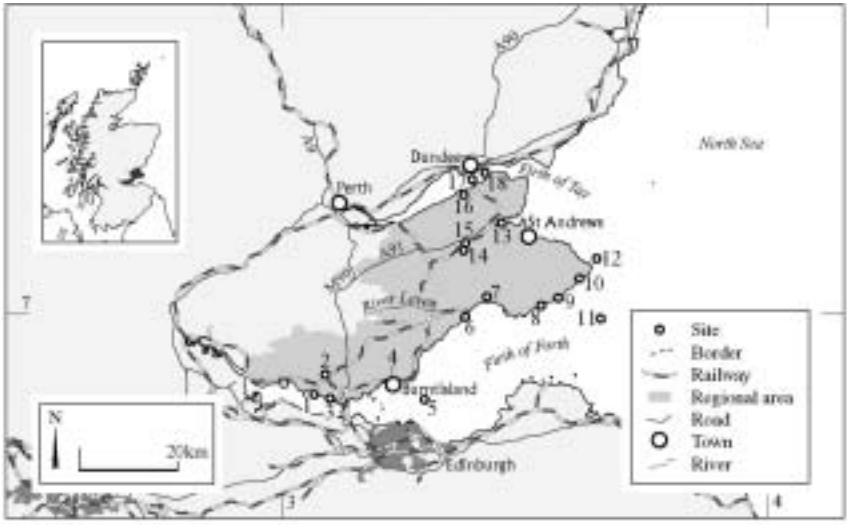


Fife

1. Charlestown Harbour
2. Glen Bridge, Dunfermline
3. Rosyth Dockyard
4. Burntisland Harbour
5. Inchkeith Lighthouse
6. Methil Docks
7. Largo Canal, Upper Largo
8. St Monance Wind Engine Tower
9. Anstruther Harbour
10. Crail Harbour, Fife
11. Isle of May Lighthouse 1816
12. North Carr Rock Beacon, Fife Ness
13. Guard Bridge
14. Garlie Bank Road, Cupar
15. Cupar Footbridge
16. Naughton Estate Footbridge (Private)
17. Tay Bridge (Railway)
18. Tay Road Bridge

7. Fife

Introduction

Fife is largely bounded by the sea and its extensive coastline has given rise to many maritime works – harbours, docks and lighthouses, many of which have an ancient past, for example, the harbours at Burntisland (1-4) and Crail (1-10), and later Anstruther (1-9), much enlarged in the 18th and 19th century with a contribution by Robert Louis Stevenson. Charlestown (1761, 7-1) can be considered the first harbour of the Industrial Revolution in Scotland serving an extensive limeworks, the lime from which, including a naturally occurring hydraulic type, found its way into numerous early building projects. Towards the end of the 19th century and in the early 20th century huge docks were created at Methil (1894–1912) for the export of coal on a massive scale. Another mammoth project, created from 1908–17, is Rosyth Naval Dockyard (1-3), whose giant Titan crane is still a landmark, and which now also serves as the terminus of the Rosyth to Zeebrugge Ferry.

Lighthouses are represented by the Isle of May (1635, 1816, 1844, 7-11) where its three towers are evocative of lighthouse practice over several centuries, with even a touch of Sir Walter Scott, and the fine architecturally styled Inchkeith (1804, 7-5), but beware of sea-birds when visiting! The North Carr Rock unlit cast-iron beacon at Fifeness (1821, 1-12) was eventually achieved by Robert Stevenson after a lengthy battle with the sea. It was the first of a type which was developed and used at numerous locations by the Northern Lighthouse Board.

The earliest stone bridge included is the medieval Guard Bridge (ca.1440–60, 1-13). Examples of early iron bridges are at Naughton Estate (1818, 7-16) and Waterend Road, Cupar (ca.1850, 1-15). An impressive, typical for its date, early reinforced concrete bridge dominates the glen at Dunfermline town centre (1932, 1-2).

Unusual works comprise improved road-making by Thomas Aitken at Garlie Bank, Cupar in the late 19th century just before the internal combustion engine brought a new lease of life to the national road network (1-14); St Monance Wind Engine Tower (1774, 1-8); the remains of Sir Andrew Wood's curious canal at Largo along which he travelled to church in style

(ca.1490, 1-7): and the River Leven Improvement, involving the partial drainage of Loch Leven in 1830 to reclaim land and regulate the water power to about 40 mills down to the sea – a project which exercised the skills of John Rennie, James Jardine, Robert Thom and others.

To the north, Angus is reached from Fife either by road or rail via impressive bridges over the Tay some $1\frac{1}{2}$–2 miles long connecting with Dundee (2-1, 2-2). From the train can be seen the pier stumps of the 1878 bridge which fell the following year in one of the world's great bridge disasters, resulting from its design and construction being inadequate to resist strong wind pressure, and which ruined the reputation of Sir Thomas Bouch.

1. Charlestown Harbour

HEW 1623
NT 0660 8347

From 1757 to 1761, as the Industrial and Agricultural Revolutions gathered momentum, the 5th Earl of Elgin developed lime production on his Broomhall Estate by quarrying limestone and building kilns, the village of Charlestown, and its harbour. Prior to this, limestone deposits had been exploited at nearby Limekilns but in a small way. The present pier there seems to be of third quarter 18th century construction with roughly squared dry (unmortared) sandstone block facings quarried nearby.

From 1774, with the opening of the original Elgin Wagonway, Charlestown was supplied with coal for lime making via Limekilns, the exporting port for coal from pits west of Dunfermline. In 1799 this wagonway was extended along the shore to Charlestown Harbour, being replaced by 1820 with a more direct line to the west with an inclined plane down to the harbour, including a substantial three-span arch bridge. The rails, at first of wood, were replaced by cast-iron in ca.1804 and malleable iron from ca.1820.

The imposing bank of draw kilns fronting the inner basin of the harbour were more or less continuously developed from 1759–90. The sickle-shaped in plan pier enclosing this basin is of similar construction to Limekilns Pier but

Charlestown Harbour

Roland Paxton

with some large blocks at the west end. Its top contains numerous mooring rings and is partly surfaced with old railway chair blocks. The inner basin entrance is 120 ft wide with an enclosed area 635 ft long by 100 ft to 180 ft wide, with a depth at Spring tides of $16\frac{1}{2}$ ft in 1844.

From ca.1813–34, as the Estate was becoming one of the largest industrial operations of its kind in Scotland, the 7th Earl engaged Charles Landale, civil engineer, to superintend work. In addition to maintaining the harbours, Landale introduced numerous improvements for transporting materials in, or to and from, the quarries and mines, including the inclined plane to the harbour and the ingenious inclined planes at Pittencrieff and Colton near Dunfermline. His salary was £250 per annum, plus expenses and the use of a horse!

The outer basin was added later, the north-west pier dating from ca.1840 and the south-east pier after 1853. In 1859 the harbour became the property of the North British Railway Company, who provided a passenger service to Charlestown in 1894. The harbour now contains about 10 ft of mud and is unused apart from small sailing boats. [1–3]

2. Glen Bridge, Dunfermline

NT 0888 8760

This elegant reinforced-concrete bridge, erected in 1931–32 carrying Bridge Street 80 ft above the Tower Burn, is 536 ft long and 40 ft wide. It has a main arch span of 185 ft with a rise of $33\frac{1}{2}$ ft and is one of the largest bridges of its type in Scotland containing about 6750 tons of concrete and about 100 miles of steel reinforcement weighing 320 tons. Designer, F. A. Macdonald & Partners, Glasgow; D. H. Shaw, Burgh Engineer; Contractor, Street & Co., Dunfermline. [4]

3. Rosyth Dockyard

NT 0986 8267

The need for an extensive naval base on the east coast of Scotland was foreseen prior to the 1914–18 war and construction began at Rosyth in 1909. *Dreadnought* battleships were part of the British fleet and the facilities required for their repair and refurbishment were formidable.

The original scheme comprised a large deep-water basin entered by a lock having a depth of water of 36 ft on the sill, two dry docks and provision for a third, and an emergency entrance for use in case of damage to the lock. Outside was a tidal basin for submarines and smaller craft. All sorts of ancillary buildings including cranes, a power station, a pumping station, workshops, storehouses, etc. were required. The site covered nearly 12 000 acres with some $2\frac{1}{2}$ miles of waterfront.

The main contractor was Easton Gibb & Son Ltd, of whom the managing director, Alexander Gibb (later Sir Alexander) was later to achieve fame as a consulting engineer. The scheduled construction time was seven years, but the difficulties to be overcome were immense and the construction methods at first specified by the Admiralty had to be replaced by more practical schemes devised by the contractor. This caused considerable delay, even with a peak workforce of 6000 men and 24 hour day working for long periods. The project, the success of which owed much to the energy and resource of Gibb, was finally completed in March 1917. [5]

4. Burntisland Harbour

Burntisland, the best natural harbour on the Forth estuary, was known in ancient times as Portus Gratiae. In ca.1540 James V caused a bulwarks and piers to be constructed within it. The west quay was reputed to have been built by Cromwell and developments continued into the 19th century with shipbuilding and herring and whale fisheries. By 1836 Farnie's dry dock, 200 ft long with a 44 ft wide gate, existed. Nothing of the early harbour now exists. **NT 2302 8541**

In 1876 the West Dock was opened and continued in use until 1962 when its entrance was widened to 80 ft and new gates were fitted. Burntisland also exported coal in large quantities, mainly through the larger East Dock, which was opened in 1903. A new industry began in 1917 when the British Aluminium Company opened a new plant for the processing of imported bauxite ore from West Africa, now demolished.

Today the harbour is operated privately by the Burntisland Shipbuilding Company, who have modernised it for use on oil industry projects and shipbuilding.

In 1850 the harbour had the distinction of being the Fife terminal of the world's first public train ferry from Granton designed by Thomas Grainger, but with an ingenious loading mechanism accommodating the state of the tide designed by Thomas Bouch.

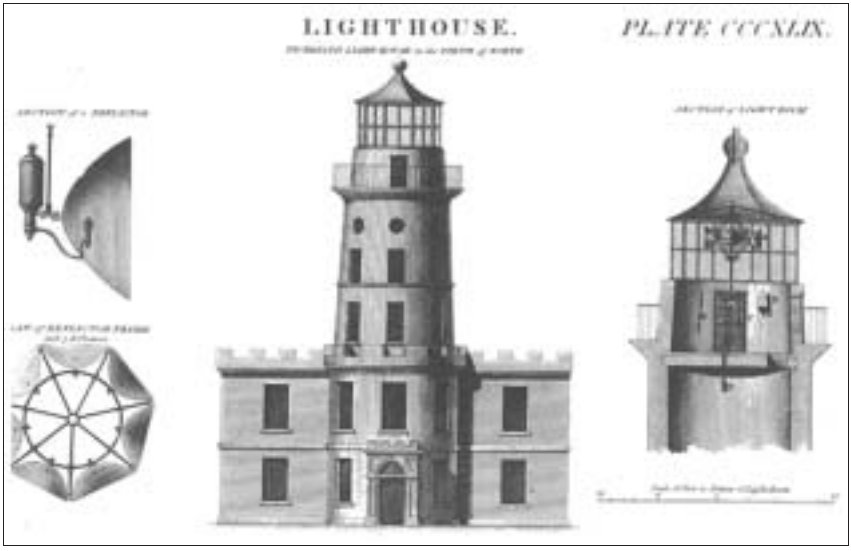
The *Leviathan* ferry-boat, built by Robert Napier & Sons on the Clyde, was used only for goods wagons except on its opening day when it transported a railway carriage with passengers. In 1862 the North British Railway took over the ferry from the Edinburgh, Perth & Dundee. The ferry continued in use until the opening of the Forth Bridge in 1890. [6]

5. Inchkeith Lighthouse

NT 2929 8288

In the 18th century the island of Inchkeith was a notorious hazard to ships in the Forth. After the *Aberdeen* was wrecked nearby in 1801, the Northern Lighthouse Board decided to build a lighthouse there.

This was the first lighthouse for which Robert Stevenson was solely responsible under Edinburgh lamp manufacturer and Northern Lighthouse Board Engineer, Thomas Smith, whom he succeeded in 1808. It is 62 ft tall and of high-quality masonry in a fashionable architectural style.



Inchkeith Lighthouse details 1814 [7]

Roland Paxton

Inchkeith Lighthouse

The foundation stone was laid in May 1803 and the work completed in September 1804, with Argand lamps and state-of-the-art silvered copper reflectors developed by Stevenson.

The convenience of the lighthouse location to the Board's headquarters facilitated numerous lighting innovations. In 1786 a new form of reflector oil lamp had been designed by Smith and first tried at Inchkeith. When the Isle of May fixed light became operational in 1816 Stevenson's apparatus at Inchkeith was converted into one of the earliest flashing lights. In 1835 Britain's first dioptric light (using refraction through lenses) was installed at Inchkeith under

Alan Stevenson's direction. The 1804 reflecting apparatus was re-installed at Cape Spear, near St John's, Newfoundland, where it remained in service until 1963 and is now preserved. In 1889 the Inchkeith light was upgraded by D. A. Stevenson and the 1835 apparatus was presented to the Industrial Museum of Scotland, Edinburgh. [7–9]

River Leven Improvement

By the 18th century the Leven, which has its source at Loch Leven, was one of Scotland's most intensively harnessed rivers as a source of water power. Rennie reported in 1810 that the surface of the loch could safely be lowered $2\frac{1}{2}$ ft to reclaim more than 500 acres of land and, by canalising and regulating the winding river at its outlet (see map), still be of advantage to mill owners. In 1813, 40 mills down to the sea were valued at £176 220. In all they had about 360 ft of falls, those with 20 ft or more being Rothes Bleachfield and Paper Mill, Balbirnie Coal Engine & Blast Furnace and Kirkland Flax Spinning Mill. But it was not until 1827 that the Leven Improvement Act eventually enabled the water level of the loch to be lowered $4\frac{1}{2}$ ft, and an additional $4\frac{1}{2}$ ft, in effect a reservoir under the control of the mill owners, providing a regular supply of 5000 cu. ft per minute.

Regulation was achieved by means of powerful sluices at the outlet of the loch at the head of a new, straight, 'cut', 32 ft wide and nearly four miles long, replacing the river to Auchmuirbridge. The engineer initially was James Brown. In 1828 the value of the water power of each of the mills on the Leven was reassessed by Robert Thom of Rothesay and Geo. Moon of Russel Mill at a total of more than £2200 per annum.

Fife contractors Walker & Burns started excavating the cut on 1 July 1828 using Irish labour. The rate for excavation was generally $3\frac{3}{4}$d per cu. yard. Wet weather adversely affected work and the final cost of the cut was just under £10 250 with a further £4350 to Robert Hutchison for masonwork on the sluices and New Gullet and Auchmuir bridges.

From October 1830 Edinburgh consulting engineer James Jardine superintended the delicate task of removing

Map showing River Leven before straightening from 1827 [Atlas of Scotland containing maps of each county, Edinburgh 1832]

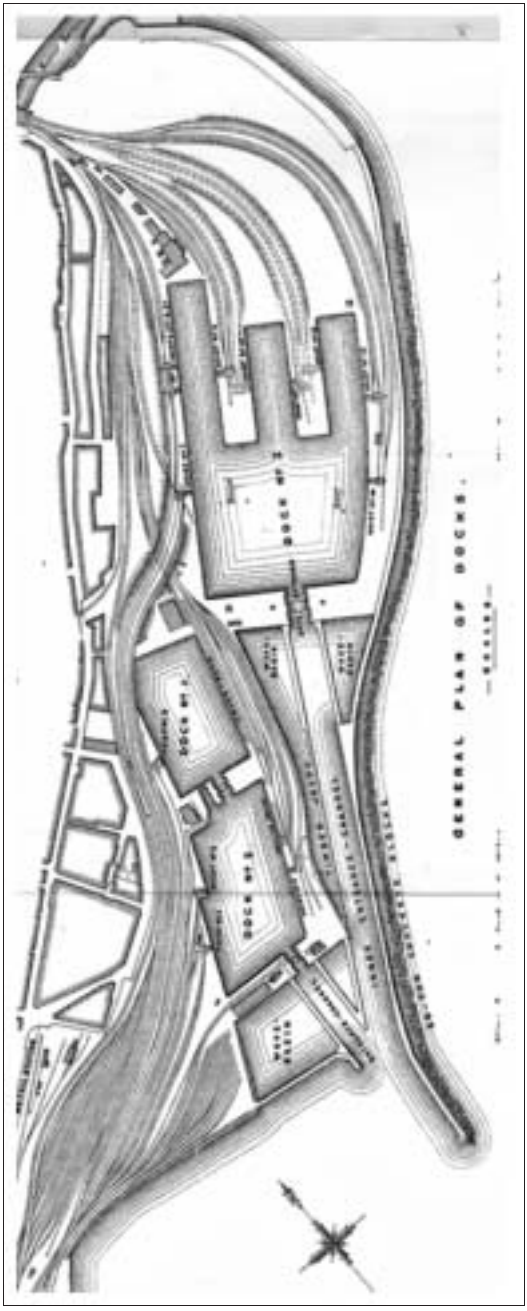
the coffer dam in front of the spillway and sluices at Loch Leven and successfully introduced its water to the 'cut' on 25 December 1830. New Gullet elliptical arch bridge (NT 1833 9972) of 35 ft span, now carrying the B920 road over the cut, has the look of a Jardine design.

The eventual total cost of about £40 000 had so much exceeded Brown's estimates that it took Jardine, who in 1831 had become Commissioner to the Improvement Trustees, until 1849, and with further acts of parliament, to close the books. The surface area of the loch was reduced from about 4506 to 3406 acres. [10, 11]

6. Methil Docks

NT 3766 9951

Although a small coal shipping dock had existed from 1860 near the mouth of the Leven it was not until 1883–87 that the first thoroughly equipped dock was built (No. 1) to meet greatly increased coal production. It occupies $4\frac{3}{4}$ acres, has a 50 ft wide entrance with 24 ft of water on the sill and had three hydraulic hoists each capable of shipping 10 000 tons of coal per week. Soon afterwards it was sold to the North British Railway Company who, from 1894–99, built an additional wet dock of 6.5 acres (No. 2) with 27 ft depth of water and similar capability, costing £300 000.



Plan of Methil Docks [12]

Methil No. 3 North Dock 1912, now infilled [14]

The third and outer dock was constructed in 1907–12, with area of $16\frac{3}{4}$ acres and a quay length of 6000 ft, at a cost of about £700 000. Its entrance was 1800 ft long by 80 ft wide with a water depth of 32 ft. The scheme required construction, often in formidable weather, of a curved seawall in mass concrete some 3600 ft long and in places 41 ft high from rock foundation to quay level. It was partially protected from wave forces by some 700 concrete blocks, each weighing 50 tons, placed on its exposed outer base by a floating Titan crane.

Floating crane placing 50 ton concrete block [14]

The contractor for this dock was Robert McAlpine & Sons and the consulting engineers were Blyth & Westland of Edinburgh. The scheme also required a power station, coal hoists, timber jetties, a railway bridge and some 14 miles of railway sidings. On its completion Methil was Scotland's largest coal port.

With the demise of the coal industry the outer dock area and sidings have been infilled and redeveloped but the original docks are still operational for present day requirements. [12–14]

7. Largo Canal, Upper Largo

NO 4213 0363 A curious canal, probably Scotland's earliest, about 200–300 yards long, said to have been made in ca.1490 by Scottish admiral Sir Andrew Wood of Largo so that he could travel in state from his castle by barge to Largo Church on Sundays. The barge is reputed to have been 'rowed by some English prisoners of war still in his service' and, at death (1539?) his remains were borne in his barge by torchlight to his last resting place in the vault of Largo Church. Part of the track of the canal at the bottom of the manse garden and westwards can still just about be seen. [15]

8. St Monance Wind Engine Tower

NO 5330 0183 The illustration from an interpretive board on site shows a notional view of the saltworks powered by the wind engine erected by landowner Sir John Anstruther and Robert Fall in 1772–74 adjacent to the estate colliery where Coal Farm now stands.

The tower, which is conical and about 27 ft high and 20 ft diameter at its base, formerly had sails, beneath which, in line with their shaft, were two reciprocating arms, the partially exposed stone-lined shaft for one of which can be seen in the photograph. The arms operated a pump which pumped sea water from the square pond on the foreshore, wooden pipes to a cistern supplying nine salterns containing the pans in which the water was boiled, using large quantities of coal, to produce salt. When in full operation it is thought that about 10 000 gallons of water would have been lifted about 16 ft from the pond.

Roland Paxton – Site plaque, Fife Council

St Monance Salterns – sketch of operation

About 20 men were employed in the salterns, which were abandoned by 1823, probably because of difficulties in obtaining cheap coal, and only their foundations now remain. A wagonway, disused from 1794, connected the saltworks and mine with Pittenweem Harbour.

The tower, now conserved as part of a visitor centre on the Fife Coastal Path, was fitted in the mid-1990s with a conical tiled roof, which was raised to accommodate a glazed viewing gallery and four indicative dummy sails of frames of steel tubing. It is reached by a short walk from the car park at St Monance. [16–18]

9. Anstruther Harbour

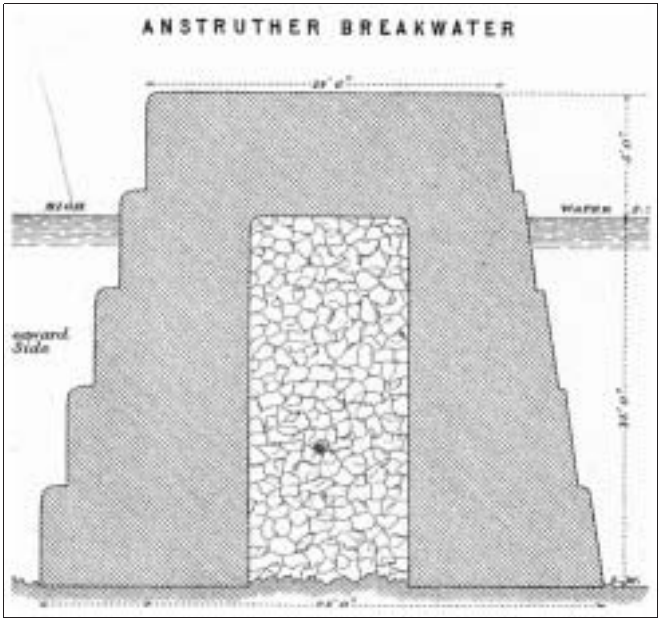
NO 5683 0341

This harbour now consists of two basins separated by the central old pier which existed in 1703 having been developed from the 16th century. This pier then ran straight out from the shore for about 540 ft and then turned west for about 100 ft. Its original features and old repairs are now obscured.

Anstruther Harbour

The harbour was much improved in 1753 with the construction of the west pier, of dry (unmortared) stone blocks, stopping short of the return of the central pier to leave an entrance to the newly formed western basin.

Between 1866 and 1877 the outer basin or Union Harbour was created. It comprised an east pier about 960 ft long and



Anstruther breakwater [21]

the state-of-the-art western breakwater (with Chalmers Lighthouse) about 470 ft long joining the old central pier. A new entrance to the inner basin was cut through the central pier and the old entrance filled up to give a total length of western pier and breakwater of about 1400 ft. The engineers for this major deep-water improvement, which cost more than £80 000, were D. & T. Stevenson.

In 1868 the young Robert Louis Stevenson gained experience on this work as part of his reluctant civil engineering training with the family firm. He watched the masons at work on the Fifeness stone 'for 6d an hour' drew the 'travellers and Jennies' used for transporting the stone blocks along the pier and into position laterally, and 'loved the green glimmer of the divers helmets far below'.

The ship at the east pier in the view is the North Carr Lightship after decommissioning in 1975. [19–21]

Bottom: Crail Harbour walling showing vertical coursing

10. Crail Harbour, Fife

NO 6216 0741

A small harbour existed here from at least as early as the 16th century, since when in its early history it seems to have been so often ruinous and under repair that it is difficult to date the earliest features with any certainty.

Roland Paxton

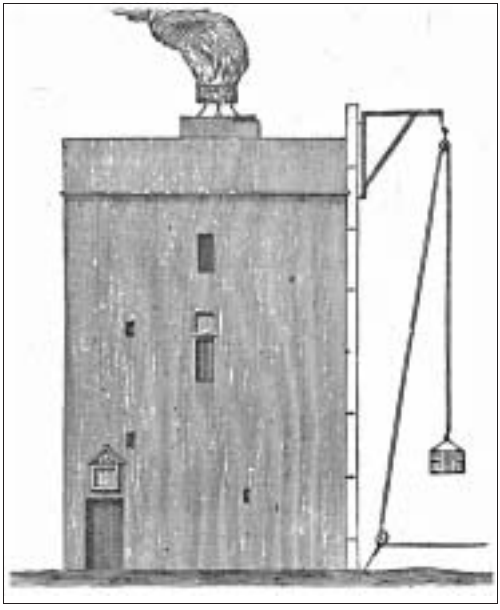
The earliest or eastern curved pier or breakwater enclosing the harbour on the seaward side is about 375 ft long. The straight west pier about 130 ft long was built from 1826 to 1828 to the design of Robert Stevenson. The estimate of contractor John Gosman of £1095 was accepted for building the pier and deepening the harbour. Since then, apart from some small extensions, repairs and improvements, the harbour is little changed.

Unusual engineering features are areas of vertically set dry-stone masonry offering greater resistance to wave pressure probably dating from the 18th or early-19th centuries and, the use in the seaward face of the curved pier of stone blocks, partly dry built and secured with wooden wedges to reduce wave force effects. [22, 23]

11. Isle of May Lighthouse 1816

NT 6650 9936

The Isle of May at the entrance to the Firth of Forth, about one mile long and one-third of a mile wide, for centuries resulted in the shipwrecks of many vessels plying to and from the Forth ports, a situation which led to the erection there of the first lighthouse in Scotland. It was privately



Isle of May Lighthouse 1635 [27]

Roland Paxton

Isle of May 1635 Lighthouse as modified ca.1816

financed and owned in the first instance by the Cunningham family of Barns in East Lothian, and later, by the Scotstarvit family.

Following the granting of a patent by Charles I, a masonry tower 40 ft high and about 25 ft square was erected in 1635. It was vaulted at the top to support a flat flagstone roof on which an iron chauffer was placed containing a coal fire. 'But its appearance was ever varying, now shooting up in high flames, again enveloped in dense smoke, and never well seen when most required.' The fire consumed up to 400 tons of coal per annum all of which had to be carried up 160 ft from the shore and then hoisted to the top of the tower.

This system operated until the erection of the present lighthouse in 1816, when it was intended to be demolished. But, following a plea by Sir Walter Scott to Robert Stevenson, when visiting the Isle in 1815, it was reprieved and 'ruined a la picturesque' to half its original height and castellated to serve as a refuge for fishermen and pilots of the Forth.

In 1843–44 a small low-level lighthouse was built to inform the mariner that when one light was above the other his ship was in line with the treacherous Carr Rocks about eight miles north. This arrangement did not prove sufficiently effective and led to the stationing of lightships off the Rock from 1877.

Isle of May
Lighthouse
1816–present

Roland Paxton

The original coal-fired light was replaced in 1816 by the present architecturally imposing lighthouse reminiscent of a small castle, with accommodation for three lighthouse keepers and their families and visiting officials, designed and erected under the direction of Robert Stevenson. It had a fixed light consisting of Argand oil lamps with parabolic silvered reflectors. In 1836 it was replaced by the first British dioptric fixed light, with novel refractors made by Cookson of Newcastle. [24, 25]

12. North Carr Rock Beacon, Fife Ness

NO 6471 1153

In 1810 Robert Stevenson designed a 42 ft high stone tower beacon to be placed at the Carr Rock, a tide covered reef

Roland Paxton – Site plaque, Fife Council

North Carr Rock Beacon workyard

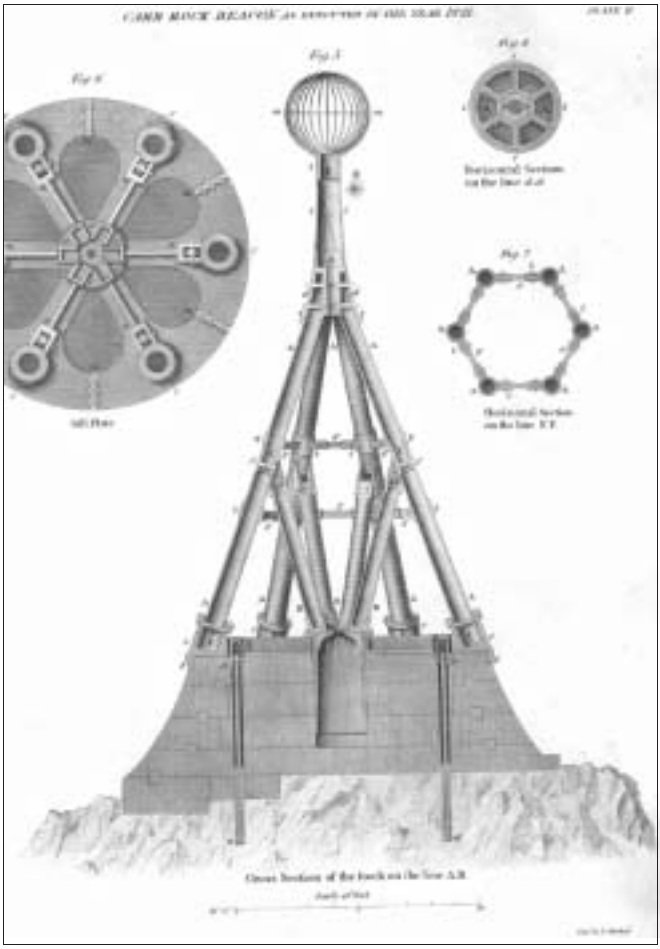
hazardous to shipping extending about $1\frac{3}{4}$ miles out to sea from the shore. The unlit tower was to have contained machinery, operated by the rise and fall of the tide within a central cavity, to toll a warning bell.

A shore station was set up to build the beacon in 1813 and work at the rock commenced under Stevenson's direction founding an 18 ft diameter base 16 ft below high-water level, partly by means of cofferdams. Stones were cut and assembled at the shore station and then shipped to site. Because of site difficulties, work proceeded slowly over the next five years and was eventually abandoned after much of the masonry had been swept away by the sea on several occasions, finally, in November 1817, after its completion.

Stevenson then decided on a cast-iron framework beacon, which was erected in 1821 on the 4th course of the former tower. This beacon, the prototype for beacons later extensively used round the coast of Scotland, was 'in perfect preservation' in 1878. It still exists and is regularly checked by the Northern Lighthouse Board who have a lighted buoy nearby. The whole project cost about £5000.

Evidence of the Carr Rock workyard can still be seen at Fife Ness on the rocky foreshore, including a level rock base which accommodated circular courses of masonry before being taken via a short railway to the jetty and shipped to site. An interpretive board at the site provides notional details of the operational arrangements.

Carr Rock
Beacon
1821–present
[26]



In 1843–44 the previously referred to small low-level lighthouse was built on the Isle of May in a position so that when the two May lights were observed one above the other the mariner knew that he was in line with the treacherous Carr Rock about eight miles north of the light.

As mentioned previously this arrangement discontinued and led to the stationing of a wooden lightship off the North Carr rocks in 1877 which was replaced by a manned ship in 1887 and in 1933 by a steel ship, the *North Carr Lightship*. This ship was manned until 1975 when it was replaced by a buoy and about the same time

the Fife Ness light at the Coastguard Station was upgraded by the Northern Lighthouse Board Civil Engineer, R. J. Mackay. This ship then served as a museum at Anstruther for many years and is now (2007) undergoing preservation at Victoria Dock, Dundee. [26, 27]

13. Guard Bridge

HEW 0335
NO 4519 1888

Guard Bridge, of six arches over the Eden, is thought to have been built under the aegis of Bishop Henry Wardlaw, founder of St Andrews University, in about 1440, or possibly even by Bishop Kennedy ca.1460. It is a good example of one of Scotland's earliest surviving pre-Reformation bridges. The first four arches from the west have spans of 38 ft to 42 ft and appear original. Their shape is almost semicircular and the masonry construction is of well-squared rubble. The most easterly arch seems to be either an addition or an early replacement, as six arches were recorded in 1792. Wardlaw's bridge may have been partly replaced in 1532–39 by Archbishop James Beaton, as the bridge bears his coat of arms and initials on one pier.

Nothing is known about the foundations, but the masonry shows no sign of significant settlement. A remarkable

Guard Bridge and railway bridge piers

Roland Paxton

feature is that the arch-rings are only 15 in. thick, much less than if determined by Alberti's Rule (1470), which would suggest one-fifteenth of the arch span as an appropriate thickness. This is indicative of considerable skill in forming the arch-rings.

The bridge was bypassed by the present three-span reinforced concrete bridge of 1935–37 by F. A. MacDonald & Partners but is still much used by pedestrians.

The illustration shows differing triangular cutwater and pier elevations, which is suggestive of building at different periods. The circular piers in the foreground are the remains of a railway girder bridge on the St Andrews branch railway from Leuchars. It is uncertain whether these piers were those constructed for the original timber bridge designed by Thomas Bouch and built by Kenneth Mathieson of Dunfermline in 1852. The line was closed in 1969. [28]

14. Garlie Bank Road, Cupar (A916 south of Cupar)

NO 3743 1348

This road, now the A916, was laid out by Fife road surveyor Thomas Aitken in the late-19th century, in the best tradition of Telford's practice. The road runs obliquely down Garlie Bank to 'link two valleys to replace a route with gradients as steep as 1 in 10 while saving $1\frac{1}{2}$ miles with a maximum gradient of 1 in 30 suitable for mixed traffic' (horse and traction engine). It has been commended as affording the finest view of the Howe of Fife.

Aitken produced a standard work on road making which served road engineers for the next half century. [29, 30]

15. Cupar Footbridge (Waterend Road)

NO 3764 1446

This light footbridge of a type now rarely seen spans the Eden between South Bridge and the recently rebuilt Victoria Bridge. It has a span of 32 ft and is 4 ft wide. Its main structure consists of two slightly arched L-sections $7\frac{1}{2} \times 2\frac{1}{2}$ in. carrying a timber deck. Ties of $\frac{3}{4}$ in. diameter link the mid-span of the L-sections with the top of the

Roland Paxton

railings at the abutments with no obvious structural anchorage. The bridge probably dates from ca.1850.

Cupar Footbridge ca.1850 (Waterend Road)

16. Naughton Estate Footbridge (Private)

NO 3739 2469

One of Scotland's earliest surviving iron bridges carrying a footpath 20 ft above a private estate road. Masonry

Roland Paxton

Naughton Estate Footbridge

abutments support an iron arch of 11 ft span, cast in 1818 by, and erected by, Henry Balfour & Co., Durie Foundry, Leven. Balfour, son of the owner of Dundee Foundry (1792–ca.1816), had purchased Leven Foundry in 1817 when Russell, the previous owner, had gone out of business. The name of the foundry and date are cast on the bridge.

The deck has been strengthened with unobtrusive steel joists and a reinforced concrete slab. Most of the original ironwork is intact and the bridge is almost certainly a unique survivor of its type.

17. Tay Bridge (Railway)

HEW 0199
NO 3914 2785

The Tay is a shallow estuary, nearly two miles wide at Dundee, with many sandbanks and a depth of water rarely exceeding 50 ft. The present railway bridge is the second at the same site, the first having collapsed barely 18 months after its opening.

The first Tay Bridge was designed in the 1870s for the North British Railway by its Engineer Thomas Bouch and carried a single line of railway on 89 spans. Thirteen of these spans were navigation spans higher and longer than the others. The spans were originally to have been carried on tall piers of brickwork founded on solid rock but, owing to faulty site investigation and difficulties with the foundations, the majority of the piers had to be lightened and were made of poorly constructed ironwork which was insufficiently anchored at its base. In a gale on 28 December 1879 all the navigation spans fell while a train was crossing and 75 lives were lost. Although the bridge had stood for only 18 months it had more than demonstrated its usefulness, and the North British Railway determined to rebuild it.

The present bridge 10 711 ft in length and double track was engineered by W. H. Barlow from 1881, assisted by his son and partner Crawford Barlow. Although structural steel was coming into use, no substantial bridges in Britain had been completed using it, and it was decided to use 21 078 tons of wrought-iron girders capable of bearing 22 tons sq. in. in tension, plus 3588 tons of steel in the flooring. The contractor was William Arrol, who designed innovative temporary works, including pontoon jack-up

Roland Paxton

Tay Bridge under construction 1886

platforms (see illustration). He proved more than equal to this mammoth task.

Construction took place from 1882–87, on a parallel line 60 ft upstream from the old bridge. The spans were kept the same as Bouch's bridge, which allowed the original iron girders (which were sound, unlike the ironwork of the piers) to be reused as facing girders except on the navigation spans which were entirely renewed. The new piers were substantial and well anchored.

Network Rail's recent sensitive refurbishment of the bridge won the Saltire Civil Engineering Award for 2003. [31–33]

18. Tay Road Bridge

NO 4156 2946

Although a high-level road bridge crossing of the Tay was considered as early as 1929, it was not until March 1963 that construction began on the present bridge which was opened to traffic in August 1966. It was then the longest river crossing of any road bridge in Britain, obviating a 50-mile detour.

The 7365 ft long bridge has 42 spans (31 of which are 180 ft span) with a deck rising from 32 ft above sea level

at Dundee to 125 ft in Fife – a gradient of 1 in 81. To reduce the cost of construction the line chosen for the bridge had its north landfall at the old tidal harbour in Dundee, which was infilled and the site used as a fabrication yard by the bridge contractors.

Concrete foundations support twin columns of developing parabolic shape. These were founded on bedrock where the water was shallow and, in deeper water, carried on pile groups driven to the bedrock. The columns support steel-plate box girders 12 ft wide by 10 ft deep with a composite top flange of concrete forming the roadway. The girders range from 10 to 20 ft deep over the navigation channel. They were fabricated in the construction yard at Dundee, and then rolled into position along a service bridge at low level before being lifted and positioned on the columns.

These beams, each weighing 200 tons, were fabricated of steel plate and stiffened internally to give them a maintenance-free exterior profile. They act compositely with the concrete deck of the roadway to form T-beams which support, along their inner edge, precast concrete units that form both a central duct for services and a pedestrian footpath. Overall, 140 000 tons of concrete and 12 750 tons of steel were used. Each carriageway is 22 ft wide and the central footway 10 ft.

The cost of the bridge and its approaches, excluding land and interest charges, was £4.8 million. It was designed by W. A. Fairhurst & Partners. The main contractor was Duncan Logan (Contractors) Ltd. The box girders were fabricated by the Caledon Shipbuilding and Engineering Co. Ltd, Dundee, with Sir William Arrol & Co. Ltd, Glasgow. These firms were subcontractors to Dorman Long (Bridge & Engineering) Ltd, who had the contract for the steelwork and were responsible for the steelwork erection. [34]

Further reading

[1] Graham, A. Archaeological notes on some harbours in Eastern Scotland. *Proc. S. A. S.* **101** (1968–69), 223–224.

[2] McNaughton, D. *The Elgin or Charlestown Railway 1762–1863*. The Author, Dunfermline, 1986, 9–10.

[3] Paxton, R. & Landale, D. *A Biographical Dictionary of Civil Engineers in Great Britain and Ireland Volume 1; 1500–1830*. ed. A. W. Skempton, Thomas Telford, London, 2002, 393–394.

[4] *The Glen Bridge, Dunfermline. Opening programme*. D. Watt, Dunfermline, 1932, 8, pls.
[5] HARRISON, G. *Alexander Gibb – The Story of an Engineer*. Bles, London, 1950.
[6] GRAHAM, A. Op. cit. 220.
[7] STEVENSON, R. Inchkeith (1814) and Lighthouse (1818). *Edinburgh Encyclopaedia*. Blackwood, Edinburgh, 1830, pl. CCCXLIX.
[8] MUNRO, R. W. *Scottish Lighthouses*. The Thule Press, Isle of Lewis, 1979.
[9] MARSHALL, D. A. *L'Ile de Chevaux – The Story of Inchkeith*, 1983.
[10] THOMSON, J. [map] Western part of Fife, . . . Edinburgh, 1827.
[11] MUNRO, D. M. *Loch Leven and the River Leven – A Landscape Transformed*. River Leven Trust, Markinch, 1994, chapters 5 and 6.
[12] BLYTH, B. H. The construction of the new dock at Methil. *Min. Proc. ICE*, 1912–13, Part 1, 76–102.
[13] RUSSELL, I. F. *Sir Robert McAlpine and Sons. The Early Years*. Parthenon, London, 1988, 123–136.
[14] MCALPINE, SIR ROBERT & Sons. *McAlpine contracts*. Authors, ca.1919, 50–59.
[15] LISTER, D. & GILLIES, J. *Largo Kirk*. Largo, 1968, 7–10.
[16] YEOMAN, P. (ed.) *The Salt and Coal Industries at St Monans, Fife, in the 18th & 19th Centuries*. TAFAC Monograph 2, Glenrothes, 1999.
[17] MARTIN, P. *Pits, Pans, and People: the Social Impact of Coal Mining and Salt Making in St Monans and Pittenweem, ca.1770–1820*. Tayside and Fife Studies, Dundee, Occasional Paper 3, 1991.
[18] REES, A. (ed.) Salt. *The Cyclopaedia*. Longman, London, 1819, **XXXI**, (4).
[19] GRAHAM, A. Op. cit. 211, 214–215.
[20] LESLIE, J. & PAXTON, R. *Bright Lights – The Stevenson Engineers 1752–1971*. The Authors, Edinburgh, 1999, 100–101.
[21] STEVENSON, R. *The Design and Construction of Harbours*. Black, Edinburgh, 1874, pl. 19.
[22] Crail Museum Trust, 62–64 Marketgait, whose display includes harbour information.
[23] GRAHAM, A. Op. cit. 226–228.
[24] MUNRO, R. W. *Scottish Lighthouses*. The Thule Press, Stornoway, 1979.
[25] STEVENSON, D. *Life of Robert Stevenson*. Black, Edinburgh, 1878, 53–56.
[26] STEVENSON, R. *An Account of the Bell Rock Light-house*. Edinburgh, 1824, pl.
[27] STEVENSON, D. *Life of Robert Stevenson*. Op. cit. 177–180, pl. 2.
[28] INGLIS, R. G. The ancient bridges in Scotland. *Proc. S. A. S.* 1912, **XLVI**, 151–177.
INGLIS, R. G. Roads and bridges in the early history of Scotland. *Proc. S. A. S.* 1913, **XLVII**, 303–333.
[29] AITKEN, T. *Road Making and Maintenance: a Practical Treatise for Engineers, Surveyors* . . . . Griffin, 1900, 49–51.

[30] McWilliam, R. C. Case study in 'Assessing the historical significance of routes'. *ICE PHEW conf. paper*, 2004, 3–7. (ICE Library)
[31] Barlow, C. *The New Tay Bridge*. Spon, London, 1889.
[32] Shipway, J. S. *The Tay Bridge 1887–1987*. ICE Edinburgh & East of Scotland Association, Edinburgh, 1987.
[33] Martin, T. *Tay Bridge Disaster*. Website. Includes animated 'collapse mechanism'.
[34] Borthwick, A. *The Tay Road Bridge*. G. Outram, Perth, 1966.