An Integrated Water Assessment Decision Support System (IWADSS) for Government Decision Makers

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EXTENDED ABSTRACT

An Integrated Water Assessment Decision Support System (IWADSS) has been developed to aid government decision makers who deal with activities that potentially affect the water quality and aquatic ecosystem health of coastal waters. The IWADSS was produced within the Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management (Coastal CRC). It is underpinned by elicited expert knowledge on water quality monitoring and modelling approaches for particular management issues. The computer-based system was designed in a generic way to be applicable for various management issues, such as licensing discharges, across different waterbody types and spatial scales.

The area of water quality modelling can be highly technical and modelling expertise can be scarce or perhaps limited to particular software or model types. Furthermore, communication between decision makers and modellers is often poor. Although water quality monitoring is better established than modelling, the emphasis needs to be on clearly communicating program objectives, being more cost effective, incorporating evolving science and improving communication of results. The interconnectedness of monitoring and modelling is seldom explored.

The IWADSS contains an assessment approach driven by the management context supported by detailed information on modelling and monitoring. The user specifies the management context guided by the system. IWADSS is most developed for assessments required for development approval but could be expanded in the future to better guide other management contexts, such as catchment planning or water resource management.

The information contained within IWADSS is made up of knowledge bases elicited from experts on modelling and monitoring approaches developed specifically for the system. The knowledge bases provide “meta data” information on types of approaches, typical uses, the type of expertise and resources required, specific data requirements, quality assurance considerations, examples of use and links to further information. Simple categories, explanations and definitions are used to assist the user. The IWADSS and associated help system will allow the user to generate suitable assessment options or determine the suitability of a given assessment, for example with proposed development applications or licensing approvals.

This paper will present an overview of the IWADSS prototype and beta version design, associated help system and knowledge bases. A description of their development will be included.

1. INTRODUCTION

Assessment of coastal systems is difficult given potentially complex environmental issues, the large range of techniques available and the significant costs involved. For assessments of potential environmental impact, they generally involve a combination of water quality monitoring and modelling. Each assessment can differ depending on the locality and type of activity being assessed and the changes being proposed. These factors are called the management context. As a result of the management context, the environmental assessment might focus on the current and/or future situation. The assessment might focus on part or all of the catchment. Only through understanding the nature of each activity and the specific management objectives for each case can an assessment approach be tailored to the decision maker's specific needs.

Even with this understanding, information on monitoring and modelling is dispersed and experts rarely cover both fields. For this reason, the "knowledge management" on monitoring and modelling approaches is important and needs further development. For coastal systems, information can be sourced from literature or elicited from experts. However, the information and language used in each field can be highly technical. A further challenge is to present this information in a way that non-technical experts can use it.

A further challenge of environmental assessments is that they are not carried out in isolation and consider other activities or influences in the catchment. An integrated catchment and systems approach that considers the whole catchment and the interactions between parts of the catchment is required.

An Integrated Water Assessment Decision Support System (IWADSS) has been developed to aid coastal decision makers who deal with activities that potentially affect the water quality and aquatic ecosystem health of coastal waters. It contains an assessment approach driven by the management context supported by detailed knowledge bases on modelling and monitoring (see Figure 1). The specific function of IWADSS will enable the user to generate assessment options or assess the suitability of a proposed assessment, for example with proposed development applications or licensing approvals.

The knowledge bases contain important "meta data" required for reviewing a monitoring or modelling assessment. As well as being used within the IWADSS, the information will also be accessible through a stand-alone html-help system.

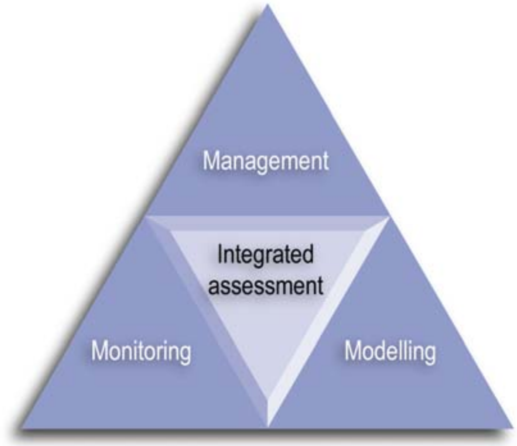

Figure 1. Relationship diagram for the three areas that drive integrated assessment within IWADSS.

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2. METHODOLOGY

The IWADSS was designed to be a desk-top delivered, knowledge-driven decision support tool. An IWADSS prototype was developed in consultation with a user group consisting of government representatives from science groups of state agencies in Australia. Broader circulation of the beta version and final product is planned. The project commenced in mid 2004 and will be completed by mid 2006.

In addition to consultation with and testing by the user group, the project involved a number of stages including conceptual design, knowledge base development, prototype design, engineering of the IWADSS software and formulation of the help system. The initial conceptual design of the system is discussed by Harris *et a.l* (2005). This formed the bases for the knowledge base development and prototype design.

The knowledge base development was a significant part of this project. External consultants were contracted to develop two knowledge bases—one for modelling approaches and one for monitoring approaches—in close consultation with the project team. A peer review process was adopted at the completion of each knowledge base. The knowledge bases were designed to allow for integration within the initial conceptual design of IWADSS.

The IWADSS prototype was largely a "mockup" with limited functionality. Its main purpose was to demonstrate the interface of the system, the types of inputs or outputs and the associated help system. The prototype was demonstrated at a user group meeting in July 2005.

The beta version of IWADSS is currently being developed in a .NET environment. The .NET environment enables development of a system in any program language with the use of Visual Studio to build the interface and links to knowledge base tables. The help system used to store all knowledge base information and descriptions of how to use the system will be developed in an authoring tool called Help & Manual. This software enables the packaging of the help system into a variety of file formats (including Adobe PDF, compressed HTML Help, plain HTML, Winhelp). The help system presents information in an easy-to-use program where information is organised through topic-based directories and is fully-searchable.

It is planned that the knowledge base information will also be released as separate published documents. Further information on products from this project are available at the website: www.coastal.crc.org.au/3M. The knowledge base and other related information will also be integrated into the OzCoast website, a key initiative of the Cooperative Research Centre (CRC) for Coastal Zone, Estuary, and Waterway Management.

3. IWADSS DESIGN

3.1. Spatial Context

One of the first challenges with development of IWADSS was how to deal with the spatial context of assessments and information. A schematic representation of the environment (land-water interface) as seen by IWADSS is broken up into three parts: the land-use activity, the freshwater system and the coastal system. This simplified spatial representation is used to aid the user to organise data availability and information needs.

Each part of the spatial environment could be considered at a local or broad scale depending on the management context. Here, local scale will generally require the user to consider the system in more detail and develop an understanding of "processes" within the system. Broad scale would generally be considered as a "black box" with a greater focus on inputs and outputs. Since the primary focus of IWADSS is with coastal systems, local scale assessment of the freshwater system will not be an option with this version of the system. Nonetheless, the freshwater system is an important consideration for coastal assessments as they are an important input to coastal systems and carry water and pollutant loads from the broader catchment basin.

An example of the IWADSS spatial analysis for a development approval for a discharge to an estuary is shown in Figure 2. It shows examples of how both land-use area and coastal waters may be considered at a local and broad scale. The local scale land-use is the development activity. The broad scale land-use would cover other discharges and diffuse run-off and may connect to the local or broad scale receiving waters. For the coastal water system, the local scale is the estuary where the discharge is occurring. The broad scale could relate to the bay or ocean adjoining the estuary. The freshwater system is only considered in broad scale as a conduit of water pollutant loads from the broader scale catchment basin.

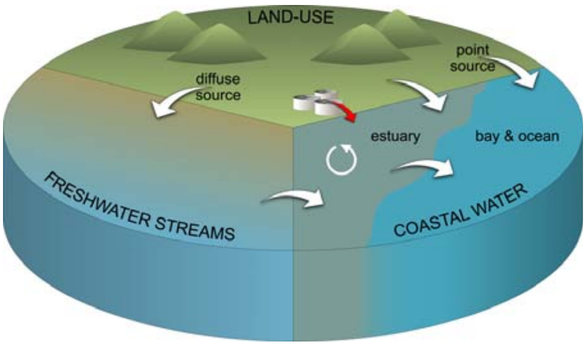

Figure 2. Example of an IWADSS spatial analysis for assessment of a new activity that discharges to an estuary

3.2. Generating Assessment Options

The first function of IWADSS is to provide the user with a means of generating assessment options for their given circumstances. This process is largely driven by information needs and data availability. The specific stages include management context, system description, data availability and assessment options. Each is discussed in more detailed below.

Stage 1- Management Context

The first stage is to define the management context. There are a number of steps to this stage. First is to define the management issue. In the first instance, this will only cover development approvals such as a new licensed discharge but in the future this step may be expanded to cover other management issues such as incident responses, catchment planning or water resource planning.

The next step of Stage 1 is to define the activity type. In the case of licensed discharges, this could include a sewage treatment plant, aquaculture farm or chemical plant and would include specific information on the exact nature of the activity. The third step is to note the location of the activity. This should be considered in context of the spatial representation discussed in Section 3.1.

Finally for this stage, the assessment objective needs to be clearly defined. In other words, what is the specific reason for the assessment? For example, for an upgrade to a large sewage treatment plant discharge, the assessment might include assessing the current ecosystem condition, the ecosystem resilience, loads to the water system, the initial mixing, the likely environmental effects of the upgrade or performance monitoring during operation.

Stage 2- System Description

The second stage in generating assessment options is to describe the system. For the specific land-use activity being assessed, this involves defining the likely hazards. As part of the monitoring knowledge base, the types and ranges of typical hazards for different management activity types has been collated and is used in the system to give a first cut of possible hazards if none are provided. The next step involves identifying the indicators for the coastal water system – local or broad scale. The IWADSS can provide a default set of indicators based on possible “hazards”, which become “stressors” on the environment. A further consideration is the type of processes that are important and should be considered. These could include physical, chemical or biological processes. In the case of organic loading as a stressor, dissolved oxygen is one indicator and important processes that can affect it include mass transfer with air, heterotrophic bacterial activity and algal respiration. It is recommended that conceptual models are developed for each stressor to understand the processes that are important.

Stage 3- Data Availability

The third stage focuses around data availability. For each potential stressor (hazard) identified in Stage 2, a set of relevant indicators can be derived. These can be divided into system inputs, coastal water attributes, coastal water processes and physical attributes. The IWADSS provides guidance as to what type of data is likely to be needed for specific assessment types. The availability of data for each is input to the system by the user. For system inputs, the availability can cover historical, current or future time periods as well as dry-weather and wet-weather times. Table 1 shows the type of information that might be captured for a sewage treatment discharge with nitrogen as the chosen stressor. Similar information could be collected for wet-weather coverage.

Table 1. Data availability of system inputs in IWADSS for a sewage treatment assessment example with nitrogen as the stressor (dry-weather coverage only)

Data Type		**Data Coverage**	
Input type	**Indicator Name**	**Current**	**Future**
Activity loads	**Total Nitrogen**	✓	✓
	Soluble Nitrogen	✓	✓
	Particulate Nitrogen	✓	✓
Other Coastal Land-use loads	**Total Nitrogen**	✓	✕
	Soluble Nitrogen	✓	✕
	Particulate Nitrogen	✓	✕
Freshwater Catchment loads	**Total Nitrogen**	**?**	✕
	Soluble Nitrogen	**?**	✕
	Particulate Nitrogen	**?**	✕

For coastal water attributes, data can also cover historical, current or future time periods, but for either the local or broad scale. Table 2 shows the type of information that might be captured for a sewage treatment discharge with nitrogen as the chosen stressor. Similar information could be collected for the broad scale.

Table 2. Data availability of coastal water attributes in IWADSS for a sewage treatment assessment example with nitrogen as the stressor (local-scale only)

Data type		**Local Scale**	
Attribute Type	**Indicator Name**	**Current**	**Future**
Chemical	nutrients (water)	✓	✕
	nutrients (sediment)	✓	✕
	chlorophyll-a	✓	✕
	dissolved oxygen	✓	✕
	temperature	✓	✕
Biological	algal blooms	✓	✕
	macrophyte biomass	✓	✕
Habitat	-	-	-

Information on data availability can be similarly generated on coastal water processes and physical attributes. The type of physical attributes required may also depend on the assessment option chosen in the end. For example, information on tides, winds and bathymetry are typically necessary for water quality modelling and subsequently highlighted by IWADSS if such an assessment option is proposed in the next stage.

Stage 4 - Assessment Options

The fourth and final stage involves generating assessment options based on the information provided on indicators and data availability. The options will cover a range of modelling and monitoring options. Firstly, data that requires checking can be used to generate assessment options. This could be the case if there is considered significant uncertainty with the measurements behind certain data. Secondly, the locations or indicators where data are not availability can be as the basis to generate assessment options to fill these data gaps. The final step takes the user through a set of principles to help refine the set of assessment. Such principles include considering the additional data required, using synergies between modelling and monitoring and using the simplest or most proven approach. Each option can then be refined and checked by using the next function of IWADSS.

3.3. Checking an Assessment Approach

The second function of IWADSS is to provide the user with a means of checking an assessment presented for a specific purpose. This is commonly required in regulatory assessments for environmental impacts of development approvals. Table 3 sets out the steps incorporated into IWADSS for checking specific modelling and monitoring approaches. .

Table 3. Stages and steps used in IWADSS to check modelling and monitoring assessments

Checking Step	Model Approach	Monitoring Approach
1. Location (Where?)	System extent (spatial boundaries, water bodies modelled)	Monitoring sites
2. Timing (When?)	Simulation periods	Sample time/frequency
3. Indicators (What?)	Inputs (baseline, scenarios) Variables (water column, sediment, biological) Processes	Measurements of system inputs or water attributes
4. Application (How?)	Model type Model design Equipment – model equations, parameters Functional tests Calibration/Validation Error/uncertainty Scenario runs Reporting	Monitoring methods Monitoring design Equipment – probe, analysers Functional tests Calibration Errors/uncertainty Field runs Reporting

The steps include checking the location of the assessment, the timing, the indicators, and most importantly, the application of the approach. In this part of the system, the user is guided through these steps and provided with relevant lists and supporting information to help with checking of the assessment approach or to do more detailed design of an assessment approach.

4. KNOWLEDGE BASES

4.1. Modelling Approaches

In general, very limited generic information is available on water quality modelling approaches for decision making. Much of the information is highly technical or relates to only specific applications. For this reason, the modelling knowledge base was developed specifically for this project. Firstly, a classification was decided for both hydrodynamic (or transport) and water quality model approaches. The classification for water quality models is shown in Figure 3. Information was then collected on 'meta data' about each classification. The information included a description, typical uses, limitations, data requirements, examples and links to further information. These categories were designed specifically to support the IWADSS functions.

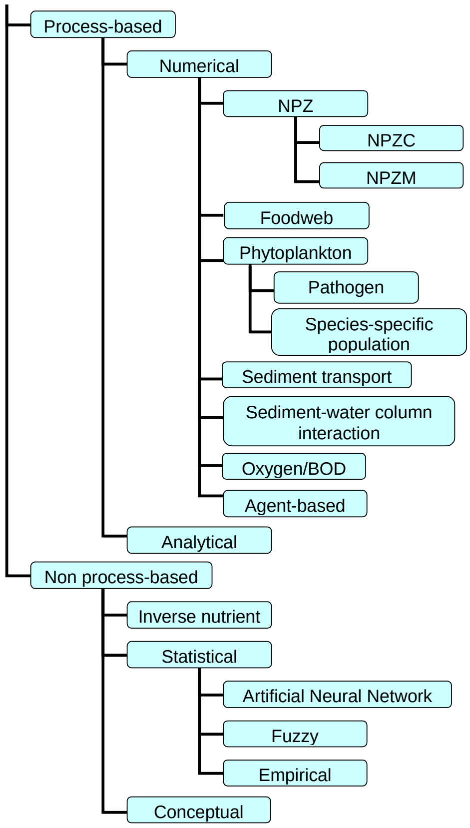

Figure 3. Water quality model classification proposed in the modelling knowledge base

4.2. Monitoring Approaches

Unlike water quality modelling, a significant amount of generic information is available on water quality monitoring. Two major resources used to structure the monitoring knowledge base included ANZECC & ARMCANZ (2000) and CRC for Coastal Zone, Estuary and Waterway Management (2004). Therefore, it was not necessary to re-develop this information as it could be used directly within the IWADSS. However, a number of areas were identified as needing to be developed. These included a better classification of monitoring that categorised existing approaches, meta data on key monitoring example across Australia and example 'end-of-pipe' monitoring data for typical industrial discharges.

5. INTERFACE DESIGN

The interface of IWADSS is currently available as a prototype version, which will differ to the final beta version of IWADSS. Figure 4 shows the introductory screen of IWADSS.

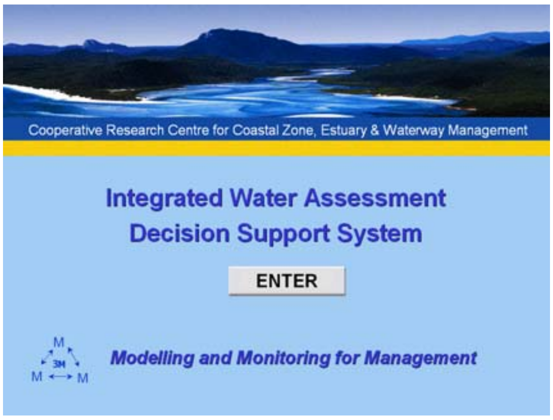

Figure 4. Introductory screen of the IWADSS prototype

Most screens appear in the form of Figure 5, which shows some questions relating to the Management Context in Stage 1. Each screen can be moved through sequentially by answering question and clicking boxes or using forward or back buttons. Alternatively, a directory is available on the left hand side of the screen and can be used to navigate back an forth through the steps. Each screen is also linked to the help screen via a help button. Other help links are also available for definition of terms and providing more information.

A view of the help system is shown in Figure 6. The directory on the left hand side can be used to navigate through information or a key word search can be used.

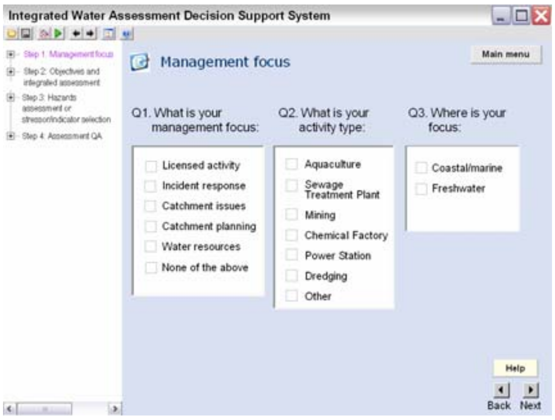

Figure 5. Typical view of a screen in the IWADSS prototype

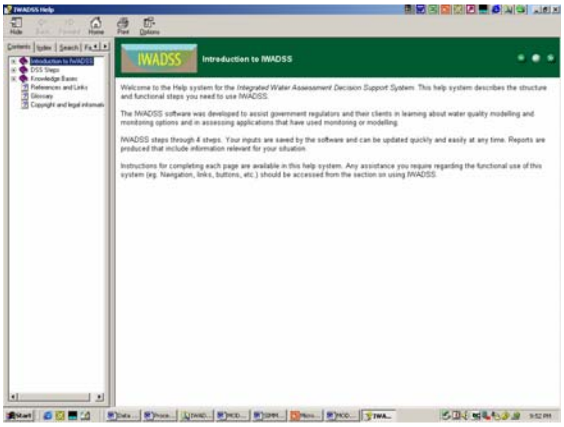

Figure 6. Typical screen of the IWADSS help system

6. DISCUSSION

There was wide support from within the Coastal CRC for the concept behind this project, which was to better integrate monitoring and modelling for management. However, such a project is potentially broad in nature, as management issues can vary significantly. Therefore, IWADSS has been designed as a demonstration project, as it was impossible to address all types of management issues. The scope of the project was limited to primarily development approval, or more specifically, licensing approvals.

Every attempt has been made to design the system in a generic framework that lends itself to further development. The IWADSS could be broadened in the future to cover other management issues such as water resourcing or over broader spatial areas such as fresh water systems. Even with a specific management focus, understanding management needs can be difficult and is the reason behind why many science-based tools are never adopted. The IWADSS has been developed in consultation with a group of government representatives with scientific backgrounds from different states of Australia in an attempt to design a useful product.

The knowledge base development was a major part of this project. The reality is that such knowledge bases should be developed over extended periods of time with input from a range of experts and updated with time. The development of the knowledge bases in this project was limited in both time and the number of experts who could be used, although an extensive review process was adopted in both cases. Also, the knowledge base development was limited to that information that was already developed and readily available.

A major focus of the knowledge bases and the IWADSS is to provide better communication of information. The products are being designed to suit a range of users and technical backgrounds. This has been challenging given the terminology or 'jargon' used in the fields of both modelling and monitoring. Some simpler language is proposed where possible. Generic classifications of approaches and terminology definitions are also proposed to provide an ease of understanding.

Given that every management case is different, IWADSS was designed to provide general guidance and promote general principles rather than provid any absolute answers. The system could also be used as a training tool for staff not familiar with water quality assessment.

A further challenge was developing a way of choosing assessment approaches as well as integrating modelling and monitoring. It was decided that indicators and data availability should drive this process, as a result of feedback from some experts. Also, IWADSS can help quality check the way that data was generated. It is noted that data may not constitute information and that interpretation is a key step in turning data into information. Some guidance for this is provided within the knowledge bases. However, guidance on turning data to information (e.g. trending, statistical tests, graphing etc) is currently beyond the scope of the IWADSS.

In the development of IWADSS, it was assumed that quantitative numbers can be generated for specific indicators. Checks of errors and uncertainty are suggested and are a critical part of the subsequent use of the data. Means of communicating uncertainty needs to be addressed further (both within IWADSS and more broadly within the field of modelling and monitoring) and could be incorporated into the IWADSS in the future.

7. CONCLUSIONS

A decision support system that assists government decision makers who deal with assessments of coastal waters has been demonstrated. The development of specific knowledge bases on modelling and monitoring approaches, development of a prototype and the use of a targeted user group were essential parts of projects. Novel parts of the decision support system include the integrated assessment framework and demonstrating its application with supporting licensing discharges approvals. In the future, the framework could be demonstrated on other coastal management issues such as catchment planning or water resource management.

8. ACKNOWLEDGMENTS

The IWADSS was funded by and produced within the CRC for Coastal Zone, Estuary and Waterway Management. The authors would also like to acknowledge the contributions of CSIRO Land and Water and NIWA Australia to knowledge base development.

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