NATIONAL WETLAND INVENTORY: DEVELOPMENT OF A WETLAND CLASSIFICATION SYSTEM FOR SOUTH AFRICA

JL Ewart-Smith • DJ Ollis • JA Day • HL Malan

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NATIONAL WETLAND INVENTORY:
Development of a Wetland Classification System for South Africa

Prepared for:

The Water Research Commission (WRC) and

South African National Biodiversity Institute (SANBI)

by

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GLOSSARY

advanced wetland layer: wetland data generated from the NLC 2000 and refined using additional modeling and mapping techniques

basin seep: a concave seep area, generally occurring on gentle slopes characteristic of a valley floor or on relatively flat ground at the head of a valley

bedrock: immovable slabs of bare rock (> the length of a tall person)

biotic: pertaining to living organisms

bog: a peatland that is hydrologically isolated so that it is influenced solely by water falling directly onto it as rain or snow and tends to have acidic waters (Dely *et al*. 1999)

boulder: sediment particle with a size > 256 mm (range includes: inside armpit to wrist; ground to waist, length of a tall person)

channel: a linear landform that, when inundated, usually carries flowing water

classification: wetland classification refers to the process of *typing wetlands* according to their biophysical characteristics and the way in which they function

cobble: sediment particle with a size-range of 150 to 256 mm (inside elbow to wrist).

descriptor: as relates to wetland classification, something that provides additional information about a wetland unit and can be applied in conjunction with the discriminators at any level of the hierarchy, depending on the purpose of classification

depression: a basin-shaped area increasing in depth from the perimeter to a central area of greatest depth

discriminator: as relates to wetland classification, a criterion used to distinguish one wetland from another and is applied consistently at different levels of the hierarchy

drainage: the source and movement of water entering, passing through and exiting a wetland

estuarine bay: a large, permanently open estuary (> 1000 hectares water surface area) receiving inflow from a riverine source but dominated by tidal exchange (>10 x 10^6 m^3 spring tidal prism) through a deep mouth (> 3 m at mean sea level)

estuarine channel: a linear landform primarily confined to the channel of a drowned river valley and dominated by processes originating in the marine environment; either permanently or intermittently open to the sea

estuarine depression: an estuarine lake system (>1000 hectares water surface area) situated in a coastal basin; either permanently or intermittently linked to the sea

estuarine system: a partially enclosed ecosystem, permanently or periodically connected to the ocean, influenced by tidal fluctuations, within which ocean water is at least occasionally diluted by freshwater derived from surface or subsurface land drainage

exposed coast: a marine area subject to significant wave energy

fen: a peatland influenced by water derived from outside its immediate limits and tending to have neutral to alkaline waters (Dely *et al.* 1999)

floating vegetation: plants that float freely, on or below the water surface

floodplain: a valley bottom area with a well-defined, gently sloped, stream channel characterised by alluvial transport and deposition of sediment, usually leading to a net accumulation of sediment (Kotze *et al*. 2005). Water enters from the main channel when the channel banks overspill

forested wetland: as relates to a wetland; one dominated by woody vegetation greater than 6 m in height

geomorphic: as relates to landscapes; shape or surface configuration/structure

habitat: the place in which an organism lives, which is characterised by its physical features or by the dominant plant types

herbaceous: of vegetation; dominated by herbaceous macrophytes including sedges, grasses, reeds, herbs and restios

hillslope seep: a concave or covex seep area occurring on a relatively steep slope

hydroperiod: degree, duration, frequency and seasonality of inundation

hydrogeomorphic: as relates to a classification system, one based on the shape of the land (landform setting) and the patterns of surface and subsurface water flow

inland system: an ecosystem that is permanently or periodically inundated or saturated and has no existing connection to the ocean, and is therefore characterised by the complete absence of marine exchange and/or tidal influence

intertidal: a periodically submerged area or one that is alternately flooded and exposed by tides

isolated subsystem: an inland system that is hydrologically isolated in terms of surface flows

kelp: large brown seaweed (algae), usually attached to consolidated substratum

lake: a permanently inundated, usually large wetland with a deepwater zone too deep to support rooted plants

landform: the “container” of a wetland, which delimits its shape, size and depth

littoral: covered by water no more than 2 m deep

limnetic: covered by water with a depth greater than 2 m

marine system: an ecosystem located along the coastline that is part of the open ocean overlying the continental shelf and/or its associated coastline

marsh: vegetated wetland with low-growing vegetation

mud/silt: sediment particle ≤ 0.06 mm (very fine material)

national land cover (NLC) 2000: 1:50 000 scale National Land-Cover based on satellite imagery from 2000 and 2001

non-isolated subsystem: an inland system with an observable hydrological connection to a surface drainage network

pan: wetland contained in a topographic depression that has a closed drainage system, is shallow (<2 m deep when fully inundated), has a flat bottom, is usually circular to oval in shape (sometimes kidney-shaped or lobed) and usually seasonally dry

peat: a dark brown or black organic soil layer, composed of partly decomposed plant matter and formed under permanently saturated conditions

pebble / gravel: a sediment particle 2 to 150 mm in length (range from fingernail size to size of a larger hand)

permanently inundated: surface water present throughout the year

permanently open: as relates to an estuary; one with a mouth that is always open to the sea

reef: a ridge-like or mound-like structure colonised by sedentary invertebrates, elevated above the surrounding substrate and characteristically interfering with normal wave action

rooted vegetation: plants rooted into the underlying substratum

river mouth: a linear landform primarily confined to the channel of a drowned river valley, dominated by riverine processes and permanently open to the sea

salt crust: a hard layer of naturally occurring alkali salts, usually formed by evaporation of water of naturally occurring salts

sand: sediment particles with a size range of 0.06 to 2 mm (course grit)

saturated: as relates to wetland sediments, waterlogged, usually resulting in hydric soils that support vegetation adapted to aquatic conditions

scrub-shrub: dominated by woody vegetation less than 6 m tall

seep: concave or convex area that is permanently or periodically saturated, usually on a slope, where groundwater or interflow meets the surface

sheltered: as relates to a coast; one where wave energy is appreciably reduced by landform

subtidal: as relates to marine or estuarine systems; one that is continuously covered with water

supratidal: as relates to marine or estuarine systems; one that is occasionally submerged, usually during extreme tidal events (the area above mean spring high tide)

swamp: permanently inundated wetland that supports tall emergent vegetation

spring: an outflow of groundwater at the surface

tarn: a high altitude depression; seasonally or permanently inundated

temporarily closed: as relates to an estuary; one with a mouth closed to the sea for varying periods

valley bottom: a low-lying, gently-sloped area that receives water from an upstream channel and/or form adjacent hillslopes, not subject to periodic over-bank flooding by a river channel

wetland: an area of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tides does not exceed ten meters

wetland spectral signatures: contrasting colours and shades of colour or black and white that are indicative of hydric conditions associated with wetlands

1 INTRODUCTION

1.1 Background and rationale for classifying wetlands in South Africa

Wetlands are inherently valuable ecosystems that are threatened by a variety of human activities. Yet, throughout South Africa, very little is known about their extent and distribution, physical and biotic characteristics, or the ways in which they function. Such information forms the basis for wetland conservation and management (Finlayson & Van der Valk 1995; Dini & Cowan 2000). As a signatory and founding member of the Convention on Wetlands of International Importance (Ramsar, Iran, 1971) and signatory to the Convention of Biological Diversity, South Africa is committed to the management, wise use and protection of its wetland resources (Cowan 1999).

What are Wetlands?

Wetlands referred to in this document include a wide variety of ecosystems, defined as areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tides does not exceed ten meters. This is an adaptation of the definition adopted by the Ramsar Convention, which limits marine water to a depth of six meters at low tide (Davis 1994). Wetlands are areas where water is the primary factor controlling the environment and, therefore, wetlands develop in areas where soils are saturated or inundated with water for varying lengths of time and at different frequencies.

In recognition of wetlands as national assets and in line with South Africa's obligations in terms of both the Ramsar Convention and the Convention on Biological Diversity, a national wetland inventory is currently being compiled. This will provide information on the extent and locality of wetlands at a national scale, as a first step in investigating wetlands in South Africa. A wetland inventory, by definition, simply provides a "list" of wetlands, usually accompanied by a map showing their spatial extent and distribution.

Although Cowan & Van Riet (1998) compiled a preliminary inventory of the major wetlands in South Africa, many key wetland scientists and managers in the country have expressed the need for a more comprehensive national inventory for wetland conservation and management purposes. Consequently, a major drive towards the development of tools for the compilation of such a national wetland inventory was initiated in the late 1990's to early 2000's (Dini & Cowan 2000; Thompson *et al.* 2002). Currently, the implementation of a national wetland inventory for South Africa is focused on the development and use of an "advanced wetland layer" based on the wetland data generated by the National Landcover (NLC) 2000 initiative, enhanced through mapping and modelling techniques (T. Landmann, CSIR, pers. comm.).

Whilst the advanced wetland layer (AWL) of the NLC 2000 initiative provides information on the extent and distribution of wetlands, the evaluation, management and conservation of wetlands requires that each wetland unit be described and classified according to its biophysical characteristics and functional attributes. Consequently, the development of a classification system to distinguish between different wetland types is fundamental to the compilation of a national wetland inventory that encompasses the full diversity of wetland types throughout South Africa.

National Land Cover (NLC) 2000

The NLC 2000 project provides a 1:50 000 scale digital map of the dominant land cover and land use throughout South Africa, based on multi-season satellite (Landsat) imagery from 2000/2001. The land cover for each (approximately) 1-2 ha unit of land has been categorised into one of 49 land cover classes (see Thompson *et al*. 2001 for details).

"Wetlands" is one of the standard land cover classes used in NLC 2000, which identifies the large, easily discernable wetland features across the country on the basis of broad spectral characteristics. An additional project is currently underway to develop an "advanced wetland layer", which will augment the standard wetland coverage of NLC 2000 through additional mapping and modelling techniques (see section 1.4, below).

Wetland classification systems have been in development internationally for close on a century (Finlayson & Van der Valk 1995; Tiner 1999). In South Africa, wetland classification has received attention for some thirty years (see literature review in Appendix 1), but there is to date no nationally accepted classification system that can be satisfactorily applied to a national wetland inventory. In many instances, wetland classification systems have been developed for specific regions of South Africa and thus cannot account for the enormous variation in wetland types throughout the country (e.g. Jones & Day 2003 – Western Cape; Dely *et al.* 1999 – Natal Drakensberg; Marnewick & Batchelor 2002 – Upper Olifants River area in Mpumalanga). In other instances, wetland classification systems are based on structural features (both abiotic and biotic) such as size and vegetation cover (e.g. Dini *et al*. 1998; Dini & Cowan 2000; Thompson *et al.* 2002). While these approaches are useful within specific contexts, an increasing number of wetland managers and scientists in South Africa have expressed the need for a classification system that groups wetlands primarily according to the abiotic features that drive their functionality and, secondarily, according to the biotic features appropriate for detailed levels of classification.

What do we mean by "classification"?

Wetland classification refers to the process of *typing* wetlands according to their biophysical characteristics and the way in which they function.

This system should not be confused with the National Water Resource Classification System (NWRCS) of the Department of Water Affairs and Forestry (DWAF), which is the process of classifying every water resource in South Africa in a complex set of technical and social interactions, to be used to guide resource development.

The present initiative endeavours to address the above-mentioned issues by reviewing existing wetland classification systems, both internationally and within South Africa

(Appendix 1), as a basis for the development of a classification system that can be satisfactorily applied to all parts of South Africa.

1.2 Terms of Reference

The Terms of Reference agreed upon for the current project were as follows:

1) Evaluate a) the efficacy of the advanced wetland layer (AWL) of the NLC 2000 for identifying existing wetlands, and b) the type of information about a given wetland that is generated from this layer.
2) Develop a wetland classification system at a national level, based on the information that can be obtained from the NLC 2000 AWL.
3) Identify research and development priorities, and draft terms of reference for the testing, refinement and application of the proposed classification system.

Initially, it was envisaged that the AWL of the NLC 2000 would provide biophysical information that would inform the selection of criteria that could be used to distinguish one wetland unit from another and thus form the basis of the classification system. Consultation with the development team of the AWL, however, indicated that no biophysical information (necessary to discriminate one wetland unit from another) is available at this stage of the development (see section 1.4). The current project has therefore aimed at developing a classification system that will be of use to wetland scientists and managers, instead of being guided primarily by the information that is available from satellite imagery. The classification system that has been developed provides a basis for establishing the attribute information required to describe and classify wetland units identified by the national wetland inventory.

1.3 Approach

It is recognised that several classification systems already exist which could be modified or updated to accommodate the complex variety of wetlands in South Africa. Consequently, the current study relied heavily on a review of existing international and national literature of wetland classification systems that have been applied in the context of wetland inventories (see Appendix 1).

Key people involved in wetland research and the conservation and management of wetlands in South Africa were consulted. This provided an understanding of what is required from a wetland classification system and what the limitations or advantages of existing classification systems are for application to wetlands in South Africa. Also, specialists from the CSIR involved with the development of the AWL of the NLC 2000 were consulted about the extent to which the AWL reflects the distribution of wetlands throughout South Africa and about the type of information that is generated from the AWL as a source of information for classification.

Both the literature review and the process of consultation were used to develop a prototype classification system for application to the AWL. The prototype then provided the basis for discussion during a specialist workshop held in Pretoria on 1 December 2005. The workshop proceedings (Appendix 2) were used to generate a wetland classification system and terms of reference for further development, testing and refinement of the classification system.

1.4 The advanced wetland layer

As part of the NLC 2000 project, a wetland data layer known as the "advanced wetland layer" (AWL) is under development. It is envisaged by the national wetlands inventory committee that the AWL, once fully developed, will form the baseline from which the South African national wetland inventory will be built.

The AWL is built primarily on five of the land-cover classes generated by the standard NLC 2000 coverage, namely Shrubland and Low Fynbos, Unimproved (natural) Grassland, Improved Grassland, Waterbodies, and Wetlands (see Appendix 3 for detailed descriptions). These five land-cover classes are considered to be the classes that could potentially contain wetlands. All other land-cover classes are excluded from further data processing, as it is assumed either that no wetlands occur within them or that the identification of wetlands within these classes would not be possible using the remote sensing techniques being used for the project (Thompson *et al*. 2002). In these cases, a given area could not be simultaneously mapped as any other land-cover class and as a wetland, since the two are considered to be mutually incompatible. For example, urban and forested land-cover classes are not considered, although wetlands within urban and forested areas will be mapped if they are large enough and distinct enough to be distinguished from the adjacent urban and forested land-cover classes.

In order to enhance the accuracy of the wetland data generated by the NLC 2000 project, additional mapping and modelling techniques, as documented in Thompson *et al.* (2002), are applied to the basic wetland data to generate the AWL. Essentially, spectral data that indicate "greenness" and "wetness" are derived from two satellite overpasses taken at different times of the year (i.e. different seasons) and these are used, together with terrain-based hydrological modelling, to predict where wetlands are likely to occur within the five pre-selected land-cover classes. The terrain-based hydrological modelling exercise uses information from a digital elevation model (DEM) (including elevation, flow accumulation, sinks and topographic position) to generate an index of "landscape wetness potential", which predicts, on a scale of 1 to 5, those areas in the landscape where water is most likely to accumulate (T. Landmann and L. Poti, CSIR, Pretoria, pers. comm.).

1.4.1 Efficacy of the advanced wetland layer for identifying existing wetlands

One of the major challenges of any approach to compiling a wetland inventory is finding an acceptable compromise between the costs involved in detecting and delineating wetlands and generating wetland data that are accurate and reliable. The techniques used in the NLC 2000 survey have considerable advantages in terms of providing an overview of wetland distribution and facilitating the creation of a wetland inventory at a national level. Using multi-temporal data sets, for example, rather than single-date imagery to enhance seasonal differences between wetland and non-wetland areas can considerably enhance the ability to detect seasonal wetlands and reduce cloud contamination. However, there are several limitations associated with the techniques used to generate the AWL, and the extent to which the AWL accurately reflects wetland areas on the ground is affected by several different factors.

Firstly, the ability of the AWL to detect wetlands is constrained by the satellite sensor system used and by the 30-meter pixel resolution as well as the minimum mapping unit (1-2 ha) of the NLC 2000 database. As a result of these limitations, all small wetlands (< 2 ha in aerial extent) are effectively excluded from the AWL, even though small wetlands may be of considerable functional and ecological significance in the landscape.

An important consideration with regard to the efficacy of the AWL is that the use of spectral signatures such as “greenness” and “wetness” assumes that all wetlands are either green (i.e. vegetated) or have open water (i.e. are inundated), whereas in reality many of South Africa’s wetlands in the arid and semi-arid regions are not *always* characterised by one of these two features. A related issue is that regional differences in biotic features such as vegetation growth-forms considerably influence the ability of the modelling and mapping techniques used to detect wetlands within the AWL. Based on the premise that wetlands are indistinguishable in land-cover classes other than the five classes used from the NLC 2000 (using spectral signatures of “greenness” and “wetness”), certain areas of South Africa are excluded from the basic AWL. For example, forested wetlands are excluded from the layer because the land-cover class of “Forest” is not included in the input map as the basis for the modelling process. Similarly, if temporary wetlands in the arid regions of South Africa were not detected as “waterbodies” during the development of the NLC 2000 map, then they are excluded from the AWL because they may be classified as “natural bare rock or soil” in the NLC 2000 map. According to the development team, the AWL model exhibits an accuracy level of between 70 and 90 % in grassland areas, short fynbos and along waterbodies because these features are relatively easy to detect using spectral signatures of “wetness” and “greenness”. In all other landscape feature areas where wetlands are not defined by “wetness” and “greenness”, the model is considered highly inaccurate (L. Poti, CSIR, Pretoria, pers. comm.). Unfortunately, it is not possible to predict the level of accuracy within these areas at this stage. Modelling of ‘landscape wetness potential’ is undertaken independently of the satellite image analysis, however, and is therefore not influenced by any spectrally defined parameters. Consequently, the model output might be used to predict likely wetland occurrence in areas that have been excluded from the five land-cover classes.

With regards to terrain features, it is evident that steep slopes in mountainous areas create topographic shadows that reduce the ability of the AWL to distinguish areas of “wetness” and “greenness” from the model. Also, fire scars limit interpretation of information in the model and, where fire scars occur, the sensitivity of the model has to be altered. Even with fine tuning of the model, however, interpretation is still relatively difficult and can contribute to inaccuracies in the detection of potential wetlands.

The model that generates the AWL does not actually delineate wetland boundaries, but rather, it predicts the probability of an area being classified as a wetland based on either its spectral characteristics in terms of “wetness” and “greenness” or where water is likely to accumulate based on position in the landscape. The wetland data generated from remote sensing techniques therefore needs to be validated using expert judgement and groundtruthing. For example, through the involvement of an expert for the north-eastern portion of the country, it became evident that such involvement could significantly improve the accuracy of the AWL (L. Poti, CSIR, Pretoria, pers. comm.). Consequently, a similar process of involving experts and groundtruthing is currently being applied to the rest of the country and will considerably enhance the accuracy with which wetlands are reflected and delineated in the AWL.

While remote sensing techniques using Landsat imagery may provide a first step in the development of a national wetland inventory, it is evident that additional data sources will be necessary to increase the degree to which the AWL accurately reflects the distribution and extent of wetlands in some parts of South Africa. These considerations are being addressed by the National Wetlands Inventory project team who are in the process of initiating an accuracy assessment of the AWL. It is envisaged that this assessment will provide a means of assigning a confidence rating to the predictions of the AWL so that the extent to which additional data sources and mapping techniques are necessary for different areas can be established.

1.4.2 Information generated by the advanced wetland layer

A prerequisite for classifying wetlands according to any classification system is biophysical information, which can be used to discriminate one unit from another and to group those units with similar attributes. The techniques used to develop the AWL are unfortunately limited to producing a map showing the spatial extent and distribution of potential wetlands, and does not include any further biophysical information about individual wetlands. For each wetland unit mapped within the AWL, no information is generated about the actual data used to distinguish it as a probable wetland. There is, however, the potential to derive attribute information for each wetland unit from the original data sources used to generate the AWL. These data can be augmented by existing geographical data, such as relevant GIS-based coverages, to develop information that could be used to discriminate between wetland types for the purposes of classification.

Based on a cursory understanding of the original data sources used to generate the AWL (obtained through consultation with the developers) and a review of the pilot study undertaken to develop and test a method for developing the national wetland inventory for South Africa (Thompson *et al.* 2002), the following were identified as potentially useful sources of attribute information for assigning wetland units to a specific class:

- *Gradient or slope,* which can be calculated from the DEM.
- *Position in the landscape*. The terrain-based analysis can be used to generate topographic characteristics such as ridge tops, valleys, mid-slopes, footslopes, upper-slopes and flat surfaces from the DEM.
- *Depressions or sinks.*
- *Greenness and wetness* spectral signatures.

Other data that could be used to supplement the original data sources (most of which are available in GIS-based format) include:

- aquatic ecosystem features (from 1: 50 000 topographical maps);
- the extent and distribution of estuaries within South Africa;
- potential groundwater-dependent ecosystems;
- geology (lithostratigraphic units); and
- vegetation types.

The above list is by no means inclusive, and establishing the attribute information that is required for linking wetland units from the AWL to the agreed-upon national wetland classification system will require an iterative process of collaboration between several groups of people. At the very least, this should involve those with the technical expertise to interrogate geographical data sources at several different levels, ranging from remote sensing through to detailed aerial photography, and wetland specialists who understand the biophysical characteristics that permit wetland units to be grouped.

2 PROPOSED CLASSIFICATION SYSTEM

2.1 Basis of proposed classification system

Central to the development of any wetland classification system is the definition of the term 'wetland' and of terms to describe different kinds of wetlands. The definition of the term 'wetland' has been the subject of much debate, with no universal agreement to date as to what constitutes a wetland (see Appendix 1).

One of the most widely accepted definitions is that of the Ramsar Convention whereby wetlands are defined as "*areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres*" (Davis 1994). This is a very broad definition, with most other widely used definitions of the term 'wetland' being more restrictive than the Ramsar definition because of the practicalities associated with using a more precise definition (Dini and Cowan 2000). For example, Cowardin *et al*. (1979) define wetlands as "*lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water*" and stipulate that, in order for an area to be classified as a wetland, it must meet at least one of the following criteria: 1) *at least periodically, the land supports predominantly hydrophytes;* 2) *the substrate is predominantly undrained hydric soil;* and/or 3) *the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season.* Cowardin *et al*. (1979) define 'deepwater habitats' as "*permanently flooded lands lying below the deepwater boundary of wetlands. They include environments where surface water is permanent and often deep, so that water, rather than air, is the principal medium within which the dominant organisms live, whether or not they are attached to the substrate*." Together, Cowardin *et al*.'s (1979) wetlands and deepwater habitats more or less constitute wetlands as defined by the Ramsar Convention.

South Africa is a signatory to the Ramsar Convention and therefore its extremely broad definition of wetlands has been adopted as the basis for development of a classification system for South Africa with a slight adaptation: whereas the Ramsar Convention includes marine water to a depth of 6 m, the definition used to define wetlands for the proposed classification system extends to a depth of 10 m because this defines the depth of the shallow photic zone (Lombard *et al.* 2005, see proceedings of specialist workshop in Appendix 2). This definition therefore encompasses *all* ecosystems characterised by the permanent or periodic presence of water other than marine waters deeper than 10 m. Nevertheless, the only legislated definition of wetlands in South Africa is contained within the National Water Act (Act No. 36 of 1998) where wetlands are defined as "*land which is transitional between terrestrial and aquatic systems, where the water table is usually at, or near the surface, or the land is periodically covered with shallow water and which land in normal circumstances supports, or would support, vegetation adapted to life in saturated* *soil*." This definition is consistent with more precise working definitions of wetlands and therefore includes only a subset of ecosystems encapsulated in the Ramsar definition. For the compilation of the National Wetland Inventory, the definition of wetlands according to the National Water Act will be used as a starting point. The full suite of wetlands according to the Ramsar definition can then be added to the inventory at a later date to make it more inclusive.

Previous efforts to develop a national wetland classification system for South Africa (Dini *et al.* 1998; Dini & Cowan 2000) have used the Cowardin and MedWet systems as a starting point, with adaptations to accommodate specific conditions in this country (see literature review in Appendix 1). Wetland classification systems based on the Cowardin approach, at the broadest level of "System", rely on the use of structural features that are relatively easy to identify from aerial photography such as size, depth, vegetation cover and presence of surface water. While Cowardin-based approaches have the advantage of being relatively easy to use for identifying wetlands from remote sources, they do not group wetlands effectively in terms of functional features and thus their usefulness in managing wetlands is limited (Brinson 1993; Sheldon *et al*. 2003; Tiner 1999, 2003). Also, the use of a mixture of abiotic and biotic features at the broadest levels of the classification can lead to confusion and inconsistent categorisations (Semeniuk & Semeniuk 1995), especially in a country like South Africa where the variety of wetland types is enormous.

Landform and hydrology are the two fundamental features that determine the existence of all wetlands, regardless of climate, soils, vegetation or origin (Brinson 1993; Semeniuk & Semeniuk 1995; Finlayson *et al.* 2002; Jones 2002; Kotze *et al.* 2005, Ellery *et al.* 2005). This is the basic premise on which the hydrogeomorphic (HGM) classification system for wetlands was developed (Brinson 1993), and forms the basis of the HGM approach to the functional assessment of wetlands (Kotze *et al*. 1995). As the key determinants of wetland structure, it follows that geomorphic and hydrological features should be the primary discriminators of wetland type at the broadest level of classification. Although Dini & Cowan (2000) considered geomorphic and hydrological aspects within the Cowardin framework, the broadest level of their classification (i.e. at the level of Systems) still invokes biotic criteria such as vegetation cover, which can result in ambiguities when applying the classification system to some non-permanent wetland ecosystems, for example.

Internationally, there is general agreement that wetland classification systems based on geomorphic and hydrologic aspects are far more robust and consistent than classification systems based on other criteria, at least at the broader levels of classification (Finlayson *et al.* 2002). Advances in modelling and remote sensing tools in recent years have allowed the detection of abiotic features such as drainage, landform, gradient and hydroperiod, thus permitting the application of HGM-based classification systems to national wetland inventories. Although the Cowardin system and adaptations of this system are still in use for national inventories in the United States (Tiner 1999) and the Mediterranean (Farinha *et al.* 1996, 2005), there seems to be a move towards the HGM approach to wetland classification

(Finlayson *et al.* 2003). Thus, the classification system that we propose for South Africa is based on the principles of the HGM approach to wetland classification but attempts to incorporate aspects of the Cowardin system, including local adaptations as previously applied in South Africa (e.g. Dini & Cowan 2000) and recently adopted by the MedWet System (Farinha *et al.* 2005).

2.2 Structure of the proposed classification system

The structure of the classification system is hierarchical, and organised according to landform and hydrological characteristics as the primary determinants of ecological character and the functions that wetlands perform. The hierarchy progresses from Systems at the most general level through Subsystems to Functional, Structural and Habitat Units at increasingly finer levels of detail (Figure 2.1). Each level in the hierarchy is based on one or more "discriminators" that distinguish one wetland type from another (see section 2.2.1). Additional information, or "descriptors" about a given wetland unit can be applied at any level in the classification hierarchy, thereby facilitating the classification process and providing information that may be useful in specific cases (see section 2.2.5).

Discriminators

Discriminators are those criteria that are used to distinguish one wetland from another and are applied consistently at each level of the hierarchy.
Primary discriminators
distinguish Functional Units.
Secondary discriminators
distinguish Structural Units.
Tertiary discriminators
distinguish Habitat Units.

Descriptors

Descriptors provide additional information about a wetland unit and can be applied at any level of the hierarchy, depending on the purpose of classification.

Where applicable, existing wetland classifications that are being used in specific regions of South Africa and/or for specific purposes have been incorporated into the proposed classification system at different levels of the hierarchy. In particular, use has been made of components of the HGM-based wetland classification systems developed by Jones & Day (2003), Kotze *et al.* (2005) and Sieben *et al.* (in progress). In addition, components of the classification system of Dini & Cowan (2000), which is based on the Cowardin approach and recently incorporated into the MedWet Habitat Description System (Farinha *et al.* 2005), have been incorporated at the finer levels of the hierarchy. The estuarine classification system of Whitfield (1992) has been used as a basis for the estuarine component of the proposed classification system.

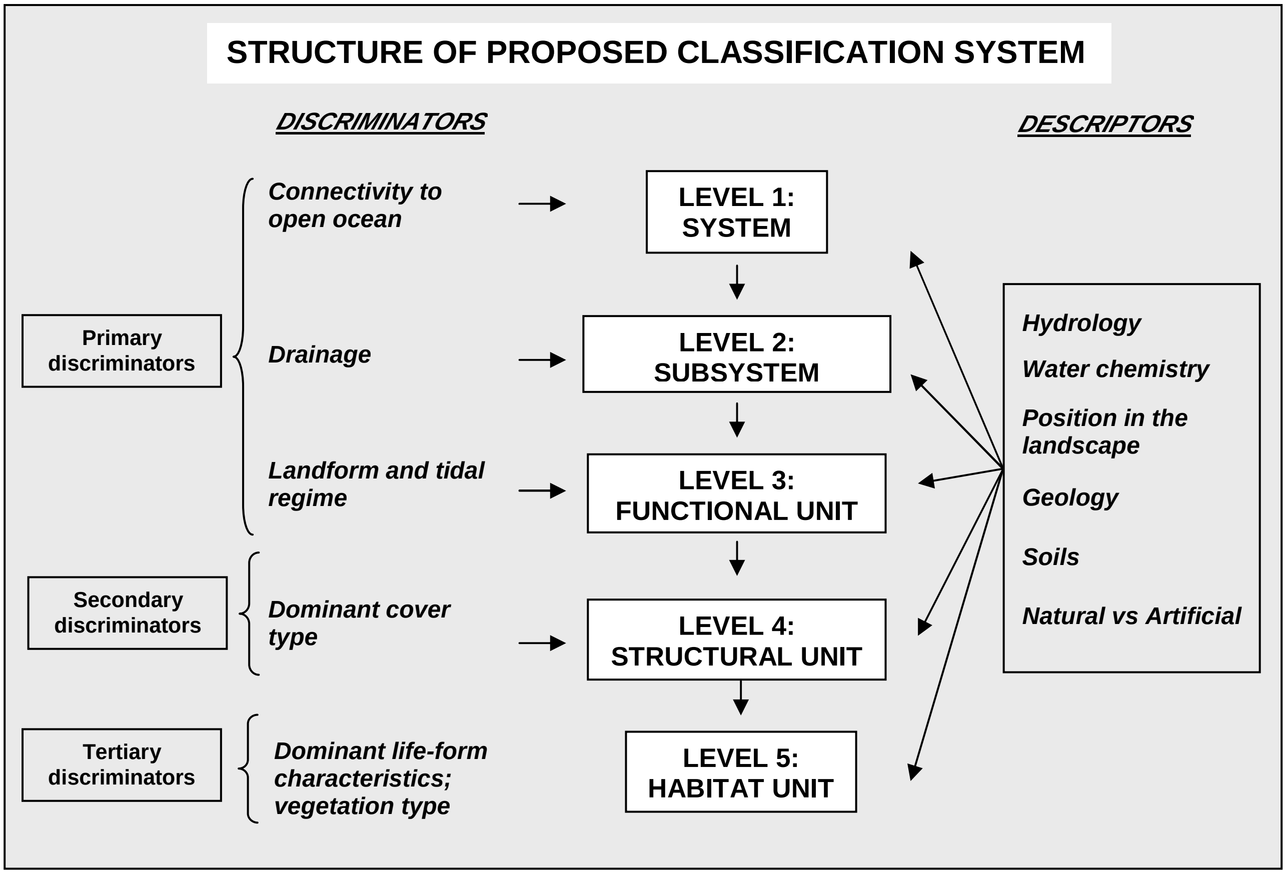

Figure 2.1: Basic structure of the proposed classification system showing how specific discriminators operate at each level in the hierarchy, while descriptors can be used to add additional information (if available) at different levels but are not essential for classifying wetlands.

2.2.1 Discriminators of wetland types at each level of classification

In the section below, an explanation is provided of the discriminators that are used to distinguish between Systems, Subsystems, Functional Units, Structural Units and Habitat Units at the respective levels of the proposed classification system.

<u>Level 1: Systems</u>

At the Systems level of the proposed classification system, a distinction is made between Marine, Estuarine and Inland ecosystems using the level of connectivity to the open ocean as a discriminator of the biophysical character of each (Table 2.1). These systems share the influence of similar hydrologic, geomorphic, chemical and biological factors and thus broadly exhibit differences in their biota and in the abiotic processes and interactions that determine the functional and structural character of each.

Table 2.1: Proposed Level 1 (Systems) classification for wetlands in South Africa

→	**LEVEL 1** **Primary Discriminator:** ***Connectivity to open ocean***
WETLANDS	**MARINE SYSTEMS** Ecosystems that are located along the coastline, and are part of the open ocean overlying the continental shelf and/or its associated coastline.
	ESTUARINE SYSTEMS Partially enclosed ecosystems that are permanently or periodically connected to the ocean, which are influenced by tidal fluctuations and within which ocean water is at least occasionally diluted by fresh water derived from surface or subsurface land drainage.
	INLAND SYSTEMS Ecosystems that are permanently or periodically inundated or saturated and have no existing connection to the ocean, and are therefore characterised by the complete absence of marine exchange and/or tidal influence.

<u>Level 2: Subsystems</u>

At Level 2 of the proposed classification system (i.e. Subsystems), tidal exchange is used as the key discriminator to distinguish between different types of Estuarine Systems, while drainage pattern is used as the key discriminator for Inland Systems (Table 2.2). Level 2 classification into subsystems is not applicable to Marine Systems. For Estuarine Systems, subsystems are distinguished on the basis of whether an estuary is permanently open or temporarily closed/open, which provides an indication of the degree of marine exchange and the residence time of either fresh or sea water. In the case of Inland Systems, subsystems are distinguished on the basis of whether they are linked to a drainage network via surface water (Non-isolated Subsystems) or not (Isolated Subsystems). The classification of inland systems into non-isolated and Isolated Subsystems was, to some extent, disputed by some wetland managers and scientists and therefore it is recommended that this distinction be further investigated as part of the proposed testing and refinement of the classification outlined in section 3.

Subsystems are to greater or lesser degree (depending on the system in question) functionally distinct units. For example, both biotic and water chemistry characteristics are controlled by tidal exchange (in the case of estuaries) and drainage (in the case of inland wetlands), which results in structurally different wetlands in terms of their biological and limnological characteristics (Jones and Day 2003). Furthermore, in the case of Inland Systems, Non-isolated Subsystems tend to transport sediment, while Isolated Subsystems retain and accumulate sediment and other material (Wilkinson 1988).

<u>Level 3: Functional Units</u>

At Level 3 of the proposed classification system, Functional Units are distinguished on the basis of several different discriminators, which vary between the different Systems (Table 2.2). Landform shape (i.e. the wetland “container”, according to Semeniuk & Semeniuk 1995) and setting (i.e. gradient and position relative to other units) are the primary discriminators common to all Systems (i.e. Marine, Estuarine and Inland) and, together, these factors determine the nature of water movement into, through and out of the ecosystem. The nature of the inputs, throughputs and outputs of water, in turn, affect the geomorphological processes such as erosion and deposition, and biogeochemical processes within wetlands.

In the case of Marine and Estuarine Systems, Functional Units are also determined by the tidal regime because the periodicity of inundation directly affects the biotic characteristics of a wetland. With the proposed classification system, a distinction is made between subtidal, intertidal and supratidal Functional Units for both Marine and Estuarine Systems. Provision is also made for Temporarily Closed Estuaries to be classified according to their depth class (i.e. littoral vs. limnetic) when they are closed because the tidal regime is not applicable in that state.

Hydroperiod, as an additional primary discriminator, was considered for inclusion to distinguish between Functional Units within Inland Systems because the frequency and degree of inundation are important characteristics that define wetlands. Nevertheless, hydroperiod is often difficult to determine without multi-temporal datasets, often requiring detailed infield data collection (J. Dini, SANBI, pers. comm.). There was, therefore, no unanimous agreement at the specialist workshop (Appendix 2) on whether or not to include hydroperiod as a discriminator. Although hydroperiod has been included as a descriptor (see section 2.2.5), rather than a discriminator in the proposed classification system, it is strongly recommended that the validity of whether or not to include hydroperiod as a discriminator be tested further (see section 3).

Table 2.2: Proposed wetland classification system for South Africa, showing the classification hierarchy as far as Level 3 (Functional Units).

LEVEL 1: SYSTEM	LEVEL 2: SUBSYSTEM	LEVEL 3: FUNCTIONAL UNIT		
		A	B	C
Primary discriminators				
Connectivity to open ocean	*Drainage*	*Landform (shape and/or setting)*		*Tidal regime / Depth class*
MARINE	**N/A**	**Exposed Coast**		**Subtidal**
				Intertidal
				Supratidal
		Sheltered Coast (Embayment)		**Subtidal**
				Intertidal
				Supratidal
ESTUARINE	**Permanently Open**	**Estuarine Bay**		**Subtidal**
				Intertidal
				Supratidal
		Estuarine Depression		**Subtidal**
				Intertidal
				Supratidal
		Estuarine Channel		**Subtidal**
				Intertidal
				Supratidal
		River Mouth		**Subtidal**
				Intertidal
				Supratidal
	Temporarily Closed	**Estuarine Depression**		**Subtidal (open) / Limnetic (closed)**
				Intertidal (open) / Littoral (closed)
				Supratidal
		Estuarine Channel		**Subtidal (open) / Limnetic (closed)**
				Intertidal (open) / Littoral (closed)
				Supratidal
INLAND	**Non-isolated**	**Channel (river)**	**Mountain headwater**	
			Mountain stream	
			Transitional	
			Upper foothill	
			Lower foothill	
			Lowland stream	
		Valley bottom	**With channel**	
			Without channel	
		Floodplain	**Meander cut-off**	
			Floodplain flat	
			Floodplain pan	
		Depression linked to a channel	**With channelled outflow**	
			Without channelled outflow	
		Seep with channelled outflow	**Basin seep**	
			Hillslope seep	
	Isolated	**Isolated depression**		
		Seep without channelled outflow	**Basin seep**	
			Hillslope seep	

<u>Level 4: Structural Units</u>

At Level 4 of the proposed classification system, Structural Units are distinguished on the basis of dominant cover type (substratum, surface/subsurface vegetation or emergent vegetation). In areas that are unvegetated or sparsely vegetated, the dominant cover is further distinguished in terms of the substratum size characteristics, while for those areas that are predominantly covered by a life-form (i.e. faunal cover or vegetation of some kind), the dominant cover is further distinguished in terms of specific life-form structure. Cover characteristics affect the habitat characteristics that determine the composition of the wetland biota and the biological functions that it can perform. Structural Units, therefore, form the basis for distinguishing Habitat Units at a finer level of the hierarchy (i.e. Level 5).

Level 5: Habitat Units

Habitat Units discriminate between specific habitat characteristics such as the dominant vegetation characteristics. For example, wetland units defined as herbaceous vegetation at the level of Structural Unit (see certain Inland Systems in section 2.2.4) can be further divided into sedge, grass, reed etc wetland types at the level of Habitat Unit. Development of Habitat Units is beyond the scope of this phase of the current project, which is aimed primarily at the development of a classification system for application to the national wetland inventory and not at high-resolution, on-site wetland mapping. Habitat Units would be a useful distinction to make at a finer level of the hierarchy because these units would form the basis of understanding the biotic integrity of a wetland ecosystem. The classification of a wetland into Habitat Units can only be undertaken with high-resolution colour aerial photography and extensive groundtruthing.

Three systems are identified at the broadest level of the classification, namely, Marine Systems, Estuarine Systems and Inland Systems. The more detailed levels of the hierarchy are described separately for each of these systems, below, and summarised in Tables 2.2 to 2.7.

2.2.2 Marine Systems

Examples of **Marine Systems** include coral reefs, rocky shores, wave cut platforms and sandy or pebble beaches

Marine Systems encompass ecosystems that are part of the open ocean overlying the continental shelf and/or its associated coastline, but not exceeding a depth of 10 m at low tide - i.e. not extending beyond the shallow photic zone, as described by the South African National Spatial Biodiversity Assessment 2004 (Lombard *et al.* 2005).

Level 2: Subsystems

This level in the hierarchy is not applicable to Marine Systems because they are open systems and, therefore, cannot be defined according to drainage patterns or tidal exchange.

Level 3: Functional Units

The Functional Units of Marine Systems are delimited firstly by landform, where landform is defined by the shape of the coastline that influences exposure to wave action. Semi-enclosed or concave forms are considered Sheltered Shores (or Embayments), whereas Exposed Shores are linear or convex features along the coastline. Secondly, Functional Units are defined by the tidal regime that determines the periodicity and inundation of the unit.

Landform:

- ***Sheltered Shore:*** A marine area where wave energy is appreciably reduced by landform.
- ***Exposed Shore*:** A marine area that is subject to significant wave energy.

Tidal regime:

- [*]***Subtidal*:** the area below mean spring low tide, where the substratum is continuously covered with water (i.e. always submerged).
- ***Intertidal*:** the area between mean spring low tide and mean spring high tide, where the substratum is alternately flooded and exposed by tides (i.e. periodically submerged).
- ***Supratidal:*** the area above mean spring high tide, where the substratum is occasionally submerged, usually during extreme tidal events.

Level 4: Structural Units

The Structural Units within Functional Units are divided on the basis of substratum type and dominant life-form, as follows:

Substratum size and character:

- ***Consolidated substratum (rock):*** Substratum with greater than 50% surface area coverage of bedrock.
- ***Unconsolidated substratum*:** Substratum with greater than 50% surface area coverage of unconsolidated particles. These Structural Units can be further divided on the basis of their substratum composition, as follows (measurements are for the beta axis):
    - *Boulders:* the substratum is dominated by particles with a size greater than 256 mm
    - *Cobbles:* the substratum is dominated by particles with a size range of 150 to 256 mm.
    - *Pebbles/Gravel:* the substratum is dominated by particles with a size range of 2 to 150 mm.
    - *Sand:* the substratum is dominated by particles with a size range of 0.06 to 2 mm.
    - *Mud/Silt*: the substratum is dominated by particles with a size less than 0.06 mm.
    - *Mixed substratum*: the substratum consists of a mixture of substratum sizes with none dominating in terms of surface area coverage.

Dominant life-form:

At this level, a further distinction is made between substrata covered by different life-forms (i.e. either faunal cover or vegetation) and those that are not (i.e. bare or sparsely covered). For Marine Systems, the presence of dominant life-forms (with coverage of more than 50%) is restricted to areas where the substratum is predominantly consolidated (i.e. bedrock), and include reefs and kelp defined as follows:

- ***Reef:*** ridge-like or mound-like structures formed by the colonisation and growth of sedentary invertebrates, which are elevated above the surrounding substrate and characteristically interfere with normal wave action. This includes reefs made of mollusc, worm or coral communities that cover more than 50% of the surface area.
- ***Kelp:*** large brown seaweed (algae), usually attached to consolidated substratum (Marine Systems only).

[*] NOTE: the subtidal zone of the Marine System corresponds approximately to the “shallow photic zone”, which is the marine area with constant light and turbulence that stretches from the mean spring low tide level to approximately 10 m depth (Lombard *et al.* 2005).

Table 2.3: Proposed classification structure for **Marine Systems**, showing the Structural Units for (a) Exposed Shores, and (b) Sheltered Shores

(a)

LEVEL 3: FUNCTIONAL UNIT		LEVEL 4: STRUCTURAL UNIT		
		A	B	C
		Secondary discriminators		
Landform (setting)	*Tidal regime*	*Dominant substratum type*		*Dominant life-form*
EXPOSED SHORE	Subtidal	Consolidated (bedrock)		With reef
				With kelp
				Without reef/kelp
		Unconsolidated	Boulders	
			Cobbles	
			Pebbles/Gravel	
			Sand	
		Mixed		
	Intertidal	Consolidated (bedrock)		With reef
				Without reef
		Unconsolidated	Boulders	
			Cobbles	
			Pebbles/Gravel	
			Sand	
		Mixed		
	Supratidal	Consolidated (bedrock)		
		Unconsolidated	Boulders	
			Cobbles	
			Pebbles/Gravel	
			Sand	
		Mixed		

(b)

LEVEL 3: FUNCTIONAL UNIT		LEVEL 4: STRUCTURAL UNIT		
		A	B	C
		Secondary discriminators		
Landform (setting)	*Tidal regime*	*Dominant substratum type*		*Dominant life-form*
SHELTERED SHORE (Embayment)	Subtidal	Consolidated (bedrock)		With reef
				With kelp
				Without reef/kelp
		Unconsolidated	Boulders	
			Cobbles	
			Pebbles/Gravel	
			Sand	
		Mixed		
	Intertidal	Consolidated (bedrock)		With reef
				Without reef
		Unconsolidated	Boulders	
			Cobbles	
			Pebbles/Gravel	
			Sand	
		Mixed		
	Supratidal	Consolidated (bedrock)		
		Unconsolidated	Boulders	
			Cobbles	
			Pebbles/Gravel	
			Sand	
		Mixed		

Examples of **Estuarine Systems** include lagoons, estuarine lakes and river mouths.

2.2.3 Estuarine Systems

Estuaries are partially enclosed ecosystems that are permanently or periodically connected to the ocean, which are influenced by tidal fluctuations and within which ocean water is at least occasionally diluted by fresh water derived from surface or subsurface land drainage.

Level 2: Subsystems

Estuarine subsystems are discriminated on the basis of tidal exchange so that permanently open estuaries are separated from those that are temporarily open/closed (Table 2.2).

- ***Permanently Open Estuaries*** have mouths that are permanently open to the sea with typical estuarine characteristics e.g. a moderate tidal prism (1-10 x 10^6 m^3), a horizontal salinity gradient and vertical salinity stratification. These subsystems are usually fed by perennial rivers (Whitfield 1992).
- ***Temporarily Closed Estuaries*** have mouths that are blocked off from the sea for varying lengths of time. These subsystems behave like typical estuaries when open and like shallow lakes when the mouth is closed but, when in flood, take on the characteristics of a river mouth. The tidal prism is small (<1 x 10^6 m^3) when the estuary is open and absent when it is closed (Whitfield 1992). These systems are usually fed by non-perennial rivers.

Level 3: Functional Units

Estuarine Functional Units are defined according to landform features and the tidal regime or depth class evident within each Subsystem (Table 2.2) as follows:

Landform:

- ***Estuarine Bay****:* Large, permanently open estuary (> 1000 hectares water surface area) that receives inflow from a riverine source but is dominated by tidal exchange (>10 x 10^6 m^3 spring tidal prism) through a deep mouth (> 3 m at mean sea level).
- ***Estuarine Depression:*** Estuarine lake system (>1000 hectares water surface area) situated in a coastal basin that is either permanently or intermittently linked to the sea.
- ***Estuarine Channel:*** Linear landform that is primarily confined to the channel of a drowned river valley and dominated by processes originating in the marine environment. It is either permanently or intermittently open to the sea.
- ***River mouth:*** Linear landform that is primarily confined to the channel of a drowned river valley and dominated by riverine processes. It is permanently open to the sea.

Tidal regime or depth class:

- ***Subtidal*****:** the area below mean spring low tide, where the substratum is continuously covered with water (i.e. always submerged).
- ***Intertidal*****:** the area between mean spring low tide and mean spring high tide, where the substratum is alternately flooded and exposed by tides (i.e. periodically submerged).

- ***Supratidal:*** the area above mean spring high tide, where the substratum is occasionally submerged, usually during extreme tidal events.

During periods of closure, Temporarily Closed Estuaries are not influenced by tidal processes and, therefore, they can be distinguished on the basis of depth at these times as follows:

- ***Littoral*:** An area covered by water with a depth of 2 m or less.
- ***Limnetic:*** An area covered by water deeper than 2 m.

Level 4: Structural Units

Estuarine Structural Units are defined firstly according to dominant cover type, and then by either the substratum size class or dominant life-form structure, whichever is applicable. The Structural Units relevant to Permanently Open Estuaries are given in Table 2.4 (a)–(d), while those for Temporarily Closed estuaries are given in Table 2.5 (a) & (b). The different categories are defined as follows:

- ***Rock / unconsolidated substratum:*** substratum with less than 50% surface area coverage by vegetation, which is therefore dominated by either bedrock (consolidated substratum) or unconsolidated particles. The rock / unconsolidated substratum category is further divided on the basis of the substratum size range or, in the case of bedrock, into areas with and without reef. Although salt crusts and peat formations are not strictly defined as substrata, they are included in this Structural Unit as unvegetated substrata. Definitions are as follows (measurements are for the beta axis):
    - o *Bedrock with reef:* the substratum is dominated by immovable slabs of rock (> the length of a tall person) with greater than 50% surface areas coverage by reef (with the same definition for reef as for Marine Systems).
    - o *Bedrock without reef:* the substratum is dominated by immovable slabs of rock (> the length of a tall person) that have less than 50 % surface area coverage with reef.
    - o *Boulders:* the substratum is dominated by particles with a size > 256 mm (range includes: inside armpit to wrist; ground to waist, length of a tall person).
    - o *Cobbles:* the substratum is dominated by particles with a size range of 150 to 256 mm (inside elbow to wrist).
    - o *Pebbles/Gravel:* the substratum is dominated by particles with a size range of 2 to 150 mm (range includes: finger nail size to size of a larger hand).
    - o *Sand:* the substratum is dominated by particles with a size range of 0.06 to 2 mm (course grit).
    - o *Mud/Silt:* the substratum is dominated by particles with a size less than 0.06 mm (very fine material).
    - o *Mixed substratum:* the substratum consists of a mixture of substratum sizes with none dominating in terms of surface area coverage.
    - o *Peat:* the substratum is dominated by partially decomposed organic debris that is compacted and saturated with water.

  - *Salt crust:* the substratum is dominated by a hard layer of alkali salts that usually form due to evaporation, which results in the concentration of naturally occurring salts.

- ***Surface/subsurface vegetation:*** Vegetated areas with greater than 50% surface area coverage dominated by plants that grow principally on or below the water surface for most of the growing season in most years. This type of vegetation is generally best developed in permanently or seasonally flooded areas or in areas subject to repeated flooding such as the intertidal zone of estuaries. This Structural Unit is further divided into the following categories:
  - *Floating vegetation:* dominated by plants that float freely in the water, on or below the water surface.
  - *Rooted vegetation*: dominated by plants that are rooted into or onto the underlying substratum.

- ***Emergent vegetation:*** Vegetated areas with greater than 50% surface area coverage dominated by rooted aquatic macrophytes that are either herbaceous or woody and which emerge beyond the water surface. This Structural Unit is further divided into the following categories:
  - *Herbaceous vegetation:* dominated by herbaceous hydrophytes, including sedges, grasses, reeds, herbs and restios.
  - *Scrub-shrub:* dominated by *w*oody vegetation less than 6 m tall, including true shrubs, young trees and trees or shrubs that are small or stunted as a result of environmental conditions.
  - *Forested*: dominated by woody vegetation greater than 6 m in height. These habitats normally possess an overstorey of trees, an understorey of young trees or shrubs and an herbaceous layer.

Table 2.4: Proposed classification structure for **Permanently Open Estuarine Subsystems**, showing the Structural Units for (a) Estuarine Bays, (b) Estuarine Depressions, (c) Estuarine Channels, and (d) River Mouths

(a)

LEVEL 3: FUNCTIONAL UNIT		LEVEL 4: STRUCTURAL UNIT	
		A	B
Landform (shape & setting)	*Tidal regime / Depth class*	Secondary discriminators	
		Dominant cover type	*Dominant substratum type / life-form*
ESTUARINE BAY	Subtidal	Rocky / unconsolidated substratum	Bedrock with reef
			Bedrock without reef
			Cobbles
			Pebbles/Gravel
			Sand
			Silt/Mud
			Mixed
		Surface/subsurface vegetation	Floating
			Rooted
		Emergent vegetation	Herbaceous
			Scrub-shrub
			Forested
	Intertidal	Rocky / unconsolidated substratum	Bedrock with reef
			Bedrock without reef
			Cobbles
			Pebbles/Gravel
			Sand
			Silt/Mud
			Mixed
			Peat
			Salt crust
		Surface/subsurface vegetation	Rooted
		Emergent vegetation	Herbaceous
			Scrub-shrub
			Forested
	Supratidal	Rocky / unconsolidated substratum	Bedrock with reef
			Bedrock without reef
			Cobbles
			Pebbles/Gravel
			Sand
			Silt/Mud
			Mixed
			Peat
			Salt crust
		Emergent vegetation	Herbaceous
			Scrub-shrub
			Forested

(b)

LEVEL 3: FUNCTIONAL UNIT		LEVEL 4: STRUCTURAL UNIT	
		A	B
Landform (shape & setting)	*Tidal regime / Depth class*	Secondary discriminators	
		Dominant cover type	*Dominant substratum type / life-form*
ESTUARINE DEPRESSION	Subtidal	Rocky / unconsolidated substratum	Bedrock with reef
			Bedrock without reef
			Cobbles
			Pebbles/Gravel
			Sand
			Silt/Mud
			Mixed
		Surface/subsurface vegetation	Floating
			Rooted
		Emergent vegetation	Herbaceous
			Scrub-shrub
			Forested
	Intertidal	Rocky / unconsolidated substratum	Bedrock with reef
			Bedrock without reef
			Cobbles
			Pebbles/Gravel
			Sand
			Silt/Mud
			Mixed
			Peat
			Salt crust
		Surface/subsurface vegetation	Rooted
		Emergent vegetation	Herbaceous
			Scrub-shrub
			Forested
	Supratidal	Rocky / unconsolidated substratum	Bedrock with reef
			Bedrock without reef
			Cobbles
			Pebbles/Gravel
			Sand
			Silt/Mud
			Mixed
			Peat
			Salt crust
		Emergent vegetation	Herbaceous
			Scrub-shrub
			Forested

Table 2.4 (cont.): Proposed classification structure for **Permanently Open Estuarine Subsystems**, showing the Structural Units for (a) Estuarine Bays, (b) Estuarine Depressions, (c) Estuarine Channels, and (d) River Mouths

(c)

LEVEL 3: FUNCTIONAL UNIT		LEVEL 4: STRUCTURAL UNIT	
		A	B
		Secondary discriminators	
Landform (shape & setting)	*Tidal regime / Depth class*	*Dominant cover type*	*Dominant substratum type / life-form*
ESTUARINE CHANNEL	Subtidal	Rocky / unconsolidated substratum	Bedrock with reef
			Bedrock without reef
			Cobbles
			Pebbles/Gravel
			Sand
			Silt/Mud
			Mixed
		Surface/subsurface vegetation	Floating
			Rooted
		Emergent vegetation	Herbaceous
			Scrub-shrub
			Forested
	Intertidal	Rocky / unconsolidated substratum	Bedrock with reef
			Bedrock without reef
			Cobbles
			Pebbles/Gravel
			Sand
			Silt/Mud
			Mixed
			Peat
			Salt crust
		Surface/subsurface vegetation	Rooted
		Emergent vegetation	Herbaceous
			Scrub-shrub
			Forested
	Supratidal	Rocky / unconsolidated substratum	Bedrock with reef
			Bedrock without reef
			Cobbles
			Pebbles/Gravel
			Sand
			Silt/Mud
			Mixed
			Peat
			Salt crust
		Emergent vegetation	Herbaceous
			Scrub-shrub
			Forested

(d)

LEVEL 3: FUNCTIONAL UNIT		LEVEL 4: STRUCTURAL UNIT	
		A	B
		Secondary discriminators	
Landform (shape & setting)	*Tidal regime / Depth class*	*Dominant cover type*	*Dominant substratum type / life-form*
RIVER MOUTH	Subtidal	Rocky / unconsolidated substratum	Bedrock with reef
			Bedrock without reef
			Cobbles
			Pebbles/Gravel
			Sand
			Silt/Mud
			Mixed
		Surface/subsurface vegetation	Floating
			Rooted
		Emergent vegetation	Herbaceous
			Scrub-shrub
			Forested
	Intertidal	Rocky / unconsolidated substratum	Bedrock with reef
			Bedrock without reef
			Cobbles
			Pebbles/Gravel
			Sand
			Silt/Mud
			Mixed
			Peat
			Salt crust
		Surface/subsurface vegetation	Rooted
		Emergent vegetation	Herbaceous
			Scrub-shrub
			Forested
	Supratidal	Rocky / unconsolidated substratum	Bedrock with reef
			Bedrock without reef
			Cobbles
			Pebbles/Gravel
			Sand
			Silt/Mud
			Mixed
			Peat
			Salt crust
		Emergent vegetation	Herbaceous
			Scrub-shrub
			Forested

Table 2.5: Proposed classification structure for **Temporarily Closed Estuarine Subsystems**, showing the Structural Units for (a) Estuarine Depressions, and (b) Estuarine Channels

(a)

LEVEL 3: FUNCTIONAL UNIT		LEVEL 4: STRUCTURAL UNIT	
		A	B
		Secondary discriminators	
Landform (shape & setting)	***Tidal regime / Depth class***	***Dominant cover type***	***Dominant substratum type / life-form***
ESTUARINE DEPRESSION	Subtidal (open) / Limnetic (closed)	Rocky / unconsolidated substratum	Bedrock with reef
			Bedrock without reef
			Cobbles
			Pebbles/Gravel
			Sand
			Silt/Mud
			Mixed
		Surface/subsurface vegetation	Floating
			Rooted
		Emergent vegetation	Herbaceous
			Scrub-shrub
			Forested
	Intertidal (open) / Littoral (closed)	Rocky / unconsolidated substratum	Bedrock with reef
			Bedrock without reef
			Cobbles
			Pebbles/Gravel
			Sand
			Silt/Mud
			Mixed
			Peat
			Salt crust
		Surface/subsurface vegetation	Rooted
		Emergent vegetation	Herbaceous
			Scrub-shrub
			Forested
	Supratidal	Rocky / unconsolidated substratum	Bedrock with reef
			Bedrock without reef
			Cobbles
			Pebbles/Gravel
			Sand
			Silt/Mud
			Mixed
			Peat
			Salt crust
		Emergent vegetation	Herbaceous
			Scrub-shrub
			Forested

(b)

LEVEL 3: FUNCTIONAL UNIT		LEVEL 4: STRUCTURAL UNIT	
		A	B
		Secondary discriminators	
Landform (shape & setting)	***Tidal regime / Depth class***	***Dominant cover type***	***Dominant substratum type / life-form***
ESTUARINE CHANNEL	Subtidal (open) / Limnetic (closed)	Rocky / unconsolidated substratum	Bedrock with reef
			Bedrock without reef
			Cobbles
			Pebbles/Gravel
			Sand
			Silt/Mud
			Mixed
			Peat
			Salt crust
		Surface/subsurface vegetation	Floating
			Rooted
		Emergent vegetation	Herbaceous
			Scrub-shrub
			Forested
	Intertidal (open) / Littoral (closed)	Rocky / unconsolidated substratum	Bedrock with reef
			Bedrock without reef
			Cobbles
			Pebbles/Gravel
			Sand
			Silt/Mud
			Mixed
			Peat
			Salt crust
		Surface/subsurface vegetation	Rooted
		Emergent vegetation	Herbaceous
			Scrub-shrub
			Forested
	Supratidal	Rocky / unconsolidated substratum	Bedrock with reef
			Bedrock without reef
			Cobbles
			Pebbles/Gravel
			Sand
			Silt/Mud
			Mixed
			Peat
			Salt crust
		Emergent vegetation	Herbaceous
			Scrub-shrub
			Forested

2.2.4 Inland Systems

Inland Systems include a wide range of wetland types ranging from rivers to seeps, pans, floodplains, marshes and

Inland systems include all ecosystems that are permanently or periodically inundated or saturated and have no existing connection to the ocean, and are therefore characterised by the complete absence of marine exchange and/or tidal influence. The largest diversity of wetland ecosystems occurs within this group.

Level 2: Subsystems

Subsystems discriminate between wetlands that are non-isolated (i.e. hydrologically connected by *surface* drainage features) and those that are hydrologically isolated in terms of *surface* flows (Table 2.2), with the respective definitions as follows:

- ***Non-isolated Subsystem:*** An Inland System that has an observable hydrological connection to a surface drainage network (i.e. Functional Units are connected via surface water movement).
- ***Isolated Subsystem:*** An Inland System that is hydrologically isolated in terms of surface water movement.

A typical non-isolated subsystem would be a hillslope seep feeding a river that spills into a floodplain during high flow conditions. A typical isolated subsystem would be a depression (e.g. a pan) that accumulates water from its immediate catchment or from groundwater but does not receive surface runoff from other Functional Units.

Level 3: Functional Units

The Functional Units for Inland Systems are separated into those that occur within Non-isolated Subsystems and those that occur within Isolated Subsystems (Table 2.2), as follows:

Functional Units within Non-isolated Subsystems

These are hydrologically linked units, defined as follows:

- ***Channel (river):*** Linear landform which, when inundated, usually carries flowing water. It includes the part of a river-bed containing its main current naturally shaped by the force of water flowing within it and its riparian fringe. Channels are subdivided further within this level of the hierarchy into six geomorphological zones, as defined by Rowntree and Wadeson (2000). These zones are based largely on gradient which influences flow velocity and channel characteristics such as substratum particle size that are important characteristics of riverine habitat types. The six geomorphological zones are described as follows (after Rowntree and Wadeson 2000):
  - *Mountain Headwater Stream:* a steep-gradient stream dominated by vertical flow over bedrock with waterfalls and plunge pools. It is normally a first- or second- order stream. Reach types include bedrock fall and cascades. Characteristic gradient: >0.1.
  - *Mountain Stream:* a steep-gradient stream dominated by bedrock and boulders, locally with cobble or coarse gravels in pools. Reach types include cascades,

bedrock fall and step-pool. There is an approximately equal distribution of 'vertical' and 'horizontal' flow components. Characteristic gradient: 0.04 - 0.99.

- *Transitional River*: a moderately steep stream dominated by bedrock and boulders. Reach types include plain-bed, pool-riffle and pool-rapid. Usually present in confined or semi-confined valleys with limited floodplain development. Characteristic gradient: 0.02-0.039.
- *Upper Foothill River:* a moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plain-bed, pool-riffle or pool-rapid reach types. The length of pools and riffles/rapids are similar. Usually present with a narrow floodplain of sand, gravel or cobble. Characteristic gradient: 0.005 - 0.019.
- *Lower Foothill River:* a lower-gradient mixed-bed alluvial channel with sand and gravel dominating the bed and sometimes locally bedrock-controlled. Reach types typically include pool-riffle or pool-rapid with sand bars common in pools. Pools are of significantly greater extent than rapids or riffles. A floodplain is often present. Characteristic gradient: 0.001-0.005.
- *Lowland River:* a low-gradient alluvial fine-bed channel. It may be confined, but has a fully developed meandering pattern within a distinct floodplain that develops in unconfined reaches where there is increased silt content in bed or banks. Characteristic gradient: 0.0001- 0.001.

- ***Valley bottom:*** A valley bottom is a Functional Unit at the bottom of a valley that receives water from an upstream channel and/or from adjacent hillslopes. The area is not subject to periodic over-bank flooding by a river channel. Valley bottoms are subdivided further into those with a channel and those without a channel as follows:
    - *Valley bottom with a channel:* a valley bottom area with a well defined stream channel but lacking characteristic floodplain features (e.g. levees and oxbow lakes). Water inputs are mainly from adjacent slopes, while the channel itself is not typically a major source of water for the wetland (Ellery *et al*. 2005).
    - *Valley bottom without a channel:* A valley bottom area of low relief with no clearly defined stream channel. It is usually characterised by alluvial sediment deposition, generally leading to a net accumulation of sediment. Water input is mainly from the upstream channel, as it widens and the flow becomes dispersed, although there can also be input from adjacent slopes (Ellery *et al*. 2005).

- ***Floodplain:*** Valley bottom area with a well defined stream channel that is gently sloped and characterised by the alluvial transport and deposition of sediment, usually leading to a net accumulation of sediment (Kotze *et al*. 2005). Water comes from the main channel when the channel banks overspill. Floodplains can be further divided on the basis of specific landform shapes, including:

  - *Meander cut-off:* a linear, bow-shaped depression that was once part of a meandering river channel and is subject to periodic over-bank flooding by the river.
  - *Floodplain flat:* a topographically homogenous area of little or no relief that experiences periodic flooding.
  - *Floodplain pan:* a shallow depression within the floodplain that experiences periodic over-bank flooding.

- ***Depression linked to a channel:*** Such a depression is a basin-shaped area that allows for the accumulation of surface water because the lowest point in the system is lower than the associated channel from which it receives and loses surface flow (Kotze *et al*. 2005). These depressions are characteristically linked by channels (i.e. true rivers) that transport water into and/or out of the depression. Depressions linked to a channel can be further subdivided into the following two types:
  - *Depression linked to a channel with channelled outflow:* a depression that receives surface water from a channel and has an outflow of surface water via a distinct channel.
  - *Depression linked to a channel without channelled outflow:* a depression that receives surface water from a channel but does not have a visible outflow of surface water via a distinct channel.

- ***Seep with channelled outflow:*** A saturated concave or convex area on a slope, either on a hillside or within a basin that is characterized by the colluvial movement of materials (i.e. transported by gravity). Water mainly comes from subsurface flow. Outflow is via a well defined stream channel connecting the area directly to the drainage network (Kotze *et al*. 2005, Ellery *et al*. 2005). Seeps can be further distinguished by their position in the landscape as follows:
  - *Basin seep:* a concave saturated area, generally occurring on gentle slopes characteristic of a valley floor or on relatively flat ground at the head of a valley.
  - *Hillslope seep:* a concave or convex saturated area, characterised by relatively steep slopes, usually on hillslopes.

Functional Units within Isolated Subsystems

These are hydrologically isolated units, which include discrete depressions and seepages that are not connected to a drainage network via surface inflows or outflows.

- ***Isolated depression*:** A basin-shaped area with a closed elevation contour that allows for the accumulation of water and is not connected via a surface inlet or outlet to the drainage network. i.e. it receives water by direct precipitation, groundwater or as limited runoff from the surrounding catchment but no channelled surface inflows or outflows are evident.

- ***Seep without channelled outflow:*** A saturated concave or convex area on a slope, either on hillsides or within basins that are characterized by the colluvial movement of materials (i.e. transported by gravity). Water inputs are mainly from subsurface flow but there is no discernable outflow via a channel. Seeps can be further distinguished based on their position in the landscape as follows:
    - o *Basin seep:* a concave saturated area, generally occurring on gentle slopes characteristic of a valley floor or on relatively flat ground at the head of a valley.
    - o *Hillslope seep:* a concave or convex saturated area, characterised by relatively steep slopes, usually on hillslopes.

Level 4: Structural Units

Structural Units for Inland Systems are defined firstly by dominant cover type, and then by either the substratum size or dominant life-form structure, whichever is applicable. The Structural Units within Non-isolated Subsystems are presented in Table 2.6 (a) to (e), while those for isolated subsystems are presented in Table 2.7 (a) & (b).

In the case of both non-isolated (i.e. channel-linked) and isolated depressions, water depth is the first of the secondary discriminators to divide the Functional Unit into structuralu because the depth of a system will determine whether or not rooted aquatic macrophytes can survive. The depth categories are defined as follows:

- ***Limnetic**:* an area that is covered by water deeper than 2 m.
- ***Littoral:*** an area extending from the inundated edge to a depth of 2 m.

The Structural Units for Inland Systems are then further categorised as follows:

- ***Rock / unconsolidated substratum:*** substratum with less than 50% surface area coverage by vegetation and is therefore dominated by either bedrock or unconsolidated particles. This Structural Unit is further divided on the basis of the substratum size range as follows (measurements are for the longest axis):
    - o *Bedrock:* the substratum is dominated by immovable slabs of bare rock (> the length of a tall person).
    - o *Boulders:* the substratum is dominated by particles with a size > 256 mm (range includes: inside armpit to wrist; ground to waist, length of a tall person).
    - o *Cobbles:* the substratum is dominated by particles with a size range of 150 to 256 mm (inside elbow to wrist).
    - o *Pebbles/Gravel:* the substratum is dominated by particles with a size range of 2 to 150 mm (range includes: finger nail size to size of a larger hand).
    - o *Sand*: the substratum is dominated by particles with a size range of 0.06 to 2 mm (course grit).
    - o *Mud/Silt:* the substratum is dominated by particles with a size less than 0.06 mm (very fine material).

  - *Mixed substratum:* the substratum consists of a mixture of substratum sizes with none dominating in terms of surface area coverage.
  - *Peat:* the substratum is dominated by partially decomposed organic debris that is compacted and saturated with water
  - *Salt crust:* the substratum is dominated by a hard layer of alkali salts that usually form due to evaporation and concentration of naturally occurring salts.

- ***Surface/subsurface vegetation:*** A vegetated area with greater than 50% surface area coverage dominated by plants that grow principally on or below the water surface for most of the growing season in most years. Surface/subsurface vegetation is generally best developed in permanent water or in seasonally flooded areas. This Structural Unit is further divided into the following categories:
  - *Floating vegetation:* dominated by plants that float freely in the water, on or below the water surface.
  - *Rooted vegetation:* dominated by plants that are rooted into or onto the underlying substratum.

- ***Emergent vegetation:*** a vegetated area with greater than 50% surface area coverage dominated by rooted aquatic macrophytes that are either herbaceous or woody and which emerge beyond the water surface. This Structural Unit is further divided into the following categories:
  - *Herbaceous vegetation:* dominated by herbaceous aquatic macrophytes, including sedges, grasses, reeds, herbs and restios.
  - *Scrub-shrub:* dominated by *w*oody vegetation less than 6 m tall, including true shrubs, young trees and trees or shrubs that are small or stunted as a result of environmental conditions.
  - *Forested*: dominated by woody vegetation greater than 6 m in height. These habitats normally possess an overstorey of trees, an understorey of young trees or shrubs and an herbaceous layer.

Table 2.6: Proposed classification structure for **Non-isolated Inland Subsystems**, showing the Structural Units for (a) Channels (rivers), (b) Valley Bottoms, (c) Floodplains, (d) Depressions linked to a channel, and (e) Seeps with channelled outflow

(a)

LEVEL 3: FUNCTIONAL UNIT		LEVEL 4: STRUCTURAL UNIT		
		A	B	C
		Secondary Discriminators		
Landform (shape) and setting		*Depth class*	*Dominant cover type*	*Dominant substratum type / life-form*
CHANNEL (river)	Mountain Headwater	N/A	Rocky / unconsolidated substratum	Bedrock
				Boulders
				Cobbles
				Pebbles/Gravel
				Mixed
			Emergent vegetation	Herbaceous
				Scrub-shrub
				Forested
	Mountain Stream	N/A	Rocky / unconsolidated substratum	Bedrock
				Boulders
				Cobbles
				Pebbles/Gravel
				Mixed
			Emergent vegetation	Herbaceous
				Scrub-shrub
				Forested
	Transitional	N/A	Rocky / unconsolidated substratum	Bedrock
				Boulders
				Cobbles
				Pebbles/Gravel
				Mixed
			Emergent vegetation	Herbaceous
				Scrub-shrub
				Forested
	Upper Foothill	N/A	Rocky / unconsolidated substratum	Bedrock
				Boulders
				Cobbles
				Pebbles/Gravel
				Sand
				Silt/Mud
				Mixed
			Emergent vegetation	Herbaceous
				Scrub-shrub
				Forested
	Lower Foothill	N/A	Rocky / unconsolidated substratum	Bedrock
				Boulders
				Cobbles
				Pebbles/Gravel
				Sand
				Silt/Mud
				Mixed
			Surface/subsurface vegetation	Floating
				Rooted
			Emergent vegetation	Herbaceous
				Scrub-shrub
				Forested
	Lowland stream	N/A	Rocky / unconsolidated substratum	Bedrock
				Boulders
				Cobbles
				Pebbles/Gravel
				Sand
				Silt/Mud
				Mixed
				Salt crust
			Surface/subsurface vegetation	Floating
				Rooted
			Emergent vegetation	Herbaceous
				Scrub-shrub
				Forested

Table 2.6 (cont.): Proposed classification structure for **Non-isolated Inland Subsystems**, showing the Structural Units for (a) Channels (rivers), (b) Valley bottoms, (c) Floodplains, (d) Depressions linked to a channel, and (e) Seeps with channelled outflow

(b)

LEVEL 3: FUNCTIONAL UNIT		LEVEL 4: STRUCTURAL UNIT		
		A	B	C
Landform (shape) and setting		Secondary discriminators		
		Depth class	*Dominant cover type*	*Dominant substratum type / life-form*
VALLEY BOTTOM	With channel	N/A	Rocky / unconsolidated substratum	Sand
				Silt/Mud
				Peat
			Emergent vegetation	Herbaceous
				Scrub-shrub
				Forested
	Without channel	N/A	Rocky / unconsolidated substratum	Sand
				Silt/Mud
				Peat
			Emergent vegetation	Herbaceous
				Scrub-shrub
				Forested

(c)

LEVEL 3: FUNCTIONAL UNIT		LEVEL 4: STRUCTURAL UNIT		
		A	B	C
Landform (shape) and setting		Secondary discriminators		
		Depth class	*Dominant cover type*	*Dominant substratum type / life-form*
FLOODPLAIN	Meander cut-off	N/A	Rocky / unconsolidated substratum	Sand
				Silt/Mud
				Mixed
				Salt crust
			Surface/subsurface vegetation	Floating
				Rooted
			Emergent vegetation	Herbaceous
				Scrub-shrub
				Forested
	Floodplain flat	N/A	Rocky / unconsolidated substratum	Bedrock
				Boulders
				Cobbles
				Pebbles/Gravel
				Sand
				Silt/Mud
				Mixed
				Salt crust
			Emergent vegetation	Herbaceous
				Scrub-shrub
				Forested
	Floodplain pan	N/A	Rocky / unconsolidated substratum	Sand
				Silt/Mud
				Mixed
				Salt crust
			Surface/subsurface vegetation	Floating
				Rooted
			Emergent vegetation	Herbaceous
				Scrub-shrub
				Forested

Table 2.6 (cont.): Proposed classification structure for **Non-isolated Inland Subsystems**, showing the Structural Units for (a) Channels (rivers), (b) Valley bottoms, (c) Floodplains, (d) Depressions linked to a channel, and (e) Seeps with channelled outflow

(d)

LEVEL 3: FUNCTIONAL UNIT		**LEVEL 4: STRUCTURAL UNIT**		
		A	**B**	**C**
Landform (shape) and setting		**Secondary discriminators**		
		Depth class	***Dominant cover type***	***Dominant substratum type / life-form***
DEPRESSION LINKED TO A CHANNEL	With channelled outflow	Littoral	Rocky / unconsolidated substratum	Pebbles/Gravel
				Sand
				Silt/Mud
			Surface/subsurface vegetation	Floating
				Rooted
			Emergent vegetation	Herbaceous
				Scrub-shrub
				Forested
		Limnetic	Unknown (open water)	
			Surface/subsurface vegetation	Floating
				Rooted
	Without channelled outflow	Littoral	Rocky / unconsolidated substratum	Pebbles/Gravel
				Sand
				Silt/Mud
			Surface/subsurface vegetation	Floating
				Rooted
			Emergent vegetation	Herbaceous
				Scrub-shrub
				Forested
		Limnetic	Unknown (open water)	
			Surface/subsurface vegetation	Floating
				Rooted

(e)

LEVEL 3: FUNCTIONAL UNIT		**LEVEL 4: STRUCTURAL UNIT**		
		A	**B**	**C**
Landform (shape) and setting		**Secondary discriminators**		
		Depth class	***Dominant cover type***	***Dominant substratum type / life-form***
SEEP WITH CHANNELLED OUTFLOW	Basin seep	N/A	Rocky / unconsolidated substratum	Sand
				Silt/Mud
				Peat
			Emergent vegetation	Herbaceous
				Scrub-shrub
				Forested
	Hillslope seep	N/A	Rocky / unconsolidated substratum	Sand
				Silt/Mud
			Emergent vegetation	Herbaceous
				Scrub-shrub
				Forested

Table 2.7: Proposed classification structure for **Isolated Inland Subsystems**, showing the Structural Units for (a) Isolated depressions, and (b) Seeps without channelled outflow

(a)

<table>
<tr><th rowspan="2">LEVEL 3: FUNCTIONAL UNIT</th><th colspan="3">LEVEL 4: STRUCTURAL UNIT</th></tr>
<tr><th>A</th><th>B</th><th>C</th></tr>
<tr><td rowspan="2">Landform (shape) and setting</td><td colspan="3">Secondary discriminators</td></tr>
<tr><td>Depth class</td><td>Dominant cover type</td><td>Dominant substratum type / life-form</td></tr>
<tr><td rowspan="14">ISOLATED DEPRESSION</td><td rowspan="10">Littoral</td><td rowspan="5">Rocky / unconsolidated substratum</td><td>Pebbles/Gravel</td></tr>
<tr><td>Sand</td></tr>
<tr><td>Silt/Mud</td></tr>
<tr><td>Peat</td></tr>
<tr><td>Salt crust</td></tr>
<tr><td rowspan="2">Surface/subsurface vegetation</td><td>Floating</td></tr>
<tr><td>Rooted</td></tr>
<tr><td rowspan="3">Emergent vegetation</td><td>Herbaceous</td></tr>
<tr><td>Scrub-shrub</td></tr>
<tr><td>Forested</td></tr>
<tr><td rowspan="3">Limnetic</td><td>Unknown (open water)</td><td></td></tr>
<tr><td rowspan="2">Surface/subsurface vegetation</td><td>Floating</td></tr>
<tr><td>Rooted</td></tr>
</table>

(b)

<table>
<tr><th colspan="2" rowspan="2">LEVEL 3: FUNCTIONAL UNIT</th><th colspan="3">LEVEL 4: STRUCTURAL UNIT</th></tr>
<tr><th>A</th><th>B</th><th>C</th></tr>
<tr><td colspan="2" rowspan="2">Landform (shape) and setting</td><td colspan="3">Secondary discriminators</td></tr>
<tr><td>Depth class</td><td>Dominant cover type</td><td>Dominant substratum type / life-form</td></tr>
<tr><td rowspan="10">SEEP WITHOUT CHANNELLED OUTFLOW</td><td rowspan="5">Basin seep</td><td rowspan="5">N/A</td><td rowspan="3">Rocky / unconsolidated substratum</td><td>Sand</td></tr>
<tr><td>Silt/Mud</td></tr>
<tr><td>Peat</td></tr>
<tr><td rowspan="2">Emergent vegetation</td><td>Herbaceous</td></tr>
<tr><td>Scrub-shrub</td></tr>
<tr><td rowspan="5">Hillslope seep</td><td rowspan="5">N/A</td><td rowspan="2">Rocky / unconsolidated substratum</td><td>Sand</td></tr>
<tr><td>Silt/Mud</td></tr>
<tr><td rowspan="3">Emergent vegetation</td><td>Herbaceous</td></tr>
<tr><td>Scrub-shrub</td></tr>
<tr><td>Forested</td></tr>
</table>

2.2.5 Descriptors

Descriptions of specific wetland units at any level in the hierarchy can provide useful information that may be necessary for certain purposes but not for others. For example, conservation planning would require a distinction between natural and man-made wetlands while such a distinction may not be necessary when assessing the functional value of wetlands. Descriptors can be applied at any level in the hierarchy, depending on the specific purpose for classification. In some cases, however, descriptors are specific to a certain level in the hierarchy and simply provide an opportunity to add additional information where such information is available. For example, it may not be possible to establish whether intertidal wetlands are irregularly or regularly flooded, exposed or saturated. Therefore, the classification only allows for the distinction to be made between wetlands that are subtidal or intertidal. Using a hydrological descriptor that allows such a level of detail to be added to the classification, if it is known, can add significant value.

Below is a list of descriptors (adapted from Farinha *et al.* 1996 and Ellery *et al*. 2005) that apply to specific Systems according to specific categories.

2.2.5.1 Hydrological

(a) Hydrological Character

The source of water and the nature of its movement through and out of the wetland (i.e. inputs, throughputs and outputs) are considered important in distinguishing different inland wetland types (Ellery *et al*. 2005). The following descriptors therefore apply specifically to inland wetland systems and should be applied at Level 3 in the hierarchy.

Inputs:

- *groundwater:* the wetland is fed predominantly by groundwater sources.
- *interflow:* the wetland is fed predominantly by near-horizontal flow of water through the subsurface soil profile.
- *precipitation:* the wetland is fed predominantly by direct rainfall.
- *channelled flow:* the wetland is fed predominantly by surface runoff that is channelled.
- *diffuse surface flow:* the wetland is fed predominantly by dispersed surface runoff.

Throughputs:

- *interflow:* water moves through the wetland predominantly by near-horizontal flow of water through the subsurface soil profile.
- *channelled flow:* water moves through the wetland predominantly by surface runoff that is channelled.
- *diffuse surface flow:* water moves through the wetland predominantly as dispersed surface flow

Outputs:

- *groundwater:* water flow directly into the groundwater once it leaves the wetland.
- *interflow:* water exits the wetland as soil water as near-horizontal flow of water through the subsurface soil profile.

- *evapotranspiration:* water exits the wetland through evaporation.
- *channelled flow:* water exits the wetland as surface flow via a defined channel.
- *diffuse surface flow:* water exits the wetland as diffuse surface runoff.

(b) Hydroperiod

These descriptors are specific to Level 3 in the hierarchy.

Marine and Estuarine Systems:

The intertidal category can be further divided into areas that are:

- *irregularly exposed:* the land surface is exposed by tides less often than daily. (e.g. areas exposed only during spring tides).
- *irregularly flooded:* tidal water floods the land surface less often than daily. (e.g. areas flooded only during spring tides).
- *regularly flooded:* the substrate is alternately flooded and exposed by tides at least once daily.
- *saturated:* the substrate is saturated to the surface for extended periods but surface water is rarely or only occasionally present. This applies specifically to estuarine systems where wetness is primarily due to capillary rise.

Inland Systems:

For Inland Systems, the hydroperiod is used as an additional hydrogeomorphic feature to further classify Functional Units. This descriptor has been limited to the frequency and level of inundation, with waterlogging or saturation not considered as a criterion because detection of the degree of saturation can be difficult without detailed, multi-temporal data. Where detailed information on hydroperiod does exist however, it is possible to further describe Inland Systems accordingly.

In the case of channels (rivers), a distinction is made as follows:

- *perennial:* rivers that flow throughout the year.
- *non-perennial:* rivers with seasonal or intermittent flow regimes.

For all other inland Functional Units, a distinction is made between permanently inundated, seasonally inundated and intermittently inundated (or saturated). These primary descriptors are defined as follows:

- *permanently inundated:* the substratum is always covered by water.
- *seasonally inundated:* the substratum is temporarily inundated but experiences periods with open water or complete dryness.
- *intermittently inundated or saturated:* the substratum is rarely inundated by open water but may experience permanent or temporary saturation.

The non-perennial category can be further divided into:

- *seasonal:* it flows at least once a year usually during the wet season.
- *intermittent:* it flows at unpredictable intervals that may be longer than a year, usually in response to rainfall events.

The intermittently inundated or saturated categories can be further divided into:

- *intermittently inundated:* surface water is rare and only present at unpredictable intervals.
- *permanently saturated:* the surface water is absent either seasonally or permanently but the surface soils are waterlogged throughout the year.
- *seasonally saturated:* the substratum is saturated for extended periods during the growing season but surface water is seldom present.

2.2.5.2 Water chemistry

These descriptors can be applied at any level in the hierarchy.

Salinity:

Different salinities are used to define salinity for Marine and Estuarine Systems compared with Inland Systems as follows:

<u>Marine and Estuarine Systems (After Farinha *et al.* 2005):</u>
Fresh – Salinity <0.5 g/l
Oligohaline – Salinity 0.5 – 5.0 g/l
Mesohaline – Salinity 5.0 – 18.0 g/l
Polyhaline – Salinity 18.0 - 30.0 g/l
Euhaline – Salinity 30.0 – 40.0 g/l
Hyperhaline – Salinity > 40 g/l

<u>Inland Systems (after Williams 1985):</u>
Fresh i.e. Salinity < 2.0 g/l
Brackish i.e. salinity is 2.0 -12.0 g/l
Saline i.e. salinity is 12.0 - 40.0 g/l
Hypersaline i.e. salinity is >40 g/l

pH:
Acid: pH < 6
Neutral: pH = 6 - 8
Alkaline: pH > 8

2.2.5.3 Artificial versus natural

These can be applied at any level of the hierarchy but are usually specific to certain systems as follows:
Marine and Estuarine Systems: harbours, marinas, excavations (including gravel pits, borrow pits and mining ponds), aquaculture ponds.
Inland Systems: canals, ditches, dams and reservoirs, salt works, wastewater treatment works, farmed (ploughed or drained) land, irrigated land, excavations (including gravel pits, borrow pits and mining ponds), aquaculture ponds.

2.3 Spatial framework: broad ecosystem context for the proposed classification system

When classifying wetlands, it is important to recognise biophysical differences between wetland types in different areas. This is usually done by developing and using a spatial framework for the application of a wetland classification system. Spatial frameworks reflect a combination of biophysical attributes within landscapes rather than specific attributes such as soils or vegetation but operate at a less detailed (bio-regional) scale. Spatial frameworks thus provide a broad ecosystem context within which particular elements can be classified according to the hierarchical classification system. Potentially relevant spatial frameworks that have been developed specifically for aquatic ecosystems in South Africa include:

- ***Ecoregions:*** were developed specifically as a context for the classification of rivers as a prerequisite for management and conservation (Eekhout 1993, Kleynhans & Hill 1999).
- ***Wetland regions:*** were developed specifically as a context for wetland ecosystem planning and management (Cowan 1995).
- ***Bioregions or biogeographical regions/zones:*** bioregions developed specifically for rivers (Brown *et al*. 1996), while biogeographic zones were developed for estuaries (Turpie 2005) and inshore bioregions were developed for marine systems (Lombard *et al.* 2005).

Both ecoregions and wetland regions are spatial frameworks derived from an amalgamation of physical characteristics such as altitude, rainfall, temperature and geology as well as the distribution of various components of the fauna and flora, whereas bioregions are based on the known biogeographic distribution patterns of biota. Wetland regions were developed to accommodate a broad definition of wetlands (as defined in this report) and thus encompass a broader set of determinants for delineation compared with those used to delineate ecoregions where the focus is on rivers *per se*. While ecoregions (and bioregions) are more specific than wetland regions, considerably more effort has been expended in developing and testing the ecoregional framework, compared with wetland regions (see Appendix 1). A spatial framework that has widespread acceptance for wetland classification has, however not yet been developed for South Africa. The appropriateness of any of these spatial frameworks as a structure for the classification system therefore requires further assessment (see section 3).

2.4 Potential application of the proposed classification system

It is essential in the development of any classification system to state what the objective is at the beginning and to keep this in view throughout. The classification system presented in this document is intended primarily as a system for classifying wetland units delineated within the AWL as a tool to assist in decision making processes for the management and conservation of wetland ecosystems. Considering the scale and resolution associated with mapping wetlands at a national level, it must be appreciated that a national inventory is only a starting point for managing wetlands and is limited in its ability to provide the level of detail that may be required for regional or local management and conservation initiatives. A classification system at the broadest level may not be useful for finer scale planning initiatives. Classification systems do not need to be mutually exclusive at different scales of detail, however. Rather, hierarchical classification systems can be applied at different levels of the hierarchy. A classification system that is organised in a spatial hierarchy would therefore satisfy the need for a multi-objective classification system, with different levels in the hierarchy applicable to the information available at that scale (Figure 2.2). At the finest levels, such a classification system might therefore be based on details that can only be gained through collection of field data, while at the broadest level it might be based largely on desktop data.

Potential uses for a wetland classification system:

- Biodiversity conservation planning.
- Prioritisation of wetlands for protection and rehabilitation.
- Water resource management (i.e. RDM).
- Catchment management planning.
- Design of monitoring programmes.
- State of Environment reporting (including wetland health assessments).
- Designation of Ramsar sites.
- Basis for Environmental Impact Assessments (EIAs).
- Strategic Environmental Assessments (SEAs).
- Assist with understand wetland functions and thus facilitate functional prioritisation.
- To help understand the origin of wetlands.

The system proposed here focuses on the broader levels of the hierarchy that are applicable at a national level and to some extent, a regional level (Figure 2.2). It leaves room for additional classes, however, and the use of lower-order discriminators to refine the classification in order to take account of local or specialist needs.

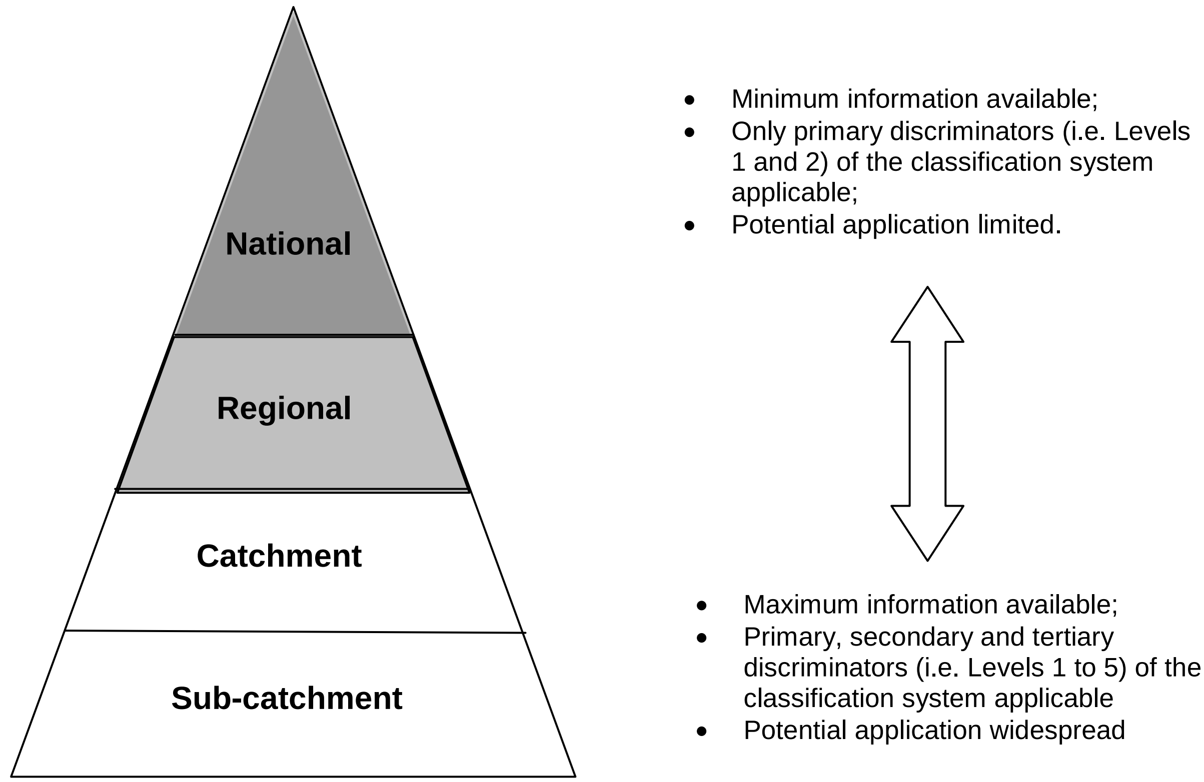

Figure 2.2: Summary diagram that emphasizes that the ability to classify wetlands at a national scale is limited by the availability of information required for classification. As the resolution at which wetlands are mapped becomes finer, so additional information necessary for distinguishing one wetland unit from another becomes available. Therefore, the potential application of the classification to wetland management increases with the availability of information at more detailed spatial scales. The classification system at this stage focuses on wetlands mapped a national level (dark grey) with some relevance to those mapped at a regional level (light grey).

3 TERMS OF REFERENCE FOR FURTHER DEVELOPMENT, REFINEMENT, TESTING & APPLICATION OF THE WETLAND CLASSIFICATION SYSTEM

To date, the national wetland inventory project has focused on the development of:

(a) a wetland map that provides information on the extent and distribution of wetlands based on the AWL (see section 1.4) and;

(b) the development of a classification system to distinguish different wetland types identified by the AWL (this project).

Further development and refinement of the AWL is currently afoot. In particular, the national Wetland Inventory Steering Committee has recognised the need for undertaking an accuracy assessment of the AWL to establish a clear understanding of the efficiency of the remote sensing and modelling techniques firstly for identifying and then for delineating wetlands at a national scale. Also, the steering committee recognise that the AWL is only the starting point for developing a national wetland inventory (J. Dini, SANBI, pers. comm.) and that the quality and completeness of the inventory will be improved incrementally over time, using supplementary data and field verification.

This report does not specifically address the requirements for further development of the wetland map that forms the basis of the national wetland inventory *per se.* Rather, it deals specifically with identifying the projects necessary to develop, refine and test the proposed classification system and, secondly, to apply the classification system to the wetland units mapped at a national scale. Considering that the classification system will be applied to the wetland map generated for the national wetland inventory, however, it is fundamental to recognise that any further development of either of these two initiatives should be closely linked.

3.1 Phase 1

Project 1: Further development and refinement of the wetland classification system

The tasks that would need to be completed as part of this project are as follows:

a) *Expand the wetland classification system to include Habitat Units at Level 5.* A number of sub-categories or Habitat Units should be developed for each Structural Unit, to enable the classification of wetlands at a fine level of resolution applicable at sub-regional and local scales. Using the broader classification system developed and presented in the current report as a basis for building these finer levels, will promote the use of a standardized protocol for the classification of wetlands at all mapping scales.

b) *Refine the rules or criteria needed to discriminate between different types of wetland units at the various levels of the proposed wetland classification system.* This will facilitate the consistent and unambiguous classification of wetlands. In refining the rules, ensure that all the terms used within the classification system (including Habitat Units) are clearly defined.

c) *Refine and, if necessary, expand the descriptors for the proposed wetland classification system.* In refining the descriptors, ensure that there are clear rules or criteria for the categorisation of each descriptor.

d) Determine whether it is appropriate to include hydroperiod as a primary discriminator for classifying Functional Units within Inland Systems. This would require the determination of whether, in most cases, it is possible to discern between permanently and seasonally inundated areas, and those that are intermittently inundated or saturated.

e) *Determine the most appropriate spatial framework/s for the application of the wetland classification system.* Spatial frameworks identified to date include: inshore bioregions, developed specifically for inshore marine systems (Lombard *et al*. 2005); biogeographical zones, developed specifically for estuarine systems (Turpie 2005); ecoregions, developed specifically for rivers (i.e. channel subsystems within inland systems) (Kleynhans and Hill 1999); and wetland regions, developed for a broad range of wetland types (Cowan 1995). Spatial frameworks provide a broad ecosystem context within which comparable systems can be classified. Application of the wetland classification within a broad ecosystem context will be invaluable for conservation planning and water resource management at a national scale (see section 2.3) because it provides an ecologically meaningful way of separating the country into regions (i.e. biophysical regions as opposed to political regions). The use of specific spatial frameworks for specific systems (i.e Marine, Estuarine and Inland systems) should be further investigated.

This project should be given the highest level of priority, as all the other projects outlined below are dependent upon the completion of the tasks associated with this project.

3.2 Phase 2

Project 2: Testing and further refinement of a fully developed version of the wetland classification system

Once the fully developed version of the wetland classification system has been developed (see project 1 above), it will be necessary to:

- Ascertain whether the classification system sufficiently encompasses the full diversity of wetland type that occurs within southern Africa.
- Ascertain whether the classification system groups wetland units in a manner that is useful in wetland management and conservation initiatives.

Testing may lead to minor adjustments to the classification system that will ultimately result in a robust classification system that can be applied with confidence. Once the appropriate spatial framework for application of the classification has been established (see Project 1 above), it is recommended that testing and further refinement of the classification system be undertaken by specialists familiar with wetland systems specifically in each biophysical region. This process should be coordinated nationally to ensure that standardised protocols (see Project 3 below) for application of the classification system are used. Furthermore, a national coordinator would be responsible for managing the project and collating all the findings so that feedback and refinement of the system is undertaken in a standardised manner.

The tasks that would need to be completed as part of this project are as follows:

a) *For each biophysical region, identify which components of the wetland classification system are relevant* (for example, Marine and Estuarine Systems will not be relevant to landlocked regions).
b) *Within each biophysical region, apply the tests of inclusivity and mutual exclusivity. By applying the classification system to a number of wetlands that encompass the diversity of wetlands in the region, it will be possible to test whether all wetland types/habitats in the region can be classified down to one or other of the Structural and Habitat Units, or whether any wetland type/habitat in the region be classified in more than one way, thereby detecting possible ambiguity in the classification system.*
c) *Apply the classification system to a series of wetland types to determine whether it can be used as a basis for further assessments*. This could involve integration with other wetland initiatives underway in South Africa such as the Wetland Health and Integrity (WHI) Research Programme.
d) *Refine the classification system, together with rules and definitions of each discriminator and descriptor accordingly.*

It is important that this project be undertaken in parallel with Project 3.

Project 3: Development of protocols and 'tools' for the testing and application of the wetland classification system

Testing and application of the wetland classification system will require a number of tools for the collection of biophysical information that is necessary for applying the rules used to discriminate between different wetland units.

The tasks that would need to be completed as part of this project are as follows:

a) *Develop a datasheet for the collection of the biophysical information necessary for the classification of wetlands at each level of the proposed classification system.* This will involve collaboration with wetland specialists already involved in the collection of geomorphological and biological data in the field, as well as technical specialists who can provide input into the type of biophysical data that can be generated from remote sensing tools.
b) *Identify sources of information that could be used to assist with the classification of wetlands at various levels of resolution* (for example, satellite imagery, aerial photographs and field data). Within each biophysical region (identified within the most appropriate spatial framework - see Project 1), identify relevant biophysical data that can be extracted from each source of information. This will provide a means of ascertaining which sources of information are necessary to reach specific levels in the classification hierarchy and how this differs between each biophysical region. For example, satellite imagery may reveal that more biophysical data are needed to discriminate between wetlands in regions dominated by grasslands, compared with those dominated by forests because spectral features of wetlands are more easily

discernable in grasslands. A comparison should be made of how useful the various sources of information are in different regions at each level of the classification system.

c) *Develop a protocol (or 'decision tree') for the application of the fully developed wetland classification system in different biophysical regions.* The protocol should include references to the potential sources of information at the different levels of the classification system. Such a protocol will therefore provide clear guidelines for application of the classification at all levels and thus ensure that data is collected in a consistent and standardised fashion – this is fundamental for assessing wetlands over time and across different spatial scales.

d) *Produce a dichotomous key and field guide for the application of the wetland classification system.* This should be a user-friendly document, which is of suitable size and durability for use in the field, and should include photographs and pictures. This could involve integration with other wetland initiatives underway in South Africa such as the Wetland Health and Integrity (WHI) Research Programme. The production of a dichotomous key and field guide could be integrated with field guides developed as part of the WHI Research Programme such that classification and wetland assessment field guides are produced together in a series.

e) *Provide input to the structure and organisation of the national wetland database that is being developed as part of the National Wetland Inventory.* It is important that the database can accommodate all information required for classifying wetlands at all levels of the hierarchy. Considering that the classification system requires further development and refinement, any input to the national wetland database should only occur once the classification system has been finalised.

f) *Promote the application of protocols and tools developed for wetland classification.* Undertaking a national "road-show" that will assist wetland scientists and managers with applying the classification in the field will promote buy-in from the different regions. This is important for ensuring that data is collected and managed in a standardised fashion.

3.3 Phase 3

Project 4: Investigate the feasibility of producing an automated wetland classification system for the National Wetland Inventory

Once the wetland classification system for South Africa has been fully developed, the feasibility of producing a computerised system that can automatically classify wetlands should be investigated. The automated classification system would be used in the National Wetland Inventory, which will be based to a large degree on the Advanced Wetland Layer (AWL) of the National Land Cover (NLC) 2000 initiative. This project will, therefore, require an iterative process of collaboration between several groups of people. At the very least, those with the technical expertise to interrogate geographical data sources at several different levels, ranging from remote sensing through to detailed aerial photography, and wetland specialists who understand the biophysical characteristics that permit wetland units to be grouped should be involved. The tasks that would need to be completed as part of this project are as follows:

a) *Identify the attribute information that would be required to produce an automated wetland classification system.* The attribute information would be based on the rules or criteria used to distinguish wetland units at different levels in the hierarchy and would form the basic input variables for the automated classification system.
b) *Determine whether the required attribute information for generating an automated classification system can be obtained from the AWL.* This will require close collaboration with the technical team responsible for further development of the AWL.
c) *Identify alternative sources of attribute information for generating an automated classification system*, *besides the AWL.* This component would rely on the outputs of task 3 of Project 3 i.e. identifying sources of information that could be used to assist with wetland classification.
d) *Determine whether the automated classification system generates reliable results.* Once a prototype of the automated wetland classification system has been developed, testing should be undertaken in the various biophysical regions across the country. This would involve ground-truthing of the outputs of the automated system for the different wetland types occurring in each region. Based on the findings of the ground-truthing exercise, the automated classification system should be refined to improve its performance. Further ground-truthing and refinement of the automated classification system should be undertaken, iteratively, until an acceptable level of accuracy is reached.
e) *Provide conclusions as to whether the development of an automated wetland classification system for the National Wetland Inventory is feasible.* If it is feasible, provide recommendations as to how the automated classification system should be developed, packaged and applied. If it is not feasible, provide recommendations as to how the classification of wetland units should be dealt with in the National Wetland Inventory.

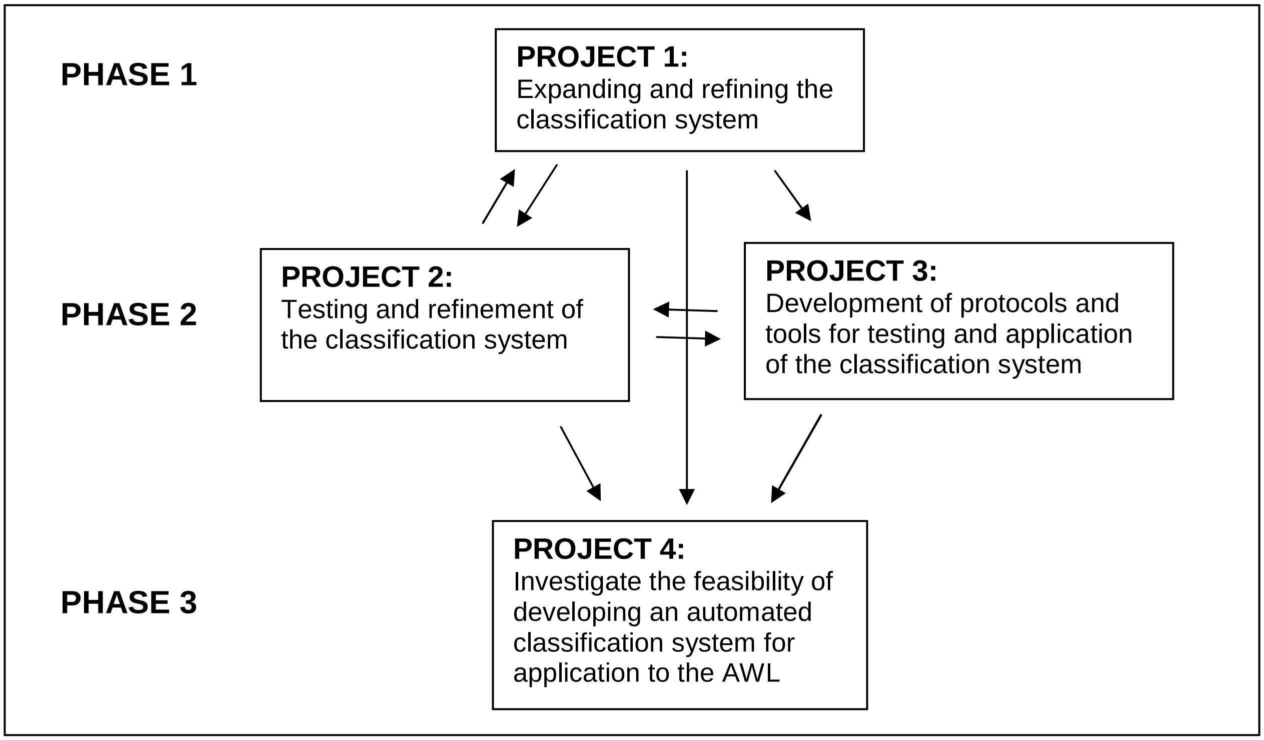

Figure 3.1: Schematic diagram showing the interrelatedness between the recommended projects needed for further development, refinement and application of the classification system. The direction of the arrows indicates transfer of information generated from one project to another.

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APPENDIX 1

NATIONAL WETLAND INVENTORY:

Development of a Wetland Classification System for South Africa

LITERATURE REVIEW

January 2005

Prepared for:

The Water Research Commission (WRC) and

South African National Biodiversity Institute (SANBI)

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INTRODUCTION

Ecosystem Classification and the Need for Classification Systems

Classification is simply the process through which similar objects are grouped together and dissimilar objects are separated. It "brings order to our thinking and communication by systematically naming the objects being classified and showing the relationship among them" (Morant 1983). Classification enables us to organise and begin to understand complex and variable objects, systems or ideas so that we can work with them more easily (O'Keeffe *et al*. 1994). There is an implicit use of classification in ecology, or in any science for that matter. Scientists and resource managers classify and label ecosystems to facilitate communication, and to simplify the amount of natural variation that has to be dealt with when attempting to detect and characterise the effects of humans on ecosystems (Adamus 2001). As a result, classification systems have been used by scientists and resource managers for centuries to organise information about ecological systems (Naiman *et al*. 1992).

Ecosystem classification, in essence, involves the grouping of habitats or natural features into categories with similar characteristics, properties, or functions (Tiner 1999). According to Morant (1983), the main objectives of an ecosystem classification system are:

- to group ecologically similar ecosystems so that value judgements can be made;
- to delineate ecosystem boundaries for the compilation of inventories and for mapping; and
- to provide a uniform base for concepts and terminology throughout the region in which the classification system is to be applied.

Classification systems, which partition and attempt to simplify complex ecosystems, are important and potentially valuable tools for ecosystem management (Froude & Beanland 1999; Adamus 2001). At the same time, it is important to bear in mind that the use that is made of the groupings generated by a classification system, and the predictions and extrapolations made from them, will only be as accurate and useful as the expertise and information available for particular ecosystems in a region (O'Keeffe *et al*. 1994).

Approaches to Ecosystem Classification

A number of different approaches can be followed in the classification of ecosystems. Comprehensive reviews of the different approaches are provided by O'Keeffe *et al*. (1994) and Jones (2002). In essence, the major differences are as follows:

- *Single-level vs. hierarchical classification*
  With single-level classification (also known as horizontal or single-scale classification), ecosystems are simply divided into a series of many classes or types. Hierarchical classification, on the other hand, consists of a number of levels for the grouping of ecosystems, with each successive level requiring more detailed information. While single-level classifications are useful for providing general descriptions of ecosystem types, they tend to be too broad and ambiguous for

scientific and resource management applications (O'Keeffe *et al*. 1994, Jones 2002, Tiner 1999). Hierarchical classification systems, by their nature, provide more flexibility and a greater level of consistency.

- *Top-down vs. bottom-up classification*
  Top-down classification uses independent physical variables (such as climate and geomorphology) as initial characteristics to group ecosystems, while the bottom-up approach uses the inherent properties of ecosystems (such as chemistry or the biota) to generate initial groupings. The top-down approach is easier to apply, as the required information is more readily obtainable, but it provides less detail than the resource-intensive bottom-up approach (O'Keeffe *et al*. 1994, Jones 2002).

- *Structural vs. functional classification*
  Classification systems can either be based on structural characteristics of ecosystems (such as geomorphology and vegetation) or on functional attributes (such as nutrient cycling or productivity). Functional classification systems reveal detailed information about the functioning of an ecosystem that can only be inferred when using structural classifications, but functional attributes are a lot more difficult to assess than structural characteristics (Jones 2002).

Whatever approach is taken to the classification of ecosystems, it has been emphasised (Mader 1991, cited by Tiner 1999) that, to maximise their usefulness, classification systems should be:

- flexible, general and of wide geographic applicability in order to predict many kinds of information over a range of environmental situations;
- professionally credible, preferably through experimental validation;
- formed on concepts and logic that are explainable to non-technical people;
- logical, consistent and objectively quantifiable so as to operate in an empirical, computer-oriented information system; and
- designed and documented so that regular professional staff can, with nominal training, use the system to identify and map field sites.

In addition to the above, classification systems should be able to stand alone, independent of the tools of inventory and the scale of the final map products, and they should be open-ended so that new elements can be incorporated as knowledge advances (Wilen 1985, cited by Breen 1988).

Wetland Classification and the Definition of 'Wetland'

Wetland classifications are basically attempts to group wetlands with common characteristics or to identify the types of environments and biota they contain (Pressey & Adam 1995). They are particularly important for conducting inventories and watershed planning, assessing biodiversity, evaluating wetland functions, assessing the impacts of wetland alteration and degradation, and considering potential wetland restoration (Tiner 1999).

The classification of wetland ecosystems goes back as far as they have been recognised as important natural resources worthy of conservation (for example, see Tiner 1999 for an historical overview of wetland classification in the USA). For, just as the conservation potential of a stream is dependent on the type of stream under consideration (Naiman *et al*. 1992), so the conservation potential of a particular wetland is dependent on the type of wetland that it is. The compilation of some kind of inventory of wetlands in a region is fundamental to the conservation and management of wetland ecosystems (Finlayson & Van der Valk 1995, Scott & Jones 1995, Tiner 1999), and the development and adoption of a wetland classification system is often the starting point for a wetland inventory (Finlayson & Van der Valk 1995). Indeed, "the first step in investigating wetlands is recognising them as 'wetlands' and then identifying the different types, and for this we need a suitable classification system" (Jones & Day 2003).

Central to the development of any wetland classification system is the definition of the term 'wetland' and of terms to describe different kinds of wetlands. The definition of the term 'wetland' has been the subject of much debate, with no universal agreement to date as to what constitutes a wetland. They have been described as "enigmatic ecosystems" that are neither fully aquatic nor terrestrial and not easily classified as ecotonal between the two (Rogers 1997). Because of the great variety of wetland types, their dynamic nature and the difficulties of precisely defining their boundaries, the classification of wetlands is inherently fraught with difficulty (Davis 1994, Finlayson & Van der Valk 1995).

One of the most widely accepted definitions is that of the Convention on Wetlands of International Importance especially as Waterfowl Habitat of 1971 (commonly referred to as the Ramsar Convention), whereby wetlands are defined as "*areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metre*" (Davis 1994). This is a very broad definition, including marine waters shallower than 6 metres, rivers and lakes. The rationale behind the very broad definition of wetlands by the Ramsar Convention was to ensure the protection of the habitats of migratory water birds (Davis 1994). Inevitably, however, such a broad definition creates problems for the development of wetland classification systems and, at a national level, many countries have adopted narrower definitions (Scott & Jones 1995).

Most other widely used definitions of the term 'wetland' are more restrictive than the Ramsar definition, usually with specific reference to the presence of saturated soils and/or hydrophytic vegetation. For example, Cowardin *et al*. (1979) define wetlands as "*lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water*" and stipulate that, in order for an area to be classified as a wetland, it must meet at least one of the following criteria: 1) *at least periodically, the land supports predominantly hydrophytes;* 2) *the substrate is predominantly undrained hydric soil;* and/or 3) *the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season.* In contrast, Cowardin *et al*. (1979) define 'deepwater habitats' as "*permanently flooded lands lying below the deepwater boundary of wetlands.*

They include environments where surface water is permanent and often deep, so that water, rather than air, is the principal medium within which the dominant organisms live, whether or not they are attached to the substrate." Together, Cowardin *et al*.'s (1979) wetlands and deepwater habitats more or less constitute wetlands as defined by the Ramsar Convention.

The United States National Research Council (1995, cited by Tiner 1999) provide one of the most robust definitions: "*A wetland is an ecosystem that depends on constant or recurrent, shallow inundation, or saturation at or near the surface of the substrate. The minimum essential characteristics of a wetland are recurrent, sustained inundation, or saturation at or near the surface and the presence of physical, chemical, and biological features reflective of recurrent, sustained inundation or saturation. Common diagnostic features of wetlands are hydric soils and hydrophytic vegetation. These features will be present except where specific physicochemical, biotic, or anthropogenic factors have removed them or prevented their development*."

In South Africa, according to the National Water Act (Act No. 36 of 1998), "*Wetlands are land which is transitional between terrestrial and aquatic systems, where the water table is usually at, or near the surface, or the land is periodically covered with shallow water and which land in normal circumstances supports, or would support, vegetation adapted to life in saturated soil*." This definition was used for the development of a methodology for the South African National Wetland Inventory (Thompson *et al*. 2002), with the addition of "*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*" taken from Cowardin *et al*. (1979).
In contrast, according to Dini *et al*. (1998), the definition of 'wetland' for the South African National Wetlands Inventory will be according to the Ramsar definition, which is encapsulated by the 'wetlands' and 'deepwater habitats' defined by Cowardin *et al*. (1979). Subsequently, however, Dini & Cowan (2000) stipulate that the definition of 'wetland' for the national inventory will be according to Cowardin *et al*.'s (1979) definition of wetlands with so-called 'deepwater habitats' excluded. The definition adopted for the most recently proposed wetland classification system for South Africa (Ewart-Smith *et al*. 2005) is that of the Ramsar Convention.

Notwithstanding some of the problems of wetland classification relating to the nature of wetland ecosystems and the difficulty of unanimously acceptable definitions, an increasing number of countries have established some kind of national wetland classification, usually in association with the development of national wetland inventories (Scott & Jones 1995).

EXISTING WETLAND CLASSIFICATION SYSTEMS

In the section below, a number of internationally utilised wetland classification systems are discussed, followed by a discussion on the development and use of wetland classification systems in South Africa.

United States Fish and Wildlife Service Classification System for Wetlands and Deepwater Habitats of the USA (1979)

To date, one of the most widely used and influential wetland classification systems worldwide is that of the United States Fish and Wildlife Service (USFWS) developed by Cowardin *et al*. (1979), or modifications thereof. Although often overlooked, it is important to bear in mind that the USFWS classification system (Cowardin *et al*. 1979) is not only for wetlands, as it also incorporates 'deepwater habitats' as described above. Comprehensive reviews of this classification system are given by Cowardin & Golet (1995) and Tiner (1999). The USFWS classification system is hierarchical, with five levels of discrimination known as Systems, Subsystems, Classes, Subclasses and Dominance Types, from the highest to the lowest level respectively (Figure 1 provides an outline of the classification system to the Class level).

Five Systems are recognised within the USFWS classification system (namely Marine, Estuarine, Riverine, Lacustrine and Palustrine), based on a number of key features such as salinity, wave energy, basin morphology, water depth and surface water area. Each System represents "a complex of wetlands and deepwater habitats that share the influence of similar hydrologic, geomorphologic, chemical, or biological factors" (Cowardin *et al*. 1979). With the exception of the Palustrine System, Systems are further subdivided into Subsystems on the basis of water depth, surface water permanence or, in the case of the Riverine System, stream gradient and extent of tidal influence. Marine and Estuarine Systems are each separated into Subtidal and Intertidal Subsystems, while the Lacustrine System is broken down into Limnetic and Littoral Subsystems. The Riverine System has four Subsystems, namely Tidal, Lower Perennial, Upper Perennial and Intermittent (Figure 1). The various Subsystems reflect different hydrological regimes.

The third level of the USFWS classification system, the Class, may be thought of as the basic habitat type (Cowardin & Golet 1995). It is based on the appearance or structural form of the ecosystem unit. In the case of vegetated habitats, the Class describes the dominant life-form of the vegetation whereas, in the case of non-vegetated habitats, it describes the form and general composition of the substrate along with the water regime. There are five vegetated classes (namely Aquatic Bed, Emergent Wetland, Scrub-Shrub Wetland, Forested Wetland, and Moss-Lichen Wetland), and six Classes of non-vegetated habitats (namely Rock Bottom, Unconsolidated Bottom, Rocky Shore, Unconsolidated Shore, Streambed, and Reef). Subclasses are further distinguished by finer differences in the vegetative life-form or substrate composition.

Dominance Type is the lowest level in the USFWS hierarchy of Cowardin *et al*. (1979). If the Subclass is based on vegetative life-form, the Dominance Type is the most abundant single species or combination of species (in the case of co-dominance) in the vegetation layer used to name the Subclass. On the other hand, if the Subclass is based on substrate composition, the Dominance Type is the predominant plant species or sedentary or sessile macroinvertebrate species occurring on the site.

Once a habitat has been placed within the classification hierarchy of the USFWS classification system, a series of so-called Modifiers can be applied to Class and lower levels of the hierarchy. Modifiers are based specifically on detailed information regarding water regime, water chemistry, soil type, and modification by humans or beavers ('Special Modifiers').

The USFWS classification system (Cowardin *et al*. 1979) is the basis of the ongoing National Wetlands Inventory in the USA (Tiner 1999). A number of countries have adapted the USFWS classification system for their region for use in the classification and inventory of wetlands, such as the MedWet Habitat Description System (Farinha *et al*. 1996, 2005) developed for the Mediterranean Wetland Inventory.

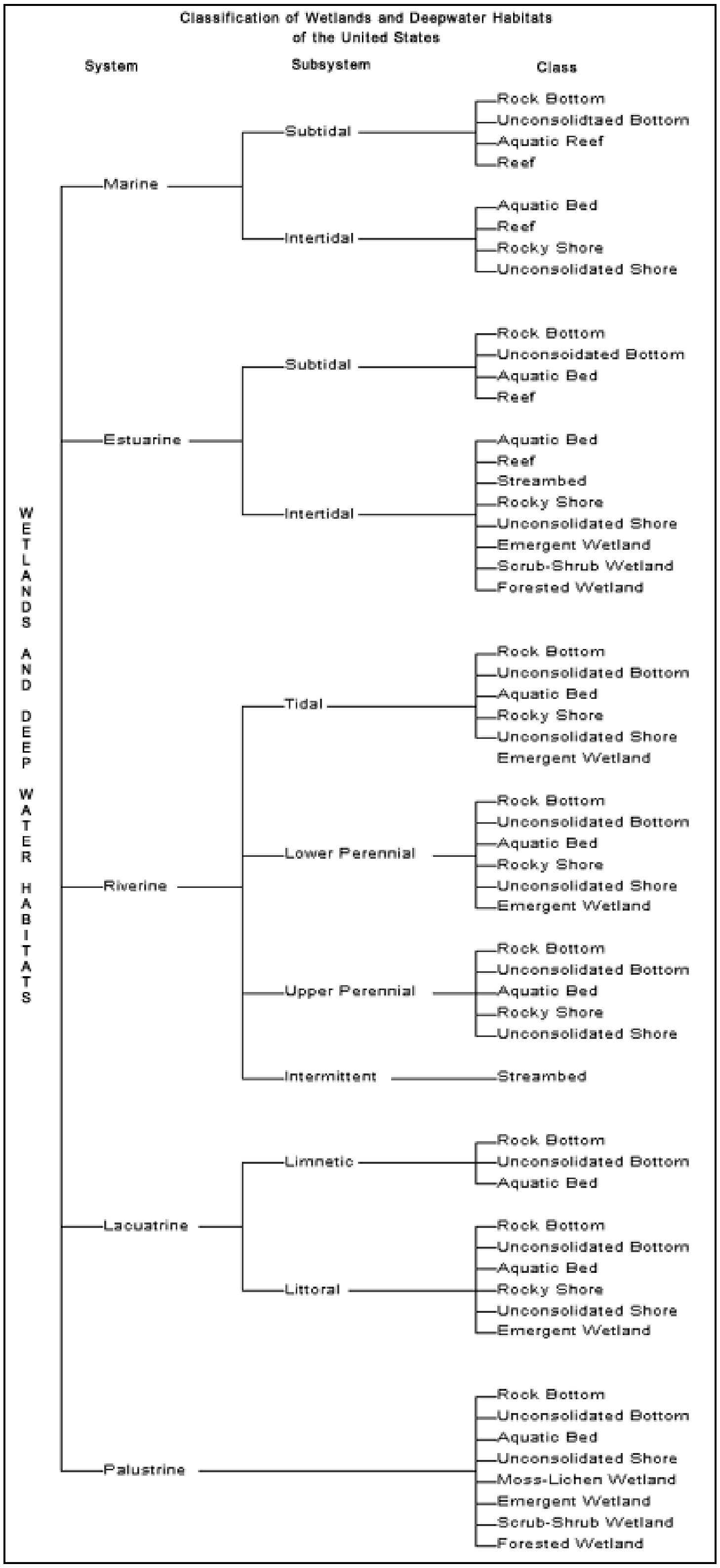


Figure 1: United States Fish and Wildlife Service (USFWS) classification system for wetlands and deepwater habitats of the United States of America (USA) (after Cowardin *et al*. 1979)

Ramsar Wetland Classification System (1990)

In 1990, at the Fourth Meeting of the Conference of the Contracting Parties to the Ramsar Convention (in Montreaux, Switzerland), a Recommendation was adopted approving an information sheet and hierarchical classification system for wetland types developed by Scott (1989, cited by Scott & Jones 1995) that is based loosely the USFWS classification system of Cowardin *et al*. (1979) (Davis 1994, Scott & Jones 1995). The main difference between the Ramsar classification system and that of Cowardin *et al*. (1979) is the separation of marine/coastal, inland and artificial aquatic systems up-front (Figure 2).

The Ramsar classification system has been used, with minor adaptations, for a number of national and regional wetland inventories such as the Directory of Important Wetlands In Australia (DEH 2001), the initial inventory of wetlands in South Africa (Cowan & Van Riet 1998) and a number of wetland inventories in Europe (Hughes 1995). A modification of the original system has also been adopted by the World Conservation Union (IUCN) for wetland classification (see Dugan 1990). It is important to bear in mind, however, that the Ramsar classification system was initially developed specifically for broadly classifying wetlands listed as being of international significance in terms of the Ramsar Convention.

Whilst the Ramsar typology of wetland habitats and ecosystems, and the USFWS classification system (Cowardin *et al*. 1979) upon which it is based are useful and have been widely used, these classification systems are based on a mixture of vegetation, soil, inundation and landform features that are often inconsistent and have led to much confusion (Semeniuk & Semeniuk 1995, Finlayson *et al*. 2002). Recent analyses and reviews of wetland classification have emphasised the need to overcome the major inconsistencies in such classifications (Finlayson *et al*. 2002).

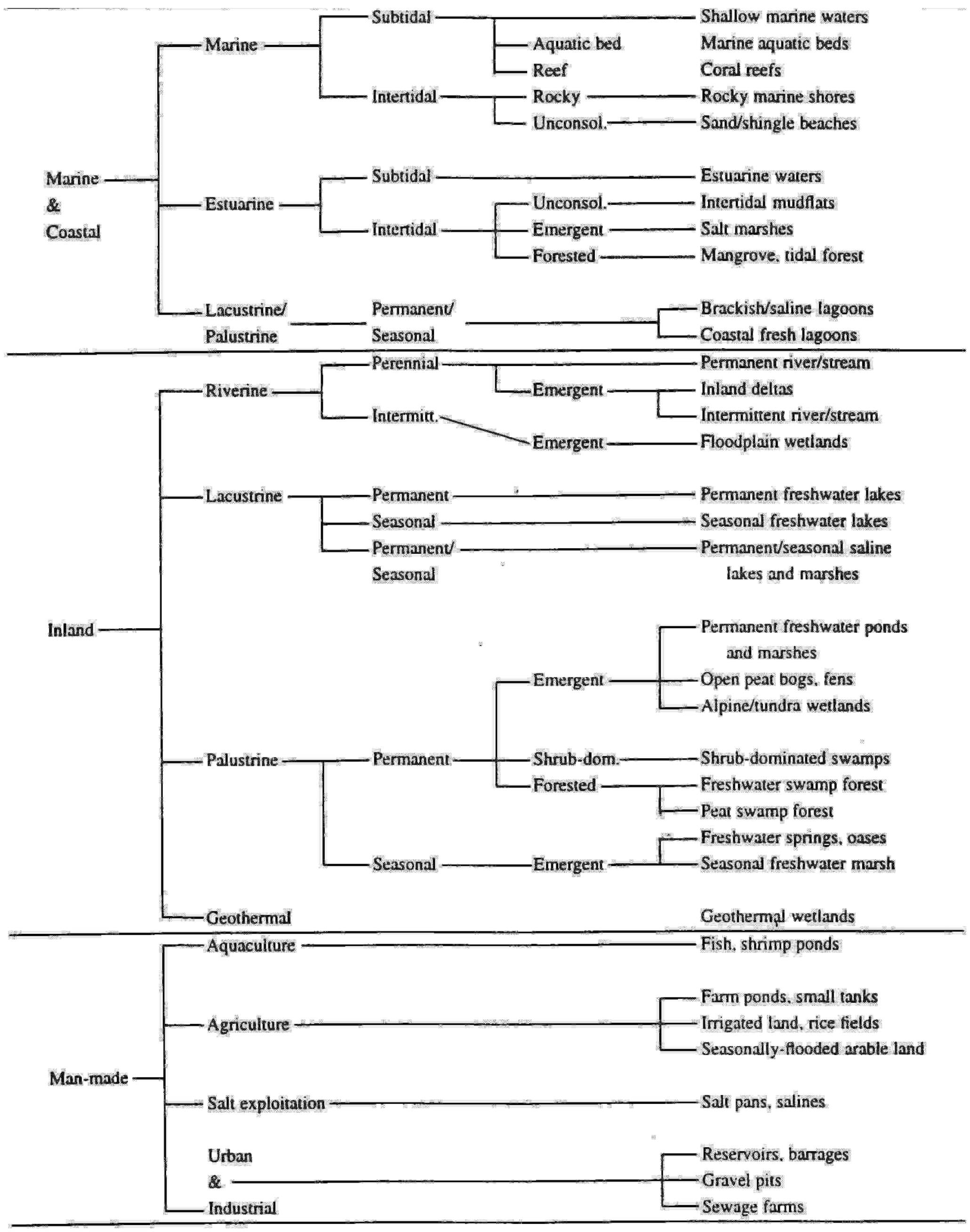


Figure 2: Wetland classification system of the Ramsar Convention Bureau (from Scott & Jones 1995)

Hydrogeomorphic Approach to Wetland Classification

An alternative to wetland classification systems like that of Cowardin *et al*. (1979) and the Ramsar Convention is an approach that is based on landform (geomorphology) and water regime (hydrology), as these are the underlying, fundamental features that determine the existence of wetlands, regardless of the climatic setting, soil type, vegetation or origin of wetlands (Finlayson & Van der Valk 1995). This alternative approach is known as the hydrogeomorphic (or HGM) approach to wetland classification. The geomorphic and hydrologic characteristics that the HGM approach focuses on are responsible for maintaining many of the functional aspects of wetland ecosystems, and the use of these basic characteristics enables all wetland types in any area to be classified with relative simplicity (Brinson 1993, Maxwell *et al*. 1995). As a result, the HGM approach is considered to be a far more robust and consistent approach to wetland classification than the traditional Cowardin approach (Finlayson & Davidson, cited by Finlayson *et al*. 2002). The understanding of wetland forms and functions should be maximised by a classification that first establishes the hydrogeomorphic context before introducing soil and vegetation factors (Maxwell *et al*. 1995).

HGM classification systems for wetlands have been developed in Australia (Semeniuk 1987 cited by Finlayson *et al*. 2002; Semeniuk & Semeniuk 1995) and the USA (Brinson 1993). The classification system of Semeniuk & Semeniuk (1995) has been proposed as the standard for a national inventory in Australia (Finlayson 1999, cited by Finlayson *et al*. 2002), while the classification system of Brinson (1993) forms the basis for wetland assessments in the USA. The "more consistent and modern" HGM approach to wetland classification has also been adopted for the Asian Wetlands Inventory, in addition to the classification provided by the Ramsar Convention's system (Finlayson *et al*. 2002).

The broad classification provided by the HGM approach can be extended by the addition of descriptors for salinity, vegetation cover, shape and size (Semeniuk & Semeniuk 1995, Finlayson *et al*. 2002), or any other descriptors that may be of relevance to a region or for a specific purpose.

HGM classification system of Semeniuk (1987) and Semeniuk & Semeniuk (1995)

The original classification system of Semeniuk (1987, cited by Semeniuk & Semeniuk 1995) for inland wetlands of the Darling System in Australia was based on the two main attributes of wetlands: their landform shape (basin, channel or flat) and water permanence or hydroperiod (permanently inundated, seasonally inundated or seasonally waterlogged). In combination, these attributes resulted in the recognition of seven common wetland types.

Semeniuk & Semeniuk (1995) extended the original classification system of Semeniuk (1987, cited by Semeniuk & Semeniuk 1995) to make it more globally applicable. Five basic landform types that determine the occurrence of wetlands were identified, namely: basins, channels, flats, slopes, and highlands or hills. Four types of water permanence were distinguished, namely: permanently inundated, seasonally inundated, intermittently inundated, and seasonally waterlogged. By combining the various types of landform with the various types of water permanence, 13 main wetland types are recognised within the classification system of Semeniuk & Semeniuk (1995), as follows:

- Permanently inundated basin (termed a "lake");
- Seasonally inundated basin (termed a "sumpland");
- Seasonally waterlogged basin (termed a "dampland");
- Intermittently inundated basin (termed a "playa");
- Permanently inundated channel (termed a "river");
- Seasonally inundated channel (termed a "creek");
- Intermittently inundated channel (termed a "wadi");
- Seasonally waterlogged channel (termed a "trough");
- Seasonally inundated flat (termed a "floodplain");
- Intermittently inundated flat (termed a "balkarra");
- Seasonally waterlogged flat (termed a "palusplain");
- Seasonally waterlogged slope (termed a "paluslope"); and
- Seasonally waterlogged highlands and hills (termed a "palusmont").

A series of descriptors were also developed by Semeniuk & Semeniuk (1995) to classify wetland types at a finer level of detail than the 13 main wetland types. These descriptors are based on water chemistry (salinity and consistency of salinity), landform (wetland size and plan shape) and vegetation (aerial extent and pattern of plant cover).

Unfortunately, the introduction of a whole new set of terms and definitions in the classification system of Semeniuk & Semeniuk (1995) has prevented the widespread acceptance and use of the system outside of the region in which it was developed (Finlayson & Van der Valk 1995). According to Tiner (1999), the classification system of Semeniuk (1987, cited by Tiner 1999) probably served as a model for Brinson's (1993) HGM classification system, although Brinson (1993) does not make any reference to the former classification system.

HGM classification system of Brinson (1993)

In the USA, the HGM approach to wetland assessment was initially developed for the regulatory needs of the US Army Corps of Engineers in terms of the Clean Water Act. Overall, the HGM approach is a collection of concepts and methods for developing functional indices for wetlands, and for using these indices to assess the capacity of a wetland to perform functions relative to similar wetlands in a region (Clairain 2002). The basic concepts of the HGM approach to wetland assessment in the USA are expanded on by Smith *et al*. (1995).

The HGM wetland classification system of Brinson (1993) was developed to aid in the functional assessment of wetlands, recognising that the Cowardin *et al*. (1979) system did not address certain abiotic (hydrogeomorphic) features that are directly linked to many wetland functions. It can be used to identify groups of wetlands that function similarly (Smith *et al*. 1995). The HGM wetland classification is, therefore, more of an approach to provide a framework for wetland evaluation, rather than a classification system specifically designed for mapping wetlands (Tiner 1999; Adamus 2001). The classification system was, after all, designed as a framework for evaluating similar wetlands in a given geographic area and for developing a set of quantifiable characteristics for 'reference wetlands' rather than for inventorying wetland resources (Smith *et al*. 1995; Tiner 1999). Nevertheless, the HGM wetland classification system has been successfully used for the inventory of wetlands (e.g. Tiner *et al*. 2000, cited by Adamus 2001), and for a number of other applications relating to the management and monitoring of wetland ecosystems.

Brinson's (1993) classification system is based on three fundamental factors that influence how wetlands function, namely: geomorphic setting, water source, and hydrodynamics. Geomorphic setting refers to the landform of a wetland, its geologic evolution, and its topographic position in the landscape. Water source refers to the location of water just prior to entry into the wetland, simplified to three categories – precipitation, surface or near-surface flow, and groundwater discharge. Hydrodynamics refers to the direction of flow and strength of water movement within the wetland (vertical fluctuations, unidirectional flow, or bidirectional flow). While each of the three factors is treated separately in the classification system it is recognised that there is considerable interaction and interdependency between them (Brinson 1993; Smith *et al*. 1995).

The HGM system identifies seven basic Hydrogeomorphic Classes, namely (Tiner 1999):

- Depressional wetlands (within topographic depressions);
- Organic soil flats (extensive peatlands);
- Mineral soil flats (broad nearly level wetlands with inorganic soils);
- Riverine wetlands (along rivers and streams), further divided into three gradients (high, middle and low gradient) that reflect stream flow and fluvial processes;
- Slope wetlands;
- Lacustrine fringe (lakeshore wetlands); and
- Estuarine fringe (tidal wetlands).

Within a specific geographic area, wetland classes can be further divided into regionally-based wetland subclasses (Clairain 2002). Classifying wetlands based on how they function narrows the focus of attention to a specific type or subclass of wetland, the functions that wetlands within the subclass are most likely to perform, and the landscape and ecosystem factors that are most likely to influence how wetlands in the subclass function. This increases the accuracy of the assessments, allows for repeatability, and reduces the time needed to conduct assessments (Clairain 2002).

The development of the HGM approach has been "explosive" and modification of the original classification system has already occurred within the USA (Tiner 1999). The HGM approach to wetland classification has spread beyond the USA and has, for example, been used within the classification framework for wetlands and related ecosystems in British Columbia (MacKenzie & Banner 2001) and it has been adopted for the Asian Wetlands Inventory (Finlayson *et al*. 2002). It is also recently begun to establish itself in South Africa (see below).

Integration of Hydrogeomorphic and Cowardin *et al*. (1979) Classification Systems

Recognising the need to better describe wetlands from the abiotic standpoint, in line with the HGM approach, the USFWS developed a set of dichotomous keys for use with National Wetland Inventory data classified according to Cowardin *et al*.'s (1979) classification system (Tiner 1997, cited by Tiner 2003).
These keys attempt to bridge the gap between the original USFWS wetland classification of Cowardin *et al*. (1979) and the HGM classification system (Brinson 1993). They do so by providing descriptors for landscape position, landform, water flow path and waterbody type (so called 'LLWW descriptors'), which are important for producing better characterisations of wetlands and deepwater habitats (Tiner 2003). The LLWW descriptors were developed primarily as additional descriptors for the existing USFWS classification system and to be applied to digital data from the USA's National Wetlands Inventory (Tiner 2003). However, they can also be used independently to describe a wetland or deepwater habitat.

Keys for assigning LLWW descriptors were initially developed for use in predicting the functions of palustrine wetlands in watersheds across the USA (Tiner 1997, 2000, cited by Tiner 2003) and, subsequently, a set of keys for 'waterbodies' was added to improve the ability to characterise all aquatic resources in watersheds. As such, the more recent versions of the dichotomous keys provide for the classification of wetlands in the broader sense of the term (i.e. including rivers, lakes, estuaries and marine waters). The keys are periodically updated based on application in various physiographic regions of the USA, with the most recent version being that of Tiner (2003). It should be possible to adapt Tiner's keys for assigning LLWW descriptors to wetlands for use in other countries. This would improve the utility of existing wetland classification systems elsewhere that are based on Cowardin *et al*. (1979) by enabling the application of the HGM approach to wetland classification and assessment.

Other Classification Systems

Some countries have developed wetland classification systems that are not based on the major systems discussed above, although elements of the various systems have generally been used to some degree. For example, a classification system for wetlands on the Indian subcontinent has been proposed (Gopal & Sah 1995), which separates tidal wetlands from inland wetlands at the first level, and is then based on vegetation form (woody versus herbaceous), flooding regime (permanent versus seasonal) and dominant vegetation type, respectively. In China, a proposed wetland classification system (Lu 1995) distinguishes 22 types of natural wetlands separated into three systems (System 1: coastal and estuarine wetlands; System 2: riverine and lacustrine wetlands, and System 3: peat bogs), and four types of artificial wetlands.

In Australia, there has been a wide diversity of approaches to wetland classification, with different States and Territories often using different systems (Pressey & Adam 1995), some of which are based on the above-mentioned systems while others have been developed specifically for local or regional applications. There have, however, also been some classification systems developed for national wetland inventories in Australia

(Pressey & Adam 1995), such as that of Paijmans *et al*. (1985, cited by Tiner 1999). Paijmans *et al*.'s (1985, cited by Tiner 1999) wetland classification system for Australia, at the broadest level, differentiates between 'lakes', 'swamps', 'land subject to inundation', 'river and creek channels', 'tidal flats', and 'coastal water bodies'.

Canadian Wetland Classification System (1987, 1997)
In Canada, two broad categories of wetland are recognised, namely organic wetlands (or peatlands) and mineral wetlands. The Canadian Wetland Classification System (CWCS) (NWWG 1997, first edition 1987) is hierarchical, but with very different categories compared to the USFWS or Ramsar classification systems (Tiner 1999). It is primarily based on the factors that are responsible for the development of different types of wetlands.

The CWCS has three levels, namely Class, Form and Type. Wetland Class reflects the "genetic" origin of the wetland and the nature of the wetland environment, Wetland Form distinguishes differences in surface morphology, surface pattern, water type and underlying soil morphology, and Wetland Type is based on the physiognomy of vegetation communities. At the level of Class, wetlands are classified as bog, fen, marsh, swamp or shallow water (see NWWG 1997 for definitions of these terms), with the different classes distinguished on the basis of hydrological and water chemistry criteria.

Zoltai & Vitt (1995) have expressed confidence that the CWCS can be applied to Boreal, Subarctic and Arctic regions of the Northern Hemisphere, but are uncertain as to its relevance to the classification of wetlands of lower latitudes. The CWCS is probably most appropriate to very wet regions where peatlands occupy a significant proportion of the landscape, such as Canada, northern Europe and Russia.

A classification framework for wetlands and related ecosystems has been developed for British Columbia in Canada (MacKenzie & Banner 2001). This rather complicated framework combines the Canadian Wetland Classification System with the HGM-based classification and British Columbia's Biogeoclimatic Ecosystem Classification System.

United States Department of Agriculture's classification system for aquatic ecosystems (1995)
A national hierarchical framework for classifying and mapping aquatic ecological units in the USA was developed by the United States Department of Agriculture (USDA) Forest Service (Maxwell *et al*. 1995). The intended purpose is to provide a framework that ensures consistency in the classifying and mapping of aquatic ecosystems, which would improve ecological analyses of aquatic systems to reflect their varied forms and functions. In the framework, aquatic ecological units are constructed by describing an aquatic system in the context of the geoclimatic and zoogeographic settings in which it is most immediately nested. Riverine, lacustrine and groundwater systems are recognised as aquatic systems, with "wetlands" (i.e. palustrine systems) included separately.

The riverine system of Maxwell *et al*. (1995) consists of stream networks within watersheds, with stream networks divided into valley segments based on hydrogeomorphic factors, and valley segments further divided into stream reaches and then channel units. The lacustrine system consists of lakes, ponds and reservoirs. For lakes, characterisations are based on whole lakes, lake zones and lake sites, at increasing levels of detail in the hierarchy. Lakes are rather arbitrarily defined as having an open water area greater than 1 ha and a maximum depth greater than 1 m at low water (versus “open-water wetlands”, which are defined to be less than 1 ha in area or less than 1 m deep at low water). The groundwater system consists of groundwater regions, aquifer zones and aquifer sites, at increasing levels of detail.

Maxwell *et al*. (1995) recognise four groups of basic hydrogeomorphic criteria for classifying “wetlands” (restricted to palustrine systems), namely physiography, climate, water source and hydrodynamics. Physiography is the location of the wetland in the general landscape, which reflects the drainage systems and patterns that influence the flow and storage of water. Five major physiographic classes (or geomorphic types) of wetlands are distinguished, namely:

- shoreline wetlands (divided into coastal and lakeshore wetlands);
- riverine wetlands (divided into intermittent stream wetlands, and steep, moderate, gentle and flat riverine wetlands based on gradient);
- depressional wetlands (divided into playa wetlands, morainal wetlands, dune field wetlands, karst wetlands, slope break wetlands, pocosins and coastal plain bays);
- peat wetlands (divided into ombrotrophic bogs and fens); and
- permafrost wetlands (divided into arctic wetlands and subarctic wetlands).

The classification of “wetlands” in terms of climate is based on precipitation and temparature regimes. The water source is identified as precipitation, groundwater discharge, or lateral inflow. The hydrodynamics class is identified as vertical fluctuations, unidirectional flow, or bidirectional flow. Further subdivisions are provided for the primary water source and hydrodynamics class. Maxwell *et al*. (1995) also provide a series of modifiers which can be used to provide additional information for each wetland type identified. These modifiers include salinity (fresh, oligsaline, mesosaline, polysaline, eusaline, or hypersaline), chemistry (based on pH), water colour, nutrient status (oligotrophic vs. eutrophic), and soils (mineral vs. organic).

The “wetland” component of Maxwell *et al*.’s (1995) classification system is similar to Brinson’s (1993) HGM classification system, including the restriction to palustrine wetland types. In its entirety, however, Maxwell *et al*.’s (1995) classification system (with riverine, lacustrine and groundwater systems included) comes closer than Brinson’s (1993) classification system to encompassing all wetland types according to the Ramsar definition.

New Zealand Wetland Classification Framework (1999)

A hierarchical classification framework for wetlands has been developed for New Zealand (Ward & Lambie 1999), which consists of a series of classification systems for 1) palustrine and estuarine wetland systems; 2) plutonic (underground) and geothermal systems; and 3) lacustrine, riverine and marine systems. The New Zealand framework comprises the following levels:

- Level I: Hydrosystems (based on salinity and broad hydrological setting);

- Level IA: Subsystems (based on flooding regime);
- Level II: Wetland Class (based on substrate, pH and/or chemistry);
- Level IIA: Wetland Form (based on the landform in which a wetland is placed);
- Level III: Structural Class (based on the growth form of the vegetation or, in the case of non-vegetated systems, the nature of the substrate); and
- Level IV: Dominant Cover (based on the dominant species associated with the dominant cover).

The palustrine and estuarine classification systems of the New Zealand Wetland Classification System (Table 1) have been refined and tested, while the components dealing with lacustrine, riverine and marine systems (Table 2), and plutonic and geothermal systems (not shown) still require testing (Ward & Lambie 1999).

One of the noteworthy features of the New Zealand classification framework is the inclusion of the basis for discrimination between different types of wetland at each level of the hierarchy (at least for palustrine and estuarine components – see last row of Table 1), which facilitates consistency in the classification of wetlands by different users.

Wetland Classification in South Africa

Wetland classification in South Africa has not yet developed to the point where there is a widely accepted classification system for use throughout the country. One of the first broad classifications of inland water ecosystems in South Africa was that of Noble & Hemens (1978), who described six categories of inland waters, namely: rivers; vleis and floodplains; endorheic pans and other lakes of the interior; artificial impoundments; coastal and estuarine lakes; and estuaries and estuarine lagoons. Breen & Begg (1989) considered two of these broad categories to be wetlands, namely vleis and floodplains, and endorheic pans. Within each broad category of inland water system, Noble & Hemens (1978) described a number of sub-categories. Breen & Begg (1989) and Jones (2002) have presented modified versions of the original classification of Noble & Hemens (1978) in an hierarchical format (Table 3). A further modification has been developed by Rogers (1997), which includes a category for “riparian fringe” but excludes estuarine systems.

A number of classification systems have been developed and used for specific wetland types, and/or for specific parts of the country. Begg (1986), for example, presented a provisional, non-hierarchical classification system for wetlands in Natal based on altitude.

Other examples include classification systems for alpine mires of the eastern Lesotho highlands (Schwabe 1995), riparian wetlands of South Africa (Rogers 1995), endorheic pans of the western Free State (Geldenhuys 1982, cited by Jones 2002) and of South Africa (Allan *et al*. 1995), coastal lakes of South Africa (Hart 1995), mires (peatlands) of South Africa (Smuts 1998, cited by McCarthy & Hancox 2000), wetlands of the Natal Drakensberg Park (Dely *et al*. 1999), inland wetlands of the Western Cape (Jones & Day 2003), and wetlands in the upper Olifants River catchment in Mpumalanga (Marneweck & Batchelor 2002).

Table 1: Proposed classification framework for Estuarine and Palustrine Systems in New Zealand (from Ward & Lambie 1999)

Level I **Hydrosystem**	**Level IA** **Sub-System**	**Level II** **Wetland Class**	**Level IIA** **Wetland Form**	**Level III** **Structural Class** [examples]	**Level IV** **Dominant Cover** [examples]
Estuarine	Intertidal	Saltmarsh	Estuary	[e.g. herbfield]	[e.g. Zostera]
(Alternating saline and	Subtidal	Seagrass meadows	Lagoon	[e.g. (wire)rushland]	[e.g. Leptocarpus/Juncus]
freshwater)					
	Non-tidal	Algalflat	Dune slack	[e.g. forest]	[e.g. Avicennia]
	Inter-dunal	Mudflat		[e.g. wormfield]	[e.g. Polychaete]
		Cobbleflat		[e.g. cocklebed]	[e.g. Austrovenus]
		Rocky reef		[e.g. gravelfield]	[e.g. Diatomfelt]
		Sandflat		[e.g. musselreef]	[e.g. Perna]
				[e.g. shrubland]	[e.g. Muehlenbeckia]
Palustrine	Permanent	Marsh	Shore	[e.g. reedland]	[e.g. Typha]
(Vegetation emergent	Ephemeral	Swamp	Artificial	[e.g. algalbed]	[e.g. Enteromorpha]
over freshwater, not incl.		Fen	Slope	[e.g. macrphyte bed]	[e.g. Ruppia]
floating plants)		Bog	Channel	[e.g. sedgeland]	[e.g. Carex]
		Flush	Flat	[e.g. cushionfield]	[e.g. Leptospermum /Cordyline]
		Seep	Basin	[e.g. rushland]	[e.g. Donatia]
			Pool	[e.g. rockfield]	[e.g. Schoenus]
					[e.g. Nostoc]
					[e.g. Spirogyra]
Basis of discrimination: Hydrological setting, Salinity	Flow Regime	Substrate, pH, Chemistry	Land Form	Biotic Structure	Dominant species

Table 2: Proposed classification framework for Marine, Lacustrine and Riverine Systems in New Zealand (from Ward & Lambie 1999)

Level I Hydrosystem	**Level IA Sub-System**	**Level II Wetland Class**	**Level IIA Wetland Form**	**Level III Structural Class**	**Level IV Dominant Cover**
Marine	Supratidal	[e.g. splashzone]	[e.g. exposed coast]	[e.g. barnacle field]	[e.g. Elmius]
(saline open water)	Intertidal	[e.g. sandy megaripple]	[e.g. embayment]	[e.g. surfclam bed]	[e.g. Spisula]
	Subtidal	[e.g. boulder reef]	[e.g. tidal bore]	[e.g. kelpforest/urchin barren]	[e.g. Ecklonia/Evechinus]
		[e.g. coral reef]	[e.g. bombie]	[e.g. staghorn coralgarden]	[e.g. Acropora]
Lacustrine	Permanent	Oligotrophic monomictic	{Marginal}	{Low mixed community}	[e.g. Isoetes]
(standing open freshwater		Oligotrophic amictic	{Littoral}	{Mound community}	[e.g. Glossostigma]
incl. lake, pond, pool)		Mesotrophic monomictic	{Sublittoral}	{Tall mixed community}	[e.g. Myriophyllum]
		Mesotrophic amictic	{Profundal}	{Characean meadow}	[e.g. Nitella]
		Eutrophic monomictic	{Pelagic}	{Bryophyte bed}	[e.g. Drepanocladus]
		Eutrophic amictic		{Algal bed}	[e.g. Zygnemopsis]
		Eutrophic polymictic		{Tall adventive community}	[e.g. Lagarosiphon]
		Dystrophic monomictic		{Floating fern/lily community}	[e.g. Azolla]
		Dystrophic amictic			
		Dystrophic polymictic			
	Seasonal	Mesotrophic amictic			
		Eutrophic amictic			
	Ephemeral	Mesotrophic amictic			
		Eutrophic amictic			
Riverine	Perennial	Stable steepland	{entrenched channel}	{Fall/cascade}	{Bedrock}
(flowing open freshwater		Variable steepland	{meander channel}	{Rapid}	{Rubble/boulder}
incl. river, stream, canal)		Flashy steepland	{braided channel}	{Riffle}	{Cobble/gravel}
		Stable midland	{anastomosing ch.}	{Run/glide}	{sand}
		Variable midland	{unincised shelf}	{Pool}	{silt/clay}
		Flashy midland		{Spring}	{vegetated}
		Stable lowland			
		Variable lowland			
		Flashy lowland			
	Tidal	Variable		{Saltwedge}	
		Flashy		{Bore}	
		Headwater steepland		{intermittent channel}	
		Floodplain lowland		{flood ponding}	

In addition, classification systems have been developed for South African estuaries (Whitfield 1992) and rivers (Brown *et al*. 1996; Rowntree & Wadeson 1999, 2000). Very few classification systems have, however, been developed for classifying all wetland types throughout the country.

Morant (1983) proposed that the Cowardin *et al*. (1979) system be used for wetland classification in South Africa with minor modifications, as it is sufficiently broad and adaptable. At a workshop on wetland inventory and classification in South Africa held in 1988, Breen (1988) suggested that Morant's (1983) modification of the Cowardin *et al*. (1979) classification system should be used as a prototype for the national inventory of wetlands, once testing of the system had been undertaken in the different regions of the country. Despite these suggestions, by the end of the 1980's, no wetland classification system had yet been adopted in South Africa and very little further progress had been made since the work of Noble & Hemens (1978) in documenting wetland variability at a broad national scale (Breen & Begg 1989)[1]. The *status quo* remained this way until the late 1990's.

1 Although a project was initiated in the late 1980's to develop an inventory and classification system for wetlands in the South-western Cape (King 1987; Silberbauer & King 1991) as part of a national wetlands research programme to develop *inter alia* a nationally applicable wetlands classification system (Walmsley 1988), the funding for the project was withdrawn before it was completed (pers.comm., Dr JM King, University of Cape Town).

Table 3: Classification system of Noble & Hemens (1978) for South African aquatic ecosystems (from Jones 2002)

Ecosystem	Wetland Type	
Rivers		
Vleis & Flood plains	Rivers source Sponges	
	Marshes and swamps	Sedge marsh Restio marsh Reedbed marsh Reed swamp Papyrus swamp Cape seasonal wetland Swamp forest Salt marsh Mangrove swamp
	Flood plains	Karoo flood flats Floodplain vleis Storage floodplains
Endorheic pans and lakes of the interioir		Salt pans Temporary pans Grass pans Sedge pans Reed pans Semi-permanent pans
Impoundments (man made)		
Coastal and Estuarine Lakes	Coastal Lakes	Brackish seepage outflow Fresh or brackish outflow to sea Fresh or brackish outflow to sea occasionally Tidal
	Estuarine Lakes	Fresh to saline, shallow Fresh to saline, deeper, stratified Fresh to hypersaline
Estuaries and Estuarine Lagoons		Estuaries forming temporary lagoons Embayment estuaries Estuaries connected to coastal estuarine lakes Typical estuaries River mouths

For a preliminary inventory of the major wetlands in South Africa compiled by Cowan & Van Riet (1998), an adaptation of the Ramsar classification system based on Dugan (1990) and Denny (1996, cited by Cowan & Van Riet 1998) was used (Table 4), in which the Ramsar wetland categories were sorted into the broad categories of Cowardin *et al*'s (1979) classification system. There has, however, been no documented use or acceptance of this classification system subsequent to the publication of the preliminary inventory.

Table 4: Classification system used by Cowan & Van Riet (1998)

COASTAL WETLANDS			
Marine	**subtidal**	1.	sea bays, straits
		2.	subtidal aquatic vegetation
		3.	coral reefs
	intertidal	4.	rocky marine shores, including cliffs, rocky shores
		5.	shores of mobile stones and shingle
		6.	intertidal mud, sand or salt flats
		7.	intertidal salt marshes
		8.	intertidal mangroves
Estuarine	**subtidal**	9.	estuarine waters
	intertidal	10.	intertidal mud, sand or salt flats
		11.	intertidal marshes
		12.	intertidal forested wetlands
(Lagoonal)		13.	brackish to saline lagoons
INTERIOR WETLANDS			
Endorheic		14.	permanent and seasonal, brackish, saline or alkaline lakes, flats, pans and marshes
Riverine	**perennial**	15.	rivers and streams including waterfalls
		16.	inland deltas
	seasonal	17.	seasonal rivers and streams
		18.	riverine floodplains
Lacustrine	**permanent**	19.	permanent freshwater lakes (> 8ha)
		20.	permanent freshwater ponds (< 8ha)
	seasonal	21.	seasonal freshwater lakes (> 8ha)
		22.	seasonal freshwater ponds (< 8ha)
Palustrine	**emergent**	23.	permanent freshwater marshes and swamps
		24.	permanent peat-forming freshwater swamps
		25.	seasonal freshwater marshes
		26.	peatlands and fens
		27.	Alpine and polar wetlands
		28.	springs and oases
		29.	volcanic fumaroles
	forested	30.	shrub swamps
		31.	freshwater swamp forests
		32.	forested peatlands
MAN-MADE WETLANDS			
Aquaculture/mariculture		33.	aquaculture ponds
Agriculture		34.	irrigated land including rice fields
		35.	seasonally flooded agricultural land
Salt exploitation		36.	salt pans and evaporation pans
Urban/industrial		37.	excavations
		38.	wastewater treatment areas
Water storage areas		39.	resevoirs
		40.	hydro-dams

Proposed Wetland Classification Systems for South Africa developed for the Department of Environmental Affairs and Tourism (DEAT)

During a national workshop held in November 1997, the USFWS classification system of Cowardin *et al*. (1979) was adopted as the basis for the South African national wetland inventory (Dini 1997, cited by Dini & Cowan 2000). Following this workshop, Dini *et al*. (1998) produced a draft classification system for comment (Figure 3), which was an adaptation of the Cowardin *et al.* (1979) system and the related MedWet Habitat Description System (Farinha *et al*. 1996). A second draft classification system was produced by Dini & Cowan (2000) based on comments received on the first draft (Figure 4). In the second draft classification system, an attempt was made to synthesise hydrogeomorphic elements into the original system because of "the increasing emphasis placed on geomorphic and hydrologic aspects of wetland classification, especially where such approaches enhance the ability of the classification to provide information on the functional aspects of wetland ecosystems (eg. Brinson 1993; Semeniuk & Semeniuk 1995; Tiner 1997)" (Dini & Cowan 2000). This draft of the proposed classification system was used to guide the development of the updated version of the MedWet Habitat Description System of Farhina *et al*. (2005).

One of the problem areas encountered in adapting the Cowardin *et al*. (1979) for wetland classification in South Africa has been deciding on how to deal with endorheic pans. The various modifications of the classification systems developed under the auspices of the DEAT have dealt with these wetland systems in different ways (see Dini *et al*. 1998; Dini & Cowan 2000; Thompson *et al*. 2002), as discussed below.

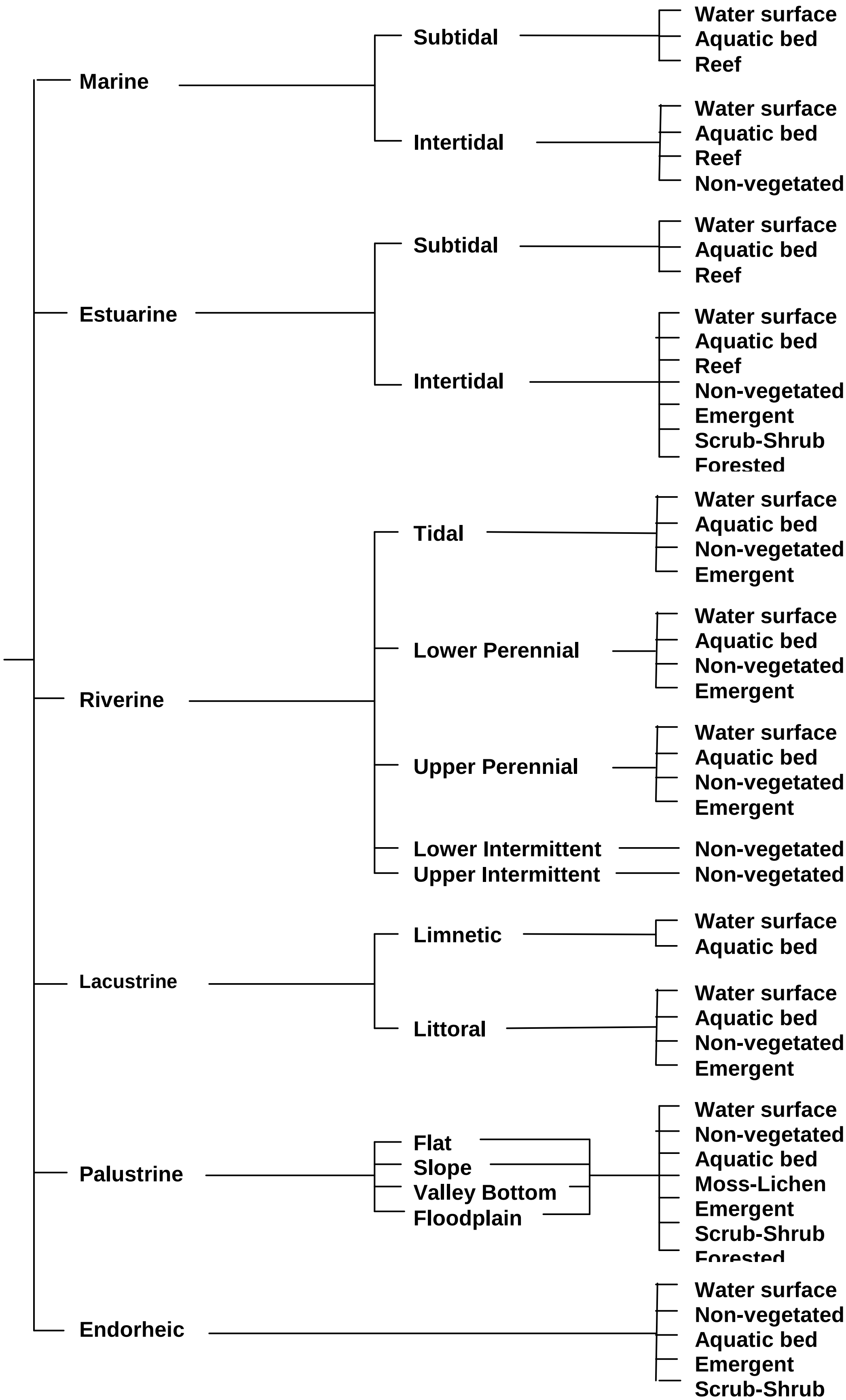


Figure 3: Dini *et al*.'s (1998) proposed wetland classification for South Africa

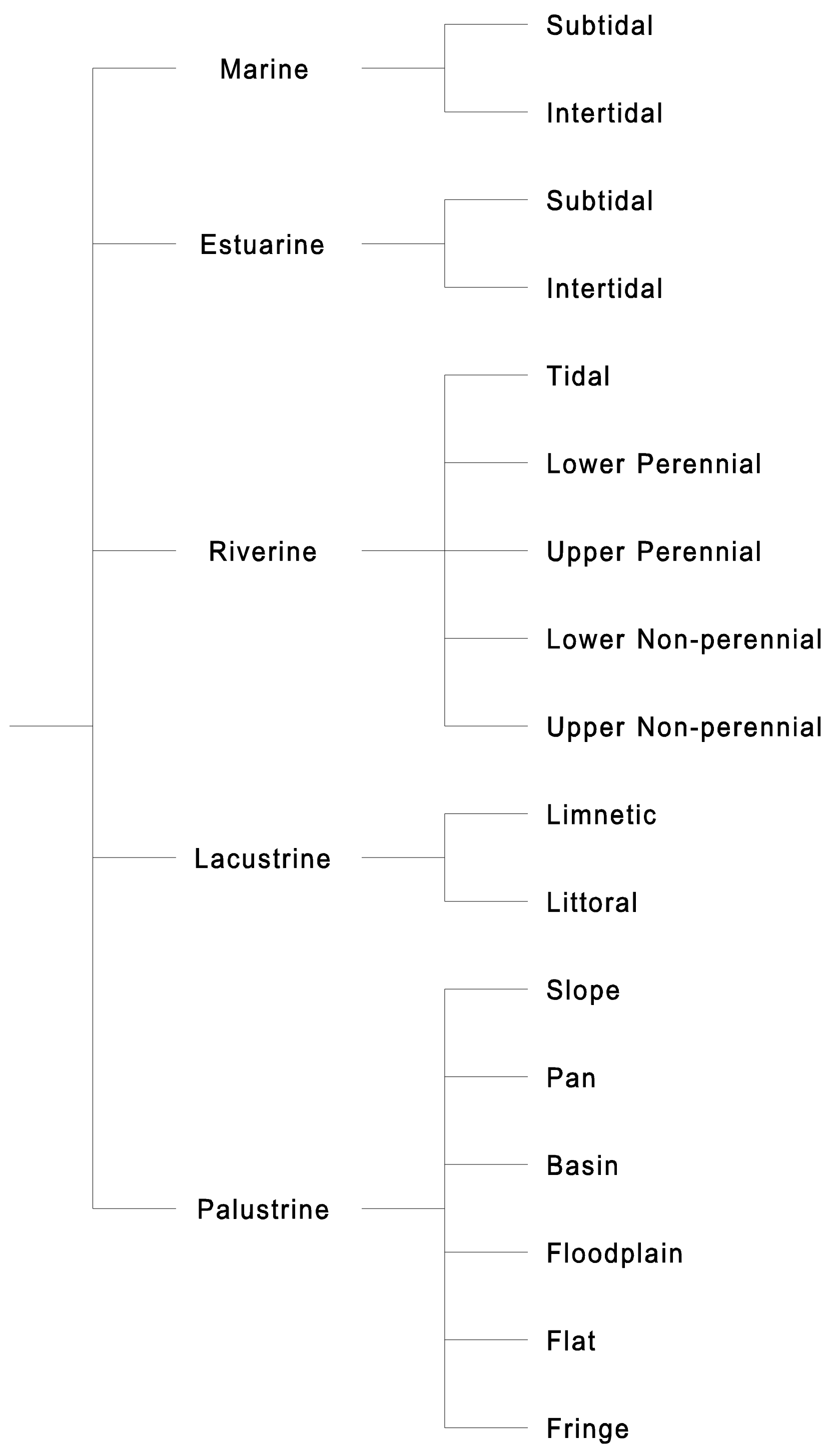


Figure 4: Dini & Cowan's (2000) proposed wetland classification system for South Africa

Marine and Estuarine Systems

In the classification systems of Dini *et al*. (1998) and Dini & Cowan (2000), the Marine System consists of the open ocean overlying the continental shelf and its associated exposed coastline. The Estuarine System consists of tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed or sporadic access to the open ocean, and in which ocean water is at least occassionally diluted by freshwater runoff from the land. Both the Marine and Estuarine Systems are divided into Subtidal and Intertidal Subsystems.

Riverine System

The Riverine System includes all wetlands contained within a channel. The following two exceptions are not considered Riverine wetlands: 1) wetlands dominated by mosses or lichens, emergents (eg. *Phragmites australis*), shrubs or trees; and 2) habitats with sea-derived salinity in excess of 0,5 g/l. The Riverine System is characterised by water which is usually, but not always, flowing in a channel. Non-wetland islands or palustrine islands may occur in the channel, or on adjacent flooded plains, but they are not included in the Riverine System. Oxbow lakes are placed in the Lacustrine or Palustrine Systems unless they are intermittently connected to a Riverine System by an open channel at both ends. Floodplain wetlands are not considered part of the Riverine System; rather, they are included in the Palustrine System.

The Riverine System is divided into five Subsystems: Tidal, Lower Perennial, Upper Perennial, Lower Non-perennial and Upper Non-perennial. Each Subsystem is defined in terms of water permanence, gradient, water velocity, substrate, and the extent of floodplain development, as well as characteristic flora and fauna.

In the classification system of Dini & Cowan (2000), emergent habitats are not considered to be part of the Riverine System, whereas they were included in the earlier classification system of Dini *et al*. (1998). Instead, all emergent habitats within the borders of the Riverine System are classified under the Palustrine System. The rationale behind this modification of the classification system is that emergent vegetation within a river channel displays different characteristics to the adjacent running water habitat and, therefore, does not strictly belong to the latter habitat. It is argued that emergent habitats within river channels usually display ecological characteristics more indicative of palustrine than riverine wetlands. In the classification system of Dini & Cowan (2000), provision is made under the Palustrine System for emergent habitats within river channels to be designated as 'riverine fringe wetlands'.

Lacustrine System

The Lacustrine System of Dini & Cowan (2000) includes wetlands possessing all of the following characteristics:

- situated in a topographic depression or a dammed river channel;
- total area greater than 8 ha; *and*
- surface area coverage by trees, shrubs or persistent emergents of less than 30%.

Similar wetlands of less than 8 ha are also included in the Lacustrine System if they possess *at least one* of the following characteristics:

- water depth in the deepest part of the basin exceeds 2 m at low water; or
- a wave-formed or bedrock feature makes up all or part of the shoreline boundary.

Wetlands which would otherwise be considered lacustrine, but which possess *all* of the following characteristics are not classified within the Lacustrine System:

- closed drainage / endorheic (lacking any outlet);
- flat basin floor;
- less than 2 m deep when fully inundated; and
- usually circular to oval in shape, sometimes kidney-shaped or lobed.

The Lacustrine System of Dini & Cowan (2000) is associated with open standing water, including permanently flooded lakes and dams. Typically, there are extensive areas of deep water, and there may be considerable wave action. Lacustrine waters may be tidal or non-tidal, but ocean-derived salinity is always less than 0,5 g/l. Limnetic and Littoral Subsystems are distinguished on the basis of depth, with all habitats within the Lacustrine System lying at a deph greater than 2 m below low water considered to be limnetic.

The Classes included for Lacustrine Systems are Rock Substrate, Unconsolidated Substrate and Aquatic Bed. As with the Riverine System, emergent habitats have been dropped from the Lacustrine System of Dini & Cowan (2000). This is a modification of the previous classification system of Dini *et al*. (1998) and of the Cowardin classification system. The rationale for this modification is identical to that cited for excluding emergent habitats from the Riverine System.

Palustrine System

The Palustrine System includes:

- all non-tidal wetlands dominated by trees, shrubs, emergents, mosses or lichens (greater than 30% surface area coverage);
- tidal wetlands where salinity due to ocean-derived salts is less than 0,5 g/l; and
- wetland habitats lacking the vegetation listed above, but with *all* of the following characteristics:
    - area less than 8 ha;
    - water depth in the deepest part of the basin less than 2 m at low water;
    - lacking active wave-formed or bedrock shoreline features; and
    - salinity due to ocean-derived salts less than 0,5 g/l.

In addition, wetlands with or without the vegetation listed in the first bullet-point above, but with *all* of the following characteristics are also considered by Dini & Cowan (2000) to be Palustrine:

- closed drainage / endorheic (lacking any outlet);
- flat basin floor;

- less than 2 m deep when fully inundated; and
- usually circular to oval in shape, sometimes kidney-shaped or lobed.

In the original classification system of Dini et al. (1998), wetlands meeting these criteria were classified separately as Endorheic Systems, a category which was dropped from the updated classification system of Dini & Cowan (2000).

The Palustrine System of Dini & Cowan (2000) groups together all wetlands characterised by emergent vegetation, which are traditionally called marshes, swamps, fens and vleis. It also includes small shallow waterbodies, and vegetated and unvegetated endorheic pans. Palustrine wetlands may be situated shoreward of river channels, lakes or estuaries; on river floodplains; in isolated catchments; or on slopes. They may also occur as islands in lakes or rivers. The Palustrine System is divided into the following six Subsystems on the basis of the host landform on which the wetland is situated: Slope, Pan, Basin, Floodplain, Flat, and Fringe. The original classification system of Dini *et al*. (1998) distinguished between four Palustrine Subsystems (Flat, Slope, Valley Bottom, and Floodplain), while the Cowardin *et al*. (1979) did not divide the Palustrine System into any subsystems.

The Palustrine Subsystems of Dini & Cowan (2000) are based on the descriptors for landform developed by Tiner (1997, cited by Dini & Cowan 2000), which were designed to merge aspects of the hydrogeomorphic wetland classification method of Brinson (1993) with the classification system of Cowardin *et al*. (1979). By including these, Dini & Cowan (2000) incorporate the abiotic features important for determining certain wetland functions into their classification system. The Wetland Classes distinguished by Dini & Cowan (2000) for Palustrine Systems are Rock Substrate, Unconsolidated Substrate, Aquatic Bed, Emergent, Scrub-Shrub, and Forested.

Below the Class level, the classification systems of Dini *et al*. (1998) and Dini & Cowan (2000) divide wetlands into Subclasses, Dominance Types and Modifiers, as with the classification systems of the USFWS (Cowardin *et al*. 1979) and MedWet (Farinha *et al*. 1996) upon which they are based.

A modified version of the classification system of Dini & Cowan (2000) was presented and used in the pilot project for the national wetland inventory (Thompson *et al*. 2002) (Figure 5). This modified version makes provision for four hydrological components at the sub-system level for Palustrine Systems (inflow, outflow, throughflow channelled, and throughflow unchannelled), in an attempt to link in with the hydrological components at sub-system level for Marine, Estuarine, Riverine and Lacustrine Systems. In addition, judging from the outline of the modified version of the classification system presented, emergent wetlands appear to have been included once again as a Wetland Class under Riverine and Lacustrine Systems.

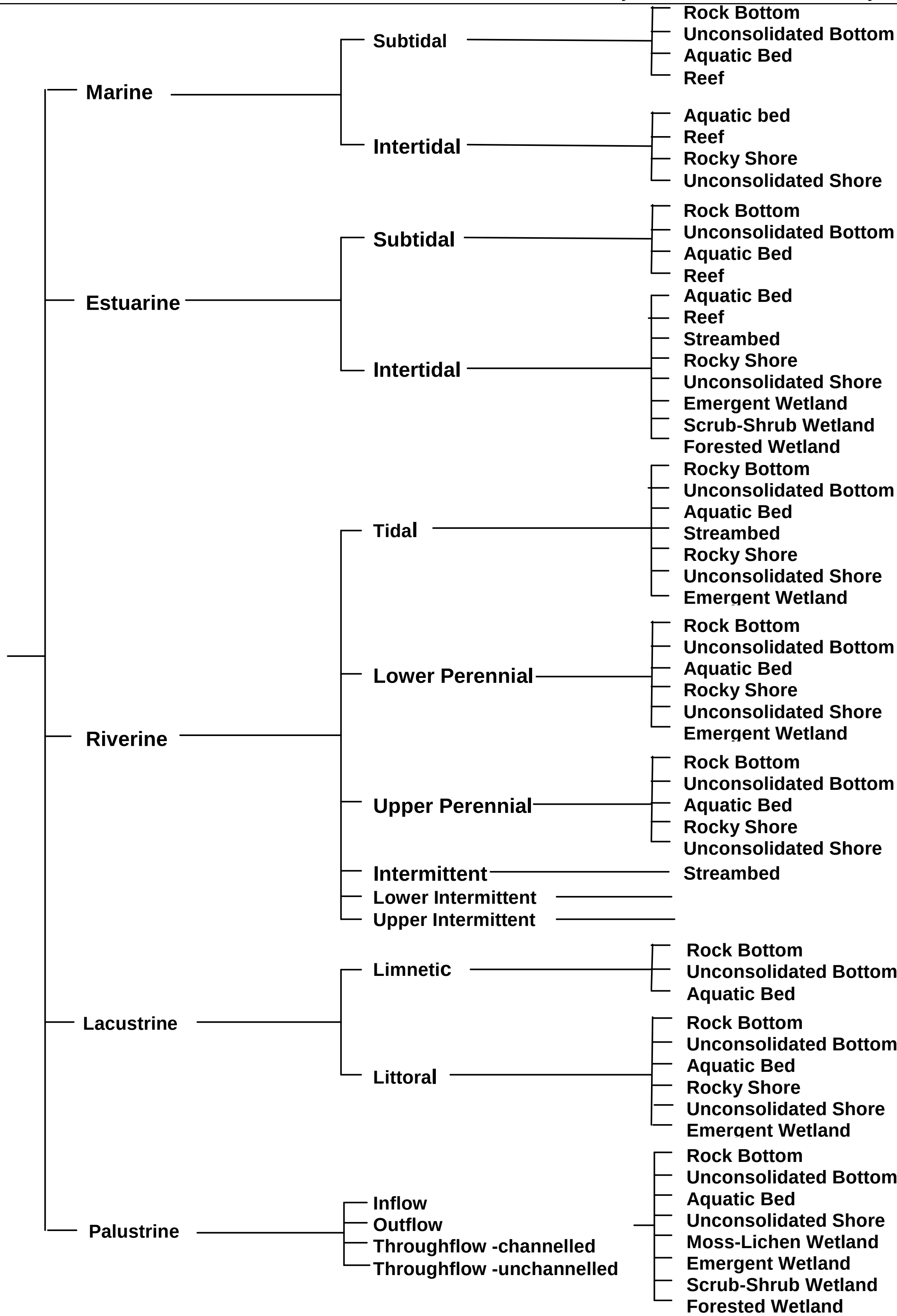


Figure 5: Proposed modification of Dini & Cowan's (2000) classification system for the South African National Wetland Inventory (as presented in Thompson *et al*. 2002)

Hydrogeomorphic (HGM) approach to wetland classification in South Africa

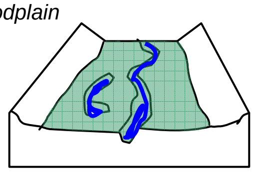
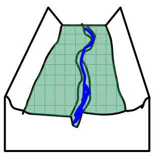
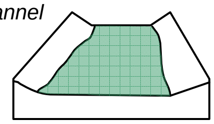
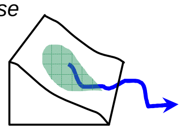
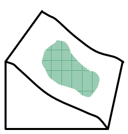
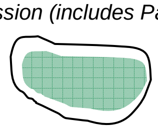
The development of 'tools' for the functional assessment of wetlands in South Africa, which is currently underway (e.g. Kotze *et al*. 2005), are based on the HGM approach to wetland classification. These 'tools' are specifically designed for palustrine wetlands (i.e. non-tidal wetlands dominated by emergent plants, shrubs or trees). For the application of these 'tools', the following HGM types or units have been defined on the basis of geomorphic setting, water source and how water flows through a wetland unit (see Table 5):

- Floodplain;
- Valley bottom with a channel;
- Valley bottom without a channel;
- Hillslope seepage feeding a watercourse;
- Hillslope seepage not feeding a watercourse; and
- Depression (includes Pans).

For the functional assessment of wetlands using the tools that are currently under development, HGM wetland units should be identified primarily from the interpretation of aerial photos at a 1: 30 000 scale or finer, viewed through a stereoscope, together with ground verification (Kotze *et al*. 2005).

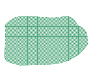
The HGM approach to wetland classification system provides a useful basis for the development of a wetland classification system for South Africa that provides information on the fundamental processes responsible for the development of different types of wetlands and the principal determinants of wetland structure and function, which has been identified as an important need on numerous occasions (e.g. Rogers 1997; McCarthy & Hancox 2000). The development of a proposed wetland classification system for South Africa, based on a broad definition of wetland (in line with that of the Ramsar Convention) and incorporating HGM elements, was initiated by the Wetland Rehabilitation Research Group at the University of KwaZulu-Natal (pers. comm., Erwin Sieben, Wetland Rehabilitation Research Group) (Table 6). This work has been taken further in a recent project to develop a wetland classification system for the South African National Wetland Inventory (Ewart-Smith *et al*. 2005).

Table 5: Wetland hydrogeomorphic types of Kotze *et al*. (2005)

Hydrogeomorphic types	Description	Source of water maintaining the wetland[1]	
		Surface	Sub-surface
Floodplain 	**Valley bottom areas with a well defined stream channel, gently sloped and characterized by floodplain features such as oxbow depressions and natural levees and the alluvial (by water) transport and deposition of sediment, usually leading to a net accumulation of sediment. Water inputs from main channel (when channel banks overspill) and from adjacent slopes.**	***	*
Valley bottom with a channel 	**Valley bottom areas with a well defined stream channel but lacking characteristic floodplain features. May be gently sloped and characterized by the net accumulation of alluvial deposits or may have steeper slopes and be characterized by the net loss of sediment. Water inputs from main channel (when channel banks overspill) and from adjacent slopes.**	***	*/ ***
Valley bottom without a channel 	**Valley bottom areas with no clearly defined stream channel, usually gently sloped and characterized by alluvial sediment deposition, generally leading to a net accumulation of sediment. Water inputs mainly from channel entering the wetland and also from adjacent slopes.**	***	*/ ***
Hillslope seepage feeding a watercourse 	**Slopes on hillsides, which are characterized by the colluvial (transported by gravity) movement of materials. Water inputs are mainly from sub-surface flow and outflow is usually via a well defined stream channel connecting the area directly to a watercourse.**	*	***
Hillslope seepage not feeding a watercourse 	**Slopes on hillsides, which are characterized by the colluvial (transported by gravity) movement of materials. Water inputs mainly from sub-surface flow and outflow either very limited or through diffuse sub-surface and/or surface flow but with no direct surface water connection to a watercourse.**	*	***
Depression (includes Pans) 	**A basin shaped area with a closed elevation contour that allows for the accumulation of surface water (i.e. it is inward draining). It may also receive sub-surface water. An outlet is usually absent.**	*/ ***	*/ ***

[1] Precipitation is an important water source and evapotranspiration an important output in all of the above settings

Water source:	*	**Contribution usually small**
	***	**Contribution usually large**
	*/ ***	**Contribution may be small or important depending on the local circumstances**



Wetland

Table 6: South African Wetland Classification System proposed by the Wetland Rehabilitation Group

System	Hydrology/Landform	Type	Regional variation
Marine wetlands	**Subtidal**	**Reef**	
		Rocky shore	
		Sand bottom	
		Seagrass	
	Intertidal	**Reef**	
		Rocky shore	
		Sand bottom	
		Seagrass	
Estuarine	**Subtidal**	**Sand bottom**	
		Rocky shore	
		Seagrass	
	Intertidal	**Sand banks**	
		Rocky shores	
		Saltmarshes	**Western + Southern, Eastern**
		Mangroves	
Rivers and associated wetlands	**Permanent river channel**	**Mountain stream**	**Fynbos, Forest, Grassland, Savannah, Thicket**
		Foothills (winding) stream	**Fynbos, Renosterveld, Grassland, Savannah, Karoo, Forest, Thicket**
		Lowlands (braided) stream	**Savannah, Grassland, Renosterveld, Karoo, Forest, Thicket**
		Waterfalls	
	Intermittent river channel	**Mountain stream**	**Fynbos, Karoo, Grassland, Savannah, Forest**
		Foothills (winding) stream	**Fynbos, Renosterveld, Grassland, Savannah, Karoo, Forest, Thicket**
		Lowalnds (braided) stream	**Savannah, Grassland, Renosterveld, Karoo, Forest, Thicket**
		Waterfalls	
	Floodplain		**Fynbos, Renosterveld, Grassland, Savannah, Thicket, Karoo**
	Valley bottom	**With channel**	**Grassland, Fynbos, Renosterveld, Thicket, Savannah**
		Without channel	**Grassland, Fynbos, Renosterveld, Thicket, Savannah**
	Seepages / Sponges	**Seepage with channel**	**Fynbos, Grassland**
		Seepage without channel	**Fynbos, Grassland**
Endorheic wetlands	**Inland lakes**		**Lake Fundudzi**
	Coastal lakes	**Estuarine lakes**	**Western + Southern, Eastern**
		Freshwater coastal lakes	**Western + Southern, Eastern**
	Man-made ponds and lakes	**Aquaculture**	
		Irrigated land	
		Salt pans	
		Excavations	
		Reservoirs and ponds	
	Dams and weirs	**Dams**	
		Weirs	
	Pans	**Salt pans**	**Karoo, Fynbos, Savannah, Grassland**
		Brackish pans	**Karoo, Fynbos, Savannah, Grassland**
	Depression wetlands	**Permanently inundated**	**Savannah, Forest, Mountainous, Maputaland, Renosterveld, Grassland**
		Seasonally inundated	**Savannah, Forest, Grassland, Fynbos, Karoo**
Underground wetlands	**Limestone caves**		

SPATIAL FRAMEWORKS AND WETLAND CLASSIFICATION

Regional variations in climate, geology, soils and vegetation are important in the development of different wetland types, and management problems often differ substantially in different regions. As such, there is a need to recognise regional differences when classifying wetlands (Cowardin *et al*. 1979). This is usually achieved by developing or using a spatial framework for the application of a wetland classification system. Spatial frameworks are simply broad-scale (national- to regional-level) maps that divide large areas into relatively homogenous units to provide a context for ecosystem management. The units that are mapped generally reflect a combination of biophysical attributes within landscapes, rather than specific attributes such as soils or vegetation in isolation.

For the application of the USFWS classification system within the USA, Cowardin *et al*. (1979) advocate the use of Bailey's (1976, cited by Cowardin *et al*. 1979) ecoregions with the addition of 10 marine and estuarine provinces as a spatial framework. The HGM approach to wetland classification in the USA (after Brinson 1993) allows for the development of regional wetland subclasses within each defined region on the basis of the geomorphic settings, water sources and hydrodynamic factors that are relevant, with the possibility of using additional ecosystem or landscape characteristics to further refine regional subclass categories (Smith *et al*. 1995).

In British Columbia (Canada), the Biogeoclimatic Ecosystem Classification for British Columbia has been used as a spatial framework for wetland classification (e.g. MacKenzie & Banner 2001). Froude & Beanland (1999) examined a number of potentially applicable spatial frameworks for the development of a wetland classification system in New Zealand. For the Asian Wetlands Inventory (Finlayson *et al*. 2002), a hierarchical spatial framework has been adopted, with 'wetland complexes' and 'wetland habitats' considered firstly within the context of major river basins, coastal regions and islands (Level 1) and, secondly, within the context of sub-basins and coastal sub-regions (Level 2).

In South Africa, a spatial framework has not yet been developed for wetland classification and management that has widespread acceptance. For the classification and management of riverine ecosystems, two spatial frameworks have been developed. One of these is ecoregions (Kleynhans & Hill 1999), which are based mainly on broad-scale patterns of physiography, climate, geology, soils and vegetation across the country. The other is bioregions (Brown *et al*. 1996), which are based on the known biogeographic distribution patterns of riverine biota. There is to date no agreement as to whether ecoregions or bioregions are the most appropriate spatial framework for the classification and management of river ecosystems, although the ecoregional framework appears to be the most widely used. The development of a widely acceptable spatial framework for wetland classification and management is at a less advanced stage than that for rivers.

Morant (1983) recommended that, at the broadest level of wetland classification in South Africa, each wetland should be placed within one of the fifteen climatic regions delineated by Schulze (1965, cited by Morant 1983). At the next level, he proposed the use of Acocks (1975, cited by Morant 1983) Veld Types as a broad habitat classification. More recently, Cowan (1995) produced a map of wetland regions for South Africa. He divided the country into four broad groups of wetland regions, based on the broad patterns of morphology. These groups are ‘plateau’, ‘mountains’, ‘coastal slopes and rimland’, and ‘coastal plain’. Cowan (1995) further sub-divided these broad groups into geomorphological provinces. Twenty-six wetland regions were then distinguished by Cowan (1995) on the basis of the geomorphological provinces and climate, with each region representing wetlands with a similar topography, hydrology and nutrient regime.

The wetland regions developed by Cowan (1995) must still be tested for its applicability as a spatial framework for wetland classification and management in South Africa. This framework should be compared with the ecoregional and bioregional frameworks that have already been developed and applied to riverine ecosystems, to determine which spatial framework is the most appropriate for wetlands. Another option that could be explored is the use of Biomes as a spatial framework for wetland classification, as proposed by the Wetlands Rehabilitation Research Group at the University of KwaZulu-Natal (Table 6).

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APPENDIX 2
PROCEEDINGS OF A
WETLAND CLASSIFICATION WORKSHOP

WETLAND CLASSIFICATION WORKSHOP

Date: 1 December 2005
***Venue*:** the Water Research Commission, Pretoria
Facilitator: Prof. Jenny Day (University of Cape Town)

Workshop attendants:

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Introduction

A background to the project was given which included the Terms of Reference (ToR). The purpose of the workshop i.e. to obtain specialist input on the proposed wetland classification system was highlighted.
Potential uses for a wetland classification system were identified as follows:

- Biodiversity conservation planning.
- Prioritisation of wetlands for protection and rehabilitation.
- Water resource management (i.e. RDM).
- Catchment management planning.
- Design of monitoring programmes.
- State of Environment reporting (including wetland health assessments).
- Designation of Ramsar sites.
- Basis for EIAs.
- Strategic Environmental Assessments (SEAs)
- Assist with understand wetland functions and thus facilitate functional prioritisation.
- To help understand the origin of wetlands

Summary of the Advanced wetland layer (AWL)

The AWL is generated by using spectral indicators of "wetness" and "greenness" from multi-season satellite imagery, together with an index of "landscape wetness potential" derived from a digital elevation model. Some of the constraints of the AWL were outlined as follows:

- Spectral confusion/accuracy constraints due to:
    - Low shrublands/impacted sites (i.e. alien invaders)
    - Topography shadows
    - Fire affected areas
    - Low variations in topography
    - Geologically diverse areas
- Gaps in the data set;
- Error propagation;
- No mapping in the Savanna biome;
- Shrubs, trees and wetlands are not spectrally separable.

Suggested future work to improve the AWL:

- Position in landscape should be more important than "greenness";
- Use of thermal data should be investigated;
- Incorporation of texture (shape) by means of hypertemporal analysis should be investigated;

Clarifications:

- Not all NLC2000 data is optimal for the AWL, with significant regional variation in data. This is because the AWL "piggy-backed" on the NLC2000 project, only being added later. Optimal data sets were used in the Pilot Study for the development of the AWL, with good results obtained, but the current AWL is not based on optimum data due to the geographic variation in the quality of the data used.
- No biophysical information can be obtained from the AWL other than the degree to which an area has the potential to hold water. For example, the AWL cannot tell you whether a particular wetland is a depression or a flat.

Background to proposed classification system

The major findings of the literature review were presented, which provided a background to the proposed classification system. Essentially, the literature review outlines how there is an international trend away from the traditional "Cowardin approach" to wetland classification towards an approach based on hydro-geomorphology (HGM).

General concerns/issues raised regarding the approach to developing a classification system.

- ***Biological vs functional approach to classification of wetlands***

The need for an *a posteriori* (i.e. bottom-up) wetland classification system based on empirical biotic data was identified. Such a system has been developed for application in KwaZulu Natal. However, general discussions throughout the workshop indicated that:

  - An abiotic template is a better starting point for classifying wetlands (i.e. an *a priori* classification system) because wetlands are, at their broadest levels, defined by abiotic features that drive biotic patterns. Also, a lack of available biotic data makes it impossible to develop or apply an *a posteriori* classification.
  - Experience in the western Cape has shown that wetlands do not adequately group according to biotic patterns.
  - PG asked why a wetland classification system based on biological factors at the broad-scale had not yet been developed for South Africa.
  - We need to know what basic biotic elements should be monitored (for Reserve determinations).

- ***Rules / criteria used to discriminate wetlands are not adequately defined.***
  In many cases, it is difficult to determine where one wetland unit starts and another ends because the rules or criteria used to discriminate wetland units are not well defined. This issue was apparent through all systems and was identified as a priority for further development and refinement of the classification system.

- ***The AWL does not provide adequate biophysical data necessary for distinguishing one wetland type from another and therefore it will be difficult to link the classification system to the AWL.*** It was stressed that it is important to be careful about limiting the classification system to the information that can be obtained from the AWL of NLC2000. The AWL is only the first step for the national inventory. A classification system is needed that can be used beyond this.

- ***Discriminators should not be exclusionary in an hierarchical classification system***. This could prevent classification beyond a high level, particularly where data sources are limited. Consideration should be given to removing discriminators from the classification system that cannot be obtained from the AWL or other remote sensing data sources, or relegating these discriminators to the lower levels of the classification system. Such discriminators could be used as descriptors instead. However, in some instances it may be necessary to use additional data sources to obtain critical information.

- ***Is it adequate to classify wetland units as vegetated or unvegetated at the structural level?***
  The need to go beyond vegetated versus unvegetated for conservation purposes was discussed (e.g. mangroves and marshes dominated by different plants need to be distinguished from one another – this information can be obtained from 1:10 000

scale aerial photographs). It does not help just knowing whether a wetland is vegetated or unvegetated. Vegetation communities should be distinguished at this level of the classification system. Although it was pointed out that the TOR for the project specified that the classification system would be developed to a level applicable to the national wetland inventory, the project team agreed to expand this level of the hierarchy further.

- ***More detailed levels of the classification system are needed for management applications***
  These finer levels should be included in the classification system but not fleshed out as part of the current project. It was suggested that, in the classification system, empty boxes be put in at the lower levels for now and these get populated as the necessary data become available.

Proposed wetland classification system

The proposed classification systems (as presented in the Workshop Starter Document) was presented and each system was discussed separately.

Marine systems (Table 2.2 in Workshop Starter Document):

Suggestions:

- The terms consolidated and unconsolidated should be used for substratum categories at Level 4, instead of rocky substrate and soft bottom, and that these categories be further divided into sand/gravel/rock/mixed sub-categories.
- The terms dissipative versus non-dissipative be considered in place of exposed coast versus embayment at Level 3. BC disagreed with this because it would result in the merging of discriminating factors used at Level 3 and 4. AW agreed with BC and pointed out that the classification of an embayment is dependent on scale.
- Consult the marine classification system used in the National Spatial Biodiversity Assessment (NSBA) for inclusion in the proposed classification system.
- An appropriate definition for embayment would include: “wave action appreciably reduced by landform”.
- Common names for an embayment are ‘bay’ and ‘cove’.
- Sub-tidal should be defined as the area below spring low tide.
- Consider inclusion of shallow photic and deep photic zones of NSBA.
- Supratidal category to be included.
- Marine versus coastal? General consensus that marine is more appropriate term.
- Separate rocky reefs and coral reefs (look at Dini *et al*. 2000: rock vs. reef vs. unconsolidated substrate).
- Subtidal – should this be subdivided into Structural Units on the basis of substrate?
- It needs to be recognised that the intertidal zone is less than 100 m wide along the SA coastline.

Estuarine systems (Table 2.3 in Workshop Starter Document):

Suggestions/ comments:

- Include a supra-tidal category at level 3 of the classification hierarchy for both permanently open and temporarily closed estuaries.
- The generally accepted cut-off point for an estuarine bay or lake is 1 000 ha.
- More refinement of the temporarily closed category was needed for certain management issues.

- The term supratidal should be used for estuaries as opposed to floodplain because tidal flats can be inundated by freshwater input (rivers) or extreme tides (marine input). Inland floodplains, on the other hand, are only inundated by river water, so there is a fundamental difference.

Inland systems (Table 2.4 of Workshop Starter Document):
Suggestions/comments:

- for floodplains (Level 3 of the classification system), consideration should be given to the inclusion of channels. For the hydroperiod, the inundated category is not applicable to certain systems (e.g. hillslope seeps) and the different categories should possibly be re-defined.
- it is also important to clarify that, although a seep may not be connected to a drainage system via surface flow, there may be a sub-surface connection. There was general agreement that isolated, instead of endorheic is a good term to use at the subsystem level. Discussion ensued around the importance of sub-surface flows and the importance of the amount of groundwater input with regard to the classification of wetlands. It was concluded that, although groundwater input is a very important factor, it cannot be inferred from aerial photographs or satellite imagery.
- "Hydroperiod" could possibly be included as a descriptor, not a discriminator. This feature can change with time, especially if a wetland is impacted.
- Meander cut-offs (oxbows) and floodplain pans – can they be distinguished from one another and should they possibly be combined into one category? However it was decided that it is important to keep them separate because they function very differently, and they should be distinguishable on the basis of their shape and position relative to the channel.
- The definitions for Functional Units need to be consistent with other documentation on wetlands in SA. The KZN document on the origin of wetlands in SA will be used where possible to assist with this.

Descriptors (Section 2.2.5 of Workshop Starter Document):
The "descriptors" that had been tentatively developed for the proposed classification system were presented and explanation was given as to how they would be applied.
Suggestions / comments:

- the salinity criteria need 'tweaking'. The distinctions made by Williams, as presented in the Starter Document, are not very useful for estuarine systems; a preferable alternative is the 'Venice system'.
- the origin (i.e. source) of water should be included as a hydrological descriptor. Consider using the terms 'water input, throughput, and output'.
- it was important to decide whether factors that are important but for which we do not have sufficient information should be included as discriminators in the classification system, or whether they should be relegated to descriptors. An example of this is the further subdivision of temporarily closed estuaries according to the length of time that the mouth is open.

Group sessions

The following groups were identified:

- Marine and estuarine systems
- Arid areas
- Inland systems – Group 1
- Inland systems – Group 2

The objective of the group session was to apply the classification system to a number of different wetland types as a means of identifying any problems with the proposed discriminators and descriptors

Report back on group sessions

Arid areas:

- Ephemeral rock pools – potentially useful descriptors include water clarity, substrate, season when inundated, frequency and duration of inundation, altitude, temperature , pH, TDS, water source, and biota.
- Endorheic pans – potentially useful descriptors include permanent vs. seasonal etc., source of water, anthropogenic disturbance, water quality, and groundwater.
- Ephemeral rivers (e.g. Molopo River) – potentially useful descriptors include alien vegetation and anthropogenic disturbances.
- The group also considered eyes (springs). How would one classify this? Is it a sponge feeding a water course? Groundwater needs to be brought into the classification system to deal with these types of wetlands.

Marine and estuarine systems:
Marine:

- Langebaan, which was given as an example of a marine embayment in the Workshop Starter Document, should go under estuaries.
- Suggested definition for embayment – "areas where wave energy is appreciably reduced by landform".
- Common name for an embayment is a bay, not a lagoon, and an example is parts of False Bay.
- Suggest four categories for the substrate class at Level 4, i.e. rock, sand, gravel/boulder, and mixed rock and sand.
- Consider extending the cutoff point for marine systems to a depth of 10 m, as opposed to Ramsar's arbitrary cutoff point of 6 m, as this more-or-less corresponds to the limit of the shallow photic zone.

Estuarine

- Length of time that the estuary is open/closed is critical – could have extra categories for temporarily closed (as additional discriminators or as descriptors).
- At Level 3 for permanently open estuarine systems, should add river mouth (freshwater at mouth) as a category. An example is the Orange River.
- For temporarily closed systems, add '/littoral' to intertidal and '/limnetic' to subtidal, to account for periods when the systems are closed.
- Add supratidal as a tidal exchange category, which could be split into flats and pans as in the case of inland floodplains (possibly at Level 5).
- Change the definition of estuary by adding "or input from groundwater". According to this definition, Langebaan is estuarine because wave action is zero.

Inland systems – Group 1

- Was a concern that a hillslope seep not feeding a watercourse, which is classified as an isolated system, actually has a sub-surface link to the drainage network. After discussing it further, however, there was general agreement in the group that it is in order to leave it

where it is in the proposed classification system as long as there is a clear explanation that it is isolated at the surface (as determined from aerial photographs).
- There was general agreement that the HGM approach to wetland classification is a good way to go, and it is relatively easy to pick up the discerning features from a map.
- Group discussed the use of a biological classification system. It was felt that water resource management and conservation planning are likely to need different classification systems. For water resource management, it is fine to bring the biota in as descriptors but for biodiversity conservation one would need to place more emphasis on biological information.
- With regard to terminology, more thought needs to go into the use of the terms "riverine" versus "non-riverine" at Level 2 of the proposed classification system.
- The classification of lakes was discussed and there was general agreement that they seem to be handled well in the proposed classification system.
- Not sure where a hillside seep that drains into a depression (pan) would fit into the proposed classification system.
- Warm-water springs and limestone caves are not accommodated in the proposed classification system.
- There was some dissatisfaction with unvegetated versus vegetated at Level 4 because this can't always be easily distinguished from remote sensing. It was suggested that open water versus emergent habitat may be better.
- Suggested that 'valley bottom' be put in as one category at Level 3, which is then further sub-divided into 'with a channel' and 'without a channel' types.

Inland systems – Group 2

- Soetendalsvlei (on the Agulhas Plain) was the first example discussed – there was confusion as to whether this should be classified as a riverine floodplain, a valley bottom with a channel or a depression linked to a channel. This led to a discussion about the level of expertise needed to apply the proposed classification system.
- It was noted that it is quite difficult to distinguish between a floodplain and a valley bottom with a channel without quite a lot of expert knowledge.
- Karlspruit (in Centurion) was the second example considered – this is currently degraded, but would have been a channelled valley-bottom in its natural state. It was noted that the natural-state classification of this system couldn't now be picked up using NLC2000.
- The group thought of a number of wetlands that would not be picked up by the AWL.
- There is a need for clear rules/descriptions of the Functional Units at Level 3.

Testing of classification system and way forward

Further development and testing of the AWL

- An accuracy assessment of the AWL of NLC2000 now needs to be done to determine whether wetlands have been identified correctly
- Considering that there is regional variation in the confidence of the results from the AWL/NLC2000, it is envisaged that a regional confidence map for the wetland mapping throughout the country will be generated to assess which regions have the best results. Some ground-truthing will be done as part of this process. It is important to realise that the AWL is just a baseline to initiate the National Wetland Inventory and that it can be added to.

Further development and testing of the classification system

- It is necessary to develop an automated classification system and then test the system to determine whether wetlands have been classified correctly. This will require that coding be written into the AWL model for the automated classification procedure. Once the national inventory committee are happy with the classification system that is developed, a publication needs to be produced.
- The importance of working closely with the UKZN group was stressed to ensure uniform terminology and integrated 'tools' relating to wetlands.
- It is important to decide on the most appropriate spatial framework for the proposed wetland classification system. i.e. ecoregions vs wetland regions etc
- It will be necessary to develop a database and sampling protocols (in a guideline document) for capturing wetland information for the national inventory (Western Cape Inventory project will be useful for this).
- It was suggested that more detailed biological studies be undertaken to determine if the proposed classification system is supported by the biotic patterns.
- Any further development or refinement should be undertaken at a regional level.
- It was suggested that the development of a wetland classification system and the National Wetland Inventory links in with DWAF's monitoring programme.
- it is important for interaction/collaboration between the development of the classification system and the completion of the National Wetland Inventory. Wetland experts need to tell the AWL modelers what they need, then it needs to be determined whether this information can be obtained from the satellite imagery used to generate the AWL or other data sources such as GIS maps and aerial photos.
- A 'decision tree' needs to be developed for obtaining information for the different levels of the classification system from the various data sources available.
- the refinement of the rules for the application of the proposed classification system needs to form part of ongoing refinement and development.

APPENDIX 3

Proposed land-cover classes for the NLC 2000 project (a subset of Appendix 4 in Thompson *et al.* (2001)

Number	Land-cover Class	Definition
4	Shrubland and Low Fynbos	Communities dominated by low, woody, self supporting, multi-5stemmed plants, branching at or near the ground, between 0.2 and 2 m in height. Total tree cover < 0.1 Typical examples are low Fynbos, Karoo and Lesotho (alpine) communities.
6	Unimproved (natural) Grassland	All areas of grassland with < 10% tree and/or shrub canopy cover, and >0.1% total vegetation cover dominated by grass like non woody rooted herbaceous plants Essentially indigenous ii species growing under natural or semi-natural conditions.
7	Improved Grassland	As above, except …. Planted grassland, containing either indigenous or exotic species, growing under man-managed (including irrigated) conditions for grazing, hay or turf production, recreation (i.e. golf) etc
13	Waterbodies	Areas of (generally permanent) open water. The category includes both natural and manmade waterbodies, which are either static or flowing, and fresh, brackish and salt water conditions. This category includes features such as rivers, major reservoirs, farm-level irrigation dams, permanent pans, lakes and lagoons.
14	Wetlands	Natural or artificial areas where the water level is permanently or temporarily at (or very near) the land surface, typically covered in either herbaceous or woody vegetation cover. The category includes fresh, brackish and salt water conditions. Examples include pans (with non-permanent water cover), and reed-marsh or papyrus-swamp.