A SYSTEM FOR SUPPORTING WETLAND MANAGEMENT DECISIONS

VOLUME 2

(Appendices)

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GUIDE FOR THE READER

The focus of this thesis was the production of practical wetland management tools. APPENDIX A, which comprises a survey of the users for which the management tools were designed, together with Kotze *et al.* (1995)[1], provide additional motivation for the thesis. Although key elements of the tools are reported in Volume 1 of the thesis, the tools are included in full in Volume 2 to enable the reader to familiarize him/herself with their contents. They comprise the following.

APPENDIX B: AGRICULTURAL LAND-USE IMPACTS ON WETLAND FUNCTIONAL VALUES

APPENDIX C: WETLAND-USE: PROTOTYPE

APPENDIX D: WETLAND-USE: FINAL DRAFT

APPENDIX E: WETLAND-USE BOOKLETS

[1] KOTZE D C, BREEN C M, and QUINN N, 1995. Wetland losses in South Africa. In: COWAN G I (ed.) Wetlands of South Africa. Department of Environmental Affairs and Tourism, Pretoria.

1. INTRODUCTION

The world's wetland area has been declining throughout history, due to development and poor land-use practices (Dugan, 1990). Estimates for the USA show that more than 54% of the wetland area has been lost to development, 87% of this being to agricultural development. There is evidence that a similar trend in wetland losses has occurred in South Africa (Walmsley, 1988). In the Mfolozi catchment, for example, Begg (1988) estimated that 58% of the original wetland area had been lost. As the remaining wetland area has steadily declined, society has begun to appreciate the numerous functional values provided by wetlands, which, until recently, have largely been overlooked.

Wetland functions refer to the many physical, chemical and biological processes that take place in a wetland. Where these functions are of value to society, such as the trapping of nutrients, they are termed functional values. In other words, functional values derive from the manner in which wetlands function and are of indirect use to society. Resource values, on the other hand, are of direct use to society in that they provide tangible resources, ranging from land for crop production to suitable sites for bird-watching (Fig. 1).

Those functional values of wetlands most commonly cited in the literature are:

1. hydrological values, which include:

    a. water purification (removal of suspended sediments, excess plant nutrients, and other pollutants);

    b. streamflow regulation (flood attenuation, water storage and enhancement of sustained streamflow);

    c. groundwater discharge and recharge;

2. erosion control value; and

3. ecological value (maintenance of biotic diversity by providing habitat for wetland-dependent fauna and flora).

The contribution of wetlands to biogeochemical cycling has also recently been recognized by some authors (e.g. Hammer, 1992).

The aim of this review is to discuss these values and focus on how they are affected by different agricultural land-uses. Whereas several reviews concerning the functional values of wetlands have been produced, including those of Reppert *et al.* (1979), Adamus (1983) and Sather and Smith (1984), there do not appear to be any reviews on the effects of different land-uses on wetland functional values, despite the importance of this subject.

A very important aspect of functional values not dealt with in this review is their economic evaluation, for which an extensive body of literature exists (e.g. Leitch and Shabman, 1988; Oellermann, 1992). Expressed in economic terms, functional values may be considerable. For example, in the Norfolk and Suffolk broadland of England, where the natural wetland vegetation that protects the river banks from erosion is destroyed, the river banks have to be artificially reinforced at a cost of approximately US$425 per metre of bank (Turner, 1989).

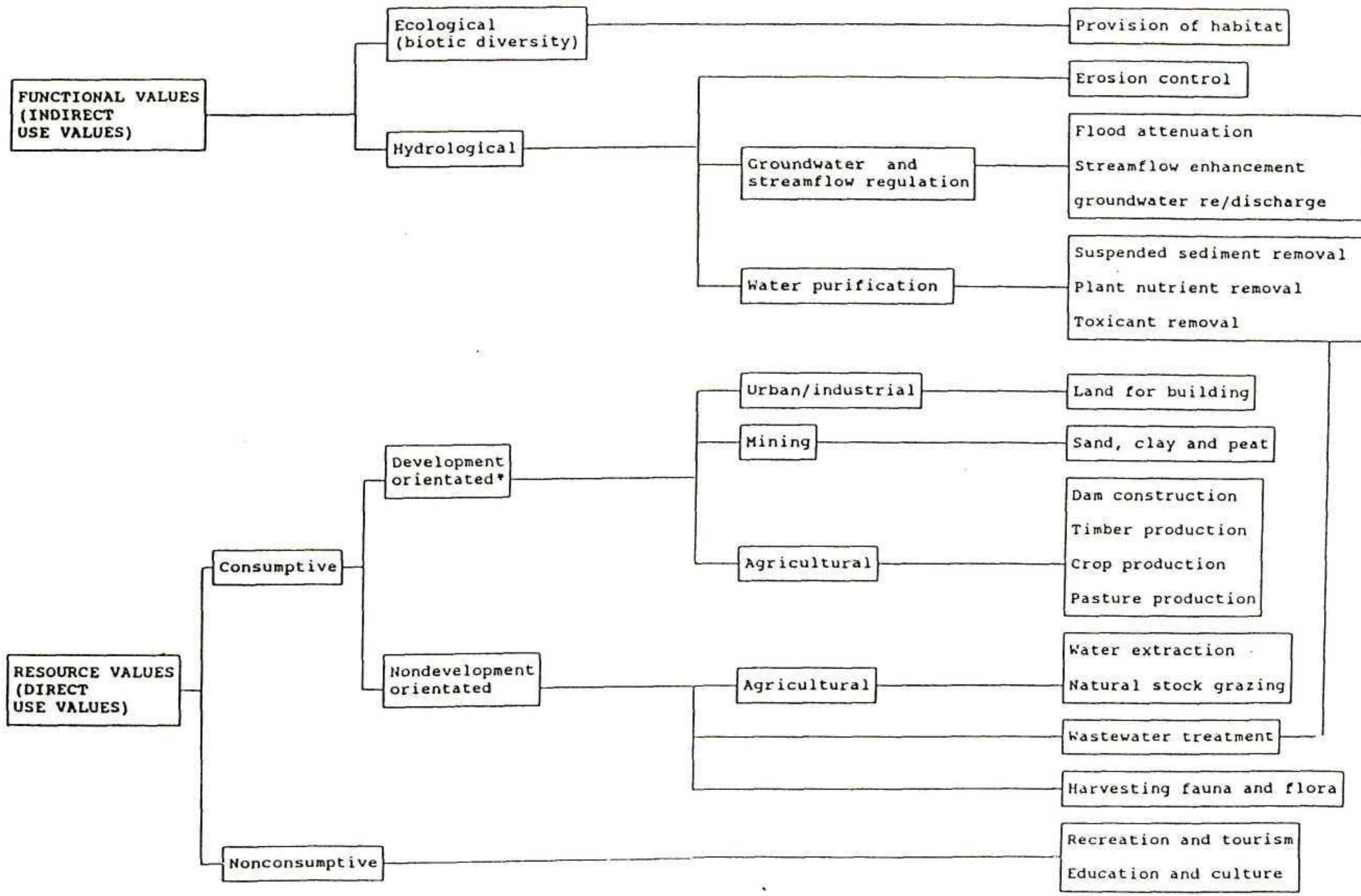


Fig. 1 Use values provided by wetlands.

* Development orientated values require that the wetland be modified by directly removing the indigenous vegetation and/or through hydrological manipulation.

Nondevelopment orientated values do not require that the wetland be modified. However, injudicious management

2. THE FUNCTIONAL VALUES OF WETLANDS

2.1 Water purification

2.1.1 Wetland attributes influencing water purification

Wetlands may contribute substantially to improving water quality by modifying or trapping a wide range of substances commonly considered to be pollutants. These include suspended sediment (such as silt and clay), excess nutrients (most importantly nitrogen and phosphorus) and toxicants (e.g. pesticides and excess heavy metals). Excess is taken to refer to concentrations high enough to render the water unsuitable for human consumption. Wetlands have several attributes that enhance their capacity for improving water quality (Kadlec and Kadlec, 1979; Mitsch and Gosselink, 1986; Hammer, 1992) including:

1. a high capacity for reducing the velocity of water flow (because of such factors as the resistance offered by wetland vegetation and the gradual slope of most wetlands) which results in suspended particles being more readily deposited;

2. considerable contact between water and sediments (because of the shallow nature of the water column, leading to high levels of sediment/soil-water exchanges);

3. a variety of anaerobic and aerobic processes, such as denitrification and chemical precipitation, that remove pollutants from the water;

4. the high plant productivity of many wetlands, leading to high rates of mineral uptake by vegetation;

5. high soil organic matter contents (accumulated primarily as a result of anaerobic conditions) which favours the retention of elements such as heavy metals; and

6. microbial decomposition of certain organic substances (such as those introduced through sewage addition). Wetland plants provide substantial surface area for the attachment of microbes, both above-ground and below-ground, due to the aerobic rhizosphere around roots.

Suspended sediments, toxicants and nutrients pass through a wetland as throughflow or are stored for varying periods in wetland storage compartments. In the case of nutrients, these compartments include macrophyte tissue, microbial tissue, detritus, sediments, waters within the soil profile and ponded waters on the soil surface which have a longer residence time than the main throughflow (Howard-Williams, 1983). According to Howard-Williams (1983) the nutrient (or sediment/toxicant) output from a wetland can be calculated as:

Nutrients out = Nutrients in - (transfers into storage compartments - transfers out of storage compartments)

Two points arise from consideration of the above equation:

1. the faster the rate of throughflow (i.e. the more channelled the throughflow) the lower will be the extent of nutrient (and sediment/toxicant) incorporation into storage (Gaudet, 1978; Day et al., 1982, as cited by Howard-Williams, 1983); and

2. although wetland storage compartments have a substantial ability to absorb excess nutrients they have finite boundaries, and once they are full, there will no longer be transfers int storage. This principle also applies to sediments and toxicants (Howard-Williams, 1983)

A wetland is considered a sink if the input of a given chemical or specific form of that chemica (e.g. organic or inorganic) is greater than the output. Conversely, if output is greater than input it is considered a source. Through transformation, a wetland may act as a sink for an inorgani form of a nutrient and a source for the organic form of that same nutrient. Determinin conclusively whether wetlands are sources or sinks for a given chemical is often hampered by th inadequacy of the techniques used to measure fluxes (Howard-Williams, 1983). In order t calculate nutrient fluxes, water budgets are needed and there are many difficulties inherent i measuring the hydrological components required for water budget determination (Carter, 1986) Thus, even with long term studies it is difficult to assess how efficiently a wetland removes a give pollutant.

2.1.2 Removal of suspended sediment

The higher the mean flow velocity, the greater the ability of water to transport particles o increasing grain size (Hjulstrom, 1935). Flow velocities through wetlands are typically lower tha in river channels and the surrounding landscape, and wetlands thus provide important areas wher the settling of suspended sediment may occur. Suspended sediment may be detrimental to wate quality in itself and it may also carry other adsorbed pollutants (Boto and Patrick, 1979) Turbidity, caused by suspended particles, attenuates light penetration, thereby decreasin photosynthesis (and oxygen production) by submerged aquatic plants. Costly filtration an flocculation processes are generally necessary to free water of particulate matter before it can b used for industrial or domestic purposes (Begg, 1986). High sediment loads are also costly in tha they lead to storage capacity loss in dams, an important problem in South Africa (Conley *et al.* 1987).

Quantitative studies demonstrating the role of wetlands in the removal of suspended solids ar lacking. However, one such study in New Zealand (Schouten, 1976 as cited by Begg, 1986 showed that all of the bedload and 50% of the suspended load were being deposited in the wetland of a particular catchment. Quantitative models exist for evaluating depositional-erosional dynamics but few studies, except that of Hickok *et al.* (1977), include an identifiable shallow-wate component (Adamus *et al.*, 1987).

Qualitative models for sediment trapping are represented in procedures by Reppert *et al.* (1979) Corps of Engineers (1988), Wolverton (1980) and Adamus *et al.* (1987). Included in the procedur of Adamus *et al.* (1987) is a simplified model indicating the gradient necessary to creat depositional velocity conditions given different depth and surface roughness categories (Table 1) The most important factor affecting the roughness coefficient is the vegetation - the greater th frictional resistance offered by the vegetation the higher the roughness coefficient. If natura wetland vegetation with a high roughness coefficient (e.g. a dense reed marsh) is replaced by crop which generally have a substantially lower roughness coefficient then this will obviously decreas sediment trapping efficiency.

Table 1 Gradient necessary to create depositional conditions given different depth and surface roughness categories (from Adamus *et al.*, 1987)

Mean Depth (m)	**N > 0.125**[1]	**N = 0.080**[2]	**N = 0.050**[3]	**N < 0.035**[4]
< 0.2	< 0.0250	< 0.0100	< 0.0038	< 0.0018
0.2-0.3	< 0.0150	< 0.0060	< 0.0023	< 0.0012
0.3-0.6	-------	< 0.0030	< 0.0012	< 0.0006
0.6-0.9	-------	< 0.0017	< 0.0006	< 0.0003
0.9-1.2	-------	< 0.0013	< 0.0005	< 0.0002
1.2-1.8	-------	< 0.0008	< 0.0003	< 0.0001
1.8-2.4	-------	< 0.0006	< 0.0002	< 0.0001
2.4-3.0	-------	< 0.0004	< 0.0002	-------
3.0-3.7	-------	< 0.0003	< 0.0001	-------

1 Most densely wooded floodplains ("N" is Manning's roughness coefficient).
2 Most densely vegetated emergent wetlands not totally submerged by floodflow.
3 Most moderately vegetated or totally submerged (by floodwater) emergent wetlands, or with boulders.
4 Mostly unobstructed channels.

2.1.3 Plant nutrient removal

In water quality studies, nitrogen and phosphorus are the nutrients most commonly identified as pollutants (Adamus *et al.*, 1987). Wetlands which receive water with high nitrogen and phosphorus concentrations usually demonstrate high removal efficiencies, at least during the growing season (Van der Valk *et al.*, 1979; Begg, 1990). This is considered to be particularly valuable because excess quantities of these nutrients promote algal blooms and population explosions of other undesirable aquatic plants, such as water hyacinth (*Eichhornia crassipes*). These in turn detrimentally affect the suitability of water for domestic consumption and recreational activities (Sather and Smith, 1984).

Freshwater wetlands receive nitrogen and phosphorus from natural sources, such as runoff from vegetated watersheds, and anthropogenic sources, such as effluent discharge, and runoff from fertilized cropland (Hemond and Benoit, 1988). There are three processes by which nutrients are immobilized or removed from wetland waters: (1) accumulation by plants and microorganisms, (2) sedimentation, and (3) denitrification and ammonia volatilization (applicable only to nitrogen). Of these, only denitrification and ammonia volatilization actually eliminate nutrients from the system by releasing nitrogen to the atmosphere. The other two only immobilize and detain nutrients. Nutrients accumulated by plants are temporarily immobilized, after which, they may be re-mobilized or accumulated in the sediment, where they remain immobilized for an indefinite period in an adsorbed or particulate form. Nutrients in the sediment may be re-mobilized and transferred to adjacent waters if, for example, a wetland is disturbed through drainage (Nichols, 1983; Bailey *et al.*, 1985, Howard-Williams, 1985; Richardson, 1985; Richardson and Marshall, 1986).

Denitrification, caused by anaerobic bacteria, is the primary mechanism for nitrogen removal from wetland waters (Sather and Smith, 1984). The denitrification rate varies according to temperature, pH, organic carbon availability, and available surface area. High denitrification rates depend on a continuous supply of NO_3 (associated with aerobic conditions) to anaerobic areas. Wetlands are often suitable sites for this as they are generally characterized by anaerobic sediments (overlain by an aerobic sediment zone, a few millimetres thick), and shallow oxygenated surface water. This, combined with the aerobic rhizosphere that surrounds wetland plant roots, maximizes the aerobic/anaerobic interface where denitrification can occur (Hemond and Benoit, 1988; Hammer, 1992). Denitrification may be enhanced further in wetlands which are alternately wet (anaerobic) and dry (aerobic). High levels of nitrogen loss have been shown to occur under such conditions (Patrick and Wyatt, 1964; McRae *et al.* 1968; Reddy and Patrick, 1984).

Nitrogen may also be removed through uptake by vascular plants and subsequent "burial" when the plants die and organic matter accumulates in the sediments. DeLaune *et al.* (1986) showed that in a freshwater marsh, a large proportion of the nitrogen incorporated in the vegetation accumulates mainly as organic nitrogen in accreted sediment.

Phosphorus immobilization through the development of organic soils is less important than for nitrogen. Richardson (1985) found that wetland mineral soils had a greater phosphorus retention capacity than organic soils. Adsorption of phosphorus onto mineral sediments appears to be the most important mechanism accounting for the removal of this nutrient (Hemond and Benoit, 1988). Phosphorus may also be removed from solution by precipitation as insoluble iron, aluminium or calcium phosphate (Nichols, 1983) or through deposition of suspended sediment to which phosphorus is already adsorbed (Boto and Patrick, 1979). Thus, the ability of a wetland to retain phosphorus through adsorption and precipitation is related strongly to its capacity to trap mineral soils (Hemond and Benoit, 1988) as well as to the particle size distribution of the trapped sediment, which affects the total surface area available for adsorption (Corps of Engineers, 1988). Van der Valk *et al.* (1979) attribute the differences among wetlands in their nutrient-trapping capacity to be primarily the result of differences in hydrology and the interaction of seasonal fluxes of nutrients within a wetland. During the growing season there is generally a high rate of nutrient uptake from the water and sediments by emergent and submerged wetland vegetation. Increased microbial immobilization of nutrients and uptake by algae and epiphytes also leads to retention of inorganic forms of nitrogen and phosphorus. Thus, there is seldom a net export of nutrients during the growing season. Lee *et al.* (1975) consider this pattern to be beneficial because wetlands are most efficient at trapping nutrients during the growing season, the time when the potential for algal blooms to occur is at its highest.

A substantial amount of the nutrients taken up by rooted emergent plants may be lost to the water at the end of the growing season through litter fall and subsequent leaching. However, this is often less than may be expected because, by the time the above-ground parts of higher plants die, most of the nutrients have been translocated to the below-ground storage portions of the plant where they may be "buried" in the deep sediments (Hemond and Benoit, 1988).

Van der Valk *et al.* (1979) list the results of 17 different studies investigating the potential of wetlands to act as nitrogen and phosphorus sinks. These were listed according to whether the wetland in question acted as a nutrient sink for nitrogen and phosphorus and whether this was seasonal. All studies for which phosphorus data are presented indicate that wetlands remove phosphorus from the water passing through them at least during the growing season, and in some cases in all seasons. The same was shown to be true for nitrogen, except for the study conducted by Shih *et al.* (1978 as cited by Van der Valk *et al.*, 1979) which showed that the given wetland acted as a nitrogen source. Overall, Van der Valk *et al.* (1979) conclude that all 17 studies show that wetlands improve water quality to some extent (i.e. in all wetlands there was at least a seasonal net retention of phosphorus and/or nitrogen).

Mitsch and Gosselink (1986) also list the results of 26 different studies of wetlands as nitrogen and phosphorus traps, using the same format as that of Van der Valk *et al.*(1979) and including six of the previously listed studies. The overall results are very similar to those of van der Valk *et al.* (1979) in that in only one of the 26 studies was a wetland shown to be a net source of nitrogen and 4 were shown to act as phosphorus sources.

In summary, Van der Valk *et al.* (1979) conclude that the general picture to emerge from the studies reviewed is that wetlands are always good-to-excellent nutrient traps during the growing season, but in the non-growing season their efficiency declines. Adamus *et al.* (1987) state that few quantitative models exist for evaluating the nutrient retention and removal capabilities of wetlands. Qualitative models include informal guidelines by Kiddy (1979) and more formal procedures by Reppert et al. (1979), Wolverton (1980) and Adamus *et al.*(1987).

2.1.4 Toxicant removal

Toxicants are taken to include metals, organic pollutants, bacteria and viruses and BOD (Biological Oxygen Demand). No specific procedures have been developed for assessing the toxicant removal potential of wetlands, but general principles will be discussed for each group of toxicants.

2.1.4.1 Metals

Metal pollution is often primarily anthropogenic in origin, with the greatest concentrations generally being found in areas with heavy industry or mining (Lazrus *et al.*, 1970). Metal removal efficiencies can vary greatly depending on the particular metals and wetland types involved (Tchobanoglous and Culp, 1980). Giblin (1985) summarized the findings of different studies investigating the passage of metals through various types of wetlands. Measured values ranged from 0% lead passing through an English bog to 100% zinc passing through a North Carolina salt marsh.

Metals may be removed from solution by adsorption onto suspended sediment (mineral and organic), and buried in the sediment when it settles. Metals may also be adsorbed directly onto already immobile sediment (Hemond and Benoit, 1988). The oxidation-reduction (redox) potential is a key factor influencing the retention of metals (Gambrell and Patrick, 1988). Certain metals, such as cadmium and zinc, are more strongly bound to humic material under anaerobic than under aerobic conditions. In contrast, other metals, such as iron (precipitated as ferric oxide under aerobic conditions) may be released back into wetland waters as ferrous iron with the onset of anaerobic conditions (Hemond and Benoit, 1988). The pH is another important factor influencing metal retention.

Most metals are sorbed more efficiently by organic than by mineral soils (Vestergaard, 1979). Since wetland sediments are usually rich in organic matter, they are likely to be better suited for sorption of metals than non-wetland soils with less organic matter. Some metal cations also appear to form organically bound complexes with soil organic matter; in such cases, sorption is essentially nonreversible provided the soil is not disturbed (Wieder and Lang, 1986).

Wetland plants are able to take up metals from the water and sediment. However, the degree to which this leads to the removal of metals depends on the extent to which the plant material is accumulated in organic sediment rather than being exported from the system as detritus (Hemond and Benoit, 1988). Plants may also accelerate the removal of mercury by emission into the atmosphere. Kozuchowski and Johnson (1978) found that there was a positive correlation between mercury emission into the atmosphere by *Phragmites australis* growing on the edge of a mercury contaminated lake, and concentration of mercury in the sediment.

Another important mechanism by which metals may be removed is through precipitation as oxides hydroxides, carbonates, phosphates and sulphides. Most transition metals are precipitated as sulphides. This occurs under anaerobic conditions and thus, provided wetlands contain appreciable sulphide ions, the conditions generally prevailing in wetlands tend to promote the precipitation of transition metals. This process is usually more important in saltwater than freshwater because of the generally higher sulphate concentration in saltwater (Hemond and Benoit, 1988).

2.1.4.2 Organic pollutants

Freshwater wetlands may detain and/or chemically degrade organic pollutants, such as pesticides. The two processes may be linked, as when a pollutant is delayed in its passage through a wetland ecosystem long enough to allow degradative processes to occur. One mechanism for the detention of dissolved organic pollutants in wetlands is sorption onto sediments (Hemond and Benoit, 1988). Several different mechanisms may be involved in the degradation of organic pollutants. Wetlands, because of the shallow nature of their surface waters, provide an ideal opportunity for photodegradation to occur (Zafiriou *et al.*, 1984). The degradation of organic pollutants under anaerobic conditions has not been well documented. However, several workers (Parr and Smith 1976; Sleat and Robinson, 1983; Suflita *et al.*, 1983; Gambrell *et al.*, 1984; Gambrell and Patrick, 1988) have shown that many organic compounds, such as halomethanes, are degraded far more rapidly under anaerobic than aerobic conditions. Thus, wetlands, which characteristically have anaerobic soils, may play a vital role in the degradation of these compounds.

2.1.4.3 Bacteria and viruses

Agricultural and urban runoff entering wetlands may contain large quantities of bacteria, particularly coliforms and pathogens such as *Salmonella* and *Enterococci*, all of which pose a potential hazard to human health. Wetlands have been shown to reduce pathogen counts entering in effluents (Rogers, 1983). Dejong (1976), for example, found bacterial contamination to be greatly reduced by a reed-pond, even during times of peak load.

Several factors may be responsible for the depletion of bacteria and viruses in wetland waters. These include adsorption onto sediments and subsequent sedimentation, exposure to solar radiation, and the presence of toxic substances such as root secretions which have been shown to kill pathogenic bacteria (Seidel, 1970; Rogers, 1983). In addition, one of the most important mechanisms for bacterial removal by wetlands is simply detention while natural die-back occurs. Pathogenic micro-organisms found in sewage effluent generally cannot survive for long periods of time outside the host organisms (Hemond and Benoit, 1988).

2.1.4.4 Biological oxygen demand

BOD (Biological Oxygen Demand) of water is a measure of the oxygen required for the degradation of organic matter. Wetlands decrease the BOD of introduced waters through the decomposition of organic matter during aerobic bacterial respiration (Hemond and Benoit, 1988). While wetland plant material is a source of BOD, the presence of wetland vegetation can also improve purifying capacity by trapping particulate organic matter and providing sites of attachment for decomposing micro-organisms (Hemond and Benoit, 1988).

De Jong (1976, cited by Hemond and Benoit, 1988) studied wastewater purification in a rush pond and found BOD reduction was a function of residence time in the pond. He concluded that removal resulted from infiltration of wastewater into the sediment followed by decomposition by soil bacteria, as well as purification of through-flowing waters by microbes in the pond.

2.2 Streamflow regulation

Wetlands usually have a number of attributes such as gentle slopes, dense vegetation and outflow constrictions that impede the rate of water flow. By delaying the passage of water through the catchment, wetlands have value in that they: (a) attenuate floodpeaks and (b) store water at the wetland site providing a more sustained supply of water during periods of low flow (i.e. they augment baseflow).

2.2.1 Flood attenuation

The ability of wetlands to spread and slow down flood waters, thus attenuating and lagging flood peaks is well known (Chow, 1959; Dugan, 1990). The attributes most often cited as contributing to the effectiveness of flood peak control are:

1. Topography of the wetland site (includes wetland slope and nature of the wetland outlet). Wetlands with constricted outlets or no permanent outlets are considered to have a high potential (Adamus *et al.*, 1987) as are wetlands with a gentle slope;

2. Size. The larger the wetland the greater the area provided for flood storage and velocity reduction;

3. Nature of the vegetation (Plate 1, p13). Tall robust vegetation offers more frictional resistance than short softer vegetation (Table 1). Essentially, the effectiveness with which vegetation attenuates floods is closely related to its effectiveness in sediment trapping, as both are a function of flow velocity reduction;

4. Water regime. The potential for a given wetland to attenuate floodflow is lower if it is already covered with standing water (i.e. if it is flooded) than if it has no standing water; and

5. Permeability of the soil. Soils with a high infiltration potential are considered to have a high potential. However, if the soils are close to saturation then their capacity to take up flood waters is low, irrespective of permeability. Thus, due to the wet nature and inherently low infiltration potential of most wetland soils, this factor is often unimportant in the attenuation of floods.

The U.S. Army Corps of Engineers concluded that a substantial reduction of floodwaters from the 1955 hurricane occurred along the Charles River because of the natural storage effect of wetlands flanking the channel. This contrasts with the far more serious flooding that occurred in the Blackstone River, which is similar but lacks natural storage (Childs, 1970 as cited by O'Brien, 1988).

A quantitative approach to the flood attenuation potential of wetlands was undertaken by Ogawa and Male (1986), who used a hydrological simulation model to investigate the relationship between upstream wetland removal and downstream flooding. The study found that the increase in peak streamflow was significant for all sizes of streams when wetlands were removed. However, although an isolated wetland may perform a significant flood control function, effective control is more often the result of the combined effect of a series of wetlands within a particular catchment (Verry and Boelter, 1978).

2.2.2 Water storage and enhancement of sustained streamflow

A popular belief is that wetlands increase dry season streamflows by acting as sponges which gradually release water from wetland storage (Ingram, 1991). This "sponge model" arose largely out of observed reductions in streamflow perenniality from catchments subject to extensive wetland destruction. Begg (1986) cites the Blaaukrantz River as a good example of this. At its headwaters were numerous wetland areas which gave rise to the river once noted as a clear strongly flowing perennial stream. Over the years the catchment, including the wetlands, became intensively farmed and overgrazed. By 1945 the flow of the river was no longer perennial, nor was the water clear. Unfortunately this example, like others of its kind, suffers from the disadvantage that it is impossible to say to what extent destruction of the wetlands *per se* led to a decrease in the water quality and sustainability of streamflow. This is because the effect of wetland mismanagement is compounded by mismanagement of the catchment as a whole (see Section 3.2.2). What is needed, then, are more rigorous investigations (e.g. comparing the measured outflow from paired catchments, that are monitored).

Schulze (1979) compared the streamflow regimes of two catchments in the Ntabamhlope area, one with very few wetlands and the other with a series of large wetlands. The coefficient of variation of streamflow was lower and the peak flow was two months later in the wetland-rich catchment. Schulze (1979) suggests that the storage effect of the wetlands is the probable reason for the delayed peak flow (Fig. 2).

Scaggs *et al.* (1991) compared continuously measured outflow rates on paired 130 ha sites (an undrained wetland site with native vegetation and an adjacent site that was drained and planted to fescue pasture) on three different soil types. Runoff hydrographs are plotted on Fig. 3 for one of the soil types over a 19 day period that included two significant rainfall events. Scaggs *et al.* (1991) found that for all soil types, peak runoff rates for the developed sites were usually 2 to 4 times greater than those from undeveloped sites. Runoff rates between peaks were substantially lower for the developed sites, clearly demonstrating the regulatory potential of wetlands.

There is, however, conflicting evidence concerning the role of wetlands in enhancing streamflow during low flow periods (i.e. base flow augmentation). Bullock (1988, cited by Ingram, 1991) showed that in Zambia, dry season flow was greater in a catchment with extensive wetlands than in one without. However, in Malawi, Drayton *et al.* (1980) found no significant difference in late dry season flows from catchments with and without wetlands. One of the major explanations for observations that wetlands do not enhance dry season flow is that evapotranspiration in the wetland depletes groundwater reserves, so reducing water available for dry season flow. A dry season water balance was calculated by Bell *et al.* (1987, cited by Ingram, 1991), for a wetland in Zimbabwe indicating that the volume of dry season flow is only 20% of the evapotranspirative losses. However, in wetlands with relatively cold dry seasons, such as those that occur in the Highland Sourveld (Acocks, 1953) almost complete die-back of the vegetation occurs in the dry season. Unless burnt, the standing dead material in these wetlands would greatly retard water loss.

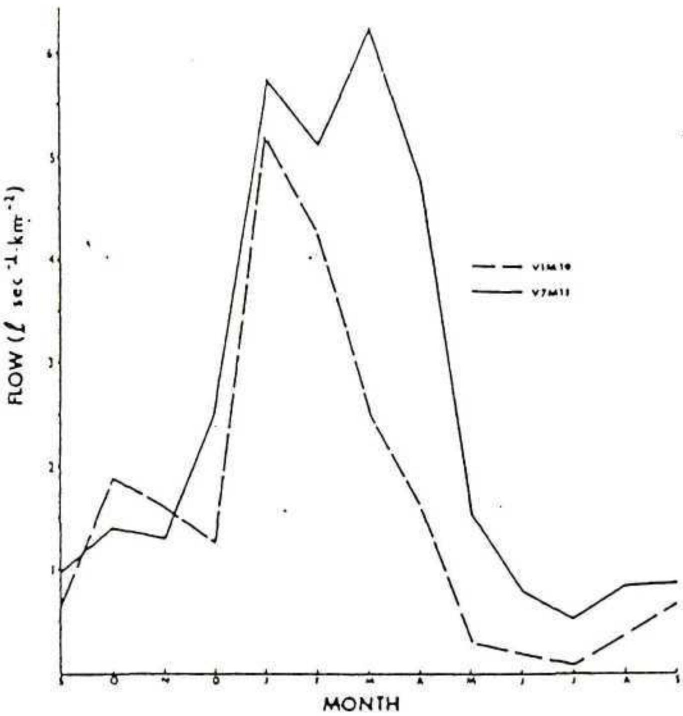


Fig. 2 Comparisons of mean monthly streamflows from a wetland rich catchment (V1M19) and a wetland poor catchment (V7M11) (from Schulze, 1979).

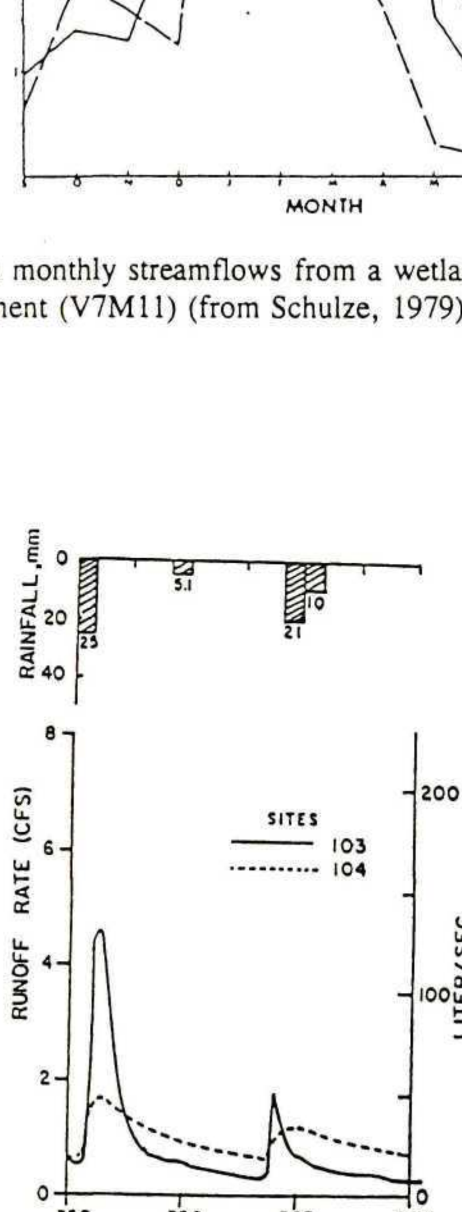


Fig. 3 Runoff hydrographs from a natural (104) and a developed site (103) in a North Carolina wetland (from Scaggs *et al.*, 1991).

The effect that wetlands have on enhancing sustained streamflow during low flow periods is influenced by much the same factors that contribute to flood peak attenuation. However, where the nature of the soil may have little effect on flood attenuation, it is frequently an important factor contributing to the enhancement of sustained flow. Wetlands tend to have a high organic content in the upper soil horizons which increases the porosity and water holding capacity of these layers as well as the overall depth of the soil profile (Begg, 1986; Mitsch and Gosselink, 1986). These factors may be important in contributing to a wetland's ability to withhold water (Angus, 1987). Not all wetlands have a high organic content, particularly those that are infrequently saturated. If this is the case and, in addition, the soils are of a shallow nature, the extent to which these wetlands would enhance streamflow during low flow periods is likely to be negligible.

In conclusion, empirical evidence shows that the popular belief of wetlands as sponges that are able to "squeeze themselves out" during dry periods is untrue. Nevertheless, evidence, such as that produced by Schulze (1979) and Scaggs *et al.* (1991), shows that wetlands do potentially have a regulatory effect by slowing down the runoff process. However, this may be offset by evapotranspirative losses if the wetland vegetation remains actively growing during the dry season. Caution should be observed in drawing conclusions from comparisons of catchments, because observed differences and/or similarities in the timing of runoff are not only a function of the wetland itself but also of the topography, soils and temporal distribution of rainfall within the wetland's catchment. Clearly, our level of understanding is not adequate to predict the regulatory effect of a given wetland with confidence. Over and above those factors already discussed, additional factors, such as the extent to which the wetland is acting as an aquifer, discharge or recharge area, need to be considered.

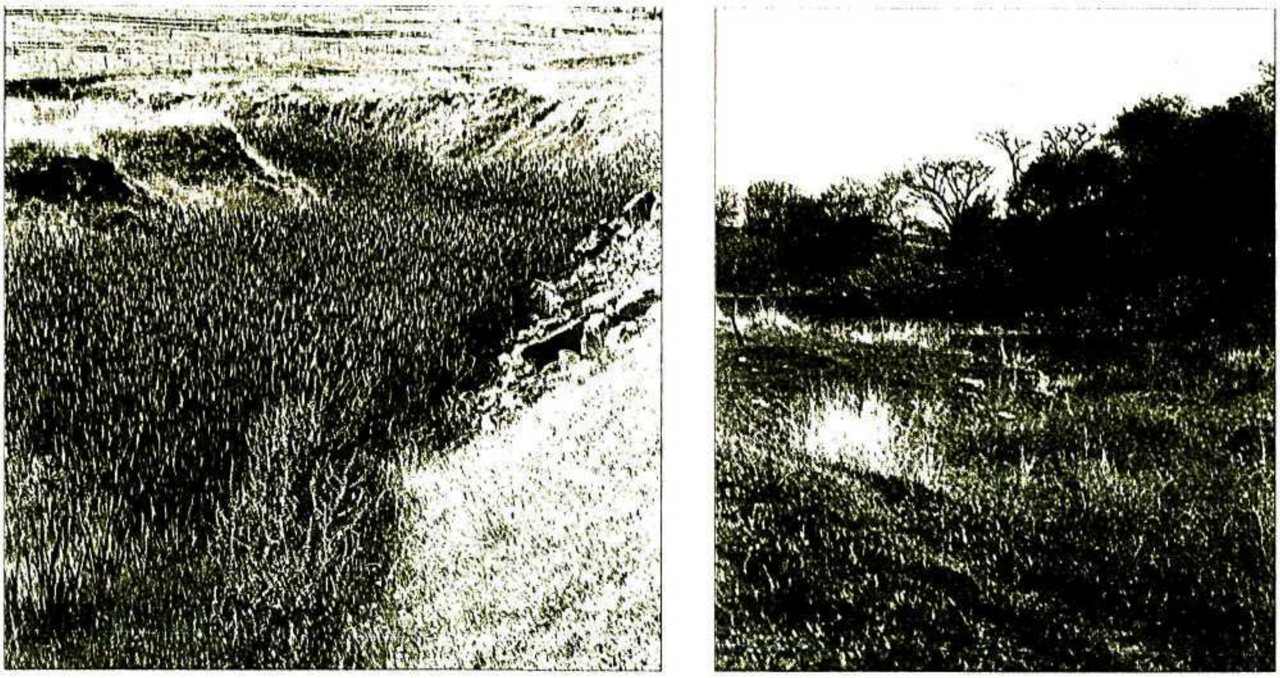
2.3 Groundwater recharge and discharge

The role that wetlands play in groundwater recharge and discharge is poorly understood. While it is agreed that some wetlands act as recharge areas, most occur where water is discharging to the surface (Carter *et al.*, 1978; Larson, 1981). The relationship of wetlands and groundwater is largely a function of their hydrological and topographical position as well as their underlying geology (O'Brien, 1988). Hydrological position refers to the position of the wetland relative to the main zone of saturation (O'Brien, 1988; Winter, 1988).

Generally speaking, wetlands perched above the main zone of saturation (the upper limit of the regional groundwater) are in a position to recharge the groundwater, while those in contact with the main groundwater zone of saturation serve as aquifer throughflow or discharge areas. In addition, some wetlands may change during the course of the year from acting as a recharge area to acting as a discharge area.

Even if a wetland acts as an aquifer discharge area, it may exert as much influence on ground water aquifers as a wetland acting as a recharge zone. Freeze and Witherspoon (1967), for example, have indicated that in small aquifers where the water table is near the surface, the recharge area tends to be large in proportion to the discharge area. Therefore, a wetland that overlies a discharge area is in a position to exert considerable control over groundwater discharge. The effect of a groundwater discharge wetland on hydraulic head distribution can be shown by digital models developed from a US Geological Survey finite difference model (Trescott *et al.*, 1976, as cited by O'Brien, 1988). While the model is subject to certain limitations, it does illustrate the potential importance of a discharge wetland in influencing head distribution and flow pattern within an aquifer.

Plate 1 A dense, tall reed stand (which proves difficult to penetrate even by an intrepid marsh explorer) offers a high degree of frictional resistance to floodwaters, thus contributing to flood attenuation.



a b

Plate 2 Wetland vegetation plays an important role in controlling erosion in previously degraded stream channels undergoing reclamation (a) and in, as yet, relatively undisturbed stream channels (b).

2.4 Erosion control by wetland vegetation

Wetland vegetation plays three major roles in erosion control: (1) it binds and stabilizes soil, (2) it dissipates wave and current energy and (3) it traps sediment (Carter *et al.*, 1978) (Plate 2). Wetland vegetation has evolved under conditions of frequent flooding, and species such as *Phragmites australis* have a high capacity for binding sediments as well as for recovering rapidly from physical damage caused by flooding. The extent to which wetlands dissipate wave and current energy depends on the hydraulic resistance of the vegetation (Table 1). The efficiency with which wetlands trap sediment is linked to the dissipation of wave and current energy, and depends on the growth-form and distributional pattern of the wetland plants.

Clark and Clark (1979, as cited by Sather and Smith, 1984) state that determining the erosion control value of vegetation in a given wetland is complicated by numerous factors. By way of a general summary they conclude that effectiveness depends on the particular plant species involved (e.g. its flood tolerance and resistance to undermining), the width of the vegetated shoreline band in trapping sediments, the soil composition of the bank or shore, and the elevation of the toe of the bank with respect to mean storm high water.

2.5 Ecological value (maintenance of biotic diversity through the provision of habitat for wetland-dependent species)

As is the case globally, the wetlands of South Africa provide habitat for a wide variety of plant and animal species, many of which are threatened. For example, of the 108 bird species included in the Red Data Book (Brooke, 1984), 36 are wetland-dependent (Goodman, 1987) (Plate 3). Species diversity is just one of many levels in the biological hierarchy at which biotic diversity may be described, including: genes, individual organisms, populations, subspecies, species, communities, ecosystems and landscapes (Noss and Harris, 1986). Biotic diversity is also commonly described at different spatial levels. In the case of species diversity, alpha diversity is the number of species within a habitat, beta diversity the turnover of species between different habitats and gamma diversity the turnover within a habitat from one area to the next (Bond, 1989).

In order to simplify biotic diversity assessment, Preston and Bedford (1988) propose two main management goals: maintaining populations of particular valued species, and maintaining biological integrity (i.e. the naturalness of the region). Species are generally considered valued if they are rare or endangered, but may also be valued for commercial, recreational or aesthetic worth, or if they are recognized for their critical roles in regulating the structure and function of ecological communities (i.e. keystone species). Biological integrity refers to the fauna and flora that are characteristic of a region and their relative abundances in the absence of human intervention (Karr, 1987). Human intervention refers to actions that markedly alter driving forces already affecting ecosystem structure and function (e.g. herbivory, fire and flooding regime) or introduce new driving forces such as landfilling and excavation. Assessing valued species is fairly clearly defined and involves determining the degree to which populations of any threatened species are being positively or negatively affected. However, evaluating the biological integrity of a wetland is far less clearly defined. Weller (1988) and Harris (1988) have discussed factors influencing diversity and suggested a number of indicators.

Several changes occur in the biota in response to stress resulting from human intervention (Preston and Bedford, 1988). Stress-induced changes may include loss of higher trophic levels, leading to shortened foodchains and loss of habitat specialists that create faunal and floral identity for an ecosystem or landscape. These changes result in a truncated biotic assemblage heavy with generalists. Thus, any measure of ecological integrity should be sensitive to changes in both the composition and structure of ecological communities. A multiparameter index for assessing biotic integrity using fish communities has been developed and is now being used successfully in water resource assessment and planning (Karr, 1987). Twelve different parameters are used to summarise the status of a community in terms of species richness, trophic composition, species abundance and condition (i.e. patterns and processes from population, community and ecosystem level are examined). Karr (1987) proposed that a similar procedure be used to develop an appropriate index of ecological integrity for wetland species assemblages for different wetland ecoregions. This will need to account for seasonal, year-to-year, and longer-term cycles characteristic of different wetlands (Karr, 1987) (Plate 4).

Since an excess of water is the dominant factor affecting the plant and animal communities in a wetland (Cowardin *et al.*, 1979), and if resources for directly assessing ecological impacts are very limited, a general assumption can be made that the greater the disruption of the hydrological regime, the higher will be the impact on the ecological values.

In both valued species and biological integrity assessments, it is important that the contribution of wetlands to biotic diversity be considered on a landscape level (Preston and Bedford, 1988). For example, wetlands occupying 7% of a study area in the highlands of KwaZulu/Natal accounted for 22% of the small mammal population (Bowland, 1990). The diet of certain carnivorous mammals, such as the serval (*Felis leptialis serval*), that range widely across the landscape, consist almost entirely of small mammals. Thus, even though serval are not considered to be wetland-dependent species, wetlands provide them with an important food source. Harris (1984) suggests that the primary factors in the landscape mosaic influencing biotic diversity are total habitat area, the size-frequency distribution and quality of habitat patches, and the distribution of these patches in relation to each other and to drainage patterns in the landscape.

Preston and Bedford (1988) propose that a landscape level standard be developed empirically from current and historical data on the size and distributional characteristics of habitats within the area subject to evaluation. Development of the standard would need to take into account the relatively short time span of historical data, and natural fluctuations in wetland size and distribution. The growing body of literature on the consequences of habitat loss and fragmentation could be included to estimate the direction and magnitude of changes in biotic diversity to be expected from the disturbance. The relative functional value of individual wetlands (based on their type, size and location) in maintaining biotic diversity at the landscape level could then be qualitatively estimated (Preston and Bedford, 1988).

It is evident from the literature on South African wetlands that there have been no attempts to measure either between-system or within-system diversity and to understand the mechanisms regulating diversity. As it is not possible at present to develop a strategy for the conservation of biotic diversity based on knowledge and understanding of local systems, an intuitive approach offers the only real prospect for wetland conservation (Breen and Begg, 1989).

Breen and Begg (1989) propose that without a technique for classification there is little hope for the formulation of a comprehensive strategy for the conservation of biotic diversity of the wetlands of South Africa. Therefore, the most urgent need is the development of a classification system that is both comprehensive and efficient at identifying the elements of diversity (Noss, 1987). Breen and Begg (1989) suggest that the Nature Conservancy System, as described by Noss (1987), appears to be an effective means of achieving this.

Plate 3 *Kniphofia multiflora* (the tallest member of the red-hot poker genus) growing in its typical habitat, permanently saturated reed marsh. This is one of the many species dependent on the particular types of habitat provided by wetlands.

Plate 4 Barbel (*Clarias gariepinus*) moving out to spawn over a seasonally flooded wetland dominated by *Leersia hexandra*.

The major components of the Nature Conservancy System are a "fine-filter" for species inventory (with the aim of maintaining populations of valued species) and a "coarse-filter" for community-type inventory (with the aim of maintaining biological integrity). The system is best understood as a set of filters designed to capture as much of the biological diversity as possible. An ideal goal for a State Heritage Programme, for example, might be to protect the best examples of each major community type in each physiognomic region in the state (Anderson, 1982 as cited by Noss, 1987). By recognizing the major community types, the coarse filter is expected to preserve perhaps 85-90% of the species complement of a state without having to concentrate on each species individually. Species that fall through the coarse filter (generally those that occur in only a few examples of recognized community types) are captured by the fine-filter of threatened and endangered species classification. In KwaZulu/Natal, some wetland community studies have been undertaken (e.g. Downing, 1966) for certain areas, but this would need to be extended over the whole province with a uniform approach being applied.

2.6 The contribution of wetlands to biogeochemical cycling

The effect of wetlands on biogeochemical cycling on a global scale is poorly understood and often overlooked. It was only recently that the value of wetlands as major sinks for carbon was recognized (de la Cruz, 1980). Substantial amounts of carbon are currently stored in wetlands and continue to be incorporated into storage. The oxidation of this carbon, caused by wetland drainage, is certainly of global significance (Armentano, 1980; de la Cruz, 1982; Gorham, 1992), especially in view of rising atmospheric CO_2 levels.

The importance of wetlands as sulphur sinks appears to also be of global significance (Hammer, 1992). Sulphur, which is a major constituent of acid precipitation, is far more readily immobilized in wetlands than in most other habitats. Sulphates entering wetlands are reduced to sulphides which react with metallic ions to form insoluble immobilized substances (Hammer, 1992). Thus, Hammer (1992) suggests that redressing some of the atmospheric imbalances caused mainly by the combustion of fossil fuels would be more effectively achieved by restoring and creating wetlands than by establishing non-wetland forests. He draws attention to the fact that the formation of much of the planet's fossil fuel reserves resulted from the immobilization of carbon in wetlands and subsequent transformations.

3 THE IMPACT OF INDIVIDUAL AGRICULTURAL LAND-USES ON WETLAND FUNCTIONAL VALUES

3.1 Drainage and the production of crops and planted pastures

3.1.1 Effects on the hydrological and erosion control values

Intensive agriculture has dramatic impacts on wetland hydrological values, and usually also detracts from the erosion control value of wetlands. The conversion of wetland to cropland is probably the most severe agricultural impact and usually involves removal of the native vegetation, hydrological alteration (typically but not always limited to drainage) (Plate 5), tillage and the application of fertilizers and pesticides (Willrich and Smith, 1970). While fertilization alone can lead to increased levels of nutrients in receiving waters, Hemond and Benoit (1988) suggest that the hydrological alterations associated with cropping and pasture production have the most profound influence on wetland water quality functions (Fig. 4).

The impacts of crop and pasture production on wetland functional values are fairly similar in as much as they both involve removal of the native vegetation, application of fertilizers and disruption of the hydrological regime. However, the impacts associated with pasture production are likely to be less severe since pastures generally provide better cover to the soils than crops (Table 2). Even if flooding occurred when the crops were fully established and cover was at its maximum, the cover provided would be lower than that offered by pastures or native wetland vegetation. If the pastures are perennial then this is likely to further reduce the impact further because:

1. the perennial pasture species commonly grown on hydric soils in KwaZulu/Natal (notably, tall fescue: *Festuca arundinacea*) tend to have greater tolerance to impeded drainage than most crops and common annual pastures such as ryegrass (*Lolium multiflorum*). As such, they require the water table to be lowered less than would otherwise be necessary for crop production, and thus they do not disrupt the hydrological regime as much (Scotney, 1970); and

2. cropping and annual pastures involve frequent (usually annual) disturbance and exposure of the soil, associated with cultivation, whereas perennial planted pastures require replanting only after several years. This has particular relevance to wetland areas prone to erosion (e.g those with the Rensburg soil form). Scotney (1970) recommends that these areas remain permanently under well managed natural vegetation. He adds that under very exceptional circumstances (including almost level slope gradients, considerable width, irrigation and effective management) the establishment of permanent pastures may be permitted. A further important consequence of frequent cultivation is the increased oxidation of soil organic matter due to the exposure of fresh soil surfaces to the atmosphere. As a result of this, carbon and nitrogen levels are generally much lower under systems of annual pastures or crops than under perennial pastures (Miles and Manson, 1992). Miles and Manson (1992) report data from Cedara, KwaZulu/Natal, where the soil organic carbon content of annual pasture was a third of that in perennial pastures.

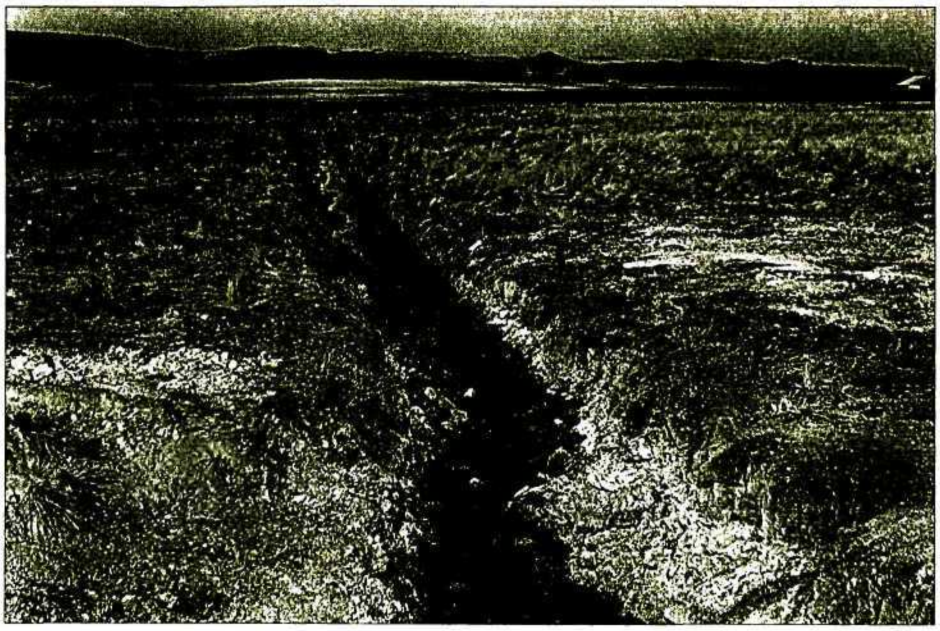


Plate 5 A typical open drainage channel dug to speed up the removal of water and allow for the establishment of planted pastures, in areas that would otherwise be too wet for pasture production.

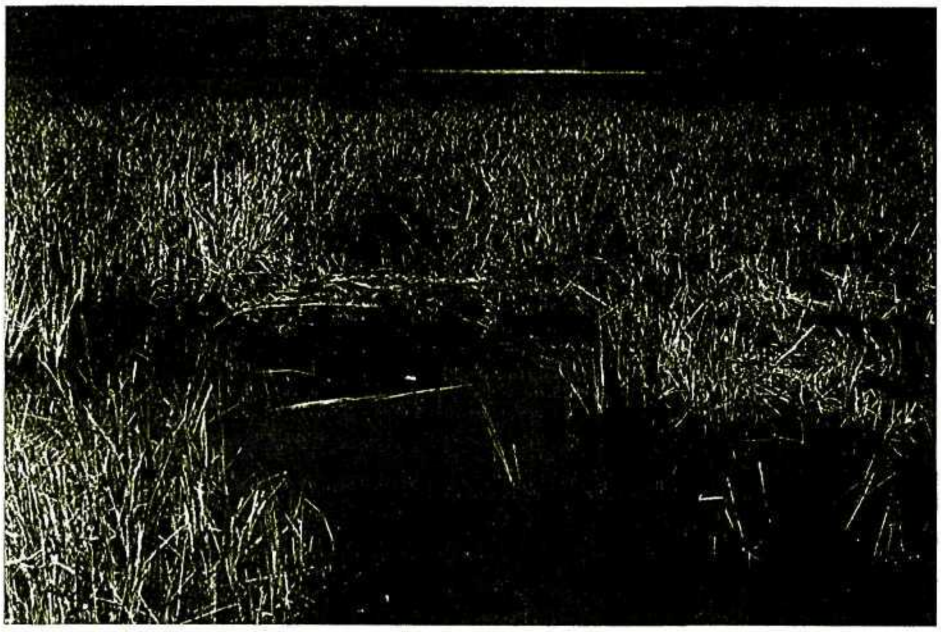


Plate 6 A wattled crane nest, showing the surrounding "moat", an essential requirement for breeding. The nest needs to be constructed in a permanently wet area because breeding occurs at the driest time of the year when the water table is at its lowest. If the wetland was drained it would render the habitat insufficiently wet for breeding.

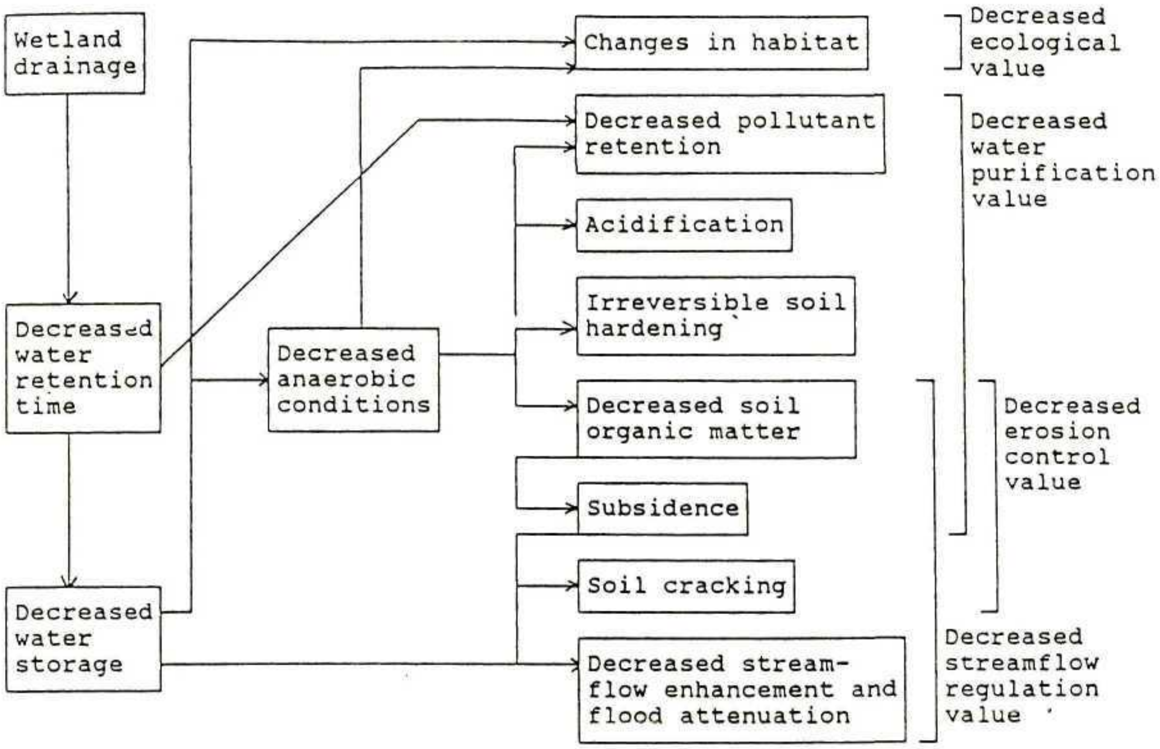


Fig. 4 A conceptual diagram showing the direct and indirect effects of drainage on wetland functional values.

Table 2 The degree to which various activities associated with cropping and annual and perennial pastures tend to detract from the hydrological and erosion control values of wetlands

ACTIVITY	CROPS	ANNUAL PASTURES	PERENNIAL PASTURES
Soil disturbance	- - - -	- - -	-
Reduction in plant aerial cover	- - -	- - -	-
Reduction in degree of wetness	- - - - -	- - - - -	- - - -
	- - -	- - -	- - -

The degree to which hydrological and erosion control values are lost

-	low
- -	moderately low
- - -	moderately high
- - - -	high
- - - - -	very high

3.1.1.1 Direct effects of wetland drainage

For both crop and pasture production, the objective of wetland drainage is to control water flow so as to decrease the volume and retention time of water in the wetland (Scotney, 1970). Most commonly, drains within the wetland are used to decrease water retention times. Additional measures, such as peripheral cut-off drains, the straightening of stream courses and the construction of levees, are sometimes used to reduce the volume of water entering the wetland.

The capacity of a wetland to enhance water quality is directly related to the extent to which flow is directed through the wetland and retained long enough for exchanges to occur with the wetland soil/sediments (Whigham *et al*, 1988). Considering this fact, it is clear that the objectives of wetland drainage are in conflict with optimizing the water storage and water quality enhancement function of a wetland. Wetland drainage, by decreasing the retention time and volume of water in wetlands, also leads to a reduction in its value for storing water and enhancing sustained streamflow. In addition, replacing the natural wetland vegetation (which in the case of the Highland Sourveld is essentially dormant during the winter) with actively growing temperate crops or pastures is almost certain to increase water use during the critical dry season period (Nanni, 1970).

The effect of wetland drainage on flood attenuation is less clear. The flood attenuation capacity of a wetland is dependent on a number of different factors, one of which is the storage capacity in the soil (Section 3.1). If the water table lies at the soil surface at the time of a flood event then the wetland will have no capacity for attenuating the flood peaks by withholding some of the flood waters in the soil. Thus, it is argued that by artificially lowering the water table, the capacity for taking up flood waters in the upper horizons of the soil will be enhanced. However, this argument does not consider that soil usually has a relatively minor contribution towards flood attenuation and that other factors are often more important.

For example, in a wetland associated with a stream, consideration needs to be given to the threshold reached when the capacity of the channel is exceeded and overbank flooding occurs. It is at this point, when flood waters are forced to flow overland, that a wetland is most effective in slowing down the flow rate as a result of such factors as the frictional resistance provided by wetland vegetation. Straightening and/or deepening a river course and creating additional drainage channels result in this threshold being elevated, decreasing the wetland's effectiveness in regulating all those flow events that fall below this threshold. Once flooding of the wetland has occurred, features associated with intensification, such as drainage channels and reduced surface roughness, increase the speed with which water drains from the wetland, and decrease its attenuation capacity. However, if the topographic setting and outlet elevation of the wetland are unaltered, a large proportion of the flood attenuation capacity will be retained, particularly for very large flood events.

Due to the important influence that groundwater discharge and recharge wetlands may exert over the regional groundwater, the effect of wetland drainage on regional groundwater should be considered. The destruction of an aquifer discharge wetland may lower the head potential within an aquifer, which could lead to a decline in the water table and a readjustment of groundwater gradients. This may be critical: it has been shown that a small decline in the groundwater level can lead to a cessation of streamflow (Goode *et al.*, 1977; O'Brien, 1977; Ivanov, 1981, as cited by O'Brien, 1988). The impact of drainage on recharge wetlands may also be considerable and is determined by the extent to which the wetland was previously contributing to groundwater recharge, and by the degree to which the retention time and volume of water in a wetland is decreased by drainage.

3.1.1.2 Indirect effects of drainage caused by a change in the soil environment

In addition to its direct impact, wetland drainage also has unfavourable effects on the soil which, in turn, lower the hydrological value of the wetland. By reducing the duration of soil saturation, drainage causes the soil environment to become more aerobic (i.e. oxidising) which affects the suite of *in situ* processes typically associated with waterlogged soils. For example, sulphides and ferrous iron, formed under anaerobic conditions, may be oxidised to free sulphuric acid and ferric iron respectively, increasing soil acidity (Ingram, 1991). If high levels of iron deposits are present in the soil then increased oxidation and the consequent formation of iron oxides may result in the irreversible hardening of the soil to form a laterite carapace ("ouklip") (Ingram, 1991). This dramatically decreases the effective depth of the soil, which would obviously have considerable hydrological and ecological impacts as well as lowering agricultural potential.

The increased oxidation following wetland drainage results in a decline in the soil organic matter content and this may have a multitude of potentially negative effects. These include reduced water holding capacity, increased susceptibility to erosion, deterioration in soil structure, a decrease in the effectiveness with which heavy metals are trapped, and subsidence of the soil (Lavesque *et al.*, 1982; Ingram, 1991). It has been shown generally that in the first few years following drainage of organic soils, rapid subsidence is caused mainly by drying, settlement and other physical agents. This initial subsidence is followed by a slow but continuous subsidence due to organic matter oxidation (Stephens and Spier, 1970; Lavesque *et al.*, 1982). Mineral soils with high *n* values (i.e. soils with high water contents under field conditions) are also prone to subsidence due to the removal of water and have a low potential for bearing loads (Pons and Zonneveld, 1965; Soil Survey Staff, 1990).

Brinson (1988) contends that drainage and other forms of wetland hydrological manipulation should be seen in the landscape context. Uplands are intrinsically erosional landforms and tend to export most elements (including nutrients, toxicants and sediments). Wetlands, however, are generally importers of elements because they are intrinsically depositional landforms. Thus, wetlands are likely to have a significant impact at the landscape level on elemental constituents in water. When a wetland is drained, eroded or otherwise deprived of its sedimentary function, it exports rather than imports elements. Such alterations normally change the direction of elemental flux from net import to net export.

Brinson (1988) emphasises that wetlands should not be assessed merely for how much nutrient and toxicant retention function is lost, but for how much nutrient and toxicant loading and potentially polluting effect is produced within a catchment unit. Certain wetlands have inherently high polluting potentials. For example, 46% of Colorado wetlands sampled by the U.S. Geological Survey contained moderate (20 ppm) or greater concentrations of uranium (some as high as 3000 ppm) based on dry weight (Owen and Otton, 1992). Disturbance of these wetlands may release the uranium and other loosely bound elements contained in the wetland sediments, particularly if it involved drainage and the resulting oxidation of sediments rich in organic matter (Owen and Otton, 1992). The amount of wetland sediment exposed to more oxidising conditions is one of the most important factors affecting the rate of elemental export from drained wetlands. On exposure, elements that have been accumulating for millennia may be released within several decades. Brinson (1988) cites such occurrences in the Florida Everglades (Stephens, 1956), California (Weir, 1950) and England's East Anglia Fenlands (Hutchinson, 1980). Brinson (1988) recommends that wetlands should be assessed not only for their capacity to trap sediments, which may be slow, but for their vulnerability to export when hydrologically altered, which may be potentially high.

3.1.1.3 Sustainability of wetland crop and pasture production

Despite all the potential negative effects of wetland drainage and intensification, the potential sustainability of crop production on dambos has been fairly widely demonstrated (e.g. Ratray *et al.*, 1953; Elwell and Davey, 1972; Whitlow, 1991) as has pasture production on drained wetlands in the upper Mgeni catchment, KwaZulu/Natal (Scotney, 1970). Dambos are seasonally waterlogged, gently sloping, treeless wetlands containing a natural drainage channel. In Zimbabwe, sustainable cultivation of dambos extends back to before the nineteenth century. Cultivation practices at that time have been documented by Scoones and Cousins (1991). Ridges were constructed parallel to the streamflow direction if the dambo was too wet and required some drainage. If conservation of water was the objective, ridges would be constructed at an angle or along the contour. The central wettest area would be left under dense natural vegetation. Maize would usually be planted on the ridges and rice in the depressions. In relatively high rainfall years the rice would usually be successful and the maize would fail, but in dry years the opposite would generally occur.

These traditional wetland cultivation methods tend to be less disruptive of wetland functioning than intensive commercial cultivation. Traditional crop varieties, for example, are not only quick maturing and pest resistant but some are also more flood tolerant. This contrasts with cultivation of high yielding varieties which require irrigation or a regular water supply and also need heavy fertilizer and pesticide applications (Kolawole, 1991).

Many traditionally used wetlands in Zimbabwe, particularly in the climatically dry areas, are utilized with very little or no drainage (Scoones and Cousins, 1991). The need for wetland drainage is minimized by:

1. cultivating areas which are generally not excessively wet; and

2. multi-cropping with species having different flood and drought tolerances, and scheduling planting correctly.

In addition, impact is also minimized by applying wise soil conservation practices such as green manuring. Thus, rather than attempting to regulate the system completely, traditional wetland cultivation methods tend to account for extremes of the system (i.e. management practices are adjusted to suit the system rather than the system's being altered to suit management requirements).

Rattray *et al.* (1953) cites two examples of contrasting response of wetlands to cultivation in order to illustrate the importance of correct management practices. In a dambo subject to continuous wheat cultivation (resulting in the break-down of organic matter) and ploughing across waterways, degradation of the resource occurred. However, in another dambo where organic matter levels were maintained by green manuring, and where manuring and fertilizer applications and sound soil conservation practices were applied, fertility had been sustained 20 years after cultivation.

In conclusion, two final comments concerning wetland cultivation deserve consideration: (1) even if a given land-use is sustainable (from the point of view of maintaining productivity and having "acceptably low" soil erosion rates), substantial loss of functional values may occur; and (2) when commenting on sustainability, short time horizons are used. Scotney (1970), for example, made conclusions concerning the sustainability of land-use practices that had been in operation for 30 years. However, the system may be slowly declining, and over 30 years this would not be detected without a thorough investigation.

3.1.2 Effects of pasture and crop production on the ecological value of wetlands

Conversion of a wetland to cropland or planted pastures involves disruption of the hydrological regime and the total replacement of the native wetland vegetation. Clearly, this is detrimental to the maintenance of biotic diversity. As is the case with the construction of dams, the altered habitat often attracts species previously not occurring in the wetland. However, these are usually commonly occurring generalist species. For example, *Praomys natalensis*, a species frequently associated with human-induced disturbances, was shown to be absent in an undeveloped wetland but present in an adjacent wetland planted to introduced pasture species (Bowland, 1990).

For the majority of valued wetland-dependent species, such as the long-toed tree frog (*Leptopelis xenodactylus*) and white-winged flufftail (*Sarothrura ayresi*), the habitat value of the wetland would be completely lost following drainage. Although other valued wetland-dependent species, such as wattled cranes (*Grus carunculatus*), continue to use drained and converted wetlands for feeding, drainage renders wetlands unsuitable for breeding (Plate 6).

3.2 Grazing of undeveloped wetlands by domestic stock

Wetlands, particularly temporarily or seasonally wet grasslands, may provide highly productive grazing-lands for wild and domestic grazers (Cooper *et al.*, 1957; Richardson and Arndt, 1989; Findlayson and Moser, 1991). Marsh areas tend to have a lower grazing value because of the relatively unpalatable nature of most mature marsh plants and the excessive wetness and softness of the soil in certain marshes, which prevents access. The high proportion of indigestible structural material is usually the most important factor rendering marsh plants unpalatable. The cell wall component of *Typha domingensis*, for example, has been shown to comprise over 70% of the dry weight of the plant (Howard-Williams and Thomson, 1985). However, young growth of certain marsh species, such as *Phragmites australis*, provide good forage for domestic stock. In its young stages, *P. australis* has a high crude protein-fibre ratio (23%:31%) and no known secondary compounds (Duncan and D'Herbes, 1982).

The two primary components of domestic stock grazing that affect wetland values are: (1) defoliation (and to a lesser extent, uprooting) of plant material as the animals feed; and (2) trampling (through hoof action) of the soil surface and plant material. Other less obvious components of grazing that would also have an effect are: (1) the deposition of urine and faeces; (2) the removal of nutrients and organic matter through meat and milk harvesting; and (3) loss of consumed organic carbon into the atmosphere through animal respiration (Jensen *et al.*, 1990).

3.2.1 Effect of grazing on the ecological value of wetlands

For many wetlands, grazing by wild herbivores has had important effects on ecosystem structure and function (Westhoff, 1971; Bakker, 1978, Gordon and Duncan, 1988). Many wetlands now lack the large indigenous herbivores that once used these areas. It is often not feasible to reintroduce these animals, but domestic stock offer a practical alternative for enhancing the biological integrity of these systems (Gordon and Duncan, 1988). However, grazing may also substantially detract from the ecological value of wetlands, particularly in those developed under low use by indigenous herbivores and in wetlands where utilization is very high relative to plant production.

Grazing by domestic stock has been shown to have a significant effect on the plant species composition and structure of *Phragmites australis* reed marshes in the Camargue (Basset, 1980; Duncan and D'Hebes, 1982) and European salt marshes (Bakker, 1989; Jensen *et al.*, 1990). *Phragmites australis* is sensitive to grazing because the meristem is at the internodes. Both horses and cattle in the Camargue feed readily in water up to 1m deep. When shoots are bitten off below water level, rotting may set in and cause the death of the shoot. Heavy grazing was shown to lower shoot density significantly from 120 to 2 shoots per m^2 and shoot height from 710mm to 160mm (Duncan and D'Hebes, 1982). Basset (1980) also found grazing to diminish *P. australis*. This removal of reeds increases the amount of open water favouring submerged aquatic plants. However, in certain areas, reduction of *P. australis* by grazing does not maintain open water but leads to the dominance of *Typha* and tall *Scirpus* species. These are resistant to grazing, either because their meristem is at or below ground level, or because they apparently contain secondary compounds unpalatable to grazers. (Duncan and D'Hebes, 1982).

Many duck species feed largely on submerged aquatic plants such as *Potamegeton* species. Thus, where grazing activity leads to a decline in reed abundance, allowing for an increase in aquatic plant abundance, these ducks would be favoured. By maintaining short vegetation, cattle also favour waders. Grazing effects on sward height in less hydric wetland areas may also have an important influence on the suitability for certain bird species. For example, black-tailed godwits (*Limosa limosa*) and lapwings (*Vanellus vanellus*) nest in wet grasslands grazed by cattle during the previous summer and avoid that which is ungrazed (Gordon and Duncan, 1988). Sheep grazing produces a finely structured sward ideal for redshank (*Tringa totanus*) (Thomas, 1982).

The creation of mud puddles, reduction in tall dense cover and maintenance of short vegetation areas by grazing stock improves the habitat for mud probing birds such as the Ethiopian snipe (*Gallinago nigripennis*). The largest concentrations of these birds are often found in heavily grazed wetland areas (Neely, 1968) (Plate 7). Prolonged heavy grazing leading to the removal of tall dense cover would, however, disadvantage bird species such as grass owl (*Tyto capensis*) (which require such cover for nesting) and flufftails (which require it for nesting and foraging). If depletion of tall reeds occurs on a large scale throughout a given wetland, it would be detrimental to those species, such as the bittern (*Botaurus stellaris*), requiring reed habitat.

Studies of domestic stock effects on ground nesting birds have shown that trampling can cause the direct destruction of many nests of such birds as lapwings (*Vanellus vanellus*) (Beintema, 1982; Duncan and D'Herbes, 1982). Duncan and D'Herbes (1982) contend that while this occurs at high stocking densities (>4 cattle/ha), at stocking densities of less than 3 cattle/ha, damage to nests is likely to be rare, unless the animals are driven in round-ups.

The decrease in plant species richness following exclusion of livestock from salt marsh has been well documented (Bakker, 1990; Jensen *et al.*, 1990). Livestock exclusion may also result in dramatic changes in the invertebrate species composition. For example, halophytic invertebrate species typical of salt marshes may be largely replaced by generalist inland species (Anderson *et al.*, 1989 cited by Jensen *et al.*, 1990). In this case, livestock clearly enhance the habitat value for wetland-dependent invertebrates. However, the ecological benefit derived from grazing "low" salt marsh, situated at the seaward extremity or on saltmarsh islands, is smaller than that derived from grazing the higher parts of the salt marsh. Grazing is not required in "low" salt marsh by species favouring short vegetation (e.g. wading birds) because these areas have inherently short vegetation. Soils are less stable than in higher marsh, and destruction of the turf leads to an increase in bare areas and a decrease in plant diversity (Bakker, 1990).

a b

Plate 7 A comparison of ungrazed (a) and grazed (b) marsh, where short term heavy grazing can be seen to have resulted in: (1) a decrease on the overall height of the canopy, and (2) open puddled areas suitable for feeding waders, particularly snipe.

Plate 8 Pronounced tussock/channel microtopography, found in many Highland Sourveld wetlands, pictured in early spring a few weeks after a burn.

Very little work has been undertaken in KwaZulu/Natal wetlands to determine the effect of stock grazing and trampling. However, comparison of differences between two adjacent sedge marsh areas in Ntabamhlope Vlei that had been subject to different grazing treatments, allows some tentative conclusions to be drawn for that area (Kotze, 1992b). When compared with the ungrazed area, the grazed area was found to have:

1. a less dense and less uniform aerial cover (provided by the dominant species, *Carex acutiformis*);

2. a higher occurrence and greater extent of exposed mud puddles; and

3. greater plant species diversity, probably as a result of the decreased cover which allows for the establishment of creeping semi-aquatic plants such as *Ludwigia palustris*, and disturbance which favours such species as *Echinochloa crus-galli*.

However, observation of these same areas in winter during a severe drought year showed the plant species diversity to be lower in the grazed area (Doyle, 1992). In the ungrazed treatment, which had abundant litter protecting the soil, the upper soil layers were found to be moist, but in the grazed treatment, which had far less litter, they were dry. It is suggested that the difference in species richness between grazed and ungrazed areas may in part be due to the indirect effect of grazing on soil moisture which affects the growth of more ephemeral species (Doyle, 1992). Kauffman *et al.* (1983b) report a decreased abundance of more hydric species and an increased abundance of species more adapted to drier environments in grazed moist meadows. They also suggest that this is due to increased soil moisture resulting from greater litter accumulation in ungrazed moist meadows.

In addition, Kauffman *et al.* (1983b) found that herbage removal altered the seasonal phenology of moist meadow plant communities, by hastening the onset of anthesis in most species. They suggest that the dense litter layers accumulated in the ungrazed areas probably kept soil temperatures below levels of initiation of growth for longer periods of time.

Trampling by domestic stock often causes wet organic soils to become more tussocky, which may increase sediment microhabitats (Jensen *et al.*, 1990). It is also claimed by Downing (1966) that in sedge meadows in KwaZulu/Natal, cattle trampling causes a very pronounced tussock/channel microtopography with high tussocks (usually > 30 cm high and 50 cm in diameter) (Plate 8). Downing hypothesises that cattle trample the wet clay soil into depressed paths which form a close, criss-crossed pattern. Vegetation in the paths is killed and in time, as cattle continue to use the same paths, they deepen to form channels. The large tussocks (hummocks) are the untrampled areas between the channels. The channels act as drains and because the tussocks are higher and have a larger surface area exposed to the air, they become drier. Martin (1960) also ascribes this tussock-channel formation to trampling by livestock.

Downing (1966) provides only speculative evidence to substantiate this claim. While cattle may be partly responsible for deepening the channels, other factors, such as building by ants and earthworms and the inherently tussocky growth form of some of the commonly occurring plant species appear to be more important (West, 1949; Kotze, 1992b). Observations of hummocks in Mgeni Vlei and Ntabamhlope Vlei, showed ants to be present in some hummocks and earthworms to be very abundant in many of the hummocks. Also, some *Cyperus unioloides* plants growing in hummocks had vertically orientated rhizomes with new growing points positioned several centimetres higher than older points (Kotze, 1992b). This sequence suggests that these mounds have been increasing in height.

An important factor determining the response of a wetland to grazing is whether the wetland developed under low or high grazing pressure. The seasonally flooded Pampa wetlands in Argentina, for example, developed under low grazing pressure. Grazing of these wetlands by domestic stock results in the dominance of cool season species, mainly exotic dicotyledonous plants of low growthform, and the replacement of large tussocks by small tussocks (Facelli *et al.*, 1989). It is suggested that the increased drought risk in summer, caused by trampling-induced infiltration reduction, disadvantages warm season plants (Facelli *et al*, 1989). Grazing caused an increase in diversity at a small scale (5 m) but decreased it at a larger scale. Cool season species were found to be uniformly dominant in grazed areas, but in ungrazed areas, warm season species dominated some patches, and cool season species, other patches. Facelli *et al.* (1989) concluded that in the absence of grazing, different competitive equilibria may occur in the different patches, probably due to subtle environmental differences. In the grazed area, the effects of domestic stock may override the environmental heterogeneity and prevent the achievement of competitive equilibria.

In contrast to the above example, domestic stock grazing may enhance micro-habitat heterogeneity, provided that the grazing intensity is intermediate (i.e. animal utilization levels are not high relative to plant production levels) (Plate 9). Bakker (1990) reports that in grazed salt marshes, the sward structure tends to have less standing dead material and a higher leaf:stem ratio leading to greater digestibility of the forage. This attracts the animals back to the previously grazed areas, even if the overall area has a fairly uniform potential palatability. Thus, if the plant production in a given area exceeds the utilization (consumption and trampling) then a pattern of closely-grazed and lightly grazed (roughgrass) patches usually develops. This grazing pattern is likely in most wetland types subject to such levels of utilization. However, if the level of utilization is high relative to forage production, this usually results in closely grazed swards with hardly any differentiation in the structure of the vegetation (Dijkema, 1984; Bakker, 1989). It can be appreciated, then, that the ratio of closely grazed and roughgrass area could be altered to suit management objectives by changing the level of utilization.

The effect of grazing on wetland communities is not only dependent on stocking rate and timing but also on the type of grazing animal. Van Deursen and Drost (1990) found that grazing of *P. australis* marsh by horses resulted in shorter and thinner shoots and more secondary shoots per primary shoot than that grazed by cattle at a comparable stocking rate. This suggests that horse grazing has a heavier impact and causes a lower-level equilibrium in reed dominance than cattle grazing (Van Deursen and Drost, 1990).

In summary, the effect of grazing on the ecological value of wetlands depends on many factors, such as the intensity and timing of grazing, type of animal, and whether or not the wetland developed under the influence of natural grazers. Generally, grazing enhances the ecological value by maintaining short vegetation areas, giving rise to a greater variety of habitats. In Europe, several conservation organizations encourage extensive grazing. However, these benefits may be lost if the level of utilization is high relative to plant production, particularly if the wetland developed under low grazing pressure.

3.2.2 Effect of grazing on the hydrological and erosion control values of wetlands

Heavy grazing pressure has been shown to have detrimental effects on the hydrological state of wetlands. In the high altitude areas of Lesotho, for example, these include: disruption of flow patterns by paths, gully erosion, an increase in the number of "dry islands" (these features being a function of a change in the hydrology of the wetland), silting up of pools, and encroachment of marginal vegetation into the wetland areas (Institute of Natural Resources, 1991). In

KwaZulu/Natal, the wetlands most severely affected by heavy grazing are those in sub-humid to semi-arid areas, which tend to be more prone to erosion than those in humid areas. While the impact of heavy grazing pressure is often fairly conspicuous, the effect of light or moderate grazing pressure is likely to be far less dramatic.

3.2.2.1 Effect of grazing animals on soil infiltration

Gifford and Hawkins (1978) reviewed the available literature for information useful in understanding the hydrological impacts of grazing intensity as related primarily to infiltration and runoff. The conclusions were that it is difficult to differentiate between the influences of moderate and light grazing. On more porous soils, moderate/light grazing reduces the infiltration rates to approximately 75% of the ungrazed condition, while heavy grazing reduces it to about 50% of the ungrazed condition. This reduction is caused primarily by soil compaction resulting from trampling. Reduced infiltration, in turn, results in higher surface runoff and more rapid loss of water from the catchment. With increased runoff, streamflow response is more rapid, flooding increases and recharge of groundwater storage falls with the result that baseflow yields also fall (Ingram, 1991). Increased runoff also increases the risk of soil loss through surface wash and rill erosion. Soil compaction may also substantially reduce plant growth (Jensen *et al.*, 1990) which further increases susceptibility to soil erosion. Three important characteristics of soil susceptible to compaction are: a low clay content, a high fine-sand fraction and a low organic matter content (Burger *et al.* 1979).

It is important to note, however, that most wetland soils in KwaZulu/Natal have inherently high runoff potentials and, hence, low potentials for losing infiltration capacity. In a list of hydrological information by soil form and series (McVicar *et al.*, 1977) for South Africa, Schulze *et al.* (1989) list the runoff potentials of all soil series. Of the four runoff potential classes, all wetland soil series are given as falling into the highest runoff potential class. Temporarily and seasonally saturated wetland mineral soils tend to have inherently high runoff potentials and low susceptibilities to compaction because of their characteristically high bulk densities and high clay contents, particularly if the clays are expansible. Organic soils and permanently saturated mineral soils, on the other hand, tend to have a low bulk density and a high field capacity. However, under such prolonged saturation conditions, the capacity of these soils for absorbing more water is limited, resulting in their having high run-off potentials. The high percentage volume of water in these soils when saturated allows soil particles to flow as a viscous liquid when trampled, avoiding compaction (Hillel, 1980).

This situation in wetlands contrasts with many non-wetland soils that have inherently high infiltration potentials, which may be lost through mismanagement. It appears then that soil compaction leading to decreased infiltration and groundwater input is more commonly a feature of injudicious grazing practices in the surrounding wetland catchments than in the wetland areas themselves. This emphasises that reduced perenniality of streamflow is often more a function of catchment mismanagement leading to reduced infiltration, than of wetland mismanagement *per se*. Thus, maintaining a sustained water supply requires more than simply managing wetland areas correctly.

3.2.2.2 Effect of grazing animals on soil erosion and soil structure

Although compaction of most wetland soils appears not to be of major concern in KwaZulu/Natal, accelerated soil loss within wetland areas is a major threat to the continued functioning of certain wetlands. Wetlands with steep slopes and soils having a high erosion hazard are the most vulnerable to excessive soil erosion. In KwaZulu/Natal, high grazing pressure leading to severe gully erosion has caused the loss of a large proportion of these wetlands. The most erodible soils generally occur under relatively dry conditions (i.e. mean annual rainfall <800 mm p.a.) (Plate 10). Under more humid conditions (e.g. in the Highland Sourveld of South Africa) soils are generally less erodible. As such, loss of wetlands through gully erosion has occurred considerably less in these areas. In addition, the decrease in basal cover associated with heavy veld utilization is often substantially greater in low rainfall areas and this makes these areas more prone to erosion. Furthermore, rainfall erosivity also tends to be higher in many of the low rainfall areas of KwaZulu/Natal.

Soil moisture content at the time of use may have an important influence on soil loss due to erosion. Generally speaking, when soils are wet they become more susceptible to compaction (Bayfield, 1973; Bryan 1977). They are also more susceptible to hoof penetration, resulting from repeated trampling, which leads to soil truncation and the disruption of soil structure. Such soil is said to be poached or puddled and is rendered more vulnerable to erosion (Bryan, 1977; Wilkins and Garwood, 1985; Vallentine, 1990). Consequently, the likelihood of excessive erosion occurring from seasonal or temporary wetlands would be reduced by confining grazing to periods when the soils are not wet. Hoof action may also destroy leaves, growing points and roots and deposit mud on the herbage, rendering it less palatable. The remoulding and dilation of soil which occurs in poached soils, allows more water to be held in the surface layer. Not only does this reduce its load bearing strength, but it also increases the time taken for soil strength to recover (Wilkins and Garwood, 1985). According to Wilkins and Garwood, the susceptibility of an area to soil poaching is dependent on:

1. Soil texture. Fine textured soils are more at risk than course textured ones;

2. The vegetation type. Certain plant species (particularly those that provide good ground cover and have a high resilience to trampling) afford greater protection to the soil than other plants;

3. The age of the sward. This applies to planted pastures, with recently established pastures being more susceptible than older pastures;

4. Stocking rate. The relationship between stocking rate and severity of poaching is clear, with severity increasing with stocking rate;

5. The grazing system. If a multi-camp rotational system includes wetland camp/s with high susceptibility and non-wetland camps with low susceptibility then a rotational system would obviously provide the flexibility permitting the exclusion of grazing from the wetland camps at the appropriate times. However, where non-wetland camps are absent, there is no consensus in the literature as to whether short intense periods of utilization with long rests are preferable to longer periods of less intense use with shorter rests; and

6. Type of grazing animal. Evidence suggests that sheep cause less damage by deep trampling than do cattle because they have a lower static load (the ratio of animal biomass to total hoof area) than cattle (0.7-0.9 kg cm^{-2} compared with 1.3-2.8 kg cm^{-2}). Impact is greater when animals are moving because in addition to vertical compression, there is horizontal rotary force when the hoof leaves the ground, and there are shear and kick components. It follows, then, that management directed to moving animals slowly and peacefully would reduce the impact of trampling.

Plate 9 An *Eleocharis dregeana* dominated marsh in Wakkerstroom Vlei grazed non-uniformly by cattle, resulting in a mosaic of shortly grazed puddled areas and ungrazed areas averaging ca 1 m in diameter.

Plate 10 Many of KwaZulu/Natal's wetlands with high erosion hazards have been subject to severe gully erosion, and gully heads often advance several meters in a single rainfall event. Pictured here is the head of a gully with sods that have broken off the eroding face and washed down the gully.

Because of their self mulching properties, vertic soils (e.g. those in the Rensburg form) are very crumbly when dry. On steeply sloped areas, at the side of a gully for example, these soils are unstable, particularly if there is traffic over them. Large amounts of soil crumble away from the steep face when dry and would be washed away later by stormflow. Sustainable utilization of these soil types requires that stock be excluded completely from the steep disturbed areas and that the undisturbed areas not be grazed when wet or when sufficiently dry to cause cracking (i.e. these soils have a narrow soil moisture range suitable for use) (Swindale and Miranda, 1981).

Soils with a very high organic content (e.g. soils of the Champagne form) are also considered to have a high erosion susceptibility. Where organic matter-rich soils occur in large wetlands (> ca 50ha) on gentle slopes, the inherent capacity of these wetlands to regulate grazing is high because of:

1. the relatively low palatability of marsh vegetation; and

2. the excessively wet and soft nature of the soils, which limits access by domestic stock.

However, those organic-rich soils occurring in small seepage slope sites are usually characterized by steeper slopes and easier access for domestic stock because the soft soil layers are shallower. As such, these wetlands are more heavily used by domestic stock, particularly where they provide the only drinking areas. They have thus suffered greater degradation, which could often have been avoided by providing alternative drinking sources and controlling access.

An important factor affecting the susceptibility of a wetland to erosional degradation is its hydrogeomorphological setting. Besides seepage slope settings, discussed above, streambank or riparian sites are also considered susceptible because they are usually steep and subject to high hydraulic energy. The most noticeable effects of grazing of streambanks are:

1. a change, reduction or elimination of stream bank vegetation (e.g. the seedlings of favoured tree species may be eaten resulting in even aged stands of aging trees [Johnson and Corothers, 1982]); and

2. a change in the stream channel morphology by widening and shallowing the channel or by accelerating stream channel incision, depending on the soils and substratum type (Aucutt, 1988).

Several studies, including those of Gunderson (1968), Dahlem (1979), Duff (1979) and Kauffman *et al.* (1983a), report degradation of stream banks as a result of use by domestic stock. However, Hayes (1978), Knight (1978), and Buckhouse *et al.* (1981) found that stream bank loss did not occur more frequently in grazed riparian areas than in ungrazed riparian areas.

Buckhouse *et al.* (1981) found no significant difference between loss of banks grazed at 25-30 Animal Unit Months (AUM) per Metre of Accessible Streambank (MAS) and ungrazed streambank. A stocking rate of 48-50 AUM per MAS did, however, show a significantly greater stream bank loss than ungrazed streambank. Buckhouse *et al.* (1981) suggest that there is a threshold response rate of streambank loss. This would obviously vary according to characteristics of the site, such as soil erodibilty, stream hydraulic energy and nature of the vegetation cover. Kauffman *et al.* (1983a) conclude that management plans need to be geared for each particular riparian ecosystem as responses from land use activities vary from stream to stream. These recommendations, which are also applicable to other wetland settings, emphasise the importance of recognizing the special management requirements of different wetland areas.

Impact on the soil is also affected by the type of animal and how the animals move (as already mentioned in the discussion on soil poaching).

3.2.2.3 Effect of grazing on nutrient cycling

Grazing is likely to have an important effect on the exchange of nutrients in wetlands. Some of the organic carbon and nutrients consumed by domestic stock is removed as secondary production (in the form of harvested milk and meat). However, a large proportion of the carbon consumed is returned to the atmosphere through animal respiration and more than 90% of the consumed nutrients are returned as urine and dung. The nutrients in urine are immediately available, and although those in dung are less available, the decay rate is usually considerably higher than that of standing dead litter (Perkins *et al.*, 1978; Jensen *et al.*, 1990). Thus, grazing stimulates the turnover of organic matter and plant nutrients. Nutrient cycling may be increased five- to tenfold in some instances, which increases the exposure of these nutrients to leaching. Thus, it will be appreciated that stock grazing may detract from the water purification value of wetlands.

While domestic stock often graze lower, wetter wetland areas, they tend to rest and ruminate in the higher, less wet areas. Thus, their urine and dung deposition tends to be concentrated around the higher areas. This behaviour pattern contributes to redistribution and transport of nutrients from the lower parts of the wetland to the upper less wet parts.

3.3 Mowing of wetlands

Mowing has a similar effect to grazing in that it involves removal of aerial plant parts. As with trampling, the movement of harvesting machinery (usually a tractor) may disrupt and/or compact the soil. However, mowing differs from grazing in the following respects:

1. herbage removal is more uniform and less selective;

2. harvesting takes only a short time; and

3. smaller quantities of nutrients are returned to the wetland (unless animals are fed hay while on the wetland).

Other management actions sometimes associated with hay production are drainage to facilitate access, and fertilizer application to increase production. By altering the hydrology, drainage would detract from the erosion control, hydrological and ecological values (see Section 4.1). Fertilizer application is likely to detract from the water purification function (see Section 4.1) and ecological function. Bakker (1989) showed that hay cutting, in association with fertilizer application, resulted in a lower plant species diversity than hay cutting alone. It is suggested that fertilizer application results in a masking of subtle abiotic differences (e.g. slight differences in ground water depths).

Bakker (1990) found that salt marsh which was mown for hay production had a lower plant species diversity than did grazed salt marsh. He attributes this to the uniform close turf that becomes established under mowing. This offers fewer micro-habitats than the grazed marsh which is more heterogeneously defoliated. Nevertheless, wetland mowing has been widely shown to encourage greater plant species diversity than does unutilized wetland (Green, 1980; Bakker, 1990).

It appears that the timing of cutting is important. In relatively low producing (400 g $dw.m^{-2}$) wetland in the Netherlands, the site cut in autumn had a higher species richness than that cut in summer, whereas the reverse was true in high producing (800 g $dw.m^{-2}$) wet meadow (Bakker, 1989). Summer cutting of a productive wet meadow in the UK also resulted in higher species diversity than non-use of the stand, but autumn cutting did not result in any significant change in species diversity (Rowell *et al.*, 1985). Bakker (1989) suggests that a large standing crop in summer (which would accumulate more rapidly in a high producing meadow) disadvantages many species. Oomes and Mooi (1981) found that in an *Arrhmatherion elatioris* dominated area in the Netherlands, it was primarily the lower growing species (e.g. *Plantago lanceolata*) that decreased under autumn cutting.

Bakker (1989) reviewed studies examining the effect of cutting frequency on plant species richness. Hay-making twice a year gave the highest species richness, followed by annual hay-making and then hay-making every second year. Abandoned (unutilized) areas gave the lowest species richness values.

Very little work has been conducted on the effect of hay cutting on wetland-dependent animals. However, it is likely that, depending on the extent and timing of mowing, animals requiring vegetation cover would be disadvantaged by the immediate effects of cutting, particularly if it occurred during breeding. Bryan and Best (1991), observing that birds were most abundant in grassed waterways, in Iowa, USA, in July, recommended that mowing should not occur until the end of August.

3.4 Burning of wetlands

3.4.1 Reasons why wetlands are burnt

Schmulzer and Hinkle (1992) cite a number of authors (e.g. Viosca, 1931; Loveless, 1959; Cohen, 1974) to show that in many wetland systems, fires have occurred independent of human influence. This is supported by the observation that many wetland plants are relatively fire-tolerant (Loveless, 1959). Prior to anthropogenic fires, lightning is considered to have been the most important cause of wetland fires.

Fire is recognized as an important driving variable in wetlands and is used widely as a tool for wildlife management (Lynch, 1941; Schlictemeir, 1967; Ward, 1968; Smith and Kadlec, 1985; Mallick and Wein, 1986) and for enhancing stock grazing value (Lynch, 1941; Begg, 1990; Kotze *et al.*, 1994a). Where wetland areas pose fire hazards, controlled burns are used to remove the risk of runaway fires (Kotze *et al.*, 1994b). Some wetland grasslands are burnt to maintain the grass in a healthy state and to assist in alien plant control (Kotze *et al.*, 1994b; Otter, 1992). Other wetlands are burnt simply because they occur in frequently burnt landscapes, such as in the Highland Sourveld, and are not considered to warrant special protection by managers.

3.4.2 Effects of sub-surface fires on wetland functional values

Two broad types of fire occur in wetlands: surface and sub-surface fires. In surface fires, which are the most common, only the above-ground plant parts are combusted. Sub-surface fires, which are less frequent but more severe, consume above- and below-ground plant parts as well as soil heterogeneously defoliated. Nevertheless, wetland mowing has been widely shown to encourage greater plant species diversity than does unutilized wetland (Green, 1980; Bakker, 1990).

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In KwaZulu/Natal, the negative effects of sub-surface fires appear to be most pronounced in wetlands on seepage slope settings due to their small size, steep gradients and shallow soils. Recovery of the vegetation at these sites appears to be very slow, particularly when the soil has burnt down to the bedrock. However, where sub-surface fires cover a small proportion of a wetland, as usually occurs in large wetlands with deep soils, and in flat or depression settings, the overall impact on the system is likely to be negligible. De Beneditti *et al.* (1984) showed that revegetation of areas of depression wetland burnt by ground fires occurred within two years. However, had the ground fires occurred on a slope, these authors suggest that this might have had a severe impact and that the vegetation would have been considerably slower in re-establishing.

Lynch (1941) observed that when peat accumulating *Panicum* and *Spartina* marshes are left unburnt for several years, plant litter accumulates, resulting in a much deeper mulch on the soil surface. The marsh plants then produce roots in this layer, reducing root production in the deeper root horizons. The thick mulch layer makes these areas more prone to sub-surface fires and the change in root distribution renders the plants more susceptible to fire damage when such fires occur (Lynch, 1941). However, this phenomenon has yet to be quantified and would differ according to wetland type.

In summary, although sub-surface fires may enhance the ecological value of a wetland, they may also substantially detract from the wetland's hydrological and ecological values. The ultimate effect varies according to wetland type and conditions at the time of the burn. If sub-surface fires are considered undesirable, burning would have to be avoided in drought years, particularly at the end of the dry season, when soils are at their driest and are most susceptible to combustion. Very little work, other than that of Ellery *et al.* (1989), has been conducted on sub-surface fires in wetlands and the remainder of the discussion will deal with surface fires.

3.4.3 Effects of surface fires on hydrological and erosion control values of wetlands

The immediate effect of surface fires is the combustion of above-ground plant material with the loss of carbon and nitrogen to the air and the deposition of phosphorus and other minerals in the ash. Ninety per cent of the nitrogen from combustible plant materials was shown to be lost as a result of volatilization in both *Juncus roemerianus* and *Spartina cynosuroides* dominated marshes (Faulkner and De La Cruz, 1982). In tropical swamps and marshes where nutrient inputs are small and productivity is maintained by efficient internal cycling, nutrient loss during combustion may, in fact, lead to a reduction in primary production (Thompson, 1976; Whitlow, 1985).

Begg (1990), citing Downing (1966), Whitlow (1985) and Thompson and Shay (1985), states that there is evidence to suggest that indiscriminate burning of wetlands can be harmful to the water storage function of wetlands. None of the papers provide conclusive evidence to support this statement. However, it is fairly certain that burning of wetlands which are characterized by dry season die-back of above-ground plant material could be harmful to the water storage function of wetlands. Donkin *et al.* (1993) showed that evapo-transpirative loss of water during winter from wetlands with abundant standing dead material is less than the evaporative loss from open water. These wetlands, particularly in marsh areas, generally produce large amounts of standing dead material of a high reflectivity, the removal of which would promote evaporative loss from the wetland as surface litter results in a reduction in evaporative soil moisture loss. This is because the more exposed, or ash covered, soil or water surface absorbs considerably more solar radiation than the surface of an unburnt wetland. It is also more exposed to the desiccating action of wind.

relationship between burning and levels of organic carbon in marsh soils found by Schmalze and Hinkle (1992). Although it appears the wetland burning often does not decrease the organic carbon content of the soil, this may not be true for soils that are not flooded or saturated at the time of burning, particularly if sub-surface burning occurs.

Because of nitrogen volatilization losses during burning and the higher rates of carbon fixation, burnt grasslands tend to have roots with lower nitrogen contents than in unburnt grasslands. This enhances the immobilization potential of the soil, resulting in a decrease in the leaching of nitrogen (Seastedt and Ramundo, 1990). It thus appears that burning generally enhances the capacity of wetlands for removing nitrogen. However, at present this is speculative as it has not been investigated in wetlands. Schmalze and Hinkle (1992) note that soil nitrogen changes are very different from those observed in many non-wetland systems, because they are affected by seasonally varying water tables as well as by fire. The volatilization loss of phosphorus is considerably less than that of nitrogen, and the effect of fire on the capacity of wetlands for removing this element is likely to be even more difficult to predict.

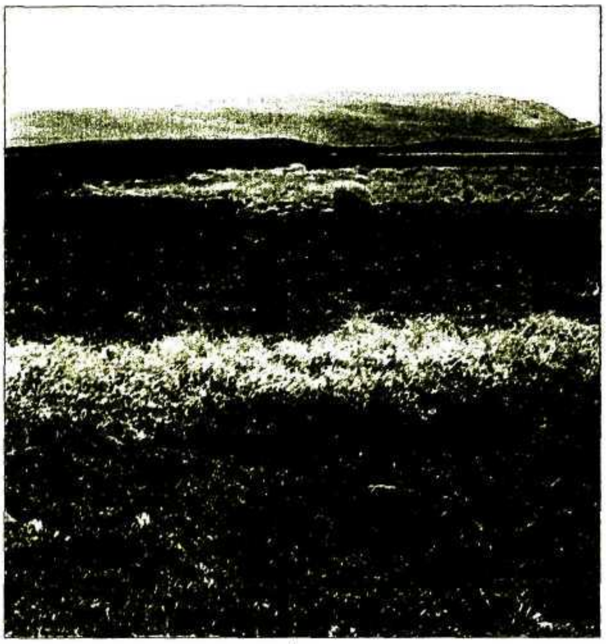
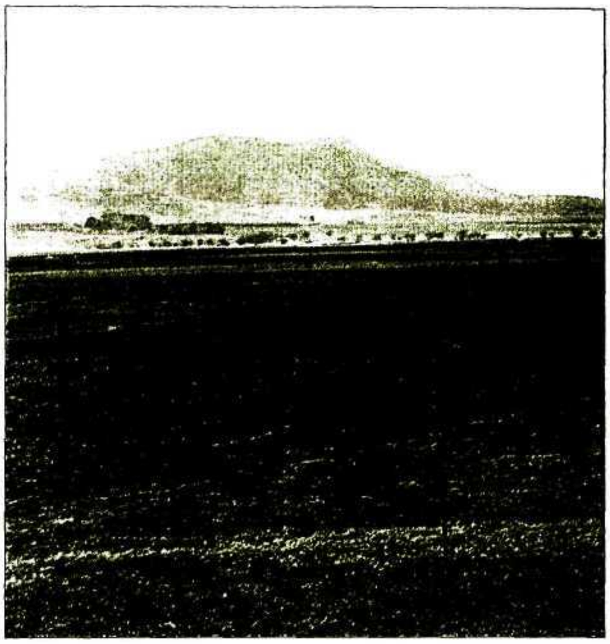
3.4.4 Effects of surface fires on the ecological value of wetlands

3.4.4.1 Effects on wetland-dependent animals

Animal species populations may respond either positively or negatively to fire, or may show no response at all. Population responses are the result of direct or indirect effects of fire on individuals. Direct effects include increased mortality (induced by heat and asphyxiation), forced emigration, and reduced reproductive effort (Kauffman *et al.*, 1990). Bigham *et al.* (1965) and Vogl (1973) report minimal direct mortalities of birds and mammals associated with fire. However, although adult individuals of most wetland-dependent bird and mammal species are able to escape the direct effects of fire, juveniles may be far more vulnerable. This applies to above-ground nesting rodents and birds, particularly winter breeding birds such as wattled crane (*Grus carunculata*). In KwaZulu/Natal, fire has been shown to be the most important known cause of wattled crane chick mortality (Johnson and Barnes, 1991).

Indirect effects of burning may result from changes in quality and quantity of food and cover, availability of nest sites, predation pressure, intensity of competitive interactions, and patterns of social interactions. Ultimately, direct and indirect affects of fire on individuals lead to shifts in population density through time as micro-environmental conditions recover to their pre-fire status in the absence of further fire (Kauffman *et al.*, 1990). The snail *Neritina usnea* is more abundant the year following a fire, while ducks using *Juncus* marsh for nesting were found to prefer marsh burnt at least three years previously (Hackney and De la Cruz, 1981).

Fire positive species will tend to reach maximum levels in a matter of months following the fire, depending, of course, on the timing of the burn. In contrast, fire negative species may do so only several years after the fire. Clearly then, if the fire return frequency is considerably shorter than the recovery period of these species then the long term viability of their populations may be low. Little work has been done in KwaZulu/Natal, or internationally for that matter, on the recovery of wetland-dependent species populations following fire. While further studies may show otherwise, no wetland-dependent species in KwaZulu/Natal have been shown to have a recovery period longer than two years. Generally speaking, in the case of small mammals in the grasslands of the Highland Sourveld, a drastic decrease in the number of individuals occurs immediately after fire, followed by a rapid recovery, with numbers reaching pre-fire densities in 6 to 15 months (Rowe-Rowe and Lowry, 1982).

a b

Plate 11 Depending on conditions at the time of the burn, the degree of patchiness of the burn varies from a highly patchy burn, through an intermediately patchy burn (a) to a complete burn (b). Unless there are other wetlands in close proximity that are left unburnt, burns such as that pictured in 11b detract from the habitat value of the wetland through extensive and complete removal of all standing dead material, which would otherwise provide cover.

Plate 12 Infrequent burning may reduce plant productivity as a result of a high accumulation of loose surface and standing litter, as is the case in this *Leersia hexandra* marsh which has not burnt for 3 years and has a dense surface litter layer of >30 cm.

3.4.4.2 Effects on wetland-dependent plants

Fires are an important factor modifying the plant species composition and structure of wetlands. For example, marsh fires have been shown to be useful in sustaining desirable members of the Cyperaceae and Juncaceae (Vogl, 1974). Nevertheless, little work has been done on the long term effect of fire on plant species composition. An important indirect effect of fire on plants is the removal of loose surface and standing dead material, which favours the growth of new plant material by emergent herbaceous plants (Plate 12). Above-ground biomass production, inflorescence density and plant height at anthesis were found to be significantly greater in *Spartina pectinata* wetland which was burnt annually than in that which was burnt biennially (Johnson and Knapp, 1993).

Burning has been generally shown to prevent the invasion of herbaceous communities by woody plants, which are generally less resistant to fire. For example, prior to the exclusion of fire from the experimental catchment 9 in the KwaZulu/Natal Drakensberg, Cathedral Peak, the wetland area in this catchment consisted of several plant communities. These were the *Scirpus costatus, Oenothera rosea, Eleocharis dregeana* herbaceous communities and the *Leucosidea sericea* woody community (Killick, 1961). After 20 years of fire exclusion, this same area was described by Granger (1976) as comprising a single *L. sericea* community. In this case, fire enabled the wetland to support a far greater diversity of species and communities. It can thus be concluded that fire contributed positively to enhancing the ecological value of the wetland in catchment 9.

While most wetland plant species are well adapted to the direct effects of fire, they vary in their relative responses. The above-ground portions of certain wetland plants (e.g. *Juncus roemerianus*) often live for more than a year, in which case a surface winter fire would destroy living tissue. In contrast, species characterized by complete die-off of the above ground parts at the end of the growing season (e.g. *Phragmites australis*), do not lose any living tissue as a result of surface winter fires. Thus, one would expect that where these groups of species occur together, frequent winter fires would favour those species characterized by winter die-back. Conversely, wetland communities dominated by plants with long-lived aerial portions are less likely to change. This is partly because these communities cannot be burnt frequently and so will also resist changes in plant community structure. Hackney and de la Cruz (1981) found it very difficult to burn *Juncus roemerianus* marsh one year after a fire as there was insufficient combustible material.

The effect of burning on wetland plant communities is partly dependent on the timing of the burns, primarily through its effect on the dominant species. Spring burning, for example, enhances the performance of *P. australis*, as indicated by higher aerial and below-ground biomass and flowering shoot density (Mook and van der Troon, 1982; Thompson and Shay, 1985). In contrast, summer burns lowered the performance of *P. australis*, suggesting that summer burning has the potential for thinning dense reed stands and enhancing plant species diversity. Autumn burning appears to have an intermediate effect, resulting in higher biomass but reduced flowering shoot density (Thompson and Shay, 1985). Thus, where *P. australis* occurs as the dominant species in a mixed community, with other species such as *Molinia caerulea* and *Cladium mariscus*, burning to favour *P. australis* is likely to disadvantage or not affect the other species (Haslam, 1971), thereby lowering plant species diversity. Conversely, where burns disadvantage *P. australis*, burning may enhance plant species diversity.

The hydrological conditions, besides being important at the time of the burn, may also be important during the period following the fire. For example, increased mortality of sawgrass (*Cladium jamaicense*) results from flooding following fire (Lynch, 1951; Herndon *et al.*, 1991). It is suggested that the plants are most vulnerable to oxygen shortage resulting from flooding of their leaves immediately after burning because this is when their leaves are shortest (Herndon *et al.*, 1991).

In a comparison of a burnt and unburnt area of Nylsvlei, Otter (1992) found that in the burnt area, the abundance of *Themeda triandra* and *Oryza longistaminata* (both valuable grazing species) was greater and the abundance of *Asclepias fruticosa* (an alien weedy species) was considerably lower. Thus, these results suggest that in Nylsvlei, fire can be used effectively to control undesirable weedy species and promote the cover of desirable species for grazing animals without any obvious detrimental effects. Personal observation (1993) of comparable burnt and unburnt areas in Memel vlei, and Natabamhlope vlei, also indicate similar beneficial effects of fire.

3.5 Damming of wetlands

Wetlands are usually characterized by an impermeable foundation or obstruction (often a dolerite dyke) and a gentle upstream gradient -the very conditions sought by engineers for dams (Nanni, 1970). Consequently, in South Africa, where natural open water areas are scarce, numerous wetlands have been inundated by dams.

While dams are able to perform certain of the functions carried out by wetlands (e.g. sediment trapping and water storage) a dam is a poor substitute in certain respects (Begg, 1986). For example, the deepwater habitat that a dam provides for fauna and flora is very different from that previously offered by the now inundated wetland. Dams will often appear to be beneficial to the wildlife of the area in that this new habitat may attract wildfowl, such as Egyptian geese (*Alopochen aegyptiacus*). However, many of these are generalist species whose breeding and feeding areas are not threatened. In contrast, the habitat required by specialist wetland-dependent species is frequently lost. Other wetland functions that accrue from their shallow nature, such as the photodegradation of certain organic pollutants and the high degree of exchange between wetland water and sediment, would also be detrimentally affected.

The characteristic vegetation of wetlands lost when inundated by a dam, may be partly compensated for by that which develops around the shoreline of the dam, particularly at the upstream end where surface water tends to be shallower. Wetland vegetation development also commonly occurs below the dam wall as the seepage through farm dam walls is frequently high. Although these vegetation developments may provide some habitats resembling the previous wetland habitats, by no means do they usually replace the lost vegetation. Seasonal drawdowns and wave action often result in armoured barren shorelines (e.g. Hendrick Verwoerd Dam) which provide very poor habitat (Bruwer and Ashton, 1989). Seen on a landscape level, dam walls may obstruct the movement of aquatic animals, most notably fish. This applies particularly to dams that lack adequate fish ladders and result in periodic dry-season cessation of flow.

Large numbers of small farm dams (having walls <5 m high) have been built on virtually every river in South Africa (Noble and Hemens, 1978). Being small, they are often mistakenly thought to have very little effect on downstream flow. While the influence of an individual small dam may indeed be negligible during periods of high flow, this is seldom the case during low dry-season flows, particularly if water extraction is occurring from the dam. Where a series of dams are built along a river, the overall effect is compounded and can lead to the complete cessation of dry season flows (Bruwer and Ashton, 1989). In the Letaba River, for example, high rates of extraction from the numerous dams on the river have effectively transformed it from a perennial to a seasonal river. Dams can, however, have the opposite effect on dry season flows. Perenniality is enhanced where water extraction is low and adequate outflow is facilitated through the dam wall outlet and/or from seepage through the dam wall.

However, irrespective of whether dams increase or decrease dry season flow, one of their most adverse effects is on the first wet season flows. During the dry season, when river flows are reduced or cease (if the river is seasonal) the levels of most dams drop through evaporation and/or abstraction. This results in the first wet season flows being retained until the dam is sufficiently full. This can cause considerable alteration in the timing, and thus, success of the life cycle stages in the river biota, as well as negatively affecting human users downstream (Bruwer and Ashton, 1989). Dams may also negatively affect downstream biota by changing water temperatures, oxygen levels, silt loads and ionic concentrations (Davies and Day, 1986). An additional disadvantage of dams occurs in the frequent case where they burst after a heavy rainfall contributing to increased flood damage and sediment release.

It has often been perceived that wetlands "waste" water as a result of their associated vegetation "pumping" water into the atmosphere through transpiration, and that local water resources could be improved by flooding the wetland area permanently with a storage dam. This view arose largely out of the earliest investigations of the evapotranspirative losses from a marsh compared with evaporative losses from open water. These studies (e.g Blaney and Ewing, 1946) reported losses to be higher from marsh areas. However, the results of these early investigations have since been called to question. Those of Blaney and Ewing (1946, as cited by Linacre *et al.*, 1970), for example, were calculated using the Blaney formula for evaporation (Blaney, 1952), which ignores the effect of humidity and wind variations. In addition, the study assumed the applicability of empirical coefficients derived from measurements 500km away (Linacre *et al.*, 1970). More recent studies (Eisenlohr, 1966; Paijmans, 1985; Chapman, 1990) have reported losses from vegetated wetlands to be similar to or lower than from open water. A number of factors contribute to this, such as the high reflectivity of the plant canopy and the shelter it provides to the water surface against wind (Linacre *et al.*, 1970).

Linacre *et al.* (1970), in a general summary, state that in dry climates wetlands usually lower evaporation, and in wet climates, while this also often occurs, the likelihood of their enhancing evaporation is higher. However, such generalizations are dangerous: there are numerous factors affecting evapotranspiration, such as solar radiation inputs, wind, surface water depth and whether the plants are vigorously growing or are dormant. In conclusion, it can safely be said that when wetland plants are not actively growing and transpiring (i.e. when die-back has occurred) water loss would be lower than that occurring from a comparable open water area.

4. CONCLUSION

In conclusion, this review demonstrates clearly that wetlands possess numerous functional values which may be of great value to society. Many of these are not readily apparent and are easily overlooked. Wetland functional values range from those which have a geographically defined service area from which benefits are potentially derived (e.g. flood attenuation) to functions which do not have geographic limits but rather have a global influence (e.g. biogeochemical cycling).

A very large body of information exists concerning wetland functional values and the effect of different land-uses on these. Much of what is known about wetland functional values is the result of short-term research projects examining a single process in one geographic location. Hence, great uncertainty is often involved in extrapolating from these studies. For example, the extent to which a wetland is trapping pollutants is not only dependent on the nature of the wetland but also on the pollutants involved. Thus, it is very difficult to predict how a given wetland is likely to carry out this function and even more difficult to quantify how this is likely to be affected by different land-uses. Nevertheless, general principles relating to the nature of wetlands and determinants of wetland structure and function, allow for qualitative predictions.

From the discussion on wetland functional values it can be seen that the hydrological regime (encompassing such factors as frequency and duration of flooding and hydrological energy) is the most important factor directly influencing physical and chemical processes in a wetland (e.g. degree of substrate anoxia, nutrient retention and sedimentation patterns). These influences on the physical and chemical environment, in turn, have a direct effect on the wetland biota. Clearly, the hydrological regime is the principal factor affecting the functional values of wetlands and it is useful to view all impacts in terms of their effect on the hydrological regime. Alterations to wetlands (arising out of different land-uses) can be reduced to two main groups of actions:

1. those that directly change the hydrological regime as a result of substrate disturbance (e.g. hoof action, tillage, and construction of drainage channels); and

2. those that remove plant material (harvesting, grazing and fire). Because of the influence of vegetation on wetland hydrology, removal and disturbance of wetland vegetation also has the potential to influence the hydrological regime.

In attempting to predict the impact of a given land use, it may be assumed that the greater the extent to which the hydrological regime is disrupted, the greater will be the impact. This review also focuses on the need for attention to additional features, including:

1. susceptibility to erosion (determined by *inter alia*: soil erodibility, hydrogeomorphological setting, slope and climate);

2. habitat value for wetland-dependent species (the greater the number of valued wetland-dependent species supported by a given wetland, the greater will be the likelihood of a loss of ecological value if the wetland is developed); and

3. extent and historical loss of wetlands in the surrounding landscape. Seen in a landscape context, the loss of functional values in a given wetland is considered to have a greater impact if a large proportion of the wetlands in the surrounding landscape had already been lost than if a small proportion had been lost.

Land-uses vary greatly with regard to the effect they have on wetland functional values (Table 3). Drainage and the production of crops represents the severest form of disruption, involving the permanent removal of the native wetland vegetation, a lowering of the water volume and retention time in the wetland and regular disturbance and exposure of the soil. Of the land-uses discussed, pasture production is second in severity. Annual pasture species having a low wetness tolerance (e.g. *Lolim multiflorum*) have a more severe impact than perennial species with a higher wetness tolerance (e.g. *Festuca arundinacea*). Judiciously managed grazing of undeveloped wetlands is considered to be the least severe as it involves minimal disruption of the hydrological regime and does not involve the replacement of the native species. However, when there is mismanagement where wetland soils are of high erodibility, grazing has the potential to be equally, and in some cases more, disruptive. Heavy stocking rates lead to accelerated erosion caused directly by hoof action on the substrate, and indirectly through a reduction in the health of the wetland vegetation and a lowering of its ability to control erosion. This leads to the formation of gullies that lower the water table, as would occur in a wetland that had been intentionally drained.

Burning is not a land-use *per se* but is often used to enhance the grazing value of wetlands. Although the loss of wetland functional values due to burning may be substantial, it is usually small and in many cases burning may enhance such values. Dams perform certain wetland functions (e.g. sediment trapping) but are often poor substitutes for others such as the provision of habitat for wetland-dependent species.

As the demand for resources escalates because of the exponentially increasing human population, it will become increasingly unrealistic to call for the non-use of wetlands. In order to achieve a trade-off between maximising the benefits derived by different wetland users and minimizing the loss of functional values to society, it is important to understand how the different wetland functional values are affected by various land-uses. This review has concentrated on those agricultural land-uses commonly applied to wetlands in the midlands of KwaZulu/Natal (Bioclimatic regions 2, 4, 6 and 8, according to Phillips, 1973). Although it has focused on the types of wetlands found in this part of KwaZulu/Natal, the general principles dealt with are equally relevant to other regions and land-uses.

Table 3 Impacts of various land-uses on the flood attenuation, baseflow augmentation, water purification, erosion control and ecological values of wetlands as mediated through important characteristics that influence such values

A. VELOCITY REDUCTION	LAND-USE				
CHARACTERISTIC	Graze	Over graze	Past-ure	Crop	Dam
Surface area of active floodplain.	0	--	-/0	-/0	0
Surface roughness (vegetation and ground surface)	-/0	-	-	-	-
Slope	0	-	0	0	0
Detention storage capacity	0	--	-	--	+/0
Sinuosity of channels	0	-/0	-	-	NA
OVERALL IMPACT	0	-	-/0	-	0

B. FLOOD ATTENUATION	LAND-USE				
CHARACTERISTIC	Graze	Over graze	Past-ure	Crop	Dam
All characteristics influencing velocity reduction.	See functional value A.				
Soil saturation	0	0	+	+	-
OVERALL IMPACT	0	-	-/0	-	0

C. EROSION CONTROL	LAND-USES				
CHARACTERISTIC	Graze	Over graze	Past-ure	Crop	Dam
All characteristics influencing velocity reduction.	See functional value A				
Vegetation cover	0/-	--	-	--	-
Disturbance level	0				
OVERALL IMPACT	0/-	-	-	--/-	0

Table 3 continued

D. WATER PURIFICATION	LAND-USE				
CHARACTERISTIC	Graze	Over graze	Past-ure	Crop	Dam
All characteristics influencing velocity reduction	See Functional Value A				
All characteristics influencing erosion control.	See functional Value C				
Vegetation cover	0/-	0/-	-	-	0
Disturbance level	0	0	-	--	0
OVERALL IMPACT	0/-	0/-	-	--/-	0/-

E. HABITAT VALUE	LAND-USE				
CHARACTERISTIC	Graze	Over graze	Past-ure	Crop	Dam
All characteristics influencing velocity reduction.	See functional value A				
Native species replacement	0	-	--	--	-
Disturbance level	+	-	--	--	+/-
OVERALL IMPACT	+/-	-	--/-	--/-	-

LEGEND

- \+ Positive influence
- \+\+ Strong positive influence
- \- Negative influence
- \-- Strong negative influence
- +/- Influence positive or negative but usually not strongly so in either direction
- 0/- Influence negative or negligible

Graze: Stock grazing of natural wetland without gully erosion occurring.
Over-graze: injudicious grazing management leading to severe gully erosion. Injudicious management associated with pasture and crop production may also lead to severe gully erosion.
Pasture: Perennial pasture production. Annual pastures are best considered with crops due to lower wetness tolerance of the species and more frequent soil disturbance.
Crop: Crop production.
Dam: The assessment of dams is made on the assumption that they do not burst, which does not always hold.

Although velocity reduction *per se* is not generally considered a functional value it is included because it directly influences all other functional values.

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6. GLOSSARY

Bioclimatic Group: Phillips (1973) classified the extremely varied natural resources of Natal into 11 bioclimatic regions based primarily on climatic parameters. These groups provide convenient natural resource classes in terms of which management guidelines can be formulated.

Biological integrity: refers to the fauna and flora that are characteristic of an area (i.e. the naturalness of the area).

Ecological value: refers to the value of the wetland in maintaining the biotic diversity of the area. Biotic diversity can be measured at many different levels making it almost impossible to prescribe a standard method to describe it. Its assessment may be simplified by determining the degree to which management is affecting biological integrity and populations of valued species.

Hydrology: is the study of water, particularly the factors affecting its movement on land.

Impact site: that part of the wetland site to which a proposed land-use is to be applied.

Hydrogeomorphological setting: the landform setting (which influences surface water flow patterns within the wetland) and the position relative to other landforms in the wider landscape.

Marsh: Marsh is usually dominated by tall (usually > 1.5m) emergent herbaceous vegetation, such as the common reed (*Phragmites australis*). It tends to be semi-permanently or permanently wet.

***n* Value:** The *n* value refers to the relationship between the percentage of water under field conditions and the percentages of inorganic clay and humus and can be approximated in the field by a simple test of squeezing the soil in the hand. It is helpful in predicting the degree of subsidence that will occur after drainage and whether the soil may be grazed by livestock or will support other loads (Pons and Zonneveld, 1965; Soil Survey Staff, 1990).

Open water: Open water comprises temporarily to permanently flooded areas characterized by the absence (or low abundance) of emergent plants.

Permanently wet: The soil is flooded or waterlogged to the soil surface throughout the year, in most years.

Permanent wetland: A wetland with a permanent water regime.

Red Data species: Red data species refer to all those species included in the categories of endangered, vulnerable or rare, as defined by the International Union for the Conservation of Nature and Natural Resources (Smithers 1986).

Roughness coefficient: The roughness coefficient is an index of the roughness of a surface and is a reflection of the frictional resistance offered by the surface to water flow.

Seasonally wet: The soil is flooded or waterlogged to the soil surface for extended periods (> 1 month) during the wet season, but is predominantly dry during the dry season.

Seasonal wetland: A wetland with a seasonal water regime.

Temporarily wet: The soil close to the soil surface (i.e. within 40 cm) is occasionally wet for periods > 2 weeks during the wet season in most years. However, it is seldom flooded or waterlogged at the surface for longer than a month.

Temporary wetland: A wetland with a temporary water regime.

Wet grassland: Wet grassland is usually temporarily wet and supports a mixture of: 1) plants which are common to non-wetland areas and 2) short (< 1m) hydrophytic plants (predominantly grasses) common to the wet meadow zone.

Wet meadow: Wet meadow is usually seasonally wet and is usually dominated by hydrophytic sedges and grasses common to temporarily or seasonally wet areas.

Wetland: Land where an excess of water is the dominant factor determining the nature of the soil development and the types of plants and animals living at the soil surface (Cowardin *et al.*, 1976).

Wetland functional values: Where wetland functions (e.g. the trapping of sediment) are of value to society, they are termed functional values. Wetland functions refer to the many physical, chemical and biological processes that take place in wetlands.

PART 1: INTRODUCTION AND OVERVIEW

1.1 Introduction

Despite legislation directed at **wetland** conservation, considerable loss of wetlands has occurred in South Africa, primarily due to agricultural development (e.g. drainage and pasture production) and poor land use practices leading to erosion. In the Mfolozi catchment, for example, Begg (1988) estimated that 58% of the original wetland area had been lost. **Wetland functional values** (e.g. water purification) have tended to be undervalued because of their *indirect* benefit to society, but recently, as the amount of wetland remaining has steadily declined, increased recognition is being given to these values and to the cost to society when they are lost.

Nevertheless, wetland use still tends to be planned from the restricted perspectives of individual wetland users or landowners with specific interests (e.g. livestock grazing). Little attention is usually given to the effects on those wetland functions which benefit society. Clearly, there is a need for a system that, using the best information currently available, would assist in making trade-offs between benefits derived by the individual wetland user and benefits derived by society. For this reason, the development of this wetland management decision support system, termed WETLAND-USE, was undertaken. The knowledge-base of the system was derived from the literature, components of existing wetland evaluation systems (notably WET: Adamus *et al*, 1987) and consultation with experts. WETLAND-USE attempts to encourage users to take adequate account of wetland functional values when planning the use of wetlands. In so doing, it will contribute to rational land-use decisions for wetlands. The functional values considered are:

1. hydrological values (water purification, flood attenuation, water storage and streamflow regulation);

2. erosion control value; and

3. **ecological value** (maintenance of biotic diversity through the provision of habitat for wetland-dependent fauna and flora).

The land-uses included in WETLAND-USE were confined to some of those most commonly applied to wetlands in the study area, namely: (1) grazing of natural wetlands by livestock, (2) burning, (3) mowing, (4) planted pasture-production, (5) crop production and (6) damming. The study area for which the decision support system was developed includes wetlands located in **Bioclimatic Groups** 3, 4, 6 and 8 (Phillips, 1973).

1.2 Agro-ecological zones and soil wetness classes used by WETLAND-USE

In order to make informed wetland management decisions, wetlands should be zoned into land capability units as homogeneous as possible. A four class system based primarily on vegetation has been developed for categorizing the zones within a wetland (Fig. 1.1, Table 1.1). The four classes are closely associated with degree of soil wetness, making them meaningful from an agricultural and ecological point of view. They are thus termed agro-ecological zones. An identification guide for the plant species common to the wetlands of the study area is given in Appendix 1.

Although dominant vegetation types are convenient for stratifying wetlands into agro-ecological zones, they cannot be relied upon for land-use assessment. Ideally, long term hydrological data should also be obtained but this is lacking for most South African wetlands. Consequently the best surrogate measure possible: soi morphology, is used, combined with additional observations of features such as drainage channels and flooc lines. If the long term hydrological regime is rendered less wet, through either natural or human-inducec causes, the morphology of the soil retains many features indicative of the water regime under which it wa formed. Such soils, which are referred to as relict hydric soils (Wetland Training Institute, Inc., 1989), do no serve as indicators of the current degree of wetness, but may be very useful in situations where the previou extent of wetlands needs to be determined in an artificially drained area. A provisional three class system fo determining the degree of wetness of wetland soils using soil morphology has been developed (Table 1.1). The characterization of soils is a very important component of WETLAND-USE because it forms the basis for land use planning.

Table 1.1 A provisional three-class system based on soil morphology, for determining the degree o wetness of wetland soils

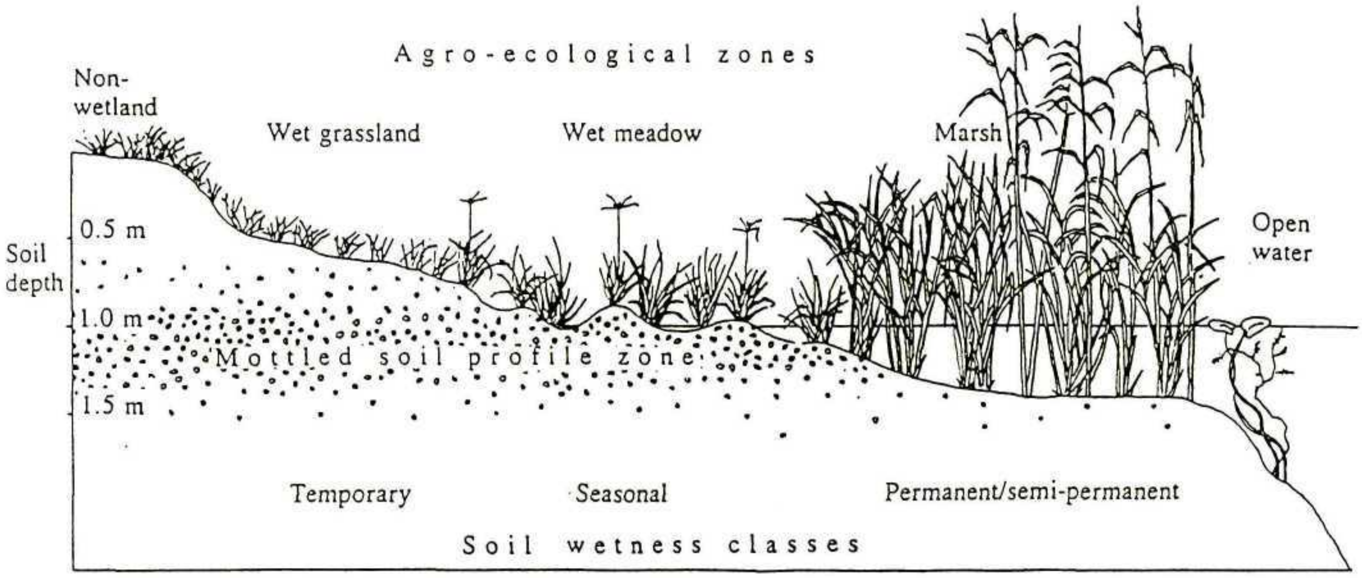
	DEGREE OF WETNESS		
SOIL	Temporary	Seasonal	Permanent/Semi-permanent
Soil depth 0-10 cm	Matrix chroma: 1-3 Few/no mottles Low/ intermediate OM Nonsulphidic	Matrix chroma: 0-2 Many mottles Intermediate OM Seldom sulphidic	Matrix chroma: 0-1 Few/no mottles High OM Often sulphidic
Soil depth 30-40 cm	Few/many mottles Matrix chroma: 0-2	Many mottles Matrix chroma: 0-2	No/few mottles Matrix chroma: 0-1
VEGETATION	Predominantly grass species	Predominantly sedges and grasses	Predominantly reeds, sedges and/or bulrushes

Key to Table 1.1:

High OM: soil organic carbon levels are greater than 5%, often exceeding 10%

Low OM: soil organic carbon levels are less than 2%

Sulphidic soil material has sulphides present which give it a characteristic "rotten egg" smell.



The wet grassland zone is temporarily wet and usually dominated by a mixture of plant species which also occur extensively in non-wetland areas, and hydrophytic plant species which are restricted to temporarily and seasonally wet areas.

The wet meadow zone is seasonally wet and dominated by hydrophytic plant species (usually sedges and grasses < 1 m tall) which are restricted to seasonally or temporarily wet areas.

The marsh zone is usually dominated by tall emergent herbaceous plants such as reeds (*Phragmites australis*) (usually > 1 m tall) and is permanently or semi-permanently wet.

The open water zone lacks emergent plants and is permanently or semi-permanently flooded.

Fig. 1.1 Agro-ecological zones used by WETLAND-USE.

The soil water regime scheme requires that certain problematic soils be accounted for. The water regimes o certain soil types are very difficult to determine through the direct application of the scheme. Thes problematic soil types, described below, include:

1. **hydric soils** which lack hydromorphic features because of factors such as being recent formation; an

2. non-hydric soils with apparent hydromorphic features, such as low chromas, that did not develop unde hydromorphic conditions.

* Mollisols (the Willowbrook form) and vertisols (the Rensburg form)

Mollisols are dark coloured, base-rich soils typically having dark topsoil layers and low chroma matrix colour to considerable depths (Wetland Training Institute, Inc., 1989). A high calcium concentration in the soil, a often occurs in these soil types, results in Ca-humate formation, which, in turn, coats the soil particles blac (Hughes, 1993, pers. comm.). Thus, even if the organic matter content is relatively low, it imparts a low valu and chroma to the soil. Consequently, the low chroma colours of Mollisols are not necessarily due t prolonged saturation. Particular caution, therefore, needs to be exercised in making wetland determination in these soils (Wetland Training Institute, Inc., 1989). Most vertic horizons in South Africa have a black o very dark colour caused by the same properties that give the melanic A horizon its dark colour (Soi Classification Working Group, 1991), and the same degree of caution must be exercised in wetlan determination in these soils.

* Soils with humic A horizons

The humic A horizon refers to a freely draining topsoil horizon with low base status, that has accumulated high amounts of humified organic matter under moist, cool or cold climatic conditions. It differs from organic horizons in that both site and profile drainage is good (Soil Classification Working Group, 1991). Humic A horizons may be particularly thick if they occur on protected south-facing valley slopes receiving little direct radiation. Humic A horizons are characterized by low chromas, and if they are deep, this may lead to the soil's being mistakenly identified as hydric.

* Entisols

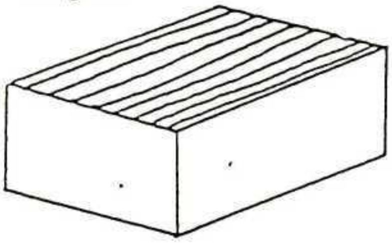
Entisols are recently formed soils that have little or no evidence of pedogenically developed horizons, e.g. soils of the Oakleaf form. Some hydric entisols are easily recognised, but others pose problems because they do not possess typical hydric soil field characteristics. Hydric entisols (with loamy fine sand and coarser textures in horizons within 50 cm of the surface) may lack sufficient organic matter and clay to develop hydric soil colours. When these soils have a hue between 10YR and 10Y, and distinct or prominent mottles, a chroma of 3 or less is permitted to identify these soils as hydric (Wetland Training Institute, Inc., 1989).

1.3 Hydrogeomorphological classes used by WETLAND-USE

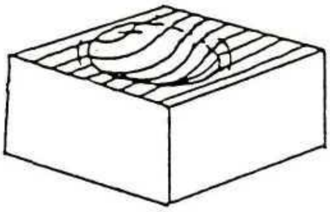
A simple hydrogeomorphological classification of wetlands was included in WETLAND-USE because of the important influence that geomorphology has on local surface and groundwater movement patterns and the degree to which wetlands are open to lateral exchanges of sediments, nutrients and other pollutants. The geomorphological classification system has two parameters: landform setting, which incorporates components of the wetland-habitat classification system of Semeniuk (1987), and terrain type, which is a modification of the system used by the Land Type Survey Staff (1986) (see Table 1.2 and Fig. 1.2).

Table 1.2 Classification of landform settings used in WETLAND-USE

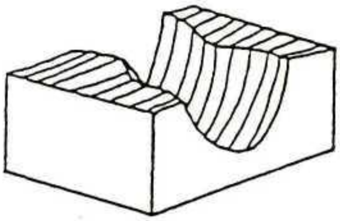
Flats have a slope of <1%, little or no relief and diffuse margins.



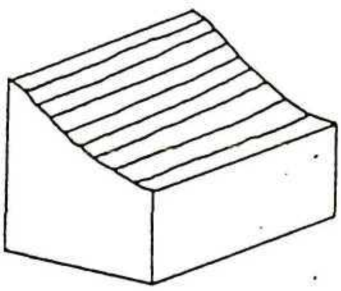
Depressions are depressed basin-shaped areas in the landscape with no external drainage. Depressions may be shallow or deep and may have flat or concave bottoms. They usually do not have clearly defined margins.



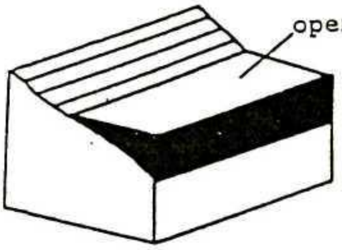
Channels refer to any incised water course. Channels may be shallow or deep but always have clearly defined margins.



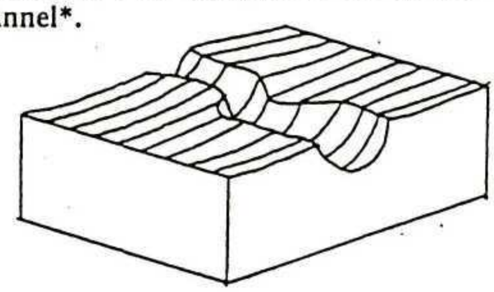
Slopes are areas with a gradient of greater than 1%, which may be concave or convex.



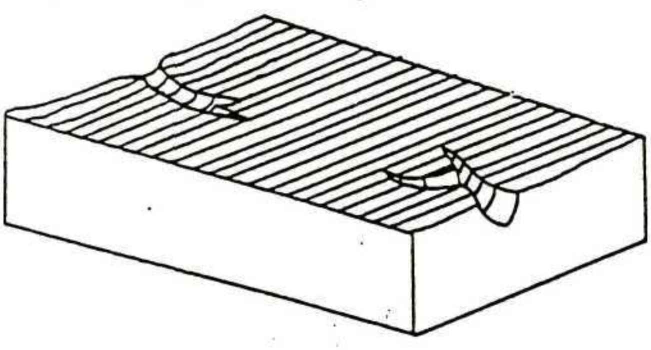
Fringes refer to areas on the edges of open water, such as that provided by lakes or dams.



Channelled flats comprise a flat incised by a channel*.



Channel-disrupting flats comprise a flat which is fed and drained by a channel*.



* Secondary landform settings

KEY

1	crest	5	valley bottom	
2	scarp		5a	valleyhead
3	midslope		5b	young valley
4	footslope		5c	mature/old valley

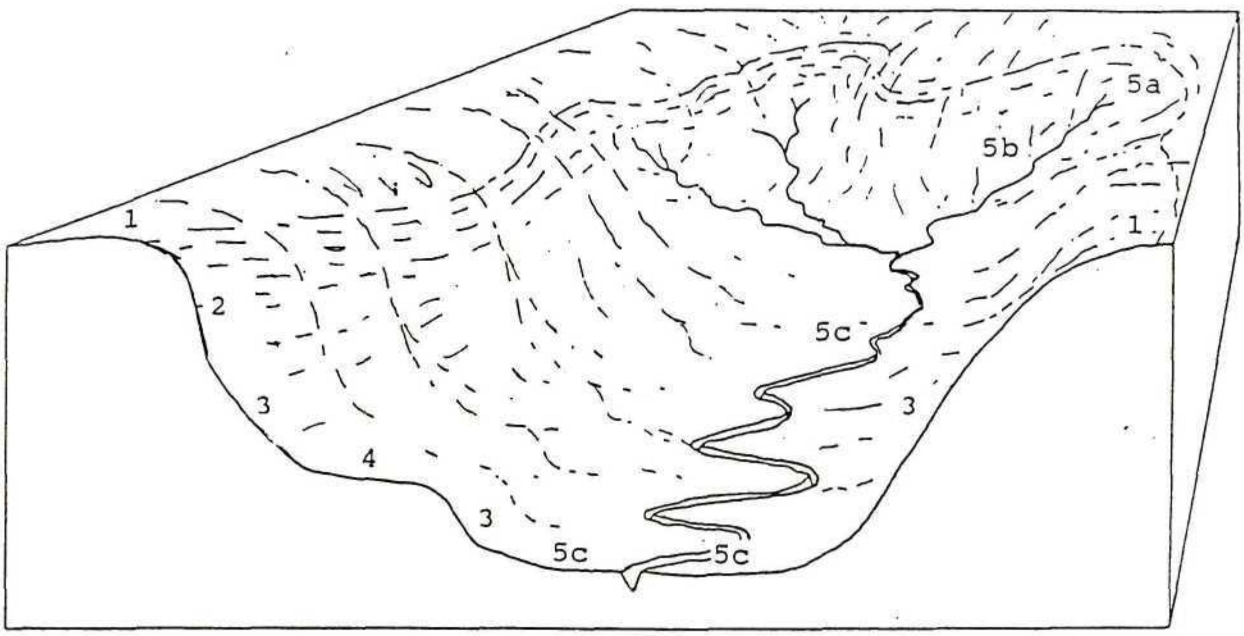


Fig. 1.2 Terrain units used by WETLAND-USE.

1.4 The conceptual design of WETLAND-USE

WETLAND-USE (included as Part 2 of this document) is a simple **rule-based model** with a conceptual desig having three main components (Fig. 1.3).

> *INFO-COLLECT* prompts the user to identify the wetland zones, record the proposed land-us information, and collect and record appropriate information on the wetland, its catchment, an downstream area.
>
> *LAND USE-ASSESS* assists in selecting an appropriate land-use alternative for a given wetland area b predicting the likely impacts of the proposed land-use (e.g. pasture production) on the functional valu for that area (e.g. water purification). An "interrogation process" is involved whereby the decisio support system uses recorded information from INFO-COLLECT to "interrogate" the proposed lanc use.
>
> *LAND USE-RECOMMEND* recommends how the wetland in question should be managed for the chose land-use. For example, if the chosen land-use is stock production from a natural (undeveloped) wetlan then the model provides information concerning such factors as stocking rate and timing of grazing.

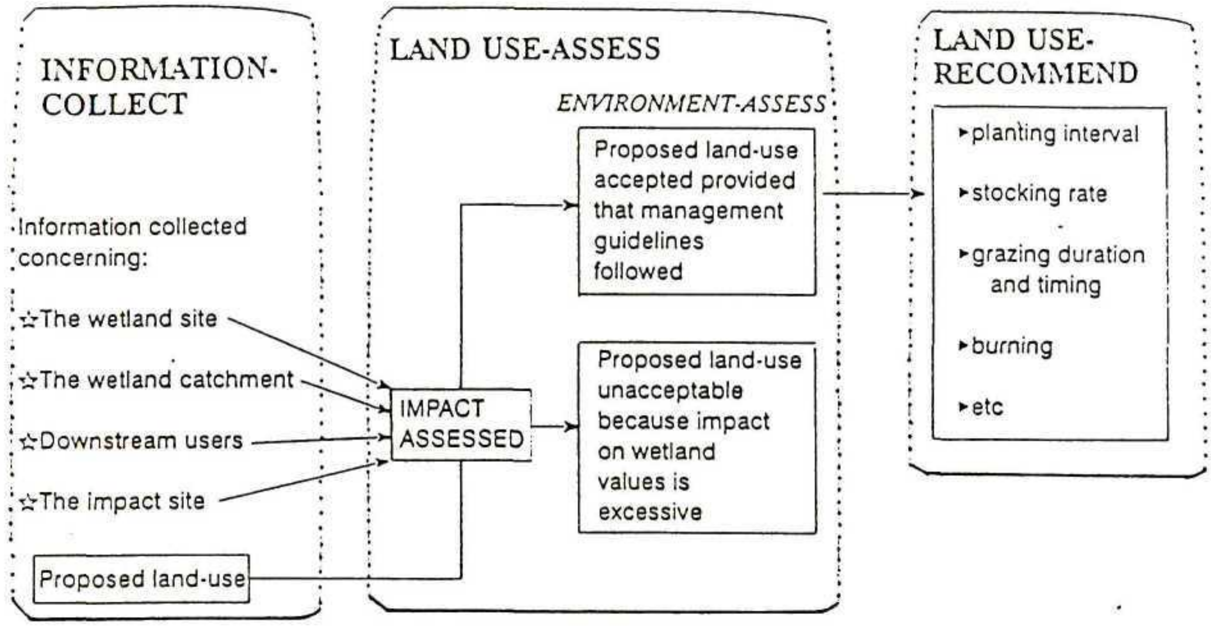


Fig. 1.3 The conceptual design of WETLAND-USE

1.4.1 INFO-COLLECT (Information concerning the wetland site, wetland catchment, downstream service area, impact area and proposed land-use)

In INFO-COLLECT, general questions are first posed by the four sub-components: WETSITE-INFO, LANDSCAPE-INFO, CATCHMENT-INFO and DOWNSTREAM-INFO in order to determine the wetland **descriptor** values (a wetland descriptor is a measurable characteristic considered useful in predicting how a wetland's functional values will be affected by management actions). The wetland descriptors concern the entire wetland, the extent and cumulative loss of wetlands in the surrounding landscape, the wetland catchment and potential downstream significance of the wetland respectively. More specific questions are posed by IMPACTSITE-INFO concerning the proposed land-use and **impact site** (that part of the wetland site to which the proposed land-use will be applied). Although the impact site may include the entire wetland, it generally consists of a portion under a single management authority, usually a farmer.

While it is preferable to obtain accurate descriptor values, this is often not possible due to time and resource limitations. In order to account for this, the user is given the option of choosing the level of detail for obtaining certain descriptor values, the level being dependent on the time and resources available. For example, in describing the distribution and extent of the agro-ecological zones, the user is provided with the following options:

1. indicate the ranked abundance of the agro-ecological zones occurring in the wetland;

2. estimate the approximate percentage contribution of each zone and sketch the approximate boundaries onto the wetland map; or

3. map the boundaries of the different zones and calculate their percentage contribution from the map.

1.4.2 WETSITE-INFO (General details concerning the wetland site)

Questions in this component, which may be used when conducting a wetland inventory over a broad area, concern:

* geographical location and altitude;
* wetland surface area;
* average slope in the direction of surface water flow;
* surface flow characteristics and hydrological disruption of the wetland;
* wetland-dependent rare and endangered species;
* current and past use of the wetland; and
* distribution, extent and degree of dispersion of agro-ecological zones.

1.4.3. LANDSCAPE-INFO and CATCHMENT-INFO (Wetland catchment information)

Questions about the surrounding landscape deal with the extent and cumulative loss of wetlands in this area. Questions relating to the wetland catchment, an area which has considerable influence on wetland functioning, are asked concerning:

* **Bioclimatic Group** (Phillips, 1973);
* Veld Types (Acocks, 1953);
* surface area;
* percentage of the wetland catchment occupied by the wetland;
* topography;
* soils; and
* current and past uses of the catchment.

1.4.4 DOWNSTREAM-INFO (Downstream information)

Questions in this section relate to the extent of water use and floodable properties in the downstream service area of the wetland. The purpose of DOWNSTREAM-INFO is to establish the current levels of benefit that would be derived if the wetland were effectively attenuating floods and purifying water. For example, if many people were dependent on potable water from the downstream area, the potential benefit would be high. It is independent of the opportunity afforded a wetland for carrying out a given function, and the effectiveness with which it does so.

The conceptual basis of this component is based on the assessment criteria used by WEM (US Army Corps of Engineers, 1988). However, an important change has been made to the means of attaching a semi-quantitative value to the potential for flooding. An assumption is made by WEM that the level of impact decreases from a purely urban area to a row crop/small grains area. However, in order for this to be true the proportion of the floodplain that is used would have to be the same for all sites. This will often not be so. For example, there may be some urban areas with little floodable property in the flood area and agricultural areas with many floodable properties in the flood area. It also does not specify the width of the area of influence and this may lead to confusion. WETLAND-USE employs the 1 in 50 year flood line. Although this is also open to confusion, it is likely to be more repeatable. In addition, WEM does not consider the current potential benefit that is derived from water quality improvement. However, it has been included in WETLAND-USE because of its potential importance.

1.4.5 IMPACTSITE-INFO (Information concerning the impact area and proposed land-use)

The user is requested to describe the impact site, which includes:

* estimating the maximum slope of the impact area; and

* describing the soil in the impact area in terms of (1) the Taxonomic System for South African (Soil Classification Working Group, 1991), and (2) wetness class and (3) *n* value (Soil Survey Staff, 1992). The *n* value is helpful in predicting the degree of subsidence that will occur after drainage and can be approximated in the field by squeezing the soil in the hand; and

* information about the land-use (e.g. pasture type) and the user (e.g. their possible alternatives to using the wetland).

The user is also requested to determine the value of certain derived descriptors (to be used directly in ENVIRONMENT-ASSESS) concerning cumulative wetland loss, pollutant input and downstream water use by synthesising information already collected (see Section 1.4.6).

1.4.6 ENVIRONMENT-ASSESS (Predicted impact of the chosen land-use)

The environmental impact of the chosen land-use is predicted by assessing the likely effects on the hydrological (water purification. flood attenuation and baseflow augmentation), erosion control and ecological (habitat provision) values or the wetland area. The severity of impact on the hydrological and erosion control values is assessed using the following criteria:

1. the extent to which the water table will need to be lowered in order to carry out the proposed land-use in an average rainfall year;

2. the extent to which the **roughness coefficient** of the wetland is decreased, either by smoothing out microtopographical surface irregularities such as hummocks or by replacing the natural vegetation with new vegetation that offers less resistance to water flow because it is shorter, softer, less dense, and/or less perennial;

3. the degree to which the soil organic matter content is likely to decrease as a result of a lowered water table leading to a less anaerobic environment;

4. the degree to which soil subsidence is likely to occur (soils with high *n* values and/or organic contents are most susceptible);

5. the degree to which the soil is disturbed; and

6. the extent to which wetland area is lost.

Hydrological and erosion control values are considered together in assessing impact because any loss of erosion control value will also detract from the hydrological values. The reverse is not necessarily true. For example, application of fertilizers to enhance crop production detracts from the hydrological value of the wetland by decreasing the wetland's water purification capacity. However, it does not directly detract from the erosion control value. Even wetland drainage, which would certainly detract from the hydrological value of the wetland, may have a small effect on the erosion control value, if it is carried out on a wetland with a low erosion hazard, and using soil conservation principles, and if perennial vegetation is maintained. However, it should be noted that many wetlands are areas of sediment accretion, and in the above example where drainage does not lead to a net loss of soil, it *would* decrease the net gain of soil trapped by the wetland. The example given of sustainable agricultural production on a drained wetland raises the point that it is possible to utilize the soil resource of a wetland on a sustainable basis, in the medium term at least, but this will detract from the values of the wetland to society.

The severity of impact on the ecological value of a wetland is assessed by determining the extent to which the land-use changes affect **biological integrity** and populations of threatened (i.e. rare, vulnerable or endangered) wetland-dependent species. It is evident from the literature on South African wetlands that there have been n(attempts to measure between-system or within-system diversity and to understand the mechanisms regulatin; diversity (Breen and Begg, 1989). For this reason, the assessment of biological integrity by WETLAND-USE will account only for obvious changes such as wetland drainage. Since an excess of water is the dominan factor affecting the plant and animal communities in a wetland (Cowardin *et al.*, 1979) it may be assumed tha the greater the disruption of the hydrological regime the greater will be the loss of ecological value. Thus, in most cases where land-use activities detract from the hydrological values of a wetland, they will also detrac from the ecological values. Known threatened wetland-dependent species occurring within the study are include:

Barbus pallidus (goldie)
Leptopelis xenodactylus (long-toed tree frog)
Grus carunculata (wattled crane)
Dasymus incomtus (water rat)
Poecilogale albinucha albinucha (African striped weasel)
Cacosternum striatus (striated caco)
Tyto capensis (grass owl)
Sarothrura ayresi (white-winged flufftail)
Felis serval (serval)

When dealing with wetland values, it is important to clarify what category of value is being referred to. WETLAND-USE accounts for this by recognizing three main categories of value and specifying which is being referred to. These categories are:

1. the effectiveness with which a wetland carries out a function (e.g. a wetland may be of value because it is effective in purifying water);

2. the opportunity afforded a wetland for carrying out a given function (e.g. a wetland may be of value because it receives waste water and has ample opportunity to purify water); and

3. the current potential benefit that might be derived if the wetland were effectively carrying out a function (e.g. if there were many potable water users downstream, the potential benefit derived if the wetland were effectively purifying water would be very high).

WETLAND-USE assesses the acceptability of different land-uses using primary and then secondary acceptance criteria. Primary acceptance criteria embody the first screening process to safeguard against the likelihood of large/obvious impacts. Essentially, the primary criteria are "threshold levels" for key descriptors (e.g. erosion hazard) beyond which a significant loss to society is likely to occur unless adequate mitigating measures are used. Secondary acceptance criteria deal with situations considered to have less impact, and attempt to capture the trade-off between benefits derived by the user and those lost by society. Development orientated land-uses tend to have a greater impact on wetland functional values than non-development orientated land-uses. Their acceptability is based on both primary and secondary acceptance criteria, whereas the acceptability of non-development orientated land-uses is based only on primary acceptance criteria.

In order to explain the interrogation process involved in assessing the acceptability of a land-use, one land-use is chosen: planted pastures. This is dealt with by PASTURE-ASSESS (Fig 1.4). PASTURE-ASSESS begins the interrogation by determining what agro-ecological zone the impact area occupies. If it is open water or marsh, the user is informed that pasture production is unacceptable because the hydrological and ecological impacts are likely to be too high. If the zone is wet meadow then pasture production is considered acceptable provided all the conditions specific to the zone are met. If any of these conditions is not met, the proposed land-use is considered to be unacceptable unless satisfactory mitigating measures are taken. If all the conditions are met then planted pastures is considered to have met the primary acceptance criteria. The user is then instructed to see if the land-use meets the secondary acceptance criteria.

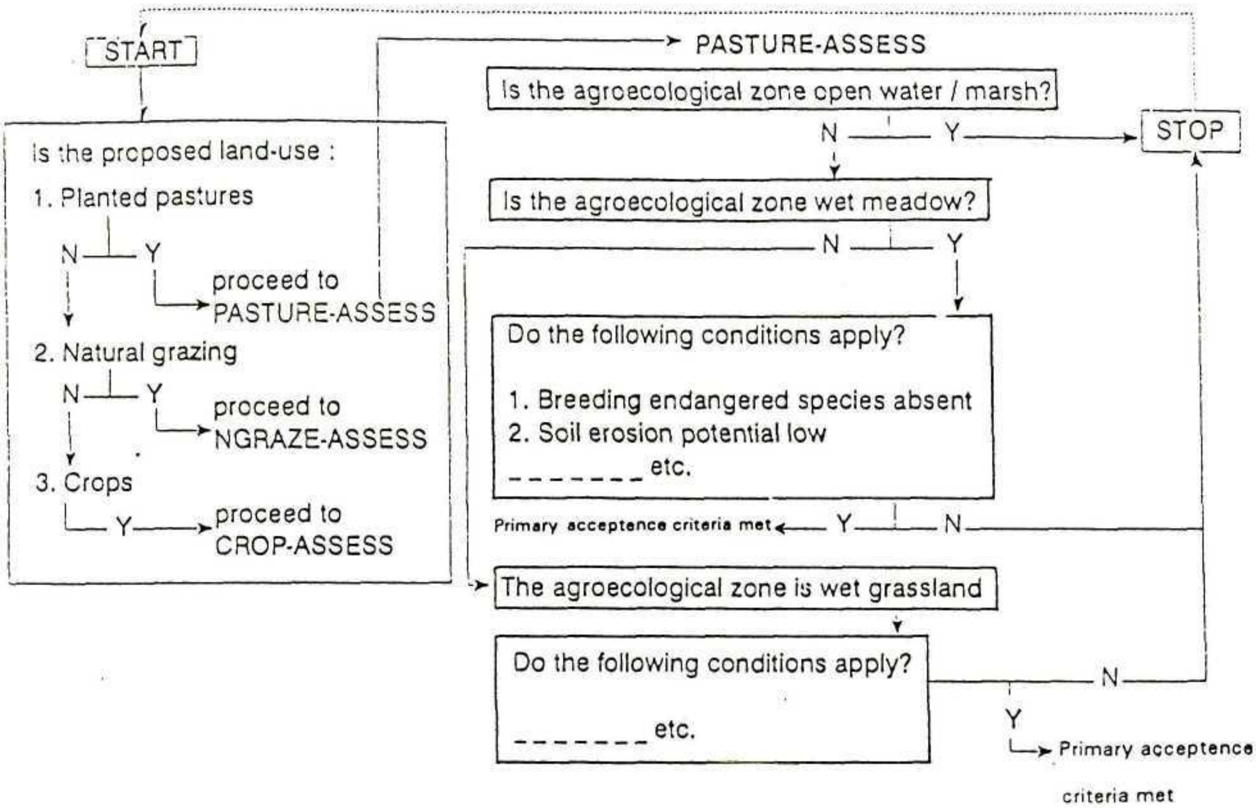


Fig 1.4 An algorithm illustrating the interrogation process of WETLAND-USE.

The rationale behind all stages of the interrogation process is revealed by the system. Much of the space is occupied by details ensuring clarity and consistency and the adequacy of the logic display function. Lay-out makes comparison of descriptor rules and values difficult, but there is a "checksheet" (see Section 2.4) where these are summarised.

1.4.7 LAND USE-RECOMMEND (Management recommendations concerning the chosen land-use)

In essence, all the recommendations in LAND USE-RECOMMEND are designed to minimize the hydrological, erosion control and ecological impacts, while at the same time maximising the land user's benefit. For crops and planted pastures, the recommendations are aimed primarily at minimizing the impact of such activities as fertilizer application on the hydrological values of the wetland. For the grazing of natural wetlands, the recommendations are primarily concerned with regulating the stocking rate and timing of grazing in accordance with the nature of the wetland. Burning recommendations concern timing and frequency of fires (Fig. 1.5) as well as measures designed to influence fire behaviour.

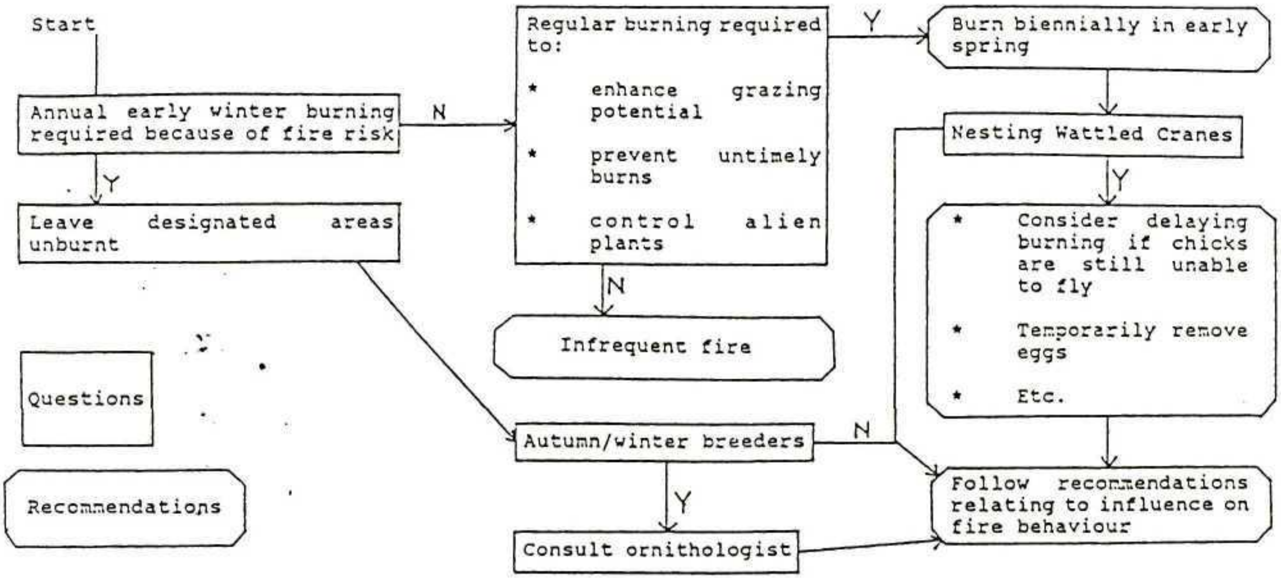


Fig. 1.5 An algorithm illustrating wetland burning frequency and timing recommendations

1.5 The degree to which the model's assumptions are backed by documentation from the literature

While a model based on assumptions not demonstrated to be technically correct may not necessarily be inaccurate, greater confidence can be placed in the predicted accuracy of a model with assumptions that are well substantiated in the literature. Because the knowledge base of WETLAND-USE was created, to a large extent from the literature, one would expect its assumptions to be supported. However, the strength of support is variable.

1.5.1 Primary assumptions of LAND USE-ASSESS

1. The greater the reduction in the degree of wetness through hydrological modification, the greater will be the impact on all the wetland's functional values[1]. This is well supported in the literature as a general principle (e.g. Goode *et al.*, 1977; O'Brien, 1977; Lavesque, *et al.*, 1982; Brinson, 1988; Ingram, 1991). However, the specific relationships are likely to depend on the nature of the particular site. For example, the relationship between level of drainage and the loss of value of a wetland for improving water quality is likely to vary according to the site.

2. The greater the reduction in surface roughness of the wetland, the greater will be the impact on the hydrological and erosion control values, because the wetland area will become less effective in slowing down the rate of water flow. This has been clearly shown in the literature (e.g. Reppert *et al.*, 1979; Adamus *et al.*, 1987).

[1] All assumptions of WETLAND-USE have been italicised.

3. *The greater the reduction in total surface area, the greater will be the impact on all the wetland's functional values.* This is well supported in the literature (e.g. Adamus *et al.*, 1987; Brinson, 1988; Preston and Bedford, 1988).

4. *The greater the extent to which the soil is disturbed, the greater will be the loss of water purification and erosion control values.* This is clear from the literature (e.g. Willrich and Smith, 1970; Miles and Manson, 1992).

5. *The greater the occurrence of soil subsidence, the greater will be the impact on the wetland's hydrological values.* Few references explicitly supporting this assumption were found, but it may be taken that subsidence leads to a decrease in the volume of soil subject to anaerobic conditions, the negative effects of which have been demonstrated (e.g. Ingram, 1991).

6. *The greater the extent to which soil organic matter levels are lowered, the greater will be the impact on the hydrological and erosion control values.* This has been well shown in the literature (e.g. Ingram, 1991; Miles and Manson, 1992).

7. *The more biological integrity and population numbers of valued wetland-dependent species are reduced, the greater will be the impact on the wetland's ecological (biotic diversity) value.* This assumption is based on the proposal of Preston and Bedford (1988) that the effect on valued species and ecological integrity be used for assessing impact on biotic diversity.

1.5.2 Assumptions concerning the erosion hazard index and individual land-uses

* **Erosion hazard index**

The three most important (readily measured) parameters which relate to the wetland site and which influence the susceptibility of an area to erosion (resulting from use by stock) are: (a) soil erodibility, (b) slope, and (c) landform.

The effect of soil erodibility and slope on erosion susceptibility have been shown in the literature (e.g. Anon, 1976). However, the slope limits employed by WETLAND-USE are not based on findings in the literature but were arbitrarily chosen in consultation with soil conservation workers from the Department of Agriculture.

Little evidence has yet been found in the literature to support the assumption that landform has an important influence on susceptibility to erosion. However, this assumption is supported by empirical evidence from wetlands in KwaZulu/Natal (e.g. Kotze 1994a and b; Kotze *et al.* 1994b, c and d). For example, wetlands in depression settings show less evidence of erosion than those in channel settings.

* **Burning**

1. *Provided that the burning recommendations (given in Part 2) concerning burning timing, frequency and influences on burning behaviour are adhered to, burning usually enhances the habitat value of wetlands.* Although there is a lack of reported work on the effect of burning, some studies have clearly demonstrated the advantages of burning to wetland-dependent species (e.g. Vogl, 1973; Smith and Kadlec, 1985).

2. *Provided the burning recommendations concerning burning timing and influences on burning behaviour are adhered to, biennial burning does not significantly detract from the ecological value of wetlands in the study area.* This assumption is based on the fact that biennial burning has not been shown to be detrimental to any valued wetland-dependent species in the study area. However, there are many species for which fire investigations have not been undertaken. Some of these species may well require a fire return frequency of

more than 2 years.

3. *When a wetland area is burnt, other wetland area/s nearby should be left unburnt to provide adequa cover for wetland-dependent species.* No evidence in the literature was found for or against this assumpti and it is based on the intuitive logic of species specialists (e.g. Dr. D Johnson, Natal Parks Boar Pietermaritzburg and Mr. B Taylor, Zoology Department, University of Natal, Pietermaritzburg).

4. *Late winter/early spring burning has the least impact on the ecologic' value of a wetland because occurs when the fewest species are breeding.* This is based on well-researched information on the life histori of wetland-dependent species, primarily birds.

5. *Fire is an important cause of chick mortality in wattled cranes.* This has been substantiated in t literature (Johnson and Barnes, 1991).

6. *Burning generally does not have a negative effect on the soil provided extensive sub-surface fires not occur.* This is supported by some literature findings (e.g. Schmulzer and Hinkle, 1992).

7. *Fire may be used to control alien plants effectively.* Although published evidence for this is lackir empirical evidence, obtained by making comparisons between unburnt and regularly burnt portions of numero wetlands in South Africa, supports this assumption (Otter, 1992; Kotze *et al.*, 1994c).

8. *From a water storage point of view, a late winter/early spring burn is preferable to an early winter bu because the wetland is left exposed (due to removal of standing dead material) for a shorter period. As suc evaporative loss is lower.* This is supported by studies (e.g. Donkin *et al.*, 1993) which show that evap transpirative loss of water from wetlands with standing dead material is less than loss from open water.

* **Grazing**

1. *If the veld condition in wet grasslands is poor, the stocking rate should be decreased to account for t lower production potential, and to allow the veld to recover.* It has been shown for non-wetland areas that ve in poor condition has a lower grazing potential than veld in good condition (Edwards and Tainton, 198 Although this is assumed to hold true for wetland areas as well, no such studies have been undertaken wetlands. There is also no published support for the arbitrarily chosen reduction factors to account for v condition. These were chosen in consultation with Prof. N M Tainton, Grassland Science Departme University of Natal.

2. *Wetlands should be rotationally grazed.* There is some published support for the merits of rotatio grazing for natural non-wetland areas in South Africa (e.g. Anon, 1951). It is also widely recommended by v management specialists (e.g. Edwards and Tainton, 1984). Although no studies of rotational grazing wetlands have been undertaken, it is assumed that the results obtained from non-wetland areas are applicab particularly to wet grasslands.

3. *Animals should be moved out of rotationally grazed wetland before it has been grazed to a specifi height.* Even for non-wetlands there is no literature to support a prescribed level of use as this is affected numerous variables (e.g. climatic variation). However, the specified height given in WETLAND-USE w based on intuitive logic, results from defoliation studies of individual species, and consultation with Prof. M Tainton.

4. *Grazing wetland areas when the soil is wet is more likely to result in erosion and/or compaction th grazing when the soil is dry.* This assumption is based on a report by Wilkins and Garwood (1986).

* Hay making/mowing

1. Mowing does not significantly detract from the ecological value of wetlands provided that not more than 30% of any agro-ecological zone in a wetland is cut at a given time. There is virtually no literature concerning the effect of hay cutting on wetland fauna. Although there are a number of European studies (e.g. Bakker, 1989) which show that cutting enhances plant species diversity, and indications that it has a short term negative effect on una by reducing cover (Bryan and Best, 1991; Kotze *et al.*, 1994c), there are no local studies and the 30% threshold was arbitrarily chosen.

2. Cutting with machinery when the soil is wet is more likely to result in soil erosion than cutting when the soil is dry. (see Grazing Assumption 4).

* **Pasture production**

1. Perennial species are preferable to annuals because they require that the soil be disturbed less often. This assumption is supported by the fact that soil disturbance has negative effects such as organic matter depletion and increased susceptibility to erosion (Miles and Manson, 1992).

2. Species with a high wetness tolerance are preferable to those with a low wetness tolerance because they require less lowering of the water table. See the reasoning for Primary assumption 1.

3. Intensive pastures, particularly those in drainage lines, may contribute to a deterioration in the quality of runoff waters. This general assumption is well supported (e.g. Amberger, 1983; Canter, 1986; and Miles and Manson, 1992). However, it is important to note that the effect of intensive pastures depends on several variables (e.g. fertilizer application rates and soil type), and may be negligible.

4. Measures should be taken to minimize fertilizer leaching losses from planted pastures. The measures recommended by WETLAND-USE for minimizing leaching losses from pastures are based primarily on those recommended by Amberger (1983) and also on those of Miles and Manson (1992).

* **Crop production**

1. Crop production is generally considered to have one of the severest agricultural impacts on wetlands. The high impact associated with wetland drainage and conversion to cropland has been well demonstrated (e.g. Willrich and Smith, 1970).

2. The recommendations and associated assumptions concerning minimizing drainage requirements and nutrient leaching from planted pastures are also applicable to crops.

3. Ley cropping should be implemented to reduce the impact. The benefits (e.g. reduced organic matter depletion) that accrue from ley cropping have been clearly demonstrated (Wardle, 1961; Lockhart and Wiseman, 1988).

* **Damming**

The loss of habitat that follows flooding by dams and the negative effect that dams have on the downstream biota due to the altered flow regime are well documented (e.g. Davies and Day, 1986; Bruwer and Ashton, 1989; Conley, 1992; Masinga, 1992). The decreased runoff that results from evaporation from dams has been clearly shown (Schulze *et al.*, 1989; Mallory 1992).

1.6 Concluding remarks

The description of soil wetness classes and agro-ecological zones employed in WETLAND-USE will contribute towards a workable means of delineating the boundary between wetland and non-wetland areas and between different zones within wetlands in the study area. The delineation of wetlands is very contentious in the USA and is bound to become more so in South Africa as the demand for land and water resources increases. Thus the potential value of these classification systems for the purposes of land-use planning and management is apparent.

It can be concluded that WETLAND-USE, by accounting for the functional values of wetlands, will assist in attempts to use wetlands in a manner in keeping with the intrinsic environmental/ ecological features of individual wetland areas. This should assist in the following areas of wetland management:

* allocating appropriate land-uses to different wetland zones; and

* making ongoing management decisions for different land-uses (e.g. timing and frequency of burning).

WETLAND-USE should improve individual site assessments undertaken by agricultural and nature conservation extension workers, and should help with policy formulation and regional planning for the wetlands of KwaZulu/Natal. Although the development of wetland management guidelines (as is being undertaken by WETLAND-USE) is considered an important part of any wetland conservation strategy (Dugan, 1992; Williams, 1992), there are very few of these guidelines available for South African wetlands. It may be worthwhile to expand the approach used in WETLAND-USE by including a wider geographic area and more land-uses, with the eventual aim of including the whole of South Africa.

Although the expert system approach to problem solving is a valuable management tool, it does not replace the expert. Caution will be required in using WETLAND-USE because such techniques are open to mis-use: as emphasised in the Preface, it is unreasonable to expect a system, such as WETLAND-USE, to provide the final answer as to the suitability of a given land-use in a particular situation. What it does, however, is assist the user in arriving at a final decision, by ensuring that adequate information on the wetland and its surrounding landscape is collected, the relevant questions are asked, and the likely environmental impact of different land-use alternatives is predicted. In addition, it ensures that a record is kept of the decision making process.

Based on an evaluation of the important assumptions of the model and the extent to which they have been substantiated in the literature, the most important knowledge gaps were identified. The knowledge gaps were mainly concerned with the effects of natural stock grazing, and of burning and satisfactorily describing the biotic diversity of the study area's wetlands and how this is affected by different land-uses. An evaluation of the limitations of WETLAND-USE revealed that:

* it uses arbitrary cut-off points and qualitative reasoning;

* some of its assumptions are not adequately supported in the scientific literature;

* it fails to consider certain interactions and cumulative effects in space and time;

* it is an oversimplification of the field situation; and

* it applies to a limited geographical area only and to a limited number of land-uses.

While all these criticisms are valid, wetland management decisions are at present being made with little or no consideration for the loss of wetland functional values. Any improvement, therefore, should be beneficial. Optimal use needs to be made of the best available information, even if this is qualitative and if arbitrary cut-offs need to be chosen. The structure of WETLAND-USE is open and can be refined later by incorporating more detailed information, as it becomes available, and/or supplementing the system with new components. In this regard, it is important to note that the building of a decision support system, or any environmental model, is never completed in the strict sense as there are invariably some components which can be improved or supplemented.

In South Africa (and in many other countries) there is growing dissatisfaction among resource managers concerning the contribution that research is making toward the enhancement of resource management (Breen, 1992). Thus, with the objective of identifying the key management issues and characterizing the decision-making process in wetlands, it is hoped that WETLAND-USE will not only contribute towards improving the current management of wetlands, but will also assist in designing relevant research programmes that enhance resource management by focusing on the most important knowledge gaps.

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1.8 Glossary

Animal unit (AU): an animal unit is defined as an animal with a mass of 450 kg and which gains 0.5 kg per day on forage with a digestible energy percentage of 55%. Other types of animals are related to such a unit according to the relationship between the three-quarter power of the mass of such animals and a similar function of the mass of a 450 kg animal, i.e. an animal with a mass m constitutes:

$$\frac{m^{0.75}}{450^{0.75}} \text{ of an animal unit}$$

Aquic moisture regime: a reducing regime virtually free of dissolved oxygen because the soil is saturated. Some soil horizons, at times, are saturated with water while dissolved oxygen is present (as may occur if the water is moving). The required **soil saturation** duration is not known (and depends on site factors such as soil texture and temperature), but must be at least a few days (Soil Survey Staff, 1992).

Bioclimatic Groups: Phillips (1973) classified the extremely varied natural resources of KwaZulu/Natal into 11 Bioclimatic Groups based primarily on climatic parameters. These groups provide convenient natural resource classes in terms of which management guidelines can be formulated.

Biological integrity: the fauna and flora that characterise an area (i.e. the area's "naturalness").

Capillary fringe: the zone just above the water table (zero gauge pressure) that remains almost saturated. In a sandy soil this zone may be only 10 cm. In loamy or clayey soil that does not shrink or swell appreciably, the thickness may be 30 cm or more, depending on the size distribution of the pores (Soil Survey Staff, 1992).

Chroma: the relative purity of the spectral colour, which decreases with increasing greyness.

Descriptor: a measurable characteristic considered useful in predicting how a wetland's functional values will be affected by management actions.

Dominant plant species: the overstory species that contribute most cover to the area, compared to other overstory species (Barbour, Burk and Pitts, 1980).

Ecological value: the value of the wetland in maintaining the biotic diversity of the area. Biotic diversity can be measured at many different levels, and it is almost impossible to prescribe a standard method of describing it. Its assessment may be simplified by determining the degree to which management is affecting biological integrity and populations of valued species.

Groundwater: subsurface water in the zone in which permeable rocks, and often the overlying soil, are saturated under pressure equal to or greater than atmospheric (Soil Classification Working Group, 1991).

Groundwater table: the upper limit of the groundwater.

Horizon: see soil horizons.

Hydric soil: 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 (vegetation adapted to living in anaerobic soils).

Hydrophyte: any plant that grows in water or on a substratum that is at least periodically deficient in oxygen as a result of soil saturation or flooding; plants typically found in wet habitats.

Hue: the dominant spectral colour (e.g. red).

Hydrogeomorphological setting: the landform setting (which influences the surface water flow pattern and is given by the landform class) and the position relative to other landforms in the wider landscape (as given by the **terrain unit class**).

Hydrology: the study of water, particularly the factors affecting its movement on land.

Impact site: that part of the wetland site to which a proposed land-use is to be applied.

Marsh zone: a wetland zone dominated by emergent herbaceous vegetation (usually taller than 1 m), such as the common reed (*Phragmites australis*). Some marsh zone areas are seasonally wet but most are permanently or semi-permanently wet.

Mottles: soils with variegated colour patterns are described as being mottled, with the most abundant colour being referred to as the matrix and the other colour/s as mottles.

***n* Value:** the relationship between the percentage of water under field conditions and the percentage of inorganic clay and humus. It can be approximated in the field by a simple test of squeezing the soil in the hand. It is helpful in predicting the degree of subsidence that will occur after drainage (Pons and Zonneveld, 1965; Soil Survey Staff, 1992).

Open water zone: permanently or semi-permanently flooded areas characterized by the absence (or low abundance) of emergent plants.

Peraquic moisture regime: an aquic moisture regime where the where the ground water is always at or very close to the surface (Soil Survey Staff, 1992).

Perched water table: the upper limit of a zone of saturation in soil, separated by a relatively impermeable unsaturated zone from the main body of groundwater.

Poaching: this occurs when soils are wet, and refers to the disruption of soil structure caused by the repeated penetration of hooves into the soil (Wilkins and Garwood, 1986). The poaching of soils should be avoided because besides decreasing herbage production, it also greatly increases the susceptibility of the soil to erosion.

Physiognomy: the outer appearance of the vegetation; a function of the architecture of the different canopy layers and the life form of the dominant plants.

Red Data species: all those species included in the categories of endangered, vulnerable or rare, as defined by the International Union for the Conservation of Nature and Natural Resources (Smithers, 1986).

Roughness coefficient: an index of the roughness of a surface; a reflection of the frictional resistance offered by the surface to water flow.

Rule-based model: a model which represents knowledge in the form of IF-THEN statements. The IF part contains a condition or premise and the THEN part contains a result, conclusion or consequence.

Soil horizons: layers of soil that have fairly uniform characteristics and have developed through pedogenic processes; they are bound by air, hard rock or other horizons (i.e. soil material that has different characteristics).

Soil profile: the vertically sectioned sample through the soil mantle, usually consisting of two or three horizons (Soil Classification Working Group, 1991).

Soil saturation: the soil is considered saturated if the water table or **capillary fringe** reaches the soil surface (Soil Survey Staff, 1992).

Stocking rate (SR): the number of AUs per unit of land for a specified period of time; it may be expressed in terms of number of land units per AU.

Terrain unit classes: areas of the land surface with homogenous form and slope. Terrain may be seen as being made up of all or some of the following units: crest (1), scarp (2), midslope (3), footslope (4) and valley bottom (5) (Fig. 1.2).

Wet grassland zone: a wetland zone which is usually temporarily wet and supports a mixture of: 1) plants common to non-wetland areas and 2) short (< 1m) hydrophytic plants (predominantly grasses) also common to the wet meadow zone.

Wetland: land where an excess of water is the dominant factor determining the nature of the soil development and the types of plants and animals living at the soil surface (Cowardin *et al.*, 1976).

Wetland catchment: the area up-slope of the wetland from which water flows into the wetland and including the wetland itself.

Wetland functional values: wetland functions (e.g. the trapping of sediment) which are of value to society. Wetland functions refer to the many physical, chemical and biological processes that take place in wetlands.

Wet meadow zone: a wetland zone which is usually seasonally wet and dominated by short (usually < 1.5 m) hydrophytic sedges and grasses common to temporarily or seasonally wet areas.

1.9 Address list

Department of Agriculture
P O Box 345
Pietermaritzburg
3200
(0331) 33371

Department of Environment Affairs
Private Bag X447
Pretoria
(012) 3103701

Department of Water Affairs and Forestry
Private Bag X9029
Pietermaritzburg
3200
(0331) 428101

Institute of Natural Resources
University of Natal
Private Bag X01
Scottsville
3209
(0331) 68317

KwaZulu Bureau of Natural Resources
Private Bag X23
Ulundi
3838
(0358) 202713

Natal Parks Board
P O Box 662
Pietermaritzburg
3200
(0331) 471961

Plant protection Research Institute
Cedara Weeds Laboratory
Private Bag
X9059
Pietermaritzburg
3200
(0331) 33371

University of Natal
Private Bag X01
Scottsville
3209
(0331) 2605911

Wildlife Society (Natal)
100 Brand Road
Durban
4001
(031) 213126

PART 2: THE DECISION SUPPORT SYSTEM

2.1 INFO-COLLECT

Note:

*1. Those **descriptors** marked with a # are not essential to the assessment of the acceptability of individual land uses and for making ongoing management decisions but, if they can be readily obtained, they may enhance th assessment and are likely to be useful for formulating an overall wetland management plan.*

2. Those descriptors which are underlined (e.g. A7) are referred to as derived descriptors and do not requir gathering of information. Instead, they are derived from other descriptors.

3. Section 2.4 contains the data sheet for recording the information requested in Section 2.1.

4. If any of the data requested is not available indicate this with an "NA".

2.1A WETSITE-INFO (Information concerning the wetland site)

Requirements:

* 1 :50 000 topocadastral maps and/or 1:10 000 orthophotos, both available from the Surveyor General Airphotos, available from the Chief Director: Surveys and Mapping, would also enhance th assessment, particularly if comparisons could be made to detect change, using a recent set and th earliest set available;

* a planimeter or other means of measuring surface area;

* at least one site visit;

* Bioclimatic Groups according to Phillips (1973);

* veld types according to Acocks (1953); and

* the relevant surface Water Resources of South Africa publication, e.g. Pitman *et al.* (1981).

Attempt to answer all the following questions concerning the wetland:

	month	year
Date of the site visit/s.	.....	......
	.....	......

A1. Wetland name ....

A2. Geographical coordinates ......° ......'S .....° ......'E

A3.1# inlet/maximum altitude (m) ....
A3.2# outlet/minimum altitude (m) ....

A3.3# Average altitude (m) ....

Note: the inlet and outlet altitudes can be obtained from orthophotos and the average wetland altitude is take as: (A3.1 + A3.2)÷2.

A4. Bioclimatic Group (according to Phillips, 1973) ....

A5# Mean annual precipitation (mm) ....

Note: if data are unavailable for A6 and A7 then these may be obtained from Phillips (1973).

A6# Annual potential evapotranspiration (mm) ....

A7. Indicate ...... (a or b) if the Bioclimatic Group (Descriptor A5) is:

a. humid to sub-humid (Bioclimatic Groups 1-6); or
b. mild sub-arid (semi-arid) to arid (Bioclim. Groups 7-11).

A8# Veld type (according to Acocks, 1953) ....

A9# Dominant soil form/s (according to Soil Classification Working Group, 1991) occurring in the wetland. ....

A10. Underlying geology ....

A11. Wetland surface area (ha) ....

Note 1: this does not refer to the area that is wet at the time of the assessment but to the area supporting wetland soils and/or vegetation (see Section 1.2). Temporary wetlands may be wet for only a few weeks in the year, or may even not be wet at all in dry years. Thus, vegetation and soils, in particular, should be used as the primary criteria for delineating wetland areas, unless long-term water regime records exist.

Note 2: although locating wetland boundaries is clearly defined, designating individual wetlands is often an arbitrary choice. As a very general guide, if a wetland area constricts to less than 3 m wide then the areas on either side of the constriction are considered as separate wetlands.

A12# Average width (m) of the wetland perpendicular to flow. ....

Note: to calculate the average width of the wetland, divide the wetland (perpendicular to the direction of flow) into 5 segments of equal length, and measure the width of each segment (at their centres and perpendicular to the direction of flow), then calculate their average by dividing their sum by 5.

A13# Length of the wetland from the outlet to the inlet (m). .....

Note: this refers to the distance that diffuse water flow would travel from the inlet to the outlet. If the wetland were curved or twisted, the wetland length would be longer than the straight line distance from the inlet to the outlet.

A14# Calculate the average slope of the entire wetland (%). ....

Note: $A14 = 100 \times (A3.1 - A3.2) \div A13$.

A15. Distribution and extent of agro-ecological zones (defined in Section 1.2). Depending on the time and resources available:

i) indicate the ranked abundance of the agro-ecological zones occurring in the wetland (1= most abundant, 2= second most abundant, 3= third most abundant and 4= fourth most abundant);

ii) estimate the approximate percentage contribution of each zone (a-l) and sketch the approximate boundaries onto the wetland map; or

iii) map the boundaries of the different zones and calculate their percentage contributions from the map.

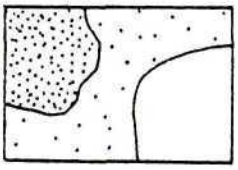
		i) rank (1-4)	ii) estimated abundance	iii) calculated abundance (%)
1.	open water	....	....	....
2.	marsh	....	....	....
3.	wet meadow	....	....	....
4.	wet grassland	....	....	....

Note:	*a. <0.01%*	*d. 11-20%*	*g. 41-50%*	*j. 71-80%*
	b. 0.01-3%	*e. 21-30%*	*h. 51-60%*	*k. 81-90%*
	c. 4-10%	*f. 31-40%*	*i. 61-70%*	*l. 91-100%*

A16 If data for plant species occurring in the different wetland zones are available, complete the species dat sheet at the end of Section 2.4.

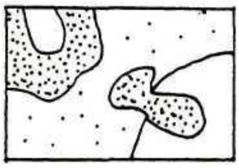
A17# Indicate which horizontal pattern of agro-ecological zones (A-C) best describes the condition in th wetland ....

A



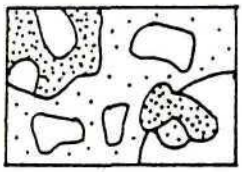
Relatively homogenous areas supporting a single zone with little or n interspersion between these homogenous areas.

B



Intermediate between A and C.

C



A highly interspersed mosaic of relatively small areas (not less than 1 m^2) which support different zones.

A18. Indicate (a-f) which landform setting/s (described in Section 1.3) best describes that of the wetlan ....

a. Flat b. Depression c. Channel d. Slope e. Channelled flat f. Channel disrupting fla

Note: if a wetland includes more than one landform setting, indicate this by recording the landform settings i the order of their occurrence in the direction of flow, separated by commas (e.g. a wetland comprising channel at its upstream end, followed by a channelled flat, should be recorded as: c,e)

A19. If the landform setting is a channel, indicate (Y or N) if emergent vegetation extends through th channel bed rather than being confined to the channel banks. ....

A20. If the landform setting is a channel disrupting flat, indicate (a-d) the prevalence of depressions withi the flat (expressed as a percentage of the total area). ....

a. < 3% b. 3-10% c. 11-30% d. >30%

A21. Indicate (a-f) on which terrain unit/s (described in Section 1.3) the wetland occurs. ....

a. Crest	c. Footslope	e. Valley bottom (young)
b. Midslope	d. Valleyhead	f. Valley bottom (mature/old)

A22. If the wetland setting is a channel disrupting flat, identify the flow concentration area and demarcate it on the wetland map. Indicate the slope (%) of the flow concentration area. ......

Note: the flow concentration area, sometimes called the "keypoint", refers to that part of the wetland where predominantly diffuse flow becomes channelized. This is usually associated with an increase in slope and is often the most erosion-prone part of the wetland. When undertaking a site visit, check this area for signs of erosion (see A40).

A23# If the wetland setting is a channel, channelled flat or channel disrupting flat, indicate (a-d) the stream order of the primary input channel. ......

a. first order b. second order c. third order d. fourth order or more

A24# Where flow in the wetland is channelled (naturally or artificially) indicate (a-d) the meander ratio. .....

a. < 1.10 b. 1.11-1.30 c. 1.31-1.50 d. > 1.50

Note: the meander ratio is calculated by dividing the distance from one point on a stream to another point on the stream (at least 500 m downstream) via the channel by the straight line distance between the same two points.

A25. List all recorded **Red Data** (threatened) plant species occurring in the wetland. Indicate their status (E= Endangered, V= Vulnerable and R= Rare) and, if possible, indicate in which zone/s they occur (O= Open water, M= Marsh, W= Wet meadow, G= Wet grassland)

	Status	Zone/s
1.	......	....
2.	......	....
3.	......	....

4. Total number of Red Data plant species ....

Note: a single site visit is not sufficient to identify all Red Data plant and animal species as some are very difficult to observe and are not identifiable or are absent during certain seasons. Consult the Natal Parks Board or approach The Wildlife Society for advice.

A26. List all recorded Red Data (threatened) animal species occurring in the wetland, indicate their status (E= Endangered, V= Vulnerable and R= Rare) and, if possible, indicate in which zone/s they occur (O= Open water, M= Marsh, W= Wet meadow, G= Wet grassland).

	Status	Zone/s
1.	......	....
2.	......	....
3.	......	....

4. Total number of Red Data animal species ....

A27. List any valued wetland-dependent species (e.g. species of direct economic importance) occurring in the wetland other than those that are threatened and, if possible, indicate in which zone/s they occur (O= Open water, M= Marsh, W= Wet meadow, G= Wet grassland).

Other valued wetland-dependent species	**Zone/s**
1.	....
2.	....
3.	....
4.	....
5.	....

Note: valued wetland-dependent species are defined in Section 1.4.6.

A28# List those valued wetland-dependent species which are known to occur in the wetland but not in neighbouring wetlands (i.e. localized species).

1. ....
2. ....

A29. Indicate (Y or N) if the wetland is known to be of a type, or to include habitat types, which are threatened or which are regionally scarce or rare ..... and if Y, name the particular type/s ....

Note: The wetlands of South Africa are very poorly described, and the information required for this descriptor is generally lacking. This descriptor will increase in importance for wetland assessments in time, as information on wetlands becomes available.

A30 Indicate (a-c) the wetland's importance for supporting migratory/nomadic birds. ....

a. negligible b. moderate (ca 100-1000 birds) c. high (> ca 1000 birds)

Note: the wetland may be important for only a few weeks each year or even less frequently but, nevertheless would still be important. It may be necessary to consult an ornithologist regarding A30 and A31.

A31 Indicate (with a Y) if the wetland is considered to be an important duck/heron breeding site. ......

A32. Indicate (a-d) the current timing of wetland fires. ....

a. winter b. early spring c. summer d. autumn

A33. Indicate (a-e) the current fire frequency. ....

a. annual b. every 2nd year c. every 3rd year
d. every 4th to 7th year e. greater than a 7 year interval

A34. List any alien invasive plants in the wetland, and if possible, record whether infestation levels for the overall wetland are: (a) high (occurs in >30% of the wetland area), (b) moderate (occurs in 5-30%

of the wetland area) or (c) low (occurs in <5% of the wetland area).

i) Alien invasive plant species list	ii) Level of infestation (a-c)
1.	....
2.	....
3.	....
4.	....
5. Total combined infestation level	....

Note: if the wetland is infested with alien plants, the local agricultural extension officer or The Plant Protection Institute should be consulted regarding alien plant control, as invasion by alien plants may pose a serious threat to the wetland.

A35. Indicate (a-f) what percentage area of the wetland has been inundated by damming. ....

a. <1% b. 1-5% c. 6-15% d. 16-30% e. 31-60% f. 61-100%

A36. Indicate (a-f, see A35) what percentage area of the wetland has been altered by drainage channels. .....

Note: a wetland area is considered to have been altered by drainage channels if its degree of wetness has been reduced. This may be deduced through airphoto comparison or on-site observation of drainage channels and soils (the soil tends to retain indicators of the previous natural water regime, see Section 1.2). Drainage channels vary in effectiveness, depending on their depth and slope and the physical characteristics of the soil. If the effect of the drains needs to be determined accurately, it may be necessary to consult a hydrologist or soil conservation officer. Generally speaking, drainage of wetlands detracts substantially from the functional values of wetlands (see Section 2.3C2, p65). Thus, the rehabilitation of drained wetlands should be given consideration, particularly if the drainage channels are not being used to increase production potential (e.g. if the area is an abandoned pasture).

A37. Indicate (a-f, see A35) what percentage area of the wetland has been altered by erosion in historical times. ......

Note: alteration due to erosion includes both the direct loss of soil and the reduction in degree of wetness caused by erosion gullies which act as drains. Functional values are lost in eroded wetlands, and it is important that these areas be rehabilitated as far as possible, particularly if erosion is severe and there has been an increase in the extent of eroded areas in the wetland (see Rule C1 Note, Section 2.2C, p51, concerning the rehabilitation of wetland areas).

A38. Through comparison of recent and past airphotos, indicate (a-f) the percentage increase over the last 20 years in the amount of area altered by erosion. ....

a. <0% b. 0% c. 1-30% d. 31-80% e. 81-150% f. >150%

Note 1: <0% denotes that the extent of the eroded area has decreased.

Note 2: due to the fact that erosion may substantially detract from the functional values of wetlands, particularly if it occurs in the flow concentration zone of the wetland (see A40), it is important that rehabilitation measures be undertaken (see the Rule C1, p51). Besides measures taken within the wetland to combat erosion, it is also important to modify land-uses contributing to the erosion in, and surrounding the eroding area, to reduce their impact.

A39. Indicate (a-d) the severity of erosion in the eroded area. ......

Severity of erosion: a. negligible erosion visible

b. mildly severe (predominantly rill erosion but shallow [< 1 m deep] gullies ma
occur)

c. severe (predominantly shallow gullies)

d. very severe (deep gullies [> 1 m deep])

Rills refer to small intermittent water courses, usually less than 3cm deep.

A40. If a flow concentration area (defined in A22) is present and eroded, indicate (a-d) the severity o erosion in that particular area. .....

A41# Indicate the total length of roads or rail-roads passing through the wetland (m). ....

A42# Indicate (with a Y) if any obvious downstream flow concentration effects caused by road or rai crossings are discernible and sketch these on the wetland map. ....

A43# Indicate (with a Y) if any obvious upstream damming effects caused by road or rail crossings ar discernible and sketch these on the wetland map. .....

Note: flow concentration and damming effects may be observed during the site visit or detected by comparin recent and past airphotos.

A44. Current use of the wetland. Depending on the time and resources available:

i) indicate (with a Y on Table A1) which land-uses occur in the wetland;

ii) estimate the percentage area of each land-use, record this on Table A1 (a-k) and sketch the approximat boundaries onto the wetland map; or

iii) map the boundaries of the different land-use areas and determine the percentage contribution of th different land-uses from the map.

Table A1 Current land-uses in the wetland

		i)	ii) area (a-k)	iii) area (%)
1.	nature conservation	....	....	....
2.	natural vegetation stock grazing	....	....	....
3.	hay cutting	....	....	....
4.	planted pastures	....	....	....
5.	crops	....	....	....
6.	forestry	....	....	....
7.	urban or industrial	....	....	....
8.	mining	....	....	....
9.	other:	....	....	....
10.	....	....	....	....

Note:
a: 0-2%
b: 3-10%
c: 11-20%
d: 21-30%
e: 31-40%
f: 41-50%
g: 51-60%
h: 61-70%
i: 71-80%
j: 81-90%
k: 91-100%

A45. Depending on the available time and resources:

i) indicate (with a Y on Table A2) which natural resources (not covered in A44.) are used in the wetland; and

ii) indicate on Table A2 the level of use (a-d) for each resource used. If payment is derived from use of any of these resources, indicate this with a P directly after the level of use (e.g. cP).

Note:	*Level of use*	*Birds shot per year*	*Man hours spent collecting per year*	*Water volume used (m^3 per year)*
	a.	*0*	*0*	*0*
	b.	*1-20*	*1-100*	*1-10 000*
	c.	*21-100*	*100-500*	*10 001-100 000*
	d.	*>100*	*>500*	*>100 000*

Table A2 Wetland natural resources

		i)	ii) (level of use)
1.	birds (hunting)	....	....
2.	reeds, sedges and bulrushes	....	....
3.	water	....	....
4.	others:	....	....
5.	....	....	....
6.	No use made of the wetland	....	

A46. Depending on the time and resources available:

i) indicate (with a Y) which recreational activities are practised in the wetland; and

ii) for each activity, score the level of use (a-c). Indicate (with a P) if payment is derived from the visitors.

		i)	ii)	
1.	bird-watching	....	....	*Note: a= 1-10 visitors per month*
2.	water sports	....	....	*b= 11-50 visitors per month*
3.	fishing	....	....	*c= >50 visitors per month*
4.	other/s (.......................)	....	....	

A47# Indicate (Y or N) if the wetland is part of, and essential to, an ongoing long term environmental research/monitoring programme. ....

A48# Indicate (Y or N) if the wetland is the closest wetland to any environmental education centre, school, university or similar education facility and is within 500 m of a public road with available parking. ....

A49. Distribution and extent of land ownership types. Depending on the time and resources available:

i) indicate the ranked abundance of the land ownership types occurring in the wetland (1= most abundant, 2= second most abundant, 3= third most abundant and 4= fourth most abundant);

ii) estimate and record the approximate percentage contribution of each landownership type and sketch the approximate boundaries onto the wetland map; or

iii) map the land ownership type boundaries and calculate their percentage contribution from the map.

		i) rank	ii) estimated abundance (a-k)	iii) calculated abundance (%)
1.	privately owned	....	....	....
2.	government owned land leased out	....	....	....
3.	declared conservation land	....	....	....
4.	state forest	....	....	....

Note: *a. 0-2%* *c. 11-20%* *e. 31-40%* *g. 51-60%* *i. 71-80%* *k. 91%*
b. 3-10% *d. 21-30%* *f. 41-50%* *h. 61-70%* *j. 81-90%*

A50. Indicate (Y or N) if there is evidence of high nutrient concentrations entering the wetland (e.g. alg blooms or actual measurement of high concentrations). ......

A51. Indicate (Y or N) if there is evidence of waterborne toxicants entering the wetland (e.g. fish kills c actual measurements of hazardous concentrations). ......

A52. Indicate (Y or N) if inflow entering the wetland is turbid following even small storm events (i.e. < 10 mm in an hour). ......

2.1B LANDSCAPE-INFO (Information concerning the extent, and cumulative loss, of wetlands in th surrounding catchment)

Indicate (a-h) the extent of wetlands in:

- B1. the wetland catchment .....;
- B2. the downstream service area .....; and
- B3. a 10 km radius around the wetland (excluding the wetland catchment and wetland service area ......

Extent of wetland area in the surrounding landscape (expressed as a percentage of the total area):

a. 0- 0.05% c. 0.6- 1.0% e. 6.0- 10.0% g. 26.0- 50.0%
b. 0.06- 0.5% d. 2.0- 5.0% f. 10.0- 25.0% h. >50.0%

Depending on which data are available, indicate (a-d) the extent of wetland loss (in the last 50 years) withi

- B4. the wetland catchment .....;
- B5. the wetland service area ......; and/or
- B6. a 10 km radius around the wetland (excluding the wetland catchment and wetland service are ....

Extent of wetland loss in the surrounding landscape:

a. Nil b. 1-30% c. 31-60% d. >60%

Note: a wetland area is considered to be lost if it has been developed or degraded to the point where it has lc a significant amount of its functional values, as would occur if it was severely eroded, dammed or drained a planted to crops or pastures. Wetland loss can be estimated by comparing recent airphotos with those tak before 1950.

2.1C CATCHMENT-INFO (Wetland catchment information)

The "wetland catchment" refers to the area up-slope of the wetland (from which water flows into the wetland) and includes the wetland itself. The wetland catchment of channelled flat settings consists of the "wetland catchment proper" and the "flood catchment". All surface water draining the wetland catchment proper passes through the site. However, surface water from the flood catchment passes through the site only when runoff events are great enough to result in streambank overspill. In other words, the size of the effective catchment for channelled flat settings increases during sufficiently high runoff events. In all other wetland settings the effective catchment remains constant. The "surrounding catchment" of all setting types refers to the entire wetland catchment but excluding the wetland area itself (see Fig. C1).

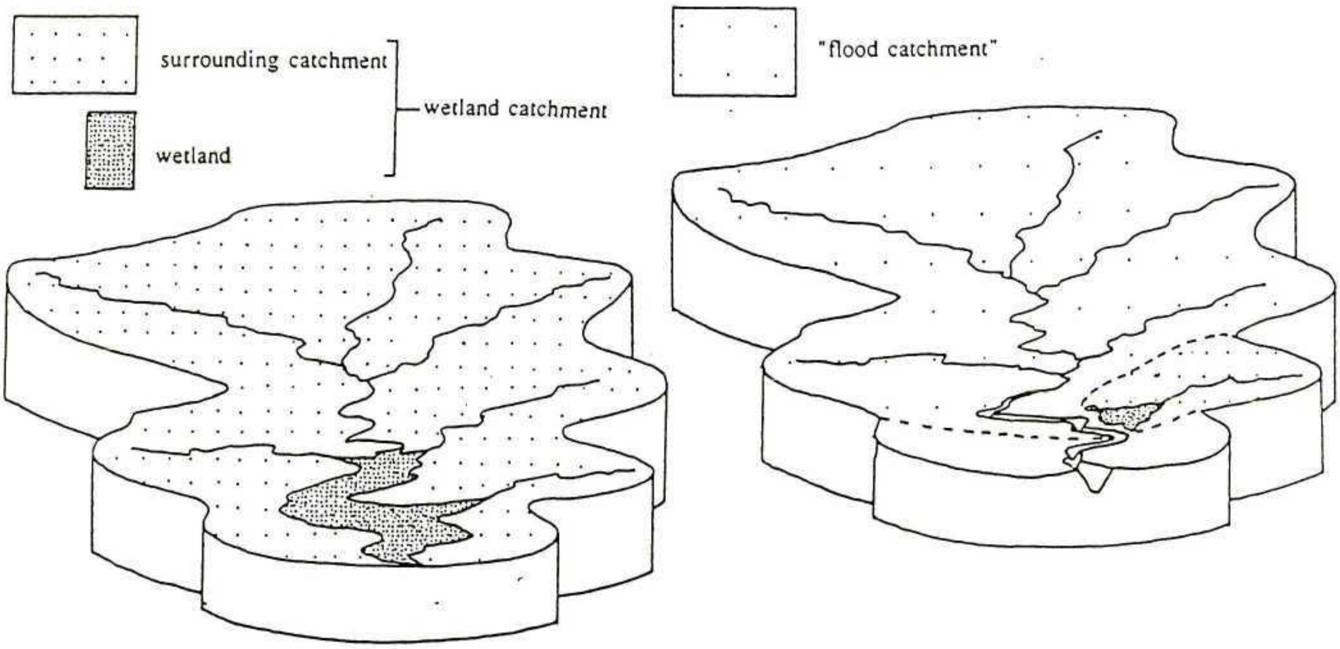


Fig. C1 Diagrammatic representation of the wetland catchment

Attempt to give the following information relating to the wetland catchment.

C1. Bioclimatic Group/s (according to Phillips, 1973) in order of decreasing contribution to the total catchment area ....

C2. Veld type/s (according to Acocks, 1953) in order of decreasing contribution ....

C3. Surface area of the wetland catchment (ha) ....

C4. Percentage of the wetland catchment occupied by the wetland ....

C5. Percentage of the "flood catchment" occupied by the wetland (for channelled flat sites only) ....

C6. Mean annual runoff generated by the catchment ....

Note: if measuring weir data are unavailable, the runoff generated by a wetland's catchment may be approximated very roughly using mean annual runoff data which have been estimated for quaternary catchments (e.g. Pitman et al., 1988). If, for example, a wetland's catchment occupies 40% of a quaternary catchment which has an estimated mean annual runoff of 54 x 10^6 then the estimated mean annual runoff from the *wetland's catchment would be:* $54 \times 10^6 \times 0.4 = 22 \times 10^6$. *If a greater level of accuracy is required for runoff estimation, predictive models which require inputs concerning the nature of the catchment (e.g. ACRU: Schulze et al., 1989) may be used. However, runoff estimation using such techniques will obviously involve considerably more time and expertise.*

C7. Current use of the surrounding catchment. Depending on the time and resources available:

i) indicate (with a Y on Table C1) which land-uses occur in the surrounding catchment; and

ii) estimate the approximate area under each land-use and record this on Table C1.

Table C1 Current land-uses in the surrounding catchment

	i)	ii) area (ha)
1. conservation	.....	......
2. livestock grazing of natural vegetation	.....	......
3. natural vegetation mowing	.....	......
4. planted pastures	.....	......
5. crops	.....	......
6. urban	.....	......
7. industrial	.....	......
8. mining	.....	......
9. other:	.....	......
10.	.....	......

C8. Indicate the total number of dams in the surrounding catchment ....

C9. Indicate the total area (ha) occupied by dams in the surrounding catchment ......

C10# Depending on the data availability, indicate according to season (a-f) the approximate percentage area of the catchment which is irrigated:

1. Spring ..... 2. Summer .... 3. Autumn ..... 4. Winter ......
5. Total for the year ......

a. <0.5% b. 0.5-2.9% c. 3-8% d. 9-20% e. 21-50% f. >50%

C11 Based on the extent of land-uses in the catchment that reduce runoff (i.e. damming, irrigation and afforestation (see Descriptors C7 to C10) subjectively rate the extent to which the natural runoff is being reduced (a-d). If a greater level of accuracy is required see Schulze *et al.* (1984).

a. negligible b. moderate c. large d. very large

C12. If water quality data are available, give details below and indicate the level of nutrient/toxicant and sediment input for C13 and C14, based on these data. Nutrient/toxicant data should preferably be measured during low flow periods and sediments during high flow periods.

....
....
....

Note 1 concerning C13 and C14: if there are no water quality data, the level of nutrient/toxicant and sediment input into the wetland should be estimated based on observations of land-uses in the catchment (see C7).

Note 2 concerning C13 and C14: a given pollution source in the wetland catchment is more likely to contribute pollutants to the wetland if it is close by than far away, particularly if it is in a drainage line. In order to account for this on a very simplified level, the primary and secondary input zones are defined. The primary input zone is taken as that defined by Adamus et al. (1987) as the area extending 100m upslope of the wetland/non-wetland boundary and including a 100 m wide corridor on either side of all tributaries that enter the wetland, extending a distance of 30 m up the tributaries for each 2.5 m of the tributary channel width at its entry point to the wetland. The secondary input zone includes the rest of the catchment. Pollutant sources in the secondary catchment are less likely to affect the wetland because of the greater distance that pollutants have to travel, thereby increasing the buffering effect of the surrounding catchment. Thus, when considering pollutant sources for Descriptors C13 and C14, consideration should be given to whether they are in the secondary or the primary input zone.

C13. Indicate (a-c) the likely level of sediment input into the wetland. Sources contributing sediments in the wetland catchment include: stormwater outfalls, irrigation return waters, surface mines or areas (>0.5 ha) containing exposed soils associated with agriculture, gullies (dongas) or severely eroding stream or road banks. ......

a. negligible/low b. intermediate c. high

C14. Indicate (a-c) the likely level of nutrient/toxicant input into the wetland. Non-point sources in the wetland catchment that may contribute pollutants include areas (>0.5ha) of fertilized crop or pasture land; areas (>0.5 ha) where the density of houses with septic tank systems exceeds 6 houses per ha; mines; pesticide treated areas; oil runoff sites. Point sources in the wetland catchment that may contribute pollutants include sewage or industrial outfalls or feedlots. As a very general rule, assuming compliance with wastewater discharge standards:

a. if wastewater input contributes <5% of the streamflow into the wetland then point source input is likely to be low;

b. if wastewater input contributes 5-20% of the streamflow into the wetland then input is likely to be intermediate; and

c. if wastewater input contributes >20% of the streamflow into the wetland then input is likely to be high.

However, if standards are not met, nutrient inputs may be high even though wastewater inputs contribute <10% of the streamflow.

<u>C15</u>. Based on the descriptor values for C13 and C14, indicate whether the combined sediment and nutrient/toxicant input is likely to be low (a), intermediate (b), or high (c). ....

IF: C13=c or C14=c or (C13=b and C14=b) or A50=Y or A51=Y
THEN: C15=c

ELSIF: (C13=b and C14=a) or (C13=a and C14=b)
THEN: C15=b

ELSIF: C13=a and C14=a
THEN: C15=a

2.1D DOWNST-INFO (Information concerning the current potential downstream significance of th wetland)

Service values are functional values which have a well-defined off-site delivery area, referred to as the servic area (Adamus *et al.*, 1987). Service values include water purification and flood attenuation. Baseflo augmentation is also a service value but is considered with water purification because water users derivin benefit from water purification are also likely to derive benefit from this function. Ability of a wetland t influence water quality and attenuate floods diminishes with increasing distance downstream of the wetlan outlet, particularly for flood attenuation. Thus, the following guidelines, adapted from the U.S. Army Corp of Engineers (1988) and Adamus *et al.* (1987), have been adopted.

If the wetland catchment is <5000 ha then:

* the service area for water quality influence is taken as ending 20 km downstream of the wetland; an
* the service area for flood attenuation is taken as ending 8 km downstream of the wetland.

If the wetland catchment is >5000 ha then:

* the service area for water quality ends 40 km downstream of the wetland; and
* the service area for flood attenuation ends 16 km downstream of the wetland.

Loss of a given wetland's water purification value would result in downstream wetlands having to contend wit increased pollutant loads. If the catchment were intensively used and pollutant loads were already high, thi may significantly lower the efficiency of downstream wetlands. Thus, although no current beneficiaries ma be present in the downstream service area, the effectiveness of other wetlands present in the service area woul be improved. The wetland would be of indirect value to potential beneficiaries in the service areas of othe wetlands lower in the catchment. Consequently, the effective downstream distance of influence would b greater than had cumulative effects not been accounted for. In addition, some nutrients and fine sediments ar likely to be carried further than 20 km, particularly if input levels are high. However, from an assessmer point of view it becomes increasingly impractical to assess downstream influence as downstream distanc increases and, for the purposes of assessment, a practicable cut-off has been chosen. It should be emphasise that there are several interacting factors determining the wetland's distance of influence, including the size c the wetland and the influence of tributaries entering downstream. These are considered to be beyond the scop of this system.

D1. Using the above guidelines, indicate the water purification service distance. ....

D2. Using the above guidelines, indicate the flood attenuation service distance. ....

Note concerning D3 to D10: if time and resources are very limited, the downstream significance of wat purification and flood attenuation may be estimated superficially by answering questions D3 and D Otherwise, they should be estimated using comprehensive data collected by answering questions D5 to D9.

D3. On the basis of the present level of water use by people in the wetland's water quality service are indicate (a-d) the current significance that the wetland would have if it was effectively purifying wate Refer to D5, D6 and D7 as a reference against which the rating should be made. ....

a. nil b. low c. moderate d. high

D4. On the basis of abundance of floodable property in the wetland's flood attenuation service area, indica (a-d) the significance that the wetland would have if it were attenuating floods effectively. Refer to D

D10 as references against which the rating should be made. ....

a. nil b. low c. moderate d. high

D5. In the water purification service area, rate (0-3) the current importance of the stream for:

1. Potable water users, which includes individuals (in most cases poor rural people) who extract water directly by hand for daily domestic use. ......

0= Nil users 1= 1-3 users/km 2= 4-50 users/km 3= >50 users/km

2. Piped water users, which includes individuals (predominantly urban dwellers) and commerce and industry who purchase piped water extracted from an impoundment for domestic and industrial use. ....

0= No extraction
1= 1-10 million m^3 extracted annually
2= 11-100 million m^3 extracted annually
3= >100 million m^3 extracted annually

3. Recreationists who use the water on site for fishing, bathing and/or water sports (expressed on a per km per month basis) ....

0= No users 1= 1-3 users 2= 4-10 users 3= >10 users

4. Stock farmers (both subsistence and commercial) that require water for stock watering. ....

0= No stock watering
1= 1-10 **animal units** (AU's) watered per km
2= 11-30 AU's per km
3= >30 AU's per km

5. Crop/pasture farmers (in most cases commercial farmers) who extract water themselves (usually free of charge) for irrigation purposes. .....

0= No extraction
1= 1-30 ha of land irrigated per km
2= 31-200 ha of land irrigated per km
3= >500 ha of land irrigated per km

and 6# rate the sensitivity of the downstream biota to increased levels of pollutants. .....

0= low 1= intermediate 2= high 3= very high

Note: It is difficult to predict the effect of water quality change on stream biota without undertaking a thorough investigation, which is clearly beyond the scope of WETLAND-USE. Biological systems are, however, considered valid users of water. Thus, a descriptor has been included to superficially account for this, and if adequate information is available, it may be included in the final score.

D6. Calculate the total current water use score (D6) .... using the following formula: D6= D5.1 + D5.2 + D5.3 + D5.4 + D5.5 + D5.6

D7. Now determine the total current significance of water purification in the downstream area of influence

(D7) ..... using the following rules:

if D6= 0 then significance = nil (a)

elseif (otherwise if) D6 <or=4 and >0 then significance = low (b)

elseif D6 <or=8 and >4 then significance = moderate (c)

elseif D5.1 >1 or D6 >8 then significance = high (d)

Downstream flood damage potential:

The benefit derived from flood reduction in a floodable zone below a wetland would obviously increase with increasing abundance of floodable property. In WETLAND-USE, floodable property is expressed in terms of Floodable Units (FU's), where 1 FU is equivalent to 1 house or 20 ha of cropland. Other features of biological, social or economic value should be subjectively allocated FU scores. A riverine forest, for example while possibly requiring some measure of flooding, may be negatively affected by a marked increase in flood peaks that could result from wetland destruction.

In order to account for the diminishing flood attenuation influence, divide the service distance into 4 reaches (each 2 km if the wetland catchment is <50 km^2 and each 4 km if the catchment is >50 km^2).

D8. To the end of reach 4, determine the current abundance of FU's occurring within the 1 in 50 year flood line for each reach, and using Table D1 then determine the score for each reach.

Note: in most cases the 1: 50 year flood line has not been mapped and will have to be estimated from a site visit, historical records and/or hydrological modelling.

Table D1 Downstream flood damage scores

	0 FU	1-10 FU	10-30 FU	>30 FU	
REACH 1	0	4	8	16	a. ....
REACH 2	0	3	6	12	b. ....
REACH 3	0	2	4	6	c. ....
REACH 4	0	1	2	3	d. ....

D9. **Calculate the total score (D8), where:**
D9= D8a + D8b + D8c + D8d TOTAL (D8) .....

<u>D10</u>. Now determine the total current significance of flood reduction in the downstream area of influence ....

TOTAL SCORE (D8)	0	1-10	11-19	>20
CURRENT SIGNIFICANCE	Nil	Low	Intermediate	High

2.1E IMPACTSITE-INFO (Information concerning the impact area and proposed land-use)

Requirements:

* As for WETSITE-INFO but Soil Classification: a taxonomic system for South Africa (Soil Classification Working Group, 1991) is also required.

Note: If the impact area includes more than one agro-ecological zone type, the assessment should be carried out separately for each zone.

E1. Indicate on the wetland map, the area to which the proposed land-use will be applied and indicate (a-f) which of the following land-uses is being considered? ....

a. natural vegetation for wildlife and/or fire breaks
b. natural vegetation for stock grazing
c. mowing
d. planted pastures
e. crops
f. dams

IF: E1=a
THEN: answer questions E6 to E9 and then proceed to Section 2.3B

ELSEIF: E1=b
(Otherwise if:)
THEN: answer questions E6 to E18 and then proceed to Section 2.2C

ELSEIF: E1=c
THEN: answer questions E6 to E18 and then proceed to Section 2.2D

ELSEIF: E1=d
THEN: answer questions E2 and E6 to E40 and then proceed to Section 2.2B.

ELSEIF: E1=e
THEN: answer questions E3 and E6 to E40 and then proceed to Section 2.2A.

ELSEIF: E1=f
THEN: answer questions E4 to E40 and then proceed to 2.2E.

E2 Indicate the intended pasture type ....

E3. Indicate the intended crop type ....

E4. Indicate (Y or N) if an outflow control is intended for inclusion in the dam wall ....

E5. Indicate (a-e) the intended use/s of the dam ....

a. irrigation b. waterfowl hunting c. stock watering d. watersports e. fishing

E6. Indicate which of the land ownership types given in A49 occur in the impact area (1-4). ....

E7. Determine the surface area of the impact area (ha). ......

E8. Calculate the percentage of the wetland occupied by the impact area. ....

E9. Indicate (a-f) which landform setting (described in Section 1.2) best describes that of the impact area
....

a. Flat	b. Depression	c. Channel
d. Slope	e. Channelled flat	f. Channel disrupting flat

E10. Estimate the slope of the proposed area. ....

E11. Using *Soil Classification* (Soil Classification Working Group, 1991) determine:

(1) the soil form ....

(2) the soil family ....

E12. Estimate (using Table E1) and indicate (0.5-0.15) the erosion hazard (i.e. the K value) of the soil ......

very high: 0.5	moderate: 0.3	very low: 0.15
high: 0.4	low: 0.2	

If soil erodibility values are not available then the following very general assumption can be made:

	K value
Humid to sub-humid (Bioclimatic Groups 1-6):	0.3
Mild sub-arid (semi-arid) to arid (Bioclim. Groups 7, 8, 9, 10, 11):	0.5

Note: The assumption concerning Bioclimatic Groups is based on the observation that wetland soils in humid to sub-humid regions tend to have a lower susceptibility to erosion than those in mild sub-arid to arid regions. This is borne out by the fact that erosional degradation of wetlands has been considerably higher in the latter regions than in the former.

E13. Determine and indicate the erosion hazard index (EH) for the site ....

EH = K x S x F where EH = Erosion hazard index
K = Soil erodability (Descriptor E12)
S = Slope factor (Descriptor E10)
F = Landform setting factor (Descriptor E9)

Note: bracketed descriptors refer to those descriptors used for deriving the factor.

Table E1 Hydrologic information for soil forms and series common to the wetlands of KwaZulu/Natal (adapted from Schulze *et al.*, 1989)

Soil Form	Code	Soil Series	Typical Textural Class	Interflow Potential	Erosion Hazard Rating
CHAMPAGNE	Ch 11	Champagne	SLm	0	High
D	Ch 21	Ivanhoe	SClLm	0	High
	Ch 10	Mposa	SLm	0	High
	Ch 20	Stratford	SClLm	0	High
KATSPRUIT	Ka 10	Katspruit	SCl	0	Mod
C/D	Ka 20	Killarney	SCl	0	High
RENSBURG	Rg 10	Phoenix	Cl	X	High
D	Rg 20	Rensburg	Cl	X	High
WILLOW-BROOK	Wo 21	Chinyika	SCl	0	High
	Wo 10	Emfuleni	SClLm	0	High
D	Wo 20	Sarasdale	SClLm	0	High
	Wo 11	Willowbrook	SCl	0	Mod
ESTCOURT	Es 20	Assegaai	LmS/SClLm	XX	V.High
D	Es 11	Auckland	LmS/SLm	XX	V.High
	Es 22	Avontuur	S/SClLm	XX	V.High
	Es 35	Balfour	LmS/SClLm	XX	V.High
	Es 40	Beerlaagte	LmS/SClLm	XX	V.High
	Es 37	Buffelsdrif	SCl/Cl	XX	High
	Es 42	Darling	S/SClLm	XX	V.High
	Es 13	Dohne	SLm/SClLm	XX	V.High
	Es 31	Elim	LmS/SLm	XX	V.High
	Es 33	Enkeldoorn	SLm/SClLm	XX	V.High
	Es 36	Estcourt	SClLm/SCl	XX	High
	Es 14	Grasslands	SLm/SClLm	XX	V.High
	Es 41	Heights	LmS/SClLm	XX	V.High
	Es 10	Houdenbeck	LmS/SLm	XX	V.High
	Es 21	Langkloof	LmS/SClLm	XX	V.High
	Es 30	Mozi	LmS/SLm	XX	V.High
	Es 12	Potela	S/SLm	XX	V.High
	Es 16	Rosemead	SClLm/SCl	XX	High
	Es 32	Soldaatskraal	S/SLm	XX	V.High
	Es 34	Uitvlugt	SLm/SClLm	XX	V.High
	Es 15	Vredenhoek	LmS/SClLm	XX	V.High
	Es 17	Zintwala	SCl/Cl	XX	High
KROONSTAD	Kd 17	Avoca	SClLm/SCl	XX	High
C/D	Kd 16	Bluebank	SClLm/SCl	XX	High
	Kd 22	Katarra	S/SClLm	XX	V.High
	Kd 20	Koppies	LmS/SClLm	XX	V.High
	Kd 13	Kroonstad	SLm/SClLm	XX	V.High
	Kd 14	Mkambati	SLm/SClLm	XX	V.High
	Kd 10	Rocklands	LmS/SLm	XX	V.High
	Kd 15	Slangkop	LmS/SClLm	XX	V.High
	Kd 12	Swellengift	S/SLm	XX	V.High
	Kd 18	Uitspan	SClLm/SCl	XX	V.High
	Kd 21	Umtentweni	LmS/SClLm	XX	High
	Kd 11	Veldrif	LmS/SLm	XX	V.High
	Kd 19	Volksrust	SCl/Cl	XX	Mod
LONGLANDS	Lo 22	Albany	SClLm	XX	Mod
C	Lo 32	Chitsa	SClLm	XX	Mod
	Lo 21	Longlands	SLm	XX	High
	Lo 10	Orkney	LmS	XX	High
	Lo 30	Tayside	S	XX	High
	Lo 31	Vaalsand	SLm	XX	High
	Lo 20	Vasi	LmS	XX	High
	Lo 11	Waaisand	SLm	XX	High
	Lo 12	Waldene	SClLm	XX	High
	Lo 13	Winterton	SCl	XX	Low
WESTLEIGH	We 10	Chinde	LmS	X	High
	We 32	Davel	SClLm	X	Mod
	We 22	Devon	SClLm	X	Mod
	We 20	Kosi	LmS	X	High
	We 30	Langkuil	S	X	High
	We 31	Paddock	SLm	X	High
	We 12	Rietvlei	SClLm	X	Mod
	We 13	Sibasa	SCl	X	Low
	We 11	Westleigh	SLm	X	High
	We 21	Witsand	SLm	X	High

Legend

A - low runoff potential
B - moderately low potential
C - moderately high potential
D - high runoff potential

0 - no/low interflow potential
X - some interflow potential
XX - high interflow potential

l - leaching
t - texture
w - water table
c - crusting

Cl - clay
S - sand
Lm - loam

Slope	S value	Slope	S value
<0.2%	1	3.1-10.0%	2.8
0.2-0.9%	1.6	10.0-20.0%	3.2
1.0-3.0%	2.2	>20%	3.6

If the landform setting is a channel or includes the channelled portion of a channelled flat or channel disrupting flat then F=2, and if it is a depression then F=0.75, otherwise F=1. If the channel is abandoned (i.e. it no longer acts as the streamcourse) then F=1.

An example of a wetland site with an extremely high erosion hazard is one with an Estcourt form, in a channel setting with a slope of 24%, where:

$$EH = 0.5 \times 3.6 \times 2 = 3.6$$

An example of a wetland site with a low erosion hazard is one with a Katspruit form, Lammersmoor family, on a flat setting with a slope of 0.1%, where:

$$EH = 0.3 \times 1 \times 1 = 0.3$$

E14. Using Fig. 1.1 and Table 1.1 (Section 1.2) determine the agro-ecological zone based on soil morphology. ....

a. open water/marsh: permanently wet (waterlogged) soil
b. wet meadow: seasonally wet soil
c. wet grassland: temporarily wet soil
d. wet grassland/non-wetland mosaic: temporarily wet/non-wetland soil

E15. Estimate the *n* value by squeezing a handful of soil. Observe how easily it flows between the fingers and indicate this .... (a-c). The soil should be taken at 10 cm below the surface and the test should preferably be conducted during the wet season and not in a drought year.

a. very high (flows easily) b. high (flows with difficulty) c. intermediate or low (does not flow)

Note: the n value refers to the relationship between the percentage of water under field conditions and the percentages of clay and humus. It is helpful in predicting the degree of subsidence that will occur after drainage and whether the soil may be grazed by livestock or will support other loads (Pons and Zonneveld, 1965; Soil Survey Staff, 1992).

E16. Indicate ..... (Y or N) if any Red Data species (Descriptors A25 and A26) occur in the impact area, and which species they are. ....

E17. Indicate ...... (Y or N) if the impact area includes any threatened or regionally scarce wetland habitat type/s recorded for the wetland (Descriptor A29) and which species they are. ....

<u>E18.</u> Indicate (Y or N) if the cumulative loss of wetlands is less than 60% (i.e. Descriptors B4, B5 or B6 do not have the value d). .....

E19. Indicate (Y or N) if the water use is nil or low in the downstream service area (i.e. Descriptors D3 or D7 have the values a or b) .....

E20. Indicate (Y or N) if the pollutant (nutrient/toxicant and sediment) input is low or absent (i.e. C13, C14, C20 or C24 do not have the values c or d and A50 and A51 both have the value N). ....

E21. Indicate (Y or N) if the wetland is in a catchment where further damming is considered undesirable and which has been designated as an area where no further dam permits will be issued by The Department of Water Affairs. ......

E22 Indicate (a-e) the extent to which the water table will need to be lowered. ......

a: 0 cm b: 1-10cm c: 11-20 cm d: 21-40 cm f: >40 cm

E23. Indicate the severity of erosion within the impact area (a-d) (see A39 Note concerning levels of severity). ......

E24 Indicate the percentage of the impact area that is eroded ....

E25. Indicate the percentage of the impact area that is already developed (i.e. planted to crops or pastures or dammed) ....

E26. Indicate (a-c) the roughness coefficient of the impact area ('N' is Manning's roughness coefficient). .....

a. Tall, dense emergent vegetation (e.g. reed marsh): N= 0.08
b. Moderately dense/tall emergent vegetation: N= 0.06
c. Short and sparse emergent vegetation: N= 0.04

E27. Estimate the soil texture class (1-11). If time is limited, the typical textural class taken from Table E1 may be used, otherwise a finger assessment may be conducted in the field (Figure E1) or a particle size analysis conducted in the laboratory. It is important to note that a high organic carbon content (ca>10% organic carbon) generally renders a finger assessment unreliable. ....

1. Clay
2. Loam
3. Sand
4. Loamy sand
5. Sandy loam
6. Silty loam
7. Sandy clay loam
8. Clay loam
9. Silty clay loam
10. Sandy clay
11. Silty clay

E28# Estimate the runoff potential (A, B, C, or D) from Table E1 and indicate this. ....

Manipulate about a heaped teaspoonful of soil with sufficient water to a state of maximum stickiness and plasticity, working out all the lumps before applying these tests.

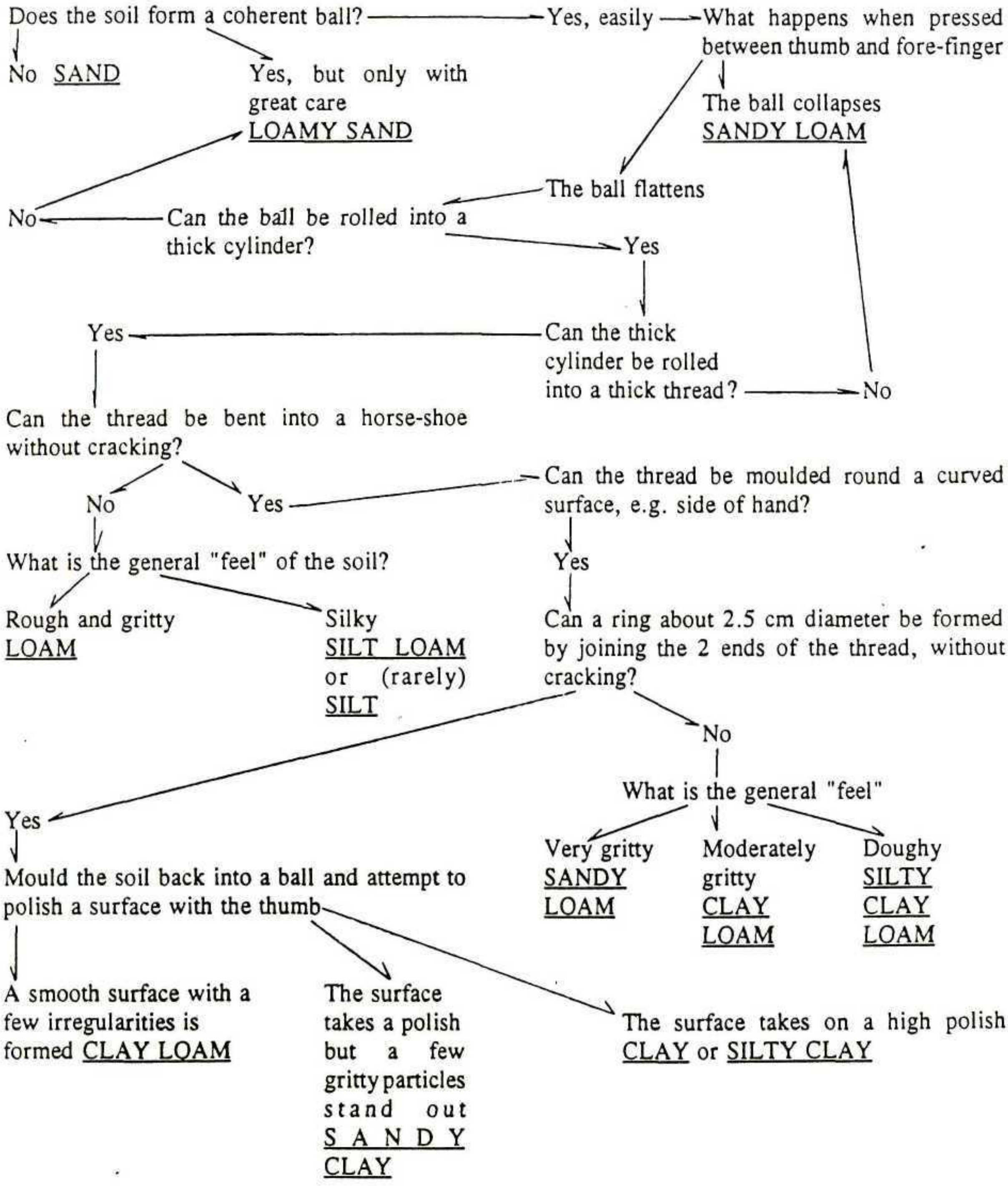


Fig. E1 Finger assessment of soil texture (from Soil Science Practical Course, Soil Science Department, Reading University).

Note concerning E29 to E40:

Descriptors E29 to E40 are required to determine whether the development orientated land-uses meet the secondary acceptance criteria. Indicate (with a 1, 2 or 3) the level of Descriptors E29 to E40 (Descriptors E35 and E36 apply to damming only). Descriptors E37 to E40 deal with socio-economic factors. These are highly complex and require a high level of subjectivity in their assessment. Even if the user is unable to make an assessment of these descriptors, it is important that he/she recognizes that they may be important considerations.

E29. Area of wetland to be developed. ....

1: small (<0.1 ha) 2: intermediate (0.1-1 ha) 3: large (>1 ha)

Note: Development refers to crop production, pasture production and damming. See Descriptor E7 giving the size of the impact area.

E30. Level to which the impact area is already developed and/or degraded due to drainage, erosion or flow concentration by a road. .....

1: high ([E24 + E25] > 60% of the impact area)

2: intermediate ([E24 + E25] = 20-60% of the impact area)

3: low ([E24 + E25] < 20% of the impact area)

Note: the loss to society that would occur with development of a wetland which has already lost its ecological integrity is obviously less than that which would otherwise occur if the wetland's integrity had been maintained. This has not been included as a primary criterion because wetlands can be rehabilitated, the expense of the operation depending on the degree to which the wetland has been eroded or developed.

E31. Availability of alternative sites with less important habitat (i.e. habitat which is less threatened, regionally scarce or rare). ....

1: low 2: intermediate 3: high

Note: this information will often be unavailable, in which case it is important that the Natal Parks Board be consulted for expert opinion.

E32. Importance for wetland-dependent birds (especially migratory, nomadic or breeding birds). ....

1: unimportant 2: moderately important 3: important

Note: if the impact area does not affect any areas used by migratory, nomadic or breeding birds then ignor this question.

E33. The cumulative loss of wetlands in the surrounding landscape (B4, B5 or B6). .....

1: < 10% 2: 11-40% 3: >40% *Note: see Descriptors B4-B6.*

E34. Roughness coefficient of the impact area. .....

1: N= 0.04 2: N= 0.06 3: N= 0.08 *Note: see Descriptor E26.*

E35. Extent to which the proposed area to be flooded by a dam will have shallows. ....

1: extensive 2: moderate 3: limited

Note: shallows refer to areas with water <1.5 m deep when the dam is full. From a habitat provisio perspective, shallows are desirable. However, for water storage, shallow water is undesirable because for a given volume of water, evaporative loss increases with decreasing depth. Thus, if the provision of water fron the wetland's catchment is considered particularly important then this criterion may be ignored.

E36. Importance of the wetland for movement of aquatic species. .....

1: unimportant 2: moderately important 3: important

Note: if an adequate "fish ladder" or a gently sloped spillway allowing movement of aquatic species is provided this criterion may be ignored.

E37. The wetland user's need for the development. ....

1: large 2: intermediate 3: small

Note: assessment of a wetland user's personal need for development requires a high level of subjectivity. A a guideline, consideration should be given to financial state. Take potential user A, who requires to develop the wetland portion of his/her farm in order to maintain the farm as a viable economic unit. In contrast potential user B, whose farm is already a viable unit, need not do this (i.e. user B's need is less).

E38. Existence of an alternative (to development) for the potential user. ......

1: large 2: intermediate 3: small

Note: as for the above Descriptor, this is subjective. As a guideline, consider the example of potential users X and Y who, both needing to fill critical gaps in the fodder flows of their farms, may either develop the wetland portions of their farms or purchase feed. Potential user X is a great distance from any reasonably priced feedsource, making the purchasing option prohibitively expensive due to the high transport costs. In contrast, user Y is close to a reasonably priced feed-source and has less need to develop the wetland.

E39. Indicate the contribution that the development will make to society, particularly to the poor. ....

1: large 2: intermediate 3: small

Note: this is even more difficult to assess than the above two Descriptors. Such factors as the provision of jobs and access to resources must be considered.

E40. Indicate the level of direct benefit (e.g. reed harvesting) that is being derived from the impact area in its natural state.

1: small 2: intermediate 3: large

Note: refer to Descriptors A45 and A46.

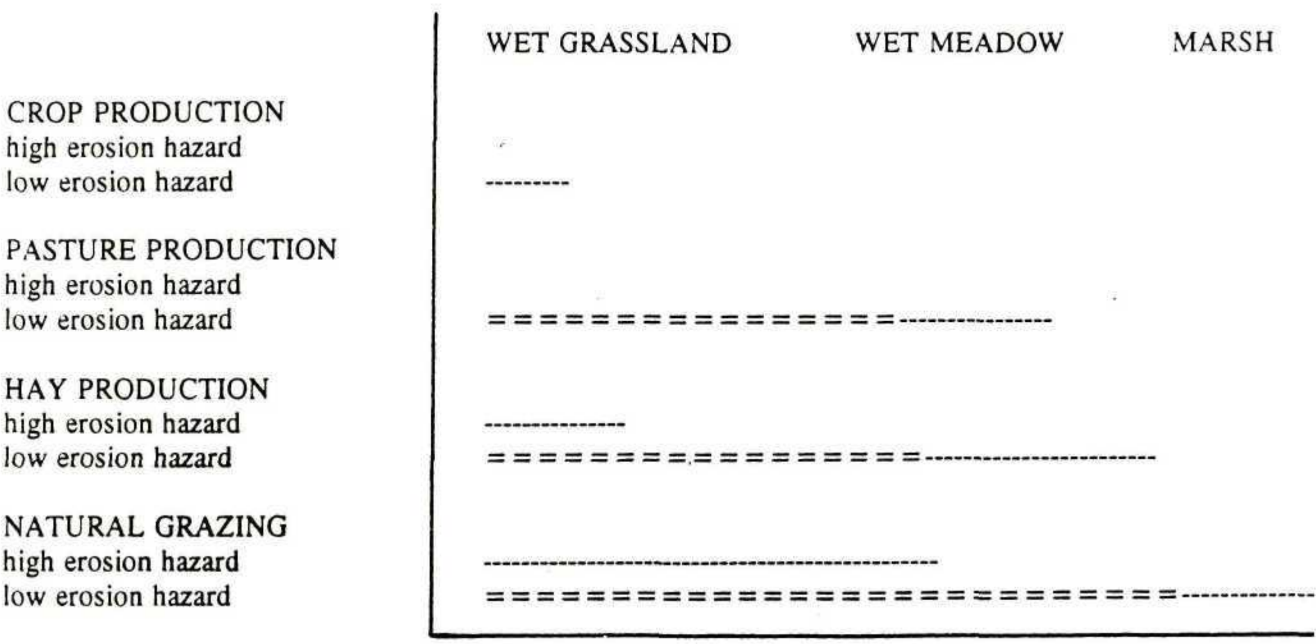
2.2 ENVIRONMENT-ASSESS: PREDICTED IMPACT OF THE CHOSEN LAND-USES

The impact on functional values caused by various land-uses included in WETLAND-USE differs. For this reason, the acceptability of the various land-uses according to agro-ecological zones has been summarized (Fig. E2). Further factors such as Red Data species and downstream water use must also be considered in determining acceptability. Thus, when a land-use is being considered, these factors should be accounted for by proceeding to the specific land-use sections (given below) which deal with the primary acceptance criteria.

a. Crop and annual pasture production: Go to 2.2A
b. Perennial pasture production: Go to 2.2B
c. Natural grazing by domestic stock: Go to 2.2C
d. Hay production: Go to 2.2D
e. Damming: Go to 2.2E

Burning is not a land-use *per se* and is dealt with in Section 2.3B

Note: annual pastures are considered together with crops because, although providing better cover once established, they involve considerably more frequent disturbance of the soil than do perennial pastures. In addition, commonly grown annual pastures tend to have lower wetness tolerances than the commonly grown perennial pasture species: Festuca arundinacea (see Section 2.3C).



KEY:

=== The land-use is acceptable provided that the other conditions (e.g. those pertaining to Red Data species) are met and the guidelines given in Section 2.3 are followed.

------- The land-use is acceptable provided that the other conditions are met and the guidelines given in Section 2.3 are followed, but particularly stringent restrictions apply.

Fig. E2 The acceptability of different land-uses according to agro-ecological zone and the erosion hazard of the wetland site.

2.2A CROP-ASSESS (CROP PRODUCTION RULE)

RULE A

IF: 1) the impact area comprises a mosaic of wet grassland interspersed with patches of non-wetland;

and 2) the erosion hazard index of the impact area is < 1.0 and the severity of existing erosion is low;

and 3) the water table owering requirement is < 10 cm;

and 4) no rare or endangered species have been known to occur at or near the proposed site;

and 5) the wetland is not known to be of a type or include habitat type/s which are threatened or which are regionally scarce or rare;

and 6) the soil *n* value is intermediate or low;

and 7) the cumulative loss of wetlands in the surrounding landscape is <60%;

and 8) water use is nil or low in the downstream service area;

and 9) pollutant (i.e. nutrient/toxicant and sediment) input is low or absent;

THEN: the primary acceptance criteria for cropping are met. Check whether the secondary acceptance criteria are met (Section 2.2F, p56).

ELSEIF: any of the conditions 1-8 are not met:

THEN: cropping is unacceptable, unless mitigation measures are implemented which will compensate entirely for the effects of the proposed land-use. For example, extra soil conservation measures may be used on a site that has an erosion hazard which would otherwise be considered too high for development. The loss of important habitat at the impact site may be mitigated by restoring an equivalent area of wetland in the surrounding landscape. If mitigation measures are being considered then refer to the secondary acceptance criteria descriptors (E29 to E40) to determine what further effects need to be accounted for.

Note: mitigation measures should not be seen as a "loop-hole" but rather as means of accounting for those instances where a potential wetland user is genuinely able to mitigate the effects of the proposed land-use such that the threshold conditions given in the rule are not violated. This will obviously require expert advice and need to be followed up by regular monitoring.

Reasoning:

* Because of the potentially severe impact of crop production, this land-use is considered acceptable only in wetland areas which are transitional between wetland and non-wetland (i.e. a mosaic of wet grassland

and non-wetland). In areas wetter than this, the hydrology would have to be altered significantl detracting from the hydrological and ecological values of the wetland area. Besides freque disturbance of the soil, crop production also involves the application of fertilizer, further detracti from the hydrological value. In addition, crop plants are less perennial and, in many cases, have lower surface roughness than wetland vegetation. As such, the hydrological value may be lowere significantly when converting wetland to cropland.

* Crop production is not considered acceptable on sites which have intermediate, high or very hig erosion hazards because it requires that the soil surface be frequently disturbed, detracting from th erosion control and hydrological values of the wetland.

* If any important wetland dependent species occur in, or adjacent to, the proposed site, draining ar producing crops in the area is likely to alter the habitat completely rendering it no longer suitable f these species.

* If the wetland is of a type or includes habitat type/s which are threatened or regionally scarce or rar the loss would obviously be greater than if this were not so. Conservation of biotic diversi encompasses more than species conservation: other considerations such as the maintenance of biologic integrity are involved (see Glossary).

* Drainage, followed by the regular application of fertilizers, detracts from the water purification valu of wetlands. If water is being used for human consumption in the downstream area, the conversio of the wetland to cropland could potentially detract from this benefit.

* Should the wetland be disturbed and its hydrology altered, this may cause the accelerated release o pollutants already trapped in the wetland sediments, and may detract from the wetland's future wat purification potential.

* If the n value is high then the likelihood of soil subsidence occurring following drainage is high.

* If wetland areas have already been lost adjacent to the impact site or in the surrounding landscape, th proposed loss is likely to have a greater impact than if no loss had already occurred.

2.2B PASTURE-ASSESS (PLANTED PASTURES RULE)

RULE B

IF: 1) the proposed area is in a wet meadow zone;

and 2) the area is non-hummocked and the water table lowering requirement is < 20 cm, or the area hummocked and the water table lowering requirement is < 10 cm;

and 3) the erosion hazard of the site is < 1.5

and 4) conditions 4-9 in the CROP-ASSESS Rule are met;

OR: 5) the proposed area is in a wet grassland;

and 6) the water table lowering requirement is <20cm;

and 7) the erosion hazard index of the impact area is <2.0;

and 8) conditions 4-9 in the CROP-ASSESS Rule are met;

THEN: the primary acceptance criteria for pasture production are met. Check whether the secondary acceptance criteria are met (2.2F).

ELSEIF: any of the conditions given in the above rule are not met

THEN: planted pastures is unacceptable, unless mitigation measures are implemented which will compensate entirely for the effects of the proposed land-use (see RULE A concerning mitigation). If mitigation measures are being considered then refer to the secondary acceptance criteria descriptors (E29 to E40) to determine what further effects need to be accounted for.

Reasoning:

* Converting wet meadow to planted pastures involves flattening of the area if any hummocks are present, thereby reducing surface roughness and lowering the hydrological value. Thus, more stringent water table lowering limits are set for hummocked than for non-hummocked wet meadow.

* see the reasoning applicable to the acceptability of crop production in wet grassland (Rule A).

* judiciously managed perennial pastures generally constitute less of an erosion hazard than does crop production. As such, the erosion hazard limitations are less stringent than for crop production.

2.2C NGRAZE-ASSESS (RULES FOR NATURAL GRAZING FOR DOMESTIC STOCK)

RULE C1

IF: 1) erosion of the impact area is severe or very severe;

OR: 2) the erosion hazard index of the site is >2.8;

THEN: stock grazing is unacceptable and should be excluded from these areas. Erosion contr structures may also need to be erected. Measures must be taken to curb erosion if the regic is sub-humid or semi-arid, as wetlands in these areas are prone to erosion. If the amount eroded area in the wetland has been increasing over the years then this adds to the urgency wi which rehabilitation should be undertaken.

ELSE: stock grazing is likely to be acceptable provided the guidelines given in Section 2.3A and 2.3B a followed and the grazing of marsh areas when wet is not intended. If the grazing of marsh areas und wet conditions is intended, proceed to Rule C2.

Note: incorrectly designed and/or positioned erosion control structures may cause further damage and a agricultural extension or soil conservation officer should be consulted. Users are also referred to the Renfreig Wetlands Campaign document: Assessment, Management and Rehabilitation of South African Wetlands (Wyat 1993).

Reasoning: Erosional degradation resulting from grazing stock mismanagement is a major source wetland loss, particularly in sub-humid and semi-arid regions, and should be taken into accoun

RULE C2

IF: moderate to heavy grazing pressure is to be applied to marsh areas in order to enhance the ecologic value by reducing reed density and height and/or increasing the extent of exposed liquid mud and sho vegetation patches;

THEN: 1) the chosen area should have a slope of <0.2% and be positioned as far away as possib (preferably >100 m) from the wetland outlet and channels within the wetland, so that th maximum area of wetland downstream will buffer the impact of reduction in the wat purification function of the wetland;

and 2) not more than 30% of the agro-ecological zone should be subject to this treatment in a giv year;

and 3) the chosen area should be routinely monitored;

and 4) a wetland specialist/hydrologist should be consulted.

Reasoning:

* It has been widely shown that the habitat value for certain species such as the Ethiopian Sni (*Gallinago nigripennis*) is improved by having cattle grazing on areas which would otherwise have ta emergent vegetation. However, if this occurs over a large proportion of the wetland, it would b

detrimental to those animals, such as flufftails, which require tall, dense emergent vegetation cover.

* Soils which have been subjected to poaching, as would occur when marsh areas are grazed when wet, become susceptible to sediment loss and possible erosional degradation. Thus, stringent limits are set concerning the slope and distance from channels of marsh areas to be grazed by cattle so as to safeguard the hydrological and erosion control values of the wetland. Nevertheless, even if these constraints are met, such use of wetlands may still constitute an erosion risk. Consultation with a wetland specialist/hydrologist and regular monitoring are advocated.

2.2D HAY-ASSESS (MOWING RULE)

RULE D1

IF: 1) no drainage channels are required;

and 2) the agro-ecological zone is not marsh;

and 3) no Red Data species are present which would be adversely affected by mowing;

and 4) the erosion hazard index of the impact area is not >2.0;

and 5) the soil *n* value is intermediate or low.

THEN: Mowing **may** be acceptable provided that the guidelines given in Section 2.3E are adhered to;

ELSEIF: Conditions 1 to 5 are not met;

THEN: the primary acceptance criteria are not met and mowing is unacceptable, unless cutting is by hand or mitigation measures are undertaken to compensate entirely for the effects of the proposed land-use (see Rule A concerning mitigation). If mitigation measures are being considered then refer to the secondary acceptance criteria (Descriptors E29-E40) to determine what further effects need to be taken into account.

Reasoning:

* Most marsh areas are inaccessible to farm machinery, even in dry years, but wet meadow areas may be accessible during drier periods in the wet season. In wet years, even wet grasslands are often inaccessible during the wet season.

* By removing cover, mowing may detract from the value of wetlands for providing habitat for wetland-dependent species requiring vegetation cover.

*	The cutting of hay by machinery constitutes an erosion risk. As such, it is not considered an acceptab land-use on sites with a high erosion hazard index.

RULE D2

IF:	1) drainage channels are required to improve accessibility for mowing;

and	2) all the conditions given for planted pastures (Section 2.2B, Rule B) are met;

THEN:	Mowing **may** be acceptable provided that the guidelines given in Section 2.3E are adhered t

ELSEIF:	Conditions 1 and 2 are not met;

THEN:	the primary acceptance criteria are not met and mowing is unacceptable, unless cutting is l hand or mitigation measures are undertaken to compensate entirely for the effects of t proposed land-use.

Reasoning: see 2.2B and 2.2D above.

2.2E. DAM-ASSESS (RULES FOR DAMMING WETLANDS)

RULE E

IF:	1) no Red Data species are present which would be adversely affected by damming;

and	2) the wetland is not known to be of a type or to include habitat type/s which are threatened or whi are regionally scarce or rare;

and	3) the cumulative loss of wetlands in the surrounding landscape is <60%;

and	4) pollutant input is not high (this is particularly important when downstream use is intermediate high);

and	5) the wetland is not in a catchment where further damming is considered undesirable and which h been designated as an area where no further dam permits will be issued by The Department of Wat Affairs. This is particularly important where extraction is planned from the dam and/or the dam is a semi-arid region, where evaporation is high;

THEN:	the dam satisfies the primary acceptance criteria. In order to determine whether it satisfies t secondary acceptance criteria proceed to 2.2F.

ELSEIF: any of the conditions 1-5 are not met;

THEN: the dam fails to meet the primary acceptance criteria and is unacceptable, unless mitigation measures are undertaken to compensate entirely for the effects of the proposed land-use (see Rule A concerning mitigation). If mitigation measures are being considered then refer to the secondary acceptance criteria (Descriptors E29-E40) to determine what further effects need to be taken into account.

Reasoning:

* Although a dam may improve the habitat provided by a wetland for certain common species such as the spur-winged goose (*Plectropterus gambensis*), the flooding of a wetland by a dam usually makes it unsuitable for specialized and threatened wetland-dependent species (e.g. the white-winged flufftail: *Sarothrura ayresi*).

* If the wetland is of a type or includes habitat type/s which are threatened or which are regionally scarce or rare then the loss would obviously be greater than if the wetland type was not scarce or rare. Conservation of biotic diversity encompass more than species conservation but also includes other considerations such as the maintenance of biological integrity.

* If wetland areas have already been lost from the surrounding landscape, the proposed loss is likely to have a greater impact than if this loss had not already occurred, when considered at a landscape level.

* Although dams perform many of the hydrological functions of wetlands (e.g. flood attenuation and sediment trapping), they are not as efficient in the removal of nutrients, particularly nitrogen. As such, the water quality constraints on dams, although accounting for situations where nutrient inputs are high, are not as stringent as for planted pastures and crops.

* Due to evaporation from dams, runoff is reduced in catchments which are dammed. This is particularly so in catchments where evaporation is high and which have a high percentage area occupied by dams. If users need to determine the extent to which runoff is likely to be decreased, they are referred to ACRU (Schulze *et al.*, 1989).

It is more difficult to set norms for dams than for the other land-uses because individual dams vary greatly with respect to:

1. depth;

2. nature of the outlet; and

3. shape and occurrence of features such as islands.

Furthermore, the use that is made of dams varies greatly, and includes: (1) irrigation (ranging from extractio of a small percentage of the stormflow to extraction of well in excess of the stormflow); (2) stock watering (3) fishing; (4) waterfowl hunting; and (5) watersports. As such, it is even more difficult to prescrib acceptance criteria than for the other land-uses, and many of the criteria considered in determining th acceptability of dams are included in 2.2F.

2.2F SECONDARY ACCEPTANCE CRITERIA

IF: most of the answers to the secondary criteria questions (i.e. E29-E40) were 1's then the land-use ma be acceptable provided that the guidelines for ongoing management outlined in Section 3 are adhere to.

ELSEIF: most of the answers to the secondary criteria questions were 2's and 3's then the land-use i unacceptable, unless mitigation measures are undertaken which will compensate entirely for th effects of the proposed land-use (including those effects revealed by both primary an secondary criteria questions).

Reasoning: see Notes for Descriptors E29-E40.

2.3 LAND USE-RECOMMEND: MANAGEMENT GUIDELINES FOR THE INDIVIDUAL LAND USES

From the sections given below which deal with ongoing management guidelines for the particular land-uses proceed to the section which deals with the land-use/s of interest.

Burning:	go to 2.3B
Natural grazing for domestic stock:	go to 2.3A and 2.3B (if burning is also applied)
Production of planted pastures:	go to 2.3C
Crop production:	go to 2.3D
Hay cutting:	go to 2.3E and 2.3B (if burning is also applied)
Dams:	go to 2.3F

2.3A NGRAZE-RECOMMEND (MANAGEMENT GUIDELINES FOR THE GRAZING OF NATURAL WETLANDS BY DOMESTIC STOCK)

Stocking rate

1) Establish in which Bioclimatic Group the impact area occurs (Descriptor A5);

2) Determine the potential grazing capacity for wetlands in the Bioclimatic Group (Table 3A1);

3) Adjust the potential grazing capacity by taking into account veld condition (Table 3A2) and the relative amounts of wet grassland, marsh and wet meadow to determine the Recommended Stocking Rate (RSR); and

4) Adjust the RSR to account for erosion hazard of the site (Table 3A3).

Fencing (camping) and grazing system

Consider the practicality of fencing off the wetland area as a special use pasture.

IF: the area has been (or will be) fenced off as a special use pasture;

THEN:
Apply the recommended rest-rotation grazing system with the proviso that animals are withdrawn if the soils are subjected to poaching;

ELSE:
Take alternative measures to reduce area selective grazing.

2.3A1 Stocking rate

Bench-mark sites, which represent areas considered productive and stable veld, have been described for all the Bioclimatic Groups of KwaZulu/Natal (Edwards and Tainton, 1981). The potential grazing capacities for these bench-marks have also been estimated (Table 3A1). Through personal observation and consultation with farmers at various wetlands in KwaZulu/Natal, it appears that the grazing capacity of natural wet grasslands is usually 1.5-3 times greater than that of the surrounding non-wetland veld. There are wet grassland areas, in Memel Vlei and Franklin Vlei for example, that are utilized at stocking rates of over 2 AU ha^{-1} on what appears to be a sustainable basis and with no obvious hydrological impacts. However, until these differences have been quantified in field studies, the grazing capacity of wet grasslands will conservatively be assumed to be 1.5 times that of the surrounding veld. This conversion figure is likely to be particularly conservative for arid and semi-arid regions because the difference in production between wetland and non-wetland is likely to increase with increasing aridity.

A widely applied method for recommending an appropriate stocking rate for an area is to conduct a veld condition assessment and to use the condition score to adjust the potential grazing capacity relevant to the Bioclimatic Group in which the area occurs. In order to determine veld condition, the species composition of the sample area is compared against that of the bench-mark for the region. Veld which is in poor condition generally has a lower potential productivity and soil protection capacity than good condition veld. Thus, the stocking rate needs to be reduced by an amount proportional to the condition score (i.e. the lower the veld condition score, the greater will be the required reduction in grazing capacity) (Edwards and Tainton, 1981).

Table 3A1 Potential grazing capacities of bench-mark sites for the different Bioclimatic Groups of KwaZulu/Natal (from Tainton *et al.*, 1980) and adjusted for wet grassland areas

Bioclimatic Group	Minimum $haAU^{-1}$ Non-wetland	Wet grassland
1	1.4	0.9
2	1.4	0.9
3	1.0	0.7
4	1.0-1.4	0.7-0.9
5	5.0	3.3
6	1.6	1.1
7	5.0	3.3
8	2.5	1.7
9	5.0	3.3
10	5.0	3.3
11	8.0	5.3

Unfortunately, bench-marks have not been described for the wetland areas within the different Bioclimatic Groups. A simplified system to be applied to wet grassland areas is proposed, whereby the recommended stocking rate is reduced by an amount proportional to the relative abundance of Increaser II species present (Table 3A2). Increaser II species have low palatability and/or perenniality, and increase in mis-managed veld where grazing pressure is heavy. *Eragrostis plana* is the most commonly occurring Increaser II species in the wetlands of the study area (see Appendix 1). A veld condition assessment should be conducted by randomly placing a point 200 times in the wet grassland zone and at each point recording whether or not the closest species is an Increaser II.

Table 3A2 Stocking rate adjusted to account for veld condition (RSR)

Percentage of Increaser II species	Stocking rate (expressed as a percentage of the potential grazing capacity for wetlands in the given Bioclimatic Group)
0- 30%	100%
30-60%	85%
>60%	70%

In the mid and late grazing season, domestic stock select strongly for wet grassland, less strongly for wet meadow, and avoid marsh. If a given wetland area were stocked without consideration for agro-ecological type then the effective stocking rates in the wet grassland areas would be considerably higher than the RSR. The stocking rate needs to be based on the proportion of wet grassland relative to wet meadow and marsh.

The extent to which marsh and wet meadow areas should be excluded in the calculation of stocking rate would be determined by the degree to which these areas are selected against. If it can be demonstrated for the given wetland area that during early spring, livestock do not show a strong preference for wet grassland then it is recommended that wet meadow and marsh areas be included in the stocking rate calculations for the early grazing season only. Stocking rates of $1haAU^{-1}$ are recommended for wet meadow and marsh in the early growing season. However, these areas should be used opportunistically under conditions that will not lead to **poaching** (the disruption of soil structure caused by the repeated penetration of hooves into the soil) (Wilkins and Garwood, 1986) (see Section 2.3A3, p60).

The stocking rate recommendations described above have been made for sites with a low erosion hazard. Thus, if the potential for erosion control value loss is high, because the wetland has a high erosion hazard, the maximum stocking rate restriction should be decreased (Table 3A3). The erosion hazard (EH) of the site is given in Descriptor E13.

Table 3A3 Stocking rate correction factors to account for erosion hazard of the site (expressed as percentages of the recommended stocking rate) and to calculate the adjusted stocking rate (ASR)

Sites with an intermediate erosion hazard (EH= 1.5-2.2):	80%
Sites with a high erosion hazard (EH= 2.3-2.7):	60%
Sites with very high erosion hazard (EH> 2.7):	exclude grazing

Provided that the recommended rest-rotation grazing system outlined in Section 2.3A3 is adhered to, and the wetland area is rested for a full year every fourth year, then wet grasslands may be grazed at the adjusted stocking rate (ASR).

2.3A2 Fencing of wetland areas and other means of reducing area selective grazing

Because wetlands have special management requirements, they should be fenced off as special use camps. However, this is often impractical. For example, wetlands in slope settings generally occur as many small areas (often < 0.5 ha) interspersed in a matrix area of predominantly non-wetland. If fencing is impractical, the following guidelines aimed at reducing the grazing pressure on wetlands should be considered:

1. herd those animals which are managed under herding away from wetland areas into under-utilized non-wetland areas;

2. ensure water availability in adjoining non-wetland sites so as to reduce animal numbers and time spent in wetland areas. This is particularly relevant to slope wetlands which often provide the only water

source in the surrounding landscape;

3. place supplementary feed in non-wetland areas where grazing is desired and minimize its location near and within wetland areas;

4. assure accessibility for livestock into non-wetland areas to be grazed, and provide stock trails and accessways over difficult terrain;

5. provide shade or shelter at strategic locations away from the wetland area; and

6. cut herbage for hay or green chop, mow old grasses, or strategically burn (in the non-growing season only) to attract more grazing to otherwise under-utilized areas away from wetland areas.

If the stocking rate for the overall area is excessive there will be few under-utilized areas in the landscape, diminishing the effectiveness of these measures. This, again, emphasises the importance of maintaining reasonable stocking rates.

2.3A3 The grazing system

In rotationally grazing a wetland area, a farmer may adopt one of two systems:

1. a fixed rotational system, with a cycle of 14 days in and 28 days out of the wetland, for example, and a full 12 months' rest every 4 years; or

2. a flexible rotational system, whereby the area is grazed until a predetermined level of use or disturbance has occurred, beyond which continued use of the wetland is likely to begin detracting from the hydrological and ecological values of the wetland and, in many cases, its current production potential. A full 12 months' rest is included every 4 years. It is very difficult to prescribe a threshold level of use, as it will depend on the vegetation type and climatic conditions. A suggested level is when the sward has been grazed to an average height of 8 cm, and/or when the favoured plants have been grazed to 4 cm high, and/or when most of the tufts of the favoured species have been grazed.

If the expertise of the manager is high and it is possible to check regularly on camps being grazed to monitor the effect of the animals, a flexible system is defenitely preferable. If, however, the manager's expertise is low and/or regular checking is impossible, the fixed system may be preferable.

Rotational grazing, be it fixed or flexible, should be discontinued if the soil becomes flooded or wet to the surface, at which stage it is recommended that grazing livestock be removed until the area dries out again. When wet, soils, particularly those with a high clay content, are more susceptible to compaction and poaching. The poaching of soils should be avoided because it decreases herbage production, and increases the susceptibility of the soil to erosion (Wilkins and Garwood, 1986).

The exclusion proviso based on soil wetness may appear to be over-conservative and unjustifiably deny the farmer valuable grazing. However, it is important to note that when the need for grazing to supplement drought-limited non-wetland grazing is high then grazing of the wetland is usually permissable. This is because it generally corresponds to times when the wetland soils are least susceptible to erosion and are acceptably dry for use. In contrast, when the use of the wetland is likely to have the greatest impact, as a result of being wet to the surface, then the need for wetland grazing is likely to be low because it usually corresponds with wet periods when non-wetland forage production is high.

2.3B BURN-RECOMMEND (MANAGEMENT GUIDELINES FOR BURNING)

There are two main groups of fire management decisions. The first concerns the time of year to burn and the frequency of burning. The second concerns the steps that can be taken to influence fire behaviour (e.g. if a low intensity fire is required, burning should not take place when the air temperature is high).

2.3B1 Recommendations concerning the timing and frequency of burning

IF: the wetland falls within an afforested area and is not burnt at all (usually because it is very small/narrow and surrounded by trees) or is burnt annually in early winter because of the fire risk to surrounding trees;

THEN: Go to 2.3B1.1 (p62)

ELSEIF: the wetland does not fall within an afforested area and regular burning is required to:

* enhance grazing potential;
* promote plant vigour and control alien plant infestation;
* enhance the habitat for wetland-dependent fauna and/or flora: or
* to prevent the build-up of exceedingly high fuel loads;

THEN: Goto 2.3B1.2 (p63)

ELSE: Goto 2.3B1.3 (p63)

2.3B1.1 Wetlands in afforested areas

*** Wetlands in afforested areas that are very seldom burnt**

Small/narrow wetlands in afforested areas but not within fire-breaks are often very seldom defoliated by burning and/or grazing. This causes the accumulation of standing dead and loose surface litter which, in turn, reduces the vigour of the vegetation, increasing its susceptibility to invasion by alien plants. In addition, runoff reduction caused by the planted trees reduces the degree of wetness of these wetland areas, making them more vulnerable to invasion by alien plants which would otherwise not have been able to tolerate the water regime of the unaltered wetland area. Often trees are planted very close to the wetland, and the wetland areas are shaded. Furthermore, plantations often harbour large populations of alien plants and provide a source for invasion into the wetland.

In such situations, it is recommended that nature conservation and/or extension officers be consulted about the various options available to increase the vigour of the natural wetland vegetation (e.g. through grazing), moving the afforested areas back from the edge of the wetland, and controlling alien plants.

*** Wetlands burnt annually in early winter because of fire risk**

From an ecological and hydrological impact point of view, an early winter burn is more destructive than a late winter/early spring burn, particularly if it is annual. In marsh, where the water table remains close to the soil surface through most of the winter season, absence of loose surface and standing plant litter (removed by the fire) for the entire winter is likely to result in a significant increase in the evaporative loss of water from the wetland. However, in wet grassland where the water table drops well below the soil surface, removal of plant litter is unlikely to have this result. This is because loss is already being limited by the upper dry soil layers. The increased evaporative loss from wet meadow is likely to be higher than in wet grassland because the upper soil layers remain wet for longer into the dry season, but this is not as prolonged as in marsh. Thus, the extent to which early winter burns increase evaporative loss will depend on the relative proportions of marsh, wet meadow and wet grassland. Little can be done to minimize the hydrological impact of early winter burning other than to protect marsh and wet meadow areas where possible. Early winter burning may detract from the grazing resource if large numbers of herbivores are attracted to the winter flush (Tainton, 1993. pers. comm.). Grazing of these areas should preferably commence only in the following season.

Measures taken to minimize the impacts of early winter fires on the ecological values of wetlands are primarily aimed at winter breeding species. One of the rarest species that may still be breeding in early winter is the grass owl (*Tyto capensis*), a late summer to early winter breeder. Other less rare species which may also be breeding at this time are the African marsh harrier (*Circus ranivorus*) and the marsh owl (*Asio capensis*). In order to cater for the needs of these species it is recommended that the areas in which they breed be burnt rotationally. An ornithologist should be asked to identify localized areas which, if rotationally burnt, would most benefit the winter and autumn breeding species.

Wetlands may be burnt rotationally through strip burning or block burning. Strip burning is probably best achieved by preparing a burning trace, using a herbicide that kills only the aerial portions (e.g. Gramoxen). Wetland areas usually comprise "tongues" within the afforested landscape. Where these wetland tongues are wide (ca >300 m), the tongue should be divided into 2 strips and burnt alternately on a rotational basis. In order to account for breeding grass owls (*Tyto capensis*), the following steps should be undertaken:

1. identify those areas used by the grass owl for breeding; and

2. check these areas before burning for currently breeding owls and/or chicks still unable to fly. This may be achieved by having 'beaters' 10 m apart walking through the area and then closely examining all localities where grass owls are flushed (Johnson, pers comm.). Areas where chicks have still not fledged would then be left unburnt for that year, or, if possible, burning for that year could be delayed.

2.3B1.2 Late winter/ early spring burning

If burning is needed to enhance grazing potential or habitat value, or to control alien plants, it is recommended that this be done every second year in early spring: this should have the least hydrological and ecological impact. Occasional late autumn/winter burns (at an average seven-year interval) should also be included to enhance diversity. Early spring burning may result in the death of wattled crane (*Grus carunculata*) chicks or eggs, as the wattled crane is a winter to early spring breeder. Thus, if this species is breeding in the wetland then:

1. consider delaying burning if the chicks are still unable to fly;

2. observe where the chicks are at the time of the burn and burn strategically; and

3. if eggs are present, temporarily remove them and replace them after the burn.

2.3B1.3 Infrequent burning

Wetlands that meet the requirements for infrequent burning should not be burnt more frequently than every five years. As the burning of wetlands, and of the landscape in general, is the norm in the humid and sub-humid grasslands and savannas of KwaZulu/Natal, the assumption is made that most wetlands in the landscape are likely to be burnt regularly. Thus, by promoting the infrequent burning of some wetlands, the diversity of habitat provided by wetlands in the overall landscape will be enhanced.

2.3B2 Recommendations relating to influence on fire behaviour

The following generally applicable recommendations are made, aimed at reducing the extent, intensity ar damage caused by fire.

* Burn when the relative humidity is high and the air temperature is low, preferably after rain, in ord to keep the fire as cool as possible and increase the likelihood of a patch burn.

* If possible, divide the wetland into two burning blocks and alternately burn each half, leaving the oth half unburnt to provide refuges for wetland-dependent animals from which recolonization of the bur areas can occur. If this is impractical, the entire wetland may be burnt every second year provide there are other wetlands nearby (preferably within 1 km) left unburnt for the year in which the wetlar is burnt. Effective fire breaks are often difficult to achieve in wetlands, as fires may easily burn acros the break through the loose surface litter on the soil surface, or even below it in the upper organ matter-rich soil layers if they are dry.

* Protect areas known to be important bird breeding areas (e.g. reed marsh areas used by herons or sedg marsh areas used by ducks) but even these may need to be burnt every fourth or fifth year to stimula new plant growth.

* If conditions are unfavourable for burning (e.g. if the soil is very dry and susceptible to sub-surfac fires or if the weather conditions are consistently unsuitable) delay burning until the following year.

* Burn areas with abundant dead (moribund) stem and leaf material that is obviously limiting new growth preferentially.

* Where wetland plants are being harvested, do this in areas useful for fire breaks, as far as is possibl

* Keep records of management practices, to monitor progress.

* Cattle, by reducing the fuel load and creating puddles, can be used to good effect in promoting patc burns.

* Head fires (burning with the wind) are generally preferable to back fires (burning against the wind Temperatures at ground level tend to be higher in back fires and consequently the impact on th growing points of plants is greater. Although the fire front advances less rapidly in a back fire direction is more difficult to predict. Also, because the fire front advances more rapidly with head tha with back fires, particularly if the wind speed is high, the fire has less time to spread laterally. Thus head fires can be used more effectively for burning only portions of the wetland without the use of fir breaks. However, this method of burning portions of a wetland is dependent on many factors outsid the managers control, such as wind direction changes, and cannot be relied upon for consistent bloc burning.

2.3C PASTURE RECOMMEND (MANAGEMENT GUIDELINES FOR PLANTED PASTURES)

2.3C1 Selection of species

Perennial species, such as *Festuca arundinacea* (tall fescue) and *Acroceras macrum* (Nile grass), are preferable to annuals, such as *Lolium multiflorum* (annual ryegrass), as they require the soil surface to be disturbed less frequently. This means that loss of erosion control value is less likely to occur.

Species with a high wetness tolerance, such as *Festuca arundinacea*, are preferable to species with a lower tolerance, such as *Medicago sativa* (lucerne) and L. multiflorum because the greater the wetness tolerance of the species, the smaller will be the need to decrease the degree of wetness of the soil. As such, the loss of hydrological values would be lower.

2.3C2 Drainage channels

Wetland drainage is discouraged by all government and non-government environmental bodies and a permit is required to drain any wetland area. Drainage will almost always detract from the hydrological and ecological values of a wetland, irrespective of how carefully planned it may be. However, an even greater loss may be avoided through careful planning. If a permit is obtained for wetland drainage, which rarely occurs, the Department of Agricultural Development should be consulted with about the final design and placement of the drainage channels. It may also be that an already drained area requires a revised drainage plan because of poor planning earlier, and consultation is strongly advised here.

The objective of wetland drainage is to lower the water table just enough to permit the successful establishment and growth of pasture. Complete control of the ground water elevation should be maintained so that the water regime of the wetland can be returned to its original state at any time (Scotney, 1970). Under no circumstances should the outlet of the wetland be altered, either by the creation of new drainage channels or by the straightening and/or deepening of existing channels. In addition, the area immediately above the outlet should be left under natural vegetation, as should the flow concentration zone of channel disrupting wetlands.

Surface drainage channels usually require regular excavation and disturbance of the soil to remove plants growing in the channels. This means that sub-surface channels are less likely to detract from the water purification function of the wetland. However, although it in no way compensates for the natural habitat lost through development, surface drainage channels provide a small amount of micro-habitat that would otherwise be absent if sub-surface drainage had been used. Thus, sub-surface drainage is likely to detract slightly more from the ecological value of the wetland than surface drainage.

2.3C3 Timing of grazing

As is the case in natural wetlands, grazing should be avoided as far as possible when the soil is saturated, because this is when the soils are most susceptible to erosion and compaction. If the pastures are irrigated, is important that a co-ordinated irrigation and grazing schedule be devised. Extra care should be exercised grazing pastures during the first year or two after planting. Older stands, particularly those providing fibro ground cover, would be at a lower risk than younger stands.

2.3C4 Fertilizer application

Measures should be taken to minimize nitrogen and phosphorus losses into drainage waters as this not onl detracts from the economic returns derived from pasture production but also from the water purificatio function of the wetland.

There are numerous possible measures available for minimizing nitrogen leaching losses (Amberger, 198 Miles and Bartholomew, 1991), including:

1. limitation and proper timing of mineral fertilizer application according to the special needs of th pasture;

2. multi-cropping with nitrogen-fixing legumes and grasses (which reduces the application requirement and possibly also mulching with straw (which decreases loss);

3. modern fertilizer technology (e.g. slow release-fertilizers); and

4. avoiding over-irrigation.

There are fewer ways of limiting phosphorus loss. As with nitrogen, the amount applied should not excee the plants' requirements, allowing for soil fixation. Determination of these requirements involves taking int account such factors as soil texture and pH (see Department of Agriculture and Water Supply, 1987). Althoug some leaching of phosphorus occurs, it leaches less readily than nitrogen, and the greatest loss generally occu in association with the loss of soil mineral particles from a pasture. Because of the association of phosphor loss with soil loss, measures taken to limit soil erosion would also assist in limiting phosphorus loss.

* **Limitation and proper timing of mineral fertilizer application according to the needs of th pasture**

Fertilizer applied should be just enough to meet the requirements of the specific pasture species (i.e. the corre fertilizer dressing should be applied). Theoretically, nitrogen losses could be reduced by perfectly matchin nutrient availability with total nitrogen requirements of the pasture, but this is very difficult to achieve und field conditions. Split applications in at least three or four dressings is recommended (i.e. frequent sma applications are preferable to infrequent large applications). As an example, Miles and Bartholomew (199 recommend that if a total seasonal nitrogen (N) rate of 300 kg/ha is required then it should be applied as si equal dressings of 50 kgN/ha rather than as three equal dressings of 100 kgN/ha. Four- to six-weekly intervals are recommended as optimal for N topdressing. Although split-dressings increase labour costs, this may be offset by more efficient nitrogen use and avoidance of possible toxic fertilizer concentrations in the soil solution.

In newly established pastures, nitrogen from decomposed organic matter is likely to meet the initial requirements of the plants. Thus, it is recommended that the first application be reduced or that nitrogen fertilizer be applied only two weeks after establishment.

When applying fertilizer, the seasonal growth patterns of the pasture should also be taken into account. In the highland sourveld (which characteristically has a humid climate) growth in the mid-winter is restricted by low temperatures and not by nitrogen insufficiency. Nitrogen dressings should be drastically reduced (or terminated) in mid-winter and the bulk of the nitrogen applied in spring and late summer/autumn (Miles and Bartholomew, 1991).

* **Intercropping with legumes and mulching**

A mixture of grasses and nitrogen-fixing legumes, provides naturally occurring nitrogen, and the amount of expensive mineral fertilizer required would be reduced. In legume/grass pastures the legume may contribute from 50 to 250 kg N/ha annually to the pasture. However, legumes cannot supply enough nitrogen for maximum grass production: although they usually supply enough for themselves, this is not sufficient to maintain the other pasture species.

An important consideration when using nitrogen fixation by the legume component of a mixed sward, is that nitrogen from the legume is made available to the grass mainly via excreta. Thus, cutting and removing material and having animals deposit their excreta off the pasture is likely to cause nitrogen deficiency and limit grass growth (Miles and Bartholomew, 1991).

Mulching, by mechanically incorporating residual pasture herbage into the soil, can be used to capture fertilizer or manure nitrogen and assimilate it into organic matter through the action of micro-organisms. This would be particularly applicable to annually established pastures and crops. This practice would assist in counteracting the steady decrease in organic matter often associated with cultivation and, in so doing, would have additional benefits such as increasing the soil's moisture holding capacity. From a plant production point of view it is important to note, however, that this biologically blocked nitrogen will not be available to the plants until the organic matter has been broken down, which may take months.

* **Modern fertilizer technology**

Fertilizer particle coatings (e.g. with sulphur) or slow release nitrogen fertilizers (which consist of either sparingly soluble material or organically combined nitrogen) can also improve nitrogen-efficiency by allowing a controlled release of nutrients to the roots. Nitrification inhibitors accumulate ammonia by retarding the nitrification of ammonium to nitrate. Leaching of nitrogen is reduced because nitrate is most prone to leachin Thus, as in coatings and slow release fertilizers, the roots are continuously supplied with small quantities nitrogen.

* **Avoiding over-irrigation**

In irrigated pastures, over-irrigation will not only waste costly irrigation water through run-off, but may cau: nutrient losses through leaching. Once the soil profile is nearing saturation, the irrigation system should l moved or shut down until the soil has dried out sufficiently to require irrigation again (Macdonald, 1991).

2.3D CROP-RECOMMEND (MANAGEMENT GUIDELINES FOR CROP PRODUCTION)

The development of wetlands for crop production is generally not considered acceptable by conservation ar environmental bodies and has never been encouraged. WETLAND-USE lists stringent requirements for th acceptability of wetland cropping, one of which is that the area must be transitional between wetland and nor wetland (see Section 2.2A). Where the conditions are met and permission has been granted for developmen caution must be exercised in utilizing these marginal cropland areas.

Recommendations concerning drainage and minimizing the impact of artificial fertilizer applications given fc planted pastures are also applicable to crop production (i.e. Sections 2.3C1-2.3C4). In addition, the Univers: Soil Loss Equation (U.S.L.E.) should be applied in order to plan contour bank spacing distances, where the are required, and other soil conservation measures (a seventeen page document "Use of The U.S.L.E. in th Natal Region" is available from The Department of Agricultural Development, Natal Regional Head Offic PB X9059, Tel: 33371).

Long ley rotations should also be implemented. In dry years, the moisture conditions in wetland areas ar generally more favourable than in drier non-wetland areas. Consequently, they may provide useful alternati dryland crop production areas during drought years but they cannot be relied upon for continuous croppin A one-in-three year ley is recommended, where for every year the area is cropped, it is left fallow or unde perennial pastures for three years. For a ley to serve its purpose (primarily to restore depleted soil organi matter levels) at least three consecutive years for each rotation is required. The most generally applicabl system would probably be three years of cropping alternating with nine years of perennial pasture ley.

2.3E HAY-RECOMMEND (MANAGEMENT GUIDELINES FOR HAY PRODUCTION)

Although the restrictions that apply to mowing are largely included in Section 2.2D, some further guidelines are given below.

* Mowing should not be carried out when the soil is wet, because, as with grazing, this increases the risk of soil erosion, particularly if machinery gets stuck.

* Consideration should be given to hand cutting. Although more labour intensive, this harvesting method is less constrained by soil surface conditions and would have less impact on the soil, thereby decreasing the loss of hydrological and erosion control values.

* If the wetland is also being used for domestic stock grazing then not more than 40% of any agro-ecological zone in the wetland should be harvested for hay, because this may detract from the ecological value and would also reduce its flood attenuation value. If the wetland is not being used for grazing then this value may be increased to 60%.

2.3F DAM-RECOMMEND (MANAGEMENT GUIDELINES FOR DAMS)

2.3F1 Construction of the dam wall and spillway

The dam wall and spillway should be built to withstand flooding because the bursting of dams usually has a high environmental impact, increasing flood peaks, sediment loads and streambank erosion. In addition, the spillway should be built to allow for the movement of aquatic species. All dams should also preferably have an outflow control (see 2.3F2).

Consult the local soil conservation officer or an engineer to plan the dam wall and spillway and to check whether it has been built to specifications.

2.3F2 Ongoing management

The main factors within the manager's control once a dam has been built and filled are:

1. water extraction;

2. outflow control; and

3. introduction of species, and harvesting of introduced and/or indigenous species.

* **Extraction of water**

Extraction of water often causes sudden, large fluctuations in the water level of a dam, hindering tl establishment and growth of wetland vegetation. Together with wave action, this also contributes to hardenir of the soil to produce an armoured shoreline, which decreases the ecological value of the area. In son instances, however, drawdown on shorelines with a soft substratum improves the ecological value as the: exposed areas are often good for mud-probing birds. If wattled cranes are breeding on the edge of the dai then winter draw-down should be limited as this is likely to leave the nest exposed and makes the site unsuitab for breeding.

* **Outflow control**

The first wet season flows from a dam's catchment are often retained in the dam because levels are deplete at the end of the dry season. This may affect both the river biota and downstream users negatively (Bruw and Ashton, 1989). It is important that the outflow from the dam be controlled so that at least 50% of the earl season flow entering the dam is released.

* **Introduction of species and harvesting of species (introduced and indigenous).**

If species are to be introduced and/or species are to be harvested, consult the local nature conservatic extension officer, because this may detract from the ecological value of the area.

2.4 WETLAND DATASHEET

Section 1 and Section 2.1-2.3 should be referred to so that the data sheet is completed with as much clarity and consistency as possible.

WETLAND SITE INFORMATION

Date of site visit/s ......(mnth.) ......(yr.) ......(mnth.) ......(yr.) ......(mnth.) ......(yr.)

Compilers'name/s...

A1 Wetland name......................................

A2 Geographic co-ordinates..........................

A3.1 Inlet altitude (m) ....

A3.2 Outlet altitude (m) ....

A3.3 Average altitude (m) ....

A4 Bioclimatic Group ....

A5 Mean annual precipitation (mm) ....

A6 Annual pot. evapotranspiration (mm) ......

A7 Humidity Category (a or b) ....
a=Bioclimatic Grps 1-6; b=Bio Grps 7-11

A8 Veld type ....

A9 Dominant soil form/s ....
....

A10 Underlying geology............................
....

A11 Total surface area (ha) ....

A12 Average width (m) ......

A13 Length (m) .....

A14 Average slope (%) ....

A15 Agro-ecol. zone abundance (1-4, a-l or %):

A15.1 Open water ......

A15.2 Marsh ......

A15.3 Wet meadow ......

A15.4 Wet grassland ......

abund. ranking: 1=1st 2=2nd 3=3rd 4=4th
a<0.01% b=0.01-3% c=4-10% d=11-20%
e=21-30% f=31-40% g=41-50% h=51-60%
i=61-70% j=71-80% k=81-90% l=91-100%

A16 Species composition: see p76.

A17 Horizontal pattern of zones (A-C) ....
A=low interspersion B=intermediate intrsp.
C=high interspersion

A18 Landform setting (a-f) ......
a=Flat b=Depression c=Channel d=Slope
e=Channelled flat f=Channel disrupting flat

A19 Emergent vegetation in channel (Y/N) .....

A20 Prevalence of depressions (a-d) ....
a<3% b=3-10% c=11-30% d>30%
of total wetland surface area

A21 Terrain unit (a-f) ....
a=Crest b=Midslope c=Footslope
d=Valleyhead e=Valley bottom (young)
f=Valley bottom (mature/old)

A22 Slope of flow concentration zone (%) ....

A23 Stream order ....

A24 Meander ratio ....

A25 Red Data plant species Status Zone
....
....

A26 Red Data animal species Status Zone
....
....

A27 Other valued species ....
....
....

A28 Localized species
....
....

A29 Threatened habitat types ....
....

A30 Migratory/nomadic species (Y/N) ......

A31 Duck/heron breeding site (Y/N) ....

A32 Timing of fires (a-d) .... a=winter
b=early spring c=summer d=autumn

A33 Fire frequency (a-e) ....
a=annual b=every 2 yrs. c=every 3 yrs.
d=every 4th-7th yr. e > a 7 yr. interval

A34 Alien invasive species Infestation level (a-c)

....

....

a > 30% of the wetland area infested

b=5-30% infested c < 5% infested

Area (a-f) of the wetland altered by:

A35 Dams ....

A36 Drainage channels ....

A37 Erosion ....

a < 1% b=1-5% c=6-15% d=16-30%

e=31-60% f=61-100%

A38 Increase in erosion (a-f, see above) ......

A39 Severity of erosion (a-d) ....

a=negligible b=mildly severe

c=severe d=very severe

A40 Severity in the flow conc. zone (a-d) ......

A41 Total length of roads/railroads (km) ......

A42 Flow concentration effect of roads (Y/N) .....

A43 Damming effects of roads (Y/N) ......

Land-uses in the wetland (Y, a-k or % of area):

A44.1 Nature conservation ....

A44.2 Natural vegetation stock grazing ....

A44.3 Hay cutting ....

A44.4 Planted pastures ....

A44.5 Crops ....

A44.6 Forestry ....

A44.7 Urban or industrial ....

A44.8 Mining ....

A44.9 Other (...........................) ....

a=1-3% b=3-10% c=11-20% d=21-30%

e=31-40% f=41-50% g=51-60% h=61-70%

i=71-80% j=81-90% k=91-100%

Natural resources level of use (Y or a-c):

A45.1 Hunting ....

A45.2 Plant harvesting ....

A45.3 Water use ....

Level of use: a=nil b=low

c=intermediate d=high

Recreation level of use (Y or a-d):

A46.1 Bird watching ....

A46.2 Water sports ....

A46.3 Fishing ....

A46.4 Other (........................) ....

A47 Part of a research programme (Y/N) ....

A48 Close to educational centre (Y/N) ....

A49 Land ownership...........................

A50 High nutrient level in wetland (Y/N) ....

A51 Toxicants in wetland (Y/N) ....

A52 Inflow turbid (Y/N) ......

SURROUNDING LANDSCAPE INFORMATION

Extent of wetlands (a-h) in:

B1 The wetland catchment ......

B2 The downstream service area ......

B3 A 10 km radius ......

a=0-0.05% b=0.06-0.5 c=0.6-1%

d=2-5% e=6-10% f=11-25%

g=26-50% h > 50%

Extent of wetland loss (a-d) in:

B4 The wetland catchment ....

B5 The downstream service area ......

B6 A 10 km radius ......

a=Nil b=1-30% c=31-60% d > 60%

CATCHMENT INFORMATION

C1 Bioclimatic Group/s ....

C2 Veld Types ....

C3 Wetland catchment size (ha) ....

C4 'flood' catchment size (ha) ....

C5 % catchment occupied by the wetland .....

C6 Mean annual runoff .....

Current land-uses in the catchment (Y or %):

C7.1 Conservation ......

C7.2 Livestock on natural vegetation .....

C7.3 Natural vegetation mowing ....

C7.4 Planted pastures ....

C7.5 Crops ..... C7.6 Urban ....

C7.7 Industrial ..... C7.8 Mining ......

C7.9 Other (..........................) ....

C8 Total number of dams ......

C9 Total surface area of dams (ha) ....

C10 % of catchment irrigated (a-e):

C10.1 (spring) ..... C10.2 (summer) .....

C10.3 (autumn) ..... C10.4 (winter) .....

C10.5 (total) .....

a <0.5% b=0.5-2.9% c=3-8% d=9-20%

e=21-50% f >50%

C11 Runoff reduction (a-d) ....

a=negligible b=moderate c=large

d= very large

C12 Water quality data (append if necessary)

....

....

....

....

....

....

C13 Level of sediment input (a-c) ....

C14 Level of nutrient/toxicant input (a-c) ....

C15 Level of combined pollutant input (a-c)

.... a=low b=intermediate c=high

POTENTIAL DOWNSTREAM SIGNIFICANCE

D1 Water purification service distance (km) ....

D2 Flood attenuation service distance (km) ....

D3 Wetland's current potential water purification significance .....

D4 Wetland's current potential flood attenuation significance .....

Current potential importance (0-3) for:

D5.1 Potable water users ....

D5.2 Piped water users ....

D5.3 Recreationists ....

D5.4 Stock watering ....

D5.5 Irrigation ....

D5.6 Downstream biota ....

Importance: 0=nil 1=low

2=intermediate 3=high

D6 Total water use score (0-15) ....

D6=D5.1+D5.2+D5.3+D5.4+D5.5+D6.6

D7 Total current significance (a-d) ....

a: D6=0 b: D6=1-4 c: D6=5-8

d: D6>8 or D5.1>1

D8 Current abundance of floodable units ....

D9 Total current significance (a-d) ....

a: D8=0 b: D8=1-10 c: D8=11-19

d: D8>20

NOTES:..

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INFORMATION ABOUT THE IMPACT SITE

Initial impact site information

E1	Land-use (a-f) ....
	a=natural vegetation for wildlife or fire breaks
	b=natural vegetation for stock grazing
	c=mowing d=planted pastures
	e=crops f=dams
E2	Pasture type ....
E3	Crop type ....
E4	Outflow control (Y/N) ....
E5	Uses of the dam (a-e) ....
	a=irrigation b=waterfowl hunting
	c=stock watering d=watersports
	e=fishing
E6	Land ownership ....
E7	Surface area (ha) ....
E8	% of wetland that is impact area ......
E9	Landform setting. ....
E10	Slope ....
E11.1	Soil form ....
E11.2	Soil family ....
E12	Erosion hazard of the soil ....

Primary acceptance criteria checksheet

Use of the checksheet involves checking each row to see if the descriptor values for the site meet th requirements given in the column of the land-use under consideration. If the site column has a value whic falls outside the limits set for the land-use for any of the rows then the land-use is considered unacceptable For example, if in the first row to be checked the impact site had an erosion hazard index of 1.9 then bot crop and pasture production would be unacceptable. Similarly, if the soil *n* value was high, crop and pastur production would be unacceptable. A '*' indicates that the land-use may be acceptable but restrictions give in Section 2.3 apply. A blank indicates that no restrictions apply for that particular descriptor and land-use The acceptance criteria and reasoning behind them are given in Section 2.2.

		Site	Graze	Mow	Dams	Crops	Pastures
<u>E13</u>	Site erosion hazard (0.3-3.6)	.....	<2.8	<2.0		<1.0	<1.5
E14	Agro-ecological zone (a-d)	.....				d	c,d
E15	*n* Value (a-c)	.....	b,c	c		c	c
E16	Red Data species (Y/N)	.....	*	*	N	N	N
E17	Threatened habitat types (Y/N)	.....	*	*	N	N	N
<u>E18</u>	Cumulative wetland loss (%)	.....			<60%	<60%	<60%
<u>E19</u>	Downstream water use	.....	*			N	N
<u>E20</u>	Pollutant input	.....			N	N	N
E21	Catchment unsuitable for dams	.....			N		
E22	Water table lowering (a-f)	.....	-	-	-	<10cm	<20cm
E23	Severity of existing erosion (a-d)	.....	a,b*	a,b*		a	a

E13 = FxSxE12

If E9 is a channel or includes the channelled portion of a channelled flat or channel disrupting fla then F=2, and if it is a depression then F=0.75, otherwise F=1.

S value: **Slope (E10)**	**S value**	**Slope**	**S value**	**Slope**	**S value**
<0.2%	1	0.2-0.9%	1.6	1.0-3.0%	2.2
3.1-10.0%	2.8	10.0-20.0%	3.2	>20%	3.6

E14: a=open water/marsh b=wet meadow c=wet grassland d=wet grassland/non-wetland mosai
E15: a=very high *n* value b=high *n* value c=intermediate or low *n* value
E22: a=0cm b=1-10 cm c=11-20 cm d=21-40 cm f >40 cm
E23: a-d see A39

Information required for the secondary acceptance criteria and LAND USE-RECOMMEND

E24 Percentage of impact area eroded ....
E25 Percentage of impact area developed ....
E26 Roughness co-efficient ....
E27 Soil texture class ....
E28 Runoff potential ....

Secondary acceptance criteria (1-3 ranking)

If all the primary acceptance criteria are met and most of the answers to the secondary criteria questions (i.e. E29-E40) are '1's then the land-use may be acceptable provided that the guidelines for ongoing management outlined in Section 3 are adhered to. Otherwise, if most of the answers to the secondary criteria questions were '2's and '3's then the land-use is unacceptable, unless mitigation measures are undertaken which will compensate entirely for the effects of the proposed land-use (including those effects revealed by both the primary and the secondary criteria questions). The notes for Descriptors E29-E40 should be referred to see the reasoning behind the ranking.

E29 Area to be developed (ha) ....
1 <0.1 ha 2=0.1-1 ha 3 >1 ha

E30 Level of development/degradation ....
1=(E24 + E25) > 60% of Impact area
2=(E24 + E25)= 20-60% of Imp. area
3=(E24 + E25) < 20% of Impact area

E31 Availability of alternative sites ....
1=low 2=intermediate 3=high

E32 Importance for birds ....
1=low 2=intermediate 3=high

E33 Cumulative loss ....
1 <10% 2=11-40% 3 >40%

E34 Roughness coefficient ....
1: N=0.04 2: N=0.06 3: N=0.08

E35 Extent of shallows ....
1=limited 2=moderate 3=extensive

E36 Aquatic species movement ....
1=unimportant 2=mod. important
3=important

E37 User's need for development ....
1=large 2=intermediate 3=small

E38 Existence of alternatives ....
1=large 2=intermediate 3=small

E39 Contribution to society ....
1=large 2=intermediate 3=small

E40 Level of direct benefit ....
1=large 2=intermediate 3=small

NOTES:..
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WETLAND-USE

A wetland management decision support system for South African freshwater palustrine wetlands

KOTZE D C and BREEN C M 2000

Report on a project executed on behalf of the Department of Environmental Affairs and Tourism as part of the *South African Wetlands Conservation Programme*

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An overview of WETLAND-USE

WETLAND-USE is designed to assist extension staff, working with local resource users and managers, in promoting the wise use of wetlands. It has two main parts, each comprising several components.

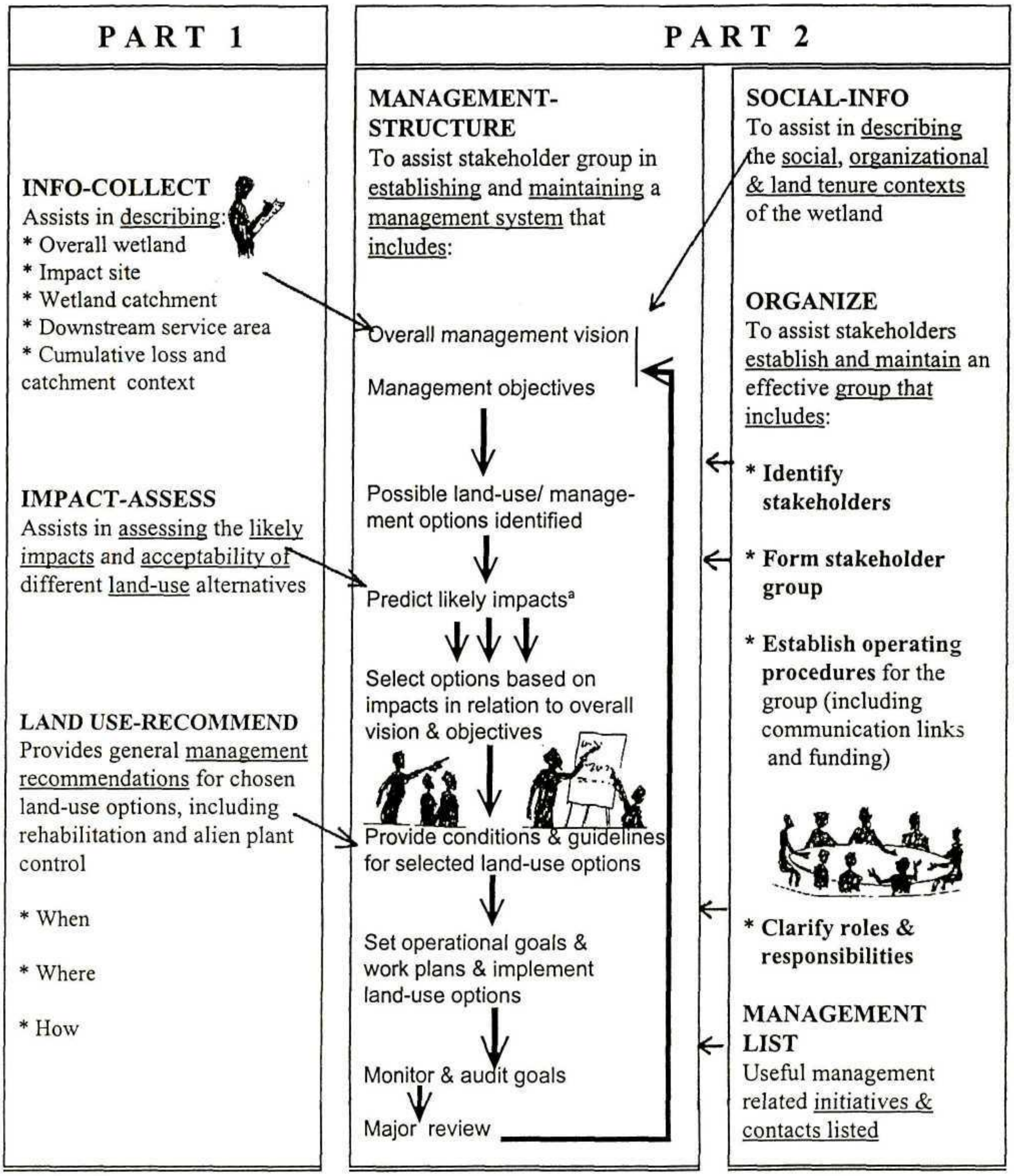
- Part 1 assists in: describing the biophysical features of the wetland that are of direct relevance to management; predicting the likely environmental impacts of different land-use options (e.g. grazing of natural vegetation); and making ongoing management decisions for particular land-use options.

- Part 2 assists in: describing the social and organizational context of the wetland (i.e. who uses the wetland directly and which organizations influence this use); and in establishing and maintaining a wetland management system.

Figure 1.1 provides an indication of how these different parts and their components relate to one another. For example, information gathered using INFO-COLLECT and SOCIAL-INFO is used in the development of an overall management vision and management objectives designed to achieve that vision.

WETLAND-USE also includes Appendeces relating to additional biophysical information and a guide to the identification of some common wetland plants.

Details of the approach used in the development of WETLAND-USE and the many different organizations and individuals that contributed to the system are given at the beginning of Parts 1 and 2.



[a] If the predicted impacts are high and the intention is still to continue with the proposed land-use option then a full impact assessment is required before proceeding. Guidelines for conducting such an assessment, which is beyond the scope of WETLAND-USE, are given in DEA (1992) and DEAT (1998a and b).

Fig 1.1 The overall structure of WETLAND-USE

WETLAND-USE

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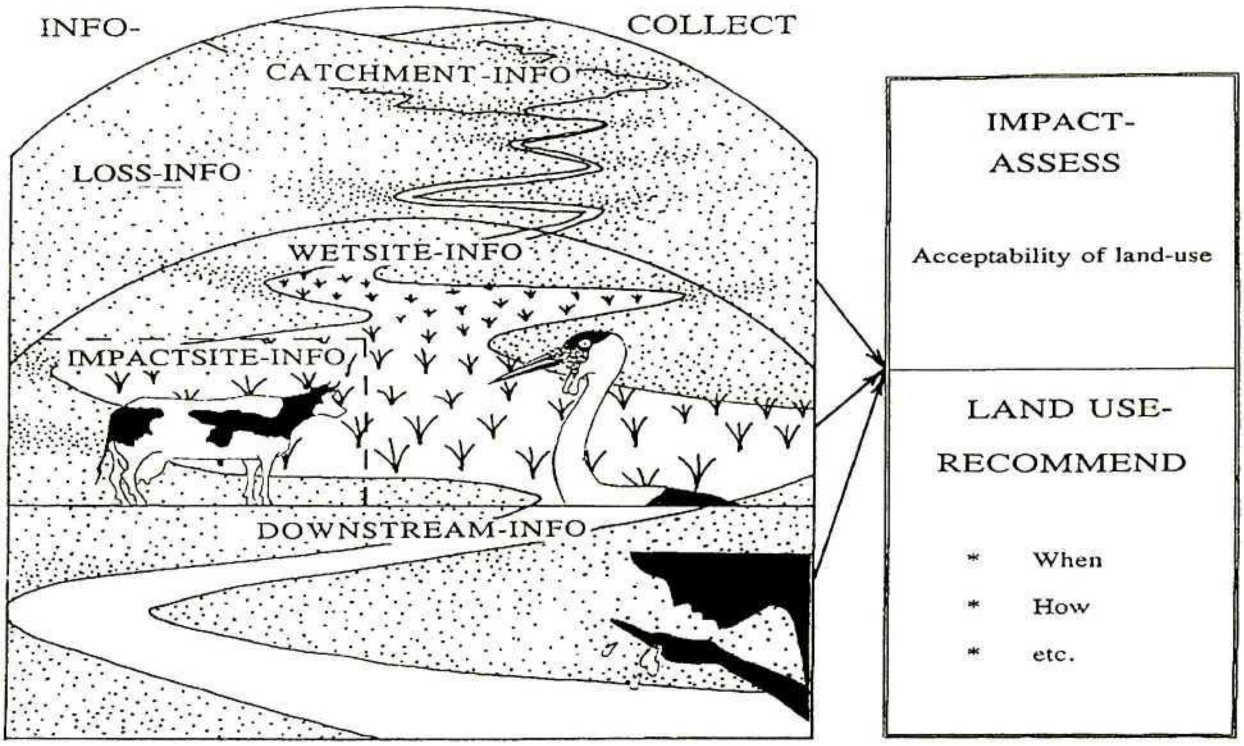
PART 1: Biophysical assessment



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PREFACE

Even though **wetlands**[1] have many benefits to society (e.g. water purification) the destruction and poor management of wetlands continues. WETLAND-USE is a tool to assist agricultural and nature conservation extension staff, working closely with local resource users and managers, in promoting the **wise use** of wetlands. It applies to fresh water **palustrine** wetlands. Although it was developed and tested primarily for the Eastern coastal slope and Northern escarpment regions given by Cowan (1995), which includes most of the higher rainfall areas of South Africa, it is likely to be relevant to other parts of South Africa. WETLAND-USE has two parts, the first dealing with biophysical features of wetlands and the second dealing with the social and organizational context of the wetland.

- Part 1 assists in: describing the **biophysical features** of the wetland that are of direct relevance to management; predicting the likely environmental impacts of different land-use options (e.g. grazing of natural vegetation); and making ongoing management decisions for particular land-use options.

- Part 2 assists in: describing the social and organizational context of the wetland (i.e. who uses the wetland directly and which organizations influence this use); and in establishing and maintaining a wetland management system.

The various components of Part 1, are shown on the cover of the document. The cow represents the direct use of wetlands, with livestock production being one of the most common direct uses made of wetlands in South Africa. The wattled crane, chosen to represent the ecological benefits of wetlands, is a threatened species for which wetlands provide essential habitat. The clean water being obtained by the person downstream of the wetland represents the hydrological benefits provided by wetlands.

Before using WETLAND-USE you should at least attend a short wetland training course (currently conducted by the Rennies Wetlands Project, phone: 011-4863294/5). Also, refer to:

- WETLAND-USE Booklet 1 (Kotze, 1997a), which describes the various benefits provided by wetlands and the impacts that different land-uses have on these benefits; and

- WETLAND-USE Booklet 2 (Kotze, 1997b), which describes what a wetland is and how to recognize a wetland, and provides basic information on wetland **hydrology** and soils.

It is best that at least both an agricultural and a nature conservation worker apply the system together, and always consider the limitations and assumptions of WETLAND-USE (see Section 5).

No guidelines, however comprehensive they may be, are a substitute for a multi-disciplinary teamwork approach in planning for the use of wetlands.

A system such as WETLAND-USE cannot provide the final answer as to what land-use is best in a particular situation. It does, however, help the user/s in arriving at a decision by assisting in the collection of relevant information on the wetland and its surrounding landscape, and in the prediction of likely environmental impacts of different land-use alternatives. It also ensures that a record is kept of how the decision was made. Furthermore, WETLAND-USE is useful for organizing the collection of biophysical data for wetland management plans and for providing a baseline for monitoring.

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[1] All terms first appearing on boldface are defined in the glossary.

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ACKNOWLEDGMENTS AND BACKGROUND

WETLAND-USE was developed in two phases. In Phase 1, funded by the Natal Town and Regional Planning Commission and the Water Research Commission, a prototype system (Kotze *et al.*, 1994) was developed for use in privately-owned, large-scale commercial farms in the KwaZulu-Natal Midlands. In Phase 2, funded by the Department of Environmental Affairs and Tourism (DEAT), the prototype system was refined and expanded to make the current system more widely applicable (see Kotze, 1999). This was undertaken through: field studies; a questionnaire survey for people familiar with WETLAND-USE; a series of field workshops which included the application of WETLAND-USE by extension workers; and the application of WETLAND-USE to case study wetlands.

The DEAT are gratefully acknowledged for funding Phase 2. Mzi Dlovu, Jane Browning and Angela Beaumont are thanked for some of the drawings, and sincere thanks is also expressed to all those individuals who provided valuable comment in the revision of WETLAND-USE Part 1, including:

- Participants in the field workshops, including: N Collins, J Dini, D Lindley, A Linström, K McCann, D. McKenzie, K Morrison, N Nsele, E. Qonya, L Shabane, G. Shaw, M St. Clair Hill, and H Urquart, and managers and wetland users from case-study wetlands, especially to the people of Mbongolwane and Wakkerstroom;
- D Lindley of the Rennies Wetlands Project, and K McCann, J Dini, N Collins and A Linström for written comment;
- C Griffon, University of Massachusetts;
- The Assessment and Participatory Management of **Riparian** Systems Project, funded by the WWF for components on alien plant control and rehabilitation;
- J Wyatt, the author of the Wetland Fix series (see References); and
- ·J Mander and N Quinn, for comment regarding the assessment of environmental impacts.

SECTION 1, OVERVIEW OF WETLAND-USE PART 1

1.1 Introduction

Presently, the use of wetlands is often planned from the narrow perspectives of those who use the wetland directly (e.g. for pasture production). Little attention is generally given to the impacts of land-use activities on indirect wetland benefits to society (e.g. water purification and **biodiversity** support). In other words, the costs to society are not considered.

In response to this situation, a wetland management **decision support system**, termed WETLAND-USE was developed to assist extension workers in providing sound land-use advice and encouraging wetland users/owners to give consideration to the impacts on indirect benefits provided by wetlands. The system enables non-specialists to undertake wetland assessments provided that they have introductory training and they seek the input from specialized disciplines where required. WETLAND-USE comprises 2 parts, the first dealing with the biophysical aspects of wetland management and planning and the second dealing with the social and organizational aspects.

1.2 The design and purpose of Part 1

Although WETLAND-USE is designed primarily for use in commercial agriculture, forestry and rural communal areas, it may also be used in areas protected specifically for biodiversity conservation. WETLAND-USE Part 1 is a rapid assessment system with three main components (see cover): (1) INFO-COLLECT, which guides the user in collecting useful information about the wetland and its catchment, cumulative loss context and the downstream service area; (2) IMPACT-ASSESS, which assists in selecting appropriate land-use alternatives for a given wetland area by predicting the likely impacts of the proposed land-uses on the indirect benefits of the wetland area; and (3) LAND USE-RECOMMEND, which recommends how the wetland area be managed for the chosen land-use. The assumptions on which WETLAND-USE Part 1 is based and the scientific support for these are given in Section 5. Part 1 may be used for three main purposes, requiring different components of the system:

Purposes of WETLAND-USE Part 1	Components you will require
Do you wish to provide an overall description of the wetland, which will serve as the basis for management and for identifying areas (e.g. an actively eroding head-cut) which require urgent attention?	INFO-COLLECT (excluding its final sub-component: IMPACTSITE-INFO)
Do you wish to assess the impacts of a proposed land-use at a scoping or pre-application level or need assistance for reviewing a scoping report involving a wetland?	INFO-COLLECT and IMPACT-ASSESS
Do you wish to provide ongoing management guidelines for particular land-uses (e.g. stocking rate) or management problems (e.g. erosion)	LANDUSE-RECOMMEND

INFO-COLLECT

INFO-COLLECT has five main sub-components.

① WETSITE-INFO poses questions regarding the overall wetland site (e.g. distribution and extent of wetness zones) and assists in identifying management concerns in the wetland (e.g. erosion).

② LOSS-INFO is concerned with the extent of cumulative loss of wetlands.

③ CATCHMENT-INFO poses questions relating to the **wetland catchment** (e.g. land-uses).

④ DOWNSTREAM-INFO deals with the extent of water use and floodable properties downstream of the wetland.

⑤ IMPACTSITE-INFO[2] requests specific information (e.g.erosion hazard) about that part of the wetland to which the proposed land-use is to be applied.

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[2]Impacts on wetlands result from both 'on-site' activities at the wetland site and from 'off-site' activities in the wetland's surrounding catchment. WETLAND-USE is designed to assess on-site impacts. The land-uses considered are agricultural, including crop and pasture production, damming and natural grazing. While the general criteria of WETLAND-USE for assessment of land-use impacts are applicable to other land-uses (e.g. peat mining), additional information about the wetland site would be required to assess these land-uses.

IMPACT-ASSESS

IMPACT-ASSESS assists in predicting the likely environmental impact of the chosen land-use by assessing its likely effects on those wetland functions indirectly benefiting society. The following indirect benefits, described in WETLAND-USE Booklet 1, are considered by IMPACT-ASSESS:

Indirect benefits from wetlands

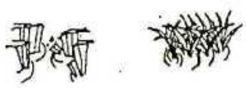
- Hydrological, which include:

  a. Water purification/**water quality** enhancement (by removing suspended sediments, excess plant nutrients, and other pollutants) 

  b. Flood attenuation/reduction 

  c. Water storage and enhancement of sustained streamflow

  d. **Groundwater** recharge and discharge 

- Erosion control; 

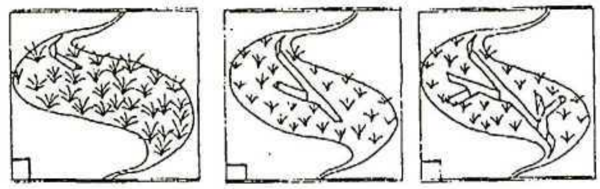
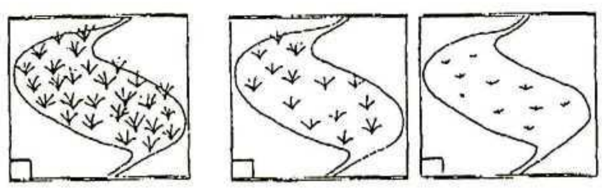
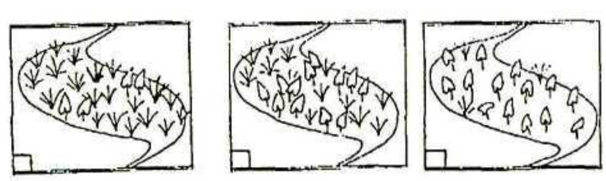
- Ecological (maintenance of biotic diversity by providing habitat for wetland-dependent fauna and flora); and 

- Global climate stabilization (primarily through wetlands storing carbon and sulphur, i.e. acting as carbon/sulphur (C/S) sinks). 

When assessing the impacts of a particular direct use (e.g. drainage and cultivation) on the indirect benefits of wetlands, eight principal factors need to be considered (see Box 1 on the following page). WETLAND-USE is designed to assist you in considering these factors with limited available time and resources.

How the above factors affect particular wetland benefits is obviously very complex, and is influenced by interacting and cumulative effects (see Brinson, 1988; Preston and Bedford, 1988). However, for the purposes of IMPACT-ASSESS these are represented in a simple matrix (Table 1.1, page's 10&11). The effect on the hydrological, erosion control and carbon/sulphur sink benefits is related directly to factors 1 to 6, as indicated in Table 1.1, and the effect on the ecological benefits is related further to factors 7 and 8. The loss of indirect benefits is likely to be high if: (1) the cumulative loss of wetlands in the region is high; (2) the wetland is hydrologically altered through drains; (3) frequent and high levels of artificial fertilizers were applied; (4) an annual crop requiring frequent disturbance of the soil is established; (5) soil organic matter is depleted as a result of (2) and (4); (6) the crop has a low surface roughness; (7) natural vegetation is replaced totally by introduced species in the area cultivated; and (8) Red Data species were lost from the area. (The loss of hydrological benefits is likely to be even higher if the pollutant inputs to the wetland were high and there was human use of water downstream.) The overall loss of indirect benefits is likely to be much lower in a situation where a **perennial crop**, not requiring drainage, and having a high surface roughness is established, and low levels of artificial fertilizers are applied and no Red Data species were previously present.

Box 1 Principal factors to consider in assessing land-use impacts on a wetland area

	Level of impact: Negligible/low	Medium	High
1. What is the cumulative loss[3] of wetland over a broader area (i.e. in the overall wetland, the Veld Type and the quaternary **catchment**)?	☐	☐	☐
2. How much is the flow pattern of water in the wetland area being altered through on-site modifications (e.g. through drainage channels or **infilling**) and/or from off-site modifications to **runoff** quantity and timing into the wetland (e.g. as a result of afforestation of the wetland's surrounding catchment)?			
3. How great is the addition of pollutants to the wetland (e.g. as a result of leaching from fertilized fields)?	☐	☐	☐
4. How extensively, and how frequently, is the soil disturbed (making it more susceptible to erosion) and how close is the disturbed area to the wetland outlet or a channel linked directly to the outlet?			
5. What amount of **organic soil material** is mechanically removed or oxidised as result of altered flow patterns causing the drying out of the wetland and/or increased soil disturbance?	☐	☐	☐
6. How much is the roughness of the wetland surface (which offers resistance to the movement of water) reduced and/or vegetation cover reduced?			
7. What amount of natural wetland vegetation is replaced by introduced/alien plants (which may not necessarily be associated with a change in vegetation structure or flow patterns)?			
8. To what extent are wetland-dependent species, particularly **Red Data species**, negatively affected?	☐	☐	☐

[3]A wetland area is considered lost when it has been altered so much that its functioning and the indirect benefits it supplies are severely limited (e.g. when it is drained and cultivated).

Table 1.1 The extent to which particular benefits[1] supplied by a wetland are potentially reduced by the eight land-use impact factors given in Box 1

1. Cumulative loss of wetland area is not included in the table because all benefits are obviously diminished by a reduction in surface area and it is assumed that the greater the cumulative loss of wetlands, the greater will be the impact of further loss on all indirect benefits.

Principal impact factors and level of each (i.e. Medium or High)	**Indirect benefits[l]**					
	Water purification[a]	Steamflow regulation[a]	Flood attenuation[b]	Erosion control	Ecological	C/S sink
2. Flow pattern disruption: Drains Med (Medium)	Med	Med	Low-med[c]	Low- high[d]	Med-high	Med[e]
High	V(very) high	High	Low-high[c]	Med-v high[d]	High-v high	V high[e]
Dams Med	Low-med	Low-high[f]	Low-med[g]	Low-high[h]	Low- high[f]	Low-med[e]
High	Med-high	Med-v high[f]	Low-med[g]	Low-v high[h]	Med-v high[f]	Med-high[e]
3. Water quality alterations Med	Low-med[i]	Low	Low	Low	Med	Low
High	Low-high[i]	Low[j]	Low[j]	Low-med[j,d]	High	Med-high[e,j]
4. Soil disturbance Med	Med-high[d]	Low	Low	Med-high[d]	Med[k]	Med[e]
High	High-v high[d]	Med	Low	Med-v high[d]	High[k]	High[e]
5. Organic matter depletion Med	Low-med[e]	Med	Low	Low-high[d]	Low-med[k]	High[e]
High	Med-high[e]	Med-high[e]	Low	Med-high[d]	Med-high[e,k]	Very high[e]
6. Roughness/ cover reduction Med	Med	Med	Med	Low-high[d]	Med[k]	Low-med[e]
High	High	High	V high	Med-high[d]	High[k]	Med-high[e]
7. Loss of natural vegetation Med	-[l]	-[l]	-[l]	-[l]	Med-high[k]	-[l]
High	-[l]	-[l]	-[l]	-[l]	High-v high[k]	-[l]
8. Loss of species/ habitats Med	-[l]	-[l]	-[l]	-[l]	Med-high	-[l]
High	-[l]	-[l]	-[l]	-[l]	High-v high	-[l]

[l]Groundwater discharge and recharge are not considered as the effect of wetlands on these processes is complex and poorly understood. However, it would appear that factors having a high impact on streamflow regulation are also generally likely to impact negatively on groundwater discharge and recharge.

Note: explanations for the ratings in the table are given on the following page.

Table 1.1 (continued) Explanations of ratings

[a] For a given impact, the loss of benefit will be greater if downstream water users are present and, in the case of water purification, also if the wetland is receiving pollutants.

[b] For a given impact the loss of benefit will be greater if there is floodable property downstream of the wetland.

[c] This depends on the size of the channels and their capacity for containing floodwaters. If this is low and the channels are readily filled and overflow occurs across the wetland then the reduction in flood attenuation benefits would be low.

[d] The impact is strongly dependent on erosion hazard and is likely to be particularly high if the erosion hazard is high.

[e] The high impact would result only if the wetland was acting as a C/S sink prior to the impact, as is likely to be the case if permanently wet areas were present. It should be noted, however, that on a global scale South Africa's wetlands contribute less than 0.05% of the worlds peat resources, which comprises the primary C sink provided by the country's wetlands (Grundling, 1997. *Pers. comm.* Council for Geoscience, Pretoria).

[f] This depends greatly on the particular outlet control and water abstraction from the dam.

[g] This depends on the extent to which the dam is maintained full and therefore with a low capacity for storing additional water.

[h] The effect of dams on erosion control is often positive but is negative where dams are incorrectly built and burst.

[i] The impacts will only be high if the wetland's capacity for assimilation is exceeded, resulting in a feedback effect.

[j] Water quality alterations would generally not detract from these benefits. Even if, for example, an increase in nutrients resulted in a change from a *Cyperus* dominated wetland to a *Typha* dominated wetland there would be little change in structure. However, if extreme water quality changes resulted in a change in structure (e.g. a dramatic increase in salinity causing the loss of *Phragmites australis*) the impacts on these benefits are likely to be high.

[k] Within a relatively small spatial area the effect may be positive, by increasing habitat diversity. This would apply particularly to wetlands which previously supported large herbivores that would naturally have disturbed the wetland.

[l] The impact of natural vegetation loss and threatened species/habitat loss on this particular benefit depends on how this in turn affects impact factors 1 to 7.

The effect on ecological benefits depends directly on the extent to which natural vegetation is replaced and populations of wetland-dependent species, particularly threatened Red Data species, are reduced (see Box 2). It also depends indirectly on factors 1 to 7. As the presence of water is the dominant factor affecting the plant and animals in a wetland, the greater the impact on the hydrology, the greater will usually be the loss of ecological benefit. Thus, in most cases where land-use activities detract from the erosion control and hydrological benefits of a wetland, they will also detract from the ecological benefit.

Box 2 Threatened animal species dependent on freshwater palustrine wetlands in South Africa

Cape caco (*Cacosternum capense*)
Striated caco *Cacosternum striatus*
Long-toed tree frog (*Leptopelis xenodactylus*)
Pickersgill's reed frog (*Hyperolius pickersgilli*)
Mist belt chirping frog (*Arthroleptella ngongoniensis*)
Micro frog (*Microbatrachella capensis*)
Cape chirping frog (*Arthrolptella lightfooti*)
Marsh frog (*Poyntia paludicola*)
Arum lily frog (*Hyperolius horstoki*)

Wattled crane (*Grus carunculata*)
White-winged flufftail (*Sarothrura ayresi*)
Grass owl (*Tyto capensis*)

Water rat (*Dasymus incomtus*)
Serval (*Felis serval*)
African striped weasel (*Poecilogale albinucha albinucha*)

Environmental Impact Assessment (EIA) and WETLAND-USE

In terms of the regulations under the Environmental Conservation Act, 1989, several activities are listed which may have a substantial detrimental effect on the environment and which require that application to be made to the relevant authority (see DEAT, 1998a). Those listed activities of particular relevance to wetlands include: the reclamation of inland water including wetlands; construction of dams, levees or weirs affecting the flow of a river; and change of land-use from use for grazing to any other form of agricultural use. IMPACT-ASSESS provides a useful framework for a scoping study as defined by DEAT (1998b) in the EIA procedure. If the scoping report shows that there are likely to be significant impacts and the intention is to continue with the proposed land-use then a full impact assessment (which is beyond the scope of WETLAND-USE) would be required to assess if the proposed land-use was acceptable. EIA falls within Integrated Environmental Management (IEM) (DEA, 1992 and DEAT, 1998b) and the Environmental Impact Management initiative of the DEAT. WETLAND-USE assists in dealing with wetlands in this broader context, which is designed to ensure that the environmental consequences of development are understood and adequately considered in planning and implementation (see WETLAND-USE Part 2). WETLAND-USE follows the underlying principles of IEM, including: decision making is informed, accountable, and open, involving the relevant authorities and stakeholders; alternative options are considered; all of the above are done from the beginning of the process; and development is equitable and sustainable (see DEAT, 1998b). *For further information see:* Part 2, Section 5.1.

LAND USE-RECOMMEND

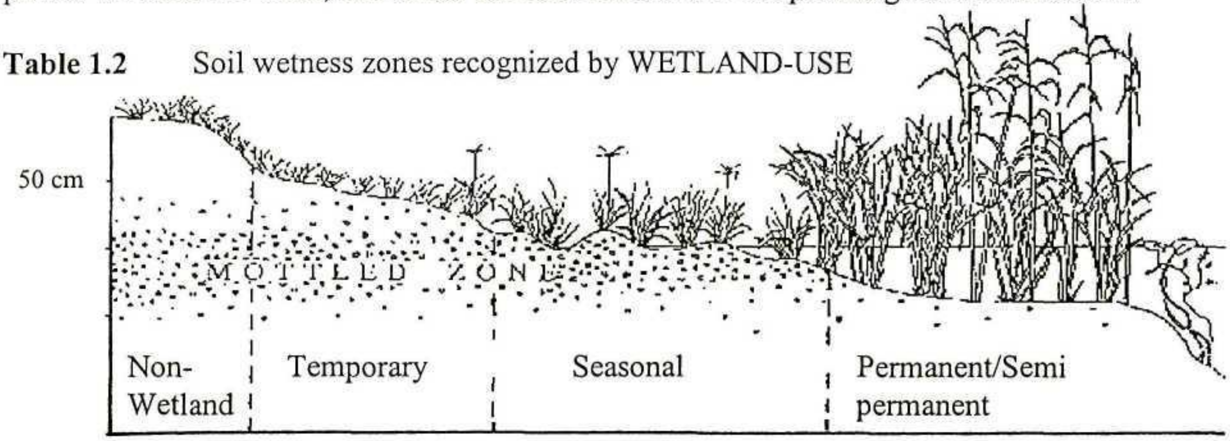
LAND USE-RECOMMEND provides recommendations aimed at minimizing the environmental impacts of the chosen land-use, while at the same time maximizing the land user's benefit. Although broad recommendations, reference documents and expertise are given for a wide range of land-uses (e.g. roads and ecotourism) the focus is primarily on agricultural land-uses, for which more comprehensive recommendations are given. For crops and planted pastures, the recommendations deal mainly with minimizing the impact of such activities as fertilizer application on the hydrological values of the wetland. For the grazing of natural wetlands, the recommendations focus on regulating the **stocking rate** and timing of grazing. Burning recommendations concern timing and frequency of fires as well as measures designed to influence fire behaviour.

1.3 Wetness zones used by WETLAND-USE to describe the wetness of wetland areas

To begin, what is a wetland? Wetlands are areas transitional between terrestrial and aquatic systems, where the soil is flooded or saturated at or close to the soil surface frequently and long enough for **anaerobic** conditions to develop which favour the growth of predominantly water loving (hydric) plants and particular soils features (e.g. low **chroma** matrix colours). A wetland is therefore defined in terms of hydrology (flooded or saturated soils), plants (adapted to saturated soils: see Appendix 3) and soil (show hydric features: see Table 1.2). Wetlands range from areas which remain permanently flooded or saturated to the soil surface for the entire year to areas which are flooded or saturated at or close to the soil surface for only a few weeks in the year but still long enough to develop anaerobic conditions. Many wetland areas are not wet all the time. The term "wetland" includes all those areas commonly called a **marsh**, **swamp**, **vlei** or **bog**.

In order to make informed wetland management decisions it is important to identify the boundary of the wetland and to zone the wetland into broad areas which are as homogeneous as possible from a management point of view. The **water regime** is generally one of the most important factors affecting functioning and management potential. Thus it is necessary to describe the wetness zones within a wetland. As long term hydrological data are usually lacking, the best surrogate (substitute) measure possible, soil morphology, is used by WETLAND-USE. A four class system is used for identifying wetness zones based on soil morphological features (notably colour of the soil matrix and the presence and abundance of **mottles**) and vegetation (Table 1.2). The description of soils, is a very important part of WETLAND-USE, and forms the basis for its land-use planning recommendations.

Table 1.2 Soil wetness zones recognized by WETLAND-USE



	SOIL WETNESS ZONES			
SOIL	Non-wetland	Temporary	Seasonal	Permanent/Semi-permanent
Soil depth 0-10 cm	Matrix usually brown/red (**chroma** >1) No/very few mottles Nonsulphidic	Matrix brown to greyish brown (chroma 0-3, usually 1 or 2) Few/no mottles Nonsulphidic	Matrix brownish grey to grey (chroma 0-2) Many mottles Sometimes sulphidic	Matrix grey (chroma 0-1) Few/no mottles Often sulphidic
Soil depth 30-40 cm	Matrix usually brown (chroma >2) No/few mottles	Matrix greyish brown (chroma 0-2, usually 1) Few/many mottles	Matrix brownish grey to grey (chroma 0-1) Many mottles	Matrix grey (chroma 0-1) No/few mottles Matrix chroma: 0-1
VEGET-ATION (see Appendix 3)	Dominated by plant species which occur extensively in non-wetland areas; hydrophytic species may be present in very low abundance	Predominantly grass species; mixture of species which occur extensively in non-wetland areas, and hydrophytic plant species which are restricted largely to wetland areas	Hydrophytic sedge and grass species which are restricted to wetland areas, usually <1m tall.	Dominated by: (1) emergent plants, including reeds (*Phragmites australis*), **sedges** and bulrushes (*Typha capensis*), usually >1 m tall (**marsh**); or (2) floating or submerged aquatic plants.

Key to Table 1.2:
Sulphidic soil material has sulphides present which give it a characteristic "rotten egg" smell, and nonsulphidic material lacks sulphides.

Soil material (usually in the seasonal zone) may be so greatly mottled that the mottles make up a greater area than the matrix, which may be confusing when determining the chroma of the matrix.

Chroma refers to the relative purity of the spectral colour, which decreases with increasing greyness. To determine chroma, a **Munsell** colour chart is required. If this is not available then in order to characterise the colour of the soil matrix, use the following colour descriptions, given in order of increasing greyness:
→Brown/Red →Greyish brown →Brownish grey →Grey

How to describe soil wetness zones in the field

Start outside of the wetland and extract a core of soil to a depth of 50 cm using a soil auger (a hand tool for boring holes into the ground). Then walk in a straight line into the wetland, extracting cores at intervals along the transect. Identify the wetness zone of each of the soil samples by using Table 1.2. The boundary of the wetland may be unclear and it may be necessary to go back along the transect and take further sample/s. Remember, however, that the boundary is a human construct that we place along a gradually changing gradient.

The upper 50 cm of soil is considered as this is where most of the roots of herbaceous wetland plants are concentrated. The presence of surface water or a shallow water table may serve as additional indicators but it should be remembered that these change according to season and rainfall pattern. Landform setting may also assist in confirming the presence of a wetland, with wetlands tending to be associated with flat, **bottomland** (valley bottom) areas, and the lowest areas generally being the wettest. However, not all bottomlands are wetlands and, furthermore, wetlands may be found on hill slopes, particularly where groundwater is discharging such as at the "eye" of a stream (see WETLAND-USE Booklet 2: Kotze 1997b).

Some problems you may have in identifying soil wetness zones using Table 1.2

In some wetlands, mottles are very scarce throughout the wetness zones. Nevertheless, the general trend is likely to be encountered of an increase and then a decrease in mottle abundance as one moves from outside the wetland and through the temporary and seasonal zones into the permanent zone.

The water regimes of certain soil types are very difficult to determine based on soil morphology. These soil types include the following.

* **Mollisols (Melanic A) and vertisols (Vertic A):** are dark coloured, base-rich soils typically having dark topsoil layers and low chroma matrix colours to considerable depths. The low chroma colours of these soils are not necessarily owing to prolonged saturation.
* **Soils with humic A horizons:** which refers to a freely draining topsoil **horizon** with low base status, that has accumulated high amounts of humified organic matter under moist, cool or cold climatic conditions. It differs from organic horizons in that both site and profile drainage is good (Soil Classification Working Group, 1991). Humic A horizons may be characterized by low chromas, and if they are deep, this may lead to the soil being mistakenly identified as hydric.
* **Entisols:** are recently formed soils that have little or no evidence of pedogenically developed horizons, e.g. soils of the Oakleaf form. Some hydric entisols are easily recognised, but others pose problems because they do not possess typical **hydric soil** field characteristics.

For further information on delineating and identifying wetland zones see Kotze (1997b) or consult someone with experience in the delineation of wetlands. For information on the South African Soil Classification System (Soil Classification Working Group) in relation to wetlands see Appendix 1. As described in Appendix 1, some of the soil forms in this system are characteristic wetland soils, while other forms are usually or only sometimes associated with wetlands.

SECTION 2, INFO-COLLECT

Note: 1. You may be unable to gather the information requested for all ***descriptors****. That which is not available indicate with "NA".*

2. Further descriptors which are not considered essential to the assessment of the acceptability of individual land-uses and for making ongoing management decisions but which provide useful background and more detailed information are given in Appendix 2.

2A WETSITE-INFO

Requirements:

☞ 1 :50 000 topocadastral maps and 1:10 000 orthophotos, both available from the Surveyor General. Airphotos, available from the Chief Director: Surveys and Mapping, would also enhance the assessment, particularly if comparisons between photos could be made to detect change, using a recent set and the earliest set available.

☞ At least one site visit, preferably with a camera.

☞ A soil auger

How to gather the information:

☞ Do a preliminary **delineation** of the wetland boundary on the othophoto or topocadastral map.

☞ Read through Descriptors A1 to E3 to see what information is required. Those descriptors marked with "⌂" can often be obtained in the office.

☞ Always obtain permission from the landowner/authority to visit the wetland.

☞ Inspect the wetland in the field with the aid of transects. Complete each transect by starting outside of the wetland, finding the boundary of the wetland (see Section 1.3) and walking in a straight line across the wetland. At least one transect every 500 m to 1000 m of the wetland is required, depending on how varied the wetland is. If the wetland is very varied and has many land-uses applied to it then transects at more regular intervals are likely to be required. Mark the transect/s on the orthophoto. For each transect note the percentage distance occupied by the temporary, seasonal and permanent zones respectively (Table 2.1). To help you identify the zones take soil samples along the transect and refer to Section 1.3. Also, take particular note of features not easily visible from the air- or orthophotos, including: artificial drains; the extent and species of alien plants; details of crops (e.g. annual or perennial) and important localized features such as headcuts of erosion gullies and point sources of pollution.

☞ Mark the location of the important localized features (e.g. headcuts of erosion gullies) on the map and take photos of those that may require management attention.

☞ From a vantage point (e.g. on a hill next to the wetland) make any changes to the preliminary delineation on the map and complete the data sheet. Take a panoramic photo of the wetland.

☞ For particularly large wetlands (i.e. > 50 ha) complete separate data sheets for the different portions of the wetland.

Date/s of site visit/s ....

A1⌂. Wetland name ....

A2⌂. Geographical coordinates ....°........'S.........°........'E

A3⌂. Quaternary catchment No. ....

See "catchment" in Glossary

A4⌂. Veld Type (Acocks, 1953) .... or vegetation type (Low & Robelo, 1996) ....

Name, address & tel. of: (1) wetland assessors
....
....
....
....

(2) wetland owner/ management authority
....
....
....

A5⌂. Wetland surface area (ha) ....

Note: the area does not have to be wet at the time of the assessment to be classed as a wetland but should have wetland soils and/or vegetation (see Section 1.3). Temporary wetland areas may be wet for only a few weeks in the year, which you may miss in your site visit.

A6⌂. Recorded **Red Data** (threatened) animal and plant species found in the wetland

1. .... 2. ....

Note: a single site visit is not sufficient to identify all Red Data species that may be present, as some are difficult to observe and are not identifiable or are absent during certain seasons. Consult the relevant Provincial Conservation Department and the Wildlife and Environment Society of South Africa for possible information.

A7⌂. Wetland habitat type/s in the impact area which are considered on a provincial or national level to have been subject to particularly high levels of loss (e.g. forested wetlands) or to be particularly rare (e.g. dolomitic eye wetlands). ....

Forested wetlands, which are dominated by trees and often referred to as swamp forests, are most extensive at low altitudes in northern KwaZulu-Natal. A Dolomitic eye is the point where a dolomitic (calcium/magnesium carbonate deposits) aquifer is exposed to the surface. This usually results in a spring, which provides points of recharge and discharge for water contained in the aquifer.

A8. Noteworthy natural features (e.g. a heron breeding colony)...

Table 2.1 Information gathered for individual transects

Transect number	Percentage distance				Notes
	Temporary	Seasonal	Permanent	Hummocked[1]	
1					
2					
3					
4					
5					
6					

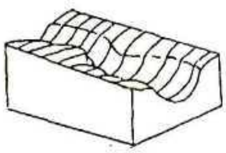
[1]"Hummocked" refers to areas with earth hummocks about 20-50 cm in diameter and 50 cm high, covered with vegetation, and usually permanently saturated between hummocks.

A9. Wetness zones (defined in Section 1.3)

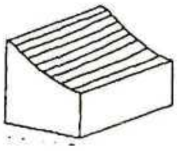
	% cover	Dominant species (see Appendix 3 for a guide to some common wetland plant species)
a. Temporary	....	....
b. Seasonal	....	....
c. Permanent	....	....
d. Hummocked	....	....

Although it is not essential to identify the dominant species for an assessment, this provides useful supplementary information

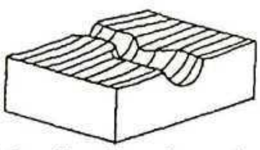
A10. Landform setting/s which best describes the form of the wetland



☐ **Channel:** a water course, which may be shallow or deep but always has clearly defined margins



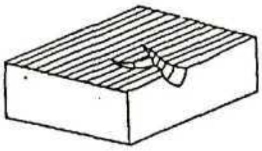
☐ **Hill slope:** situated outside of valley bottom areas and is characterized by colluvial (i.e. transported by gravity) movement of material.



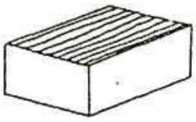
☐ **Channelled valley bottom:** a valley bottom area, often described as a floodplain, through which a channel passes.

* flooding from the main channel is frequent (i.e. more frequently than one out of every three years) ☐
* flooding is infrequent ☐

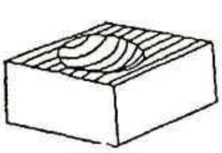
Valley bottoms are the low-lying areas of a valley characterized by the alluvial transport and deposition of materials by a stream/river.



☐ **Flow concentration area:** that area where diffuse flow, either across a non-channelled valley bottom or down a slope, concentrates to flow within a channel.



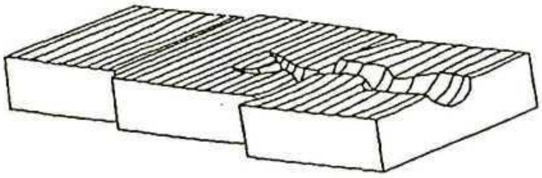
☐ **Non-channelled valley bottom:** a valley bottom area lacking a channel (and therefore characterized by the diffuse flow of water across its surface).



☐ **Depression:** a basin shaped area which is inward draining and has no outlet and usually does not have clearly defined margins.

*found within a valley bottom area ☐
*found outside of a valley bottom area ☐

Remember that a wetland may consist of a combination of landforms. One of the commonest of these, particularly in large wetlands, is shown here: In this case you would mark all of the three landforms as present.



A11. Percentage area and rating of on-site land-use impacts on the indirect wetland benefits

		Level of impact (negligible, low, medium, high)	Describe effect on wetland (only medium & high)	*For guidelines for ongoing management see:*
Dams	☐ .....%	☐☐☐☐	....	*Section 4.6*
Weirs	☐ .....%	☐☐☐☐	....	*4.6*
Planted pastures (Drains: Yes ☐ No☐)	☐ .....%	☐☐☐☐	....	*4.3*
Subsistence crops (Drains: Yes ☐ No ☐)	☐ .....%	☐☐☐☐	....	*4.4*
Commercial crops (Drains: Yes ☐ No ☐)	☐ .....%	☐☐☐☐	....	*4.4*
Sugar cane (Drains: Yes ☐ No ☐)	☐ .....%	☐☐☐☐	....	*4.18*
Forest plantations	☐ .....%	☐☐☐☐	....	*4.18*
Buildings/infrastructure	☐ .....%	☐☐☐☐	....	*4.13&4.10*
Informal settlement	☐ .....%	☐☐☐☐	....	*4.13*
Eroded land	☐ .....%	☐☐☐☐	See A13	*4.7*
Other disturbed areas (e.g. mining)	☐ .....%	☐☐☐☐	....	*4.11*
Infilling	☐ .....%	☐☐☐☐	....	*4.10*
Alien invasive vegetation	☐ .....%	☐☐☐☐	Alien species:..	*4.8*
Natural vegetation (with artificial drains)	☐ .....%	☐☐☐☐	....	*4.1&4.7*
Natural vegetation (without artificial drains)	☐ .....%	-	....	*4.1*
Natural vegetation (rehabilitated)	☐ .....%	-	....	*4.1*
Livestock: grazing	☐ -	☐☐☐☐	....	*4.2*
movement (trampelling)	☐ -	☐☐☐☐	....	*4.2*
Mechanized cutting of natural vegetation	☐ -	☐☐☐☐	....	*4.5*
Hand cutting of natural vegetation	☐ -	☐☐☐☐	....	*4.5*
Hunting	☐ -	☐☐☐☐	....	*4.16*
Fishing	☐ -	☐☐☐☐	....	*4.16*
Medicinal plant harvesting	☐ -	☐☐☐☐	....	*4.17*
Water abstraction	☐ -	☐☐☐☐	....	*4.6*
Bird-watching	☐ -	☐☐☐☐	....	*4.15*
Water sports	☐ -	☐☐☐☐	....	*4.15*
Solid waste (litter)	☐ -	☐☐☐☐	....	*4.20*
Roads and rail roads	☐ -	☐☐☐☐	....	*4.12 & 4.10*
Bridges	☐ -	☐☐☐☐	....	*4.12 & 4.10*
Powerlines	☐ -	☐☐☐☐	....	*4.14*
Other/s	☐ -	☐☐☐☐	....	

Note: "impact" refers to an effect which reduces the indirect benefits supplied by a wetland. When assessing level of impact see Box 1 and Table 1.1.

A12. Total % of the wetland lost ...... *Note: a wetland area is "lost" if it has been developed or degraded so that the indirect benefits it supplies are severely limited, as would be the case if it was eroded, dammed or drained and planted to crops or pastures. A12=100% - (Natural vegetation without artificial drains + Natural vegetation rehabilitated).*

A13. Erosion type,

Erosion type		Severity (negligible, low, med., high)	Describe whether currently active & the causes & effect on wetland
Streambank	☐	☐☐☐☐	....
Gully, within flow concentration area	☐	☐☐☐☐	....
Gully, outside of flow conc. area	☐	☐☐☐☐	....
Sheet	☐	☐☐☐☐	....

Note: when assessing gully erosion, pay particular attention to the headcut/s of the gully to see if they are actively eroding or have stabilized.

A14. What is the frequency (e.g. every year) and timing (e.g. winter/early spring) of burning? .... *(For management recommendations see Section 4.1)*

A15. Land ownership types in the wetland and estimated % contribution of each land ownership type (indicate the boundaries on the wetland map)

Privately owned land	☐	Declared protected area	☐ ....
Government owned/ municipal land	☐	Natural Heritage Site*	☐ ....
Communally owned tribal land	☐	Site of Conservation Significance*	☐ ....

**These are not land ownership types but are of relevance to the use of land.*

A16. Is there evidence of high nutrient concentrations entering the wetland (e.g. algal blooms or actual measurement of high concentrations)? ....

Note: consult the local water authority for information they may have regarding descriptors A16-A18 (for ongoing management recommendations see Section 4.19).

A17. Is there evidence of waterborne toxicants entering the wetland (e.g. fish kills or actual measurements of hazardous concentrations)? ....

A18⌂. Water-associated diseases (e.g. bilharzia) known to be present in the wetland. ....

Note: consult the local hospital or health office for information (see also Section 4.21).

A19. Is the wetland culturally important and, if so, for what reason (e.g. it is a site for religious ceremonies). ....

2B LOSS-INFO

Requirements:☞ All <u>available wetland inventory information</u> for the region. For much of the country wetland inventory information is lacking. Wetland inventories have, however, been conducted for some **catchments.** See DEAT (1998c) for a listing of inventories.

B1⌂. Extent of wetland loss (expressed as a % of total wetland area) in the quaternary catchment in which the wetland falls .....

Each primary catchment in South Africa has been sub-divided into secondary catchments, which, in turn have been divided into tertiary and finally into quaternary catchments. These sub-divided catchments provide the basis on which catchments are sub-divided for integrated catchment planning and management (see DWAF [1994]).

B2⌂. Extent of wetland loss (expressed as a % of total wetland area) in the Veld Type (Acocks, 1953) .or the vegetation type (Low and Robelo, 1996) in which the wetland falls ....

Note: if information on wetland loss for the Veld Type is lacking then information on the general loss of the particular Veld Type may be used (see Descriptor B3) based on the assumption that if this is high then the loss of wetland area within the Veld Type will also be high.

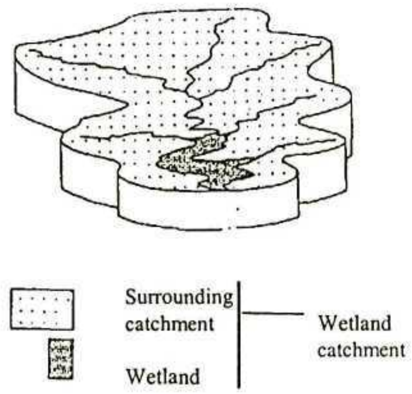
B3⌂. Extent of overall loss of the Veld Type (Acocks, 1953) or the vegetation type (according to Low and Robelo, 1996) in which the wetland falls ....

Several provincial conservation organizations have records of loss of natural vegetation either according to the system of Acocks (1953) or Low and Robelo (1996).

2C CATCHMENT-INFO

Requirements:☞ 1:50 00 map and orthophotos and the latest airphotos, if available.

The "wetland catchment" refers to the area up-slope of the wetland (from which water flows into the wetland) and includes the wetland itself. The "surrounding catchment" excludes the wetland itself.



C1. Land covers in the surrounding catchment and the approximate % area under each.

		With irrigation?		
			Dams	□ .....%
Planted pastures	□ .....%	Yes □ No□	Eroded land	□ .....%
Subsistence (non-mech'ed) crops	□ .....%	Yes □ No□	Buildings & informal settlements	□ .....%
Commercial (mechanized) crops	□ .....%	Yes □ No□	Mining	□ .....%
Commercial sugar cane	□ .....%	Yes □ No□	Natural vegetation	□ .....%
Forest plantations	□ .....%		Other:	□ .....%

C2. Extent to which the natural runoff is being reduced by land-uses in the catchment that reduce runoff (i.e. damming, irrigation and afforestation).
Negligible □ Low □ Moderate □ High □

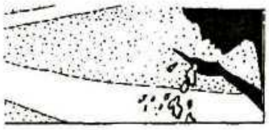
C3. Level of sediment input into the wetland. Sources contributing sediments in the wetland's catchment include: areas (>0.5 ha) which are cultivated or eroded land, roads, surface mines and forest plantations.
Negligible □ Low □ Moderate □ High □

Note: the closer a sediment or nutrient/toxicant source is to the wetland the more likely it is to contribute to input into the wetland, particularly if it is connected directly to the wetland by a stream.

C4. Level of nutrient/toxicant input into the wetland. Non-point sources in the wetland's catchment include areas (>0.5 ha) of fertilized crop or pasture land; areas (>0.5 ha) where the density of houses with septic tank systems exceeds 6 houses per ha; mines; pesticide treated areas; and oil runoff sites (*see C3 Note*). Point sources in the wetland catchment that may contribute pollutants include sewage or industrial outfalls, dairies or feedlots. See also A16 and A17.
Negligible □ Low □ Moderate □ High □

C5. Based on the descriptor values for C3 and C4, indicate the level of combined sediment and nutrient/toxicant input.
Negligible □ Low □ Moderate □ High □

2D DOWNSTREAM-INFO



Requirements:☞ 1:50 00 map and orthophotos and preferably a brief visit.

All wetlands are considered to be hydrologically important, and the two descriptors below seek to determine whether a wetland is particularly important from the point of view of having *identifiable* downstream beneficiaries. This concerns the extent of water use and floodable properties downstream of the wetland. This information is useful in determining the hydrological benefits currently being provided by a wetland. Although enhancement of sustained streamflow is not considered specifically, water users deriving benefit from water purification are also likely to derive benefit from sustained streamflow. Ability of a wetland to influence water quality and attenuate floods decreases with increasing distance downstream of the wetland outlet, and from an assessment point of view it becomes increasingly impractical to assess downstream influence as downstream distance increases. A cut-off of 12 km is used. It should be emphasised, however, that there are several interacting factors determining the wetland's distance of influence, including the size of the wetland and the influence of tributaries entering downstream. However, these are considered to be beyond the scope of WETLAND-USE.

D1. Is there direct use of stream water downstream of the wetland by people for irrigation, stock watering or, particularly, for domestic use?
Yes □ No □

D1 and D2 will generally need to be described based on local knowledge. If this is lacking and you do not have time to inspect the downstream area, these descriptors should best be left out. Descriptors D3-D8 given in Appendix 2 provide a semi-quantitative means of describing the level of water use and amount of floodable property in the downstream area of influence based on an inspection of the area.

D2. Is there floodable property downstream of the wetland?
Yes □ No □

2E OVERALL CURRENT STATE AND FUTURE THREATS

E1. Assess the overall level of impact on the wetland based on on-site and catchment impacts.
Negligible □ Low □ Moderate □ High □

E2. Likely future changes (notably, active erosion and further invasion by alien plants) ....
....

E3. Which are the priority management activities that need to initiated? (i.e. where are the "flashing lights"?). *Consider E1 and other land-uses given in A11.*
....
....

2F IMPACTSITE-INFO

This concerns the <u>area to which the proposed land-uses are to be applied</u>. If the impact area includes more than one wetness zone type (e.g. temporary, seasonal and permanent) then for the purposes of the assessment the wetness zone should be taken as the wettest zone.

Requirements:☞ as for WETSITE-INFO but Soil Classification: a taxonomic system for South Africa (Soil Classification Working Group, 1991) is also required.

F1⌂. Indicate on the wetland map, the area to which the proposed land-use will be applied and which of the following land-uses is being considered? ....
- a. natural vegetation for stock grazing: answer questions F6 to F12
- b. cutting/harvesting natural vegetation: answer questions F6 to F12
- c. planted pastures: answer questions F2 and F6 to F19
- d. crops (mechanized): answer questions F3 and F6 to F19
- e. crops (non-mechanized/traditional): answer questions F3 and F6 to F19
- g. dams: answer questions F4 to F7 and F14 to F20

F2⌂. Pasture species............................, and whether □ annual or □ perennial
F3⌂. Crop type ....
F4⌂. Indicate (Y or N) if an outflow control is intended for inclusion in the dam wall ....
F5⌂. Intended uses of the dam: □ irrigation □ waterfowl hunting □ stock watering □ watersports □ fishing
F6. Under which of the land ownership types given in A15 does the impact area fall. ....

F7. Surface area of the impact area (ha). ....

F8. Landform factor (L) of the impact area (see A10). ......
□ Impact area is a flow concentration zone then L=5
□ Impact area includes a channel then L=2
□ Impact area is a slope or valley bottom flat or depression (away from any flow concentration area or channel) then L=1
□ Impact area is a depression outside of a valley bottom then L=0.5

F9. Slope factor (S) of the impact area. *This should preferably be estimated from 1: 10 000 orthophotos.*
□ <1% Slope: S=1 □ 1-3% Slope: S=2 □ 4-15% Slope: S=3 □ 16-30% Slope: S=4 □ >30% Slope: S=5
Note: in a 1% slope, for every 100m travelled horizontally there is a vertical drop of 1 m.

F10. Soil form .... and soil family .... according to *Soil Classification* (see Soil Classification Working Group, 1991 in References).

F11. Erodability (i.e. the K value) of the soil (using Appendix 1, Table A2) ....
Very low (0.15) □ Low(0.2) □ Moderate (0.3) □ High (0.4) □ Very high (0.5) □

F12. Erosion hazard index (EH) for the site ......, where EH= L x S x K, and L= Landform setting factor (Descriptor F8); S= Slope factor (Descriptor F9); K= Soil erodability (Descriptor F11).
An example of a wetland site with an extremely high erosion hazard is one in a channel, with a slope of 24% and with an Estcourt form (which has a very high erodability), where: EH =2 X 4 X 0.5 =4. An example of a wetland site with a low erosion hazard is one on a flat setting away from a channel, with a Katspruit form, Lammermoor family (moderate erodability) and a slope of 0.1%, where: EH =1 X 1 X 0.3 =0.3.

F13. Using Table 1.2, Section 1.3, determine the soil wetness zone.
Permanent □ Seasonal □ Temporary □
Note: if an area is hummocked it should be considered as permanent. If more than one wetness zone is present in the impact area, that which is wettest should be taken.

F14. Red Data species (see Descriptors A6) in the impact area. ....
Note: a Red Data species present in the overall wetland may not be present and dependent on the impact site. Consult the relevant Provincial Conservation Department and the Wildlife and Environment Society of South Africa for possible information.

F15. Wetland <u>habitat type/s</u> in the impact area which have been subject to <u>high levels of loss or</u> are <u>rare</u> (see Descriptor A7). ....

F16. Severity of existing erosion within the impact area.
Negligible □ Low □ Moderate □ High □

F17. Extent (in hectares) of the impact area that is currently untransformed (i.e. not drained, planted to crops or pastures or dammed) .....

F18. Roughness of the wetland surface in the impact area ('N' is Manning's **roughness coefficient**).
□ Tall (>3 m), dense, robust emergent vegetation: N= 0.08
□ Moderately tall (1-3 m), dense, robust emergent vegetation: N= 0.06
□ Short and sparse emergent vegetation: N= 0.04
Note: the roughness of the wetland surface slows down the flow of water, which assists in erosion control and water purification.

F19. Direct benefits (e.g. harvesting of plants for craftworks, medicinal plants, natural grazing) currently being derived from the impact area in its untransformed state (see A11).
Negligible □ Low □ Moderate □ High □
Describe the benefits ....
Note: this refers to the benefits that would be lost with transformation.

F20. Is the wetland in a catchment where further damming is undesirable from a water supply point of view and therefore which has been designated as an area where no further dam permits will be issued by The Department of Water Affairs and Forestry? Yes □ No □

SECTION 3, IMPACT-ASSESS

The impact of different land-use activities on the indirect benefits provided by wetlands varies considerably according to the nature of the wetland area and its context (e.g. does it have Red Data species or are there people downstream of the wetland that use the water that has flowed through the wetland?) and according to the nature of the particular land-use (e.g. does it involve intensive and frequent disturbance of the soil?).

3.1 Steps to follow in carrying out an assessment

In order to assess the level of impact and the acceptability of a proposed land-use you will need to have completed INFO-COLLECT. Now, follow these three steps:

①Complete Table 3.1, page 24, by following the instructions given in the table →

②Assess the overall level of impact using Box 3

③ Seek alternatives to the proposed land-use using Box 4

- Low: the proposed land-use is acceptable, proceed provided that recommendations in Section 4 are followed
- Medium
  - No alternative: the proposed land-use is acceptable, proceed provided that **mitigation** is carried out (see Section 3.3) and that recommendations in Section 4 are followed
  - Alternative present: the proposed land-use is unacceptable
- High
  - No alternative: if the applicant wishes to proceed, a comprehensive impact assessment is required, possibly including tools such as benefit-cost analysis and Scenario-based Policy Planning, which is beyond the scope of WETLAND-USE[4]
  - Alternative present: the proposed land-use is unacceptable

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[4]A cost-benefit analysis requires the expertise of an economist and possibly also biological or hydrological expertise to gather and interpret more comprehensive data on the indirect benefits provided by the wetland. Consideration would need to be given to the direct benefits for the user as well as the contribution it will make to the economy, particularly how it affects poor people (e.g. how will it stimulate new employment opportunities or stabilize existing employment levels in the local region; stimulate the local economy; generate significant new taxes; or contribute to local food security?). Scenario-based Policy Planning (SBPP) incorporates diverse and conflicting objectives into public policy evaluation in a systematic and coherent manner. It provides a uniform framework for handling and comparing tangible and intangible goals of society without reducing these to monetary or similar terms (Stewart *et al.*, 1997).

Table 3.1 Checksheet for determining the likely impacts of particular land-uses (additional land-uses are given on the following page)

Descriptors (obtained in INFO-COLLECT)		*Site*	*Example*	**Impact level for individual land-uses:** *Trad. crops*			*Mech. crops*		
				Low	**Med.**	**High**	**Low**	**Med.**	**High**
F14& F15	Red Data species or Threatened habitat types	.....	No	No □		Yes □	No □		Yes □
A12, B1&2	Cumulative wetland loss	.....	30%	<20%□	20-50%□	>50%□	<20%□	20-50%□	>50%□
F12	Site erosion hazard	.....	1.2	<0.4 □	0.4-1.0 □	>1.0 □	<0.4 □	0.4-1.0 □	>1.0 □
F13	Wetness zone	.....	S	T/S □		P □	T □		S/P □
D1	Downstream water use	.....	N	N □	Y □		N □		Y □
C5	Pollutant input	......	M	N/L □	M □	H □	N/L □	M □	H □
F16	Severity of existing erosion	......	L	N/L □	M □	H □	N/L □	M □	H □
F17	Extent of impact area untransformed	......	2 ha	<0.5ha□	0.5-5ha□	>5ha□	<0.5ha□	0.5-5ha□	>5ha□
F18	Roughness coefficient	.....	0.06	<0.05□	>0.05□		<0.05□	>0.05□	
F19	Current direct benefits	.....	L	N/L □	M □	H □	N/L □	M □	H □
F20	Catchment unsuitable for dams	.....	N	-	-	-	-	-	-

Degree of wetness: T= Temporarily wet S= Seasonally wet P= Permanently wet

Level of impact: N=Negligible L=Low M=Medium H=High

Instructions for use of the checksheet

- Fill in the site column for all descriptors relevant to the land-use that is being proposed (e.g. traditional crops). Those descriptors which are not relevant to a particular land-use are indicated by a '-' in the land-use column in question.
- Based on the descriptor values, indicate with a cross in the appropriate box the level of impact associated with each descriptor.
- For all of the land-use types assessed it is assumed that the ongoing recommendations given in Section 4 will be followed (e.g. the area will not be grazed more heavily than recommended).

Note for A12, B1, & 2 (Cumulative loss): include the proposed area to be transformed with the existing values for A12, B1 and B2 (e.g. if 25% of the wetland was developed and the proposed development would add a further 5% to the area developed then A12=30%). Out of the respective values for A12, B1 and B2 take that which is highest percentage. For example, if A12=30%, B1=28%, and B2=41% then the cumulative loss for the assessment would be taken as 41%..

Note for F17: the loss of indirect benefits to society as a result of transformation of a wetland which has already been developed/transformed is less than that which would otherwise result if the wetland was not transformed.

Note for traditional crops: it is assumed that artificial drainage channels are not involved, crops tolerant of waterlogging are planted and pesticides, chemical fertilizers and herbicides are not used. If these assumption do not hold then it should be considered as mechanized crops.

Note for annual pastures: if a pastures is annual, consider it as mechanized crops because, although providing better cover once established, annual pastures involve considerably more frequent disturbance of the soil than perennial pastures. In addition, commonly grown annual pastures tend to have lower wetness tolerances than the commonly grown perennial pasture species: Festuca arundinacea and Acroceras macrum (see Section 4.3).

Note for dams: it is assumed that the dam will be structurally sound and have an adequate spillway. Consult the local soil conservation officer for more information.

Note that non-mechanized cutting of natural vegetation is not included in Table 3.1 but restrictions on the timing and extent of cutting (hand and mechanized) are given in Section 4.5.

Table 3.1 (continued) Checksheet for determining the likely impacts of particular land-uses

Impact level for individual land-uses:

Descriptor	*Graze*			*Mech. Cutting*			*Dams*			*Mech. Pastures*		
	Low	**Med.**	**High**	**Low**	**Med.**	**High**	**Low**	**Med.**	**High**	**Low**	**Med.**	**High**
F14&15	-	-	-	-	-	-	No □		Yes □	No □		Yes □
A12, B1&2	-	-	-	-	-	-	<20%□	20-50%□	>50%□	<20%□	20-50%□	>50%□
F12	<1.0□	1.0-2.8□	>2.8□	<1.0□	1.0-2.8□	>2.8□	-	-	-	<0.7□	0.7-1.8□	>1.8□
F13	T/S □	P □		T □	S □	P □	-	-	-	T □	S □	P □
D1	N □	Y □		-	-	-	N □	Y □		N □		Y □
C5	-	-	-	-	-	-	N/L □	M □	H □	N/L □	M/H □	
F16	N/L □	M □	H □	N/L □	M □	H □	-	-	-	N/L □	M/H □	
F17	-	-	-	-	-	-	<0.5ha□	0.5-5ha□	>5ha□	<0.5ha□	0.5-5ha□	>5ha□
F18	-	-	-	-	-	-	<0.05□	>0.05□		<0.05□	>0.05□	
F19	-	-	-	-	-	-	N/L □	M □	H □	N/L □	M □	H □
F20	-	-	-	-	-	-	No □		Yes □	-	-	-

Box 3 Criteria for assessing the likely overall level of impact of the land-use on the indirect benefits of the wetland:

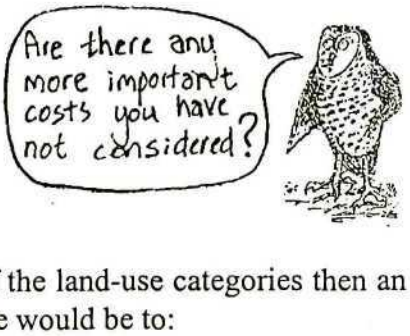
High= At least one of the relevant descriptors is high

Medium= At least three of the relevant descriptors are medium, and none are high

Low= Less than three of the relevant descriptors are medium, and none are high

In the example site given in Table 3.1 (which has an erosion hazard of 1.2) if traditional crops were being considered then the impact level for site erosion hazard is high and the likely overall impact would therefore be high. If, however, perennial pastures were being considered for the example site, the impact levels are predominantly medium (i.e. 6 out of the 10 relevant descriptors are medium) and none are high, resulting in the overall likely impact being medium. If, to take another example, the site had an erosion hazard index of 2.9 then both crop and perennial pastures are likely to have high impacts because both of their erosion hazard impact levels would be high. The reasoning behind the criteria is given in Section 3.2.

Note: additional factors that the assessor or stakeholders raise as further issues may need to be added to the assessment. For example, a wetland may be particularly important in providing natural habitat which acts as a corridor for the movement of certain animals and if the wetland were cultivated this would be lost.



If an assessment is required for a project which does not fit any of the land-use categories then an alternative way of assessing the likely impact of a proposed land-use would be to:

- Refer back to Box 1 and answer the 8 questions each dealing with a particular aspect of impact; and
- Assess how the above are affecting the indirect benefits provided by the wetland, by referring to Table 1.1.

This alternative method of assessing impacts is open to greater personal interpretation, and would be of particular use to assessors with much experience in wetland assessment.

Box 4 Considering alternatives to the proposed project

Is there an alternative site available outside of the wetland for the proposed development which has habitat that is less threatened or which has already been transformed; or is there opportunity for an alternative lower impact land-use within the wetland (see below)? □ yes □ no

Some possible low-impact alternative uses of natural wetlands

- Ecotourism: See Section 4.15
- Harvesting of indigenous plants for crafts: See Section 4.5 (note particularly Box 5)
- Livestock grazing: See Section 4.1 and 4.2
- Fishing and hunting: See Section 4.16

If managed correctly, the above land-uses provide possible ways of using a natural wetland area on a sustainable basis, with little or no loss in the indirect benefits provided by the area. Such land-uses may result in just as much economic benefits to wetland owners and local wetland users as uses (e.g. cultivation) which result in high impacts to wetlands. Another advantage is that the same area can be used for all of the above (i.e. a multiple-use system). This contrasts with many high impact land-uses that tend to reduce the number of uses available in the wetland.

The greater the benefits that are derived by a wetland owner from a functioning natural wetland, the smaller will be the incentive to modify/transform the wetland (e.g. by drainage). Consequently, the loss of value of the wetland to society that would occur with modification, would be avoided.

CONSIDER THE "NATURAL ALTERNATIVES!"

3.2 Reasoning behind the impact level criteria (see Section 5 for more detail)

Habitat, threatened species and cumulative wetland loss

Crop (mechanized and traditional) and planted pasture production involve the total replacement of the indigenous vegetation. Although a dam may improve the habitat provided by a wetland for certain common species such as the spur-winged goose (*Plectropterus gambensis*), the flooding of a wetland by a dam usually also results in the loss of most of the indigenous vegetation and makes the wetland unsuitable for specialized and threatened wetland-dependent species (e.g. the white-winged flufftail: *Sarothrura ayresi*). Consequently it is considered together with crop and pasture production as "transformation-orientated land-uses".

If any threatened wetland-dependent species or habitat types are present in the proposed site, or if the cumulative loss of wetlands in the individual wetland, the local quaternary catchment, or the Veld Type is high (i.e. >50%) then any transformation orientated land-use is likely to have an unacceptably high impact on the ecological benefits provided by the area. This is because wetlands with threatened species or habitats are of particular **ecological value**. Also, aside from the presence of Red Data species, if the cumulative loss of wetland area is already high, further loss is likely to have a greater impact than if the level of existing loss was low. The cumulative loss of wetlands is also of great relevance to the hydrological benefits provided by wetlands.

Site erosion hazard

On sites with very high erosion hazards no form of cultivation or any land-use involving machinery (including mechanized vegetation cutting) is considered acceptable. On sites which have medium erosion hazards, crop production is not considered acceptable because it requires that the soil be frequently disturbed (rendering it vulnerable to erosion) but perennial pastures are considered acceptable because the soil is disturbed considerably less frequently. Judiciously managed perennial pastures generally constitute less of an erosion hazard than crop production.

Wetness zone

Generally the wetter the area, the greater the likelihood that cultivation will have a high impact on the wetland (e.g. as a result of organic matter depletion). In permanently wet areas no form of cultivation is considered acceptable because no commonly grown crops are able to tolerate such conditions and the hydrology would have to be altered significantly, detracting from the hydrological and ecological values of the wetland area. In seasonally wet areas only pastures (e.g. tall fescue or Nile grass) and crops (e.g. madumbes) which are able to tolerate **waterlogged** conditions are considered acceptable as they do not require extensive hydrological modification.

Downstream water use

Drainage, disturbance of the soil and regular application of fertilizers, detracts from the water purification value of wetlands. Furthermore, should the wetland be disturbed and its hydrology altered, this may cause the accelerated release of pollutants already trapped in the wetland sediments, and may detract from the wetland's future water purification potential. Thus, if water is being used for human consumption in the downstream area, the conversion of the wetland to cropland could potentially detract from this benefit. Although dams are not as efficient in the removal of nutrients, particularly nitrogen, they perform a degree of water purification, notably in the trapping of sediment. As such, the water quality constraints on dams, although accounting for situations where pollutant inputs are high, are not as stringent as for the cultivation of crops.

The retention of water in wetlands is diminished when wetlands are drained, with the result that the streamflow regulation benefit provided by wetlands is reduced.

Pollutant input

If there was pollutant input to a wetland then the wetland is afforded opportunity for the purification of water. Thus, if its capacity for water purification were diminished (e.g. through drainage) then the loss of water purification benefits would be potentially greater than if it was not afforded this opportunity.

Catchment unsuitable for dams

Runoff is reduced in catchments which are dammed. This is particularly so in catchments where **evaporation** is high, where a high percentage area is occupied by dams and where there is abstraction of water from the dams. Thus, in certain catchments considered particularly important from a water supply point of view, severe restrictions have been placed on the construction of further dams to prevent excessive runoff reduction.

Extent of existing transformation of the wetland

If a wetland area is already transformed (e.g. if it is artificially drained) then the loss of benefits resulting from a further transformation (e.g. damming of the drained area) in the same area is likely to be less than would result if the area was un-transformed. This is not to exclude the possibility of rehabilitating transformed areas, but it is based on the premise that it is generally more cost-effective to place a priority on securing intact (un-transformed) wetlands than rehabilitating degraded ones.

Roughness coefficient

Transformation-orientated land-uses (including crops, pastures and dams) generally have a low surface roughness. Thus, if surface roughness is high in an untransformed wetland then surface roughness and its associated benefits are likely to be lost if any of these land-uses are applied to the wetland area.

3.3 Mitigation of impacts

Mitigation measures should compensate for the effects of the proposed land-use. For example, extra soil conservation measures may be used on a site that has an erosion hazard which would otherwise be considered too high for cultivation. The loss of important habitat at the **impact site** may be mitigated by restoring an equivalent area of wetland in the surrounding landscape. It should be stressed, however, that mitigation measures should not be seen as a "loop-hole" but rather as means of accounting for those instances where a potential wetland user is genuinely able to mitigate the effects of the proposed land-use. This will obviously require expert advice and need to be followed up by regular monitoring. Mitigation may be either on-site or off-site.

On-site mitigation
On-site mitigation may include such measures as:
- Avoiding changes to water flow patterns in the wetland
- Avoiding all unnecessary disturbance and soil compaction within the wetland
- Avoiding depositing spoil in wetland areas or having spoil washing into the wetland from nearby
- Keeping the area of impact as small as possible
- Controlling alien plants that may increase as a result of the disturbance
- Minimizing the impact on flow patterns through the wetland
- Setting aside topsoil from the area and using it for rehabilitation

Off-site mitigation
Off-site mitigation can be undertaken by:
- Creating, in other nearby location/s, the wetland area that has been impacted; or
- Rehabilitating existing degraded wetlands in other nearby locations.

In the USA the creation of original impacted wetlands in different locations has become a common mitigation strategy for balancing demand for land for development with the protection of ecosystems (LaRoe, 1986; and Kusler *et al.*, 1988). Creation of wetlands as a means of mitigation should, however, be approached with caution because these so called "created" wetlands often do not adequately compensate for the original (Kusler *et al.*, 1988). Furthermore, in South Africa we have very little experience in the re-creation of wetlands. Thus, it will be expected that the created wetlands are unlikely to be of equivalent quality as the original wetlands, and will only be possible for certain wetland types. Depression wetlands are likely to be the easiest to create. Wetlands on slopes are often found where particular geological phenomena result in the discharge of groundwater (see WETLAND-USE Booklet 2), making it very difficult to re-create these wetlands. Thus, it is recommended that wetland rehabilitation is preferable to wetland creation but this would obviously depend on suitable sites being available.

SECTION 4, LAND USE-RECOMMEND: MANAGEMENT GUIDELINES FOR INDIVIDUAL LAND-USES

From the sections given below, which deal with ongoing management guidelines for particular land-uses, proceed to the section which deals with the land-use/s that interest you.

Land-uses	Relevant sections
1. Burning[1]:	4.1
2. Natural grazing for domestic stock:	4.2 and 4.1 (if burning is also applied)
3. Planted pastures:	4.3
4. Crop production:	4.4
5. Vegetation cutting (for hay, crafts & construction):	4.5 and 4.1(if burning is also applied)
6. Dams, weirs and water abstraction:	4.6
7. Rehabilitation[1]:	4.7
8. Alien plant control[1]:	4.8
9. Spring protection[1]:	4.9
10. Infilling:	4.10
11. Mining:	4.11, 4.7 & 4.8
12. Roads, including bridges and culverts:	4.12, 4.7, 4.8 & 4.10
13. Infrastructure:	4.13, 4.7, 4.8 & 4.10
14. Powerlines:	4.14, 4.7, 4.8 & 4.13
15. Ecotourism:	4.15
16. Hunting and fishing:	4.16
17. Harvesting of medicinal plants:	4.17
18. Forest plantations and sugar cane:	4.18, 4.7 & 4.8
19. Wastewater treatment:	4.19
20. Solid waste (litter):	4.20
21. Control of water associated parasitic diseases[1]:	4.21

[1] These are not land-uses *per se* but may be important activities required to meet wetland management objectives.

The primary focus of WETLAND-USE is on the agricultural uses of wetlands (Items 1 to 6), for which comprehensive management guidelines are provided. Brief guidelines and directions to important documents are given for Items 7 to 21.

4.1. Management guidelines for burning

4.1.1 Positive and negative effects of burning

The burning of wetlands has several potential positive effects, including: assisting in alien plant control; increasing plant productivity by removing old dead material; improving the habitat value for wetland dependent species and improving the grazing value. However, burning may also have negative effects. The young of wetland-dependent species are particularly vulnerable to the direct effects of burning, heat and asphyxiation. Most species are summer breeders and are therefor little affected by winter/early spring burns. Some species, notably the wattled crane, are, however, winter breeders. In South Africa, fire is one of the most important causes of wattled crane egg failure and chick mortality. Fire may also negatively affect autumn/early winter breeding species such as the grass owl. Furthermore, combined with other factors such as grazing, fire may contribute to increased levels of erosion. Thus, it is very important that the guidelines in the following section are followed.

There are two main groups of fire management decisions: (1) the time of year to burn and the frequency of burning; and (2) additional actions to influence fire behaviour (e.g. burning with or against the wind).

4.1.2 Recommendations about the timing and frequency of burning

- See 4.1.2.1 if the wetland falls within an afforested area.
- See 4.1.2.2 if the wetland is not within an afforested area and regular burning is required to:
    * enhance grazing potential;
    * promote plant vigour and control alien plant infestation;
    * enhance the habitat for wetland-dependent fauna and/or flora; or
    * to prevent the build-up of exceedingly high fuel loads;
- Otherwise see 4.1.2.3

4.1.2.1 Wetlands in afforested areas

May wetlands in afforested areas are burnt annually in early winter because of the fire risk that wetlands pose to the trees. Early winter burns generally have greater impacts on the hydrological and ecological benefits of wetlands than late winter/early spring burns. Absence of loose surface and standing plant litter (removed by the early winter fire) for the entire winter is likely to result in a significant increase in the evaporative loss of water from permanently wet areas, where the water table remains close to the soil surface through most of the winter season. The increase in evaporative loss as a result of burning is likely to be lower in seasonally wet areas and considerably lower in temporarily wet areas, where the water table normally drops well below the soil surface and evaporative loss is limited by the upper dry soil layers. Little can be done to minimize the hydrological impact of early winter burning, other than to protect permanently and seasonally wet areas where possible. Early winter burning may detract from the grazing resource if large numbers of herbivores are attracted to the early winter flush, and grazing of these areas should preferably commence only after the end of winter.

Late summer/winter breeding species, notably the threatened grass owl and the African marsh harrier and the marsh owl may be severely affected by early winter fires. In areas in which these species breed, burn rotationally through block burning and check before burning by having 'beaters' 10 m apart walking through the area and then closely examining all localities where these birds are flushed (Johnson, *Pers comm.*, KwaZulu-Natal Nature Conservation Services). Leave areas unburnt where chicks have still not fledged, or, if possible, delay burning for that year. Wattled crane may also have started breeding at this time (see recommendations in following section).

4.1.2.2 Late winter/ early spring burning

If burning in late winter/early spring, do so approximately every second year if the rainfall is >800 mm per year or every fourth or fifth year if the rainfall is <800 mm per year. Occasional late autumn/winter burns (at an average ten-year interval) may also be included to enhance diversity. Early spring burning may result in the death of wattled crane chicks, as the wattled crane is a winter to early spring breeder. Thus, if this species is breeding in the wetland then:

- If a nest with eggs is present temporarily remove the eggs and place in a small incubator (an insulated box warmed with hot water bottles can be used but do not place the eggs directly on the hot water bottles).
- Consider delaying burning until the chick can fly and therefor escape the fire
- If burning cannot be delayed long enough then attempt to catch the chick, perform a patchy burn and then release the chick after the burn. Alternatively, if the chick cannot be caught (which will probably be the case, observe where the chick is at the time of the burn and burn strategically, sometimes having to burn a break around where the chick is hiding.
- In all cases it is vitally important that a patchy burn is performed so as to leave sufficiently tall vegetation areas for the chick to hide from predators.

For information about cranes and burning, contact the Southern African Crane Foundation 0333-32737.

4.1.2.3 Infrequent burning

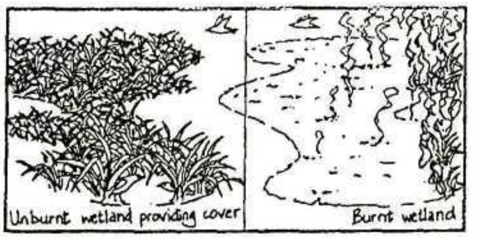
Wetlands that meet the requirements for infrequent burning should not be burnt more frequently than every ten years. As the burning of wetlands, and of the landscape in general, is the norm in the humid and sub-humid grasslands and savannas of South Africa, the assumption is made that most wetlands in the landscape are likely to be burnt regularly. Thus, by promoting the infrequent burning of some wetlands, the diversity of habitats provided by wetlands in the overall landscape will be enhanced.

4.1.3 Additional actions to influence fire behaviour

The following generally applicable recommendations are made, aimed at reducing the extent, intensity and damage caused by fire.

- Burn when the relative humidity is high and the air temperature is low, preferably after rain, in order to keep the fire as cool as possible and increase the likelihood of a patch burn.
- Head fires (burning with the wind) are generally preferable to back fires (burning against the wind). Temperatures at ground level tend to be higher in back fires and consequently the impact on the growing points of plants is greater. Although the fire front advances less rapidly in a back fire, direction is more difficult to predict. Also, because the fire front advances more rapidly with head than with back fires, particularly if the wind speed is high, the fire has less time to spread laterally. Thus, head fires can be used more effectively for burning only portions of the wetland without the use of fire breaks. However, this method of burning portions of a wetland is dependent on many factors outside the manager's control, such as wind direction changes, and cannot be relied upon for consistent block burning.
- If conditions are unfavourable for burning (e.g. if the soil is very dry and susceptible to sub-surface fires or if the weather conditions are consistently unsuitable) delay burning until the following year.
- Give preference to burning areas with abundant dead (moribund) stem and leaf material that is obviously limiting new growth.

- If possible, divide the wetland into two burning blocks and alternately burn each half, leaving the other half unburnt to provide refuges for wetland-dependent animals from which they can recolonize the burnt area/s. If this is impractical, the entire wetland may be burnt every second year provided there are other wetlands nearby (preferably within 1 km) left unburnt for the year in which the wetland is burnt. Effective fire breaks are often difficult to achieve in wetlands, as fires may easily burn across the break through the loose surface litter, or even below the soil it in the upper organic matter-rich soil layers if they are dry.



- Protect areas known to be important bird breeding areas (e.g. reed marsh areas used by herons or sedge marsh areas used by ducks) but even these may need to be burnt every fourth or fifth year to stimulate new plant growth.

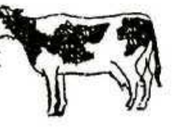
- Where wetland plants are being harvested, do this in areas useful for fire breaks, as far as is possible.

- Keep records of management practices, to monitor progress.

- Cattle, by reducing the fuel load and creating puddles, can be used to good effect in promoting patch burns, but this would obviously need to be where erosion hazard is low.

For more information on burning and its affects, contact your provincial nature conservation organization.

4.2 Management guidelines for the grazing of natural wetlands by domestic stock



4.2.1 Positive and negative effects of grazing by domestic stock

Many wetlands evolved with grazing by indigenous animals such as buffalo, which would have had an important effect on the habitat provided by the wetlands. Where these indigenous animals no longer occur, domestic livestock may have a similar and therefor positive effect in maintaining particular habitats. This is particularly so where a diversity of tall and shortly grazed areas result from the grazing. However, where wetlands are grazed heavily and uniformly short, the quality and diversity of habitats provided is likely to be decreased. Wetlands with high erosion hazards may erode easily when disturbed by trampelling and grazing, with the soils being particularly susceptible when they are wet. The flow concentration zone (see Section 2, Descriptor A7) is generally the most sensitive part of the wetland and disturbance of this area by cattle may cause gully erosion to advance into the wetland, drying it out and destroying most of its value. Thus, it can be seen that the impact of grazing depends on grazing intensity and timing and location relative to sensitive areas. Therefor it is important that the guidelines in the following section are followed to avoid the negative effects and maximize the positive effects.

4.2.2 Stocking rate

Potential grazing capacity, which refers to the amount of grazing that can be sustained in a particular area, varies according to bioclimatic region. Contact your nearest Department of Agriculture office to obtain the recommended potential grazing capacity for the bioclimatic region in which the wetland falls. For a given bioclimatic region, grazing capacity tends to be higher in temporarily wet areas than in nearby non-wetland areas, and is estimated to be 1.5 times greater than the Department of Agriculture's recommendations for non-wetland areas.

Grazing capacity also depends on the condition of the veld and is lowered with a reduction in veld condition. Thus, reduce stocking rate by an amount proportional to the veld condition (see Table 4.1). In non-wetland areas veld condition is determined by comparing species composition with that of a benchmark site. Benchmarks have not been described for wetlands. Thus, a simplified system to be applied to temporarily wet areas should be used, whereby the recommended stocking rate is reduced by an amount proportional to the relative abundance of Increaser II species present. These species have low palatability and/or perenniality, and increase in mis-managed veld where grazing pressure is heavy. *Eragrostis plana* is one of the most common Increaser II species in the wetlands of the South Africa (see Appendix 3). A veld condition assessment should be conducted by randomly placing a point 200 times in the temporarily wet zone and at each point recording whether or not the closest species is an Increaser II. Consult your agricultural extension officer for assistance in conducting a veld condition assessment.

Table 4.1 Stocking rate adjusted to account for veld condition:

Percentage of Increaser II species	Stocking rate (expressed as a percentage of the potential grazing capacity for wetlands in the given Bioclimatic Group)
0- 30%	100%
30-60%	85%
>60%	70%

If seasonally and permanently wet areas are used by livestock, include them in the stocking rate calculations for the spring season only, when plants in these areas are most palatable. Later in the season, plants in these areas become much less palatable and the soils are also often too wet for use. A maximum stocking rate of 0.5AU/ha is recommended for these areas during spring only. During droughts these areas can be used as an emergency food supply and grazed for more extended periods.

Calculations:

A. Recommended grazing capacity for non-wetland areas:	..... AU/ha
B. Increased grazing capacity for wet grasslands:	A x 1.5 = ... AU/ha
C. Stocking rate adjusted for veld condition:	B x 1.0 (veld condition good), x 0.8 (veld con. medium), or x 0.75 (veld con. poor) =......AU/ha
D. Total area of wet grassland	......ha
E. Total AU's the temporarily wet area can support for the grazing season	C x D =......AU.
F. Total area of wet meadow and marsh	......ha
G. Total additional AU's the area can support during spring only	0.5AU x F =......AU

Example Site: falls within an area having a recommended grazing capacity in non-wetlands of 0.4AU, and 46% of Increaser II species (which according to Table 4.1 is medium condition veld), and has 50 ha temporarily wet and 30 ha seasonally/permanently wet.

A. 0.4 AU/ha
B. 0.4 x 1.5 = 0.6 AU/ha
C. 0.6 x 0.85 (veld con. medium) = 0.51 AU/ha
D. 50 ha
E. 0.51 x 50 = 26 AU
F. 30ha
G. 0.5AU x 30 =15 AU

Remember the recommended adjusted stocking rate is only a guideline and may need to be modified to account for particular local circumstances

4.2.3 Fencing of wetland areas and other means of reducing area-selective grazing

Because wetlands have special management requirements, grazed wetlands should be fenced off as special use camps if possible. However, this is often impractical, particularly for small wetlands. Alternatively, reduce area selective grazing by:

- Herding animals away from the wetland into under-utilized non-wetland areas;
- Ensuring water availability in nearby non-wetland areas, which is particularly relevant to slope and channelled wetlands as they are generally susceptible to erosion cause by the trampelling of cattle going to drink;
- Placing any supplementary feed and provide shade or shelter in non-wetland areas rather than within wetland areas. Also ensure that supplementary feed is not in a place that results in the animals having to repeatedly cross a particular wetland area; and
- Cutting herbage for hay or green chop, mow old grass, or strategically burn (in the non-growing season only) to attract more grazing to otherwise under-utilized areas away from wetland areas.

4.2.4 The grazing system

Graze wetlands using a rotational system, whereby the animals are moved out of the wetland area before the vegetation has been grazed to an average of ≤8 cm or when most of the tufts of the favoured species have been grazed. A full 12 months' rest is included every 4 years.

If the soil becomes flooded or saturated to the surface, remove grazing livestock until the area dries out again. Soils, particularly those with a high clay content, are more susceptible to compaction and **poaching** when wet. Poaching, which refers to the disruption of soil structure caused by the repeated penetration of hooves into the soil, decreases herbage production, and increases susceptibility to erosion. The exclusion of grazing when soils are wet can usually be easily accommodated in a grazing system because when the need for grazing to supplement non-wetland grazing is high it is usually in dry periods when the wetland soils are acceptably dry for use. When wetland soils are too wet for use it is often during wet periods when non-wetland forage production is relatively high. If downstream water users are present (see Descriptor D1) it is particularly important that the wetland not be grazed when flooded as livestock may contaminate the water through defecation and urination.

For more information contact your provincial departments of agriculture and nature conservation.

4.3. Management guidelines for planted pastures

4.3.1 The negative effects of planted pasture and crop production

Drainage and the production of pastures or crops in wetlands has several negative effects and most of the indirect benefits of the wetland are lost. The removal of indigenous plants greatly reduces the habitat value for most wetland dependent species. Drainage channels speed up the movement of water through the wetland, reducing its effectiveness in regulating streamflow and purifying water as well as increasing the danger of erosion. The addition of fertilizers and pesticides further reduces the effectiveness of the wetland in purifying water. The disturbance of wetlands, whether it be for the cultivation of pastures or crops or for any other purpose, is strongly discouraged by conservation and environmental bodies. There are two important regulations, the Conservation of Agricultural Resources Act and the Environmental Conservation Act, which are applicable to wetland disturbance and must be adhered to (see Part 2, Section 5.1).

Because of the impacts discussed above, consider the possibility of rehabilitating areas currently converted to planted pastures or crops and returning them to their natural state (see Section 4.7). For those areas which are being legally and safely cultivated under planted pastures, follow the guidelines given below to avoid still further loss of benefits.

4.3.2 Selection of species

Perennial species, such as *Festuca arundinacea* (tall fescue) and *Acroceras macrum* (Nile grass), are preferable to annuals, such as *Lolium multiflorum* (annual ryegrass), as they require the soil surface to be disturbed less frequently, detracting less from the erosion control value of the wetland. Species with a high wetness tolerance, such as *Festuca arundinacea*, are preferable to species with a lower tolerance, such as *Medicago sativa* (lucerne) and *L. multiflorum* because they require less alteration of the hydrology, and consequently they detract less from the hydrological values of the wetland.

4.3.3 Drainage channels

As emphasised in the previous section, wetland drainage is strongly discouraged by all government and non-government environmental bodies and a permit is required to drain any wetland area (see Part 2, Section 5). Drainage will always detract from the hydrological and ecological benefits of a wetland. It may also be that an already drained area requires a revised drainage plan because of earlier poor planning. For areas that have permits for drainage the following should be adhered to: the water regime should not be altered any more than is necessary, and complete control of the ground water level should be maintained so that the water regime of the wetland can be returned to its original state at any time (see Scotney, 1970). Under no circumstances alter the outlet of the wetland, either by the creation of new drainage channels or by the straightening and/or deepening of existing channels. In addition, the area immediately above the outlet and any flow concentration areas in the wetland should be left under natural vegetation. The Department of Agriculture should be consulted about the final design and placement of the drainage channels.

Surface drainage channels usually require regular excavation and disturbance of the soil to remove plants growing in the channels, which may further detract from the water purification benefits of the wetland. However, although it in no way compensates for the natural habitat lost through development, surface drainage channels provide a small amount of micro-habitat absent from sub-surface drained areas Thus, it detracts less from the ecological benefits.

4.3.4 Timing of grazing

As is the case in natural wetlands, grazing should be avoided when the soil is saturated, making it susceptible to erosion and compaction. If the pastures are irrigated, it is important that a co-ordinated irrigation and grazing schedule be devised. Extra care should be exercised in grazing pastures during the first year or two after planting. Older pastures are at a lower risk than younger pastures.

4.3.5 Fertilizer application

Measures should be taken to minimize nitrogen and phosphorus losses into drainage waters as this not only detracts from the economic returns derived from pasture production but also from the water purification benefits of the wetland. These measures include:

- Limitation and proper timing of fertilizer application according to the special needs of the pasture

- Multi-cropping with nitrogen-fixing legumes and grasses (which reduces the application requirements) and possibly also mulching with straw (which decreases loss)
- Modern fertilizer technology (e.g. slow release-fertilizers)
- Avoiding over-irrigation
- Limiting soil erosion, as the greatest loss of phosphorus is generally in association with the loss of soil mineral particles (phosphorus leaches less readily than nitrogen) (see Section 4.3.3).

Limitation and proper timing of mineral fertilizer application according to the needs of the pasture
Fertilizer applied should be just enough to meet the requirements of the specific pasture species. Split applications in at least three or four dressings is recommended for nitrogen (i.e. frequent small applications are preferable to infrequent large applications). Although increasing labour costs, nitrogen use is generally more efficient and toxic fertilizer concentrations in the soil solution are less likely. In newly established pastures, nitrogen from decomposed organic matter is likely to meet the initial requirements of the plants. Thus, it is recommended that the first application be reduced or that nitrogen fertilizer be applied only two weeks after establishment.

When applying fertilizer, take the seasonal growth patterns of the pasture into account. In the highland sourveld, for example, growth in the mid-winter is restricted by low temperatures, and nitrogen dressings should be drastically reduced during this period.

As with nitrogen, the amount of phosphorus applied should not exceed the plants' requirements, allowing for soil fixation. Determination of these requirements involves taking into account such factors as soil texture and pH (see Department of Agriculture and Water Supply, 1987).

Intercropping with legumes and mulching
Nitrogen-fixing legumes, provide naturally produced nitrogen, and the amount of expensive mineral fertilizer required would be reduced. In legume/grass pastures the legume may contribute from 50 to 250 kg N/ha annually to the pasture. Some of the nitrogen from the legume is made available to the grass via excreta. Thus, cutting and removing material and having animals deposit their excreta off the pasture is likely to reduce the available nitrogen and limit grass growth (Miles and Bartholomew, 1991).

Mulching involves placing pasture herbage back onto the soil, and can be used to capture fertilizer or manure nitrogen and assimilate it into organic matter through the action of micro-organisms. This is particularly applicable to annually established pastures and crops, and would assist in counteracting the steady decrease in organic matter often associated with cultivation and, in so doing, would have additional benefits such as increasing the soil's moisture holding capacity. It is important to note, however, that this biologically-blocked nitrogen will not be available to the plants until the organic matter has been broken down, which may take months.

Modern fertilizer technology
Slow release nitrogen fertilizers can improve nitrogen-efficiency by allowing a controlled release of nutrients to the roots. Nitrification inhibitors accumulate ammonia by retarding the nitrification of ammonium to nitrate. Leaching of nitrogen is reduced because nitrate is most prone to leaching. Thus, as in coatings and slow release fertilizers, the roots are continuously supplied with small quantities of nitrogen.

Avoiding over-irrigation
Over-irrigation will not only waste costly irrigation water through run-off, but may cause nutrient losses into the drainage system through leaching. Once the soil is nearing saturation, the irrigation system should be moved or shut down until the soil has dried out sufficiently to require irrigation again.

For more information see Macdonald (1991) and contact your provincial department of agriculture.

4.4 Management guidelines for crop production

See section 4.3.1 emphasising the severe impacts that may result from cultivation of any form within wetlands. Crop production tends to have an even higher impact than planted pastures and LANDUSE-ASSESS lists stringent requirements for the acceptability of wetland cropping (see Section 3.1). Where these requirements are met and permission from the relevant authorities have been granted for development, great caution must nevertheless be exercised in utilizing these areas.

Recommendations concerning drainage and minimizing the impact of artificial fertilizer applications given for planted pastures are also applicable to crop production (see Sections 4.3). Also implement long ley rotations. In dry years, the moisture conditions in wetland areas are generally more favourable than in drier non-wetland areas. Consequently, they may provide useful alternative dryland crop production areas during drought years but they cannot be relied upon for continuous cropping. A one-in-three year ley is recommended, where for every year the area is cropped, it is left fallow or under perennial pastures for three years. For a ley to serve its purpose (primarily to restore depleted soil organic matter levels) at least three consecutive years for each rotation is required. The most generally applicable system would probably be three years of cropping alternating with nine years of perennial pasture ley.

Traditional cultivation tends to have much lower impacts on wetlands than commercial mechanized cultivation provided that you follow the practices such as those listed below. (Several of these practices may be incorporated into commercial mechanized crop production.)

- Grow crops such as madumbes (*Colocasia esculenta*) which are tolerant of waterlogging, in preference to crops with low tolerance as this minimizes the need to reduce the wetness of the soil.
- Do not use artificial drains.
- Till and harvest by hand, which results in less soil compaction and disturbance than with mechanical tillage and harvesting.

- Avoid the use of heavy machinery.
- In the case of shifting cultivation, leave areas fallow for at least 2 to 3 years for every year cultivated.
- Add mulch to reduce soil organic matter depletion and associated problems (e.g. increased erosion hazard).
- Leave strips of indigenous vegetation between crop patches, which would assist in reducing flood water velocity, thereby reducing the loss of the crop (a short-term loss) and loss of soil (a long-term loss of the productivity of the area).

- Do not use of pesticides and artificial fertilizers, thereby reducing the impact on water quality.

For more information generally contact your provincial department of agriculture and for information on ecological agriculture contact the Valley Trust (Tel: (031) 7771955)

4.5 Management guidelines for the cutting of natural wetland vegetation for hay, crafts and construction

The cutting of natural vegetation generally has a lower impact on a wetland in comparison to cultivation because there is minimal disturbance to the soil. It may, however, result in some unnecessary impacts on the wetland, particularly if extensive areas are cut. To avoid such impacts follow the guidelines below.

- If the wetland is also grazed by domestic stock then ≤30% of any wetness zone in the wetland should be harvested in any one year because, if exceeded, this may detract from the ecological value and would also reduce its flood attenuation value. If the wetland is not being used for grazing then this value may be increased to 50%.

- Do not carry out mechanized cutting when the soil is wet! As with grazing, this increases the risk of soil erosion, particularly if machinery gets stuck.

- If mechanized cutting is being used consider using hand cutting. Although more labour intensive, this harvesting method is less constrained by soil surface conditions and would have less impact on the soil, thereby decreasing the loss of hydrological and erosion control benefits.

- Harvesting should preferably take place outside or towards the end of the breeding season of bird species, thereby minimizing direct disturbance of the birds. Late summer/autumn breeding species may nevertheless be negatively affected. See the recommendations for these species in Section 4.1.2.1, paragraph 2.

- Rather than cutting a single extensive large area it is better to break up the cut area into several small areas, which provides more suitable habitat for wetland dependent species.

- When cutting by hand, avoid unsustainable harvesting practices involving the cutting of all culms (including short young ones) and discarding material to form a mat of litter that retards new culm growth. Instead, select and cut/pull only suitable culms. This applies particularly to highly sought after species such as *Juncus krausii* (incema). If harvesting is beyond the resource's capacity for renewal, the resource will be degraded and the benefits derived by the users will be lost.

In wetlands where the removal of leaf material through other factors (e.g. grazing and burning) is limited then cutting may improve the habitat benefits provided by the wetland. Cutting would reduce the standing dead material, which would otherwise develop under a very infrequent burning regime. Such dead plant material reduces plant productivity and restricts the movement of secretive wetland birds such as flufftails (Taylor P B, 1997 *Pers. comm.* Department of Zoology and Entomology, University of Natal, Pietermaritzburg). The use of harvested wetland plants may also be particularly useful in providing material for poor rural people to generate income (see Box 5).

Cultivation of sought-after species such as incema will aid in reducing the demand for harvesting the wild plants. *For information on the cultivation of incema see Mander et al. (1996).*

Box 5 Craft production from wetland plants as a low impact use of wetlands for promoting rural development

Several different wetland plant species are currently used for weaving crafts, including the salt marsh rush, *Juncus krausii* and the freshwater sedges: *Cyperus latifolius*, *C. textilis* and *C. sexangularis*. All of these species are used for making sleeping mats and sitting mats but *J krausii* is used to make a wider range of products, including decorative wall mats, rolled twine and beer strainers.

The harvesting of wetland plants for craft and construction purposes represents one of the simplest examples of management for sustainable resource utilization, mainly because the plants being exploited are generally very productive and resilient to harvesting . Handcraft production from wetland plants has many benefits as a development option in poor communities: it makes use of local traditional skills; it requires a low capital input and has the potential for immediate cash returns; it increases the net inflow of financial resources into rural communities; and, by increasing the financial benefits to the users, it reduces the incentive to transform the utilized wetland, thereby contributing to the conservation of natural habitats. However, the activity and associated income are obviously dependent on harvesting the wetland plants on a sustainable basis.

Craftworks are traded at three levels: informal (inter-homestead sales or barter), semi-formal (roadside stalls and travelling markets) and formal (bulk trading by wholesalers and urban craft shops). Historically trade was predominantly informal but recently semi-formal and formal craftwork trade has increased greatly. In order to promote craft production as a means of rural development it will be necessary to explore semi-formal and formal markets. In order for this to be viable products will need to be identified for which there is a particular demand in these markets. It will often be necessary to develop new products, particularly those which can be produced using existing skills and materials. For example, at Mbongolwane wetland, KwaZulu-Natal, craftworkers have adapted the traditional sleeping mat made from the locally common *Cyperus latifolius* (ikhwane) to produce place mats and pinboards made from the same material and using similar methods.

4.6 Management guidelines for dams, weirs and water extraction

Whilst dams perform certain wetland functions (e.g. sediment trapping) they do not perform other functions well. The habitat required by specialised wetland dependent species is frequently lost when a wetland is dammed. Dams may greatly reduce the streamflow, particularly when water is pumped out of dams. Furthermore, bursting of farm dams is a frequent occurrence that may have high impacts on downstream areas. As is the case with cultivation, application must be made to the relevant authorities for damming. In order to minimize the negative impacts of dams that are legally and safely in place it is important that the guidelines given below are followed.

Construction of the dam wall and spillway

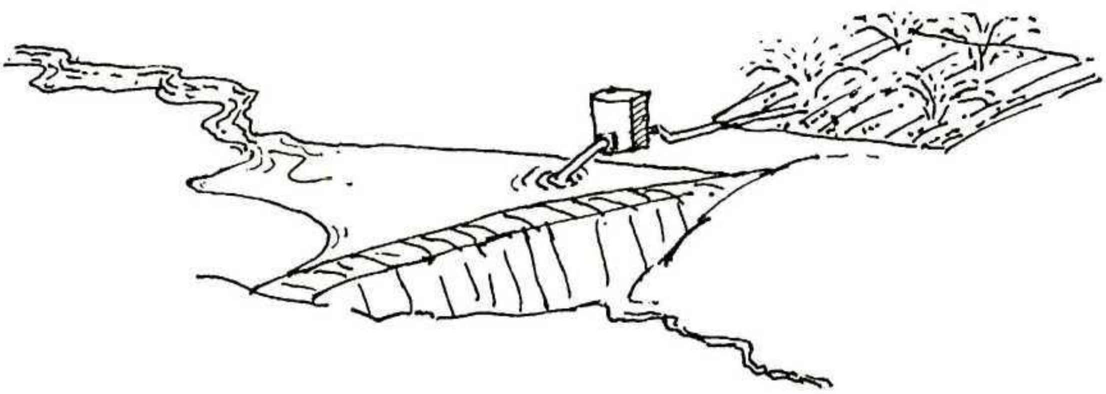
The dam wall and spillway should be built to withstand flooding because the bursting of dams usually has a high environmental impact, increasing flood peaks, sediment loads and streambank erosion. In addition, weirs and spillways should be built to allow for the movement of aquatic species. All dams should also preferably have an outflow control. Consult the local Department of Agriculture soil conservation officer or an engineer to plan the dam wall and spillway and to check whether it has been built to specifications.

Ongoing management

The main factors within the manager's control once a dam or weir has been built are: (1) water extraction; and (2) outflow control.

The first wet season flows from a dam's catchment are often retained in the dam because levels are depleted at the end of the dry season This may impact both the river biota and downstream users (Bruwer and Ashton, 1989). Thus, take measures to ensure water release through the outflow control so that at least 50% of the early season flow entering the dam is released. Extraction of water from a dam or directly out of the stream channel can also potentially alter the water regime of the wetland on-site, as with drainage of a wetland area. In managing the outflow control and extraction of water it is essential that the needs of the downstream water users and the natural environment are accounted for (see Section 5, Part 2 which deals with water law and includes some of the key principles to follow).

Extraction of water often causes sudden, large fluctuations in the water level of a dam, hindering the establishment and growth of wetland vegetation. Together with wave action, this also contributes to hardening of the soil to produce an armoured shoreline, which decreases the ecological value of the area. In some instances, however, drawdown on shorelines with a soft soil improves the ecological value as these exposed areas are often good for mud-probing birds. If Red Data species (e.g. wattled cranes) are breeding on the edge of the dam then winter draw-down should be limited as this is likely to leave the nest exposed and make the site unsuitable for breeding.



For more information contact your provincial department of environmental affairs and the National Department of Water Affairs.

4.7 Rehabilitation of wetlands

Although wetlands are areas where sediment is characteristically trapped, sometimes wetlands erode and more sediment is removed from the wetland than is trapped. Wetlands with high erosion hazards (e.g. those with erodible soils and steep slopes See Section 3, Descriptor F12) are the most susceptible to erosion. The most common erosion problem in wetlands is gully erosion. The head of a gully may move rapidly into a wetland particularly if the area is disturbed by cattle, sometimes advancing several metres in a single storm. The erosion of channels, both natural and artificial is another common problem in wetlands. Erosion gullies not only increase the amount of soil lost by the wetland but, as with drainage channels, they also dry out a wetland. Thus, they detract greatly from the indirect benefits supplied by the wetland, and rehabilitation of eroded areas (particularly areas which are currently actively eroding) and drained areas (particularly areas which are not being used for production) should be considered. Rehabilitation can be very costly. Thus, choose priority wetlands which will supply the greatest increased benefits. When prioritizing wetlands for rehabilitation it is important to have a catchment and landscape perspective, with rehabilitation best placed in catchments and portions of catchments with water quality problems and in ecoregions (i.e. Veld Types) where the loss of wetlands has been high.

Several methods are available for rehabilitating eroded or drained areas (see Fig 4.1 for some examples).

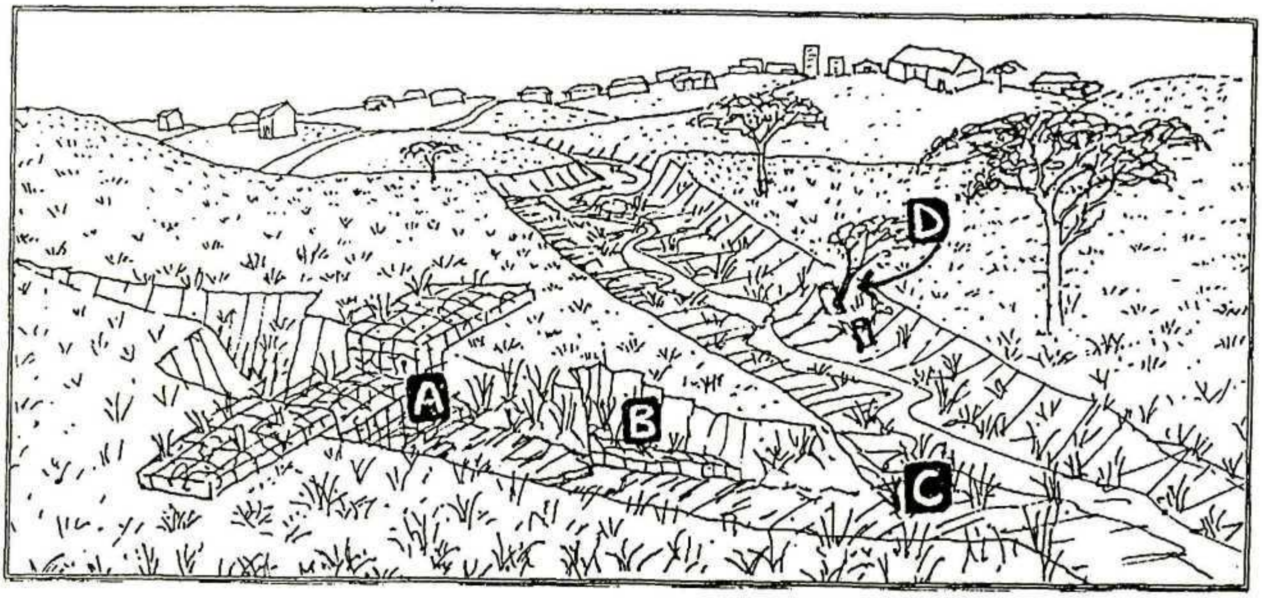
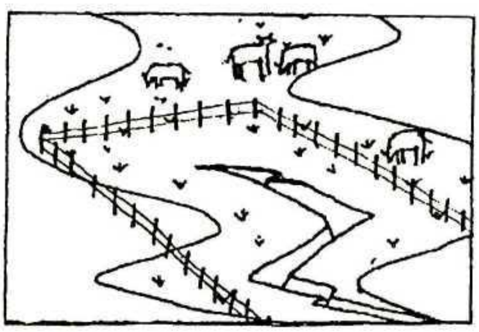


Fig 4.1 Some methods for stabilizing stream channels and erosion gullies. (A) Gabions, which are well anchored into the banks, are preventing the head of the gully incising further by trapping sediment and stabilizing the gully bed. Plants that establish in the gabions also assist. (B)Grasses planted on the streambanks and gabions placed at the base of a collapsed bank assist in stabilizing the banks. (C) Grasses and sedges planted, and allowed to establish naturally in the channel, trap sediment and stabilize the channel bed. (D) Trees established on the banks of a wide channel and next to the channel assist in stabilizing the banks.

See WETLAND FIX Part 3 (Wyatt, 1993), where these, and additional methods are given in detail and guidelines in choosing between the use of woody or herbaceous plants for the rehabilitation of particular situations. Remember:



- Address all factors contributing to erosion or the problem will start all over again. These may include disturbance by livestock or cultivation, or changes to the water flow pattern which result in more concentrated water flow in the wetland. If livestock were contributing they would need to be excluded from the area.
- Never underestimate the power of floodwaters!
- Any streambank stabilization and erosion control structures need to be properly anchored into the river bank otherwise they are likely to make the problem even worse (see A, Fig 4.1)!
- It is essential that land owners/users take ownership and responsibility for the structures, which may require maintenance from time to time.

For additional advice on wetland rehabilitation contact: Directorate Resource Conservation, National Dpt. of Agriculture (012) 3196000 and your provincial Department of Agriculture

4.8 Alien plant control

Invasion by alien plants, which out-compete the indigenous plants, may greatly reduce the indirect benefits provided by a wetland because:

- The quality of habitat and the biodiversity support benefits provided by the wetland are reduced
- Many alien plants (e.g. wattle trees) are less effective in controlling erosion than the indigenous

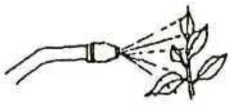
plants, which are specifically adapted to these conditions

- Some alien plants use more water through transpiration than the indigenous plants, which leads to a reduction in the natural flow in streams

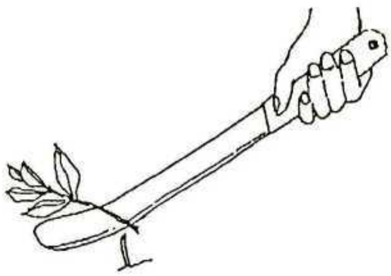
- The grazing value of most alien plants is lower than the indigenous grasses and sedges that they replace.

The first step in controlling alien plants is to identify the particular species of alien plants that are to be controlled. See WETLAND FIX Part 6 (Wyatt, 1993), which covers the control of 29 alien plant species known to invade wetlands and streambanks in South Africa. Controlling alien plant species requires that appropriate pre-treatment, initial treatment, and follow-up treatment/s be applied that vary from species to species.

Pre-treatment by cutting or burning may be necessary where herbicide treatment is required and the alien plants are too tall and/or dense to reach. Initial and follow-up treatments may be carried out through:



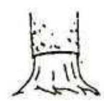
Application of herbicide to growth or regrowth (following pre-treatment or a previous treatment)

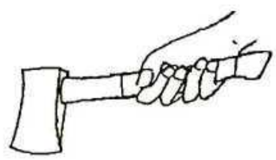


Cutting and/or grazing to deplete the nutrient reserves of the plant, *which usually will then require several follow-up* treatments.

Hand-pulling, particularly of young plants where the roots can be easily pulled out

Ring and strip-barking





Felling of trees

Burning (see Section 4.1)

Always remember to conduct follow-up treatments. Many people fail to do this, which allows the alien plants to regrow and is a waste of the initial effort and money spent!

The importance of using herbicides with caution:
- Consider alternatives to herbicides (e.g. cutting and ring-barking)
- Use only chemicals with a toxicity rating of III (requires caution=table salt) or IV (not harmful);
- Do not use any chemical that is not clearly labelled
- Follow the guidelines on the label for safe and efficient application methods and storage
- When in doubt always consult an expert!

Effective alien plant control needs to be well co-ordinated and the responsibilities for carrying out different actions clearly defined. Some strategies that may be used to increase the level of support for the control of alien plants are:
- "Adopt a wetland" where an organization such as a scout group may assume responsibility for controlling alien plants in a particular area.
- Alien plant clean-up days, where, for example, an urban conservancy may organize a day where volunteers clear alien plants in collaboration with the local authority, who may provide expertise and equipment.

- Programmes such as the Working for Water Programme (see Part 2, Section 5) which may potentially fund local, unemployed people to clear alien plants.

For more advice refer to WETLAND-FIX Part 6 (Wyatt, 1993)Alien plant control guide or consult the Plant Protection Institute (012-8080364; 0331-3559100).

4.9 Spring protection

Springs refer to localized areas where groundwater is discharging to the surface (sometimes referred to as the eye of the stream). If a spring needs to be rehabilitated as a result of erosion or modified to allow for the improved collection and storage of water then see WETLAND-FIX Part 4 (Wyatt, 1993). It must be remembered that the modification of a spring may alter its ecological character (e.g. it may cause the loss of a Red Data species) and therefor the impact that this modification needs to be assessed (See Section 3). If a spring is a favoured drinking area for cattle, in addition to providing an alternative drinking area it may also be necessary to exclude cattle by fencing off the spring.

4.10 Infilling

Infilling of a wetland involves the dumping of soil or solid waste onto the wetland surface. Infilling generally has a very high and permanent impact on wetland functioning, and a full assessment of the impact and application to the relevant authorities is required by law. The impacts of infilling are similar to drainage in that the upper soil layers are rendered less wet, usually so much so that the area no longer functions as a wetland. Flow patterns in the wetland are altered and the natural vegetation is lost. Factors to consider in minimizing impacts of infilling include:
- Avoid unnecessary disturbance and compaction of the surrounding area
- Minimize the change in flow patterns within the wetland
- Control invasion of alien plants, which generally increase rapidly in disturbed areas (see Section 4.8).

4.11 Mining (excavation)

Mining is generally one of the most destructive land-uses applied to wetlands, certainly in the short term, and an assessment of the environmental impact and approval by the relevant authorities are obviously required. Two very important issues are the manner of mining and rehabilitation following excavation. Some general factors to consider in minimizing the impact of mining include:
- Avoid unnecessary disturbance and compaction of the surrounding area
- Set aside the upper soil layer (preferably more than 50 cm) with vegetation material included
- Restore the original flow patterns in the wetland as closely as possible
- Re-establish indigenous vegetation, which will be considerably easier if the upper soil layers are set aside
- See also Section 4.7 dealing with rehabilitation
- Control alien plants, which are prone to increase rapidly in disturbed areas (see Section 4.8)

The main forms of mining that take place within wetlands are sand-winning and peat mining. For peat mining, contact the Directorate of Agricultural Resource Conservation (012-3196000) to obtain the manual and proforma for the drafting of an "Operational and rehabilitation plan for the cultivation of a vlei for the purpose of harvesting peat". The manual provides detailed guidelines. See Directorate of Agricultural Resource Conservation (1995; 1996) in the References in Section 6. It is important to stress, however, that peat is not a renewable resource like wood. It forms over very long periods and a peatland can only return to its origional state if left for hundreds or even thousands of years (Grundling and Dada, 1999). Peat extraction drastically reduces the water storage and filtering properties of wetlands. Thus, the negative impacts of peat extraction are enormous and last for generations (Grundling and Dada, 1999). Peat, which is used in the horticultural and mushroom industries, can be substituted with numerous viable alternatives, and Grundling and Dada (1999) emphasise that extraction in South African peatlands cannot be sustained ecologically or economically.

For sand-winning, which also has the potential to have an extremely high impact on a wetland, contact the Department of Minerals and Energy (012-3179000) to obtain the document "Impact assessment and management programme for sand-winning".

4.12 Roads, including bridges and culverts

Road crossings may greatly modify local water flow patterns in wetlands, and the building of structures in a wetland requires that, by law, application be made to the relevant authority. In addition to having a damming or draining effect on the flow upstream of the road, causeways and culverts often concentrate water flow downstream and increase its flow energy. This will not only dry out the area out but often also results in serious gully erosion, detracting from the ecological and hydrological values of the wetland. Unless the road is raised above the wetland, there will obviously be complete destruction of all habitat and associated functions and values in the areas directly in the road path. In the areas adjacent to the road, the following additional impacts are anticipated:

- Direct interference in the movement of animals, including the mortality of animals crossing the road;
- Disturbance of animals, particularly large birds such as cranes which may breed in the wetland;
- A source of pollutants washing off the road, particularly from roads which carry many vehicles

In addition to referring to the recommendations for minimizing the impacts of infilling, which are directly applicable to roads, also consider the following:

- Seek an alternative route
- Ensure that causeways have minimal disruption to flow patterns, both upstream and downstream of the crossing. Adequate culverts are required so as to have minimal impact on water flow patterns through the wetland.
- Manage runoff from roads, which may be a potential source of pollution.

For more information contact your provincial Department of Environmental Affairs.

4.13 Infrastructure

Wetland soils generally present problems for construction, particularly in the case of soils with shrink-swell clays (i.e. Rensburg form and, to a lesser extent, the Willowbrook form, which are commonly found in wetlands) and soils prone to subsidence (i.e. soils with high organic matter levels or high ***n*** **Values**). Many wetland areas are also subject to flooding, placing buildings and lives at risk. Furthermore, the construction of infrastructure in wetlands generally requires either drainage or infilling and obviously the total replacement of indigenous vegetation at the building site and often much further away. Thus, only under very exceptional circumstances, where there is no possible alternative site, should wetlands be used as construction sites and this would obviously require a full assessment of impact and approval by the relevant authorities. Such situations are most likely to arise in urban areas, where space is limited. In addition to the general regulations relevant to wetlands, the requirements of the local town planning ordinances also need to be met.

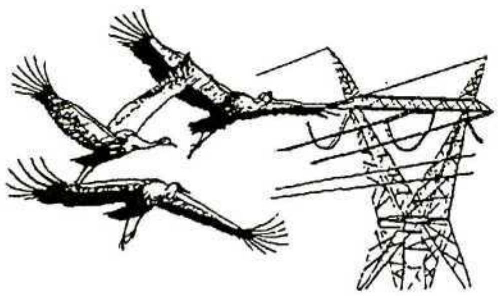
In order to minimize the impact of construction on the wetland:

- See Section 4.9 dealing with infilling
- Avoid unnecessary destruction of wetland areas alongside any buildings. This can be achieved by maintaining these wetland areas as attractive features and including innovative building features such as buildings on stilts and the use of board walks.

- Pit latrines should under no circumstances be within or adjacent to a wetland

4.14 Powerlines

The company responsible for electrical power provision in South Africa is Eskom. In terms of the Eskom guideline for environmental legislation, issued by the Distribution Engineer Manager, damage to wetlands both on farmland and elsewhere (e.g. conservation areas) is prohibited. See Section 4.13 giving recommendations on infrastructure in wetlands.



Besides the direct disturbance that pylons may have on a wetland, powerlines within and near to wetlands pose a particular threat to large wetland dependent birds (notably cranes) that may fly into the powerlines. Any incidents of bird mortalities on powerlines or any other interactions between birds and electricity infrastructure can be reported to the Eskom/Endangered Wildlife Trust Partnership at 0800111535 or by e-mail to Chris van Rooyen at EWT (chrisewt@global.co.za). Eskom and EWT will be able to investigate the incident and take action to try and prevent the incident re-occurring (e.g. modifying the transformer).

4.15 Ecotourism

Ecotourism is by definition a low impact, culturally sensitive land-use with the potential for generating income for local people. However, it is only be feasible at a wetland with a reasonable tourist potential; and should be conducted in an appropriate manner. In order to determine the tourism potential of a wetland and its surrounding area consider the following:

- Does the wetland have reasonable access?
- Does the wetland provide attractive scenery, including a diversity of colours and textures, preferably with some interspersed water?
- Is there a diversity and abundance of wildlife?
- Are there other features of interest (e.g. cultural and historical)?
- Does the wetland fall within a general area with a reasonable tourism potential?
- Is there existing infrastructure?

To ensure that ecotourism operations are carried out in an appropriate way make sure that:

- All developments have low environmental impact.
  * If infrastructure, such as a hide, is specifically required in the wetland it should have minimal hydrological impact (e.g. by building it on stilts (see Section 4.13). An assessment of the impact of such infrastructure would obviously be required (see Section 3).
  * All other infrastructure and roads should be located outside of the wetland or any other sensitive natural areas. (See section 3 & 4.11 and 4.12)
  * Any sanitation system would need to account for the fact that wetlands are characterized by high watertables, which are areas considered unsuitable for pit latrines
  * Disturbance of animals by human presence should be minimized. Certain species may be vulnerable to disturbance caused by human presence, particularly during breeding season (e.g. wattled crane). Thus, it may be necessary to implement control measures such as restricting access during these times (contact your provincial nature conservation office).

- Any infrastructural or other developments should have low visual impact

- The local economy is supported (e.g. where ever possible employ local people (e.g. as guides, caterers or builders).

- There is meaningful involvement of local people and sensitivity to their culture
- Local skills are harnessed and there is provision for the transfer of skills.

Usually one of the greatest attractions of wetlands for tourists are the bird-watching opportunities that the wetland provides. Threatened species are a particular asset because of their rareness value. With this in mind there are several management actions that can be undertaken (e.g. maintenance of mudbanks for waders and managing burning and grazing [see Section 4.1 & 4.2]) to attract a diversity and abundance of birds. There are also several actions that can be conducted to optimize the visitors' bird watching experience (e.g. erection of hides, creation of trails and the production of resource material).
For further information and advice contact your provincial nature conservation organization, existing ecotourism operators in the general area and SATOUR. (012-3056693). Much can be learnt for existing ventures (see Box 6).

Box 6 Wakkerstroom: an example of wetland ecotourism

The Wakkerstroom vlei lies next to the small town of Wakkerstroom in the upper Tugela catchment. It supports numerous breeding pairs of crowned crane and many other bird species, notably the white-winged flufftail, one of Africa's rarest birds. Most of the wetland is owned by the Wakkerstroom municipality and leased out for grazing, which, together with ecotourism, is one of the main direct uses of the wetland.

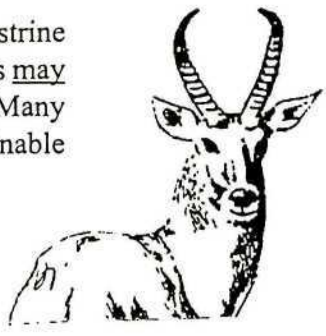
The Wakkerstroom Natural Heritage Association (WNHA), which was founded in 1991 and has many local people, gained a 10 year lease of the wetland, commencing in July 1992. Information on the wetland and its use and management was gathered and management guidelines drawn up in consultation with the primary users of the wetland. The overall management goal for the wetland is the **sustainable use** of the wetland while maintaining its functioning and the benefits it provides to local people and society. Through the work of the WNHA and the co-operation of the local people in controlling such aspects as grazing, burning and illegal hunting of birds, the functioning of the wetland and its value for eco-tourism is being assured. The town now has several guesthouses and bed and breakfast facilities, and the wetland and its associated birdlife is one of the key attractions for visiting tourists. Interest in the WNHA has continued, as measured by the increasing annual membership and volunteer time is provided by several key members of the WNHA. Contact: Warwick Tarboton, 014-7431438.

4.16 Hunting and fishing

With the exception of some wetlands such as the Pongola Floodplain, the fish stocks of most palustrine wetlands in South Africa are generally low. Although this can be increased through the construction of dams and introduction of species, these actions may have severe impacts on the wetland. If a dam is considered then its impact, which is often great, should also be assessed (see Section 3). The introduction of fish into drainage systems where they did not previously occur, may negatively affect the indigenous species through predation and competition for space and food. This may cause the loss of Red Data species if present. In addition, indigenous species should not be moved between different drainage systems as they may be genetically different and this will reduce the genetic diversity of the species. Thus , it is important that by law application must be made to the Provincial

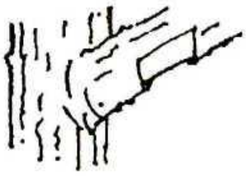
Nature Conservation Department before any species are moved or introduced.

Although the potential for hunting wildfowl is relatively low for many palustrine wetlands in South Africa, the harvesting of waterfowl on a sustainable basis may be viable for some of the commoner species such as spur-winged goose. Many wetlands support southern Reedbuck, which can readily be hunted on sustainable basis. The Provincial Nature Conservation Department should be contacted for further information and to obtain the necessary approval.

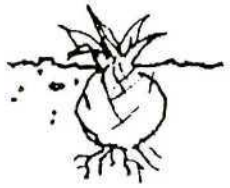


4.17 Harvesting of medicinal plants

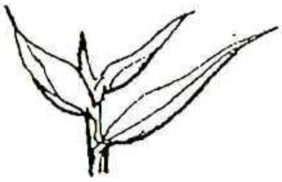
A wide range of plants are harvested for medicinal purposes. Although little is understood about the details of exactly how harvesting affects populations of particular species, it is well known that harvesting can have very severe impacts. The harvesting of particular plant parts may have potentially much greater impacts than harvesting others (e.g. the harvesting of bulbs generally has greater impact than harvesting of leaves, which usually regrow more readily). Some very general guidelines for the harvesting of different general types of plant parts should be followed:



Bark. Never take more than 1/10 of the bark and always harvest the bark from side branches rather than the main trunk, particularly near its base where extensive harvesting may cause the tree to be ring-barked and die.



Rhizomes, tubers and bulbs. Never take more than 1/4 of the material in an area in a particular year



Leaves If only young leaves are harvested then never take more than 1/3 of the young leaves; and if mature leaves are harvested then never take more then 1/2 of the leaves in a particular year (See Section 4.5).

In the case of all the different plant parts, if the supply of the plant resource is decreasing in a particular area then harvesting should be stopped until it recovers. Also, it is preferable to grow indigenous plants and use the wild plants for replenishing the supply of cultivated plants. This applies particularly to slow growing species. For more information regarding the collection of medicinal plants, particularly those which are protected, contact your Provincial Nature Conservation Organization. See also "Growing indigenous medicinal plants" by Mander *et al.* 1995.

4.18 Forestry and sugar cane plantations

Sugar cane is a commercial crop with high levels of artificial fertilizer application and a tolerance to waterlogging which is medium to low. The planting of sugar cane in wetlands is not considered generally acceptable, particularly where drainage channels are used because of the impact on the hydrological benefits of wetlands. Both forest plantations and sugar cane within wetlands also greatly reduce the value of the habitat that wetlands provide for wetland dependent species. Thus, this crop should preferably be withdrawn from wetland areas. If, however, sugar cane plantations which are legally in wetlands are to be retained, see the recommendations given for planted pastures (Section 4.3). For more information contact the SA Sugar Association, (031) 3056161.

Regulations governing plantations and wetlands are contained in the Forest Act, and for further information on forestry management see "Guidelines for environmental conservation management in commercial forests in South Africa" by the Forestry Industry Environmental Committee (1995). According to the Forest Act, forest plantations in wetlands are not considered acceptable because of the high water use of trees. Forest plantations within wetlands often have high alien plant infestations (see Section 4.8) which further adds to the impact of afforestation in wetlands. Serious consideration should be given to withdrawing forest plantations from within all wetlands.

4.19 Wastewater treatment

As indicated in Table 2 and the WETLAND-USE Booklet 1, wetlands perform a very useful function in purifying water. The use of wetlands to treat wastewater may, however, reduce other benefits provided by the wetland, particularly if inputs are high and exceed the wetland's capacity for assimilation. It is very important to emphasise that wetlands should not be regarded as substitutes for water treatment. If a natural wetland in a water course is to be used for purification, the effluent entering it must comply with the water quality standards set by the Department of Water Affairs and Forestry for that particular catchment. If this is not the case then constructed wetlands may assist in the purification of poor quality effluent, but the quality of the water leaving these systems and entering the streamcourse must, again, comply with the relevant Water Quality standards. Two key questions need to be addressed when examining the use of wetlands for wastewater treatment:

1. What is the wetland's capacity to assimilate the pollutants it will be receiving?

2. How will use of the wetland for wastewater treatment impact the wetland and the other benefits that it provides?

The wetland's capacity to assimilate pollutants

The capacity of a wetland to improve water quality is difficult to predict and will depend on the particular pollutants and the nature of the wetland. A specialist should therefor be consulted if a wetland is to be used for wastewater treatment. Some general features that enhance the capacity of wetlands for improving water quality that would need to be considered in assessing the effectiveness of a particular wetland, include:

- Flow patterns in the wetland. Diffuse flow (where flow is spread evenly across the wetland) is more effective than channel flow (where flow is largely confined to a small portion of the wetland).

- Factors which slow down the flow of water, notably a gradual slope and the resistance offered by wetland vegetation, which results in water being retained in the wetland for longer periods and suspended particles being more readily deposited.

- Contact between water and sediments (with diffuse flow and shallow water leading to high levels of sediment/soil-water exchanges).

- A variety of anaerobic and **aerobic** processes, such as denitrification and chemical precipitation, that remove pollutants from the water;

- The high plant productivity of many wetlands, with high productivity leading to high rates of mineral uptake by vegetation.

- High soil organic matter contents (accumulated primarily as a result of anaerobic conditions) which favours the retention of elements such as heavy metals.

- Microbial **decomposition** of certain organic substances (such as those introduced through sewage addition). Wetland plants provide substantial surface area for the attachment of microbes, both above-ground and below-ground due to the aerobic rhizosphere around the roots.

Impacts of wastewater inputs

Assessing the impacts of particular wastewater inputs is extremely complex and again specialist input will often be required to do so. Some of the general impacts commonly associated with particular groups of pollutants are given below.

Nutrient enriched effluents. The ability of different plant species to respond to enriched nutrients varies, with the result that species composition may change drastically, eventually comprising a few dominant species, such as *Typha latifolia* that have a high ability to respond. The increased plant production may result in increased decaying plant material which would increase the Biological oxygen demand (BOD) and this in turn may have severe impacts on aquatic life.

Suspended sediment. Accumulating sediment may change the flow patterns in the wetland, decreasing the extent of diffuse flow. In addition, other pollutants attached to the sediment would be introduced along with the sediment.

Acid and saline deposits. Most of these substances affect the physiological functioning of plants and animals and may have extremely severe impacts. Tolerance levels vary greatly among species, which makes setting an acceptable water quality standard for acidity and salinity levels difficult. Increased acidity may also cause toxic effects from certain metals such as mercury which, under acidic conditions, are soluble and extremely toxic to wetland biota. These heavy metals persist in the sediment indefinitely and may be released back into the water in response to a change in pH.

Biocides are specifically targeted at organisms and it is therefore inevitable that wetland biota will be negatively affected.

Pathogens. A number of bacteria and viruses are found in wastewater, particularly sewage effluent. Besides being effective at removing these, most wetlands are little affected by these pathogens.

For further information on the effectiveness of wetlands in treating wastewater and in predicting the likely impacts of wastewater on the wetland contact: A Batchelor, CSIR, (012) 8413461, and Dr N Kleynhans, Institute for Water Quality Studies, Department of Water Affairs and Forestry (DWAF), (012) 8080374. For information on the legal aspects of wastewater treatment contact your DWAF regional office (012-3387500; http://www-dwaf.pwv.gov.za).

4.20 Solid waste (litter)

Solid waste is a common problem associated with wetlands in urban areas. One of the primary impacts of solid waste is a reduction in the aesthetic appeal of the wetland. Try to find the source of the litter. It may be:

* far away from the wetland area and be carried there by stormwater drains;
* from local residents; or
* from people from elsewhere who use the wetland.

Look for ways to reduce the amount of litter at the source (e.g. by creating awareness and motivating for refuse bins). It may be difficult to control the source of the litter, and ongoing effort will be needed to clear the litter from the wetland. As is the case with alien plant control, it is useful to devise a litter control plan in which responsibilities are clearly defined. One of the most effective ways of clearing litter is to involve youth groups in litter clearing events. For advice and assistance contact the Institute of Waste Management (011-7823503/4) to see if your town has a local "keep clean association".

4.21 Water-associated parasitic disease control

The two primary diseases that are associated with wetlands in South Africa are bilharzia and malaria, both of which occur mainly in the sub-tropical parts of the country. Although there may be little that a wetland manager do about these diseases, factors affecting the occurrence of the disease would need to be considered as part of an integrated management system. In the case of both bilharzia and malaria, the disturbance of the wetland for development often provides ideal breeding places (e.g. in drainage channels) for these species. Thus, measures to prevent such practices may need to be taken. For more information on the individual diseases see Appleton *et al.* (1995) and contact your local health office to find out about any disease control programmes.

Bilharzia is particularly common amongst children who have contact with water.

SECTION 5, ASSUMPTIONS OF WETLAND-USE PART 1

5.1 Primary assumptions of IMPACT-ASSESS

1. The greater the cumulative loss of wetland, the greater will be the impact resulting from further loss[5]. At a very general level this is well supported in the literature (e.g. Brinson, 1988; Preston and Bedford, 1988; Johnston, 1994). However, several different relationships between function and area may exist which would vary according to several factors, including the function examined and spatial configuration of the wetlands, and empirical evidence allowing for specific function-area relationships are largely lacking (Johnston, 1994).

2. The greater the alteration of flow patterns in the wetland, leading to a change in the wetland's hydrological regime, the greater will be the impact on all the wetland's indirect benefits. This is well supported in the literature as a general principle (e.g. Goode *et al.*, 1977; O'Brien, 1977; Lavesque, *et al.*, 1982; Brinson, 1988; Ingram, 1991). Again, the specific relationships are likely to depend on the nature of the particular site. For example, the relationship between level of drainage and the loss of value of a wetland for improving water quality is likely to vary according to the site and its context.

3. The greater the change in water quality the greater the greater the likelihood of impacts on wetland functioning. There is much literature showing the high level of impact a change in water quality may have on the functioning of a wetland (e.g. Coetzee, 1995; Ewel, 1997) but the impact is obviously very specific to the type of change (e.g. an increase in nitrates) and the nature of the wetland. A high nutrient input has been widely shown to generally decrease plant species diversity (Sather and Smith, 1984; Cooke *et al.*, 1990; Ehrenfield *et al.*, 1991; Ewel, 1997). High *E. coli* levels, however, generally have a lesser effect on wetland functioning (Coetzee, 1995).

4. The greater the extent to which the soil is disturbed, the greater will be the loss of water purification and erosion control values. This is general support for this assumption (e.g. Willrich and Smith, 1970; Miles and Manson, 1992). The ultimate effect will, however, obviously depend on several interacting factors, including the erodibility of the soil on the wetland site (See Section 5.2).

5. The greater the extent to which soil organic matter levels are lowered, the greater will be the impact on the hydrological and erosion control values. There is support for this general assumption (e.g. Ingram, 1991; Miles and Manson, 1992) but, again, this will depend on the interacting factors affecting the above item.

6. The greater the reduction in surface roughness of the wetland, the greater will be the impact on the hydrological and erosion control values, because the wetland area will become less effective in slowing down the rate of water flow. This has been clearly shown in the literature (e.g. Reppert *et al.*, 1979; Adams *et al.*, 1987) as has the relation between detention time and wetland function (Kadlec and Kadlec, 1979; Hammer, 1992).

7. The greater the loss of indigenous vegetation, the greater will be the impact on the wetland's ecological (biotic diversity) value. This assumption is backed by the fact that the indigenous vegetation makes up a component of the biodiversity of wetland as well as forming a key component of the structure and functioning of wetlands (Mitsch and Gosselink, 1986).

8. The greater the extent to which wetland dependent species, particularly Red Data species are negatively affected, the greater will be the impact on biodiversity. Species make up an important, and readily measured, component of biodiversity (Noss, 1990) and Red Data species are those which have been identified as having a high priority from a species conservation point of view (see Breen and Begg, 1989).

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[5] All assumptions of WETLAND-USE have been italicised

5.2 Assumptions concerning the erosion hazard index and individual land-uses

* **Erosion hazard index**

The three most important (readily measured) parameters which relate to the wetland site and which influence the susceptibility of an area to erosion (resulting from use by stock) are: (a) soil erodibility, (b) slope, and (c) landform.

The effect of soil erodibility and slope on erosion susceptibility have been shown in the literature (e.g. Anon, 1976). However, the slope limits employed by WETLAND-USE are not based on findings in the literature but were arbitrarily chosen in consultation with soil conservation workers from the Department of Agriculture.

Little evidence has yet been found in the literature to support the assumption that landform has an important influence on susceptibility to erosion. However, this assumption is supported by empirical evidence from wetlands in KwaZulu/Natal (see Kotze 1999, Chapter 5). For example, wetlands in depression settings show less evidence of erosion than those in channel settings and the transition (i.e. the flow concentration zone) from non-channelled to channelled valley bottom areas has high incidence of gully erosion.

* **Burning**

1. Provided that the burning recommendations (given in Part 2) concerning burning timing, frequency and influences on burning behaviour are adhered to, burning usually enhances the habitat value of wetlands. Although there is a lack of reported work on the effect of burning, some studies have clearly demonstrated the general advantages of burning to wetland-dependent species (e.g. Vogl, 1973; Smith and Kadlec, 1985; Taylor, 1994; D Johnson, 1994. *Pers. comm.* KwaZulu-Natal Nature Conservation Services and B Taylor, 1994. *Pers comm.* Zoology Department, University of Natal, Pietermaritzburg; W Tarboton, 1994. *Pers. comm.* Nylstroom).

2. Burning every 2 to 3 years generally does not significantly detract from the ecological value of wetlands in the study area. This assumption is based on the fact that biennial burning has not been shown to be detrimental to any valued wetland-dependent species in the study area.(D Johnson,1994. *Pers. comm.* and B Taylor 1994. *Pers. comm.*). However, there are many species for which fire investigations have not been undertaken. Some of these species may well require a fire return frequency of more than 2 years.

3. When a wetland area is burnt, other wetland area/s nearby should be left unburnt to provide adequate cover for wetland-dependent species. No evidence in the literature was found for or against this assumption and it is based on the intuitive logic of species specialists (D Johnson,1994. *Pers. comm* .; B Taylor 1994. *Pers. comm.*; W Tarboton, 1994. *Pers. comm.*).

4. Late winter/early spring burning has the least impact on the ecological value of a wetland because it occurs when the fewest species are breeding. This is based on well-researched information on the life histories of wetland-dependent species, primarily birds.

5. Fire is an important cause of chick mortality in wattled cranes. This has been substantiated in the literature (Johnson and Barnes, 1991) and based on personal observation (McCann, 1998, *Pers. comm.*, Eskom/EWT National Crane Conservation Project, Mooi River).

6. Burning generally does not have a negative effect on the soil provided extensive sub-surface fires do not occur. This is supported by some literature findings (e.g. Schmulzer and Hinkle, 1992) and observation by fieldworkers with extensive experience in wetlands, notably J Wyatt (1998, *Pers. comm.* KwaZulu-Natal Nature Conservation Services, Congela, Durban).

7. Fire may be used to control alien plants effectively. Although published evidence for this is lacking, empirical evidence, obtained by making comparisons between unburnt and regularly burnt portions of numerous wetlands in South Africa, supports this assumption (Otter, 1992; Kotze and Breen, 1994).

8. From a water storage point of view, a late winter/early spring burn is preferable to an early winter burn because the wetland is left exposed (due to removal of standing dead material) for a shorter period. As such, evaporative loss is lower. This is supported by the study of Donkin *et al.* (1993) which show that evapotranspirative loss of water from wetlands with standing dead material is less than loss from open water.

* **Grazing**

1. The grazing capacity of wet areas are generally at least 1.5 times greater than the Department of Agriculture's recommendations for non-wetland areas. This is based on information gathered from isolated wetlands, notably Blood River in KwaZulu-Natal and Memelvlei in the Free Sate (Oellermann, 1994), and may need to be modified when further research has been conducted.

2. If the veld condition in temporarily wet areas is poor, the stocking rate should be decreased to account for the lower production potential, and to allow the veld to recover. It has been shown for non-wetland areas that veld in poor condition has a lower grazing potential than veld in good condition (Edwards and Tainton, 1981). Although this is assumed to hold true for wetland areas as well, no such studies have been undertaken in wetlands. There is also no published support for the arbitrarily chosen reduction factors to account for veld condition. These were chosen in consultation with N M Tainton, a grazing specialist, Grassland Science Department, University of Natal.

3. Wetlands should be rotationally grazed. There is some published support for the merits of rotational grazing for natural non-wetland areas in South Africa (e.g. Anon, 1951). It is also widely recommended by veld management specialists (e.g. Edwards and Tainton, 1981). Although no studies of rotational grazing in wetlands have been undertaken, it is assumed that the results obtained from non-wetland areas are applicable, particularly to temporarily wet areas. Rotational grazing also allows greater flexibility in the grazing system (e.g. to exclude wetlands areas when conditions are unfavourable and have reserve grazing during drought periods).

4. Animals should be moved out of rotationally grazed wetland before it has been grazed to a specified height. Even for non-wetlands there is little literature to support a specific prescribed level of use as this is affected by numerous variables (e.g. climatic variation). However, the specified height given in WETLAND-USE was based on the recommendations of a grazing specialist Prof. N M Tainton. It is assumed that grazing beyond the prescribed level is likely to begin detracting from the hydrological, ecological and production potential benefits of an area.

5. Grazing wetland areas when the soil is wet is more likely to result in erosion and/or compaction than grazing when the soil is dry. This assumption is based on a report by Wilkins and Garwood (1986).

* **Hay making/mowing**

1. Cutting of natural vegetation does not significantly detract from the ecological value of wetlands provided that not more than 30% of any wetness zone in a wetland is cut in a given year if the wetland is being grazed and not more than 50% of any wetness zone if the wetland is not being used for grazing. There is little research available concerning the effect of hay cutting on wetland fauna. Although there are a number of European studies (e.g. Bakker, 1989) which show that cutting enhances plant species diversity, and indications that it has a short term negative effect on fauna by reducing cover (Bryan and Best, 1991; Tarboton, 1994. *Pers. comm.*) there are no local studies and the 30% and 50% thresholds were arbitrarily chosen based on the assumption that in a grazed area the cover would have already been partly reduced.

2. Cutting with machinery when the soil is wet is more likely to result in soil erosion than cutting when the soil is dry. (see Grazing Assumption 5).

* **Pasture production**

1. Perennial species are preferable to annuals because they require that the soil be disturbed less frequently. This assumption is supported by the fact that soil disturbance has negative effects such as organic matter depletion and increased susceptibility to erosion (Miles and Manson, 1992).

2. Species with a high wetness tolerance are preferable to those with a low wetness tolerance because they require less lowering of the water table. See the reasoning for Primary assumption 1.

3. *Intensive pastures, particularly those in drainage lines, may contribute to a deterioration in the quality of runoff waters.* This general assumption is well supported (e.g. Amberger, 1983; Canter, 1986; and Miles and Manson, 1992). However, it is important to note that the effect of intensive pastures depends on several variables (e.g. fertilizer application rates and soil type), and may be negligible.

4. *Measures should be taken to minimize fertilizer leaching losses from planted pastures.* The measures recommended by WETLAND-USE for minimizing leaching losses from pastures are based primarily on those recommended by Amberger (1983) and also on those of Miles and Manson (1992).

* **Mechanized crop production**

1. *Crop production is generally considered to have one of the severest agricultural impacts on wetlands.* The high impact associated with wetland drainage and conversion to cropland has been well demonstrated (e.g. Willrich and Smith, 1970).

2. The recommendations and associated assumptions concerning minimizing drainage requirements and nutrient leaching from planted pastures are also applicable to crops.

3. *Ley cropping should be implemented to reduce the impact.* The benefits (e.g. reduced organic matter depletion) that accrue from ley cropping have been clearly demonstrated (Wardle, 1961; Lockhart and Wiseman, 1988).

* **Traditional crop production**

The impacts of traditional cultivation are considered to be lower than commercial cultivation based on observations at KwaZulu-Natal wetlands (see Kotze, 1999) and evidence presented by Whitlow (1991) and Dadnadji and van Wetten (1993). For this to be so, however, It is assumed that in traditionally cultivated areas:

1. The crops grown are tolerant of waterlogging, minimizing the need to alter the water regime.
2. Tillage and harvesting is by hand, which results in less disturbance, and hence potential erosion, than with mechanical tillage and harvesting.
3. Pesticides and artificial fertilizers are not used, reducing the impact on water quality.
4. Mineral soils are cultivated, with some of the soils in areas where sediment from excessive erosion in the uplands has recently been deposited, and thus cultivation does not lead to extensive depletion of soil organic matter as would be the case in cultivated organic soils.
5. areas cultivated are shifted from year to year, with most individual patches being continuously cultivated for less than 4 years compared with large-scale cultivation where areas are continuously cultivated and not shifted;
6. The spatial configuration of areas cultivated is generally in the form of small isolated areas rather than larger consolidated areas
7. Areas with moderate or high erosion hazards are avoided (see Descriptor F12).

If these assumptions are not met then the impacts are likely to be closer to those associated with commercial cultivation.

* **Damming**

Dams generally have a negative effect on the habitat in the area which it floods and often also on downstream habitats as a result of altered flow regimes. The loss of habitat that follows flooding by dams and the negative effect that dams have on the downstream biota due to the altered flow regime are well documented (e.g. Davies and Day, 1986; Bruwer and Ashton, 1989; and Conley, 1992). The decreased runoff that results from evaporation from dams has been shown (Schulze *et al.*, 1989).

SECTION 6, REFERENCES

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SECTION 7, GLOSSARY

Aerobic: having molecular oxygen (O_2) present.

Anaerobic: not having molecular oxygen (O_2) present.

Animal unit (AU): an animal unit is defined as an animal with a mass of 450 kg and which gains 0.5 kg per day on forage with a digestible energy percentage of 55%. Other types of animals are related to such a unit according to the relationship between the three-quarter power of the mass of such animals and a similar function of the mass of a 450 kg animal, i.e. an animal with a mass *m* constitutes:

$$\frac{m^{0.75}}{450^{0.75}}$$ of an animal unit

Aquic moisture regime: a reducing regime virtually free of dissolved oxygen because the soil is saturated. Some **soil horizons**, at times, are saturated with water while dissolved oxygen is present (as may occur if the water is moving). The required **soil saturation** duration is not known (and depends on site factors such as soil texture and temperature), but must be at least a few days (Soil Survey Staff, 1992).

Biodiversity: the variety of life in an area, including the number of different species, the genetic wealth within each species, and the natural areas where they are found.

Biophysical features: biological (e.g. threatened species) and physical (e.g. soil wetness zone) features.

Biological integrity: the fauna and flora that characterise an area (i.e. the area's "naturalness").

Bog: a **mire** (i.e. a **peat** accumulating wetland) that is hydrologically isolated, meaning that it is only fed by water falling directly on it as rain or snow and does not receive any water from a surrounding catchment. Bogs have acidic waters and are often dominated by mosses (Mitsch and Gosselink, 1986). The term bog is frequently used much more broadly in South Africa to refer to high altitude wetlands that have organic-rich soils. Many of these wetlands would not be bogs in the correct sense.

Bottomland: the lowlands along streams and rivers, on alluvial (river deposited) soil.

Catchment: all the land area from mountaintop to seashore which is drained by a single river and its tributaries. Each catchment in South Africa has been sub-divided into secondary catchments, which, in turn have been divided into tertiary. Finally, all tertiary catchments have been divided into interconnected quaternary catchments. A total of 1946 quaternary catchments have been identified for South Africa. These sub-divided catchments provide the main basis on which catchments are sub-divided for integrated catchment planning and management *(see DWAF [1994])*.

Chroma: the relative purity of the spectral colour, which decreases with increasing greyness.

Decision support system: procedures (often, but not always computer based) designed to assist in promoting more informed decision making.

Decomposition: the breakdown of dead organic matter into simpler substances.

Delineation (of a wetland): to determine the bounday of a wetland based on soil, vegetation, and/or hydrological indicators (see defenition of a wetland).

Descriptor: a measurable characteristic considered useful in predicting how a wetland's indirect benefits will be affected by management actions.

Direct (wetland) benefits: have worth, quality or importance to humans and are realized by individuals actively using a wetland (e.g. for recreation, or pasture production).

Dominant plant species: the overstory species that contribute most cover to the area, compared to other overstory species.

Ecological value: the value of the wetland in maintaining the biotic diversity of the area. Biotic diversity can be measured at many different levels, and it is almost impossible to prescribe a standard method of describing it. Its assessment may be simplified by determining the degree to which management is affecting biological integrity and populations of valued species.

Evaporation: the change from a liquid or solid state to a vapour.

Fen: a mire (i.e. a peat accumulating wetland) that receives some drainage from mineral soil in the surrounding catchment.

Gley: soil material that has developed under anaerobic conditions as a result of prolonged saturation with water. Grey and sometimes blue or green colours predominate but **mottles** (yellow, red, brown and black) may be present and indicate localized areas of better aeration.

Groundwater: subsurface water in the zone in which permeable rocks, and often the overlying soil, are saturated under pressure equal to or greater than atmospheric (Soil Classification Working Group, 1991).

Groundwater table: the upper limit of the groundwater.

Horizon: see soil horizons.

Hydric soil: 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 (vegetation adapted to living in anaerobic soils).

Hydrophyte: any plant that grows in water or on a substratum that is at least periodically deficient in oxygen as a result of soil saturation or flooding; plants typically found in wet habitats.

Hydrology: the study of water, particularly the factors affecting its movement on land.

Hue: the dominant spectral colour (e.g. red).

IEM: see Integrated Environmental Management

Impact site: that part of the wetland site to which a proposed land-use is to be applied.

Indirect (wetland) benefits: have worth, quality or importance to humans but do not require active use of wetlands by individuals in order for the benefits to be realized. Instead, the wider public benefits indirectly from the services that wetlands provide (e.g. purification of water).

Infilling: dumping of soil or solid waste onto the wetland surface. Infilling generally has a very high and permanent impact on wetland functioning and is similar to drainage in that the upper soil layers are rendered less wet, usually so much so that the area no longer functions as a wetland.

Integrated Environmental Management (IEM): A nationally accepted procedure for promoting better planned development by ensuring that the environmental consequences of development are understood and adequately considered in planning and implementation.

Marsh. a wetland dominated by emergent herbaceous vegetation (usually taller than 1 m), such as the common reed (*Phragmites australis*) which may be seasonally wet but are usually permanently or semi-permanently wet.

Mire: a peat accumulating wetland, including both bogs and fens.

Mitigate: to take actions to reduce the impact of a particular proposal.

Monitor: to keep a check on, and record of something, which would allow changes to be detected.

Mottles: soils with variegated colour patters are described as being mottled, with the "background colour" referred to as the matrix and the spots or blotches of colour referred to as mottles.

Munsell colour chart: A standardized colour chart which can be used to describe hue (i.e. its relation to red, yellow, green, blue, and purple), value (i.e. its lightness) and chroma (i.e. its purity). Munsell colour charts are available which show that portion commonly associated with soils, which is about one fifth of the entire range.

***n* Value:** the relationship between the percentage of water under field conditions and the percentage of inorganic clay and humus. It can be approximated in the field by a simple test of squeezing the soil in the hand. It is helpful in predicting the degree of subsidence that will occur after drainage (Pons and Zonneveld, 1965; Soil Survey Staff, 1992).

Open water zone: permanently or semi-permanently flooded areas characterized by the absence (or low abundance) of emergent plants.

Organic soil material: soil material with a high abundance of undecomposed plant material and humus. According to the Soil Classification Working Group (1991) an organic soil horizon must have at least 10% organic carbon by weight throughout a vertical distance of 200 mm and be saturated for long periods in the year unless drained. According to the Soil Survey Staff (1975) definition, in order for a soil to be classed as organic it must have >12% organic carbon by weight if it is sandy and >18% if it is clay-rich.

Palustrine (wetland): All non-tidal wetlands dominated by persistent emergent plants (e.g. reeds) emergent mosses or lichens, or shrubs or trees (see Cowardin *et al.*, 1979).

Peat: organic soil material with a particularly high organic matter content which, depending on the definition, usually has at least 20% organic carbon by weight.

Peraquic moisture regime: an aquic moisture regime where the where the ground water is always at or very close to the surface (Soil Survey Staff, 1992).

Perched water table: the upper limit of a zone of saturation in soil, separated by a relatively impermeable unsaturated zone from the main body of groundwater.

Perennial crop: lasting throughout the year and through many years.

Permanently wet soil: soil which is flooded or waterlogged to the soil surface throughout the year, in most years.

Poaching: this occurs when soils are wet, and refers to the disruption of soil structure caused by the repeated penetration of hooves into the soil (Wilkins and Garwood, 1986). The poaching of soils should be avoided because besides decreasing herbage production, it also greatly increases the susceptibility of the soil to erosion.

Physiognomy: the outer appearance of the vegetation; a function of the architecture of the different canopy layers and the life form of the dominant plants.

Ramsar Convention: an intergovernmental treaty which provides the framework for international cooperation for the conservation of wetland habitats.

Red Data species: all those species included in the categories of endangered, vulnerable or rare, as defined by the International Union for the Conservation of Nature and Natural Resources.

Riparian: the area of land adjacent to a stream or river that is influenced by stream-induced or related processes. Riparian areas which are saturated or flooded for prolonged periods would be considered wetlands and could be described as **riparian wetlands**. However, some riparian areas are not wetlands (e.g. where alluvium is periodically deposited by a stream during floods but which is well drained).

Roughness coefficient: an index of the roughness of a surface; a reflection of the frictional resistance offered by the surface to water flow.

Rule-based model: a model which represents knowledge in the form of IF-THEN statements. The IF part contains a condition or premise and the THEN part contains a result, conclusion or consequence.

Runoff: total water yield from a catchment including surface and subsurface flow.

Seasonally wet soil: soil which is flooded or waterlogged to the soil surface for extended periods (>1 month) during the wet season, but is predominantly dry during the dry season.

Sedges: Grass-like plants belonging to the family Cyperaceae, sometimes referred to as nutgrasses. Papyrus is a member of this family.

Soil drainage classes: describe the soil moisture conditions as determined by the capacity of the soil and the site for removing excess water. The classes range from very well drained, where excess water is removed very quickly, to very poorly drained, where excess water is removed very slowly. Wetlands include all soils in the very poorly drained and poorly drained classes, and some soils in the somewhat poorly drained class. These three classes are roughly equivalent to the permanent, seasonal and temporary classes

Soil horizons: layers of soil that have fairly uniform characteristics and have developed through pedogenic processes; they are bound by air, hard rock or other horizons (i.e. soil material that has different characteristics).

Soil profile: the vertically sectioned sample through the soil mantle, usually consisting of two or three horizons (Soil Classification Working Group, 1991).

Soil saturation: the soil is considered saturated if the water table or **capillary fringe** reaches the soil surface (Soil Survey Staff, 1992).

Stakeholders: the people or organizations that have a direct interest in a particular issue (e.g. a wetland).

Stocking rate (SR): the number of animal units AUs per unit of land for a specified period of time; it may be expressed in terms of number of land units per AU.

Sustainable use: use of natural resources which allows that resource to renew itself and which is within biological limits and meets the ecological, social and economic needs of humans such that the future is not compromised for the present (a temporal dimension) and geographic area(s) are not compromised for other geographic area(s) (a spatial dimension).

Temporarily wet soil: The soil close to the soil surface (i.e. within 50 cm) is wet for periods > 2 weeks during the wet season in most years. However, it is seldom flooded or saturated at the surface for longer than a month.

Terrain unit classes: areas of the land surface with homogenous form and slope. Terrain may be seen as being made up of all or some of the following units: crest (1), scarp (2), midslope (3), footslope (4) and valley bottom (5).

Transpiration: the transfer of water from plants into the atmosphere as water vapour

Vlei: a colloquial South African term for wetland.

Water regime: When and for how long the soil is flooded or saturated.

Water quality: the purity of the water.

Waterlogged: soil or land saturated with water long enough for anaerobic conditions to develop.

Wet grassland: a wetland area which is usually temporarily wet and supports a mixture of: 1) plants common to non-wetland areas and 2) short (< 1m) hydrophytic plants (predominantly grasses) also common to the **wet meadow** zone.

Wetland: land where an excess of water is the dominant factor determining the nature of the soil development and the types of plants and animals living at the soil surface (Cowardin *et al.*, 1976); lands that are sometimes or always covered by shallow water or have saturated soils long enough to support plants adapted for life in wet conditions.

Wetland catchment: the area up-slope of the wetland from which water flows into the wetland and including the wetland itself.

Wetland delineation: the determination and marking of the boundary of a wetland on a map.

Wet meadow: a wetland area which is usually seasonally wet and dominated by short (usually <1.5 m) hydrophytic sedges and grasses common to temporarily or seasonally wet areas.

Wise use (of wetlands): synonymous with **sustainable use** .

APPENDIX 1: WETLAND SOILS

As indicated in Kotze *et al.* (1996) the South African Soil classification system (Soil Working Group, 1991) does not require that the soil water regime be determined and the depth to upper limit of the G horizon or any other horizon with signs of wetness is not specified. It may range from <200 mm to >800 mm. This is an important weakness of the system when applied to hydric soils as the depth of waterlogging is crucial in determining whether a soil is hydric or not (Kotze *et al.*, 1996). *Soil Taxonomy* (Soil Survey Staff, 1992), which is the most commonly used soil classification system worldwide, recognizes the aquic water regime. Aquic soils are recognized based on the presence of features of wetness (e.g. mottling and a low chroma matrix) that are visible at <0.5 m from the soil surface. It is within this upper 0.5 m of soil that most of the roots of herbaceous plants are situated.

Despite the limitation of the South African system, it is worthwhile to identify the hydric character of the different soil forms associated with wetlands. This has been done at a preliminary level (see Table A1). Hydric character refers to whether soils in a particular form are always, usually or sometimes hydric (wetland) soils, depending on the depth of the horizon with indications of wetness. The soil forms in the first group (Always Hydric) consistently have signs of wetness close (within the upper 50 mm) to the soil surface identifying them as hydric. It may, however, be that a soil belonging to one of these horizons is encountered that has signs of wetness that are deeper than is usually the case, making the soil non-hydric, but this is the exception. Soil forms in the second group (Usually Hydric) are usually found in wetland areas, depending on the depth of characteristics associated with wetness and the intensity of the indicators of wetness (e.g. the soft plinthic horizon varies according to the intensity of wetness indicators within the profile). Soils in the last group (Sometimes Hydric) are usually non-hydric but, again depending on the depth and intensity of wetness indicators, may sometimes be hydric.

It must be stressed that this is a very preliminary list and it would be great to get wider comment on it.

Table A1 A preliminary classification of the hydric character of soil forms characteristically associated with wetlands.

Diagnostic Horizons and Materials				Hydric character	Soil Form
Topsoil	Subsoil				
Organic	unspecified			Always	CHAMPAGNE
Vertic	G horizon			Always	RENSBURG
Melanic	G horizon			Always	WILLOWBROOK
Orthic	G horizon			Always	KATSPRUIT
Orthic	E horizon	G horizon		Usually	KROONSTAD
Orthic	E horizon	soft plinthic B		Usually	LONGLANDS
Orthic	E horizon	hard plinthic B		Sometimes	WASBANK
Orthic	E horizon	yellow-brown apedal B		Sometimes	CONSTANTIA
Orthic	E horizon	podzol B + placic pan		Sometimes	TSITSIKAMMA
Orthic	E horizon	podzol B	unconsolidated material with signs of wetness	?Sometimes	LAMOTTE
Orthic	E horizon	podzol B	saprolite	Sometimes	HOUHOEK

Orthic	E horizon	prismacutanic B		Sometimes	ESTCOURT
Orthic	E horizon	lithocutanic B		Sometimes	CARTREF
Orthic	E horizon	unspecified		Sometimes	FERNWOOD
Orthic	soft plinthic B			Sometimes	WESTLEIGH
Orthic	yellow-brown apedal B	soft plinthic B		Sometimes	AVALON
Orthic	yellow-brown apedal B	unspecified material with signs of wetness		Sometimes	PINEDENE
Orthic	red apedal B	unspecified material with signs of wetness		Usually?	BLOEMDAL
Orthic	podzol B	unconsolidated material with signs of wetness		Usually?	WITFONTEIN
Orthic	pedocutanic B	unconsolidated material with signs of wetness		Usually?	SEPANE
Orthic	neocarbonate B	unspecified material with signs of wetness		Usually?	MONTAGU

Note: soil forms not listed are absent or very seldom associated with wetlands

Table A2 Erosion hazards for the primary soil forms associated with wetlands in South Africa

Soil Form	Code	Soil Series (Families)	Erosion Hazard Rating (K)
Champagne	Ch 11 Ch 21 Ch 10 Ch 20	Champagne Ivanhoe Mposa Stratford	high high high high
Katspruit	Ka 10 Ka 20	Katspruit Killarney	mod high
Rensburg	Rg 10 Rg 20	Phoenix Rensburg	high high
Willowbrook	Wo 21 Wo 10 Wo 20 Wo 11	Chinyike Emfuleni Sarasdale Willowbrook	high high high mod

Estcourt	Es 20	Assegaai	v.high
	Es 11	Auckland	v.high
	Es 22	Avontuur	v.high
	Es 35	Balfour	v.high
	Es 40	Beerlaagte	v.high
	Es 37	Buffelsdrif	high
	Es 42	Darling	v.high
	Es 13	Dohne	v.high
	Es 31	Elim	v.high
	Es 33	Enkeldoorn	v.high
	Es 36	Estcourt	high
	Es 14	Grasslands	v.high
	Es 41	Heights	v.high
	Es 10	Houdenbeck	v.high
	Es 21	Langkloof	v.high
	Es 30	Mozi	v.high
	Es 12	Potela	v.high
	Es 16	Rosemead	high
	Es 32	Soldaatskraal	v.high
	Es 34	Uitvlugt	v.high
	Es 15	Vredenhoek	v.high
	Es 17	Zintwala	high
Kroonstad	Kd 17	Avoca	high
	Kd 16	Bluebank	high
	Kd 22	Katarra	v.high
	Kd 20	Koppies	v.high
	Kd 13	Kroonstad	v.high
	Kd 14	Mkambati	v.high
	Kd 10	Rocklands	v.high
	Kd 15	Slangkop	v.high
	Kd 12	Swellengift	v.high
	Kd 18	Uitspan	v.high
	Kd 21	Umtentweni	high
	Kd 11	Velddrif	v.high
	Kd 19	Volksrust	mod
Longlands	Lo 22	Albany	mod
	Lo 32	Chitsa	mod
	Lo 21	Longlands	high
	Lo 10	Orkney	high
	Lo 30	Tayside	high
	Lo 31	Vaalsand	high
	Lo 20	Vasi	high
	Lo 11	Waaisand	high
	Lo 12	Waldene	high
	Lo 13	Winterton	low
Westleigh	We 10	Chinde	high
	We 32	Davel	mod
	We 22	Devon	mod
	We 20	Kosi	high
	We 30	Langkuil	high
	We 31	Paddock	high
	We 12	Rietvlei	mod
	We 13	Sibasa	low
	We 11	Westleigh	high
	We 21	Witsand	high

APPENDIX 2: ADDITIONAL DESCRIPTORS FOR DESCRIBING THE WETLAND AND ITS CONTEXT

A20. Terrain unit/s (according to Land Type survey Staff [1986]) on which the wetland occurs.
Crest ☐ Footslope ☐ Scarp ☐ Valley bottom ☐ Midslope ☐

A21 Mean annual precipitation (mm) ....
A22 Mean annual potential evaporation (mm) ....

Note: if data are unavailable for A23 and A24 then these may be obtained from Schulze (1997).
A23 Veld type (according to Acocks, 1953) ....
A24 Dominant soil form/s (according to Soil Classification Working Group, 1991) occurring in the wetland.
....

A25. Underlying geology ....
A26 Average width (m) of the wetland perpendicular to flow. ....
Note: to calculate the average width of the wetland, divide the wetland (perpendicular to the direction of flow) into 5 segments of equal length, and measure the width of each segment (at their centres and perpendicular to the direction of flow), then calculate their average by dividing their sum by 5.

A27 Length of the wetland from the outlet to the inlet (m). .....
Note: this refers to the distance that diffuse water flow would travel from the inlet to the outlet. If the wetland were curved or twisted, the wetland length would be longer than the straight line distance from the inlet to the outlet.
A28 Calculate the average slope of the entire wetland (%). ....
Note: A28= 100 x (Altitude of inlet-Altitude of outlet)÷A27.

A29 What is the stream order of the main input channel.
☐ first order ☐ second order ☐ third order ☐ fourth order or more

A30 What is the importance of the wetland for supporting migratory/nomadic birds.
☐ negligible ☐ moderate (ca 100-1000 birds) ☐ high (> ca 1000 birds)
Note: the wetland may be important for only a few weeks each year or even less frequently but, nevertheless, would still be important. It may be necessary to consult an ornithologist.

A31 Indicate (Y or N) if the wetland is part of, and essential to, an ongoing long term environmental research/monitoring programme. ....

A32 Indicate (Y or N) if the wetland is the closest wetland to any environmental education centre, school, university or similar education facility and is within 500 m of a public road with available parking. ....

C6. Surface area of the wetland catchment (ha) .....

C7. % of the wetland catchment occupied by the wetland ....

C8. Mean annual runoff generated by the wetland's catchment
Note: The mean annual runoff generated by a wetland's catchment may be approximated very roughly by using mean annual runoff data which has been estimated for quaternary catchments (e.g. Pitman et al. 1981). If for example a wetlands catchment occupies 40% of a quaternary catchment which has an estimated mean annual runoff of $54 \times 10^6\ m^3$ *then the estimated mean annual runoff from the wetland's catchment is* $54 \times 10^6 \times 0.4\ m^3 = 22 \times 10^6\ m^3$.

Note: D3 to D6 provide a more comprehensive and semi-quantitative means of obtaining the information requested in D1 and D2.

D3. In the water purification service area, rate (0-3) the current human use of the stream for:

1. Potable water users, which includes individuals (in most cases poor rural people) who extract water directly by hand for daily domestic use. ......
   0= Nil users 1= 1-3 users 2= 4-50 users 3= >50 users

2. Piped water users, which includes water for irrigation, domestic and industrial purposes
   0= No extraction 2= 11-100 million m^3 extracted annually
   1= 1-10 million m^3 extracted annually 3= >100 million m^3 extracted annually

3. Recreationists who use the water on site for fishing, bathing and/or water sports (expressed on a per km per month basis) ....
   0= No users 1= 1-10 users 2= 10 - 20 users 3= >20 users

4. Stock farmers (both subsistence and commercial) that require water for stock watering. ....
   0= No stock watering 2= 11-30 AU's per km
   1= 1-10 **animal units** (AU's) watered per km 3= >30 AU's per km

D4. D4=D3.1+D3.2+D3.3+D3.4

D5. Now determine the total current importance for human use of water purification in the downstream area of influence using the following rules:

if D3.1 >1 or D4 >6 then significance = high □

otherwise if D4≤ 6 and >2 then significance = moderate □

otherwise if D4> 0 and ≤ 2 then significance = low □

otherwise if D4= 0 then significance = nil □

D6. Downstream flood damage potential. To the end of the downstream service are, determine the current abundance of FU's (Floodable Units, see notes) occurring within the 1 in 50 year flood line and determine the total current significance of flood reduction in the downstream area of influence

TOTAL NO. OF FU's	0	1-10	11-19	>20
CURRENT SIGNIFICANCE	Nil □	Low □	Medium □	High □

Note: the benefit derived from flood reduction in a floodable zone below a wetland would obviously increase with increasing abundance of floodable property. In WETLAND-USE, floodable property is expressed in terms of Floodable Units (FU's), where 1 FU is equivalent to 1 house or 20 ha of cropland. Other features of biological, social or economic value should be subjectively allocated FU scores. A riverine forest, for example, while possibly requiring some measure of flooding, may be negatively affected by a marked increase in flood peaks that could result from wetland destruction.

F30. Estimate the *n* Value by squeezing a handful of soil. Observe how easily it flows between the fingers and indicate this. The soil should be taken at 10 cm below the surface and the test should preferably be conducted during the wet season and not in a drought year.
□ very high (flows easily) □ high (flows with difficulty) □ medium or low (does not flow)

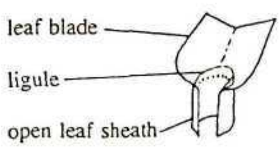
Note: the n Value refers to the relationship between the percentage of water under field conditions and the percentages of clay and humus. It is helpful in predicting the degree of subsidence that will occur after drainage *and whether the soil may be grazed by livestock or will support other loads (Pons and Zonneveld, 1965; Soil Survey Staff, 1992). The n Value may depends on the conditions at the time of measurement and is therefore not used as a criterion for assessing level of impact.*

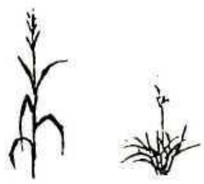
APPENDIX 3: SOME PLANT SPECIES COMMON TO WETLANDS IN THE HIGH SUMMER RAINFALL AREAS OF SOUTH AFRICA

Some of the plant families common to wetlands are listed, followed by descriptions of how to identify selected species, including their general height and the **wetness zones in which they characteristically occur**. Use a hand lense or binoculars up-side-down to observe any fine detail required. The focus of this appendix is on grasses, sedges and rushes. There are clearly many wetland species in these and other families which are not included. Reference was made to the following documents: Gibbs Russell *et al.* (1991); Gordon-Gray (1995); Obermeyer (1985); and Pooley (1998) from which more detailed information can be obtained. Acknowledgement is also made for seven of the grass diagrams taken from: Tainton N M, Bransby D I, and Booysen P deV, 1976. Common veld and pasture grasses of Natal. Shuter and Shooter, Pietermaritzburg.

GRAMINEAE (GRASSES) ❑ (page 71-73)

All grasses have an open leaf sheath and stems with nodes, unlike sedges.

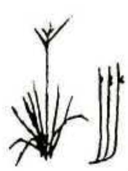


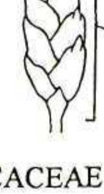


CYPERACEAE (SEDGES) ■ (page 74-75)

Sedges resemble grasses but most sedges lack stem nodes and all sedges have a closed leaf sheath, if present.

Closed leaf sheath





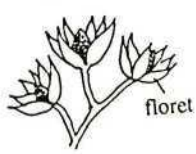
Florets generally arranged in spikelets as in grasses

Spikelet

JUNCACEAE (RUSHES) ■ (page 75)

Rushes characteristically have cylindrical stems and leaves. They may be confused with certain sedges (e.g. *Eleocharis* spp. and *Schoenoplectus* spp.) but their flowers are distinctly different.

Florets with 6 stamens and 6 whorled bracts



TYPHACEAE ■ (page 76)

Bullrushes

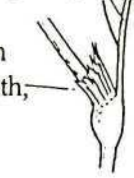
Inflorescence cigar shaped; leaves in a single plane

POTAMOGETONACEAE ■ (page 76)
"Pondweeds"
Submerged or floating leaved, flowers in erect spikes

ASPHODELACEAE ❑ (page 76)
"Red-hot pokers"
Thick succulent leaves in a radiating cluster

AMARYLLIDACEAE ❑ (page 76)
Includes "vlei lilies"
Bulbous herbs, inflorescence with stalks arising from a common point like an umbrella

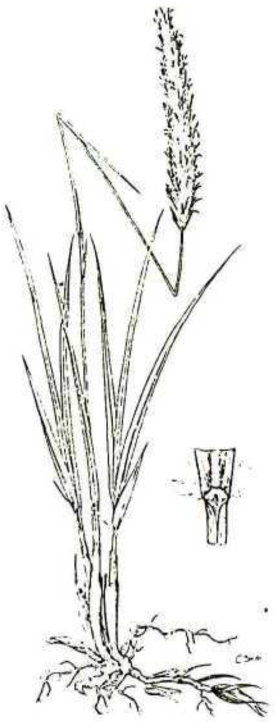
POLYGONACEAE ■ (page 76)
Includes "knotweeds"
Base of stem often swollen like a knot and with a sheath, flowers in dry bracts



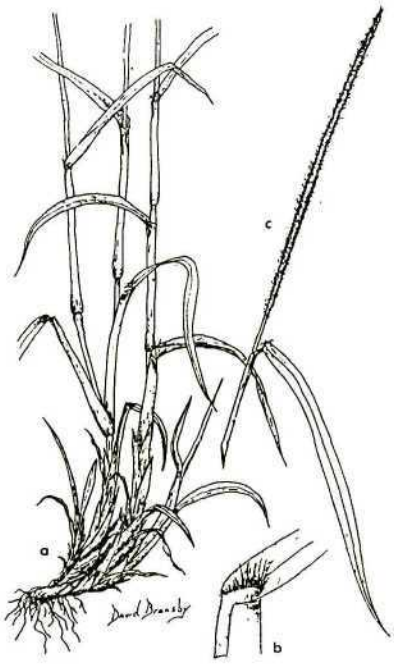
■ Most of the species in the family are dependent on wetlands

❑ The family includes wetland-dependent and non-wetland species

✖ While common in wetlands, these species occur extensively outside of wetlands.



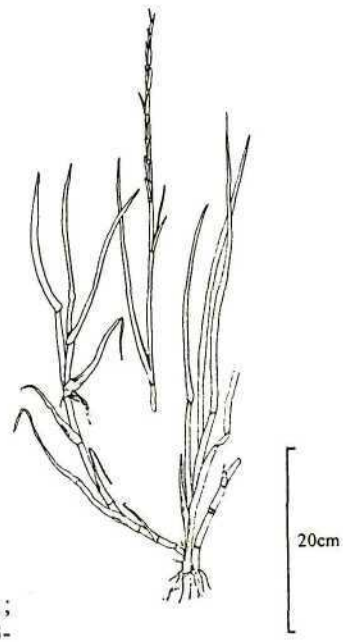
Imperata cylindrica:
strongly rhizomatous; leaves broad in middle, narrow at tip, red in winter; inflorescence white; **temporary wetness**.



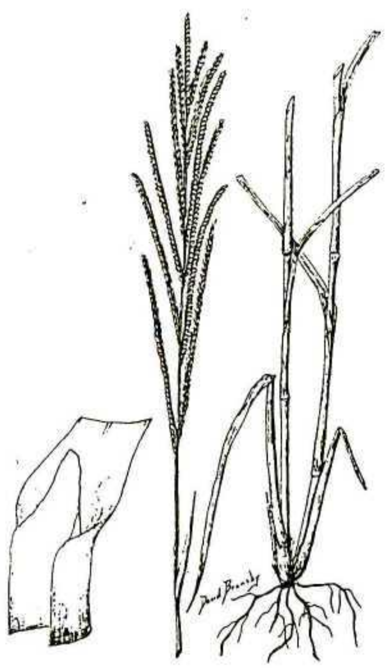
Setaria sphacelata:
rhizomatous or tufted;0.3-1.5cm; inflorescence golden yellow, 7-40cm long; **temporary, seasonal wetness ×**.

Pennisetum thunbergii:
tufted; 0.3-1.0m; inflorescence purple, 3-5cm long; **temporary, seasonal wetness**.

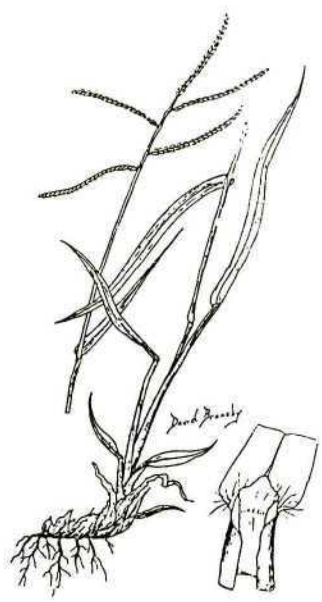
Pennisetum macrourum:
tufted; 0.4-1.5m; inflorescence light green, 12-25cm long; **temporary, seasonal wetness**.



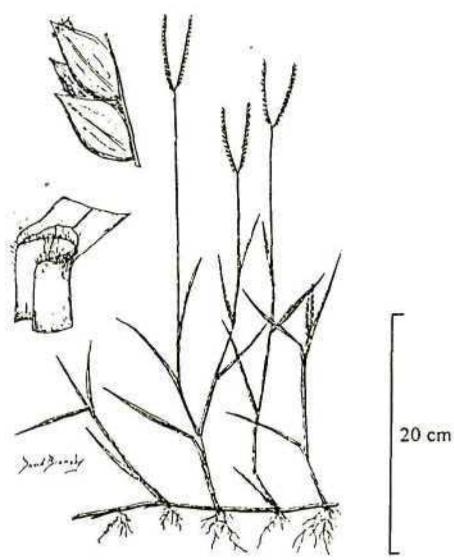
Hemarthria altissima:
creeping, stoloniferous; leaves turn red; **temporary, seasonal wetness**.



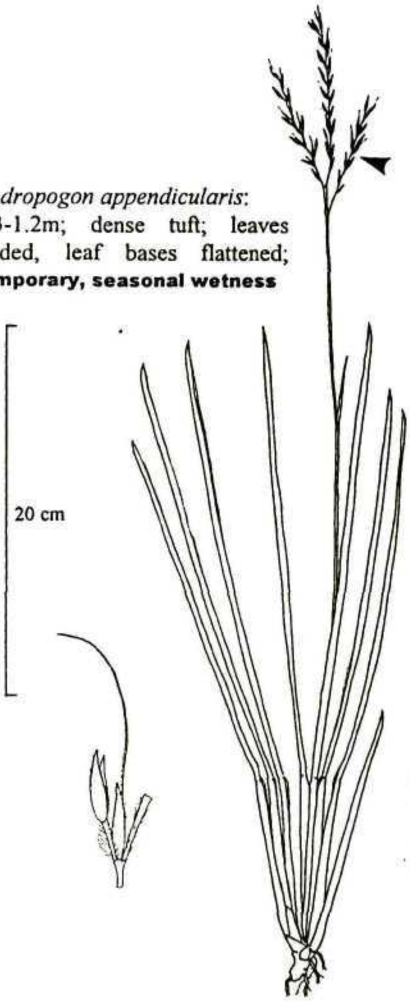
Paspalum urvillei:
rhizomatous or tufted;1.0-2.5m; inflorescence with 10-30 racemes on axis; conspicuous membranous ligule; **temporary wetness**.



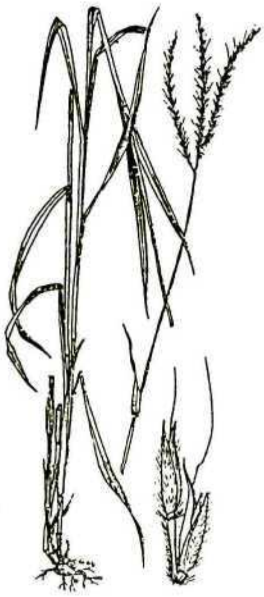
Paspalum dilatatum:
rhizomatous or tufted;0.3-1.3m; inflorescence with 4-9 racemes on axis; conspicuous membranous ligule; **temporary wetness**.



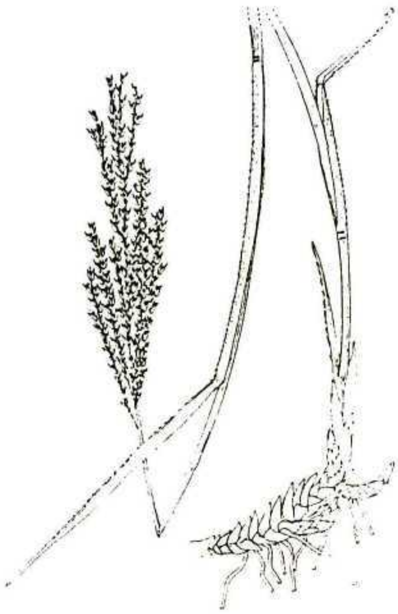
Paspalum distichum:
rhizomatous or stoloniferous (strongly creeping);<1.0m; inflorescence with a pair of racemes on end of stem; **seasonal, permanent wetness**.



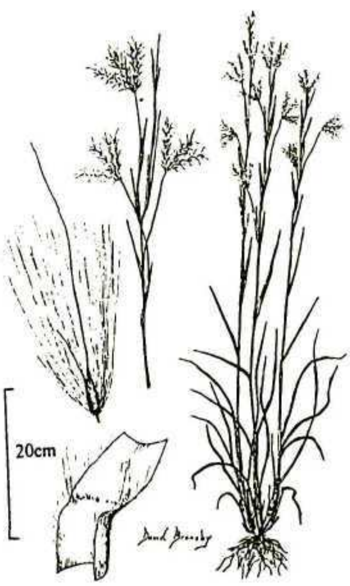
Andropogon appendicularis: 0.3-1.2m; dense tuft; leaves folded, leaf bases flattened; **temporary, seasonal wetness**



Ischaemum fasciculatum: rhizomatous; 0.3-0.9m; leaves light green turning reddish; common on edge of stream; **temporary-permanent wetness**.

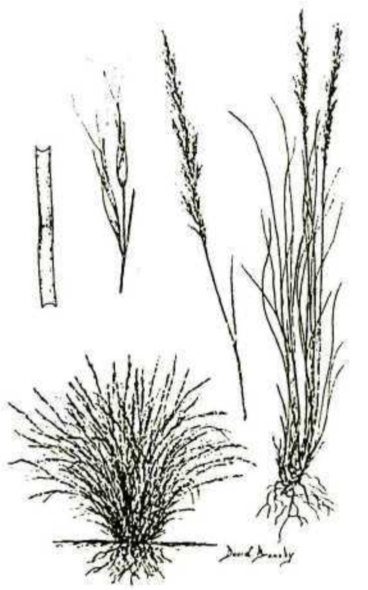


Arundinella nepalensis: rhizomatous; 0.6-1.5m coarse, stiff leaved with expanded blades; rigid inflorescence; **temporary, seasonal wetness**.



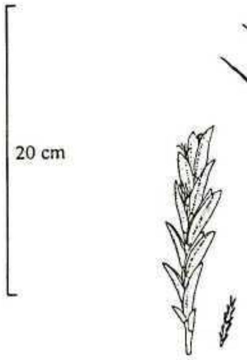
Andropogon eucomis: tufted; 0.2-0.9m; infloescence with white silky hairs; **temporary, seasonal wetness.**

Festuca caprina: tufted; 0.2-0.6m; leaves fine; old leaf bases persist as fine fibres; >1500m altitude; **temporary, seasonal wetness**.

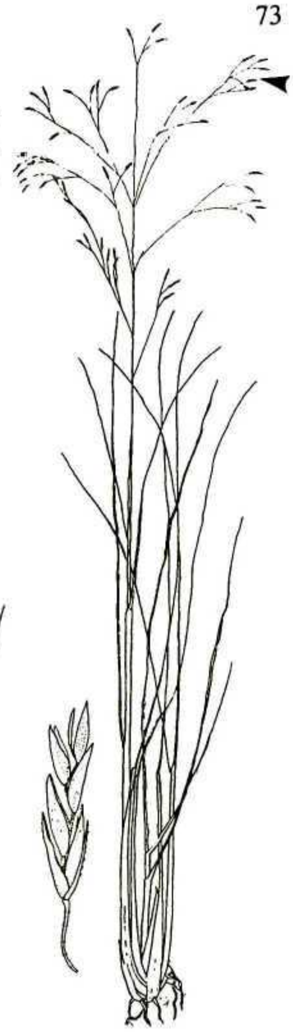


Aristida junciformis: densely tufted; 0.3-0.9; leaves wirey, rolled and narrow; **temporary, seasonal wetness x**.

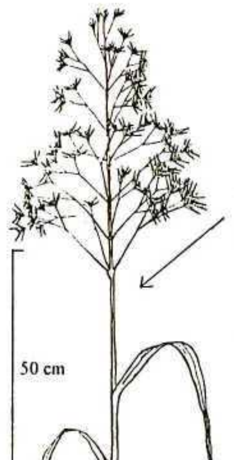
Eragrostis plana:
0.2-1.0m; tufted; flattened fan-shaped leaf base; leaves strong and smooth; **temporary wetness ✖**.



Eragrostis planiculmis:
resembles *E. curvula* but hairs absent from the base of the plant; inflorescence much branched; **temporary, seasonal wetness**.

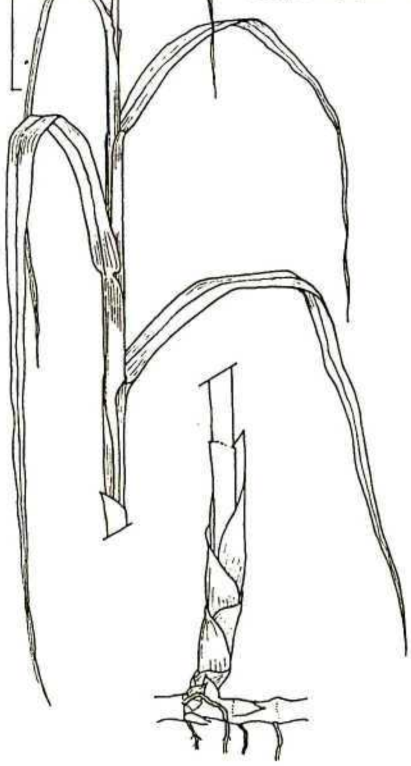


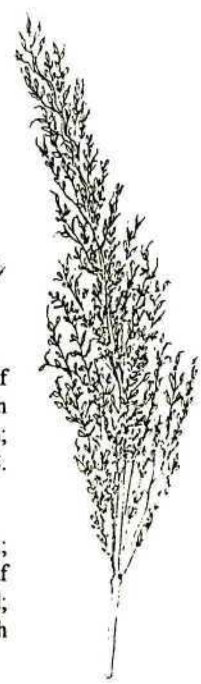
Leersia hexandra:
toothed ligule; tiny hairs on nodes; **temporary-permanent wetness**



Phragmites australis:
0.6-4.0 m; leaves break off at base of leave blade; **usually permanent wetness**.

Phragmites mauritianus:
resembles *P. australis* but leaves break off at the base of the sheath and have rigid sharp points; **temporary-permanent wetness**.



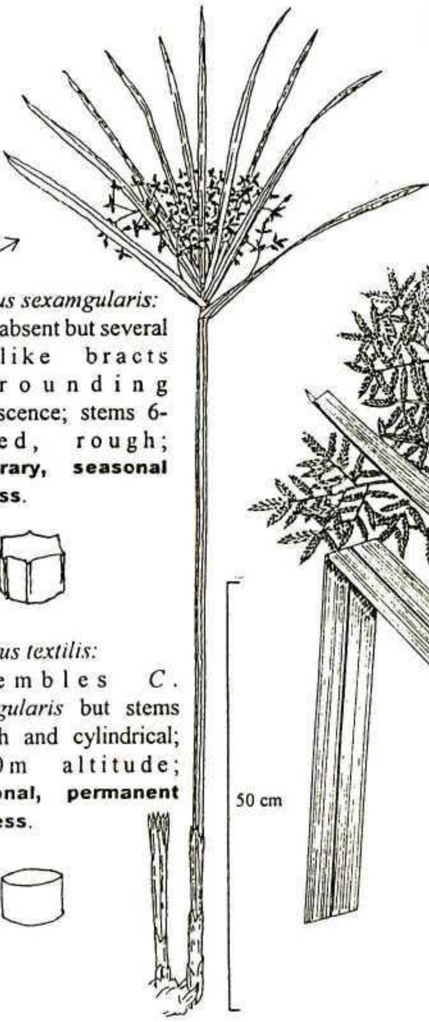


Miscanthus capensis:
tufted and robust; 0.5-2.5m; leaf blades >1.0cm wide; distribution generally south-east of Ladysmith; **temporary, seasonal wetness ✖**.

50 cm

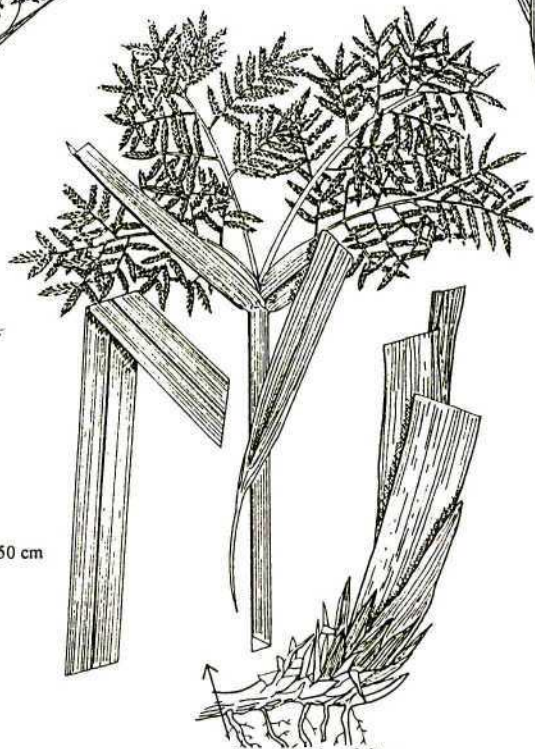
Miscanthus junceus:
tufted and robust; 0.5-2.5m; resembles *M. junceus* but leaf blades <0.4cm wide and rounded; generally north-west of Ladysmith **temporary, seasonal wetness**.

CYPERACEAE
(SEDGES)



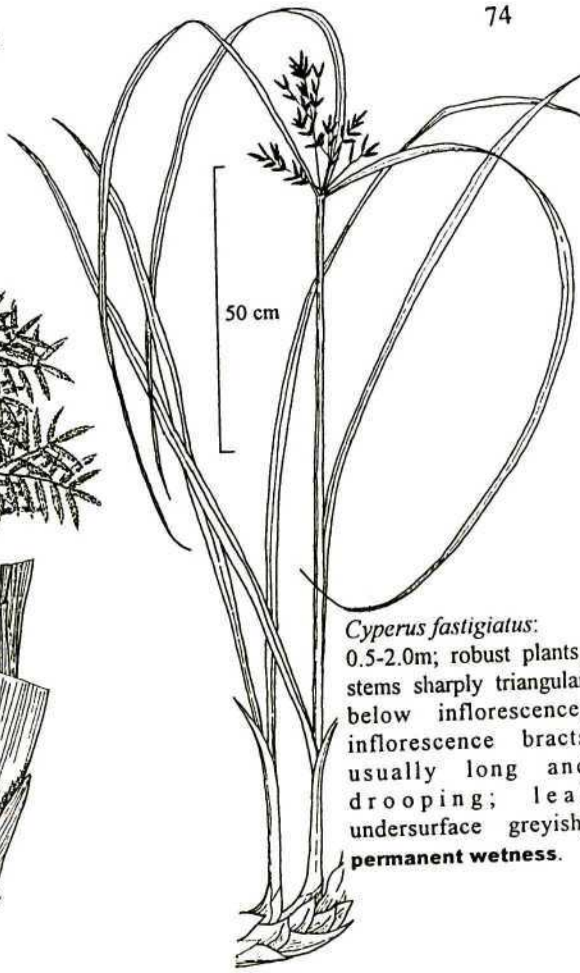
Cyperus sexamgularis:
leaves absent but several leaf-like bracts surrounding inflorescence; stems 6-angled, rough; **temporary, seasonal wetness**.

Cyperus textilis:
resembles *C. sexangularis* but stems smooth and cylindrical; <800m altitude; **seasonal, permanent wetness**.

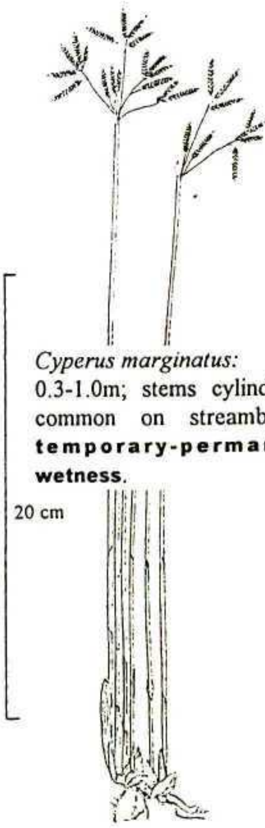


Cyperus latifolius:
0.5-2.5m; robust plants; leaves stiff, usually>1cm wide; leaf margins smooth; **seasonal, permanent wetness**.

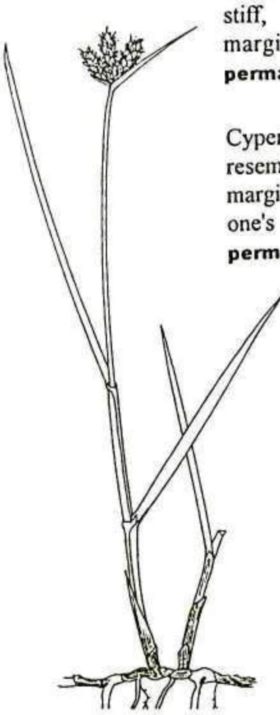
Cyperus dives:
resembles *C. latifolius* but leaf margins rough and readily cut one's finger; <900m altitude; **permanent wetness**.



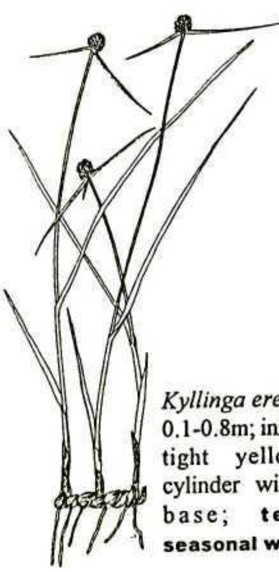
Cyperus fastigiatus:
0.5-2.0m; robust plants; stems sharply triangular below inflorescence; inflorescence bracts usually long and drooping; leaf undersurface greyish; **permanent wetness**.



Cyperus marginatus:
0.3-1.0m; stems cylindrical; common on streambanks; **temporary-permanent wetness**.

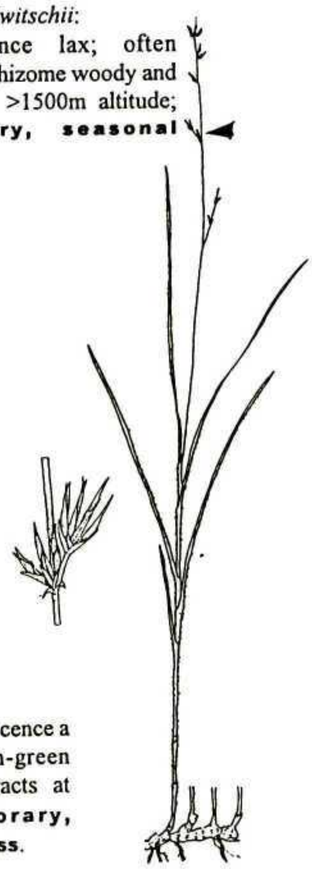


Fuirena pubescence:
0.3-1.0m; well developed rhizome; hairs on inflorescence; **temporary, seasonal wetness**.

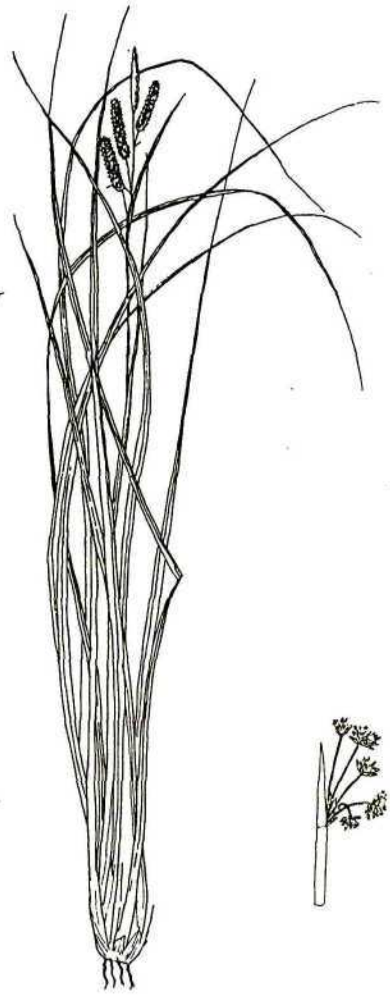


Kyllinga erecta:
0.1-0.8m; inflorescence a tight yellowish-green cylinder with bracts at base; **temporary, seasonal wetness**.

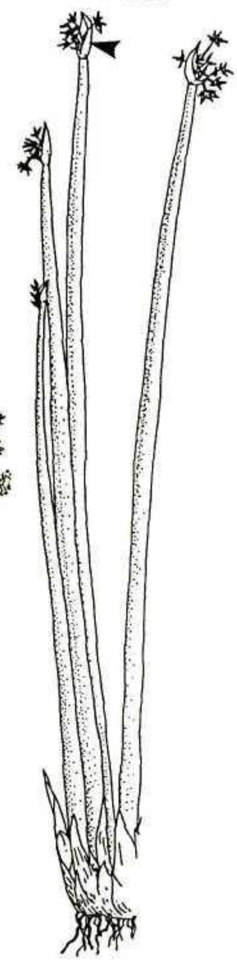
Scleria welwitschii:
Inflorescence lax; often drooping; rhizome woody and horizontal; >1500m altitude; **temporary, seasonal wetness**.



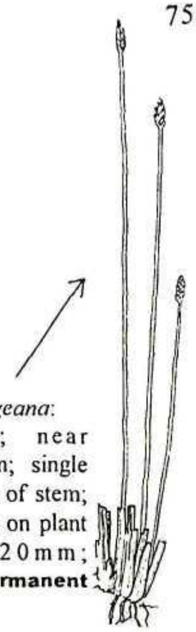
Carex cognata:
tufted; 0.5-0.8m; inflorescence 4-5 drooping "cat-tail" spikes; leaves bright green; **permanent wetness**.



Carex acutiformis:
rhizomatous, often densely covering large areas; "cat-tail" spikes usually pointing upwards; leaves greyish green; **permanent wetness**.

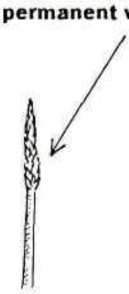


Schoenoplectus corymbosus:
robust, cylindrical stems, 5-8mm in diameter; inflorescence on side of stem close to tip; **permanent wetness**.



Eleocharis dregeana:
rhizomatous; near cylindrical stem; single spikelet on end of stem; longest spikelet on plant usually <20mm; **seasonal, permanent wetness**.

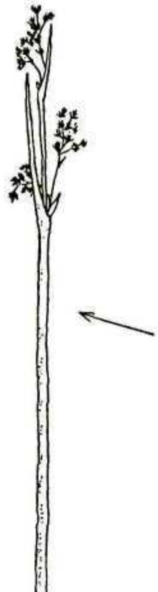
Eleocharis limosa:
Similar to *E. dregeana* but cylindrical stem; longest spikelet on plant usually >22mm; **permanent wetness**.



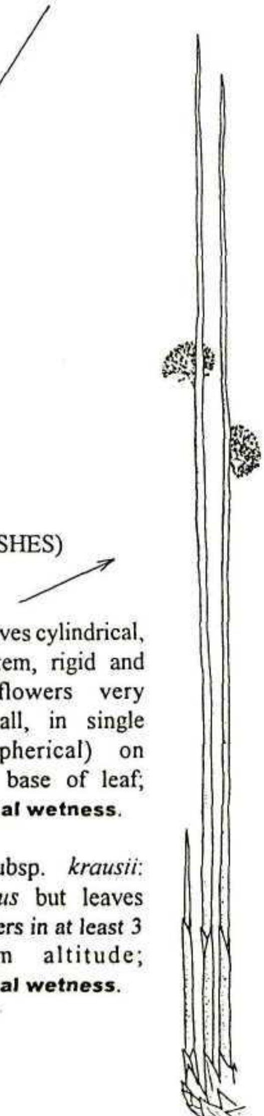
Juncus oxycarpus:
flowers in many small sherical clusters on branchlets of varying length; leaves with open sheaths, 3-5 leaves per flowering stem; **seasonal, permanent wetness**.

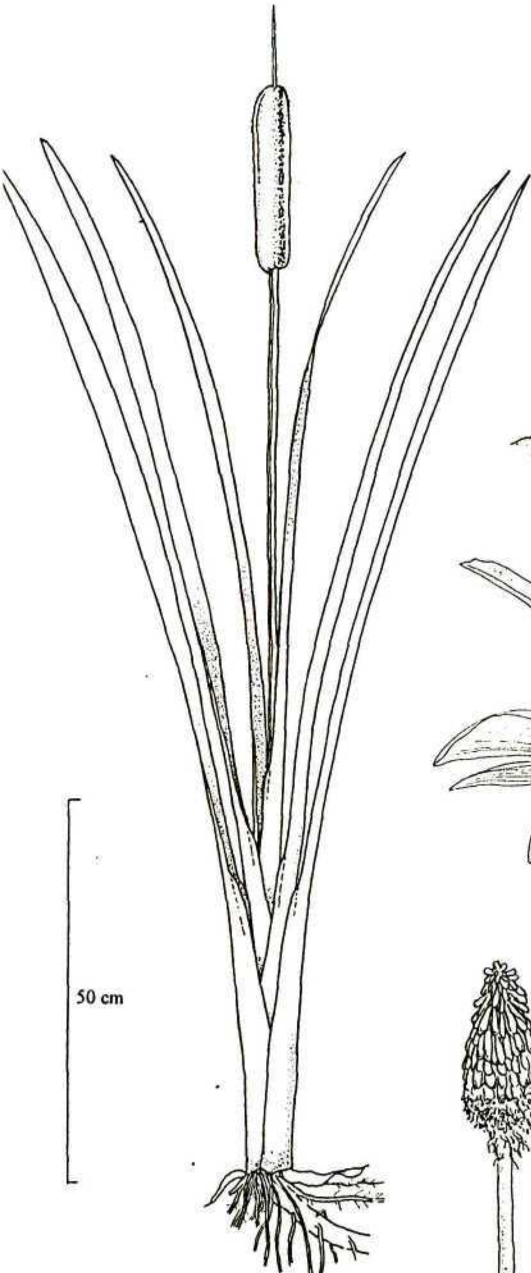
JUNCACEAE (RUSHES)

Juncus effusus:
tufted; 0.4-1.0m; leaves cylindrical, arising from the stem, rigid and sharp pointed; flowers very numerous and small, in single cluster (often spherical) on flowering stem at base of leaf; **temporary, seasonal wetness**.



Juncus krausii subsp. *krausii*:
resembles *J. effusus* but leaves more rigid and flowers in at least 3 clusters; <500m altitude; **temporary, seasonal wetness**.

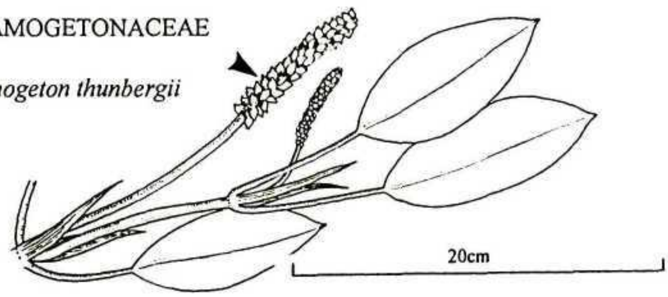




Typha capensis: **permanent wetness**.

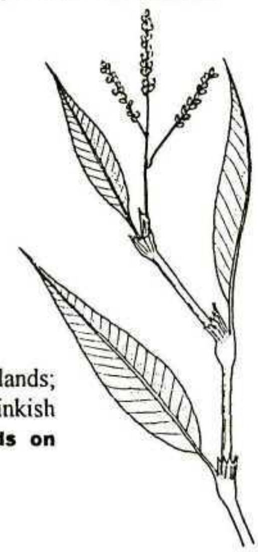
POTAMOGETONACEAE

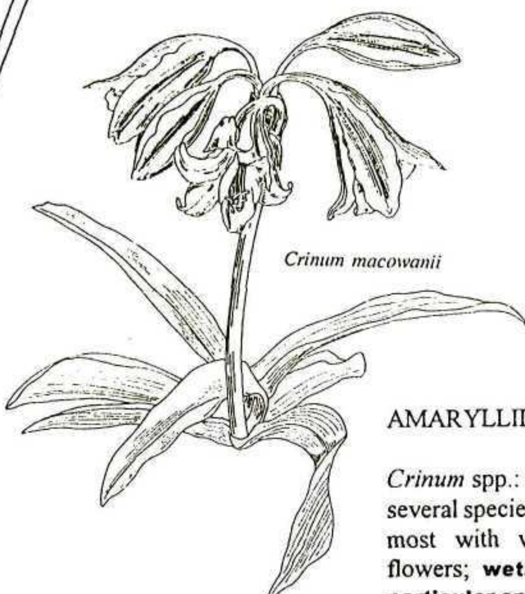
Potamogeton thunbergii



POLYGONACEAE

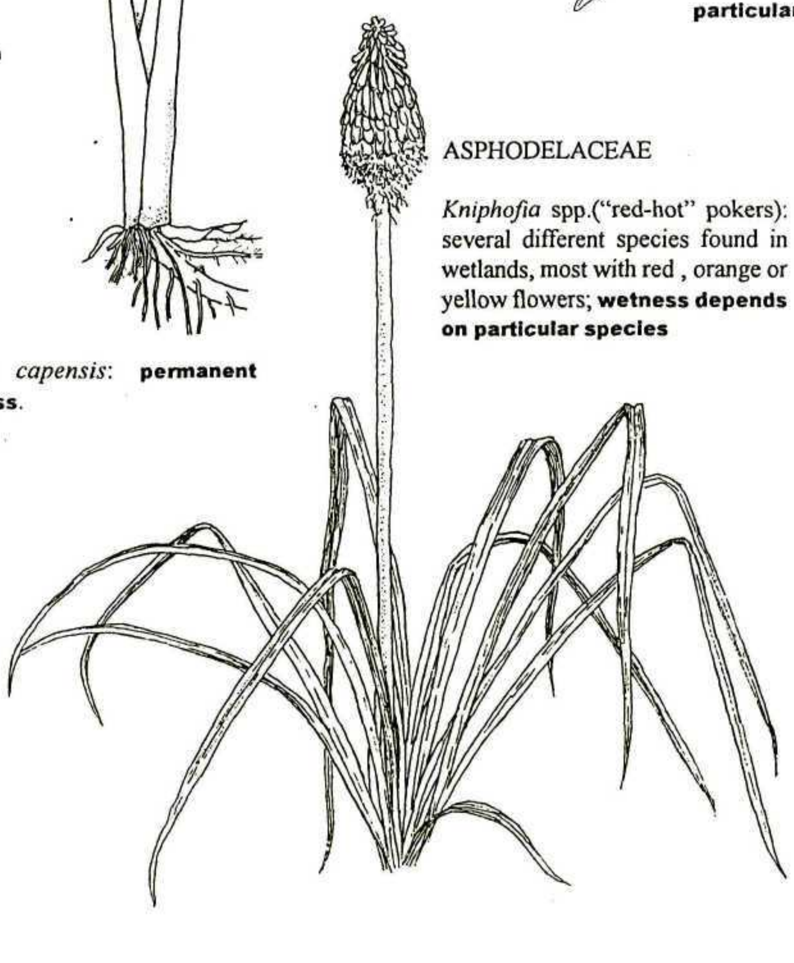
Persicaria (Polygonum) spp. (knot weed):
seasonal, permanent wetness.





AMARYLLIDACEAE

Crinum spp.:
several species found in wetlands; most with white and pinkish flowers; **wetness depends on particular species**



ASPHODELACEAE

Kniphofia spp.("red-hot" pokers): several different species found in wetlands, most with red , orange or yellow flowers; **wetness depends on particular species**

Terms:

Inflorescence: flowering shoot bearing more than one flower

Spike: a simple elongate inflorescence with stalkless flowers

Raceme: a simple elongate inflorescence with stalked flowers

Rhizomatous: with a rhizome (i.e. a horizontal underground stem)

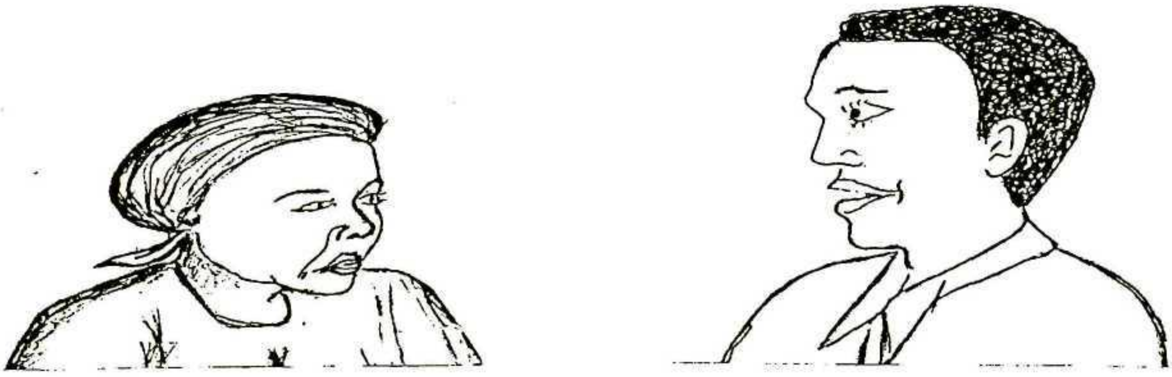
Stoloniferous: with a stolon (i.e. a horizontal stem that creeps above ground)

W E T L A N D - U S E

A wetland management decision support system for South African freshwater palustrine wetlands

PART 2: Organizational assessment and development and a structure for planning wetland management

KOTZE D C 2000



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PREFACE

Although wetlands have many benefits to society (e.g. water purification) the destruction and poor management of wetlands continues. WETLAND-USE is a tool to assist agricultural and nature conservation extension staff in working closely with local resource users and managers to promote the wise use of wetlands. It applies to fresh-water palustrine wetlands and has 2 parts. Part 1 assists in: describing the biophysical features of the wetland; predicting the likely environmental impacts of alternative land-use options; and making ongoing management decisions for particular land-use options. Part 2 assists in: describing the social and organizational context of the wetland (i.e. who uses the wetland directly and which organizations influence this use); and in establishing and maintaining a system for planning the management of the wetland and the necessary organizational structures in which the system operates.

ACKNOWLEDGEMENTS

The Department of Environmental Affairs and Tourism (DEAT) are gratefully acknowledged for funding the development of WETLAND-USE Part 2. Sincere thanks is also expressed to all those individuals and projects who provided valuable input to its development, including:

- Participants in the field workshops (see Part 1);
- Managers and wetland users from case-study wetlands. Of particular note are the local people from Wakkerstroom, especially At and Elna Kotze, and the Mbongolwane community from whom I have learnt a great deal, especially Sister Ntuli, Mr Nene and Mr Ntuli, a Senior Tribal Councilor, for their warmth and understanding;
- D Lindley, The Rennies Wetlands Project;
- G Verdoorn for "Tips on talking to farmers and farm workers" (see Reference Section) which provided valuable material for Box 3 of this document;
- .The Assessment and Participatory Management of Riparian Systems Project, conducted by the Institute of Natural Resources and funded by World Wide Fund for Nature;
- The Working Together for Landcare Project, National Soil Conservation Programme, Australia;
- Prof. K Rogers, Wits University, for contributing to the development of a management framework;
- Prof. Breen, Institute of Natural Resources, for general comment; and
- Mzi Ndlovu, from Mbongolwane, for several of the drawings.

TABLE OF CONTENTS

SECTION 1, OVERVIEW OF WETLAND-USE PART 2

The empowerment of local people to become better organized for managing their natural resources (including wetland resources) is a key principle common to many conservation initiatives (e.g. "A Guide to Sustainable Living": Yeld, 1997) and several successful integrated catchment management initiatives. Relevant and accessible information and clear operating procedures are very useful in promoting this local participation. The WETLAND-USE system is designed to provide such information and procedures specifically for wetlands. Part 2, which deals with the organizational aspects of management, has 4 components.

① SOCIAL-INFO assists in describing the social, land tenure and policy contexts of individual wetlands.

② ORGANIZATIONAL-ARRANGEMENTS assists in establishing and maintaining organizational arrangements required for wetland management.

③ MANAGEMENT-STRUCTURE provides a structure for local wetland users and managers to plan the management of their wetland.

④ MANAGEMENT-LIST lists and describes the regulations, programmes, initiatives and organizations relevant to wetland use and management.

SECTION 2, SOCIAL-INFO

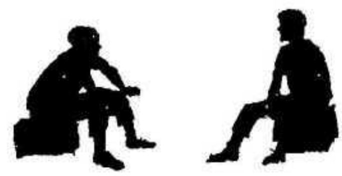
Whilst a certain level of understanding of the biophysical system is required, resource management often has more to do with the people who use the resource than with the resource itself. Thus, it is necessary for those involved in the management of a particular wetland to have a reasonable understanding of its social context. It is usually necessary to gather information in order to gain this understanding. WETLAND-USE assists by providing the following.

- Methods and general principles for gathering information.
- A set of specific leading questions for structuring the gathering of information.
- Suggestions for integrating the information into the management process.

2.1 Methods and general principles

The following ways of gathering information may be useful.

Open Community workshops | Focus group workshops | Interviews with individuals



The complexity of wetland use and management will vary greatly from a situation where there is a single owner of a wetland and very few other stakeholders, to a situation where the wetland is communally owned and used, and there are many stakeholders.

In the case of a single owner, an interview with the owner may be all that is required. In situations where there are many stakeholders it is often best to start with an open community workshop, where local people are able to raise any issues relating to the wetland, and then to deal with these in more detail through focus groups. For example, the cultivation of wetlands may be raised as an important issue, in which case a focus group may be organized including people who cultivate and also those with the responsibility of regulating cultivation. Interviews with individuals, particularly elderly people can provide valuable information about the history of the area.

While guiding questions are given in the following section, these should not dictate exactly what information is collected. As far as possible, involve local people in deciding how the information is gathered, and also in the gathering and processing of information (see Box 1). If the wetland is communally used, the social context tends to be very complex and input should be obtained from workers experienced in dealing with such communities and in using participatory approaches such as Participatory Rural Appraisal (Box 1) A comprehensive and very useful review of factors, conditions and criteria for the successful management of natural resources held under a common property regime is given in Shackleton *et al.* (1998).

Facilitate, don't dictate

Box 1 Participatory Rural Appraisal

The participation of local people[1] in development projects is widely advocated and documented, but there is still a wide gap between theory and field reality (Chambers, 1994). In the 1990's a practical set of approaches, termed Participatory Rural Appraisal (PRA), evolved. PRA is designed to enable local people to express, enhance, share and analyse their knowledge of life and conditions and to plan and act (Chambers, 1994).

There are fundamental differences between the information gathering of traditional research and PRA. In traditional research, the outside researcher determines the agenda, designs formal questionnaires and surveys (directed by the researcher's own personal values) obtains and takes possession of the data, removes it, organizes and analyses it, and plans and writes reports. In PRA, the outsider acts as facilitator, learner and consultant, designs materials to stimulate participation and reflection, encourages local people to determine much of the agenda, to gather, express and analyse information, and to plan. The following are some of the most important principles underlying PRA.

1. Learning is from, with, and by local people, eliciting and using their criteria, classifications and categories, and understanding and appreciating indigenous technical knowledge, viewpoints, skills and practices.

2. Learning is rapid and progressive, building through flexible, exploratory, interactive and inventive methods.

3. Materials and methods are used that empower local people to express and analyse their knowledge. Visual sharing of maps, models, diagrams or units (stones, seeds etc.) provide the means by which even illiterate people can quantify, rank or score, point to, see, discuss and manipulate physical representations. Rural people have a greater capacity to map, model, observe, quantify, estimate and compare than outsiders often suppose.

3. "Handing over the stick/pen": practitioners start the process then "step back", allowing local people to do many of the things that outsiders formerly did: making maps and models, investigating and interviewing, etc.. Because the local people are more in command of the investigation, and own and retain more of the information, they are in a strong position to identify the priorities for action, and to control that action.

4. Finding out only what needs to be known and not measuring it more accurately than is needed.

5. Triangulation: comparing information collected using different methods and sources of information, and cross checking to get closer to the truth through successive approximation (building on what has been done).

6. Remembering the importance of the practitioner's behaviour in establishing and maintaining a relaxed and open rapport throughout the process (e.g. by showing humility and respect, taking an interest in what people have to say and show, not rushing, and not interrupting).

[1]The term "local people" is generally used in the context of rural people with a low level of formal eduction but the principles and approaches discussed also have application for urban people with a higher level of formal education.

2.2 Leading questions

The following questions will assist you in gathering information about the social context of a wetland (an example is given in Box 2).

1. Which of the following broad land tenure systems is operating?

   * Formally conserved land
   * Private land with a single owner
   * Private land with several owners
   * Government owned land
   * Communal, rural land
   * Communal, town-lands
   * Company-owned land

2. Who is the management authority responsible for land allocation and regulation of wetland use?

3. Who makes use of the wetland and what resources are used?

4. Who influences resource use decisions?

5. Which local rules and beliefs govern resource use, and are the rules enforced (i.e. how much "illegal" use takes place)?

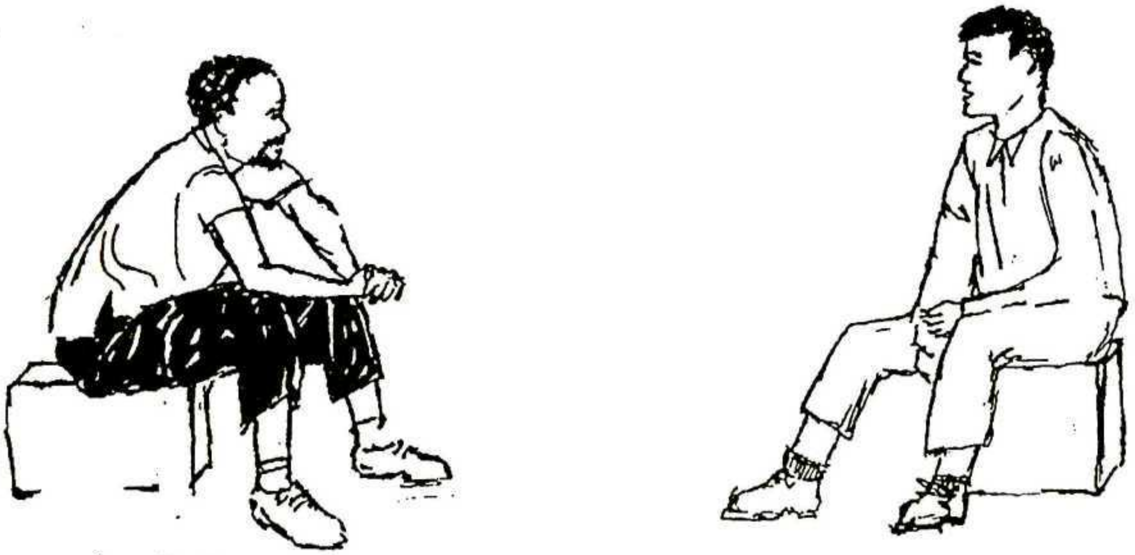
6. Does the wetland have a management plan with measurable objectives?

7. Are roles and responsibilities clearly defined?

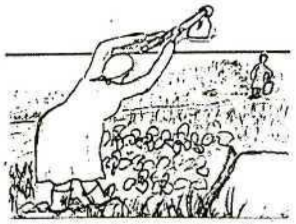
8. How coherent is the local community and what is the existing level of organization and co-operation in the management of natural resources generally?

9. What is the economic status and literacy level of the wetland users (on a very general level)?

10. Do the local authority and other stakeholders have policies regarding wetlands (e.g. as part of company policy)? (If so, obtain copies)



Box 2 A summary of the results obtained for Mbongolwane wetland based on the leading questions



1. The wetland is being used under a rural, communal tenure system.

2. The KwaNtuli Tribal Authority is the primary management authority responsible for land allocation and regulation of wetland use.

3. The wetland is used by most households in the Ntuli Tribal Ward, which is divided into 22 sub-wards, 9 of which include parts of the wetland. Wetland resources used include fibre for handcrafts and construction, land for cultivation, grazing for livestock, water for domestic use, and wild sources of medicinal plants (e.g. *Ranunculus multifidus*). The most widely harvested species harvested for fibre are the sedge *Cyperus latifolius,* (referred to by the Zulu people as ikhwane) which is commonly used for the production of woven sleeping/sitting mats, and reeds (*Phragmites australis)*, commonly used for thatching. Many households are involved in weaving mats for own use or local sale and all households, both poor and wealthier, make use of mats, which have a high cultural value, being used as traditional wedding gifts. However, only the poorer households still use them as sleeping surfaces (as was traditionally the case). Similarly, greater use is made of *P. australis* thatching by poor households as the wealthier households more commonly use commercially produced roofing materials.

Most households within at least 1.5 km of the wetland cultivate within the wetland. The most common crop type is *Colocasia esculenta*, a root crop native to southeast Asia which was introduced to southern Africa several centuries ago and is referred to by the Zulu people as amadumbe. It is tolerant of waterlogged conditions and is grown mainly in *C. latifolius* marsh, and is eaten by most households. Mixed vegetable patches (including maize, potatoes, tomatoes, cabbages, pumpkins and legumes) are found predominantly in the wet grassland areas, but several of these patches, especially those with maize and pumpkins, are also in *C. latifolius* marsh.

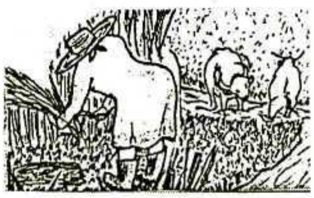
4. Use of the wetland is influenced primarily by the Tribal Authority (mainly through regulation) and to a lesser extent by the Department of Agriculture (primarily through the support they give to community gardens in the wetland) and the KwaZulu-Natal Conservation Services (through awareness activities).

5. A local rule enforced by the Tribal Authority specifies that reeds only be harvested after April, and most people adhere to this rule. No rules apply to ikhwane and medicinal plants. Cultivation takes place within community gardens and in isolated individual patches. Permission is obtained from the Tribal Authority for all community gardens. Although in some sub-wards permission is obtained from the Tribal Authority to cultivate individual patches within the wetland, in many sub-wards no permission is obtained, and there is therefor a low level of control over this activity.

6. A management plan is being developed. An overall management vision has been adopted and issues relating to this have been identified through community workshops, and various mini-projects have been initiated to address these issues. However, there is no full management plan with measurable objectives .

7. Roles and responsibilities have been defined for certain mini-projects but for other areas of management they are still very unclear.

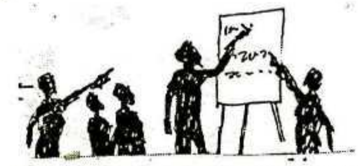
8. The local community is relatively co-herent. However, the existing level of organization and co-operation in the management of natural resources varies. The level of organization around general rural development is very low.



9. Most households are relatively poor and unemployment levels are high and the literacy levels among adult local people is low.

10. The local authority and other stakeholders do not have explicit

2.3 Integrating the information with management of the wetland

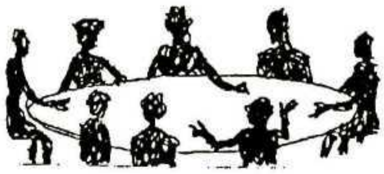


It is essential that those involved in the gathering of information should report back to local users and present the information gathered in a form that is easily understood. If local people (including managers and users) are actively involved in information gathering and processing (as recommended in Section 2.1) it is generally much easier to integrate the information into the management of the wetland. This information, together with relevant policy, should be used when setting the vision and objectives for the wetland as it provides guidance in determining what is desirable and feasible. It should also be used when selecting land-use options, setting operational goals and in defining specific roles.

SECTION 3, ORGANIZATIONAL ARRANGEMENTS

Although there is no set procedure for establishing effective organizational arrangements for the management of wetlands, the suggested steps are set out below.

1. Identify stakeholders (i.e. the people or organizations that have a direct interest in a wetland).



2. Establish an appropriate organizational structure for management of the wetland.

3. Establish operating procedures and norms.

4. Clarify roles of stakeholders and have stakeholders take responsibility for their roles.

Identify stakeholders according to IEM procedures (DEAT, 1998a), where it is usually necessary to call a meeting and to use stakeholders to identify further stakeholders.

Information from SOCIAL-ASSESS is used as an important source in deciding on an appropriate organizational structure. Various options are available, ranging from a committee with a constitution, office-bearers and funds to administer to an informal network primarily involved in the exchange of information and advice. The greater the number of individuals with rights of use, the greater the variety of uses (particularly if they are competing uses), and the less developed the existing organizational arrangements, the more complex the management is likely to be and the greater will be the investment required to develop the necessary organizational arrangements.

Under communal or multiple use conditions involving many users (such as is found at the Mbongolwane wetland) formalized communication structures and working groups to deal with particular issues will be required.

At the other extreme of a single owner/user it will probably be necessary to involve only a few people in an informal network (e.g. the owner, the nature conservation extension officer and the agricultural extension officer).

Operating procedures and norms that need to be established would include mechanisms for: maintaining effective communication (e.g. meetings); conflict resolution; ensuring participation, particularly of those groups which are often marginalised; raising and administering funds; and, ultimately promoting accountability at all times.

Closely linked to establishing operating procedures for the group is clarifying the roles of individual members of the group and having organizations and individuals taking responsibility for these roles/actions. This is done both at a fairly broad level (e.g. who has the role of regulating use) and at a more specific level (e.g. who has the role of monitoring a road development during its 3 month construction phase). The specific roles will emerge out of the management process when operational goals and work plans are set (see Section 4).

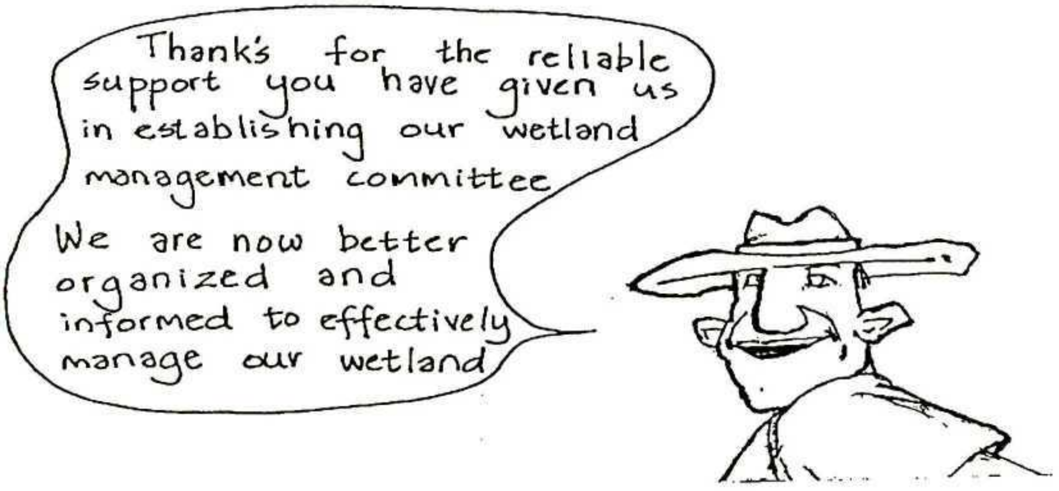
The establishment of organizational arrangements is not something that takes place before and separately from the establishment of a management plan. Rather, the management process should take place within the organizational structure (i.e. they are developed together). In both cases an essential principle should be that local people play a central role in the organizational arrangements. To do this:

- Local people should be encouraged to take ownership and drive the management process. It will help to identify and foster local champions, but at the same time remaining aware of the danger that success will depend on just one or two individuals.

- Local people should gain access to relevant information and useful contacts so that they are well informed (see INFO-COLLECT in Part 1 and SOCIAL-INFO) and have an effective network from which to draw on outside expertise (see Section 5).

- Involvement of outsiders (e.g. extension workers) should be consistent, so that if an extension worker is transferred there is effective hand-over of responsibilities.

- The trust of local people should be earned (see the principles of PRA given in Box 1) and an appropriate attitude and approach are required in working with local people. Box 3 gives several hints, based on the experience of environmental workers.

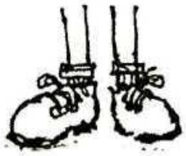


Box 3 *Hints for positively influencing farmers, farm workers and local communities*

The right attitude

See yourself as a "facilitator" rather than an "educator" - remember communication is a two-way process and there is much to be learned from local people.

So be open minded and willing to learn.



Enter with a low conflict attitude and be prepared for conflict.

Have a sympathetic attitude - farmers and local communities often have to deal with may difficulties. Find out what it is like "to be in their shoes".

Be holistic. See where the conservation and wise use of wetlands fits in with peoples broader goals for making a living and deriving satisfaction from life.

Be enthusiastic - show that you are interested in your subject matter and what local people have to contribute! ☺✓

Guard against developing a negative attitude too easily and becoming despondent - be prepared for setbacks. There are always likely to be times when local interest is low. ☹✗

The right approach

Start with what people perceive as their immediate problems or areas of interest.

Use visual aids - these may range from slides and overheads to drawings in the sand.

Where necessary provide refreshments - some people may have travelled far to a meeting.

Avoid concentrating on a single age group and gender - include males and females and young and old people.

If you have written material, go through it verbally with the people you are giving it to.

Work through and build on existing groups (e.g. woman's groups) or initiatives (e.g. a conservancy).

Make use of local events such as festivals, farmers days or flea markets.

If possible, try to speak the local language.

Avoid talking about politics or becoming involved in local politics.

Avoid visiting in a busy season or time of year (e.g. during harvesting time).

Work through influential people and local champions.

Develop incentives for farmers and local people to monitor their own natural environment.

Help give people a sense of importance and ownership (e.g. take a photo of them at the wetland).

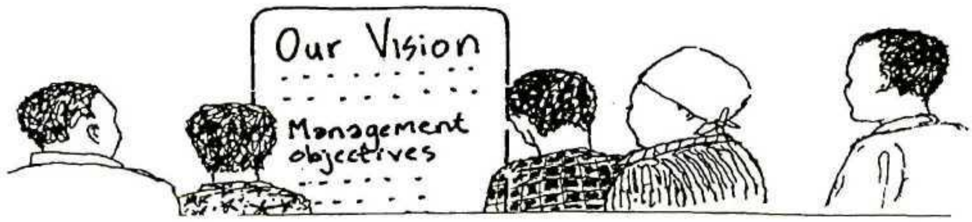
For more information see Shackleton *et al.* (1998) and Verdoorn (1998).

SECTION 4, MANAGEMENT STRUCTURE

4.1 Steps in the management process

The following are suggested steps (based on the Ramsar Convention guidelines [Ramsar Convention Bureau, 1997] and [Rogers and Bestbier, 1997]) for structuring the management process and establishing a management plan with measurable objectives.

Stakeholders jointly develop an overall vision and identify the management objectives required to achieve that vision (which provides a local policy for the wetland), taking into account the nature of the wetland, its landscape and catchment context (WETLAND-INFO in Part 1) and its social context (SOCIAL-INFO).



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Stakeholders identify possible land-uses and, based on the description of the wetland and its landscape context, assess their likely impacts using LAND USE-ASSESS (Part 1).

↓

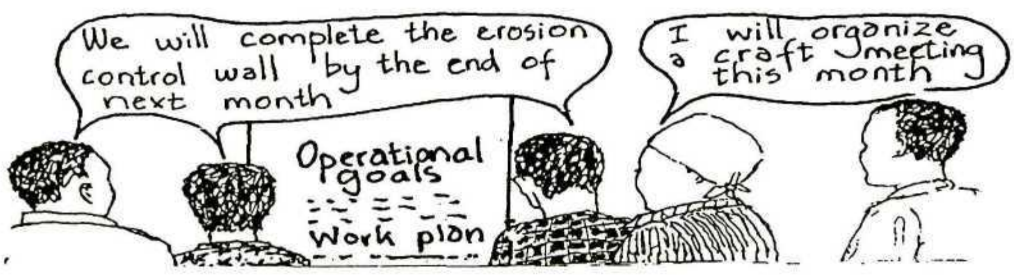
Based on the predicted impacts and social context, stakeholders select those land-use option/s that are compatible with the overall vision and objectives.

↓

With the assistance of LAND USE-RECOMMEND (Part 1), provide explicit criteria and guidelines (e.g. stocking rate) for the selected land-use options.

↓

Stakeholders set operational goals and supporting work plans (including designated roles and responsibilities and specific actions with time frames) and implement land-use options



↓

Monitor achievement of operational goals

↓

Major review (audit) of vision and objectives.

The Vlei Lily Award (see Section 5.8) provides a basis on which local managers commit in writing to a management plan such as that given above and receive recognition for their contribution. If more detail is required about the management process and hierarchical goal setting and monitoring achievement of goals then refer to Woodhill and Robins (1998) and Rogers and Bestbier (1998). Woodhill and Robins (1998) is a particularly useful document on participatory evaluation for LandCare and catchment groups written in an easily understood style. Rogers and Bestbier (1997) is also useful in providing information on the theoretical context of managing natural systems.

Two key questions are of particular relevance to extension workers in relation to their involvement in the management process.

1. What types of outside involvement are required to assist in achieving the overall vision and objectives for a wetland (see Section 4.2)?
2. What regulations, programmes and initiatives are relevant and available which could assist in making this involvement effective? Local managers and even extension workers are often not aware of the full range of possibilities, of which some of the most important are outlined in Section 5. Check the various possibilities to see to what extent they may be able to address the particular needs of your situation. As a general rule: build on what is available, "don't re-invent the wheel".

4.2 Types of involvement by extension workers

In order that the overall vision and objectives of the wetland be achieved it is important that the right combination of types of involvement are used. Each situation is obviously unique. However, some general guidelines have been developed based on the experiences drawn from a wide range of case studies. There are 5 different broad types of involvement.

1. Raising awareness and giving encouragement.
2. Improving organizational and management capacity and developing local policy.
3. Promoting alternative land-uses and land-use practices.
4. Regulation of use.
5. Rehabilitation (e.g. erosion control structures).

Raising awareness and giving encouragement

Wetland users are often not aware of the costs that particular land-uses and practices have on the indirect benefits provided by wetlands (i.e. the environmental costs of their activities). Extension workers are in a position, using resources such as WETLAND-USE Part 1 and Booklet 1, to alert local users to the impacts of different land-use options. Raising the awareness of local users/owners (and giving them encouragement to continue with wise wetland use) may be all the outside input that is required, particularly in the case of more affluent owners/users. It is recognized, however, that awareness of particular land-use impacts does not necessarily alter perceptions and even if perceptions are altered, users may not have the means, particularly if they are poor, to change patterns of resource use. Thus, additional inputs are usually required.

It is always important to take a positive approach and give local users encouragement by providing recognition for their contribution to the wise use of a their wetland. This is likely to increase their motivation to continue with sound management. Programmes such as the Natural Heritage Site Programme and Sites of Conservation Significance and awards such as the Vlei Lily Award or Soil Conservation Awards (see Section 5) provide possible means of giving formalized recognition.

Organizational and management capacity of local people and development of local policy
A reasonable organizational structure is required to develop a management system with an overall goal and objectives and to define roles and responsibilities of stakeholders (see Section 3). Involvement which increases the local capacity to organize and manage is particularly important in communal areas and in wetlands under multiple single ownership, where the level of co-ordination between neighbouring owners is often poor. This involvement may include: encouraging local people to take ownership and drive the management process; assisting local people in gaining access to relevant information and useful contacts (see Section 3).

Policy refers to a purposive course of action in dealing with a matter of concern based on shared values. Policy is not just developed at high organizational levels such as nationally, but as shown in Section 4.1 is also developed at a local level. Assisting in the development of local policy will help guide day-to-day actions taken at a wetland.

Promoting alternative low impact land-uses
If high impact land-uses are discouraged/disallowed in a wetland it is important that viable alternative low impact land-uses are sought that still allow users to derive benefits from the wetland. This is particularly important if the users are poor and use of the wetland represents the only, or one of a few options available for producing food or generating income.

Wetlands vary greatly with regard to the direct benefits that they are able to provide in their natural, untransformed state compared with various transformed states (see Part 1, Box 4). It cannot, for example, be assumed that all wetlands have potentially high ecotourism value. As an extension worker you can promote alternative low impact land-uses by assisting in:

- improving local organizational capacity (e.g. help facilitate the establishment of a craft group);
- establishing contact with important outside organizations (e.g. ecotourism operators or craft dealers); and
- providing useful management information.

Regulation of activities
If regulation is considered necessary, it is preferable to reinforce positive internal mechanisms rather than trying to introduce external ones, particularly in wetlands in communal areas where there are often established local traditional norms and rules. Many companies have their own internal codes of practice based on international trading standards (see ISO1400, Section 5) which do more than just conform to environmental legislation. Failing the success of internal mechanisms there are several laws applicable to wetlands, which are given in Section 5.

Rehabilitation of damage caused by past mismanagement
It is sometimes necessary to provide outside assistance in repairing/rehabilitating damage caused by past mismanagement. Local people would need to take responsibility for maintaining structures and the management factors causing the degradation would also need to be addressed (see Part 1, Section 4.7).

Accountability at all times

SECTION 5, MANAGEMENT-LIST

Having identified the types of involvement required to achieve the vision and objectives for the wetland see which of the regulations, programmes and initiatives given in Table 5.1 could assist you in making these inputs. These include both regulatory and non-regulatory measures (for more information see Begg, 1990).

Table 5.1 Regulations, programmes and initiatives relevant to wetland use and management, with contact details of organizations given in Section 5.9

Relevant regulations, programmes & initiatives	Purpose	Outputs/deliverables	Limitations	Organization responsible for support
National Environmental Management Act (presently a Draft Bill)	National environmental policy	National Environmental Policy Commission for sustainable use Procedures for co-operative government IEM (see below)	The Bill is still being developed	Department of Environmental Affairs & Tourism (DEAT) - national & provincial
Integrated Environmental Management (IEM) & the Environmental Conservation Act, 1989	Laws and procedures to ensure that the environmental consequences of development proposals are adequately considered	A nationally accepted framework and guidelines for planning development supported by legislation.	Legislation and framework newly developed and enforcement capacity is still low	DEAT
Conservation of Agricultural Resources Act	Laws to protect agricultural resources (including wetlands) against inappropriate agricultural development	Legislation that serves as a disincentive for unsound development	Weak and poorly enforced legislation, currently under revision.	Department of Agriculture: Directorate Resource Conservation
Water Act	Laws to ensure equitable and efficient water use	Legislation that serves as a disincentive to the inequitable and inefficient use of water.	Legislation and enforcement capacity is still being developed	Department of Water Affairs and Forestry
National Wetland Policy (contained within the policy on the conservation and sustainable use of South Africa's biological diversity).	Policy to ensure the conservation of South Africa's wetlands so that the ecological and socio-economic functions, products and attributes of wetlands are maintained for present and future use	* Policy goals * Guiding principles to be used in the implementation of the policy	There is currently no strategy for implementing the policy	DEAT

Department of Environmental Affairs . Wetland Conservation Programme	See National Wetland Policy	Support provided for several initiatives: * Interdepartmental coordination * South African Ramsar Working Group * National inventory of wetlands * National policy on wetland conservation * Research programme * Wetland information dissemination * International actions	Several of the initiatives (e.g. the National inventory of wetlands) are still in early phases of development. The programme is that of DEAT and not shared by other organizations.	DEAT
Rennies Wetlands Project	To promote the wise use and sustainable management of wetlands	* Build capacity and understanding of wetland functioning and importance * Generate mass media publicity on wetlands * Initiate wetland identification and assessment and wetland management and rehabilitation programmes * Lobby key national and provincial decision makers	Operates in only selected priority areas of the country. Relies on continued interest from landowners, conservation and agricultural extension services and volunteers.	Rennies Wetlands Project (including regional working groups)
South African Crane Action Plan	Ensure the long term survival of South Africa's three crane species through the protection of their habitat	* Co-ordination and network of all crane conservation work in the country * Identify key crane habitat sites * Promote awareness and participation of landowners at the key sites	Relies on continued interest from landowner/s In certain areas (e.g. the former Transkei) the network is not well developed	South African Crane Working Group (including regional groups)
South African Natural Heritage Site Programme	Promote conservation of significant natural features outside of formally conserved areas (sites of national conservation importance).	Provides recognition to land-owners for maintaining significant natural features and provides an incentive for conservation through the prestige afforded to owners	Relies on continued voluntary support from landowner/s	DEAT Provincial nature conservation authorities
Sites of Conservation Significance Programme	See above (sites of provincial or local conservation importance)	See above. Only applied in KwaZulu-Natal	see above	KwaZulu-Natal Nature Conservation Services

Ramsar convention (now becoming known as the Convention on Wetlands)	International cooperation for the conservation of wetland habitats , through an intergovernmental treaty	* Guideline documents * Increased co-operation among different countries * Access to useful international contacts * International pressure to ensure wise use (but presently only applies to designated sites)	At present it has little influence on the management of unregistered sites in South Africa	Administered by DEAT and provincial nature conservation authorities in South Africa
Convention on Biological Diversity	The conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources.	* Principles * Protocols * Avenues for co-operation between different countries	Still in the process of being adopted at provincial level	DEAT
Agenda 21	Sustainable development through the integration of economic, environmental and social components	Sustainable development principles and programme	Still in the process of being adopted at local level	DEAT; provincial organizations responsible local government and housing
ISO 14 000	An environmental management system that adequately addresses environmental concerns	Standardized internationally recognized guidelines for implementing environmental management, including allocation of resources, assignment of responsibilities and ongoing evaluation	Only used by some companies	The South African Bureau of Standards
Integrated water resources management programme	To ensure water is managed in a sustainable way and to provide an adequate supply which is fit for all current and future uses	Facilitate the establishment of: * Catchment management forums representing the full range of interests in the catchment * Catchment management agencies * Catchment management plans	The overall programme is new and has only been initiated in a few isolated pilot catchments	DWAF , local water authorities and other stakeholders
Mountain Catchment Areas Act	To provide for the conservation, use, management and control of land situated within declared "mountain catchment areas"	A high level of control over activities affecting catchment water quantity and quality	Only a small proportion of South Africa falls within mountain catchment areas.	DWAF

Conservancy programme	Harness local interest in wildlife to combine the joint resources of landowners to achieve shared conservation objectives.	Facilitation of improved co-operation among members and enhanced security Procedures for running a conservancy Support provided through extension workers and the Conservancy Association	Only in parts of the country. Relies on local interest which may be lacking	Provincial conservation authorities
Working for Water Programme	To recover water presently being lost to invading alien plants, create jobs, empower individuals and build communities, and conserve biological diversity, ecological integrity and catchment stability	Facilitate and assist in providing resources for clearing alien plants, providing jobs and enhancing the capacity of individuals involved	The programme is reliant on central government funds	DWAF
Protected area*	To secure natural areas through formal declaration as a protected area	Securing of the natural area, which is legally binding not reliant on landowners for support	Public funds are extremely limited for the purchase of land. Only effective if the catchment is in reasonable condition	Provincial or national conservation authorities
Leasehold agreements with interested groups*	To promote conservation of natural features outside of formally conserved areas	Land secured without relying on State funds for purchase	Reliant on there being an interested group willing to pay	Various

*These are not formal programmes as such but are directly relevant to wetland use and management

5.1 South African law applicable to wetlands

Laws protecting wetlands in South Africa are fragmented and are represented in various acts which are enforced by a diversity of authorities, including the Department of Agriculture, Department of Water Affairs and Forestry and provincial Environmental Affairs departments.

Integrated Environmental Management (IEM) and the Environmental Conservation Act

In South Africa, as in so many other countries, much destruction of the environment has taken place because of poorly planned development. An Integrated Environmental Management (IEM) procedure has been developed for South Africa to promote better planned development. IEM is designed to ensure that the environmental consequences of development proposals are understood and adequately considered in planning and implementation. The following are some of the underlying principles of IEM.

- Development is sustainable and equitable.
- Decision making is informed, accountable, and open, involving the relevant authorities and stakeholders (including the public).
- Alternative options are considered.
- The environment is considered in its broadest sense, including physical, biological, social, cultural and economic factors.
- All of the above are done from the beginning of the process and not just when the proposal has been completed.

IEM procedures exist for: land-use zoning plans and schemes, new activities, and existing activities. The IEM procedure for new activities includes several steps.

1. Development of the proposal, which is directed by the underlying principles given above. Early consultation with stakeholders and authorities will help to identify the alternatives and issues that should be considered.

2. Authority review to determine potential conflict and areas of potential environmental stress for inclusion as issues in the scoping process.

3. Scoping, which must be conducted by an independent consultant, to identify significant issues of concern that must be addressed, the development of alternatives to the proposed activity, and the development of a schedule for the planning and approval cycle.

4. Review of the scoping report by the relevant authority and the interested and affected parties. If there is sufficient information in the report it may either be refused or accepted. Should there be insufficient information or if the potential environmental impacts identified in the scoping report are significant, an environmental impact assessment will be requested.

5. Environmental Impact Assessment (EIA), which must be done by an independent consultant and based on the issues identified in the scoping report, and may sometimes include a benefit-cost analysis. The EIA report will be subject to review. Permission for the activity may be refused or approved subject to certain conditions, or the proposed activity may be referred back to the proposal or scoping stage (e.g. if substantial issues were omitted from the original scoping report).

6. Condition agreement, which sets the conditions by which the activity is allowed to take place if it is approved.

7. Environmental Management Programme (EMP) which is a detailed programme for implementation of the conditions agreement.

8. Review to determine whether the EMP conforms to the conditions agreement and approval when

the authority is satisfied that it does conform.

IEM, which is nested within the Environmental Management Initiative, is supported by the Environmental Conservation Act 73, 1989. In terms of this act, certain activities, such as the reclaiming of wetlands (e.g. through drainage or infilling), dam building, river diversion and changes in land-use require some form of environmental investigation. IEM provides a very useful and nationally accepted framework for planning development, and WETLAND-USE has specifically been designed to fit easily within this framework.

For more information see: WETLAND-USE Part 1, Section 3; and DEAT (1998a and b) listed in the References Section.

Conservation of Agricultural Resources Act, No. 43 of 1983

Land users are forbidden (without successfully obtaining the necessary permission) to drain or cultivate any vlei, marsh or water sponge or portion thereof on their land or to cultivate any land within the flood area of a water course. Although there are weaknesses in this legislation (e.g. the terms vlei, marsh and water sponge are not defined) it is one of the most important Acts protecting wetlands.

The Water Act

Water law is one of the most complicated fields of law. A comprehensive revision of the South Africa's water law has recently been undertaken. The new legislation is based on several principles which attempt to meet the requirements of our new constitution (to which all law in the country must be subject); what makes most sense in terms of our present understanding of the environment around us on which we all depend; and how we should manage a scarce resource for development and prosperity. Some of the key principles of particular relevance to wetlands are given below.

- *In a relatively arid country such as South Africa, it is necessary to recognise the unity of the water cycle and the interdependence of its elements, where evaporation, clouds and rainfall are linked to underground water, rivers, lakes, wetlands estuaries and the sea.*

- *The variable, uneven and unpredictable distribution of water in the water cycle should be acknowledged.*

- *All water, wherever it occurs in the water cycle, is a resource common to all, the use of which should be subject to national control.*

- *There shall be no ownership of water but only a right to its use.*

- *The quantity, quality and reliability of water required to maintain the ecological functions on which humans depend should be reserved so that the human use of water does not individually or cumulatively compromise the long term sustainability of aquatic and associated ecosystems* (including wetlands).

Mountain Catchment Areas Act

This Act provides for the conservation, use, management and control of land situated in declared "mountain catchment areas". Particular emphasis is placed on the prevention of soil erosion and the protection of natural vegetation through the control of fire. Any wetlands within mountain catchment areas are protected under provisions of the act.

Forest Act, No. 122 of 1984

This act, which is administered by the Department of Water Affairs and Forestry, provides for the prohibition of tree planting or reafforestation within any areas necessary for the protection of any natural source of water. The act is reliant upon the judgement of the forest officer to assess whether an area is a wetland and to judge the distance from the wetland to which afforestation could be allowed. Afforestation is currently being controlled through Forestry Review Panels. The White Paper on Sustainable Forest Development in South Africa identifies the necessity to replace the present Forest Act, and a new Forest Act is currently being developed (DWAF, 1997). ***For more information see:*** DWAF (1997, Chapter 24, Providing law for the sustainable development of the forest sector).

5.2 The national policy on wetlands (as contained in DEAT, 1997)

The degradation of South African wetlands, and their vulnerability to human-induced changes in catchments and in the sea, is a concern recognised by Government as requiring urgent action and cooperation between a diversity of sectors and institutions. Wetlands represent some of our most threatened ecosystems, and as such their conservation and sustainable use is a crucial component of this policy. Government acknowledges that insufficient attention has been given in the past to secure the effective management of the country's wetlands, and it undertakes to ensure that the future management of such areas will take place in an integrated manner, in accordance with the objective of conserving and using biological resources sustainably, and minimising adverse impacts on aquatic biodiversity. This approach will recognise and accommodate conflicting needs and values.

Several measures already govern the conservation and use of South Africa's wetlands, and many new initiatives are under way, as a result of the revision of the country's water law. Wherever possible and appropriate, Government will bolster such initiatives and, in collaboration with interested and affected parties, will:

1. Support the principle that basic domestic needs and environmental needs will enjoy priority use of water, the latter through reserving the quantity, quality and reliability of water required to maintain natural flow regimes and habitat complexity for aquatic and riparian ecosystems (see the last Water Law Principle given in Section 5.1).

2. Facilitate the development of appropriate legislation to secure the conservation of South Africa's wetlands, and to maintain their ecological and socio-economic function.

3. Promote the establishment of a National System of Protected Wetlands as part of the protected area system (see Objective 1.3).

4. Prevent inappropriate activities and development around wetlands, and that of linear development in particular. Ensure that adequate buffer strips are retained around wetlands, taking due cognisance of the 1:50 year floodline.

5. Introduce policy measures to ensure that the price of water reflects the full social, economic and environmental costs and benefits of water provision, taking into consideration the need to maintain life-line tariffs to ensure a basic level of health and quality of life.

6. Through establishing appropriate mechanisms and procedures, recognise the functions and values of wetlands in resource planning, management and decision-making.

7. Ensure that considerations relating to the biodiversity of aquatic areas and wetlands are adequately incorporated into the national policy on integrated pollution control and waste management.

8. Determine the impact of commercial, recreational and subsistence fishery practices on fisheries, fish, and

their habitats, and develop guidelines for managing such fisheries on an ecologically sustainable basis.

9. Determine the impact of aquaculture species and management practices on biodiversity, and develop appropriate guidelines for aquaculture developments.

10. Strongly promote the development of catchment-specific partnerships and joint management plans between the range of institutions, organisations and individuals engaged in managing and using wetlands, catchments and associated marine and coastal areas.

11. Provide leadership in international wetland conservation efforts, through the effective and coordinated management of transboundary water and biological resources in southern Africa.

5.3 Integrated Catchment Management

The term Integrated Catchment Management (ICM) represents a systems approach to the management of natural resources, in particular water resources, within the bounds of a geographical unit which is based on the catchment area of a single river system, which is divided further into sub-catchments. ICM recognizes the need to integrate all environmental, economic and social issues within a river basin into an overall management philosophy, process and plan (a product). This is ultimately aimed at deriving the maximum the optimum possible mix of sustainable benefits for future generations and for the communities in the area of concern, whilst protecting the area's natural resources. The implementation of ICM is usually assessed through the establishment of a catchment management forum, the composition and nature of which will depend on the particular situation. The new Water Act is supportive of ICM and encourages the establishment of such fora.

For more information contact: the Director Catchment Management, DWAF , (012) 3388670 or Keith Cooper, Wildlife and Environment Society (031) 210909.

5.4 The Ramsar Convention (now becoming known as the Convention on Wetlands)

What is the Ramsar Convention?

The health of wetlands depends on their supply of water, and factors impacting this supply may be considerable distances away, in may cases beyond national borders. Furthermore, many wetland dependent species, particularly birds, are migratory or nomadic, and cross national borders as they move between wetlands. Thus, cooperation among different countries may be necessary for effective wetland conservation.

The Convention on Wetlands of International Importance especially as Waterfowl Habitat, known as the Ramsar Convention from its place of adoption in Iran in 1971, is an intergovernmental treaty which provides the framework for international cooperation for the conservation of wetland habitats.

One of the misconceptions about the Ramsar Convention is that it exits only for wetlands that support large numbers of waterfowl. It is much broader than this. The objectives of the Ramsar Convention are to stem the loss of wetlands and to ensure their conservation and wise use. To achieve these objectives the countries which become contracting Parties to the Convention accept four main obligations.

1. Designate at least one wetland for inclusion in the List of Wetlands of International Importance, and to ensure the maintenance of their ecological character. Selection is to be based on their international significance in terms of ecology, botany, zoology, limnology or hydrology.

2. Formulate and implement their planning so as to promote, as far as possible, the wise use of wetlands in their territory. 'Wise use' involves recognition of the functions and values of wetlands for the benefit of people who live in and around wetlands and depend on them for their livelihood and survival.

3. Establish nature reserves on wetlands and promote training in the fields of wetland research and protected area management.

4. Promote international cooperation by consulting with other countries about implementing their obligations, especially as regards transfrontier wetlands and water systems, shared species and development aid for wetland projects.

The Ramsar Convention has contracting Parties from all regions of the world. The United Nations Educational, Scientific and Cultural Organization (UNESCO) serves as the depository for the Convention. The Secretariat, or Bureau, shares headquarters with the IUCN - The World Conservation Union in Gland Switzerland.

The implementation of the Convention in South Africa
South Africa took a leading role in the development of the Convention, becoming the fifth contracting Party in 1975. The Department of Environmental Affairs and Tourism is the administrative authority responsible at the national level for implementation of the Convention. As at of June 1998 South Africa had designated 16 sites. The Convention has been used as a rallying point for several of these wetlands when they have come under threat, including the St Lucia System, Langebaan, Blesbokspruit and the Orange River Mouth.

For more information, contact: The Ramsar Convention Bureau, Rue Mauverney 28, CH-1196 Gland, Switzerland. (e-mail: ramsar@hq.iucn.org, Web: http://iucn.org/themes/ramsar/) or see Davis (1994).

5.5 Agenda 21

Agenda 21 of the United Nations Conference on Environment and Development (1992) held in Rio de Janeiro, has the following principles:

* The environment and development should be put at the centre of economic and political decisions.

* Development should be economically efficient, socially equitable and environmentally sound.

* Establishment of consultation mechanisms that bring together all interested stakeholders in the development process.

* Provision of relevant information to the public thus ensuring accountability for environmental implications.

The DEAT, Directorate: Sustainable Development, is responsible for promoting Agenda 21 at a national level. Linked to Agenda 21 is Local Agenda 21 (LA21) which addresses the implementation of sustainable development at the level of local authorities. Many of the major towns in South Africa are busy developing their own LA21 programmes.

For more information see: DEAT (1998c).

5.6 ISO 14000

The ISO 14000 series, which was designed primarily for commerce and industry, provides interantionally recognized guidelines for implementing an Environmental Management System. It provides order and consistency for an organization to address environmental concerns through allocation of resources, assignment of responsibilities and an ongoing evaluation of practices and procedures. Specific performance standards for implementing ISO 14 000 and given in ISO 14001.

Central to ISO 14 001 is setting of an environmental policy, which is the statement by the organization describing its intentions and principles in relation to its overall environmental performance. Requirements of an environmental policy include:

* Commitment to continual improvement and prevention of pollution

* Commitment to comply with relevant environmental legislation and go beyond regulations and requirements

* It should be documented, implemented, maintained and communicated to all employees

* It should be available to the public

* It should not contain statements or targets which the organization cannot hope to achieve.

In South Africa, ISO 14001 is administered by the South African Bureau of Standards and a specially convened national committee. National guidelines have been published to aid with the implementation of the standards. *See:* SABS (1996).

5.7 The South African Natural Heritage Programme (SANHP)

The SANHP aims to encourage the conservation of important natural sites, large or small, in private and public land outside of formally conserved areas. The SANHP gives particular recognition to the work done by the owner of such a site . When a site is registered, the owner receives a certificate signed by the State President as well as a bronze plaque. One of the primary benefits received by the owner is the satisfaction gained by voluntarily participating in a national conservation programme. The criteria for registration of a site are one of the following:

* stands of special plant communities
* good examples of aquatic habitats
* sensitive catchment areas
* habitats of threatened species
* outstanding natural features

Natural sites which do not meet these criteria but are nonetheless important from a conservation point of view at a provincial, catchment or local level may be declared as Sites of Conservation Significance. By informing the landowner of the conservation importance of their site, registration as a Natural Heritage Site or Site of Conservation Significance reduces the chance that the area may unknowingly be damaged. The owner maintains full rights over the property and is able to withdraw from the programme.

For more information see: Cohen (undated) and Cohen (1989)

5.8 The Vlei Lily Award

The Vlei Lily Award is given to management authorities, including private landowners and communal land authorities, for commitment to the sustainable use of their wetland. It includes written commitment by the management authority to a management plan that they have developed with the assistance of an extension worker. Although this is not legally binding it encourages the management authority to set and monitor management goals, thereby promoting greater accountability. The award takes the form of a plaque, a certificate, and a brief management policy and plan. It is administered provincially by the provincial nature conservation department and endorsed nationally by the Department of Environmental Affairs and the Department of Water Affairs. The award has been very recently developed and is currently being put into place within the KwaZulu-Natal Midlands as a pilot area.

5.9 Organizations and key contacts

Table 5.2 Some of the main organizations and key contacts involved with wetland management in South Africa (A comprehensive list of researchers involved with wetlands has also been compiled by the Department of Environmental Affairs and Tourism (DEAT, 1997).

Organization	Key contacts and Address	Area of operation	Land-uses of concern	Types of involvement
Avian Demography Unit	James Harrison, University of Cape Town, P.O. Rondebosch, 7700, Tel: (021) 650 2423 Fax: (021) 6503726	National	General	Research
C.S.I.R.	Allan Batchelor, P O Box 395, Pretoria, 0001, Tel: (012) 8413461 P.O. Box 17001, Congella, 4013, (031) 815851 P.O. Box 320, Stellenbosch, 7600, (021) 8875101	National	General	Research, wetland creation
Department of Agriculture: Directorate Resource Conservation	P.Bag X250, Pretoria, 0001, (012) 3196000	National	Agricultural development	Regulation, awareness
Department of Environmental Affairs & Tourism (national)	Geoff Cowan, John Dini, Retha van de Walt, P.Bag X447, Pretoria, 0001, (012) 3103695	National	General	Co-ordination, awareness, regulation
Department of Environmental Affairs (provincial)	Eastern Cape, Tel: (041) 3338891 Free State, Tel:(051) 4033773 Gauteng, Tel: (011) 3551937 KwaZulu-Natal: Nhlanhla Nsele, Tel: (0354) 74433; or (0331) 471820 Mpumalanga, Tel: (013) 7594043 Northern Cape, Tel: (0531) 811121 Northern Province, Tel: (015) 2959300 North West, Tel: (0140) 895126 Western Cape, Tel (021) 4833925	Provinces	General	Regulation, awareness
Department of Mineral and Energy Affairs	P.Bag X59, Pretoria, 0001, (012) 3179000	National	Mining	Regulation, awareness
Department of Transport	P.Bag X193, Pretoria, 0001, (012) 3283084	National	Roads	Road development
Department of Water Affairs	Heather MacKay, P.Bag X313, Pretoria, 0001, (012) 2999111	National	Water resources	Regulation, co-ordination, awareness, rehabilitation

Field workers active in wetland conservation	Eastern Cape: Eric Qonya, (0433) 21001 Eastern Cape, Krom River: Vincent Eagen, (0423)51155 Eastern Cape, Ugie-McClear: Andre Marais, (0453) 331042 Free State, Nacel Collins (05862) 23520 KwaZulu-Natal North: Stoffel de Jager, (0381) 812492 & Duncan McKenzie (0381) 812910 KwaZulu-Natal Midlands: Gavin Shaw (0332) 307097 & Damion Walters (0332) 301731 KwaZulu-Natal South: Div de Villiers, (037) 7274322 Mpumalanga, Lydenberg: Anton Linström, see Mpumalanga Parks Board Mpumalanga, Piet Retief: Frans Maritz, 0828002165 Western Cape, George, Alister Mac Donald, (04487) 42160	Provincial	General	Awareness, co-ordination, rehabilitation, regulation
Eskom/EWT Partnership	Chris van Rooyen, P.Bag X11, Parkview, 2122, Tel: (011) 4861102 Fax: (011) 4861506 E-mail: chriswt@global.co.za	National	Powerlines	Co-ordination, research, awareness
Free State Nature and Environmental Conservation	Koen Erasmus, P.O. Box 517, Bloemfontein, 9300, (051) 4054974 Nacel Collins, Harrismith (05862) 23520	Free State	General	Awareness, co-ordination, rehabilitation
Highlands Crane Group	Lindy Rodwell, P.Bag X11, Parkview, 2122, Tel:(011) 48961102 Fax: (011) 4861506 E-mail: ewtsa@global.co.za Kerryn Morrison, Tel: (013) 2540191	Mpumalanga	General (affecting cranes)	Awareness
Hlatikulu Crane and Wetland Sanctuary	Helena Wilkins, P.O. Box 905, Mooi River, 3300 Tel: (0333) 37248 Fax: (0333) 37248	KwaZulu-Natal	General (affecting cranes)	Awareness, captive breeding of cranes
Institute of Natural Resources	Charles Breen, Don Kotze, Jenny Mander, Neville Quinn, P.Bag X01, Scottsville, 3209, (0331) 460796	South Africa	General	Research, awareness, co-ordination
KwaZulu-Natal Nature Conservation Services	Mike Coke, Peter Goodman , Dave Johnson, P.O. Box 662, Pietermaritzburg, 3200, (0331) 471961	KwaZulu-Natal	General	Awareness, co-odination, research
KwaZulu-Natal Town and Regional Planning Commission	P.Bag X9038, Pietermaritzburg, 3200, (0331) 952036	KwaZulu-Natal	General	Research funding
KwaZulu-Natal Wildlife Conservancey Association	29 Oakleigh Drive Howick, 3290, (0332) 304843	KwaZulu-Natal	General	Awareness

Mpumalanga Parks Board	Anton Linström, P O Box 4442, Lydenberg, 1120, Tel: (013) 2352395/7, Fax: (013) 2351674, E-mail mlinst@lantic.co.za	Mpumalanga	General	Awareness, coordination
Overberg Crane Group	Wicus Leeuwner, P.O. Box 541, Calendon, 7230, Tel: (0281) 48905 Fax: (0281) 48916	Western Cape	General	Awareness
Plant Protection Research Institute	Cedara Weeds Laboratory, P.Bag X9059 Pietermaritzburg, 3200, (0331) 3559100; P.Bag X134, Pretoria, 0001, (012) 8080364	National	General	Expertise for clearing alien plants
Poison Working Group	Gerhard Verdoorn, P.O. Box 72334, Parkview, 2122, Tel: (011) 4681157 Fax: (011) 6464631 E-mail: nesher@global.co.za	National	General	Awareness and lobbying about poisons
Rand Water	Mark de Fontaine, P.O. Box 1127, Johannesburg, 2000, Tel:(011) 682 0911	Vaal catchment	Water resources	Awareness, rehabilitation
Rennies Wetlands Project	David Lindley (co-ordinator), P O Box 44189, Linden, 2104, Tel: (011) 4860938/9 or 0832287949, Fax: (011) 4863369 *Working groups: see "Field workers active in wetland conservation"*	National, but concentrating on selected priority areas	General	Awareness, co-ordination, training, lobbying
Share-Net	Jim Taylor, P.O. Box 394, Howick, 3290, Tel:(0332) 303931	National	General	Awareness
South African Crane Fondation	Charles Byron, Secretary, P.O. Box 905, Mooi River, 3300, Tel: (0333) 37248 Fax: (0333) 37248	KwaZulu-Natal	Cranes	Awareness
South African Crane Working Group	Kevin McCann Tel: (0333) 32750, 0834470657	National	Cranes	Awareness, co-ordination
WWF, South African	P.O. Box 456, Stellenbosch, 7600, Tel:(021) 8872801	National	Biodiversity	Awareness, co-ordination
South African Sugar Association	P.Bag X02, Mount Edgecombe, 4300, Tel:(031) 593205	National		
Umgeni Water	P.O. Box 9, Pietermaritzburg, 3200, Tel:(0331) 3411111	KwaZulu-Natal	Water resources	Awareness
Wakkerstroom Natural Heritage Association	Warwick Tarboton, P.O. Box 327, Nylstroom, 0510, Tel: (014) 7431438 Fax: (014) 7431442	Wakkerstroom area	General	Awareness
Water Research Commission	P.O. Box 824, Pretoria. 0001, Tel: (012) 3300340	National	General	Research
Wildlife and Environment Society of South Africa	KwaZulu-Natal: Kieth Cooper100 Brand Road, Durban, 4001, (031) 213126 Drakensberg Wetlands Project, Mooi River (0333) 32441 Gauteng: P.O. Box 44344, Linden 2104, (011) 4863295 Western Cape: P.O. Box 30145, Tokai, 7966, (021) 7011397	National	General	Awareness, co-ordination

SECTION 6, ASSUMPTIONS OF WETLAND-USE PART 2

WETLAND-USE does not require that a formal survey of stakeholders' perceptions be undertaken. Instead it is assumed that perceptions are expressed as preferences for particular goods and services and would also shape the vision and objectives jointly developed by stakeholders.

WETLAND-USE advocates the use of a structured management system on the assumption that this will lead to more sustainable use than if decisions are taken on an *ad hoc* basis. Although empirical evidence of this at particular wetlands is lacking, the usefulness of a structured approach has generally been well demonstrated in natural resource management and in the business sector (see Ramsar Convention Bureau, 1997; Rogers and Bestbier, 1997).

In WETLAND-USE it is assumed that if users are better informed they will take greater consideration of the indirect benefits of wetlands. However, this is obviously within the constraints of their socio-economic situation. While science is viewed as having a potentially positive contribution to sustainable use, WETLAND-USE does not have a strong positivist logic which, as described by Quinlin (1997), presumes an unfolding of solutions on the basis of scientific observation. WETLAND-USE ascribes to a participative approach, as advocated by Chambers (1994) and Taylor (1997), where the fieldworker acts as facilitator.

The recommendations of WETLAND-USE Part 2 are not based on a mechanistic investigation of human behaviour but rather on an empirical approach of observing what has been shown to be successful for a range of socio-economic contexts. These observations have been drawn from the following sources.

1. Descriptions of the management of six wetlands in South Africa under a diversity of social contexts (Kotze, 1999).

2. Surveys and workshops undertaken with extension workers in South Africa (Kotze, 1999).

3. Successful natural resource management case studies in southern Africa reported by Turner (1995).

4. An assessment of several community wildlife management initiatives in southern Africa (Mander and Steytler, 1997).

5. Ramsar wetland site management case studies (Davis, 1993).

6. Observations made of the role of institutions in natural resource management (Murphree, 1993).

7. Comments and suggestions from fieldworkers involved with wetlands, including:
   - i. N Collins, K Erasmus, Free State
   - ii E Qonya,, Eastern Cape
   - iii. S Roberts, S de Jager, J Wyatt, N Nsele, KwaZulu-Natal
   - iv. A Linstrom, Mupalanga
   - v. D Lindley, national

The assumption of WETLAND-USE that land tenure generally has a profound influence over natural resource use is widely accepted (Uphoff, 1986; Turner, 1995). WETLAND-USE assumes further that sustainable natural resource use is possible under communal tenure. Although it is argued by Hardin (1968) that communal use leads to unsustainable practices, this has been countered by Uphoff, (1986) and Turner (1995), who present empirical evidence to demonstrate the sustainability of communal use regimes. They point out that it is open access regimes which are, in fact, inherently unsustainable.

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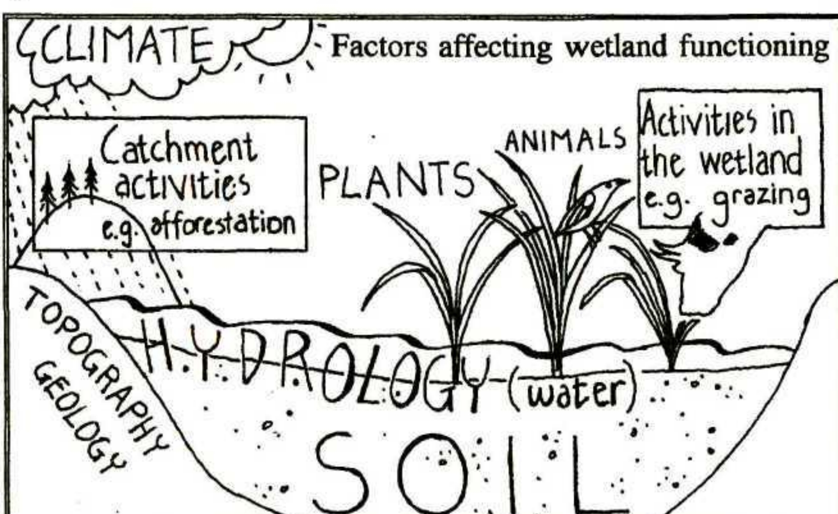
INTRODUCTION

Without water there would be no life on earth. Plants, animals and people need water to survive and grow. South Africa does not have an abundance of water, and the water in many streams is polluted. Both droughts and floods are common. Wetlands are able to reduce the severity of droughts and floods by regulating streamflow. Wetlands also purify water and provide habitat for many different plants and animals. Besides these **indirect benefits** to society, wetlands provide many **direct benefits** in the form of resources such as fibre for making crafts. Until very recently the benefits of wetlands to society were often not recognized, and many wetlands have been destroyed or poorly managed.

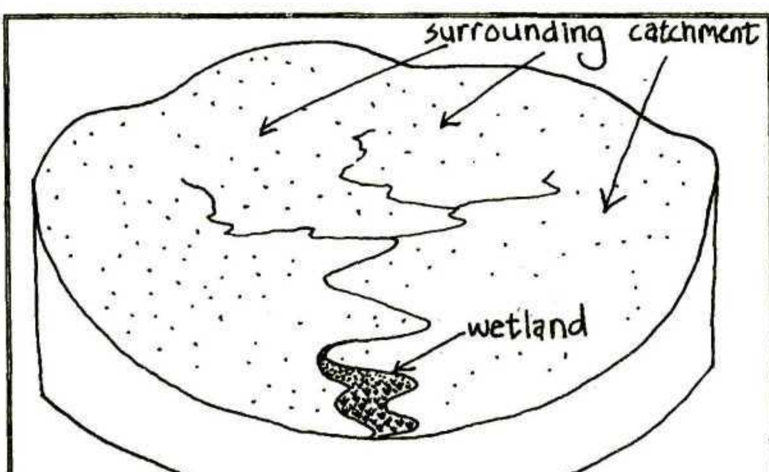
Section 1 of this booklet introduces you to the indirect and direct ways in which wetlands benefit society. Section 2 helps you to understand how these benefits are affected by the activities of people. Below is a brief overview of the factors affecting wetland functioning (for more detail see Booklet 2). It will be worthwhile keeping these factors in mind when using the rest of the booklet. A third booklet in the series, which is currently being drafted, indicates how this increased understanding can be used to improve the management of wetlands.



Water which falls as rain or snow on the **catchment**, and which is not lost to the atmosphere through **evaporation** or **transpiration**, moves through the catchment to the sea. Wetlands are found where the landform (topography) or geology slows down or obstructs the movement of water through the catchment (e.g. where the landform is very flat) causing the surface soil layers in the wetland area to be temporarily, seasonally or permanently wet.

This provides an environment where particular plants (e.g. reeds) that are adapted to wet conditions tend to grow in abundance. The plants, in turn, affect the soil and **hydrology** (e.g. by further slowing down the movement of water and by producing organic matter that may be accumulated in the soil). The plants provide shelter and food for particular animal species.

The functioning of a wetland is also affected by other factors, many of which result from the activities of people. These include "off-site" factors which take place in the surrounding catchment (e.g. a change in landcover from natural grassland to a gum tree plantation which would decrease the amount of water reaching the wetland) and "on-site" factors which take place at the wetland (e.g. fire).



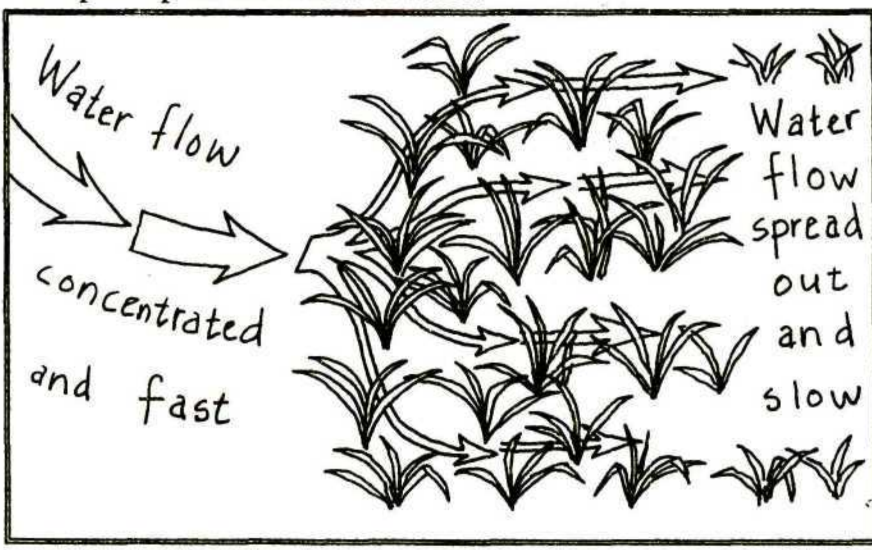
SECTION 1: WHAT BENEFITS DO FUNCTIONING WETLANDS HAVE?

INDIRECT BENEFITS

Hydro-logical benefits	Water purification	
	flood reduction	
	sustained streamflow	
	groundwater recharge and discharge	
	erosion control	
Biodiversity benefit (habitat for wetland dependent species)		
Biogeochemical cycling benefit		

Flood reduction and streamflow regulation

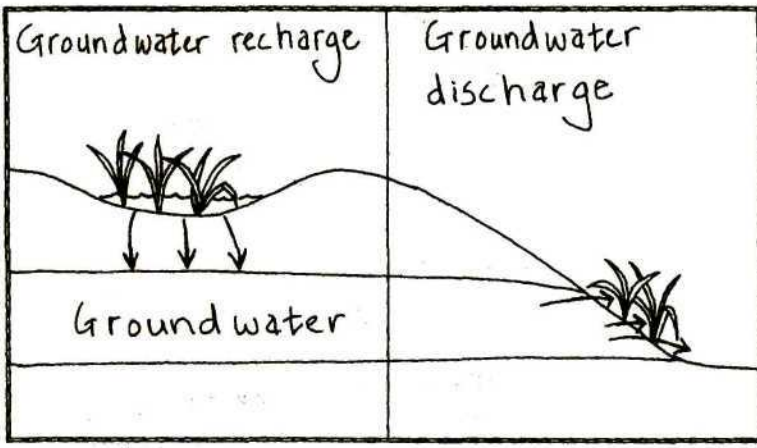
Wetlands spread out and slow down water moving through the catchment because of: (1) the characteristically gentle slopes of wetlands and (2) the resistance offered by the dense wetland vegetation. Also, many wetlands do not have well defined channels that would otherwise speed up the movement of water.



By slowing down the movement of water and detaining it for a while wetlands act like sponges which reduce floods and also prolong streamflow during low flow periods. Loss of water to the atmosphere through evaporation and transpiration does, however, reduce the amount of water available to prolong low flows. When wetland vegetation is growing, water is lost from the leaves through transpiration. However, the water lost into the atmosphere from a vegetated wetland is usually less than would be lost from the surface of an **open water** area such as a dam. This is because the cover provided by wetland vegetation reduces evaporation from saturated or flooded soil by sheltering it against the sun and wind. When the vegetation dies back, there is no loss of water through transpiration and the dead leaves remain, continuing to shelter the soil. During such times, water loss is most effectively regulated.

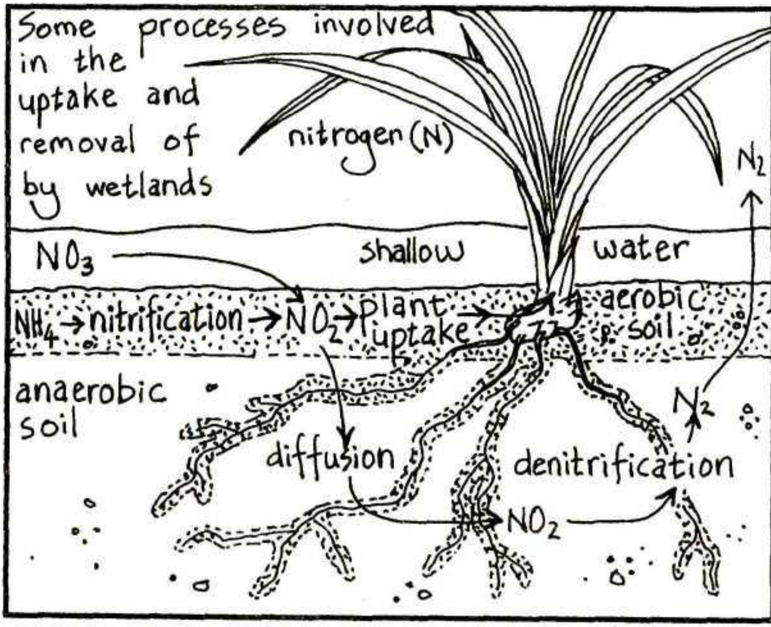
Groundwater recharge and discharge

Wetlands may have an important influence on the recharge or discharge of groundwater. Groundwater recharge refers to the movement of surface water down through the soil into the zone in which permeable rocks and overlying soil are saturated. Groundwater discharge, in contrast, refers to the movement of groundwater out onto the soil surface. Although poorly understood, it appears that most wetlands are groundwater discharge or throughflow areas. Wetland areas where groundwater is discharging are often referred to as seepage wetlands because they are places where the water seeps slowly out onto the soil surface (see Booklet 2).



Water purification

Wetlands are natural filters, helping to purify water by trapping pollutants (i.e. sediment, excess nutrients [most importantly nitrogen and phosphorus] heavy metals, disease-causing bacteria and viruses and synthesised organic pollutants such as pesticides). Thus, the water leaving a wetland is often purer than the water which enters the wetland. Wetlands are able to purify water effectively because:
*they slow down the flow of water (see flood reduction and streamflow regulation) causing sediment carried in the water to be deposited in the wetland. This also results in the trapping of other pollutants (e.g. phosphorus) which are attached to soil particles;



*surface water is spread out over a wide area, making it easier for exchanges between soil and water;

*there are many different chemical processes taking place in wetlands that remove pollutants from the water. For example, wetlands provide a suitable place for denitrification because **anaerobic** and **aerobic** soil zones are found close together. Denitrification is important because it converts nitrates, which could potentially pollute the water, to atmospheric nitrogen which is not a pollution hazard;

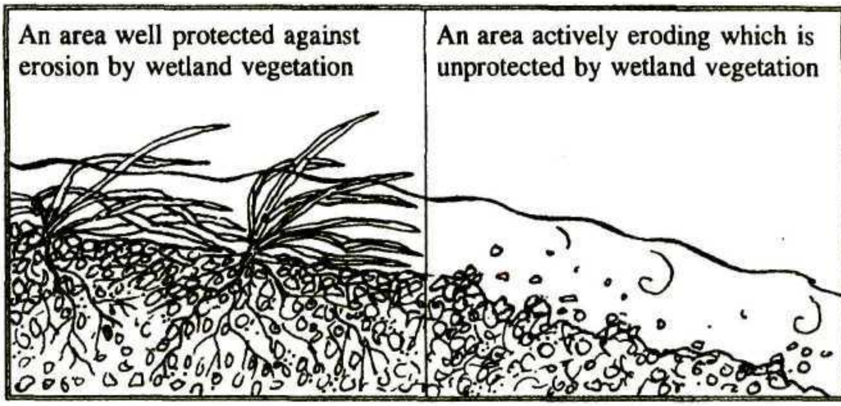
*some pollutants such as nitrates (NO_3) are taken up by the rapidly growing wetland plants;

*the abundant organic matter in wetland soils provides suitable surfaces for trapping certain pollutants such as heavy metals; and

*wetland micro-organisms help decompose man-made organic pollutants such as pesticides.

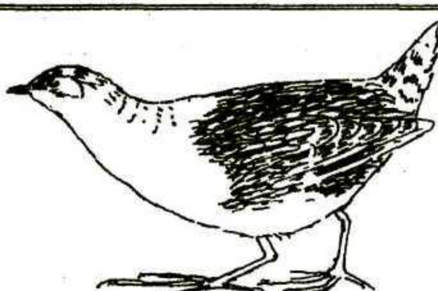
Erosion control by wetland vegetation

Wetland vegetation is generally good at controlling erosion by: (1) reducing wave and current energy; (2) binding and stabilizing the soil; and (3) recovering rapidly from flood damage.



Biodiversity

Wetlands are usually places where there is much plant growth because of the abundance of water and nutrients in the soil. The plants, in turn, provide food and shelter for animals. There are many different plants and animals that depend on wetlands, and without the habitat that wetlands provide, they would not be able to survive. Several of these species, such as the white-wing flufftail and wattled crane, are threatened.



The white-winged flufftail is totally dependent on the habitat provided by wetlands. This bird is so rare and secretive that no one has ever seen it nesting

Chemical cycling

In wetlands, the **decomposition** of organic matter is slowed down by the anaerobic conditions present in wetlands. This results in wetlands trapping carbon as soil organic matter instead of releasing it into the atmosphere as carbon dioxide. Presently too much carbon dioxide is being released into the atmosphere when fossil fuels (i.e. coal and oil) are used to produce energy, resulting in the global climate being disrupted. Coal is, in fact, formed from plant material accumulated under wetland conditions in **swamps** that existed millions of years ago. Thus, instead of destroying wetlands and releasing carbon dioxide into the atmosphere, we should be conserving wetlands which will help reduce carbon dioxide levels in the atmosphere.

DIRECT BENEFITS

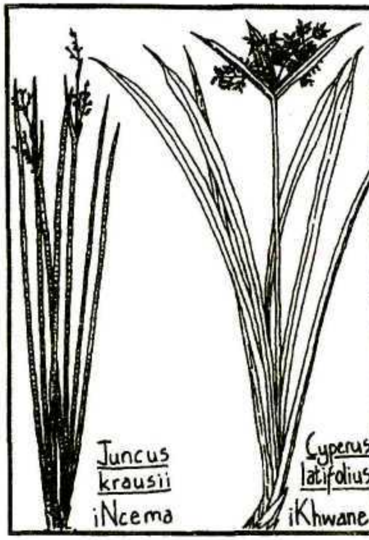
Livestock grazing

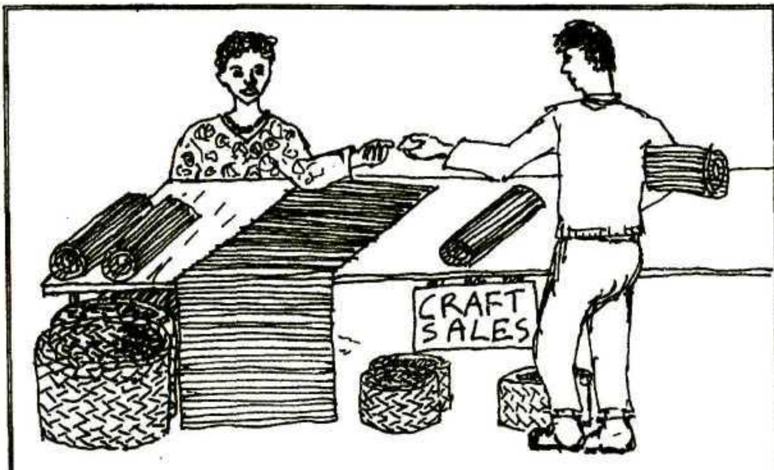
Wetlands, especially temporarily and seasonally **waterlogged** areas, may provide very valuable grazing-lands for domestic and wild grazers. This is particularly so in the early growing season and during droughts when grazing reserves are low in the surrounding veld (rangeland) but the wetlands continue to produce a lot of grazing. Permanently wet **marsh** areas tend to have a lower grazing value because most mature marsh plants are unpalatable, and the excessive wetness may stop animals getting into the wetland. Utilization needs to be **sustainable** if the wetland is to maintain its value for grazing. As with dryland pastures, wetlands are only able to sustain a certain amount of grazing. Particular care is required in wetlands where the erosion hazard is high (see Section 2).

Fibre for construction and handcraft production

Wetland plants have been used for thousands of years, providing valued materials for products such as mats, baskets and paper (produced from papyrus, which is a sedge). There are several plant species which are suitable and are used extensively for making handcrafts in South Africa, such as the rush *Juncus krausii* (iNcema), and the **sedges** *Cyperus latifolius* (iKhwane) and *C. textilis* (iMisis). The common reed (*Phragmites australis*) is used for construction purposes. Some wetland plants are also collected for medicines.

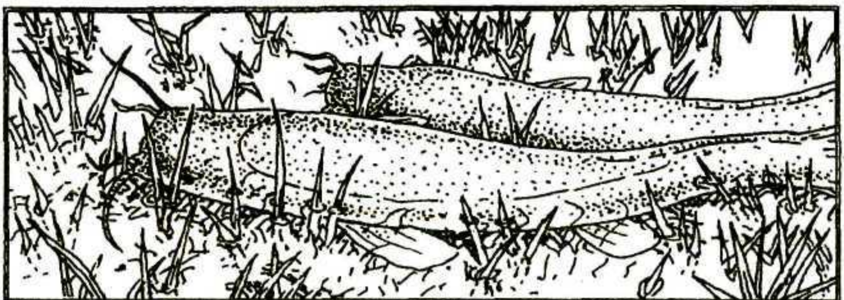
Handcraft production from harvested wetland plants has many benefits as a development option in poor communities: it makes use of local traditional skills; it has the potential for immediate cash returns and, by increasing the financial benefits to the local people, it increases the incentive not to destroy the wetland, thereby contributing to the conservation of natural habitats. However, harvesting needs to be sensitive to the functioning of the wetland (see Section 2).





Valuable fisheries

Although the value of wetlands for fisheries varies greatly, floodplain wetlands (e.g. Pongola River Flats) and estuaries (e.g. Kosi Bay) are typically valuable in the production of fish for human consumption. Many sea fishes in South Africa spend some of the early phases of their life cycles in estuaries, and freshwater fishes such as barbel also use wetlands.



Barbel moving into a wetland to spawn

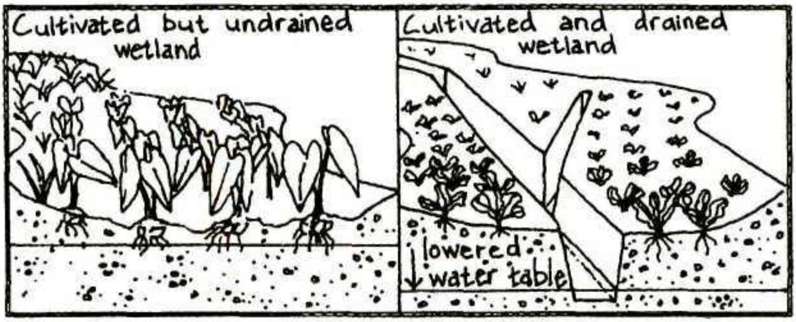
Hunting waterfowl and other wildlife

Some wetlands are important places where waterfowl (including ducks and snipe) and other wildlife such as reedbuck can be hunted. In the USA a great many people take part in the recreational hunting of waterfowl which depend on wetlands for breeding and food. In fact, duck hunters have helped to conserve many wetlands. The hunters recognize the importance of wetlands for ducks and are willing to pay to make sure that the wetlands remain in their natural functioning condition.

Valuable land for cultivation

Wetland soils are potentially productive. However, the anaerobic conditions associated with wetlands exclude most commonly grown crops except for those specially adapted, such as madumbes

(*Colocasia esculenta*) and rice. Thus, wetlands are often drained so that plants not adapted to the waterlogged conditions can be grown. This has important environmental impacts, requiring that the cultivation of wetlands be well controlled (see Section 2).



Some wetlands are used for timber production but because of the impact that trees have on wetland benefits, strict controls are required (see Section 2).

A valuable source of water

Because water is stored in wetlands, they provide sites for the supply of water for domestic and livestock use, as well as for irrigation. The storage capacities of wetlands are sometimes increased through damming. However, this often has important negative effects on other benefits (see Section 2).

Economically efficient wastewater treatment

You will have learned in the water purification section that wetlands purify water. Natural wetlands provide this service to society "free of charge". Thus, natural wetlands are sometimes purposefully used to treat polluted water and many artificial wetlands are being created for wastewater treatment. When using a wetland to treat wastewater, several factors need to be considered to assess how effectively a wetland will purify water:

*the pollutant, the wetland soil, flow patterns in the wetland, the size of the wetland, and the climate affecting the wetland, which all determine the capacity of the wetland for purifying the wastewater. For example, more pollutants are likely to be trapped in a wetland where the flow is spread out across all of the wetland than in a wetland where a channel concentrates flow in only part of the wetland. If the pollutants are heavy metals then a wetland with soils rich in organic matter is likely to be more efficient at trapping heavy metals than a wetland with soils poor in organic matter; and

*the amount of pollutant relative to the capacity of the wetland. The capacity of the wetland is obviously limited, and if the amount of pollutant greatly exceeds the capacity, the wetland will not effectively purify the water. The impacts of pollutants on the wetland also need to be considered (see Section 2).

Aesthetics (beauty) and nature appreciation

Although wetlands which fringe estuaries, rivers and streams are next to open water, most natural inland wetlands have fairly limited open water associated with them. Thus, they are generally not good sites for water sports. However, wetlands are good places to see birds. Large numbers of birds are often attracted to wetlands, with many of these birds found only in wetlands. Wetlands also add to the diversity and beauty of the landscape. Wetlands have a diverse range of colours and textures and some very attractive flowers, such as those of **vlei** lilies (*Crinum* spp.) and ground orchids.

SECTION 2: HOW DO OUR LAND-USE ACTIVITIES AFFECT WETLANDS?

The manner in which we use wetlands and the scale on which we do so determines the extent of our impact. Uses which provide good economic returns are not necessarily sustainable. Land-use activities (e.g. growing crops or damming water) often affect how a wetland functions and what benefits it provides to society. In many cases, the effects are negative, such as when a wetland is disturbed in order to plant crops, the wetland's function of trapping sediment and holding the soil is reduced. This reduces the benefits that society receives from the wetland in purifying water and controlling erosion.

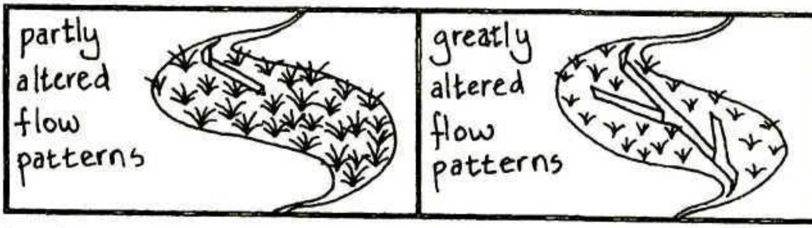
Impacts on wetlands result from both 'on-site' activities at the wetland site (e.g. drainage, disturbance through cultivation, infilling, and flooding by dams) and from 'off-site' activities in the wetland's surrounding catchment (e.g. afforestation, mining and crop production) (see Introduction, page 1).

ON-SITE LAND-USE IMPACTS

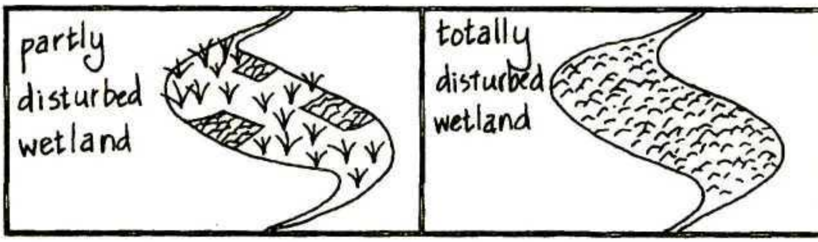
How do on-site land-uses affect the functioning and benefits of wetlands?

Below are four points to consider when assessing the general "on-site" impacts of land-uses on wetlands (for more information see references).

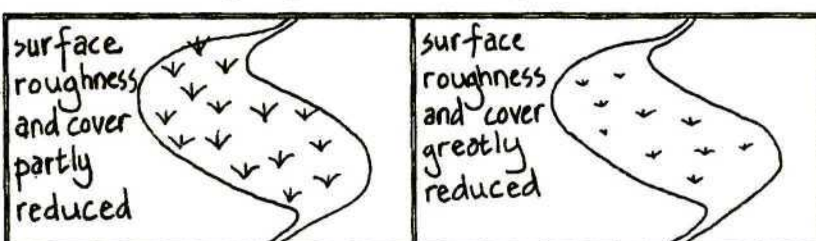
Changes to the flow pattern within the wetland through drainage channels which cause flow to become more channelled and less diffuse, thereby reducing the wetness of the area.



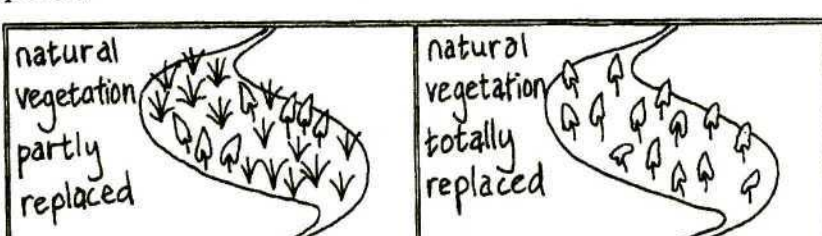
Disturbance of the soil, making it more susceptible to erosion.



Changes in the surface roughness and vegetation cover (when these are reduced the ability of the wetland to slow down water flow, reduce erosion and purify water is reduced).



Replacement of the natural vegetation by introduced plants, which generally reduces the value of the wetland for wetland dependent species.



Drainage and the production of crops and planted pastures

When wetlands are converted to cropland most of the indirect benefits of the wetland are lost, especially if the wetland is drained. Drained wetlands are less effective at regulating streamflow and purifying water because the drainage channels speed up the movement of water through the wetland. Drainage increases the danger of erosion by concentrating water flow and thus increasing the erosive power of the water. Also, the hydrological changes resulting from drainage have negative effects on the soil (e.g. reduced soil organic matter and moisture levels and, sometimes, increased risk of underground fires and increased acidity due to the oxidation of sulphides to produce sulphuric acid).

The soil is disturbed when crops are planted, and crops do not bind or cover the soils as well as the natural wetland vegetation (see Section 1). Thus, erosion is controlled less effectively, which may be a very serious problem in areas with high erosion hazards. Adding fertilizer and pesticides (which may leach into the river system) further reduces the effectiveness of the wetland in purifying water. The impact of cultivation can be reduced if practices characteristic of low input/ traditional cultivation are followed.

Traditional cultivation practices, which are more sensitive to the functioning of the wetland, include:

*planting crops (e.g. madumbes) which are tolerant of waterlogging, minimizing the need to drain;

*tillage and harvesting by hand, resulting in less soil compaction and potential disturbance than with mechanical tillage and harvesting;

*not using pesticides and artificial fertilizers, which reduces the impact on **water quality**; and

*not planting extensive areas but leaving indigenous vegetation between cultivated patches

In South Africa wetlands are protected by the Conservation of Agricultural Resources Act 43 of 1983 (administered by the Directorate: Resource Conservation) that prevents land users from cultivating or draining wetlands.

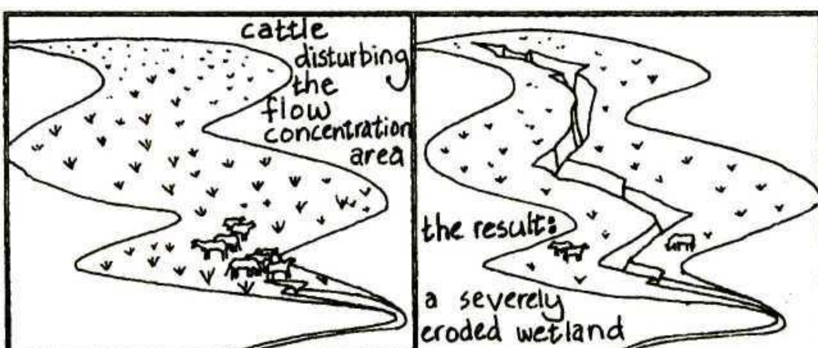
Timber production

Timber plantations have a high impact on the water storage function of wetlands because a lot of water is lost by the trees through transpiration. Some trees (e.g. gum trees) use more water than other trees (e.g. poplars, which lose their leaves in winter). Trees also have a strong negative effect on the habitat value of wetlands. Under increased shading beneath the trees, the vigour of indigenous plants which are not adapted to these conditions is reduced and they are often out-competed by alien invasive plants. In South Africa there is a law (Section 75 of the Forestry Act No 122 of 1986) which prevents the planting up of wetlands to timber.

Grazing of undeveloped wetlands by domestic stock

Grazing may have both positive and negative effects on the indirect benefits of wetlands. In wetlands which have some areas grazed short and other areas left tall, the diversity of habitats is increased. In wetlands which are grazed short completely, the diversity of habitats is decreased.

Heavy grazing may cause valuable grazing species to be replaced by less productive and/or palatable species. Some wetlands erode easily when disturbed by trampling and grazing. The most easily eroded are those wetlands with unstable soil and where water flowing diffusely across the wetland concentrates into a channel. In these situations erosion can cause the channel to cut up into the wetland and dry it out, destroying most of its value. Thus, grazing pressure should not be too high and cattle need to be kept away from these flow concentration areas.



Causes and effects of wetland erosion

As we described at the beginning of this section, wetlands are characteristically areas where the movement of surface water is slowed down and sediment is deposited. Sometimes, however, wetlands with high erosion hazards erode and more sediment is removed from the wetland than is deposited. The erosion hazard of the wetland depends on several factors, including the erodibility (stability) of the soil, slope and landform setting. Other factors which are influenced by management, such as vegetation cover and disturbance of the soil (e.g. by cattle or farm machinery), also contribute to erosion. As a very general rule, soils from dry areas (i.e. <750 mm of rainfall per year) tend to be less erodible than soils from wetter areas (>750 mm rainfall). The particular type of rock from which the soil is formed also affects its erodibility. Landforms that are steep and landforms that have open drainage tend to erode more easily than those which are gently sloped and those which have inward drainage.

Erosion of wetlands may result in deep gullies which drain the water rapidly from the wetland and make the water regime much less wet. This often greatly reduces the values of the wetland (see Booklet 1).

Mowing and harvesting of plants

Mowing and harvesting of plants by hand tends to have much less of a negative impact on the indirect benefits of wetlands than cultivation. Cutting plants has similar effects to grazing and generally increase habitat diversity, provided that extensive areas are not mown or cut at one time. Mowing and harvesting may also be harmful if done while animals are still breeding. In the case of mowing, the machinery used for cutting may also disturb the wetland soil and increase the danger of erosion. This would not occur when plants are harvested by hand. Harvesting must be done on a sustainable basis if we are to continue to benefit from the wetland plants. If harvesting is beyond the resource's capacity for renewal, resource degradation will occur and the benefits derived by the users will be lost. Plants should not be harvested more than once a year, and areas which are harvested should be rested for a whole year at least every third or fourth year.

Fishing and hunting

In order that hunting and fishing be sustainable, the number of animals caught or hunted should obviously not exceed the capacity of the population to renew itself. If too many animals are caught or hunted there will not be enough left to reproduce and to replace the one ones that are removed. Consequently, the value of the wetland to continue providing these resources will be reduced.

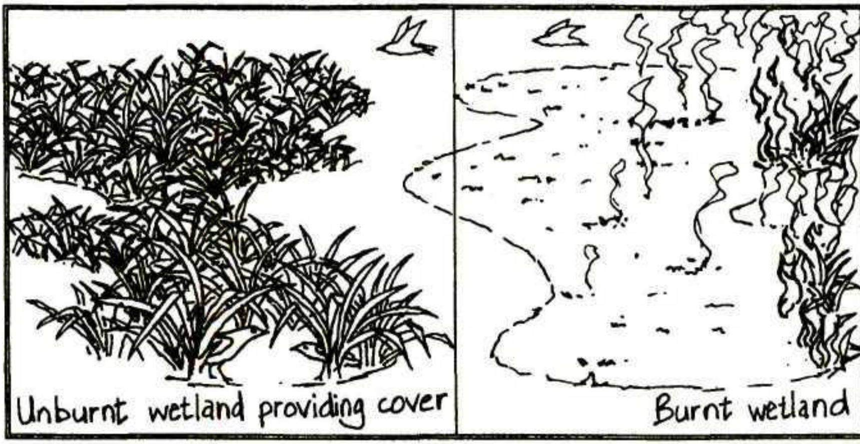
Burning

Wetlands are burnt for many reasons: to improve the grazing value for livestock by removing old dead material and increase productivity; to improve the habitat value for wetland dependent species; to assist in alien plant control; and, to reduce the risk of run-away fires.

Wetland fires usually only burn above-ground plant parts and most plants recover rapidly from this. Some fires also burn soil and plant parts below the ground, which usually destroys the plants. This generally detracts from the values of the wetland (e.g. by increasing the risk of erosion). However, by burning away the upper soil layers, open water areas may be created which may enhance the diversity of the wetland.

While burning has short term impacts such as killing some animals which are not able to escape, it also has many positive effects (e.g. controlling alien plants and increasing the productivity of the indigenous plants which may increase the breeding success of certain wetland dependent animals). Whether or not the overall effect will be positive or negative depends on many factors including: timing, frequency and extent of the fire, and the type of fire (determined by conditions at the time of the fire, such as humidity and air temperature). Late winter burning is least likely to impact on breeding animals, as very few species are likely to be breeding at this time. Early winter or summer burns are more likely to affect breeding animals.

It appears that in the high rainfall areas of South Africa, a fire every second year is unlikely to have a negative effect on known wetland dependent species. However, when a wetland area is burnt it is important that unburnt areas are present nearby where animals can seek cover while the burnt area is re-growing.



Back fires (burning against the wind) tend to have a greater impact on the growing points of plants than head fires (burning with the wind). Burning when humidity is high and air temperature low, generally has a lower impact than burning when humidity is low and air temperature high.

Damming

Many wetlands in South Africa have been flooded by dams, as wetlands are often found in places which are ideal dam sites. Whilst dams perform certain wetland functions (e.g. sediment trapping and water storage) they do not perform other functions well. The habitat required by specialised wetland dependent species is frequently lost when a wetland is dammed. The vegetation which develops around the shoreline is limited in many dams by sudden fluctuations in the water level and by the steep sides of the dam. When a series of dams occurs along a stream, the cumulative effect that the dams have in reducing the streamflow may be considerable, particularly where water is pumped out of the dams. The effects of dams are usually most noticeable in the early wet season, when dams are at their lowest levels after the dry season and retain the early flows.

Purification of wastewater

From Section 1 we saw that wetlands are generally very effective at purifying polluted water. However, using a wetland to purify wastewater will affect the functioning of the wetland and may cause a loss of some of the other benefits of the wetland, particularly if the pollutant loadings are close to or greater than the capacity of the wetland for purification. For example, under increased nutrient inputs the bulrush (*Typha capensis*), a very common wetland species that competes well under nutrient-rich conditions, may out-compete and eliminate less common wetland species. This would reduce the diversity of the wetland. Standards have been set by the Department of Water Affairs and Forestry for the discharge of wastewater into streams (see references) and these should not be exceeded.

OFF-SITE IMPACTS

Most of the water in a wetland derives from the catchment surrounding the wetland. Therefore wetlands are strongly influenced by activities in the surrounding catchment even when they are distant from the wetland. When assessing the impacts of off-site land-uses on wetlands one needs to look at how the land-uses change the quality and quantity of water entering the wetland from the surrounding catchment and how this, in turn, affects the functioning and benefits of the wetland.

How do off-site land-uses affect the quality and quantity of runoff?

Probably the two most important land-uses affecting **runoff** quantity and timing from the wetland's surrounding catchment are damming/ pumping of water (usually for irrigation) and afforestation. As a general rule, trees use more water than natural grassland. Gum trees use the most water (sometimes increasing water loss by more than twice that of natural grassland) followed by wattle and pine trees. Sugarcane also increases water loss. The extra water used by trees, sugarcane or any other crop that has a high transpiration rate would no longer reach the wetland. Dams reduce runoff through evaporation from the dam surface. Dams also allow for large quantities of water to be abstracted and used for irrigation, which may greatly reduce runoff to the wetland.

There are several land-uses that may affect the quality of runoff, including:

- mining
- intensive animal production
- sewage works
- industries
- crop production
- poorly managed grazing lands
- human settlements with inadequate sanitation

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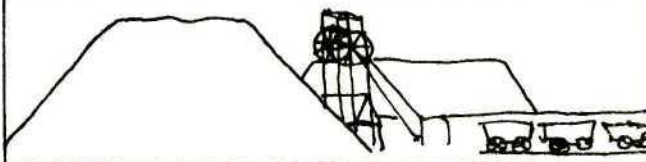
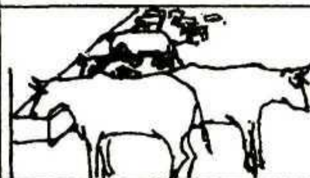
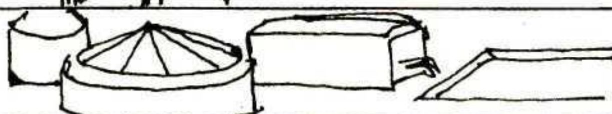
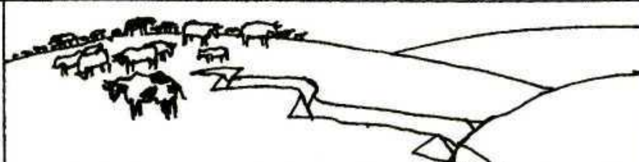
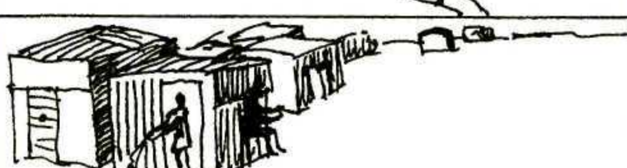
Some land-uses that may potentially generate pollution from concentrated sources (point source pollution)	
Mining	
Intensive animal production (e.g. feedlots, dairy)	
Sewage works	
Industries	

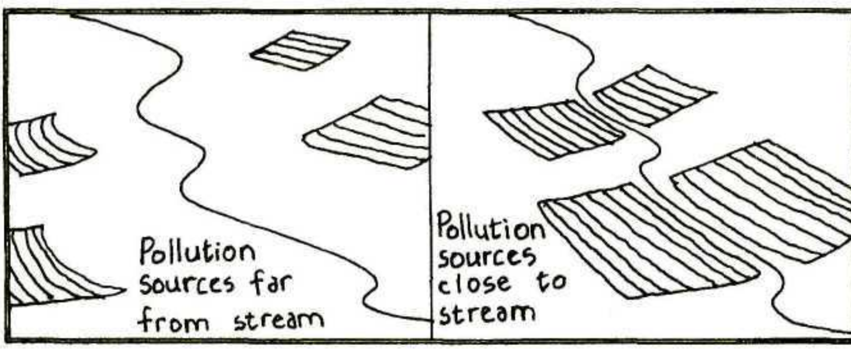
Some land-uses that may potentially generate pollution from a wide area (non-point source pollution)	
Crop production	
Poorly managed grazing lands	
Human settlements with inadequate sanitation	

In order to determine the potential problems that may be generated by a pollution source (point source and non-point source) you will need to find out:

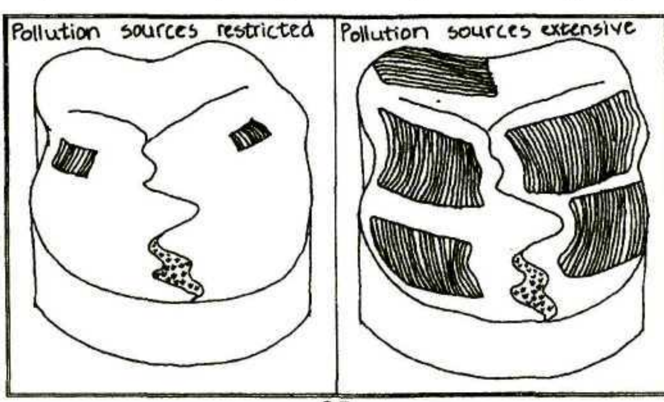
*Are the water quality standards of the Department of Water Affairs being met (see references)?

*what is the type of pollutant being released and what are its concentrations (this may vary greatly through the year)?

*How close is the pollution source to a stream (pollution which enters directly into a stream is likely to have a greater impact than pollution which has to pass overland first, particularly if it moves through wetland areas)?



*in the case of non-point source pollution, what is the extent in the catchment of the area generating the pollutant (the greater the area occupied by the land-use, the greater the potential impact)?



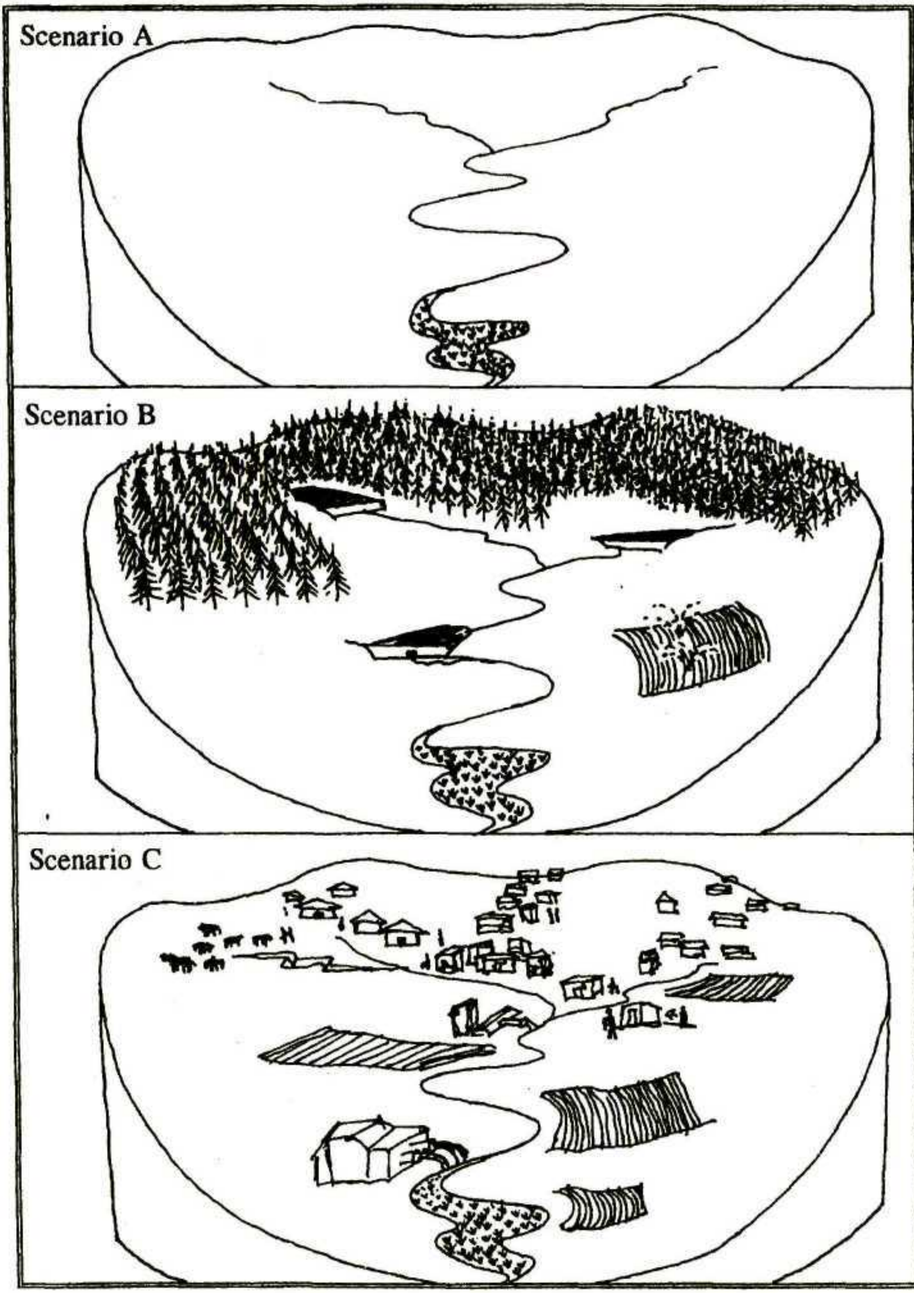
Runoff from mines typically has high pollutant levels. For example, iron sulphate-bearing rocks dug up to mine coal are exposed to oxygen and water, which produces sulphuric acid, and, under the acidic conditions metals such as manganese and zinc become more soluble and may reach toxic concentrations. Wastewaters from many industries also have high levels of pollutants, including a wide range of pollutant types. Wastewaters from intensive animal production operations and sewage works typically have high levels of nutrients and disease-causing bacteria and viruses.

By law, water from point sources has to meet certain water quality standards set by the Department of Water Affairs and Forestry (see references). However, in many cases even though wastewaters receive some treatment before being allowed to continue down the catchment, the water quality standards are not met.

Well-managed veld used for grazing generally has a low level of impact on runoff. However, heavy grazing pressure may have a high impact particularly if it leads to high levels of soil erosion. Also, heavy grazing pressure, causing decreased vegetation cover and increased soil compaction, decreases infiltration and groundwater recharge. This, in turn, increases floods and reduces dry season flows from the catchment.

The disturbance involved in crop production and the reduced vegetation cover increases soil loss, leading to increased sediment loads. It has been shown that even if lands are protected, and acceptable levels of soil loss are occurring, soil loss is still likely to be greater than that which would occur from well-managed natural veld. Thus, where lands are inadequately protected the potential impact may be considerable.

Human settlements without adequate sanitation usually produce pollutants consisting of nutrients and disease-causing bacteria and viruses.


Scenario A
Scenario B
Scenario C

Let us look at the surrounding catchment of a wetland under different land-use scenarios and see to what extent the quality and quantity of runoff is likely to differ (refer to the diagrams on page 27). Scenario A has very little human activity and is likely to yield unaltered volumes of good quality water, which would benefit downstream users. In Scenario B, a large proportion of the catchment is afforested and there are several dams and some irrigation. Scenario B is likely to yield less water for downstream users, which may be of a slightly lower quality than in Scenario A. Scenario C has no afforestation and damming but has cultivation and human settlements with poor sanitation situated close to the streams. It is therefore likely to have poorer water quality than Scenarios A and B but yield more water than Scenario B. Imagine a combination of catchment B and C where the quality and quantity of water would be lowered.

How do off-site impacts on runoff affect wetlands?

The effect of a change in the water quality of the runoff on the functioning and benefits of a wetland depends very much on the type and concentrations of the pollutant and the type of wetland (see wastewater treatment, page 19). The deposition within the wetland of excess sediment from the wetland's catchment will alter the wetland landform, which may then affect the hydrological regime of the wetland. For example, if a wetland depression is filled with deposited sediment, it will retain less water than previously.

A reduction in the quantity of runoff obviously changes the hydrology of the wetland. If the runoff is greatly reduced, the wetland may become much less wet. This would happen if the wetland was artificially drained, causing many of its benefits to society to be lost. A change in the timing of runoff would also alter the hydrology of the wetland, and is likely to cause some of the wetland benefits to be lost. The species found naturally in a wetland may be adapted to wetness at a particular time and they may not be able to survive if this is changed.

Besides reducing the amount of water reaching the wetland, trees planted close to the wetland may increase shading of the natural vegetation and allow the establishment of alien plants. Wetland dependent species, such as wattled crane, which use non-wetland grassland areas nearby for feeding would also be negatively affected by trees planted close to the wetland.

CONCLUSION

We have seen that functioning wetlands have many benefits to society. Some of these benefits, particularly the indirect benefits, are not obvious and can be easily overlooked. This is partly why many of the wetlands in South Africa have been destroyed through development and degradation. Unless action is taken to positively influence the activities of people affecting wetlands, the results could be very serious. In a water-poor country such as South Africa, continued destruction of wetlands will result in:

*lower agricultural productivity;
*less pure water;
*less reliable water supplies;
*increased downstream flooding; and
*increasingly threatened plant and animal resources.

From the discussion on wetland benefits and land-use impacts we have seen that the hydrology of a wetland is the most important factor determining its functioning. Thus, as a general rule, the more you alter the hydrology of a wetland the greater will be the effect on its functioning. When people use wetlands or their catchments to obtain resources, the functioning and indirect benefits of the wetland are often affected negatively. However, some uses (e.g. sustainable harvesting of wetland plants) are much less destructive than others (e.g. draining and cultivating crops). These uses which do not alter the hydrology and which do not affect the functioning of the wetland negatively need to be promoted. By doing this, local people can benefit directly from the wetland while, at the same time, the benefits received by society are not lost (i.e. more people benefit and the total value of the wetland is increased).

If you use a wetland directly or are giving advice, it is important to know how different land-use choices affect the functioning of the wetland and the benifits it provides to society. This booklet and the references given below will help you. Advice may also be obtained from the several organizations concerned with wetlands which are also listed.

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GLOSSARY OF TERMS

Aerobic: having molecular oxygen (O_2) present.

Anaerobic: not having molecular oxygen (O_2) present.

Biodiversity: the variety of life in an area, including the number of different species, the genetic wealth within each species, and the natural areas where they are found.

Biological integrity: refers to the fauna and flora that are characteristic of an area (i.e. the species that would naturally be in an area)

Bog: a mire (i.e. a **peat** accumulating wetland) that is hydrologically isolated, meaning that it is only fed by water falling directly on it as rain or snow and does not receive any water from a surrounding catchment. Bogs have acidic waters and are often dominated by mosses (Mitsch and Gosselink, 1986). The term bog is frequently used much more broadly in South Africa to refer to high altitude wetlands that have organic-rich soils. Many of these wetlands would not be bogs in the correct sense.

Bottomland: the lowlands along streams and rivers, often on alluvial (river deposited) soil.

Catchment: all the land area from mountaintop to seashore which is drained by a single river and its tributaries.

Chroma: the relative purity of the spectral colour, which decreases with increasing greyness.

Decomposition: the breakdown of dead organic matter into simpler substances.

Direct (wetland) benefits: have worth, quality or importance to humans and are realized by individuals actively using a wetland (e.g. for recreation, or pasture production).

periodically deposited by a stream during floods but which is well drained).

Roughness coefficient: an index of the roughness of a surface and is a reflection of the frictional resistance offered by the surface to water flow.

Runoff: total water yield from a catchment including surface and subsurface flow.

Seasonally wet soil: soil which is flooded or waterlogged to the soil surface for extended periods (>1 month) during the wet season, but is predominantly dry during the dry season.

Sedges: Grass-like plants belonging to the family Cyperaceae, sometimes referred to as nutgrasses. Papyrus is a member of this family.

Soil drainage classes: describe the soil moisture conditions as determined by the capacity of the soil and the site for removing excess water. The classes range from very well drained, where excess water is removed very quickly, to very poorly drained, where excess water is removed very slowly. Wetlands include all soils in the very poorly drained and poorly drained classes, and some soils in the somewhat poorly drained class.

Soil saturation: when all spaces between the soil particles are filled with water.

Sustainable use: the use of a resource in a way which allows that resource to renew itself so that it will continue to be available for the benefit of future generations.

Swamp: a wetland dominated by trees or shrubs (USA definition). Swamp is also sometimes used to refer to reed or papyrus dominated areas.

Marsh: a wetland which is seasonally or permanently flooded/ ponded, with soils which remain semi-permanently or permanently saturated, and which is usually dominated by tall (usually >1.5m) emergent herbaceous vegetation, such as the common reed (*Phragmites australis*).

Mire: a peat accumulating wetland, including both bogs and fens.

Mottles: soils with variegated colour patters are described as being mottled, with the "background colour" referred to as the matrix and the spots or blotches of colour referred to as mottles.

Open water: temporarily to permanently flooded areas characterized by the absence (or low abundance) of emergent plants.

Peat: soil material with a high organic matter content. According to the Soil Survey Staff (1975) definition, in order for a soil to be classed as organic it must have >12% organic carbon by weight if it is sandy and >18% if it is clay-rich.

Perched water table: the upper limit of a zone of saturation in soil, separated by a relatively impermeable unsaturated zone from the main body of groundwater below.

Permanently wet soil: soil which is flooded or waterlogged to the soil surface throughout the year, in most years.

Red data species: all those species included in the categories of endangered, vulnerable or rare, as defined by the International Union for the Conservation of Nature and Natural Resources.

Riparian: the area of land adjacent to a stream or river that is influenced by stream-induced or related processes. Riparian areas which are saturated or flooded for prolonged periods would be considered wetlands and could be described as **riparian wetlands**. However, some riparian areas are not wetlands (e.g. an area where alluvium is

Estuary: where the river and sea meet and the fresh water from the river mixes with the sea water.

Evaporation: the change from a liquid or solid state to a vapour.

Fen: a mire (i.e. a peat accumulating wetland) that receives some drainage from mineral soil in the surrounding catchment.

Gley: soil material that has developed under anaerobic conditions as a result of prolonged saturation with water. Grey and sometimes blue or green colours predominate but **mottles** (yellow, red, brown and black) may be present and indicate localized areas of better aeration.

Groundwater: subsurface water in the zone in which permeable rocks, and often the overlying soil, are saturated.

Groundwater table: the upper limit of the groundwater.

Hydric soil: soil that in its undrained condition is saturated or flooded long enough during the growing season to develop anaerobic conditions favouring growth and regeneration of hydrophytic vegetation (i.e. wetland soil).

Hydrology: the study of water, particularly the factors affecting its movement on land.

Hydrophyte: any plant that grows in water or in soil that is at least periodically anaerobic as a result of saturation; plants typically found in wet habitats.

Indirect (wetland) benefits: have worth, quality or importance to humans but do not require active use of wetlands by individuals in order for the benefits to be realized. Instead, the wider public benefits indirectly from the services that wetlands provide (e.g. purification of water).

Temporarily wet soil: The soil close to the soil surface (i.e. within 40 cm) is occasionally wet for periods > 2 weeks during the wet season in most years. However, it is seldom flooded or saturated at the surface for longer than a month.

Transpiration: the transfer of water from plants into the atmosphere as water vapour

Vlei: a colloquial South African term for wetland.

Water quality: the purity of the water.

Waterlogged: soil or land saturated with water long enough for anaerobic conditions to develop.

Wet grassland: an area which is usually temporarily wet and supports a mixture of: (1) plants which are common to non-wetland areas and (2) short (< 1m) hydrophytic plants (predominantly grasses).

Wet meadow: an area which is usually seasonally wet and dominated by hydrophytic sedges and grasses which are common only to wetland areas.

Wetland: a collective term used to describe land where an excess of water (i.e. waterlogging) is the dominant factor determining the nature of the soil development and the types of plants and animals living at the soil surface (Cowardin *et al.*, 1976); lands that are sometimes or always covered by shallow water or have saturated soils, and where plants adapted for life in wet conditions usually grow.

Wetland soil: synonymous with hydric soil.

Wetland catchment: all of the land area upslope of the wetland (from which water drains into the wetland) and including the wetland itself. The "surrounding catchment" refers to that part of the wetland catchment excluding the wetland.

ORGANIZATIONS CONCERNED WITH WETLANDS

Your provincial Nature Conservation Department

Directorate: Resource Conservation
Department of Agriculture
P/Bag X120
Pretoria, 0001

Department of Environmental Affairs and Tourism
Private Bag X447
Pretoria, 0001

Your provincial Department of Agriculture

The Wildlife and Environment Society of South Africa
P O Box 394
Howick, 3290

Southern African Crane Foundation
P O Box 905
Mooi River, 3300

Rennies Wetland Project
P O Box 44344
Linden, 2104

If you have a general concern for wetlands, increase your understanding of wetlands and support the wetland activities of organizations such as the Wildlife Society. These activities include: campaigning for wetlands that are threatened; collecting information that will be used to assist managing wetlands; rehabilitating (restoring) wetlands by controlling alien plants and blocking drainage channels (see references); and making other people aware of the benefits of wetlands to society. For more information on rehabilitating wetlands see references, Wyatt (1995)

QUIZ

In order to test yourself and see whether you have a reasonable understanding of this booklet, you should be able to answer the following questions:

1. Suggest some differences between direct and indirect wetland benefits recieved by people from wetlands, and give some examples of each?
2. What is groundwater discharge? (page 5)
3. Name some features make wetlands good at purifying water? (pages 5 and 6)
4. What are some of the negative effects of artificial drainage on the indirect values of wetlands? (page 15)
5. Are the following statements true or false (explain your answers):
    a. all wetlands erode very easily (page 17)
    b. wetlands should never be burnt (page 18)
    c. dams are able to perform all the functions of wetlands (20)
6. How is a wetland likely to be affected if its entire surrounding catchment is afforested with gum trees? (pages 24-26)

notes

notes

OTHER SHARE-NET RESOURCES TO SUPPORT WETLAND AND WATER STUDIES

Wetlands-Use Booklet No. 1: *Wetlands and People*

Hands-On: *Stream and Pond Life*
Grasses and Grassland Life
Soil and Compost Life

Beginners' Guides: *Common Freshwater Fishes of Natal*
Some Common Water Birds

Action Series: *Riverine Vegetation of Natal*

Water Quality Testing: *Catchment Action Starter Kit*
GREEN Manual

CONTENTS

INTRODUCTION

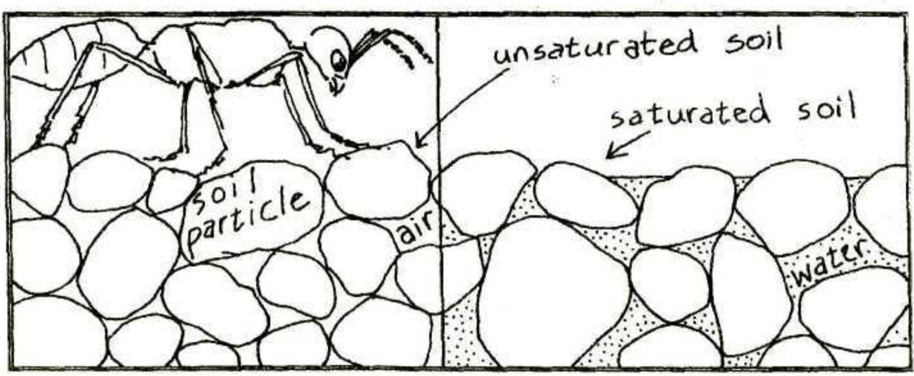
Even though **wetlands** have many benefits to society, such as purifying wate controlling erosion and providing habitat for wetland dependent species, the continue to be destroyed and poorly managed. This is usually because th benefits are poorly understood (Booklet 1) or they benefit people distant fror the wetland. In order to begin improving the management and protection c wetlands, one needs to have a better understanding of how wetlands functio

In South Africa there are many terms commonly used to refer to wetland including **marsh**, **sponge**, **vlei** (Afrikaans), and iXhaposi (Zulu). Th booklet, which includes a comprehensive glossary at the end, aims to assi you in recognizing wetlands and improving your understanding of ho wetlands function. It examines **hydrology** and soils in Section 1 an landforms and geology in Section 2, introducing the various topics through series of questions.

SECTION 1: WHAT IS A WETLAND?

In trying to understand wetlands, a good place to start is with the questio ***what is a wetland?***

A wetland is wet land (i.e. land which is wet)! But not all wet land results i a wetland. Why is this so? A wetland is found where the land is wet enoug (i.e. **saturated** or flooded) for long enough to be unfavourable to most plan but favourable to plants adapted to **anaerobic** soil conditions.



ɔil becomes increasingly wet, the water starts to fill the spaces between ɔil particles. When all the spaces are filled with water the soil is said to turated. In areas which are not wetlands, water drains away quickly and ɔil does not remain saturated. However, in wetlands the water persists or ıs away very slowly and the soil remains saturated or flooded for long ɔds. Soil in these conditions is said to be waterlogged. Depending on ɔrs such as temperature, it usually takes a week or so for the plant roots and r living organisms in the soil to use up the oxygen, causing anaerobic litions to develop in the waterlogged soil.

ıt are anaerobic soil conditions and what importance do they have for ts?

erobic conditions occur when there is no, or very little oxygen present in ;oil. This is important to plants because plant roots require oxygen to live function. **Hydrophytes** are plants that have special adaptations for living naerobic soils (e.g. specialized air spaces which allow oxygen to move ly from the leaves and stem/s down into the roots).

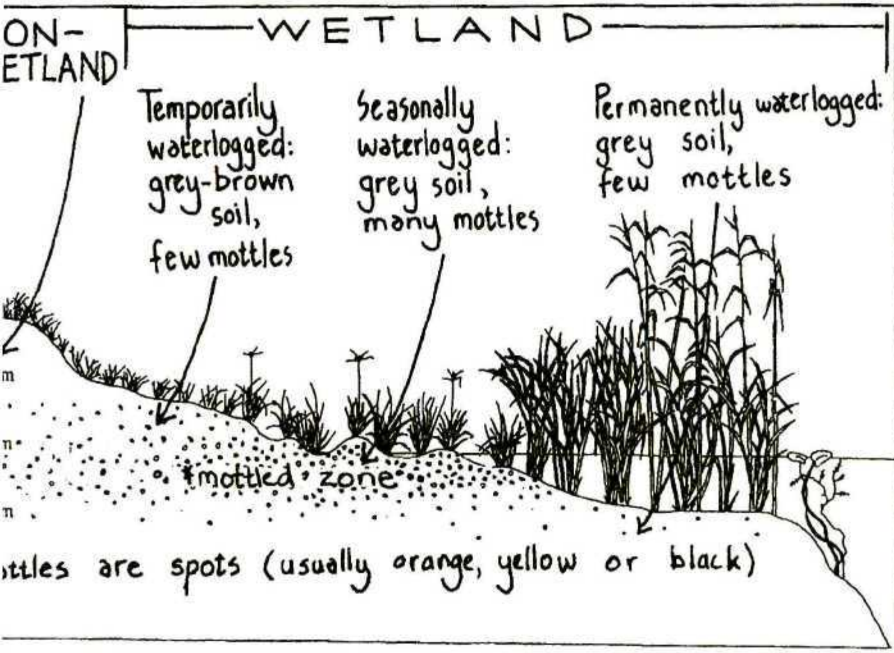
erobic conditions may contribute to the ability of wetlands to purify water ıuse many chemical processes that help in removing pollutants from the er require anaerobic conditions (see Booklet 1). If the soil is saturated and anaerobic zone is within the upper 50 cm of soil (i.e. the main rooting e), it is generally close enough to the soil surface to significantly influence plants growing in the soil. This will cause the area to develop racteristics of a wetland. However, if the waterlogged layer always ıains below 50 cm from the soil surface it would probably be too deep to ıificantly influence the vegetation (i.e. there is sufficient aerated surface for non-wetland conditions to prevail). Such an area is unlikely to elop the characteristics of a wetland.

ıat causes anaerobic conditions to develop in saturated soils?

answer this question we need to examine the relative speed with which ʻgen diffuses through air and water. There is, in fact, a tremendous ference, with oxygen diffusing 10 000 times more quickly through air than through water. Thus, when roots and soil micro-organisms use the oxygen i the soil, the rate at which it is replaced by oxygen diffusing from the air abov the soil and down through the soil is much slower if the soil is saturated tha if it is unsaturated. In saturated soil, the water in the spaces between the so particles effectively "blocks" the diffusion of oxygen.

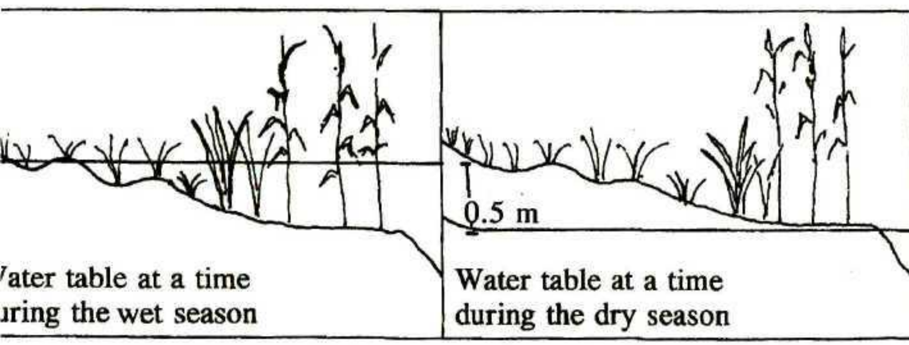
To summarize: we have seen that, expressed very simply, a wetland is just th - it is a wet land. More specifically it is land which is wet at or close to the so surface for long enough for anaerobic conditions to develop. The land doe not have to have surface water to be considered a wetland.

Water regime is a term used to describe how the wetness of the soil change over time. ***Do all wetlands have similar water regimes?*** No -wetlands ca have quite different water regimes, from permanently waterlogged area which remain flooded or saturated to the surface for the entire year, t temporarily waterlogged areas, which are flooded or saturated to close to th soil surface for only a few weeks in the year (but still long enough to develo anaerobic conditions and determine the nature of the plants growing in th soil).

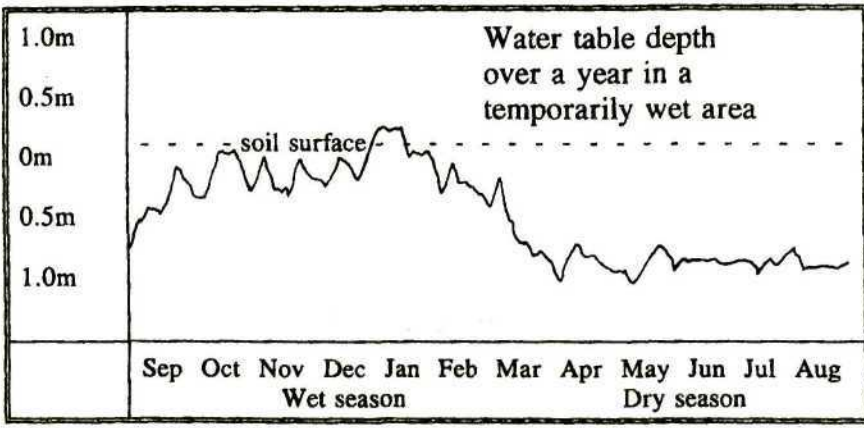


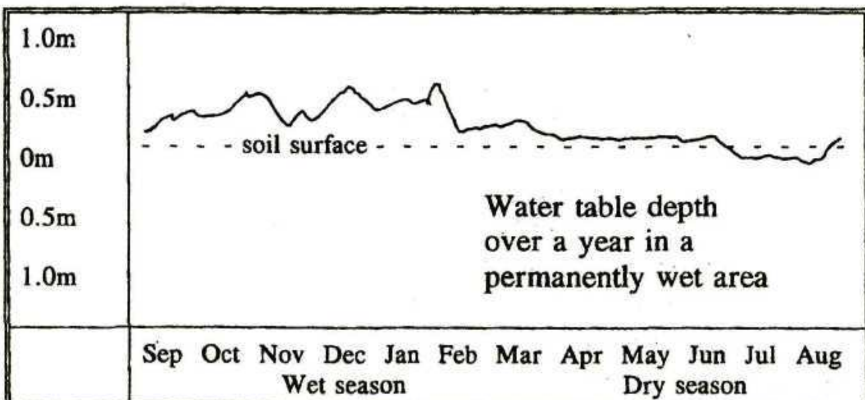
transect in a wetland showing areas with different water regimes

: upper limit of the saturated zone in the soil is referred to as the **undwater table**. In most parts of the landscape the water table lies many tres below the soil surface. However, in wetlands the water table usually close to or above the soil surface. Even so, the water table depth changes esponse to climatic changes (e.g. from year to year, season to season, and hin a season). This is most noticeable in seasonally and temporarily terlogged areas (see diagrams below).



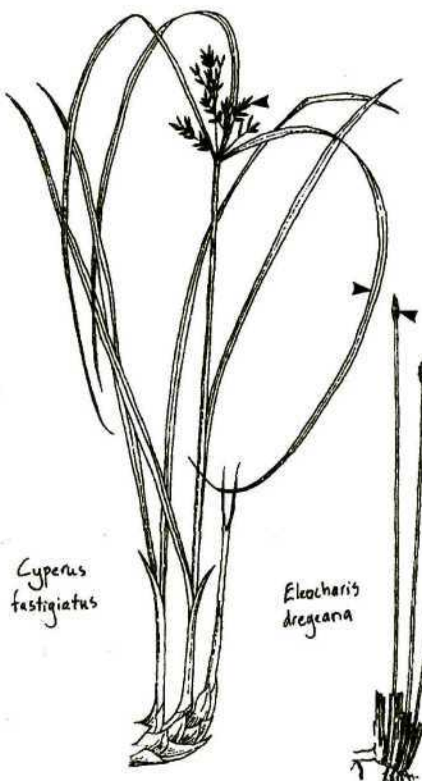
ter table differences between the wet and dry seasons in a hypothetical wetland





Graphs showing water table changes over a year in two hypothetical wetland areas

To see the depth of the water table at a particular time: simply dig a hole in the ground until water is reached and measure the depth once the water level has stabilized. If you find that the saturated zone is close to the soil surface (i.e. within 50 cm) you are probably in a wetland. If, however, you find that the saturated zone is not close to the soil surface, this does not necessarily mean that the area is not a wetland. You may be in a temporary wetland and you will need to wait for some months before water is visible close to the soil surface s, it is usually not enough to simply know where the water table is at one ınce in time. One needs a general picture of how it changes over time (i.e. needs to determine the water regime). One way of doing this is to directly sure the water regime over a long time (preferably for more than a year) ugh the use of a measuring well. Because of the expense and time, this is lly not possible. Alternatively, indirect indicators of the water regime d be used. The best indirect indicator is the soil morphology (i.e. the ur patterns and general appearance of the soil). The presence of plants are adapted to certain water regimes may also be used as indicators. In th Africa most **sedge** species are confined to wetland areas. There are, ever, exceptions such as *Cyperus esculentus*, a common weed in lands, which occurs widely outside of wetlands.



ome common sedges found in wetlands

How can soil colour patterns be used to indicate soil water regime?

The water regime has a strong effect on the colour patterns of the soil. One ca say that the water regime leaves its signature on the soil. So different wate regimes leave different signatures. This means that we can indirectl determine what the water regime is for a particular area by interpreting th area's soil colour patterns (i.e. by "reading its signature") from a single sit visit. Because these signatures develop slowly they reflect 'average conditions over a long time. They save us the time and effort of measuring th water regime continuously.

Well drained soils that are seldom saturated have enough oxygen present t oxidise the iron, resulting in the soil being uniformly red/brown in colou usually without **mottles** (see Glossary: soil drainage classes). Under **aerobi** conditions iron in the soil is not soluble in water, and thus it is not leached ou of the soil and the soil retains its red/brown colour. In contrast, unde anaerobic conditions the iron oxides are reduced and broken down and th effect that they would have in making the soil red/brown is lost. Thus, we fin that wetland soils, often referred to as **hydric soils**, are generally grey i colour. On a colour chart these soils have a **chroma** of 2 or less.

You can demonstrate the effect of anaerobic conditions on iron by seeing wha happens when a mild steel welding rod is inserted into a permanentl anaerobic soil and left for several months. Where it is inserted into the soil th rod does not rust because there is no oxygen in the immediate environment t react with the iron in the rod and form iron oxides (rust), as would occur to a iron rod inserted in an aerobic soil.

Although temporarily wet soils tend to be anaerobic for shorter periods an less close to the soil surface than seasonally wet soils, both of these soil alternate between being anaerobic (mainly in the wet season) and anaerobi (mainly in the dry season). When anaerobic soil dries out, iron oxides form i patches, resulting in mottles. Mottles often form around plant roots, whicl provide a route for oxygen to move down into the soil. Thus, soil which i grey but has many mottles may be interpreted as indicating a zone with fluctuating (rising and falling) water table.

en a wetland is drained and the water regime is changed the soils retain r characteristic colour signatures. Thus, soils are useful for indicating if ained area used to be a wetland. This helps in mapping where wetlands d to be and assists in working out the extent of wetland loss.

v do anaerobic conditions affect organic matter in the soil?

ides affecting the mineral chemistry of soils (with iron being especially ceable) the water regime of wetlands also has an important influence on organic matter. Most micro-organisms which **decompose** (break down) anic matter use oxygen in the process. So when oxygen is depleted these anisms cannot function. Although other organisms gain energy by erobic respiration they decompose organic matter much more slowly. s increases the amount of organic matter in the soil. Thus, the wettest parts he wetland, which are most anaerobic, tend to have the highest organic ter contents in a given wetland.

v temperatures also promote organic matter accumulation, so that for a ticular water regime, more will accumulate in a cool climate than in a mer one. Soil with a very high organic matter content is referred to as **t**. In cold areas such as Ireland and Canada many of the wetlands have peat s. Under the warmer conditions of Africa, peat is much less common but till found in many permanently wet areas. Wetlands with peat soils are rred to as **bogs** or **fens**.

ich of the soil forms in the South African Soil classification system are land soils?

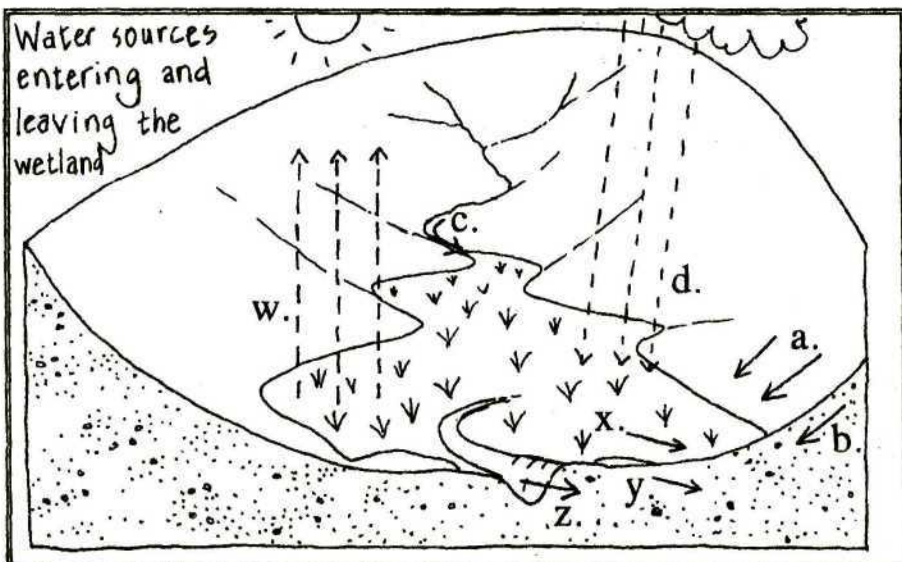
soil forms (categories in the classification system) common to South ican wetlands are Champagne, Katspruit, Willowbrook and Rensburg. Champagne form consists of a soil layer with greater than 10% organic bon. The others are all characterized by the presence of a G horizon (i.e. **leyed** soil layer) immediately below the surface horizon. There are also er soil forms which are found mainly in non-wetland areas but which are found in temporary wetlands. These include the Kroonstad, Westleigh, iglands and Estcourt. The Dundee form is found near rivers but it is ierally well drained and would not be considered a wetland soil.

Soil maps showing the distribution of different soil forms exist for some part of South Africa, with one of the most extensively mapped areas being th Tugela **catchment** in KwaZulu-Natal. These maps are very useful in showin the distribution of wetlands.

SECTION 2: WHERE ARE WETLANDS FOUND?

From Section 1 we have seen how important water is in affecting th functioning of wetlands. Unless there is a supply of water to the wetland an the water is retained there will be no wetland!

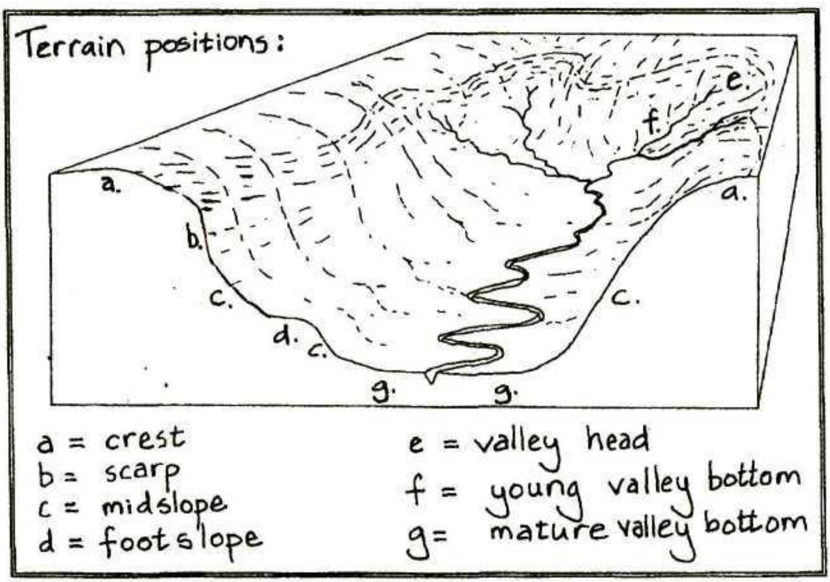
Water which falls as rain or snow on the catchment, and which is not lost t the atmosphere through **evaporation** or **transpiration**, moves down throug the catchment to the sea. It moves (see diagram below) as: (a) overland flo on the soil surface; (b) subsurface flow beneath the soil surface; and (streamflow. Wetlands are found where this movement of water through th catchment is slowed down or obstructed, resulting in waterlogged soil Water also reaches the wetland directly as rain or snow (d). Water may be lo from the wetland in several ways: (w) loss into the atmosphere throug evaporation and transpiration; (x) overland flow; (y) **groundwater** flow; ar (z) streamflow.



slowing down of water flow is important for many wetland functions (e.g. deposition of sediment) and waterlogging is also important for many tions (e.g. removal of pollutants such as nitrogen from the water). These tions have several benefits to people, such as erosion control and water fication (see Booklet 1).

important question we should answer in trying to understand a wetland er is: what is causing these particular areas to be wet (i.e. what is ntaining the wetlands as wet areas)? This may be difficult to find out, but egin it is helpful to look at the wetland's terrain position and landform ng.

at is the wetland's terrain position?



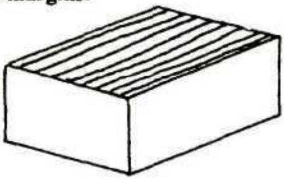
tlands are characteristically found in **bottomland** positions, which have tle slopes giving rise to poorly drained conditions where water is retained he soil. However, wetlands are also found in other positions, including:

otslopes, which have gentle slopes;
id-slopes, in small areas where groundwater discharges; and
lleyheads, where groundwater may also be discharging

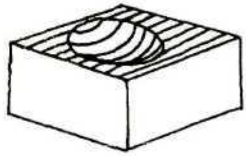
What is the landform setting of the wetland?

Wetlands have a wide range of landform settings shown below.

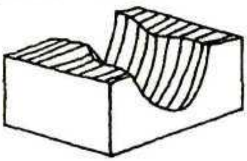
Flats have a slope of <1%,little or no relief and diffuse margins.



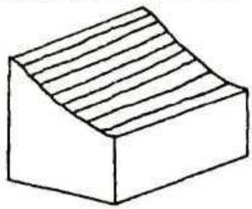
Depressions are depressed basin-shaped areas in the landscape with no external drainage. Depressions may be shallow or deep and may have flat or concave bottoms.



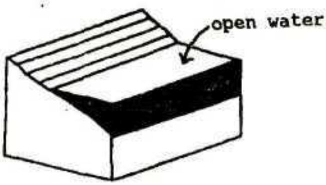
Channels refer to any incised water course. Channels may be shallow or deep but always have clearly defined margins.



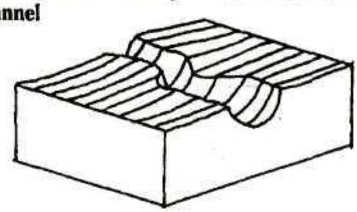
Slopes are areas with a gradient of greater than 1%, which may be concave or convex.



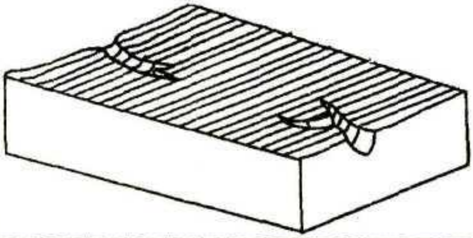
Fringes refer to areas on the edges of open water, such as that provided by lakes or dams.



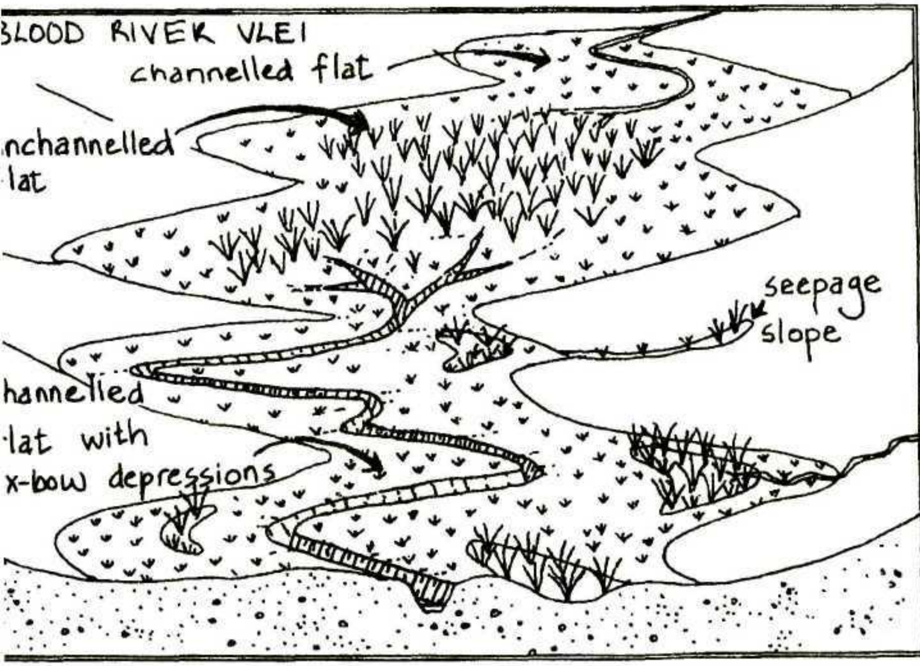
Channelled flats comprise a flat incised by a channel



Channel-disrupting flats comprise a flat which is fed and drained by a channel



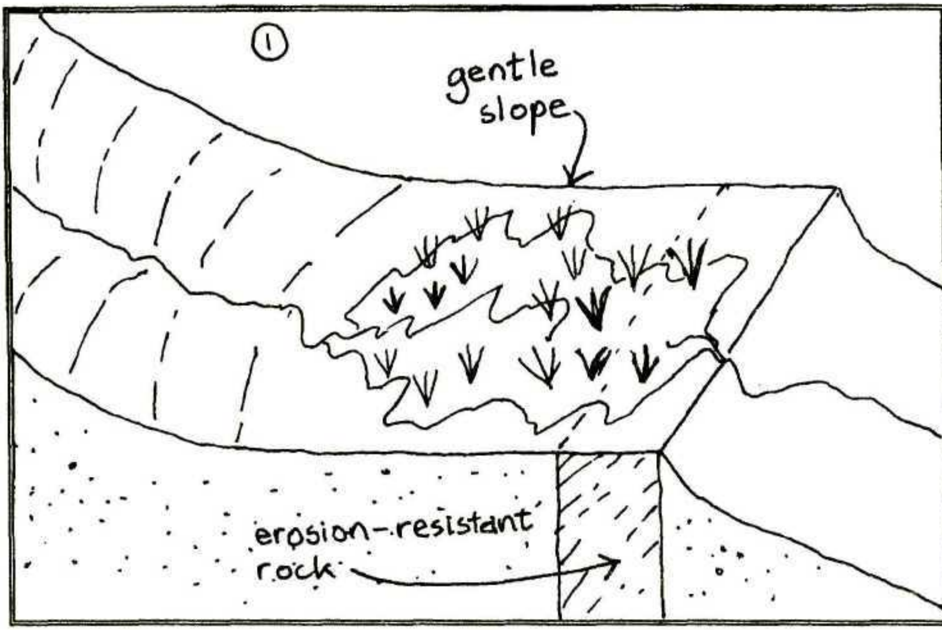
any wetlands, particularly those which are large, consist of a combination of ndform settings. A good example of this is the Blood River vlei, shown low



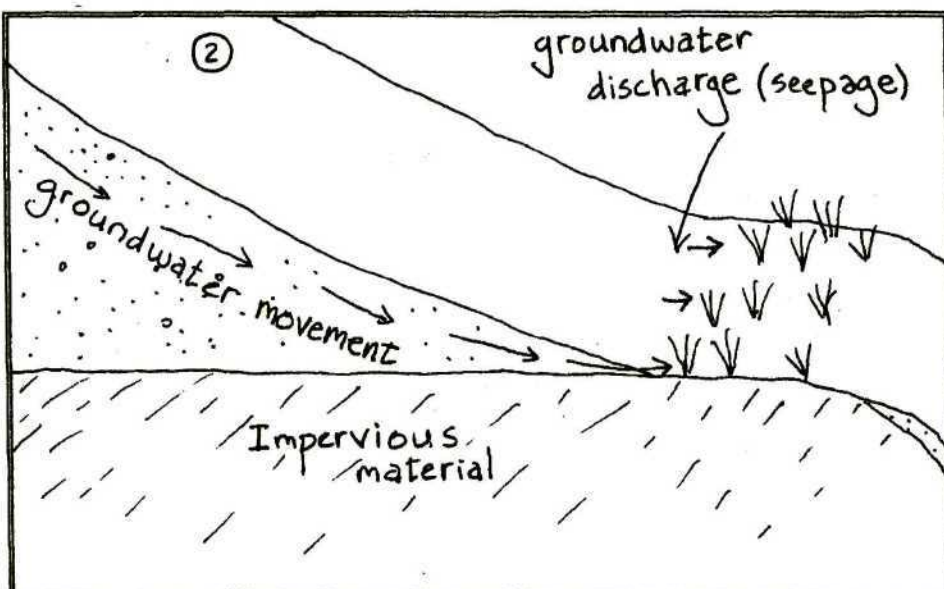
hat part does geology play in the formation of wetlands?

trying to establish further why a wetland is found in a particular place, it is lpful to examine the geology of the area. Generally, there are two main ays in which the geology contributes to wetlands forming:

A geological obstruction may resist downward erosion, resulting in tensive flat areas where water accumulates if there is a sufficient source, ually surface water but also groundwater. This obstruction (sometimes ferred to as the key point of the wetland) often consists of very hard erosion-sistant rock, such as dolerite, but alluvial soil deposits may also act as an ostruction. An obstruction may further be caused through geological ulting, as is the case in the Okavango Swamps.



2. Impervious material close to the surface forces groundwater movement very close to or onto the soil surface discharging groundwater (see Booklet 1).



NCLUSION

s introductory booklet has dealt with only a few aspects of wetland ctioning. There are other important aspects which need to be considered en managing wetlands. One of the most important is the quality of the er entering the wetland and how this is affected by wetland functioning. se factors are dealt with in more detail in Booklet 1 and in the references en below.

w that you have read this booklet you should have a better understanding (1) what a wetland is; (2) the source/s of water that maintain wetland water imes and what geological and landform factors cause water to accumulate vetland sites; (3) anaerobic conditions and how they develop in wetlands; 1 (4) how wetland water regimes vary greatly, from areas which remain manently wet to areas which are only temporarily wet. This understanding wetland functioning will add to your understanding of the benefits and uses wetlands gained from Booklet 1.

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GLOSSARY OF TERMS

Aerobic: having molecular oxygen (O_2) present.

Anaerobic: not having molecular oxygen (O_2) present.

Biodiversity: the variety of life in an area, including the number of different species, the genetic wealth within each species, and the natural areas where they are found.

Biological integrity: refers to the fauna and flora that are characteristic of an area (i.e. the species that would naturally be in an area)

Bog: a mire (i.e. a **peat** accumulating wetland) that is hydrologically isolated, meaning that it is only fed by water falling directly on it as rain or snow and does not receive any water from a surrounding catchment. Bogs have acidic waters and are often dominated by mosses (Mitsch and Gosselink, 1986). The term bog is frequently used much more broadly in South Africa to refer to high altitude wetlands that have organic-rich soils. Many of these wetlands would not be bogs in the correct sense.

Bottomland: the lowlands along streams and rivers, often on alluvial (river deposited) soil.

Catchment: all the land area from mountaintop to seashore which is drained by a single river and its tributaries.

Chroma: the relative purity of the spectral colour, which decreases with increasing greyness.

Decomposition: the breakdown of dead organic matter into simpler substances.

Direct (wetland) benefits: have worth, quality or importance to humans and are realized by individuals actively using a wetland (e.g. for recreation, or pasture production).

stuary: where the river and sea meet and the fresh water from the river ixes with the sea water.

vaporation: the change from a liquid or solid state to a vapour.

en: a mire (i.e. a peat accumulating wetland) that receives some drainage om mineral soil in the surrounding catchment.

ley: soil material that has developed under anaerobic conditions as a result f prolonged saturation with water. Grey and sometimes blue or green colours edominate but **mottles** (yellow, red, brown and black) may be present and idicate localized areas of better aeration.

roundwater: subsurface water in the zone in which permeable rocks, and ften the overlying soil, are saturated.

roundwater table: the upper limit of the groundwater.

Iydric soil: soil that in its undrained condition is saturated or flooded long nough during the growing season to develop anaerobic conditions favouring rowth and regeneration of hydrophytic vegetation (i.e. wetland soil).

Iydrology: the study of water, particularly the factors affecting its novement on land.

Iydrophyte: any plant that grows in water or in soil that is at least eriodically anaerobic as a result of saturation; plants typically found in wet abitats.

ndirect (wetland) benefits: have worth, quality or importance to humans ut do not require active use of wetlands by individuals in order for the enefits to be realized. Instead, the wider public benefits indirectly from the ervices that wetlands provide (e.g. purification of water).

Marsh: a wetland which is seasonally or permanently flooded/ponded, with oils which remain semi-permanently or permanently saturated, and which is usually dominated by tall (usually >1.5m) emergent herbaceous vegetation, such as the common reed (*Phragmites australis*).

Mire: a peat accumulating wetland, including both bogs and fens.

Mottles: soils with variegated colour patters are described as being mottled, with the "background colour" referred to as the matrix and the spots or blotches of colour referred to as mottles.

Open water: temporarily to permanently flooded areas characterized by the absence (or low abundance) of emergent plants.

Peat: soil material with a high organic matter content. According to the Soi Survey Staff (1975) definition, in order for a soil to be classed as organic i must have >12% organic carbon by weight if it is sandy and >18% if it is clay rich.

Perched water table: the upper limit of a zone of saturation in soil, separate by a relatively impermeable unsaturated zone from the main body o groundwater below.

Permanently wet soil: soil which is flooded or waterlogged to the soil surfac throughout the year, in most years.

Red data species: all those species included in the categories of endangere vulnerable or rare, as defined by the International Union for the Conservatio of Nature and Natural Resources.

Riparian: the area of land adjacent to a stream or river that is influenced b stream-induced or related processes. Riparian areas which are saturated c flooded for prolonged periods would be considered wetlands and could b described as **riparian wetlands**. However, some riparian areas are nc wetlands (e.g. an area where alluvium is periodically deposited by a strear during floods but which is well drained).

Roughness coefficient: an index of the roughness of a surface and is reflection of the frictional resistance offered by the surface to water flow.

ıoff: total water yield from a catchment including surface and subsurface r.

sonally wet soil: soil which is flooded or waterlogged to the soil surface extended periods (>1 month) during the wet season, but is predominantly during the dry season.

ges: Grass-like plants belonging to the family Cyperaceae, sometimes rred to as nutgrasses. Papyrus is a member of this family.

drainage classes: describe the soil moisture conditions as determined by capacity of the soil and the site for removing excess water. The classes ge from very well drained, where excess water is removed very quickly, to / poorly drained, where excess water is removed very slowly. Wetlands ude all soils in the very poorly drained and poorly drained classes, and e soils in the somewhat poorly drained class.

saturation: when all spaces between the soil particles are filled with er.

tainable use: the use of a resource in a way which allows that resource to ew itself so that it will continue to be available for the benefit of future erations.

amp: a wetland dominated by trees or shrubs (USA definition). Swamp is sometimes used to refer to reed or papyrus dominated areas.

nporarily wet soil: The soil close to the soil surface (i.e. within 40 cm) is asionally wet for periods > 2 weeks during the wet season in most years. wever, it is seldom flooded or saturated at the surface for longer than a nth.

anspiration: the transfer of water from plants into the atmosphere as water our

ei: a colloquial South African term for wetland.

Water quality: the purity of the water.

Waterlogged: soil or land saturated with water long enough for anaerobic conditions to develop.

Wet grassland: an area which is usually temporarily wet and supports a mixture of: (1) plants which are common to non-wetland areas and (2) short (< 1m) hydrophytic plants (predominantly grasses).

Wet meadow: an area which is usually seasonally wet and dominated by hydrophytic sedges and grasses which are common only to wetland areas.

Wetland: a collective term used to describe land where an excess of water (i.e. waterlogging) is the dominant factor determining the nature of the soil development and the types of plants and animals living at the soil surface (Cowardin *et al.*, 1976); lands that are sometimes or always covered by shallow water or have saturated soils, and where plants adapted for life in wet conditions usually grow.

Wetland soil: synonymous with hydric soil.

Wetland catchment: all of the land area upslope of the wetland (from which water drains into the wetland) and including the wetland itself. The "surrounding catchment" refers to that part of the wetland catchment excluding the wetland.

ORGANIZATIONS CONCERNED WITH WETLANDS

ɔur provincial Nature Conservation Department

irectorate: Resource Conservation
epartment of Agriculture
Bag X120
etoria, 0001

epartment of Environmental Affairs Tourism
ivate Bag X447
etoria, 0001

our provincial Department of Agriculture

he Wildlife & Environment Society of South Africa
O Box 394
owick, 3290

outhern African Crane Foundation
O Box 905
looi River, 3300

ennies Wetland Project
O Box 44344
inden, 2104

QUIZ

In order to test yourself, and see whether you have a reasonable understandir of this booklet, you should be able to answer the following questions:

1.What is a wetland? (page's 1 & 2)

2.Why do plants not adapted to wetland conditions find it difficult to grow i wetlands? (page 3)

3.Are the following statement true or false (explain your answers

a.An area which remains saturated to the soil surface for periods of only thre weeks would not be a wetland (page's 2 & 3).

b.A soil with a high chroma (e.g. chroma 5) is unlikely to be a wetland (page 5)

c.An area must have surface water to be considered a wetland (page 3)

d.Wetlands are only found in valley bottom positions (page 8)

OTHER SHARE-NET RESOURCES TO SUPPORT WETLAND AND WATER STUDIES

Wetlands-Use Booklet No. 2: *How Wet is a Wetland?*

Hands-On: *Stream and Pond Life*
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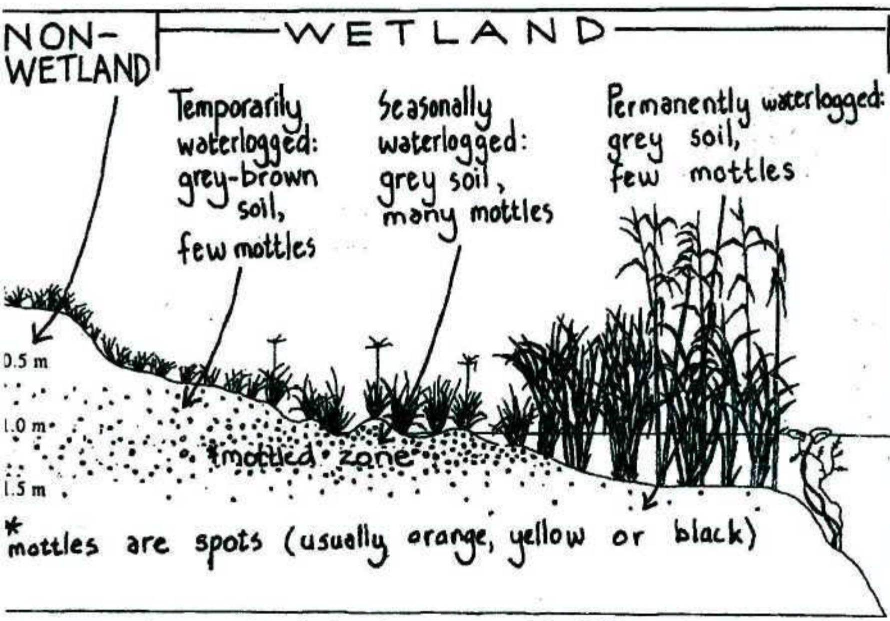
GREEN Manual

HOW WET IS A WETLAND?

AN INTRODUCTION TO UNDERSTANDING WETLAND HYDROLOGY, SOILS AND LANDFORMS

WETLAND-USE BOOKLET 2



A transect in a wetland showing areas with different water regimes

Donovan C. Kotze
Edited by **Prof. C.M. Breen**

Mondi Paper
WILDLIFE AND ENVIRONMENT SOCIETY OF SA

PREFACE

This booklet is one of 2 booklets (see references) designed to assist a range of people, including extension workers and high school children, in understanding the functioning values and management of **wetlands** (All terms first appearing in bold are defined in th Glossary). The series forms part of a research project, funded by Department of Envir mental Affairs and Tourism, which aims to improve the management of our wetlands.

The term wetland refers to an extremely wide range of habitats from freshwater **marsh** and **wet meadows** to estuarine mangrove **swamps**. The booklets deal with freshwater inland wetlands but many of the principles would also apply to coastal wetlands.

Any comments that you have about the booklet would be greatly appreciated as the booklet will be revised. Your comments should be sent to: Donovan Kotze, Grasslan Science Dept., Univ. Natal, P/Bag X01, Scottsville, 3209.

A SHARE-NET RESOURCE

People
Places and
Publications for
Environmental Education.

ACKNOWLEDGEMENTS

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APPENDIX A
EXTENSION SERVICES AND WETLAND MANAGEMENT: A QUESTIONNAIRE AND WORKSHOP BASED STUDY

1 Introduction

This investigation was motivated by: (1) the increasing demand for natural resources in developing countries, which necessitates the promotion of sustainable use of wetlands rather than excluding all direct use (Gopal, 1991; Maltby, 1991); (2) the importance of considering the social context within which wetlands are used and investing in social processes in order to conserve these systems (see Gopal, 1991; Maltby, 1991; Breen *et al.*, 1997); and (3) the potentially important role that extension workers play in working directly with wetland users to promote sustainable use. The objectives of this pilot study were to determine:

1. the extent to which wetlands are co-operatively managed by different land-owners or that have some form of management system with measurable objectives that explicitly account for indirect benefits to society; and

2. the extent of involvement of extension workers in the development of local policy for promoting the sustainable use of wetlands.

2 Methods

The primary focus of the study, conducted in 1997 and 1998, was on KwaZulu-Natal, the Free State and Mpumalanga (Fig. 1). The following methods were used for gathering the information.

1 A postal questionnaire survey for extension workers in the three provinces, of their knowledge of wetland management and use outside of formally protected areas, and their involvement in this management (see Box 1).

2 Two workshops with extension workers specifically involved with communal areas. Both workshops, which included participants working in different communal areas across KwaZulu-Natal, commenced by introducing participants to wetland structure and functioning followed by a questionnaire (see Box 1) and open discussion.

3. A desktop investigation of programmes raised in the postal survey and workshops as being relevant to the activities of extension workers in promoting the wise use of wetlands.

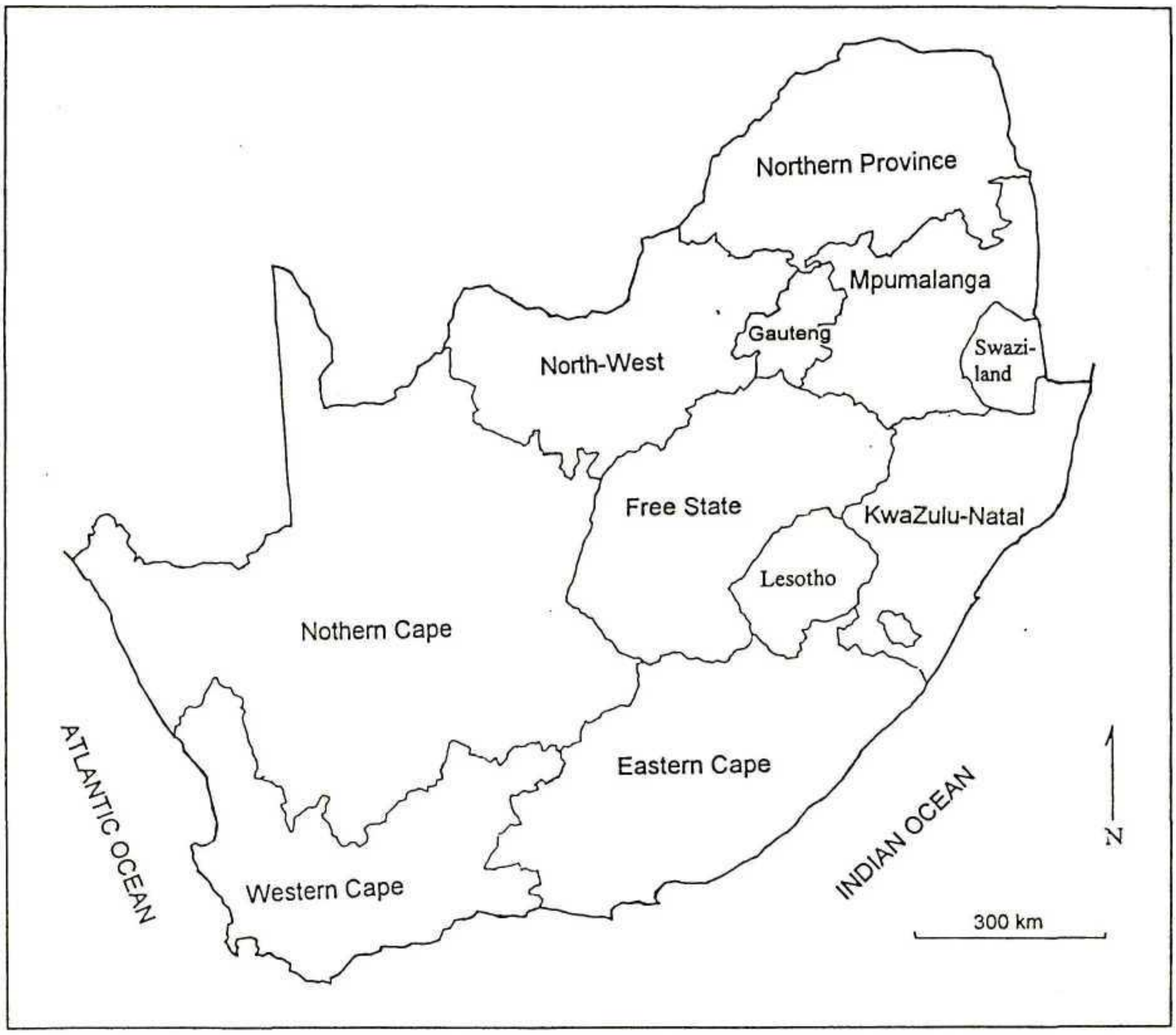

Fig. 1 Provinces of South Africa, also showing Lesotho and Swaziland.

Box 1 Questionnaires used in the study

Postal questionnaire for extension workers

1. What is your general impression of wetland management in your district?

2. Do you know of any wetlands that span the boundaries of several farms or are in communal areas and are co-operatively managed by the different landowners/users?

3. Do you know of any wetlands in your district that are managed according to a management plan with an overall goal/vision and measurable objectives? Please provide details.

4. Have you personally been involved in promoting conservation of wetlands outside of formally protected areas? Please describe briefly.

Questionnaire for extension workers involved in communal areas

1. How much of the wetland area in your extension area do you think has been developed to cropland?

2. What crops are mainly grown?

3. Have you given advice to people who are cultivating wetlands?

4. Have you tried to persuade people not to cultivate wetlands, and if so how successful have you been?

5. Does the Tribal Authority get involved in regulating the use of wetlands?

6. Other observations you have made concerning wetlands and their use?

7. What do you suggest should be done in the future?

3 Results

The postal questionnaire survey for extension workers

A total of 47 questionnaires were sent out and a return rate of 51% was obtained. The majority of respondents reported that their overall impression for their district was that management of wetlands was poor (Table 11.1). It was acknowledgement by several extension workers that there is much that can be done to improve the state of wetland management and, expressed by one of the respondents, "we have a long way to go". Thus, it is recognized that for the three provinces examined, interventions by extension services in the use of wetlands have, at best, had only partial success.

In KwaZulu-Natal only three of the 11 respondents reported known cases of co-operative management of wetlands by different landowners/users in their districts. Two of the cases were for wetlands within forestry company land. The third case was of co-operation among private farmers which, according to the extension worker, was motivated through their membership of the local conservancy (discussed later). In Mpumalanga the only example of co-operative management was that of co-operation among a group of farmers in order to artificially drain a wetland. The Free State was similarly lacking in co-operative management examples. The only case reported was that of Memelvlei which is a formally protected area, portions of which are leased to farmers for livestock grazing. No cases were reported from any of the provinces of co-operative management or management plans in communal tribal lands.

Table 1 Summary, from the postal survey, of wetland management features observed by extension workers for their district

Region	**Number of respondents**	**General impression of management in the respondent's district**				**Co-operative management examples reported**	**Management plans reported**
		Unknown	Poor	Medium	Good		
KwaZulu-Natal	11	0	8	3	0	3	3
Mpumalanga	5	1	2	1	0	0	0
Free State	8	1	4	2	0	0	1

In KwaZulu-Natal, only three of the 11 respondents reported wetlands in their district managed according to a management plan, in the Free State one was reported and in Mpumalanga only one at Wakkerstroom was reported (see Chapter 11). Two of the KwaZulu-Natal wetlands with management plans were in forestry company land.

In all three provinces, the primary involvement of extension workers has been through raising awareness and influencing perceptions of landowners and users. Two programmes commonly used by extension workers to promote awareness are the Natural Heritage Sites Programme and the Sites of Conservation Significance Programme (discussed later). Apart from enforcing regulations relating to hunting, involvement of extension workers in regulating the use of wetlands was limited to some extension workers reporting infringement of regulations (e.g. the Soil Conservation Act) to the relevant authorities. There was very little reported on the involvement of the extension workers in the development of management plans or in promoting the co-operative management of wetlands under multiple ownership.

In the Free State and KwaZulu-Natal there was also some involvement reported in facilitating the rehabilitation of degraded wetlands. In the Free State, much of the involvement of the extension staff with regard to wetlands in 1997 and 1998 has been the rehabilitation of degraded wetlands in the upper Vaal catchment, which supplies the Gauteng region with water. This rehabilitation has been sponsored by Rand Water, the primary water supply company in Gauteng. The involvement of extension staff has included attempts to raise awareness among the farmers who own the wetlands being rehabilitated. However, it has not included any involvement in the development of local policy and goal maintenance systems for the landowners. No formal commitment has been obtained from these landowners in terms of a management plan and goals for the areas rehabilitated, which would encourage greater accountability among landowners.

Workshops with extension workers specifically involved with communal areas

Most of the extension workers who responded to the postal survey were primarily involved in commercial, privately owned areas. Environmental issues in poor, communal areas are often overlooked by outside organizations. However, this sector should not be ignored as it includes many wetland areas and has associated with it unique social issues (see Chapters 9 to 11 of the thesis). Furthermore, there are often high levels of dependency by poor, rural people on the life support function of wetlands (Davis, 1993). Thus, this context required specific investigation, and two workshops were undertaken involving extension workers operating in different communal areas in KwaZulu-Natal. These revealed that wetlands were cultivated in all the reported extension wards. Many extension workers were unsure of the extent of this cultivation. However, of those that were able to make a rough estimate, approximately 40% stated that more than half of the wetlands in his/her ward were cultivated. Taro (*Colocasia esculenta* (L)) locally known as amadumbe, was the most commonly grown crop, followed by vegetables (e.g. Swiss chard and tomatoes), sugarcane and bananas.

Although an estimate was not obtained of the proportion of extension workers involved, several indicated that they had assisted in establishing and supporting community gardens on the margins of wetlands. Particularly in low rainfall areas, extension workers often encourage the cultivation of wetland margins owing to the ready supply of water. In a survey of approximately 32 community gardens in the KwaZulu-Natal Midlands and South Coast, over a third of the community gardens included wetland areas within their boundaries (S Adey, 1997. *Pers. comm.* Department of Microbiology and Plant Pathology, University of Natal, Pietermaritzburg). Just over half of the extension workers had given advice to people cultivating in wetlands. Ten of the 21 extension workers reported that they had tried to persuade people not to cultivate in wetlands, with all respondents reporting very little success. Some of the extension workers who had not done so indicated that this was because they were not aware of the values of wetlands and the damage that may be caused by wetland cultivation. Almost all extension workers reported that the Tribal Authority does not get involved in regulating the use of wetlands. These results accord with the findings at the communally-used Mbongolwane wetland (see Chapters 10 and 11 of the thesis).

The problems raised by the participants that would need to be addressed when trying to improve the management of wetlands in communal areas were: (1) lack of respect for the traditional leadership system; (2) political instability with rapidly changing leadership; (3) very high population pressure and need for agricultural land; (4) poverty; and (5) lack of local employment opportunities.

A desktop investigation of relevant programmes

The review of programmes relevant to the use and management of wetlands outside of protected areas was not exhaustive but rather focused on that which was raised in the postal survey and workshops as being relevant to the activities of extension workers involved in promoting the sustainable use of individual wetlands. It is recognized that additional initiatives such as the Ramsar Convention, ISO 14000, Agenda 21, as well as legislation applicable to wetlands, while not included, are likely to have an important contribution to future management and use of wetlands in the contexts examined.

The Conservancy Programme

The conservancy programme, initiated by the former Natal Parks Board, is very widespread in KwaZulu-Natal covering 14 500 km^2, which is 20% of the province. The extent of conservancies is also growing rapidly in the other provinces. A wide range of conservation issues on private land are dealt with by conservancies and the emphases differ from conservancy to conservancy (Byron, 1996). However, the main focus of most conservancies is security of game and personal security. No formal review or evaluation of the conservancy system has been conducted. Thus, a specific investigation was undertaken to examine the extent of collaborative wetland management (encompassing the setting of an overall vision and goals) of major wetlands within conservancies. A review of all the quarterly newsletters of the Natal Conservancies Association since 1983 showed that although conservancies contribute to wetland conservation by securing game, including wetland dependent species such as reedbuck, and foster concern and interest for some wetland dependent bird species such as cranes, very few references were made to collaborative management examples, other than that of the Mvoti Conservancy. The main area of collaboration among farmers in this conservancy is the burning of the Mvoti vlei, a 2 800 ha wetland near Greytown, which is burnt in consultation with the KwaZulu-Natal Conservation Services.

The South African Natural Heritage Programme and the Sites of Conservation Programme

The South African Natural Heritage Programme (SANHP) aims to encourage the conservation of important natural sites outside of formally protected areas in private and public land. The SANHP gives particular recognition to the work done by the owner of such a site (Malan and Wahl, 1996). When a site is registered, the owner receives a certificate signed by the State President as well as a bronze plaque. One of the primary benefits received by the owner is the satisfaction gained by voluntarily participating in a national conservation programme. By informing the landowner of the conservation importance of his/her site, registration reduces the chance that the area may unknowingly be damaged. The owner maintains full rights over the property and is able to withdraw from the programme. The programme has stringent requirements for the declaration of sites in terms of their conservation significance. Thus, many wetland areas, for example, would not qualify even though they may be very important when considered at a catchment scale. While the Natural Heritage Site Programme has an important role at a national level, there is clearly also a need for a more inclusive system which gives land-owners/users recognition for their contribution to the conservation of natural features at a more localized level. This is accounted for in the Sites of Conservation Significance Programme. However, although this is a national programme, KwaZulu-Natal is the only province to have promoted it.

The format of the Sites of Conservation Significance datasheet requires that the local extension worker provide recommendations concerning such factors as burning and grazing. However, there is no explicit commitment on the part of the landowner/user to implement the guidelines, and the program does not include protocols to allow the landowner/users to develop their own vision and operational goals against which the success of management can be monitored, thereby promoting accountability. This, together with the stringent requirements of the Natural Heritage Sites Programme, is considered to be an important deficiency in these programmes as widely applicable instruments for promoting the sustainable use of wetlands.

4 Conclusion

Overall, the results of this investigation indicate that in both the communal and private farmland contexts, extension workers have had little influence over the use of wetlands. The main form of intervention of extension workers was aimed at raising awareness and influencing perceptions among wetland users of the services provided by wetlands. However, many extension workers, particularly those working in communal areas, were poorly informed of wetland services and land-use impacts on these services, and were therefore not in a position to promote sustainable natural resource use. Even among informed extension workers there was very little direct involvement in the development of local policy. There were very few wetlands outside formally protected areas which have an explicit policy and measurable management goals. The development of these would assist in promoting wise use by ensuring that consideration of services provided by wetlands is explicitly included in the management and use of wetlands.

In none of the provinces were there protocols with which to assist landowners in setting their own policy and establishing a goal maintenance system, and the development of such protocols is clearly required. A protocol for the definition of a desired state of riverine systems was developed by Rogers and Bestbier (1997) with specific reference to protected areas. Although this system, which is fairly complex, is not entirely suitable, it provides a useful basis for the development of these required protocols and is discussed in Chapters 3 and 12 of this thesis.

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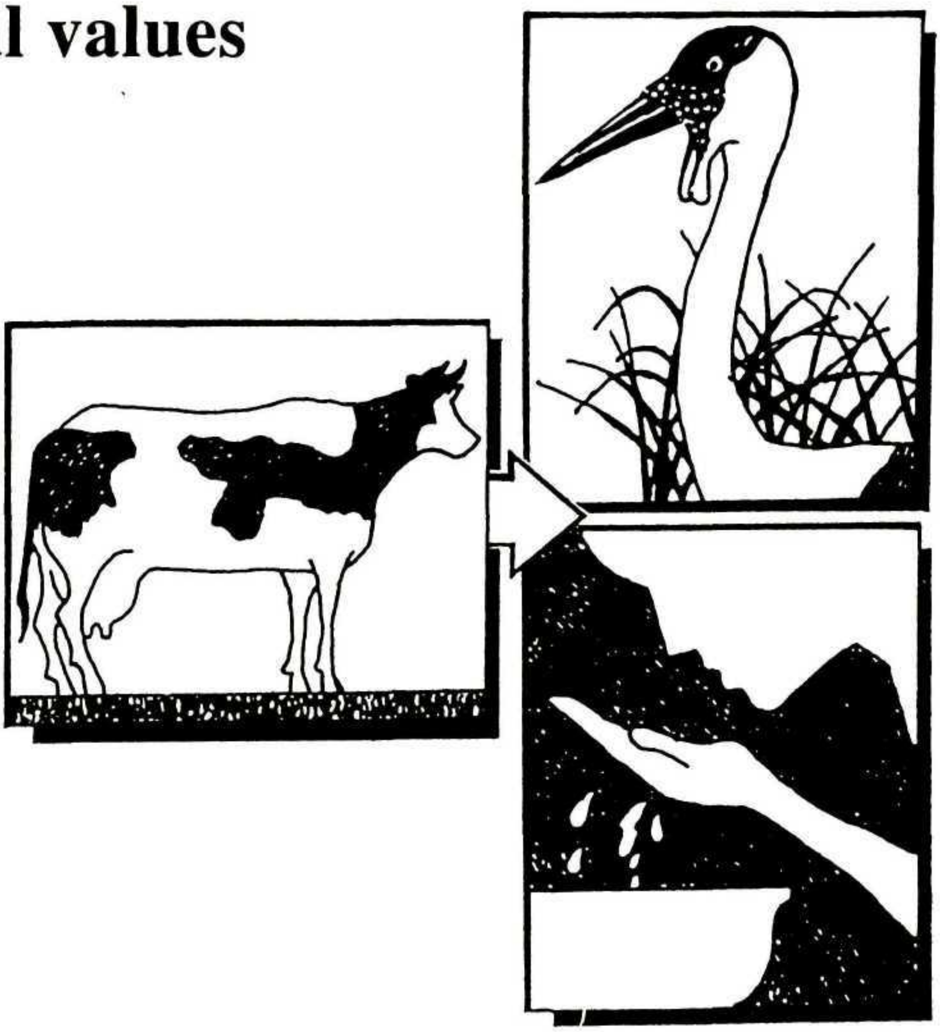
APPENDIX B

AGRICULTURAL LAND-USE IMPACTS ON WETLAND FUNCTIONAL VALUES

Agricultural land-use impacts on wetland functional values



KOTZE DC, BREEN CM

Report to the
WATER RESEARCH COMMISSION
by the
INSTITUTE OF NATURAL RESOURCES and
DEPARTMENT OF GRASSLAND SCIENCE
UNIVERSITY OF NATAL

WRC Report No 501/3/94

REPORT TO THE WATER RESEARCH COMMISSION

AGRICULTURAL LAND-USE IMPACTS ON WETLAND FUNCTIONAL VALUES

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PREFACE

This document is one of a series arising from a project designed to improve the management of wetlands in KwaZulu/Natal. The project includes the following documents:

KOTZE D C, BREEN C M, and KLUG J R, 1994. A project to improve the management of wetlands in the KwaZulu/Natal Midlands: an overview. WRC Report No 501/1/94, Water Research Commission, Pretoria.

KOTZE D C, BREEN C M, and KLUG J R, 1994. WETLAND-USE: a wetland management decision support system for the KwaZulu/Natal Midlands. WRC Report No 501/2/94, Water Research Commission, Pretoria.

KOTZE D C, and BREEN C M, 1994. Agricultural land-use impacts on wetland functional values. WRC Report No 501/3/94, Water Research Commission, Pretoria.

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EXECUTIVE SUMMARY

INTRODUCTION (1[1])

The unprecedented global decline in the extent of wetlands is worrying because functioning wetlands have many values which benefit society. This review discusses wetland functional values and how they are affected by different land-use practices. Those commonly cited are:

1. hydrological values (water purification; streamflow regulation, including flood attenuation and baseflow augmentation; and groundwater discharge and recharge);

2. erosion control value; and

3. ecological value (maintenance of biotic diversity through the provision of habitat for wetland-dependent fauna and flora).

THE FUNCTIONAL VALUES OF WETLANDS (2)

Water purification (2.1)

Wetlands may contribute substantially to the improvement of water quality by removing sediment, excess nutrients (most importantly nitrogen and phosphorus) and toxicants (including metals, organic pollutants such as pesticides, bacteria and viruses and biological oxygen demand). Wetlands have several attributes that enhance their water purification potential, including:

1. a high capacity for reducing water flow velocity (see flood attenuation) leading to sediment deposition and increased retention of toxicants and nutrients;

2. the shallow nature of wetland waters, leading to high sediment-water exchange and photodegradation of certain pollutants;

3. a variety of chemical processes (both aerobic and anaerobic) that remove certain pollutants from the water. For example, denitrification, which depends on an aerobic/anaerobic interface, is one of the most important mechanisms accounting for nitrogen removal; while adsorption onto mineral sediment appears to be the most important mechanism accounting for the removal of phosphorus;

4. high rates of mineral uptake by vegetation, due to characteristically high productivities;

5. high soil organic matter levels that favour the retention of pollutants such as heavy metals; and

6. microbes that decompose organic pollutants.

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[1] Numbers in brackets refer to the relevant sections in the main body of the document.

Streamflow regulation (2.2)

By delaying the passage of water through the catchment, wetlands have value in that they:

1. attenuate (dampen) floodpeaks; and
2. store water at the wetland site, providing enhanced streamflow during periods of low flow (i.e. baseflow augmentation).

Flood attenuation (2.2.1)

Attributes contributing to the characteristically high ability of wetlands to attenuate floods include (1) the frictional resistance offered by wetland vegetation, and (2) characteristically gentle slopes.

Water storage and enhancement of sustained streamflow (2.2.2)

Although many wetlands have been shown to enhance streamflow during low flow periods (e.g. Schulze, 1979; and Scaggs *et al.*, 1991), this is not always so. This effect depends on characteristics of the specific site (e.g. whether or not winter die-back of vegetation occurs). Water storage and streamflow enhancement are influenced by factors that contribute to flood attenuation, as they are closely associated. However, additional factors such as the nature of the soil and vegetation die-back are more important than in flood attenuation.

Groundwater recharge and discharge (2.3)

Although poorly understood, it appears that more wetlands act as groundwater discharge areas than recharge areas (Larson, 1981). Wetlands perched above the regional groundwater table generally recharge the groundwater, while those in contact with the regional groundwater serve as aquifer discharge or throughflow areas. Wetlands acting as discharge zones should not be considered less important than those acting as recharge zones, as this zone may exert considerable influence over an aquifer (O'Brien, 1988).

Erosion control by wetland vegetation (2.4)

Wetland vegetation generally has a high capacity for controlling erosion by: (1) binding and stabilizing sediment; (2) dissipating wave and current energy; (3) trapping sediment; and (4) recovering rapidly from flood damage (Sather and Smith, 1984).

The ecological value of wetlands (2.5)

Wetlands provide habitat for a diverse assortment of wetland-dependent species, many of which are threatened. For example, of the 108 bird species included in the Red Data Book, 36 are wetland-dependent. Biotic diversity encompasses many levels (e.g. genes, species or communities). To simplify biotic diversity considerations, Preston and Bedford (1988) propose that impact on biotic diversity be assessed by examining the effect on biological integrity (naturalness) and populations of threatened species.

Contribution of wetlands to biogeochemical cycling (2.6)

The contribution of wetlands to biogeochemical cycling, particularly in terms of acting as carbon sinks, has been recognized (de la Cruz, 1982). Hammer (1992) suggests that the restoration and creation of wetlands would be effective in decreasing atmospheric CO_2 levels.

THE IMPACT OF INDIVIDUAL AGRICULTURAL LAND-USES ON WETLAND FUNCTIONAL VALUES (3)

Drainage and the production of crops and planted pastures (3.1)

Conversion of wetland to cropland usually involves complete removal of the native vegetation, hydrological manipulation, tillage, and the application of fertilizers and pesticides (Willrich and Smith, 1970). Pasture production has a similar level of impact but is usually less severe because it generally provides better vegetative cover for the soil than does cropland. If the pastures are perennial then this is likely to reduce the impact further, because commonly grown perennial pasture species tend to have higher wetness tolerances than most crops and annual pastures. Also, perennial plants require the soil to be disturbed and exposed less frequently.

The objective of wetland drainage, which is to decrease the volume and retention time of water in the wetland, is directly opposed to the water storage and purification function of the wetland. If a wetland is acting as a groundwater discharge or recharge area, the effect on streamflow regulation may be considerable (O'Brien, 1988). In addition, wetland drainage may detract from the flood attenuation capacity of a wetland, and replacing the wetland vegetation with actively growing temperate crops or pastures increases water use during the critical dry-season flow period. Wetland drainage also indirectly lowers the wetland's hydrological values through: acidification; a lowering of soil organic matter levels caused by oxidation; increased susceptibility to erosion; the release of toxic elements such as uranium; and subsidence caused by the reduced organic matter and water content of the soil.

Crop or pasture production is clearly detrimental to the maintenance of biotic diversity because it involves disruption of the hydrological regime and the total replacement of the native vegetation. Consequently, the habitat value would be lost for the majority of wetland dependent-species.

Grazing of undeveloped wetlands by domestic stock (3.2)

Although permanent wetlands tend to have a relatively low grazing value, temporary or seasonal wetlands may provide important grazing-lands. Grazing animals affect wetland functional values primarily through defoliation, trampling and deposition of urine and faeces.

Effect of grazing on the ecological value of wetlands (3.2.1)

Domestic stock grazing has been widely shown to have a positive effect on the ecological value of wetlands. For example, grazing may significantly reduce the abundance of reeds in some areas, resulting in an increase in the abundance of aquatic plants and waterfowl that utilize such habitat (Duncan and D'Herbes, 1982). The creation of short muddy areas by grazing stock favours mud probing species and grazing of wet grassland favours breeding lapwings (*Vanellus vanellus*) (Gordon and Duncan, 1988). Furthermore, the positive effect of grazing on plant species richness in salt marshes is well documented (Bakker, 1989; Jensen *et al.*, 1990). Grazing has also been shown to have a positive effect on salt marsh invertebrate species. However, if utilization levels were high relative to plant production levels, diversity may be lowered and ecological integrity lost, particularly in wetlands developed under low grazing pressure (Facelli *et al.*, 1989). Extensive reduction of plant cover would be detrimental to many animal species requiring such cover (e.g. flufftails). By increasing soil exposure and consequent evaporation, it appears that grazing may alter the plant species composition by disadvantaging the more hydric species (Kauffman, 1983b).

Effect of grazing on the hydrological and erosion control values of wetlands (3.2.2)
Most wetland soils have inherently low infiltration capacities (Schulze *et al.*, 1989) and consequently have a low potential for losing infiltration capacity through trampling-induced compaction. Many wetlands do, however, have high erosion potentials (e.g. those with the Rensburg soil form). Such soils generally occur under dry climatic conditions, where the erosional degradation of wetlands has generally been high.

Hydrogeomorphological setting and slope also affect the susceptibility of wetlands to erosion. Wetlands in seepage slope and channel or riparian sites are most susceptible. Soil moisture at the time of use has an important influence because the susceptibility to erosion increases when soils are wet (Wilkins and Garwood, 1985).

Mowing of wetlands (3.3)

Although similar to grazing, mowing differs in that the removal of herbage is less uniform and harvesting is stricted to a much shorter period. Plant species diversity tends to be lower than in grazed areas, but wetland mowing has been widely shown to result in a higher plant species diversity than in unutilized wetland (Green, 1980). Timing of cutting contributes to the effect of mowing. In low producing wetlands, autumn cutting was shown to affect species richness more positively than summer cutting, while in high producing wetlands, the reverse was true (Bakker, 1989). Depending on the extent and timing of mowing, animals requiring vegetation cover could be negatively affected, especially if cutting occurs during the breeding season.

Burning of wetlands (3.4)

Reasons why wetlands are burnt (3.4.1)
Fires, largely caused by lightning, have occurred independently of humans in many wetlands (Loveless, 1959; Schmulzer and Hinkle, 1992). Prescribed burning continues to be used for wildlife management, enhancing stock grazing value, reducing fire risk, and assisting in alien plant control.

Effects of sub-surface fires (3.4.2)
Wetland fires include surface fires, where only the above-ground plant parts are burnt, and sub-surface fires, which consume above- and below-ground parts, as well as soil material. In surface fires, wetland plants usually re-establish rapidly from the undamaged below-ground parts and the soils remain largely unchanged physically (Ellery *et al.*, 1989). In contrast, dramatic changes in vegetation and soil may result from sub-surface fires. By burning away the upper soil layers, sub-surface fires may create open water areas, as appears to be the case in the Okefenoke Swamp, USA (Cypret, 1961), and Wakkerstroom vlei (Kotze, 1992a). In the Okavango Delta, sub-surface fires facilitate the change from declining permanent swamp in abandoned channels, to a seasonally inundated floodplain or mixed terrestrial/aquatic habitat (Ellery *et al.*, 1989). Thus, from an ecological point of view, localized sub-surface fires appear to be generally favourable in that they enhance habitat diversity. However, they may substantially detract from the hydrological and erosion control values of wetlands, particularly when they occur in erosion-prone situations, in that they: (1) destroy organic matter and disrupt soil structure, rendering the soil more susceptible to erosion and decreasing the water storage volume of the soil; (2) release trapped nutrients; and (3) destroy emergent vegetation.

Effects of surface fires on hydrological and erosion control values of wetlands (3.4.3)
By enhancing early spring growth of wetland vegetation, burning increases transpirative loss of water from wetlands for the first few weeks of the growing season. In wetlands with dry-season dormant vegetation, burning is also likely to promote evaporative loss of water by removing non-transpiring standing dead material, which would otherwise protect the soil or water surface from radiation and wind exposure. This effect may last for several months if the wetland is burnt in early winter.

Few studies exist on changes in soil nutrients in wetlands following fire. That of Faulkner and de la Cruz (1982) showed that a brief increase in pH and a more prolonged increase in organic matter and Ca, Mg, K and P occurred.

It is commonly held that fire, by reducing litter input into the soil, decreases the organic matter content of soils. However, this is not necessarily so. In *Phragmites australis* marsh, for example, burning generally stimulates below-ground production, leading to increased root detritus production (Thompson and Shay, 1985), which would offset the reduced incorporation of aboveground litter.

Effects of surface fires on the ecological value of wetlands (3.4.4)
Species populations vary in their recovery rate following fire. The snail *Neritina usnea* was found to be most abundant in the year following a fire, while duck species using *Juncus* marsh for nesting were found to prefer marsh burnt at least three years previously (Hackney and de la Cruz, 1976). Although little fire-related research has been done in KwaZulu/Natal wetlands, it appears that a fire return frequency of 2 years is unlikely to have a major detrimental effect on any of the known wetland-dependent species in the humid to sub-humid areas of this region. However, this may be strongly dependent on the presence of unburnt refuges from which recolonization may occur.

Timing of burning is important, with early winter burning adversely affecting winter breeding animal species and summer burning affecting summer breeding species. Late winter/early spring burning is least likely to impact on breeding animals, as very few species are likely to be breeding at this time.

Fires modifying the plant species composition and structure of wetlands, tending to favour those species characterized by winter die-back. A comparison of burnt and unburnt areas in Nylsvlei (Otter, 1992), Memel vlei (pers. obs., 1993), and Ntabamhlope vlei (Kotze, 1992b) suggest that fire may be used to control alien plants.

Damming of wetlands (3.5)

Many of South Africa's wetlands have been flooded by dams as they often provide ideal dam sites. While dams perform certain wetland functions (e.g. sediment trapping and water storage), they are poor substitutes for others. Notably, the habitat required by specialised wetland-dependent species is frequently lost. Where there is a series of dams along a stream, the cumulative effect in reducing streamflow may be considerable, particularly where extraction occurs (Bruwer and Ashton, 1989). Dams can, however, increase dry season flow if water extraction is low and outflow or seepage through the wall occurs. However, irrespective of whether dams increase or decrease dry season flow, the first wet season flows are often retained in the dam because its water level is low at the end of the dry season. This may have a negative effect on both the river biota and downstream users (Bruwer and Ashton, 1989). The bursting of small dams is an additional disadvantage which may contribute to increased flood damage and sediment release.

It has often been observed that water resources could be conserved by flooding wetlands by damming, since transpiration by wetland plants increases water loss to the atmosphere. However, many workers (e.g. Eisenlohr, 1966; Paijmans 1985; Chapman, 1990) have reported evapotranspirative losses from vegetated wetlands to be similar or less than from open water, particularly when the vegetation is dormant.

CONCLUSION (4)

Much information exists concerning wetland functional values and their tremendous worth to society, but most of this is derived from short-term research projects that examine a single process in one geographic location. Extrapolation of these results may therefore be unreliable. Nevertheless, general principles relating to the nature of wetlands and determinants of wetland structure and function allow qualitative predictions to be made.

The water regime is the primary determinant of wetlands. It follows, then, that when assessing the impact of different land-uses, one of the most important factors to consider is the degree to which the hydrological regime is altered. Important factors concerning the nature of the wetland that should also be considered include:

1. susceptibility to erosion (determined by, *inter alia*: soil erodibility, hydrogeomorphological setting and slope);

2. habitat value for wetland-dependent species; and

3. extent and historical loss of wetlands in the surrounding landscape.

Land-uses vary greatly in the impact they have on wetland functional values. Crop production on drained wetland represents the severest impact. This is followed by annual and then perennial pastures. The grazing of undeveloped wetlands has the least severe impact and frequently enhances the habitat value of wetlands. However, where poor grazing management leads to erosional degradation, the loss of functional values may be considerable. The effect of fire depends strongly on the timing and nature of the fire and although substantial loss of functional values may occur, the effect of burning on wetland functional values is often neutral or positive. Dams fullfill certain wetland functions but are usually poor substitutes for others.

By synthesising information concerning the effect of different land-uses on wetland functional values, this review will assist in developing a system for achieving trade-offs between maximising the benefits derived by different wetland users and minimizing the loss of functional values, which benefit society at large. The need for this to be done will increase with the demand for resources.

ACKNOWLEDGEMENTS

The funding of this project by the Water Research Commission and the Natal Town and Regional Planning Commission, who funded the first year of the project and the plates and colour covers for some of the final documents, is gratefully acknowledged. Sincere thanks is also expressed to all those organisations and people who provided valuable comment on the model and case study management plans. In particular, contribution by individuals in the following organizations is acknowledged:

Department of Agriculture
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Environmental Advisory Services
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KwaZulu Bureau Of Natural Resources
Louisiana State University, Centre for Wetland Resources
ManTech Environmental Technology, Oregon
Natal Parks Board
Natal Town and Regional Planning Commission
Renfreight Wetlands Campaign
South African Timber Growers Association
Steffen, Robertson and Kirsten Consulting Engineers
The Wildlife Society of Southern Africa
Umgeni Water
Water Research Commission
University of Natal, Departments of Agronomy, Grassland Science and Zoology.

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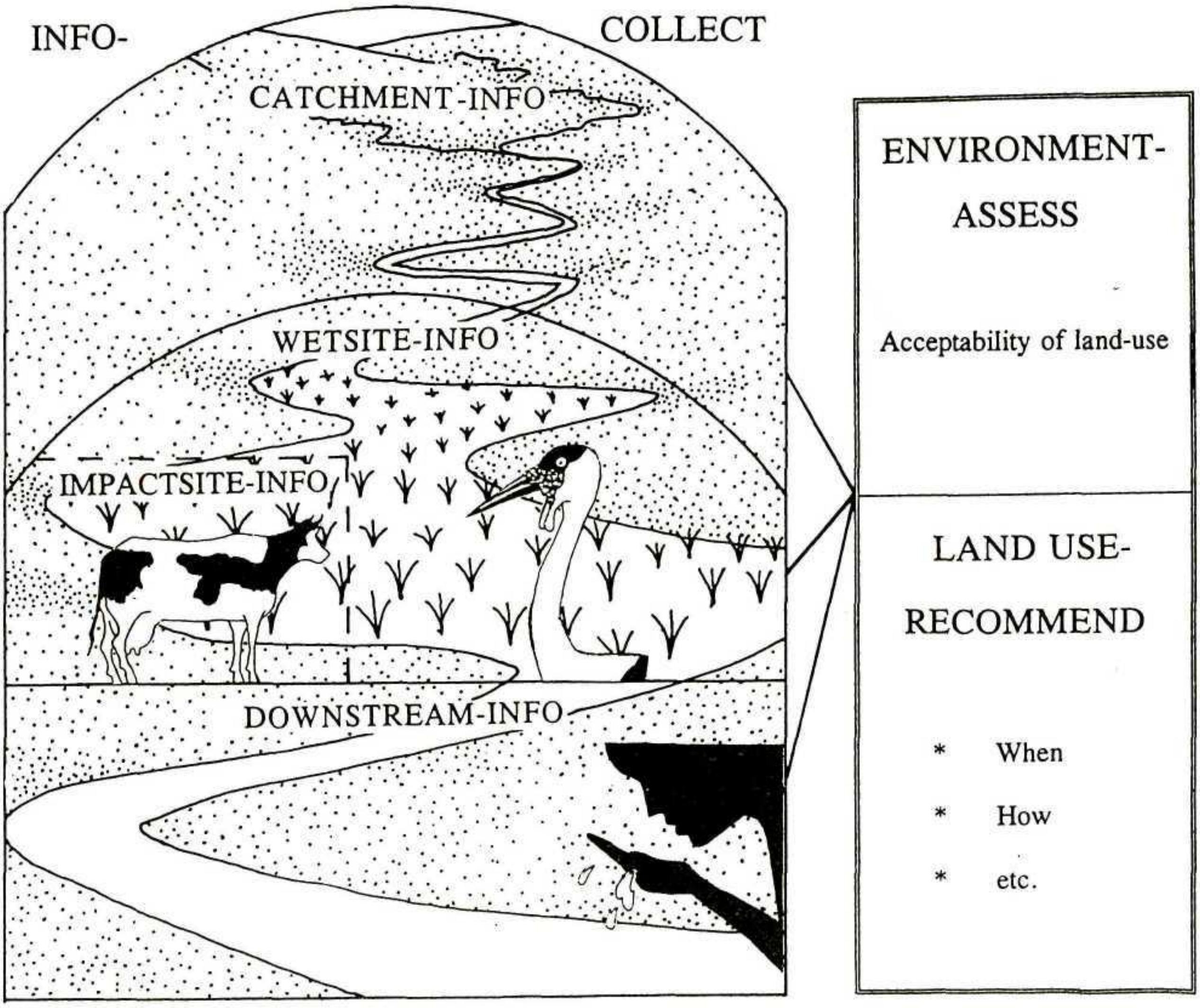
WETLAND-USE: PROTOTYPE

WETLAND-USE

A wetland management decision support system for the KwaZulu/Natal Midlands



KOTZE DC, BREEN CM, and KLUG JR

Report to the
WATER RESEARCH COMMISSION
by the
INSTITUTE OF NATURAL RESOURCES and
DEPARTMENT OF GRASSLAND SCIENCE
UNIVERSITY OF NATAL

WRC Report No 501/2/94

REPORT TO THE WATER RESEARCH COMMISSION

WETLAND-USE: A WETLAND MANAGEMENT DECISION SUPPORT SYSTEM FOR THE KWAZULU/NATAL MIDLANDS

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PREFACE

This document is one of a series arising from a project designed to improve the management of wetlands in KwaZulu/Natal. The project includes the following documents:

KOTZE D C, BREEN C M, and KLUG J R, 1994. A project to improve the management of wetlands in the KwaZulu/Natal Midlands: an overview. WRC Report No 501/1/94, Water Research Commission, Pretoria.

KOTZE D C, BREEN C M, and KLUG J R, 1994. WETLAND-USE: a wetland management decision support system for the KwaZulu/Natal Midlands. WRC Report No 501/2/94, Water Research Commission, Pretoria.

KOTZE D C, and BREEN C M, 1994. Agricultural land-use impacts on wetland functional values. WRC Report No 501/3/94, Water Research Commission, Pretoria.

KOTZE D C, HUGHES J C, BREEN C M, and KLUG J R, 1994. The development of a wetland soils classification system for KwaZulu/Natal. WRC Report No 501/4/94, Water Research Commission, Pretoria.

KOTZE D C, BREEN C M, and KLUG J R, 1994. A management plan for Wakkerstroom vlei. WRC Report No 501/5/94, Water Research Commission, Pretoria.

KOTZE D C, BREEN C M, and KLUG J R, 1994. A management plan for Ntabamhlope vlei. WRC Report No 501/6/94, Water Research Commission, Pretoria.

KOTZE D C, BREEN C M, and KLUG J R, 1994. A management plan for Mgeni vlei. WRC Report No 501/7/94, Water Research Commission, Pretoria.

KOTZE D C, 1994. A management plan for Blood River vlei. WRC Report No 501/8/94, Water Research Commission, Pretoria.

KOTZE D C, 1994. A management plan for Boschoffsvlei. WRC Report No 501/9/94, Water Research Commission, Pretoria.

OELLERMANN R G, DARROCH M A G, KLUG J R, and KOTZE D C, 1994. Wetland preservation valuation, and management practices applied to wetlands: South African case studies. WRC Report No 501/10/94, Water Research Commission, Pretoria.

WETLAND-USE (a **wetland**[1] management decision support system) has been developed as a tool to assist agricultural and nature conservation extension personnel provide wetland management and land-use planning guidelines. This document has two parts:

* Part 1, describing:

    a. the conceptual design of WETLAND-USE;

    b. the agro-ecological, soil wetness and hydrogeomorphological classification systems used by WETLAND-USE; and

    c. the primary assumptions on which the system is based; and

* Part 2, comprising the decision support system and data sheet for the information required in the assessment.

The emblem on the cover depicts the various features accounted for by the model namely: the surrounding catchment and associated land-uses, the wetland and its hydrological and ecological values (represented by the wattled crane and the person benefiting from the water respectively), and the direct use that is made of wetlands (represented by the cow). The central problem addressed by the system is: how does one allow for the user to benefit from the wetland but at the same time minimize the impact of such use on the wetland's hydrological, erosion control and ecological values?

Although not essential, it is preferable when using WETLAND-USE to make reference to the accompanying document: *The impacts of agricultural land-uses on wetland functional values* (WRC Report No 501/3/94). This is a comprehensive review outlining the effects that all those land-uses considered by WETLAND-USE (i.e. crop production, planted pasture production, natural grazing by stock, burning, mowing and damming) have on the functional values of wetlands. It is recommended that users read the relevant sections of this document before using WETLAND-USE.

Caution will be required in using WETLAND-USE because such techniques are open to mis-use by users with expectations that are too high. In such cases, insufficient consideration is usually given to the limitations and unsubstantiated assumptions of the model. Furthermore, when applying WETLAND-USE to problems, it should be remembered that no guidelines, however comprehensive they may be, are a substitute for a multi-disciplinary approach in planning for the use and/or development of wetlands. It is unreasonable to expect a system, such as WETLAND-USE, to provide the final answer as to whether a given land-use is acceptable or not in a particular situation. What it does do, however, is assist the user/s in arriving at a final decision, by ensuring that adequate information on the wetland and its surrounding landscape is collected, the relevant questions are asked, and the likely environmental impact of different land-use alternatives is predicted. WETLAND-USE also provides a means of structuring the collection of data for wetland management plans.

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[1] All terms first appearing on boldface are defined in the glossary.

EXECUTIVE SUMMARY

Introduction

Presently, wetland use tends to be planned from the restricted perspectives of individual landowners with specific interests (e.g. livestock grazing). Little attention is given to the effects on wetland functional values (e.g. water quality improvement) which benefit society. Also, there are very few guidelines available for the management of wetlands in South Africa. Thus, a wetland management decision support system, termed WETLAND-USE was developed to assist agricultural and nature conservation extension workers in providing sound land-use advice for wetland areas. The study area chosen for developing the system is in KwaZulu/Natal and includes Bioclimatic Groups 3, 4, 6 and 8 (Phillips, 1973).

Agro-ecological zones and hydrogeomorphological classes used by WETLAND-USE

In order to make informed wetland management decisions it is important to zone wetlands into land capability units which are as homogeneous as possible. The hydrological regime is generally the most important factor accounting for zonation within wetlands. Ideally, long term hydrological data should be obtained, but this is lacking for most South African wetlands. Consequently, the best surrogate measure possible: soil morphology, is used. A provisional three class system for determining the degree of wetness of wetland soils using soil morphological features (e.g. colour of the soil matrix) was developed. The characterization of soils is a very important component of WETLAND-USE because it forms the basis for land-use planning.

A four class system based primarily on vegetation has been developed for assisting with categorizing the zones within a wetland. The four classes, open water, marsh, wet meadow and wet grassland, are associated with degree of soil wetness, making them meaningful from an agricultural and ecological point of view. They are thus termed agro-ecological zones.

A simple hydrogeomorphological classification of wetlands was also included in WETLAND-USE because of the important influence that geomorphology has on wetland functioning. This classification system has two parameters: landform setting and terrain type.

The conceptual design of WETLAND-USE

WETLAND-USE has three main components: (1) INFO-COLLECT, which prompts the user to collect the appropriate information about the wetland, its catchment and the downstream service area; (2) ENVIRONMENT-ASSESS, which assists in selecting appropriate land-use alternatives for a given wetland area by predicting the likely impacts of the proposed land-uses on the functional values of the wetland area; and (3) LAND USE-RECOMMEND, which recommends how the wetland area be managed for the chosen land-use.

INFO-COLLECT comprises four sub-components:

1. WETSITE-INFO, which poses questions regarding the wetland site (e.g. landform setting, distribution and extent of agro-ecological zones, wetland dependent threatened species and current and past use of the wetland) and would be useful when conducting a wetland inventory over a broad area;

2. CATCHMENT-INFO, which poses questions relating to the wetland catchment (e.g. percentage occupied by the wetland and current and past uses);

3. DOWNSTREAM-INFO, which is concerned with the extent of water use and floodable properties in the downstream service area of the wetland; and

4. IMPACTSITE-INFO, which requests more detailed information (e.g. the erosion hazard of the site) than WETSITE-INFO, is concerned with that part of the wetland to which the proposed land-use is to be applied. The user is also requested to determine certain derived descriptors concerning cumulative wetland loss, pollutant input and downstream water use by synthesising information already collected.

ENVIRONMENT-ASSESS predicts the environmental impact of the chosen land-use by assessing the likely effects on the hydrological (water purification, flood attenuation and baseflow augmentation), erosion control and ecological (habitat provision) values of the wetland area. The severity of impact on the hydrological and erosion control values is assessed using the following criteria:

1. the extent to which the water table will need to be lowered in order to carry out the proposed land-use in an average rainfall year;

2. the extent to which the roughness coefficient of the wetland is decreased, either by smoothing out microtopographical surface irregularities such as hummocks or by replacing the natural vegetation with new vegetation that offers less resistance to water flow because of it being shorter, softer, less dense, and/or less perennial;

3. the degree to which the soil organic matter content is likely to decrease as a result of a lowered water table leading to a less anaerobic environment;

4. the degree to which soil subsidence is likely to occur;

5. the degree to which the soil is disturbed; and

6. the extent to which wetland area is lost.

Hydrological and erosion control values are considered together in assessing impact because any loss of erosion control value will also detract from the hydrological values.

The severity of impact on the ecological value of a wetland is assessed by determining the extent to which the land-use changes affect biological integrity and populations of threatened (i.e. rare, vulnerable or endangered) wetland dependant species. Due to a lack of knowledge for South Africa, the assessment of biological integrity by WETLAND-USE only accounts for obvious changes such as wetland drainage. Since an excess of water is the dominant factor affecting the plant and animal communities in a wetland, a general assumption can be made that the greater the disruption of the hydrological regime, the greater will be the loss of ecological value. Thus, where land-use activities detract from the hydrological values of a wetland, they will usually also detract from the ecological values.

WETLAND-USE assesses the acceptability of different land-uses using primary and then secondary acceptance criteria. Primary acceptance criteria encompass the first screening process to safeguard against the likelihood of large/obvious impacts. Essentially, the primary criteria are "threshold levels" for key descriptors (e.g. erosion hazard) beyond which a significant loss to society is likely unless adequate mitigation measures are undertaken. Secondary acceptance criteria deal with situations considered to have a lesser impact, and attempt to capture the trade-off between benefits derived by the user and those lost by society at large.

LAND USE-RECOMMEND provides recommendations to minimize the hydrological, erosion control and ecological impacts, while at the same time maximising the land user's benefit. For crops and planted pastures, the recommendations are aimed primarily at minimizing the impact of such activities as fertilizer application on the hydrological values of the wetland. For the grazing of natural wetlands, the recommendations are concerned primarily with regulating the stocking rate and timing of grazing in accordance with the nature of the wetland. Burning recommendations concern timing and frequency of fires as well as measures designed to influence fire behaviour.

The degree to which the model's assumptions are backed by documentation from the literature

The assumptions on which WETLAND-USE is based are clearly stated. While the general primary assumptions of the system are well substantiated in the literature, many of the assumptions concerning the individual land-uses have little literature support and are based largely on expert opinion.

Concluding remarks

When using WETLAND-USE it is important that adequate consideration be given to its limitations. These include that it uses arbitrary cut-off points and qualitative reasoning and that it applies to a limited geographical area and to a limited number of land-uses. Nevertheless, WETLAND-USE, by accounting for the functional values of wetlands, will assist in attempts to use wetlands in a manner which is in keeping with the intrinsic environmental and ecological features of individual wetland areas. This will contribute to allocating appropriate land-uses to different wetland zones and to making ongoing management decisions for different land-uses (e.g. timing and frequency of burning). Consequently, WETLAND-USE is likely to improve individual site assessments undertaken by agricultural and nature conservation extension workers, as well as contributing towards policy formulation and regional planning for South African wetlands.

ACKNOWLEDGEMENTS

The funding of this project by the Water Research Commission and the Natal Town and Regional Planning Commission, who funded the first year of the project and the plates and colour covers for some of the final documents, is gratefully acknowledged. Sincere thanks is also expressed to all those organisations and people who provided valuable comment on the model and case study management plans. These included contributions by individuals in the following organizations:

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South African Timber Growers Association
Steffen, Robertson and Kirsten Consulting Engineers
The Wildlife Society of Southern Africa
Umgeni Water
University of Natal, Departments of Agronomy, Grassland Science and Zoology.
Water Research Commission

The following individuals, who made a significant contribution to developing the model by willingly sharing their expertise, are acknowledged gratefully: Dr A Wood, Steffen Robertson and Kirsten; Prof N M Tainton, Grassland Science Department, University of Natal; Dr D Johnson, Natal Parks Board; and Mr W Russell, Department of Agriculture.

The valuable contributions made by Prof K Gordon-Gray and Mrs J Browning in the identification of plant species from the various case study wetlands are acknowledged.

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APPENDIX 1: SOME PLANT SPECIES COMMON TO THE WETLANDS OF THE KWAZULU/NATAL MIDLANDS

The agro-ecological zones in which the species characteristically occur, as well as their heights, are given in the list below. Diagnostic features are indicated with arrows on the species drawings and in the list.

TYPHACEAE (BULRUSHES)

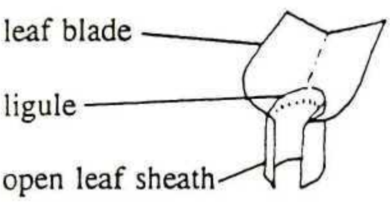
Typha capensis: marsh; 1.5-3m.

POTAMOGETONACEAE

Potamogeton thunbergii: open water, floating.

GRAMINEAE (GRASSES)

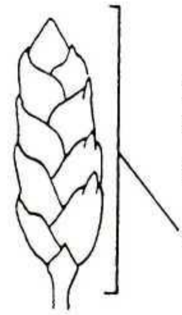
Grasses resemble some sedges but, unlike most sedges, all grasses have a ligule and an open leaf sheath.



Phragmites australis: marsh; 1.5-4.5m
Andropogon appendiculatus: wet grassland, wet meadow; 0.3-1m.
Eragrostis plana: wet grassland; flattened leaf base; up to 1m.
Eragrostis planiculmis: wet grassland, wet meadow; resembles *Eragrostis curvula* but hairs are absent from the leaf bases; up to 1.2m.
Leersia hexandra: marsh, wet meadow; 0.3-1.2m.

CYPERACEAE (SEDGES)

Most sedges lack a ligule and almost all sedges lack an open leaf sheath (i.e. if present, the leaf sheath is closed).

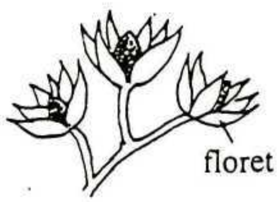


Florets are generally arranged in spikelets, as in grasses.

Carex acutiformis: marsh; 0.6-1.8m.
Carex cognata: marsh; 0.6-1.6m.
Cyperus fastigiatus: marsh 1-2.2m
Eleocharis dregeana: marsh, wet meadow; 0.3-1.4m.
Schoenoplectus corymbosus . subsp. *brachyceras*: marsh; 0.6-1.5m.
Scleria welwitschii: wet meadow; 0.4-1m.

JUNCACEAE (RUSHES)

Rushes may be confused with certain sedges but their flowers are distictly different.



Florets with 6 stamens and 6 whorled bracts.

Juncus species have leaves that are round and resemble stems.
Juncus effusus: marsh; 0.8-1.8m.
Juncus oxycarpus: marsh;0.5-1.5m.

POLYGONACEAE

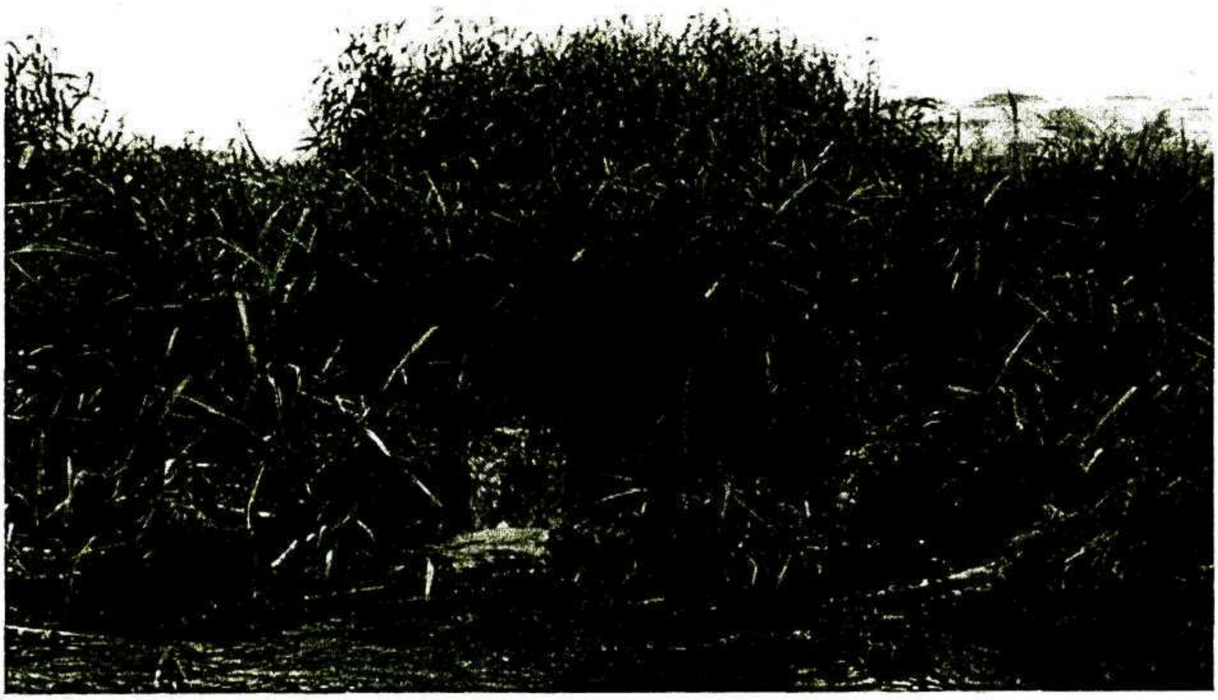
Polygonum spp.: marsh, wet meadow; up to 2m.

APPENDIX D

WETLAND-USE: FINAL DRAFT

WETLAND-USE

A wetland management decision support system for South African freshwater palustrine wetlands



KOTZE D C and BREEN C M 2000

South African Wetlands Conservation Programme
Department of Environmental Affairs and Tourism

APPENDIX E

WETLAND-USE BOOKLETS

WETLANDS AND PEOPLE

WHAT VALUES DO WETLANDS HAVE FOR US AND HOW ARE THESE VALUES AFFECTED BY OUR LAND-USE ACTIVITIES?

WETLAND-USE BOOKLET 1

Donovan C. Kotze

***Edited by* Prof. C. M. Breen**

Mondi Paper

WILDLIFE AND ENVIRONMENT SOCIETY OF SA

People caring for the Earth

PREFACE

This booklet is one of 2 booklets (see references) designed to assist a range of people including extension workers and high school children, in understanding the functionir values and management of **wetlands** (All terms first appearing in bold are defined in Glossary). The series forms part of a research project, funded by Department of Envi mental Affairs and Tourism, which aims to improve the management of our wetlands.

The term wetland refers to an extremely wide range of habitats from freshwater **mars** and **wet meadows** to estuarine mangrove **swamps**. The booklets deal with freshwate inland wetlands but many of the principles would also apply to coastal wetlands.

The cover shows a woman making direct use of a wetland by harvesting *Cyperus latij* (iKhwane) for the production of sleeping mats.

Any comments that you have about the booklet would be greatly appreciated as the booklet will be revised. Your comments should be sent to:

Donovan Kotze, Department of Range & Forage Resources, University of Natal,
P/Bag X01, Scottsville, Pietermaritzburg, 3209.

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Mr D Mynhardt, Directorate: Resource Conservation;
Ms S Adey, University of Natal; and
Ms K le Roux and Dr J Taylor, Wildlife and Environment Society of SA.

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