CASE STUDY

FELINDRE-TO-TIRLEY
1200-MM GAS PIPELINE
Project description

RSK was contracted to provide specialist technical services to a section of the Felindre-to-Tirley gas pipeline project. The 107-km-long section of the 1220-mm-diameter, high-pressure, welded-steel pipeline stretches from Brecon in South Wales to Tirley in Gloucestershire and was constructed by Murphy Pipelines Ltd. Initially, RSK’s work involved the design, procurement, management and supervision of the ground and groundwater investigation of the proposed route; analysis of the collected data; and submission of the appropriate recommendations with respect to design, construction and the final choice of route. The ground investigation included conventional techniques and the innovative use of geophysics techniques where access precluded the use of boreholes and trial pits.

The results of the ground investigation were given in interpretative reports that presented the vast amount of data in formats that were tailored to the needs of the design and construction teams.

Following the ground investigation, special studies were undertaken into landslide hazard, mining and quarrying. An earthquake and fault hazard assessment was also performed.

The landslide hazard assessment identified several slopes that were potentially unstable, especially during seismic events. These were investigated further by a combination of boreholes and geophysics techniques. The results were fed into state-of-the-art FLAC3d models to determine the stability of the slopes under static and dynamic conditions.

3D slope and geology models

The seismic hazard risk assessment work led to the permanent installation of four seismometers at selected locations along the route. Data is recorded locally and streamed to a secure server for subsequent engineering analysis. The system is likely to be upgraded in the near future to a 24-hour, real-time monitoring and control system.

State-of-the-art groundwater modelling was undertaken by RSK and the British Geological Survey (BGS) to determine the feasibility of installing the pipeline across a 200-m section of a shallow gravel aquifer at Vowchurch, which is the sole water supply for 15,000 people in the Dore Valley. The modelling also included an assessment of the impact of the installed pipe.

RSK also provided project management and technical support during the design and implementation of the surface water and groundwater monitoring regimes during the pre-, during and post-construction periods.

Main site investigation

The main ground investigation provided considerable challenges owing to the remote locations and rugged terrain in the foothills of the Brecon Beacons. Because of the environmentally sensitive location, National Grid was especially concerned that this phase of the work was carried out to the highest standards with minimal impact on the land during and after drilling. RSK therefore elected to deploy crawler-mounted Pioneer drilling rigs. These rigs are clean, modern, highly mobile and ideally suited to the soil profile. The Pioneer drill is capable of dynamic soil sampling in superficial deposits to obtain near-undisturbed continuous samples, which are up to 112 mm in diameter and retained in a plastic liner. On encountering rock head, the rig can readily switch to rotary coring mode using a water flush to recover high-quality cores up to 116 mm in diameter.

However, in some of the remoter areas even the Pioneer rigs could not gain access. To overcome this, the RSK geophysics team developed the concept of virtual trial pits to investigate the soil characteristics and the rock head profile. The virtual trial pits involved using the seismic refraction technique, which is based on the propagation of seismic waves through the subsurface and their refraction at interfaces across which there is a sufficient increased contrast in acoustic velocity. Seismic energy is generated using multiple hammer blows to a hammer plate. Analysis of the time taken for the seismic energy to travel from the shot point to an array of distances from the source can provide information on the geometry, depth and elastic properties of subsurface materials, which can be related to geology. At each site, two orthogonal spreads of geophones, each some 48-m long, were deployed. After processing, the resulting data enabled imaging to depths of 5 m into the bedrock. Details of the varying thicknesses and depths of key horizons were determined according to their mechanical properties. Verification drilling at two locations confirmed the ability of the virtual trial pits to accurately identify rock head.

Although RSK used innovative and unusual approaches to gather ground investigation data, it also worked closely with the designers, construction crews and quantity surveyors to develop new ways to make the borehole and laboratory test data timely, relevant and meaningful. One outcome of this was that the interpretative report contained very little text. Most of the analysis of the engineering properties of the soils and rocks and the groundwater data, and the assessment of construction issues such as trench stability and trafficability were presented as a series of traffic-light colour-coded bars along the base of A3-size long sections. As a result, the non-specialist members of the project team could easily identify potentially problematic areas. An intuitive cross-referencing system provided simple access to greater detail in the factual report. These books of long sections became widely used throughout the project, and the team welcomed this approach enthusiastically.
Mining and quarrying hazard assessments

Mining and quarrying hazard assessments were undertaken to provide a basis for evaluating the presence and likely zones of influence from historic, current and planned mining, along with an assessment of the potentially economic mineral reserves that might be mined in the future. This assessment involved desk studies and ground investigation. The work facilitated the creation of a generic model of the geological and related potential mineral resources versus historical, contemporary and possible future mineral extraction patterns. From this, a pipeline-route-specific matrix of potential mineral resources versus generic and the more detailed regionally customised methods of extraction was developed for all of the possible types of mineral resource present. All forms of hazard were assessed, including traditional hazards such as ground subsidence, void migration and shaft collapse, and less common hazards such as gas emissions, aggressive mine waters and biological hazards from diseased animals and waste.

The resulting dataset was assessed using a qualitative risk assessment approach with one of four risk categories, very low to high, being assigned to each actual or potential occurrence. For each moderate to high risk rating, mitigation measures were proposed. These ranged from the complete excavation and recompack of loose backfill at a former shallow stone quarry to in-trench clay barriers where the pipeline passed close to an animal burial site.

Landslide hazard assessment

Ground conditions and stability were also critical for the operational integrity of the pipeline. A landslide hazard assessment was undertaken by RSK to assess the pipeline corridor for areas of potential slope instability. RSK’s work was peer reviewed by Kingston University.

The initial screening process used an advanced geographical information system (GIS) based approach to integrate lidar digital elevation data with BGS digital geology maps and air photographs. Maximum safe slope angles were allocated to each geological unit; where the lidar data indicated that these angles had been exceeded, further investigation was undertaken. The output from the GIS comprised slope angle summary maps with colour-coded zoning of slope angle. This approach, although relatively common in the USA, is believed to have been unique to the UK. The high-tech GIS-based analysis saved weeks of conventional walkover survey work.

Subsequent ground investigations to confirm the ground profile at each of the potential landslide locations incorporated more innovative use of technology. In conjunction with conventional core logging, downhole optical and acoustic scanning were used to provide high-resolution, true-colour images of the borehole wall that identified bedding, fractures and discontinuities. These data were automatically analysed to provide computer-generated rose diagrams and stereonet depictions of discontinuity dip and dip azimuth.

In addition, innovative geophysical techniques were used to determine the structure and physical properties of the subsurface where the slope angles precluded the use of conventional borehole techniques.

The intrusive and geophysical data were fed into state-of-the-art 3D numerical models (using FLAC3D) to accurately simulate the response of slopes to natural earthquakes. As a result, the risks to the pipeline from earthquake-triggered slope failure were quantified and included in the design. This was the first implementation of a continuous workflow from detailed site investigation through to cutting-edge computer simulation.

Seismic hazard assessment

That South Wales is one of the most seismically active regions of the UK was of particular concern. To assess the risk, RSK assembled a team of experts to conduct an earthquake and fault hazard assessment. This included a group of highly qualified and experienced staff from Aspinall Associates, many of whom were part of the Seismic Hazard Working Party set up in 1982 by the Central Electricity Generating Board and who have subsequently worked for Nuclear Electric, British Energy and British Nuclear Fuels.

The assessment provided a basis for evaluating the probability of external forces being placed on the pipeline as a result of direct fault displacement, earthquake ground motions or seismically induced liquefaction.

In terms of the exposure of the pipeline to ground motion hazard, the study gave its conclusions in the form of uniform risk spectra and appropriate peak ground acceleration hazard curves relating free field peak horizontal acceleration to its annual probability of exceedance.

The study recommended ongoing monitoring and, in early 2008, several seismic monitoring stations were installed along the pipeline route to monitor natural ground movements. Another first was the installation of permanent seismometers on the pipe structure itself to provide information on the dynamic response of the pipe to ground motion, and offer the potential to provide real-time information on pipe integrity. These data are recorded locally, streamed to a secure data server and analysed for natural earthquakes. The system is expected to be upgraded in the near future to a real-time, 24-hour warning system that will enable selective shutdown if the ground accelerations exceed the permitted thresholds.
Groundwater modelling
RSK provided assessments of the likely effects on surface groundwater resources, including flood risk assessments wherever the route crossed the floodplain.

The Vowchurch shallow gravel aquifer along the River Dore in Herefordshire was of particular concern, as it provided the sole source of drinking water for 15,000 residents. It was vital that pipeline construction did not affect water quality or yield. There was strong opposition to traditional open-cut construction, the preference being for much more expensive horizontally direct drilled or tunnelled solutions.

Following a detailed site investigation, RSK commissioned the BGS to construct a numerical groundwater flow model using the state-of-the-art, object-oriented ZOOMQ3D package, which was developed jointly by the BGS, Environment Agency and Birmingham University. After running numerous what-if scenarios, the modelling predicted that dewatering during construction would have a small but acceptable impact on the aquifer and that any turbidity would be lost during the 100-day travel time. The impact of the completed pipeline on the groundwater flow and the groundwater heads was also shown to be minimal. The conclusions from the modelling work were tested during a full-scale well-point dewatering test in April/May 2007. The pipeline was installed successfully into a dewatered open cut trench in June/July 2007. Neither Welsh Water nor the Environment Agency observed any significant aquifer derogation. RSK and the BGS subsequently published the results of the study in a paper.

RSK provided project management and technical support during the design and implementation of the surface water and groundwater monitoring regimes spanning the pre-, during and post-construction periods.

Following an initial screening study to identify potentially sensitive areas of groundwater and surface water resources, several groundwater and surface water monitoring locations were agreed. This involved installing standpipes to monitor shallow groundwater levels close to the pipeline route and, in addition, at approximately 40 surface watercourse-crossing points.

RSK hydrologists also conducted an initial screening exercise on more than 100 private water supplies located near the pipeline route. Following site-specific investigations to evaluate the potential effects that the pipeline might have, RSK designed and supervised the implementation of a pre- and post-construction sampling programme for approximately 50 of these sites.

Current status
The construction of the pipeline is complete. Most of the above-ground installations are complete.