Integrated monitoring, modelling and management of wastewater systems

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Wastewater systems have traditionally been fit-and-forget; designed to operate passively with intervention only required to address problems as and when they occur. However long-term-pressures of increased needs and reduced budgets combine to require a new approach. Integrating the monitoring, modelling and management of wastewater systems to drive Active System Management (ASM) can help to deliver improved performance at less cost.

We have recently completed an UKWIR report that sets out our vision for how wastewater systems could be actively monitored, modelled and managed by, say, 2025 and identifies what actions are required to get achieve it.

A framework for integration

We have classified systems in two ways to provide a structure to the assessment and guidance:

- How the operator or control system knows what is happening or is going to happen in the sewerage system.
- How actions are taken to manage the system based on that knowledge.

The range of complexity of systems against these two measures is shown in the matrix below with case studies identified.

Knowing what is happening		Warnings	Despatch	Operator	Local rules	Area rules	Optimiser
	Fast forecast model						Copenhagen
	Fast predictive model						
	Forecast model	Floodline	London	Portsmouth			
	Predictive model						
	Data analysis	Coastwatch		Tyneside		Cardiff Y&P S Rotterdam South Bend	
	Predictive triggers				CENTAUR		
	Reactive triggers	Flood alarm			Pump control		
		Decisions and actions					

The complexity and capability of the systems increases from the bottom left to the top right of the table; but the cost of developing implementing and operating the system also increases with complexity. There is therefore no implication that a complex method is the "best" but rather that the optimum method depends on the hierarchy of drivers and the details of the catchment.

System knowledge

Monitoring of sewer flows is increasing in the UK. For many active system management applications can be achieved by measuring only the level of water in the sewers; which fortunately is the simplest and most reliable parameter to measure. For predictive and certainly for forecasting decision strategies it is also necessary to measure rainfall to be able to predict the future flows and levels in the system.

Data communication, management and analysis is developing rapidly in other industry sectors including clean water and these technologies can be transferred to wastewater. This includes use of machine to machine mobile phone and radio communication; often referred to as the "internet of things".

Data security will be a constant battle but SCADA and data management suppliers are putting considerable effort into firewall solutions and this does provide a feasible approach for distributed area wide control and monitoring of a sewerage system.

The use of on-line modelling is relatively new in the UK. There are four types of model that may be run on-line:

- Detailed deterministic models
- Fast deterministic models
- Black box models
- Combined deterministic and black box models

For a system that incorporates active system control black box models can only be used for the parts of the system that are passively controlled and this needs to be combined with a deterministic model of the parts of the network that have the active components.

Decisions and actions

Flow controls are already in use in wastewater systems but improvements in technology are required. The most significant will be in the smart monitoring of performance and conditions so that controls are integrated with monitors of the flow conditions and also monitoring of the operation of moving parts and blockages so that conditions that require remedial action will be raised as an alarm.

There is increasing use in the UK of integrated monitoring and modelling for operator controlled systems that still retain the human operator in the decision making process but provide a decision support system that shows the operator information on the system conditions. This type of system means that operators have a much clearer picture of the day-to-day operation of their sewerage networks and their network's response to a range of circumstances, such as storms, or control strategies.

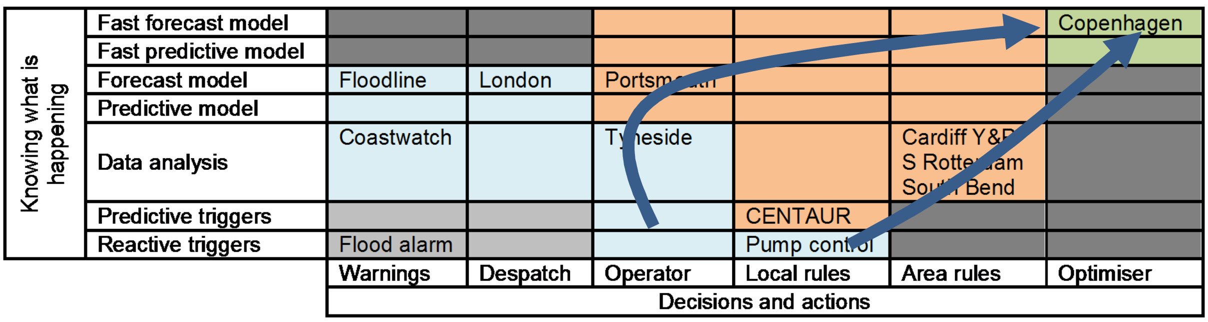
Simple flow controls are widely used but in the UK it is not usual to have more nuanced control strategies that attempt to reach a balance between conflicting objectives under a wide range of conditions. This type of system is more common elsewhere in Europe and in the USA.

Some systems in other countries use an optimisation engine to analyse many different possible control decisions for the current situation and identifies the one that gives the best outcome. The optimiser will often use a genetic algorithm method to start with a wide range of potential decisions and then combine those that give good results until an optimum is found.

A roadmap

Active system management does not have to be complex nor expensive – it is a tool that can be implemented to support management from very simple situations through to highly complex ones. The use of on-line models guiding operator managed or controlled systems is a sensible step for systems where there is an existing detailed off-line model and a need for intervention either by despatching field staff or operation from the control room.

Figure 1 Development routes



The incremental approach of developing from reactive local rules through predictive area rules and more complex area or global control rules gives a step by step approach with limited commitment of expenditure and risk at each step.

The figure also illustrates that it can be developed as time goes by, as confidence in its ability is gained, and if the need arises. It is useful to think of the future possibilities from the very first stage to ensure that any early infrastructure and strategy is capable of supporting future system developments, should the need arise, in order to get the most out of these investments in the long term.

Steps in implementing ASM

The generic steps for implementing active system control are similar whether it is for a local control or a global control but the level of detail and the amount of work in each step will depend on the scope and complexity of the proposed system.

Stakeholder engagement

Stakeholder engagement is important for best value for all sewerage outcomes but it is particularly important for active system control

Early engagement with environmental regulators, is important for the acceptance of active system control.

Specifically for active system control it is also important to engage with the operational and maintenance teams of the water company. Their role in ensuring that the chosen system can and will be operated and maintained is more significant for active system control than for passive systems.

Identify points of impact

This step identifies those points in the sewerage system where impact will first occur; whether flooding, water quality impact or other impacts. These are potential points for monitoring conditions in the sewers to drive control rules or algorithms.

Bear in mind that the most reliable form of monitoring is to measure the depth of flow. Monitoring any other parameters will incur additional costs for installation and maintenance and will give more uncertainty in data.

At this stage the ideal location is identified; practical considerations of installation, operation and maintenance will be addressed later.

Identify points of control

This step identifies those points in the sewerage system where control structures could be used to mitigate the impacts by restricting or diverting flow. The three main types of control structure available are pumps, flow controls and adjustable weirs.

Develop control rules

Develop conceptual control rules to minimise the identified impacts using the control structures. The rules should start simple with controls based on a single measure of impact but then develop to matrix decisions based on multiple impacts if required.

The rules can be reactive, based on current conditions in the sewerage systems, but can also be predictive based on short term predictions of future conditions based on the rate of change of conditions in the system.

Allocate hierarchy

Once the potential rules are identified they should be sorted into a hierarchy based on the value of the impact that they prevent. It is usual to put the least important rules first and the most important rules last so that as the list is worked through the more important rules can over-ride the earlier less important one.

Demonstrate feasibility

The hierarchy of control rules should then be incorporated into a simulation model of the system and their performance tested for a wide range of conditions to refine and improve the rules.

The performance should be assessed using the concept of system efficiency, looking at incidents where the performance of the system has impact but while there is still capacity available elsewhere in the system.

Install monitoring

Once the initial concept of the control rules has been proven then monitors should be installed in the sewerage system at the identified impact points to start to collect data to further understand the system performance and to help to identify suitable monitoring locations. This phase should last for 2 to 3 months.

Bear in mind that experience suggests that up to 50% of monitors need to be moved to give better monitoring conditions. It may even be necessary to carry out some minor rehabilitation works to provide suitable monitoring conditions at a required location.

It is advisable to have the monitors record more data than is likely to be required for the implementation of the control system; for example record at 2 minute intervals under all flow conditions. This will have an impact on battery life and data transfer costs but this is worthwhile for the initial few months of data collection.

Analyse and understand data

The data acquired from the monitors should be analysed for reliability and trends. It is important that this analysis is done as the data is received so that monitors can be moved to better locations if necessary.

Refine and confirm control rules

The control rules should now be refined based on the trend analysis from the monitors. In particular this will help with developing short term predictive rules based on rate of change of measurements.

The improved rules should be modelled and tested using a wide range of conditions including the rainfall and flow conditions measured during the data collection phase. At this stage the need to move to an optimising decision making strategy rather than a trigger or matrix strategy should be considered. The extra performance benefits of this should be balanced against the higher implementation and operation costs.

The revised rules will need to be agreed with stakeholders including the environmental regulator and the operations team.

Ongoing review

Once the system is operational there should be ongoing review process after each significant event or any system failures. There should also be an annual review to identify any longer term trends including changes in the contributing catchment, seasonal changes in infiltration flows and changes to the sensitivity of receiving waters.

Conclusions

Integrated monitoring, modelling and management of wastewater systems can be implemented to support management from very simple situations through to highly complex ones. Its consideration for all wastewater systems should be encouraged.

The use of on-line models guiding operator managed or controlled systems is a sensible step for systems where there is an existing detailed off-line model and a need for intervention either by dispatching field staff or operation from the control room.

An incremental approach of developing automated control rules from reactive local rules through predictive areas rules and more complex area or global control rules gives a step by step approach with limited commitment of expenditure and risk at each step.

Optimised automated control rules will probably require the combined use of deterministic and “black box” on-line models and a standard approach to this joint use needs to be developed so that these opportunities can be explored.