DEVELOPMENT OF INNOVATIVE SEWERAGE SYSTEM ANALYSIS TOOLS FOR MELBOURNE METROPOLITAN SEWERAGE STRATEGY

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ABSTRACT

A key aspect of the Melbourne Metropolitan Sewerage Strategy involved the development and application of innovative hydraulic / pollutant modelling and assessment tools that enabled the holistic evaluation of the impacts on the sewerage system resulting from a diverse range of possible future loading conditions, customer behavioural changes, climate change and modifications to the sewerage collection system.

The tools covered the areas of dry weather flow, wet weather flows, energy use and potential energy recovery, production of greenhouse gases, costs, hydrogen sulphide generation, corrsion rate predictions and TBL analysis.

Evaluation of the possible future scenarios using the developed tools demonstrated their suitability as a platform for future integrated water system analysis and planning and assisted in the development of guiding principles used in the creation of the Metropolitan Sewerage Strategy.

INTRODUCTION

The Melbourne Metropolitan Sewerage Strategy was developed as a joint initiative by Melbourne Water and the three retail water businesses serving the city of Melbourne: Yarra Valley Water, City West Water and South East Water. The Sewerage Strategy required the creation and application of innovative hydraulic and pollutant modelling and system assessment tools developed by a partnership of Halcrow, Urban Water Solutions (UWS) and Commonwealth Scientific and Research Organisation (CSIRO).

The objective of the Strategy was to establish long term principles and near term actions to produce a robust sewage management system for Melbourne that is flexible enough to account for possible fundamental changes in sewage production (dry/wet weather flows, levels of contamination), and sewage use (recycling).

It was envisaged that the Strategy would produce:

- Analysis of the possible future changes to Melbourne due to urban growth, population, climate change and living standards;
- Tools to model the impact of those changes on Melbourne's sewerage system, and assess options to provide sewage management services in the future;
- Principles for sewage and biosolids management (i.e. a strategic direction); and
- Near term actions (5 to 10 years) in line with the identified principles for sewage and biosolids management.

Because the future is so uncertain, the Strategy used a scenarios planning methodology. This method establishes a range of plausible future scenarios, and identifies the common elements of sewage and biosolids management between the scenarios. These common elements are then used to establish the Strategy's principles for sewage and biosolids management.

To enable a holistic assessment of the impacts of a range of possible future loading regimes, behavioural changes, climate change and modifications to the Melbourne sewerage network, a suite of integrated analysis tools was developed.

The tools created and developed to undertake this analysis will be described in the following paper and their unique application to the Melbourne Sewerage Strategy will be explained.

FUTURE SCENARIOS

Uncertainties facing sewage management over the next 50 years mean that forecasting based on historical trends is not a viable approach. An expert panel developed a series of plausible future scenarios for Melbourne. Scenarios are not predictions, and are made extreme so as to test strategic approaches. The spectrum of possible scenarios was narrowed to two for a more detailed investigation using the developed modelling and assessment tools. These scenarios detailed anticipated sewage management challenges over the next 50 years. These challenges encompass the following areas:

- Climate Change and the effects on wet weather flows and coastal infrastructure;
- Water Efficiency and the effects on dry weather sewage flows, pollutant concentrations and treatment systems;
- Changing urban form and population; and
- Changing customer demands for water, recycling and sewerage systems.

MODELLING AND ASSESSMENT TOOLS

The overarching requirement of the suite of tools was to enable objective comparison of the future system performance of the two scenarios covering a range of network options. The quantitative outputs produced by the assessment tool enabled comparisons of flows, nutrients, energy use, potential energy production, Hydrogen Sulphide generation, prediction of corrosion rates, Greenhouse Gas (GHGs) production and costs across the sewerage system.

Methodology

To cover the extensive comparison requirements, a suitable tool was defined for each of the elements to be assessed (i.e. flows, nutrients, energy H_2S, GHG, corrosion and costs). This resulted in individual assessment tools being created to specifically allow a comparison of each element. The following modules were developed:

- *Hydraulic Model* – covering flows and nutrient transportation;
- *Treatment Plant / Energy Module* – covering final effluent, solids and gaseous outputs as well as energy use, energy recovery and greenhouse gas production;
- *Hydrogen Sulphide / Corrosion Rate Module* – covering H_2S and corrosion predictions;
- *Costing Module* – covering capital cost and the distribution of both capital and operating costs; and
- *Triple Bottom Line Assessment* – covering the TBL.

The primary analysis platform for the tool was the InfoWorks CS hydraulic modelling software package. The series of modules identified above and discussed further below were used to post process the InfoWorks output results.

Figure 1 illustrates schematically the interaction of the various modules which made up the full Melbourne Assessment Sewerage Strategy Tool (MASST).

Hydraulic Model

The initial phase of the modelling aspect entailed the upgrading of an existing InfoWorks CS macro model of the complete Melbourne sewerage system. An extensive geoprocessing exercise was undertaken incorporating the 2006 Census data with individual customer water billing data from the approximate 1.5 million residential and 120,000 non-residential sewerage customers. Detailed deterministic dry weather inflows were developed for both residential and non-residential sources across the system. The modelled system was required to convey eight important nutrients/pollutants:

- Biological Oxygen Demand (BOD);
- Total Suspended Solids (TSS);
- Total Dissolved Solids (TDS);
- Total Kjeldahl Nitrogen (TKN);
- Total Phosphorus (TP);
- Ammonia (NH_4);
- Copper (Cu); and
- Zinc (Zn).

Residential pollutant loads were initially developed with reference to the eight nutrients/pollutants used by Gray/Becker (2002) for residential households together with the detailed sewage sampling data collected by City West Water in the Ibrahim (2006) report.

The existing dry weather flows and pollutant loads from the model were then verified against historical data collected at over 70 monitoring sites located around the system and at the two existing Wastewater Treatment Plants (WWTPs).

With minor adjustments to the pollutant and flow parameters, the model reasonably reflected daily flows and pollutant loads across the system and at the two major WWTPs.

Developing a model that transparently and accurately reflected the current sewage and nutrient flows throughout the system was an important aspect of the whole modelling and assessment tool/modules process. Any proposed changes to population, customer behaviour and the effects of climate change could be altered in the upgraded hydraulic model and the output results would be post processed by the suite of modules to establish the comparisons between the current conditions and the future scenario conditions.

Figure 2 illustrates the Macro Model of the Melbourne sewerage system.

Treatment Plant / Energy Module

The development of mass balance treatment plant modules that processed flow and pollutant load outputs from the InfoWorks CS hydraulic model simulations was undertaken by CSIRO. These modules were based on assessing the output results from the hydraulic model with conversion assumptions based on Metcalf & Eddy (2003) and Karlsson (1996). The modules were developed to replicate the functionality of the existing Eastern and Western Treatment Plants.

The modules were used to calculate energy use, potential energy recovery and production of Greenhouse Gases (GHGs), utilising the nitrification relationship from Green, Friedler *et al*. (1998), energy demands from Kadar and Siboni (2006), energy production from Lui (2003) and GHG emissions factors from NGA (2008).

The module also included routines to process the hydraulic results from the InfoWorks CS hydraulic models to determine the energy use at the major sewage pumping stations throughout the system.

Hydrogen Sulphide/Corrosion Rate Module
An assessment of the implications that the identified future scenarios could potentially have on sewerage pipelines required an odour generation and corrosion rate module to be developed. This module, based on the Hydrogen Sulphide Control Manual (1989), processed the hydraulic model outputs and calculated the Hydrogen Sulphide generated and predicted the corrosion rates within each nominated sewer pipe.

Investigation into the control of the production of hydrogen sulphide within the sewerage system is important for reasons of safety, odour reduction and corrosion prevention.

A selection of the main trunk sewers within the Melbourne system was identified and assessed for the production of hydrogen sulphide gas and predicted corrosion rates. These were large concrete, cement lined and brickwork (with cement mortar) sewers which are most prone to the attack of aerobic bacteria, a direct cause of sulphide generation.

The spreadsheet based module allowed the adjustment of different sewage flow parameters: flow, mean hydraulic depth, Biological Oxygen Demand (BOD), temperature and pH levels. This allowed the module to assess the changes for the future scenarios as these changed the characteristics of the flows and loadings within the sewerage system.

The corrosion rate within any sewer is dependant on the levels of sulphide gas generated. Assessment of the hydrogen sulphide generated allowed the predicted corrosion rates to be calculated (and contained within a single module). The calculated corrosion rates allowed theoretical estimations to be completed on the life expectancy of the sewers. This assessment used the difference in the predicted corrosion rates for each future scenario to determine the likely increase/decrease in sewer life expectancy.

Costing Modules
To determine the impact of the future system costs, two modules were developed to assess the monetary value of the future scenarios. These were the Capital Cost and Cost Distribution modules.

The determination of the capital costs through refinement of a Capital Costing Module allowed the impacts of the future scenario changes to be undertaken (these changes were confirmed through results from the hydraulic model). The module has allowance for costs of sewer pipelines, additional wet weather storage facilities, Wastewater Treatment Plant upgrades and additional transfer systems to be determined. Typical sewer pipeline augmentation and upgrading costs were determined for a combination of sewer dimensions, depth of sewer and location of sewer installation.

The capital cost information was transferred into the Cost Distribution Module to allow the determination of the cost implications of each of the future scenario options.

In order to determine the cost of providing sewerage services at any point across the system, both capital and operating costs associated with each future scenario were distributed using the Cost Distribution Module.

The principles behind the Cost Distribution Module were defined as follows:

- Costs associated with operating the transfer system are distributed proportionally across the system on the basis of the length of each link and the rate of flow in that link (product of flow and length of link);
- Capital costs associated with augmentations to the transfer system (e.g. sewer augmentations, balancing storages) are distributed across the system on the basis of flows arriving at the site of the augmentation and source of those flows; and
- Costs associated with each treatment plant (both operation and capital) are distributed across the system on the basis of flows arriving at the treatment plant and the source of those flows.

These principles were then used to assign both operating and capital costs to each individual sewer link within the sewerage system in a cumulative manner, thereby providing the functionality basis for the Cost Distribution Module. The basis of this module identifies the cost at any sewer length as "*the cost of transferring flow through a section of sewer plus the cost at the downstream node/manhole".*

Triple Bottom Line Module

The Triple Bottom Line (TBL) assessment module utilised the work completed by Yarra valley Water in developing a TBL Assessment Model. This includes the three primary assessment criteria: Economic, Social and Environmental. An appropriate methodology, approach and scoring criteria were specifically developed to accommodate the potential impacts of the future scenarios.

RESULTS

The results identified challenges such as increases in odour and corrosion, increase in wet weather spills, capacity constraints, WWTP limitations and aging assets. Opportunities identified included the potential ability to recycle resources within the sewerage, i.e. water, nutrients/biosolids and energy.

The future scenarios produced for assessment in the project are by definition extreme, although plausible, and as such the results have not been commented upon at this stage.

CONCLUSIONS

The modelling and assessment tool/modules were created, developed and tested via a number of representative future sewerage system configurations and behavioural changes. The results illustrated a number of key areas for further detailed investigation and successfully demonstrated their suitability as a platform for future integrated water system analysis and planning. This enabled the production of the draft 2009 Metropolitan Sewerage Strategy detailing the direction and recommended actions for the Melbourne Sewerage System for the next 50 years.

ACKNOWLEDGMENTS

The authors would like to acknowledge the assistance for various staff members within Melbourne Water and the three retail water businesses: Yarra Valley Water, City West water and South East Water for their cooperation during this project.

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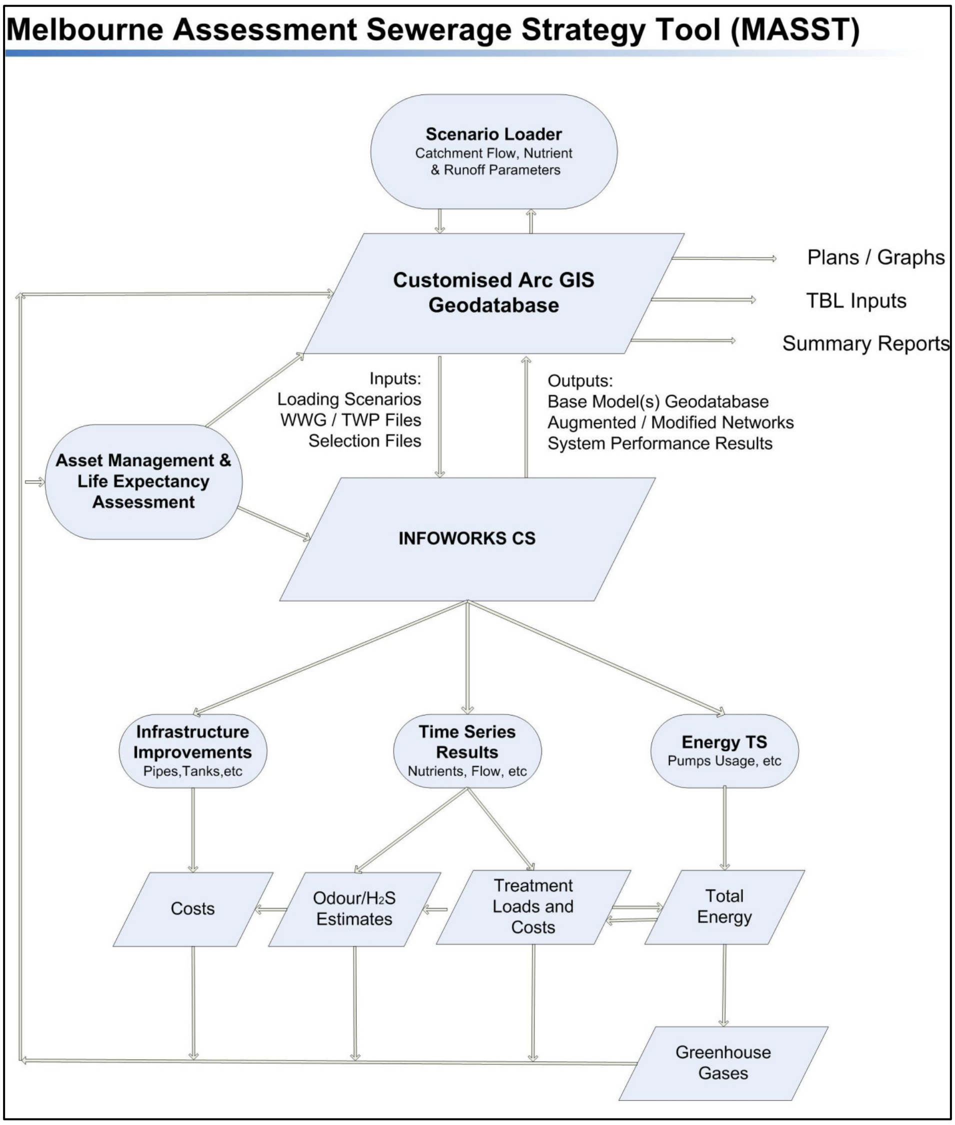

Figure 1: Melbourne Assessment Sewerage Strategy Tool (MASST)

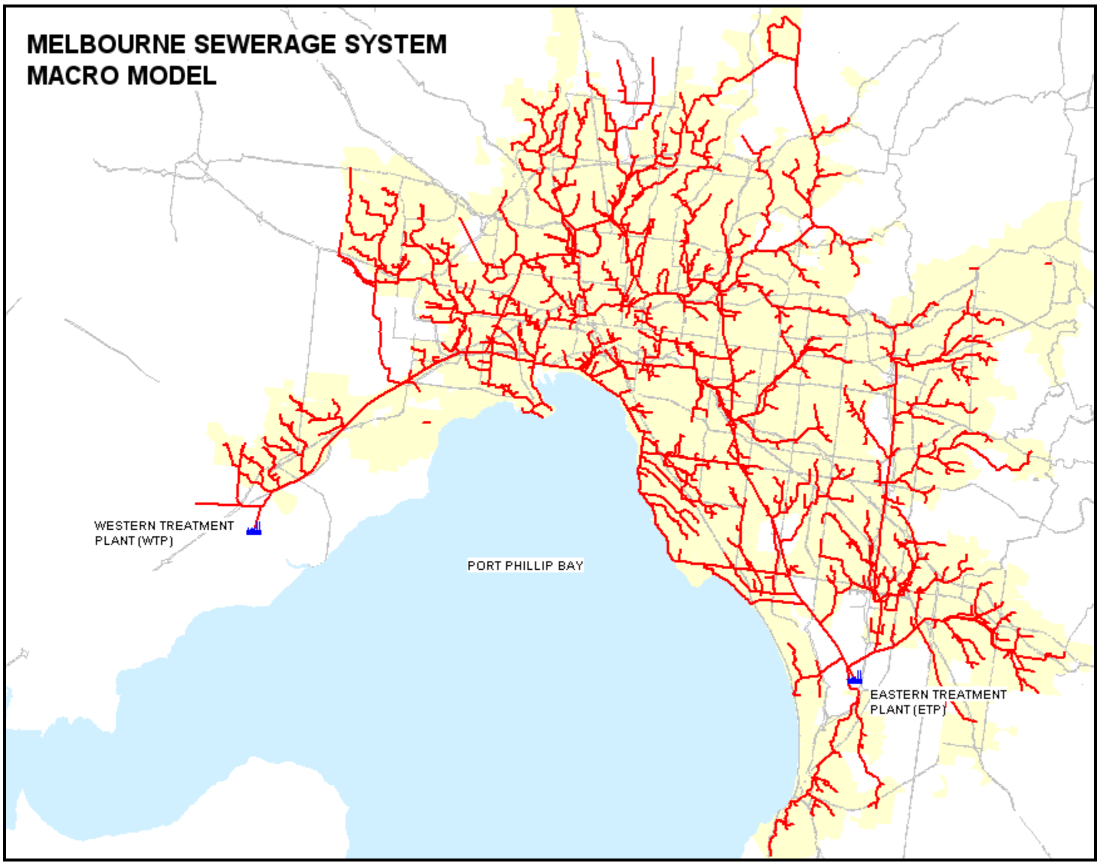

Figure 2: Melbourne Sewerage System Macro Model