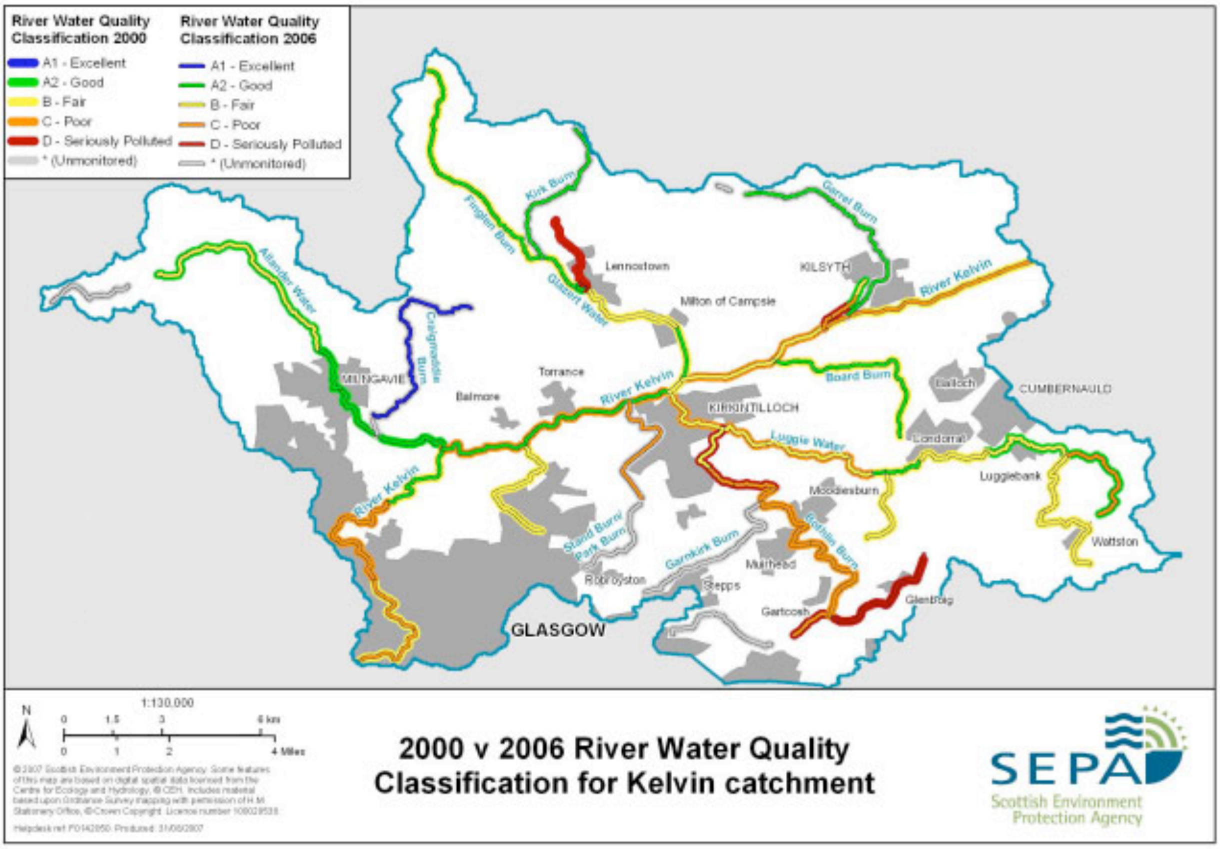
Case Study 1: The Kelvin’s water quality is improving!

Almost 25 km of waters in the River Kelvin catchment have improved in the last seven years from the lower classes (C and D) to higher classes (A1, A2 and B).

River Kelvin catchment: water quality in 2000 compared with 2006



This significant improvement in water quality is due largely to the £67 million Kelvin Valley Sewer (KVS) Project, which resulted in the closure of a number of separate sewage treatment works (STWs) between 1997 and 2003 (see table). Sewage from a number of communities is now diverted via the valley sewer and treated to a higher standard at Glasgow's Dalmuir STW before being discharged to the Clyde Estuary.

List of STWs replaced by KVS

Location of STW	Date of closure	Receiving water
Torrance	May 1997	River Kelvin
Bishopbriggs	February 1998	Bishopbriggs Burn
Kirkintilloch (Dryfield)	November 1998	Glazert Water
Milton of Campsie (Birdston)	February 2000	Glazert Water
Queenzieburn	August 2001	River Kelvin
Twechar	October 2001	River Kelvin
Cumbernauld (Deerdykes)	January 2002	Luggie Water
Kilsyth	January 2002	Dock Water
Croy	March 2002	Board Burn
Auchengeich	March 2003	Bothlin Burn

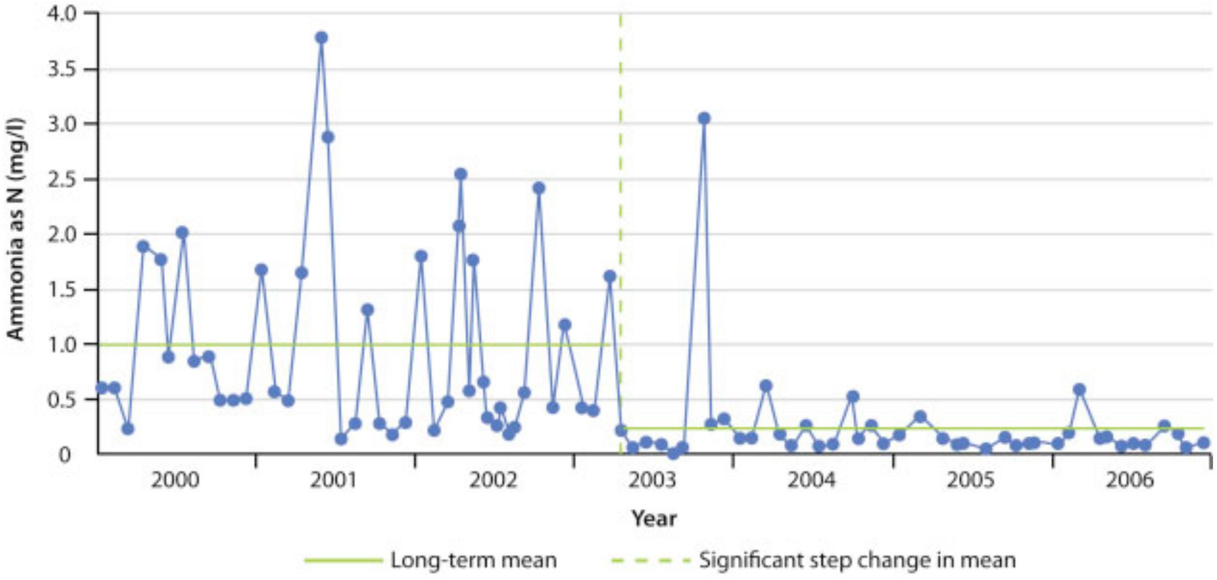
The systematic removal of sewage inputs from the River Kelvin and its tributaries produced an immediate improvement in chemical quality and, more recently, ecological improvements downstream of the former discharges. Some of these improvements are detailed below.

It is particularly encouraging that the lower reaches of both the Luggie Water and Bothin Burn recorded improved macro-invertebrate scores in 2006. Macro-invertebrates provide information on the long-term status of the river because they are slower to react to changes. Improvements in biological quality need various elements to be working together to provide the correct environment for invertebrates to thrive.

River Kelvin

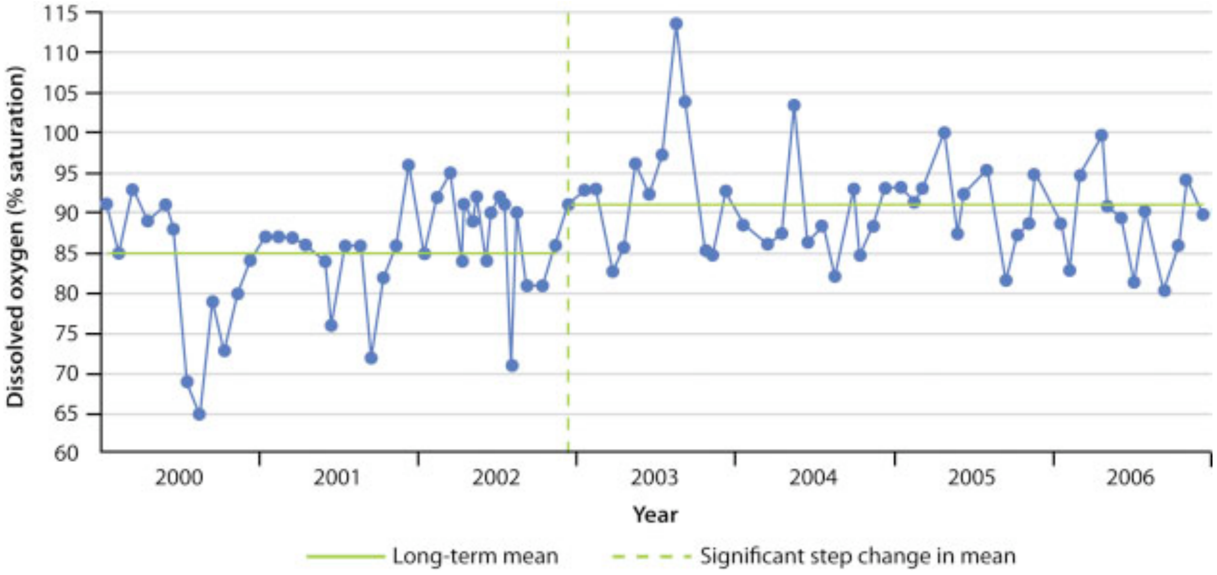
The River Kelvin at Springfield Farm Bridge is the first routine SEPA monitoring point on the main river downstream of the confluence with the Luggie/Bothlin catchments. The major improvements in water quality at this site – as shown by its ammonia and oxygen levels (see graphs) – and other monitoring points further downstream at Torrance and Bardowie have been attributed to the closure of STWs in the upstream catchment.

Ammonia levels in River Kelvin at Springfield Farm Bridge, 2000-2006



The significant drop in 2003 was attributed to the closure of Auchengeich STW in March of that year.

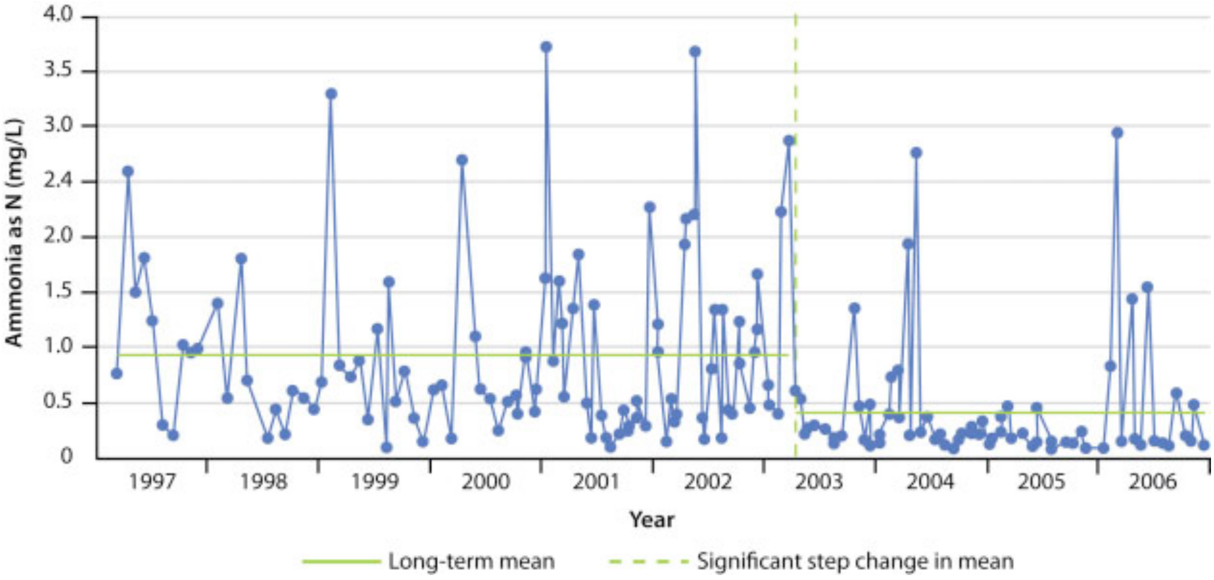
Dissolved oxygen levels in River Kelvin at Springfield Farm Bridge, 2000-2006



The removal of these discharges has consequently raised oxygen levels in the water, allowing an increased number and variety of fish to live.

Several sites on the River Kelvin upstream of the Luggie/Bothlin confluence are also showing a steady improvement. Unfortunately the same cannot be said for the lower reaches of the river. The area around Glasgow is affected by numerous unsatisfactory combined sewer overflows (uCSOs), which discharge untreated organic pollution at times of high rainfall. Although average ammonia levels have declined and in fact went through a step change in early 2003, the lower Kelvin still receives ‘spikes’ of ammonia each year (see graph below) which keep it in Class C (poor quality). In the summer months, the river around Glasgow can also suffer from oxygen depletion. Coupled with low flows and higher water temperatures, this has lead to fish fatalities in recent years.

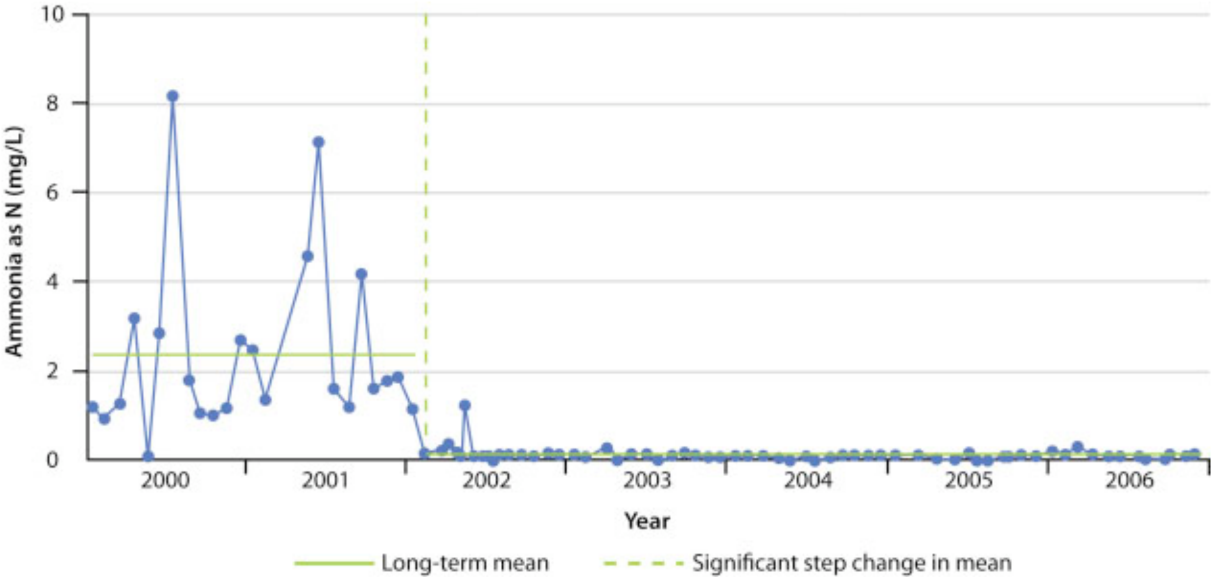
Ammonia levels in the River Kelvin at Killermont Bridge, 1997-2006



The Luggie Water
On the Luggie Water, the closure of Cumbernauld's Deerdykes STW in January 2002 has resulted in an improvement in overall water quality downstream. Sewage is now diverted via the Kelvin Valley Sewer and treated in Glasgow, though the river is still affected by sewer overflows.

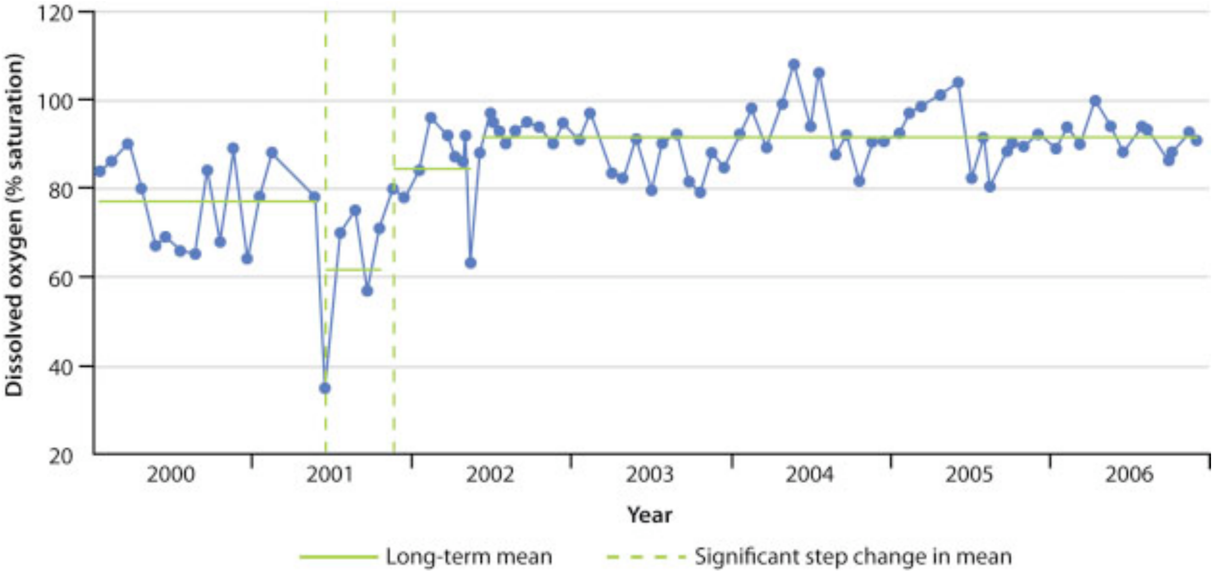
Chemical water quality showed almost immediate improvement as represented by the ammonia levels at Waterside Bridge (see graph). Biological quality took longer to recover, but is now showing signs of improvement, e.g. at the most downstream monitoring site at the foot of the Luggie Water below its confluence with the Bothlin Burn.

Ammonia levels in Luggie Water at Waterside Bridge, 2000-2006



Like the River Kelvin, oxygen levels in the Luggie Water have steadily increased (see graph), allowing an increased number and variety of fish to live in the water.

Dissolved oxygen levels in Luggie Water at Waterside Bridge, 2000-2006

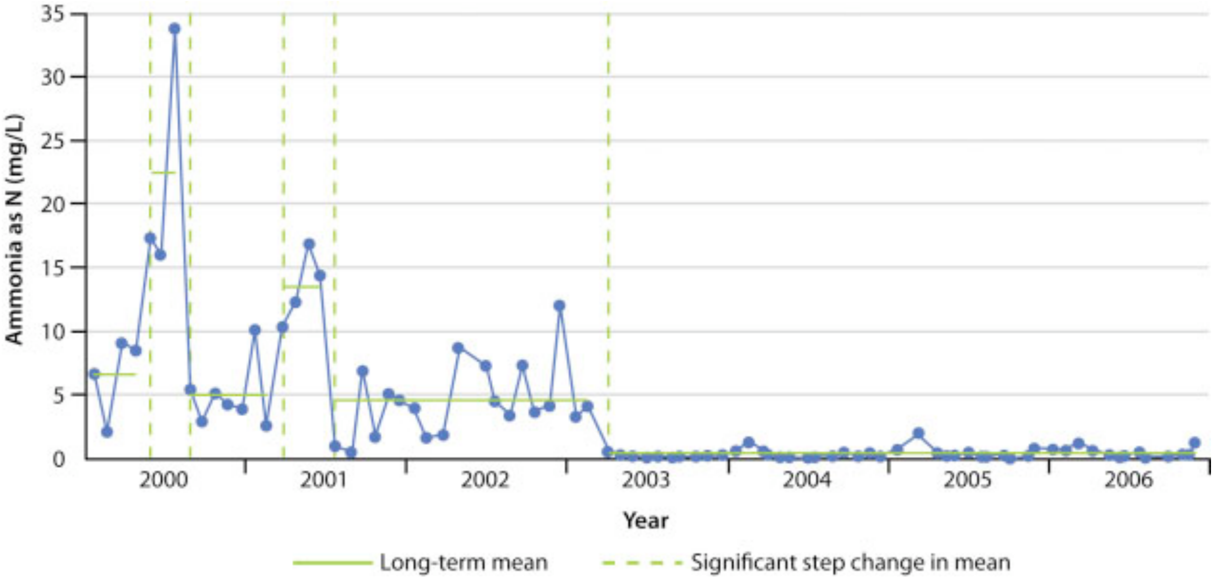


The Bothlin Burn

Water quality in the Bothlin Burn was affected by the discharge from Auchengeich STW which closed in March 2003. Sewage is now diverted via the Kelvin Valley Sewer and treated in Glasgow. The closure lead to a dramatic drop in sewage in the river as measured by its ammonia content and there is now almost no ammonia present in the river (see graph).

Chemical water quality has improved considerably; some results show a hundred-fold reduction in ammonia levels in the river. Levels of dissolved oxygen in the water increased at the same time as the treated sewage effluent was removed. As a result the water can support an increased amount and variety of fish life. The Bothlin Burn is now in its best condition since monitoring began in the 1970s.

Changes in the ammonia level in Bothlin Burn, 2000-2006



Coupled with the chemical improvement, the return of clean water (pollution-sensitive) macro-invertebrates demonstrates that the ecological quality of the Bothlin Burn is improving.

Case Study 2: Steady improvement in water quality of the River Almond

The River Almond, once perhaps the most polluted river of its size in Scotland, is being brought back to good quality. A partnership approach to catchment management has achieved significant improvements to water quality but there are still hurdles to overcome. The river is approximately 50 km long, draining an area mainly within West Lothian. It runs from the Cant Hills above Harthill to the Forth Estuary at Cramond.

The presence in the catchment of the central Scottish coalfield and the Lothian oil shale field means that mining operations have affected water quality in the past. With the end of mining, regeneration initiatives have led to substantial urban development and demographic changes. The increase in urban development has affected water quality in the River Almond and its tributaries and, as urban areas continue to expand, careful management of the catchment is needed to ensure water quality does not deteriorate further. Flows of sewage, surface water and infiltration water have all increased. Standards of effluent treatment have more than kept pace, but storm overflows remain a problem as the capacity of treatment works is being stretched to their limit.

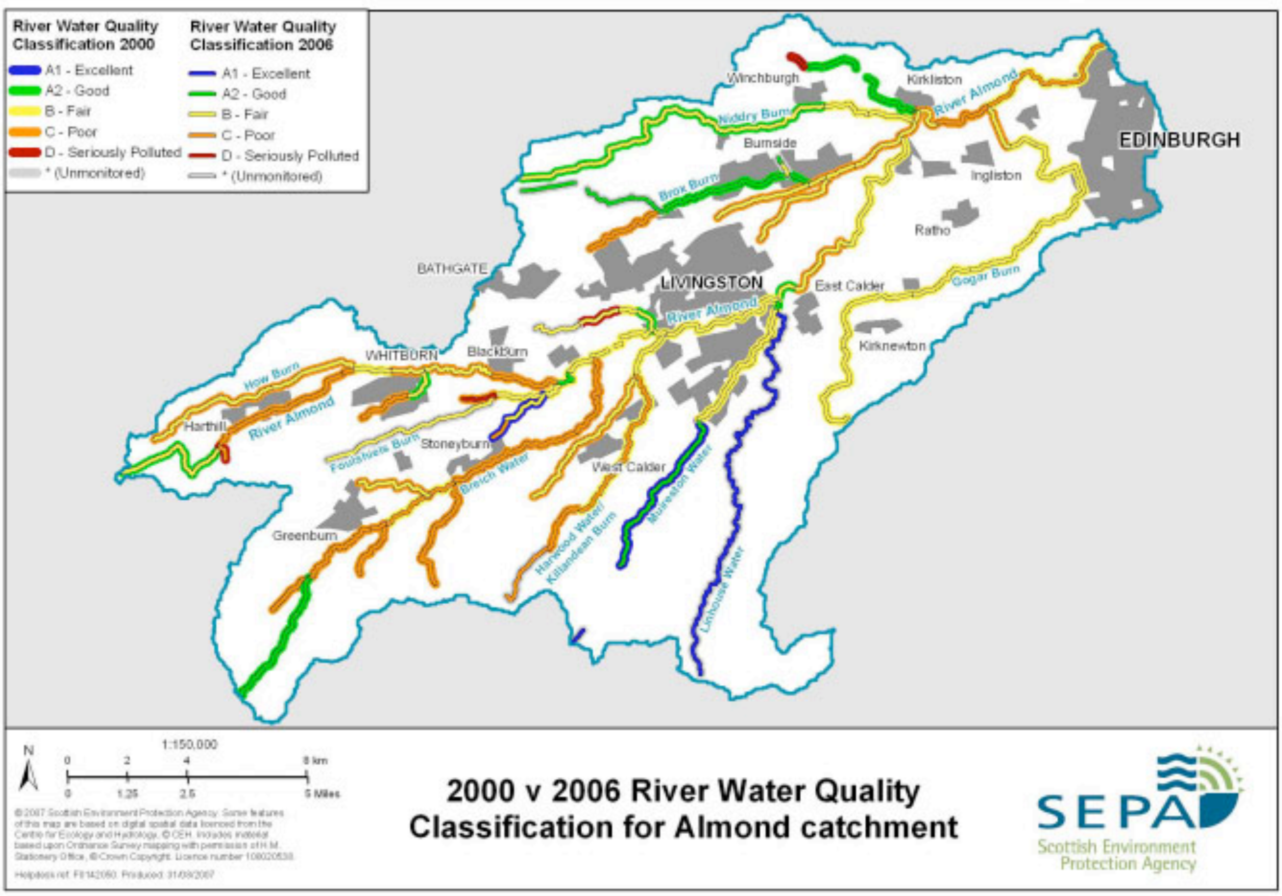
The River Almond has considerable amenity value as it passes through Polkemmet Country Park, Almondell Country Park and the Craigiehall/Cramond area of Edinburgh. The river is a focal point for a number of walkways through Livingston and there is an active yacht club at Cramond. There is limited fishing interest, though there are salmon and trout in the river. Many salmonids are seen and are thought to breed in the good quality tributaries. The water quality of the lower reaches is therefore important since fish pass through them on the way to breed in the tributaries. The river is also used as a water resource and water is abstracted from the river at Almondell Country Park to feed the Union Canal. The water quality varies over time and along the length of the river.

The overall quality has improved between 1996 and 2006 (see table). While some individual stretches have shown slight improvements or slight deterioration (usually weather driven), there has been a net overall reduction in the length of poor quality from 29.8 km in 1996 to 15.9 km in 2006. The majority of the catchment is now described as fair quality (Class B) with an increasing length of excellent/good (Class A) quality water.

Classification data for the River Almond (main river only), 1996-2006

Year	Length (km)		
	Class A1/A2 (excellent/good)	Class B (fair)	Class C (poor)
1996	0	15.4	29.8
1997	4.8	9.3	31.2
1998	4.8	18.4	22.0
1999	0	32.7	14.0
2000	5.6	21.4	19.6
2001	0.8	29.4	16.4
2002	0	34.1	12.5
2003	0	33.3	13.3
2004	0	35.9	10.7
2005	0.76	22.1	23.7
2006	0.76	29.9	15.9

River Almond catchment: water quality in 2000 compared with 2006



While overall classifications have improved, some parameters have shown more significant improvements; for example, ammonia and phosphorus concentrations have fallen considerably. .However with increasing urbanisation, some stretches have deteriorated. The causes of some stretches being downgraded varies along the length of the river although iron, biochemical oxygen demand (BOD) and biological status are the most common reasons.

The water quality of this river is heavily influenced by the increasing and varied land use in the catchment. Urban development has led to increased flows of sewage, surface water and infiltration water. As a result, untreated sewage entering the river during storms has increased as the capacities of sewage treatment works are stretched to their limits.

In addition, impermeable urban surfaces do not allow for the normal permeation of rain water into the ground, allowing increasing amounts of water to be washed into the river. This contributes to flooding and poor water quality by washing silt, metals and hydrocarbons into watercourses. Another factor affecting water quality in the River Almond has been the discharge of de-icing agents from Edinburgh International Airport during the winter. These can result depletion of oxygen in the river and SEPA now requires treatment of surface water discharged from the airport.

The water quality of the Almond’s tributaries can exhibit a measurable effect on the quality of the main river. The How Burn and the Breich Water are examples of poor quality tributaries along with the Caw and Ryal Burns, which combine with the Brox Burn before entering the River Almond. These contribute towards lower water quality in the River Almond. Some tributaries (e.g. Gogar Burn) suffer from a degraded habitat as a result of their highly engineered structure and the construction of culverts. There are also pressures on the tributaries and the River Almond from invasive (‘alien’) species such as Giant Hogweed, Japanese Knotweed and Himalayan Balsam. These pressures on habitat discourage diverse communities and reduce the biological value of the river corridor.

Although many tributaries suffer from poor quality, some have good quality. To the south, the Linhouse Water and Murieston Water are of good quality and pour clean water into the River Almond below Livingston – vital for the fish populations that use the tributaries to breed.

Historically, minewaters have contributed to the poor water quality of the River Almond and its tributaries. Although most mining operations have ceased and remediation projects are ongoing, abandoned operations still pose a threat to water quality (especially iron levels).

Remediation projects have addressed some of the polluting sources. Polkemmet and Cuthill minewater discharges are both now treated. Further improvements are anticipated with a steady decrease in discharges from other former mining operations and the regeneration of the Polkemmet Colliery site and the surrounding land at Whitburn. The completion of a leachate treatment system at Foulshiels mine in 1998 has contributed to the improved water quality of almost 6 km of the Foulshiels Burn, which was previously of poor quality and is now borderline fair/good quality. There is still work to be done elsewhere in the catchment as iron levels have increased in some areas (e.g. in the Breich Water) as a result of increasing minewater discharges.

Diffuse pollution has also been addressed, partly through the implementation of SUDS. Projects such as the Claylands and Newbridge Ponds have been successful in regulating flow during storm events and reducing the amount of metals and hydrocarbons washed into the river. They have also resulted in better habitat. For example, a 3.4 km section of the Caw Burn near Broxburn has been upgraded following the installation of a surface water treatment facility at Houston Industrial Estate. Further SUDS projects are planned for the catchment.

SEPA has worked with a number of organisations and dischargers to develop a partnership approach to catchment management. Improvements identified by the Catchment

Management Plan (CMP) for the River Almond (http://www.sepa.org.uk/dpi/campaign/west_lothian/almond.htm) are being implemented by the Almond Pollution Management Group led by West Lothian Council. The CMP sets objectives for improving aspects of the environment including:

- water quality and quantity;
- habitats and biodiversity;
- fisheries;
- recreation;
- land use planning and development.

As the population continues to grow, additional sewer capacity and sewage treatment is required. In addition, sewage overflows during storms and the issue of surface water run-off must be addressed. It is also necessary to ensure that any reduction in river flow arising from long-term reduced rainfall or the cessation of pumping from mines does not impact water quality due to reduced dilution of the treated effluent inputs.

The pressures affecting the River Almond are varied and in some cases increasing. It is essential that the current river water quality and habitats do not deteriorate. SEPA has worked to:

- influence the adoption of SUDS;
- ensure the setting up of minewater treatment schemes;
- require improvements in sewage treatment and associated infrastructure.

The issues of urban drainage and mining remain the main impacts on water quality in the catchment. Improvements in the River Almond have already been seen – most of the river supports trout populations and kingfishers are established around it. Further enhancement is possible and necessary to maintain the amenity and resource value of the Almond and boost biological communities.

Sources of further information

Details	**Available from:**
The River Almond Catchment: A Plan for Integrated Management. River Almond Catchment Partnership Group, 1997.	Scottish Wildlife Trust
Managing a Complex River Catchment: A Case Study on the River Almond. P Pollard, M Devlin and D Holloway, 2001.	Science of the Total Environment, Vol. 265, 343–357

Case Study 3: The Mouse Water – a success story!

The Mouse Water catchment in South Lanarkshire, which includes the Dippool Water, has historically been affected by ferruginous (iron-bearing) minewater from abandoned mines. The very small iron-rich particles (ochre) cause a pronounced turbidity in the main river and, in severe cases, can coat the riverbed, smothering invertebrates. This has associated effects on fisheries and river ecology in general. Iron levels in the catchment in previous years averaged >2.0 mg/litre, which resulted in SEPA classifying the watercourses as Class C (poor).

By the end of 2004 the Coal Authority (http://www.coal.gov.uk) had completed two mine water remediation systems, on the Mouse Water and at Pool Farm. The treatment schemes, costing a combined £1.5 million, work by removing the ochre before it enters the river. The scheme is entirely passive, using only gravity to move the minewater around the site. The system of lagoons and reed beds reduces the iron content of the minewater from 25 mg/litre to <1 mg/litre.

This improvement in discharged water quality enabled 6 km of river within the catchment to be upgraded from Class C to Class B in 2005 and a further 7 km in 2006, making a total upgrade of 13 km so far (see map). Further improvements are anticipated in the future.

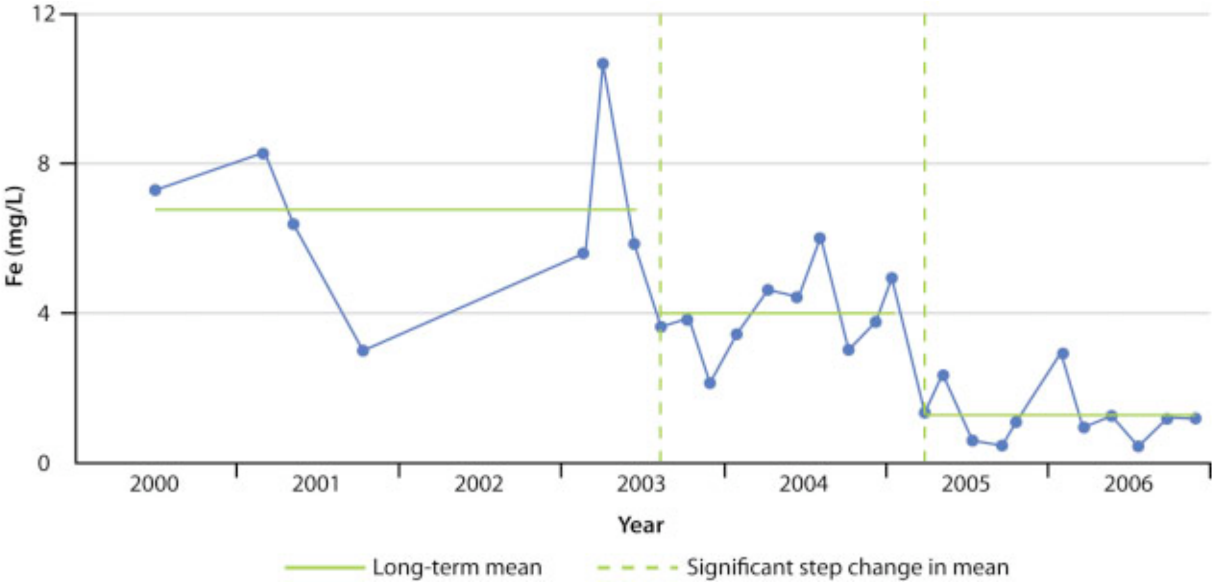
The constructed wetlands protecting the Mouse Water also form a concentrated habitat for insects and birds. The Mouse Water wetland incorporates pathways and benches, and has become established as an important amenity within the local community. The Mousewater leaflet, distributed to local residents and interested parties gives more details on the treatment scheme.

The three graphs below show the step changes in iron (Fe) reduction at locations in the Mouse Water catchment. Most results at these locations are now <2.0 mg/litre.

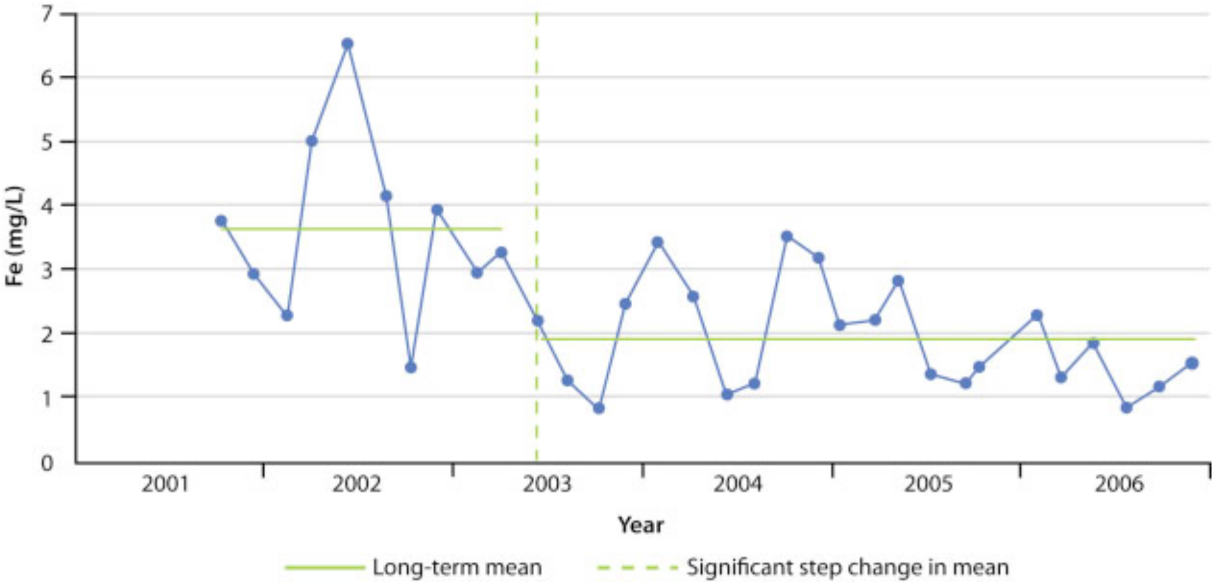
Water quality improvements in Mouse Water catchment before and after Coal Authority remediation work

Note: The upper Dippool Water has been borderline ecological class B/C for a number of years.

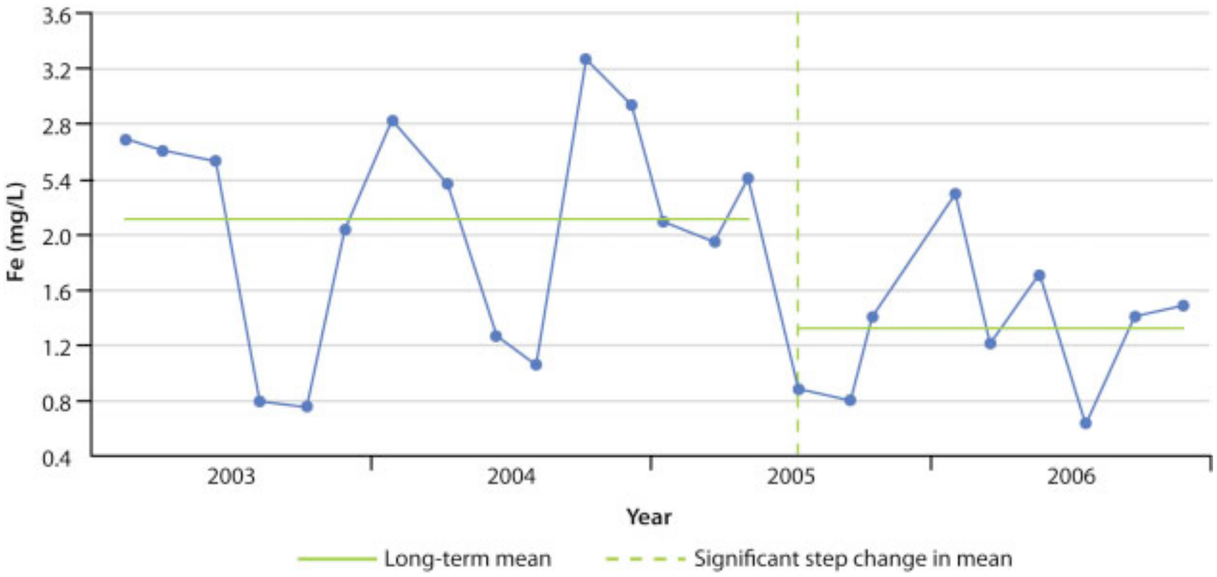
Iron concentrations in Mouse Water at Gowmacmorran near the town of Forth, 2000-2006



Iron concentrations in Dippool Water at Westshield Bridge, 2001-2006



Iron concentrations in Mouse Water at Cowford Bridge, 2003-2006



Case Study 4: Changes combine to boost water quality in the Clyde Estuary

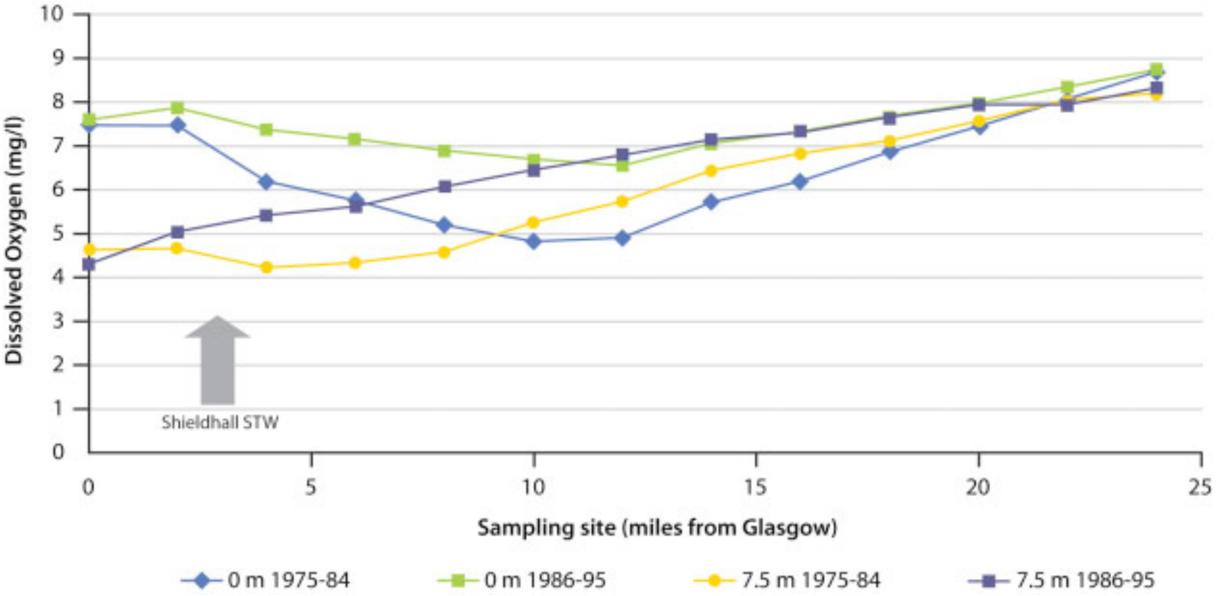
The steady improvement in water quality seen in the Clyde Estuary over a number of years is the result of a number of interacting factors – a reduction in heavy and polluting industry, tighter environmental regulations and investment in sewage treatment. Details of some important changes in the Clyde Estuary area are described below.

Sewerage investment

The main point sources of impact in the Clyde Estuary are the various sewage treatment works serving the population of Greater Glasgow. In recent years several of the large works discharging to the Clyde catchment have been upgraded to meet the requirements of the Urban Waste Water Treatment Directive.

The upgrading of one of the largest sewage works at Shieldhall in 1985 contributed to a significant improvement in water quality in the estuary as demonstrated by its dissolved oxygen levels (see graph).

Dissolved oxygen levels (surface and bottom) in the Clyde Estuary before and after improvements at Shieldhall STW

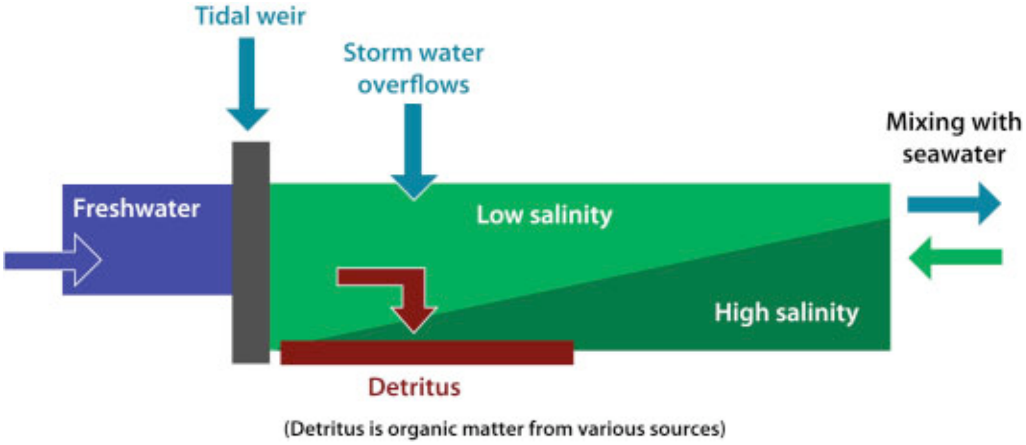


The graph shows dissolved oxygen levels in the Clyde Estuary for the ten years (1975-1984) before Shieldhall STW was upgraded and ten years (1986-1995) since. In the area downstream, dissolved oxygen levels improved by up to 2.0 mg/litre in surface waters (0 metres depth) and up to about 1.5 mg/litre in bottom waters (7.5 metres depth). However, there was little improvement at the head of the estuary upstream of Shieldhall STW. Furthermore, the improvement in the upper estuary (e.g. 2 miles from the centre of Glasgow) was less than in the lower estuary (e.g. 10 miles downstream from Glasgow).

These differences are due to a combination of processes linked to seasonal changes in rainfall, river flows and water temperature which mainly affect water quality in the upper estuary. During the winter months, river flows are relatively high. Freshwaters flowing into the estuary are well oxygenated and the water column is well mixed vertically – even in the upper estuary. This means that there is little vertical variation in dissolved oxygen levels in the upper estuary. But during the spring months, river flows decrease and the water column in the upper estuary becomes stratified. This causes bottom waters to become isolated from waters overlying them so that exchange of oxygen becomes less.

The canalised form of the estuary, the naturally poor flushing mechanisms and the relatively low freshwater flows and reduced mixing in spring and summer also make the upper estuary susceptible to organic inputs, both natural and as a result of human activities. Natural inputs include leaf litter and detritus from the River Clyde, while human activities include discharges of untreated sewage from storm overflows. These combine to give rise to deoxygenation of bottom waters as a result of microbial digestion of detritus and the impact of anoxic sediments on the bed of the estuary (see diagram).

Sedimentation at the head of the Clyde Estuary



The increasing residence times for bottom waters and the oxygen demand from the anoxic bed sediments cause oxygen levels in these waters to become depleted almost to zero during the summer months. This situation typically lasts until the autumn months when river flows increase again and higher quantities of well oxygenated freshwater ‘flush’ the estuary. There are no longer any areas of Class D (seriously polluted) waters in the main channel of the Clyde Estuary, but the extent of the area at Class C arising from this cause has remained unchanged for many years.

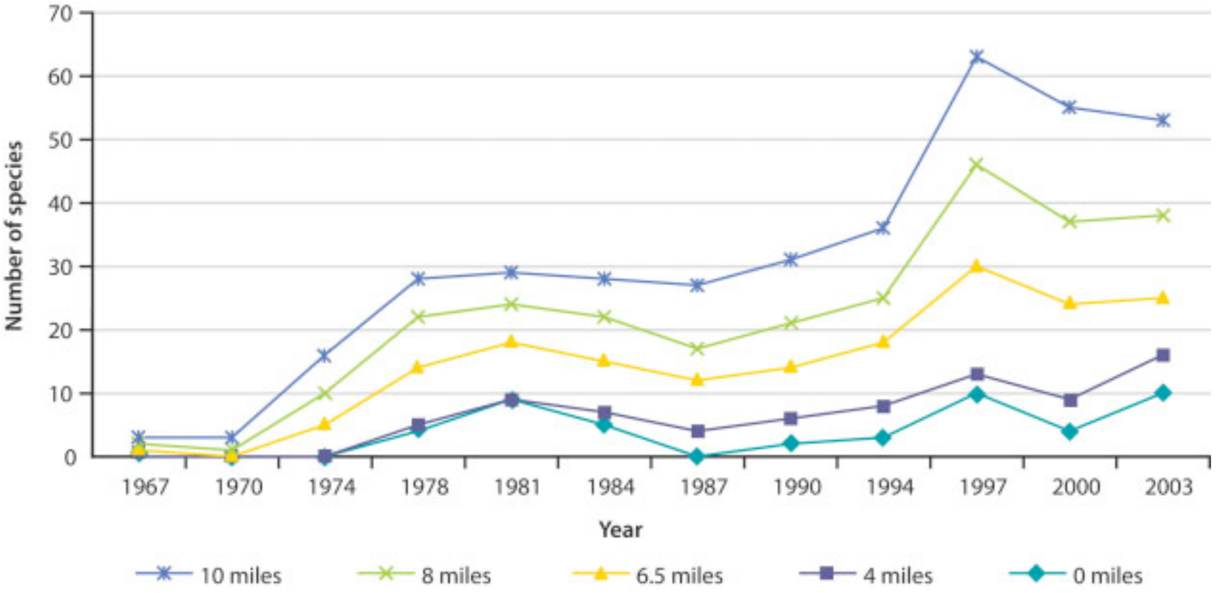
Further downstream, Dalmuir STW was upgraded in 2001 to provide secondary treatment. A new Ardoch STW serving Dumbarton and the Vale of Leven was completed in 2001. This provides secondary treatment for sewage and replaced former septic tank discharges. A new secondary treatment works was also constructed at Ardmore in 2001 to serve Helensburgh and Craigendoran. Many homes with untreated or private septic tank discharges were connected to this system, eliminating numerous small unsatisfactory shoreline discharges that caused aesthetic impact and microbiological (bacterial) pollution.

Although major investment has resulted in water quality improvements, other localised problems persist and continue to cause problems. Poor aesthetic conditions still result from insufficiently treated storm water overflows. In 2004, Glasgow City Council began using a specialist boat to remove unsightly litter and other debris from the estuary and river. This work has proved invaluable in tackling litter problems; in its first year, the *St Mungo* removed 330 tonnes of debris from the Clyde, filling 259 skips.

Invertebrate data

The invertebrate fauna dwelling in estuarine sediments provide a useful quality assessment. The number of species present is a useful overall indicator compared with the abundance of invertebrates, which can vary considerably on a seasonal basis. The graph shows the long-term trend in the number of invertebrate species found at the monitoring sites throughout the estuary. The faunas are naturally impoverished in the low salinity inner estuary (i.e. 0 miles in Glasgow) and generally increase in diversity in a seaward direction as salinity increases and there is an influx of marine species (i.e. 10 miles at Erskine). In addition to this natural gradient, the graph shows a gradual increase in species diversity throughout the estuary over a period of years as water quality improved and sensitive species began recolonisation. This is especially the case with the more marine sites of the outer estuary.

Invertebrate fauna in the Clyde Estuary, 1967-2003

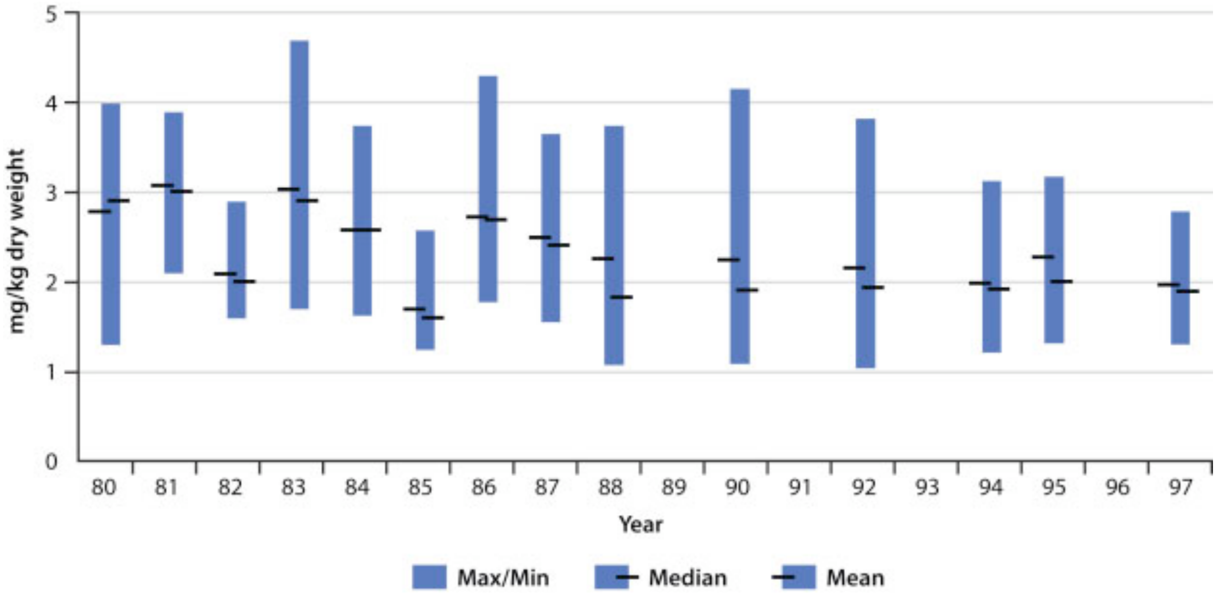


Contaminated sediments

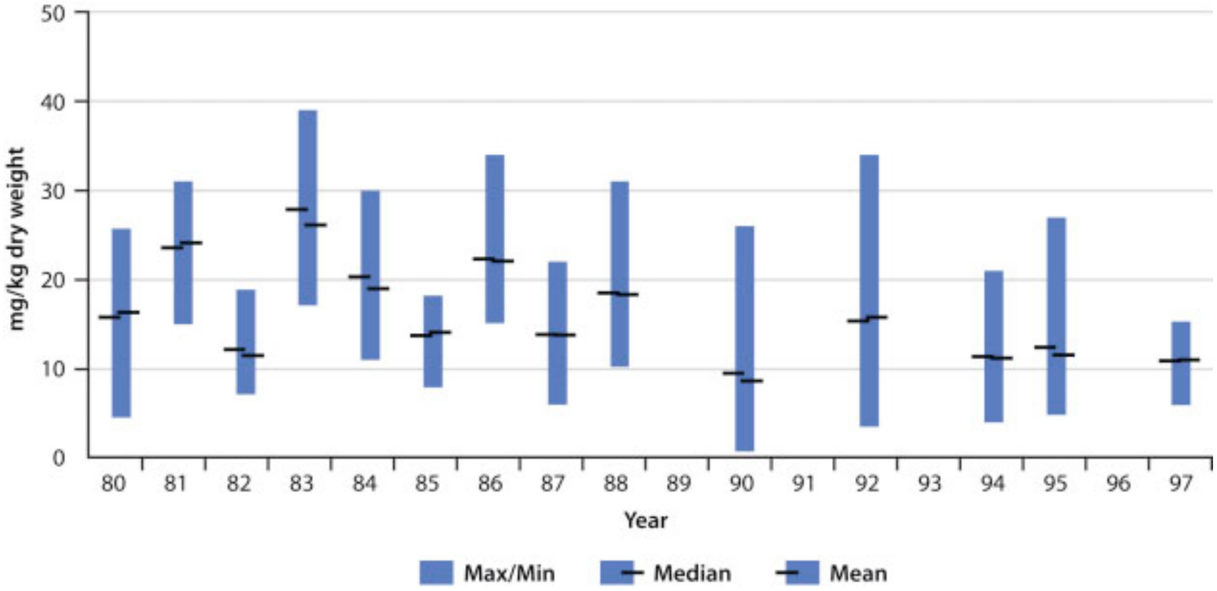
In the past, historical metal contamination manifested itself in the recording of some high levels (and small pockets of Class C within the estuary – see Maps 3 & 4) although the quality standards prescribed under the EU Dangerous Substances Directive have not been breached.

Mussels are used as biomonitors for chemical contaminants such as trace metals and organic compounds because they bioaccumulate elevated concentrations of these substances over time. Some areas of the estuary have been downgraded due to elevated levels of persistent, potentially dangerous, substances such as lead, chromium and polychlorinated biphenyls (PCBs) in mussels. However, long-term temporal trends show that cadmium and lead concentrations in mussels fell significantly between 1980 and 1997 (see graphs). The downward trend for cadmium was broadly in agreement with the trend in loadings from point sources (i.e. rivers and sewage works) and may reflect a general decline in heavy industry in the area. The decrease in lead levels may be linked to the introduction of lead-free petrol in the UK in 1983.

Cadmium levels in mussels collected in the Clyde Estuary, 1980-1997



Lead levels in mussels collected in the Clyde Estuary, 1980-1997



Recent data for 2006, which became available after the official classification results for 2006 were published, show that contaminant concentrations in mussels from the Clyde Estuary continue to decline and are lower than in previous years. Chromium concentrations at previous pockets of Class C at Cardross, Woodhall, Port Glasgow, Helensburgh, Portkil Bay, Ardmore and Dunoon East have fallen, indicating that these areas have improved to Class B.

Nutrient levels

As in the Solway Firth, there have been concerns regarding nutrient concentrations in the Clyde Estuary. SEPA records the levels of nutrients entering estuaries in terms of loadings from rivers and STWs each year. The most recent data show that nitrogen and phosphorus loadings to the Clyde Estuary and eventually the Firth of Clyde are falling.

For more information on nutrient trends and to see reports presenting the eutrophication assessment of the Clyde Estuary and the Inner Firth of Clyde.