



Practical Wetland Management

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CONTENTS

1. WETLANDS ARE CRUCIAL

2. WETLANDS- WHAT AND WHERE?

- **A. WHAT ARE WETLANDS?**

1. Water logged soils
2. Hydrophytes
3. High water table

- **B. WHERE ARE WETLANDS FOUND?**

3. WHY ARE WETLANDS IMPORTANT?

- **A. FUNCTIONS OF WETLANDS**

1. Flood reduction and streamflow regulation
2. Groundwater recharge and discharge
3. Water purification
4. Erosion control by wetland vegetation
5. Biodiversity
6. Chemical cycling

- **B. VALUES OF WETLANDS**

1. A valuable source of water

2. Economically efficient wastewater treatment
3. Livestock grazing
4. Fibre for construction and handcraft production
5. Valuable fisheries
6. Hunting waterfowl and other wildlife
7. Valuable land for cultivation
8. Aesthetics

4. WETLAND PROBLEMS

- **A. IMPACTS IN WETLANDS**

1. Drainage for crops
2. Cultivation
3. Poorly managed burning
4. Poorly managed grazing
5. Timber production
6. Roads
7. Irresponsible damming
8. Mowing and harvesting of plants
9. Alien plants
10. Purification of waste water
11. Non-sustainable fishing and hunting

- **B. IMPACTS IN THE CATCHMENT**

5. MANAGEMENT OF WETLANDS

- **A. DELINEATION OF A WETLAND**

- **B. WETLAND ASSESSMENT**

- **C. BASIC MANAGEMENT OF WETLANDS**

1. Burning
2. Grazing
3. Cultivation
4. Damming
5. Alien plants
6. Roads
7. Rehabilitation of wetlands
8. Monitoring rehabilitation in wetlands

- **D. MANAGEMENT FRAMEWORK**

6. CONCLUSION

7. APPENDICES

- **A. SUMMARY OF ALL WETLAND BENEFITS IN SOUTH AFRICA**
- **B. SUMMARY OF ALL WETLAND IMPACTS IN SOUTH AFRICA**

- C. WETLAND STOCKING RATES

8. ADDITIONAL INFORMATION

- A. WHAT IS THE RENNIES WETLANDS PROJECT
- B. GLOSSARY OF TERMS
- C. USEFUL REFERENCES

1. WETLANDS ARE CRUCIAL

Why are wetlands crucial in South Africa, why should the man in the street be concerned about wetlands? They have a real economic worth. These wetland systems - which range from springs, seeps, mires and bogs in the mountains, to midland marshes and floodplains, to coastal lakes, mangrove swamps and estuaries at the interface with the sea - have an enormous monetary value and make huge, direct contributions to national economies and the creation of wealth.

Nature - one of the most respected scientific journals in the world - reported recently that, world-wide, wetlands are worth some \$4.9 trillion (R30 trillion) a year!

Why are they so valuable? Because their primary task is to manage water. Wetlands hold back water during floods and release it during dry periods. And in a dry country like South Africa, this is crucial. By regulating water flows during floods, wetlands reduce flood damage and help prevent soil erosion. Wetlands also purify water by acting as natural filters and trapping pollutants, which include heavy metals and disease-causing bacteria and viruses. In addition to these valuable water management functions, wetlands are treasure troves of biodiversity. When taking in to account the enormous range of wetland types, from seeps to coral reefs, the biological diversity of wetlands ranks with that of rainforests.

Wetlands are crucial to our national economy and the well being of all South Africans. When the real value of their free 'service' is calculated, one realises that wetlands earn South Africa millions of rands each year. But wetlands are also severely threatened, and we have lost an estimated 50% in South Africa already. This is predominantly through unwise development and poor land management.

Apart from the obvious land use impacts on wetlands (drains, agriculture in wetlands, erosion and so on), three of the biggest threats to South Africa's wetland are:

- lack of wetland management training;
- lack of people working in wetland conservation outside reserves;
- lack of co-operation - NGOs, government departments, land owners and public should all work together on wetland conservation issues.

If we are to make a meaningful contribution to the management of our wetland, these three threats must be overcome. By involving future landowners and managers in South Africa, training students at tertiary institutions can make significant progress towards this.

2. WETLANDS - WHAT AND WHERE?

A. WHAT ARE WETLANDS ?

A wetland is a family name given to a whole lot of different wetland types that occur from the top to the bottom of the catchment.

They include:

- SPRINGS AND SEEPS
- MARSHES
- FLOOD PLAINS
- SWAMP FORESTS
- MANGROVE SWAMPS
- ESTUARIES
- CORAL REEFS

and all these are connected by RIVERS and RIPARIAN AREAS.

According to the definition in the South African Water Act a wetland is a:

" water dominated area with impeded drainage where soils are saturated with water and where there is characteristic fauna and flora".

There are therefore three criteria for a piece of land to be classified as a wetland:

- The soil must be saturated (waterlogged soils) for long enough for anaerobic conditions to develop.
- These conditions favour the growth of water loving plants (hydrophytes)
- A high water table that results in the saturated soil conditions.

Anaerobic conditions occur when there is no or very little oxygen present in the soil. This is important to plants because plant roots require oxygen to live and function.

Hydrophytes are plants that have special adaptations for living in anaerobic soils (e.g. specialized air spaces, which allow oxygen to move easily from the leaves and stem/s down into the roots).

1.WATERLOGGED SOILS

As soil becomes increasingly wet, water starts to fill the spaces between soil particles. When all the spaces are filled with water the soil is said to be saturated. In areas, which are not wetlands, water drains away quickly and the soil does not remain saturated. However, in wetlands the water persists or drains away very slowly and the soil remains saturated or flooded for long periods. Soil in these conditions are said to be waterlogged.

Depending on factors such as temperature, it usually takes a week or so for the plant roots and other living organisms in the soil to use up the oxygen, causing anaerobic conditions to develop. Oxygen diffuses 10 000 times more quickly through air than through water. Thus, when roots and soil micro-organisms use the oxygen in the soil, the rate at which it is replaced by oxygen diffusing from the air above the soil and down through the soil is much slower if the soil is saturated than if it is unsaturated. In saturated soil, the water in the spaces between the soil particles effectively "blocks" the diffusion of oxygen.

If the soil is saturated and the anaerobic zone is within the upper 50 cm of soil (i.e. the main rooting zone), it is generally close enough to the soil surface to significantly influence the plants growing in the soil. This will cause the area to develop characteristics of a wetland. However, if the waterlogged layer always remains below 50 cm from the soil surface it would probably be too deep to significantly influence the vegetation (i.e. there is sufficient aerated surface soil for non-wetland conditions to prevail). Such an area is unlikely to develop the characteristics of a wetland.

How do anaerobic conditions affect organic matter in the soil?

Besides affecting the mineral chemistry of soils (with iron being especially noticeable) the water regime of wetlands also has an important influence on soil organic matter. Most micro-organisms

which decompose organic matter use oxygen in the process. So when oxygen is depleted these organisms cannot function. Although other organisms gain energy by anaerobic respiration they decompose organic matter much more slowly. This increases the amount of organic matter in the soil. Thus, the wettest parts of the wetland, which are most anaerobic, tend to have the highest organic matter contents in a given wetland.

Low temperatures also promote organic matter accumulation, so that for a particular water regime, more will accumulate in a cool climate than in a warmer one. Soil with a very high organic matter content is referred to as peat. In cold areas such as Ireland and Canada many of the wetlands have peat soils. Under the warmer conditions of Africa, peat is much less common but is still found in many permanently wet areas.

2. HYDROPHYTES

Hydrophytic plants are plants that have adapted to surviving in waterlogged soils. They generally have a rooting depth of 50 cm, and therefore need to be in contact with the water table at this depth, or less. It is for this reason that you only sample the soil for signs of hydromorphy up to this depth.

3. HIGH WATER TABLE

The upper limit of the saturated zone in the soil is referred to as the groundwater table. In most parts of the landscape the water table lies many metres below the soil surface. However, in wetlands the water table usually lies close to or above the soil surface. Even so, the water table depth changes in response to climatic changes (e.g. from year to year, season to season, and within a season).

Wetlands range from areas which remain permanently flooded or saturated for the **entire year (permanently saturated)** to areas which are flooded for **5-11 months of the year (seasonally saturated)** or saturated at or close to the soil surface for **1-4 months (temporarily saturated)** in the year but still long enough to develop anaerobic conditions. The water regime is generally one of the most important factors affecting functioning of a wetland. It is therefore necessary to describe the wetness zones within a wetland.

Water regime is a term used to describe how the wetness of the soil changes over time.

Do all wetlands have similar water regimes? No - wetlands can have quite different water regimes, from permanently waterlogged areas, which remain flooded or saturated to the surface for the entire year, to temporarily waterlogged areas, which are flooded or saturated to close to the soil surface for only a few weeks in the year (but still long enough to develop anaerobic conditions and determine the nature of the plants growing in the soil).

B. WHERE ARE WETLANDS FOUND?

Water which falls as rain or snow in 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 waterlogged. This provides an environment where particular plants (e.g. reeds) that are adapted to wet conditions tend to grow in abundance.

Water moves (**Diagram 1**) as: (a) overland flow on the soil surface; (b) subsurface flow beneath the soil surface; and (c) streamflow. Wetlands are found where this movement of water (surface and groundwater) through the catchment is slowed down or obstructed, resulting in waterlogged soils. Water also reaches the wetland directly as rain or snow (d). Water may be lost from the wetland in several ways: (w) loss into the atmosphere through evaporation and transpiration; (x) overland flow; (y) groundwater flow; and (z) streamflow

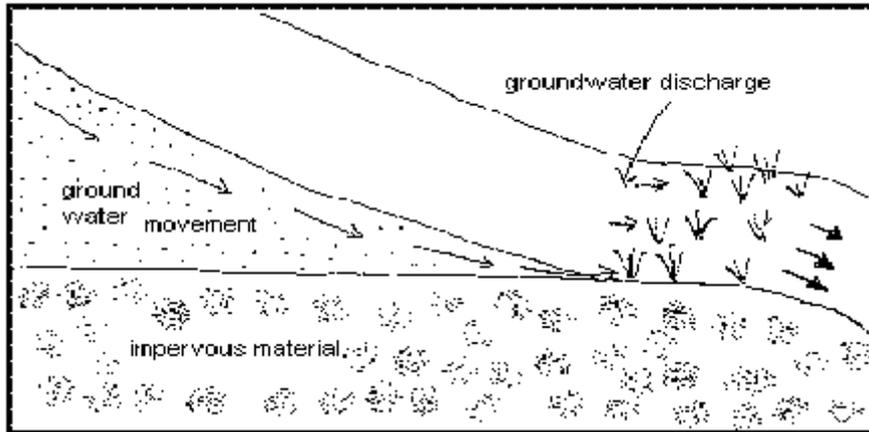


DIAGRAM 1. Cross-section of a catchment showing water sources entering and leaving the wetland

What part does geology play in the formation of wetlands?

In trying to establish why a wetland is found in a particular place, it is helpful to examine the geology of the area. Generally, there are two main ways in which the geology contributes to wetlands forming:

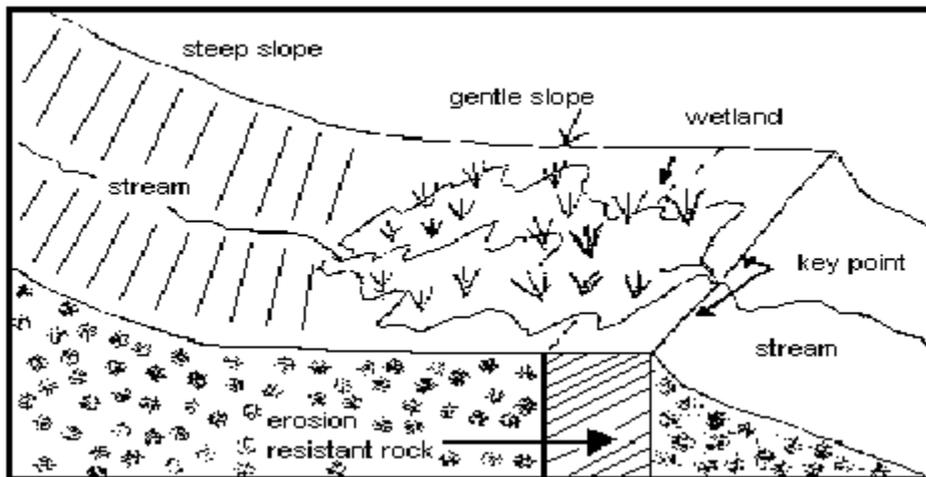


DIAGRAM 2. CROSS SECTION OF THE GEOLOGY OF A WETLAND

1) A geological obstruction may resist downward erosion, resulting in extensive flat areas where water accumulates if there is a sufficient source, usually surface water but also groundwater. This obstruction (sometimes referred to as the key point of the wetland) often consists of very hard erosion-resistant rock, such as dolerite, but alluvial soil deposits may also act as an obstruction. An obstruction may further be caused through geological faulting, as is the case in the Okavango Swamps. The water then accumulates behind the obstruction and the soils become waterlogged. A wetland then starts to form.

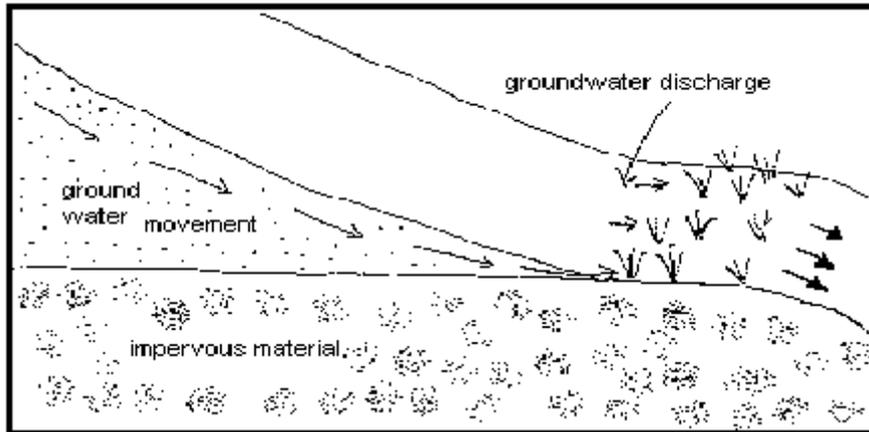


DIAGRAM 3. CROSS SECTION OF THE GEOLOGY OF TYPICAL SEEP

2) Impervious material close to the surface forces groundwater movement very close to or onto the soil surface discharging groundwater. Wetlands that form around these areas are called seeps.

3. WHY ARE WETLANDS IMPORTANT?

Wetlands are important for the functions they perform and their values. In the following chapter the functions and values have been split into two groups for the purpose of the manual.

A. FUNCTIONS OF WETLANDS

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, water in many streams are 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.

1. Flood reduction and streamflow regulation

Wetlands slow down water moving through the catchment because of:

- characteristic gentle slopes of wetlands
- resistance offered by the dense wetland vegetation.
- water being spread out over a wide area of a wetland.
- many wetlands do not have well defined channels (speed up the movement of water).

By slowing down the movement of water and detaining it for a while, wetlands act like sponges, which can absorb large amounts of water due to their high organic contents. This can 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. 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 effectively regulated.

2. 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 water

table. Through this way empty aquifers may quickly be recharged by surface water, rather than the slow movement of ground water. Groundwater discharge, in contrast, refers to the movement of groundwater out onto the soil surface. Wetlands therefore provide a point of exit for groundwater and free access to a resource that would otherwise be costly to retrieve. 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.

3. Water purification

Wetlands are natural filters, helping to purify water by trapping pollutants (they do this by removing the sediment, excess nutrients [most importantly nitrogen and phosphorus] heavy metals, disease-causing bacteria and viruses and synthesised organic pollutants such as pesticides). 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 chemical interactions 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 (NO₂) are utilised 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.

4. Erosion control by wetland vegetation

Wetland vegetation is generally good at controlling erosion by:

- Reducing wave and current energy, this is caused by the resistance of wetland plants to the water which slows it down. The slower the water travels the lower the erosive power of the water.
- Binding and stabilizing the soil, the roots of the wetland vegetation bind the soil and deposited silt to the wetland floor. This prevents the soil from being washed downstream, which in turn reduces the erosive power of the water.
- Recovering rapidly from flood damage, when flood damage does occur the vegetation can rapidly grow back and stabilise the soil.

5. Biodiversity

Wetlands are one of the richest ecosystems in terms of biodiversity. They 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 listed as Red Data species.

6. Chemical cycling

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 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 that will help reduce carbon dioxide levels in the atmosphere.

B. VALUES OF WETLANDS

Wetlands have numerous values. **Refer to Appendix 1** for a summary of the full values of wetlands in South Africa. The following values are 8 of the more common ones.

1. 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.

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". 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, 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.
- 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

3. 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 winter and the early growing season especially during droughts when grazing reserves are low in the surrounding veld 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. Utilization needs to be sustainable if the wetland is to maintain its value for grazing. As with pastures, wetlands are only able to sustain a certain amount of grazing. Particular care is required in wetlands where the erosion hazard is high.

4. 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 sedge). There are several plant species which are suitable and are used extensively for making handcrafts in South Africa, such as the rush *Juncus kraussii*, and the sedges *Cyperus latifolius* and *C. textilis*. The common reed (*Phragmites australis*) is used for construction purposes e.g. houses. 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.

5. 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. A large portion of marine fish rely on estuaries as breeding grounds. To a large degree the fishing industry in South Africa are dependent on estuaries for its survival.

6. Hunting waterfowl and other wildlife

Some wetlands are important places where waterfowl (including ducks and snipe) and other wildlife such as reedbuck can be sustainably hunted. In the South Africa a great many people take part in the recreational hunting of waterfowl which depend on wetlands for breeding and food.

7. 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*), an indigenous type of sweet potatoe, 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. Some wetlands are used for timber production such as the growing of poplars. However, due to the impact that trees have on wetland benefits, strict controls are required.

8. Aesthetics

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.

4. WETLAND PROBLEMS

Wetlands can be utilized- however it must be **sustainably**, with an **acceptable impact**. 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 drained in order to plant crops. As the wetland dries out its 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.

Erosion of wetlands often result from over grazing and incorrect burning. It may result in deep gullies which drain the water rapidly from the wetland and make the water regime much less wet. They also reduce water quality through increasing the sediment load in the water. This often greatly reduces the functions and values of wetlands. Impacts on wetlands result from both **activities in the wetland** (e.g. drainage, disturbance through cultivation, infilling, and flooding by dams) and from activities in the **wetland's surrounding catchment** (e.g. afforestation, mining and crop production).

A. IMPACTS IN WETLANDS

There are numerous impacts that affect wetlands. **Refer to Appendix 2** for a full summary of the wetland impacts in South Africa. The following impacts mentioned are the more common ones in South Africa.

1. Drainage for crops

When wetlands are converted to cropland most of the functions of the wetland are lost, especially if the wetland is drained and dried out. 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. Thus, erosion is controlled less effectively, which may be a very serious

problem in areas with high erosion hazards. 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. Adding fertilizer and pesticides (which may leach into the river system) further reduces the effectiveness of the wetland in purifying water.

2. Cultivation

Cultivation refers to the mechanical or manual disturbance of the soil, which is done to prepare the soil for the propagation of a crop or pasture. As part of the cultivation and subsequent planting of crops and pastures in wetlands the following impacts occur.

- Natural vegetation is removed, leaving the soil bare.
- Organic matter in the soil is decreased.
- Water is polluted through the leaching of fertilisers and pesticides, often these agrochemicals are taken up in the ground water.
- Increased risk in soil erosion through compaction caused by machinery during planting and other functions.

3. Poorly managed 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.

Well managed wetland fires usually only burn above-ground plant parts and most plants recover rapidly from this. Poorly managed fires also burn soil and plant parts below the ground, which usually destroys the plants. This can have a significant impact on the wetland, for example by increasing the risk of erosion. 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.

4. Poorly managed grazing

Heavy grazing may cause valuable grazing species to be replaced by less productive and/or less 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.

Grazing may have both positive and negative effects on the indirect benefits of wetlands. In well managed wetlands which have some areas grazed short and other areas left tall, the diversity of habitats is increased. In poorly managed wetlands which are grazed short, the diversity of habitats is decreased.

5. Timber production

Exotic timber plantations that have been planted in wetlands have a high impact on the water storage function of wetlands because a lot of water is lost by the trees through transpiration. These trees also use more water than the indigenous wetland plants, as they utilise more water, and their roots

penetrate deeper into the water reserve. This usually alters the hydrological regime of the wetland. Trees also have a strong negative effect on the habitat value of wetlands. Under increased shading beneath the trees, the vigor 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.

6. Roads

Road crossings may greatly modify water flow patterns in wetlands, and the building structures in a wetland requires that, by law, application be made to the relevant authority. In addition to having a damming affect or draining affect on the flow upstream of the road, causeways and culverts often concentrate water flow downstream and increase its flow energy. This will not dry out the area out but often also result 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 impacts are anticipated:

- interference in the movement of animals
- disturbance of animals, such as cranes that breed in wetlands
- source of pollution washing off the road.

7. Irresponsible 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 (such as the purification of pollutants other than sediment, flood attenuation and the maintenance of biodiversity). The vegetation which develops around the shoreline is limited from spreading throughout the dam by sudden fluctuations in the water level and by the steep sides of the dam.

This loss in vegetation is directly related to the loss in wetland functions. The habitat required by specialised wetland dependent species is frequently lost when a wetland is dammed. 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.

8. Mowing and harvesting of plants

Mowing and harvesting of plants by hand tends to have much less of a negative impact on the functions 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.

9. Alien plants

Invasion by alien plants, which out-compete the indigenous plants, may greatly reduce the functions provided by wetlands:

- the quality of habitat and the biodiversity functions are reduced.
- many alien plants are less effective in controlling erosion than their indigenous counterparts.
- some alien plants use more water through transpiration than the indigenous plants, this can lead to a reduction in the natural flow of streams.
- grazing value of most alien plants is lower than the indigenous grasses and sedges that they

replace.

10. Purification of wastewater

Earlier 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 functions of the wetland. If the pollutant loadings are greater than the capacity of the wetland for purification the ecosystem may be destroyed or 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, and its functioning of the wetland.

11. Non-sustainable 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.

B. IMPACTS IN THE CATCHMENT

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 catchment impacts affect the 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. 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. 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.

How do catchment impacts affect the quality of runoff ?

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.

5. MANAGEMENT OF WETLANDS

A. DELINEATION OF A WETLAND

In the past Forestry, Agriculture and urban development were the main culprits in the destruction of South Africa's wetlands. One of the main reasons for this has been the lack of clear guidelines for delineating the boundaries of wetlands. Since the Afforestation Permit System came about in the early 70's, permits to plant exotic trees issued by the Department of Water Affairs and Forestry, have stipulated that planting may only occur a set distance away from the wetland. The Department of Water Affairs and Forestry were unable to inform permit holders how to find the edge of a wetland, therefore without the correct delineation the correct buffer distances could not be adhered to. Therefore to conserve wetlands it is of utmost importance that the boundary of a wetland can now be delineated, by looking for 3 key indicators.

As was mentioned in section A there are three indicators which allow us to decide whether a piece of land is a wetland or not: a high water table, hydromorphic soils, and hydrophytic plants living in these soils. When delineating a wetland, these same 3 indicators are used.

1. High water table: Water is crucial for wetlands to survive, and should therefore be essential when determining the wetland boundary. However, as the water table depth changes in response to climate change (from year to year, season to season, and within a season) the presence of water within the soil profile, cannot always be used as a reliable field indicator. This is most noticeable in temporarily and seasonally waterlogged areas. However, the soil morphology also indicates the water regime very clearly. It is for this reason, that we concentrate on looking at hydromorphic soils, and hydrophytic plants for the delineation.

2. Hydromorphic soils: The water regime has a strong effect on the colour patterns of the soil. This means that we can indirectly determine what the water regime is for a particular area by interpreting these patterns.

Because the colour patterns develop slowly they reflect 'average' conditions over a long time. They save us the time and effort of measuring the water regime continuously. These colour patterns are read by looking at the soil colour, and the presence of mottles in the top 50 cm of the soil profile.

Soil colour: Well drained soils (dryland) that are seldom saturated have enough oxygen present to oxidise the iron, resulting in the soil being uniformly red/brown/yellow in colour. Under these aerobic conditions iron in the soil is not soluble in water, and thus it is not leached out of the soil and the soil retains its red/brown colour. In contrast, under anaerobic conditions the iron oxides are reduced and broken down and the effect that they would have in making the soil red/brown/yellow is lost. We therefore find that wetland soils, are generally grey in colour.

Besides affecting the mineral chemistry of soils the water regime of wetlands also has an important influence on soil organic content. Most micro-organisms which decompose organic matter use oxygen in the process. So when oxygen is depleted these organisms cannot function. Although other organisms gain energy by anaerobic respiration they decompose organic matter much more slowly. This increases the amount of organic matter in wet soils. Thus, the wettest parts of the wetland, which are most anaerobic, tend to have the highest organic matter contents. This results in the soil colour being darker in colour than dryland soils, and getting progressively darker/blacker as you move into the wetter sections of the wetland. When looking at the soil colour, the wetland soils are darker (higher organic content), and greyer (reduction of the iron oxides).

Mottles: Although temporarily wet soils tend to be anaerobic for shorter periods and less close to the soil surface than seasonally wet soils, both of these soils alternate between being anaerobic (mainly in the wet season) and aerobic (mainly in the dry season). When anaerobic soil dries out, iron oxides form orange or red spots called mottles. These little spots can be clearly seen in the soil. In

permanently wet soils, mottles often form around plant roots, which provide a route for oxygen to move down into the soil. These are called oxidised rhizospheres. Thus, soil which is grey but has many mottles may be interpreted as indicating a zone with a fluctuating (rising and falling) water table. When a wetland is drained and the water regime is changed the soils retain their characteristic colour signatures. Thus, soils are useful for indicating if a drained area used to be a wetland. This helps in mapping where wetlands used to be and assists in working out the extent of wetland loss.

3. Hydrophytic plants: Hydrophytic plants are plants that have adapted to surviving in waterlogged soils. They generally have a rooting depth of 50 cm, and therefore need to be in contact with the water table at this depth, or less. It is for this reason that you only sample the soil for signs of hydromorphy up to this depth.

Important note: If a wetland has been drained, the soil colour pattern will show that it was a wetland. However, as the wetland dries out, the hydrophytic plants will be replaced by dryland plants. This often happens in wetlands that have been severely impacted upon by donga erosion or drains.

Do all three indicators need to be present for delineation?

- As the water table is often difficult to identify, especially for temporary and seasonal wetlands, it is not essential for this characteristic to be visibly confirmed. The soils will indirectly do this.
- **Hydromorphic soils must always be present.**
- The hydrophytic plants should preferably be present as it will allow the delineation to be more accurate. However if crops were planted in the wetland, or the hydrological regime altered (eg by draining), then hydrophytic plants will obviously not be present. In this case, the plants cannot be used as an indicator.

The different wetness zones in a wetland. Some parts of the wetland are saturated to different degrees than others. The permanently saturated zone, is waterlogged for 12 months of the year. The seasonally saturated zone is waterlogged for 5 - 11 months of the year, and the temporarily saturated zone, for 1 - 4 months. Under high rainfall conditions, all three zones are likely to be represented in a wetland. While under drier conditions, the permanent zone may well be absent. Both the soil hydromorphy and the hydrophytic vegetation will change from one zone to another. **Refer to Diagram 5** which clearly shows how the colour of the soil changes, together with the appearance and disappearance of mottles, and the changing vegetation composition.

Important note:

- An important point to remember is that in some wetlands, especially those where the iron content of the soil is low, mottles may be scarce throughout the 3 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.
- In wetlands which are covered in very sandy soil or coarse sediment, the organic material and iron oxides are often leached out. This gives the soils a white bleached look. In this case you will not be able to use colour or the presence of mottles to delineate the wetland. Instead use other indicators such as the presence of hydrophytic plants or hydrology.

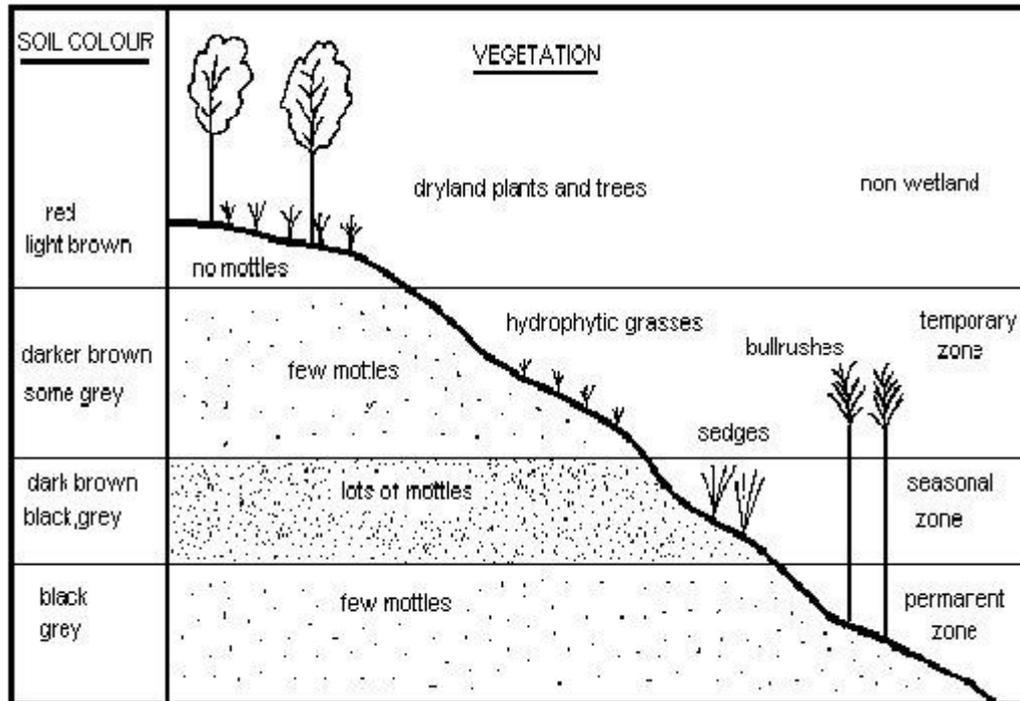


DIAGRAM 4. CROSS SECTION OF A WETLAND.

Delineation in the field

A wetland boundary is identified by finding the point of transition between the dryland soils and the wetland (hydromorphic) soils. This is done by sampling the soil along a transect using a soil auger. The transition zone where hydromorphic soils begin to appear within the top 50cm of the soil profile, is regarded as the wetland boundary. This can be confirmed by the change in plant communities from mesophytes (plants adapted to living in well drained soils) to hydrophytes (plants adapted to living in waterlogged soils), as the degree of waterlogging in the soil increases. **Refer to Appendix D** for plant species common to wetlands in the higher summer rainfall areas of South Africa.

Begin the transect of soil samples in an area that you know is definitely out of the wetland. Take a sample to a depth of 50cm, and note the characteristics of the soil. Look for any signs of hydromorphy such as the low chroma of the soil colour, mottles or oxidised rhizospheres. Use the **WETLAND DELINEATION FIELD GUIDE** at the end of the book to help in the field. Move forward at intervals of 10 m towards the wetland, until you have discovered this. When you do, find it, note the degree of hydromorphy, and the vegetation that is growing there. The dominant vegetation should be hydrophytic species, unless the wetland has been drained or cleared for the growing of crops. Now retrace your steps moving out of the wetland, and at 1m intervals sample the soil until the presence of hydromorphy disappears out of the top 50cm of the soil profile. When this happens, you have reached the edge of the wetland. Walk around the wetland, following this boundary, confirming it's presence by sampling the soil every 20m. When finished, map the boundary.

Refer to Figure 1 for a framework for wetland delineation. **Refer to Figure 2** for the criteria for using soil as an indicator of hydromorphic conditions.

FIGURE 1. FRAMEWORK FOR WETLAND DELINEATION

FIGURE 2. CRITERIA FOR USING SOIL MORPHOLOGY AS AN INDICATOR OF HYDROMORPHIC CONDITIONS.

B. WETLAND ASSESSMENT

During the delineation of a wetland it is important to try and assess impacts that are affecting the functioning and the hydrology of the wetland. You should be asking yourself the following questions while you are assessing a wetland:

- How much wetland surface area has been lost?
- Has the natural flow pattern of water been altered by mans intervention?
- Has the natural water regime been affected?
- Have any pollutants been added to the wetland?
- How much of the natural vegetation has been disturbed?

With these questions in mind Refer to Appendix E for an example of a data assessment sheet used in the field.

C. BASIC MANAGEMENT OF WETLANDS

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 values and land-use impacts we have seen that the hydrology of a wetland is the most important factor determining its functioning. **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).

The following questions must be asked before considering certain activities in a wetland:

- Is the activity going to affect the wetness of the soil?
- Is the activity going to alter the plant growth in the wetland?
- Is the activity going to affect the wetlands potential to slow down water flow ?
- Is the activity going to affect the speed in which water moves through the wetland?

If any of the questions above are answered with a **YES!** **The wetlands functions and values will be decreased.** The following information will help a potential managers to decrease the affect of a certain activities on wetlands.

1. Burning

Wetlands are **burnt** for many reasons: to improve the grazing value for livestock by removing old dead plant material and increase productivity; to assist in alien plant control; to reduce the risk of run away fires; and to improve the habitat for wetland dependant species. When planning the burning of wetlands the critical issues are determining:

1. which wetland type to burn
2. climatic conditions under which to burn
3. desired frequency of burning

Which wetland types do you and burn?

- **Stream source wetlands** (seeps and springs) with a herbaceous cover are often subjected to local veld or firebreak burning because of their position on the slopes. They are prone to

subsurface fires as their small size steep gradients and shallow soils allow them to drain and dry out frequently. Extreme care needs to be taken in selecting correct burning conditions as the recovery of the post burning vegetation at these sites appears to be very slow.

- **Plains wetlands** (flood plains and marshes) have gentle gradients and tend to be relatively large in size with corresponding higher potential for hydrological functions. Burning methods on plains wetlands with an herbaceous cover should allow for rapid plant regrowth so as to enhance the functions whilst inhibiting evaporative loss and retaining unburnt wildlife refuge patches.
- Burning the herbaceous layer of **streambanks** can assist in maintaining plant vigor thus enhancing their ability of combating scour and improving bank stability.

How often should you burn? When and how?

- Burn the wetland every **second year** if the rainfall is **more than 800 mm** per year.
- Burn every third of **fourth year** if the rainfall is **less than 800 mm** per year.
- **In Cape Fynbos regions burn at up to 30 year intervals.**

Where practical divide the burning into burning blocks and burn each half alternately leaving the other half unburnt to provide wildlife refuge. Where this is not practical, attempt to rotate burning with other wetlands in close proximity. Apply cool "patch" burns by burning when the fuel is moist after rain, or in the evenings or early mornings after dew when there is a high relative humidity and low air temperature. Burn at the onset of the growing season so as to ensure rapid plant regrowth. This is vital. Burning a wetland when it is dry, can result in underground fires if the wetland soils have a high organic content. If the wetland plants are damaged by a very hot fire, they will not re-establish in the growing season and headcut erosion may occur.

Use a head-fire (burn with the wind) as this is more controllable and less damaging to plant growth points. Back burns, burning against the wind raises ground temperatures which has a greater impact on the growing points of plants, and encourages the fire to move laterally making control more difficult. Delay burning to another day or even year if in dry years there is a danger of soil ignition, when weather conditions are consistently unsuitable or if winter breeding animals (eg wattled cranes) have not completed breeding. Keep records of when you burn, where you burn and the conditions under which you burnt to monitor and improve your burning techniques.

Wetlands in afforested areas

Many wetlands in afforested areas are burnt annually in early winter because they form convenient firebreaks without losing valuable arable land, and due to the fire risk that wetlands pose to the afforestation. 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 the permanently wet areas, where the water table remains close to the soil surface through most of the dry winter season. Little can be done to minimise 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.

2. Grazing

In suitable wetland types the grazing and trampling of wetlands plants by cattle, is a particularly important disturbance factor that encourages biological diversity. However, it is imperative to manage the grazing correctly.

The critical issues are:

- which wetland to graze
- when
- for how long to allow stock grazing to continue before resting the area

When should you graze a wetland and for how long?

On average the grazing capacity in a wetland is 1,5 times higher than in a non wetland area, but this is dependent on many factors such as species composition and the water regime of the wetland. Annexure will help you determine your wetland carrying capacity on your own. Ensure that this grazing capacity is not exceeded. Where regular monitoring of grazing is possible apply a flexible rotational system where the grass sward is allowed to be grazed down to a threshold level of 8cm and/or when the most favourable plants have been grazed down to 4cm high. Where regular monitoring is not possible apply a fixed rotational grazing system of 14 days in and 24 days out of the wetland.

Either graze the entire wetland and allow a full growing season rest period every 4 years, or graze three quarters of the wetland excluding one quarter from stock on an annual rotational basis. One way of introducing this rest is to make use of a patchy burn, which leaves approximately one quarter of the vegetation unburnt and encourages stock to graze on the remaining post burn areas. All grazing must be discontinued when the soils are waterlogged (as this is when erosion can set in) until conditions have improved. The exclusion of grazing when soils are waterlogged can usually be accommodated in a grazing system. Use non-wetland grazing when the wetland soils are sodden. Once they dry out, it is safe to use the wetlands for grazing once more.

3. Cultivation

Wetlands should preferably not be cultivated. The recommendations below refer to lowering of impacts on wetlands which are already cultivated.

Several management techniques can be used to reduce the effect of cultivation in a wetland. If cultivation should occur, no more than 30% of the temporary zone of a wetland should ever be cultivated. No parts of the seasonal or permanent zone should be cultivated under any circumstances.

- **No drainage of the area to be cultivated should be undertaken** (i.e plant tolerant crops and avoid the wetter areas).
- **Minimum tillage** techniques should be used to reduce the amount of soil disturbance.
- **Ley cropping** - this refers to the practice of planting a plant cover to protect the soil (from compaction caused by rain drops, moisture loss through evaporation and water erosion).
- Leave strips of wetland vegetation between cultivated areas.
- Adding organic matter on to the soil in the form of a **mulch**.
- Do not cultivate the same area every season. Leave cultivated areas fallow but vegetated periodically.
- **Plant perennial pastures** where possible.

The impact of cultivation can be reduced if practices characteristic of low input/traditional cultivation are followed. These effects can be reduced by:

- Correctly applying fertilizers (i.e. split applications at the right rates at the correct growth stages of the plant). Spilt applications, however, increase machinery costs and compaction but save in fertiliser costs.
- Irrigate correctly to avoid over irrigation and the subsequent leaching of fertilisers (as well as causing erosion and wasting water).

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.

4. Damming

Whilst dams perform certain wetland functions (e.g. sediment trapping and water storage) they do not perform other functions well (such as the purification of pollutants other than sediment, flood attenuation and the maintenance of biodiversity). The vegetation which develops around the shoreline is limited from spreading throughout the dam by sudden fluctuations in the water level and by the steep sides of the dam. This loss in vegetation is directly related to the loss in wetland functions. The habitat required by specialised wetland dependent species is frequently lost when a wetland is dammed. 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.

Furthermore, bursting of farm dams is a frequent occurrence that may have high impacts on downstream areas. Applications must be made to the relevant authorities for damming. In order to minimise the negative impacts of dams that are legally and safely in place it is important that the guidelines given below are followed.

- Place the dam at the lowest part of the wetland. This allows the wetlands to carry on performing its functions.
- The amount of dams in the wetland have a cumulative effect on the wetland.
- Construction of the dam wall and spillway.
It is vital that the dam wall and spillway should be built to withstand one in fifty year flooding. If not the bursting of dams usually has a high environmental impact, increasing flood peaks, sediment loads, streambank erosion and a waste of money on part of the dam owner. In addition, weirs and spillways should be built to allow for the movement of aquatic species. Consult the local Department of Agriculture soil conservation officer or an engineer to plan the dam wall and spillway.
- Ongoing Management
The main factor within the managers control once the dam or weir has been built is the outflow control. The first wet season flows from a dams catchment are often retained in the dam because levels are depleted at the end of the dry season. This may impact both on the river biota and the downstream users. Measures must be taken to ensure water release through the outflow control so that at least 50% of the early season flow entering the dam is released. In managing the outflow control it is essential that the needs of the downstream water users and the natural environment are accounted for.

5. Alien plants

The first step in controlling alien plants is to identify the particular species of alien plants that are to be controlled. Controlling alien plants species requires that appropriate pre-treatment, initial treatment and follow-up treatments 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 or too dense to reach. Initial and follow up treatments may be carried out through:

1. application of herbicide to growth or re-growth
2. cutting or grazing to deplete the nutrient reserves of the plant, will then require several follow up treatments
3. hand pulling, particularly for young plants where the roots can be easily pulled out
4. ring and strip-barking
5. felling of trees
6. burning.

Refer to Wetland Fix for detailed information on alien plants.

Always remember to conduct follow up operations, if not you have wasted your money !!

6. Roads

The following must be considered when involved with conflicting roads and wetlands:

- Try and seek an alternative route.
- Ensure that causeways have minimal disruption to flow patterns, both upstream and downstream of the crossing.
- Adequate culverts are required as to have a minimal impact on water flow patterns through the wetland.
- Runoff from roads must be managed, both erosion and pollution problems can occur.

7. Rehabilitation of wetlands

The plants that grow in wetlands and on riverbanks are vital for preventing erosion, they play a role in the purification of water, reducing the severity of floods and regulating water especially during droughts. The moment the vegetation is destroyed, these valuable functions disappear.

Wetlands are often drained for the production pastures and crops, such as sugar cane. Erosion, in the form of head-cuts and their dongas, often occur in wetlands as a result of over grazing, excess cattle trampling, the wrong burning regime or even planting of crops in wetlands. A head-cut (see diagram below) is a type of erosion that eats uphill towards the flow of water, leaving a huge donga (see diagram below) behind it. These channels and head-cuts essentially drain the wetland, drying it out, and ultimately killing it. They also increase the amount of sediment in the water thereby decreasing water quality. Much of South Africa's worst erosion occurs along riverbanks.

The cause of this erosion is most often a result of poor land management - removal of streambank vegetation, invasion of alien plant species, excess cattle trampling, overgrazing, and flooding because of land disturbances in the upper catchment. Wetland rehabilitation is a very viable process that can be highly successful and rewarding. Rehabilitation can range from corrective management strategies through to large soil stabilization projects. It is vital to make informed decisions when undertaking wetland rehabilitation and if ever one is ever in doubt acquire specialist advice.

Principles for successful wetland rehabilitation

- **Remove the cause** of the damage, not the symptoms and manage the resource correctly.
- **Re-establish the natural water flow** patterns within the wetland.
- Do not concentrate water always try and spread it out, this should reduce the possibility of erosion occurring.
- Do not underestimate the **force of the water** during high flow periods.
- Many **wetland soils** are **highly erodible**, be aware of this when designing structures.
- There are two ways of deciding what method of rehabilitation to initiate and that is either **stabilising the problem area and maintaining the present condition** of the wetland or secondly to try and **reclaim the wetland area that has been lost**.

The following are set of general ideas that can be used in soil stabilization projects and hydrological profile re-establishment. You may use a variety of methods, using herbaceous or woody plants, hay bales, clay, gabions filled with rock, or if lined with a geo-textile, soil, or even just pack loose rock against headcut faces. What you decide to use may depend on availability of resources and finances, or what you are familiar with.

Drains and dongas lower the water table and effectively dry out the wetland, and produce excess sediment ultimately smothering the wetland below. It is important to either stabilize gully sides and more importantly stop the verticle erosion in the donga to prevent the further lowering of the water table or re-establish the moisture status of the soil.

Plants are the best and cheapest solution to solving riverbank erosion. When using plants the key questions to ask are:

- Should you use herbaceous (grasses, bulrushes or reeds) or woody (trees) vegetation?

- Which species are best for the job?
- What type of rehabilitation method is best suited for the problem you have?

A large variety of herbaceous plants with their rapidly spreading capabilities and dense near surface root mat, and surface cover, are extremely effective firstly against scouring of riverbeds and wetlands, and secondly for enhancing the stability of gentle or shallow banks. The plant stems induce sediment deposition tending to raise the floor of eroded channels, even widening the channel profile. Herbaceous plants absorb the energy of fast flowing water rather than reflecting it. The combination of these factors, plus the ability of many herbaceous plants to thrive in direct sunlight, of being fire tolerant and having strong regenerative powers, makes them ideal for rehabilitating streambanks and wetland erosion.

Whilst a herbaceous cover is probably the most effective with respect to gentle and shallow banks, they have little effect on the stability of steep banks due to their shallow rooting depth. Trees contribute cohesion and stability to steep banks - providing the roots reach down to full bank height, and the toe hold and bank face are protected from undercutting by tree roots and an established cover. In some instances, such as in KwaZulu-Natal coastal regions, certain tree species grown in narrow channels will develop entwined root "weirs", forming an effective channel plug for donga and channel erosion. Unlike herbaceous plants trees generally are not tolerant to frequent fire.

For rehabilitation it is important to be deliberate in both the selecting and placing of plants with vigorous rooting growth characteristics, that will accelerate natural plant succession and deal directly with the problem on site. Local plant species native to streambanks and wetlands should be used. The right species to use depends entirely on what area of the country you are in. The best is to look around and see what indigenous species are growing in the area you are about to rehabilitate.

Refer to Wetland Fix for more information on wetland rehabilitation.

8. Monitoring

Once the rehabilitation has been completed a monitoring scheme should be implemented to ensure the objectives are being met which were decided upon. A monitoring plan encompasses:

- **Setting management objectives**
The implementation of such a program will be of benefit to the managers of the wetland, as it will give them tangible feedback as to the effectiveness of the rehabilitation and corrective management program. The following four steps are used to develop the program
 1. Why does the rehabilitation need to be monitored?
 2. How is the monitoring going to be implemented?
 3. Who is going to be responsible for the monitoring?
- **Decide on techniques to monitor the rehabilitation**
There are numerous methods that can be used to monitor sites, two of the more common methods are described below.

Fixed point photography
Specific sites are chosen and photographs are taken from predetermined fixed points (permanent) at the same time of the year as to assess the effectiveness of the structure and the development of wetland vegetation.

Placing stakes in the field.
The rehabilitation site can be measured and staked accordingly in the field. The stakes are placed to represent measurements taken and by comparing the measurements to the stakes the effectiveness of the rehabilitation structure can be measured.

The most effective method is to utilise both of these methods, this will give comprehensive information on the effectiveness of the rehabilitation.

- **Site visits to monitor the rehabilitation**
The following aspects of the rehabilitation require monitoring:
 - the effectiveness and integrity of the soil conservation measure

- vegetation assessment, assessing the change in the species composition from dryland species to wetland species.
- Repair any damage to the rehabilitation The soil conservation measures should be monitored for stability (i.e. A visual check on the stabilisation of the active erosion sites). If damage is detected measures must be taken to ensure the effectiveness of the structure.

This guideline has highlighted the importance of monitoring the wetland rehabilitation. This process should be initiated before the rehabilitation begins as to ensure a benchmark comparison can be made. This program will serve as the only feedback available to the manager and thus must be initiated as soon as possible. The methods described are examples of what can be done and should be modified to suite the specific situation. **However the use of fixed-point photography should be seen as the minimum requirement.**

D. MANAGEMENT FRAMEWORK

1. **Delineate the wetlands of concern**
2. **Assess the condition of the wetland**
3. **Assess the present management of the land in terms of possible impacts.**
4. **Source information from organisations that can help.**
5. **Improve present management by using the information gathered from the assessment.**
6. **Rehabilitate problem areas**
7. **Monitor the wetland and the rehabilitation sites.**
8. **Ensure that the correct legislation is being adhered to.**

6. CONCLUSION

Now that you have read these notes you should have a better understanding of:

- **what is a wetland**
- **why is a wetland important**
- **what are the problems in wetlands**
- **how to rehabilitate problems**
- **how to monitor the success of the rehabilitation**
- **how to delineate and manage a wetland**

We have seen that functioning wetlands have many benefits to society. Some of these benefits, particularly the values, 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.

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 benefits it provides to society. This booklet and the references listed in the additional information chapter will help you. Advice may also be obtained from the several organizations concerned with wetlands, which are also listed.

7. APPENDICES

APPENDIX A.

SUMMARY OF ALL WETLAND BENEFITS IN SOUTH AFRICA

Wetland benefits are those functions, products, attributes and services provided by the ecosystem which have a value to humans in terms of worth, merit, quality or importance. These benefits may derive from outputs that can be consumed directly; indirect uses which arise from the attributes or functions occurring within the ecosystem; or possible future direct outputs or indirect uses.

The following benefits may be provided by South African Wetlands.

1. Water supply
 - direct extraction
 - to other locations
 - to an aquifer
 - to another wetland
2. Flow regulation, primarily flood control
3. Erosion control
4. Sediment removal and/or retention
5. Nutrient removal and/or retention
6. Toxicant removal and/or retention
7. Source of natural products (wetland)
8. Source of natural products (catchment)
9. Significant for conservation
 - significant habitat for the life-cycles of important species of animal and plants
 - presence of rare species, habitats, communities, ecosystems, landscapes, processes or wetland types
10. Recreation and tourism
11. Socio-cultural significance
 - aesthetic significance of a landscape or landscape component
 - religious and spiritual significance
 - presence of distinctive human activities
 - wilderness
 - historically important site
12. Significant for research and/or education
13. Contributes to the maintenance of existing processes or natural systems
 - ecological, geomorphological and geological processes and systems
 - carbon sink
14. Good representative example of this class of wetland

Provision of benefits by a wetland is closely linked to the systems biological, chemical and physical characteristics, as well as the interaction between these characteristics. As a result, wetlands do not automatically provide all of the benefits listed above. Furthermore, the role that two different wetlands can play in a given process may vary considerably, both in importance and quality.

APPENDIX B.

SUMMARY OF ALL WETLAND IMPACTS IN SOUTH AFRICA

Causes of impacts which have the potential to decrease the value of the wetland benefits. These have been grouped into five general classes:

1. ALTERATION OF HYDROLOGICAL REGIME

- Drainage
- Channelisation of rivers
- Diversion of water from wetlands
- Construction of dams and weirs
- Abstraction of water

2. ALTERATION OF FLORAL COMPOSITION

- Removal of vegetation
- Excessive harvesting of products
- Incorrect planting operations

- Accidental introduction of alien species

3. ALTERATION OF FAUNAL COMPOSITION

- Excessive harvesting of products
- Incorrect management
- Accidental introduction of alien species

4.ALTERATION OF WETLAND SUBSTRATE

- Removal
- Addition
- Compaction
- Earthworks

5. POLLUTION

- Oil
- Chemical
- Radioactive
- Domestic waste
- Sewage
- Industrial waste
- Thermal pollution

APPENDIX C.

WETLAND STOCKING RATES

Potential grazing capacity, which refers to the amount of grazing that can be sustained in a particular area, varies from area to area. For a given region the 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. This in turn reduces the stocking rate by an amount proportional to the veld condition.

A system applied to temporary wet areas should be used, whereby the recommend stocking rate is reduced by an amount proportional to the relative abundance of Increaser² species present These species have low palability or perenniality, and increase in mismanaged veld where grazing pressure is heavy. *Eragrostis plana* is one of the most common Increaser² species in wetlands in S.A. A veld condition assessment should be conducted by randomly placing a point 200 times in the temporary wet zone and at each point record whether or not the closest species is an Increaser². Consult your agricultural extension officer for assistance in conducting a veld condition assessment

Stocking rate adjusted to account for veld condition.

Percentage of Increaser species	Stocking rate (expressed as a % of the potential grazing capacity for wetlands in a given area)
0-30%	100%
30-60%	85%
>60%	70%

If seasonally and permanently wet areas are used for livestock, include them in the stocking rate calculations for the spring season only, plants are most palatable. 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 (good veld condition)

X 0.8 (medium veld con.) X

0.75 (poor veld con.)

=U/ha

D. Total area of wet grassland

ha

E. Total AU's the temporary wet area can support for the grazing season

C x D

=AU

F. Total area of wet meadow or marsh

ha

G. Total additional AU's the area can support during spring only

0.5AU x F

=AU

REMEMBER THE RECOMMENDED STOCKING RATE IS ONLY A GUIDELINE AND MAY NEED TO BE MODIFIED FOR PARTICULAR LOCAL CIRCUMSTANCE

APPENDIX D PLANT SPECIES COMMON TO WETLANDS IN THE HIGH SUMMER RAINFALL AREAS OF SOUTH AFRICA

APPENDIX E WETLAND ASSESSMENT FIELD FORM

8. ADDITIONAL INFORMATION

A. GLOSSARY OF TERMS

Aerobic: having molecular oxygen (O₂) present.

Anaerobic: not having molecular oxygen (O₂) 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.

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.

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 patterns 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 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.

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: According to the definition in the South African Water Act a wetland is: " water dominated area with impeded drainage where soils are saturated with water and where there is characteristic fauna and flora".

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.

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