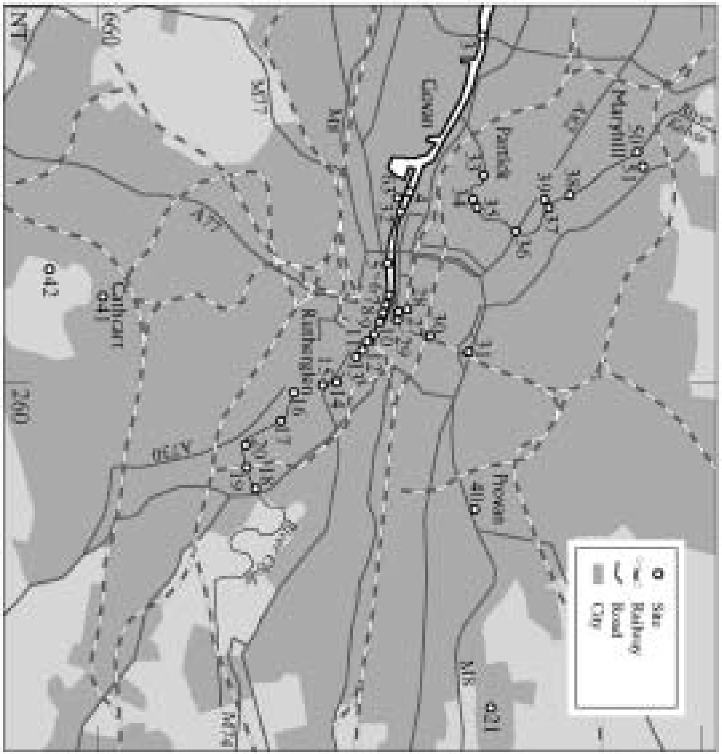
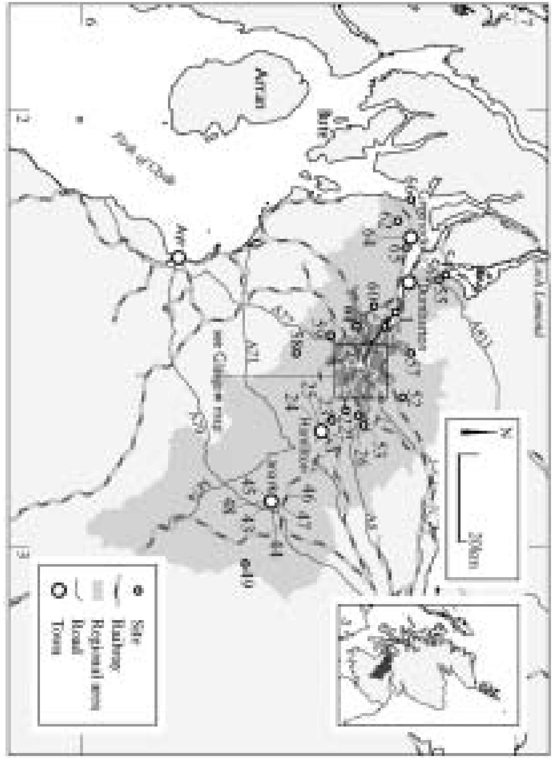

Site
Railway
Road
City


Site
Railway
Regional area
Road
Town

Lanarkshire and Glasgow, Renfrewshire, and Dunbartonshire

1. Erskine Bridge
2. Titan Crane, Clydebank
3. Clyde Tunnel
4. Bell's Footbridge
5. Kingston Bridge
6. George V Bridge
7. Caledonian Railway Viaducts
8. Jamaica Street or Glasgow Bridge
9. Portland Street Suspension Footbridge
10. Victoria Bridge
11. Clyde Viaduct, Union Railway
12. Albert Bridge
13. Weir and Pipe Bridge, Glasgow Green
14. St Andrew's Suspension Footbridge
15. King's Bridge
16. Polmadie Footbridge
17. Rutherglen Bridge
18. Dalmarnock Bridge
19. Dalmarnock Bridge (Railway)
20. Dalmarnock Sewage Treatment Works
21. Garthamlock Water Tower
22. Clyde Viaduct, Uddingston
23. Bothwell Bridge
24. M74 Interchange, Hamilton
25. Old Avon Bridge, Hamilton
26. Bargeddie Bridge (Railway)
27. Gardner's Warehouse, Jamaica Street
28. Central Station
29. The Subway
30. Queen Street Station Roof
31. Cowlairs Incline
32. Harbour Tunnel
33. Partick Bridge
34. Kelvin Way Bridge
35. Kelvingrove Park Footbridge
36. Great Western Road Bridge
37. Queen Margaret Bridge
38. Kirklee Bridge
39. Kibble Palace, Glasgow
40. Provan Gasholders
41. Old Snuff Mill Bridge, Cathcart
42. Linn Park Bridge, Netherlee
43. Bonnington Hydro-Electric Scheme
44. Hyndford Bridge, Lanark
45. Clydesholm Bridge, Lanark
46. Cartland Crags Bridge, Lanark
47. Ravenstruther Bridge
48. New Lanark Water Power
49. Biggar Gas Works
50. Kelvin Aqueduct
51. Maryhill Locks
52. Luggie Aqueduct, Kirkintilloch
53. Monkland Canal
54. Balloch Bridge
55. River Leven Barrage, Balloch
56. Dumbarton Bridge
57. Mugdock and Craigmaddie Reservoirs, Milngavie
58. Dunwan Dam Draw-off Tower, Eaglesham
59. Gorbals Water Works
60. Selvieland Farm Bridge, Renfrew
61. Blackhall Bridge, Paisley
62. Greenock Water Works – Loch Thom & 'Cut'
63. Prince's Dock and Pumping Station
64. Garvel Dry and Wet Docks
65. Clyde Dry Dock, Inchgreen, Greenock
66. Cloch Lighthouse, Gourock

4. Lanarkshire and Glasgow, Renfrewshire, and Dunbartonshire

Introduction

This chapter covers Glasgow and its surrounding areas. The city is bisected by the Clyde and the Kelvin, and as a result our coverage includes no less than 24 bridges and six tunnels, extending from the slender and elegant Erskine Bridge (1971, 4-1) to Dalmarnock and beyond, including James Watt's bridge of 1774–75 at Rutherglen (4-17) now long gone but illustrated here for the first time. At the Union Railway Viaduct of 1870 (4-11) innovative cylindrical foundation construction was employed to reach firm material at the great depth of 100 ft. The present bridge (1898, 4-11) was ingeniously built around it to avoid disrupting traffic. Telford's Glasgow Bridge (1834, 4-8) became so much a part of the city that its profile was retained when it was replaced (1899, 4-8). Perhaps the most elegant of Glasgow's existing masonry bridges is the triple-span elliptical arch bridge of Kirklee (1901, 4-38).

The tunnels include the early Harbour Tunnel of 1895, the first shield driven example in Scotland; the Subway Tunnels (4-29); and the modern Clyde Tunnel at Whiteinch (1964, 4-3).

Perhaps the greatest factor in the development of Glasgow and its environs was the improvement of the Clyde Navigation between Port Glasgow and the Broomielaw over 150 years from 1771 onwards. By 1871 the original 4 ft deep channel was deepened to 22 ft. Extensive docks were constructed. Later in the 1930s the river was dredged to a depth of 35 ft from Clydebank to allow the passages of the 'Queens' after completion. Earlier, in 1762, Port Glasgow had been developed some 18 miles downriver to avoid using the then shallow Clyde.

Glasgow possesses a unique water supply dating from 1852 (4-58, 4-59) when J. F. Bateman harnessed Loch Katrine and brought its pure water 36 miles by aqueduct into the city. This work and its extensions serve the city adequately to this day.

The development of the West of Scotland also benefited from the opening of the Forth & Clyde Canal in 1790 (4-51, 4-52) and the earlier Monkland

Canal of 1773 (4-53). The two canals were joined in 1792 and the Union Canal to Edinburgh was linked to the Forth & Clyde in 1822 at Lock 16. The rejuvenation of the Forth & Clyde by the Millennium Link Project, including the 'Falkirk Wheel' (6-38), became operational in 2002.

Road improvement is represented by the pre-railway Glasgow and Carlisle and Lanarkshire roads constructed under Telford's direction from 1815–25 (4-25). Also by the Glasgow and Edinburgh road of 1932.

The construction of the railways led to major termini in Glasgow of which Central and Queen Street stations remain (4-28 and 4-30). Both boast roofs which are significant feats of structural engineering. The completion of the Subway in 1896 (4-29) gave Glasgow the only underground railway in Britain outside London and the third in the world.

Lighthouses are represented by the Cloch Lighthouse, Gourock (1797, 4-66), but its light has been long superseded since the creation of the buoyed channel extending both up and downriver.

Unusual items in this chapter include the elegant iron-framed glass Kibble Palace of 1873 (4-39); the mammoth Titan Crane (4-2), a relic of the locomotive and ship construction era; and the two immense gasholders at Provan (1903, 4-40).

1. Erskine Bridge

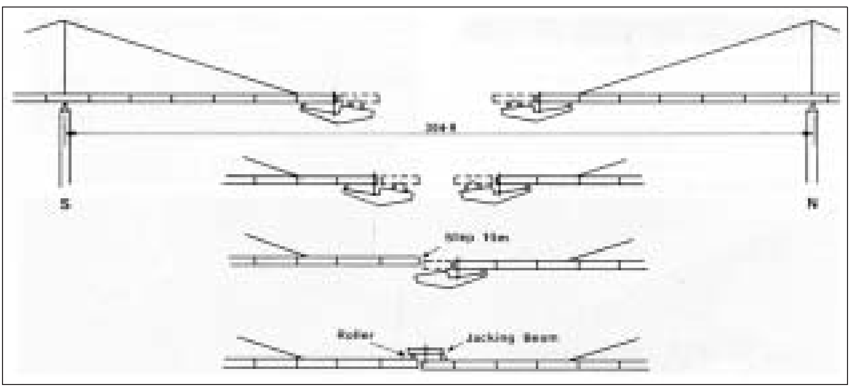
NS 4610 7242

This state-of-the-art cable-stay bridge erected over the Clyde from 1967–71, a precursor of the recent Millau Viaduct in Southern France, has a main span of 1000 ft supported from two 125 ft steel towers on 175 ft tall slender concrete piers clear of the river. Its aerodynamically designed continuous high-yield welded steel box-girder deck of basically trapezoidal cross-section carries dual two-lane carriageways, footways and cycle tracks.

The bridge is notable for its economy of material, the dead-weight of the steel superstructure plus roadway being only 141 lb sq ft, and as the only bridge in Scotland with single cables over central towers above main piers. The steel cable over the saddle on each tower comprises 4272 0.2 in. diameter wires in 24 strands each with a minimum specified breaking load of 500 tons. The cables are anchored in the median area between the carriageways, an arrangement preferred by its designers to the more usual 'harp' style. Achieving closure of the half-span cantilevers at mid-span was a particularly delicate operation.

The fabricated steel work weighed 11 700 tons and 1250 miles of galvanised wire were used. The total cost including approaches was £10.5m.

The bridge was designed by Freeman, Fox and Partners of whom Oleg Kerensky FRS was the partner in charge. W. A. Fairhurst and Partners designed and supervised the construction of the piers and foundations, and the consultant architect was R. E. Slater. [1]



Erskine Bridge – erection of closing box [1]

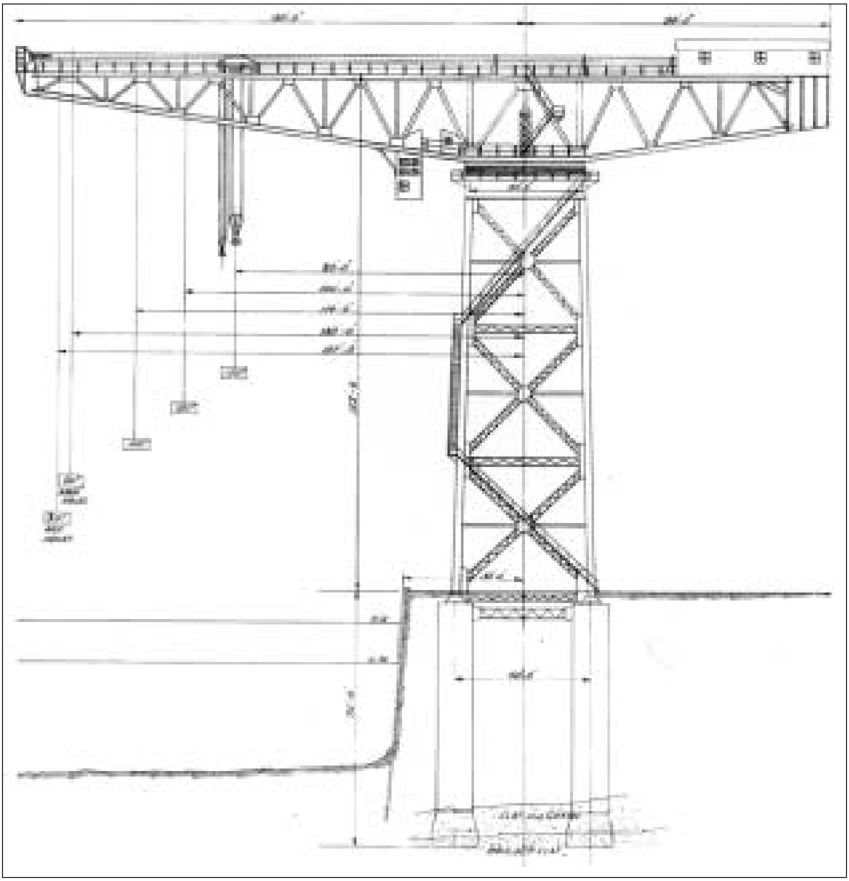
2. Titan Crane, Clydebank

NS 4948 6975

A giant overhead rotating cantilever steel crane designed by Sir William Arrol and Company and erected by the firm in 1907 at John Brown's shipyard. It is about 160 ft high, has cantilever frames 150 ft and 90 ft long and a capacity of 150 tons. This type of crane was much used in ship construction and for loading heavy items such as locomotives into ships.

Other surviving Titans in Scotland are at Rosyth (1917), 250 tons capacity; Finnieston; Stobcross Quay, 150 tons capacity; and at Greenock. [2]

Titan Crane



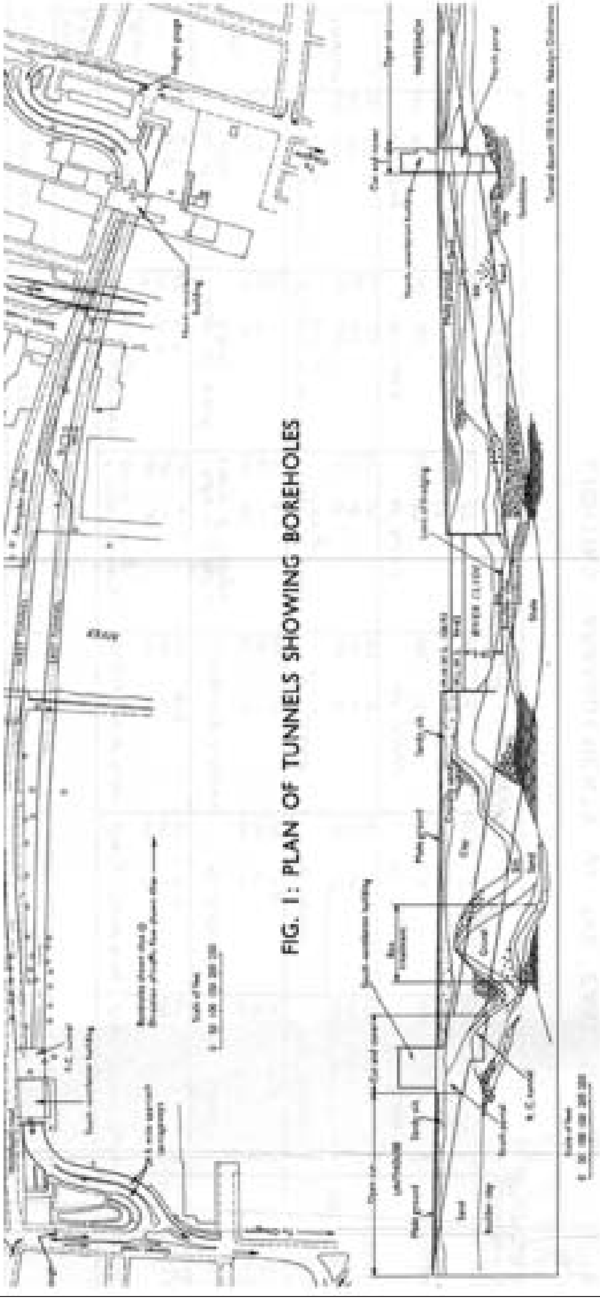


FIG. 1: PLAN OF TUNNELS SHOWING BOREHOLES

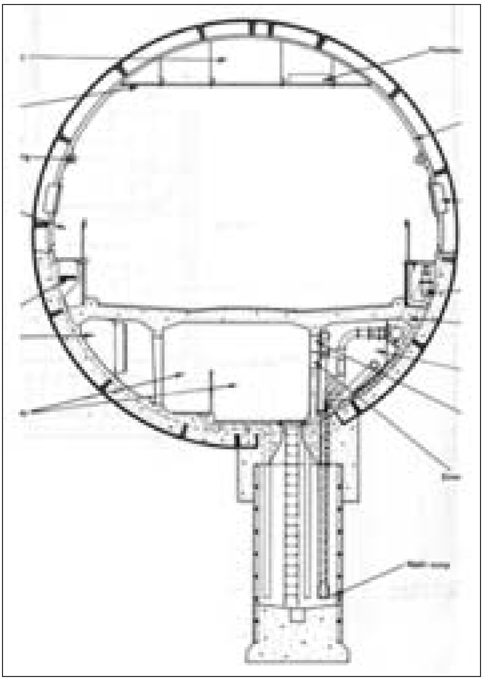
Clyde Tunnel [3]

3. Clyde Tunnel

NS 5422 6641

This $\frac{1}{2}$-mile long dual carriageway tunnel, the longest and most advanced of its kind in Scotland, was shield driven under the Clyde from 1957–64, joining Linthouse and Whiteinch. Each tunnel has a heavy cast-iron lining of about 32 ft diameter containing a dual carriageway with a maximum design capacity of 5200 veh/hr and with a cycle track and walkway beneath (see figures).

The approach gradients are 1 in 16 with a short level length at the tunnel centre. The portals and approaches are constructed in heavy reinforced concrete and, as most of each approach was below the water table, flotation had to be resisted, including by means of wide holding-down piles. Generous ventilation provision was made with a building over each portal, carriageway road heating was built into the approaches, and special provision made for lighting, and pumping from four pump rooms with nine pumps each capable of delivering more than 400 gallons/min.



Clyde Tunnel – cross-section [3]

The approximate cost of the civil engineering works was £10.5m. The consulting engineers to Glasgow Corporation were Sir Wm. Halcrow & Partners, with design and planning by Sir A. M. Muir Wood. The main contractor was Charles Brand & Son Ltd. The architect for the ventilation buildings and landscaping the approaches was E. J. D. Mansfield. [3, 4]

Caledonian Railway

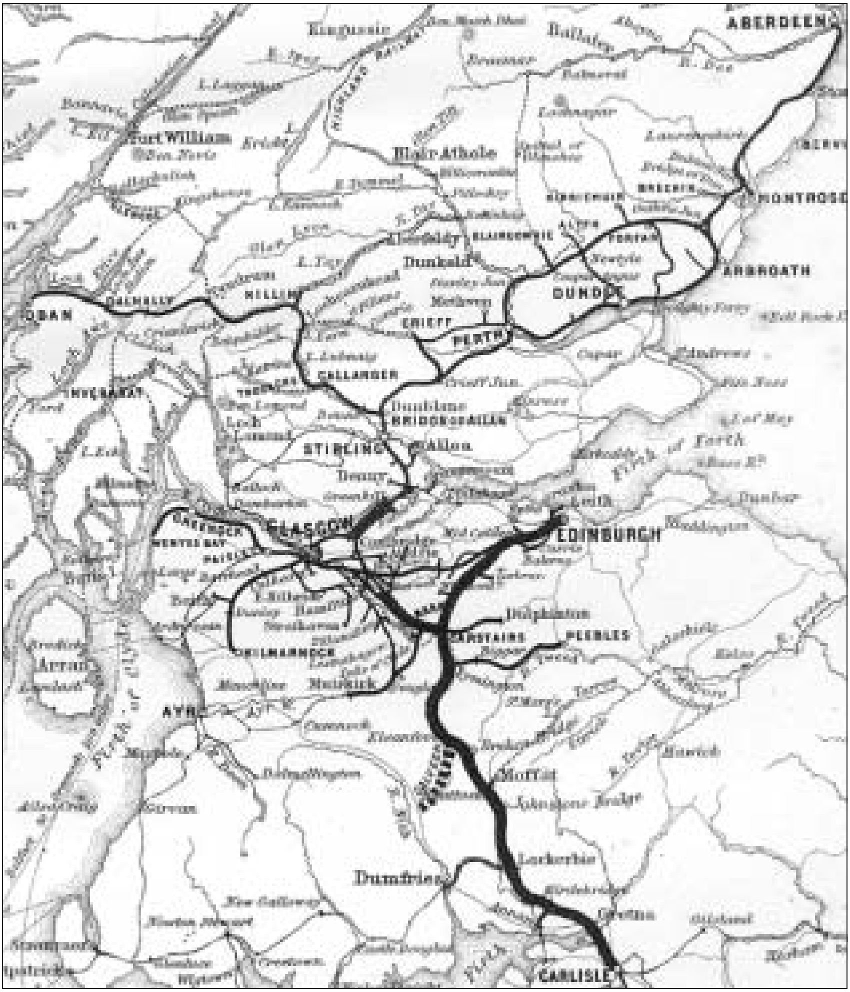
HEW 0443

The Caledonian Railway from Carlisle to Castle Cary with branches from Carstairs to Glasgow and Edinburgh was planned as a northwards extension of the Lancaster & Carlisle Railway. An Act for its construction was passed in 1845 and the line was opened to Glasgow and Edinburgh on 15 February 1848. The map shows the extent of the railway in 1888 by which time it was the largest in Scotland for traffic receipts and second only to the North British for mileage, extending to Oban, much of central Scotland, the Clyde ports and Aberdeen.

The original line was engineered by Joseph Locke who bequeathed it a troublesome legacy in the form of Beattock Summit, 10 miles of 1 in 70 gradient reaching 1012 ft whose steep incline required banking engines for trains until the advent of diesel locomotives and electrification. The original contract with Mackenzie, Brassey and Stephenson was for 122 miles of railway, the largest ever placed for a British line. By August 1847, 20 000 men were at work (see 4-22, 4-47).

The company's first Glasgow terminus was at Bridge Street south of the Clyde. In 1879 the line was carried over the river to Gordon Street which was to become part of Central Station, the later development of which by 1890 and then from 1901–06 comprised a second bridge and a vast concourse with 13 platforms (see 4-7, 4-19 & 4-28).

All the above was achieved in competition with its formidable rival the North British. There was even competition in running trains to Aberdeen, leading to the famous 'Race to the North' episodes in the summer of 1890. The Caledonian did not possess the outstanding engineering works of the North British but nevertheless



had substantial bridges over the Clyde and at Connel Ferry.

Caledonian Railway map [5]

The Caledonian steamer fleet operated both from Gourock and Wemyss Bay, whose landmark pier and station were built in 1865 (see 5-3). Between that year and the end of the century the Caledonian Steam Packet Company had the largest number of steamers on the Clyde and their familiar yellow and black-topped funnels could be seen up until the 1939–45 war.

The Caledonian was absorbed into the LMS Railway in the re-grouping of 1923. [5, 6]

Central Glasgow Clyde Bridges

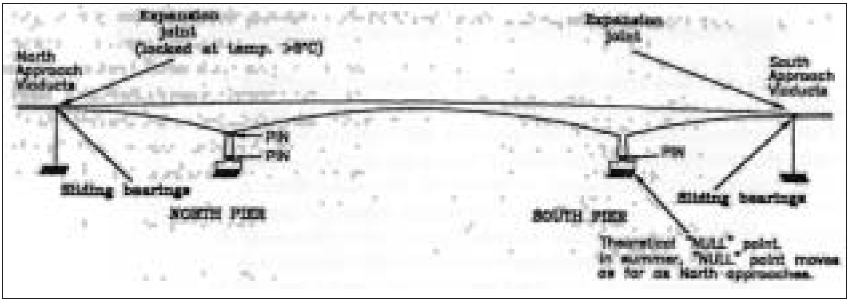
4. Bell's Footbridge

NS 5681 6519

A steel stay swing bridge built for the Glasgow Garden Festival in 1988. Overall length 127 m with cantilever spans of 44 m which can rotate to accommodate a 35 m wide navigational channel. The consulting engineers were Crouch & Hogg, design concept Alasdair Wallace. The contractors were Lilley Construction for the civil and structural work and Barback & Primrose for the mechanical and electrical engineering.

Downstream, is a 426 ft long footbridge designed by the Babtie Group and completed in 2002 to serve the Science Centre with its innovative 100 m high tower. The navigational opening is provided by twin leaf bascules each 17.4 m long, operated hydraulically, which can be opened by remote control from Bell's Bridge. [7]

Bell's Footbridge [7]



5. Kingston Bridge

NS 5799 6485

This bridge, built from 1967–70, consists of two parallel structures 68 ft wide each carrying five lanes of traffic on one of Europe's busiest roads. It is of pre-stressed concrete box-girder cantilever construction joined at the centre and cost about £2.4m exclusive of approaches. The main river span is 470 ft with 60 ft clearance above high water and side spans of 205 ft (fig. 4-7). The engineers were W. A. Fairhurst & Partners and the contractor, Logan, Marples Ridgway joint venture.

Top: Kingston Bridge [9]

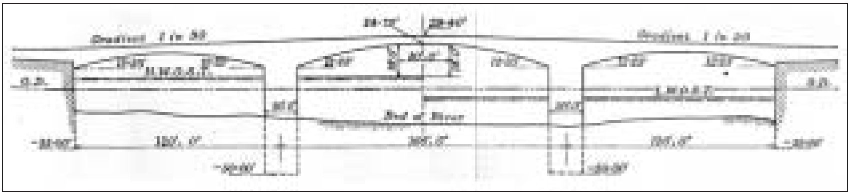
By the late 1980s the quay wall in front of the north-west footing was bulging and concrete spalling at the rotation joint at the base of the north piers, movements giving rise to concern which led in 1996 to a start on a major refurbishment which included new bearings and omission of pin joints at the base. This operation involved jacking the twin concrete box girders, weighing nearly 25 000 tons each, clear of the existing bearings. [8, 9]

6. George V Bridge

NS 5864 6481

A three-span, polished Dalbeattie granite-faced reinforced concrete beam bridge of box girders with curved soffits continuous over the piers. It was proposed before the Great War but not erected until 1924–27.

The bridge has been regarded by some as an elegant fraud, in that it appears to be an arch bridge built entirely of granite, which would have been impracticable. In fact, the City Engineer adopted the arch form and granite finish in order to blend it in with Telford's Jamaica Street Bridge elevation in Aberdeen granite. The



George V Bridge [10]

central span is 166 ft with a clearance above high water of only $18\frac{1}{2}$ ft.

Each pier is founded on cylindrical caissons which were floated into position on the ebb tide and settled on to the river bed. They were then sunk into final position by removing their temporary bases and excavating down to a solid foundation. The superstructure rests on cast-steel roller bearings set on the lintel girders, which resist the thrust arising from pressure on the abutments.

The cost was about £170 000, of which approximately a quarter was for the granite facing. The engineer was T. P. M. Somers, City Engineer, the designer, Considère Construction, and the contractor, Melville, Dundas & Whitson. [10, 11]

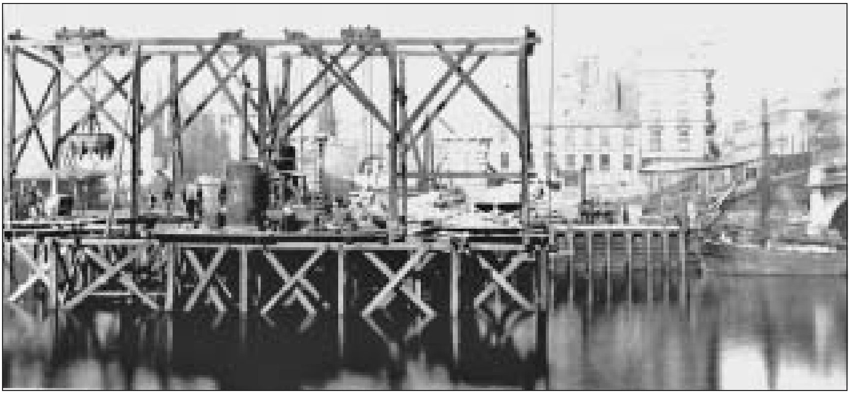
7. Caledonian Railway Viaducts

NS 5868 6480

The first viaduct at this site was erected from May 1876 to October 1878. It had three main wrought-iron lattice spans, with slender diagonal web members, notable for having its rivets silently driven by hydraulic riveters invented by William Arrol.

As part of the early planning, a proposal was made in 1873 for a light twin-track, 11-span, wrought-iron plate-girder bridge supported on cast-iron columns resting on a westerly extension of the piers of Telford's Jamaica Street Bridge. The finely executed model for this proposal is now at the Institution of Civil Engineers' museum at Heriot-Watt University. This proposal was abandoned in favour of the as-built design in 1875. An earlier proposal for a bridge at this site was in the 1840s to connect with the Edinburgh & Glasgow railway via a tunnel.

The 1878 viaduct's central span was 186 ft. Its superstructure was demolished in 1966–67 except for its cylindrical piers now standing as sentinels to the operational



Blyth & Blyth

Caledonian Viaduct under construction

viaduct. These remarkable piers, consisting of pairs of 15 ft diameter cast-iron shafts, were sunk by open grabbing (see left in above view) to bedrock 85 ft below high water level ordinary spring tide. Its engineers, also for the 1873 proposal, were Blyth & Cunningham, and the contractor was Wm. Arrol & Co. The cost was £64 400.

The present viaduct, immediately adjoining the first, was erected from 1899–1905, and comprises steel Linville trusses in three spans. The central truss spans 194 ft and is 15 ft 9 in. deep. The parapet girders are of traditional lattice construction and about 10 ft deep. Each river pier

Caledonian Viaduct and Kingston Bridge

Roland Paxton

consists of five granite-faced concrete columns resting on blue brick columns resting upon concrete-filled steel caissons sunk, partly by means of excavation within a compressed air chamber, to foundation level at a depth of about 44–48 ft below the river bed.

The considerable width of the viaduct, which carries ten tracks and varies from 118–205 ft supported on eight parallel main girders, resulted from the enlargement of Central Station from that achieved under the direction of Caledonian Railway engineer George Graham in 1890. The engineers were D. A. Matheson, Caledonian Railway and Sir Wolfe Barry, consulting. The contractors were Sir William Arrol & Co. & Morrison and Mason. [12, 13]

8. Jamaica Street or Glasgow Bridge

NS 5876 6478

Telford's classical style seven-arch masonry bridge erected at the Broomielaw by Gibb & Son, resident engineer Atherton (the team from Dean Bridge, Edinburgh), from 1833–35 was the widest in Britain at the time. It replaced a masonry seven-arch, 42 ft wide bridge designed by Mylne and built from 1768–72 by John Adam. The progressive effects of navigational dredging had weakened the foundations of the earlier bridges. Also a wider bridge had become necessary for increased capacity.

Jamaica Street Bridge and Caledonian Railway Viaduct

Blyth & Blyth

In 1892 Blyth & Westland proposed a granite arch bridge with four spans from 88 ft–92½ ft and 100 ft wide between parapets, estimated to cost £240 000. Glasgow Corporation declined this proposal because, apart from costing more than rebuilding the original, Telford's bridge was held in high regard by Glasgow people. In 1894 work began and Telford's elevation with its gently curving extrados rising less than 3 ft from the banks to the centre and spans from 52 ft to 58 ft 10 in. was retained. Much of the original Aberdeen granite was reused and the bridge, completed in 1899 cost just over £100 000.

The present bridge is 20 ft wider than its predecessor at 80 ft and has much deeper foundations consisting, instead of timber piles, of 15 ft diameter steel cylinders sunk by pneumatic pressure. Excavation for these piers was done manually in a 9 ft high air compression chamber, 43 lb sq in. of pressure being required at the greatest depth, a condition under which it was almost impossible to get the men to work. The cylinders were then filled with concrete. Some piers are founded more than 100 ft below springing level. A temporary eight-span bridge 60 ft wide consisting of steel beams on timber piles was erected to accommodate traffic during construction.

The engineers were Blyth & Westland and the contractor, Morrison & Mason, Glasgow, with steelwork by Sir William Arrol & Co.

Sir Alexander Gibb dubbed Telford's creation 'perhaps the most beautiful of all his bridges . . . a fitting crown to his creative life'. Despite developments since 1835 it is still possible to appreciate something of the bridge's style and elegance. [14–17]

9. Portland Street Suspension Footbridge

HEW 0710
NS 5890 6472

With a suspension span of 414 ft and Greek-style towers in the form of triumphal arches, this bridge, designed by A. Kirkland, architect and G. Martin, engineer, has a claim to being Glasgow's most elegant bridge. It was opened in 1853, replacing a state-of-the-art 14-span timber bridge designed by Robert Stevenson and built by William Robertson in 1832 to accommodate traffic during the building of the Broomielaw Bridge and retained for pedestrian use until 1846. James Walker submitted designs for suspension and iron arch bridge replacement footbridges neither of which was implemented.

The suspension bridge deck is 13 ft wide and supported by four eye-bar link chains with 10 ft long links. The dip of the chains is about 26 ft, giving a dip-to-span ratio of 1 to 16. In 1870–71 the ironwork underwent reconstruction under the direction of Bell & Miller at a cost of £6836. The contractors were Hanna, Donald & Wilson, Paisley.

Further refurbishment was carried out in 1898, 1926 (Sir W. Arrol, cost £4400), 1996 and 2004, by which time all the hangers had been replaced and the main chains had been strengthened at the anchorages. A 5 m long Arrol hanger is preserved at the Institution of Civil Engineers Museum at Heriot-Watt University. [18]

10. Victoria Bridge

HEW 0815
NS 5917 6457

This bridge, between Stockwell Street and Gorbals Street, is now the oldest road bridge crossing the river. It has five low-rise segmental arches on a skew of 61° varying in span from 67 ft to 80 ft at the centre, where the rise is only 10 ft 6 in. It is constructed in light-coloured local sandstone and faced with granite from Kingston, near Dublin, and is one of the finest examples of its type in Scotland.

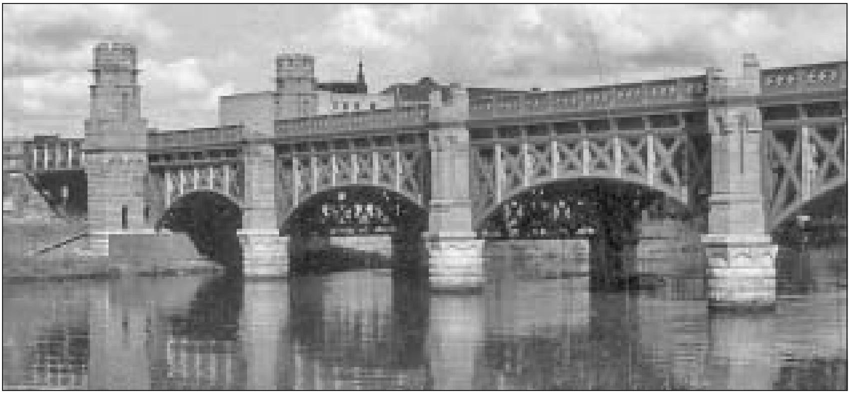
The foundation stone was laid on 9 April 1851 by the Duke of Atholl and the bridge was opened on 1 January 1854. The engineer was James Walker and the contractor, William Scott. The cost was about £46 000. [19]

11. Clyde Viaduct, Union Railway

NS 5928 6450

This viaduct, erected from 1897–98 by the Glasgow & South Western Railway, developed the existing twin-line strategic crossing of the Clyde shown below to carry four lines of track into St Enoch's Station. But its curious appearance as five spandrel braced arches of riveted steelwork, three spans of $84\frac{1}{2}$ ft and two of 69 ft, each consisting of two ribs, and a lattice girder span over adjacent streets at each bank, is misleading.

In fact, the structure consists of two variable depth ($8\frac{1}{4}$–24 ft) continuous girders supported on cast-steel bearings,

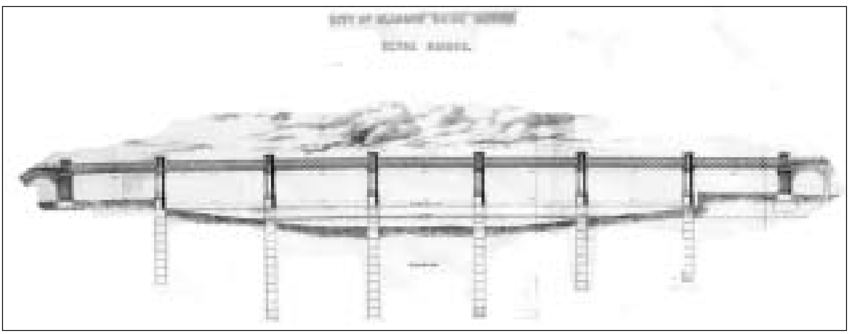


Clyde Viaduct – Union Railway [*Railway Heritage Trust Annual Report* 1987–88, 12]

which were fabricated either side of and below the 1870 superstructure (see figure). The girders are fixed at the two centre piers but with expansion rollers at the two landward piers and abutment. There is a decorative cast-iron cornice and parapet on all river spans, with crenellated half turrets of red sandstone at the piers, and abutment towers in the same style.

The twin-track seven-span iron-girder viaduct, opened in 1870 on the City of Glasgow Union Railway, the first city railway crossing of the Clyde connecting the Glasgow & Paisley Joint and North British lines, was kept operational whilst the present bridge was ingeniously built around it. The engineers for the 1870 bridge, with its typical double-lattice girders 8 ft deep, were John Fowler and J. F. Blair and the contractors, Brassey & Co.

An innovative construction feature was the use of 8 ft diameter cast-iron cylindrical foundations achieved by



Clyde Viaduct Elevation 1870 – note deep cylindrical foundations [cont. lithograph] means of Milroy's excavator and cylinder sinking method to reach a firm base up to 100 ft below. The cylinders were sunk by applying curved weights on top to force down those below. The soft earth from within was removed by a 5 ft diameter grab type excavator. Keeping the cylinders full of water enabled about $\frac{3}{4}$ cubic yards of soft earth to be brought to the surface at each lift. The cylinders were then filled with concrete and brickwork and are believed to still exist.

The 1898 bridge is founded on 13 ft diameter steel piers sunk by means of compressed air to within 2–3 ft of the bottom of the existing cylinders. The engineer was William Melville and the contractors, Hanna, Donald & Wilson, Paisley and Sir Wm. Arrol & Co. (steelwork). The cost was £67 970.

Although St Enoch's Station was closed in 1966 and subsequently demolished, the viaduct is still in use, mainly for freight traffic. [20, 21]

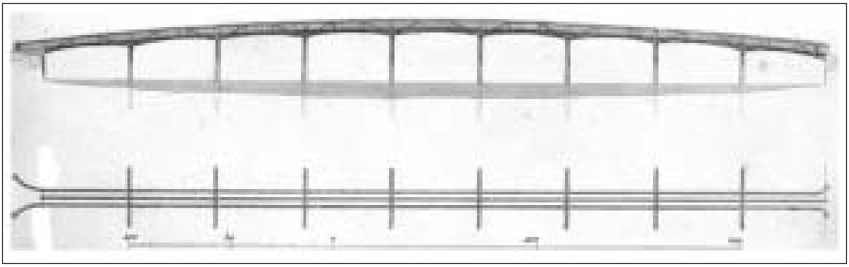
12. Albert Bridge

HEW 1330
NS 5941 6444

This 60 ft wide wrought-iron elliptical arch structure, with a central span of 1214 ft and an 108 ft span on each side crossing the river at the Saltmarket, was built in 1871–72. Each span is carried on eight riveted ribs.

Influenced by the successful foundations at the first Clyde Viaduct, its masonry piers and abutments were carried on cast-iron cylinders founded some 86 ft below high water level. The parapets are of ornamental cast-iron design. The cost was £62 328. The engineers were Bell & Miller and the contractor, Hanna, Donald & Wilson, Paisley.

This bridge replaced Robert Stevenson's elegant five-span masonry, low-rise segmental arches, Hutcheson Bridge built by John Steedman from 1831–34, described by Fenwick of the Royal Military Academy as one of the 'best specimens' of its type. But Daniel Miller, of Bell & Miller, with the support of Fowler, was keen to build a new bridge. Parliamentary evidence of 1865 indicates that they overstated the extent to which the foundations had collapsed from navigational deepening. David Stevenson, James Leslie, Sir James Falshaw and Thomas Page all indicated how the bridge could be



Nicholson's Hutcheson timber bridge 1803 [24]

saved at a fraction of the cost of its replacement, but to no avail.

The first successful bridge near this site was an elegant timber footbridge erected in 1803 at a cost of £1200 to a design by Peter Nicholson, with an elevation of 'one grand sweep of 340 ft' and eight supporting piers. It followed the failure in a flood of the first Hutcheson Bridge of five stone arches when it was nearing completion in 1795. Rennie proposed elegant designs in iron and stone for its permanent replacement in 1815, but it was Robert Stevenson's design which was eventually implemented. [22–24]

13. Weir and Pipe Bridge, Glasgow Green

NS 5951 6437

This weir consists of three spans of spandrel braced steel arches erected in 1949 to carry machinery for raising and lowering gates to control the flow of water and its level upstream. They can be raised at high tide to allow the passage of small boats. The engineer was Robert Bruce, City Engineer, and the contractor, Crowley Russell.

In 1852 a combined lock and weir costing about £65 000 was built nearby under the direction of James Walker to maintain the water level and allow navigation. Its demolition in 1879 resulted in extensive erosion of the banks and siltation downstream and led to the first control gate structure, erected by Morrison & Mason from 1896–1901 under the direction of City Engineer A. B. MacDonald, with Sir B. Baker as consulting engineer. The gates were designed by F. G. M. Stoney. Scour undermined this bridge in 1941 leading to its collapse. [25, 26]

14. St Andrew's Suspension Footbridge

HEW 1876
NS 5995 6440

A wrought-iron chain-link suspension bridge with classical style towers constructed in 1853–54 at Glasgow Green. Its span is 220 ft and the dip of the chains is about 22 ft. Each tower comprises two pairs of cast-iron Corinthian columns of 27 in. diameter and 20 ft high, each pair being capped by a cage of 12 rollers on which rests a cast-iron plate to which the chains, which are 4 in. deep and in two tiers, are connected. The rod suspenders are connected to the chains by a Brunel-type attachment. The designer was Neil Robson and the contractor, P. & W. McLellan. The cost was £6348.

In the 1950s the original lattice parapet stiffening girders were replaced by more robust girders of the Warren type. There is a model with the original parapets in the Glasgow Museum of Transport. [27]

15. King's Bridge

NS 6000 6377

This bridge, linking King's Drive and Ballater Street with four equal spans of about 70 ft, each of 11 parallel steel-plate girders supporting a reinforced concrete deck slab 70 ft between parapets, was built from 1930–33. It is a good example of best practice in ca.1930. The engineer was T. P. M. Somers, City Engineer and the contractor Sir William Arrol & Co. The cost was £113 130.

The first bridge on this site, of five spans, was erected by Wm. Kennedy of Partick in 1901 at a cost of £10 076, using mainly timber salvaged from the service bridge used in the reconstruction of Broomielaw Bridge. [28]

16. Polmadie Footbridge

NS 6012 6329

A pre-stressed four-span concrete footbridge built in 1954–55 at Glasgow Green. The engineer was Robert Bruce.

This bridge replaced one with a span at each side of 40 ft flanking two central ones of 60 ft 6 in. using girders 4 ft deep with piers formed of three rows of timber piles. When built from 1899–1901 this bridge, costing £10 076, was enclosed in timbered ornamental work giving it the appearance of an arch bridge. It was opened on 13 June, the same day as the first King's Bridge. Polmadie Bridge was partially destroyed by fire in 1921 and new girders supplied for the central spans. The timber arch-work was omitted. It was closed in 1939.

The contractor for the 1901 bridge was William Kennedy of Partick and Sir William Arrol & Co. for the 1921 refurbishment. [29]

17. Rutherglen Bridge

NS 6060 6308

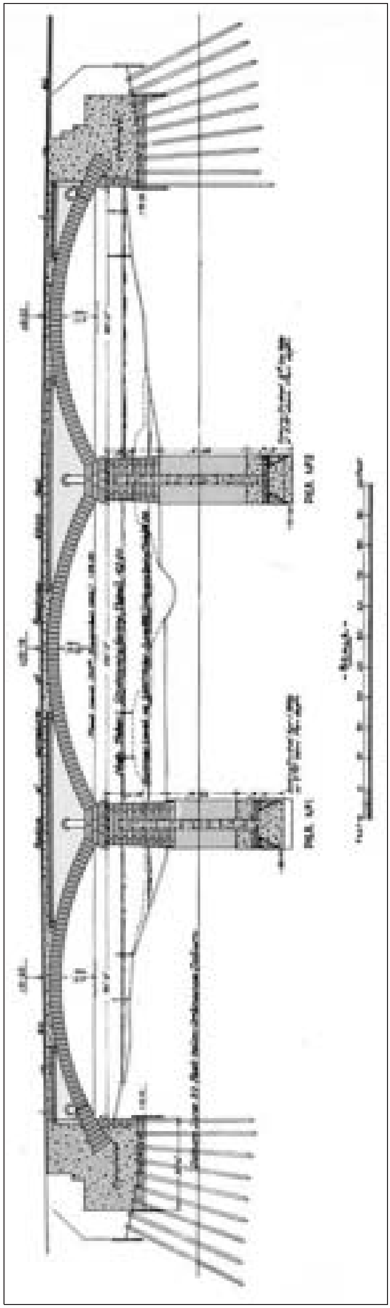
This bridge, built from 1893–96, links Main Street to Shawfield Drive. It consists of three low-rise segmental masonry arches of 90 ft and 100 ft span faced with grey granite from Cornwall, Dalbeattie and Aberdeen. The engineers were Crouch & Hogg and the contractor, Morrison & Mason. The temporary steelwork for the erection of the bridge was furnished by Sir Wm. Arrol & Co.

This bridge replaced a five-span segmental arch stone bridge, 16 ft wide between parapet faces, built in 1774–75 to the design of James Watt and costing about £2000. It had segmental arch spans from 60 ft–65 ft–70 ft, all with the same radius of 41 ft, and 1 in 25 gradients from the abutments to the centre. Watt drew the plan on 19 April 1774, during the same week that he was preparing plans for his Caledonian Canal proposal with 32 locks.

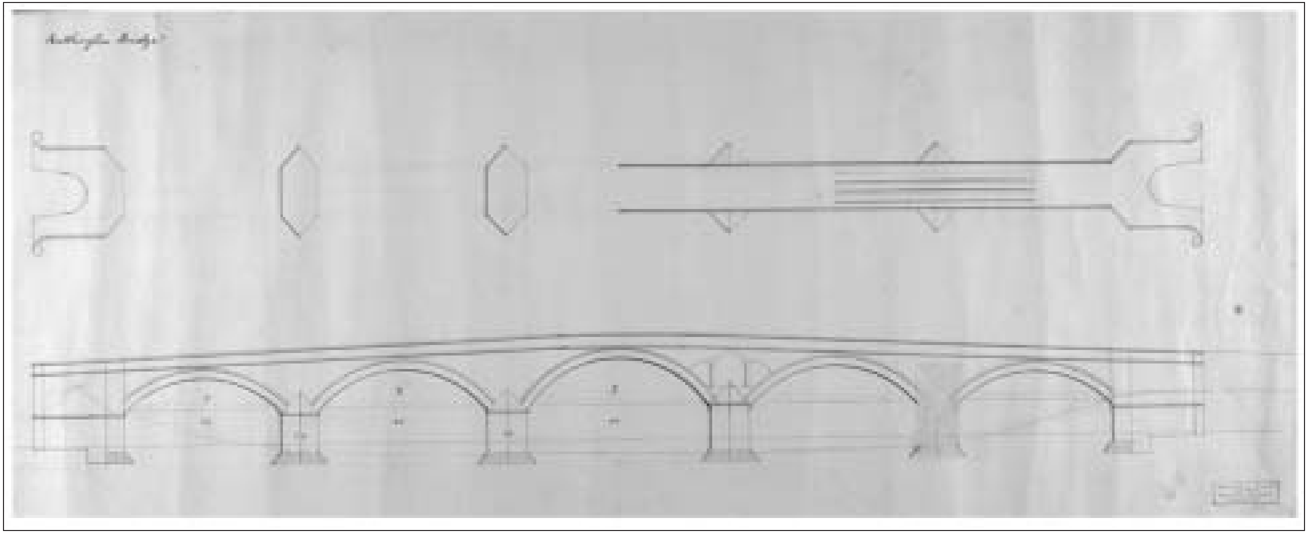
The specification called for the piers to be founded on fir platforms 3 ft below the lowest part of the river bed surrounded by 4 in. grooved sheeting piles driven down 6 ft. Each pier was to be founded on 56, 9 in. diameter iron-shod bearing piles 8 ft long. Execution was to be within cofferdams until the masonry was brought above water, and the spaces between pile heads were to be filled with rammed rubble.

Watt's drawing shows weight reduction provision by means of spandrel cavitation above a central arch pier and in the longitudinal form practised by Smeaton at Perth Bridge (6-16). The outside spandrel walls were 'to be 4 ft thick and the remaining space is to be divided into three by two walls of 20 in. running the lengthway of the bridge. These spaces are to be covered at the top by three Gothic (pointed) arches of two feet rise.'

Watt's bridge, despite its narrowness and steep roadway, lasted well but the removal of the weir (4-13)



Rutherglen Bridge [31]



Rutherglen Bridge – Watt's drawing

Birmingham City Archives, Central Library, UK. MS 3219/4/220, James Watt Papers on completion of a temporary service bridge hastened its demise in 1890. The temporary bridge, of eight timber spans of 32 ft and a central steel span of 55 ft, was erected by Hugh Kennedy & Sons, Partick, at a cost of £2936. [30–32]

18. Dalmarnock Bridge

NS 6172 6265 This 30 ft wide bridge erected from 1889–91 consists of five spans of 54 ft 6 in. carried on six plate girders. Its piers are founded on concrete-filled wrought-iron caissons 63 ft × 9 ft in plan at the cutting edge, sunk under compressed air to a depth of 56 ft below low water level. The cost was £30 500.

The engineers were Crouch & Hogg and the contractor, A. H. Boyle, Bonnybridge. The steelwork was sublet to Goodwins, Jardine & Co., Motherwell, and the cast ironwork to W. MacFarlane & Co., Glasgow.

The bridge replaced a wooden one of 1820–21, superseding a ford, which was replaced by another timber bridge in 1848. This bridge, in turn, was renewed in 1887, after a temporary timber bridge with ten spans of 32 ft costing £1105 had been erected alongside by Alex. Eadie to accommodate traffic while the present bridge was being built. These bridges confirm about three decades as the life of a timber bridge in the Scottish climate.

The 1891 bridge deck was replaced by Glasgow City Council Roads in 1997 with weather resistant steel beams and a reinforced concrete deck. The original masonry, cast-iron parapets and ornamental outer beam fascia panels were refurbished. The contractor was Mackenzie Construction, Glasgow, and the cost £145 000. [33]

19. Dalmarnock Bridge (Railway)

NS 6136 6251 A wrought-iron twin-track bridge on the Caledonian Railway (Dalmarnock branch) erected between 1859 and 1861. It comprised three tied-arch river spans of 70 ft and four 50 ft wrought-iron plate-girder land spans. The main girders were of bowstring construction 7 ft $7\frac{1}{2}$ in. deep at the centre and crossed the river on a skew of 61° 30′. Only its piers now remain. The engineer was George Graham.

An early example of pier founding using concrete-filled cast-iron cylinders sunk by open grabbing, in this instance to a depth of 14–22 ft below low-water level. There are three $5\frac{1}{2}$ ft diameter cylinders to each pier and five braced together at each abutment.

In 1897 a new twin-track bridge was completed immediately upstream with three arch main spans 60 ft 7 in. on the square, the river piers being in line with those of the existing bridge. Each span consists of six, two-pinned steel arch ribs 2 ft 8 in. deep. The longitudinal plate girders over the arched ribs are 14 in. deep. The river piers are of ashlar masonry with rubble hearting founded on two concrete-filled steel caissons $22 \times 16 \times 8\frac{1}{2}$ ft deep. The contractor was Michael Alexander.

In 1923 the bridge was widened to take four tracks by P. & W. Anderson. [34]

20. Dalmarnock Sewage Treatment Works

NS 6100 6249

This was Scotland's first large scale sewage treatment works which, from 1904 with the Dalmuir Works to the west, greatly improved public health in the city. Dalmarnock Works was constructed from 1893–94 to the design of Danish engineer, G. Alsing, an acknowledged authority on chemical precipitation. The treatment then, and still does, involve separating out the solid component of the sewage effluent in settlement tanks in the form of sludge. This was then de-watered in a filter press.

Three years later a Cumnor drying plant was installed to produce sludge cake which was marketed as 'Globe Fertilizer' for agricultural use. By 1911 32 000 tons per annum were being sold, but it was never possible to utilise the entire production and, from 1915, the surplus sludge was pumped into a purpose-built boat and taken daily down the Clyde and discharged in the Firth off Garroch Head, Isle of Bute.

Research into the use of more efficient biological filtration occurred from 1913 with the inauguration of two hectares of filter beds. By the mid-1930s the works were reaching the end of their useful life and, in 1937, an experimental plant using the Simplex Activated Sludge Process

Dalmarnock Sewage Works

Babtie 1895–1995

was installed, but it was not until 1962–68 that a full activated sludge plant was constructed at a cost of about £4 m. The consulting engineers for this improvement were Babtie, Shaw & Morton. [35, 36]

21. Garthamlock Water Tower

NS 6535 6655

A circular concrete water tower with unrestrained, laterally unsupported, columns 100 ft high. This is the second highest water tower in Britain, but is the largest, holding 1 000 000 gallons. The tank with a water depth of 22 ft 9 in. and a top water level of 485½ ft above ordnance datum was built from 1956–58 by Holst & Co. Ltd to designs of F. A. Macdonald & Partners for Glasgow Corporation.

Another significant water tower is at Bearyards, Bishopriggs (NS 6120 7060) 80 ft high. It is one of several holding

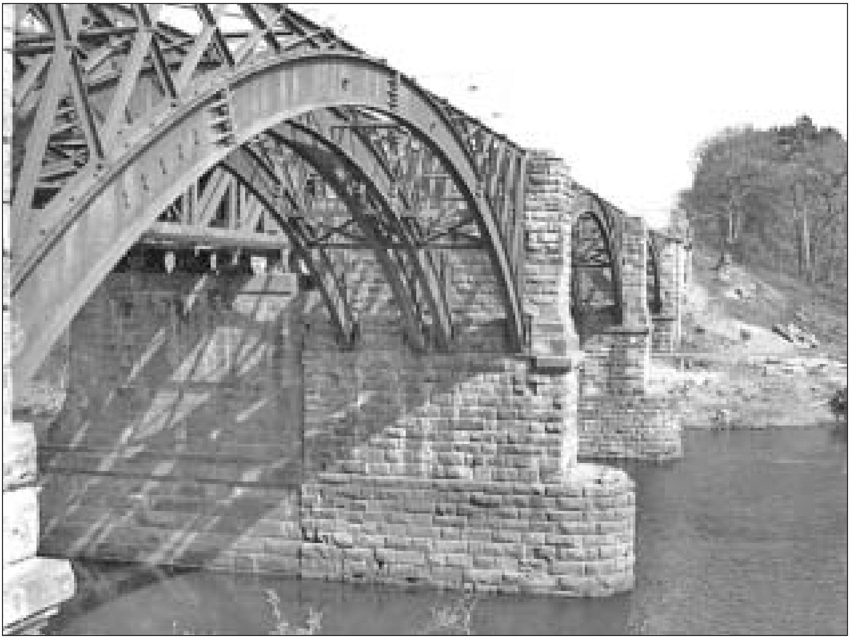
Garthamlock Water Tower [37]

600 000 gallons and was completed in 1959 by Drummond, Lithgow & Co. to designs of F. A. Macdonald & Partners. Also, at Motherwell (NS 7690 5500), is the first UK steel tower in the US 'Horton' ellipsoidal design built for a local authority. It is 91 ft high and 40 ft diameter and was designed and erected by Motherwell Bridge & Engineering Co. [37]

22. Clyde Viaduct, Uddingston

NS 6879 6088

This major three-span cast-iron arch viaduct crosses the Clyde at Bothwell on the former Caledonian Railway Clydesdale Junction line linking the Pollok & Govan and Wishaw & Coltness railways. It was bypassed in 1903 by the adjoining operational viaduct.



Duncan Sooman

Clyde Viaduct, Uddingston

Each 95 ft arch span consists of four I-section ribs 30 in. deep, overall spaced from 4 ft to 8 ft apart. The ribs are made up of four segments bolted together with cross-bracing between. The spandrel lattice frames are bolted to the upper flanges of the ribs. The abutments are built of hammer-dressed sandstone blocks, on which many of the shallow indentations used to lift them by means of lifting shears are still visible.

The viaduct was designed in ca.1847 by the company's engineers, Locke and Errington and became operational when the line was opened on 1 June 1849. The contractor was John Stephenson & Co.

The structure is of outstanding historical interest as Scotland's earliest surviving cast-iron railway viaduct. Alongside, on an extension of the same piers, its successor exhibits the best practice of half a century later using steel Pratt-type trusses to achieve the same spans. The site is of particular interest in demonstrating the transition in bridge development from the use of cast-iron in compression in arch form to steel in tension and compression in an economical open framework.

23. Bothwell Bridge

HEW 0314
NS 7107 5776

Bothwell Bridge or Brig is one of the few ribbed-arch mediaeval masonry bridges remaining in Scotland. It gained everlasting fame as the site of the battle of 1679 in which the Covenanters were tragically defeated by the Duke of Monmouth.

The bridge, dating from ca.1490, which has four slightly pointed arch spans of 45 ft, was originally 11 ft 6 in. wide between parapets but was widened in 1826. It now carries the B7071 road over the Clyde between Uddingston and Hamilton. [38]

24. M74 Interchange, Hamilton

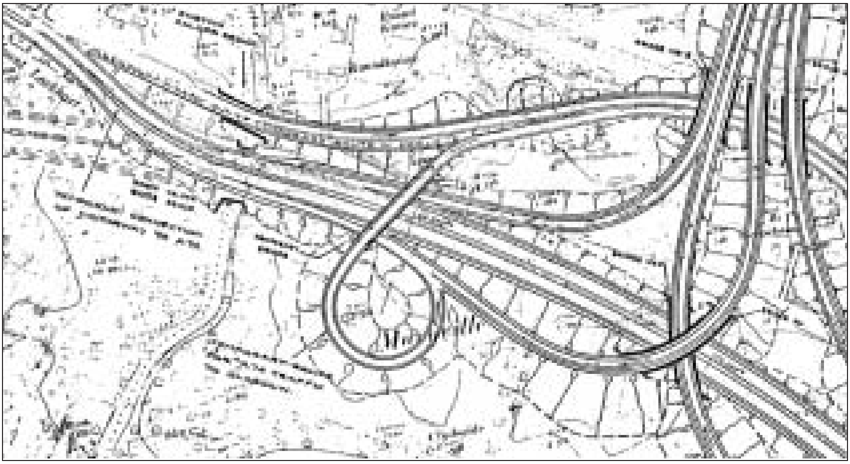
NS 6900 6200

It was not until the early 1960s that work commenced on upgrading Scotland's major routes to motorway standard. This three-level interchange at Maryville, linking the M74 and M73 motorways, was the first to be constructed in Scotland. It was completed in 1968 as part of the Hamilton Bypass.

The northern section of the bypass, some five miles in length, followed low undeveloped ground alongside the Clyde. Ground conditions were particularly difficult. In some places the ground had subsided 17 ft as a result of mining. Severe flooding was also a frequent occurrence. Earthworks involved the disposal of large quantities of unusable material including peat and soft silty clay.

The interchanges at the north end of the bypass where two slip roads cross the motorway at different levels, in plan crossing each other on the centre line of the motorway, give rise to the three levels of construction. The lower bridge consists of four spans and the upper of six spans. They are of composite construction with skew spans ranging from 48–82 ft. A 9 in. thick reinforced concrete deck slab acts compositely with box girders 1 ft 6 in. wide × 3 ft deep supported by reinforced concrete frames. The exception is the central support to the upper bridge which is required to span the lower bridge. This is a steel portal frame with raking legs all of box sections. Piled foundations were widely used in the poor ground.

The project was carried out under the direction of J. S. McNeill, Chief Road Engineer Scottish Development



Top: M74 Interchange, Hamilton Bypass [39]

Babtie, Shaw & Morton brochure 1969

Bottom: Maryville Interchange

Department. The consulting engineers were Babtie, Shaw & Morton who were also responsible for Scotland's most spectacular four-level motorway interchange at Baillieston, east of Glasgow, linking the M73, M74, the M8 to Edinburgh and the A80 to Stirling, in April 1980. [39]

Glasgow & Carlisle Road (Lanarkshire) (1815–25)

This major road improvement, the equivalent of a motorway in its time, has been generally described already (pre 1-40). On the Lanarkshire section, the turnpike trusts were allowed to retain control of an 11 mile length between Glasgow and Hamilton and a 13 mile length at the boundary of Lanarkshire and Dumfriesshire. The remainder was remade or improved under Telford's direction as engineer to the Highland Road Commission on the principles already described. The main bridges on this section included Abington (Glengonan) of 30 ft span, Elvanfoot 90 ft span and the surviving Avon, Hamilton 80 ft span (see 4-25), of which the first two were built in 1824–25 by John Park of Highstoneridge, Dumfriesshire.

In 1820 Telford was in Lanarkshire preparing plans, specifications and estimates for the improvement of two major routes connecting with the Glasgow & Carlisle Road known as the Lanarkshire Roads. These were a 41 mile length from Cumbernauld via Airdrie and Lanark to Abington, now the A73 road, and, a 24 mile length from Briech Water in the east via Allanton, Garrion Bridge erected by Ken Mathieson in 1817, and Strathaven to Loudoun Hill, now the A71 road. Cartland Crags Bridge (see 4-46) was on the former; also Fiddler's Burn (see 1-40), Birkwood Burn and Cander Water bridges all of which were built by 1825. [40, 41]

25. Old Avon Bridge, Hamilton

HEW 1171
NS 7332 5463

This ribbed-arch bridge over the Avon, about a mile from its confluence with the Clyde, was constructed in the 16th century. It is a three-arch dressed stone masonry structure 144 ft long and of 10 ft 3 in. clear width between parapets. The main segmental arch spans vary from $30\frac{1}{2}$–32 ft with a rise of $8\frac{1}{2}$ ft and the accommodation arch has a span of 10 ft. The piers are 9 ft wide and the road level is about 30 ft above the river bed. The bridge is now privately owned and restricted to pedestrian use. In 1825 it was bypassed nearby by:

Avon Bridge

HEW
NS 7350 5480

A striking single-span dressed stone structure with a segmental arch of $81\frac{1}{2}$ ft span and 20 ft rise designed by Telford and built from 1823–25. The arch ring is 3 ft thick and the roadway about 45 ft above the river bed. The spandrels are hollow in accordance with Telford's practice for large spans, with longitudinal, parallel-sided walls and four covered cavities extending from the arch upwards to just under the roadway (see figure in 1-40). There is a 12 ft wide semicircular arch accommodation span alongside.

Although partly bypassed by the M74 motorway in 1969, this bridge still carries the A72 trunk road joining Larkhall and Lanark. A toll house still exists at the east end of the bridge. [40, 41]

26. Glasgow & Edinburgh Road (1932) – Bargeddie Bridge (Railway)

NS 6985 6377

In 1923, in order to accommodate increasing motor vehicle use and to alleviate unemployment, a new major road was promoted between Scotland's largest cities. It was estimated to cost £2.33 million of which almost three-quarters was contributed by the Ministry of Transport.

The road was 36.7 miles in length, of which 15.7 miles replaced existing roads, excluding a section to link with Leith, bypassing the city centre. For the first 3.85 miles from Glasgow the road was 120 ft wide between fences with two 30 ft carriageways and a central reservation of 30 ft. The remainder was to be 100 ft wide with, originally, a 30 ft carriageway, later operated as a three-lane arrangement as the A8 trunk road before it was bypassed by the M8 motorway from the 1970s.

The late David Donald

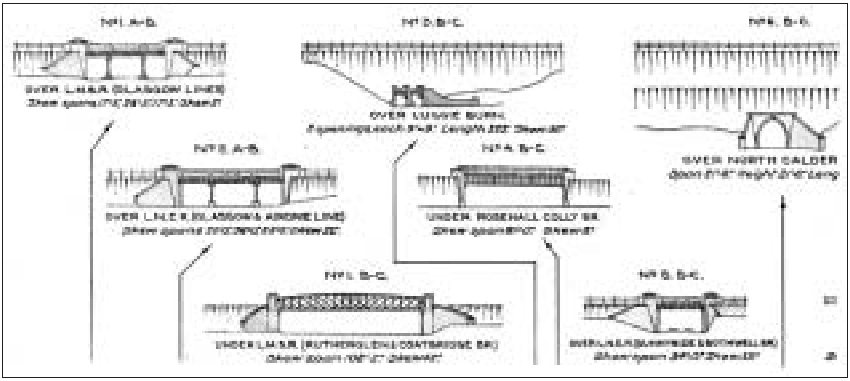
Glasgow Road Bridge under construction near Maybury Junction, Edinburgh

The line passed through several mining areas and provision had to be made in the design of structures for possible subsidence. Some sections of the road itself were constructed on reinforced concrete rafts. The work was completed in 1932.

Provision for the second carriageway, which was never built, including bridge parapets in characteristic red brick, can still be seen at various places. Occasional use was made of super-elevation and vertical curves.

Rutherglen & Coatbridge Branch Railway Bridge, Bargeddie

Jim Shipway



Bridges at west end [Chief Engineer's drawing]

Of the many bridges along the route, two of the most visible now are the railway bridge carrying the Rutherglen & Coatbridge Branch of the former LMS railway over the A8 east of the present Baillieston interchange, a steel bridge with a skew span of 120 ft of the Whipple–Murphy type with an upper chord of parabolic hog-backed members (see drawing and photograph). The other, shown in the first photograph, is the oblique steel-plate girder bridge carrying the A8 road over the former LNER line near Maybury Junction, Edinburgh.

In January 1932 the Chief Engineer for the project David Donald reported that during the six and a half years of operations the average daily number of men employed had been 750 and the total wages paid out £785 763.

27. Gardner's Warehouse, Jamaica Street, Glasgow

HEW 1342
NS 5879 6501

This historic structure, sometimes called 'The Iron Building', built in 1855–56 is probably the oldest surviving fully cast-iron frontage commercial building in the UK. The architect was John Baird, who had exposed an iron frame to public view as early as 1827 in the hammer beam roof of the Argyle Arcade.

The building is straightforward and logical in its use of materials and in 1855 was state of the art. It is four storeys high, fronting Jamaica Street with four bays and the adjacent side street with three bays. Each bay above the ground floor is divided into lights by simple iron mullions. All the mullion façades are moulded, slightly differing from storey to storey and were cast to form modules of 21 ft span between columns on the Jamaica Street elevation and $17\frac{1}{2}$ ft spans at the side street.

Internally the timber floors are carried on iron beams resting on cast-iron columns. Although not strictly civil engineering, the building is a masterpiece of cast-iron functionality and elegance. [42]

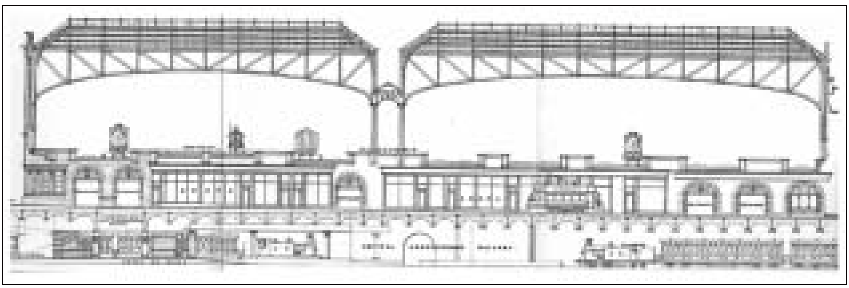
28. Central Station

HEW 0443/01
NS 5875 6516

The most remarkable feature of the Central Station is its concourse, a long and wide triangular area with its north base at the entrance from Gordon Street. This area gives access to 13 platforms arranged in echelon formation with platforms 1 and 2 nearest the entrance and the higher numbers extending as far as the bridge over the river.

Roofing the vast concourse was done by simple deep steel Warren girders in a pleasing design by Donald A. Matheson, the Caledonian Railway's engineer-in-chief, who was also responsible for the bridge over the Clyde. These girders reach a maximum clear span of the order of 350 ft supporting a glazed roof on subsidiary girders between the main spans.

An arcade of octagonal built-up steel columns between platforms 9 and 10 support the same style of roof members but in a twin-span arrangement of smaller girders having semi-elliptical curved lower flanges. Matheson chose this attractive shape deliberately 'in order to relieve the depressing effect from their solidarity



Central Station [34]

and heaviness'. Most of the present station complex dates from 1901–06. [43, 44]

29. The Subway

HEW 1399
NS 5893 6500
(St Enoch Station)

'The Subway', as it was called from its inception, was an ambitious railway project for its time, extending six and a half miles below the city streets in twin tunnels 11 ft diameter side by side. The gauge is 4 ft and the work was completed in 1896. It was modernised in the 1970s by Sir William Halcrow & Partners. The original engineers were Simpson & Wilson of Glasgow.

When the subway opened in 1896 trains were hauled by an endless cable running in sheaves between the rails. The train drivers controlled a device called 'the gripper' which could grab or release the cable as required. This method of traction was unique for a suburban railway of this size.

In 1935 Glasgow Corporation acquired the subway and electrified it. It was fully modernised in 1977.

In tunnelling under Glasgow, the engineers and contractors encountered a wide variety of material, from sandstone rock and coal measures, to soft clays and silts. Many problems had to be overcome, not least when

'The Subway' – St Enoch's Station [old postcard]

tunnelling under the Clyde, which is crossed in two places, at Custom House Quay to the east and between Govan and Partick to the west. At the former site the river broke in and flooded the workings on ten occasions.

The completion of the river crossing by grouting behind the iron-ringed lining made them remarkably watertight, so much so that the sections under the river are among the driest parts of the whole system.

There are 15 stations, each with 10 ft wide island platforms located on summits with 1 in 20 flanking gradients to assist braking and acceleration. There are no surface stations, and removal of the train cars for servicing to the surface was then a complicated business involving lifting them bodily via a special access pit. Twin rail tunnels 11 ft diameter lined with cast-iron segments cross the river between Govan and Partick. In the past, even with their 1 in 18 gradient approaches, these tunnels were often used in preference to the ferries.

The works were carried out from 1891–96 by several contractors, including Sir Robert McAlpine & Sons, and Charles Brand. [45, 46]

30. Queen Street Station Roof

HEW 0444
NS 5920 6554

From 1877–88 much of Queen Street High Level Station was reconstructed to give additional space and the present roof was constructed in 1879 under a £17 500 contract awarded to P. & W. MacLellan. It was designed by James Carswell, North British Railway engineer, and is in the form of a glazed tied segmental arch of 170 ft span, 450 ft in length and 79 ft maximum height, the largest of its kind remaining in Scotland following the demolition of St Enoch's Station's roof with an arched span of 204 ft.

The tied arches are at 41 ft 6 in. centres and are carried on cast-iron columns 21 ft high. The columns have Corinthian capitals and are carried on bases spreading the load to nine 12 in. square timber piles under each column.

A small part of what may be the original 1842 roof of the station still exists on the extreme west side at platform 1 adjacent to the main arched roof, embodying iron rod trusses of great simplicity. [47]

RCAHMS: John Hume

31. Cowlairs Incline

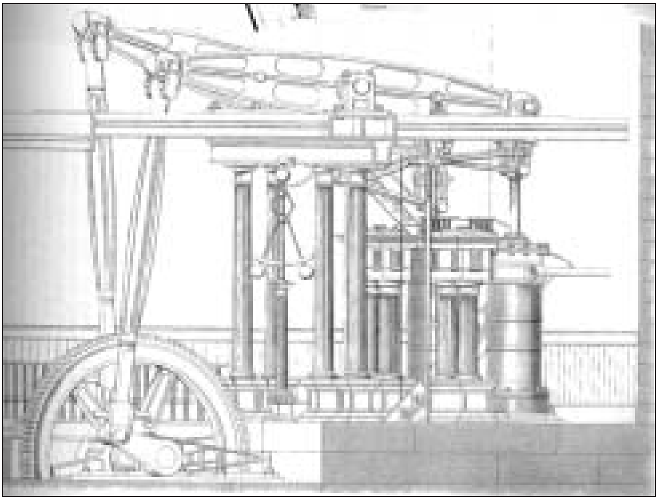
HEW 1058
NS 5945 6619

Top: Queen Street Station roof ca.1879

The entry to Queen Street High Level Station for railway traffic is through a tunnel 1040 yards long on an inclined plane of about twice that length with an ascending gradient of 1 in 44 to Cowlairs Station, where a steam-operated winding engine originally existed until 1968 although the machinery was scrapped in 1909. The tunnel, built by Marshall & Co., consisted of three parts, Bell's Park 272 yards, Asylum 292 yards and Broomhill 476 yards.

These works were constructed in 1840–42 by the Edinburgh & Glasgow under the direction of Miller, at the end of a line he had engineered almost level. The incline was too steep to be worked by the locomotives of the day and each train had to be assisted by rope haulage and controlled by a special brake wagon when descending. By the end of 1841 the tunnel was white-washed and gas lit and, on Miller's authorisation, was opened to the public on New Year's Day 1842 for the benefit of the Paisley Relief Fund and workmen injured on the railway.

The rope haulage system, similar to that on the earlier Liverpool & Manchester, was in the form of an endless cable operated by a winding engine in a special building



Cowlairs Incline steam engine [49]

at the top of the incline (see figure). Trains were connected to the rope as they left Queen Street Station and cast off the connection at the top. This inconvenient method of working lasted from 1842 to 1908, when banking engines took over.

As a train began to leave the station there was a momentary pause for the rope to be attached. This allowed many a late arriving passenger a few moments more to catch the train! [48, 49]

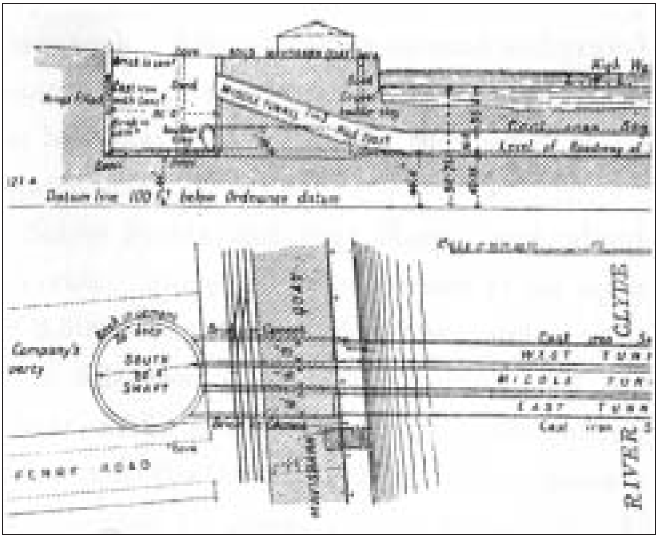
32. Harbour Tunnel

NS 5713 6505

This project comprised three parallel tunnels, two for vehicular use and the middle one for pedestrians, and is notable as the first shield driven tunnel in Scotland. One of the two 17 ft 3 in. diameter shields used, both made by Markham & Co., Chesterfield, is shown in the figure – note the two hand pumps which worked a series of 13 small hydraulic rams with a stroke of 2 ft to drive the shield forward.

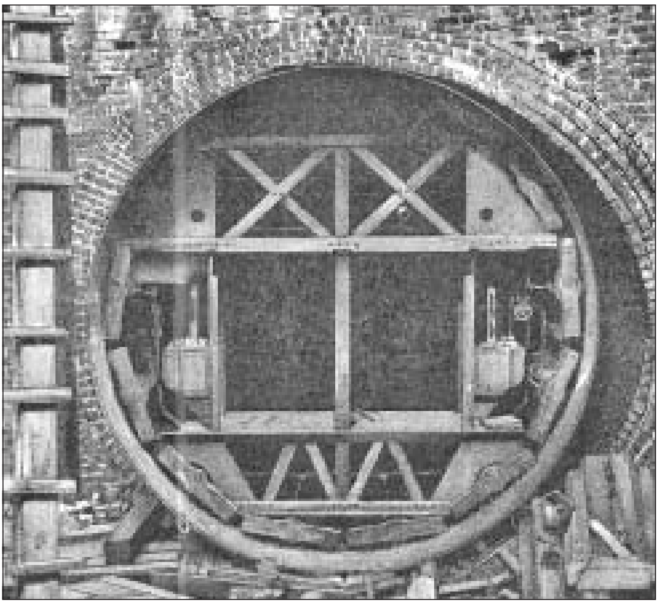
The tunnel connecting Kingston and Finnieston was driven under one of the busiest stretches of the Clyde from 1890–95, using compressed air varying from $2\frac{1}{2}$–18 lb sq in. of pressure to reduce water ingress. Similar to Brunel's Thames Tunnel, the project had large vertical access shafts capped by prominent circular red brick

Harbour Tunnel – layout and section [50]



'rotundas', the one on the north bank now being conserved as 'The Rotunda' restaurant, opened in 1988.

The access shafts are 80 ft in diameter and each held six hydraulically-operated lifts for vehicles erected by the



Harbour Tunnel – shield used in construction [50]

American Elevator Company, the fitting of the girders for which was done by Findlay & Co., Motherwell. The twin tunnels were 720 ft long between the shafts, 16 ft in diameter, and built partly of brick and partly of cast-iron segments. They were closed to vehicular traffic in 1943 and the pedestrian tunnel in 1980, although it still accommodates services.

The engineers were Simpson & Wilson, of Glasgow, the resident engineer was Alexander Simpson, Jr, and the contractors, Hugh Kennedy & Sons, Partick, and Findlay & Co., Motherwell, for the steelwork. [50]

33. Partick Bridge

NS 5653 6643

A gothic style decorated single-span open cast-iron arch formed of nine ribs crossing the Kelvin on a pronounced skew, erected from 1876–78 as a replacement for the old bridge. Its wing walls are of red sandstone ashlar with semi-octagonal towers rising to parapet level.

The bridge was built for the Glasgow and Yoker Turnpike Road Trust. The engineers were Bell & Miller and the contractor, Hugh Kennedy. The old masonry bridge of three arches built ca.1800 still exists, ivy covered and now serves as a footbridge.

34. Kelvin Way Bridge

NS 5694 6625

An ornamental single-span masonry late-19th century arch in red sandstone carrying a 60 ft wide roadway over the Kelvin. It carries bronze sculptures in pairs at each abutment, eight in all, damaged during Second World War, by a German air raid.

The engineer was A. B. MacDonald, City Engineer and the contractor, John Emery & Sons. [51]

35. Kelvingrove Park Footbridge

NS 5705 6631

An elegant structure with a span of 135 ft and width of 12 ft erected in 1964 from a design thought to be influenced by Swiss engineer Robert Maillart's three-hinged concrete arches. The engineer was W. T. Doherty of Ronald Walker & Co.

36. Great Western Road Bridge

HEW 1158
NS 5746 6697

Completed in 1891, this bridge carries one of Glasgow's busiest commuter routes over the Kelvin. Almost at the end of the cast-iron arch bridge era, it has four graceful cast-iron Gothic style segmental arch spans, the two centre ones being 91 ft with a rise of 18 ft 3 in. The deck is carried on steel cross girders with brick jack arches.

The western abutment overlies old coal workings at shallow depths and is carried on a steel frame resting on cast-iron columns which penetrate the workings to a secure foundation below. The engineers were Bell & Miller and the contractor, Sir William Arrol & Co.

37. Queen Margaret Bridge

NS 5707 6751

This bridge, carrying Queen Margaret Drive over the Kelvin on a slight skew, was erected from 1926–29. It comprises a 135 ft span reinforced concrete arch clad in red sandstone and is 80 ft wide. At river level there are small pedestrian arches through each abutment. It has similarities with the larger scale George V Bridge.

The engineers were Considère Construction Ltd and T. P. M. Somers, City Engineer and the contractor, Wm. Taylor & Son.

38. Kirklee Bridge

NS 5685 6786

This bridge, crossing the Kelvin between Kirklee Road and Clouston Street, was built from 1899–1901 at a cost of £22 000 of which a £9000 contribution was payable by the Caledonian Railway for disturbance of city streets by railway operations.

A substantial traditional style 50 ft wide single-span semi-elliptical arch of 80 ft span with a rise of $31\frac{3}{4}$ ft 9 in., and adjacent 18 ft wide arches for pedestrian use in the abutments, all in red sandstone. Its embellishments include pairs of Ionic columns in polished pink granite and elaborately carved Glasgow coats-of-arms on each elevation. The balustrades also are of pink granite. A bridge with gravitas!

The engineer was Charles Forman (d. 1901) of Formans & McCall and the contractor, Wm. & Charles Wilson. [52]

Top: Kirklee Bridge [old postcard]

39. Kibble Palace, Glasgow

NS 5693 6744

The use of glass in conjunction with slender iron glazing bars seen in the Kibble Palace was almost unique in the 19th century. It was based on the development of arched domes without tie rods and the manufacture of the structure was effectively based on a form of industrialised building, the structural frame elements being mass produced. These frames were made from wrought-iron and were supported internally on iron ring beams and cast-iron columns. The building was a state-of-the-art solution for that time.

The Palace was built by John Kibble, a native of Glasgow who had his residence in Coulport on Loch Long. He was born in 1819, the son of a wealthy merchant. He had a varied career as a metal merchant but described himself as an engineer, and his many interests included the construction of glass houses.

In 1865 he is reputed to have designed the conservatory for his house at Coulport. It was claimed that Kibble was influenced by Paxton's 1851 design of the Crystal Palace, but his pursuit of glass building construction also reflected a wide and growing interest at the time. A daily newspaper in 1866 described Kibble's conservatory in the most glowing terms, and speaks of the overarching glass dome supported by 12 fluted columns. In 1871 Kibble proposed that his building be dismantled and erected in the

Kibble Palace

Crown Copyright: RCAHMS

Botanic Gardens at Glasgow and the 'Kibble Art Crystal Palace' was opened on its present site in 1873, considerably extended by Kibble. Its manufacture and erection were undertaken by James Boyd & Co. of Paisley, who were also involved in a similar work at the People's Palace on Glasgow Green. The main dome is 146 ft in diameter and 43 ft high and after 140 years is lasting well and carefully maintained. [53]

40. Provan Gasholders

NS 6206 6628

The two most historic gasholders at Provan, Nos. 1 and 2, built side by side in 1903, are identical, and highly visible from the M8 motorway east of the city centre. They measure 283 ft 7 in. in diameter and have a capacity of up to 8.77 million cu. ft of natural gas. The holders are made of steel and are retained by vertical guides of 30 steel lattice columns 153 ft high, connected by four tiers of horizontal lattice girders, all of elegant construction.

The base of the holders is located in tanks 51 ft deep constructed in brickwork and sealed with puddle clay, the builders of which, together with the retort houses and other operational buildings (now demolished), were Sir Robert McAlpine as part of their £300 000 contract. No. 1 gasholder was fabricated by Mechans Ltd and No. 2 by Barrowfield Ironworks Co. Ltd. The Glasgow Corporation engineers were W. Foules and A. Wilson.

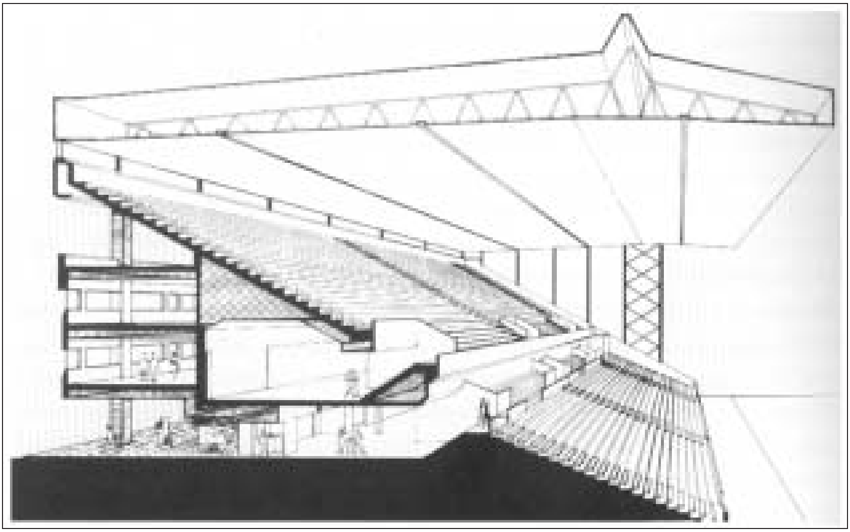
As the strata consisted of boulder clay, McAlpine's erected a complete brick-making plant with an output of 40 000 bricks per day and all the common bricks used in construction were made on site.

No. 3 gasholder to the north, built in 1970, averages 197 ft diameter and has a capacity of up to 5 million cu. ft. Both holder and tank were constructed by Newton Chambers Engineering Ltd. [54]

Glasgow's Stadia – Celtic Park, Ibrox and Hampden

Glasgow is well known throughout the football world for its three major stadia, all of which have been redeveloped in recent decades. The first to be so developed was at Ibrox for Rangers Football Club originally opened in 1899. The present stadium was commenced in 1978 after a disaster in 1971 when overcrowding on Stair 13 resulted in 66 deaths and 145 injuries. Only the south main stand of 1929 was retained, the other three sides of the ground were provided with new individual stands having open corners to assist wind flow on to the pitch.

The new Ibrox stadium was opened in 1981, play having continued uninterrupted during construction, and was an immediate success. All the new stands have an unusual structural arrangement in which the roof did not cantilever from the rear but was supported at the gable near to its front edge by a massive lattice girder spanning the full width of the seating and allowing column-free viewing. These girders span 256 ft at the east and west spans (see



Glasgow Stadium at Ibrox 1981 [55]

figure) and 356 ft at the Govan stand. The slopes of the seating tiers range from 22° to 34°.

Later the main stand was developed in the same way with a girder spanning 476 ft which was at the time the largest clear span of its type in the world. This form of construction is relatively expensive and now rarely used in stadium design. The engineers for the new Ibrox Stadium were Thorburn Colquhoun.

Development at Celtic Park followed after Ibrox, the original 'new' stand on the south side being built in the 1970s and the others surrounding the ground were completed in stages up to 1998 using conventional cantilevered roofs. An unusual feature of an earlier development at Celtic Park, now demolished, was a moveable column support hinged and parked at roof level at the front of the roof. In times of high winds the column could be lowered and fixed at ground level to provide extra support.

Hampden Park with stands roofed by cantilever steelwork in the conventional manner was completed in 1999. [55]

41. Old Snuff Mill Bridge, Cathcart

NS 5854 6011

An historic bridge with a 59 ft span segmental arch of squared, coursed sandstone masonry over the White Cart

Water. The roadway is on a downwards gradient from west to east and is 10 ft wide between parapet faces. Three iron tie bars through the crown and spandrel walls probably date from the 19th century.

A small flood relief semicircular arch on the downstream face of the east abutment bears the date 1624.

42. Linn Park Bridge, Netherlee

HEW 0405
NS 5809 5924

In 1820 a wealthy Glasgow merchant, Colin Campbell, bought what he named the Linn Estate, after a waterfall there and built a mansion as a summer residence. The estate eventually became the Linn Park and the house is now a visitor centre.

The waterfall occurs where the White Cart flows over a dolerite sill with a drop of 12 ft. About 100 yards upstream the river is bridged by an elegant cast-iron footbridge of some 43 ft span with sandstone masonry abutments.

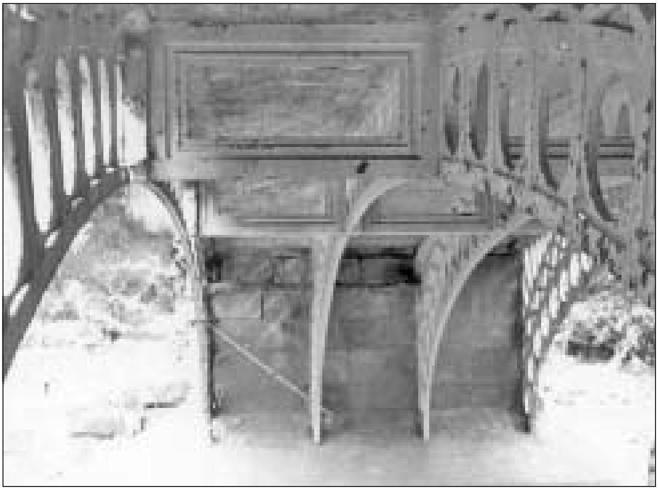
The arch is semi-elliptical in shape and formed of four ribs spaced 4 ft apart and braced at the third points by rectangular frames held by bolts with square nuts. No bolts show on the elevations of the ribs, which are pierced by ornamental tracery in the spandrels. The bridge is 12 ft wide between iron parapets which may well be original. The designer and ironfounder are unknown but the bridge probably dates from the 1820s.

In the late 1940s a haunching of concrete was placed around the seatings of the arch ribs to provide protection. The bridge is now restricted to pedestrian use.

Linn Park Bridge

Roland Paxton

Linn Park Bridge – underneath



Roland Paxton

Another cast-iron estate bridge within 30 miles, also notable for its early construction, exists in the grounds of Hafton House at Hunter's Quay, Dunoon (NS 1760 7983). It is 8 ft wide and spans 12 ft on a slight skew across what appears to be a long disused water course and is now without its deck.

The bridge's long-gone timber deck was supported on three flangeless solid plate, slightly curved on the lower edge, beams about 12–15 in. deep × $\frac{3}{4}$ in. thick (estimated). The outer beams, which have an ornamental slightly raised cruciform Telford Bonar Bridge pattern rib elevation, are surmounted by contemporary handrailing. The ironwork, which may be unique in Scotland, probably dates from 1815–20.

43. Bonnington Hydro-Electric Scheme

HEW 1627
NS 8839 4167

The Bonnington Hydro scheme on the Clyde, about four miles from Lanark, was constructed in the mid-1920s and opened in December 1927. It was the first major hydro-electric project for the public supply of electricity in Scotland.

The scheme utilises the head or height of water provided by two of the Falls of Clyde, Bonnington Linn and Cora

Linn. Water is abstracted at intakes above the falls by automatically adjusted tilting weirs, and conveyed by tunnels 10 ft in diameter, totalling some 1200 yards in length, to the power station downstream where twin turbo-alternators produce 9.8 MW of electricity.

The working head of water in the Bonnington scheme is 189 ft, and for Stonebyres, 98 ft.

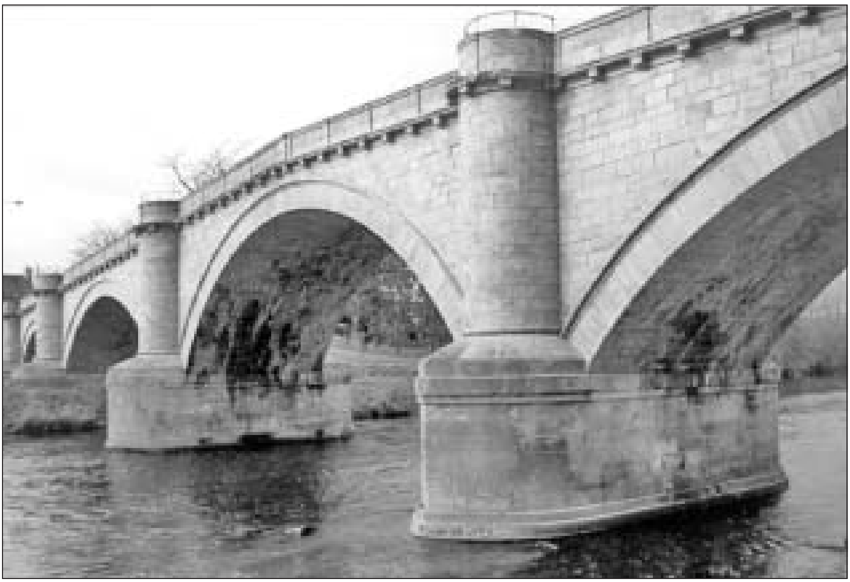
The project was designed by Buchan & Partners of Edinburgh, and the contractors were Sir William Arrol & Co., and the English Electric Company. [56]

44. Hyndford Bridge, Lanark

HEW 1694
NS 9147 4146

Hyndford Bridge was built from 1771–73 and exhibits a surprising degree of design sophistication for a Scottish bridge of this date. It carries the A73 over the Clyde about two miles south-east of Lanark, and is a five-span sandstone masonry arch bridge. The central arch is of 60 ft span and 17 ft rise, flanked by spans of 55 ft and 30 ft on each side. All are segmental in shape, with a curving moulding over the $2\frac{1}{2}$ ft deep archstones.

The approach parapets are adorned by plain masonry obelisks and the clear width between parapets is 19 ft.



Roland Paxton

Hyndford Bridge, Lanark

The cutwaters are of streamlined curved form – a shape imported from France and also seen on Teviot Bridge, Kelso, by the same designer. Above the piers are semi-circular buttresses rising to parapet level. Several mason marks can be seen on the approaches.

The designer and builder was Alexander Stevens, a leading bridge builder of his time. [57]

45. Clydesholme Bridge, Lanark

NS 8687 4391

An impressive three-span mainly rubble masonry bridge erected over the Clyde from 1696–99 with near semi-circular arches of 60 ft span and triangular cutwaters extended up to form refuges. Its roadway is about 50 ft above the river. The designer and Master of Works was a Mr Lockhart of Birkenhead, Lanark.

A fine example of late-17th century bridge building largely by direct labour, for which contemporary details of disbursements exist. The Master of Works received a salary of 20s per diem and in 1699 'fiftie merks Scottis as a gratuite for his good service at the bridge'. Now used as a footbridge. [58]

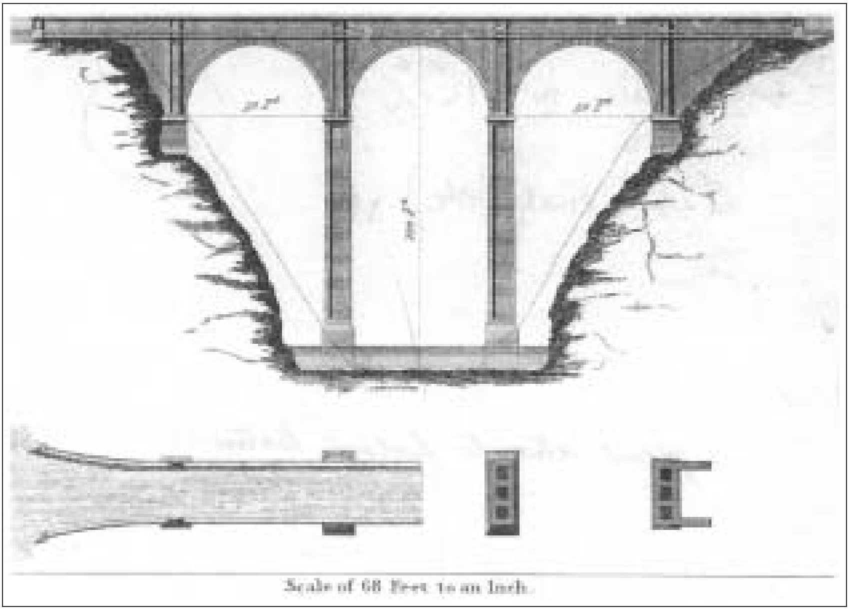
46. Cartland Crags Bridge, Lanark

HEW 0323
NS 8687 4448

This is an imposing bridge carrying the A73 about 129 ft above the Mouse Water at Cartland Crags, about a mile to the north-west of Lanark.

The bridge, designed by Telford and built by William Minto as a subcontractor to John Gibb in 1821–22, with Henry Welch as inspector, has three 50 ft semicircular arch spans springing from neat abutments founded on solid rock. Its slender piers are of ashlar masonry, slightly ornamented with recesses on each face, the line of which extends through the spandrels to relieve their plainness with the suggestion of a pilaster – a good example of Telford's aesthetic approach to design in detail, although less dramatic than his later use of ascititious arches.

The contract sum was £4425, considerably less than the cost of a Telford/Hazledine standard cast-iron lozenge-lattice spandrel bridge span (at Tewkesbury ca.1825 the 170 ft span ironwork alone cost £4500), which is presumably



Top: Cartland Crags Bridge – elevation [41]

Roland Paxton

Cartland Crags Bridge – pier and arch detail why Telford did not use one here. Telford also designed the tollhouse.

Originally the bridge was about 22 ft wide between parapets but, in 1959–60, a reinforced concrete deck was introduced and a 5 ft wide footpath cantilevered out on the north side to the design of Babtie, Shaw and Morton, Glasgow.

In 1995 the bridge's future was ensured by rock stabilization of the abutment foundations, work which attracted a Saltire Civil Engineering Awards conservation commendation on the recommendation of the Scottish Group of PHEW. [59, 60]

47. Ravenstruther or 'Paraffin' Bridge

HEW 1713
NS 9076 4437

This bridge carries the A743 road over a branch railway to Lanark from the West Coast Main Line about three miles west of Carstairs junction. It dates from the construction of the Caledonian Railway in ca.1846 and is a single-span skew arch bridge of cast-iron arched ribs, each of 52 ft span between bearings, with a rise of 5 ft. The arches spring from sandstone masonry abutments and exert a considerable thrust because of their low rise–span ratio of

Ravenstruther Bridge

Roland Paxton

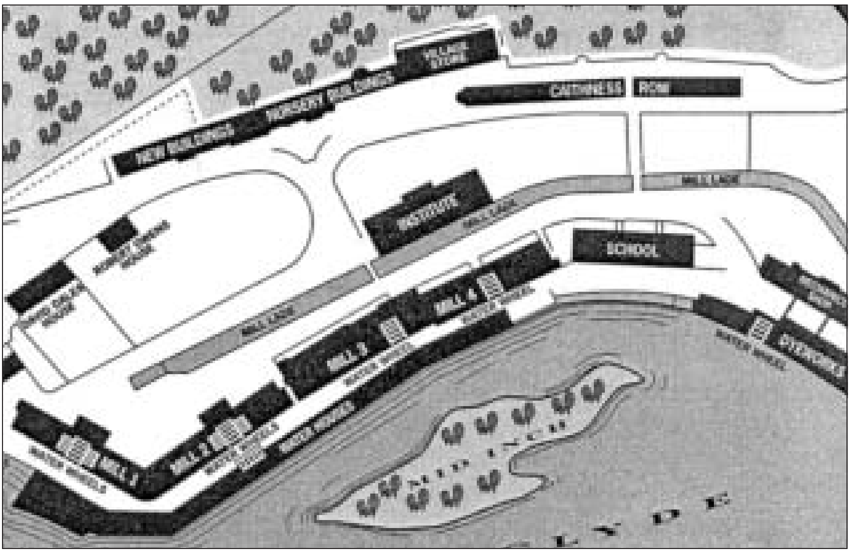
1:10. One of the few 1840s iron railway bridges now remaining in Scotland.

48. New Lanark Water Power

NS 8795 4255

The village of New Lanark was founded in 1785 by David Dale, a Glasgow merchant, and Richard Arkwright, the cotton spinning pioneer. It is located in a heavily wooded gorge south of the market town of Lanark, the site being chosen for the availability of water power from the Clyde to drive the machinery of the newly developed spinning mills.

Dale and his engineer William Kelly are understood to have directed the substantial work in harnessing of the water power and its transmission to the mill machinery and by 1786 Mill No. 1 (of four) was operational. Dale's son-in-law, Robert Owen the social reformer, became manager of the mills in 1800. He dismissed Kelly and appointed Robert Humphreys as works manager. Owen introduced conditions and educational opportunities for his workers that were a hundred years ahead of their time and the venture prospered, becoming one of the world's largest cotton mill centres supporting 2500 people.



New Lanark – location of lade and water wheels based on a plan of 1852 [61]

New Lanark Clyde Timber Dam [61]

Roland Paxton

Jim Arnold NLCT Director pointing out ca.1816 central heating in the Institute

Roland Paxton

Cast-iron beam bridge over lade at the Institute

The water power was derived from a dam built on the side of the river, later crossing it, from where the water was led through a tunnel approximately 250 yards long and about 12 ft diameter under the rocky hillside into the lade about 22 ft wide and 6 ft deep which runs through the heart of the village. The lade provided water to intake sluices at each mill into which it was led to turn basement high breast-shot wheels of up to about 26 ft diameter to power machinery. In 1852 ten wheels were producing a total of about 450 hp. Later these wheels were gradually replaced by water turbines and electric motors, with steam engines being used as a supplementary source of power when required.

A fascinating example of cast-iron technology can be seen in the bridge crossing the lade at the back of the Institute, which was built in ca.1816. The cast-iron beams may date from about the same period, and probably originate from Mill No. 3, which was rebuilt to a fireproof design after burning down in 1819. This has similar beams in its cast-iron frame, a section of which has been preserved. In elevation the beams are hogged, being about 23 in. deep at the centre and 15 in. at each end and, characteristically for beams of this date, they do not have top flanges.

Mill No. 3 also has an unusual fire resistant roof structure; it is floored with cast-iron plates at attic level, while the roof at the eastern end consists of slates wired on to an iron frame. The Institute is also of historical engineering interest for its original heating system in which hot air was passed through the cast-iron support columns to warm the upper rooms.

The village and mills survived as a manufacturing concern until 1968 when they finally closed. In recent decades the buildings have been restored and have developed a new life as a World Heritage Site with outstanding interpretive and visitor facilities. [61]

49. Biggar Gas Works

HEW 0810
NT 0388 3768

As early as 1805 some shops in Glasgow and the lecture theatre of Andersonian Institute there (later Anderson's College) were lit by gas made at the point where it was used. The idea of a central plant with a distribution system was developed in London by Samuel Clegg in 1812. In 1816 the Edinburgh Gas Light Company was established, and Glasgow followed in 1817. Subsequently some 12 gasworks were built in the 1830s of which that at Biggar, now preserved as a museum, affords an excellent small-town example.

Approximately 68 000 cu. ft of gas per day was produced until 1973, when the national grid distribution system took over. The original gasworks was built in 1839, but only the original retort house has survived, as a coal store. The gasworks was extended in 1858 when offices, workshops and a second gasholder were built. The capacity of this holder was increased to its present size in 1918 by Balfour & Company of Leven who re-sheeted it in welded steel in 1965. The gasworks closed in 1973 when North Sea gas was brought to Biggar.

The earliest works were designed by John Ritchie of Lanark and the apparatus and pipework were supplied by Robertson & Wilson of Glasgow. Masonry work was by Watson & Robertson of Biggar. The gasworks has been scheduled as an ancient monument and is curated by the Royal Museum of Scotland.

Forth & Clyde Canal

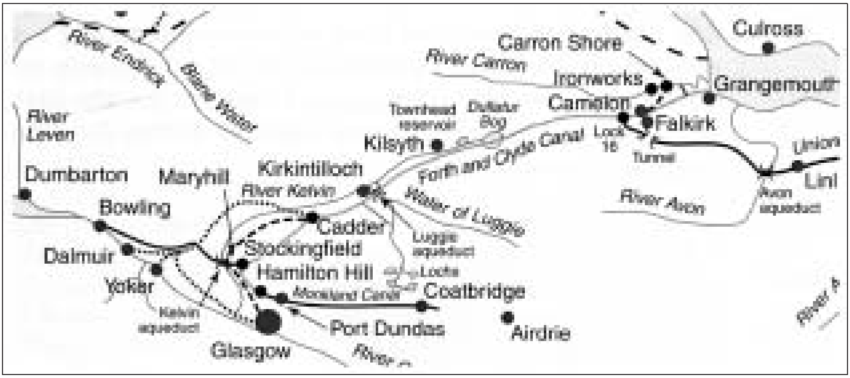
HEW 0474

The idea of a canal linking the east and the west coast of Scotland obviating the long and hazardous northern route via the Pentland Firth seems to have been first mooted in the 17th century during the reign of Charles II. But it was not until the onset of the Industrial Revolution that the concept began to make real progress with an invitation to Smeaton in 1764 to report on possible lines.

In 1767 Smeaton proposed a 7 ft deep canal from Carronmouth (now Grangemouth) via Dullatur Bog, Kirkintilloch and the valley of the Kelvin and across to Dalmuir on the Clyde. This project estimated to cost £147 349 formed the basis for the founding act of 1768. It was to accommodate small ocean-going ships with unlimited headroom by means of 43 aqueducts and 33 timber draw bridges and was referred to enthusiastically at the outset as the 'Great Canal' and favourably compared by Smeaton to the 17th century Languedoc Canal connecting the Atlantic and Mediterranean seas.

Construction from the east westwards began by contract in 1768 with Smeaton as engineer and Robert Mackell as resident engineer. By 1770 nine miles of canal 56 ft wide had been cut from the Forth and all 20 locks east of the summit were finished, each lock being 70 ft long and 20 ft wide. Mackell suggested an alteration in line taking the canal nearer to Glasgow even though this would require a major aqueduct over the Kelvin, and Smeaton agreed. The canal reached Kirkintilloch in 1773 and Stockingfield near Maryhill by 1775. Water for lockage to the 16-mile summit level was obtained by the construction of a new reservoir at Townhead, Kilsyth, and from several smaller sources.

By 1777 the Glasgow branch canal from Stockingfield had reached Hamiltonhill Basin but, owing to lack of funds from 1777–85, the terminus at Port Dundas was not completed until 1791. The canal from Stockingfield via Maryhill Locks and Kelvin Aqueduct to Bowling was completed to a depth of 8 ft by Robert Whitworth, Brindley's former assistant, between 1787 and 1790, when the canal was opened from sea to sea. In 1791 it was connected via Tennant's St Rollox chemical works to Port Dundas. The Monkland Canal, although now closed, still supplies water to the summit level. In 1822 the Edinburgh



Forth & Clyde Canal plan [63, fig 1]

& Glasgow Union Canal connected with the Forth & Clyde at Lock 16.

The navigation attracted considerable traffic from its outset and had an annual operating profit of the order of twice the annual expenditure throughout most of the 19th century. Its use declined in the 20th century with the development of railways and the canal was eventually closed to navigation in 1963. Some sections were filled in and opening bridges were replaced, but many fine buildings and old wharves remained.

The whole came back to life with the £78 million Millennium Link project, including the state-of-the-art Falkirk Wheel (pre 1-60) which restored navigation with the Union Canal after a break of 67 years. Both canals are now attracting increasing leisure traffic. [62, 63]

50. Kelvin Aqueduct

HEW 0474/01
NS 5615 6898

This aqueduct, crossing the Kelvin, is the major engineering structure on the Forth & Clyde Canal. It was built from 1787–90, under Whitworth's direction by William Gibb and John Muir of Falkirk at a cost of £9058. The aqueduct was Gibb's last work before his death in 1791. He was the founder of an engineering dynasty which eventually became Sir Alexander Gibb & Partners. His family motto was *Fides Praestantior Auro* (to keep faith is better than riches), and in completing the aqueduct within the contract time he is reputed to have made a devastating loss, such was his integrity.

The aqueduct is 400 ft long, 68 ft high, and has four arches of 50 ft span. The distinctive features of the aqueduct are the curved retaining walls adjoining the water channel which act as horizontal or lateral arches giving rise to significant reactions at the piers which are resisted by substantial buttressing. This feature was similar to that employed by Smeaton and Mackell to the same span at Luggie Aqueduct 15 years earlier.

The Kelvin aqueduct was the largest in Europe in 1790. It is also noteworthy for the variety of mason marks to be seen on the stonework, particularly near ground level. [63, 64]

51. Maryhill Locks

HEW 0474/02
NS 5639 6907

This impressive flight of five locks, Locks 21 to 25, dropping the canal 40 ft from its summit level to immediately east of Kelvin Aqueduct, was built at the same time by Gibb & Muir, also under Whitworth's direction. The lock dimensions basically conformed to Smeaton's practice. As at Camelon they were designed singly so as to 'treasure up' at least a lock full of water in the basin between each lock enough to accommodate more than one vessel for flexibility in use.

On the north bank off the basin below Lock 22 is Kelvin Dock, a small dry dock which for many years was used for shipbuilding and repairs. [62, 63]

52. Luggie Aqueduct, Kirkintilloch

HEW 0474/03
NS 6574 7393

This masonry segmental-arch aqueduct carries the canal over the Luggie near Kirkintilloch, and was the first major canal aqueduct in Scotland. It was designed by Smeaton, with minor modifications by Mackell, and built by Gibb and Muir from 1772–74 and is about 124 ft long overall, 50 ft high and 90 ft wide. The original design was for a single arch span of 60 ft.

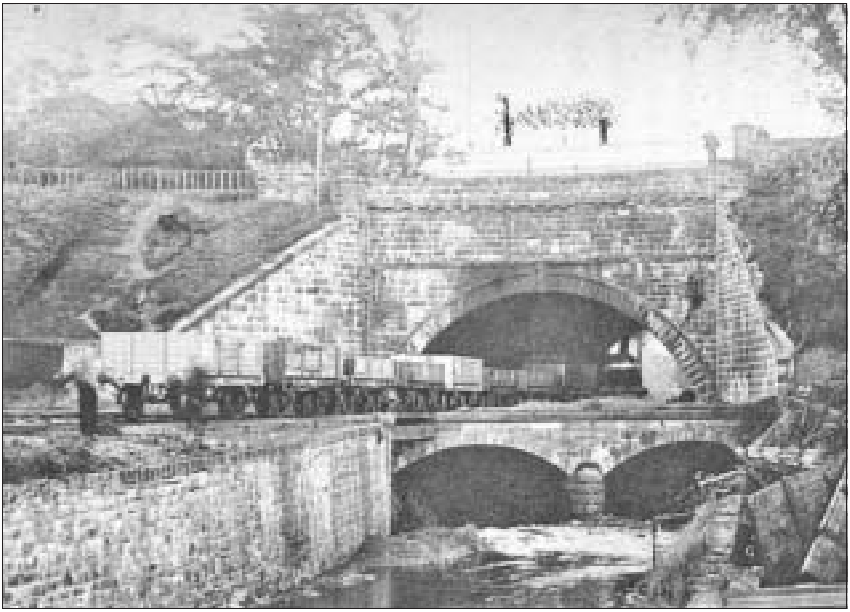
Interesting features are that, unlike at Kelvin Aqueduct, the canal passes over the Luggie at full width providing the operational benefit of uninterrupted two-way passage; horizontal side arches adjoining the waterway are provided for lateral stability; and the 90 ft tunnel of the arch was built in three stages by means of a full span

Maryhill Locks and Kelvin Dry Dock

British Waterways Scotland

timber centring devised by the contractors which moved on rollers. The two joints are scarcely discernable. The lateral arches have a rise of about one-tenth span and bear on the abutment walls at their ends.

In 1858 the Campsie Branch of the Edinburgh & Glasgow Railway was constructed, crossing the canal through the arch of the Luggie Aqueduct. The Luggie Water was contained within a twin-arched culvert to allow the railway to pass over it (see view). [65]



53. Monkland Canal

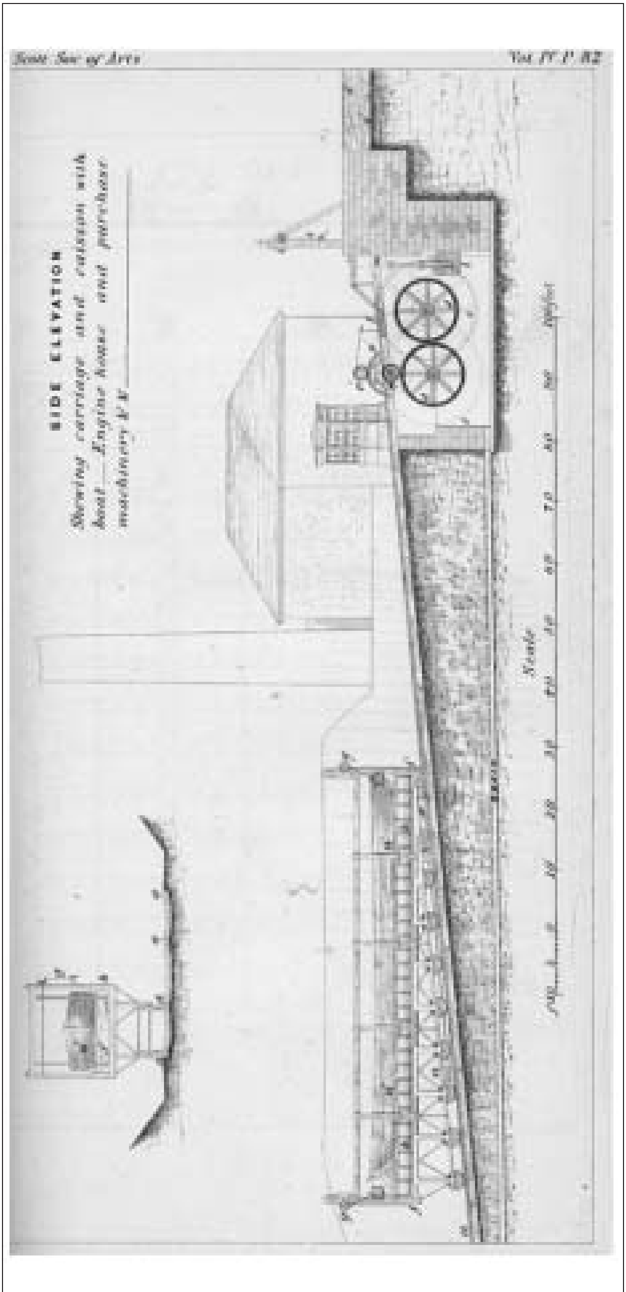
HEW 2439
NS 7215 6498
(Coatbridge end, Blair Road)

Top: Luggie Aqueduct 1894 [65]

The growth of Glasgow's industries and population in the 18th century created a demand for coal and iron which led to a proposal for a canal without lockage on two levels linking the city with the Monklands collieries. In 1770 an Act was passed for its creation and work was planned and executed under the direction of James Watt from 1769–73. The canal was 35 ft wide and 5 ft deep.

Watt wrote on 24 November 1772 that the work included 'eight stone bridges 9 feet high to the spring of the arch which is 16 feet span and rises 4 feet, the towing path passes under; the passage for the boats is 12 feet wide – one drawbridge of a new construction – one aquaduct do. over a burn 16 feet wide and 72 feet long, 6 feet high in the side walls, the water of the burn being one foot above the spring of the arch at low water and in floods rises 3 feet above the crown of it . . . four large tunnels . . . 120 feet long . . . We have now four and a half miles actually filled with water and in use.'

Work stopped from 1773–82 with seven and a quarter miles from Sheepford, near Airdrie, most of the upper



Blackhill Inclined Plane [68]

level, completed and in partial use. The lower level, about one and a half miles long, extended from the Monkland Basin, St Rollox to the foot of Blackhill, on the same level as the summit reach of the Forth & Clyde. At Blackhill an inclined plane connecting the levels, 96 ft apart vertically, was effective but involved the time and cost of unloading the coal into and from wagons.

In ca.1788 a set of locks consisting of four double locks 75×14 ft, each having two lifts of 12 ft, was constructed at Blackhill to obviate double-handling of cargos and two locks were built at Sheepford, extending the canal two miles to Woodhall. The canal was connected to the Glasgow Branch of the Forth & Clyde in 1791. The engineer was Robert Whitworth.

The coal traffic proved so great that the Monkland became Scotland's most profitable canal. But even the building, in 1841 at Blackhill, of a second set of four double locks, acting independently of the first and costing above £30 000, could not pass boats without unacceptable delay in 1849 because of water shortage.

The problem was resolved by the installation in 1850 of a state-of-the-art inclined plane to the design of James Leslie costing £16 500. It was 1040 ft long with a 1 in 10 gradient. Each boat was conveyed afloat in an iron caisson with traction by means of 2 in. diameter wire ropes and two 25 hp high-pressure steam engines. Until its closure in 1887, boats ascended the incline in about 10 minutes compared with up to 40 minutes via the locks.

The canal was closed for navigation in ca.1935. Although much of the canal, particularly at the western end on the route of the Monkland motorway, has been filled in, its water, now piped, is still the major source of supply to the Forth & Clyde. Substantial sections of the eastern reach, for example at Coatbridge, continue to survive as an attractive feature of the environment. [66–68]

54. Balloch Bridge

NS 3910 8194

The modern bridge replaced a late-19th century five-span road bridge over the Leven comprising three lattice truss spans and a shorter plate-girder span on each side. This superstructure was supported on cylindrical masonry piers. The view shows work in progress on its recent recon-

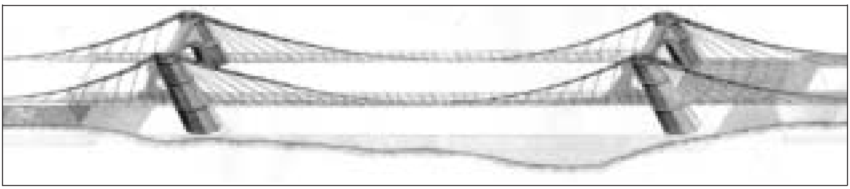
Dumbarton Council – Duncan Stirling

Balloch Bridge under reconstruction

struction with the girders on one side still in position. The modern bridge utilises the original piers.

The late-19th century bridge replaced an innovative Dredge suspension bridge with a 200 ft main span and side spans of 45 ft erected in 1841. The calculations for Dredge's bridge have survived in Weale's *The Theory, Practice and Architecture of Bridges*. [69]

Dredge's Bridge 1841 [69]



55. River Leven Barrage, Balloch

NS 3929 8147

This barrage was completed in 1971 and is designed to maintain an optimum water level in Loch Lomond to serve boating, fishing and tourist interest. It consists of seven tilting gates each hinged at the base and 24 ft × 10 ft 3 in. high, weighing approximately 6 tons. They are electrically operated and can be fully raised or lowered in just over 6 minutes.

The gates are mounted between seven concrete piers and an abutment and control the water level in Loch Lomond between the statutory control level of 26 ft AOD and the barrage sill level of 20 ft AOD. If the water level rises above 26 ft AOD the gates are fully lowered and the river flow is unrestricted.

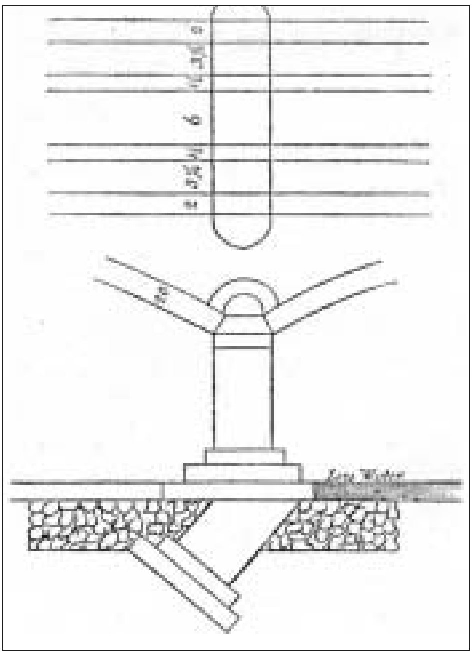
There is a fish pass at the east bank. Instead of a lock, two ramps and a boat trolley are provided to transfer craft of up to 5 tons weight past the barrage, and a floating boom is installed upstream for safety in keeping small craft away from the gates.

The engineers for the scheme were Crouch & Hogg and the main contractor, F. J. C. Lillie Ltd. The owners are Scottish Water.

56. Dumbarton Bridge

NS 3926 7535

The bridge was built in 1765 by John Brown, a builder of considerable repute who was responsible for several public buildings in Scotland. It is of masonry with five segmental arches comprising three spans of 62 ft and two of 42 ft. The clear width between parapet faces was 20 ft.



Dumbarton Bridge – Smeaton's pier replacement [70]

The Leven is fast flowing with a bed of alluvial material of unknown depth. Almost immediately on completion there was failure of one pier and a collapse of two arches.

Smeaton, in May 1768, reported on the sunken pier, of which the bottom was about 17 ft below low water. He advised that because of the difficulty and expense of getting the pier out and the great uncertainty of better success with its replacement 'that the best probable chance' was to found a new pier on the ruins of the old, lightening the spandrels above by means of three longitudinal cavities, similar to the practice he adopted at Perth Bridge.

This measure is thought by the present maintainers to have been implemented and the pier is still in service.

The bridge was widened in 1884 with 8 ft 6 in. wide cantilevered footpaths carried on steel beams. In 1933 this steelwork was found to be badly corroded and was replaced in reinforced concrete during a complete refurbishment of the bridge in 1934 by F. A. Macdonald and Partners.

In 1999 the bridge failed a structural assessment, but was again successfully refurbished and reopened in 2005. [70]

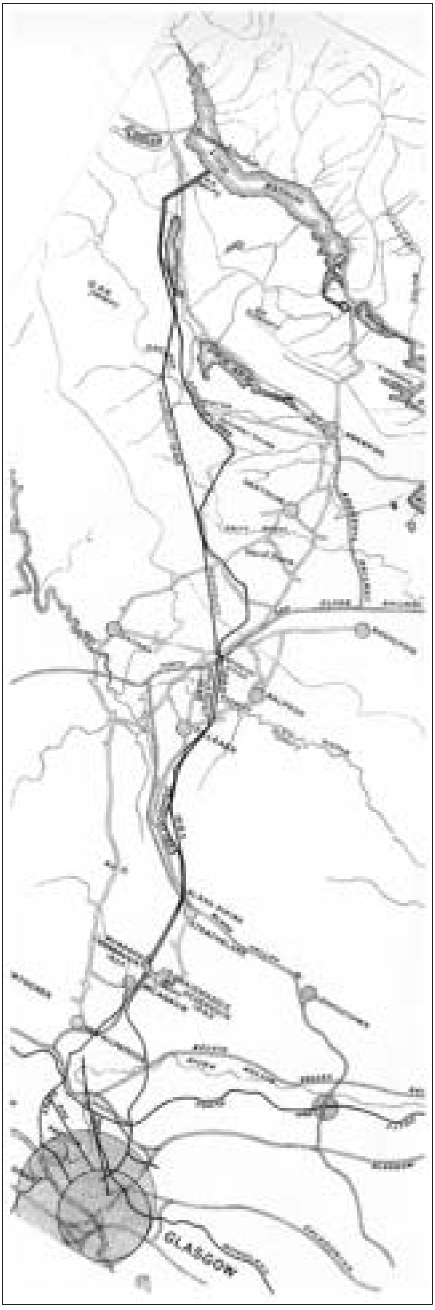
Glasgow Water Supply

HEW 1808

Until the beginning of the 19th century the town's water was drawn from wells and streams which, with industrialisation, were increasingly becoming polluted. In 1806 Telford as engineer to the newly formed water company, and James Watt of Boulton & Watt reorganised the supply from a new works built on the north bank of the river at Dalmarnock.

These works, operational in 1807, included sand filter beds, ponds and two steam engines which were used to pump water to service reservoirs at Sydney Street, Drygate and Rottenrow. The filters soon had difficulty in passing sufficient water and it was decided to tap into a good supply of naturally filtered water from sand beds at the south bank of the river.

A major problem was the conveyance of this water, derived from a tunnel with open-jointed brickwork in the sand beds, across the river into the works. This was solved with the invention by Watt of a cast-iron main with partial ball and socket joints, an idea suggested to



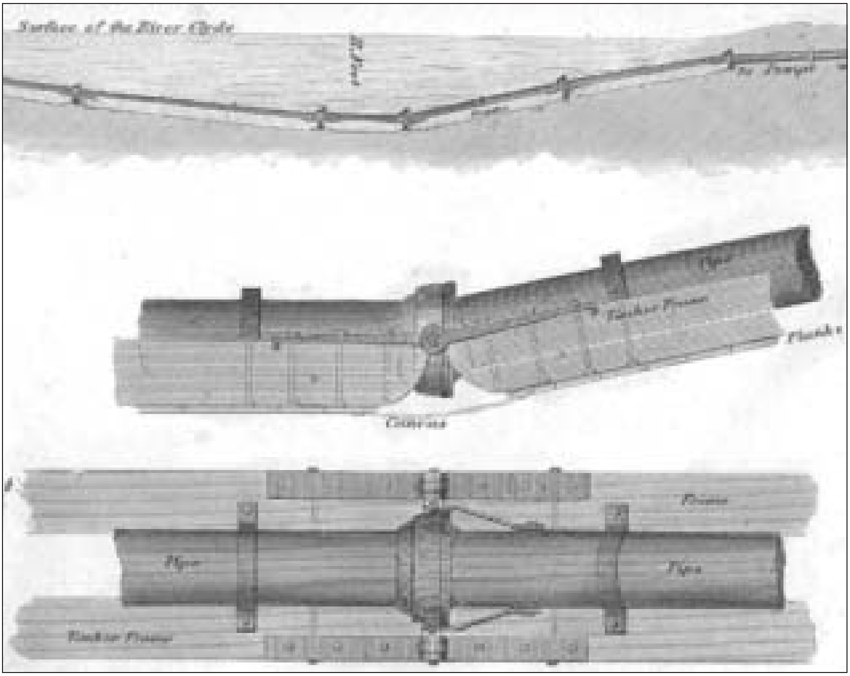
Glasgow's Loch Katrine Water Supply map [74] him by the flexibility of a lobster's tail. A shallow trench was dredged in the river bed and 15 in. diameter pipes cradled in timber frames were dragged into position under water by machinery and in operation by 1810. Three further mains were added later.

The Dalmarnock and nearby Cranstonhill works which from 1819 derived its water in a similar manner. In ca.1840, after amalgamation of the companies, two 180 hp Cornish single-acting condensing beam steam engines named 'Samson' and 'Goliath' with 72 in. diameter cylinders and 10 ft stroke made by Neath Abbey Company were erected and pumped over $8\frac{1}{2}$ million gallons per day. They were installed under the direction of Water Company engineer Daniel Mackain and broken up for scrap in ca.1860 after the Loch Katrine supply was introduced.

As the river became more polluted there were frequent complaints about the quality of the Dalmarnock water. Following an Act of 1846 the Gorbals Gravitation Water Company introduced high-quality water to south-central Glasgow and Renfrew from new reservoirs to the south-west of the city. But it was not until Loch Katrine was harnessed that a plentiful supply of water was obtained from one of the largest waterworks ever constructed either in ancient or modern times, and constructed under the direction of the leading water engineer of the day, J. F. la Trobe Bateman, with a key contribution by J. M. Gale as resident engineer for the rearrangement and redistribution of the pipework within the city.

The idea of bringing in water to the city by gravity from Loch Katrine some 35 miles away, with a catchment area of 22 800 acres, was suggested by Prof Lewis Gordon CE as early as 1846, but revived and developed by Dr J. Macquorn Rankine and J. Thomas CE in 1852.

Late in 1852 leading water engineer J. F. la Trobe Bateman was brought in to review the various possibilities for improving Glasgow's water supply. In 1853 he reported that raising Loch Katrine's natural level only 4 ft by means of a small dam and by providing a draw-off 3 ft below the natural outlet, use could be made of the top 7 ft of water to supply 50 million gallons a day to the city by gravity. He advised that '*no other source*' than Loch Katrine '*will meet all the requirements of the case*'. This view was supported by R. Stephenson and I. K. Brunel in 1854. The scheme was



Watt's flexible main crossing the Clyde [71]

approved and Bateman designed and constructed the works as built. J. M. Gale made a key contribution as resident engineer for the rearrangement and redistribution of the pipe-work within the city.

The scheme, opened by Queen Victoria in 1859, had all the hall marks of engineering genius – a plentiful high quality water supply at relatively low cost.

The works, including the first and second aqueducts from Loch Katrine to the new Mugdock and, later, Craigmaddie reservoirs at Milngavie, were constructed under Acts of 1855 and 1885, respectively (see 6-28).

The number of people employed on the whole works, exclusive of ironfounders and mechanics, was generally about 3000. The total cost was about £630 000 (Bateman, September 1859).

Compensation water was obtained by raising the level of lochs Vennacher and Drunkie with a drainage area of 23 000 acres. Loch Arklet was dammed and brought into service in 1914 and Glenfinglas Reservoir in 1965 (see 6-29, 6-30). [71–74]

57. Mugdock and Craigmaddie Reservoirs, Milngavie

HEW 1808/01
NS 5563 7582

These adjoining service reservoirs are about ten miles from the city centre to which they are connected by an extensive pipe network. Mugdock Reservoir, constructed from 1855–59, has embankments across two valleys which are respectively 69 ft and 53 ft high, a water surface of 62 acres, a depth of 50 ft and a storage capacity of 540 million gallons. The water is retained by a clay embankment.

Craigmaddie Reservoir was first planned in 1880 to provide extra storage, but construction did not begin until 1886 after the completion of road and stream diversions. An embankment 1592 yards long and 93 ft high was required. Badly fissured rock was encountered in the cut-off trench to be filled with clay puddle to form an impervious barrier. In one place it had to be excavated to a depth of 193 ft below ground level.

The construction of this trench took more than six years and caused the resignation of the first contractor. The work was thereafter withdrawn from contract and executed by direct labour. The reservoir was finally completed in 1896 and cost about £337 000, more than two and a half times the original estimate. The reservoir has a water surface of 88 acres, a depth of 42 ft and a storage capacity of 700 million gallons.

The works were designed and superintended by J. M. Gale, Engineer, Glasgow Water Department. [72–74]

58. Dunwan Dam Draw-off Tower, Eaglesham

HEW 1808/02
NS 5558 4943

Dunwan Dam and reservoir are located above Eaglesham close to the B764 Fenwick Road. In any draw-off tower the problem is that the high pressure of the depth of water in the reservoir can lead to leaks in the tower, excessive dampness and corrosion in the pipework.

At Dunwan in the 1930s the engineers Kyle & Frew devised an ingenious solution to the problem by siting the tower inside a bellmouth spillway, giving two concentric circular concrete structures. Thus the draw-off tower is separated from the water pressure of the reservoir, and operates in dry conditions. Fifty years later in the 1980s the engineers for the Megget Reservoir supplying Edinburgh R. H. Cuthbertson & Partners devised the same solution independently not knowing of its previous use. As far as is known these are the only two examples in Scotland of this innovative construction. [75]

59. Gorbals Water Works

HEW 1771
NS 5147 5734
(Balgray Reservoir)

Gorbals Gravitation Water Company was formed in 1845 to promote a water supply for the southern districts of the city. An Act was obtained in 1846 and by 1849 the company had introduced, via sand filters and a 24 in. main, a supply of high-quality filtered water from the Ryatt Linn, Littleton and Waulkmill Glen reservoirs about two miles south-east of Barrhead. Balgray Reservoir, about 352 ft above sea level with a main embankment 520 yards long by 47 ft high, was constructed in 1853–54.

The works were designed and executed under the direction of the company's engineer William Gale, whose younger brother J. M. Gale also assisted. The scheme was extended to Renfrew in 1853.

The total output was above five million gallons per day and the works originally supplied the whole area south of the Clyde. The subsequent development of this area, however, meant that augmentation from Loch Katrine was eventually necessary. [76, 77]

60. Selvieland Farm Bridge, Renfrew

HEW 1549
NS 4477 6738

A single girder span of 62 ft 6 in. crossing the Gryffe from the B790 road. At first sight the bridge appears to be an ordinary plate girder but is, in fact, notable as being the first all-welded plate girder bridge in the UK. The main girders, 4 ft 5 in. deep and of 15 in. × 4 in. channel section, are at 16 ft 3 in. centres and support seven cross girders carrying a reinforced concrete deck. The welding was done by the shielded arc process using covered electrodes.

The bridge was designed and built by Sir William Arrol & Co. Ltd and opened in 1931. Another unusual feature, for a small bridge, is the support to the flanges by raking outrigger stays. [78]

61. Blackhall Bridge, Paisley

HEW 0813
NS 4940 6336

A freestone masonry segmental arch bridge of 88 ft 6 in. span and 19 ft rise now carrying the Paisley Canal single track railway from Glasgow Central over the White Cart at a height of about 30 ft. Its archstones are about 3 ft 4 in. deep at the crown, similar in keystone detail to Dunkeld Bridge apart from slight ornamentation.

The bridge was designed and built under Telford's direction from 1808–10 as an aqueduct on the Ardrossan Canal for which he was the engineer. The contractor was John Simpson and the cost £5440. No drawings appear to have survived, but the spandrels are presumably hollow conforming to Telford's usual practice for large spans for example at Tongland Bridge (see 1-19).

Until widened and converted to twin track railway use in 1885, the aqueduct formed part of the Glasgow, Paisley & Johnstone Canal. The canal reached Johnstone in 1811 but because of delay in its extension the project was overtaken by steam boat development and Clyde navigation improvements in the 1820s and never reached Ardrossan. A railway connection was achieved via the Glasgow, Paisley, Kilmarnock & Ayr line in 1840.

The bridge is probably the longest span masonry aqueduct of the canal age on a British canal and one of the world's earliest bridges carrying a public railway. [79–81]

62. Greenock Water Works – Loch Thom and 'Cut'

HEW 0616
NS 2524 7287

Following an Act in 1773, James Watt planned and supervised the provision of an improved water supply from two small reservoirs built on the lower slopes of Whinhill, from which water was conducted in wooden pipes to a cistern at the Wellpark. Although augmented, by the 1820s the supply had become inadequate and the town embarked on an innovative 'green' project designed and directed by Robert Thom, owner of Rothesay Cotton Mills, Bute, and a leading hydraulic civil engineer at Rothesay Mills, where he had a 'green' power scheme operational by 1820.

The Shaws Water Company, as Thom's Greenock scheme was known, involved creating behind the town

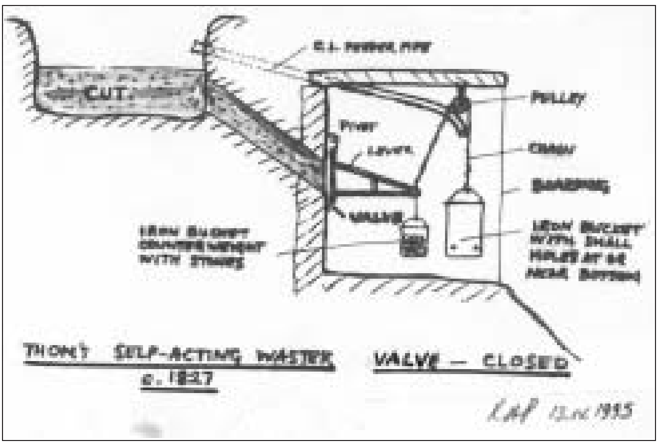
Shaws Water lades from the Town Reservoir at *N* [82]

from 1825–27 the 'Great Reservoir', later renamed 'Loch Thom' by means of an earth dam about 48 ft high. It had a capacity of about 1800 million gallons. From a 'Compensation Reservoir' to the west, water was fed into an almost level (1 in 600) open five and a half mile 'Cut', as it still is known, along the hillside to the contour Town Head service reservoir at Overtown ('*N*' on above figure) about 512 ft above the Clyde (see plan). The estimated cost of the scheme in 1824, including numerous smaller reservoirs and channels, was £16 000.

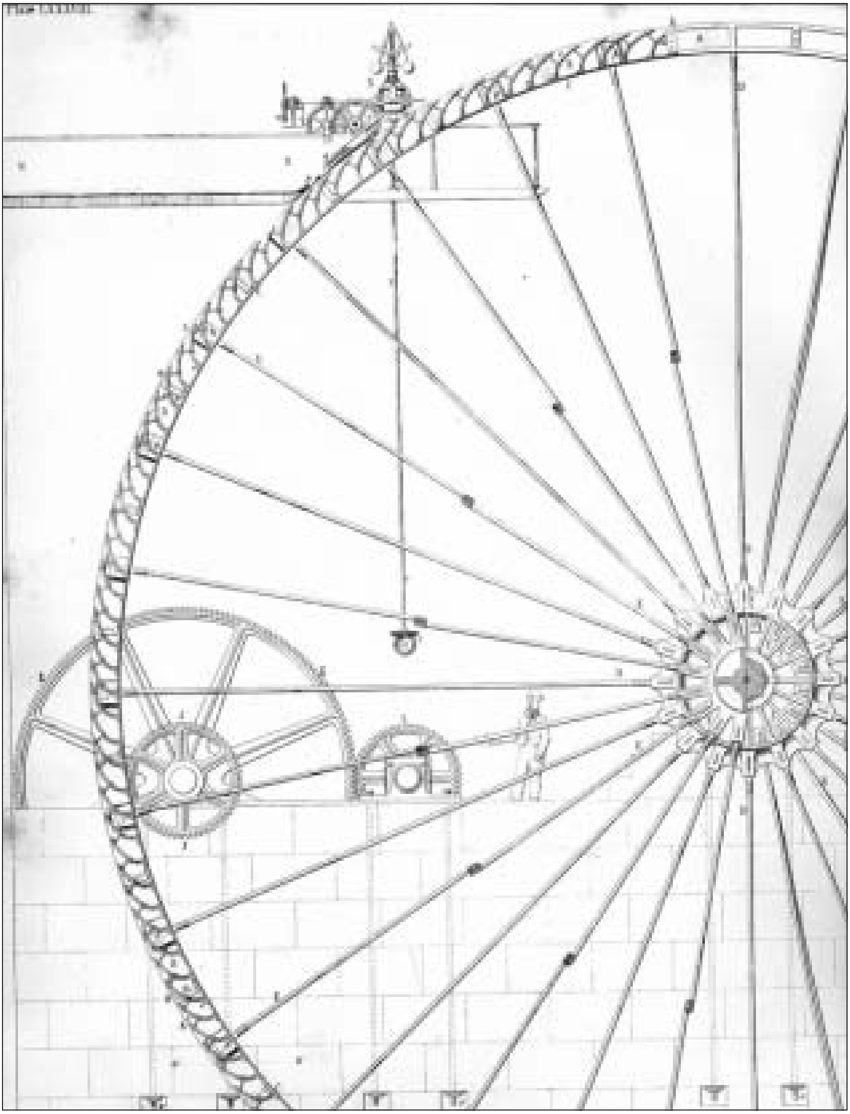
The Cut, which falls about 50 ft over its length, intercepted intervening burns, is about 5 ft wide and when

Town Reservoir ca.1827 showing lade sluice

operational contained up to about 2 ft of water, is rubble-masonry lined and has a downside bank and inner clay puddle wall. At intervals there are stone waster sluice houses and 22 hump-backed bridges. The work was done by contractors responding to local advertisements. A William Kirkwood was paid £6 10s for building a bridge.



Full sketch of Thom's self-acting waster ca.1827 – valve closed



Shaws Water Cotton Spinning Company's water wheel [84]

The project abounded with novel self-acting machinery of which an example, although not now working, of one of his more simple mechanisms has survived at a waster (NS 9076 4437). When maximum water level in the Cut was reached, water passed via a pipe into a suspended cylindrical bucket with small holes at its base. As the bucket increased in weight it descended and operated a mechanism which opened the waster valve. Being no longer fed, the water in the bucket ran out through the holes causing it to rise and thus close the valve.

From sluices at the service reservoir, Greenock was supplied with water for domestic and industrial consumption and, via a lade with two branches down to the Clyde, power at 'mill-seats' or falls en-route for waterwheels at mills, factories, and other industrial concerns.

The first phase of the scheme was completed in 1827. The Company guaranteed a specified supply of up to 1200 cu. ft of water per minute, 12 hours a day, 310 days a year, to its subscribers. As late as 1900 there were still 25 falls let on the lade. They varied in the power produced from 21 hp at Scott's sugar refinery to 578-hp in the six falls at the mills of Fleming, Reid & Co.

The Shaws Water Cotton Spinning Company harnessed its falls of 64 ft to a remarkable iron water wheel of 70 ft 2 in. diameter, 12 ft wide, weighing 117 tons; one of the world's largest and most powerful, designed and made by the engineer James Smith at his Deanston works, Doune, in the 1830s. The wheel produced about 192 hp net, assuming 75% efficiency, and operated 25 760 mule and throstle spindles. It was replaced in use by a turbine in 1881 and dismantled in 1918.

Thom's success led him in 1829 to propose a supply and power scheme for Edinburgh from a reservoir at Harperrig to a cistern at Craiglockhart 227 ft above Haymarket, and several schemes in and around Glasgow from 1835–41. Only one, at Paisley, seems to have been executed, although an almost identical Harperrig scheme was executed under Leslie's direction for Edinburgh water supply in 1859 as compensation water, mainly for mills.

Of three Glasgow schemes his most ambitious was for a 30 ft wide canal 30 miles long from the Clyde above Stonebyres Falls, via Airdrie, to a ten acre night storage reservoir at Glasgow, 220 ft above the Clyde. He envisaged producing 3850 hp and an annual income from water power alone of £92 750 for an outlay of £318 560. There were drawbacks and neither this nor his other proposals for Glasgow in 1836–37 were adopted.

The Cut, disused and deteriorating since it was bypassed in 1971 by Loch Thom Tunnel (consulting engineers, Babtie, Shaw & Morton), is now part of Clyde–Muirsheil Park. There is local interest in its retention as an outstanding landmark and in 1995 consulting engineers Scott, Wilson, Kirkpatrick were commissioned and reported fully on the feasilibility of restoration. [82–85]

Clyde Navigation Improvement, Glasgow to Port Glasgow

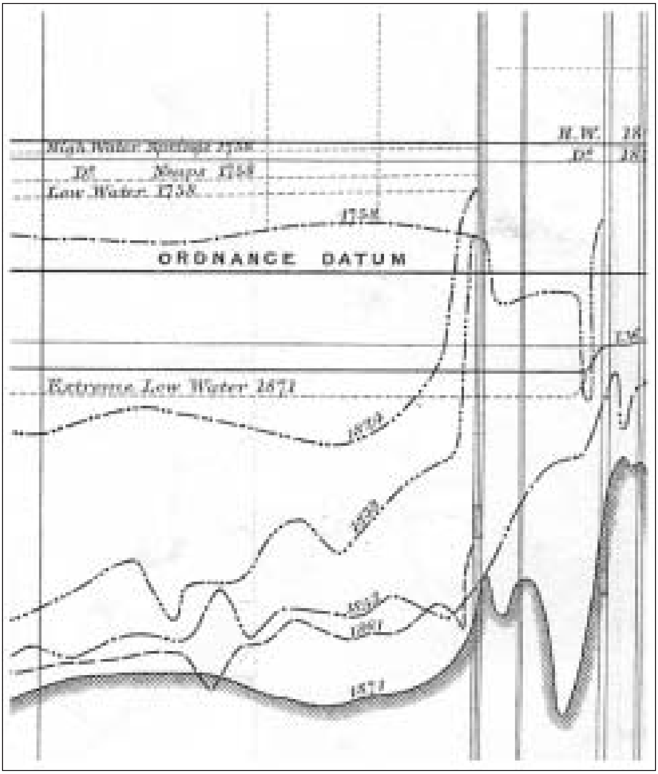
HEW 2442

At the end of the 17th century Glasgow had a population of about 12 000, chiefly engaged in fishing, weaving and manufacturing and traded mostly with Ireland and England. The harbour at the Broomielaw then consisted of an area of about 2.5 acres with a quayside extending for some 260 yards on the north bank of the Clyde. The depth of water in the harbour was often less than 4 ft at high tide. By 1871 this had reached a minimum of 22 ft and Glasgow was the Clyde's greatest port with a population of nearly half a million.

Because of the shallowness of the Clyde in the 17th century, ocean-going vessels had difficulty in reaching the Broomielaw. In 1662 the magistrates of Glasgow purchased land about 18 miles down river where there was deeper water and built harbours at what became Port Glasgow. Here, Scotland's first dry dock, 243 ft long by 36 ft wide at the bottom, now filled in, was built in 1762 to accommodate two vessels of 500 tons.

This dry dock built for the magistrates of Glasgow in 1758 was 'in a great measure useless' as its bottom was too low to drain and always contained 2 ft 5 in. of water. Smeaton was consulted and in 1767 designed a pump to be made by Mackell which was constructed and horse operated. In 1769 Watt was employed as a consulting civil engineer, probably his first such post, and found the masonry sound but the floor beams rotted. He directed the refurbishment of the dock, including gates, and the work was completed in November 1771 at a cost of £680 7s 10d.

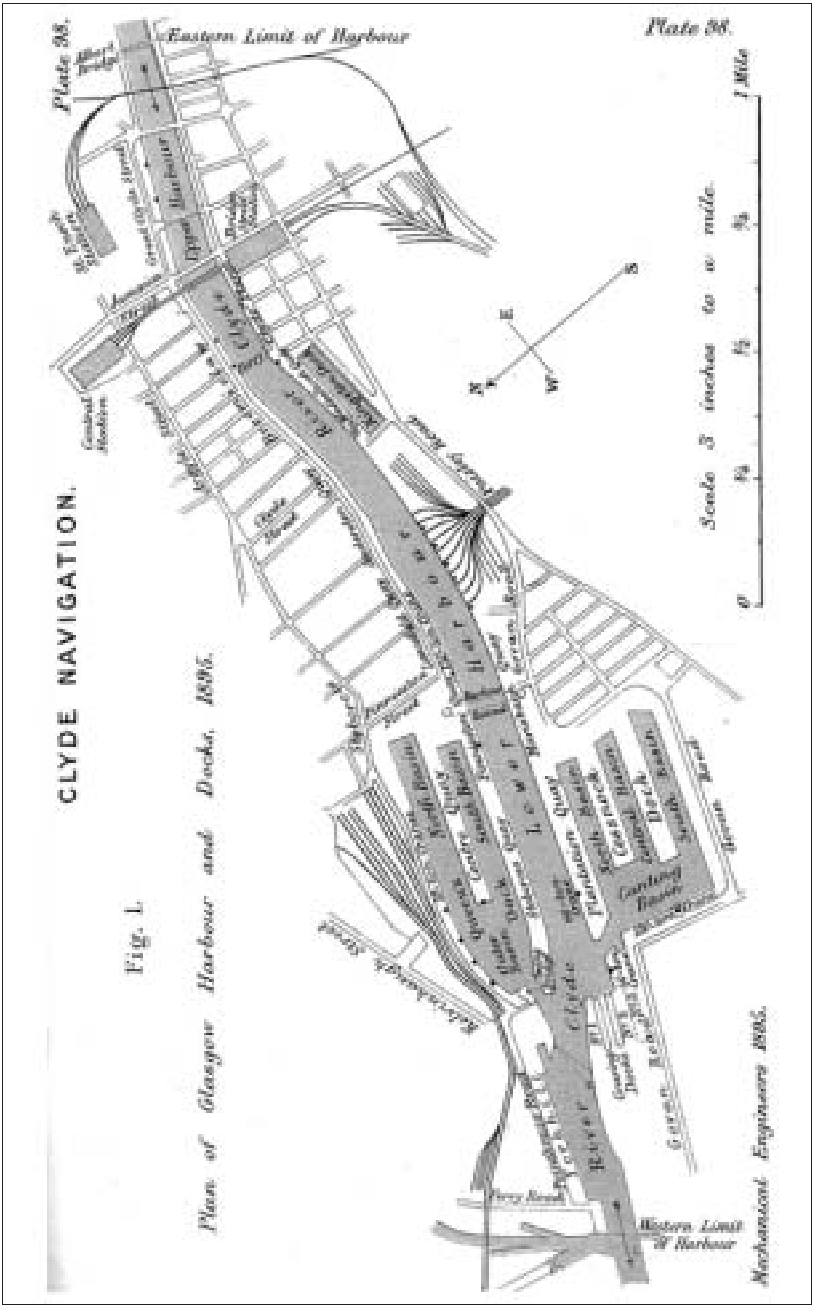
A flourishing trade with the American colonies developed and in 1759 the first of many acts of parliament was passed for improving the navigation of the Clyde up to Glasgow. Eminent engineers of the day were consulted,



Clyde Navigation – increase in river depth diagram 1758–1871 [86]

including Smeaton, but the first large scale measure, engineered by John Golborne was the building out from the banks at regular intervals of stone groynes or jetties to constrict the width and scour the river bed. This worked and from 1771–75 the river was deepened from 4 ft to 7 ft, reaching 12 ft by 1781.

From 1799 Rennie proposed various improvements which resulted in the number of groynes being increased from 50 to more than 500 and regulated in length with rubble training walls joining the ends of some of them. From 1806 on the advice of Telford some groyne lengths were shortened and the river was brought to a uniform width at various locations by completion of the parallel walls across their ends. Telford, who had used steam dredgers to great effect on the Caledonian Canal in 1806, seems to have played a part in their introduction on



Plan of Glasgow Harbour and Dock 1895 [88]

Crown Copyright: RCAHMS

Fairfield's fitting out basin

the Clyde in 1824. By 1830 a depth of 15 ft had been achieved.

David Logan and later engineers continued the practice and by 1871, under the direction of Clyde Navigation Engineer James Deas, a minimum depth of 22 ft at high water was available between Greenock and the Broomielaw quays, a distance of some 22 miles.

In 1867 the five-acre Kingston Dock was opened, the first dock outwith the river basin. Major developments after this included the 61-acre Queen's Dock built from 1872–80 with basins 1866 ft, 1647 ft and 1000 ft long and, from 1886–97, the immense Cessnock Dock to the south (see plan).

All three, and the three now-disused graving docks near the entrance of the latter of $551 \times 72 \times 22$ ft 10 in. deep (1875), $575 \times 67 \times 22$ ft 10 in. deep (1886) and $880 \times 83 \times 26\frac{1}{2}$ ft deep, 130 ft longer than the Prince of Wales Dock, Southampton (1897), were built under the direction of Deas and exemplify the heyday of Glasgow as a mercantile port and, in terms of population, Britain's second largest city.

Fairfield's fitting out basin in 1930 was a busy place as can be seen from the view with the Titan crane. Deepening and widening of the river reached its zenith in 1936 with the passage downriver from Clydebank of the Cunard liner *Queen Mary* after her completion at John Brown's shipyard. She drew 35 ft of water. D. & C. Stevenson as engineers to the Clyde Lighthouses Trust directed the necessary deepening operations west of Port Glasgow. At about this time the maximum draught of general cargo vessels and liners visiting Glasgow had stabilised at about 32 ft.

Civil engineers contributed fundamentally to the well-founded adage 'Glasgow made the Clyde, and the Clyde made Glasgow'. [86-91]

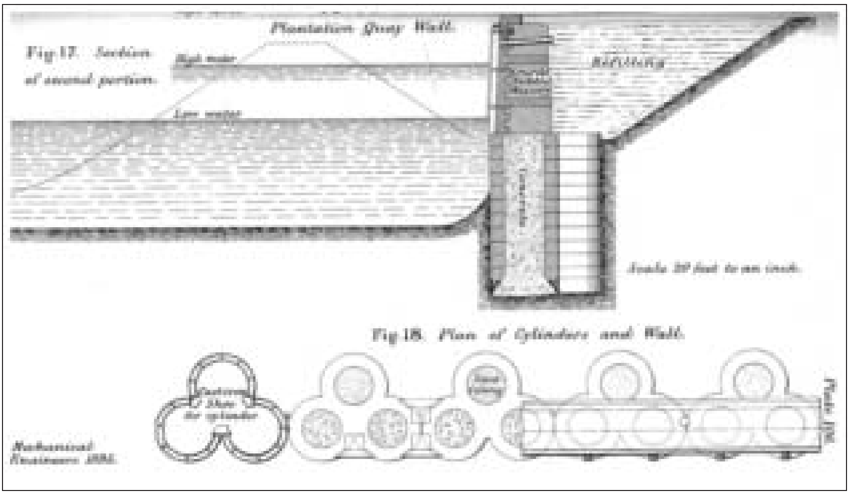
63. Prince's Dock and Pumping Station

NS 5690 6500

This dock was known as Cessnock Dock until renamed Prince's Dock at its opening by the Duchess of York in September 1897. Its entrance was at the north-west corner of a 35 acre site, with an extreme length of water area of 2000 ft by 1100 ft wide, leading to a large canting basin at the east side of which were three parallel basins 200 ft wide, 25 ft deep, with more than two miles of quayage. The total cost excluding land was about £1.5 million.

Deas devised an ingenious system of cylindrical foundations for constructing the quay walls in soft ground. The cylinders were triple of pre-cast concrete and built up of

Deas's cylindrical foundations at Prince's Dock (Plantation Quay) [88]



ten rings, each 2 ft 6 in. deep and one of 1 ft 6 in., making, with shoe, 28 ft total height. When assembled the sand and gravel was dug out simultaneously from within the cylinders by specially designed excavators. Segmental weights of 300–400 tons were required to force each group of cylinders down to 50 ft below cope level. The cavity was then filled with concrete.

The dock was filled in during the 1980s to allow the development of the Garden Festival site of 1988. The hydraulic pumping station designed by J. J. Burnett and J. A. Campbell in 1894, which operated numerous hydraulic cranes, lifts and pumps, at a pressure of 750 psi obtained from an accumulator with a 20 in. diameter ram and 20 ft stroke has been conserved and serves as a welcome reminder of the project's grandeur.

This station, the dock's main architectural feature, has at its north end the massive water tower providing the hydraulic head of water to the accumulator, designed in the style of an Italian campanile with ornamental corbelling. At its south end is an octagonal brickwork chimney with eight sculptured panels representing winds, inspired by the Tower of the Winds at Athens. [88, 91–93]

Greenock Harbour

NS 2850 7600

The harbour includes Cartsburn or Scott's Graving Dock (NS 2870 7580) completed in 1767 and enlarged and reopened in 1810. It was of masonry construction, 365 ft long at floor level and 48 ft wide at its entrance. With only 13 ft of water over its sill at high tide, its use by Scott–Lithgow before closure was restricted to submarines and smaller ships. The dock was infilled in 1989.

An Act of 1803 empowered the town to improve its facilities, including the construction of a dry dock, and Rennie prepared a scheme for the extensive East (India) Harbour of nine acres. The foundation stone was laid in May 1805 and the works cost £43 836, exclusive of land.

Later the quays were broadened and the dry dock built from 1818–25, measures which reduced the water area to six and three-quarters acres. This harbour was 1030 ft long by 450 ft wide with an entrance width of 160 ft. The depth at low water was 12 ft. The length of quays inside

Greenock Harbour Plan 1885

Groome's Ordnance Gazetteer of Scotland (1885) and outside the harbour was 3 500 ft. The dry dock, built in 1818 and now disused, was 356 ft long at floor level and had an entrance 38 ft wide with 11 ft depth of water and cost £20 000. This harbour, now little used, may be converted into a marina.

In 1830, when the Town Council learned of proposals to construct extensive wet docks at Glasgow, they consulted Telford about further improvements at Greenock. Telford's modification of the somewhat ambitious proposals of a local engineer, involving a new eight acre wet dock at the west end of the existing harbour or one of nine acres to the east, was accepted, but he took no further part in the project.

Victoria Harbour designed by Locke and built by Stephenson, McKenzie & Brassey from 1846–50 at a cost of £120 000. Its area was in excess of six acres, with a depth at low water of 14 ft (high water 24 ft) and its length of quayage was 2350 ft. The harbour is now little used and may be converted into a marina. [89, 91, 94–96]

64. Garvel Dry and Wet Docks

HEW 2444/01
NS 2953 7588

On 6 July 1871 the foundation stone of the Garvel graving dock to the design of the Harbour Trustees' engineer W. R. Kinipple was laid. The dock was 650 ft long, built of Dalbeattie granite and completed in 1877 at a cost of £80 000.

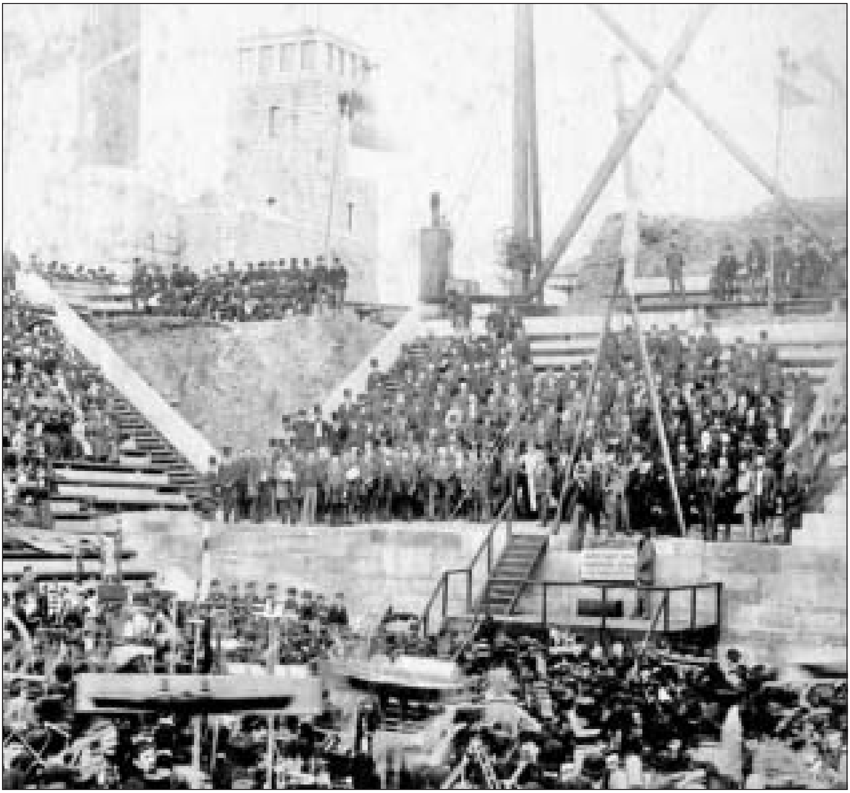
Also on the Garvel estate, to the south of this dock, was the James Watt Dock, named after the town's eminent son. The first sod was cut on 1 August 1879, the foundation stone was laid on 6 August 1881 and the dock was opened in 1886. It is 2000 ft long, 400 ft wide and 32 ft deep at low water. It is now little used.

About the same time a massive river wall was built from Garvel Point to Inchgreen embracing the tidal harbours and bringing the total harbour accommodation of Greenock to more than 100 acres.

65. Clyde Dry Dock, Inchgreen, Greenock

NS 3078 7519

This dock is part of a large self-contained ship repair installation constructed for the Firth of Clyde Dry Dock Co. Ltd



James Watt Dock opening 1886 – note ship models in foreground [photograph 1886]

from 1961–64. The dock is 1000 ft long, 145 ft wide at the entrance and 156 ft wide inside, with 27 ft depth of water over the sill at low water and 37 ft at high water. The walls are of the traditional gravity-type constructed in mass concrete, 10 ft wide at the base, battered slightly on the face, and up to 50 ft high. The head wall in plan is a semicircular arch of concrete backed with steel sheet piling.

The dock gate is of the box or flap type, 150 ft × 43 ft × 11 ft and weighs 150 tons. It was constructed upriver by the Fairfield Shipbuilding Company. The engineers for the project were a co-partnership of T. F. Burns and Partners and Babtie, Shaw & Morton. The main contractor was Edmund Nuttall Sons & Co. Ltd. The cost of the civil engineering works was £1.37 million, excluding plant and equipment.

Clyde Dry Dock, Inchgreen, Greenock

Crown Copyright: RCAHMS

The dock is of interest for having been tested in 1965 by the arrival for repairs to the *Queen Elizabeth*, then the largest liner afloat at 85 000 tons displacement. She was too long for the existing facility and a sizeable notch

Inchgreen Dock – *Queen Elizabeth* in 1965 [97]

Crown Copyright: RCAHMS

had to be cut into the dock head to accommodate her bow. [91, 97]

66. Cloch Lighthouse, Gourock

HEW 1016
NS 2031 7588

The first light at Cloch Lighthouse was installed on its completion in 1797 by Robert Stevenson acting for the Cumbrae Lighthouse Trust's engineer Thomas Smith. This was four years after the present lighthouse on Little Cumbrae had been modernised by the Trust.

Cloch light was improved in 1825 and 1903 and, by means of a wireless innovation by C. & D. A. Stevenson in 1930 which attracted a Royal Society of Arts award, became a talking lighthouse in poor visibility. The light is no longer used and the building is now a private residence. Ships now use a buoyed channel.

In the 19th century the distance between Cloch and Little Cumbrae lighthouses was used for speed trials. The practice of 'Running the Lights' became an event on the Clyde for any new steamer, and a fast ship could run the

Cloch Lighthouse

Roland Paxton

distance of approximately 16 miles in 48 minutes (17.4 knots). [98, 99]

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