EXECUTIVE SUMMARY

A GUIDE TO CATCHMENT-SCALE EUTROPHICATION ASSESSMENTS FOR RIVERS, RESERVOIRS AND LACUSTRINE WETLANDS

Background to the study

Eutrophication is the enrichment of waters with plant nutrients which results in an array of symptomatic changes, namely increased production of algae and aquatic macrophytes, deterioration of water quality and other undesirable changes that interfere with water uses. In South Africa, eutrophication has been recognized as a priority water quality problem for over 30 years and in a study on the eutrophication status of a number of South African reservoirs, it was found that the extent of eutrophication had increased since the problem was first identified in the 1970s. A study commissioned in 2000 by the Water Research Commission (WRC) found that South Africa's policy and approach to eutrophication control has been inadequate over the last 20 years. A strong need was identified to remobilise and redevelop the WRC's capacity to manage eutrophication. A workshop followed in 2001, to discuss research and capacity building within the field of eutrophication and the assessment of the eutrophication problem was identified as the highest priority research area.

At the same time as the WRC eutrophication policy study was underway, the Department of Water Affairs and Forestry (DWAF) commissioned a project to develop a generic Guide to Conduct Water Quality Assessment Studies. The DWAF Guide suggested a protocol to undertake catchment scale water quality assessment studies to support the development of catchment management strategies.

The objective of the current WRC project was to use the DWAF protocol as the backbone for developing an Eutrophication Assessment Guide for Rivers, Reservoirs and Lacustrine Wetlands in Southern Africa. The guide would ensure that the development of eutrophication management strategies was aligned with current water resource management policies and procedures endorsed by DWAF.

Aims of the project

- To provide professional guidance to practitioners in using assessment protocols that were aligned with national catchment water quality assessment studies, to assess eutrophication-related catchment and receiving water body characteristics.
- To provide a means by which local and international best eutrophication assessment practice (methodologies and protocols) could be captured and made available to a wide range of catchment assessment practitioners in Southern Africa.
- To develop tools and course material that could be used to fast-track capacity building in eutrophication-related water quality assessment and management.

Output products of the project

Three products were produced as output from the project:

- A guide to assess eutrophication-related water quality for rivers, lakes/reservoirs and lacustrine wetlands,
- An internet-based Nutrient Enrichment Assessment Protocol (NEAP)
- A course outline and training material for a short course in eutrophication assessment.

These output products are described in more detail below.

A GUIDE TO ASSESS EUTROPHICATION-RELATED WATER QUALITY

Catchment management, catchment assessment studies and catchment water quality assessment studies

The National Water Act specifies that *catchment management strategies* (CMS) must be developed to manage water resources at a catchment scale. It goes on to describe, in broad terms, what a CMS should consider and what must be included in the strategy. A CMS is supported by a *catchment assessment study* (CAS) which deals with water-related natural resources in a catchment, including the human impacts on those resources, and the need to protect, use, develop, conserve, manage and control those resources. A *catchment water quality assessment study* is designed to assess water quality, at a catchment scale, in a systematic way and to develop integrated water quality management strategies. These topics are introduced in **Part 1** of the Guide document.

A Guide to assess eutrophication at a catchment scale

Eutrophication is one of the priority water quality problems in South Africa. **Part 2** of the Guide document describes, in detail, the key study components required to assess the eutrophication status of a catchment or sub-catchment and to develop management options that take into account the needs and aspirations of stakeholders and the constraints imposed on a particular catchment. The Guide is structured around six management questions:

- What is the eutrophication-related status of the study area and how did it get to this point?
- Who are the eutrophication-related stakeholders and institutions in the study area and what are their respective jurisdictions, relationships, linkages and roles?
- What are the study area's eutrophication-related issues, concerns, problems and opportunities?
- Where the eutrophication-related status of the study area might be heading in the future?
- What are the appropriate priority eutrophication management options?
- Has catchment management achieved its objectives?

For each management question, a management task has been formulated to provide the answers to the question (as illustrated in the table below). Each management task has a number of components or sub-tasks to collect the required information to answer the question.

Component	*Eutrophication Management Question 1:* **What is the eutrophication status of the study area and how did it get to this point?** *Eutrophication Assessment Task 1:* **Characterisation of the current eutrophication status and historical trends**
0	Inception summary of existing understanding, knowledge and past studies with regard to eutrophication related water quality in the catchment
1	Details of natural, developmental and administrative attributes and characteristics of the catchment relevant to the assessment of the eutrophication status
2	Requirements of the National Water Resource Strategy and Resource Directed Measures with regard to nutrient management
3	Water use and conservation related to eutrophication assessment
4	Overview of adequacy of water availability
5	User water quality requirements and constituents of concern relating to eutrophication
6	Eutrophication related water quality of streamflow, reservoirs, estuaries, wetlands and groundwater
7	Point source waste discharges and source characteristics relating to eutrophication
8	Non-point source water quality loadings and impacts relating to eutrophication

9	Configured and calibrated predictive tools/models with regard to eutrophication related water quality
10	Reconciliation: catchment nutrient sources and eutrophication related water quality patterns
11	Status reports on eutrophication monitoring, physical data and characterisation information
	Eutrophication Management Question 2: **Who are the water-related stakeholders and institutions in the study area and what are their respective jurisdictions, relationships, linkages, and roles?** *Eutrophication Assessment Task 2:* **Engagement of water-related institutions and stakeholders in CAS process**
12	Stakeholder details and participation processes
13	Water-interest institutional arrangements and linkages
	Eutrophication Management Question 3: **What are the study area's eutrophication related water quality issues, problems, concerns and opportunities?** *Eutrophication Assessment Task 3:* **Formulate and record eutrophication related water quality issues, concerns, problems, and opportunities**
14	Record of eutrophication related water quality issues and their origins
15	Catchment management implications of eutrophication related water quality issues
16	Vision (or long-term resource objectives) for eutrophication related water quality
	Eutrophication Management Question 4: ***Where the eutrophication related water quality status of the study area might be heading in the future?*** *Eutrophication Assessment Task 4:* ***Projection of eutrophication related water quality impacts of future water-related development scenarios***
17	National and regional plans and projections of future water demands and catchment development
18	Predicted future eutrophication related water quality at sites of management focus
	Eutrophication Management Question 5: **What are the appropriate (priority) eutrophication management options?** *Eutrophication Assessment Task 5:* **Formulate and prioritise eutrophication management options**
19	Eutrophication related management units and assessment of spatial and temporal resolutions
20	Prioritised eutrophication management options
	Eutrophication Management Question 6: **Have eutrophication management strategies achieved their objectives?** *Eutrophication Assessment Task 6:* **Monitoring and auditing of implementation of eutrophication management strategies**
21	Monitoring and auditing assessment of eutrophication management strategies

Links to the DWAF catchment water quality assessment guide

This guide document mirrors the key features of the DWAF *Catchment Water Quality Assessment Guide* document. This approach was adopted to ensure that the outputs of an eutrophication assessment study are compatible with the overall objectives of a catchment assessment study. The hypertext-enabled version of the Eutrophication Assessment Guide has live links to websites where background information, examples of good practice, etc., can be found.

Application of the eutrophication assessment guide

The application of the guide would help a user to undertake an eutrophication-related catchment water quality assessment study, which in turn, can be used to support the development and

implementation of catchment management strategies to address the causes and consequences of eutrophication.

A WEB-BASED NUTRIENT ENRICHMENT ASSESSMENT PROTOCOL (NEAP)

What is NEAP?

NEAP is an internet-based phosphorus ((P)-based) nutrient loading tool for lakes and/or reservoirs which, depending on the level of information entered, allows the user to select one or more outputs that describe, for example, the P-load generated by the catchment, the trophic condition of the lake, and the lake's likely response to a change (increase or reduction) in phosphorus (P) loading.

NEAP is based on a range of existing phosphorus load: response relationships. Insofar as is possible, using available information, NEAP V1.0 has been calibrated for use under South African conditions, and in particular, for use in reservoirs as opposed to lakes.

NEAP development philosophy

NEAP has been purposefully designed as a simple, phosphorus-based, eutrophication screening tool. As such, it provides a non-data intensive means of determining the trophic status (degree of nutrient enrichment) of open-water environments. Once calibrated, it allows the user to determine the manner in which the annual mean concentration of phosphorus is likely to change in response to an increase or decrease in the loading of this element. Such determinations can be made with NEAP at a high (70%) level of confidence.

NEAP as a screening tool

The purpose of a screening tool, such as NEAP, is to provide management-related answers without having to resort to an extended period of data collection. In many cases, simple models such as NEAP target the key drivers that are essential for first-level appreciations. The underlying philosophy with NEAP has been to provide a fast and simple-to-use approximation of the level of eutrophication in a particular reservoir, and to inform options for management. Should more detailed examinations be required thereafter, more complex models can be employed as the required data becomes available.

Future developments

It is intended that subsequent releases of NEAP will incorporate a level of functionality that will support the integration of biogeochemical processes (fate and loss relationships), as well as refinements such as the inclusion of aquaculture impacts. Importantly, later versions will be able to include support for assessing 'virtual' nutrient load reductions relating to management approaches targeting 'top-down' foodweb manipulation. In the case of Hartbeespoort Dam, restructuring of the fishery is estimated to bring about a change in conditions equivalent to a reduction of some 25-40% in external phosphorus loading.

Knowledge of eutrophication to apply NEAP

It is extremely important that the NEAP user has a reasonable working understanding of what eutrophication is – i.e. that eutrophication is not simply a function of phosphorus loads and concentrations – and that a wide variety of biophysical and chemical factors can enhance or constrain the observed level of eutrophication in a particular waterbody. It is as important for the water resource manager to be able to determine whether or not a particular resource is eutrophic as it is to determine the likelihood of it becoming so, or where it lies on a trend towards an impaired trophic state. Unfortunately, appropriate management strategies directed against eutrophication are seriously constrained by a widespread lack of understanding of the problem – particularly at the decision-making level. Recent work carried out at Hartbeespoort Dam has suggested that with due attention, significant remedial changes are indeed possible, and not as insurmountable as has been the popular belief in South Africa for many years.

COURSE OUTLINE AND TRAINING MATERIAL FOR A SHORT COURSE IN EUTROPHICATION ASSESSMENT IN SOUTHERN AFRICAN WATER BODIES

Introduction

In the late 1990s, researchers felt that there was little effort made to review eutrophication policy in the light of the monitoring results and that the country regressed in terms of its capacity and ability to deal with eutrophication. This observation provided motivation to develop, as part of this project, the outline of a short eutrophication assessment course with the Eutrophication Assessment Guide document as the background document for the course. The primary target audience for the course material on the Southern African water resource practitioner, water resource manager and freshwater scientist. Students at tertiary training institutions would be a secondary audience.

A two-tiered training course

A need was identified for a two-tiered approach. The first tier would be an introductory course designed as a general introduction to eutrophication and its assessment at a catchment scale. The first tier course would be aimed at a person at management level who needs to understand the scope of catchment eutrophication assessment studies. The course would also serve as an introduction to the more detailed second tier short course designed for someone who would be responsible for undertaking a catchment scale eutrophication assessment study.

An introduction to eutrophication assessment

Focus and nature of the course

This short course introduces the topic of eutrophication and nutrient enrichment and what the basic steps are for assessing the problem at a catchment scale, to support the development of a catchment management strategy. Eutrophication is introduced by examining some of the key concepts, the causes, consequences and impacts of nutrient enrichment, and basic monitoring requirements. Catchment scale eutrophication assessment is then introduced along with the NEAP tools that were developed to support a first order assessment. The course is concluded with an overview of the different approaches to managing eutrophication.

This course is a prerequisite for the second short course that deals with the details of a catchment eutrophication assessment study.

Required outcomes

After completion of this short course, the student should be able to:

- Provide a broad overview of eutrophication and nutrient enrichment, the factors leading to eutrophication related problems and how these are manifested in rivers, reservoirs and lacustrine wetlands.
- Provide a time-line of eutrophication problems in South Africa (SA), measures to manage the negative impacts, the current situation in the country and approaches to deal with the problem under the National Water Act.
- Describe the basic steps to undertake a catchment scale eutrophication assessment study.
- Describe the basic approach to a first order assessment of eutrophication.
- Describe the main approaches to managing the negative impacts of eutrophication.

Catchment eutrophication assessment protocol

Focus and nature of the course

This two day short course introduces the topic of eutrophication and catchment eutrophication assessment during the first day (as described above). On the second day of the course, the context within which a catchment scale eutrophication assessment study is undertaken is discussed in more detail. The different tasks and sub-tasks of such a study are then discussed in detail using the eutrophication assessment guide (this document) as a manual. The NEAP web-based software is then used to undertake a hands-on assessment of a specific case study selected by the course leader. The purpose of the case study is to give students the opportunity to apply the concepts introduced during the preceding day and a half, to a specific case study.

Required outcomes

After completion of this short course, the student should be able to:

- Provide a broad overview of the key tasks in a catchment scale eutrophication assessment study.
- Decide on the scale and depth of the eutrophication assessment study for different parts of a catchment study area.
- Apply the NEAP suite of models and assessment tools to undertake a first order assessment of the scope of an eutrophication problem for a specific water body.
- Participate in a detailed eutrophication assessment study as part of a catchment assessment study.

CONCLUSIONS AND RECOMMENDATIONS

Catchment Eutrophication Assessment Guide

Discussion

The Catchment Eutrophication Assessment Guide mirrors the DWAF Water Quality Assessment Guide. The guide is a first attempt to identify those aspects that would differentiate an eutrophication assessment from an assessment of other water quality variables. It was often difficult to decide how much guidance should be given to water quality specialists undertaking an assessment study. The guide now needs to be applied to a number of real world eutrophication problems to identify aspects that need to be improved. A mechanism should also be developed to elicit feedback from users and to update the guide document from time to time.

Recommendations

1. That the WRC and DWAF should promote the use of the guide as a tool to support catchment water quality assessment studies.
2. That a mechanism be developed to obtain feedback from users and to update the knowledge base of the guide. An Internet based discussion forum may offer a way of capturing feedback from users.
3. That the integration of the eutrophication assessment with other water quality variables may require some investigation.
4. That similar guides should be developed for other priority water quality problems in the country. The two highest priority issues are probably salinisation and microbiological pollution.

NEAP (Nutrient Enrichment Assessment Protocol)

Discussion

The work undertaken for the NEAP component of this project has only established a platform for further development and application of subsequent releases of NEAP. The work undertaken will have been pointless if further in-depth analyses of the relevance of the models to a wider South African dataset are not undertaken. Only in this manner

will the correct calibrations and application ranges relevant to NEAP become available.

There is no generic, NEAP-predictable eutrophication response applicable to all water supply reservoirs in the country. In many cases, the available water quality records contain few or no data for phosphorus. If the NEAP-based approach is to reach its full potential, the development of regional and/or special climate zone datasets need to be compiled and integrated as loadable calibration sets into future versions of NEAP.

Future versions of NEAP will need to incorporate increased flexibility for dealing with the manner in which phosphorus is assimilated within particular reservoir environments, and particularly with reference to the question of internal loading. The precise role and extent of internal phosphorus loading in highly flushed, shallow and warm South African reservoirs will only become apparent from a more detailed analysis of the available data.

Also critical to the value of NEAP is user-feedback. The developers of NEAP believe that use of this tool has been limited by (a) a general lack of understanding of what NEAP can do, and with this paucity underpinned by (b) inadequate understanding of eutrophication, and eutrophication in reservoirs, in particular.

Recommendations

1. That the value of NEAP be promoted through the convening of a small number of user-targeted workshops;
2. That the project be continued to further develop the local (South African) applicability and scope of NEAP – this by assessing all SA impoundments and their water quality databases through the same process used to select the models used in NEAP V1.0;
3. That the foregoing wider assessment include a catchment analysis and back-calibration of export coefficients in order to expand the relevance and local applicability of nutrient export coefficients by land-use type;
4. That NEAP V1.0 be expanded to include second and higher layers to accommodate biogeochemical processes;
5. That the NEAP V1.0 database and feedback system be maintained and used to both inform the user-friendliness of V1.0 and the relevance of the calibrations.

Eutrophication assessment training course outline and material

Discussion

The course material developed as part of this project was aimed at increasing the capacity to undertake eutrophication assessments at a catchment scale. There is a need to update the material from time to time to reflect advances in the knowledge base on eutrophication assessment. There is also a need to develop similar material to increase capacity to manage eutrophication in reservoirs and urban ponds, and to use more sophisticated assessment tools such as deterministic eutrophication models.

Recommendations

1. That a mechanism be found to update the training material based on feedback from users, updates to the presentations submitted by lecturers, and to keep up to date with advances in the knowledge base of eutrophication assessment methods.

2. That a training course be developed on the control and management of eutrophication in reservoirs and urban water bodies.
3. That a training course be developed on the use of more sophisticated assessment tools such as deterministic river and/or reservoir models.

Capacity building initiatives

Support for tertiary student training

Under the guidance of Prof Fatoki, the studies of two M.Sc students from the University of Venda, Ms M Mamali and Ms D Maluleke, were funded from this project. Ms Mamali undertook her MSc studies on the assessment of the eutrophication status of Vondo and Albasini Dams in Venda. She used the NEAP model during her studies and submitted her thesis during the first quarter of 2005. Ms Maluleke investigated the development of sustainable development indicators. She applied the indicators for case studies of Makhado and Thulamela municipalities. Some of the principles of eutrophication assessments were applied in her studies.

A short course, "Eutrophication Short Course and Modelling Workshop", was presented from 24-25 May 2005 to DWAF staff and others at Roodeplaat Dam. Mr Rossouw and Ms van Ginkel of DWAF presented the Eutrophication Assessment component on the 24th of May, and Prof Friedrech Recknagel from Adelaide University presented the Eutrophication Modelling component on the 25th of May.

Presentations at workshops and conferences

The work undertaken in this project was presented at the inaugural meeting of the WISA Nutrient Management Division, the joint ZSSA/SASAqS conference, and the annual conference of the North American Lake Management Society:

- Rossouw, J N, Harding, W R, Fatoki, O S (2003). Guide to Conduct Eutrophication Assessments for River, Lakes and Wetlands. WISA Nutrient Management Division seminar, Rand Water, 28 March 2003.
- Rossouw, J N and Harding, W R (2003). Bridging the gap between Science and Practice: Development of an Eutrophication Assessment Guide. Joint ZSSA/SASAqS Conference, Cape Town, 29 June to 4 July 2003.
- Rossouw, J N and W R Harding (2005). *Development of a Catchment Scale Eutrophication Assessment Guide to support catchment management in South Africa.* 25th Annual Conference of the North American Lake Management Society, November 9-11, 2005.