West-East Link Main

the challenges met in delivering detailed design of the 55km pipeline

by Martin Meadows I Eng AMICE AMIStructE

Effective water resource management and ensuring security of supply are key issues for water companies. United Utilities is committed to improving both for the North West region - particularly the major population centres of Liverpool and Manchester - and recognised that these could be achieved by connecting the two independent systems that transport water from the Lake District and North Wales to their customers. The resulting £125 million West-East Link Main project delivered 55km of 1.2m diameter welded steel pipeline, which is capable of bi-direction flow and carrying up to 100 million litres of water a day through gravity and pumped systems. The project formed part of United Utilities' £2.9 billion AMP4 investment programme between 2005 and 2010 to improve water quality and the environment but was approved and planned to be delivered through the end of the AMP4 period and beginning of the AMP5 period. The design and build contract was awarded in late 2008 to Murphy Pipelines. Atkins and Nomenca supported Murphy's detailed design team to deliver this project.

Motorway crossing — *Courtesy of Atkins*

Getting started

On reviewing the preliminary design, the team identified a change in route that would mitigate a number of major construction challenges; this change at detailed design stage created a staggered programme for the team. Work continued on the original route while planning applications were made across a number of councils for the re-routed section.

The final route crosses five golf courses and runs beneath the West Coast Main Line railway, the Bridgwater canal, and the M6, M61 and M66 motorways. The two and a half year project incorporates 10 (No.) major tunnel crossings and a further 19 (No.) other tunnel crossings along the route. Atkins' geotechnical and tunnelling experts met head on the challenges associated with crossing such varied ground, such as identifying the varied geology along the route and designing a supplementary ground investigation accordingly.

The following table summarises the varied stratigraphy encountered along the route of the pipeline:

Made Ground	Period
Peat	Recent
Alluvium	
Shirdley Hill Sand	
River Terrace Deposits	
Laminated Clay	Glacial
Glacial Sand & Gravel	
Glacial Till	
Sherwood Sandstone	Permo-triassic
Coal Measures	Carboniferous

As the ground conditions were identified, the team addressed the following main issues:

Mining and opencast mines

35km of the pipeline route crossed over coal measures strata and backfilled opencast pits, which had the potential to cause settlement and buckling to the pipeline if no remediation was undertaken. The team took a risk-based approach to assess the extent of the remediation with United Utilities playing an integral part of the remedial team to assess risk versus cost. M & J Drilling undertook the significant investigation and remedial works with many mine shafts and adits to be treated. Many of these were in difficult to access locations.

Peat

9km of the pipeline was routed through Chat Moss with all the compressible and long term settlement issues of peat potentially affecting the pipeline. Atkins undertook detailed geological mapping and site investigation to target the thickness and type of the peat. The result was that the length of the pipeline where significant excavation and remedial measures were required was reduced to about 25% of the original estimate.

Tunnels and approvals

Atkins' tunnel designs were relatively routine for small diameter (1.8m) pipejacks. However, a number of pipeline crossings required permission from the Highways Agency and Network Rail and - although this in itself is not unusual - the pressures of a continuous tunnelling programme meant that all parties had to work together to successfully and speedily resolve design issues before they happened. Atkins worked closely with Murphy's sub-contractors on tunnelling methods before making submissions to the regulatory bodies.

To minimise waste removed from the site and maximise reuse of materials, the team assessed the various ground conditions down to formation level for reuse as embedment and backfill materials. The sustainable use of as dug material for structural side fill required careful selection processing and control of compaction on-site to meet the calculated proctor densities. The team achieved site control using cleg hammers calibrated for each side fill material. This reuse of native soils significantly reduced costs associated with importing and disposing of materials.

Imported pipe bedding was used to bed the pipe and ensure adequate compaction under the pipe haunches. The integration of the geotechnical, civil and land contamination teams lead to a single sheet deliverable, which summarised all the required data on the long sections, including the health, safety and environment issues to be aware of along the route.

The development of the pipe structural design including connections lead to a flexible steel 10mm thick pipe to BS EN 1295 being specified. The deflection was limited to 3% to prevent damage to pipeline coatings. A number of different suppliers were used to meet the order because of the large volume of pipes and fittings required and additional checks were carried out to confirm the jointing system and pipes were compatible.

Hydraulic design

Hydraulic design for a bi-directional pipe of this magnitude require consideration of a number of criteria - but before the team could begin to even consider any of these, it had to overcome uncertainty over the initial details, which included:

- Final pipe route.
- Tunnels.
- Losses associated with the proposed welded insulated sleeve joints.
- The detailed pipework arrangements at Prescot and Bury at the time when the critical path items of pumps and motors had to be ordered.

Site investigation *Courtesy of Atkins*

Logging peat *Courtesy of Atkins*

To overcome the initial uncertainty, the team carried out a 'worst case' and sensitivity approach to the likely numbers of bends and the losses at each joint, which informed the M&E design and established the required maximum motor and variable speed drive power to facilitate selection. To aid the assessment of losses for the 5,000 joints, a computation fluid dynamics CFD analysis was undertaken to refine the initial calculated values.

The team carried out surge analysis of both the pumped and gravity flow scenarios in-house using Deltares Wanda software and resulting in a requirement for two duty and one standby surge vessel each of 80m^3 and a two-stage 15min closure of the main 700dia control valve to ensure pipeline pressure never goes sub-atmospheric, preventing possible contamination being drawn in via the air valves. To prevent the surge vessel air expanding and being lost into the pipeline during high gravity flow operation, a control sequence vents off the excess air via heated and silenced expansion valves when higher flows are selected.

The unconventional position of the surge vessels some 100m downstream of the pumps – as a result of the lack of space in the existing pumping station area - required specific analysis and assessment of alternative fast acting nozzle type NRVs to ensure the NRV slam caused by the surge wave reflection from the surge vessels was controlled to within the 20bar surge pressure limit of the PN16bar valves in the pump station. Hydrotec was commissioned to carry out physical hydraulic modelling to assess the implications of repositioning the existing pumps and pipework to make space for the new WELM pumps. The model extended into the Prescot service reservoir to ensure the culvert intake arrangement did not create unacceptable swirl or vortices at the pump impellers.

Prescot Pumping Station

Connecting into the existing pumping station posed a significant challenge as the large diameter pipework had to be threaded

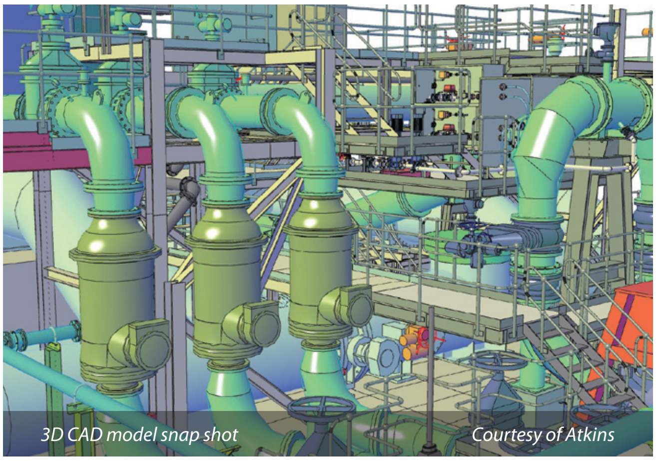
Construction work underway *Courtesy of Atkins*

through the existing infrastructure within the pumping station at Prescot. The construction, access, lifting and maintenance issues associated with this part of the solution required a high level of accuracy and multiple stage assessment to ensure the pipework could be installed and maintained safely.

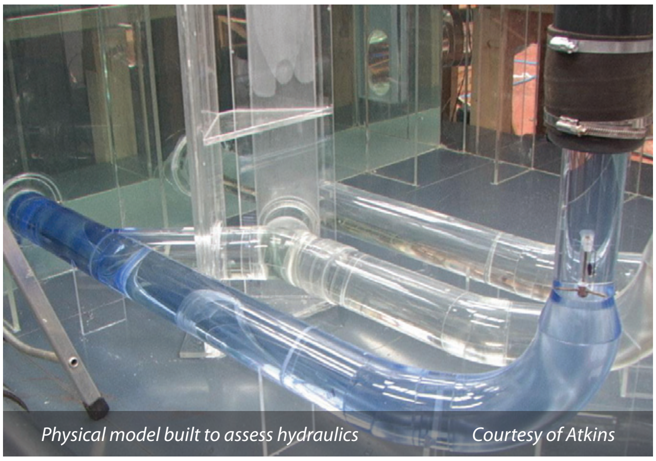
The use of a laser survey which was converted to a 3D CAD model was invaluable in meeting the design team and client's requirements in developing the solution. The 3D model was used in the ALM to show the client operational staff how the new sections would integrate with the existing pumping station and how they could access the plant to operate it.

Electrical systems

The integration of the supporting electrical systems for the WELM pumps and the existing pumping station required the amalgamation of the new 4kV pumping equipment together with the existing distribution systems which served 4 (No.) existing



3D CAD model snap shot *Courtesy of Atkins*



Physical model built to assess hydraulics *Courtesy of Atkins*

11kV/400v transformers together within the new switch panel.

The team developed the HV system to include the two (No.) 4kV - 2164kVA pumps and the connection point for a 2000kVA standby generator to serve the West-East Link Main.

The increased power and security of supply requirements were met through the upgrading of the Scottish Power (DNO) supply to the site to enable two number separate services from the primary systems within their network.

The scheme required not only the grading of the 4kV pumps with the new DNO supplies and the WELM site incomers, but also to enable the grading across the existing transformers to be included in to the new scheme panel, together with the system protection requirements served standby generator. The team had to model the systems to develop the fault levels over a series of scenarios using the Amtech Power Net and Protect. Detailed analysis and hand calculations of the Amtech software package were carried out to compare the many facets of the relay protection curves.

Conclusion

There were many design challenges to meet across the whole scheme but the integration of the detailed design team with the construction team lead to the successful delivery of the West East Link Main pipeline to United Utilities, which will provide security of supply to the North West of England for generations to come.

The editor and publishers wish to thank the following for preparing the above article for publication. Martin Meadows, Project and Design Manager, Jill Given, Assistant Project Manager and Civil Designer, David Mitchell, Hydraulic and Civil Design Lead, Joyce Brady, Geotechnical and Tunneling Design Lead, and Michael Collinson, Building Services Design Lead. All are with Atkins.