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Delivering a spatial infrastructure water-modelling and management solution

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Purpose of paper

GI technologies are increasingly prevalent in the management of civil infrastructures. Yorkshire Water Services (YWS) is one such utility that places a high value on the benefits of GIS. YWS has invested and developed a substantial GI-based business model for the operations and management of its asset records. Their GI-technologies support the complete business life-cycle from planning through to decommissioning of the network. YWS have also pioneered a number of innovative business support tools to aid the management of the networks

This paper presents a modelling application that has been developed by Kellogg Brown & Root (KBR) to assist YWS in solving a specific business need. Fundamental to the success of this project was KBR's understanding of the clients engineering problem and its ability to realise a GI solution with tangible business improvements.

The paper discusses:

- Background to the project
- Why a GI-based approach?
- The key issues
- The solution
- Business improvement
- Where next..?

Background to the project

Yorkshire Water Services (YWS), part of the Kelda group, is responsible for the operation and management of the water and wastewater infrastructure including the conurbation's of Leeds, Bradford, Sheffield and Hull. At the centre of the operations is the process and planning for new infrastructure and the on-going management of the existing facilities.

KBR in association with Scott Wilson is a Service Partner to YWS, proving engineering expertise under a framework agreement. As part of this framework, KBR were requested to investigate the engineering work with respect to YWS's water and wastewater networks that would arise from the construction of the Leeds SuperTram.[1]

The SuperTram has defined a corridor along which the tram will run. This has a geographic extent that is expected to impact utilities within this corridor. The key business requirement was therefore to identify

[1] The Supertram is a new tram scheme proposed to connect the conurbations of north and south Leeds, via the town centre

those sections of the water and wastewater network that would conflict with the 'foot print' and hence require works diversions to minimise future disruption to the tram's operation and ensure YWS access to their infrastructure. Thereby provide a proactive approach to the management of the diversions.

Why a GI-based approach?

Initially the engineering team from KBR were provided paper maps showing the location of the SuperTram 'swept' path[2]. Additionally, YWS provided AutoCAD paper map-based records of their water and wastewater networks. KBR's engineers began using this information to manually identify locations where YWS networks overlapped the proposed tram corridor.

However, this approach was both time consuming and problematic, as each change in the tram corridor triggered the reinvestigation of conflicts. As a result, KBR's GIS Services team were invited to assess whether the process for conflict identification could be improved through the application of GI-technologies.

Initial discussions with KBR's engineering team and YWS confirmed that a GI-approach would deliver significant business advantages and efficiencies. This was most appropriate in change management as and when revisions to the proposed tram corridor arose.

The entire water and wastewater network is held within YWS's asset register, including the spatial component on the location of the assets. This is stored in a customised GIS designed to assist in the day-to-day business operations. As a result, KBR have used these asset records to aid an application that could automate the clash detection process.

Additionally, the SuperTram proposed corridor was also available in digital format (DXF), thereby enabling a direct spatial relationship to be established with YWS's network. This was subject to further value-adding enhancement brought about by KBR's engineering knowledge (as discussed below).

The key issues

Discussions between KBR's GIS Services and engineering teams identified a number of key issues that were subsequently reinforced during follow on discussions with members of YWS and the SuperTram team. These are:

- To identify the conflicts between the tram 'swept path' with the water and wastewater network;
- The ability to model a user defined work zone alongside each edge of the tram 'swept path', such that a 'protected' corridor could be modelled. This would act as a safe working area between the tram and YWS network.
- Each of the YWS network sections were depicted as a single line. In terms of conflict detection, it was vital to model the extent of each of the network section diameters.
- The model should include for a repository of associated engineering documentation;
- The model should be able to provide data reporting in a format that can be readily used to produce engineering costings for the work diversions

The solution

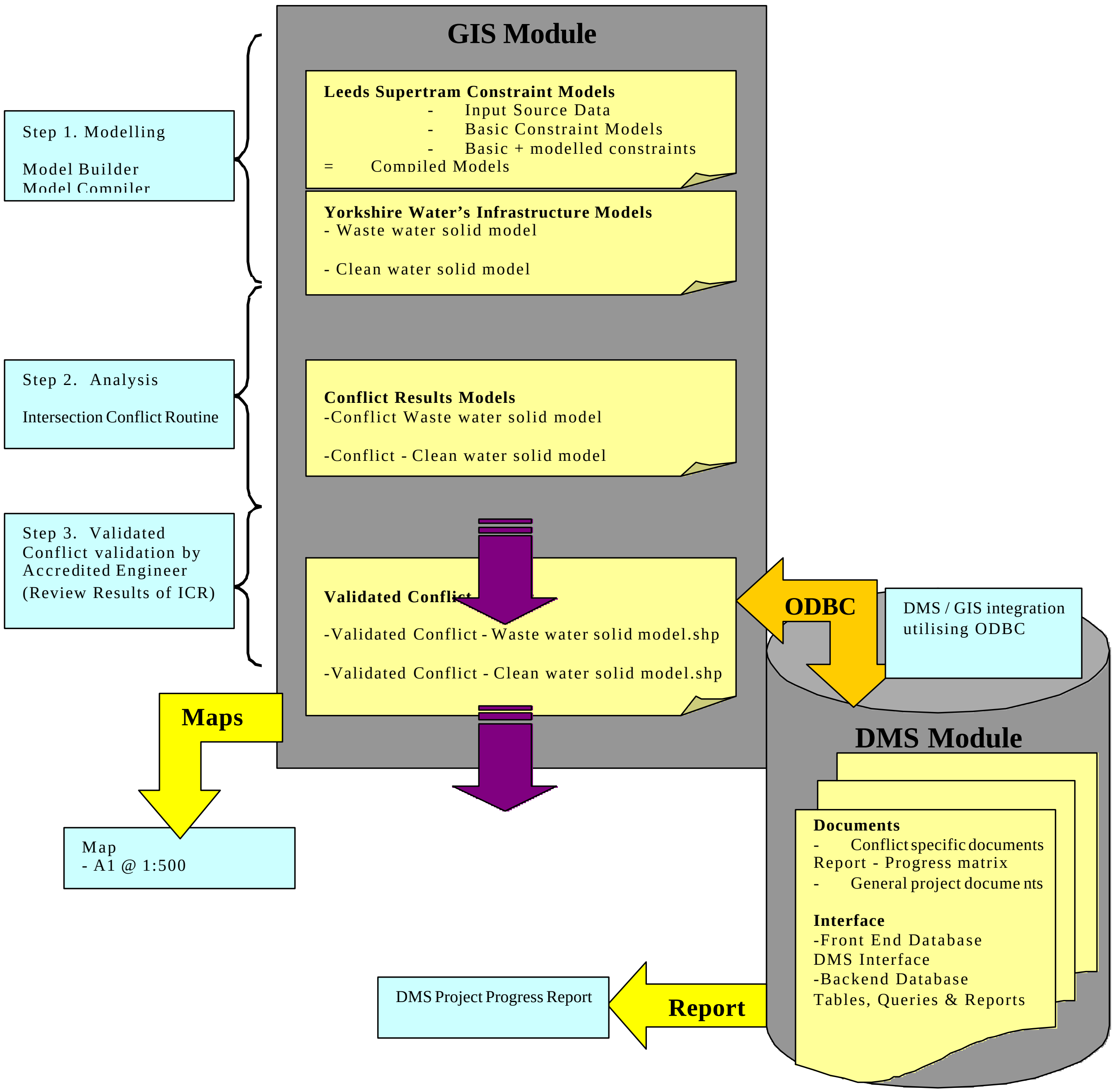
In response to the engineering issues highlighted, a customised GIS and integrated Document Management System (DMS) was developed to provide solutions and potential business improvements to the YWS SuperTram project.

The system was built in ESRI's ArcView environment through the Avenue programming language in addition to VBA modules created for the Document Management System residing in Access. This system design was

[2] The 'swept' path refers to the extent of the corridor that buffers the main tram line, including areas to accommodate the tram's overhang.

chosen with consideration to the clients operating platform, project cost and development time. An overview of the integrated GIS & DMS solution is presented below, this diagram outlines the GIS utility modelling and conflict identification process and how the DMS is integrated with the DMS. The attribute table of the validated conflicts modelled by the GIS are then shared with the DMS via an ODBC connection, see figure 1.

Figure 1. Overview of GIS solution



After the implementation phase, the Water modelling and Management GI system was perceived to bring a plethora of benefits to the project team. And these will now be discussed, grouped under four categories which represent the key features and benefits of the system.

GIS modelling of Utility network footprint and SuperTram Infrastructure

One of the key components to the GIS system was the addition of a modelling element, which provided the functionality to model utility polyline data into realistic geometrically correct networks, built from the pipeline's engineering diameters. The distinct advantage of this when running "clash detection scenarios"[3] is all too apparent as the respective water pipe network's solid dimensions are taken into account, and the process is run on these realistic metrics and not the centre lines of the pipeline network. The later of which would result in potential conflicts not being identified, see figures 2a & 2b.

Figure 2a; Showing YWS Waste and Clean Water Utility Networks as a polyline network. In this case a conflict was not identified with the swept path of the Central Route of the SuperTram.

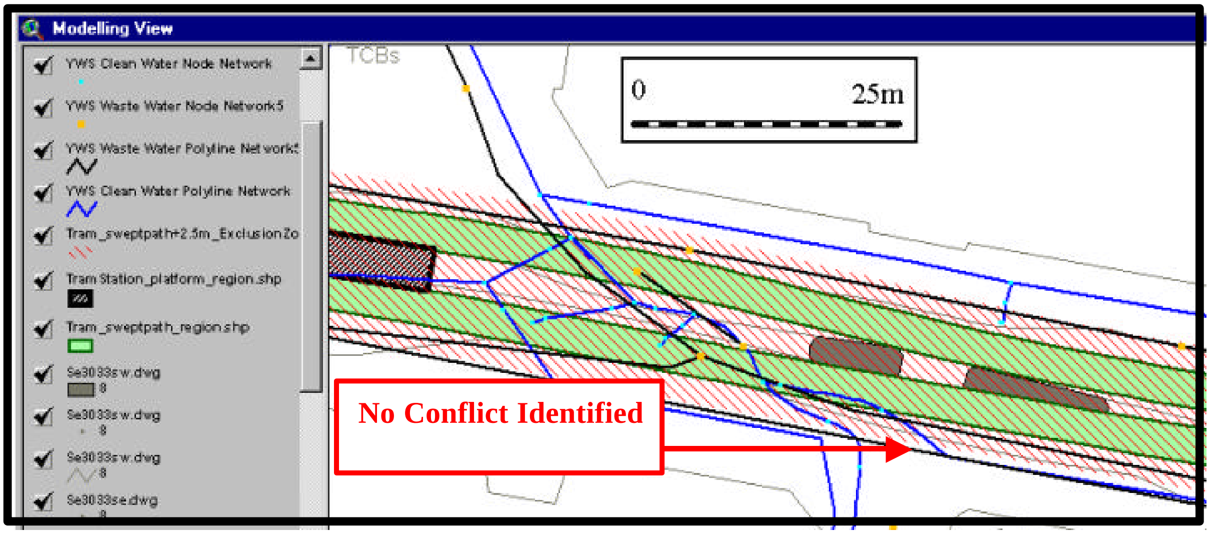
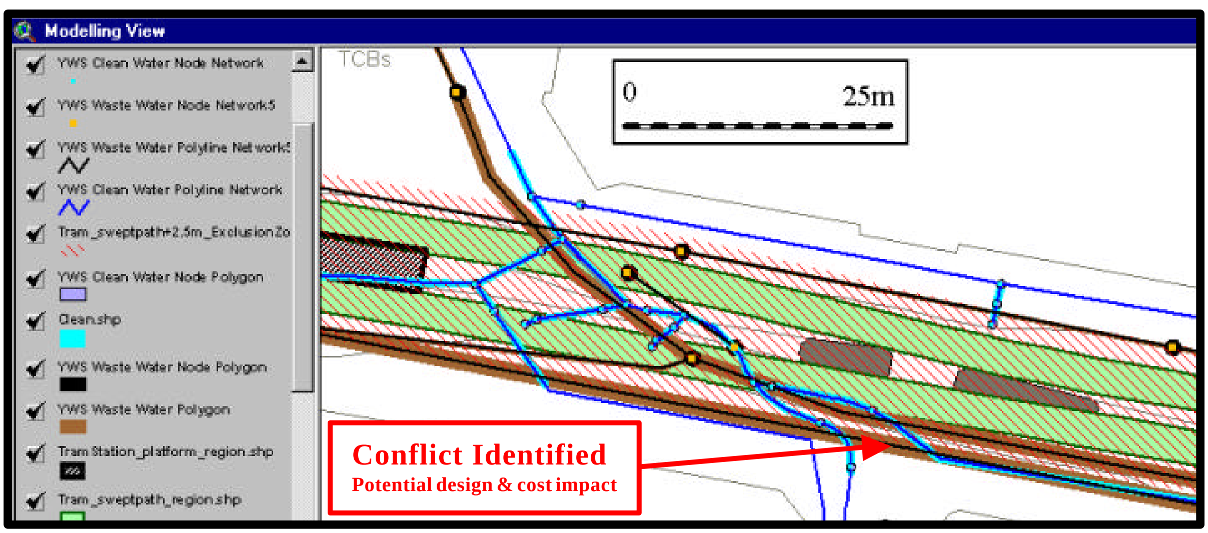


Figure 2b; showing YWS Waste and Clean Water Utility Networks as a Solid Model. In this case a conflict was identified with the swept path of the Central Route of the SuperTram. OS landline data is shown.

Note: A Conflict is identified where the utilities running parallel with the swept path. The application was able to identify a number of potential conflicts which would have a significant impact on the engineering costs was identified by the analysis.



Note: This report contains Ordinance Survey Landline data, supplied by YWS.

[3] A process to identify where conflicts occur between the pipe network and the SuperTram swept path.

The modelling functionality also enabled the SuperTram Infrastructure to be built, with the inclusion of all the various elements, such as the SuperTram Path, the Exclusion Zone, Tram platforms, OHLE (Overhead Line Equipment) and trees.

The inclusion of these features adds another dimension to the clash detection routine and enables YWS to effectively model the SuperTram infrastructure. These infrastructure elements combined with the modelled water and waste water pipe networks help build and replicate a more realistic solid model of the network.

Additionally, the dynamic nature of the modelling function meant that each individual element could also be continuously remodelled based on different inputs, a prime example was the extension of the Exclusion Zone which was originally stated as being 1.5m and then altered to 2.5m to allow for modelling a "working zone".

Once the modelling has been completed, the infrastructure conflict routine can be run, identifying the areas of potential conflict arising between the SuperTram Infrastructure and the existing Yorkshire Water clean and waste water pipe network.

As a direct result of this process the intersecting sections of pipes are clipped by the SuperTram Infrastructure and created into new geometric shapes within a new GIS layer and intersection lengths for each are calculated and stored in the attribute table, along with all their pre-clipped attribution to allow for pipeline identification and association.

Document Management for Project Management

The Document Management System (DMS) was developed as a document archive and retrieval system linked to the GIS. It is a structured RBMS which supports the project management by monitoring the progress of conflict identification and re-engineering.

The DMS's link to the GIS provides Yorkshire Water with the ability to select geographic features in the GIS and ascertain their related documentation in the DMS; the selected documents can then be opened in their native programs.

The DMS offers a general facility for searching and retrieving documents, and has been structured as two separate document management components in order to satisfy the two distinct functional requirements, one being conflict specific documents the other being general project documents.

The conflict specific documents component was designed to cater for the documentation linked to the validated conflicts layer. This dynamic link is established between the DMS and GIS via Open Database Connectivity (ODBC) technology. The conflict numbering system resulting from the C3 engineering phase[4] has been established as the primary key index. This index relates the DMS records with the geographic features within the GIS, with this index being common to both modules.

An additional feature of the DMS is its ability to operate as a separate system, allowing individuals within the project team who have no desire to operate GIS technology can directly search and call documents from the database, providing they have Microsoft Access on their machine. Moreover, this enables project progress to be monitored, enabling the project to produce a "progress matrix". This matrix confirms that the key documents have been loaded into the DMS and a project management report illustrates the overall progress measurement by identifying the percentage of key documents loaded to the DMS for each respective route.

[4] C3 & C4 engineering terms relate to phases of the detailed design and review process.

Figure 3. DMS Project Progress Report

Project Progress Report
Conflict Numbers

Brown & Root in association with

Route	Sheet	ID	C3 Designs	C3 Cost Estimate	Interim C4 Design	Interim C4 Cost Estimate	C4 Designs	C4 Cost Estimates	Final Designs
02									
	01								
02	01	C01	☑	☑	☑	☑	☐	☐	☐
02	01	C02	☑	☑	☑	☑	☐	☐	☐
02	01	C03	☑	☐	☐	☐	☐	☐	☐
02	01	C04	☑	☑	☑	☐	☐	☐	☐

The second general project document component acts a general repository for the project documents such as technical reports and policies. This component of the system caters for the documents, which do not relate to specific conflicts and hence do not have a geographic equivalent object in the GIS.

Scenario Modelling

The dynamic nature of the GIS Water modelling and Management system enabled the project team to easily analyse a number of alternative tram routes for the SuperTram scheme. These varying options can then be compared to indicate the relevant number and scale of conflicts resulting from the different proposed tram routes.

The flexibility of the system through utilising simple functions and processes that form the key stone of GI technologies, has greatly reduced the time and cost needed for Yorkshire Water to run initial clash detection and comparison analysis.

Value comparison of the manual method versus the GIS method

There is a financial gain to be had through using the system to run iterative clash detection processes, as illustrated through the following simplified example.

Comparison of labour required for Manual and GIS methods

Manual Method		**GIS Method**	
DURATION	RESOURCES	DURATION	RESOURCES
Initial Survey and conflict identification Process			
6 weeks	3 men	6 weeks	2 men *(Inc: Software development)*
Typical change revisions arising from alternative "foot prints"			
1-3 weeks	2 men	0.5 week	1 man

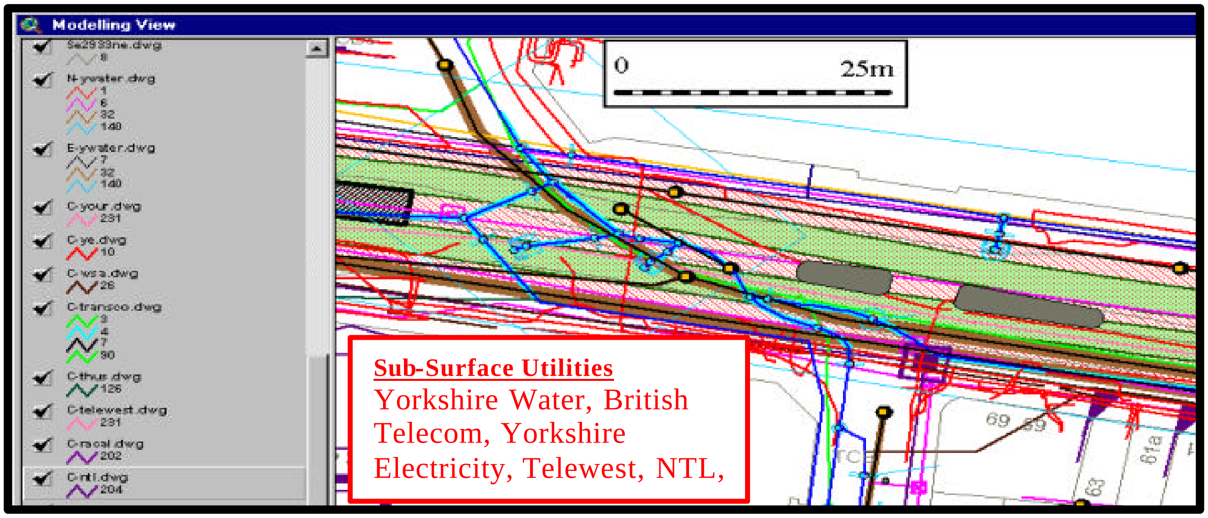
Conclusions

GI technologies have a demonstrated benefit as a utility and infrastructure management tool also enabling the interface management between these elements. However, the system is fundamentally dependent on the asset records held within Yorkshire Water's database. This project has demonstrated the significant value of a utility company maintaining its records to an appropriate standard.

The system has provided Yorkshire Water with improvements in main areas and has highlighted that GI technologies are ideally suited to undertaking clash detection processes, reducing labour costs, aiding in the visualisation of assets and conflicts, enabling greater flexibility and adaptability in responding to changing conditions, providing an easy and efficient way for project progress management in addition to facilitating an easier method in which to disseminate information.

The relative successes of the system have only re-enforced the fact that a GI led system can hold great benefits to all utility companies that require identification of potential conflicts and management of these issues, see figure 3.

Figure 3. Leeds City Centre, Tram Route along The Headrow; showing sub-surface utilities.



Where next?

The project, thus far, has achieved the original objectives and demonstrated the power of GI-technologies. The key business improvements now being considered are:

- Development of a generic model that YWS can use on a number of their projects to assess and plan for water and wastewater network model, with the potential for multi-utility clash detection management. A number of new projects are expected for this tool, and YWS and KBR are currently discussing how to enhance the functionality, accordingly;
- YWS have developed as part of their research and development programme, Augmented Modelling (AR), and it is proposed that YWS consider a greater level of integration of the GI and virtual reality models. The first stage would involve importing those sections of the networks were clashes have been identified into the AR model such that YWS engineers can visualise the on-site locations of the proposed diversion works.

Glossary and Abbreviations

DMS	Document Management System
GIS	Geographic Information System
ICR	Infrastructure Conflict Routine
ODBC	Open Database Connectivity
OHLE	Over Head Line Equipment
YWS	Yorkshire Water Services
DWG	Design Exchange Format
CAD	Computer Aided Design
RDBMS	Relational Database Management System

DOCUMENT HISTORY RECORD

Doc No. **Title:**					
Rev	**Date**	**Description/Reason for Issue**	**Orig**	**Ckd**	**Appd**
R3	21 June 03	**DELIVERING A SPATIAL INFRASTRUCTURE WATER MODELLING AND MANAGEMENT SOLUTION (R03)**	DTM		
R4	09 July 03	**DELIVERING A SPATIAL INFRASTRUCTURE WATER MODELLING AND MANAGEMENT SOLUTION (R04)**	PSG		
R5	15 July 03	**DELIVERING A SPATIAL INFRASTRUCTURE WATER MODELLING AND MANAGEMENT SOLUTION (R05)**		PSG/DTM	
R6	23 July 03	**DELIVERING A SPATIAL INFRASTRUCTURE WATER MODELLING AND MANAGEMENT SOLUTION (R06)**			NR