The Wigan flood detention reservoir

A.J. BROWN, Jacobs, Leatherhead, UK
D. CLOUGH, Axis, Chester, UK
E. GODDARD, Environment Agency, Warrington, UK
J. D. GOSDEN, Jacobs, Croydon, UK

SYNOPSIS. The paper describes the promotion and design of a new flood detention reservoir on the River Douglas, upstream of the town centre in Wigan, north-west England. The reservoir includes two of the largest Hydro-Brakes® installed in UK and stabilisation of old workings in two coal seams which outcrop in the reservoir basin. The paper also highlights some of the environmental challenges facing the design team and provides thoughts on lessons learned on mitigating the adverse effects of a major new engineering structure.

WIGAN FLOOD ALLEVIATION SCHEME

There is a long history of flooding from the river in Wigan, with the most recent events occurring in 2000, 2004 and 2007. The pre-scheme standard of protection was a 1 in 10 year event with approximately 610 residential and 170 non-residential properties at risk from a 1 in 100 year standard.

The river is heavily modified and largely 'canalized' through the town with an artificial channel bed and defences varying from minor coping stones to raised embankments and masonry floodwalls to a maximum height of 1.6m above local ground level.

The existing defences were 'informal' and not owned or maintained by the Environment Agency. An inspection of these defences identified significant sections as poor or very poor condition. Of particular concern were the masonry and reinforced concrete walls protecting the bus depot and residential properties around Eleanor Street. As recently as August 2004, leakage through this asset contributed to flooding on Eleanor Street (Figure 1 inset).

The scheme was developed through a Flood Risk Strategy for the River Douglas, with the business case for the Wigan scheme approved by the

Managing Dams: Challenges in a Time of Change. Thomas Telford, London, 2010

Environment Agency's Board in 2005. The approved scheme comprised upstream storage and downstream defences which, when operational, deliver a 1 in 100 standard of protection to Wigan town centre.

Funding availability meant that the scheme was spilt into two phases. Phase 1 comprises 1000m of new and raised walls and 300m of flood embankments to the south of the town centre and provides a 1 in 20 year protection. The new floodwalls were in places up to 1.8m high, so to mitigate the visual impact the adjacent footpath and cycleway were raised allowing pedestrians to have views of the river. Phase 2 comprises the reservoir and associated structures which will provide 1:100 year protection.

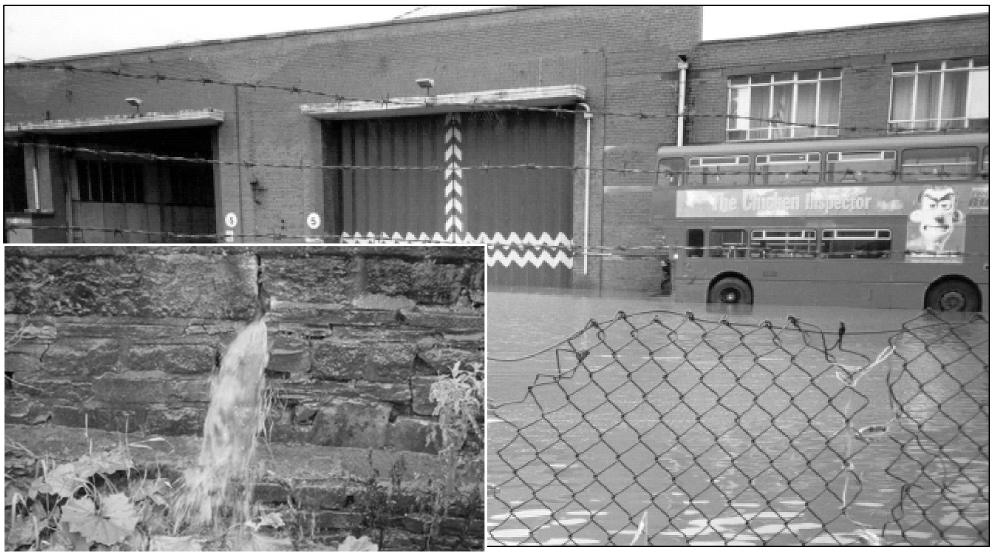

Figure 1. Flooding at Eleanor Street in 2004

Figure 2. Phase 1 wall with riverside footpath/ cycleway

THE FLOOD DETENTION RESERVOIR

Reservoir operation

The hydraulic design of the flood alleviation scheme required that the pass forward flow be limited to a maximum of $20m^3/s$, the flow capacity of the newly enhanced channel through the town with Phase 1 defences completed. Mean flow in the river, as measured at a gauging station just downstream, is $1.2m^3/s$. The adopted scheme has a reservoir volume of $400,000m^3$.

The dam has been designed so that the crest can be raised to accommodate predicted increases in flood flows resulting from climate change. This will also involve providing local flood defences to six properties at the most upstream location of the storage basin, which would be within the footprint of the enlarged reservoir.

Reservoir location and choice of dam site

The reservoir is sited in the Douglas valley as shown in Figure 3. Limiting factors for the dam included the A49 road downstream, and the need to avoid increasing flood risk to properties at Leyland Mill upstream.

Other constraints on maximum reservoir level included Aspull (Great Haigh) Sough which is the outfall from a major underground minewater drainage system. The discharges are now pumped to a series of minewater treatment lagoons further up the side valley. Fortunately the level of the Sough was such that it was possible to mitigate the effects of the reservoir by getting the Coal Authority to raise the level of the control kiosk. A further complication was a massive masonry (Haigh Hall) bridge, partway up the reservoir, which will be submerged to deck level when the reservoir fills. The bridge deck will be lowered at the east end, to provide an overflow path and thus prevent backing up of water levels which would have flooded properties at Leyland Mill.

Other influencing factors on choice of dam site included the gardens of residential properties on valley sides which could be affected by temporary storage, and the embankment for the A49.

The decision was taken in August 2008 to site the dam upstream of Coppull Lane based on a comparison of costs and benefits with inputs from the contractor under the Early Contractor Involvement scheme.

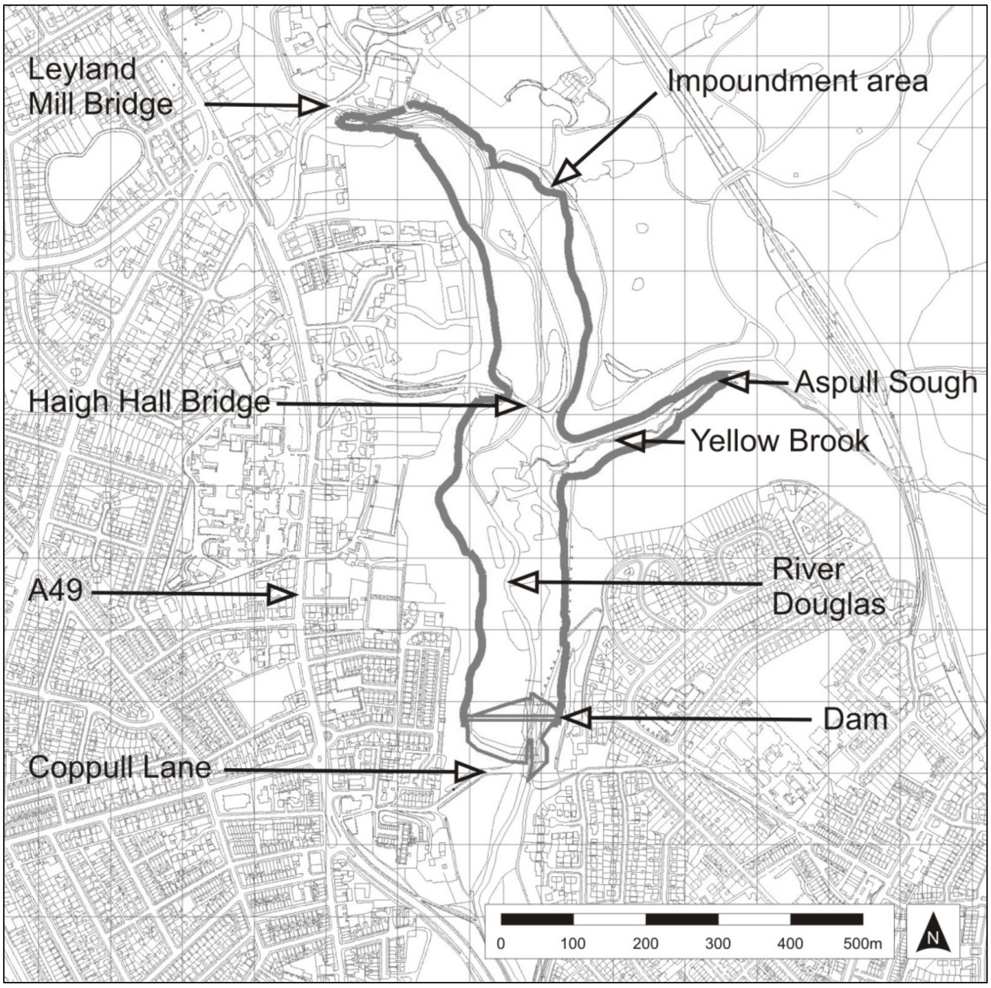

Figure 3. Plan of dam and flood detention limits in the Douglas valley

Environmental constraints on dam and reservoir

The lack of any statutory landscape or nature conservation designations demonstrates that the Douglas Valley was not of national importance in environmental terms. However, at a local level the valley is highly valued as an amenity and nature conservation resource and the design of the dam and reservoir needed to respect these considerations.

Protected species included *Water Vole* (confirmed within the storage area but not affected by construction works) and *Great Crested Newt* (remote from the storage area so unaffected by works or storage). The wetland habitat to the north and east of the storage area was protected by non-statutory *Site of Biological Importance*. Woodland on the south side of Yellow Brook, a left bank tributary of the Douglas, is categorized as *semi-natural Ancient Woodland*. Elsewhere the valley floor has extensive coverage of young woodland, invasive weed *Japanese Knotweed* is prevalent around the proposed dam site and *Himalayan Balsam* is prolific.

Haigh Hall Country Park, also designated ‘Historic Park and Garden’ covers the northern half of the storage area reinforcing recreational and heritage importance. The Haigh Sough mine portal on Yellow Brook is a designated Scheduled Ancient Monument while Sutton Mill and Bottling Wood on the dam axis provide areas of local archaeological interest, comprising an old mill and previous settlement removed as part of slum clearances in the 1930s.

The Douglas Valley north of Coppull Lane is protected by Green Belt requiring the planning authority to satisfy tests of ‘openness’ and ‘need’ before approving any new development. The valley is also overlooked by residential properties to the west adding to the sensitivity of the site. Several footpaths cross the river valley and are well used by the public for recreation and for access to other parts of Wigan.

THE DAM

The dam is an earth embankment 6.5m high above flood plain with a crest length of 120m. Most of its length comprises an overtoppable spillway as shown in Figure 4.

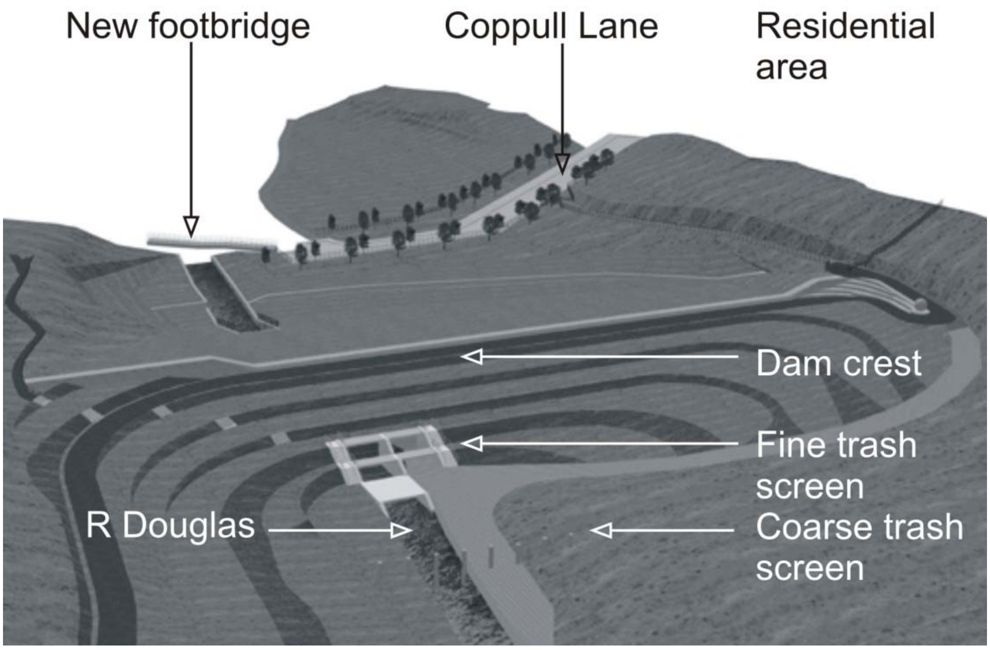

Figure 4. Impression of dam from upstream

Geological setting
The site is situated on Coal Measures, with a thick sandstone band present just below base of the valley, and two coal seams outcropping along the east side of the reservoir with one under the left abutment of the dam. Limited glacial deposits lie under the dam footprint, with soft clay and local granular alluvial material. There is extensive made ground present under the dam footprint, interpreted as mainly colliery spoil.

Micro-location of dam
The dam axis was selected to be just upstream of Coppull lane, to minimize encroachment into Green Belt whilst allowing Coppull Lane to be left largely undisturbed. The control structure is located close to the existing watercourse to minimize changes in river regime in normal operation. The existing vehicle crossing of the river under the dam footprint is removed with the dam crest providing a replacement river crossing. A footbridge just downstream of the dam which obstructed the channel was removed and relocated downstream, immediately upstream of an existing 250mm cast iron water pipe bridge which was retained.

Control Structure
Options considered included gates and hydrobrake, the latter being selected primarily as being a reliable system which does not require electrical or mechanical inputs. In discussion with Hydrobrake International two $10m^3/s$ units were selected as being the maximum size that could be prefabricated and transported to site, each unit having a 2m diameter outlet orifice and 6m long. The units were specified with adjustable intakes, such that the discharge could be varied in future by ±20%. As part of the design additional physical model testing was carried out to confirm how the shape of the discharge curve varied as bars were added to or removed from the inlet with discharge curves shown in Figure 5.

Rockhead in the valley floor was typically one to two metres below river bed, with the foundation excavation taken down to rock and backfilled with engineering fill up to formation level of the structure.

The control structure included an intake structure to house the hydrobrakes protected with standard trash/security screens and coarse trash posts upstream. The lowest channel screen was located upstream of a 6m long section of culvert, suitable for a Hiab lorry to park with outriggers extended while removing trash mechanically. To avoid siltation problems the channel screen and culvert were set equal to the width of the existing river channel, whilst the flood plain screens were wider to suit the size of Hydro-Brakes® and provide the required screen area.

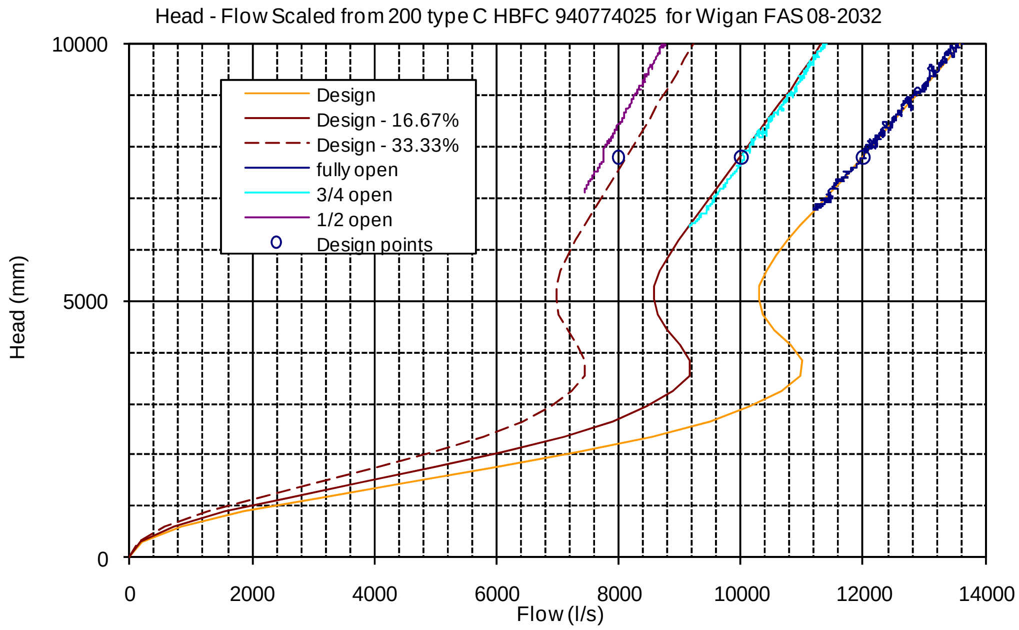

Figure 5. Discharge curves for hydrobrakes

The culvert was large at 6m wide by 2.6m high in order to pass the $20m^3/s$ pass forward flow as open channel flow, although being locally larger at the upstream end to provide a stilling area for the hydrobrake outlets. A 300mm thick gravel bed was provided to minimize fragmentation of the aquatic environment by the culvert. The top of the culvert was shaped using 45° fillets to reduce differential settlement across the side of the structure.

<u>Treatment of old coal workings</u>

The Ince Furnace coal seam is believed to outcrop under the left abutment of the dam as shown on Figure 6, continuing into the reservoir. There are known abandoned workings at depth in the hillside and two adits are recorded as about 20m downstream of the dam axis. In addition a second, higher, seam outcrops further up the reservoir. Issues for dam safety included both the foundation for the embankment and leakage around the dam in disturbed ground and through old workings. Issues for public safety included the risk of impounding events flooding old workings and displacing mine gases into the overlying houses.

The need for, and extent of, treatment of coal seams outcropping on the left side of the valley was determined on the basis of risk assessment, this risk assessment and consequential extent of treatment being agreed with the Coal Authority at planning stage.

The workings were grouted where present under the dam footprint, to ensure no leakage around the abutment and also provide a structural foundation. A search and sealing exercise was also carried out of two suspect adits under the downstream shoulder of the dam.

In the reservoir area, as underground workings do not normally continue to outcrop, partly for stability reasons and also to control ventilation, it is expected that there should be a line of intact coal present just down dip of the outcrop. Thus treatment was limited to probe drilling to search for any adits, which where present were grouted.

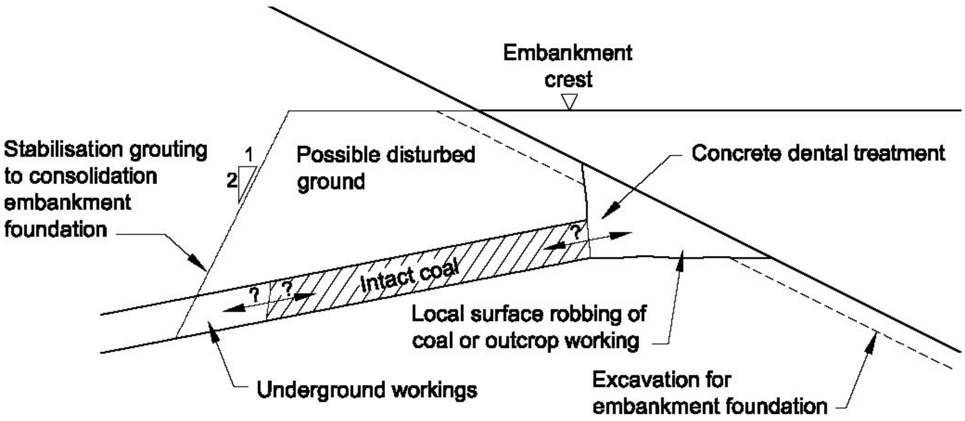

Figure 6. Indicative section on coal seam under left abutment

Embankment

The embankment was formed of a vertical clay core, founded on rock. Upstream and downstream slopes are 1V:3H and 1V:6H respectively. The clay was imported, with shoulders formed of material excavated on site from the core trench and structure excavation. Total volume of fill is 27,000m^3, of which 4,500m^3 is imported clay and filter sand. In view of the foundation to the shoulders comprising made ground over alluvium a two month settlement period, with associated settlement monitoring, was specified before the grasscrete armour layer could be cast.

Spillway

The dam is classified as a Category A structure in accordance with Floods and Reservoir Safety (ICE, 1996), being designed to pass the Probable Maximum Flood (PMF) which was assessed as 246m^3/s. The width of the valley is such that the maximum length of embankment which could be used as an overtoppable spillway is 95m. Consideration was given to both concrete wedge blocks and concrete reinforced grass, with the landscape architect and planners both having a strong preference for the latter. A grasscrete armour system was therefore adopted, although the downstream slope had to be flattened from 1V:4H to 1V:6H to bring flow velocities down to the limiting velocity given in CIRIA Report 116 (1987). As the unit discharge is close to the upper limit for concrete reinforced grass a concrete crest slab with cutoff upstream and downstream was adopted, to provide a second line of defence in the event of failure of the grasscrete system. This is indicated on Figure 7.

A 1m deep stilling basin was provided, designed to operate up to a 1 in 1000 year flood, and detailed to limit damage in more extreme floods.

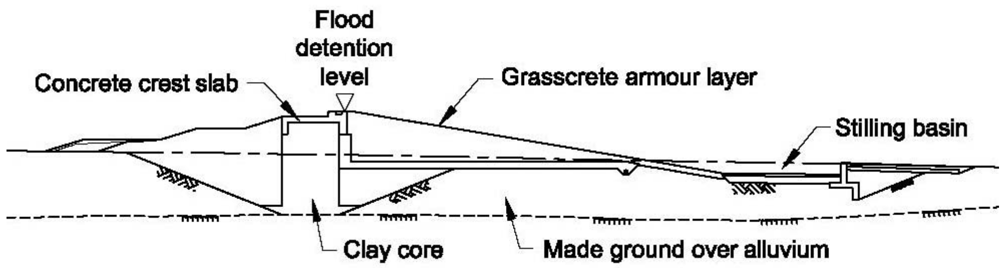

Figure 7. Cross section on spillway

<u>Control of river during construction</u>
The planning and tender designs were based on constructing the control structure in the existing river channel, to avoid any change in the position of the watercourse, with the river temporarily diverted into an excavated channel on the west side of the valley. However, in the early stages of construction, due to concern over the large volume of excavation, and consequential increased loss of trees to accommodate the temporary stockpile areas, the design was changed to construction of the control structure in a cofferdam to the west side of the existing channel, which was thus retained to pass river flows.

LANDSCAPE DESIGN AND ENVIRONMENTAL MITIGATION
The landscape design sought to achieve the following objectives.

<u>To fit a large man-made engineering structure into a wooded valley</u>
The straight angular form of the embankment is disguised by augmenting the upstream face with additional earth mounding and providing flowing contours to help the embankment grow naturally out of the valley sides. The terraced upstream face breaks down the length of consistent shallow gradient into a more human scale and provides added interest through the shade cast in certain lighting conditions. Tree planting was not acceptable from a dam safety perspective.

A grasscrete surface was chosen for the downstream face of the dam as the only material capable of withstanding the PMF whilst also having the potential to support grass. The less critical upstream face is to be grass but geotextile reinforced in places where likely to be prone to severe erosion.

<u>To maintain access across and along the valley for all user groups</u>
The usage of this part of the valley is maintained as an amenity area for dog walking, picnicking and informal ball games by maximising public access to the structure and minimising the fenced off areas, whilst addressing health and safety issues. The design maintained vehicular access for council maintenance vehicles via the dam crest whilst also providing 'Environment Agency only access routes' for maintenance vehicles to gain access to all critical parts of the dam structure (coarse trash posts/ trash screens/ Hydro-brakes®) and the river channel up- and down-stream of the dam.

Coppull Lane has historically been used as the main vehicular access route into the valley where cars and larger vehicles have tended to park on rough ground alongside the road. The design of Coppull Lane includes a turning head suitable for all likely vehicle sizes; formalised off-road car parking; a new footpath link to the replacement footbridge; and an avenue of new trees along the realigned highway; all providing a significant enhancement.

<u>To provide a high quality and robust addition to the wider public realm</u>
The public realm will extend from Coppull Lane via a new all-user route across the dam crest and looped access path/ seating area providing new opportunities to appreciate views along the valley. In addition, public art features and information boards will provide interpretation of the function of the dam and features of archaeological interest.

<u>To deter anti-social behaviour by unruly elements of society</u>
The local community initially expressed concerns that anti-social behaviour currently experienced in this part of the valley would be made worse by the dam. Loitering youths would have a structure to frequent especially during hours of dusk and darkness. Users of off-road motorbikes would use new paths and surfaces around the dam as race tracks with the attendant noise nuisance and dangers for walkers. These concerns were addressed by providing motorbike deterrent access controls on paths, with barriers and kissing gates difficult for bikes to negotiate. Other paths were designed to be narrow and unsuitable for motorbike use. Circuitous routes around the dam structure were avoided and sturdy oak bollards and trees were located to prevent car and motorbike access. Sturdy estate railings defining public areas would further deter unauthorised access. Concerns expressed by the

Police Architectural Liaison Officer resulted in an anti graffiti compound being applied to selected vertical concrete surfaces along the dam crest.

PLANNING

The Environment Agency used its permissive powers under the General Permitted Development Order for Phase 1 of the scheme. However, the dam and reservoir required a planning application, which was submitted to Wigan Council in late January 2009. Despite prior public exhibitions and meetings the application prompted many letters of objection and a petition signed by over 200 people. This meant that the application was not considered until August 2009, almost 12 weeks longer than the prescribed period. Reasons for the delay included that Wigan Council required further assessment of the scale of tree loss for construction and operational impacts on the ecology and tree cover due to occasional flooding. The planning decision notice took a further 8 weeks to issue due mainly to the need for a S106 agreement. It was therefore only in October 2009 that the Environment Agency received approval, the decision notice including a total of 17 conditions, many having to be discharged before construction could start.

As part of a planning obligation secured by Wigan Council, the Environment Agency will provide a new habitat enhancement area and a commuted sum towards its maintenance for a 15 year period. A Woodland and Ecological Mitigation and Management Plan has been prepared in response to concerns about adverse impacts of temporary flooding on the long term health of the woodland and habitats. Baseline surveys would be updated at a number of key transect lines and further survey undertaken following a flood event.

PROCUREMENT AND CONSTRUCTION

The Environment Agency set up a Framework of Contractors in 2002 and this Framework was re-tendered in 2007. Morrison Construction Ltd joined the Framework in 2007 and won the mini-bid for Phase 1. Following a further mini bid, Morrison was awarded the contract to construct Phase 2 in December 2009. The Target cost was £4.36M and construction work started on 4 January 2010 on an 18 month contract period.

The contract was awarded under NEC Option C whereby the contractor is paid actual costs plus a fee for overheads and profit. The challenge for the contractor is to work efficiently and to make sure that his final actual cost is less than the target cost, allowing a share of the saving.

CONCLUSIONS

When completed in early 2011 and in combination with Phase 1, the reservoir will reduce flood risk to 780 properties in Wigan to less than a 1 in 100 chance per year, and thus contribute to the Environment Agency's high level target of removing 45,000 homes from significant flood risk by the end of Comprehensive spending review 07 (March 2011).

Challenges for the Environment Agency's consultant team included the timely granting of planning approval, winning over the local community and maintaining landscape design quality within available budgets.

The reservoir engineering is unusual in that it includes two of the largest Hydro-Brakes® installed in UK; requires stabilisation of old coal workings; and is constructed close to a town centre in a valley surrounded by housing and crossed by many footpaths.

ACKNOWLEDGMENTS

The Environment Agency and Defra funded this project. The authors gratefully acknowledge the key individuals within these organizations who shared the vision of the scheme and benefits that it will produce.

REFERENCES

CIRIA (1987). *Design of grass reinforced spillways*. Report 116
ICE (1996). *Floods and Reservoir Safety*. 3rd Edition
Jacobs (2005). *Project Appraisal Report for Douglas through Wigan FAS*