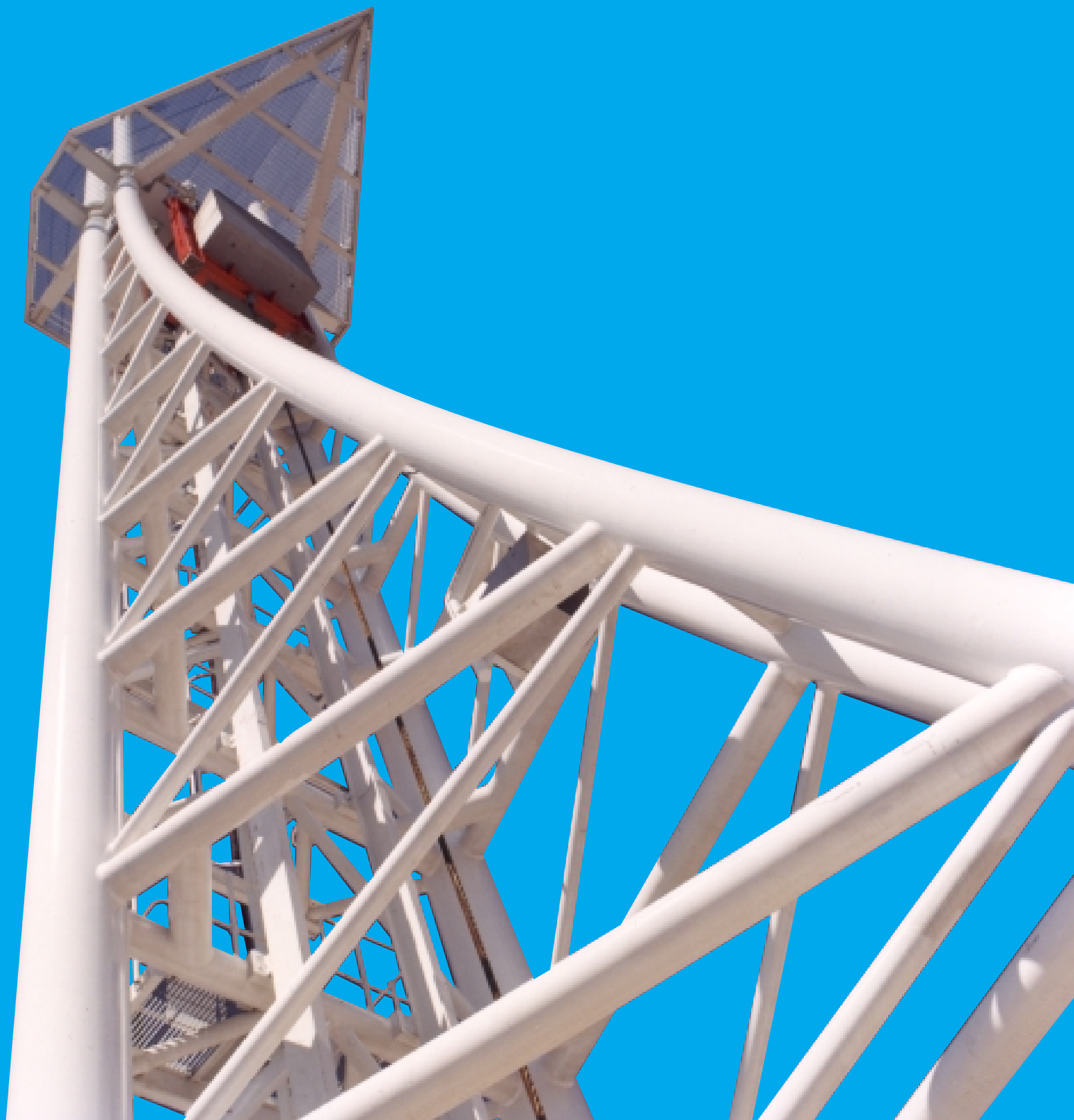
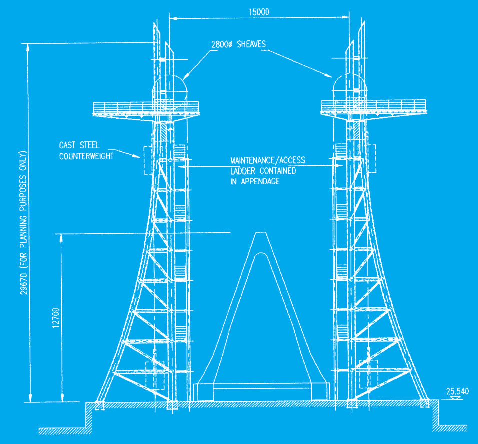
Corus Construction Centre

Lowry footbridge

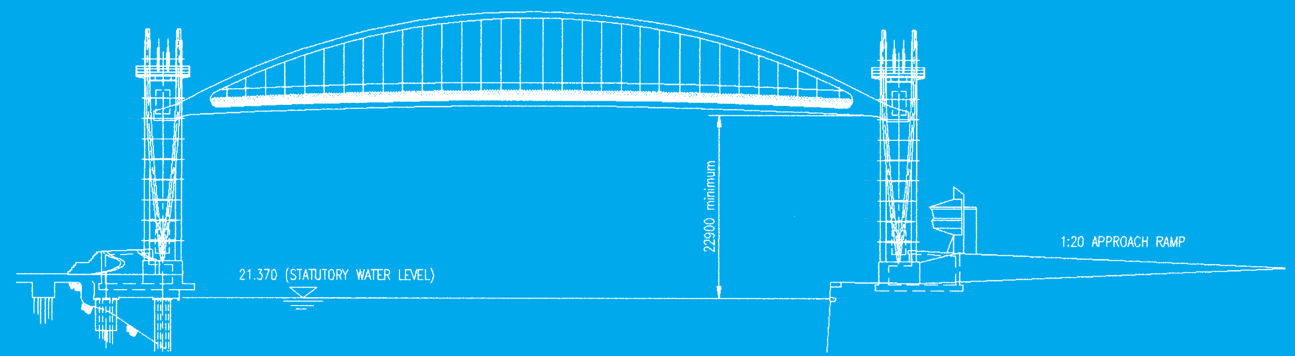
Bridged in steel



Facts and figures



Client: **Lowry Centre Development Company Ltd**	Fabrication commenced: **December 1997**
Consulting Engineers for Project Management and Design: **Parkman Ltd**	Erection completed: **January 1999**
Consulting Engineers for Superstructure Design: **Carlos Fernandez Casado ltd**	Steel tonnage: **Superstructure - 220 tonnes** **Towers - 150 tonnes**
Consulting Engineers for Mechanical and Electrical Design: **Bennett Associates**	Steel quality: **Plates - S355J2G3 Tubes - S275J2H**
Main Contractor: **Christiani and Nielson Ltd**	Protective treatment: **Aluminium metal spray** **Zinc phosphate high build epoxy undercoat** **MIO high build epoxy undercoat** **Polyurethane finish**
Steelwork Contractors: **Fairport Steelwork Ltd** **Lengthline Ltd**	Design load: **Standard footway loading** **in accordance with BS 5400**
Agent authority for bridge adoption and maintenance: **Salford City Council**	Design Code: **BS5400 as implemented by the Highways Agency**
Agent authority for bridge operation: **Manchester Ship Canal Company**	



ELEVATION OF BRIDGE IN RAISED POSITION
(Scale 1:500)

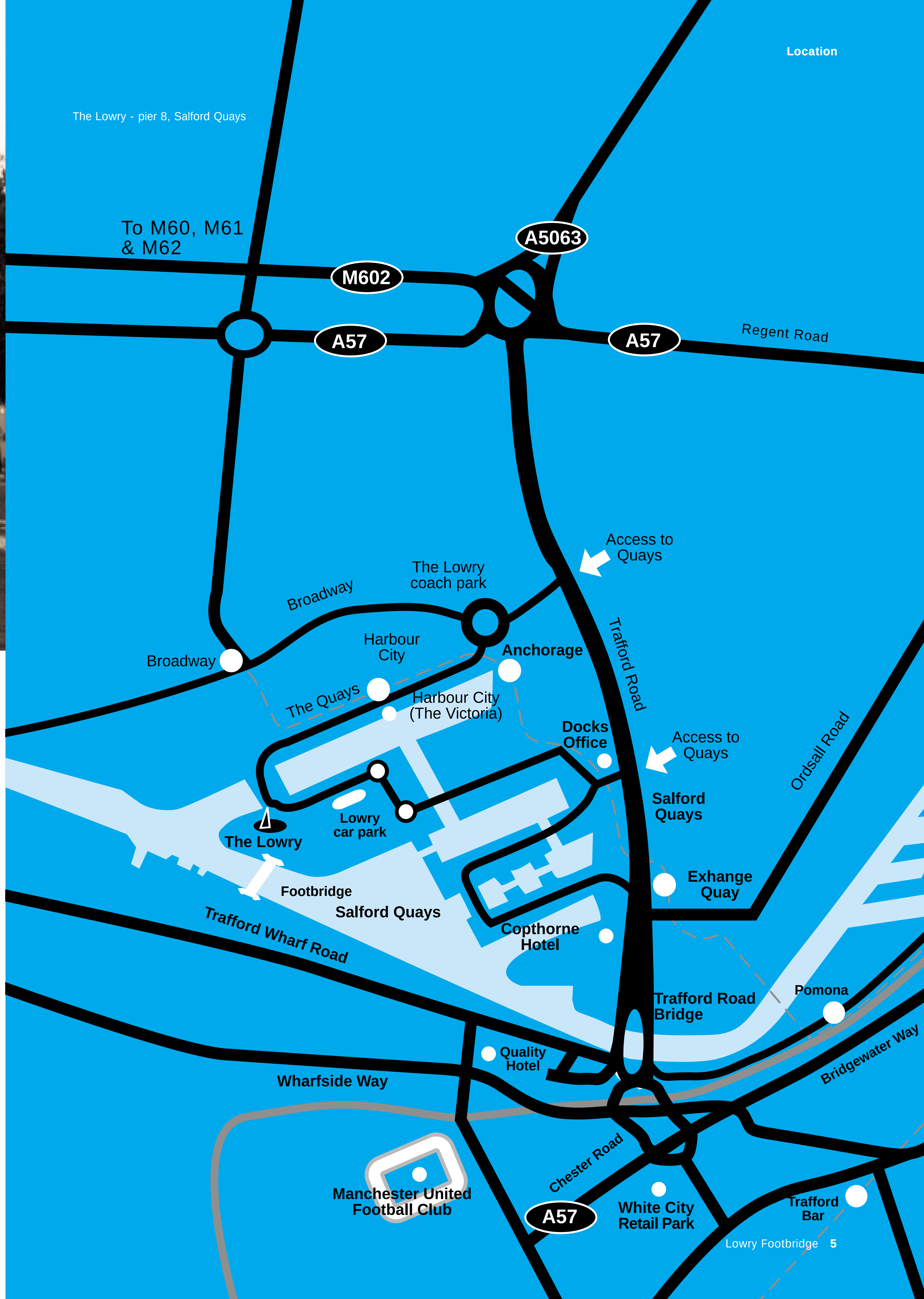
The location

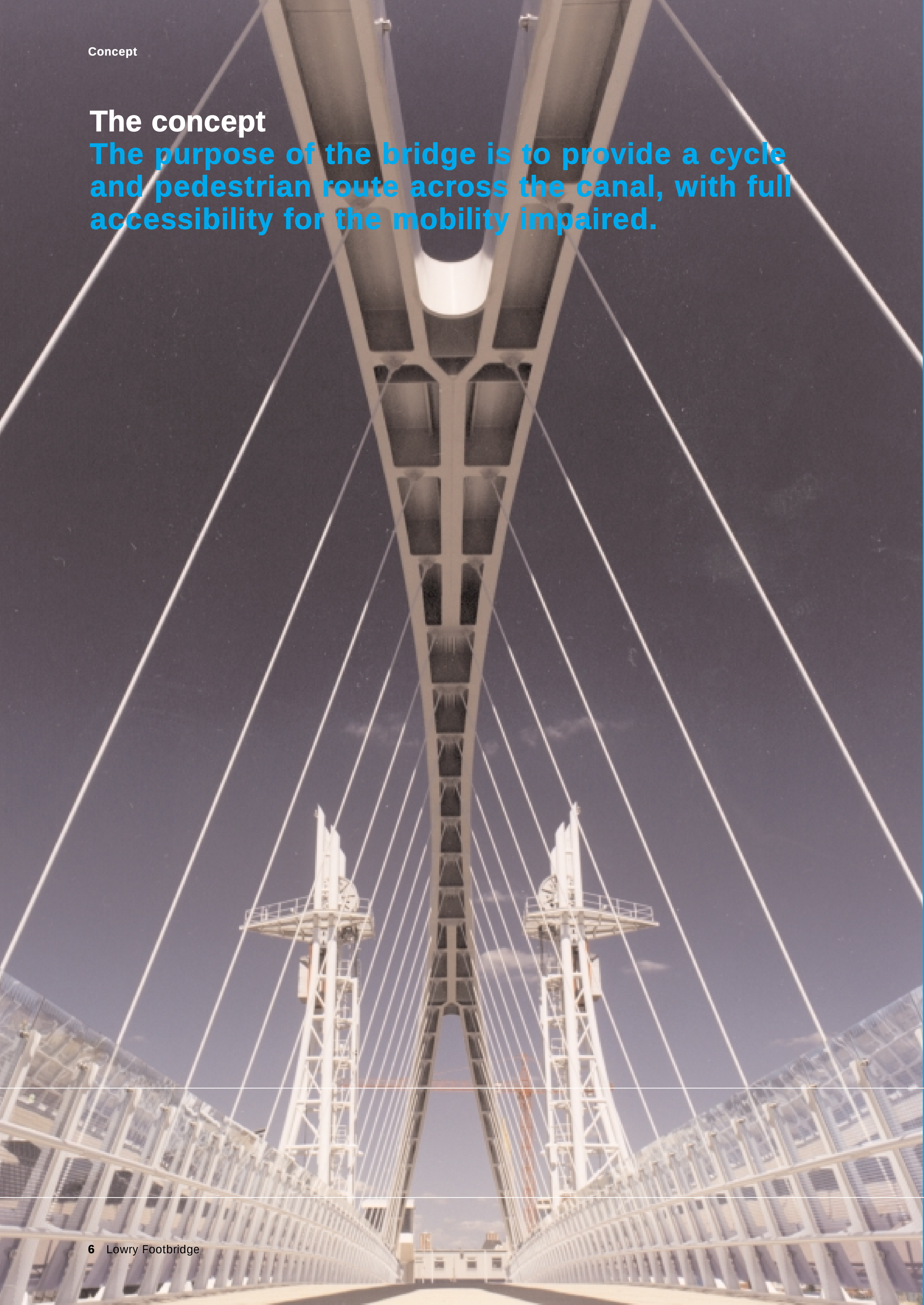
The Lowry Footbridge is located at the upper reaches of the Manchester Ship Canal at Salford Quays, an area of major redevelopment.

Salford Quays originated as the Port of Manchester, although merchant shipping ceased to use the port in the early 1970's, for several years the site lay derelict until Salford City Council took the decision to implement a major regeneration project.

Plans were made for the dock area to be redeveloped to provide a mixture of commercial, recreational and housing use. During the late 1980's and throughout the 90's there was major investment in creating a new infrastructure on the site.

Pier 8 of the dock area, fronting onto the Ship Canal, was selected as the site of a new cultural centre for the North West, which would house the works of local artist, LS Lowry, and provide a major venue for the performing arts. This development, known as The Lowry Centre, is located on the North side of the Ship Canal. On the south bank, directly opposite The Lowry, is the site of the Imperial War Museum for the North, and approximately half a mile to the east is the Old Trafford football stadium. These, and other major tourist attractions for the area, brought about the need for a footbridge, which would enable direct and convenient pedestrian access across the canal.





The concept

The purpose of the bridge is to provide a cycle and pedestrian route across the canal, with full accessibility for the mobility impaired.

Although buildings constructed on each side of the Ship Canal border the site, the bridge is very exposed to the weather, with the canal providing a natural corridor for westerly winds.

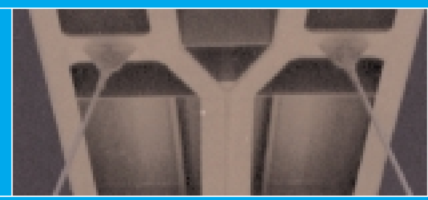
There is no longer a need to provide for merchant shipping. However the canal is still navigable at the bridge site and an essential instruction of the design brief was that the structure would maintain the statutory navigation requirements of the Manchester Ship Canal Company. In addition, there were constraints placed upon the designers, by the navigation authority, to ensure that the existing canal water level would remain within 10mm of its existing maintained level.

With these requirements in mind the concept of a single span, vertical lift bridge, incorporating weather protection, emerged as the design solution. In its open (to pedestrians) position the bridge span sits at low level, providing a 5.08 metres clearance to the canal. When raised for the passage of shipping, the soffit of the deck is at the statutory height of 22.9 metres above the canal water level. Span supports are located back from the water's edge, thereby avoiding any interruption to water flow, navigable width, or change in water level.

The bridge span comprises a pair of steel bowstring arches of 96 metres overall length, and 91.2 metres span between bearings. The arches are at 10.9 metres spacing at the bearings, and meet over mid span, where they rise to a height of 11.2 metres above the surface of the deck. The span is lifted at its four corners by hydraulically driven winches, with cast steel counterweights provided at each lift point to minimise mechanical effort.

All winches and drive motors are housed within the bridge abutments, each of which supports a pair of steel lattice frame towers constructed in tubular steel. The four towers stand at a height of 31 metres and each support a pair of high level sheaves, which carry the ropes connecting the deck and counterweights. The 250 tonnes deck is balanced by the counterweights, such that, under 'no wind' conditions only 10 tonnes of effort is required from each of the winches to raise and lower the bridge.

Architectural features of the bridge include coloured glass wind deflectors along each edge of the span, behind the parapets. These are designed to afford pedestrians protection from strong winds and driving rain. Lighting was an important consideration in the finishes to the bridge, and details include strip lights incorporated within the tubular steel handrails, which not only illuminate the walkway but also reflect off the coloured glass wind shields. Additional feature lighting depicts the profile of the arch, and illuminates the upper sheaves and counterweights. These latter features demonstrate the mechanical process of movement and balance, when the bridge lifts, and it was an essential aim of the design team in the development of the solution that this should be exhibited to visitors to the bridge.



Design details

Design details

Meticulous attention to detail has resulted in one of Britain's most innovative bridges

Span
Because of the bridge type it is essential that the weight of the bridge span be kept to an absolute minimum. The orthotropic steel deck comprises of 10mm thick plate stiffened transversely by 171x178 inverted tee-sections. It is supported along its edges by 600mm wide x 800mm deep, 8mm thick 'inverted U' plate girders, which also provide the reaction to horizontal thrust from the arch. Transverse stiffening to the edge girders is provided at 2.5 metre centres by 8mm thick steel diaphragms. These are located at suspension points, where 28mm diameter steel tension bars connect to the deck from anchorages on the arch members.

The arch also comprises a pair of 600mm wide x 800mm deep 'inverted U' plate girders, which are inclined inwards to become a single unit over the central portion of the span. Plate thicknesses vary between 8mm and 20mm and, as with the deck girders, the arches are stiffened transversely at hanger positions.

In the analysis of the span the deck was modelled as a space frame with individual members representing deck girders and deck stiffeners, and the floor plate idealised as a series of diagonal members. The arch members were incorporated into the same model as a series of beam elements, which coalesced into one in the centre of the span. Hangers completed the model and were represented as truss elements. A local finite element analysis was performed on the orthotropic steel deck to evaluate local loading effects.

The stability of the structure was verified by aerodynamic tests carried out at the University of Liverpool on a scale model of the span. The tests were undertaken on a 1/50th scale model of the bridge, which was subjected to a range of scaled wind speeds from 2m/s to 31m/s, applied to the bridge in the open and closed positions. An interesting conclusion, from the tests, was that the glass wind shields, located along each edge of the deck, made a positive contribution to the stability of the span.

Towers
The four towers are identical, and constructed of tubular steel hollow sections forming a lattice structure. In each tower there are four main members, arranged in plan in trapezoidal formation. The towers support vertical load, transmitted through the upper sheaves from the span and counterweights, and resist horizontal wind load from the deck. The front legs are vertical and comprise 660mm diameter circular hollow sections. The rear legs comprise 508mm diameter circular hollow sections and these are curved in both elevations, meeting as a single member at their base.

In the design of the towers a linear elastic analysis was carried out using a space frame computer program, and, in addition, a critical buckling check was undertaken using non-linear analysis.

Abutments
The abutments to the bridge not only support the towers but also house the operating machinery for the lift mechanism. Each is constructed of reinforced concrete and founded on 600mm and 750mm diameter cast insitu bored piles. Both abutments comprise a deep slab base, slender perimeter walls, and a roof slab, which contains a removable precast cover to facilitate future removal of the winch drums. A separate compartment in each abutment contains an electricity substation to facilitate the independent power supply delivered to the two ends of the bridge.

The south abutment is located within a section of wharf, which had been constructed during the 1930's to receive shipments of grain for processing in the adjacent Trafford Park. The wharf comprises a cellular concrete deck supported on concrete caissons, which themselves are founded on piles driven into the underlying bedrock. The vertical load capacity of the existing piles was not sufficient to carry loading from the bridge, and the cellular deck in particular is weak. The abutment, therefore, was designed to be independent of the wharf, in so far that vertical loads are carried by an independent foundation. However, the wharf foundations had been designed to resist impact from ships and, similarly, they are used to resist any such forces applied to the bridge abutment.

Bridge mechanism and operating system
The machinery at each end of the bridge is almost identical, and each receives its power from an independent mains electricity supply. Control of the machinery takes place from a single control point at the north end of the bridge with hard wire communication, ensuring full synchronisation, taken to the south end via the bridge span. For simplicity the machinery is described for one end of the bridge only.

The bridge is raised and lowered by means of a closed loop rope system, operated by a single winch. The winch pulls on single ropes attached to the underside of the bridge deck (the 'down haul' ropes), and the underside of the counterweights (the 'up haul' ropes). The deck and counterweights are connected by a pair of ropes (the 'counterweight' ropes), which are attached to the top of each and pass over the high level sheaves, thereby completing the loop.

The winch consists of a central winding drum, constructed in three sections, producing four winding zones. The winding zones are of helical form (two right-handed and two left-handed) so that for any direction of drum rotation two zones pay in and the other two pay out. Attached to one end of the winding drum are six hydraulic motors and gearbox assemblies, which comprise the drive mechanism. Should one of the motors malfunction at any time then the bridge can be operated using the remaining five.

Compensating sheave assemblies, located in the machine room, apply a nominal force on each haul rope, ensuring minimum tension at all times and providing for changes in rope length due to temperature effects and stretch. The compensating assemblies comprise a steel frame, which supports a sheave carried by a pivotting counterbalance. The haul rope passes around the sheave, and by means of the pivot mechanism, a nominal 1 tonne tension is continually applied.

Two upper sheaves, 2.8 metres in diameter, are provided at the top of each tower and these allow the counterweight ropes to pass over the tower as the bridge raises and lowers. The sheaves, supported on a plummer block incorporating spherical roller bearings, are of steel fabricated construction, with a machined circumference to provide the rope groove. Counterweights, incorporated within the 'closed loop' balance approximately 90% of the dead weight of the span, thereby minimising the effort required of the machinery to raise the bridge. In order to prevent wind uplift when the bridge is sat on its bearings hydraulically actuated span locks - horizontal pins - anchor the span to each abutment.

The bridge takes three minutes to raise and a similar time to lower. It can be operated in winds up to 22m/s gust speed, and this is monitored and controlled by an anenometer located at the head of one tower and connected to the bridge control system.

Operation of the bridge is undertaken from an elevated control kiosk, located at the north end of the bridge. From the kiosk there are uninterrupted views of the canal and pedestrian areas. Direct vision is however supplemented by CCTV with images shown on a television monitor within the control kiosk. Operation of the bridge is controlled by hard wired program logic control system and can be undertaken in automatic or manual mode. In the event of a mains electric failure, power is provided by diesel generators located within each machine hall.

Fabrication

All fabrication of the towers and arch took place off site.

Towers were fabricated at Fairport Steelwork Ltd's workshop in Lancashire and delivered to site, by road, for erection. The arch was fabricated at two locations, one of which was Fairport's workshop, and the other Lengthline, a local ship builder / repairer, who had a fabrication shop and dock facilities on the Ship Canal, approximately 500 metres from the bridge site. The location of this facility was a key factor in the Contractor's choice of supplier for it provided the opportunity to assemble the bridge span close to the site and transport into final position by tug towed barge.

The geometry of both the towers and the span is complex, all are of fully welded construction, and each had a substantial amount of steelwork requiring to be curved in two planes, with accurate fit an absolute necessity to ensure that the required profiles were achieved. In the fabrication of the towers this was achieved by computer controlled cutting and assembly with a full trial erection carried out prior to delivery to site. However, the scale of the span was such that a trial erection was not practical and its construction could not be undertaken in a fabrication workshop.

The span was fabricated in twenty five discrete units, all of which were transportable by road, enabling some components to be fabricated off site at Fairport's works. Prior to final assembly all components were transferred to and from the paint shop, located in Merseyside, for application of the protective system. Before leaving the fabrication shop each component was trial assembled against its adjacent element, to ensure accurate alignment and fit. The final stage of assembly was carried out at Lengthline's shipyard. As final fabrication progressed from each end towards the centre of the span, continuous alignment checks were carried out to ensure that the required degree of accuracy was achieved.

In preparation for the structure's transportation along the canal the span was assembled alongside an adjacent dry dock, and was built on scaffold to provide the elevation necessary for it to be transferred by bogey onto a barge.

The construction
Due to their size the towers were delivered to site in three sections.

Towers

Although all four towers are identical, different erection procedures had to be adopted for each end of the bridge. The weak condition of the south wharf was a major factor in the size of cranage, which could be used, and the proximity of existing buildings also meant that there was only limited working space. However, on the north side there was ample working space and, other than immediately adjacent to the canal, there were no restrictions on loading.

All four towers were delivered to site by road, in three sections. Taking advantage of the conditions at the north side, each of the three tower sections were laid down, adjacent to the abutment, and welded together, before lifting the two complete North towers into their final position. Restrictions on the south side, however, meant that it was necessary for the lower section of each tower to be erected, before placing the remaining sections on top and welding insitu.

Span

Three options for installation of the span were considered, including lifting, launching, or floating the bridge into position. Physical constraints at the bridge site dictated that heavy lifting equipment could not be operated on the south bank of the canal, without the construction of extensive and expensive temporary works, and cranage was considered to be unviable. The second option of launching the bridge, from the north bank, was feasible but again physical constraints, this time in the form of adjacent construction activities, meant that the option could not be pursued. In the event the third solution, to float the bridge into position was the option chosen.

The sub-contract for transportation and placing of the bridge span was awarded to Econofreight Project Management. Its responsibility was for the safe delivery of the span but it was a requirement of the navigation authority that the canal could only be closed for a maximum duration of four days. Within this period the bridge had to be delivered, erected and handed back to the main contractor who then had the task of connecting the lifting mechanism and ensuring that the bridge was capable of being raised to the statutory navigation clearance of 22.9 metres.

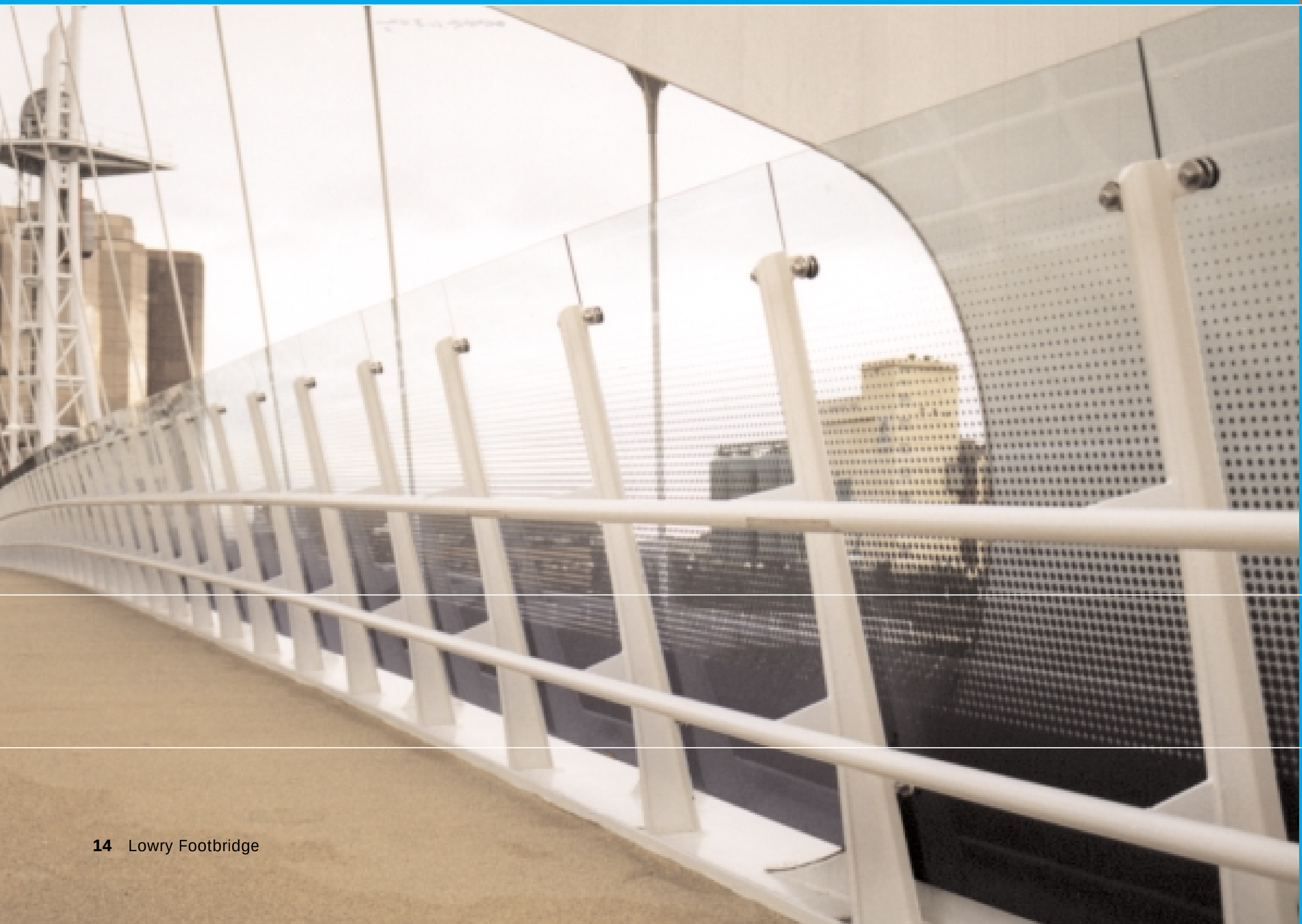
The erection procedure involved several stages:

- Transfer of the span from the scaffold to two heavy duty, eight axle, computer controlled transporters, located at 1/5 span.
- By means of the transporters travel the bridge across temporary linkspan bridges from the dockside on to a 2000 tonne barge moored in the adjacent dock.
- Secure the bridge and tow the barge from the dock to the bridge site using two tugs.
- At the site, moor the barge to canal side bollards (two on each bank) by means of four winches anchored to its deck, and remove the tugs.
- Using the winches manoeuvre the barge across the canal, threading the span between the towers over its final position.
- Using jacks on the transporters, lower the span onto temporary stillages on each abutment.
- Ballast and lower the barge, and remove from site.
- Connect haul ropes and ensure that bridge mechanism operates satisfactorily.

The transport of the span presented several challenges, including two of particular significance. The first involved maintaining stability of the barge during load transfer from the dockside. This was achieved by continuous monitoring of levels, and controlled adjustment of water in the ballast tanks achieved this. Once at the bridge site the span had to be manoeuvred into position, which involved pulling the leading end between and beyond the south towers, then reversing the pull, using the north winches, to locate the deck centrally between all four towers. Other than a strong wind, which caused the operation to be postponed by one day, the whole operation was carried out according to plan.

Inspection and maintenance

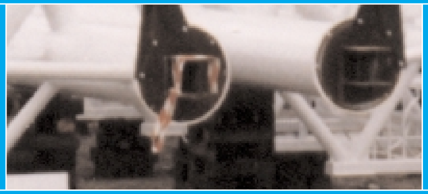
The design of the bridge incorporates several features, which were included with maintenance in mind.



For example: steel details avoid the potential for accumulation drawn up of water and detritus and all locations are accessible for inspection without the need for expensive equipment. The span includes under-slung runway beams, designed to carry a travelling gantry, and the deck is capable of carrying a small mobile elevated work platform to provide access to the arch members. There is ladder access to the top of each tower, all of which can be readily inspected using roped access methods.

Mechanical elements have been designed to require low maintenance and, if necessary, easy replacement, and include back-up systems to ensure that operation of the bridge can be maintained in the event of a power failure, or breakdown of a hydraulic motor. Rope replacement is anticipated after twenty years and to facilitate this suitable spragging and lifting features are incorporated in the structure.

Major mechanical components, such as the upper sheaves and winch drums can have bearings replaced insitu. However, should it be necessary to completely replace either of these elements then provision for access and lifting has been made in the structural design.



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