1. INTRODUCTION

Protecting the earth and her natural resources by managing man's activities sustainably, is the single most important objective of the environmental manager of today. Environmental Impact Assessment (EIA) is a tool developed within the framework of Integrated Environmental Management (IEM) to gather facts about the environment surrounding these proposed activities and then to assess the impacts they will have on the environment.

The purpose of an EIA is to provide decision makers (be they government authorities, the project proponent or financial institutions) with sufficient and appropriate information about the potential positive and negative impacts of a proposed activity or development and associated management actions in order to make an informed decision whether or not to approve, proceed with or finance the development (Münster, 2005).

During the process of compiling the EIA document, it is the very important function of the EIA practitioner and environmental specialists involved with the project to accurately assess the foreseeable impacts. This is evaluated under the section impact assessment, which aims to adequately assess and evaluate the impacts and benefits that will be associated with the new activities. It is necessary to use clearly defined criteria in order to determine the potential significance of the predicted impact or benefit on the surrounding natural and/or social environment.

The section within an EIA document which deals with cumulative impact assessment is where the specialist must consider potentially significant direct and indirect cumulative impacts. The level of detail to which these should be considered will be influenced by the nature of the proposed project and issues raised through the scoping process which precedes the EIA document.

This study is aimed at highlighting the importance of cumulative impact assessments by assessing the cumulative impacts that coal mining has on wetlands, taking into account the various methodologies used internationally and comparing them to those employed in South Africa. The benefits and shortcomings that will be determined will be illustrated by using an example of the cumulative impacts that coal mining has on wetlands.

It is widely recognised that no amount of theoretical information on how best to plan and co-ordinate specialist inputs, or to provide or review specialist input, can replace the value of practical experience of co-ordinating, being responsible for and/or reviewing specialist inputs relating to an EIA study. Only such experience can develop sound judgement on such issues as the level of detail needed or expected from specialists to inform decision-makers such as government departments or banking institutions adequately. It is the intention of this research to provide guidance in determining and assessing cumulative impacts more thoroughly and accurately.

1.1. Background

South Africa has a number of natural and artificial wetlands situated within the mainland and along the coastline (Heydorn, 1996). Wetlands have for many years been seen as wastelands, and therefore their importance and vital functioning have not been fully understood by many. Many wetlands occur in areas of South Africa that have vast mineral deposits at or near the surface. Depending on the extent and nature of the proposed mining project, an EIA will be required by law before mining is to take place. This EIA will have to comply with criteria as set out by the Department of Minerals and Energy (DME) for a mining related EIA.

By conducting an EIA, the practitioner or specialist will need to incorporate the wetland into his/her specialist study of the surface water on site. As the wetland could already have been investigated (in lesser detail) during either the screening or scoping phase which would have preceded the EIA, no fatal-flaws would have been detected thus far (otherwise the project would have been halted or abandoned if no alternatives were found). A detailed study would then be required to be conducted which would include the assessment of environmental impacts and more importantly an assessment of cumulative impacts (DME, 2006).

1.2. Purpose of the study

The purpose of the study is to create a set of guideline methods which can be used to facilitate the specialist or practitioner to accurately and thoroughly assess the cumulative impacts a proposed project, such as coal mining, will have on wetlands. Africa has a number of different wetland types which support large and diverse numbers of animal and plant species. They provide large human populations with a supply of water for domestic and industrial uses, drinking sites for animals, and provision of material for use as firewood and for building (Heydorn, 1996).

This will be achieved by highlighting the importance of cumulative impact assessments by taking into account the various methodologies used internationally and comparing them to those employed in South Africa. The cumulative impacts that coal mining has on wetlands will be used as an example to illustrate the usefulness of various methodologies. The fact that wetlands occur throughout South Africa, are severely vulnerable to developments such as new coal mining activities and play an extremely vital role in the environment, makes them such a valuable feature that needs to be protected.

1.3. Objectives of the study

The objective of the study is to develop a framework methodology that can be used to accurately and comprehensively assess cumulative impacts as part of an EIA study in South Africa. This methodology will act as a framework that can be utilised by a number of individuals (managers, specialists, practitioners, local government and developers) who deal with EIAs and especially for assessing cumulative impacts related to coal mining.

This research and the subsequent methodology have been produced through an intensive literature review of the information relating to cumulative impacts and the various methodologies employed. Information has been gathered from a number of sources such as the library at the University of Johannesburg, Department of Environmental Affairs and Tourism (DEAT), Department of Water Affairs and Forestry (DWAF), Council for Scientific and Industrial Research (CSIR) as well as many other provincial departments and private organisations. The gathered information has been subsequently synthesized to produce a final methodology.

1.4. Intended and recommended use of the guide

The purpose of the study is to be used as a framework with which to accurately and efficiently assess cumulative impacts that coal mining has on wetlands. It is intended for use by the following:

- project managers who oversee the project process;
- environmental practitioners in the compilation of the EIA;
- specialists in their investigative studies;
- individuals and groups who are the Interested and Affected Parties (I&APs);
- decision-making authorities who review the findings of the EIA; and
- authorities who are responsible for the Record of Decision (ROD).

Many individuals and specialists have their own set methodologies in place which they follow. This document serves only to act as a guide in aiding any of the above persons, especially when conducting an assessment of the cumulative impacts for a coal mining related EIA with one or more wetlands concerned.

1.5. Assumptions and limitations to the guide

It is assumed that the guide document will be a useful and accurate tool which will be used to assess the cumulative impacts by making use of a set methodology. It is intended to improve the level of assessments being conducted by environmental practitioners, specialists or any other individuals involved in the process. It is intended to give more insight into the necessity of undertaking these assessments as holistically and accurately as possible. This will prove both beneficial to wetlands, the surrounding environment and ultimately, man. Due to the nature of this study, the extent of research was limited to a mini-research paper and thus the study is not an in depth account of the topic being researched.

2. PROBLEM STATEMENT

Cumulative impacts are not assessed very accurately and thoroughly in South Africa as part of an EIA for coal mining activities which occur in wetland areas. This has detrimental effects on the eco-systems of wetlands when coal mining activities proceed in such areas. A framework methodology is required in South Africa to more accurately and thoroughly assess cumulative impacts that coal mining has on wetlands.

3. RESEARCH METHODOLOGY

Despite the fact that legislation exists (for example the Water Act No. 84 of 1998, the National Environmental Management Act No. 107 of 1998 and the Environment Conservation Act No. 73 of 1989) which requires the minimisation of impacts on the country's water resources, the fact that South Africa is a water-scarce country (Harmse, 2001) and that we are a signatory to the Ramsar Convention, we still tend to treat our wetlands as wastelands.

Mining in South Africa is very extensive as it's contribution to gross value added to the South African economy was calculated at around 7,1% for 2004 (Burger, 2005). Mining activities occur throughout mostly the northern and eastern areas of the country. Many wetlands and pans occur on the eastern half of South Africa on predominantly the Karoo Supergroup on which the coalfields of South Africa are situated (Vorster, 2001). Opencast or strip mining is a widely used technique where the mineral is close to the surface and occurs as a bedded deposit such as a coal seam. The overburden is removed in strips and placed into areas from where the mineral has already been removed. Whilst mining is in progress this is used to reduce the visual impact of the operations and is returned when the operation is finished (Kelly, 1988).

Extensive opencast coal mining operations mine large surface areas in South Africa to get to the carbonaceous deposits below, often resulting in catastrophic consequences for wetlands nearby. Wetlands are not properly managed in South Africa as half of the natural wetlands in South Africa have already been destroyed by man and his activities (Dini *et al*, 1998).

There is thus a necessity to greatly increase the accuracy, efficiency and thoroughness of assessing the cumulative impacts on wetlands as they are fragile and vulnerable eco-systems which are very important functions of the natural environment and need to be conserved.

To achieve the aim of this study the following needs to be accomplished:

1. undertake a literature review. This review will comprise four main sections:
    a. The first section will deal with environmental impact assessment and will give the reader a general introduction and background.
    b. The second section will discuss cumulative impact assessment and it's importance and necessity when conducting a mining-related EIA.
    c. The third section will review the South African methodologies that are used for cumulative impact assessments.
    d. The fourth section will review the international methodologies that are used for cumulative impact assessments.

2. A description of wetlands and the general locality of wetlands in South Africa and specifically in Mpumalanga and also a description of the main opencast coal producing areas in South Africa.

3. A description of the coal mining industry in South Africa and specifically in Mpumalanga.

4. A discussion of the main impacts and problems associated with opencast coal mining that affects wetlands in general and highlight those impacts which lead to significant cumulative impacts.

5. The drawing up of a generic methodology for cumulative impact assessment incorporating aspects of existing methodologies (international and local). The proposed framework methodology will accurately and efficiently assesses the cumulative impacts that coal mining has on wetlands.

4. LITERATURE REVIEW

Due to the nature of this study, it is required that a literature review be undertaken of relevant information pertaining to the chosen topic. During the literature review phase, various sources will be consulted and thoroughly studied so that a full understanding of the key findings can be presented to the reader in this chapter. The results will differ from source to source so that a holistic understanding of cumulative impact assessment techniques can be achieved. The findings of the literature review will be used to evaluate the nature and effectiveness of the different local and international cumulative impact assessment techniques.

4.1 Environmental Impact Assessment

The origins of EIA lie in the USA with the passage of the National Environment Policy Act (NEPA), in 1969. Since then the EIA system has spread throughout the world, and was formally brought to Europe in 1985, when the European Community introduced its Directive on the assessment of the effects of certain public and private projects on the environment. It was recognised from the inception of EIA that many of the most detrimental environmental effects may not result from direct impacts from individual projects, but from a combination of impacts from one development, or from minor impacts generated by a number of developments. Such impacts, over time can cause a significant impact (Parr, 1999).

The term environmental impact assessment consists of three words and the meaning thereof can be made clearer. Environment can be described as the biophysical and socio-economic elements that surround us. An impact can be defined as the result which is felt after an activity or event has taken place, this normally implies either a positive or negative outcome. Assessment is simply the process of evaluating something and giving it a rating on some predefined scale.

An EIA can be described as the process carried out by an environmental consultancy or specialist for evaluating a proposal, including its alternatives and objectives, and its effect on the environment, including the mitigation and management of those effects. The process extends from the initial concept of the proposal through implementation to commissioning and operation and, where appropriate, decommissioning. An EIA process would normally culminate in the compilation of an environmental impact assessment report (EIAR) which is submitted in accordance with legislation to justify the proposal (Gilpin, 1995).

According to the National Environmental Management Act (NEMA) of 1998, environmental impact assessment is defined: "*in relation to an application to which scoping must be applied, means the process of collecting, organising, analysing, interpreting and communicating information that is relevant to the consideration of the application* " (DEAT, 2006a p. 7).

The process which is generally followed during an EIA, begins with a public participation process (PPP), during which interested and affected parties are identified and consulted in terms of the project information and any objections they have are normally dealt with during an information meeting. Local and provincial authorities are also consulted during this time. Specialist studies are initiated at the same time and they comprise of site investigation and documentation, evaluation of the possible impacts and mitigation measures during the commissioning, operating and decommissioning phases of the project. The sections that are required to be covered by the EIA can be found in the National Environmental Management Act (NEMA, Act No. 107 of 1998) under regulation no. 32 and under regulation no. 50 of the Minerals and Petroleum Redevelopment Act (MPRDA Act No. 28 of 2002).

4.2 Cumulative Impact Assessment

Cumulative impacts follow the actual EIA process whereby predicted impacts and their significance are described. Impacts are assessed for three phases of the proposed project; during construction, operation and after the project has reached the end of its life, commonly called decommissioning of the project (DME, 2006). The impacts that are assessed are only relevant to the duration of the project's three phases, as they are site specific. It is the all important section of an EIA report which deals with the cumulative impacts. Cumulative impacts tend to be more far-reaching and complex in nature as they have a number of influencing factors. Cumulative impact assessment differs in important ways from conventional environmental assessment (DEAT, 2006a). Typically, cumulative effects assessments are expected to:

- assess effects over a larger area;
- assess effects during a longer period of time; and
- consider the effect of an activity in combination with other actions - not just the direct effect (DEAT, 2006a).

It is important to understand what a cumulative impact is in order to evaluate them. According to NEMA, a cumulative impact can be defined as the following: "*in relation to an activity that in itself may not be significant but may become significant when added to the existing and potential impacts eventuating from similar or diverse activities or* *undertakings in the area*" (DEAT, 2006a, p.7). Cumulative impacts can also be seen as those effects that are caused by the accumulation and interaction of multiple stresses affecting the parts and the functions of ecosystems (DEAT, 2006a).

To a large extent, all environmental effects can be seen as cumulative, in that all environmental effects occur in environments that are already stressed by either natural activities and events, or human activities. Cumulative effects are not a distinct or new type of environmental effect, the difference lies in the way we perceive environmental effects. Instead of looking at one effect in isolation from the other, cumulative environmental assessment implies looking at environmental effects in a more holistic way, as part of a larger ecosystem (Davies, 1992).

Of particular concern is the knowledge that ecological systems sometimes change abruptly and unexpectedly in response to apparently small incremental stresses. An EIA is required by law to have a section included in it which covers cumulative impacts (DME, 2006). Both the NEMA and MPRDA acts are vital as they regulate the majority of EIAs in South Africa. The Department of Minerals an Energy (DME) is especially important as they regulate, review and control all the EIAs which are mining related. It is the mining of mineral and petroleum resources which account for the disturbance of surface features such as wetlands in South Africa. Wetlands are just an example of a sensitive ecological system which could have significant negative cumulative impacts if disturbed.

The MPRDA under regulation 50 (c) and NEMA under regulation 32(1) (k) states that an EIA report must include the following: "*an assessment of the nature, extent, duration, probability and significance of the identified potential environmental, social and cultural impacts of the proposed mining operation, including the cumulative environmental impacts*" (DEAT, 2006a, p.30). There are various methods that are used to assess the cumulative impacts arising from a proposed project. The various methodologies that are used in South Africa and internationally will now be discussed in the following section.

4.3 South African Methodologies

There are few methodologies which are used by environmental practitioners in South Africa. Due to the highly complex interactions between the different actions and their associated effects, which vary by resource area, it is not possible to simply add or subtract each adverse impact and each beneficial or positive impact across a row to obtain a cumulative effect. Two or more effects may be additive, synergistic (multiplicative), or opposing. Thus, the ratings for the cumulative impacts reflect professional judgment as to how the different effects interact. When evaluating the cumulative impacts one also has to take into account future developments e.g. for a new mine one has to consider the development of other mines in the area or even the possibility of a residential area (DEAT, 2006a).

According to the Department of Environmental Affairs and Development Planning (DEA&DP) of the Western Cape, the specialist must consider potentially significant direct, indirect and cumulative impacts of a proposed activity. This requires the following:

- conceptualisation of possible cause-effect pathways resulting from the proposed development;
- an understanding of current and future plans, projects and activities in the same area;
- an awareness of other threats or trends that could affect the system, communities or species;
- an understanding of the likely resilience and status of affected systems, communities or species; and
- an understanding of broader strategic goals or targets for the area that would be affected by the proposed project (Münster, 2005).

The level of detail to which these should be considered will be influenced by the nature of the proposed project and issues raised through the scoping process. Where potentially significant cumulative effects are likely and cannot be addressed in the EIA, the specialist should alert the EIA practitioner and decision makers to these effects and make explicit recommendations as to ways of addressing them (e.g. through a strategic environmental assessment or systems-based approach) (CES, 2001). The definitions and components of a basic methodology where cumulative impacts are simply "labelled" can be seen in Table 4-1 below.

Table 4-1: Definitions and components of direct, indirect and cumulative effects (Cooper, 2004)

Cumulative Impact Assessment Methodology	
Direct (primary) effects Effects on the environment that occur at the same time and place as the initial cause or action (activity).	**Indirect (secondary) effect** Secondary effects which occur in locations other than the initial action (activity) or significantly later in time.
Cumulative effects:	
Additive:	The simple sum of all the effects.
Synergistic:	Effects interact to produce a total effect greater than the sum of individual effects. These effects often happen as habitats or resources approach capacity.
Time crowding:	Frequent, repetitive impacts on a particular resource at the same time.
Neutralising:	Where effects may counteract each other to reduce the overall effect.
Space crowding:	High spatial density of impacts on an ecosystem.

As stated earlier, DEAT (2006a), requires that an EIA be conducted with the assessment of each identified potentially significant impact, including:

- cumulative impacts;
- the nature of the impact;
- the extent and duration of the impact;
- the probability of the impact occurring;
- the significance of the impact;

- the degree to which the impact can be reversed;
- the degree to which the impact may cause irreplaceable loss of resources; and
- the degree to which the impact can be mitigated.

The methodology that will be discussed in the following paragraphs is based on the above points and covers the required aspects as they are set. The methodology is widely used in South Africa by EIA practitioners and specialists under impact assessment sections which are followed by the assessment of cumulative impacts. Many practitioners and specialists use the methodology as a basis for later conducting cumulative impact assessments.

In order to adequately assess and evaluate the impacts and benefits that will be associated with a proposed project, it is necessary to develop a methodology that will scientifically achieve this and reduce the subjectivity involved in making such evaluations. Legal requirements and clearly defined criteria must be implemented in order to accurately determine the significance of the predicted impact or benefit on the surrounding natural and/or social environment. For this to be done, the context of the project must be considered according to the area and the people that will be affected. Of necessity, impact assessment will always contain a degree of subjectivity, as it is based on the value judgment of various specialists and members of society. The evaluation of significance is thus contingent upon values, and dependant upon the environmental and community context. Therefore, ultimately, impact significance involves a process of determining the acceptability of a predicted impact to society (CES, 2001).

Environmental and social impacts are discussed according to different stages of the proposed project, namely: the construction phase, the operational phase, the decommissioning phase, and post closure. Impacts and benefits are assessed before the application of any mitigatory measures, and refer to effects on both the ecological and social environment. The holistic environment that will be affected by the project is thus considered, and includes a combination of all social, cultural, historical, economic, political, and ecological aspects. The various environmental impacts and benefits for any proposed project will be specifically discussed according to: the nature of impact, duration, extent, significance, probability, and whether or not mitigation will be required.

Nature of impact:

The nature of the impact is discussed and can be described as being either:

- negative: a cost to the holistic environment;
- positive: a benefit to the holistic environment; and
- neutral: no cost or benefit (CES, 2001).

Duration of impact:

The duration refers to the temporal scale of the impact or benefit, in terms of the period of time that the surrounding environment will be affected or altered by the proposed project. This is determined according to the scale in Table 4-2.

Table 4-2: Duration of impact (CES, 2001)

Rating	**Description**
Short term	0 – 5 years in duration. Quickly reversible change. Less than the project lifespan/ construction phase.
Medium term	5 – 25 years in duration. Change is reversible over time. Approximately the lifespan of the project/ operational phase.
Long term	25 – 40 years in duration. Permanent from a human perspective. Extends beyond the decommissioning phase.
Permanent/Residual	Over 40 years in duration. Permanent impact – change is irreversible.

Extent of impact:

This refers to the spatial scale of the impact or benefit of the proposed project, and the area over which it extends. Here a description is provided of whether effects are limited in extent, or affect a wide area or group of people. The extent is rated according to the scale in Table 4-3.

Table 4-3: Extent of impact (CES, 2001)

Rating	**Description**
Regional	Widespread effect. Extends far beyond the site boundary. Regional/national/international scale.
Local	Extends beyond the site boundary. Affects immediate surrounding areas.
Site specific	Effects occur within the site boundary.

Probability of impact:

Here, a description of the degree of certainty of the impact or benefit is provided. This refers to the confidence with which one can predict the occurrence, significance and severity of an impact. A "degree of probability" scale has thus been developed as can be seen in Table 4-4.

Table 4-4: Probability of impact (CES, 2001)

Rating	**Description**
Definite	Over 90% sure that the impact or benefit will occur Substantial data available to verify the assessment Impact will occur regardless of prevention measures
Probable	Between 70% and 90% sure that the impact or benefit will occur
Possible	Between 40% and 70% sure of an impact or benefit occurring
Unsure	Less than 40% sure of the likelihood of an impact or benefit occurring

Unlikely	Less than 20% sure that the impact or benefit occurring. It is thus unlikely that the impact will occur.

Significance of impact:

The environmental significance of an impact or benefit evaluates the relative importance thereof, according to the specific context of the project and area under consideration. The assumption is that mitigation has not yet taken place, and the significance or weight of the impact will therefore be altered after the application of mitigatory measures. These measures or recommendations should be included in the report in order to lessen the significance of negative impacts, and enhance the significance of environmental benefits. The Table 4-5 below represents the significance scale that is used to evaluate the impacts and benefits to the environment.

Table 4-5: Significance of impact (CES, 2001)

Significance	**Interpretation**
Low Significance	Short term effects on the natural and social environments. Effects are not substantial and are often viewed as unimportant. Mitigation is cheap, easy, quick or often not required.
Moderate Significance	Medium or long term effects to the environment. These effects are real but not substantial and are viewed as not very important. Mitigation is possible and fairly easy.
High Significance	Long term/permanent change to the natural or social environment. Impacts viewed in a serious light and modification of the project may be necessary in order to mitigate to impact. This mitigation is usually time consuming, difficult and costly.

The significance rating thus gives an overall view of the importance and relative magnitude of the impact or benefit, while taking into consideration both public and specialist opinion.

Mitigation of impact:

This refers to whether or not mitigation will be required to lessen negative impacts or enhance benefits associated with the proposed project. Should mitigation be required, recommendations and mitigation measures should be suggested specific to the project and affected area.

It can thus be seen that through implementing a specific process for evaluating impact significance, subjectivity is reduced and accuracy is optimised. The process allows public input to influence the significance rating, and is thus subject to value judgments. The impact significance will thus always be subjective to a certain degree, but the use of clearly defined parameters minimises this as far as possible (CES, 2001).

From the above it can be seen that the specialist or practitioner needs to have good background knowledge of the project and the present and future plans of the area in order to successfully assess the cumulative impacts. It is also accepted that assessment is not merely following a set method step by step, but rather pooling together all insight and knowledge of the project in order to accurately assess the cumulative impacts by using professional judgement (DME, 2006). It must be noted that many variations of the above methodologies do exist in South Africa as they differ slightly from one consultancy or user to the next.

3.4 International Methodologies

To date practitioners and researchers have published few methodologies for the assessment of indirect and cumulative impacts and impact interactions. Those that have been published have generally been designed for individual projects and have limited application. Davies (1992) has identified six themes as relevant to the development of a methodology. These themes often reoccur in the published methodologies and are as follows:

- defining boundaries;
- assessing interactions between the environmental impacts of the project;
- identifying past projects and activities and their environmental impacts;
- identifying future projects and activities and their potential environmental impacts;
- assessing interactions between the environmental impacts of past projects and future projects and activities; and
- determining the likelihood and significance of the indirect and cumulative impacts and impact interactions.

According to Parr (1999) there is a wide range of techniques and methods for impact assessment which are available to undertake an EIA. The same techniques can be applied for the assessment of indirect and cumulative impacts and impact interactions. They can be divided into those that are analytical or quantitative in nature and those that are planning orientated.

Analytical Method include:

- spatial analysis;
- network analysis;
- biogeographic analysis;
- interactive matrices;
- ecological modeling; and
- expert opinion.

Planning Methods include:

- multi-criteria evaluation;
- programming models;
- land suitability evaluation; and

- process guidelines.

An outline of some published methodologies is presented in Table 4-6 below.

Table 4-6: Summary of published methodologies (Adapted from Parr, 1999).

Methodology	**Description**	**Critique**
Integrating cumulative impact assessment into the EIA Planning Process (Lawrence, 1994).	It is essential to recognise that cumulative assessment is not a stage to be added to the EIA process, but that it is a dynamic EIA approach which facilitates systematic consideration of interactions among project characteristics, environmental components and other activities. It should therefore be incorporated into every stage of project-level EIA.	The approach is generally applicable to project types and environmental conditions. It is, however, highly theoretical, offering apparently little advice to the EIA practitioner as to how to undertake cumulative assessment, especially within Europe, where institutional arrangements are so different to that of South Africa.
Seven Steps to Cumulative Impacts Analysis (Clark, 1994).	The seven steps can be summarised as follows: 1. Set goals 2. Establish spatial and temporal boundaries 3. Establish the environmental baseline 4. Define impact factors 5. Identify threshold values 6. Analyse the impacts of proposals and their alternatives 7. Establish monitoring	This appears to be the most useful in terms of implementing a methodology to assess indirect and cumulative impacts, as well as impact interactions at the project-EIA level. It is general enough to be applicable to any type of project and environmental condition. It is non-prescriptive and with its emphasis on utilisation during the scoping stage of EIA, is flexible and cost-effective enough to fit in with the South African style of EIA. Cumulative impacts, indirect impacts and impact interactions are given early consideration. Its major drawback is its lack of detail in exactly how this consideration should be undertaken.
Addressing cumulative impacts through Acts with Regulatory Powers (Bardecki, 1990).	According to Bardecki (1990), the management of cumulative impacts is to some extent already being accomplished in	This approach has several major disadvantages. Firstly the methodology is based firmly in the planning approach

	a variety of situations in many jurisdictions, through the operation of regulatory frameworks. It is suggested that this vehicle for addressing cumulative impacts could be utilised more efficiently, by recognising the significance of cumulative impacts, identifying specific concerns and tailoring the regulatory powers accordingly.	developed in Canada and which differs fundamentally from the South African approach to EIA. Secondly, if the system were to be used in South Africa, the institutional changes required may result in unacceptable complexity and consequent loss of cost-effectiveness.
Assessment of cumulative impacts based on Monitoring and Modelling (Contant & Wiggins, 1991).	A methodology based on the presumption that to be comprehensive it must include mechanisms that capture the two broad categories of cumulative impacts; impacts resulting from a project's relationship to another development's activities, and impacts produced by an activity's presence within a set of many natural systems. The suggested methodology responds to these contextual issues and furthermore, is focused upon the tasks of monitoring and modelling. It relies on establishing comprehensive levels of baseline environmental data.	Unfortunately the level of baseline environmental data available to be used in models is negligible and the costs of environmental monitoring required to provide the information for accurate modelling may be prohibitively expensive. However, the principles of the methodology provide a useful basis for assessing cumulative impacts where suitable data and models do exist.

Questionnaire Checklist Approach (Canter & Kamath, 1995).	A questionnaire checklist for use in scoping indirect and cumulative impacts, as well as impact interactions, addressing detailed impact issues and summarising the results of indirect, and cumulative impact considerations and impact interactions. While all the items in the proposed questionnaire checklist will not be applicable to all projects and impact studies, it is argued that this methodology will provide a good basis for systematically addressing indirect and cumulative impacts, as well as impact interactions.	The questionnaire checklist approach does not set out to be a comprehensive methodology, but does provide a practical approach towards project level assessment of indirect and cumulative impacts, as well as impact interactions which can be implemented at the scoping stage.
A Synoptic Approach to Cumulative Impact Assessment (US Environment Protection Agency, 1992).	In 1992 the US Environmental Protection Agency proposed a methodology to assist wetland regulators in assessing the cumulative effects of individual wetland impacts within the landscape. Although designed for this particular purpose, and with a focus on state or regional wide assessments rather than individual cases, it is suggested that the methodology has broader applications and that it could be applied to issues at different geographic scales.	Such a methodology would be very difficult to use in any other country due to its prescriptive and selective nature.

Seven Step Framework for Cumulative Effects Assessment (Damman *et al,* 1995).	A methodology developed for the cumulative effects assessment of five uranium mine developments in Saskatchewan, Canada. A team of specialists was hired to undertake the assessment and specifically to identify significant impacts that could result from interactions between projects, interactions that might not be apparent from project specific environmental impact statements. The team's objective was to develop and apply a methodology that was consistent with prevailing theory and achievable within the limits of data, resources and time.	Damman's methodology provides a very thorough and transparent assessment process. It facilitates the setting of both spatial and temporal boundaries sufficiently broadly to be relevant for the assessment of indirect and cumulative impact as well as impact interactions. It takes into account wider interests of the community concerned and provides a very clear display of the thought process and results of the assessment. In addition, it is adaptable enough to provide a practical and beneficial guide to assessing cumulative and indirect impacts and impact interactions within the South African EIA system.
Impact Interaction Networks (Sporbeck, 1997).	The methodology, which was developed to consider impact interactions in road projects and concentrates on ecosystem and landscape units and differentiates between three elements of impact interaction: eco-systematic interactions, impact-upon eco-systematic interactions and impact shifts. The methodology is expressed in the form of a cause and effect diagram, which is enables the identification of direct impacts on primary receptors but also follow on impacts on other elements of the ecosystem resulting from impact interactions.	The complexity of this methodology is its main drawback, acting as a barrier for its use on small-scale project EIAs that are commonly conducted in South Africa and other countries. It has also yet to be demonstrated that the methodology can be adapted to other project types.

Cumulative impact assessment through Combining Individual Environmental Impact Assessments (Environmental Resources Management, 1994).	A methodology was specifically developed for the assessment of the cumulative impacts of two projects in the UK, the Channel Tunnel Rail Link and the widening of the M2 motorway. Combined impacts are identified as those that are additional to the impacts of the individual schemes or their simple additive impact.	This method was considered to be far too limited in its approach to be useful within the context of this study. It is possible the methodology could only be realistically employed where two very large scale, large budget projects have the potential to coincide.

In practice, the application of these methodologies for the identification and assessment of impacts is either limited or has not been developed to its full potential. It is widely accepted that a single method would be unlikely to meet all the criteria required for the effective assessment of indirect and cumulative impacts and impact interactions. It would be expected that various methods and techniques in an adaptive approach would be combined to perform individual assessments. The most suitable combination of methods will depend on the nature of the problem, purpose of the analysis, access to and quality of data, and available resources (Parr, 1999).

The development of methodologies in Europe and in North America is quite different as they reflect the institutional policies of those countries. Methodologies also vary vastly depending on the nature, size and complexity of projects. It can be concluded from the literature study that the importance of cumulative impact assessment is to some extent overlooked in South Africa, as the methodologies are very basic and limited in scope. There is little emphasis placed on developing a thorough methodology to accurately and efficiently assess the cumulative impacts of a proposed project (Sporbeck, 1997).

International methodologies are far more advanced than their South African counterparts, and place a greater emphasis on the importance and necessity of conducting a thorough investigation. This is perhaps due to the fact that the international field of environmental management is a number of years ahead of the South African context. It is of great importance that cumulative impact assessments in South Africa become far more advanced with greater emphasis placed on its necessity and relevance, especially with the rapid growth being felt in the mining sector in South Africa (Parr, 1999).

5. WETLANDS IN SOUTH AFRICA

In this section the reader will be introduced to the various types of wetlands found in South Africa, their functions, classifications and characteristics. The aim of this section is to highlight the importance and necessity of wetlands to the environment as well as the role they play towards man.

5.1 Wetlands of South Africa

Wetlands play an important role in the human and physical environments, providing food, shelter and breeding havens for fauna and flora, and water for people. Wetland functions extend beyond their boundaries into surrounding communities. By identifying the various types of wetlands in South Africa, a greater knowledge and understanding of these ecosystems can be gained and the wetlands can be protected for their natural functions that include water purification, flood attenuation, sediment removal and others. If suitably protected and conserved, wetlands can provide areas for social enjoyment and recreation, as well as contributing towards an aesthetically pleasing environment (Lindley, 2005).

But how does one define a wetland? The generic 'term' wetland is used to describe any ecosystem that has an aquatic base or hydrological driving force and possesses both upland and aquatic characteristics. Many terms have been used to describe wetlands (marshes, swamps and bogs) and the definitions vary according to the function of the wetland (Lyon, 1993). The great diversity in morphology, geographical location, and dominant faunal and floral characteristics makes it difficult to define wetlands universally (Williams, 1990).

There are a variety of definitions, but perhaps the most universally accepted is that by the Ramsar Convention, which defines wetlands as "*areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters" (*National Research Council, 1995, p. 23).

The definition developed by Cowardin *et al* (1979, p. 4) states that: "*wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water"*. For purposes of this definition, wetlands must have one or more of the following three attributes: (1) at least periodically, the lands must support predominantly hydrophytes, (2) the substrate must consist of predominantly undrained soil, and (3) the substrate must be non-soil and must be saturated with water or covered by the shallow water at some time of the growing season of each year (Cowardin *et al*, 1979).

The definition provided by the U.S. Army Corps of Engineers (USACE) has been operational since 1977 and states that wetlands are "*those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas*." (National Research Council, 1995 p.12).

Walmsley & Boomker (1988, p. 6) define a wetland as "*land where an excess of water is the dominant factor determining the nature of soil development and the type of plants and animal communities living at the soil interface. It spans a continuum of environments where terrestrial and aquatic systems intergrade".*

Wetlands therefore consist of water and have impeded drainage, waterlogged soils and characteristic fauna and flora. They occupy the transitional zone between permanently wet and generally dry environments. Wetlands are all relatively dissimilar to one another and vary in terms of their individual features (Semeniuk, 1987). Wetland areas may fit the definition but may differ in habitat or physical features such as depth of water, perennial flow and vegetation type. It is therefore important and useful to classify wetlands according to different characteristics (Tammi, 1994).

5.2 Classification system for wetlands

There are a large number of wetland classifications around the world given by Cowardin *et al*, 1979; Larson *et al*, 1989; Scott, 1989 and Dugan, 1990, as cited by Cowan & Van Riet (1998). The most widely used and accepted classification system is by Cowardin *et al*, (1979). This system was developed in 1979 for the U.S. Fish and Wildlife Service (USFWS). The purpose of the classification system is to define or describe the ecological units of a wetland that have certain homogeneous natural attributes (Breen, 1988). The system can be used to assist in decisions about resource management, develop units for inventory and mapping, and provide uniformity in wetland concepts and terminology (Breen, 1988). Breen (1988) states that decision makers cannot make informed decisions about wetlands without knowing the number, their type and location.

The classification system is based on ecological functions and defines deepwater habitats. The USFWS classification system is hierarchical and includes several layers of detail for wetlands including a subsystem of water flow; classes of substrate types; subclasses of vegetation types and dominant species. Figure 5-1 illustrates the system to the 'class' level (Dini *et al*, 1998). The classification system groups wetlands into five major systems: *marine, estuarine, lacustrine, riverine* and *palustrine*, which combine a variety of hydrologic, geomorphic, chemical and biological factors. The subsystems reflect hydrologic conditions within the systems, and the classes describe the appearance of the wetland based on vegetal physiognomy or substratum where vegetation is absent (Breen, 1988). The sub-classes describe the within-class differences based on vegetal physiognomy or substratum where vegetation is absent. Finally use is made of modifiers to describe more precisely the water regime, the salinity, the pH and the soil (Breen, 1988).

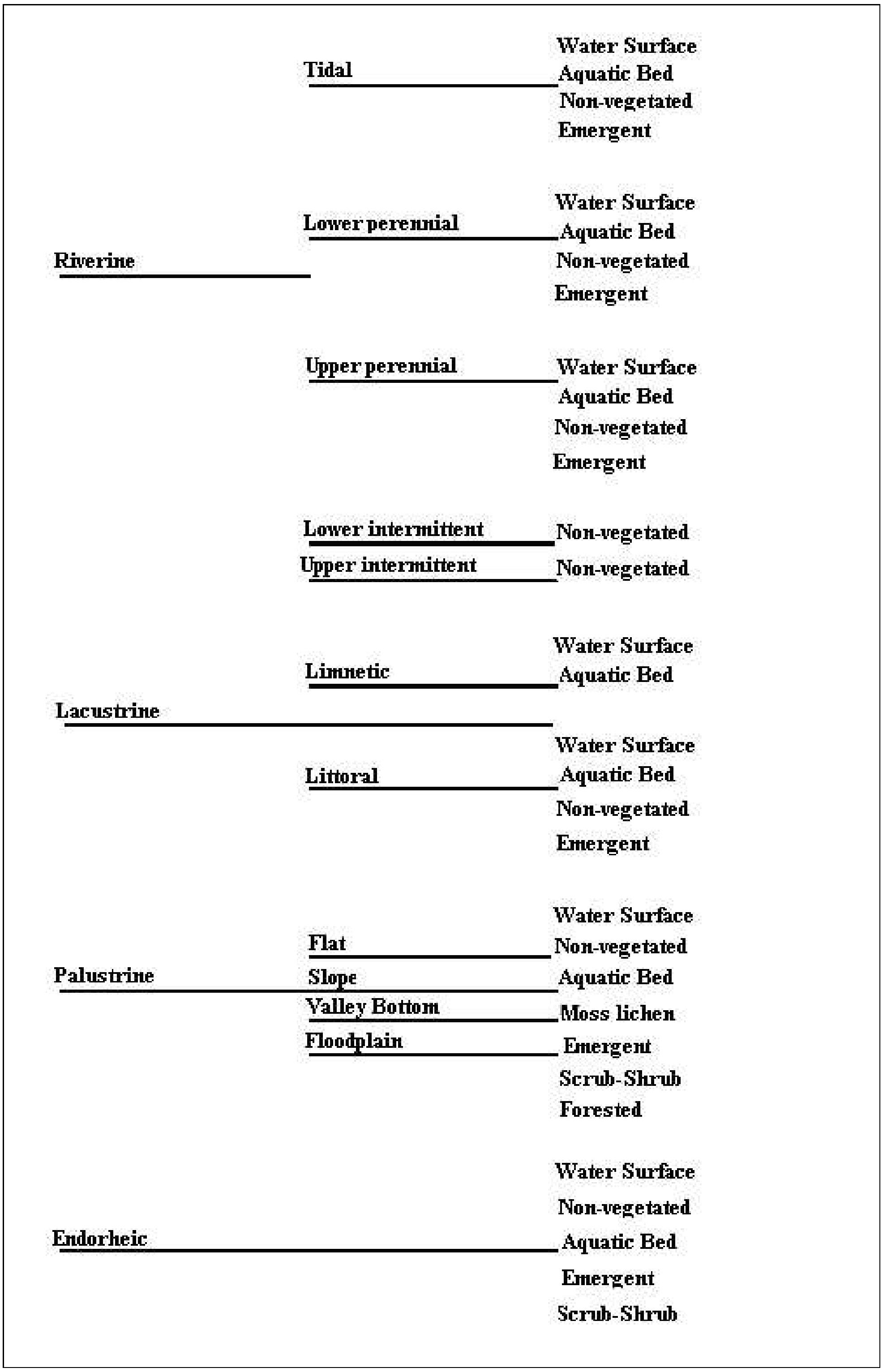

Figure 5-1: South African wetland classification system, to class level excluding marine estuarine wetlands (Dini *et al*, 1998)

The Department of Environmental Affairs and Tourism have developed a wetland classification system for South Africa based on the Cowardin *et al* (1979) system. It was proposed that the Cowardin system could be utilised for South Africa since it was a hierarchical and open structure, simple and clear, consistent and comprehensive (Dini *et al*, 1998). The classification system uses the wetland definition by Cowardin *et al*, (1979): *"lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water"* (in Dini *et al*, 1998 p.18). Using the Cowardin system as a basis, a new classification system for South Africa was developed that accommodates the physical and ecological diversity of South African wetland systems. The structure is also hierarchical and progresses from systems (marine, estuarine, lacustrine, riverine, palustrine and endorheic) to subsystems and classes (Dini *et al*, 1998). The various levels have the same descriptive purposes as those of the Cowardin system discussed above.

Wetlands are highly valuable and productive ecosystems in ecological, social and economic terms. However, the wetlands in South Africa are rapidly being lost or degraded through human activities. The classification system for South Africa will help provide baseline information on the wetland characteristics for a national inventory that will assist the development, implementation and monitoring of wetland conservation strategies at all levels of the community.

5.3 Wetland Characteristics

The three important characteristics that are associated with and used to indicate if an area constitutes a wetland include hydrology, hydrophytic vegetation and hydric soils (Braack *et al*, 2000). Each characteristic will be discussed in more detail in the following sections. Other characteristics of wetlands that will also be discussed include wetland morphology and wetland fauna.

5.3.1 Hydrology of Inland Wetlands

Hydrology is generally viewed as the driving force of creating and maintaining wetlands, but is often considered the least useful for wetland delineation due to the dynamic nature that varies daily, seasonally and annually (Ingram, 1983 & Tiner, 1993a). The hydrology and associated anaerobic conditions controls the abiotic (soil, colour, soil texture and water quality) and biotic (abundance of plants, vertebrates, invertebrates and microbes) characteristics of the wetland (National Research Council, 1995). Indicators of wetland hydrology include the soil colour and mottling, flood "markings" on the soil surface and coatings of silt or clay particles on plants (Lyon, 1993).

Water is introduced to a wetland through direct precipitation, overland flow (or runoff), channel flow and groundwater discharge (Ingram, 1983 & Williams, 1993a). Storage of this water occurs in the channel, the basin and groundwater table. The final hydrological processes include the removal of the water through evaporation, plant transpiration, runoff and groundwater recharge (Ingram, 1983 & Williams, 1990). This process of water introduction, storage and removal is referred to as the water budget.

The soils must be saturated long enough for anaerobic conditions to develop, therefore the water regime is one of the most important factors affecting the functioning of a wetland (Williams, 1993b). The surface water processes within a wetland are related to the local and regional precipitation patterns (Williams, 1993b). The precipitation influences the wetland water budget directly through rain within the physical boundaries of the wetland and the associated runoff, or indirectly through inflows from upstream watersheds (Williams, 1993b). Surface water can be lost through evaporation which is determined by air temperature, humidity and wind speed, vegetative cover and soil moisture content. Water can also be lost through transpiration which results from root uptake by emergent plants and the loss through the surface area of the plants (Williams, 1993b).

Hydrology may not be the most important factor for delineating wetlands, but a slight disturbance in the hydrological characteristics caused by water abstraction, drainage or construction works can result in enormous biological consequences (Etherington, 1983). Therefore, hydrology, which may not be as tangible as hydrophytic vegetation or hydric soils, must still be protected for the benefit of the wetland and humans.

5.3.2 Hydrophytic Vegetation of Inland Wetlands

Wetlands have distinctive and characteristic vegetation that differs from terrestrial vegetation. The vegetation (hydrophytic) is adapted to wet conditions, areas that are covered by water for at least part of the growing season, and therefore deficient in oxygen (Riemer, 1984; Tiner, 1993b and Cowan & Van Riet, 1998). The wet or damp nature of these habitats exerts a major influence on the species composition of wetland flora and increases the productivity of these systems. Wetland vegetation may respond to the topography and hydrology of the land by forming zones of dominant plant species or complex mosaics of plant communities (Tiner, 1993b & Bacon, 1997).

Apart from *Water plants of Natal* (Musil, 1973) there is little published information on the specific aquatic plants that occur in wetlands of Southern Africa (Glen *et al*, 1999). There are a number of terms given to aquatic plants, such as water plants, freshwater macrophytes, wetland plants, hydrophytes and semi-aquatic plants. Cook (1990) divides the large number of classifications of aquatic plants into two main categories:

- hydrophytes: plants that are physiologically bound to water where at least part of the generative cycle takes place in or on the water surface. This category can be further subdivided into:
    - *submerged* : all photosynthetic parts submerged, assumed to be bottom-rooted;
    - *emergent*: some photosynthetic parts are in contact with air and therefore they are assumed to be bottom-rooted with assimilating parts in the air; and

- Ø helophytes: essentially terrestrial plants of which the photosynthetically active parts tolerate long periods of submergence or floating on the water (Glen *et al*, 1999).

Aston (1973, p.11) states: "*there is no firm boundary dividing aquatic from non -aquatic species, nor has any universally acceptable definition of an aquatic plant been developed. Aquatic species are considered to be those adapted to growing in or on permanent water, either completely submerged or emergent, and having a definite life form (habit, structure) related to this aquatic environment*". The definition of an aquatic plant used in South Africa is based on the definitions of Cook (1990) and Aston (1973) together with fieldwork and information from herbarium specimens.

An aquatic plant is defined as: "*a plant belonging to the Charophyta, Byrophyta, Pteridophyta or Spermaphyta of which the photosynthetically active parts are permanently or at least for several months of each year submerged or float on the surface of water. These plants are entirely dependent on the presence of water, are adapted in various forms to live in this environment and are unable to complete their reproductive life cycle unless they have this close association with water for at least part of their life cycle*" (Glen *et al*, 1999, p.137).

Cowan (1999) has collated information on aquatic plants that are typical of South Africa. The data provides an idea of the range of species found in South Africa, indicates their red data status, and in which habitats they are likely to be found. The flora is dependent on other plants living either in or on the water for part of their life cycle and are adapted to the aquatic environment (Tiner, 1996).

5.3.3 Hydric Soils of Inland Wetlands

Kotze *et al* (1996, p. 28) have described hydric soil as "*soil that in its undrained condition is saturated or flooded long enough during the growing season to develop anaerobic conditions favouring the growth and regeneration of hydrophytic vegetation*".

The hydric soils are physically volatile and are continually changing with the decomposition of the vegetation and the erosion of sediment with river flow and flooding. The water level, sedimentation and decomposition result in the transformation and trapping of nutrients and organic matter leading to a fertile soil. The anaerobic conditions that are developed through the waterlogging of the soils are stressful to terrestrial plants because the oxygen supply is limited and the metals are in their chemically reduced and therefore more toxic forms (Kotze *et al*, 1996).

5.3.3.1 Types of Hydric Soils

Organic soils: Hydric soils are deficient of oxygen and impede the decomposition of organic matter. Wetland zones that are subject to the longest wet periods generally accumulate the highest level of organic matter (Kotze *et al*, 1996). Low or cool temperatures also promote the accumulation of organic matter. There must be at least 400mm of organic material within the upper 800mm of the soil, or organic material of any thickness extending from the soil surface to rock or gravel (Kotze *et al*, 1996).

Mineral soils: Soil material that has OC (organic carbon) limits of less than 10-12% is classed as a mineral soil (Brinkman & Van Diepen, 1990 & Kotze *et al*, 1996). The properties of texture, pH and mineralogy vary greatly between mineral soils. Gleying is a process that occurs when prolonged saturation reduces the level of mineral soils. The colours grey, and to a lesser extent blue and green, dominate in gleyed soil material (Etherington, 1983; Brinkman & Van Diepen, 1990 & Kotze *et al*, 1996).

5.3.3.2 Soil Colour

The water regime within a wetland has a strong effect on the colour patterns of the soil. In dryland (well drained) soils there is enough oxygen to oxidise the iron in the soil resulting in a uniformly red/brown/yellow soil (Braack *et al*, 2000). The aerobic conditions and the lack of water prevent the leaching of the iron from the soils thus retaining the red/brown colour. In saturated and anaerobic conditions the irons are leached from the soils resulting in a grey soil colour (Braack *et al*, 2000). The presence of water in the soil also reduces the rate of decomposition of organic matter. Therefore the level of organic matter is higher in wetland soils than in dryland soils, resulting in the soil being darker/blacker in the wetter areas. Wetland soils are thus darker and greyer. If anaerobic soils dry up or are drained, the iron oxides form orange or red spots called mottles (Braack *et al*, 2000).

5.3.3.3 The Water Regime, Degree of Wetness and Soil Morphology

The depth and duration of waterlogging depends on where the wet/dry continuum of the wetland lies (Kotze *et al*, 1996). This "position" is often referred to as the degree of wetness. The reader must note that wetlands occur as transitional areas between terrestrial (dry) and aquatic (wet) systems. The water regime describes when and to what extent the soil profile is saturated or flooded and is the most important factor that affects both plant species composition and the agricultural limitations of a wetland (Kotze *et al*, 1996). Hydric soils have great ecological and agricultural importance to South Africa. There is nevertheless a shortage of information relating to these soils in South Africa. The American Soil Taxonomy system (Soil Survey Staff, 1975), which is used to describe soil morphology was found to be superior to the South African system for classifying and describing hydric soils because it accounted for the depth of waterlogging, but unfortunately did not adequately account for the degree of wetness (Kotze *et al*, 1996).

Kotze *et al* (1996) has devised a three-class system for determining the degree of wetness that could be used together with the Soil Taxonomy system or the South African Soil Classification system to enhance the description of hydric soils in South Africa (Soil Classification Working Group, 1991). An illustration of the three class system is available in Table 5-1. The system was based on the fact that wetlands are not permanently flooded throughout the year and some may only contain water above the surface for a few weeks of the year (Kotze & Marneweck, 1999). Wetlands are therefore not all the same and should be divided into three primary zones based on the degree of wetness.

Table 5-1: A provisional three class system for determining the degree of wetness of wetland soils based on soil morphology (Dely *et al*, 1999; Kotze & Marnweck, 1999)

	Degree of Wetness		
Soil	**Temporary**	**Seasonal**	**Permanent/Semi-permanent**
Soil depth 0 – 10cm	Matrix brown to greyish brown (chroma 0-3, usually 1 or 2). Few/ no mottles. Low/intermediate OM (organic matter) Non-sulphide	Matrix brownish grey to grey (chroma 0-2) Many mottles Intermediate OM Sometimes sulphide	Matrix grey (chroma 0-1) Few mottles High OM Often sulphide
Soil depth 30 – 40cm	Matrix greyish brown (chroma 0-2, usually 1) Few/many mottles	Matrix brownish grey to grey (chroma 0-2) Many mottles	Matrix grey (chroma 0-1) No/few mottles Matrix chroma 0-1

High Organic Matter (OM): soil organic carbon levels are greater than 5% often exceeding 10%. Low Organic Matter (OM): soil organic carbon levels are less than 2%. Sulphide soil material has sulphides present which give it a characteristic ‘rotten egg’ smell. The seasonal zone tends to be greatly mottled and may make up a greater area than the matrix. In arid and semi-arid conditions the permanent/semi permanent wet zone is generally absent.

This class system has not been adequately tested and the results from the pilot study are only broad generalisations. The researchers therefore recommend that local studies be undertaken in other settings incorporating a wider range of wetland types. Local soil morphology/water regime studies will help improve the capacity for adequately describing hydric soils in South Africa (Orme, 1990).

5.3.4 The Fauna of Inland Wetlands

The variety of living organisms that have adapted to the different wetland habitats tends to be high with many of the major animal groups present (Gopal, 1990 & Bacon, 1997). The high production levels of the wetland plants support the large number of faunal species. The vegetation distribution and the water level fluctuations provide changing habitats for a number of terrestrial and aquatic species throughout the year. Wetlands support grazing and browsing animals such as the buffalo (*Syncerus caffer)* and hippopotamus (*Hippopotamus amphibious)* and a number of invertebrates including snails (*Gastropoda)* and crustaceans (*Crustacea)*, and many fish (Bacon, 1997). Frogs, toads and birds are also characteristic of wetlands. Many different kinds of birds with a wide range of feeding and breeding habits are found in and around wetlands. The wetlands also serve as resting and feeding stations along migratory routes for ducks (family *Anatidae)* and other shorebirds (*Charadriiformes*) (Gopal, 1990 & Bacon, 1997). Wetlands are ideal feeding, breeding and nursery habitats for birds (Gaigher, 1990). Wetlands also provide habitats for a wide range of invertebrates. The invertebrates obtain food from feeding on organic deposits and living plant tissue, filtering organic particles out of the water, capturing living organisms and scavenging (Gaigher, 1990).

Cowan (1999) has also collated information relating to the fauna of wetlands, and includes: amphipods, crabs, odonata (Dragonflies), fish, amphibia, reptiles, birds and mammals. As for the wetland fauna, Cowan (1999) has developed tables of wetland fauna to provide information on the range of species in South Africa, their red data status, and the habitats in which they are likely to be found. These habitats are based on the wetland classification developed by Cowardin *et al* (1979). The criteria that were used to identify a wetland species were based on whether it was dependent on water, wetland flora or other wetland fauna for any major part of its life cycle (Cowan, 1999). These tables are not complete for the whole of South Africa and should be supplemented with further research in the future.

5.3.4.1 Wetland Associated Amphipods (crustaceans)

A large majority (80%) of the known amphipod species belong to the suborder *Gammaridea* (Stewart, 1999a), which include marine, freshwater and terrestrial species. The freshwater amphipod fauna are made up of three taxonomically and geographically distinct elements. The paramelitides and the sternophysingids, two of the elements, are members of the super-family *Crangonyctoidea* of the suborder *Gammaridea*. The third element is a group of five cave-dwelling species that fall into the suborder *Ingolfiellidea*, which is the smallest of the four suborders within the *Amphipoda* (Stewart, 1999a).

5.3.4.2 Wetland Associated Mammals

Wetlands such as floodplains and temporary pools offer refuge, water points, feeding and breeding grounds for a wide range of mammals, and are therefore of great ecological and conservation importance. The mammals may be dependent on the availability of water, the associated vegetation, or a complex combination of biotic and/or abiotic interactions. There is a presence of 44 wetland associated mammals in South Africa which represents 15.1% of the total southern African and 5.8% of African mammalian fauna (Chimimba & Cowan, 1999). These species include representatives of seven (*Insectivora*, *Chiroptera*, *Carnivora*, *Cetacea*, *Artiodactyla*, *Rodentia* and *Lagomorpha*) of the 15 mammalian orders recognised in South Africa (Chimimba & Cowan, 1999). Fourteen of the species are red data species (endangered, vulnerable, restricted, peripheral, rare, very rare, indeterminate or threatened) and include the endemic Riverine rabbit (*Bunolgus monticularis*).

5.3.4.3 Wetland Associated Reptiles

South Africa has a large reptile diversity consisting of 411 species and subspecies (Jacobsen, 1999a). Less than eight percent or about 32 reptile taxa are to a greater or lesser extent dependent on wetlands for their continued existence. The study allows for those reptiles that are also of border line to be included. Of the 32 taxa associated with wetlands, only ten are endemic to South Africa with twelve occurring in the Cape (Jacobsen, 1999a).

5.3.4.4 Wetland Associated Amphibia

South African frogs tend to be terrestrial, using the wetlands for breeding purposes. South Africa has 92 frog species, of which 20 are permanent residents of wetlands (the genera *Xenopus, Rana, Ptychadena* and *Strongylopus*). Seventy species use wetlands for breeding and feeding; and fourteen do not or marginally use wetlands (Jacobsen, 1999b). Forty-nine percent of these frog species are endemic to South Africa.

5.3.4.5 Wetland Associated Birds

There are large numbers of birds that are dependent on wetlands for their survival, breeding and habitats. These birds do not necessarily qualify as waterfowl species (Cowan & Randall, 1999). Cowan & Randall (1999) identified 58 bird species associated with wetlands who were either totally dependent on wetlands for food, shelter and breeding habitat, or required wetlands for at least a phase of their annual cycle, and those that frequently use wetlands. There are about 234 species of wetland birds found in South Africa of which 70% can be classified as waterfowl according to the definition of the Ramsar Convention (Cowan & Randall, 1999). Twenty-four of the 234 wetland species have been accorded red data status. Ten of the 234 species are endemic to southern Africa and 37 species are alien to South Africa (Cowan & Randall, 1999).

5.3.4.6 Wetland Associated Fish

Skelton & Cowan (1999) have produced lists of typical wetland fish species. The list includes all fish occurring in South African rivers. There are 97 indigenous freshwater fish and 147 estuarine fish in South Africa (Skelton & Cowan, 1999). The estuarine fish will be excluded from this study but can be located in the original text *Biota of South African Wetlands in relation to the Ramsar Convention* (Cowan, 1999). Man has also introduced roughly 18 alien species of fish.

5.3.4.7 Wetland Associated Crabs

There have been a total of 44 crab species recorded from the inland and estuarine waters of South Africa, of which 12 live only in freshwater habitats (Stewart, 1999b). These river crabs form an important part of the food chain for carnivores such as fish, otters and birds, and are also important as detritivores. Crabs are also viewed as transmitters of disease, ‘pests’ to farmers and fulfill a medicinal function (Stewart, 1999b).

5.3.4.8 Wetland Associated Dragonflies (Odonata)

South Africa has 155 species of dragonfly and of these, 56 are fairly widespread. Another 67 species are highly localised or generally rare (Samways, 1999). South Africa has 29 endemic species of Odonata and this figure includes *Metacnemis angusta* Selys and *Paragomphus dicksoni* Pinhey (Samways, 1999). The odonata species are being threatened by increased silt loads, decreased oxygen levels, lowering of the water table, major or minor impoundments, fluctuating water levels and over extraction of water (Samways, 1999). Other threats include the introduction of exotic fish (rainbow trout) and trees (black wattle), damage to riverbanks and plantation trees. There are currently eight species that are red data listed.

5.4 South African Wetland Types

The diversity of natural conditions in South Africa has resulted in a number of different wetland types. South Africa is an arid country with an average rainfall of about 497mm per annum, which is much lower than the world average of 860mm (Cowan & Van Riet, 1998). Sixty-five percent of the country has a mean annual precipitation of less than 500mm while 21% receives less than 200mm. The annual evaporation ranges from 1100mm in the east to over 3000mmm in the west, which is well over the annual rainfall (Cowan & Van Riet, 1998).

The various climatic conditions occurring around South Africa have resulted in different types of wetland areas. Cowan & Van Riet (1998) have divided South Africa into various wetland regions according to climate, and these have been further sub-divided into four broad groups based on the geomorphology of the country: plateau, mountains, coastal slopes and rimland, and coastal plain. The geology will determine minor wetland groups within these regions. It must be remembered that wetlands typical of a region are not necessarily exclusive to that region (Cowan, 1995).

5.4.1 Endorheic Pans

Endorheic pans are common in many of the world's arid zones and consist of brackish, saline or alkaline lakes, flats, pans and marshes (Cowan & Van Riet, 1998). They may also be referred to as playas in geomorphological literature. A pan can be described as a closed basin that accumulates rainwater only after sufficient rainwater has fallen (Allan, 1987). Some pans can be completely without vegetation except after good rains. The process of pan formation begins with periodic flooding followed by desiccation that results in an area of exposed soil in a depressional setting. Winds then scour out and enlarge the circular-shaped basin (Allan, 1987).

Endorheic pans may be identified by their circular to oval shape. They are shallow (less than three metres deep) even when inundated and have a closed drainage system (no drainage outlet). The majority of the water lost from the pans is through evaporation, which tends to increase the levels of salinity of the water. Inundation is typically ephemeral (of a short period) and some pans in the dry western regions may be dry for years between flooding (Cowan & Van Riet, 1998 and Dini *et al*, 1998).

The pans in South Africa are the most common in the western, southern and eastern plateau wetland regions. Their highest concentration occurs in areas with a mean annual rainfall of less than 500mm and an average net evaporation loss of 1000mm per annum (Cowan & Van Riet, 1998 and Dini *et al*, 1998). The '*Directory of South African Wetlands'* compiled by Cowan & Van Riet (1998) has recorded a total of 289 endorheic pans, which is by no means the total number in South Africa. The Department of Surveys and Mapping have recorded 1772 pans at a scale of 1:500 000. Allan, (1987) identified 7600 pans from the 1:50 000 map series for the plateau region north of the Vaal River. At this scale roughly 16% of the smaller, well-vegetated pans may still not have been identified (Cowan & Van Riet, 1998).

Endorheic pans have a large variety of characteristics and have therefore been differentiated into a number of groups. Cowan & Van Riet (1998) have described the groups as follows:

- salt pans: dry for most of the year but may contain perennial pools filled by springs. These pans have extremely saline substrata and are virtually restricted to the dry western areas of South Africa. These pans are bright white when dry and may be surrounded with the sedge *Schoenoplectus triqueter* on the shoreline (Allan, 1987).
- temporary pans: dry for long periods, although flooded during the rainy season, and is usually moderately saline.
- grass or diplachne pans: seasonal and covered by a thick growth of hygrophilous grasses and other low terrestrial vegetation. The waters are fresh to slightly saline and are crucial breeding grounds for the near-threatened bullfrog (*Pyxicephalus adspersus* and *P. edulis*).
- reed pans and sedge pans: temporary or semi-permanent with dense stands of reeds (*Phragmites)* and sedges (*Cyperaceae)*. The submergents may include *Lagarosiphon* and *Potamogeton* (Allan, 1987). The sedge pan is generally smaller than the reedpan. The two dominant sedges are Matjiesgoed (*Schoenoplectus corymbosus)* and *Eleocharis palustris* (Allan, 1987).
- open pans: these pans are usually devoid of vegetation except around their shorelines.The vegetation consists predominantly of the grass, *Cynodon dactylon,* sedges *(Scirpus dioecus* and *Cyperus* species), various *Juncus* species and the small flower, *Limosella.* Their substrate is shallow soil or exposed rock.

In the process of urbanisation, the pans of South Africa and especially those situated around Gauteng, are being drained, filled, covered over or used as dumpsites, while those wetlands occurring in South Africa's coalfields are being severely affected by mining activities. Afforestation affects the landscape characteristics of the wetland and the water supply that sustains the pans (Cowan & Van Riet, 1998). Pans are divided by power-lines, roads and railways, and the basins are excavated for road construction material (Allan, 1987).

5.4.2 Riverine Wetlands

South African rivers are regarded as young in the geological history of the country. They tend to be fast flowing, but can be highly variable in their flow regime. Cowardin *et al* (1979) limits these riverine systems to positions within a channel, and which contain continuously or periodically moving water. Cowardin *et al (*1979*)* and Dini *et al* (1998) exclude those wetlands that are (1) dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) which have habitats with ocean derived salinities in excess of 0.5 parts per thousand. The perennial systems include rivers, streams, waterfalls and inland deltas, whilst seasonal riverine wetlands include seasonal rivers and streams, and riverine floodplains.

Two of South Africa's Ramsar sites are part of riverine floodplains (Seekoeivlei and Ndumo). The wetlands play a vital role in regulating flow and maintaining high water quality standards of major rivers, such as the Vaal River. In comparison to the pans discussed in the previous section, the riverine wetlands can be valuable as fish breeding sites and play a key role in the hydrological cycle (Cowan & Van Riet, 1998 & Dini *et al*, 1998).

Riverine wetlands are subjected to the dumping of chemical loads from factories and industrial activities. Fortunately, riverine wetlands have been known to metabolise these nitrogen and phosphorous loads (Allanson, 1995). The fast flowing water assists in the dilution and dispersion of the pollutants - a form of water purification. This valuable function requires the restoration of damaged wetlands or the construction of artificial wetlands in stream channels where high loads of nitrogen and phosphorous could be harmful to downstream water users. In addition, the hydrophytes also remove the nutrients from the soil, transfer them to shoots and leaves where they are immobilised until the plants die naturally and the process of decay returns the nutrients back into the system (Allanson, 1995).

Davies (1993, p. 12) states that: "*there are few rivers in Southern Africa that have not been overexploited, degraded, polluted or regulated by impoundments, and we know of many that were once perennial, but which now flow only seasonally or intermittently*". Other major threats to rivers include catchment degradation and associated sediment production, organic and mineral pollution, over abstraction of water, salinisation, and the introduction of alien invasive species (Cowan & Van Riet, 1998). Many of South Africa's riverine wetlands have been altered or drained by farmers who utilise the hydric soils, which structure these wetlands, for agricultural purposes (Allanson, 1995).

5.4.3 Lacustrine Wetlands

Lacustrine wetlands have been defined as areas of permanent water with little flow (Cowan & Van Riet, 1998). Cowardin *et al* (1979) defines lacustrine wetlands as those: (1) situated in a topographic depression or a dammed river channel; (2) lacking trees, shrubs, persistent emergents, emergent mosses or lichens with greater than 30% areal coverage; and (3) whose total area exceeds eight hectares; or an area less than eight hectares if the boundary is active wave-formed or bedrock or if water depth in the deepest part of the basin exceeds two metres at low water (Dini *et al*, 1998).

These wetlands include seasonal freshwater lakes (smaller than 8ha in size), ponds and pans (smaller than 8ha in size). There are disputes as to what constitutes a lake. Hart (1995) excludes pans from lakes because lakes are extensive and relatively deep open waters. Cowardin *et al*, (1979); Cowan & Van Riet, (1998) & Dini *et al*, (1998) are all of the opinion that a pan is a lake type. In essence, a wetland should be considered a pan when its water depth is less than three metres.

Although many authors refer to a pan as a type of lake, lakes are more permanent in nature, larger in size, have a greater water depth and support a wider variety of fauna and flora. A large number of freshwater permanent and temporary pans, which form part of floodplain systems, are listed as lacustrine wetlands (Cowan & Van Riet, 1998). The water of these lakes may become slightly saline as they dry out but are still included as lake systems. Most of the major lake systems have been included as Ramsar sites and been afforded legal protection (de Hoop, de Mond, Kosi System, Lake Sibaya, Ndumo, St Lucia System, Verlorenvlei and Wilderness Lakes).

The major threats to the lacustrine wetlands include agricultural and silvicultural developments in their catchments (Cowan & Van Riet, 1998). These developments reduce water flows into the lakes, cause nutrient loading and herbicide, and biocide pollution. Industrial developments also increase the amount of toxic and non-toxic pollutants entering the wetland system. Recreational demands and over-exploitation of water resources due to the expanding population, as well as land reclamation are leading to sediment loading and changes in the hydrological regimes of the lakes (Cowan & Van Riet, 1998).

5.4.4 Palustrine Wetlands

Palustrine wetlands can best be defined as ecosystems occurring between terrestrial and aquatic systems with an excess of water as the dominant factor (Cowan & Van Riet, 1998). Cowardin *et al* (1979) and Dini *et al* (1998) include all non-tidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens. Palustrine wetlands consist of a wide range of physical situations, water regimes, chemistries and vegetation types. These wetlands include permanent marshes and swamps, permanent peat-forming swamps, seasonal marshes, peatlands and fens, alpine and polar wetlands, springs and oases, volcanic fumaroles, shrub swamps, swamp forest and forested peatland.

Palustrine wetlands are found in the areas with a mean annual rainfall greater than 500mm with the main exceptions being those found along the main watercourses and those developed around dolomitic eyes. The largest wetland of this type may be found on the physiographically flat areas of the coastal plains.

Volcanic fumaroles have not been identified by Cowan & Van Riet (1998), but a number of hot springs have been developed into health and recreation resorts (Warmbad and Badplaas). A majority of the springs are related to dolomitic eyes in the north east of the western plateau wetland region. Many endemic fish are located in these areas, which are presently facing threats from the introduction of alien invasive fish species and agricultural pollution (fertilisers and pesticides). These ecosystems are also being drained for urban, industrial and agricultural use. Dewatering of the dolomitic compartments for the coal mining processes are destroying these palustrine wetlands. Cowan & Van Riet (1998) have identified four different types of freshwater marshes. These are as follows:

- sedge marshes: dominated by sedges, hygrophilous grasses and similar plants up to one metre high (*Scirpus littoralis, S. ficniodes, Festuca caprina, Juncus maritimus, J. kraussi, J. oxyxapus, Leersia hexandra, Sporobolous virginicus, S. consimilis* and *paspalum vaginatum*);
- restio marshes: typical of South-western Cape and dominated by Restionaceae (characteristic of the Cape Floral kingdom) and sedges. Three communities have been identified: the *Restio compressus* community of seepage steps, the *Eligia cuspidate – Prismatocarpus sessilis* community of recently burnt , seasonally moist sites, and the *E. cuspidate-Bobartia india* community of unburnt, marshy flats;
- reedbed marshes: dominated by *Phragmites* species. Stands of *Typha*, *Scirpus* and *Cyperus* can be found in the areas where water levels remain close to the soil surface during the dry season. These marshes intergrade with sedge marshes at higher altitudes; and
- cape seasonal wetlands: these wetlands include a number of floral communities, a temporary sand plain community, a limestone community, a coastal Renosterveld community and a strand community.

Cowan & Van Riet (1998) have also identified two types of freshwater swamps:

- reed swamps: perennial standing water on floodplains that fringe many costal and estuarine lakes. They are dominated by *Phragmites australis* or *P. mauritianus* while *Typha capensis* often occurs in patches in these swamps; and
- papyrus swamps: require a stable hydrological regime and are dominated by *Cyperus papyrus* and occur in the sub-tropical coastal plain wetland region.

Peatlands are also a part of the palustrine category of wetlands (Cowan & Van Riet, 1998). The main peat forming flora include *Cyperus papyrus* and *Phragmites australis* in papyrus or reed swamps; *Ficus trichopoda* and *Syzigium cordatum* in swamp forests, and *Fimbristylus longiculmis* and *Leersia hexandra* in sedge dominated peatlands. Peatlands are used in subsistence farming as sources of fresh water, fodder and biomass for local communities. These wetlands are being threatened by afforestation, which lowers the water table, and commercial horticulture (Cowan & Van Riet, 1998).

5.4.5 Man-made Wetlands

Artificial wetlands are of major significance in South Africa and can have a profound effect on the natural wetland landscape (Cowan & Van Riet, 1998). Due to the lack of significant lakes, a large number of dams have been developed in South African rivers to supply water for industry, irrigation, mining, municipal and domestic use, power generation, and stock watering. These artificial impoundments drown the natural wetland systems and change the hydrological character of the rivers. Impoundments alter the natural flow regime of rivers and exert a number of other influences such as:

- retention of water may result in the increased growth of algae and other aquatic plants resulting in eutrophication;
- the discharge patterns from the impoundments may impact on the downstream natural wetlands, floodplains, flora and fauna; and
- water releases from impoundments may result in floating aquatic plants such as the water hyacinths (*Eichhorma crassipes*) in the Vaal River (Allanson, 1995).

There are however a number of benefits to be had from these artificial impoundments. Some of the large dams have provided a refuge for large numbers of waterfowl during the dry seasons. Commercial fisheries and aquaculture works can also be constructed on the larger dams which provide food and employment in the country (Cowan & Van Riet, 1998).

6. LEGISLATION GOVERNING WETLANDS

In South Africa, water resources and especially wetlands are protected by certain legislation and agreements aiming to control and limit the interference with them. National legislation as well as international agreements will be briefly discussed below to familiarise the reader with the various types of law that aim to protect wetlands from exploitation.

6.1 National Water Act of 1998

As with any resource in South Africa, water resources are very highly regarded and important in a water scarce country such as South Africa. It is therefore the responsibility of the Minister of Water Affairs and Forestry in accordance with National Water Act of 1998 (Act no. 36 of 1998) to ensure that the protection, use, development, conservation, management and control of the water resources of South Africa, is met on a sustainable basis. The requirements prescribed in terms of the regulations must be seen as minimum requirements to fulfill this goal.

The Department subscribes to the principles of co-operative governance and recognises the role of the Department of Minerals and Energy to co-ordinate environmental management within the mining industry and the role of the Department of Environmental Affairs and Tourism as the lead agent on matters affecting the environment. The roles of Environmental Management Programme Reports and Environmental Management Programme Performance Assessment Reports required in terms of the Minerals Act, 1991 (Act No. 50 of 1991), the Environmental Impact Assessment Reports required in terms of the Environment Conservation Act, 1989, (Act No. 73 of 1989) are recognised and supported by the Department. Any information, obligations, programmes, permissions and commitments contained in the above reports, procedures, consultation requirements and decision-making processes will be recognised by the Department.

The National Water Act comprises various chapters which deal with certain aspects of sustainable water resource use in South Africa. Regulation no. 704 is very important with regards to mining as it sets out the regulations on use of water for mining and related activities aimed at the protection of water resources. This regulation clearly spells out the precautions and measures that are required when wanting to mine within or nearby any watercourse, especially wetlands. The regulation sets out the restrictions on locality, material use, it sets out the requirements and procedures for applying for exemption to mine in these areas, it also sets out the required security and rehabilitation measures required for such a coal mining activity to be conducted in close proximity to a water course such as a wetland. If any of the requirements are not met by the responsible party or mine and it is found that mismanagement of the water resource has occurred, then severe penalties could be imposed such as hefty fines or even imprisonment.

6.2 The Ramsar Convention on Wetlands

The convention on wetlands, signed in Ramsar, Iran, in 1971, is an intergovernmental treaty which provides the framework for national action and international co-operation for the conservation and wise use of wetlands and their resources. There are presently 152 contracting parties to the convention, with 1611 wetland sites, totalling 145.2 million hectares, designated for inclusion in the Ramsar list of wetlands of international importance (Ramsar Convention Bureau, 2000).

South Africa is a signatory to the Ramsar convention and has 17 wetlands identified to be of international importance covering a total area of 498 721 hectares (Table 6-1).

Table 6-1: South African Ramsar wetlands of international importance (Ramsar Convention Bureau, 2000)

Name of Wetland	**Size**	**Province**	**Date which it was added**
Barberspan	3 118 ha	North-West	12/03/75
Blesbokspruit	1 858 ha	Gauteng	02/10/86
De Hoop Vlei	750 ha	Western Cape	12/03/75
De Mond (Heuningnes Estuary)	918 ha	Western Cape	02/10/86
Kosi Bay	10 982 ha	Kwazulu/Natal	28/06/91
Lake Sibaya	7 750 ha	Kwazulu/Natal	28/06/91
Langebaan	6 000 ha	Western Cape	25/04/88
Natal Drakensberg Park	242 813 ha	Kwazulu/Natal	21/01/97
Ndumo Game Reserve	10 117 ha	Kwazulu/Natal	21/01/97
Nylsvley Nature Reserve	3 970 ha	Limpopo	07/07/98
Orange River Mouth	2 000 ha	Northern Cape	28/06/91
St. Lucia System	155 500 ha	Kwazulu/Natal	02/10/86
Seekoeivlei Nature Reserve	4 754 ha	Free State	21/01/97
Turtle Beaches/Coral Reefs of Tongaland	39 500 ha	Kwazulu/Natal	02/10/86
Verloren Valei Nature Reserve	5 891 ha	Mpumalanga	16/10/01
Verlorenvlei	1 500 ha	Western Cape	28/06/91
Wilderness Lakes	1 300 ha	Western Cape	28/06/91

The Convention on Wetlands is the only global environmental treaty that deals with a particular ecosystem. The Convention's member countries cover all geographic regions of the planet (Ramsar Convention Bureau, 2000).

The convention's mission is: "*the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world*" (Ramsar Convention

Bureau, 2000). All wetlands are in this way protected under the convention based on the country being a signatory of the convention

The Conference of the Contracting Parties (COP) meets every three years and promotes policies and technical guidelines to further the application of the convention. The standing committee, made up of parties representing the six Ramsar regions of the world, meets annually to guide the convention between meetings of the COP. The scientific and technical review panel provides guidance on key issues related to the application of the convention. The Ramsar secretariat, which shares headquarters with the World Conservation Union (IUCN), in Gland, Switzerland, manages the day-to-day activities of the convention. The MedWet initiative, with its out posted co-ordination unit in Athens, Greece, provides a model for regional co-operation for implementation of the convention (Ramsar Convention Bureau, 2000).

Nationally, each contracting party designates an administrative authority as its focal point for implementation of the convention. Countries are encouraged to establish national wetland committees, involving all government institutions dealing with water resources, development planning, protected areas, biodiversity, tourism, education, development assistance, etc. Participation by Non-Government Organisations (NGOs) and civil society is also encouraged. Ramsar sites facing problems in maintaining their ecological character can be placed by the country concerned on a special list, the “Montreux Record”, and technical assistance to help solve the problems can be provided. Eligible countries can apply to a Ramsar Small Grants Fund and Wetlands for the Future Fund for financial assistance to implement wetland conservation and wise use projects (Ramsar Convention Bureau, 2000).

7. COAL MINING IN SOUTH AFRICA

For many centuries it has been man's main source of heat and energy. Coal suffered a major decline when the oil industry displaced it as the world opted for liquid fuel. Gaseous fuels, initially the by-product of oil, also grew in importance and once again coal stuttered. Oil became the substitute for coal and defeated coal in most of its traditional markets. Oil not only dominated the world's transport scene; it came to have widespread use in domestic and industrial heating and for power generation. In short, in many countries, oil became the prime source of energy. That situation still prevails on a global basis as oil and gas are still the most widely used fuels. Since the oil price explosions of the 1970s, which restored coal as the dominant fuel for power stations and cement works, coal has steadily come back into favour as a primary source for energy generation, especially electricity (Prévost & Msibi, 2005). Many wetlands occur on the Karoo Supergroup rocks of the Mpumalanga province were South Africa’s vast coal deposits occur. The sedimentary rocks of this area host both coal deposits and wetlands due to the highly erodible geology underlying the surface.

7.1 Geology

Coal is formed when the residue of decomposed vegetation is subjected to pressure and temperature over a long time period. Generally, the greater the pressure and temperature, the higher the coal rank or maturity. Coal rank ranges from peat to lignite to bituminous to anthracite. Coal reserves in South Africa are found in sediments of Permian age which overlie a large area of the country. They generally occur as fairly thick, flat, shallow lying coal seams. In the Witbank area of Mpumalanga, which contains extensive coal reserves and is the country's most productive coalfield, five major coal seams occur at intervals within a sedimentary sequence deposited during a 35 million year geological time period (Prévost & Msibi, 2005).

7.2 Occurrence and Production

The coalfields in the country are spread over an area of 700 kilometres from north to south and 500 kilometres from east to west. Generally the rank or carbon content of the coal increases eastwards while the number of seams and their thickness decrease. Thus, Mpumalanga and Limpopo coals are usually classified as bituminous, occurring in seams up to several metres thick, while KwaZulu-Natal coals are often anthracitic and are found in relatively thin seams. The recoverable coal reserves in South Africa amount to about 28.9 billion tons, equivalent to nearly 6 percent of the world's total (this figure excludes low-grade, high-ash content coal which could add as much as 25 percent to the country’s total reserves). Most of South Africa’s coal is of a bituminous thermal grade, while only two percent is anthracite, and 1.6 percent is of metallurgical quality. At current production levels, South Africa’s coal reserves are estimated at around 200 years (Prévost & Msibi, 2005).

South Africa is the fifth biggest coal producer in the world. South African collieries range in size from small operations with output limited to a few thousand tons of coal per year to Secunda, the world’s largest underground coal mining complex, which has an annual production of about 35 million tons. Almost 90 per cent of the country's saleable coal is mined in the Mpumalanga province. For the past number of years, the domestic coal industry consistently increased production, albeit very slowly (Prévost & Msibi, 2005).

7.3 Mining Methods

Around 40 percent of coal comes from opencast operations, some of which have recovery rates approaching 90 percent. Coal lying less than 70 metres below the surface is extracted from a progressive series of parallel, long, narrow trenches. Overburden rock and soil lying above the coal seams is blasted and scraped out of the currently mined trench and tipped into the mined-out void of the previous trench.

Walking draglines with large scraper buckets slung beneath long, crane-type boom arms carry out the stripping operation. The exposed underlying coal seams are drilled and blasted loose and hauled out of the pit by heavy duty trucks. When the coal from all viable seams has been removed and the spoil of the next parallel trench has been deposited in the void, the rehabilitation process begins. The overburden is flattened, the previously stored top soil is spread over it and the area is seeded with a mixture of grasses to return the landscape to its ecological balance (Prévost & Msibi, 2005).

7.3.1 Three different mining methods used in underground mines

The most common technique, accounting for just under half of total production, is the ‘bord and pillar’ method. Bord and pillar mining is ideal for relatively shallow deposits where overlying rock pressure is low. Seams are mined leaving in situ coal pillars, which are big enough to support the roof indefinitely, and a checker-board pattern of mined-out ‘rooms’. This method currently permits around 65 percent of the available coal to be extracted.

The adoption by several collieries of the ‘squat-pillar’ method developed by the now defunct Chamber of Mines Research Organisation (COMRO), and approved by the Government Mining Engineer (GME), will increase extraction rates, especially at depth, through the employment of bord and pillar mining of smaller pillars than were previously thought necessary. When the overlying strata impose no restrictions, ‘total-extraction’ mining can take place (though, in reality, somewhat less than 90 per cent is recovered on average) (Prévost & Msibi, 2005).

There are two major underground total extraction systems employed in South Africa. In rib-pillar extraction, a continuous miner machine cuts a roadway up to 1.5 kilometres in length through the coal and five metres in from the edge of the area to be mined. This leaves a five metre wide band of coal in the form of a long, isolated rib pillar along one side of the tunnel (Prévost & Msibi, 2005).

With the aid of timber or hydraulic props to hold up the now unstable roof, the continuous miner cuts away the rib pillar in a series of curved cutting sweeps. The machine repeats the cycle by mining into the remaining coal area, again cutting a tunnel and leaving a rib pillar.

The other total extraction method employed is long-wall mining. Long walls are usually several hundred metres long and essentially consist of a corridor in which one wall and the roof are formed by steel supports capable of resisting hundreds of tons of pressure from the subsiding mine roof above. The second side of the corridor is formed of coal and is the actual face from which coal is cut.

A mechanical coal cutter, bearing two large revolving shearing drums with steel picks, runs the whole length of the coal face on rafts. This cuts into the coal and widens the corridor during each sweep, thus advancing the coal face. The mined coal falls on to a conveyor and is drawn out of the long-wall face. Hydraulic rams linked to the line of props push the conveyor and coal cutter forward into the newly mined-out section in the face. In turn, each hydraulic support is then released from its position and hauls itself forward after the advancing face, reinstalling its steel canopy against the recently exposed area of face roof (Kelly, 1988).

7.4 Domestic Uses

Coal is South Africa's primary energy source and has been a major stimulus to economic growth and a significant factor in the country's industrialisation. It provides 88 percent of commercial energy needs and plays a vital role in meeting liquid-fuel requirements. The South African coal mining industry is fortunate to be supported by a large domestic market as well as having a strong international position. Domestic sales are dominated by electricity generation (53 percent), synfuels and petro-chemicals (33 percent), with metallurgical and other users accounting for the remaining 14 per cent. About 40 percent of all bituminous coal produced in South Africa is used in the generation of electricity, making this industry the largest single user of coal in the country (Prévost & Msibi, 2005).

With power generation demand likely to keep on rising there is the inevitable question of how long South Africa's coal reserves will last. Assuming growth rates of between three and five per cent, the coal used by 2030 (when estimates suggest electricity demand is likely to peak at 75 000 megawatts), together with coal dedicated to future use by power stations either operating or under construction in 40 years time, amounts to a staggering 30 billion tons, roughly the majority of the country's reserves. By that time today's power stations will have reached the end of their useful lives and consumed most of the coal reserves of the dedicated collieries (Prévost & Msibi, 2005).

Inevitably, alternative methods of generating electricity will need to be phased in alongside South Africa's coal-fired programme. More nuclear power stations are likely to come on stream in the early years of the 21st century and by the year 2030 fast-breeder reactors will probably take up the base-load of electricity production. In the meantime, Eskom has demonstrated with its Lethabo power station, which at times uses coal with an ash content as high as 42 percent, that low grade coal can be used in power generation, so adding up to 25 percent to the total of the South Africa's proven coal reserves.

The second most important coal user in the home market is Sasol, the only successful commercial oil-from-coal plant in the world. Sasol uses the Fischer-Tropsch indirect liquefaction method (which has the added benefit of being able to process high-ash content coal), to convert coal into petrol and diesel fuels, and provides raw materials for the petro-chemical industries and other important by-products such as fertilizer (Prévost & Msibi, 2005). Other significant domestic users are Iscor's (Mittal Steel) metallurgical plants (the steel industry requires coking coal to be prepared in coke ovens to provide metallurgical coke capable of reducing and melting iron ore to liquid iron in blast furnaces), the cement industry and large municipalities. In the last few years, off take by Eskom, the railways and the mining industry has shrunk, while demand from Sasol and the metallurgical sector is flat. Any capacity for local consumption added to the South African coal mining industry in the foreseeable future, therefore, is likely to be replacement, rather than additional, capacity (Prévost & Msibi, 2005).

7.5 Exports

South Africa is the world's fourth largest coal exporting country and the fifth largest producer. South African saleable coal production has increased at an average rate of over 4.8 percent a year to just over 242.8 Mt (million tons) in 2004. Total coal exports from South Africa reached 67.9 Mt in 2004 (Prévost & Msibi, 2005).

7.6 Future Developments

On the local market, Eskom, the largest steam coal consumer, is now generating less power, while Sasol's consumption has increased. The rest of the local industry, using only 9 per cent of the total supply, shows little change and its influence on demand and price is limited. With the implementation of the South Dunes Coal Terminal (SDCT) to aid the Richards Bay Coal Terminal (RBCT), export capacity will increase to 92 Mt per annum which is projected for 2008 (Eskom, 2005).

8. IMPACTS AND PROBLEMS ASSOCIATED WITH MINING IN WETLAND AREAS

Before an attempt to identify the cumulative impacts that coal mining activities will have on wetlands, it is necessary to firstly identify the main impacts associated with coal mining in a wetland area from pre-mining to post-mining. The main impacts that are caused by opencast and underground coal mining will be discussed.

Many different types of pollution are associated with coal mining. These commonly involve acidity and suspended solids and, occasionally, heavy metals. Surface or open cast mining for coal is nearly always on a larger scale than underground mining. The largest strip mines extract up to 50 000 tons per day compared with 6000 tons per day for underground mining (Kelly, 1988). Excavation on this scale results in large piles of spoil and overburden which are prone to erosion, releasing large amounts of sediment, acid and toxic leachates into watercourses, unless there are runoff ponds and drains to prevent this.

Strip mines are also more likely to intercept surface streams and precipitation due to their larger surface area. In a survey of Canadian mines, Watkin (1983) estimated a mean flow of water of about 13 800 litres min^{-1} into open pits compared with about 1000 min^{-1} into active underground mining. Despite this, the majority of acid mine drainage problems do not originate from surface mines but from active or abandoned underground mines (Kelly, 1988).

Owing to the varying nature of planned opencast mining the following are some generic impacts applicable to the South African coalfields, that will affect all the wetland types in an area where opencast mining is planned:

1. Vegetation destruction due to removal of top soil prior to the removal of overburden. This extends to vegetation clearing of the site (including the wetland vegetation if it falls in the planned coal reserve to be mined).

2. Transport and deposition (erosion) of sediment in the valley bottom wetlands associated with runoff should site clearing occur in summer when heavy rainfall occurs.

3. Interruption of the key hydrological processes that support the wetlands not directly affected by the opencast mining, namely:
   a) Interruption of the perched groundwater flows that support the hillslope seepage wetlands. This normally occurs if a strip or cut is mined through the point were groundwater passes to or from a wetland. This could potentially lead to pit-flooding.
   b) Possible interception of weathered Karoo stratigraphy such as a sandstone aquifer (which predominates throughout the Mpumalanga coalfields as well as the Highveld region), that is suspected of underlying the floodplain alluvium. This again will inhibit the groundwater flow, eventually drying out the wetland if it is entirely dependant on groundwater for replenishment or recharge.

c) Drainage lines will be affected by being redirected or cut-off due to site clearing, road construction, or other infrastructure being set up for mining operations to commence. A change in the drainage lines will eventually lead to surface water flow being inhibited or totally cut-off from the wetland. The mining of strips or cuts will almost certainly affect wetlands adjacent to mining areas.

4. Water pollution of wetlands occurs when contaminated water on the coal mining site enters water courses which flow into the wetland catchment. Pollution normally occurs from spilled or leaked hydrocarbons associated with the mining operations and its machinery. The hydrocarbons could escape from the mining area in times of heavy rainfalls, when polluted water could dam and flow over the pollution-prevention berms and into sterile watercourses. Contaminated water could also be released into these water courses through human negligence.

   Acid mine drainage (AMD), is acidic water that flows into streams from abandoned mines or piles of coal mining waste or tailings. The acid arises from the oxidation of iron sulphide compounds, such as pyrite, in the mines by air, dissolved oxygen in the water, and chemoautotrophs, which are bacteria that can use the iron sulphide as an energy source. Iron sulphide oxidation products include sulphuric acid, the presence of which has reduced or eliminated aquatic life in many streams in coal mining regions.

5. Underground coal mining will have very little impact on wetlands, as the main impacts have already been discussed and could be true for underground mining with clearing of wetlands for the building surface infrastructure. The only serious impacts that could occur as a result of underground mining is the occurrence of stooping, sinkhole formation and subsidence on the surface. This has the potential for surface water to seep underground, leading to the wetland losing vast amounts of water and eventually drying up. However, unless there is a direct connection between surface waters and underground workings, the inter-connectivity and

likelihood of it occurring is very low. The impact is thus much more related to possible seepage on the surface.

6. Dust and noise pollution is created by haul trucks being driven on unsealed roads, the coal crushing operations, drilling operations and the wind blowing over areas disturbed by mining. The dust generated in this way can lead to it being transported and deposited in wetland areas, leading to siltation. Noise which is created by the above activities can cause scare off wildlife such as birds and other aquatic species associated with wetlands in the vicinity, leading to a disruption in the food chain of these wetlands.

The planned opencast operations for a coal mine usually take on various phases, namely:

- construction phase;
- operational phase; and
- decommissioning phase.

The following phases should be well managed as to allow minimal impacts on wetlands in or adjacent to the coal mining area. The following phases are an example of what impacts are expected to occur and how they should be managed.

8.1 Construction Phase

During the construction phase the opencast areas will be stripped of topsoil, berms, trenches and power lines will usually be constructed and roads will be upgraded. Removal of vegetation and movement of soils will allow erosion to take place and silt could be added to the surface water environment such as wetlands. Due to the possibility of other wetlands in the area, mitigation will be required.

8.2 Operational Phase

During the operational phase, the opencast areas, which could include wetlands, will effectively be removed from the various catchments. Small areas should gradually be added to the catchment as rehabilitation should commence during the operational phase and those areas should be allowed to discharge. During coal mining, whenever rain water is trapped by the opencast areas it should be re-used as this will reduce the run-off water reporting to local streams, wetlands and dams. Mitigation is required to rehabilitate opencast areas to be free draining and maximise run off in the long term.

If seepage from the opencast spoils does occur on the surface, it will impact on the water quality, potentially in terms of dissolved salts. This water should be contained and kept within a closed circuit in order to minimise the impact. All water used on site will be considered to be polluted and thus should be contained to ensure it does not reach the local water courses. Coal spillages from trucks normally occur and will require mitigation to ensure that the coal does not negatively impact on water quality of the surrounding areas. Roads and spoil heaps should be kept vegetated and stabilised to ensure the potential for erosion and siltation is decreased.

8.3 Decommissioning Phase

Surface water quantity should be restored after decommissioning and closure due to the rehabilitation of the opencast and underground workings. Catchments should be restored, although potentially altered, and water should no longer be extracted from local water resources.

There could be a potential for groundwater in the underground workings to rise and seep into the environment and contaminate downstream water sources. This impact is potentially significant and mitigation is required. Rehabilitation must be adequate to ensure erosion is reduced and slopes of a natural gradient are required to reduce fast flowing run-off.

9. PROPOSED METHODOLOGY FOR CUMULATIVE IMPACT ASSESSMENT OF WETLANDS

It is clearly evident that a disparity exists between the way cumulative impacts are assessed in South Africa and the way they are assessed by developed countries. With South Africa's constitution and legislation being on a par with most developed countries, it is no surprise that there is a need to get in line with these developed countries as far as cumulative impact assessments are concerned. During this section a framework for a more thorough and accurate methodology for cumulative impact assessment will be proposed. This methodology can be utilised by a number of individuals (managers, specialists, practitioners, local government and developers) who deal with EIAs and especially for assessing cumulative impacts related to coal mining. The guide should be carefully studied so that the necessary methods required for the applicable project can be followed.

During the process of compiling the EIA document, it is the very important function of the EIA practitioner and environmental specialists involved with the project to accurately assess the foreseeable impacts. This is evaluated under the section impact assessment, which aims to adequately assess and evaluate the impacts and benefits that will be associated with the new activities. It is necessary to use clearly defined criteria in order to determine the potential significance of the predicted impact or benefit on the surrounding natural and/or social environment. The relevant specialist is normally responsible for conducting an assessment for each of their specialist sections pertaining to the EIA.

The section within an EIA document which deals with cumulative impact assessment is where the specialist or specialists must consider potentially significant direct and indirect cumulative impacts. The level of detail to which these should be considered will be influenced by the nature of the proposed project and issues raised through the scoping process which precedes the EIA document. From the above it can be seen that it is a necessity to get a suitable specialist for investigating the proposed activities and their predicted impacts. When a wetland is being assessed, it is almost a given that a wetland specialist will conduct the specialist investigations, which include the cumulative impact assessment process. This is not the case in South Africa, as many “general” environmental practitioners are tasked with these specialist studies, often resulting in an inadequate review or investigative process. This potentially leads to a “flawed” and insufficient cumulative impact assessment of the wetland under investigation.

After it has been established that the correct specialist be involved in the wetland assessment, the focus will be on the steps and processes to be followed in order to achieve a more thorough and accurate cumulative impact assessment. It is proposed that a form of classification first be introduced as the type of wetland being affected could determine the nature and extent of cumulative impact assessment required. The need for a more involved assessment will then become evident, thus determining whether a single specialist will be sufficient or rather a panel of specialists.

9.1 Classification of Wetlands

Wetlands first need to be classed as being either lacustrine, palustrine, riverine, endorheic or man-made wetlands (Dini *et al*, 1998). The type of wetland involved will determine various aspects which will need to be assessed as wetlands differ by the type of hydrology, geomorphology, chemistry and biology as discussed in Section 5.4. It is therefore essential that a reputable and suitably qualified wetland specialist investigate and determine firstly the type of wetland involved and the set of characteristics associated with the wetland type. The wetland needs to be identified and its characteristics documented. The wetland fauna and flora needs to be recorded so that any red data species can be dealt with appropriately.

It is required that the wetland specialist or project manager contact the relevant DWAF officer who is responsible for the river catchment in which the wetland falls. It is necessary to involve DWAF as they are the controlling body for all water related activities and activities which influence or impact on any river catchment. DWAF will also have significant insight into the nature of the wetland under consideration, thus proving useful to the project as a whole as it will eventually aid the cumulative impact assessment process by making it more transparent. DWAF has vast records relating to specific wetland types and their locations in their wetland inventory which will help in identifying and interpreting the wetland correctly. The DWAF catchment officer may require the project manager or specialist to accompany him/her on a site visit of the wetland identified. Any immediate problems that could be foreseen may be dealt with at this stage. An assessment will need to be made of the ecological status of the wetland, this will be described in Section 9.3.

The reader can refer back to Section 5.4 for the various wetland definitions. The following are the different types of wetlands and the different types of impacts normally associated with them:

- Endorheic wetlands or pans: they are not extremely sensitive wetlands that might be easily affected by pollution through mining activities nearby or activities that might pollute the water directly. The impact of pollution can easily be contained and restricted to the wetland without being able to exit the wetland by means of connecting watercourses.

  Most endorheic pans are not very well vegetated, thus the impact on the natural habitat of wetland species is minimal. Pans are however home to the near-threatened Bullfrog, which needs to be addressed accordingly by relocating this affected species.

- Riverine wetlands: these wetlands are subjected to the dumping of chemical loads from factories and industrial activities. Fortunately, riverine wetlands have been known to metabolise these nitrogen and phosphorous loads (Allanson, 1995). The fast flowing water assists in the dilution and dispersion of the pollutants – a form of water purification. This valuable function requires the restoration of damaged wetlands or the construction of artificial wetlands in stream channels where high loads of nitrogen and phosphorous could be harmful to downstream water users. In addition, the hydrophytes also remove the nutrients from the soil, transfer them to shoots and leaves where they are immobilised until the plants die naturally and the process of decay returns the nutrients back into the system (Allanson, 1995).

It is therefore necessary to limit the polluting of these wetlands by mining activities as they are directly related to major water courses in our country upon which we are reliant for potable water. It is also extremely important to conserve these types of wetland vegetation as they fulfill an important function in cycling nutrients and other chemicals.

- Lacustrine wetlands: these wetlands are associated with greater vegetative habitats that support larger numbers of aquatic species and birds. They can be isolated from watercourses or connected making them vulnerable to pollution from upstream coal mining activities or potentially hazardous if they become polluted, making them able to discharge polluted water to other water courses or wetlands. Mining and other activities cause nutrient loading and herbicide, and biocide pollution.

- Palustrine wetlands: these wetland types are perhaps the most complex to understand as they have such far ranging characteristics that form complex interactions with each other. For this reason, it is required that a thorough assessment be undertaken for these wetland types as they produce the most complex cumulative impacts. Their hydrology is far reaching and so pollution is a great cause for concern as other water courses are easily affected. They tend to have an abundance of vegetative habitat for a great many aquatic, bird and other species, due to the high rainfall areas they occur in. These wetlands are regarded as being the most ecologically sensitive of the above mentioned wetlands.

Only once the type of wetland has been identified and this has been verified by the relevant DWAF catchment officer, can it then be established whether or not the wetland is protected by some national or international law or agreement. This is an important step as it could lead to the project either going ahead or it being scrapped at this stage.

9.2 Conservation Status

It is further required that the wetland specialist has sufficient project background knowledge and that he or she is fully aware of the proposed coal mining or other activities which are going to impact on the wetland directly or indirectly. It is expected that the wetland specialist determine the conservation status of the wetland if one exists. This should be done by working closely with the relevant DWAF catchment officer. It must be noted that a project ‘fatal flaw’ will be encountered if the wetland is protected by national conservation status (being listed) or by the Ramsar convention, which means that the project will lead to a ‘no go’ option and alternatives will need to be investigated. Wetlands found to be in pristine ecological state should be approached cautiously as the wetland may be in the process of becoming listed or may even belong to an extremely sensitive eco-system. This should be judged by the discretion of a suitably qualified wetland specialist as such wetlands should rather be preserved and alternative sites be investigated for coal mining activities.

Wetland conservation in South Africa is supported by the Wetlands Conservation Bill (Bill No. 3 of 1995). Its aim is to provide an application in South Africa of the convention on wetlands of international importance especially as waterfowl habitat; the prohibition of prospecting or coal mining of listed wetlands; the prohibition of detrimental activities in wetlands and listed wetlands; and the prohibition of activities detrimental to catchment areas; and to provide for matters connected therewith.

It is important that listed wetlands are not in any way affected by the proposed activities as this could have serious consequences for the project as fines and even prison sentences are handed down to those in contravention of this legislation (DEAT, 2006b).

9.3 Influence of Project Activities

The influence of coal mining activities needs to be fully understood so that a detailed understanding of the extent and degree to which the wetland will be influenced can be achieved e.g. mining directly into the wetland with its complete removal or mining adjacent to a wetland affecting its watercourses, etc. This is necessary so that the scope of work can be determined and the appropriate planning can be conducted for the next step.

The project manager or specialist needs to involve the mining engineer and geologist at this point in clearly delineating the extent of coal mining activities as far as the wetland is concerned. All surface infrastructure as well as the mining plan needs to be mapped so that a better spatial understanding of the entire project can be made. All surface water features such as drainage lines, rivers, streams, channels, wetlands, boreholes, etc need to be indicated so that likely problem areas can be determined early on and mitigation measures be implemented.

9.4 Impact Assessment

A present ecological status (PES) assessment needs to be undertaken before the cumulative assessment process. The PES assessment is a subjective assessment of the situation in the wetland catchment. It is a basic assessment in the sense that it only describes the status of the wetland as being one of the following:

- totally natural with no modifications (with a PES rating of A);
- largely natural with few modifications (with a PES rating of B);
- moderately modified (with a PES rating of C); or
- largely modified (with a PES rating of D).

The PES rating is determined by a suitably qualified wetland specialist. The total area of the wetland which falls into the various categories above should be represented spatially by compiling a map and the various areas totals expressed in hectares and as a percentage of the total wetland area (WCS, 2006).

An ecological importance and sensitivity (EIS) analysis needs to be conducted after the PES assessment. It is required to determine a scoring system as applied in the procedure for determination of Resource Directed Measures for wetland eco-systems (DWAF, 1999). Modified categories based on those by Kleynhans (1996 & 1999) are used for the assessment.

The next step involves conducting the impact assessment associated with the wetland under investigation. Aspects such as the nature of the area, geology, soils, vegetation, surface water, groundwater, etc as described in an EIA will need to be assessed in order to determine possible direct impacts associated with the proposed activity taking place. These direct impacts will lead to a greater understanding of the cumulative impacts that will be assessed later on. The physical, biological and cultural features that will need to be assessed for each of the project phases and each by its own specialist in that field are shown in Table 9-1.

The various aspects will need to be assessed by conducting a desktop study of the impacts likely to occur and then by conducting a site visit to the area concerned. The site visit will entail the relevant specialist going out to the area and recording its current status by evaluating the nature and status of the environment in relation to the specific physical feature. The specialist must then determine if the proposed activity will impact on the physical aspect concerned (taking PES and EIS into consideration), and whether or not it will have a positive or negative impact, the duration, extent and severity will also need to be determined. The specialist will also need to make predictions on the future impacts that are most likely to occur as a result of the proposed activities. The project impacts will need to be assessed during the construction, operational and decommissioning phases.

Table 9-1: Impact assessment of the various features throughout the project lifetime

Aspects	Nature of Impact	Certainty	Duration	Extent	Probabilty	Significance of Impact	Mitigation Required
Climate	Neg, Pos or Neutral	Yes or No	Short, Med, Long or Perm	Reg, Local or Site spec	Def, Prob, Possible, Unsure or Unlikely	Low, Moderate or High	Yes or No
Topography	Neg, Pos or Neutral	Yes or No	Short, Med, Long or Perm	Reg, Local or Site spec	Def, Prob, Possible, Unsure or Unlikely	Low, Moderate or High	Yes or No
Geology	Neg, Pos or Neutral	Yes or No	Short, Med, Long or Perm	Reg, Local or Site spec	Def, Prob, Possible, Unsure or Unlikely	Low, Moderate or High	Yes or No
Soils Erosion Contamination	Neg, Pos or Neutral	Yes or No	Short, Med, Long or Perm	Reg, Local or Site spec	Def, Prob, Possible, Unsure or Unlikely	Low, Moderate or High	Yes or No
Surface Water Quality Quantity	Neg, Pos or Neutral	Yes or No	Short, Med, Long or Perm	Reg, Local or Site spec	Def, Prob, Possible, Unsure or Unlikely	Low, Moderate or High	Yes or No
Groundwater Quality Quantity	Neg, Pos or Neutral	Yes or No	Short, Med, Long or Perm	Reg, Local or Site spec	Def, Prob, Possible, Unsure or Unlikely	Low, Moderate or High	Yes or No
Land Capability	Neg, Pos or Neutral	Yes or No	Short, Med, Long or Perm	Reg, Local or Site spec	Def, Prob, Possible, Unsure or Unlikely	Low, Moderate or High	Yes or No
Land Use	Neg, Pos or Neutral	Yes or No	Short, Med, Long or Perm	Reg, Local or Site spec	Def, Prob, Possible, Unsure or Unlikely	Low, Moderate or High	Yes or No
Air Quality	Neg, Pos or Neutral	Yes or No	Short, Med, Long or Perm	Reg, Local or Site spec	Def, Prob, Possible, Unsure or Unlikely	Low, Moderate or High	Yes or No
Noise	Neg, Pos or Neutral	Yes or No	Short, Med, Long or Perm	Reg, Local or Site spec	Def, Prob, Possible, Unsure or Unlikely	Low, Moderate or High	Yes or No
Vegetation	Neg, Pos or Neutral	Yes or No	Short, Med, Long or Perm	Reg, Local or Site spec	Def, Prob, Possible, Unsure or Unlikely	Low, Moderate or High	Yes or No
Fauna	Neg, Pos or Neutral	Yes or No	Short, Med, Long or Perm	Reg, Local or Site spec	Def, Prob, Possible, Unsure or Unlikely	Low, Moderate or High	Yes or No
Archaeological Areas	Neg, Pos or Neutral	Yes or No	Short, Med, Long or Perm	Reg, Local or Site spec	Def, Prob, Possible, Unsure or Unlikely	Low, Moderate or High	Yes or No
Sensitive Areas	Neg, Pos or Neutral	Yes or No	Short, Med, Long or Perm	Reg, Local or Site spec	Def, Prob, Possible, Unsure or Unlikely	Low, Moderate or High	Yes or No
Visual Aspects	Neg, Pos or Neutral	Yes or No	Short, Med, Long or Perm	Reg, Local or Site spec	Def, Prob, Possible, Unsure or Unlikely	Low, Moderate or High	Yes or No
Socio-economic	Neg, Pos or Neutral	Yes or No	Short, Med, Long or Perm	Reg, Local or Site spec	Def, Prob, Possible, Unsure or Unlikely	Low, Moderate or High	Yes or No

The various aspects that are assessed for the different project phases will later on be useful in aiding the assessment of cumulative impacts. It is very important that the above table is completed by suitably qualified professionals in the various specialist fields in order to accurately assess the various impacts.

9.5 Review Process

By this stage the magnitude and severity of the proposed activity will become evident, leading to a decision being made on whether the cumulative impact assessment process can be done by a specialist alone or a panel of specialists who will need to convene and discuss and assess the cumulative impacts using objective judgement. This decision will be based on the intricacy and extent of the impacts assessed during the previous step. Not only will the applicable technique relevant to the situation be brought in at this point, but also the processes required, structures needed to be put in place and procedures to be followed, etc.

Although the environmental practitioner or specialist must draw from the available methods, techniques, and tools it is important to understand that a study-specific methodology is necessary. Designing a study-specific methodology entails using a variety of methods to develop a conceptual framework for the cumulative impact assessment. The conceptual framework should constitute a general causal model of cumulative effects that incorporates information on the causes, processes, and effects involved. A set of primary methods can be used to describe the cumulative impact assessment in terms of multiple causation, interactive processes, and temporally and spatially variable impacts. The primary methods for developing the conceptual causal model for a cumulative impact assessment are:

1. Questionnaires, interviews, and panels to gather information about the wide range of actions and effects needed for a cumulative impact assessment.

2. Checklists to identify potential cumulative impacts by reviewing important human activities and potentially affected resources.

3. Matrices to determine the cumulative impacts on resources, ecosystems, and human communities by combining individual effects from different actions.

4. Networks and system diagrams to trace the multiple, subsidiary effects of various actions that accumulate upon resources, ecosystems, and human communities.

5. Modeling to quantify the cause-and-effect relationships leading to cumulative impacts.

6. Trends analysis to assess the status of resources, ecosystems, and human communities over time and identify cumulative impact problems, establish appropriate environmental baselines, or project future cumulative impacts.

7. Overlay mapping and GIS to incorporate locational information into the cumulative impact assessment and help set the boundaries of the analysis, analyse landscape parameters, and identify areas where effects will be the greatest.

After developing the conceptual framework, the environmental practitioner or specialist must choose a method to determine and evaluate the cumulative impacts of the proposed project activities. This method must provide a procedure for aggregating information across multiple resources and projects in order to draw conclusions or recommendations.

The simplest method is the comparison of project alternatives qualitatively or quantitatively in tabular form. Tables and matrices use columns and rows to organise effects and link activities (or alternatives) with resources, ecosystems, and human communities of concern. The relative impacts of various activities can be determined by comparing the values in the cells of a table. The attributes of each cell can be descriptive or numerical. Tables are commonly used to present proposed activities or actions and reasonable alternatives (including no-action) and their respective impacts on resources of concern. Tables can be used to organise the full range of environmental and socio-economic effects. Depending on how the table is constructed, a cell may represent a combination of activities and therefore be cumulative, or it may include a separate column for cumulative impacts.

In the case of an example of a cumulative mining impact, the estimated effect of the proposed coal mining activities on each resource (e.g., wetland wildlife habitat) is evaluated as both a direct impact and as a cumulative impact in combination with past mining losses. Quantitative short-term and long-term impacts (measured in hectares) can be calculated. An example of how the cumulative impact can be assessed quantitatively is represented below in Table 9-2.

Table 9-2: An example of the cumulative impacts of mining on a wetland assessed quantitatively

Drainage Area	**Habitat (Hectares)**		**Long-Term Impacts (Hectares)**			**Short-Term Impacts (Hectares)**	
	Pre-mining	**Existing (% Pre-mining)**	**Past Mining Loss**	**Alternative Mining Loss**	**Cumulative Loss**	**Alternative Mining Loss**	**Cumulative Loss**
A	1227	1101 (89.7)	126	30	156	26	182
B	2081	1376 (66.1)	705	20	725	14	739
C	1158	1148 (99.1)	10	20	30	11	41
Sub-Total	**4446**	**3615 (81.2)**	**841**	**70**	**911**	**51**	**962**
D	833	777 (93.2)	56	20	76	16	92
Total	**5299**	**442 (83.1)**	**897**	**90**	**987**	**67**	**1054**

In the case of an example of a specific wetland plant, the potential direct, indirect, and cumulative impacts on the genetic resource of the plant can be summarised qualitatively (e.g., risk of genetic erosion at the edge of a wetland). Some tables are designed explicitly to aggregate impacts across resources (including weighting different impacts). Table 9-3 illustrates this method of assessment.

Table 9-3: An example of the cumulative impacts of the genetic resource of a wetland plant assessed qualitatively

Mining Alternative	**Direct effects on existing levels of genetic variation**	**Indirect effects on levels of genetic variation in future generations**	**Cumulative effects**
A	Risk of losing small populations at edge of wetland, thereby reducing existing levels	Risk of losing small populations at edge of wetland, thereby reducing future levels.	Risk of genetic erosion at edge of wetland
B	None	None	Would negate risk to small populations and halt genetic erosion
C	Risk of slightly reducing levels within population for some populations. No effect on overall variation.	Risk of slightly reducing some populations. No effect on overall variation or values	Would enhance gene variation.
D	Within population levels could be reduced more than in Alternative C. No effect on overall genetic variation.	Could be reduced more than in Alternative C. for some populations. No overall effect.	Same as Alternative C.
E	Within population levels could be reduced more than in Alternative D. Overall levels of variation would be reduced slightly.	Could be reduced more than in Alternative D. Potential significant reduction in adaptability of some populations and some reduction in values.	Same as Alternative C.
F	Same as Alternative D.	Same as Alternative D.	Same as Alternative C.
G	Same as Alternative D.	Same as Alternative D.	Gene conservation would not be well served because of fewer reserves.

Grand indices that combine impacts and ecological rating systems for wildlife habitat and other natural areas should be avoided. Such approaches have been relatively unsuccessful because intentional or unintentional manipulation of assumptions can dramatically alter the results of aggregated indices, and because complex quantitative methods for evaluating cumulative impacts make it more difficult for the public to understand and accept the results. Although it may not be possible to combine highly diverse resource impacts, different resource impacts that cumulatively affect interconnected systems must be addressed in combination. Greater efforts need to be made to present the full suite of adverse and beneficial impacts to the decision-maker so that comparisons are clear and understandable.

Although tables and matrices are the most common method for evaluating the cumulative impacts of alternatives, map overlays and modeling should be used to summarise and evaluate cumulative impacts. The environmental impact assessment methods illustrated below can be combined effectively to address cumulative impacts (Figure 9-1). Two aspects of cumulative impact assessment, however, warrant special analysis methods: (1) the need to address resource sustainability, and (2) the need to focus on integrated ecosystems and human communities. By definition, cumulative impact assessment involves comparing the combined effect with the capacity of the resource, ecosystem, and human community to withstand stress. Carrying capacity analysis has been applied to a wide range of resources to address cumulative impacts.

Cumulative impacts are a more complex problem for whole ecosystems, because ecosystems are subject to the widest possible range of direct and indirect impacts. Analysing the cumulative impacts on ecosystems requires a better understanding of the inter-relationships of ecological systems and a more holistic perspective. Specifically, ecosystem analysis entails new indicators of ecological conditions including landscape-scale measures. In addition to these two special methods, analysing cumulative impacts on human communities requires specific economic impact assessment and social impact assessment methods which falls outside of the scope of this study.

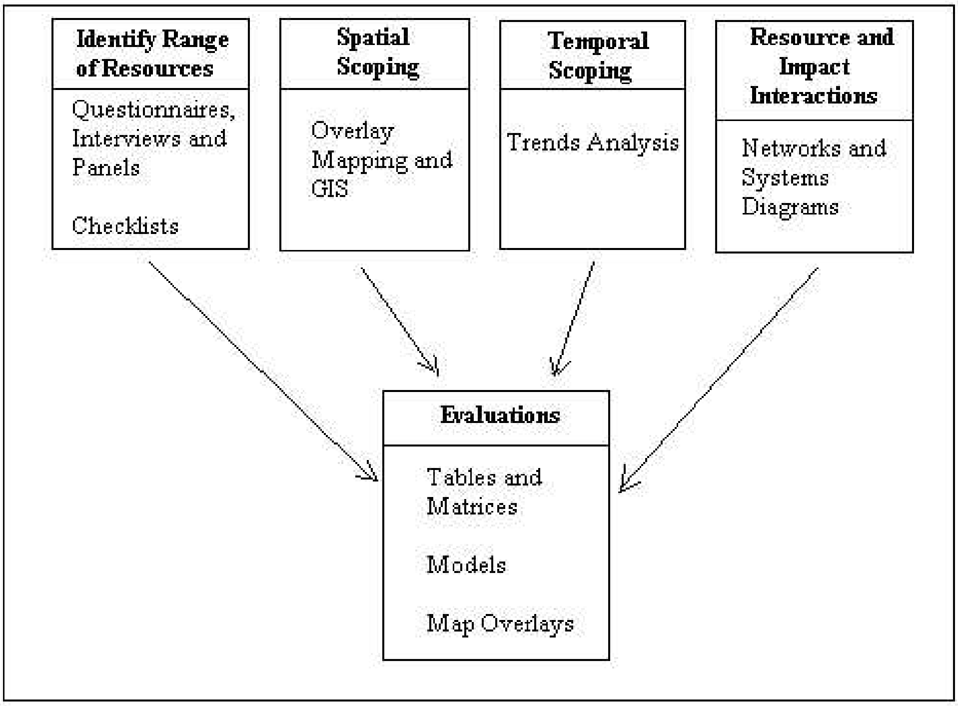

Figure 9-1: Conceptual model for combining primary methods into a cumulative impact assessment.

From Figure 9-1 it can be seen that a framework can be distinguished by the way a specialist would firstly identify the range of resources by making use of questionnaires, interviews, checklists and panels. Secondly, spatial scoping would require the use of overlays, mapping and GIS to represent the information visually to the specialist. Temporal scoping would follow by making use of a simple trend analysis, observing the resources over a period of time and comparing the end state with the initial state in order to determine any change in the eco-system. This will further involve resource and impact interactions by using networks and systems diagrams that will allow the resources to be tabled and analysed in a matrix. The outcomes will be results in tabular form that have been deducted from the matrices, models and map overlays. It is the discretion of the specialist to determine the level of detail required for cumulative impact assessment as the scope of the proposed coal mining activity will influence the need to assess impacts in great detail.

10.CONCLUSION

South Africa has a wide range of different wetland types each with their own unique characteristics. The purpose of this study is to provide a guide document that would assist environmental practitioners, specialists, project managers and government authorities to identify and delineate wetland areas, to determine the types of wetlands and their respective characteristics and functions so that the cumulative impacts that a proposed activity such as coal mining would have in the area could be better understood.

It is important to accurately and efficiently assess the cumulative impacts that an activity such as coal mining would have on wetlands as they are highly sensitive eco-systems which need to be preserved as they provide an invaluable number of functions to the natural environment and man. Wetlands are being affected in South Africa by the extensive opencast and strip mining coal operations in the Mpumalanga Province. The need exists to halt or at least lessen the impacts caused by such activities on wetlands and other natural features of the environment.

The cumulative impact assessment process is not very extensive in South Africa, and so the literature review indicated the disparities between South Africa and other the first world community, who are using more accurate and complex methods to assess cumulative impacts, making the process of cumulative impact assessment far more thorough. There is clearly a need to at least implement a framework which will help to determine the scope of work required, the necessary specialists needed to be involved so that each aspect can be examined by the relevant specialist using tools such as tables and matrices for evaluation. Furthermore, the entire process needs to be closely involved with DWAF as they are the authority affected by such activities.

The project manager or environmental practitioner cannot determine cumulative impacts on their own as they do not have the relevant expertise in the various fields needed to be investigated, making it very important that the correct specialists are involved in the project. A panel will need to convene once all specialist investigations are complete so that the indirect impacts can be tabled and discussed more effectively.

The need to more accurately and efficiently assess cumulative impacts will hopefully help in prolonging the life of wetlands so that they can continue to provide an important service to the environment surrounding them. Managing and operating coal mining activities in wetland areas more sustainably will eventually help the environment to cope better with the vast stresses and strains placed on it by man and his activities on earth.

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