Intelligent Asset Management & The Means For Dynamic Consenting

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Abstract

Increased pressure is being applied to our sewerage systems and the way that we manage them. Climate change is placing increasing hydraulic demands on systems at a time when environmental legislation is increasing. This is set against a backdrop of reduced public spending. Alternative methods should be utilised to operate our assets more intelligently and to meet the direct demands of the receiving environment.

Dynamic and catchment based permitting have been proposed as potential solutions as they offer the possibilities of reduced energy, chemical and carbon use. Dynamic consenting is already commonly applied in the form of wastewater disinfection during the bathing season; similarly, seasonal consents can exist where there is a large variation in summer and winter river flows to dilute effluent. However, dynamic consenting has not generally been applied at a catchment scale due to the perceived complexity of developing such a system and the difficulties in accurately predicting the environmental impact of discharges in the required timeframe.

This paper sets out a system developed to utilise modelling tools to rapidly determine the likely environmental impacts resulting from forecast meteorological conditions. In this first stage of application, the method was applied to provide predicted advice to bathers on whether to enter the bathing water or not. The real time water quality predictions were subsequently tested against measured data and were found to be accurate and offer significant improvements over previous methods.

It is proposed that such a method could be connected up via Active System Control to provide the opportunity for dynamic consenting on a catchment-wide basis. It is proposed that the current technologies exist to facilitate this, but that a significant shift in the way that discharges are licenced would be required.

Keywords

Active System Control, dynamic consenting, Intelligent Asset Management, Real Time Control, system optimisation, water quality modelling

Introduction

Despite the advances in drainage system modelling and assessment, our urban drainage networks are coming under increasing performance pressures. These pressures emerge from the familiar areas of budget constraints, tighter environmental standards and climate change. The water industry has responded accordingly, developing solutions based on Total Expenditure (TOTEX) rather than Capital Expenditure (CAPEX) and an increased asset base. However as demonstrated by European Court of Justice rulings, any approach that is taken must be based on sound science representing Best Technical Knowledge Not Entailing Excessive Cost (BTKNEEC) and be clearly supported by an analysis that weighs robust costs against predicted impacts. The case for maximising the performance of our existing assets using novel methods and technologies has therefore never been stronger.

Greenhouse gas emissions from wastewater treatment in England amount to 2.1 million tonnes CO_2 equivalent ($MtCO_2e$) per annum, with potable water treatment totalling around 0.6 $MtCO_2e$. There is clearly a large cost that goes along with this, and the addition of new pollutants and priority substances will likely add further to the demand on resources. This is clearly unsustainable, and water companies are obliged to contribute towards Climate Change Act targets. However, changing current practice is constrained by the current permitting system that has been assessed by the Environment Agency (EA) as: limiting innovation; having no ability to recognise or reward outperformance; can lead to tighter standards through being able to outperform; does not encourage multiple benefits; can be complex and bureaucratic (Environment Agency, 2011).

Dynamic and catchment based permitting have been proposed as potential solutions as they offer the possibilities of reduced energy, chemical and carbon use. Dynamic consenting is already commonly applied in the form of wastewater disinfection during the bathing season; similarly, seasonal consents can exist where there is a large variation in summer and winter river flows to dilute effluent. However, dynamic consenting has not generally been applied at a catchment scale due to the perceived complexity of developing such a system and the difficulties in accurately predicting the environmental impact of discharges in the required timeframe.

Active System Control (or Real Time Control) has fallen out of favour in recent years. However, the pressures detailed above are reigniting interest in its use. It allows significant opportunities for system improvement, with sensor, telemetry, data management and modelling methods all now at the required standard to allow complex real-time decisions to be made for catchment operation in response to forecast and observed conditions (Osbourne & Kellagher, 2013). In terms of environmental pollution studies, ASC can be linked with knowledge of the receiving environmental impacts to produce intelligent asset management that allows the pollutant load from wastewater assets to be varied in response to the demands of the environment.

This approach has a number of advantages including:

- Reduced energy and chemical use
- Manage fluctuations in wastewater influent
- Protect watercourses from acute impacts
- Reduce storage requirements by using in-sewer storage more efficiently
- Holistic approach including upstream catchment inputs
- Service incidents and operating costs reduced

It has been estimated by UKWIR that even under the current permitting regime, ASC could result in energy savings of up to 20% (UKWIR, 2013). Under a dynamic permitting system, these savings could be expected to be larger. Additionally, it has also been estimated that ASC solutions are typically less than 50% of the cost of removing the same pollutant load than traditional storage solutions (Meguro et al., 2007).

What is Intelligent Asset Management?

The application of ASC allows the drainage system to behave with intelligence. The intelligence of a drainage catchment could be defined in terms of having knowledge of current conditions and the capability to assess future conditions to determine the best course of action to achieve specified goals.

The key elements of this intelligence are:

Specified Performance Targets

The first stage of designing the system is to assess the performance criteria that should be aimed for. This may not be as simple as it sounds as in some cases, different required targets can compete against each other. e.g. Water Framework Directive drivers for a watercourse may prefer a treatment works to be removed from a catchment, but this may in fact make Fundamental Intermittent Standards more difficult to meet as a result of reduced flow to act as dilution. Customer performance targets, willingness to pay and company strategy will also all require to be considered in some cases and weighted accordingly.

Environmental Sensors

The sensors are deployed to gather critical data to inform the system of current conditions. To date, this has typically focussed on in-sewer hydraulics and rainfall. However, to obtain a full picture of the environmental impacts arising from a rainfall event, it is proposed that in-sewer quality, environmental hydraulics and environmental quality are added as these can significantly influence the decision of whether an environmental discharge is damaging or not. Technological advances in wireless, mobile miniaturisation and sensor development mean that a range of water quality parameters can now be monitored continuously including bacteria.

Rainfall Forecasting

As rainfall is the key driver, the accuracy of the predictions is key. Forecasts can be over the period of days in advance (lower forecast accuracy) or hours (high forecast accuracy). Historical data can also be useful in the case of assessing the impact of an unplanned event.

Drainage System Modelling

The modelling system used to determine flooding and CSO spills from the drainage network must be fast enough to allow a real time forecast approach to be taken. Prolonged run-times for large networks would prohibit their use.

Impact Assessment

The key criteria to be met are a consequence of the impacts that are caused. The ability to reliably predict the impacts is therefore critical and is the stage that offers the greatest possibilities for efficiencies to be achieved in design or operation. The analysis must be robust and acceptable to all stakeholders.

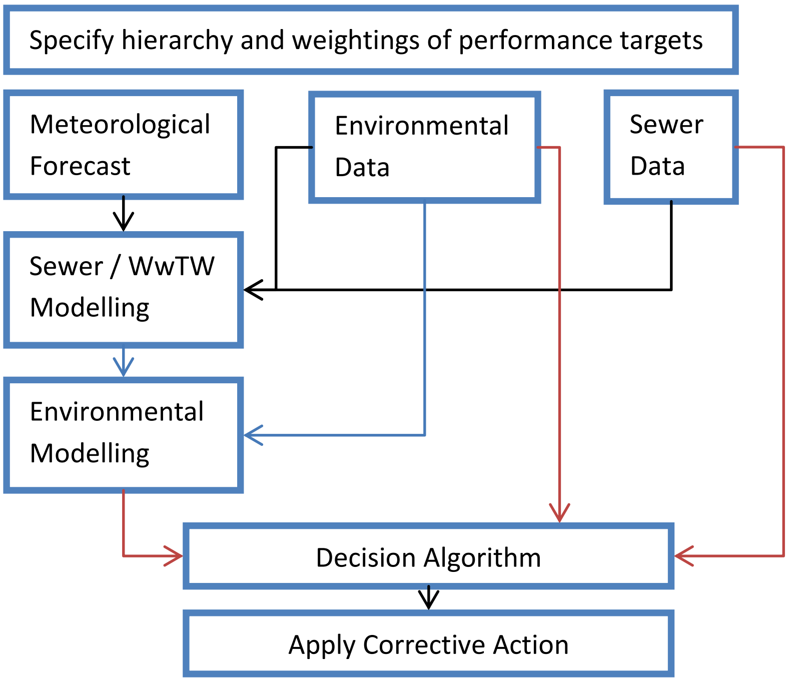
Decision Making & Implementation

This is arguably where the intelligence is applied. Within this part of the process, the relative importance of the specified criteria is taken into account, the modelling results reviewed, their reliability assessed, and decisions made to minimise the risk to customers and the environment. This stage may be undertaken either by human system controllers or may be assisted by decision making tools utilising techniques such as optimisation or neural networks.

Fitting It All Together – A System

A generic flow chart of the intelligent asset management process is given below.

Figure 1: Intelligent Asset Management System



Applying Intelligent Asset Management – Beach Management System (BMS)

The above approach was applied to the area of beach management. Under the revised Bathing Water Directive (rBWD), discounting of failing samples may be applied as long as adequate signage is in place to inform bathers that they should not use the bathing water. A variety of approaches have been developed for this, some of which address the inherent complexity of forecasting bathing water quality by being excessively conservative. Thus at some complex locations, this conservatism can lead to the closure of the bathing water following any rainfall.

To address this conservatism and the resulting poor predictions that it produces, Intertek worked in collaboration with Yorkshire Water to produce an approach that is robust enough for complex situations, yet is still flexible and fast enough to respond to rapid changes in forecast conditions or emergency situations. Figure 2 shows the schematic of the intelligent asset management approach as applied to beach management. As the system must provide rapid predictions either in response to meteorological forecasts or emergency spill events, detailed network and environmental impact modelling of each specific event was not deemed appropriate. Instead, an approach was taken whereby a very large database was created that gave both the sewerage network's response to a wide variety of rainfall events, and the receiving environment's response to a wide variety of rainfall, wind, and tidal conditions. These pre-prepared databases of modelling results allow the BMS to compare forecast conditions to all of the previously modelled scenarios and pick out the most similar to determine the resulting environmental impact. The outputs of the system were integrated into the signage system and the client's GIS systems to provide real-time updates of forecast bathing water quality and advice to bathers.

Figure 3 shows an example of the GIS based output produced by the BMS, in addition to the predicted compliance at the bathing water, a breakdown of the key contributing sources is provided along with monitoring records and details of the meteorological conditions that were used in the prediction. This provides an auditable log for all bathing water advice.

Figure 2: Beach Management System Schematic

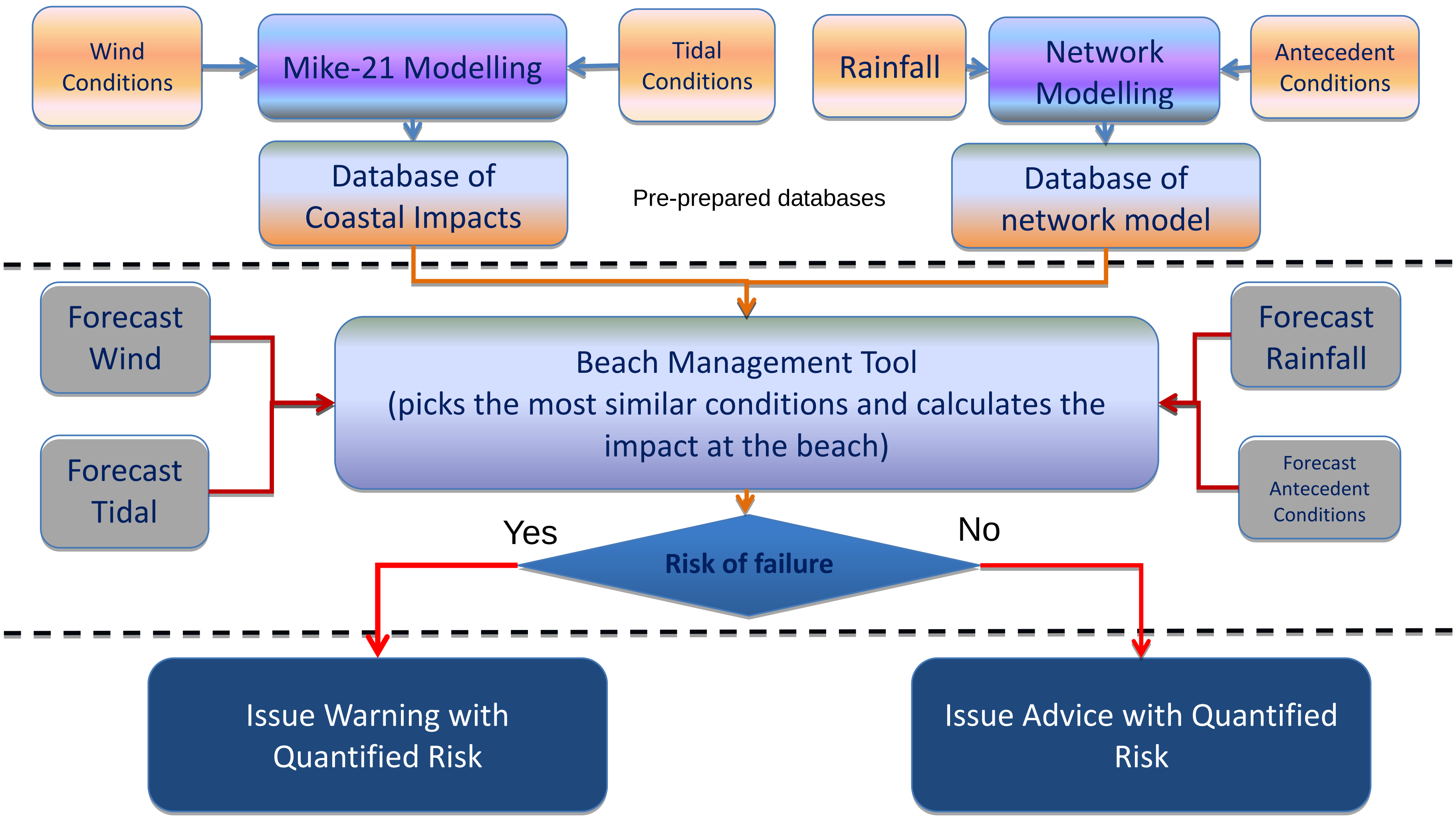
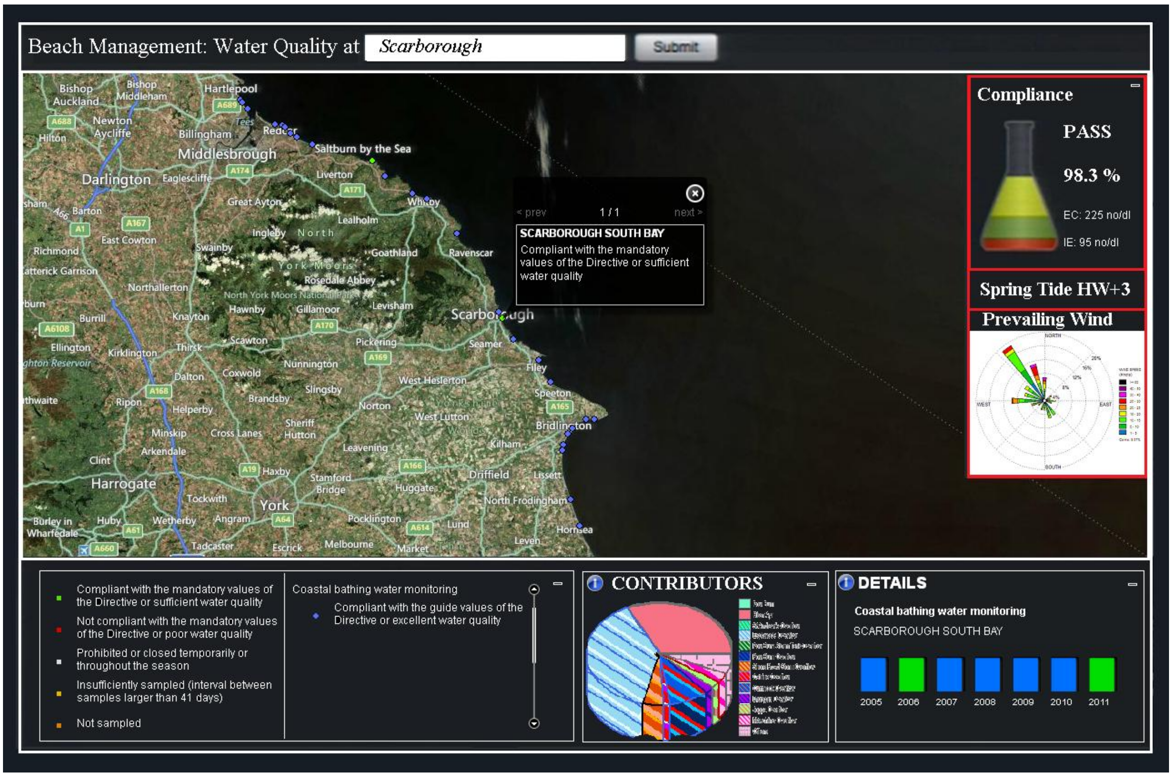


Figure 3: Beach Management System Dashboard



In the example of BMS, the implementation of the required action is very simple, as the required action is only whether to advise against bathing or not. Clearly, in large catchments looking at water quality, controlling spills, flooding and wastewater treatment performance, the sophistication of telemetry and automatic adjustment of the system is much higher. In these cases although a more complex case with increased feedback and control is required, the same basic tools and principles can be applied.

Beach Management System Validation

The BMS predictions based on weather forecasts were validated against recorded bathing water sample data. The comparisons were generally very good with three exceptions. These sites were all characterised by being dominated by diffuse or unknown non water company sources that are more difficult to define than the drainage system inputs. If these three sites are omitted from the assessment, the approach was found to be 96% accurate. The remaining 1.6% of false negative results were reviewed and in these cases the accuracy of rainfall and consistency of sample data were believed to be impacting issues.

Overall, the BMS is a significant advance over previously applied methods due to its accuracy and ability to link water quality to individual discharges and spill events. The work carried out demonstrates the applicability of the approach for the rapid prediction of water quality in response to meteorological forecast data and proves the concept for further development of linking environmental and drainage asset modelling with more complex ASC scenarios.

Table 1: Beach Management System Prediction Validation

Beach	True Positives	True Negatives	False Negatives	False Positives
Bathing Water 1	91.2%	0.9%	5.3%	2.7%
Bathing Water 2	92.3%	0.0%	3.8%	3.8%
Bathing Water 3	95.0%	0.0%	5.0%	0.0%
Bathing Water 4	75.4%	3.5%	17.5%	3.5%
Bathing Water 5	89.1%	0.0%	7.3%	3.6%
Bathing Water 6	95.5%	0.0%	0.0%	4.5%
Bathing Water 7	98.2%	0.0%	0.0%	1.8%
Bathing Water 8	85.0%	0.0%	0.0%	15.0%
Bathing Water 9	65.0%	0.0%	35.0%	0.0%
Bathing Water 10	100.0%	0.0%	0.0%	0.0%
Bathing Water 11	100.0%	0.0%	0.0%	0.0%
Bathing Water 12	56.1%	1.9%	41.1%	0.9%
Bathing Water 13	95.0%	0.0%	0.0%	5.0%
Bathing Water 14	94.5%	0.0%	2.8%	2.8%
Bathing Water 15	99.1%	0.0%	0.0%	0.9%
Bathing Water 16	100.0%	0.0%	0.0%	0.0%
Bathing Water 17	100.0%	0.0%	0.0%	0.0%
Bathing Water 18	99.1%	0.0%	0.0%	0.9%
Average	**90.7%**	**0.5%**	**6.7%**	**2.1%**
Average Ignoring 3 other sources sites	**95.60%**	**0.06%**	**1.61%**	**2.73%**
Correct	**91.2%**			
Correct + Precautionary	**97.9%**			

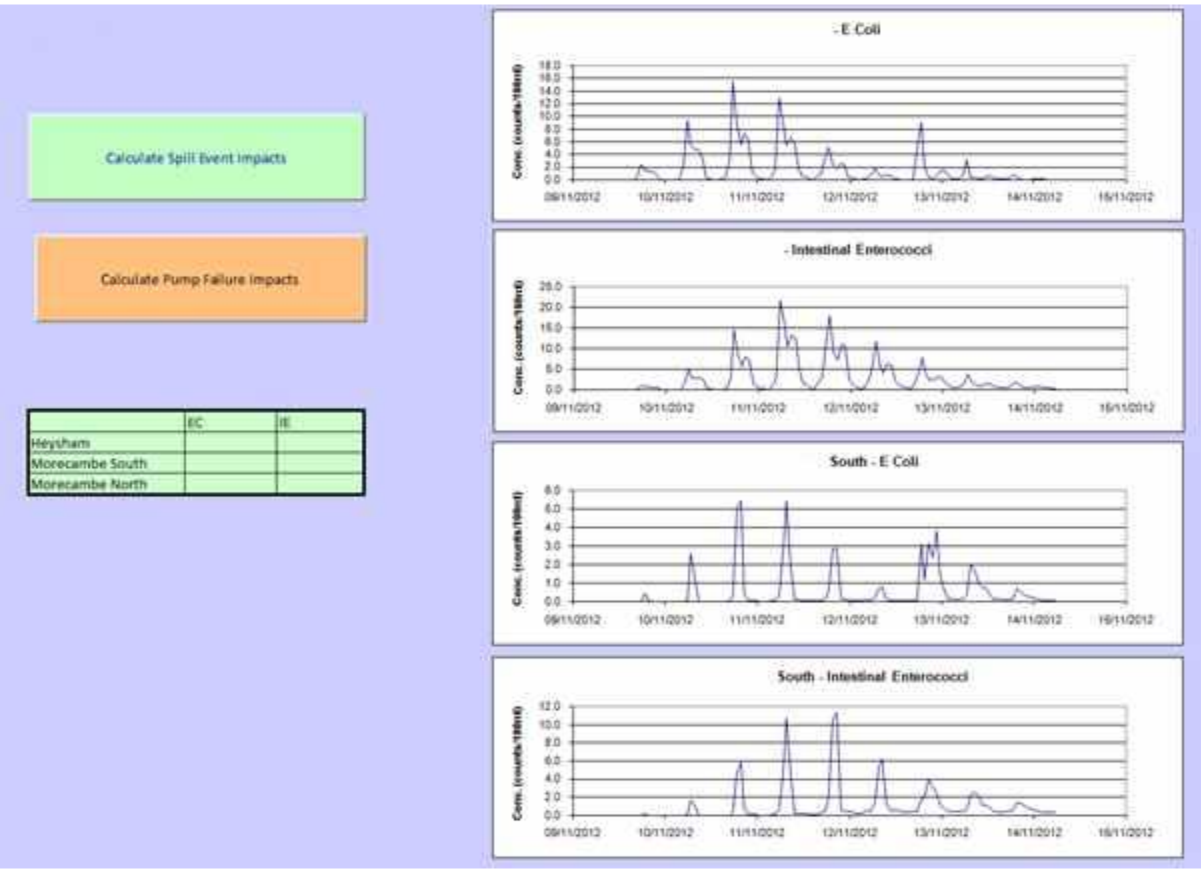
The Future of Intelligent Asset Management - Dynamic Consenting & Optimal Solutions

Current development work is on-going and is looking to apply the approach to the management of emergency operational failures and to allow system preparation before large storm events occur.

In the case of emergency operational failures, the same fundamental marine impacts database as used for the BMS is used to assess the impacts from failed assets. However, rather than using network model output data, the known failure discharge rate is used either from telemetry or from knowledge of the asset itself.

Figure 4 shows the output for four bathing waters following the theoretical failure of two assets nearby for three hours. The predictions show that the impacts are limited, could be expected to last for up to four days and that there is a significant variation in the scale of the impact depending on the tide. The instant access to such information is important in planning emergency response and providing assurance to customers that the issues are understood and are being actively managed. Additionally, such an approach allows the planning of proactive maintenance to minimise the risks of environmental incidents, or in preparation for a forecast large storm, through emptying the system prior to the event at the times least damaging to the environment.

Figure 4: Emergency Asset Failure Modelling



The approach is also being extended further to river catchments. This is more complex, but opens up increasing potential for the application of dynamic consenting and considering the entire river catchment through the use of global optimisation and decision making tools. Currently, a phosphate model has been developed that interfaces with an automatic water quality optimiser. Test catchments with phosphate issues are being sought to further test and develop this tool. Initial results have demonstrated the accuracy of the modelling and greater functionality of the optimiser and decision making tools are being developed.

Ideally this technology is proposed to be applied alongside ASC, to realise a truly dynamic catchment wide approach to water quality. Such a system would allow the optimum balance of water quality and efficiency to be achieved across an entire river catchment, varying storage and treatment levels at a number of works in response to environmental data (either forecast or recorded). At the catchment scale, the opportunities for energy savings, cost efficiencies and targeting the correct pollutant sources become viable, but this requires an alternative approach to be taken by sewerage operators, external stakeholders but most significantly the regulators. In the case of the regulator, a shift towards dynamic consenting looking at the catchment in a holistic way would be required.

Conclusions

The stresses applied to our delivery of sewerage network performance are increasing. The current approach of addressing increased legislation, storm severity and budget pressures is not sustainable. Current test projects have demonstrated that the technology exists to implement the rapid calculation of sewerage system performance and the associated environmental impacts. This is opening up new possibilities in terms of how we inform the public on bathing water performance, manage our risks and operate our assets.

A concerted push in the direction of dynamic consenting should be pursued as a means of ensuring environmental compliance, maximising the performance of our assets at least cost and reducing our carbon footprint.

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