Decision Support System for Developing Community-Driven Water Quality Monitoring Plans

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EXTENDED ABSTRACT

There is an increasing awareness among regional natural resource managers of the value of data collected by community groups. This includes monitoring of surface rivers, streams, lakes, reservoirs, wetlands, estuaries, coastal waters and groundwater. Water quality and condition data collected by community groups supplements information collected by state, regional and local resource management and planning agencies. However, a recent review of community water monitoring in Queensland suggests a lack of confidence among natural resource managers in community-generated datasets. A significant proportion of this concern stems from inconsistent formats for project planning and documentation practices among community groups.

In Queensland, State Investment Programs (SIPs), funded through the National Action Plan for Salinity and Water Quality (NAPSWQ), have been established to assist in the development of regional natural resource management capacity. The NAP Water Quality SIP team has designed and developed user-friendly decision support software (DSS) to assist community groups in developing monitoring plans that are both defensible and rigorous. The software is based on the concept of water quality monitoring plans developed by the United States Environmental Protection Agency (USEPA) and adapted by Waterwatch Australia. The DSS was structured in four major basic steps so that the user works through these steps as shown in Figure 1 and the DSS provides information to assist in setting objectives, selecting indicators, monitoring design, data management, interpretation and reporting. The prototype was tested and evaluated using the NAP regional officers in Queensland and received very positive feedback.

The DSS will enhance data confidence by developing a strong quality assurance statement that includes all relevant information regarding the design, implementation, analysis and dissemination associated with the project. The DSS has the capacity to generate standardised reports, such as data confidence statements and data management statements, to help communicate various aspects of the monitoring plan. Other functions include direct access to searchable help directories including technical reference materials and the ANZECC 2000 Guidelines for Fresh and Marine Water Quality.

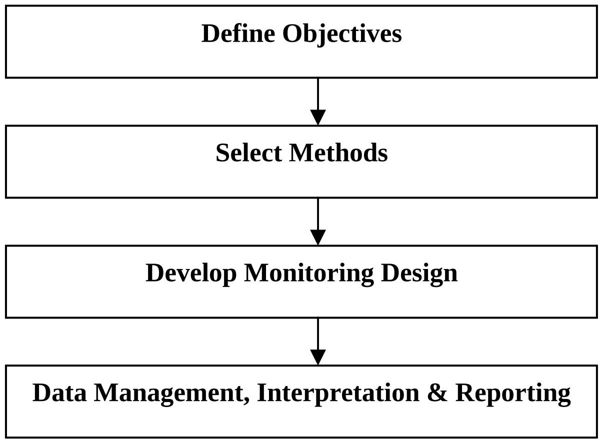

Figure 1. Major steps in the DSS

The standardised nature of the DSS has been promoted as a way to assist regional natural resource managers to integrate information from a wide variety of community monitoring programs with other monitoring activities in their region. Through this integration, the software should allow the development of monitoring partnerships between regional bodies, community groups and other monitoring agencies. Pilot projects have been established in a number of regions to trial the software and determine how it should be best used to facilitate monitoring partnerships.

1. INTRODUCTION

Over the last decade, community interest and involvement in water quality monitoring programs has increased. This is due to a growing awareness in the general community of the importance of protecting our waterways. As a result, community monitoring programs have been established to foster stewardship towards freshwater and marine environments. Such programs allow members of the community to learn about their local waterway whilst collecting water quality data that is potentially useful to a wide range of stakeholders.

There are currently hundreds of community groups conducting water quality monitoring across Queensland. These consist of a consortium of 'Friends Of' groups, Landcare groups, industry groups, schools and local councils among others. Community groups may be entirely independent or associated with either regional, state or federal agencies, environmental organisations or research and education institutions.

Recently there has been increased interest from both regional bodies and the community groups themselves in better utilising the data collected though community monitoring. This is due to the new natural resource management arrangements brought in by the Federal Government that specify a regional-based model. Regional bodies are now required to regularly report on the condition of their catchment and assess the effectiveness of management actions. It is envisaged that community-generated data be used to supplement data collected by state agencies when assessing catchment condition.

However, integration of community monitoring into regional monitoring partnerships has been hindered for a number of reasons. A recent survey of community water monitoring within Queensland indicates that there is a lack of confidence among natural resource managers in community collected water quality data (Cawley 2004). This has been attributed to a feeling that community monitors lack sufficient experience and technical knowledge. Additionally, communication barriers have often resulted in the collection of incomplete or poor quality data with limited suitability for regional decision making processes in regards to natural resource management.

The NAP Water Quality SIP's have established a project to support and assist community groups to better participate in regional water quality monitoring and planning processes. This project undertook a review of existing institutional arrangements and government support for community monitoring programs to establish suitable mechanisms for the engagement, support and integration of community-collected water quality into regional natural resource management processes (Chinn and Cawley 2005). Benefits associated with a strategic approach include higher return benefits from the investments made in supporting community monitoring programs. These investments include the time, energy and money expended by communities in undertaking monitoring, as well as financial and in-kind support from government agencies and other organisations.

It was determined that, in the first instance, monitoring activities would be best run on a project basis. The development of a strong and defensible project plan provides an excellent quality assurance statement to allow the quality and suitability of the collected data to be assessed by independent third parties.

Decision support systems technology can be effectively used to provide low-cost information, knowledge and instruction to community groups. One of the latest definitions for Decision Support System (DSS) is an integrated, interactive computer system, consisting of analytical tools and information management capabilities, designed to aid decision makers in solving relatively large, unstructured problems (Shim *et al* 2002). The issue of designing a water quality monitoring plan is an appropriate candidate for development a DSS. Designing a water quality monitoring plan is a fairly complex domain and requires inputs from a number of areas such as water science, statistics, hydraulics, environmental values and economics.

The NAP Water Quality SIPs have designed and developed user-friendly decision support software to assist community groups in designing a technically sound, rigorous and defensible monitoring plan that provides quality assurance as well as storage and communication capabilities. The prototype developed was based on the concept of water quality monitoring plans as developed and promoted by Waterwatch Australia (Waterwatch Australia 2002). These plans have evolved out of the community watershed monitoring program developed by the USEPA (USEPA 1997) and are intended to build *a priori* data confidence into community monitoring activities. The planning process comprises of eleven questions grouped under four major sections: defining objectives; method selection;

monitoring design and data management. The system was designed to guide the user in a sequential order to collect and record the water quality monitoring plan information. The system also contains a comprehensive help system and is compatible with ANZECC guidelines for fresh and marine water quality (ANZECC & ARMCANZ 2000a). A prototype was developed using an expert systems shell, which runs under Microsoft Windows environment and only public knowledge was integrated. The DSS was evaluated and tested using selected groups in Queensland and received very positive feedback.

2. DEVELOPMENT OF PROTOTYPE

Prototyping is an important strategy in DSS development in which a small scale system or part of a system is constructed in a short period of time and improved in a number of iterations (Walters and Nielson 1988). A prototype of the monitoring planning tool was designed to test the effectiveness of the overall design being used for assisting community groups in preparing a monitoring plan. A knowledge engineering software tool called "Xpert Rule knowledge builder" (Attar Software Limited 2004) was used in developing the prototype. This software tool provides facilities for quick interface development and a range of knowledge representation methods. The targeted end users are community groups and the user interfaces were designed in consideration of their highly variable requirements, knowledge and skills.

The process of developing a monitoring plan involves answering a series of questions and sub-questions under each of the four project design steps. Through the process of consulting, researching and assembling answers to these questions, the DSS takes the user, in a stepwise process, through all the considerations necessary when designing and developing a monitoring project. The user can answer these questions simply by inserting text or making selections from available options. At the end of the process, the DSS will compile all the information captured and produce a number of detailed project reports. The following section gives the brief detail on each of the steps and questions set up in the prototype.

2.1 Define Objectives

Identifying monitoring objectives is the critical first step in designing a monitoring program that is efficient and effective in generating data that meets the data users requirements. In developing project objectives, it is necessary to identify the issue being investigated and reasons for monitoring as well as defining how and by whom the data and knowledge generated will be used. Such an approach recommends review of available information, development of system understanding (conceptual model) as well as open discussion and communication between stakeholders (ANZECC 2000b).

Q1. Why are you monitoring?
The user needs to specify the reason for water quality monitoring. Reasons for initiating a community monitoring project may include: increasing the awareness and skills of the local community, developing baseline data, documenting water quality changes over time, screening for potential water quality problems, checking whether waters are suitable for different environmental values, etc.

An individual program might be monitoring for a number of reasons and it is important to identify those reasons and design the monitoring plan based on those objectives. To do this it is important to explore the both issues being investigated as well as the motivations for monitoring.

Q2. Who will use your data?
Identifying data users is essential to the monitoring program development process. Potential data users might be quite varied, ranging from students to researchers or governments. Identifying and discussing the needs of each data users helps to focus the issues and objectives for the study. In addition, each of these users will have different data quantity and quality requirements. Therefore, information on the range of user is important to determine the required level of data quality. A number of rules based on the type of users their data needs were developed to determine the broader categories of data quality.

Q3. How will the data be used?
How the data are to be used is the primary driver in determining the required data quality to enable the project to meet its objectives. Community collected data can be used for various activities such as educating school children, influencing local planning decisions or determining suitability for uses. Each of these data uses also potentially have different data quality requirements. Broad categories of data use defined in this system are 'demonstrative', 'indicative' or 'analytical'. The user must select the most stringent type of data use to design a monitoring plan.

After answering the above three questions, the user is asked to develop a succinct objective statement indicating the "What-Where-When-Why" associated with the proposed monitoring program. The DSS has been designed to capture and record this information.

2.2 Select Methods

In this step the user determines the monitoring methods they will use and the quality control procedures to ensure data quality meets the needs of the objective. They are asked to consider the types of indicators that correspond to the issue, the data quality required to meet the intended data use and to specify their methods.

Q4. What will you monitor?
Selection of appropriate key and supplementary parameters from a large number of available water quality indicators is an essential in developing any monitoring program. Determining what to monitor will depend on the objectives of the monitoring program, but will be constrained by the groups resources and technical capacity.

The monitoring plan DSS aims to match parameter selection to issue and objectives. For example, if the program's objective is to determine whether a creek is suitable for primary recreation, parameters such as faecal coliform concentrations should be monitored. If the objective is to determine aquatic ecosystem health, parameters might include dissolved oxygen concentration and variations in water temperature. Comprehensive help materials regarding selection of indicators have been added into the system and the users can easily refer this information if assistance is required in selecting parameters.

Q5. What data quality do you need?
Generally data quality is measured in five ways; accuracy, precision, completeness, representativeness, and comparability. The required level of data quality will depend on the objectives of the study, particularly how the data will be used. For example, high level of data quality is required if the data are used to prove compliance with environmental regulations. Lower data quality is usually sufficient if the data are used for demonstration purposes. In this DSS, required data quality is determined based on the data users and the data use (question 2 & 3). The DSS will make data quality recommendations for both key and supplementary indicators.

Q6. What methods will you use?
The methods adopted depend primarily on how the data will be used and the required data quality. There are many sampling techniques available and considerations include: the methods for how samples will be collected, the type of instruments and calibrations used, specific quality control procedures used, and the competency of those undertaking monitoring. For each selected indicator, the user is asked to specify the sampling methods to be used and their relevant technical information. Help is provided to assist users to ensure that the methods adopted meet the quality expectations articulated within the monitoring objectives.

2.3 Develop Monitoring Design

This step involves determination and recording of the spatial and temporal configuration for the monitoring program.

Q7. Where will you monitor?
Monitoring sites must be selected to represent the conditions associated with the project objectives. The other factors considered in choosing monitoring sites include accessibility, safety, relevance, and relationships to other sites and the study area (scale). In most of the cases a number of sites need to be monitored to achieve the formulated objectives.

All the site information including the geographical location can be entered and saved in the system. This information will be integrated with GIS software in future evolutions to enhance reference and reporting purposes. In addition to spatial data, the DSS will provide users with the opportunity to assemble and save site photos, access considerations and relevant Occupational Health and Safety information for each site, thus building a site database to facilitate site registration and management.

Q8. When and how often will you monitor?
The monitoring plan needs to specify the timing, duration and frequency of measurements. The time and frequency will depend on the parameters, objectives and the available resources. In this DSS, monitoring strategies have been broadly separated into routine and event-based. The user can select either one or both of these options.

2.4 Data Management, Interpretation and Reporting

This step summarises how the data are handled from the point of collection to the communication of data and knowledge products to clients.

Q9. Who will be involved and how?
In community monitoring programs, it is important to keep records of all participants in the program. This information is useful for quality assurance, day-to-day project management, as well as to manage training requirements and capacity building opportunities. The DSS has been designed to capture and store the names, roles, and contact information of all participants as well as specific training requirements. In addition, documentation of roles and capacity of all participants and provides further confidence in the data generated by the project. The information can be easily updated whenever details change.

Q10. How will the data be managed?
The monitoring plan provides the opportunity to indicate a clear plan for managing, storing and communicating the collected data. Field and lab data sheets need to be checked for completeness and a database should be developed or adapted to store and manipulate the data. This DSS has capabilities to capture description of data trails from point of capture, document data storage methods, and provide facilities to produce reports on data management.

Q11. How will you ensure data credibility?
Data quality is built into a monitoring program at every stage. It is important to ensure that the collected data are credible and well documented. The project-level documentation provided by the monitoring plan DSS will enhance the confidence of data users to decide whether the data generated by the project is suitable for their given needs. The DSS generates a written plan, known as a quality assurance project plan. This is an essential feature to explain how the data were generated. Without such knowledge, the data cannot be used with confidence.

Monitoring plans should be used as a basis to establish and maintain communication between all stakeholders in the monitoring project. Through the process of thinking about the questions asked, answering them and discussing these answers with others, potential conflicts or differences of opinion have the potential to be resolved with mutual benefits to all.

3. DEVELOP USER INTERFACE

The targeted end users for this system are community groups, potentially with limited computer equipment and skills, and unreliable internet access. Having focused on user requirements and capabilities, the interface was developed for simple and intuitive operation by selecting available options or simply answering questions appearing in the screen and Figure 2 shows the interface designed for capturing monitoring site details. A comprehensive help system has been built into the system to explain each step and provide technical support to assist in running the software. A significant effort have been made to design user friendly and intuitive interfaces, which is likely to have a significant influence on whether or not this DSS is adopted and used by community groups.

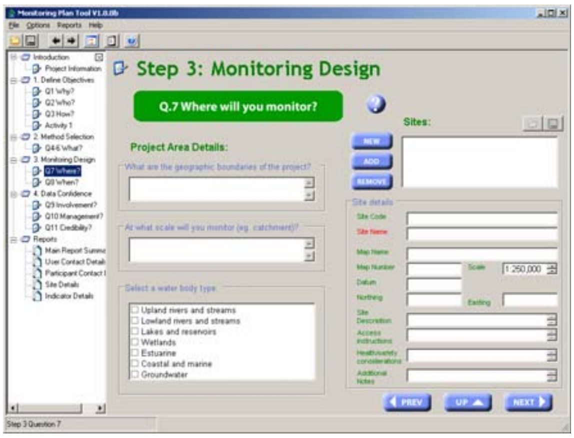

Figure 2. Interface for capturing monitoring site details

4. PROTOTYPE EVALUATION

Evaluation of a DSS is the assessment of the overall performance of the system and evaluation was done by validation and verification of the system. The system was verified to ensure that the DSS is properly constructed so that it functions as intended. The prototype was validated using approximately 25 end-users representing different community groups and Queensland NAP regional officers to determine whether the system could achieve a satisfactory level of performance with respect to assisting community groups to set up a monitoring plan. Feedback received includes possible improvements in the user interface, inclusion of some monitoring plan examples and the integration of technical information into the DSS as help materials. We also received positive feedback on the use and benefits of the DSS from the end users and it is anticipated to evaluate the beta version using a larger group of end users across the state.

5. DEVELOPMENT OF BETA VERSION

The prototype was refined by repeating a number of development and evaluation cycles. The changes include improvements in the user interface for easy inputs, inclusion of help material for selecting appropriate indicators, customised report generation and the development of an operational guide as a standard help system. A few examples of water quality monitoring plans designed for validating catchment hydrology models (SedNet, EMS, E2 etc) were also added. The prototype was modified based on user feedback and the system was coded using Visual Basic language, which runs under .NET environment. Most of the products developed under Queensland NAP SIPs will use the .NET environment, which provides a common flat form facilities share input data between tools. Further, we adopted catchment hydrology software tool kit's protocols in developing the beta version of this DSS. The beta version was tested and released in July 2005. A number of workshops for DSS demonstration were carried out in southeast Queensland and feedback is being collected from users.

6. FUTURE IMPROVEMENTS

The current version has a limited capacity in providing assistance to design a comprehensive monitoring plan. This version collects project information based on the eleven questions and helps users to establish a sound foundation for monitoring plans. However, decision support functions to assist answering those questions have not yet been included. The following decision support facilities could be embedded into the system giving subsequent versions the capacity to provide expert advice on various aspects of designing a water quality monitoring plan.

Include expert knowledge: The monitoring plan DSS offers the opportunity to acquire specific knowledge from water quality experts on a variety of topics including; identification of water quality issues, formulation of objectives, site selection, selection of core and supplementary indicators, the selection of instruments and appropriate calibration and deployment strategies. This expert knowledge can be processed and represented in the DSS using knowledge representation techniques such as production rules, decision trees or case tables.

Statistical analysis advice: Input from statisticians is essential in designing a monitoring plan and it is often difficult to access statisticians in regional areas where most of the monitoring planning takes place. Such advice can be incorporated into the DSS, including advice on statistical designs, sample optimisation, estimation of decision errors and guidance for statistical analysis of collected data.

Conceptual models: Use of conceptual models is an effective way of exploring water quality processes and their effects on environment. Conceptual models are used to identify the linkages between information and data, and to generate or test hypotheses about relationships among components or elements of a system. A number of conceptual models could be developed and incorporated into the DSS. Potential functions include: pollutants origin, transport and depositions and their adverse effects on aquatic ecosystems. Such tools would assist community groups to identify issues and formulate objectives that are matched to environmental functions. They could also assist communities to take actions to prevent water pollutions in steams and other water bodies.

Health and Safety considerations: It is also very important to provide adequate health and safety measures for community groups when they are involved in water quality monitoring activities. The DSS provides potential to provide both generic and specific guidance to minimise risks for participants. For example, safety instructions for collecting samples, use of sampling equipment, site-based safety considerations, etc.

Additional knowledge on maintaining data quality objectives, data management, data analysis and reporting and program evaluation will also be added as text information.

7. CONCLUSIONS

The monitoring plan tool DSS holds great potential as a planning and operating tool that could be used in all stages of a community water quality monitoring project. The DSS provides a mechanism to provide comprehensive, case-specific, technical assistance to enable community groups to formulate a defensible and rigorous monitoring plan.

In addition, the monitoring plan DSS develops and stores a comprehensive *a priori* quality assurance statement that has potential to greatly enhance data confidence associated with community-collected water quality data. Finally, the common recording and reporting features of the DSS have the potential to greatly enhance the communication between community groups and natural resource managers and allow greater upward-integration of community monitoring activities into sub-regional and regional monitoring strategies.

8. ACKNOWLEDGMENTS

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