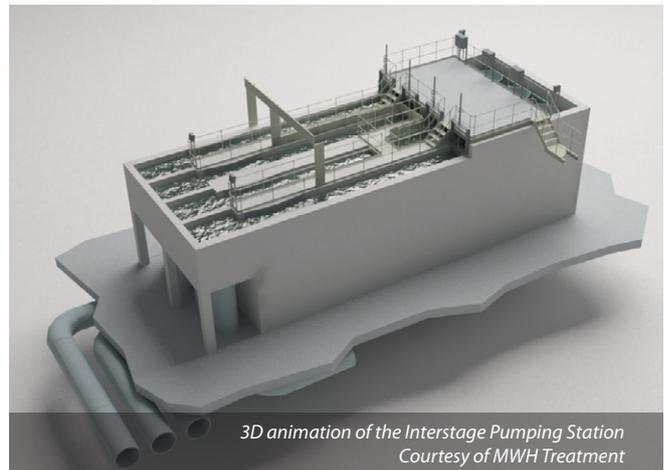


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Physical hydraulic model of Interstage Pumping Station  
Courtesy of MWH Treatment



3D animation of the Interstage Pumping Station  
Courtesy of MWH Treatment

#### Ground penetrating radar eliminates service diversions

Due to the congested nature of the site it was essential to undertake a ground penetrating radar (GPR) survey where new structures and pipelines were to be constructed. A detailed drawing of all services was produced by the in-house survey team and passed to the MWH designers to incorporate into the detail design. Trial holes were then used to verify final positions. This early work substantially minimised the risk of service strikes during construction and allowed piling layouts to be revised to avoid service diversions and associated deep excavations. The need to divert a Victorian Sewer was avoided eliminating a deep excavation and saving £70,000 and 4 weeks programme time.

#### Protecting wildlife

Ecology and habitat surveys were carried out which identified a live badger main sett with thirteen entrances in the construction area. A mitigation strategy was developed with environmental consultants, Middlemarch Ltd, to relocate the badgers prior to closing the sett under licence from English Nature. The new artificial badger sett was constructed from recycled material outside the site boundary on the high ground adjacent to the woods where the badgers forage. The relocation, using a peanut butter bait trail, took place between July and November and the badgers successfully adopted the new sett, which was a record 450m away from their original habitat.

#### Flood risk assessment minimises environmental impact

The site is in the flood plain of the Rivers Trent & Dove, so a

comprehensive flood risk assessment was carried out to analyse the 100-year flood conditions. This proved that the boundary could not be significantly extended as it would create a pinch point which would restrict flood flows. The flood embankment had to be realigned to provide space to construct the new works, but a compensation area had to be provided at the far end of the site. Proactive programme management allowed this area to be delivered two years early. Early consultations with the Environment Agency (EA) were extremely beneficial and an alternative sheet piling solution was accepted which saved time and cost.

#### Physical modelling optimises interstage pump performance

The interstage pump sump and ASP distribution chamber were combined to give a compact layout. Hydrotec Ltd conducted physical modelling to optimise the sump configuration in conjunction with Bedford Pumps. Additional baffles were added to improve flow characteristics resulting in an extremely efficient design which will benefit the OPEX and extend asset life. A de-gassing chamber was added on the ASP feed pipes to eliminate entrained air flowing into the anoxic zone.

#### Biological phosphorus removal process avoids chemical dosing

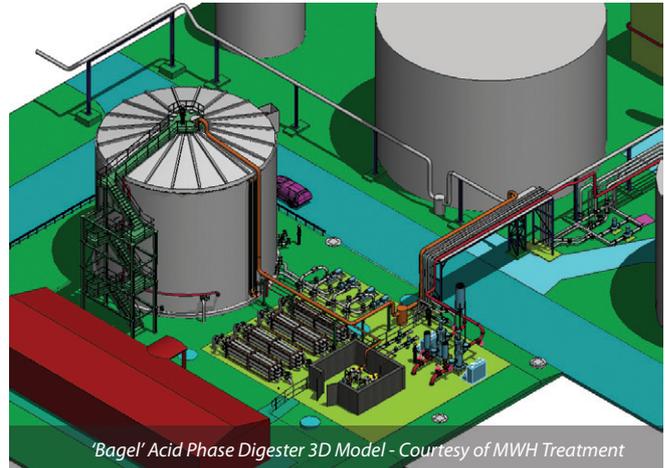
The Activated Sludge Plant (ASP) has a volume of 30,000m<sup>3</sup> which is split into four double-pass lanes. The anoxic mixers are Chemineer paddle type as they are slow speed, well proven, robust and reliable. The diffusers are Suprafil PTFE encapsulated EPDM domes which offer high efficiency, enhanced chemical resistance and extended life of 14 years. The blowers are ABS HST centrifugal type which offer



Clay Mills STW panoramic - Courtesy of MWH Treatment



Aerial Photo of the FST - Courtesy of MWH Treatment



'Bagel' Acid Phase Digester 3D Model - Courtesy of MWH Treatment

high efficiency and low maintenance due to the electromagnetic bearing system. DO control is via Hach Lange instruments which are fitted with self-cleaning compressors.

#### Precast final settlement tanks maximise productivity

6 (No.) 35.8m diameter FSTs have been constructed from precast concrete segments supplied by Carlow Precast Ltd. This innovative technique saved £100,000, reduced the number of HGV movements across the railway by 12%, required fewer site operatives, and shortened the programme by six weeks. The FSTs are fitted with MWH full-bridge scrapers with McKinney baffles fixed to the diffuser drum to ensure accurate flow distribution. The final effluent gravitates from the FSTs via a new 1,200mm diameter Weholite main into the existing filter distribution pipework.

#### Sludge thickening plant designed for safe operation

The sludge thickening equipment will be housed in a portal frame clad building to provide a secure and safe working environment for the gravity belt thickeners and polymer dosing plant. The layout evolved in conjunction with the operators, site construction team, suppliers, lessons learnt from previous projects and was reviewed using a 3D model produced by MWH design. This collaboration has achieved an effective plant layout, providing good clear access around the equipment and an overhead gantry crane has been provided to cover all maintenance lifting requirements.

There has been an increase in stainless steel theft so it was decided to complete the building and then use the upgraded 5T gantry

crane to install the units to ensure security. The thickened sludge pumps were selected as Mono wide-throat type to minimise the risk of blockage with EZstrip™ for ease of maintenance. By sinking the pumps into a central chamber the presses were able to be installed at ground level avoiding access platforms to the benefit of the operators.

#### 'Bagel' acid phase digester reduces construction footprint

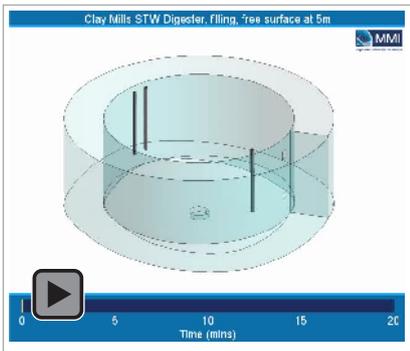
The e5 sludge core team worked with Severn Trent Water to develop an optimised design for the Acid Phase Digestion (APD) process based on 'lessons learnt' from operating the APD at Derby. 2 (No.) acid phase digesters in series give a total of two days retention at peak flow configured as a tank within a tank to give a more compact footprint.

The "Bagel" APD is constructed from epoxy coated steel (efusion™ 1500) with a stainless steel roof for maximum corrosion resistance. The APD is gas mixed to give a 90% effective volume and heated to 42°C although there is flexibility to lower temperatures during process optimisation to minimise OPEX.

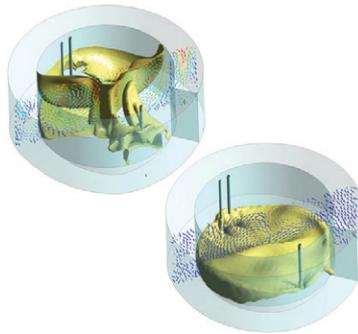
Corrugated tube heat exchangers were designed by HRS Heat Exchangers to allow ease of cleaning and the hot water loop was restricted to 60°C to minimise the risk of Vivienite build-up.

The APD process is predicted to increase the gas yield by 23% and an additional 1MW CHP unit was fast-tracked to maximise revenue generated from the Renewable Obligation Certificate (ROC).

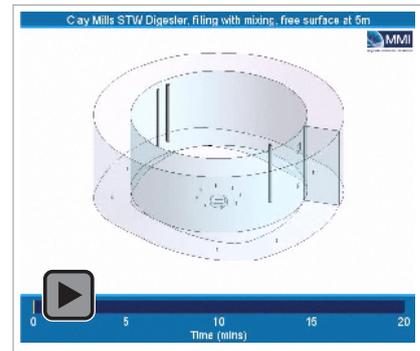




**Click to play:** Feed sludge passage through the digester during filling **without** mixing - Courtesy of MMI Engineering



Isosurfaces of feed sludge at 2/100th of initial concentration during filling with and without gas mixing (after 5.5 minutes), also showing velocity vectors



**Click to play:** Feed sludge passage through the digester during filling **with** mixing - Courtesy of MMI Engineering

### CFD modelling verifies APD process design

MMI Engineering were responsible for the CFD modelling of the Acid Phase Digester to determine the extent of short circuiting of feed sludge between tanks 1 and 2 during filling. This verified that the transfer pumps could be engineered out and replaced by cross connections. The modelling captured the non-Newtonian rheology of the sludge, temperature gradients, along with the interaction between the biogas and sludge when gas mixing was in operation. The analysis determined the best mode of operation for filling is to stop the mixing; this resulted in only 2% short circuiting which is acceptable compared with 4% when mixing is on.

### Energy management

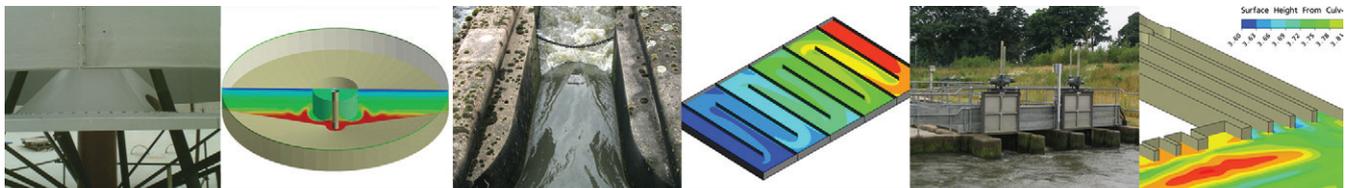
State of the art energy monitoring equipment has been installed enabling energy usage trending for each area of equipment. This was made possible using intelligent iMCCs and a new supervisory, control and data acquisition (SCADA) system linked together using a dual redundant fibre optic network.

### Carbon footprint - 25% reduction

The site has used 23,693 tonnes of CO<sub>2</sub> in the construction process, which is a huge 25% reduction (7,982 tonne) when compared with the original design, which had a total CO<sub>2</sub> usage of 31,675 tonnes.

Savings in CO<sub>2</sub> were due to several key design changes including:

- Combining the interstage and RAS pumping stations with the ASP distribution chamber which avoided using 361m<sup>3</sup> of concrete.
- Using Weholite HDPE and PE pipework instead of ductile iron saved 5,666 tonnes of CO<sub>2</sub>.
- The building of the ASP and FSTs as well as other structures above ground meant 72,994 tonnes of soil was diverted from landfill.
- Using PowerCem ground stabilisation as a piling mat for the ASP saved importing 7,680 tonnes of recycled aggregates.



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- Building the FSTs from precast sections rather than in-situ saved 20% on the concrete and rebar materials.
- The acid phase digestion process will increase the gas production by 23% which will offset the CO<sub>2</sub> as it will be used to generate 1.8MW of electricity. Also the digester is constructed from steel rather than concrete.

### Two ICE Merit Awards

The team were delighted to receive recognition from the ICE East Midland Region who commented:

*"The Merit Award winner of the Small and Medium Project category was Clay Mills STW, submitted by MWH, for its precast final settlement tanks where significant project cost and time savings in creating an aesthetic solution impressed the judges. Also their soil stabilisation project which involved the introduction of a new product to the UK and combined with innovative and courageous thinking by those involved marked them out as winners."*

### Considerate Constructors Silver Award 2013

The Clay Mills team worked tirelessly over two years with the local community and councillors to establish the least disruptive HV cable routes between the primary substation and the site, taking into account school holidays, mass traffic, local resident's disruption and parking constraints.

This proactive approach culminated in avoiding laying cable down Wetmore Road which would have disrupted 300 households. A public exhibition was held at Burton Albion Football stadium.

The project has been well rewarded with a Silver Award from the Considerate Constructors Scheme, which acknowledges the project's efforts to 'improve the image of construction' and respect the scheme's core values.

### Clay Mills Victorian Pumping Station Trust

A good relationship has been developed between the volunteers who run the steam pumps and site team. We have provided wood for the boilers, car parking, construction tour and organised two steaming events where the 130 year old steam pumps were run which was a fascinating experience for the site team.

Presentations were given to local schools on sewage treatment as part of their educational visits where they were given a fantastic insight into Victorian life.

### Summary

The Clay Mills Scheme is progressing very well with construction complete and MEICA installation well advanced. Turn of flows is on target for January 2014 with completion forecast for June 2014, three months ahead of the regulatory Q date.

The filter refurbishment will commence in March 2014 and run until March 2015. The close collaboration and knowledge sharing between the e5 partners and the supply chain has produced innovations which have generated value engineering savings of £2.6m. This should ensure the team deliver to the 'stretch' target to the mutual benefit of Severn Trent Water and e5 partners.

*The Editor & Publishers thank Adrian Bancroft, Programme Manager with Severn Trent Water, and Richard Thomson, Project Manager with MWH, for providing the above article for publication.*

*The authors thank the following for their input and assistance with this paper:*

*Patrick Heffernan, Site Manager; David Bennett, Principal Mechanical Engineer; Jeff Briggs and Peter Boden; Civil Design Engineers; Darren Chiles Principal Electrical Engineer; and Alex Stubbs, Engineer; all with MWH.*

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