Effectiveness of Faecal Indicator Organisms (FIO) monitoring in prioritising investment for Scotland's bathing waters

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Abstract

Scottish Water (SW) is working in partnership with the Scottish Environment Protection Agency (SEPA) to minimise the impact of our assets on the 60 identified bathing waters and assist in achieving the targets for compliance set by the EC Bathing Water Directive.
This paper describes the development of a methodology aimed at assisting SW's capital expenditure decision-makers to ensure that investments are targeted to the assets that have the highest impact on the bathing waters. The application of this methodology not only can provide invaluable information and data for refining and validating current and future models, but can also provide significant savings by allowing the funds to be effectively targeted while minimising environmental impacts.

Introduction

The Bathing Waters Directive[1] was instituted in 1976 with the aim of protecting water and public health. The Directive applies to all fresh or salt waters where bathing is explicitly authorised or traditionally practised by "large numbers" of bathers (Article 1). The Member State is then required to achieve mandatory biological standards and work towards higher guideline standards for the designated waters[2].

Scotland has 60 Bathing Waters identified under the Bathing Waters (Classification) (Scotland) Regulations 1991 (The 1991 Regulations[3]) and both the Scottish Executive and the Scottish Environment Protection Agency (SEPA) are committed to achieving these standards at all designated bathing waters around Scotland.

A variety of causes may contribute to failures of bathing water quality, including farming practices and diffuse pollution of animal origin. However sewage effluent e has significant impact on Bathing Waters around the country. Despite the efforts of governing and regulatory bodies throughout the UK, several identified bathing waters have failed to achieve the set standards and currently a European Court of Justice case is in progress over the consistent non compliance with the set standards.

Water utilities around the country are investing large amounts of capital in upgrading of sewerage systems and Waste water Treatment Works (WwTW). Scottish Water (SW) is in the process of delivering a major investment programme, partly aimed at improving the status of the sewerage infrastructure. However, even with compliant discharges, bathing waters are still susceptible to failure, producing adverse publicity to the water industry and compromising the value of new investments. Many of the failing waters receive polluted watercourses affected by faecal inputs of agricultural, animal or/and human origin.

Scottish Water Environmental Quality team has developed a methodology to assess the impact of its own assets on these watercourses and ultimately on the Bathing Waters and to ensure capital expenditure is well targeted at reducing the chances of failure due to sewage inputs. This was initially applied to the Figgate Burn in Edinburgh as part of a project aimed at improving water quality at the Bathing Waters of Portobello West.

[1] 76/160/EEC
[2] Mandatory limits as defined in EEC Directive 76/160 concerning the quality of bathing water are stated below:
EC Mandatory Limits = 2000 FC/100-ml, 10000 TC/100-ml (95% of samples). (Note there is no mandatory standard for FS)
EC Guideline Limits = 100 FC/100-ml, 500 TC/100-ml, (80% of samples), 100 FS/100-ml (90% of samples).
[3] SI 1991 No 1609 (S.144)

Because of its success, the same methodology was subsequently applied to the River Nairn catchment in the North East of Scotland and the Irvine catchment in the south west of Scotland.

This paper will describe the three case studies where this methodology was applied and the results of this approach.

Method

In many UK catchments the source of Faecal Indicator Organisms (including *faecal coliforms, Total coliforms* and *Faecal streptococci*) can be attributed to untreated or partially treated sewage entering the marine and fresh water environment. However this is not the only source and the importance of diffuse pollution of animal origin has been recognised has having a significant impact on water quality, especially in those catchments characterised by extensive agricultural practices[4]. This suggests that even for those areas where sewage treatment facilities have been installed or upgraded, achieving bathing waters directive standards is not always possible. It is becoming increasingly important to be able to quantify the relative contributions of the different pollution sources and, for water utilities, it is essential that any investment towards improving the sewerage infrastructures is made with a certain amount of confidence in the results.

Although a number of models can be used to assess the impact of the sewerage infrastructures on the water environment, most of them deal with identified sources spill volumes and/or frequencies rather than directly with water quality issues.
To address this and to identify sources which may be missed by the surveys carried out to build the hydraulic models, SW developed a programme of sampling to take place along those watercourses which are likely to impact on bathing water quality because of their bacterial content.

The programme is constructed around the catchment characteristics and usually runs throughout the bathing season (June-September). For this purpose, sampling points are set along the watercourse according to their proximity to possible sources of bacteria such as Combined Sewers Overflows (CSOs) and Surface Water Outfalls (SWO) and according to data gathered from any previous study of the catchment.
Samples are taken under both wet and dry weather conditions and are analysed for Faecal coliforms (FC) Total coliforms (TC) and Faecal streptococci (FS) content.
The results are then used to identify stretches of the watercourse where a more detailed investigation should take place.

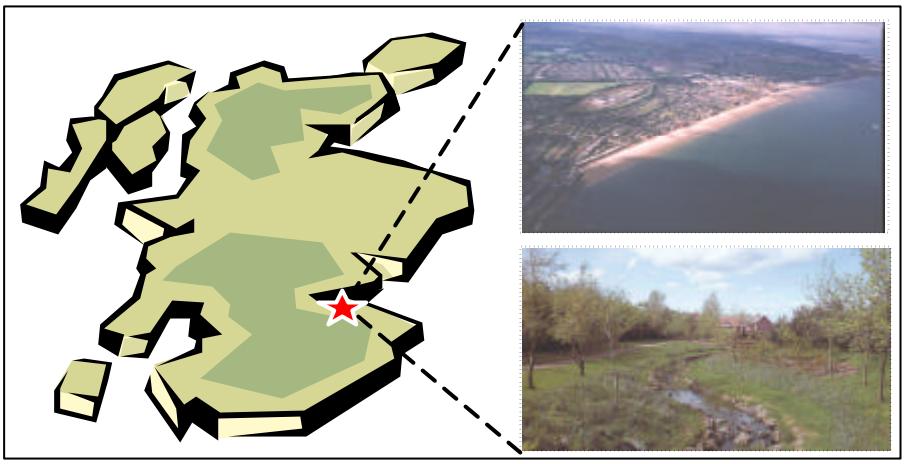
The relationship between rainfall and FIO concentration can give an indication of the nature of the bacterial input. Generally high rainfall levels correspond to high FIO concentrations, as the bacteria are washed through the catchment and into drainage systems. Those catchments characterised by combined sewer networks receive further inputs from CSO and, in extreme conditions, from pumping stations and WwTW emergency overflows. Alternatively, constantly high FIO concentration during dry weather periods often indicate the presence of a continuous discharge, while intermittent discharges such as those caused by wrong connections to SWO are often characterised by samples which give variable results not necessarily linked to rainfall conditions.

The data gathered can be used to carry out further studies on the relationship between FIO and other environmental variables such as flow, tidal conditions and salinity, allowing a greater insight on the relationship between bathing water quality, riverine inputs and environmental conditions. This knowledge can then be used in the development of water quality models.

[4] Wyer, M.D.; Crowther, J.; Kay D. and Fewtrell L. (1999) *Faecal indicator organisms sources and budgets for the Irvine and Girvan catchments, Ayrshire.* A report to West of Scotland Water, The Scottish Environment Protection Agency and South Ayrshire Council. June 1999.

Case studies:

1. The Figgate Burn Project



1.1 Introduction

Portobello, now a suburb of Edinburgh, is located on the Firth of Forth to the north east of the Scottish capital and has traditionally been used as a recreational resort. Identification of Portobello as a Bathing Water occurred in 1999. Because of its size and the variability in water quality along its length, the beach was divided into Portobello West and Portobello Central. Until the mid 70s untreated sewage was discharged from a number of short outfalls along the Edinburgh and Portobello coast. Bathing Water quality started to improve after the commissioning of Edinburgh WwTW at Seafield in 1978. Some of the untreated discharges remained up into the1990s. Despite a series of measures taken to improve the situation by diverting major untreated discharges to Seafield, Portobello West was still prone to failure and the Figgate Burn, outflowing close to these bathing waters, was identified as a potential source of failure.

The Figgate Burn rises in the Pentland Hills and flows through the city of Edinburgh. It is part of the Eastern Edinburgh Catchment, an 84% combined system, and there are 12 Combined sewer Overflows (CSOs) potentially discharging into the burn making this a primarily urban catchment with minimal agricultural inputs.

Since 1999 SW (East of Scotland Water[5] at the time) and SEPA have been working in partnership to address the issue of sewage discharges into the watercourse and ensure its impact on Portobello West does not significantly compromise compliance with the directive.

1.2 Aims

- To achieve guideline bathing water quality at Portobello West and Central bathing waters by reducing the load from the Figgate burn discharge.

It was established that in order to achieve this the overall water quality of the burn (especially for the downstream reaches) should be no higher that the equivalent of the bathing waters mandatory standard as enough dilution would be provided by sea water to greatly limit the impact of the watercourse.

1.3 Sampling programme

SW, in collaboration with SEPA, developed a sampling programme to try and identify and quantify the sources of the largest FIO inputs into the burn. Sample locations were defined accordingly to their proximity to Surface Water Outfalls, Combined Sewers Overflows and other potential sources of contamination located through examination of the GIS records and

[5] The water utility previously providing water services to the East of Scotland.

from a number of Drainage Area Studies already carried out. The samples along the watercourse were taken on the same day as the official SEPA bathing water samples at Portobello West, so as to determine the relationship between the water quality of the burn and that of the bathing waters. The samples were taken to the SW laboratories in Edinburgh for analysis. In addition to this, visual inspections were carried out regularly to identify the presence of any Sewage Related Debris (SRD).

The results were analysed in relation to the occurrence of rainfall events both to ascertain whether an increase in coliforms inputs was a dry or wet weather problem, and to identify any continuous discharge which would indicate a possible under performing asset. Relationships were also drawn between FIO levels rainfall and flow to determine the background levels, loads and response to changing environmental conditions.

1.4 Results

As a result of this study, a number of cross connections, private chokes, malfunctioning dual manholes were identified together with any input of animal origins reaching the watercourse through surface water outfalls. In particular one of the surface water discharges was, on occasions, found contained in excess of 500,000 faecal coliforms per 100 ml. Investigations traced the source of this contamination to a pigeon roost below a railway bridge. The faecal matter from this location would reach the SWO through road gullies when the local authority pressure hosed the walkway twice weekly.

This process allowed SW to target those inputs which, although significant, could be addressed relatively quickly and at reasonable costs. Figure 1 shows the improvement in the water quality of the burn as the median FC concentration recorded at each sampling point along the Figgate Burn.

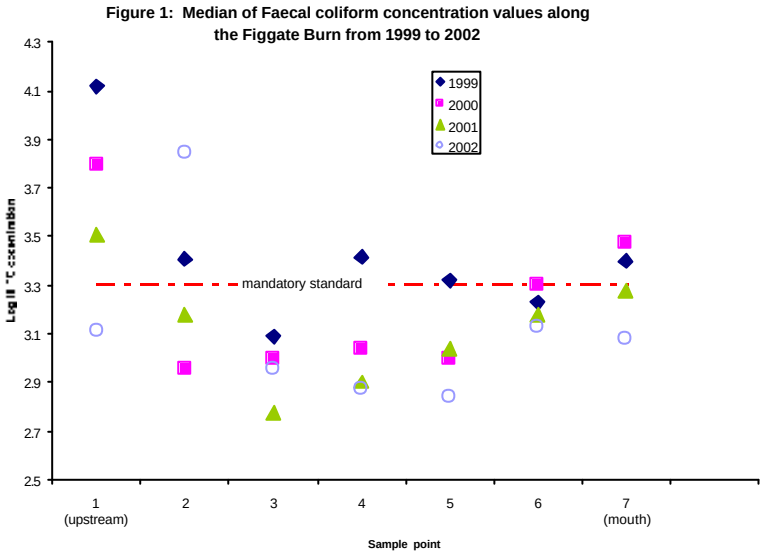


Figure 1 shows the Faecal coliform concentration (median values) recorded along the Figgate Burn between 1999 and 2002 during the Bathing Season. A series of improvement took place within this time frame, their effect is captured by the improvements in water quality seen throughout the burn (except for sample point 2 where the problem has been identified and work to rectify it will go ahead in the near future). These included the connection of a private septic tank to the sewer system, the reduction in spilling frequency of 1 CSO (from 74 times per year to 3 per Bathing Season) clearing of private sewers chokes, fixing of dual manholes and rectification of a cross connection.

All but one sampling point in the year 2002 showed a median water quality below the mandatory standard set in the bathing water directive.

The improvement in the burn water quality is also showed by the decrease in the FC loads reaching the bathing waters. Figure 2 shows how increases in flow correspond to greater loads for 2001 bathing season the 2002.

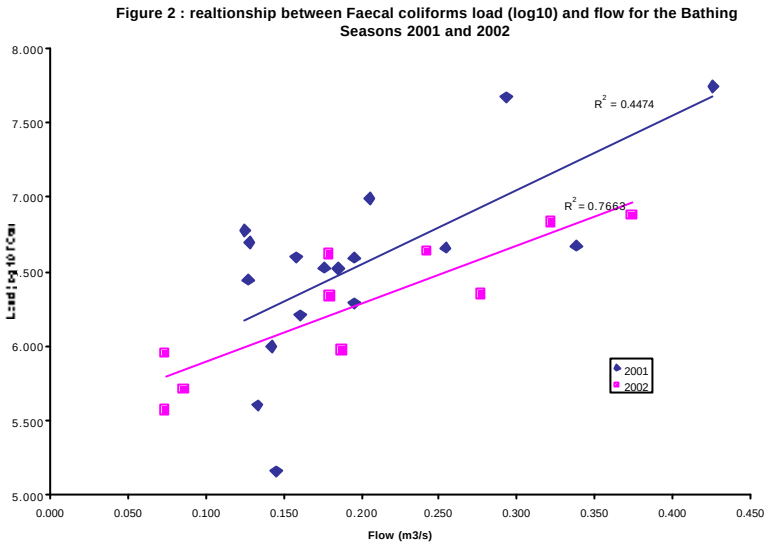


Figure 2: This graph shows the relationship between faecal coliforms load and flow at the mouth of the Figgate burn. Loads are generally smaller during the 2002 season than the 2001 season under all flow conditions.
It should however be kept in mind that the flow gauge used to gather flow data is located around 3 miles upstream of the Figgate Burn mouth

This improvement in the Figgate Burn water quality corresponds to an improvement in the water quality of Portobello West (figure 3).

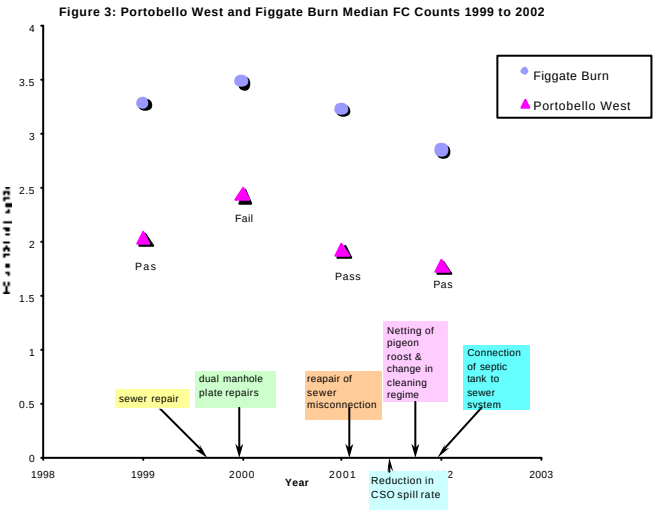


Figure 3: The improvement in the water quality of the bathing beach of Portobello West appears to be closely matched by the improvement in the water quality of the Figgate Burn, achieved through the years 1999 to 2001 (graph shows median values of all samples taken during the 4 bathing seasons).
The graph also shows some of the measures taken to improve water quality, both in terms of Scottish Water assets and of inputs from diffuse sources.

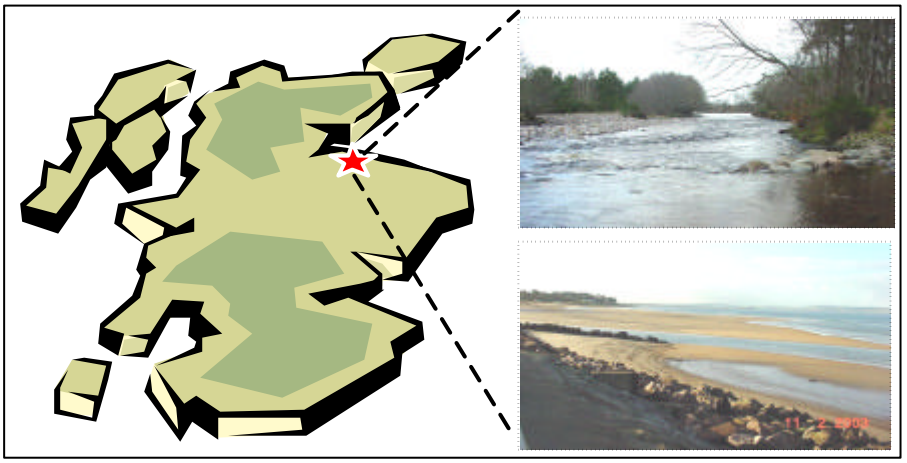
1.5 Conclusion and Current Project Status

SW original solution to address the water quality problems of the Figgate Burn and Portobello West was to replace the sewer system draining the area (the Pow Burn sewer) at a cost of around £7 million. This would not only have been a sizeable expense but it would have also meant a lot of disruption to the local community affected by the building works, significant disturbance to the wildlife and natural habitat in the large areas of parkland present along the watercourse and the use of resources such as concrete and aggregates.

The Figgate Burn project cost to date is of around £1.5m, including studies, sampling and remediation work, with the added notable advantage of having solved many of the issues in a sustainable and environmentally aware manner. In addition this project ensured that the large investments already made to eliminate direct sewage discharges into the bathing waters were not compromised by the continuous failure of Portobello West due to inputs from other sources along the watercourse, including those sources outwith SW remit.

Currently the sampling programme has been reduced to only a few sampling points and under wet weather conditions only, as it has now been established that dry weather inputs have been reduced to a minimum.

2. The River Nairn Project



2.1 Introduction

The River Nairn is located on the coast of the Moray Firth, in the North East of Scotland
In 2002, the two designated bathing waters at Nairn – East Beach, and Central Beach - were identified as being "at risk" of failing the bathing water standards. A new biological WwTW was built at East Beach in 1999, and commissioned in 2000. At the same time considerable work was undertaken modelling the network to meet regulatory requirements, and provide sufficient storm storage to ensure that the bathing water quality was not compromised. Since the new plant was commissioned the East Beach has met guideline standards for 2000 bathing water season and mandatory standards for 2001 and 2002 seasons. The Central Beach met guideline standards in 2000 and 2001, and mandatory standards in 2002.

Although Nairn Waste water Treatment Works discharges directly to the East Beach, the River Nairn (which bisects the two beaches) is believed to be a major contributor of pollutant load. A preliminary study undertaken by WRc[6] on behalf of the HRPB[7] in 1992 reported

"…it is clear that the river is a major contributor and that significant reductions in bacteriological load from upstream of Nairn will be needed to ensure compliance with the guideline values. This will be necessary even after secondary treatment is provided for the main outfall and the sewerage system is upgraded to reduce storm discharges."

[6] Water Research Centre
[7] Highland River Purification Board

Because of this SW decided to undertake a sampling programme to assess the impact of its assets on the river Nairn and the bathing waters.

2.2 Aims

- To assess the bacteriological inputs from the main Scottish Water assets
- To assess the bacteriological inputs from the Alton Burn;
- To assess the bacteriological inputs from the Auldearn Burn;
- To generate sufficient data to assist in contesting the imposition of any new standards and assessing the requirement for additional improvements.

2.3 Method

Spot samples of sewage effluents were taken at a series of WwTW discharging within the river Nairn catchment. In addition spot samples were taken from the main flow of the river upstream and downstream of the outfall pipes. Upstream samples were taken within 5m of the outfall, and downstream samples were taken a minimum of ten river widths from the outfall, access and safety permitting. At Piperhill and Croy, where the effluent is pumped to the river, samples were taken to coincide with pumping cycles to ensure representative results were obtained.

2.4 Results

The results of this sampling programme showed that although some of the WwTW have a significant impact on the riverine water quality, unidentified sources are present in at least one of the Nairn tributaries, which will undergo further sampling. The data gathered during this programme will be used to target investments at reducing the impact of SW assets into the bathing waters quality by reducing the number of assets and focussing on those areas recognised as having the greatest significance rather than upgrading each treatment work individually.

2.5 Conclusion and current project status

The Nairn project was developed as a short term monitoring programme aimed at assessing the status of SW assets and identifying areas requiring more detailed investigation.
These aims were achieved and the data gathered will be used to take the project further producing the most sustainable and efficient solution to reduce the chance of failure for the bathing waters of Nairn East and Central.

3. The Irvine Catchment Project

3.1 Introduction

The River Irvine is located on the coast of North Ayrshire in the south west of Scotland, where relatively intense agricultural activity surrounds urban developments set in a landscape characterised by hills and short rivers discharging directly into the sea. In common with all areas in the west coast of Scotland it suffers from high rainfall and occasional intense rainfall events.

The river discharges onto the bathing waters of Irvine Gailes and a number of studies have identified this watercourse to be a very significant contributor of FIO to the marine environment. The bathing waters of Irvine/Gailes have a poor track record of compliance with the bathing water standards, only achieving a mandatory pass in 2002 bathing season as a result of wet weather waiver allowances[8] and dry weather sampling.

3.2 Aims

- To assess the effectiveness of the Urban Waste Water (UWW) collection systems, urban drainage systems and septic tanks within the Irvine catchment to allow prioritisation of mitigation measures and help identify potential treatment options.

- To assess the relationships between environmental variables (rainfall, flow etc.) and faecal indicator organisms (FIO) with a view to refine and validate current and future models and studies.

- To provide information for use in ongoing modelling studies

3.3 Method

A number of sampling points were identified along the River Irvine and one of its tributaries, the Annick Water, based upon their position in relation to possible inputs and the presence of foot or road bridges from which samples could be taken. The River Irvine is characterised by a long tidal stretch. In addition to FC, TC and FS concentration, samples taken from this area were analysed for chloride content, as a surrogate of salinity. Relationships were then drawn between FIO concentration, salinity and tidal conditions.

3.4 Results

The results from this study pinpointed the major source of bacteria in terms of SW assets and highlighted the impact of environmental conditions on the water quality of both the river and Irvine Bay. Major sources of bacterial inputs were identified as being a faulty, undersized storm attenuation tank and a series of CSOs which, although taken individually are not considered to spill very frequently or in large volumes, have a great impact on water quality because of their proximity to each other and because of their location close to the bathing waters and the tidal reaches of the river.

Because of the nature of the programme and the limited amount of samples available per sampling point, it is difficult to quantify what proportion of FIO comes from the agricultural activity and what from sewage related inputs.

The analysis of the relationship between tide and bacterial concentration revealed the impact of the river itself on the bathing water quality (figure 4) as bacterial concentration in the bathing waters was found to be significantly higher during periods of receding tide than periods of rising tide. In addition it raised the suspicion that samples taken from the bathing waters under different tidal conditions are likely to give different results.

[8] wet weather waivers are only allowed in cases of rainfall event considered to be "extreme" depending on the area in which they occur

Figure 4 : Mean FC concentration at rising at receding tide

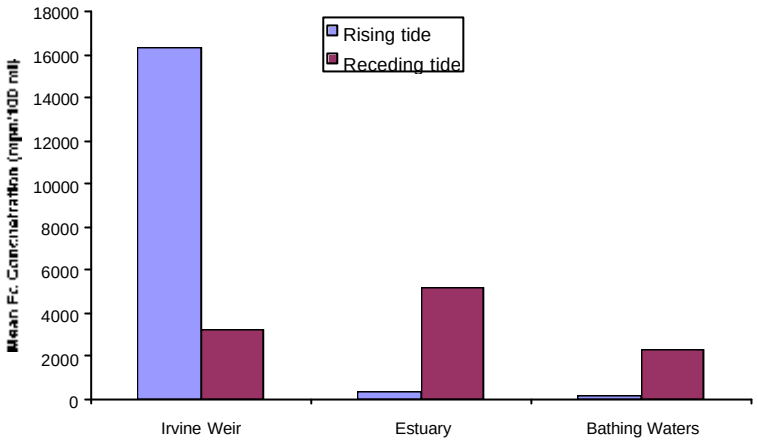


Figure 4 shows the relationship between FC concentration at the tidal sample points along the River Irvine and at the bathing water of Irvine/Gailes and tidal conditions. The mechanisms by which this occurs are not entirely clear but one explanation could be that at rising tide the flow of the river is stopped at the weir thus the higher concentration. As the tide changes the flow is allowed to reach the bathing waters causing a raise in FIO inputs (note: the same relationship occurred for TC and FS)

3.5 Conclusion and current project status

The Irvine Catchment Project is part of a strategic project aimed at improving water quality at all Ayrshire bathing waters. The Irvine catchment and the river itself are much larger and more complex than the Figgate Burn in Edinburgh, therefore the sampling programme cannot be used on its own to address the issues related to the sewerage infrastructures. However, after only one year of its implementation, the value of such an approach has been recognised by all those involved in addressing the water quality issues in Ayrshire.
As a result, data gathered during this exercise will be used to improve the predictive ability of the models being currently developed to ensure an acceptable outcome both for SW and the regulator.

The sampling programme itself will continue to take place during the 2003 Bathing season and it will be extended to cover areas, which are deemed to require further investigations and monitoring.

4. Conclusion

Monitoring of Faecal Indicator Organisms has proved to be very useful in prioritising investments for Scotland's bathing waters in a cost effective way by individuating a large number of inputs, some of which cannot be identified by common approaches such as Drainage Area Studies and modelling alone.

The Figgate Burn Project in particular shows this type of approach to be a sustainable process which identifies low cost solutions rather than focussing exclusively on high tech or heavy engineering solutions such as replacement of sewerage infrastructures and building of large concrete storm attenuation tanks. In a cramped urban situation it can prove especially difficult to find suitable sites, acceptable to the local community, in which to carry out large engineering projects of this kind. In addition such projects require a large number of resources such as concrete and aggregates and will have significant other environmental impacts and their construction, maintenance and ongoing operational costs are likely to be vastly greater than a sampling programme followed by a remediation programme.