WET WEATHER SEWAGE OVERFLOW ABATEMENT PROJECT: LOTA CREEK PILOT STUDY

P Pollard

Summary
The Coastal Zone, Estuary and Waterway Management (Coastal CRC) has pooled its collective multidisciplinary expertise with Brisbane City Council (BCC) in an Effluent Management project to determine the impacts of wet weather sewage overflows on public and ecosystem health. This paper outlines a pilot study in the waterways of the coastal suburb of Lota, a residential catchment in Brisbane City.

Introduction
Sewerage systems in Australia are designed with wet weather overflow structures that discharge into local waterways when the capacity of the sewer is exceeded. Their purpose is to prevent untreated sewage backing-up and flowing into people’s homes and onto private property. Wet weather overflows are mainly caused by the infiltration of water into the sewerage system during heavy rainfall to a point where the hydraulic capacity of the system is exceeded. Water enters the sewer through the illegal connection of roof and stormwater drains (inflows) or through poorly sealed access chambers and through cracked pipes and defective joints (infiltration).

Untreated sewage is a mixture of domestic sewage, industrial and commercial wastewaters. Its final composition depends on the activities in the catchment. The overflow often comprises high concentrations of suspended solids, pathogenic microorganisms, toxic pollutants, floatables, nutrients, oxygen-demanding organic compounds, detergents, oil, and grease. Their impact on the receiving water quality may be acute or chronic, affecting water quality, posing risks to human health and the aquatic ecosystem, and potentially impairing the public use of the waterway. However, current water quality guidelines are based primarily on physicochemical, rather than biological indicators and do not accurately assess the public or ecosystem health risks associated with sewage overflows. Also the parameters used for compliance with regulatory guidelines are not sufficient to separate the stormwater impacts from those of an overflow nor do they give us the ability to follow the sewage pulse through waterway (Figure 1).

Figure 1. Sewage overflow structure in the Lota catchment with wet weather inflow and infiltration causing untreated sewage to overflow into the local waterways. Separating the impacts of the overflow from that of the storm water is critical to the success of the project.

Figure 2. The impact of the wet weather overflow must incorporate three events (a,b,c) and also separate the impacts of the stormwater from those of the overflow both in time and space. This is achieved by sampling the overflow, the receiving water upstream and downstream of the overflow during rain (a), when there is no overflow with rain (b) and when there is no overflow and no rain (c).
We are addressing the difficult issues of event sampling, sourcing and tracking the untreated sewage in the receiving waters while developing the tools to assess the impacts of overflows on the receiving waters. Here I describe the project’s innovative research approach and some preliminary results.

Project objectives

Wet weather sewage overflow concerns are common and the Effluent Management project aims to 'Research the ecological and public health impacts of wet weather sewage overflows' initially in a pilot study of Lota Creek, Brisbane'. Specifically we want to use existing methods to measure microbiological, physical and chemical water quality to assess the risk to human and ecosystem health. At the same time we aim to develop an innovative ‘tool-box’ of technologies to identify, quantify and track sources of human pollution in the receiving waters. In the pilot phase of the project our motive is to understand overflow impacts in typical urban streams to help BCC provide management options based on abatement solutions that the community is prepared to accept.

The water quality objectives and methods are based on the Australian Water Quality Guidelines for Freshwater and Marine Waters (ANZECC, 2000), BCC Water Quality Objectives and those recognised by the EPA. However, ultimately we want to establish the relationship between environmental values and water quality that mean something to the stakeholders, ie Brisbane City Council ratepayers.

Research Plan

This pilot study is focused on a single sub-catchment in Brisbane and relies on short term (12-18 months) collection of data using parameters based on:

- Environmental values (including those set by BCC for this planning unit)
- Water quality of the receiving waterways
- Composition of sewage in the Lota catchment
- Robust spatial and temporal sampling design
- Methods available to assess microbial, nutrient and toxicological risk

The sampling plan distinguishes the impact of the wet weather overflow from that of the wet weather event itself by sampling the overflow, the receiving water upstream and downstream of the overflow, during three different weather and overflow conditions (Figure 1 and Figure 2).

- Wet weather with overflow
- Wet weather without overflow
- Dry weather without overflow

The research is divided into four tasks:

Task 1. Characterisation of the Sewage in the Lota catchment
Task 2. Effluent Pathways and Ecosystem Health
Task 3. Management Options
Task 4. Decision Support and Public Participation

These four tasks are interdependent. Each relies on the other to generate information to move the project forward. For example, the components of the sewage in the study catchment were first identified and quantified. The parameters that we are monitoring in the waterways were chosen on the basis of the components of
the sewage. Knowing the composition and concentration of the components of the sewage and the hydraulic loads in the receiving water also allowed us to assess the potential hazard of an overflow event. With this data we can begin to formulate management options based on existing environmental values and guidelines for the receiving waters (Task 3 is linked directly to the outputs of Tasks 1 and 2).

Task 4 will provide technical input to the development of the detailed decision support system. This task will develop appropriate multi-objective decision making frameworks to determine effective sewage overflow management options and resolve conflicting resource uses. In this way environmental planning and resource management options are rigorously and transparently assessed using the knowledge gained in Task 1 and 2. However, the community participate in setting the water quality standards. The value placed on the environment will be determined by the cost to engineer solutions – put simply, what ratepayers are prepared to accept for sewage management options.

Methods

The Lota catchment is an urban coastal environment, south east of Brisbane’s CBD. Lota Creek is the main waterway through the Lota catchment. Tingalpa Creek, in Redland Shire, is the main waterway in the adjoining catchment to the south. Both Lota and Tingalpa Creeks meet in an estuary of Moreton Bay. The Coastal CRC project focus is on the lowest lying sub-catchment of Lota (defined by BCC planning unit LT/010), a predominantly residential area.

One of the biggest challenges to the project is separating the impact on microbial and nutrient water quality of the urban stormwater from that of the overflow itself. The project is simultaneously determining when an overflow occurs, the frequency, volume and the rate that sewage and the rainfall runoff enters the waterway. This is critical if we are to assess the risk to human and ecosystem health related only to the overflow event.

To meet the above challenges we have developed an innovative alert and monitoring system for the receiving waterways and overflow structures (Figure 3). These are now operating on all the overflow structures in the Lota study catchment. The system uses alerts and loggers positioned at the Lota Creek overflow outlets to determine the angle of the flap-valve and warns the project leader when an overflow occurs. Flows in Lota Creek and important tributaries are being monitored as well as the overflow pipes. Rainfall is being monitored using six rainfall gauges in the catchment while in the receiving waters pH, dissolved oxygen, temperature and conductivity are continuously measured and logged. Each of these parameters can be checked remotely at any time.
Once the project leader is alerted to a flap-valve opening, he remotely initiates a sampling routine. The routine starts with the triggering of autosamplers in the receiving waterways, he then runs checks with BCC that the overflow is not due to a sewerage system failure. When sure that the overflow is due only to the wet weather event and considering the weather pattern, he mobilises a 'tactical response team' (TRT) to sample Lota Creek and its tributaries. This ensures that the spread of the untreated sewage through the catchment can be captured and monitored. Our initial trials of the system and sampling routine showed that the auto-samplers could be triggered within a few minutes of an overflow event while the TRT were mobilised to sample the waterway within 60 min of the alert. There was also sufficient time to recharger the auto-sampler carousels with clean sterile sample bottles while the filled auto-sampler bottles were taken to the field laboratory for processing (Figure 4).

As the TRT collects samples they are immediately taken back to the onsite field laboratory (Figure 4) for initial processing for microbial water quality, nutrients and toxics. This laboratory is a 'pre-loved' refrigerated shipping container without the refrigeration unit (2.4m x 6m x 2m).

Inside the laboratory the temperature variation is ± 2°C. We have installed benches, sinks, mains power and lighting to ensure on-site rapid processing of biological water quality testing at any time of the day or night. The field laboratory

Table 1. Microbial water quality of Lota's untreated Sewage. Samples were taken from the 'Wet-Well' during peak flows. The analyses were carried out as per the recommended methods of the 'American Public Health Association' and also by Queensland Health and Scientific Services. Total bacterial numbers were determined using epifluorescence microscopy according to Pollard and Greenfield (1997).

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>Unit</th>
<th>Lota Sewage</th>
<th>Domestic Sewage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacteria</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Number of Bacteria</td>
<td>cells per ml</td>
<td>98 300 000</td>
<td>400 000 000*</td>
</tr>
<tr>
<td>Faecal Coliform</td>
<td>CFU per 100ml</td>
<td>35 000 000</td>
<td>100 000 000*</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>CFU per 100ml</td>
<td>35 000 000</td>
<td>10 000 000*</td>
</tr>
<tr>
<td>Faecal streptococci</td>
<td>CFU per 100ml</td>
<td>1 300 000</td>
<td>1 000 000*</td>
</tr>
<tr>
<td>Enterococci</td>
<td>CFU per 100ml</td>
<td>600 000</td>
<td>100 000*</td>
</tr>
<tr>
<td>Clostridium perfringens</td>
<td>spores per 100ml</td>
<td>280 000</td>
<td>10 000*</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>CFU per 100ml</td>
<td>50 000</td>
<td>100 000*</td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td>CFU per 100ml</td>
<td>10 000</td>
<td>1 000*</td>
</tr>
<tr>
<td>Salmonella spp</td>
<td>per 1L</td>
<td>typhimurium isolated</td>
<td>40 000*</td>
</tr>
<tr>
<td>Vibrio cholerae</td>
<td>per 1L</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td><strong>Protozoa</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Giardia cysts</td>
<td>per 1L</td>
<td>3,000</td>
<td>30 000*</td>
</tr>
<tr>
<td>Cryptosporidium oocysts</td>
<td>per 1L</td>
<td>&gt;25</td>
<td>10-100*</td>
</tr>
<tr>
<td><strong>Viruses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Somatic Coliphage</td>
<td>PFU per 100ml</td>
<td>79,000</td>
<td>1 200 000*</td>
</tr>
<tr>
<td>ND = not detected</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFU = Colony Forming Units</td>
<td>+Long and Ashbolt, 1994</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PFU = Plaque Forming Units</td>
<td>@Lucena et al., 1996</td>
<td></td>
<td></td>
</tr>
<tr>
<td># Pollard and Greenfield, 1997</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
is also an important secure and dry storage area for field sampling gear and monitoring equipment. The QCA’s Fine Arts department at Griffith University incorporated the theme of the project (Figure 4) in the art covering the shipping container. Their work is appreciated by the local residents and has earned the respect of the local graffiti taggers.

Results and Discussion

The first of the four project tasks listed above have been completed. We found constituents of the sewage were consistent with the land use of Lota’s catchment – typically domestic. Pesticides and herbicides, phenols and chlorinated hydrocarbons were either below detection, or below the ANZECC (2000) trigger values. However, some metals and estrogens hormones have been found at biologically active concentrations in Lota’s sewage and therefore they are being monitored in the receiving environment.

The wet weather event will dilute the sewage in the sewerage system and in the waterway; our project will determine the degree of this dilution. However at this stage of the study, we have found that more than half of the organic matter present in the sewage in dry weather is in the form of particulate organic matter, with the turbidity measurement an order of magnitude greater than recommended by the ANZECC (2000) guidelines for aquatic ecosystems in estuaries and low land rivers. Increases in particulate matter in aquatic ecosystems have the potential to adversely impact the waterway downstream of an overflow in two ways.

The first is by reducing the light and limiting primary production (algae and cyanobacteria). The second is related to human health. Pathogenic bacteria and viruses adhere to particulate organic material. This makes them more stable in the water column than their free-floating planktonic counterparts. However, in terms of future management options this observation is very valuable. It suggests that removing the particulate material from the effluent at an overflow structure would halve the organic material as well as removing the more stable adsorbed pathogens. Determining the value of removing this particulate material from the untreated sewage will be a valuable outcome of the project.

Microbial Indicators of water quality

Many different microorganisms have been shown to be involved in waterborne disease outbreaks. It would be impossible to routinely test for every viral, bacterial, fungal or protozoan pathogen that represents a risk to human or ecological health. Apart from both the cost and the immense resources required, the diversity and complexity of the methods make it impractical (Moe 1997). Water quality objectives are usually based on monitoring indicator organisms which represent the behavioural and survival characteristics of potential pathogens (WHO, 1998; Baker and Herson 1999; Ashbolt et al., 2001). E. coli/enterococci indicators, persistent spores from the faecal bacterium, Clostridium perfringens and coliphages are often used to indicate the possible presence of the hardier enteric pathogens (Ashbolt et al., 2001). Therefore, we are monitoring these indicator organisms in the receiving waterways of Lota to model the survival of pathogens and assess the public health risk.

Table 1 compares the types of indicator organisms we found in Lota’s sewage with those one can expect. Most pathogen indicators were five to six orders of magnitude greater than the World Health Organisation (WHO) Microbiological Water Quality guidelines (2001) and the ANZECC (2000) for recreational use and also the Water Quality Objectives set by BCC in 2001 for Lota Creek (faecal coliforms). The release of wastewater containing pathogens into the receiving waterway is of public health concern because concentrations of indicator organisms in overflows are usually greater than 10⁸ per 100 ml, as is the case for Lota’s untreated sewage (Table 1). Dilution into the receiving water is rarely sufficient to eliminate the potential risk (Moffa 1990).

E. coli are a subset of the thermotolerant (faecal) coliforms and the preferred group (WHO 2001) to indicate faecal contamination from warm-blooded animals, including humans. Table 1 shows that faecal indicators exceed guideline values set for recreational waters and primary contact for Brisbane City Council. BCC’s guideline for microbial water quality parameters for ecosystem protection and visual recreational value is faecal coliforms at 1000 organisms per 100ml. For recreational or primary contact the limit is 150 organisms per 100 ml. Table 1 shows Lota’s sewage exceeds this limit by between five and six orders of magnitude under dry weather conditions. To meet the guidelines for Lota Creek the receiving waters must...
assimilate this high microbiological load rapidly through either dilution or decay in a wet weather event.

Most of the physical and chemical characteristics were between one and two orders of magnitudes greater than the recently released guidelines set for aquatic environment by ANZECC (2000). These parameters have a greater potential for dilution down to acceptable concentrations in the receiving waters during a wet weather event.

Coliform counts are set down as the basis of the regulatory guidelines for microbial water quality. However, in the research context of this project we need more sensitive and specific parameters to follow human contamination in the receiving water. Human sterols are proving to be a reliable means of separating the faecal coliforms of humans from that of other warm blooded animals (Leeming, 1996; Leeming et al., 1996;1998). Leeming (CSIRO, Hobart) is applying these methods in this pilot study to show a similar ability. In dry weather sampling of our study catchment the main source of coliform contamination in the receiving waters has been herbivore in origin (there are horse paddocks in the study catchment). This observation would not have been possible if we had only used coliforms as indicators of human faecal contamination.

**Conclusion**

The rate of dilution of the overflow due to rainfall is going to play a major role in determining concentrations of the pathogens and chemicals in the receiving waters of Lota Creek. In a wet weather event, untreated sewage will be diluted by stormwater entering the sewer as well as when the effluent enters the waterway. The results of our study highlight the importance of quantitatively measuring the volume and flow rate of the effluent leaving the overflow structure and the rate of dilution in the receiving waters of Lota. Quantitatively measuring these parameters is a major research focus of Task 2. We are developing innovative technologies for an in-field 'tool-box' that can be used to sample, track and source individual overflows. This innovative research is essential because there are no methods to unequivocally identify sources of faecal contamination, nor are there methods that allow the tracking of pulses of sewage entering a waterway. This will be accompanied by quantitative assessment of the longer-term spatial and temporal risk assessment and impacts of nutrients, pathogens and toxicants on public and ecosystems health. This pilot study of Lota will be completed by the middle of 2003, assuming there is sufficient rain to cause overflow events this coming summer.

**Participants**

This is collaborative multidisciplinary project involving, Brisbane City Council, Griffith University, CSIRO Marine Research, Natural Resources and Mines, CRC for Water Quality and Treatment, The University of NSW, The University of Queensland, Queensland Environmental Protection Agency and Queensland Health and Scientific Services.

**Acknowledgements**

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