The PortsE2 Decision Support System – An Application of E2

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EXTENDED ABSTRACT

The E2 catchment modelling software was used to build a decision support system, named PortsE2, to support catchment management scenario investigation being undertaken as part of the 'Better Bays and Waterways' initiative. The model developed covers the catchments of Port Phillip and Western Port Bays (Victoria) (Figure 1).

PortsE2 has 189 sub-catchments, with a network that supports sub-catchment and basin scale load estimation. It has 12 Functional Units (FU) based on land use, and one Point Source FU. Major water storages and flow control structures are represented, as are major diversions. Point sources are lumped within sub-catchments, and represented by weighted flow and concentration. Five years of climate data (1994-98) drive the default scenario. This period contains dry (1997), average (1998) and wet (1995) years. Five climate-land cover groups (forest west, non-forest west, forest east, non-forest east, and urban) were used to support regionalised flow calibration. Water quality (TN, TSS, TP, Pathogen, Toxicant) parameters were obtained from field data and literature.

Management scenarios tested in PortsE2 include land use change, water sensitive urban design (WSUD) interventions, adoption of agricultural best management practices, intensification of agricultural practices, changes to point sources, climate change, and septic tank management.

Land use change planned under 'Melbourne 2030' yielded marginal increases in overall loads. An additional 180 t/a of TN is predicted to be generated within the region by 2030, putting an increased strain on the Port Phillip Bay receiving environment. Medium implementation rates of WSUD had the potential to reduce approximately 450 t/a of TN (8%), 5,300 t/a of TSS (22%), 70 t/a (4%) of TP and 15 t/a of toxicants (43%).

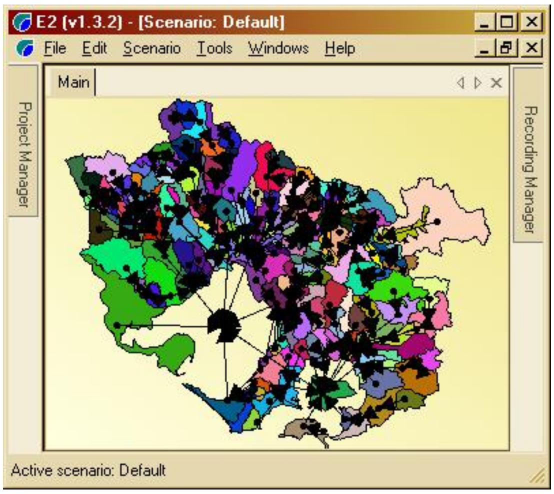

Figure 1. PortsE2 catchments and network

Adoption of agricultural BMPs cut approximately 55 t/a (1%), 3200 t/a (3%), 5 t/a (<1%) and 0.2 t/a (<1%) of TN, TSS, TP and toxicants, respectively, with climate change scenarios yielding similar scale TN, TSS and TP reductions of approximately 310 t/a (2%), 3500 t/a (3%) and 95 t/a (5%). Moderate agricultural intensification had no discernible effect on load, as did septic tank numbers, while significant reductions were found to arise from point source management. Results for a medium level bushfire scenario showed Port Phillip Bay would be most affected by fire in the Upper Yarra, with increased generation of 35% TSS and 4.5% TN. A fire in the Bunyip/Tarago area was found to generate almost 25% more TSS for Western Port. These limited scenarios suggest WSUD interventions may offer the greatest load reductions.

Development and testing of these scenarios showed the significant strengths of E2 for this kind of work, with two areas identified for improvement being point source representation and model parameterisation based on small scale stormwater modelling results.

1. INTRODUCTION

Environmental managers have been making increasing use of computer simulation over recent decades, in line with both increasing complexity of the management environment and increasing understanding and experience with the use of such tools. The health of the catchments and waterways of Port Phillip and Western Port Bays (Victoria, Australia) has received much attention recently (Harris *et al.*, 1996; Government of Victoria, 1997; Argent and Mitchell, 2003; Wallbrink and Hancock, 2003), and associated with this has been the development and adoption of a range of decision support tools, such as Krakatoa (Stewardson *et al.*, 1995), FILTER (Argent and Mitchell, 2003) and YarraSIM. These tools have provided a range of both complexity and scale of coverage, and have been used to address various management issues over the past decade.

'Better Bays and Waterways' is a partnership between the Department of Environment and Water Resources, Melbourne Water and EPA Victoria, and involves funding from the Australian Government's Coastal Catchment Initiative Program, Melbourne Water and EPA Victoria. 'Better Bays and Waterways' is providing an overarching water quality management plan for the Port Phillip and Western Port region, and will coordinate investment amongst the various stakeholders involved in water quality management in the region. A focus of this program was to gain a better understanding of how current management activities are impacting on water quality. Current activities include urban development, agricultural activities, irrigation and urban water system activities, and a changing and variable climate. Six supporting projects will enhance the outcomes of the Plan. One of these supporting projects is using environmental modelling to provide a decision support system (DSS) for water quality management, described in the following.

2. SELECTION OF E2

The E2 catchment modelling software (Argent *et al.*, 2005) provides a useful and flexible tool for constructing exploratory models of catchment behaviour. It was selected for development of a DSS for Better Bays and Waterways due to the capacity to represent typical catchment-scale activities and processes at a level of complexity appropriate to current knowledge and data across the catchments, and also due to the capacity for added complexity in modelling and analysis in future as knowledge and experience develop.

3. PORTSE2 DSS

The PortsE2 DSS is an E2 model developed for the catchments of Port Phillip and Western Port Bays (Figure 2).

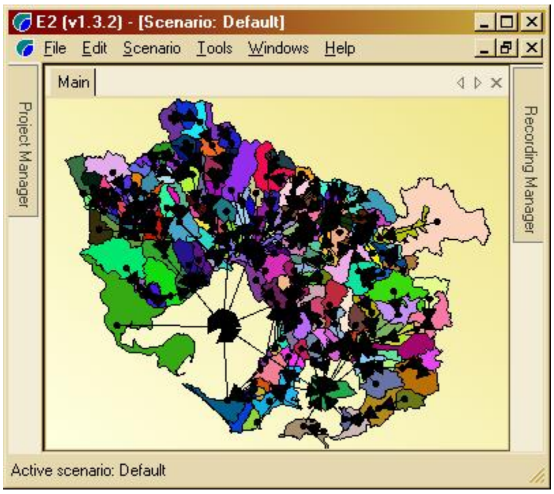

Figure 2. Default scenario for PortsE2

Construction of the model included application of a regionalised approach to flow modelling and calibration, combined with representation of the dominant flow controlling structures within the catchment waterways. Water quality was generally modelled using an event mean concentration / dry weather concentration (EMC/DWC) approach, with selection of parameters based upon a combination of monitoring data and values from literature.

3.1. Working group role and decisions

One of the key approaches contributing to the success of PortsE2 was the use of a working group in a decision making role in model development. The working group had representatives from major organisations with a stake in catchment management, including Melbourne Water (MW), the Victorian Departments of Primary Industry (DPI) and Sustainability and Environment (DSE), the Port Phillip and Westernport Catchment Management Authority (PPWCMA), Corangamite Catchment Management Authority (CCMA), and the Environment Protection Authority (EPA.

The working group took an active role in identification and specification of sub-catchments, grouping and characterisation of land uses, selection of constituents to be modelled, and representation of climate variability through development of a default scenario encompassing possible dry, wet, and 'average' conditions.

The operation of the working group was found to have benefits for stakeholders in familiarity with the modelling approach and representation of the catchment processes in E2, understanding of the data needs and knowledge underlying the DSS, and development of skills in operation of the PortsE2 DSS in a scenario investigation role.

3.2. Construction of PortsE2

Development of PortsE2 is detailed in Argent (2006). In brief, PortsE2 contains 189 sub-catchments based largely upon those used in the Port Phillip and Westernport Regional River Health Strategy. The catchment network is designed to support examination of modelled loads at basin scale (Figure 2). The model has 12 Functional Units (FU) based on land use, and one Point Source FU. Major water storages and flow control structures are represented by various methods, including E2 storages, observed flow nodes and demands. Key flow diversions are modelled using loss nodes. A range of point sources are modelled, each of which are lumped within sub-catchments, and represented by a weighted flow and concentration combination. Five years of climate data (1994-98) are used to drive the default run as these contain years that can be considered representative of dry (1997), average (1998) and wet (1995) conditions, in addition to a 'warm-up' year (Figure 3). Flow calibration was regionalised to represent five dominant characteristic climate-land cover groups (Forest West, Non-forest West, Forest East, Non-forest East, and Urban).

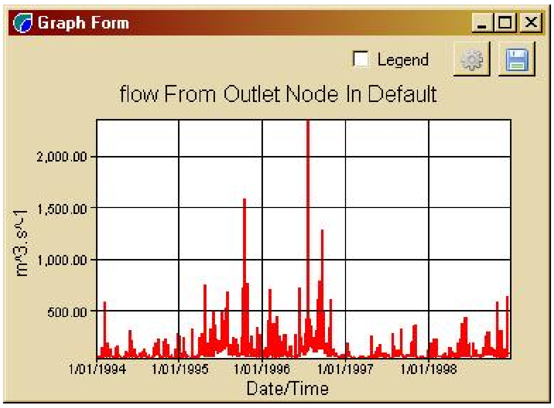

Figure 3. Flow at the outlet node, showing response to dry (1997), average (1998) and wet (1995) climate

4. DECISION SUPPORT ASPECTS

E2 is designed to offer many features for decision support in catchment management. A focus in the design of PortsE2 was clear support for decision making, including spatially explicit load information and statistics, and spatial and temporal data export for use in external applications. As with all E2 models, time series data are available for all nodes, links and sub-catchments, providing access to data for both individual and grouped areas of interest. Maps of sub-catchments loads (total and per unit area) provide key information on contributing areas, while the ability to change models, driving data and parameters provides considerable flexibility for scenario development. Post-processed information, such as statistics and exceedance charts, informs a broad range of management questions while the use of 'plug-in' models expands the set of features dramatically to also include custom built analysis and reporting tools.

4.1. Model results and outputs

The default model in PortsE2 provides a calibrated representation of the Port Phillip Bay and Western Port region, at a level of sophistication appropriate determined by the needs indicated by the DSS working group, the limitations of the DSS development project and the publicly available features of E2. It has improved understanding and knowledge of the system by providing for the first time a consistent representation of the catchment processes in one application in a format that is understood and agreed upon by all major stakeholders. The output from the default run (eg Figure 3) provides management relevant information on key hot spots, and has emphasised for the working group the importance of point source contributions to water quality and the need for accurate point source data.

5. MANAGEMENT SCENARIO TESTING

PortsE2 was built to support scenario construction and comparison, modelling the effect of scenarios on total nitrogen (TN), phosphorus (TP) and suspended solids (TSS), toxicants and pathogens, with the latter two being less certain due to sparse input data. Management scenarios tested in PortsE2 and discussed in the following sections, include land use change, climate change, the impact of fire and management actions aimed at improving water quality. These are only a few examples of the flexibility of the system, and one of the strengths of PortsE2 is the capability to support other scenarios over time as interest and needs change.

5.1. Land use change

Predicted changes in land use in greater Melbourne by 2030 suggest that there will be greater amounts of urban (residential, commercial and industrial), and both irrigated and non-irrigated pasture/cropping, and reductions in the amount of horticulture and forest (pers. comm. Department of Sustainability and Environment, 2006). A '2030' land use pattern was loaded into PortsE2, and run using the default climate series containing dry, average and wet years.

Despite more urban pollutant-generating land uses, the modelled rise in pollutants is marginal in terms of overall percent. An additional 180 tonnes of TN is predicted to be generated within the region by 2030. This result is unexpected to a degree, but not surprising given the change in runoff characteristics and concentrations from urban areas.

5.2. Water Sensitive Urban Design interventions

PortsE2 shows that although only 25% of land in the Port Phillip and Western Port region is urban, it accounts for over 65% of the pollutants generated. Accordingly, scenarios were run with PortsE2 to a) retrofit water sensitive urban design (WSUD) into existing urban areas and b) adopt best practice for all new residential development to meet 80% TSS, 45% TN and 45% TP reduction targets, in line with Clause 56 of the Victorian Planning Provisions for urban development.

Retrofitting water sensitive urban design looked at three options:

- building regional wetlands;
- incorporating raingardens (biofiltration systems) into road upgrades, and
- introducing rainwater tanks.

For each of these, low, medium and aspirational implementation figures were modelled, firstly combined within a MUSIC model (www.toolkit.net.au/music), and then the results transferred into PortsE2 through model parameterisation.

Using results from the medium scenario it was found that large reductions in all pollutants were possible, and that the most significant benefits to waterways and bays on a region-wide basis would arise from introduction of water sensitive urban design.

Within the region by 2030, model results showed that through medium implementation rates, WSUD could reduce approximately 450 t/a of TN (8%), 5,300 t/a of TSS (22%), 70 t/a (4%) of TP and 15 t/a of toxicants (43%).

5.3. Adoption of agricultural Best Management Practices (BMPs)

Almost 50% of the land in the Port Phillip and Western Port region is agricultural, and produces over 20% of pollutants. In view of that, introducing agricultural BMPs would play an important part in helping reduce overall pollutant generation within the region. However, there is a limited ability to represent these accurately in a model such as PortsE2 due to the lack of data and knowledge at appropriate scales and locality.

Based on a review of Australia-wide literature (WBM, 2006), it was anticipated that a reduction in generation of 80% TSS, 50% TN, 50% TP and 42% toxicants and pathogens could be achieved by introducing agricultural BMPs. The review also indicated that an average uptake rate of 30% could be achieved. When combined, these aspects suggest agricultural BMPs could reduce generation of pollutant loads by 25% for TSS, 15% for TN, 15% for TP, and 12.5% for toxicants.

Modelled results using these generation reductions for agricultural lands, found that agricultural BMPs could reduce generated loads of TN by approximately 55 t/a (1%), TSS by 3200 t/a (3%), TP by 5 t/a (<1%) and toxicants by 0.2 t/a (<1%). On subsequent review of results, these figures are considered more aspirational than achievable, depending on the level of incentives that were offered. The response to agricultural BMPs would also likely differ across the Port Phillip and Western Port region due to the strong rainfall gradient across the region. The west generally has significantly less rainfall than the east, indicating that returns on BMPs may be limited in the west due to the lesser volume of surface runoff.

5.4. Intensification of agricultural practices

Attempts were made to model the intensification of agriculture in PortsE2. Data were sourced from a report outlining broad changes to agriculture (Barr, 2005). To put this into the model, an assumption was made that 25% of non-intensive agricultural land uses would change to more intensive forms, i.e. that 25% of perennial horticulture would change to annual horticulture, and 25% of non-irrigated cropping/pasture change to irrigated cropping/pasture.

Modelled results showed that this had no effect on pollutant loads generated within the region. This may be because the 25% land use change was cancelled out by the additional predicted changes in land use by 2030, or simply that this 25% change was too subtle to be picked up by such a large-scale regional model.

5.5. Changes to point sources

Point sources within the model were a combination of wastewater treatment plants and industrial discharges. Only significant discharges licensed by EPA were included within the model, with flow and concentration data used where available, and licensed volumes used otherwise.

The scenario assumed that all point sources would be upgraded to a ‘best practice’ level of 20mg/L TSS, 3mg/L TN and 1mg/L TP by 2030. Where existing point sources were discharging at better quality than that proposed as ‘best practice’, no changes were made to the model.

Modelled results showed that large reductions in pollutant generation could be achieved from implementing this management option. However, there are issues with point sources as currently represented in the model. As licensed levels are modelled in situations where flow data are unavailable, there is assumed to be a general overestimation of discharged volumes and, therefore, impact on pollutant generation. In addition, some larger point source dischargers (e.g. Melbourne Water’s Western Treatment Plant) have been upgraded subsequent to the data collated for the model, and are having less of an impact than in the default PortsE2 scenario.

Modelling of point sources in PortsE2 highlighted not only data problems, but also some limitations in the publicly available version of E2. Point sources can have significantly diverse flow patterns, such as week-day, diurnal, and seasonal fluctuations. These are currently difficult to implement in E2, particularly when there are multiple point sources of different types within one sub-catchment. Addition of a custom-built plug-in model, that delivered one or many point source flows of different kinds to a node may be one solution to this, also this might confound those seeking to include point sources loads within their contributing sub-catchment.

5.6. Climate change

The potential effects of climate change were modelled in PortsE2. Average figures from a climate change study carried out by CSIRO on the Port Phillip and Western Port region suggested that by 2020 rainfall would be reduced by 2.7% and evaporation would increase by 4.7%.

Modelled results showed that reduced rainfall would reduce stream flows, and consequently reduce TN, TP and TSS loads by approximately 310 t/a (2%), 95 t/a (5%) and 3500 t/a (3%), respectively.

Additional climate change effects, such as more intense rainfall events and longer dry spells were not readily incorporated into the PortsE2 model with the available project resources.

5.7. Septic tank management

Septic tanks are a contributor of pathogens in the region and were modelled through an external process to PortsE2. The pathogen results from the PortsE2 default scenario were loaded into an external model for analysis.

Information on the location of septic tanks was surprisingly difficult to source, and was inferred through statistics from water company data on customers who paid a water rate but not a drainage rate. Data were available from Yarra Valley Water and South East Water, but these did not cover the whole Port Phillip and Western Port region.

The proximity of a septic tank to a waterway is a key factor on its effect on water quality. The spatial location of tanks was combined with a digital elevation model to identify those that were within 100m of a waterway, between 100-200m and greater than 200 metre from a waterway.

Loads from a ‘typical’ tank were estimated, along with an assumption of the percentages of tanks that are not performing to the correct standard. These loads were then combined with the location of tanks and their proximity to a waterway in order to assess their impact.

The assessment found that septic tanks have only a small influence on a regional scale, but have localised impacts on waterways, contributing up to a maximum of 10 per cent of the total pathogen load in unsewered areas. Identified hot spots were Drum Drum Alloc. (along Bass Strait), Mullum Mullum Creek, Yarra River at Warrandyte, Andersons Creek and the Dandenong Ranges. These results are in agreement with previous findings from the Goulburn River catchment (Victoria), where order of magnitude increases in septic tank numbers produced insignificant load changes at regional scales.

5.8. Fire

Although few sources of literature were available to base assumptions on the effects on pollutant generation from fire, results from a study on fire in East Gippsland, Victoria, by Feikema *et al* (2005) suggests a 15-fold increase in TSS, 2.7-fold increase in TN and a 2.8-fold increase in TP. Two additional cases were modelled to apply a concentration factor of ±30% to account for the high degree of uncertainty in the data being used. No literature was available that identified the impact of fires on toxicants and pathogens, so these were excluded from the modelling.

As the probability of fire affecting the whole catchment at any one time is very small, a number of spatially specific bushfire scenarios were considered. Six areas in the region were identified as areas subject to potential fire risks. These were French Island, Dandenong Ranges, upper Bunyip/Tarago forests, upper Lerderderg, upper Yarra and upper Maribyrnong (Figure 4).

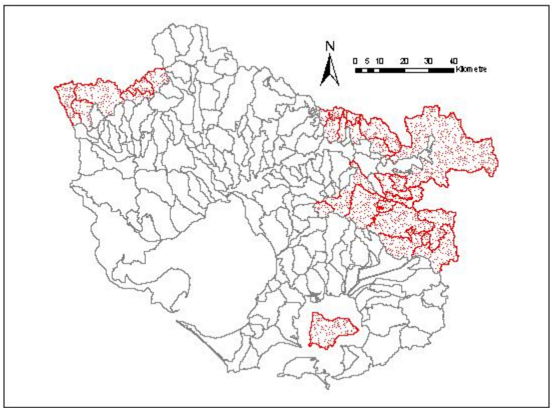

Figure 4. Catchment areas (red shaded) considered subject to fire risk.

It was assumed that one major fire would occur in any given year, and that the fire would affect 40% of the total area of forest in the selected sub-catchments. Modelling was based on a 12-month period following a major fire for the 'average' model year of 1998. It did not account for expected additional run-off from burnt ground.

Two new functional units were then created ("Burnt Forest" and "Burnt Plantation"), with areas of these FUs allocated within each of the 6 regions. Changes were made to the EMC for the additional TSS, TN and TP that would be generated.

Results showed that for the medium scenario, Port Phillip Bay would be most affected by a fire in the Upper Yarra, with 35% more TSS and 4.5% more TN being generated. Western Port would be most affected by a fire in the Bunyip/Tarago area, generating almost 25% more TSS than under normal conditions.

6. DISCUSSION

E2 was used to create a DSS, PortsE2, for the Port Phillip and Western Port Bays region. All significant factors for catchment scale modelling, such as land uses and water management, were able to be represented in the model in sufficient detail to meet the needs of the DSS working group.

Application of PortsE2 to a range of typical scenarios of interest to land managers, such as adoption of BMPs and land use change, was undertaken. In general it was found that PortsE2 supported the general range of scenarios of interest, providing relevant information on possible changes to constituent loads and allowing comparison of the effects of different combinations of actions. The scenario results suggest WSUD interventions may offer the greatest load reductions.

In some domains a lack of relevant data and knowledge hindered the parameterisation of models within PortsE2, such as with some agricultural BMPs. Although data do exist on the local scale effects of some BMPs, the knowledge of how these individual effects scale up to sub-catchments is unclear. Similarly, assumptions need to be made on the efficiency of various treatments on various constituents, with the potential for different levels of uptake also being considered.

Two areas of limitation were found with E2, one relating to point sources and the other to representation and inclusion of local scale stormwater treatment. For the first of these, improvements in the capacity to represent multiple point sources with different flow and concentration characteristics within any sub-catchment would be useful, and could possibly be delivered through development of a customised plug-in. In the second, the link between modelled stormwater improvements shown by MUSIC had to be manually translated into E2 parameters. This process may be enhanced in future by collation of the approaches and results of these types of conversions, to build up a body of useful parameterisation knowledge, and also by creating a more automatic connection between E2 and MUSIC.

Despite these few limitations, E2 was found to provide a robust platform for development of a catchment management DSS to meet the needs of a working group with a broad range of stakeholder information needs.

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