SIMPLIFIED SCIENCE: THE DST FOR LAKE CONJOLA ENTRANCE MANAGEMENT

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Abstract: A Decision Support Tool (DST) has been developed to assist Shoalhaven City Council to determine entrance management procedures for a barrier estuary, Lake Conjola, NSW. This paper outlines the steps in scientific assessment, modelling and data analysis that have led to the development of a dynamic web-based monitoring system. This system provides a transparent, accessible and updatable set of procedures linking to a works program to achieve the objectives of the Lake Conjola Entrance Management Plan. The full scope of the project has been developed within a broad decision framework, incorporating community inputs, scientific studies and interrogation of available databases. The DST is the component of this plan which describes the system for monitoring the entrance performance, the conditions that trigger initiation of entrance maintenance operations and the procedure for initiating works.

Keywords: decision support, estuaries, management, modelling, harmonic analysis

INTRODUCTION

Management of estuaries in NSW has increasingly incorporated the aim of reducing the level of interference with the natural opening and closing regime of estuaries. Entrance conditions vary in response to the balance between coastal storms which tend to close the entrance and catchment flows which enhance the tidal scouring flows through the channel. Individual estuaries range between the extremes of permanently open and almost permanently closed depending largely on this balance. Estuaries which experience significant periods of closure have been classified as Intermittently Closed and Open Lakes and Lagoons (ICOLL) and have been identified as important contributors to the spectrum of estuarine ecological conditions. As a consequence, State Government policy is to allow the entrances to open and close in as near a natural pattern as possible. However, the presence of low-lying assets surrounding some of these estuaries and the fact that many coastal villages are still unsewered introduces flooding and water quality issues that drive the pressure to manipulate the entrance conditions, usually in the form of mechanically removing the entrance constriction.

The Lake Conjola Estuary Management Plan was completed in 1998 by an Estuary Task force set up by Shoalhaven City Council under the NSW Estuary Management Program. As well as a range of strategies for the broader issues of management of the estuary, the plan identified the need to undertake an entrance management study with the objective of clearly defining the conditions under which the entrance would be opened. During its development, this objective was expanded to include consideration of works that extended beyond the immediate entrance and works that would maintain the entrance flows over a sustained period. A Decision Support Framework was constructed within which a number of scientific and modelling studies were undertaken (see Figure 2). The preparation of the Lake Conjola Entrance Management Plan is the culmination of these efforts and describes the system for monitoring the entrance performance; the conditions that trigger initiation of entrance maintenance operations; the procedure for initiating works; the works required; and the responsibilities for management of the entrance (MHL, 2002). The background studies and the Decision Support Tool developed during this process are described in this paper.

BACKGROUND

Lake Conjola Estuary

Lake Conjola is a medium sized barrier estuary located 210 kilometres south of Sydney on the NSW South Coast (Figure 1.). It has a water body area of approximately 4.3 km^2 and a catchment area of 145 km^2. While the lake body is comparatively deep with a maximum depth of 10 metres, a shallow reach some 3 kilometres long forms the lower section of the estuary adjacent to the entrance. The entrance channel is characterised by a high level of frictional attenuation of the ocean tide both via initial loss through the constricted entrance and further frictional losses along the entrance channel itself. The lake tide is in the order of 20% of the ocean tide when the entrance is open.

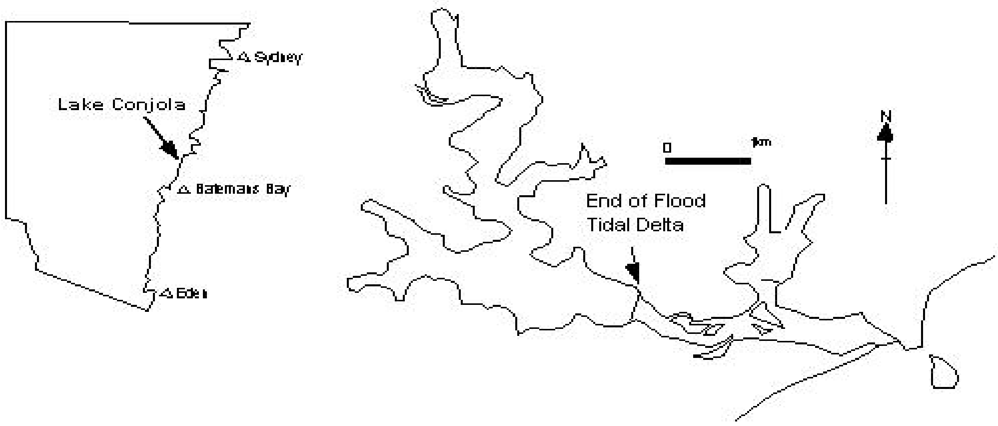

Figure 1 Lake Conjola – Location and geometry

DECISION SUPPORT FRAMEWORK

Decision support systems have become increasingly used to assist environmental managers to make complex decisions via a set of simplified rules or conditions. These support systems are generally not restricted to a single model, but rather a range of analytical and numerical tools that collectively provide a basis for making an assessment (Townend, 2002). An hierarchy of decision structures has been described by Lawrence, etc. al. (2002) including Decision Environment and Decision Frameworks. Decision Support Tools could be regarded as single components, generally more quantitatively-based; incorporated within a broader Decision Framework that would usually contain both qualitative and quantitative information. The Decision Support Framework for this study is illustrated in Figure 2.

Townend (2002), in discussing methods to identify and predict change in estuaries, stresses the need to clearly couple methodologies with temporal scales. He further asserts that, in a complex dynamic system, the system is more likely to be moving towards a steady state rather than already be in a steady-state condition. Therefore what we might wish to achieve is:

- an understanding of the various steady-states,
- an understanding of the forcing mechanisms, and
- methods to determine the trajectory of the system at various time scales.

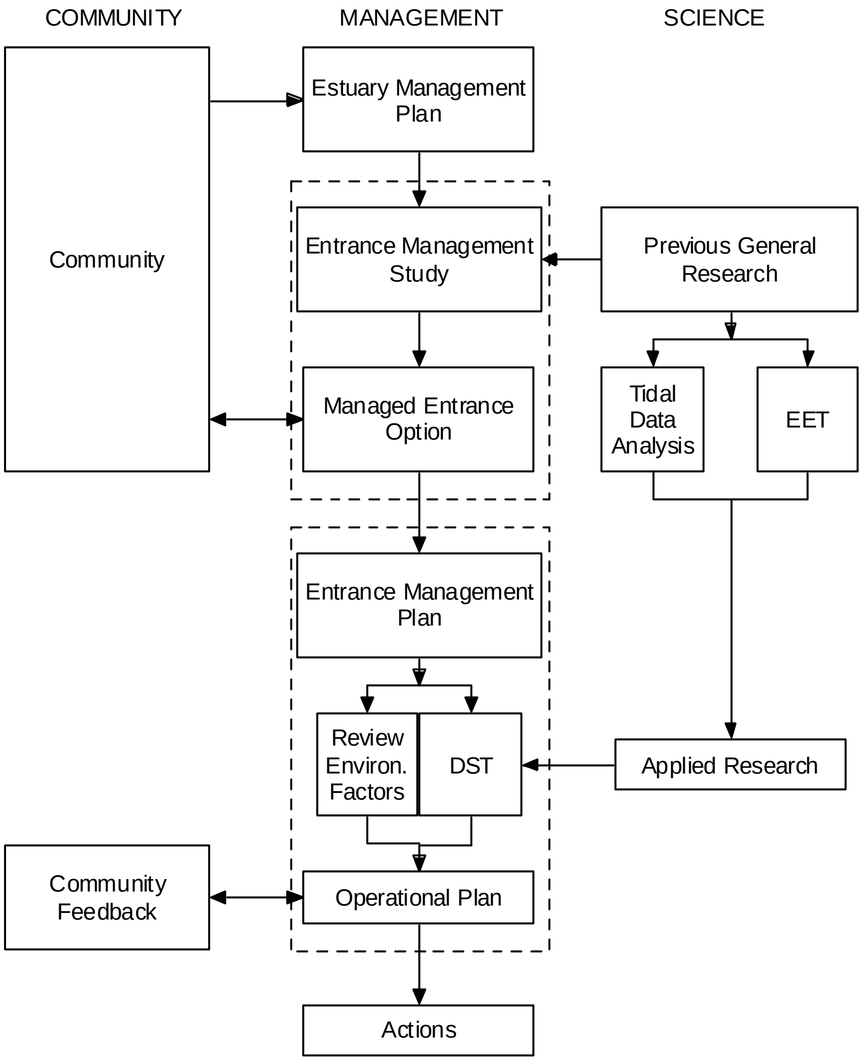

Figure 2. Decision Support Framework for Lake Conjola Entrance

Conventional mathematical models are usually limited to the exploration of single, or sequential process states and are best used to simulate and predict explicit scenarios (e.g. effects of dredging, change in system dimensions) at a point in time. In order to predict system response to net changes in processes over time, empirical or other models which illustrate the broad range of estuary response to one or two parameters (e.g. catchment flows and entrance resistance) may be more useful. The ability to track changes progressively is useful where explanation of system change is needed to develop management responses. For longer-term changes, continuous monitoring of a selected indicator (e.g. water level in the estuary) can be used as a surrogate measure of change which incorporates most of the resultant morphologic shift in the system. Thus, the Decision Framework for Lake Conjola entrance management includes methodologies that move from explanation through analysis of system states and pathways to the selection of a simple monitoring methodology, linked to trigger conditions for management actions.

The following sections describe the individual components of this framework.

Lake Conjola Entrance Study

Patterson Britton & Partners were commissioned to undertake a study of the entrance conditions over a range of forcing conditions and to present options for measures which would maintain the entrance in an open condition. The study objectives included;

- development of an understanding of existing lake processes;
- the effect of existing and previous entrance conditions on flooding and water quality;
- options for entrance management to alleviate flooding and water quality concerns.

After extensive community and stakeholder consultation, the outcomes of the study included the selection of the most appropriate entrance management regime to ensure limitation of the flooding and water quality effects through the provision of a sustainable tidal entrance to the lake.

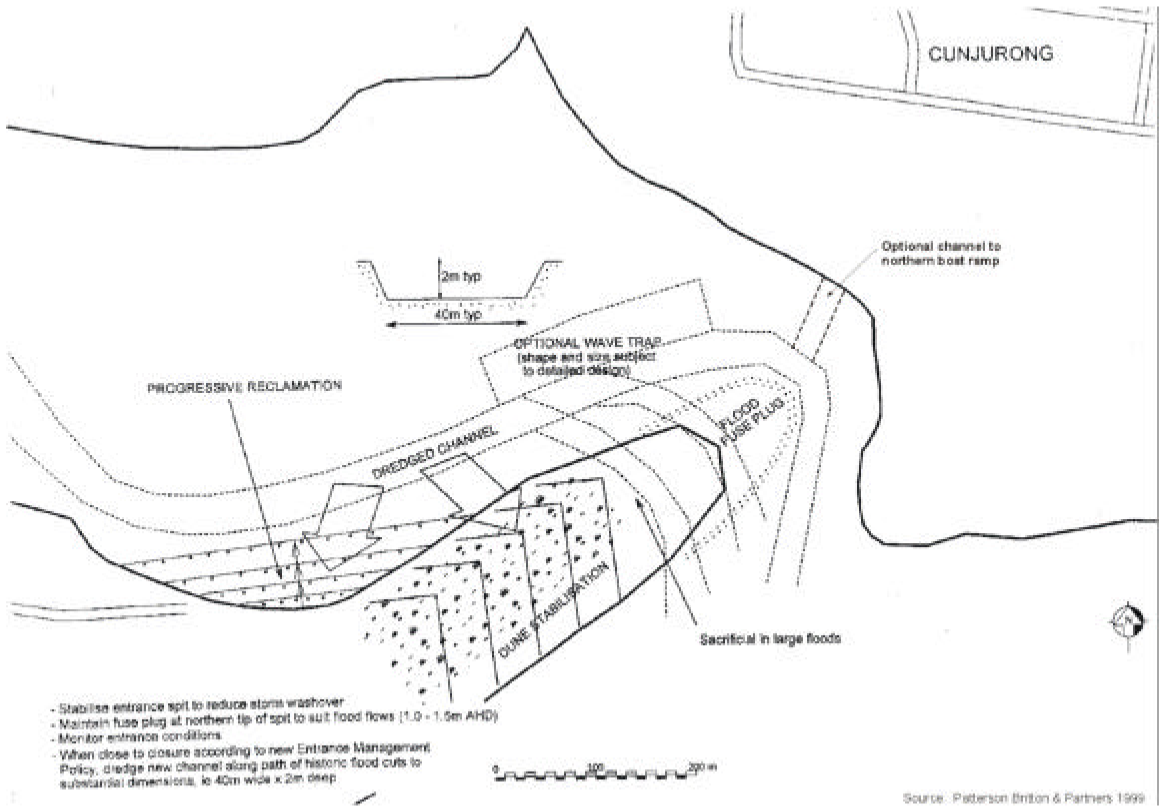

Figure 3. Selected entrance option: Managed Entrance

Methods used in the study included review of all existing data and literature on the lake processes, documentation of historical entrance closure conditions and the use of an hydrodynamic model (RMA-2) to evaluate the channel location and dimensions that would lead to a sustainable entrance. Aerial photography, hydro-survey, a tidal gauging, photogrammetry, offshore wave records, local tidal and meteorological data and existing entrance surveys were reviewed and a number of typical entrance states determined. These included closed, regime, flood-scoured and intermediate depending on the balance between the entrance maintaining tidal and catchment flows on the one hand and the injection of sand from the nearshore to the inlet via longshore drift and storm washover effects. It was clearly identified that, when catchment flows were at a minimum, the tidal flows through the entrance would gradually reduce through the action of sand transport into the entrance through the combined action of tidal asymmetry and wave stirring. If the entrance moved towards a heavily shoaled state, it was increasingly prone to closure during larger storm events via direct sand feed to the inlet as well as washover effects over the entrance sand spit.

The study developed a number of entrance management options for discussion. The final entrance option selected was for a Managed Entrance (Figure 3), based on the regime state identified during the study. This option did not include any hard works, being based on monitoring of the entrance and channel dredging when the entrance was identified as heading into a shoaled state. An entrance channel 40 metres wide and 2 metres deep was to be dredged and the sand used to build up the entrance spit to a level which would prevent washover in all but extreme coastal storms. The documentation and understanding of entrance processes outlined in this study were to underpin both the following research and the development of the Entrance Management Plan.

Tidal Data Analysis and Modelling

Previous research on the effects of a major coastal storm on inlet entrances, McLean and Hinwood (1999) had used harmonic analyses of available tide gauge records located in entrance channels to illustrate the inlet response. Pre and post-storm conditions were analysed for two different types of estuaries, including an estuary (Burrill Lake) similar to Lake Conjola, which was closed at the time of the storm. The progressive harmonic analysis methodology, developed for this earlier study was later employed for the Lake Conjola water level data to illustrate both short-term storm fluctuations and the gradual shoaling and then storm effects over a 10 month period (Figure 4). Details of these analyses and a numerical model have been reported elsewhere (Hinwood & McLean, 2001, McLean & Hinwood, 2000). Figure 4 illustrates the running 14 day value for the M2 tidal constituent compared with the original data series.

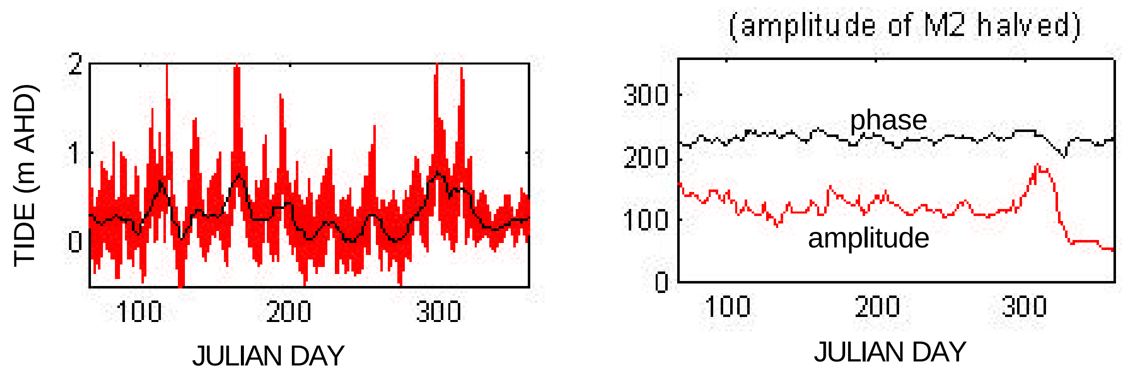

Figure 4. Progressive Harmonic Analysis for M2 - Lake Conjola Water Level Data

These analyses were accompanied by the development of simple numerical model, the Estuary Entrance Tool (EET), a single-cell model reported by Mclean and Hinwood (2000) which simulates the response of a simple estuary basin to tidal forcing and fluvial inflow. Two dimensionless parameters, a resistance parameter, *c*, and a river flow parameter, *Q*, form the basis for the model although the outputs may be dimensionalised for individual estuaries such as Lake Conjola. Outputs of the model included diagrams of tidal attenuation and entrance velocities as functions of entrance resistance and fluvial inflow. Fluvial, tidal and morphological data were examined to provide data on the progression of entrance conditions from partly closed, through scoured and partial closure by an overwash event. The entrance states identified by the Patterson Britton study can be generally located on the model output diagram. While not able to depict an inlet entrance with the same detail as a full hydrodynamic model, it has the advantage of being able to explain and predict the changes in the tidal regime of inlets under changing entrance conditions. The model has recently been further developed (Estcell Model) and is reported elsewhere (Hinwood, et al.2003).

Longer-term Analysis (MHL)

Manly Hydraulics Laboratory was commissioned to undertake the synthesis and review of available information and develop a final decision support structure in a form that could be easily accessed and used in a practical sense to manage the estuary entrance. MHL reviewed all available data and selected a modification to the methodology outlined in McLean and Hinwood (2000) to analyse the water level data for the Lake Conjola entrance channel since 1992. The only major closure event (absolute change in system state) for which records were available was the closure at the beginning of November 1994.

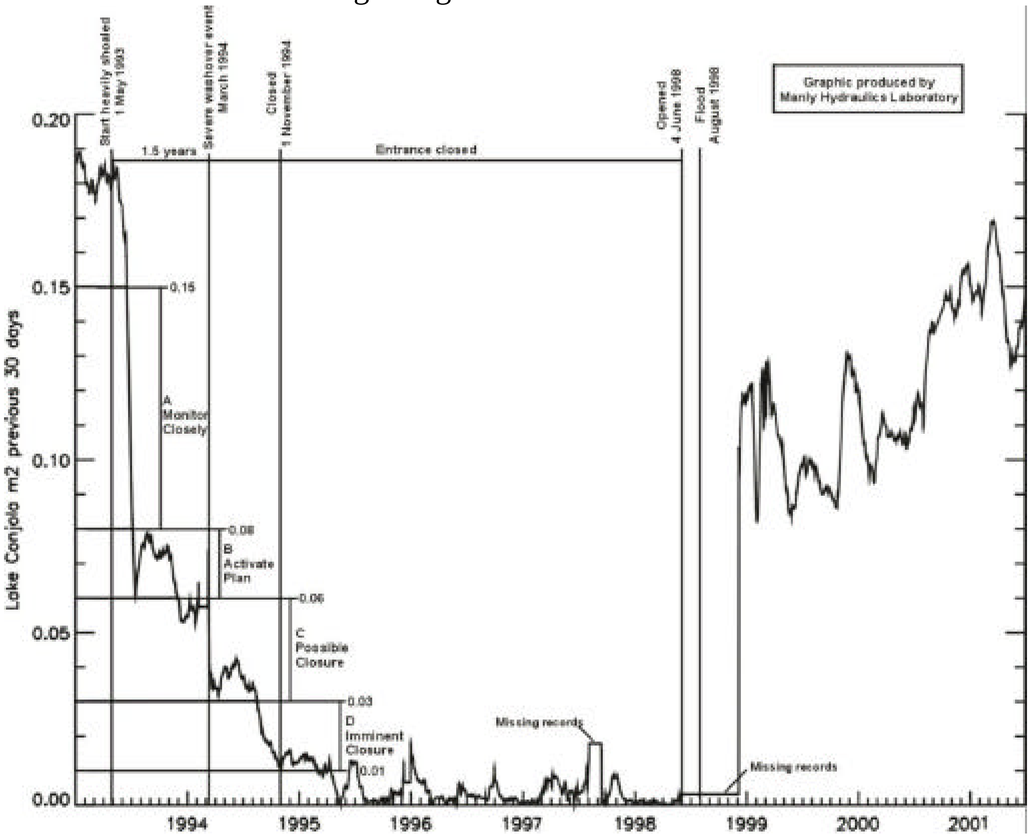

Figure 5. Lake Conjola trigger Conditions Superimposed on Plot of M2 vs Time

An harmonic analysis was conducted over the whole period of data and the constituents obtained and analysed. From this, it was determined that the M2 constituent showed a good correlation with the level of constriction of the entrance. A rolling window of 30 days was selected to illustrate the changes in the value of M2 over the period (see Figure 5). Correlation with both local meteorological data as well as wave power averages over the same time revealed the changes in tidal amplitude were not simply related to either changes in wave power or the local meteorological variables and, since only one major closure event was evident in the record, could not be represented statistically or in a probability sense.

The uncertainties arising from such a single system transfer are difficult to resolve. A number of other estuaries may be examined to determine the range of estuary response to the same sequence of events but because of different initial system conditions and local effects (i.e. too many parameters) this approach would not be productive. Tools such as the EET could be used to illustrate the effects of net changes in process versus instantaneous response to major events but it was considered preferable to use available data rather than model predictions. The most appropriate method would track the system condition over time and permit at least a qualitative assessment of the likelihood of system instability leading towards closure.

The Decision Support Tool

The method selected is to continuously measure the water level in Lake Conjola. Using a rolling 30 day window, the amplitude of the M2 constituent is obtained on a daily basis. The M2 amplitude is plotted on the trigger level diagram. Assessment of the amplitude and its trend permits both the current status and its direction of movement to be evaluated relative to the trigger levels (see Figure 6). These trigger levels were selected, based on a comparison of entrance states explained in the Entrance Management study (Patterson and Britton, 1999) with the longer-term water level and process analysis conducted by MHL.

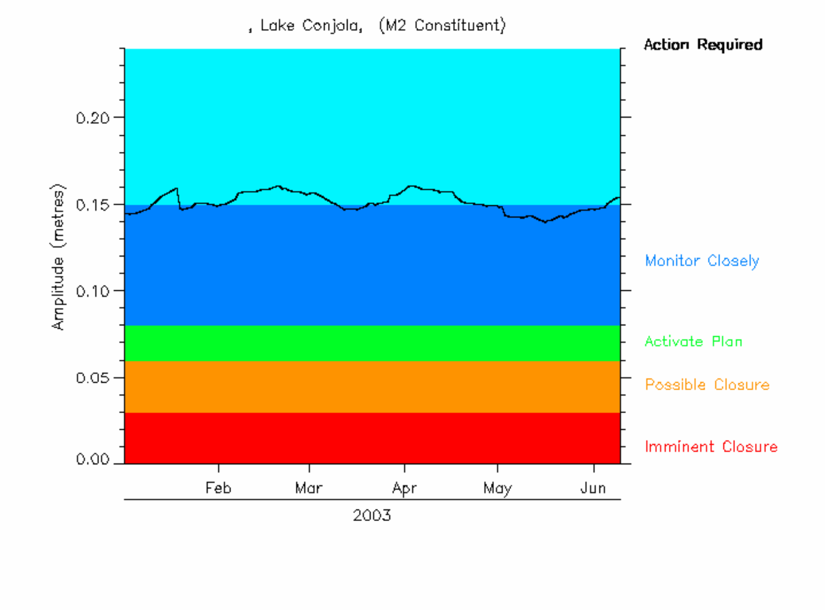

Figure 6. Trigger Level Diagram -Web-based Plot of M2 for Selected Time Period

Trigger Level A - Monitor Closely. M2 Values 0.15 - 0.08

Early signs of increasing entrance constriction, monitor carefully

Trigger Level B - Activate Plan. M2 Values 0.08 - 0.06

Constriction increasing, increasing risk of closure if major ocean storms occur but entrance may scour if there is a major flood. Commence pre-dredging activities.

Trigger Level C - Possible Closure. M2 Values 0.06 - 0.03

Entrance constricted. Complete pre-dredging activities and commence dredging.

Trigger Level D - Imminent Closure. M2 Values 0.03 - 0.01

It is imperative that dredging commence as soon as possible.

If the entrance state as depicted on the trigger level diagram moves through a trigger threshold, the next level in the Entrance Management Plan is activated. In the case of M2 values between 0.15 and 0.08, this action consists of regularly checking the M2 trend which may fluctuate, as shown in the plot in Figure 6. A consistent downward trend could provide early warning of a net movement towards closure requiring the initiation of works. The trigger levels B through D relate to the works in response to the closure trend and state and are clearly tied to the works program.

The Decision Support System will be operated by MHL on behalf of Shoalhaven City Council for an initial period of one year. A web-based monitoring system (see Figure 6) is hosted on Council's web page on the MHL web site with password protected access. The system is also available on an additional public access page. A report is to be produced by MHL including a summary of entrance performance over the year. The actions indicated by the trigger values are contained in detail in the Lake Conjola Entrance Management Plan prepared in conjunction with the DST.

CONCLUSIONS

The scientific studies relevant to environmental analysis and modelling underlying the DST for the Lake Conjola Entrance Plan have been described in this paper. The framework presented here integrates that knowledge and understanding with a simple monitoring system which incorporates key triggers and procedural steps to be undertaken if the entrance is increasingly constricted and moves towards closure. This framework and the accompanying DST have allowed the transfer of policy decisions relating to the estuary entrance to an operational tool for its management. It is both transparent and simple enough to inform the community while incorporating a range of scientifically valid studies and models in its development. Perhaps its most significant value is the transfer of operational responsibility for this management closer to the people it directly affects.

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KEYWORDS

Decision support, estuaries, management, modelling, harmonic analysis