CARTOGRAPHIC GIS STANDARDS ADOPTED BY THE DEPARTMENT OF WATER AFFAIRS AND FORESTRY

A CASE STUDY

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Submitted in part fulfilment of the requirements of the Degree of Master of Science in Applied Science in the Department of Surveying and Geodetic Engineering, University of Cape Town.

OCTOBER 1995

ACKNOWLEDGEMENTS

The assistance of Mrs F Jonck, First Cartographer, Department of Water Affairs and Forestry is gratefully acknowledged. The support and encouragement from family, friends and colleagues has been much appreciated.

TERMS OF REFERENCE

This report on cartographic standards, which have been developed and implemented by the Department of Water Affairs and Forestry, is being submitted as a dissertation in part fulfilment of the requirements of the degree Master of Science in Applied Science, at the Department of Surveying and Geodetic Engineering at the University of Cape Town.

The opinions expressed in this report are those held by the author at the time of writing and are not those of the Department of Water Affairs and Forestry.

ABSTRACT

The Department of Water Affairs and Forestry (DWAF) acquired a Geographic Information System (GIS) in 1987. The purpose of acquiring such a system was to aid the department in implementing their water resource management strategy of that time. On acquiring this system it was well recognised that the GIS would need to communicate geo-referenced information, generated by analysis and modelling to decision makers by means of graphic representations or maps (Olivier *et al.*, 1990:1473).

Towards the end of 1990 it became apparent that the department needed to standardise cartographic output of this system. Maps on the same theme, which were produced at different sites were not comparable and graphic communication was not effective. A consultant was appointed, who, in conjunction with the departmental digital cartographer, established criteria and standards which were flexible enough to accommodate mapping on a wide variety of themes. These standards were implemented, to a limited extent in July 1994.

Standards were set for map encoding, map content and map composition. This report investigates how effective these standards have been. The effectiveness of these standards have been measured in terms of the five recognised cartographic design principles that have been identified by Robinson *et al.* (1984), Wood (1992) and Dent (1990). These include the clarity and legibility of maps, the distinction between figure and ground, the hierarchical organisation of mapped information, the visual contrast of marks on maps and the visual balance or layout of the finished map.

A sample of maps made after the implementation of cartographic standards at the department was compared to a sample of comparable maps made prior to the implementation of these standards. In a large organisation like the department the success of such standards do not depend on the standards alone but also on their implementation. Implementation related problems were identified by comparing standardised maps with the standards.

The outcome of the investigation proved that the effectiveness of graphic communication had indeed improved albeit to a varying degree. In most cases the standards were adequate and the main problems actually lay with their implementation. Recommendations on the implementation and the few aspects of the standards that require amendment have been included in this report.

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1

INTRODUCTION

"... a man shal more profite, in one wike, by figures and chartis, well and properly made, than he shal by the only reding or herying the rules of that science by the space of halfe a yer at the lest..."

Thomas Elyot, 1531

The Department of Water Affairs and Forestry (DWAF), formerly the Department of Water Affairs (DWA), acquired a Geographic Information System (GIS) in 1987 (Olivier *et al.*, 1990:1471). The GIS was acquired to assist the department in implementing its national water management strategy (Olivier *et al.*, 1990:1471).

Decisions on the management of scarce water resources in the Republic of South Africa (RSA) needed to be supported by "modern data processing facilities" which would allow for the "convenient storage, retrieval, manipulation, analysis and the effective presentation" of alphanumeric and graphical data (Department of Water Affairs and Forestry, 1986:6.6). Although GIS is seen as a technology which is used for scientific modelling, the results of such modelling as well as that of spatial analysis executed by such a system, needs to be visualised and presented to decision makers (Olivier, *et al.*, 1990:1473).

Water resource planning requires a multi-disciplinary approach (Sutherland and Lambourne, 1991:281). In the context of the DWAF, GIS is used by decision makers who are involved in the fields of engineering, hydrology, geohydrology and land surveying. The graphical communication of information needs to address the requirements of several disciplines and requires a high degree of flexibility and versatility (Olivier *et al.*, 1990:1473).

A corporate geo-referenced data base is situated at head office. GIS is however also used at the departmental regional offices in Durban, Cape Town, the Highveld Region of the department as well as the Institute for Water Quality Studies (formerly the Hydrological Research Institute) at Roodeplaat dam. Since the early 1980s river basin studies have been carried out to asses the historical and potential development of water demand in the major drainage basins of the RSA (McPherson, 1994,63). As from 1989 many of these basin studies as well as hydrological system analyses have been carried out using GIS technology. Civil engineering consultants who are experienced in water resource management and hydrological analysis are appointed to carry out these studies (McPherson, 1994, 63). All these studies generate a large volume of thematic maps.

It soon became apparent that mapping efficiency was greatly enhanced by the acquisition of GIS. Maps could be produced with relative ease and amended and updated as and when required. The maps that were produced by GIS were however not effective in terms of communicating the thematic message they were intended to convey. Maps on the same map theme which were produced for studies done in adjacent drainage basins were not visually comparable. There was no standardised use of map symbols. This was largely due to the fact that maps could now be made by GIS operators who, though computer- and GIS-literate were not cartographically literate. A contributing factor was the large number of default map symbols which are part of the GIS software package which is used by the department. Operators had a free hand to use whichever colours and whichever default symbols they fancied.

The departmental GIS Coordinating Committee recognised the problem and a sub-committee was appointed in 1992 to oversee the development of cartographic standards for the department. It was apparent from the outset that these standards would need to be versatile to accommodate the variety of map themes which were associated with the many GIS applications and the resultant variety in map scales of maps that were produced by the department. Due to an acute shortage of cartographers who are skilled in digital mapping, a consultant was appointed in 1992 to assist the department with this endeavour.

There is a lack of standardisation in the field of cartography. Many efforts have also been made to standardise cartographic principles but no universally acceptable set of standards or rules exists. It is well recognised that it is possible to standardise certain aspects of a map series but that standardisation of thematic mapping is a lot more complex (Liebenberg, 1986:60). This has made the efforts of the department doubly difficult.

The problem concerning the lack of map effectiveness of digital mapping at the DWAF is a problem which has been universally recognised (Buttenfield and Mackaness, 1991:430). They also pointed out that many of the cartographic problems which are experienced with maps which are produced digitally can be attributed to the lack of knowledge of good cartographic principles by GIS software architects.

Since the advent of digital cartography much research attention has been focused on the technology or skill of map making, and design aspects have received less attention (Wood, 1992:436). It is however universally recognised that map design and excellence in graphic communication are closely linked (Wood, 1992:435).

The setting of standards at the department was achieved after consulting widely with GIS users. The most often used map themes and related features were identified. Relevant map symbols were designed for specific map scale ranges. In addition to standards set for encoding, general rules were established for map content and map composition. Once completed, a users guide was compiled and the standards implemented in the GIS data management section as a pilot project. Implementation was, after a period, extended to other GIS sections.

The purpose of this report is to evaluate whether the implementation of these standards , across such a wide field of map themes, has indeed contributed to more effective communication of geographical information to decision makers. The standards were evaluated by comparing maps that were produced after their implementation with previously made maps. This evaluation was done by way of the five cartographic design principles identified by Robinson *et al.* (1984), Dent (1990) and Wood (1992). These principles are clarity and legibility, differentiation between figure and ground, the hierarchical organisation of information, visual contrast and the visual balance of the map.

The success of such standards in a large organisation like the department depends not only on the standards but also on their implementation. Where applicable, implementation problems have been highlighted and recommendations have been made in terms of both the standards and their implementation.

In Section 2 of this report the problems experienced at the DWAF and the problem which the report is addressing is described in detail. Section 3 contains a review of related literature. In Section 4 the actual cartographic standards which have been adopted by the department is discussed in detail. The evaluation of maps made with these standards is detailed in Section 5. Section 6 contains recommendations to the department. These recommendations are based on the findings in Section 5. The report is concluded in Section 7.

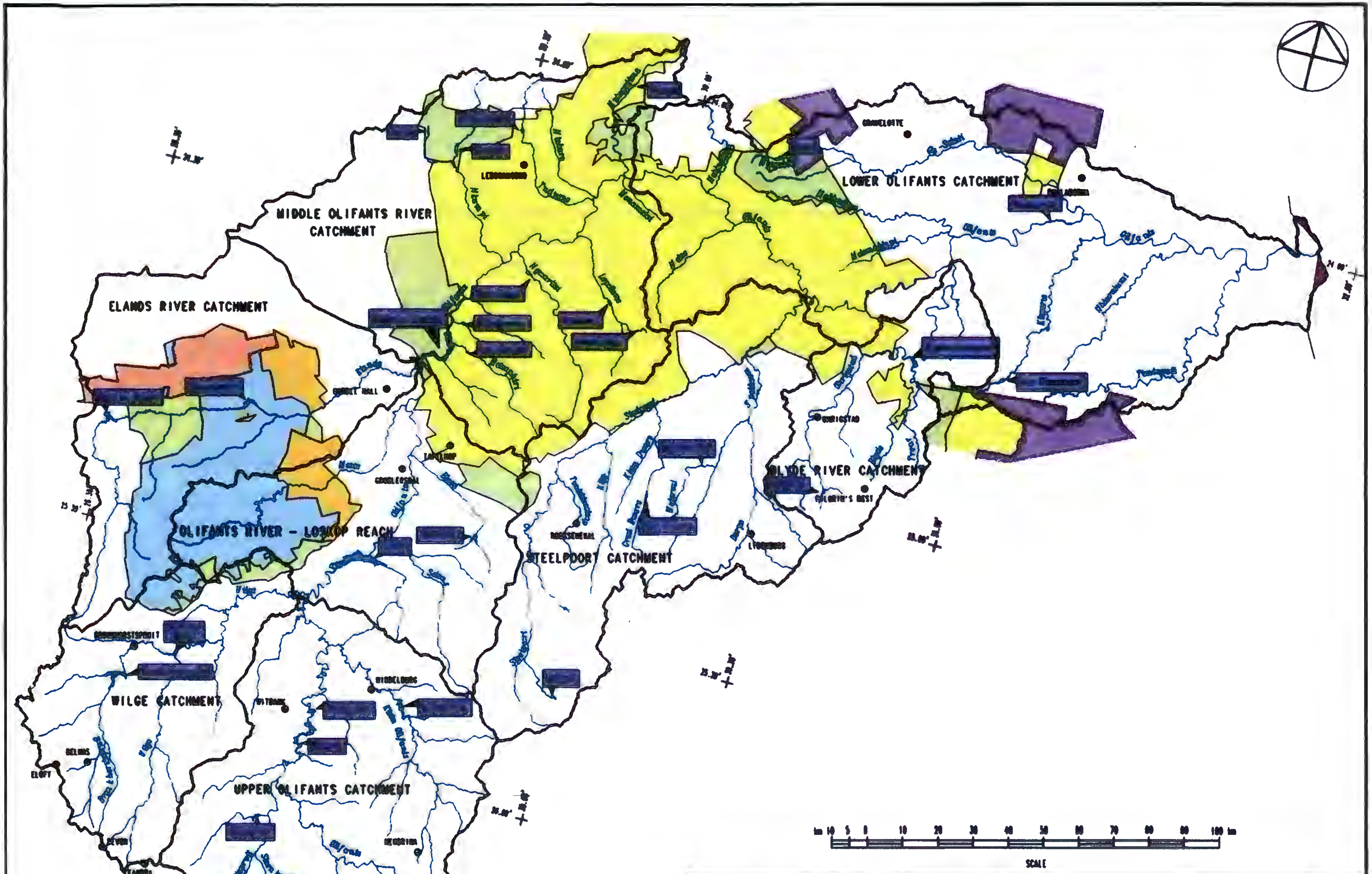
2

NATURE OF THE PROBLEM BEING INVESTIGATED

A Geographic Information System is a computer system which stores, manipulates, analyses and transforms geo-referenced information to assist decision makers (Cowen, 1988:1554). Maps which are the output of such a system are an important way of communicating information to decision makers.

Thematic maps generated by the DWAF GIS are made at many different geographical locations namely at head office, regional offices and in the offices of the consulting engineering firms who undertake basin studies and system analyses on behalf of the department. Thematic maps are a specific map type that graphically communicate information on the spatial variation of a single phenomenon on the surface of the earth or a relationship amongst selected phenomena (Robinson *et al.*, 1984:8). The basin studies and system analyses in particular generate 20-30 thematic maps each. These maps ultimately form part of study reports. Figures 2.1 and 2.2 are two examples of such maps. Both indicate major dams and sub-catchments for the Olifants River Basin study (1991) and the Riviersonderend Systems Analysis (1992) respectively. Apart from these maps 240 thematic maps have been made at head office on an *ad hoc* basis from 1 July 1992 to 31 June 1995. Figure 2.3 is an example of such a map which was produced in 1993.

Maps are made at all these locations by computer operators who have no cartographic background and thus have no knowledge of sound cartographic principles. Although GIS has greatly increased mapping efficiency, it has had a detrimental effect on mapping effectiveness and the cartographic quality of the maps being produced by GIS led to a misinterpretation of the cartographic message. The usefulness of maps rests to a large extent on how well good mapping techniques have been incorporated into map design.



Consulting Engineers
Theron Prinsloo Grimsehl & Pullen
Stewart Sviridov & Oliver

Olifants River Basin Steering Committee
Directorate Project Planning
RSA Department of Water Affairs

OLIFANTS RIVER BASIN STUDY

MAJOR DAMS

Figure No
2.1

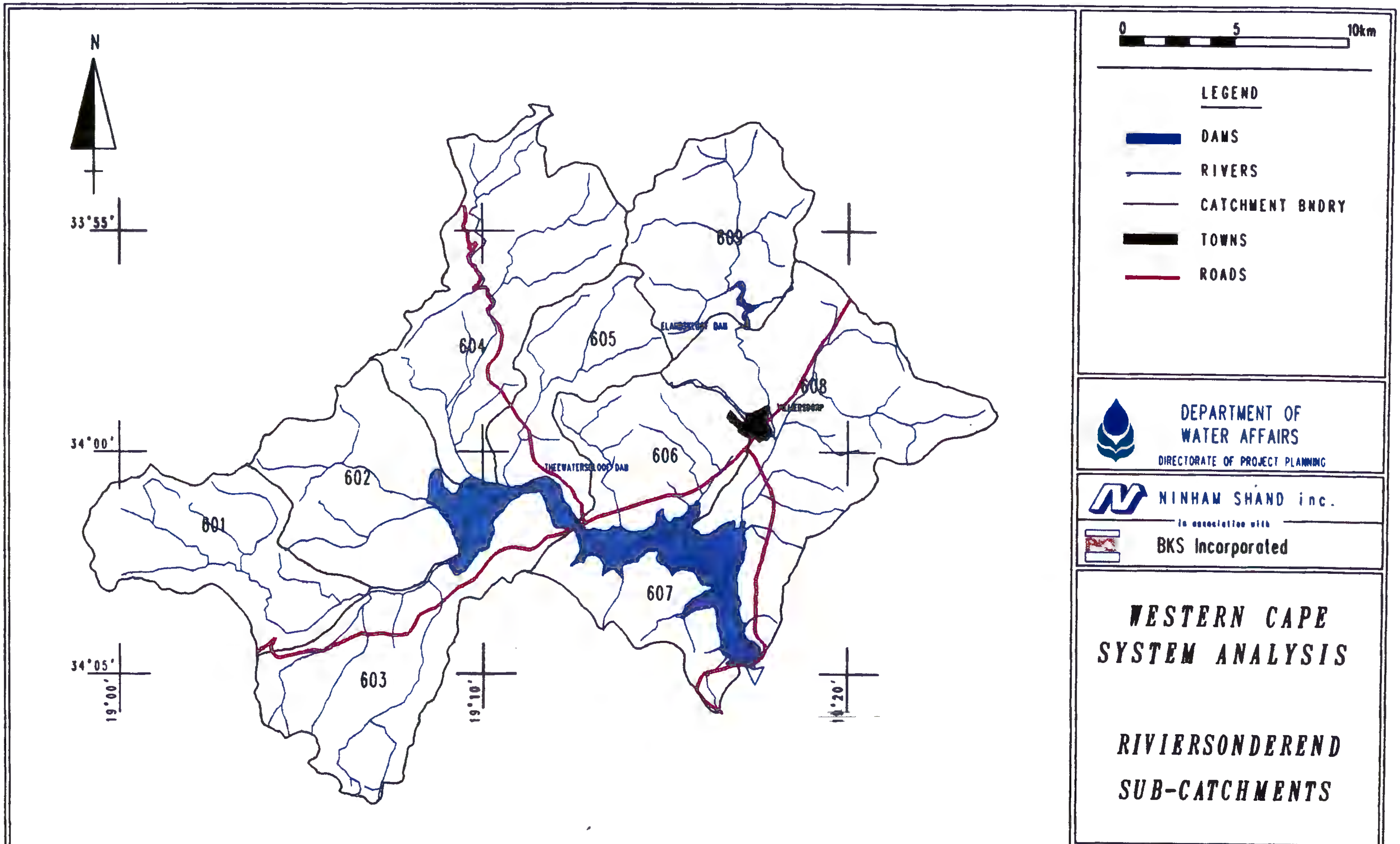

N
33°55'
34°00'
34°05'
19°00'
19°10'
19°20'
601
602
603
604
605
606
607
608
609
0
5
10km
LEGEND
DAMS
RIVERS
CATCHMENT BNDRY
TOWNS
ROADS
DEPARTMENT OF
WATER AFFAIRS
DIRECTORATE OF PROJECT PLANNING
NINHAM SHAND inc.
BKS Incorporated
WESTERN CAPE
SYSTEM ANALYSIS
RIVIERSONDEREND
SUB-CATCHMENTS

Fig. 2.2

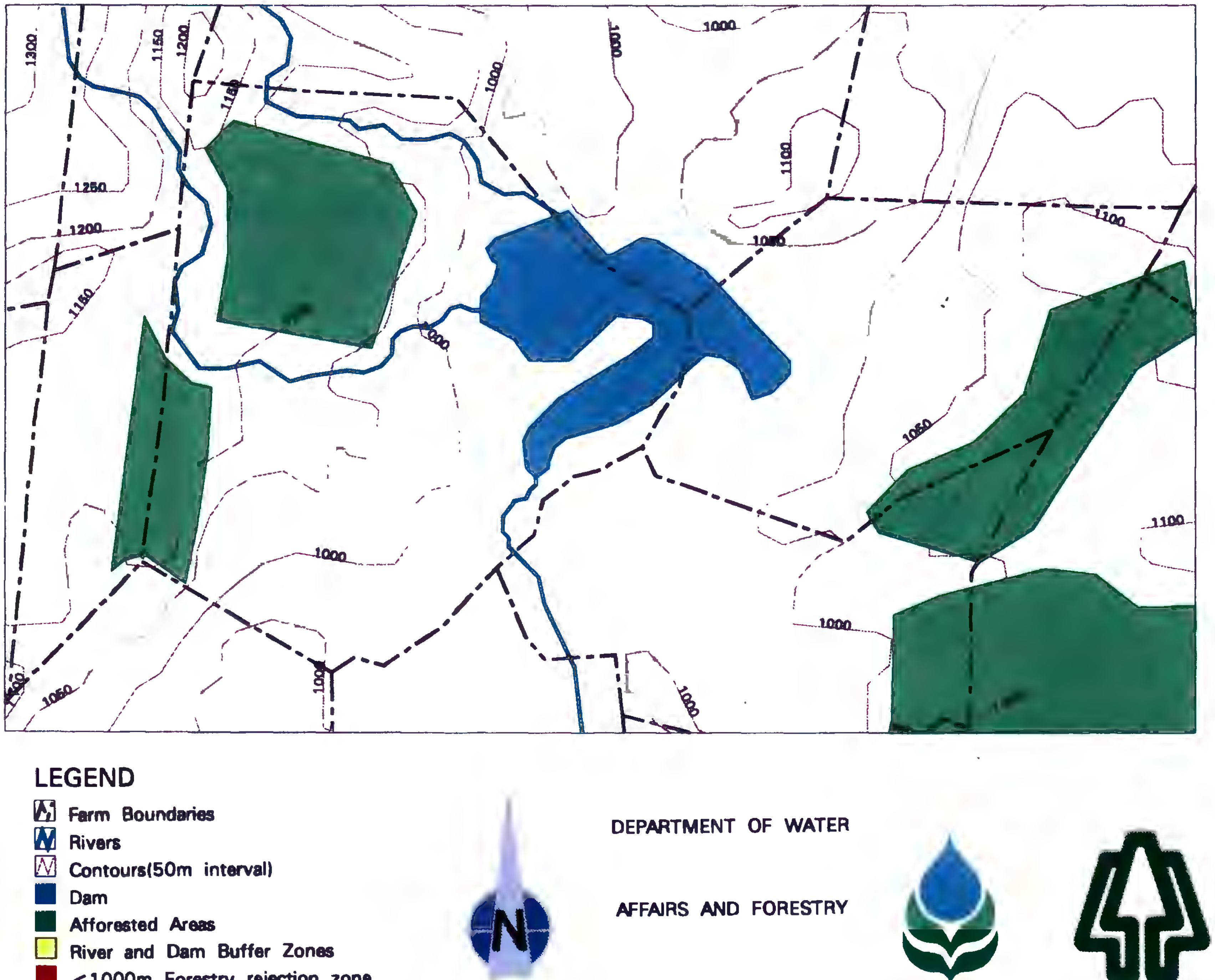

LEGEND
Farm Boundaries
Rivers
Contours(50m interval)
Dam
Afforested Areas
River and Dam Buffer Zones
<1000m Forestry rejection zone
N
DEPARTMENT OF WATER
AFFAIRS AND FORESTRY
WAGIS 1993

Fig. 2.3

Towards the end of 1990, it became increasingly apparent that maps on the same theme, which had been generated by different studies and at different locations, should be visually comparable. It was also necessary to ensure more effective graphic communication of spatial information. This was recognised by the DWAF GIS Coordinating Committee which set up a sub-committee in 1992 to investigate the standardisation of cartographic output (Water Affairs GIS, 1990:3).

2.1 THE NEED FOR CARTOGRAPHIC STANDARDS AT THE DEPARTMENT OF WATER AFFAIRS AND FORESTRY

A consultant was appointed to assist the department in the setting of these standards. The standards needed to achieve consistent cartographic display of GIS output and had to be capable of accommodating the required versatility.

2.1.1 GIS APPLICATIONS AND RESULTANT MAP THEMES

The large number of different GIS applications within the department needed to be taken into account. These included the following:

- River basin studies and hydrological system analyses (McPherson, 1994, 63);
- Forestry applications such as the afforestation permit system (McPherson, 1994, 63);
- Applications such as those pertaining to the implementation of the water quality policy of the department (McPherson, 1994, 64);
- Groundwater studies on the location and exploitability of groundwater resources in areas where surface water is inadequate (McPherson, 1994, 64);
- Flood damage studies (McPherson, 1994, 63);
- Drought relief studies and programmes (McPherson, 1994, 64);

- Hydrological and engineering modelling applications (McPherson, 1994, 64);

- Reservoir zoning where GIS is used to define specific recreational zones for various water levels around state owned dams and reservoirs (McPherson, 1994:64); and

- Demographic studies which are vital to strategic water resource planning (McPherson, 1994:65).

Such a range of applications leads to a need for thematic maps on a variety of themes. These are summarised in Table 2.1.

ENVIRONMENT	MAP THEME
SCIENTIFIC & NATURAL	Geohydrology Hydrology Meteorology Geology Geomorphology Pedology Vegetation
INFRASTRUCTURE	Distribution Network Structures
LAND USE	Agriculture Forestry Conservation Industrial Recreation
SOCIAL & CULTURAL	Administrative Cadastral Social Statistical Water Management

Table 2.1. Most commonly used map themes.
(Source: Compiled by the author from information contained in Wolfer, 1992:4-6.)

The left column is based on the departmental classification scheme for geo-referenced data (Water Affairs GIS, 1989:22-23). The right column indicates the map themes which were identified by GIS users in the department in 1992.

2.1.2 SCALE OF MAPPING

2.1.2.1 SOURCE SCALES OF DIGITAL DATA

The data in the departmental corporate spatial data base has been captured at a great variety of different map scales. A list of these scales is given in Table 2.2. In addition to this, the departmental spatial data base also contains gridded data. Elevation, evaporation and mean annual precipitation data sets are in the form of regular minute grids. An elevation data set with an irregular or varied grid of 400 meter and 200 meter is also stored in the data base. These data sets are used to generate isopleth coverages with the desired contour interval for mapping and presentation purposes.

Small Scale	1 :4 000 000
	1 :2 000 000
	1 :1 500 000
	1 :1 000 000
	1 : 500 000
	1 : 250 000
Large Scale	1 : 50 000
	1 : 10 000
	1 : 5 000
	1 : 2 000

Table 2.2. Scales at which geo-referenced data was captured for the corporate spatial data base.
(Source: Compiled by the author from information contained in the departmental spatial data inventory.)

Other data sets, such as a national data set of dam locations as well as national borehole data have been captured by keyboard entry. Only degrees and minutes of the location of each dam and degrees, minutes and seconds of the location of each borehole have been recorded.

2.1.2.2 OUTPUT SCALES

Many of the studies undertaken by the department result in a set of hard copy reports. The maps in these reports are on either A4 or A3-sized paper and map scales are adapted accordingly. The results of analysis or investigations regarding, for example, a proposed dam site which was conducted at a scale of 1:10 000 are then represented at a much smaller scale than the digital data which was used for analysis. On investigation it became apparent that output scales varied from 1:5 000 to 1:5 850 000 (DWAF Map Archives).

In Figures 2.1 and 2.2 for example, the map scales are 1:750 000 and 1:450 000 respectively. Figure 2.3 gives no indication of map scale.

2.1.3 CARTOGRAPHIC ENCODING

The encoding of maps is the process whereby a message is represented in an abstract way (Knöplfi, 1990:72). Map symbols are the distinctive marks which are created and arranged to encode a graphic message (Robinson *et al.*, 1984:137).

In ARC/INFO, which is the software package which is used by the department, map symbols are divided into four groups namely, line, marker, shade and text symbols. When drawing either a line, point or polygon in the ARCPLOT environment of ARC/INFO the appropriate symbol group is automatically used (Environmental Systems Research Institute, 1991:3-1). Each of these symbol set files contain 100 map symbols which are made up of 25 patterns in 4 different colours. These are the software package default symbols (Environmental Systems Research Institute, 1991:3-11). Computer operators used these default symbols in their map compositions and each operator chose those symbols which he/she deemed to be the most appropriate for a specific purpose. No symbols were being consistently used at particular map scales to represent or symbolise particular physical features on the earth's surface.

In Figures 2.1 and 2.2 for example, there are catchment and sub-catchment boundaries. Neither map does in fact distinguish graphically between the two types of boundaries. Although rivers have been indicated in a blue colour on both maps, and both maps were plotted on the departmental electrostatic plotter, the colour of these map symbols differ. This contributed greatly to the lack of comparability between maps of the same theme.

The use of the software default symbol for compiling map references, also proved to be a problem. This is illustrated in Figures 2.3 and 2.4.

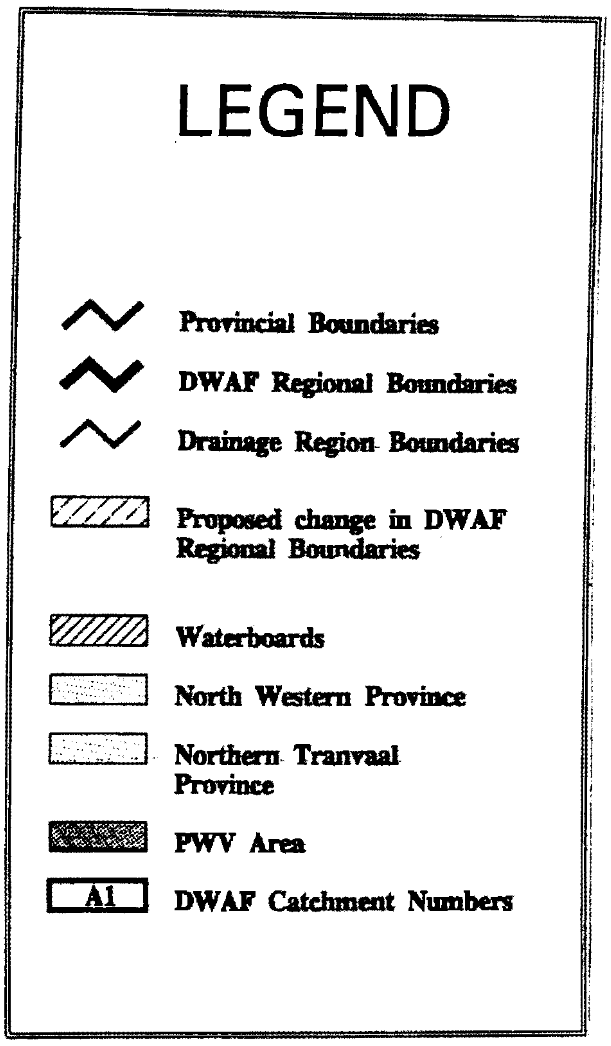


Fig. 2.4. Example of a map reference where software default map symbols were used.
(Source: DWAF Map Archives, 1992.)

Line symbols are indicated as a zig-zag symbol in the map reference.

2.1.4 MAP CONTENT AND ADDITIONAL MAP INFORMATION

The content of a message which is to be communicated is of prime importance. In cartographic context this involves the selection of geographical features and additional information which will be required to communicate a particular message (Knöpfli, 1990:72). The following aspects proved, in the departmental context, to be a problem.

2.1.4.1 MAP ORIENTATION

At the department very little base map information to orientate map users in terms of the geographical location which was being mapped was shown on maps. This is well illustrated in Figures 2.1, 2.2 and 2.3. A town name can be distinguished on Figure 2.2 but town names are difficult to find on Figure 2.1. Neither map indicates what surrounds the mapped area. Roads are indicated in Figure 2.2 but these seem to go to nowhere as they end abruptly at the edge of the mapped area. River names have been indicated on Figure 2.1 but no river names are indicated on Figure 2.2. This again indicates inconsistencies. Figure 2.3 has no map title, no roads are indicated and a guess as to where the mapped area is located, is left entirely to the map user or decision maker.

North arrows were not always included. This does not apply to Figures 2.1 to 2.3. The placement of the north arrow is however inconsistent and the actual size of the map was not taken into consideration when a decision was made on the size of the north arrow. The latter is applicable to Figure 2.3 in particular.

2.1.4.2 MAP REFERENCE

Reference has already been made to the way in which map references were encoded (See 2.1.2 and Fig. 2.4). In some instances however, they were completely omitted (See Fig.2.1) and in many cases although present, were incomplete.

2.1.4.3 ORGANISATIONAL LOGOS

Logos were seldom overlooked but no consideration was given to their size in relation to that of the map, their grouping or actual placement on the map sheet. This is well illustrated in Figure 2.3 where the logos of the department dominate the entire map.

2.1.4.4 CO-ORDINATES

In GIS software the geographical coordinates of the corner points of maps, (corner graticule intersections), are used to register the position of maps when capturing data. Map makers used these points, indicated as crosses on maps, to indicate the geographical coordinates of a mapped area. This is illustrated in Figure 2.5.

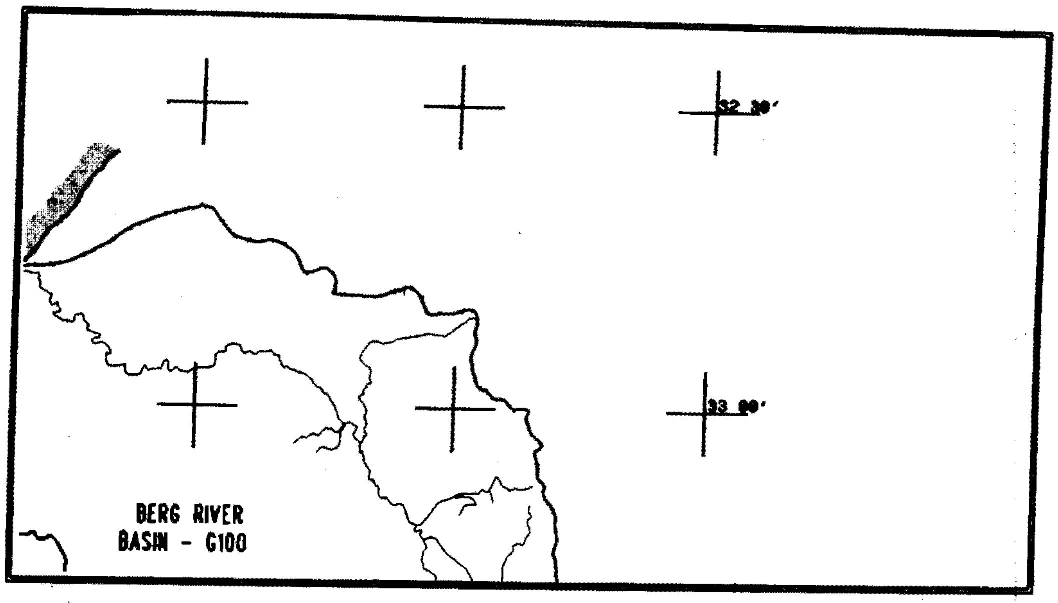


Fig. 2.5. Geographical coordinates indicated by graticule intersections at map sheet corners of the source documents used to capture the data.
(Source: DWAF Map Archives, 1992.)

The same method of indication of geographical position has been used in Figures 2.1 and 2.2. but no indication is given in Figure 2.3.

2.1.4.5 MAP SCALE

Map scales were indicated as proportional scales, word scales and line scales. Subdivisions of 6.2 and 12.5, as is shown in Figure 2.6 were not uncommon.

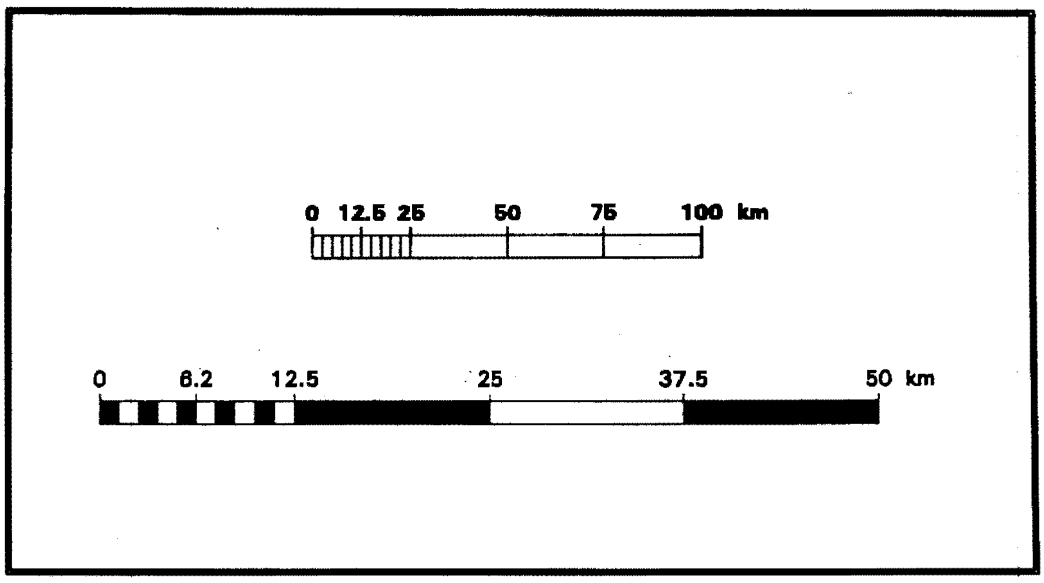


Fig. 2.6. Line scale or scale diagram used for mapping at the department prior to the implementation of cartographic standards.
(Source: Jonck *et al.*, 1994:10.)

2.1.4.6 ADDITIONAL MAP INFORMATION

Additional map information such as the date on which the map was produced, the name of the map compiler, reference numbers, map projection and projection parameters, information sources and copyright statements were inconsistently included or left off maps. This is once again clearly indicated in Figures 2.1 and 2.2. Figure 2.1, for example, has no map reference, no indication of data sources and no copyright statements. None of these maps contain projection information, or have a map grid.

2.1.5 MAP COMPOSITION

2.1.5.1 MAP SHEET LAYOUT AND MAP TITLES

There was no consistency regarding map layout. This is clearly seen in Figures 2.1, 2.2, and 2.3. Map titles were either left off as in Figure 2.3 or not placed in a prominent enough position or in a type which distinguished it from the rest of the map. The map user therefore often had to guess what message the map was attempting to convey.

2.1.5.2 MAP PLACEMENT

Map placement, especially in terms of map orientation on the actual paper was left entirely to the discretion of operators. This led to bad overall map design and visual balance in terms of layout and map composition.

2.1.5.3 MAP EXTENT

As has been discussed in 2.1.4.1, the map user was given no indication of the area surrounding the mapped area, and most catchments appeared as "islands" as no boundaries were extended to the neat line of maps. This is illustrated in both Figures 2.1 and 2.2.

2.1.5.4 INDEX AND INSET MAPS

Index maps were seldom used. This proved to be particularly confusing as far as catchment and basin studies were concerned as many people who use the reports that these studies generate are unfamiliar with the departmental demarcation of the country into drainage basins. Inset maps, supplying more detailed information on specific areas of a main map, were seldom used, but when they were required, no indication was given of either their scale or position in terms of the main map. Also, map making operators were inclined to add a second map reference or omit an explanation of the symbology used for such maps.

2.1.5.5 TYPOGRAPHIC DESIGN

Various methods were used to enhance the status of names. The boxes placed around the dam names in Figure 2.1 are a good example of this. River names were not printed consistently in cyan or cursive letters. The use of black was preferred. This applied also to ocean names, if included. No distinction was made between main and secondary towns. Name placement was particularly troublesome as is shown in Figure 2.7.

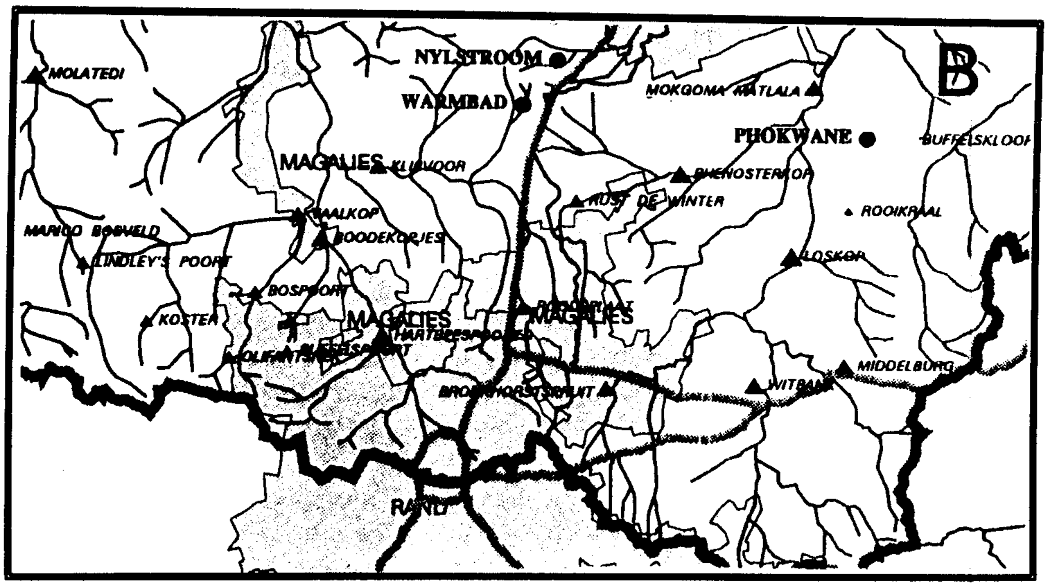


Fig. 2.7. Example of name placing problems at the department prior to the implementation of cartographic standards.
(Source: DWAF Map Archives, 1992.)

2.1.5.6 MAP PROJECTIONS

The geographical extent covered by these thematic maps varied from the zoning for individual reservoirs (1:5 000) to that of the whole of South Africa at 1:5 850 000. Central meridians and standard parallels were not used consistently. The central meridian for a map with a geographical extent covering the whole country varied from 23° E to 24° E. Operators had no knowledge of the properties of different map projections or the principles which govern the choice of map projection.

2.2 SETTING OF CARTOGRAPHIC STANDARDS

The need to integrate the many map themes and mapping applications mentioned above excluded the straightforward approach of setting standards for every map theme, such as geohydrology or mean annual run-off as a separate entity and designing standards for each in turn. Instead, a more integrated approach had to be taken which was based on an earlier stage of information processing in GIS. Such an approach would ensure maximum flexibility.

At the outset, the aim of these standards was to provide a common language and identify good cartographic practice. Successful standards need to reflect existing technology but must also be able to adapt as technology matures (Cooper, 1993:95).

The aim of these standards was to address map effectiveness in terms of the graphic communication of information and not map-making efficiency. The department only attempted to standardise the following cartographic aspects:

cartographic encoding;
map content; and
map composition.

These standards were to apply to hard copy map output only.

2.3 IMPLEMENTATION

The standards designed by the department were implemented within the GIS data management section at head office during 1994. The implementation was initially limited as the use of the standards at head office was to firstly experiment and prove their technical feasibility. Implementation was also limited at first in order to serve as a demonstration to other units of the department and to allow for amendment to the standards if required.

2.4 PURPOSE OF INVESTIGATION

No universally acceptable set of rules or standards exists for map design (Buttenfield and Mackaness, 1991:436). Many attempts have however been made to establish such rules and standards for map encoding or symbolisation and text placement. These aspects have however always been seen in isolation. Every map does however remain unique and the mapping itself depends to a very large extent on the intuition and creativity of the map maker. The question is however whether thematic mapping, which is both an art, science and skill can in fact be successfully standardised and whether such standardisation does contribute to the communication of graphic information?

The aim of this report is to determine whether the DWAF have improved the communication of graphic information as a whole by adopting the standards which have been set for cartographic encoding, map content and map composition.

The success with which geo-referenced data or information is communicated graphically depends on the way in which such a message is represented (compiled) and encoded (Knöpfli, 1990:72). The success of representation in turn is dependent on compliance to sound cartographic principles (Robinson *et al.*, 1984:145).

2.4.1 MAJOR PROPOSITION

The major proposition namely that **the implementation of cartographic standards at the Department of Water Affairs and Forestry for GIS hard copy map output has improved the graphic communication of geo-referenced information**, cannot be validated as a whole, and has therefore been subdivided into three minor propositions.

2.4.2 MINOR PROPOSITIONS

The following minor propositions were formulated:

Minor proposition one states that the implementation of standards for **cartographic encoding** has improved the graphic communication of geo-referenced information on hard copy maps produced by the departmental GIS.

Minor proposition two states that the implementation of standards for **map content** has improved the graphic communication of geo-referenced information on hard copy maps produced by the departmental GIS. The variables addressed by the department in this regard were;

- base map information (the orientation of the mapped area),
- the map reference,
- the use of logos,
- indication of coordinates of the mapped area,
- scale bars,
- the use of north arrows, and
- additional map information.

Minor proposition three states that the implementation of standards for **map composition** has improved the graphic communication of geo-referenced information on hard copy maps produced by the departmental GIS. The variables the department addressed in this regard were

- map layout and title,
- map placement
- map extent,
- index and inset maps,
- typographic design, and
- map projections

2.4.3 VALIDATION OF PROPOSITIONS

Each of the three minor propositions will be validated in terms of sound cartographic design principles. The validation will not apply to the standards as such but to the maps which were produced by the departmental GIS. Maps made prior to the adoption of these standards will be compared to maps made after the implementation of these standards.

"The graphic constituents of design are those attributes of the marks used for representation that either by themselves or in organised array are visually significant to the total graphic presentation" (Robinson *et al.*, 1984:145). Cartography involves a combination of many ingredients, such as graphic composition, mathematics etc. (Robinson *et al.*, 1984:145). For the purpose of this report, only the most important cartographic design principles which were identified by Robinson *et al.* (1984), Dent (1990) and Wood (1992) will be considered.

These include the following:

a) Clarity and legibility;
b) Figure-ground;
c) Hierarchical organisation;
d) Visual contrast; and
e) Visual balance.

Once the minor propositions have been verified the major proposition can be accepted as being either true or false.

3

REVIEW OF RELATED LITERATURE

In this review of related literature a brief history of cartography and GIS will be discussed. This historical background will concentrate on the origins of thematic mapping in particular. This will be followed by an overview of the nature of cartography. A discussion on the communication concept in cartography and cartographic conventions and standards will follow as these aspects are central to the aim of this report. A brief discussion on digital cartography and GIS concludes this section of the report.

3.1 HISTORICAL BACKGROUND

3.1.1 CARTOGRAPHY

Academic geography has played a major role and has had a major influence on cartography in the sense that trends in geography have influenced map design (Taylor, 1983:7). Scholars have from time immemorial been seeking for more useful knowledge on the surface of the earth and man's use of it (James, 1972:177). The questions these scholars have asked over the centuries have basically remained the same and can be summarised as follows:

- Which phenomena in the universe should man select to observe and record?
- What is the best way to observe the selected phenomena?
- How can the observations be generalised to reveal significant geometric arrangements and patterns on the earth's surface?
- How can patterns and arrangements be explained?, and
- How can the results be communicated? (James, 1972:177).

The 16th century was the century of discovery. In the world, as discovered by the explorers, there was no lack of subjects and objects to be observed recorded and mapped. The 17th century witnessed the beginning of the scientific revolution which led to more useful ways of generalising, explaining and communicating geographical information. References to "weird creatures and phenomena", mapped by explorers other than the Portuguese, who only recorded scientific observations, started giving way to the reporting of similarities between different parts of the earth's surface rather than concentrating on the differences (James, 1972:177). This trend in reporting was reflected cartographically by de l'Isle and also by Jean d'Anville in 1761, when he started to remove the drawings of "strange creatures" which had, until then, filled the empty spaces on maps (James, 1972:178).

In the mid-18th century advances in the physical and social sciences provided geographers with the intellectual tools for spatial analysis (Parent and Church, 1989:10). At the same time, statistical techniques, number theory and advanced mathematics began to develop (Parent and Church, 1989:10). Most of the present fields of science had their roots in the 18th century. These, then new fields of study, became what Immanuel Kant called the logical divisions of knowledge (James, 1972:178). It was also at this time that the so-called, 'New Geography' and 'New Cartography' emerged (James, 1972:187). Scholars of the 'New Geography' had the following three main tasks:

- to collect information about unknown or inadequately known places or parts of the earth;
- to explain or illustrate certain processes to assist in the practical needs of government administrators, military commanders or business men who needed descriptions of facts and conditions relevant to particular problems at particular places; and
- to formulate geographical concepts, generalisations, hypotheses and theories.

The 'New Cartography' went along with the 'New Geography'. To further the aim of the first task of geography, large scale topographic mapping was further explored by the Cassinis in France and by Nicolas Cruquius in the Netherlands (James, 1972:187). The second geographical task stimulated the first thematic mapping, where the emphasis was on map content rather than on location alone (Taylor, 1983:7). Thematic mapping was greatly advanced by the contribution made by the geographer Alexander von Humbolt (Taylor, 1983:7 and Parent and Church, 1989:10). In Europe, the first geological map of Paris appeared in 1811 and this was soon followed by a geological map of London in 1815 (Parent and Church, 1989:10). The work of Alexander von Humbolt, who was arguably the last great figure to claim universal scholarship (James, 1972:178), was influential in the production of both these maps (Parent and Church, 1989:10).

By 1835, technology, science and social awareness had advanced and was evident in the development of cartographic techniques, social science theory and environmental responsibility (Parent and Church, 1989:10). The integration of these three factors was further aided by the Industrial Revolution which supported more comprehensive thematic mapping (Parent and Church, 1989:10). The increase in data and information which needed to be mapped played a major role in thematic mapping (Taylor, 1983:7).

The cartographic catalysts of technology, science and social awareness, reasserted themselves in the mid-20th century and in the late 1940s with the development of the first electronic computer (Parent and Church, 1989:11). The capability to print out digital geographical data in a cartographic format was established when computer-generated maps were used in the 1950s by meteorologists, geophysicists and geologists (Parent and Church, 1989:11). The development of computer technology and its application to graphics had a profound influence on cartography (Cromley, 1992:1). Some scholars profess that this has led to a paradigm shift in cartography. Others, like Cromley do not believe that this is necessarily the case (Cromley, 1992:1).

3.1.2 GEOGRAPHIC INFORMATION SYSTEMS

The origins of GIS are usually traced back to early work in computer mapping (Cowen, 1988:1551). The capabilities of GIS today does however include a lot more than the automated linking of symbology to geographical entities or features which are stored in a digital spatial data base. GIS has the ability to not only store, retrieve and display spatial, or geo-referenced, data but also allow for data analysis and manipulation (Cowen, 1988:1551).

The history of the development of GIS has been poorly documented (Coppock and Rhind, 1991:21). Four distinct developmental phases have been identified by Coppock and Rhind (1991). The first, pioneering and developmental phases which lasted from 1950 - 1970, was largely dominated by role players in the United States and United Kingdom (Coppock and Rhind, 1991:39). This phase was characterised by the contributions of individuals. The second phase was characterised by experimentation which was done with government funding. The third and fourth phases, marked by commercialisation and an increasing dominance by users, has led to fierce competition amongst vendors of GIS software (Coppock and Rhind, 1991:21). The third and fourth phases were further characterised by the rapidly changing technological setting as computing power increased by a factor of two every year (Goodchild, 1991:53).

It does however need to be kept in mind that a GIS is not necessarily by definition a computer system, despite the fact that it is generally regarded as such (Parent and Church, 1989:9). This opinion is also held by Coppock and Rhind who refer to the "manual predecessors" of computer-based GIS (Coppock and Rhind, 1991:21). Cromley also refers to a "printed multi-attribute map" as a geographic information system (Cromley, 1992:306).

If the definition of GIS as a decision making tool is accepted, it can be said that these events led to the first GIS. In 1838 an "Atlas to Accompany the Second Report of the Irish Railway Commissioners" was published (Parent and Church, 1989:10). This atlas consisted of a series of maps depicting population, traffic flow, geology etc. Each of the maps were based on a uniform base map of the same scale. By mentally overlaying these maps, decisions on transport-related issues could be made (Parent and Church, 1989:10).

3.2. DEFINITIONS

3.2.1. CARTOGRAPHY

There are many definitions for cartography, a few relevant ones are cited here. Meyen defined cartography in 1973 as "The art, science and technology of making maps, together with their study as scientific documents and works of art. In this context maps may be regarded as including all types of maps, plans, charts and sections, three dimensional models and globes representing the earth or any celestial body at any scale" (Fischer and Lindenberg, 1989:1431).

Fischer and Lindenberg offer an alternative definition which reads as follows " Cartography is the field which is involved with the graphic communication of spatial relationships and distributions, and includes the analysis and manipulation of geographic data to enhance representation" (Fischer and Lindenberg, 1989:1434).

Muehrcke distinguishes between cartography and map making and defines cartography as "...the study of the philosophical and theoretical bases of the rules for map making, including the study of map communication" (Fischer and Lindenberg, 1989:1431). He goes further and defines map making separately as "..the aggregate of those individual and largely technical processes of data collection, cartographic design and construction (drafting, scribing, display) reproduction etc." (Fisher and Lindenberg, 1989:1431).

3.2.2 MAPS

The definitions of Meyen and Muehrcke refer directly to maps whereas the definition offered by Fischer and Lindenberg refer to maps indirectly as the "representation" of "spatial relationships and distributions". Dent defined maps as being "graphic representations of the cultural and physical environment" (Cromley, 1992:4). Maps have also been defined as "a generalised and reduced representation of a portion of the curved surface of the earth on a flat surface or plane" (Liebenberg, 1986:1).

Both definitions use the word "representation" which implies that maps are models that represent elements or features in the real world. Cromley thus describes maps as being a combination of symbolic and analogue models (Cromley, 1992:6). He defines symbolic models as "highly idealised representations of reality in which a language is substituted for real world objects", whereas analogue models "represent real world features with look-alike features" (Cromley, 1992:6).

A clear distinction is made between topographical or general maps and thematic maps. Petchenik refers to them respectively as being "place maps" and "space maps" (Taylor, 1983:7). Taylor explains that "place maps", or topographical maps, emphasize location and "space maps" emphasize content (Taylor, 1983:7). The design objectives of these two main map types are entirely different (Robinson *et al.*, 1984:140). As this report is concerned mainly with thematic mapping, additional definitions and descriptions of this type of map deserve further investigation.

Robinson *et al.* define a "pure thematic map" as being "primarily concerned with portraying the overall form or structure of a given spatial distribution" (Robinson *et al.*, 1984:140). Cromley offers a more comprehensive definition for what he calls "traditional thematic maps" and explains that such maps "consist of two important components: a geographic base map representing the spatial attributes and a thematic overlay representing some non-spatial attribute of the features being mapped" (Cromley, 1992:6).

Meyen's definition , and the concept that cartography is both an art, science and technology, appears repeatedly in the literature (Buttenfield and Mackaness, 1991:436). Another concept which also appears repeatedly is that of graphic communication (Robinson *et al.*, 1984:137; Taylor, 1983:1; Wood, 1992:435; and Freeman, 1991:445). These four aspects, namely art, science, technology and graphic communication in a cartographic context therefore deserve further attention.

3.2.3 GEOGRAPHIC INFORMATION SYSTEMS

Cowen has distinguished a variety of definitions for GIS and has identified four different approaches to defining such systems. These include a process-orientated approach, where the emphasis is on the data-processing capabilities of such systems, an applications approach, a toolbox approach and a data base approach (Cowen, 1988:1551 - 1552). Cowen did however conclude that "GIS is best defined as a decision support system involving the integration of spatially referenced data in a problem solving environment" (Cowen, 1988:1554). This definition has been widely accepted by many authors such as Parent and Church (1989:9) and Cromley (1992:304). This definition is the one preferred by the author and is also the definition which is used throughout this report.

3.3 CARTOGRAPHIC COMMUNICATION

The communication properties of graphics have been appreciated for many years and was recorded by Thomas Elyot in 1531: ".. a man shal more profite, in one wike, by figures and chartis, well and properly made, than he shal by the only reding or herying the rules of that science by the space of halfe a yer at the lest..." (Taylor, 1983:2).

However, the communication theme has only received serious theoretical attention in terms of cartography since the early 1960s (Taylor, 1983:2). At the fourth International Cartographic Conference of the ICA (International Cartographic Association) in Nieu Delhi, in 1968, a working group on communication in cartography was formed (Taylor, 1983:3). Lech Ratajski was the chairman of this working group and it was he who developed the communication concept into a general theory of cartography (Taylor, 1983:3).

Petchenik has argued that the process of scientific research in communication is both cognitively and epistemologically different from the intuitive nature of the design process and that the use of science in design is inappropriate (Taylor, 1983:6). It is however this non-rational and non-scientific perception of the intuitive aspects of cartography that has stimulated the theory of communication as a scientific basis for cartography (Taylor, 1983:6).

Bertin's (1967) graphic semiology is however the first systematic detailed and comprehensive analysis of the elements of graphics which could constitute a graphic language for visual perception (Taylor, 1983:2). Knöpfli formalised the communication process by saying that successful communication depended upon how messages were encoded (abstracted), whether only relevant information was included in the message and whether the transfer of messages was more successful in the absence of 'noise' in the communication process (Knöpfli,1990).

The communication concept has had a great influence on cartography over the last two decades. A better understanding of graphic communication has however not led to better maps (Taylor, 1983:1). This could be attributed to the fact that the understanding of communication theory is as yet incomplete and that the linkage between theory and practice is very complex (Taylor, 1983:1). Communication theory is today pursued with much less energy and it appears as if it has been taken for granted that cartography aims to communicate spatial information graphically (Wood, 1992:435).

The advent of computer or digital cartography, and the ease with which maps can be produced, updated and amended, has highlighted the need for closer inspection of map design principles which is accepted to be of prime importance in communicating graphic messages more effectively (Clarke, 1990:10 and Wood, 1992:436).

3.3.1 APPLICATION OF THE COMMUNICATION CONCEPT TO MAPPING

The communication concept or approach to cartography attaches equal importance to map making and map use as maps are made in such a way that they enhance the user's ability to retrieve information (Robinson *et al.*, 1984:15). This aim is particularly appropriate to thematic mapping where the goal is to create a general impression of a phenomenon's spatial distribution rather than to provide information about the location of individual objects or features. (Robinson *et al.*, 1984:15). It allows for considerable latitude in applying cartographic principles even though it includes all mapping activities, embraces the full range of mapping sciences and relies heavily on input from associated disciplines (Robinson *et al.*, 1984:17).

The actual map making steps which are necessary to compile a map with this approach are schematically represented in Figure 3.1.

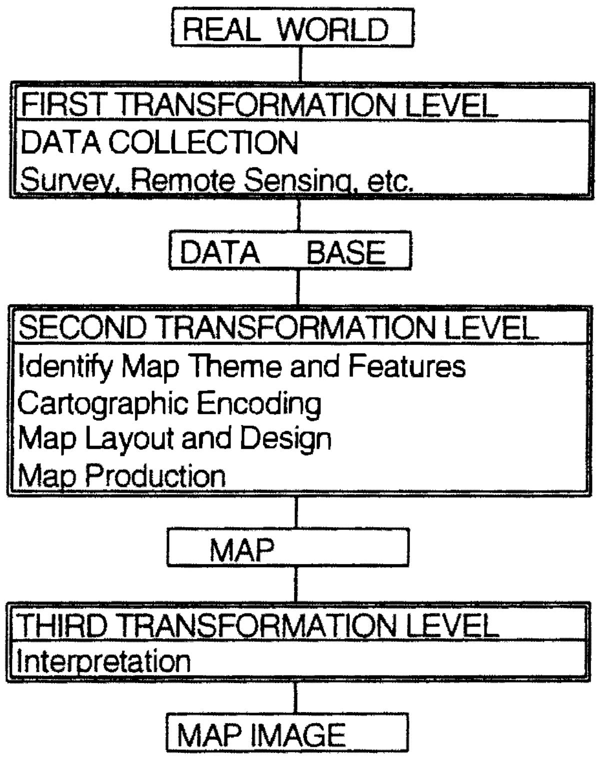


Fig. 3.1. Schematic representation of map making process when using the communication concept of cartography.
(Source: Adapted by the author from Robinson *et al.*, 1984:16.)

The map making process is seen as a series of transformations, each of which has the power to alter the appearance of the final product. At the first level of transformation spatial data is collected or acquired. In a digital environment this is done by remote sensing, a global positioning system, and/or the scanning or digitizing of existing maps. Such data will then, in a GIS environment, be stored in a data base. At the second level of transformation the digital data is selected, classified, symbolised, generalised and a map compiled. The map itself is then used by the map user for analysis and interpretation in the third level of transformation (Robinson *et al.* 1984:16).

3.4 CARTOGRAPHY AS AN ART

Visualisation has a powerful role to play in map interpretation in the sense that it encompasses the "creation and manipulation of mental images" (Buttenfield and Mackaness, 1991:432). The aesthetical appeal of maps embraces harmony, composition and clarity as integral components of the map design. Buttenfield, Mackaness and Knöpfli concede that the perception of these qualities will vary between users (Buttenfield and Mackaness, 1991:438) and will depend on both the nature and the level of training of the map user.

Although it appears as if the communication theory in cartography is receiving less attention today, design research is still a very much researched topic (Wood, 1992:435). Differentiation between design and graphic communication is however difficult as they are "inextricably linked" (Wood, 1992:435). Wood emphasises that this, like the research done on graphic communication, has not produced the desired results and he ascribes this to two factors: first, the lack of understanding of cognitive processes and, secondly to the pre-occupation with technological developments and the advent of automated or digital cartography in particular (Wood, 1992:436).

3.5 CARTOGRAPHY AS A SCIENCE

Knöpfli defines the scientific aspect of cartography as being only the content of a message which needs to be conveyed or communicated (Knöpfli, 1990:71). The whole drive of the concept of communication in cartography was, in part, aimed at providing cartography with a sound scientific base (Taylor, 1983:6). Wood reiterates that the communication concept in cartography has gone the same way as the so-called "quantitative revolution" in geography in that it is no longer receiving the same amount of attention and has been accepted (Wood, 1992:435). No conclusive body of scientific theory has however emerged from it (Wood, 1992:435; Taylor, 1983:6). Maps are however documents that represent scientific facts.

3.6 CARTOGRAPHIC DESIGN PRINCIPLES

A number of researchers have attempted to encapsulate the art and science of cartography in graphical terms. In 1942 Arthur Robinson mentioned that the lack of the formalisation of cartographic principles was a much neglected aspect of cartography (Buttenfield and Mackaness, 1991:429). The formalisation of principles for graphic design in cartography is fairly new. The academic study of map design did not emerge as a scientific discipline until after the second world war when mapping gained global prominence for intelligence and strategic planning (Buttenfield and Mackaness, 1991:429).

In 1990, Dent formalised principles for map design in an attempt to direct the perceptual tasks of map reading (Buttenfield and Mackaness, 1991:430). These principles included symmetry, visual balance, contrast and figure-ground relations. These are also principles upon which Robinson *et al.* expanded. They do, however, refer to them as the "components of graphic map design"(Robinson *et al.*, 1984:145). They expand upon this in explaining that the constituents of cartographic design are those attributes or characteristics of the marks used for representation, that either by themselves or in an organised array are significant in terms of the total graphic presentation (Robinson *et al.*, 1984:146). In addition to the principles mentioned by Dent, they include in this, 'Clarity and Legibility' as well as the 'Hierarchical Organisation' of cartographic marks (Robinson *et al.*, 1984:147).

3.6.1 CLARITY AND LEGIBILITY

The communication of information by means of encoding or symbolisation requires that the actual marks used to represent real world entities or objects are clear and legible. Clarity and legibility of such marks depend on the choice of lines, shapes and colours as well as their delineation.

Size. The size of a symbol plays a vital role in its clarity and legibility. Although there is not total agreement on this, Robinson *et al.* (1984:142) gave the guidelines contained in Table 3.1.

Viewing Distance	Minimum Size of Legible Point
50 cm	0,3 mm
2 m	1,15 mm
5 m	2,9 mm
10 m	5,8 mm
15 m	8,7 mm
20 m	11.,6 mm
25 m	14,5 mm
30 m	17,4 mm

Table 3.1. Approximate minimum sizes for the legibility of point symbols. (Source: Robinson *et al.*, 1984:142.)

The viewing distance for maps contained in reports is approximately 50 centimetre and the minimum width of a point symbol would then be 0,3 millimetre. Not all map symbols are points. Lines for example, have length which enhances visibility and the actual width of a line can therefore be slightly less than what is specified in Table 3.1 above. Size can also be used to emphasise importance.

Apart from size, the following primary graphic elements can be used to differentiate between marks and the background against which they are mapped:

a) **Colour**

The word 'hue' also commonly refers to colour. Perception of colour is visually complex. Colour can be used to differentiate between map symbols representing different objects or phenomena. See Figure 3.2 where the use of colour to distinguish between point, line and areal symbols is illustrated.

b) **Value**

Value refers to the relative lightness or darkness of a colour (Robinson *et al.*, 1984:142). Map symbols that have the same colour blue for example can be differentiated by means of a dark and light blue. See Figure 3.2.

c) **Shape**

Shape is a graphic characteristic which refers to the form of a map symbol or an area which is being mapped (Robinson *et al.*, 1984:142). Examples of how this graphic element can be used to differentiate between point, line and areal symbols is illustrated in Figure 3.2.

d) **Size**

Marks or symbols vary in size when they have different dimensions in terms of width, height, diameter and/or area (Robinson *et al.* 1984:142). See Figure 3.2.

e) **Spacing**

When a sign is made up of a number of component marks such as dots or lines, the spacing can be varied. The closer the spacing, the finer is the texture of such a symbol (Robinson *et al.*, 1984:142). See Figure 3.2.

f) **Orientation of markings**

This refers to the directional orientation of markings and is most often used when hatchings are used as areal map symbols (Robinson *et al.*, 1984:142). Figure 3.2 also indicates how this can be used to differentiate between point and line symbols.

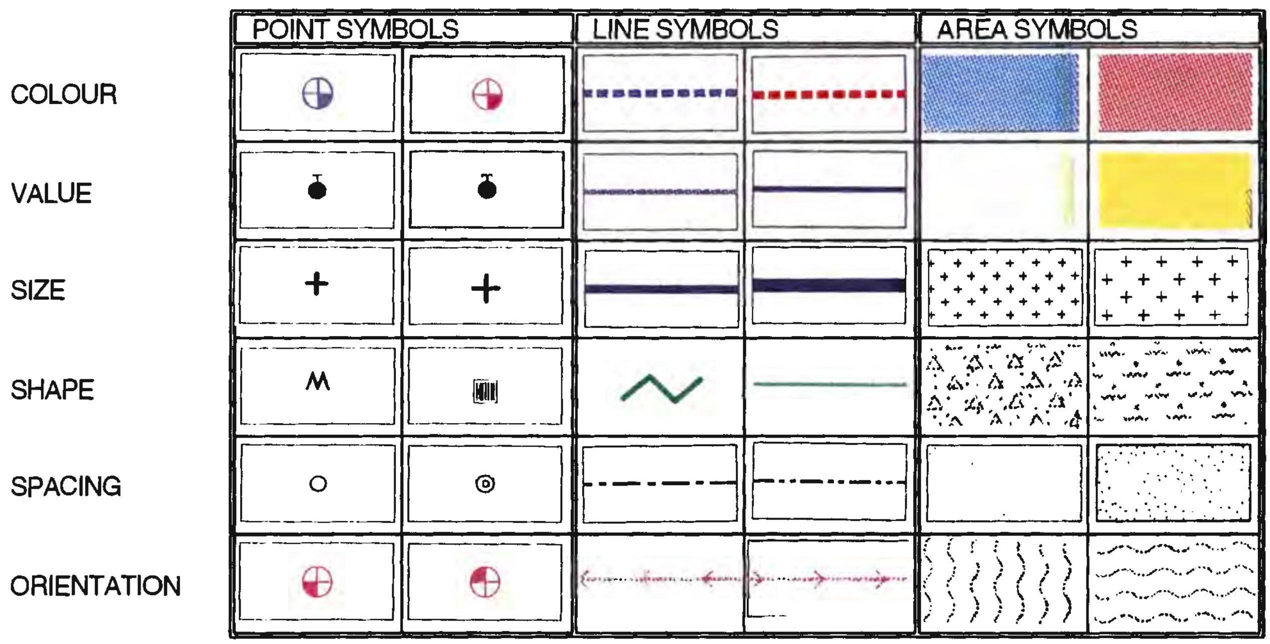


Fig. 3.2. The use of primary graphic elements to differentiate between point, line and areal map symbols. (Source: Compiled by the author.)

The two left columns show how the primary graphic elements can be used to differentiate between point symbols. The middle and right column indicate how the same elements can be used to distinguish between line and areal symbols respectively.

3.6.2 FIGURE-GROUND

In the visual field there are generally two areas, one that seems to stand out, which is generally known as the 'figure', and the remainder which is known as the 'ground'. In this relationship, the figure is more dominant, better described and more impressive than the ground (Wood, 1992:436). A good figure-ground relationship improves cartographic communication in that it eliminates ambiguity and leads to instant recognition (Wood, 1992:439).

The separation of the visual field into figure and ground is automatic and in no way a conscious act or operation by the reader (Robinson *et al.*, 1984:149). It is a natural and fundamental act of visual perception.

In cartographic terms the distinction between figure and ground must be of such a nature that the attention of the map user is focused immediately on the objectives of the cartographer or map maker. One of the first tasks when compiling a map is to decide which elements belong to these two different areas of a map (Wood, 1992:437). There must be differentiation between the figure and the ground for one area to emerge as figure (Robinson *et al.*, 1984:150). Apart from the use of a linear map symbol to indicate the 'edge' between figure and ground, Wood (1992:438) and Robinson *et al.* (1984:150) have outlined the following ways in which such a distinction can be made:

The graphic elements of **size, spacing, shape, orientation, colour and value** can be used to differentiate between figure and ground. The following variables can also on their own, or in combination, be used to the same effect:

a) **Closed forms**

Enclosed forms such as islands are easier to identify than partially shown forms (Robinson *et al.*, 1984:150). See Figure 3.3 a).

b) **Brightness**

Robinson *et al.* state that a darker tonal value tends toward figure (Robinson *et al.*, 1984:150), but this is contradicted by Dent who believes the opposite to be true (Wood, 1992:439). Robinson *et al.* do however concede that in graphic composition "all other things are not usually equal" and that under specific circumstances the opposite may well be more effective. This is illustrated in Figure 3.3 b) and c).

c) **Size or Area**

Robinson *et al.* mention that smaller areas tend to emerge as figure in relation to larger areas (Robinson *et al.*, 1984:151). They go further to state that the actual proportion can, as a result of research, be quantified in that for thematic mapping, which is of importance in terms of this report, the figure:ground ratio which is the total map area minus the area of figure divided by the area of figure should be between 1:4 and 1:1.5. If the ratio is smaller than 1:1.5 there may be confusion between figure and ground.

d) **Centrality**

The actual placing of the area to be mapped in relation to the optical centre of the map also has a influence on the perception of figure and ground (Wood, 1992:439).

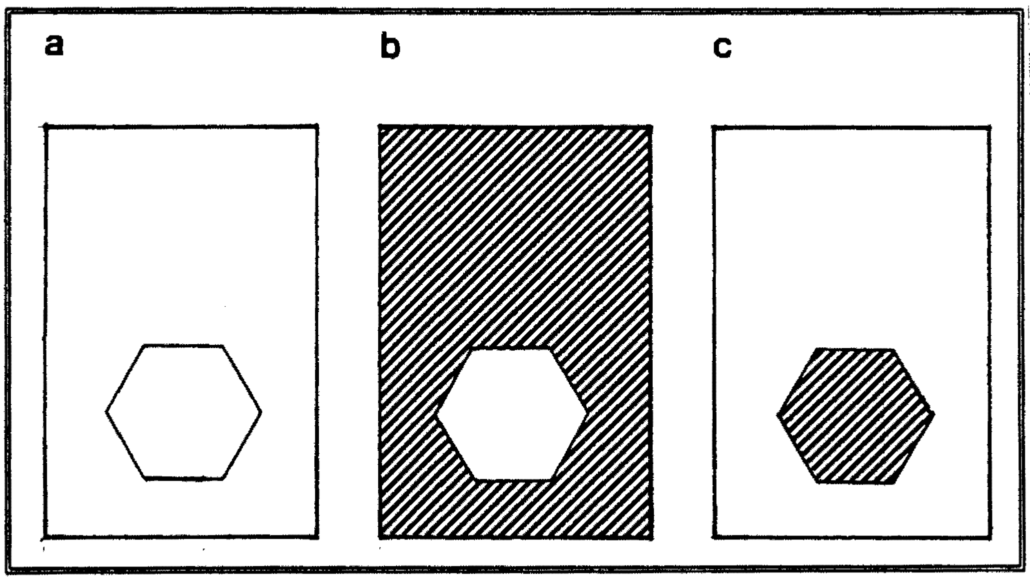


Fig. 3.3. The influence of a closed form, brightness and size of an area which is to be mapped on the distinction between figure and ground.
(Source: Wood, 1992:439.)

e) **Good contour**

This is the graphical equivalent of unambiguity or logic. When something appears to be continuous or symmetrical it leads to figure-ground differentiation (Robinson *et al.*, 1984:150).

f) **Articulation**

The articulation of an area refers to it being segmented or covered by internal markings. Such markings can consists of boundaries, smaller polygons or areas as well as text. This helps an area to emerge as figure (Robinson *et al.*, 1984:150).

g) **Familiarity**

This has a very marked influence on the recognition of figure. The less well-known an area is the more attention needs to be paid to distinguishing it as figure (Robinson *et al.*, 1984:150). The reader can be familiarised with a mapped area by including base map information such as main towns and roads on a map. The inclusion of geographical coordinates also plays a role in familiarising the reader with the area which has been mapped.

Robinson *et al.* caution that some geographical relationships have inherently bad contour, cannot be closed etc. and standard specifications for this aspect of cartographic design cannot be made. This is confirmed by Wood who reiterates that "rarely can a map designer base design decisions on objectively produced principles of figure-ground differentiation" (Wood, 1992:439).

3.6.3 HIERARCHICAL ORGANISATION

Maps incorporate elements of information which require some organisation into different visual levels. This is illustrated in Figure 3.4.

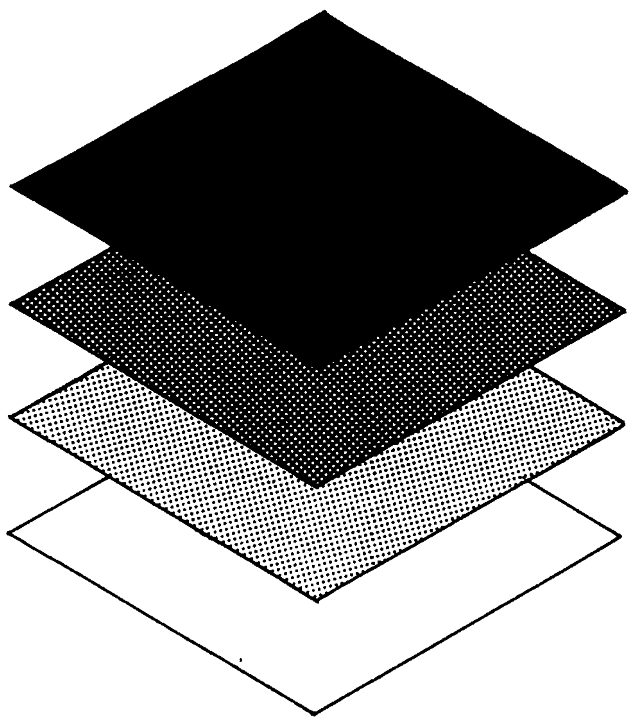


Fig. 3.4. Vertical hierarchical organisation of map information.
(Source: After Dent, 1990 (Wood, 1992:436).)

The black layer represents the highest level of organisation and the white layer the lowest level. If each layer or level represents an information component of a map, the more important layers would be at the top. The hierarchical order of such layers would depend on the map designer's understanding of the communication requirements which is dictated by the data (Wood, 1992:437). An understanding of the communications requirements dictated by the data which is to be mapped, enables the map designer to organise the map elements in such a way that the reader will perceive the required visual organisation of the mapped information (Wood, 1992:437).

In terms of thematic mapping, base map information must appear as being subordinate, or at a lower level in the hierarchy than the thematic mapping elements (Wood, 1992:437). Robinson *et al.* distinguish three different kinds of hierarchical organisation:

a) **Extensional organisation.**

This concerns the portrayal of lines or points that vary in terms of significance. Stream order or different classes of roads are examples of this type of organisation which is based on the ordinal scale of measurement. The graphic display of the relative importance of an object or phenomenon can be achieved by using the graphic elements of **size, value** and **colour** (Robinson *et al.*, 1984:151).

b) **Subdivisional organisation**

This organisation entails the internal divisions of hierarchy and is usually applicable to areal symbols (Robinson *et al.*, 1984:151). Primary catchments areas are, for example, subdivided into secondary, tertiary and quaternary catchments. Graphic elements used to differentiate these are colour and pattern (Robinson *et al.*, 1984:152).

c) **Stereogrammic organisation** gives the map user the impression that the map components lie at different visual levels (Robinson *et al.*, 1984:152). The principles involved are similar to those that apply to distinguishing between figure and ground. Related techniques which can be used include:

- superimposition;
- progression of size;
- progression of weight; and
- value progression.

3.6.4 VISUAL CONTRAST

"Contrast is the basis of seeing" (Robinson *et al.*, 1984:146). If a mark on a map is large enough to be seen, the contrast between that mark and the background as well as between other surrounding marks will affect its visibility. This does not necessarily mean that maximum contrast is always necessary. The amount of contrast should however, in some way or other, reflect the difference (Robinson *et al.*, 1984:146). Contrast is achieved by modulating graphic elements which include colour, value, shape, orientation, size and spacing. If marks differ in terms of two graphic elements this is normally sufficient, but the more complex marks are, the more graphic elements are needed to visually differentiate between them (Robinson *et al.*, 1984:146).

3.6.5 VISUAL BALANCE

Visual balance refers to the general arrangement of the basic display. It is achieved by the logical positioning of the visual components of a display and depends on:

- the visual importance (Robinson *et al.*, 1984:147);
- the relative position of the basic parts of a map (Robinson *et al.*, 1984:147);
- the relation of each item to the optical centre of the map and to other items (Robinson *et al.*, 1984:147); and
- the visual weights of map items (Robinson *et al.*, 1984:147).

The optical centre of a map lies 5% of the height of a map above the centre of the map border or neat line. See Figure 3.5.

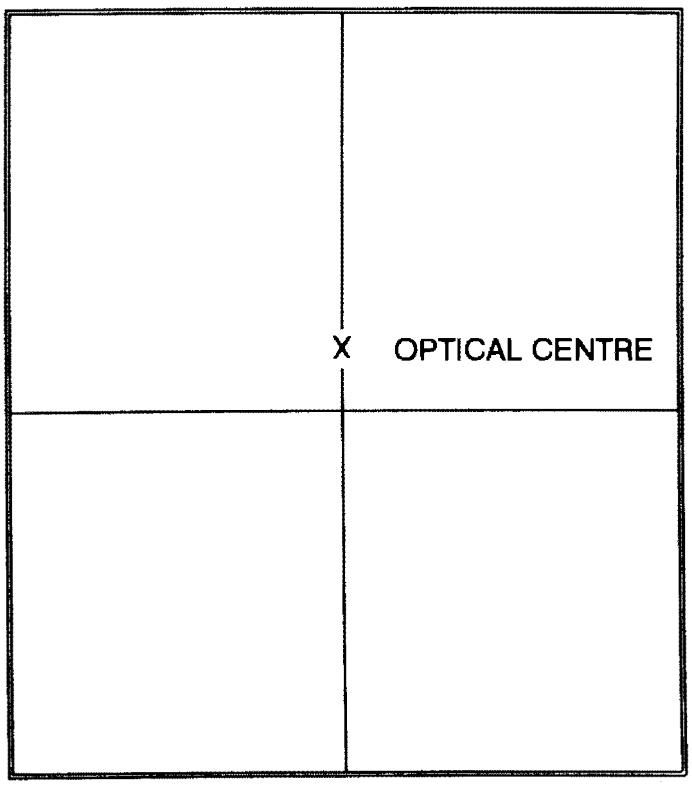


Fig. 3.5. Optical centre of the image area of a map.
(Source: After Robinson *et al.*, 1984:147.)

If the margins of maps are used for legends, scales, acknowledgements etc. these masses also need to be well-balanced (Robinson *et al.*, 1984:148). The size and shape of the image area is very important. The shape of the area to be mapped is fixed but it can change to an unexpected degree depending on the projection used. A general rule is that the sides of the mapped area should have a proportion of 3 to 5 (Robinson *et al.*, 1984:148).

3.6.6 STANDARD MAP ELEMENTS

Standard map elements have a denotative function in identifying the area that has been mapped, the subject matter and the explanation of symbolisation. They also play a role in the graphic organisation of a map. According to Robinson *et al.* (1984:158), such information includes the following:

- Map title;

- Map reference or key;
  - All symbols that are not self-explanatory should be included in the map reference;
  - Symbols in the reference should be exactly the same size as those used on the map; and
  - A range of values should be arranged in such a manner that the lowest value in the range appears at the bottom.

- A graphic scale.

A summary of the standard map elements which appear on national topographic and geological maps in South Africa are listed below:

- Map name and number;
- Proportional scale;
- Scale diagram or line scale;
- Copyright statement;
- Co-ordinate system;
- Projection and projection parameters;
- Date of publication;
- Publisher; and
- Printer.

3.7 CARTOGRAPHIC ENCODING

Interest in symbol design for statistical and thematic mapping began to develop with the publication of a cartographic textbook by Erwin Raisz in 1948 (Buttenfield and Mackaness, 1991:429). Robinson followed in 1953 in the first edition of his text book "Elements of Cartography". In 1973, Bertin developed a system of visual variables and demonstrated their manipulation in graphic displays and spatial analyses (Buttenfield and Mackaness, 1991:430). Bertin also formulated principles for the appropriateness for displaying quantitative and qualitative variables (Buttenfield and Mackaness, 1991:430). These are illustrated in Figure 3.6.

Robinson *et al.* also paid particular attention to the design of map symbols. Their point of departure as far as this aspect is concerned is that "positional distinction among data is the primary purpose of a map, but if that were all a map could reveal, there would be little communication" (Robinson *et al.*, 1984:141). They go further to say that if map symbols are to be "meaningful" they need to appear "more or less distinctive and prominent in any finite number of ways" (Robinson *et al.*, 1984:141). The way in which this can be achieved is to ensure that graphic elements between symbols differ (Robinson *et al.*, 1984:142). He distinguished the following graphic elements: colour, value, shape, spacing, orientation and location (Robinson *et al.*, 1984:143). In addition to this, mention is also made of focal quality, chroma, position, texture and intensity (Robinson *et al.*, 1984:144).

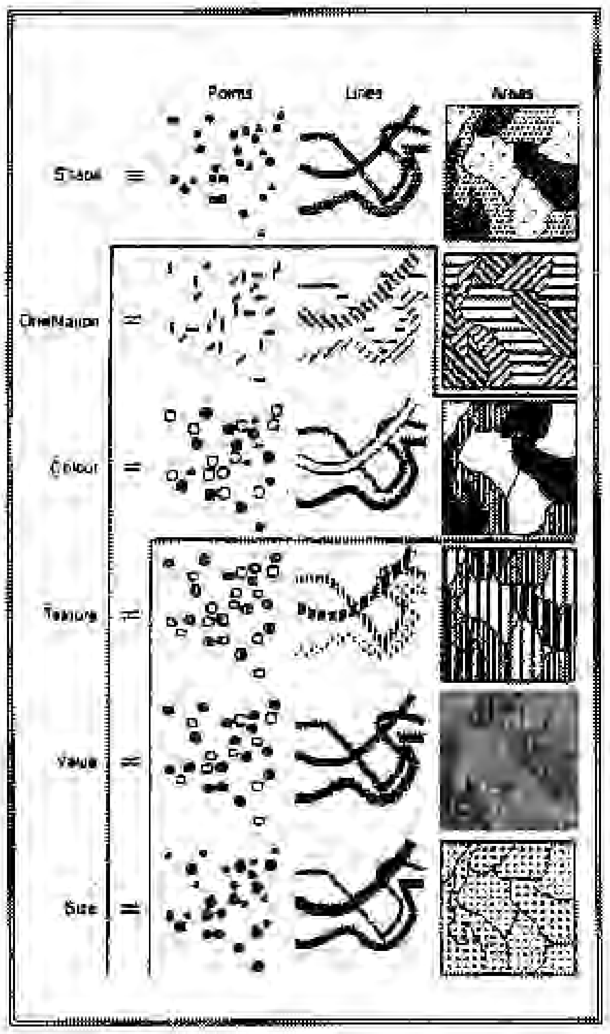


Fig. 3.6. The application of visual variables to cartographic representation of spatial or geo-referenced variables.
(Source: After Bertin, 1983 (Buttenfield and Mackaness, 1991:431).)

The equivalence sign opposite the variable of 'Shape' in Figure 3.6 indicates that this variable should not be used to differentiate between different categories of feature types such as points, lines or polygons (areas) as it does not in itself provide sufficient contrast. The not equivalent signs opposite the variables of 'Orientation' and 'Colour' are an indication that categorical distinctions or differences between symbols are made visually noticeable by these variables. This does however not apply to the orientation of areal symbols. The not equivalent signs opposite the variables of 'Texture', 'Value' and 'Size', indicate that metric or ordinal distinctions apply to points, lines and areal cartographic symbols (Buttenfield and Mackaness, 1991:431).

3.8 TEXT PLACEMENT

Name or text placement has received much attention in cartographic literature. Cartographic name placement guidelines have been well described by Imhof in 1962 (Freeman, 1991:447). In broad terms these can be summarised as follows:

- A given feature or object and its name must be unambiguously associated;
- if line feature names overlap with the feature the underlying feature should be interrupted;
- place names should not overlap;
- area place names should be spaced to conform to the shape of the feature;
- names should be distributed in such a way that the placement appears natural and not contrived; and
- on small scale maps, horizontally placed names should conform to the horizontal curvature of the parallels (Freeman, 1991:447) .

No rules actually address "specialised thematic and topographic map configurations or unusual map projections" (Freeman, 1991:452). No universally acceptable set of cartographic rules therefore exist for this cartographic aspect of design.

3.9 GENERAL

There are other aspects of cartography that have defied all attempts at standardisation despite the efforts of many cartographers to analyze the associated processes (Muller, 1991:457). One of these is map generalisation. In 1960 Robinson reiterated that cartographic generalisation is essentially a creative process and that it is not possible to standardise this process in any way (Muller, 1991:457).

Research has thus focused on cartographic aspects such as cartographic principles, symbolisation and text placement which are aspects that can be compartmentalised (Buttenfield and Mackaness, 1991:437). No integrated solution to the formalisation of cartographic design principles has emerged as the processes mentioned above have been studied in isolation (Buttenfield and Mackaness, 1991:437). The various attempts have, however, highlighted the need for a better understanding of cognitive processes (Buttenfield and Mackaness, 1991:438).

The lack of formal cartographic rules for map design is not the result of a lack of interest on behalf of cartographers in map users, nor is it the result of incompetency on behalf of the cartographic profession (Buttenfield and Mackaness, 1991:436). It merely indicates the complexity of deducing a set of cartographic rules which would be universally applicable. Cartographic decision-making is subjective, retrospective, and the cartographic evaluation tasks are complex and ill-defined (Buttenfield and Mackaness, 1991:437).

3.10 CARTOGRAPHY AND GEOGRAPHIC INFORMATION SYSTEMS

The advent of computer technology has revolutionised the way cartography is perceived and practised (Cromley, 1992:1). Over the last two decades cartographic research has to a large extent focused on "automating traditional cartographic representations and techniques" (Buttenfield and Mackaness, 1991:430). These efforts thus concentrated on the hard copy static map and little attention was paid to design and the development of new methods (Buttenfield and Mackaness, 1991:430).

There are several recognised stages of adaptation to any new technology that have been described by Clarke and Cromley as having had an influence on cartography (Clarke, 1990:pxii and Cromley, 1992:2). These can be summarised as follows:

- a reluctance to use the technology (Clarke, 1990:2);
- a tendency to use the new technology to replicate things as they were done with the old technology (Clarke, 1990:2); and
- full implementation of the new technology and use of the new capabilities offered by the new technology (Clarke, 1990:3).

3.10.1 ADVANTAGES OF DIGITAL CARTOGRAPHY

The new computerised technology, and GIS in particular, has had many cartographic advantages. These are briefly summarised below.

- Computer-assisted cartography has facilitated the manipulation of large quantities of data (Taylor, 1983:7 and Buttenfield and Mackaness, 1991:428);
- Tedious mathematical operations, survey adjustments, ellipsoidal calculations and map projection calculations can be performed with ease and at greater speed (Clarke, 1990:pxii);
- Digital cartography has increased mapping speed and efficiency and has increased potential mapping accuracy (Clarke, 1990:6);
- The reduction in mapping speed reduced the emphasis which had previously been placed on cartographic production technology (Clarke, 1990:8);
- Maps are easily updated, and computer technology allows for interactive changes and modifications which has led to a trend to produce simpler maps and has emphasised the need for emphasis on design and aesthetics (Clarke, 1990:8-10); and
- GIS has provided the cartographer with a whole new set of tools for visualisation of spatial data which allow for the graphic display of such data as three-dimensional images, in animated form and as geographical flows (Buttenfield and Mackaness, 1991:431).

3.10.2 DISADVANTAGES AND PROBLEMS

At the same time, the use of computers also has distinct cartographic disadvantages. These include the following:

- Generalization algorithms are unable to simulate the objective and subjective thinking which is involved in manual generalisation procedures (Muller, 1991:457);

- Text placement;

- An increase in the amount of technical training cartographers require; and

- The popularisation of mapping has made it possible for operators who have not been trained in cartography to produce maps with relative ease (Clarke, 1990:10).

Problems relating to text placement are discussed in more detail below.

3.10.2.1 POSITIONING OF TEXT

In a spatial or geo-referenced data base, digital data is stored as layers which contain single map features such as rivers, wetlands, dams, etc. (Freeman, 1991:446). These layers continue across map borders and each feature has an associated layer with map text. If an area is to be mapped, the relevant portion or part of a continuous map in the data base is clipped out together with the relevant part of the text layer (Freeman, 1991:446). The resultant cartographic problems are three-fold.

a) It may well be that text pertaining to the area which has been clipped for mapping will in fact fall 'outside' the actual map (Freeman, 1991:447). This is illustrated by Figure 3.7 (Freeman, 1991:447).

b) If different features need to be combined for mapping and the relevant text layers are combined, text may well overlap with other text or with features on the map and thus be illegible (Freeman, 1991:447).

c) The text in the data base has been captured to be plotted at a specific scale. If the data is plotted at a smaller or larger scale, the text size is not altered (Freeman, 1991:447).

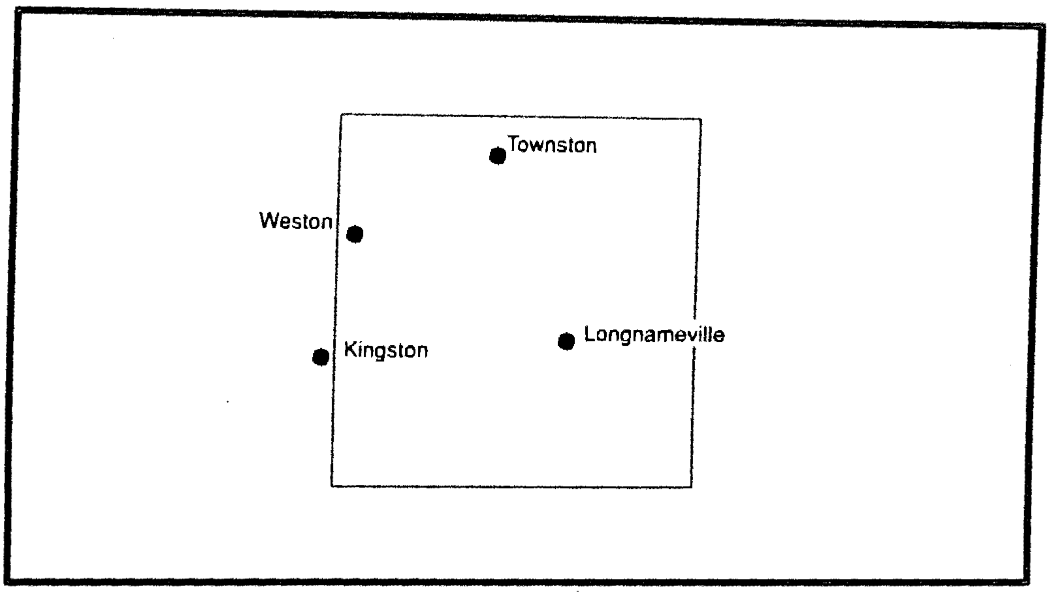


Fig. 3.7. Problems which may arise when text is clipped from a text layer for mapping purposes.
(Source: Freeman, 1991:447.)

Freeman (1991) has actually made some suggestions to solve these problems but these have not been incorporated in commercially available software packages.

3.10.3 GIS AND CARTOGRAPHIC STANDARDS

It is only recently that the need for standards for GIS are being addressed. To date none of these standards are addressing the issue of the representation or visualisation of digital geographical or cartographic data. The fields which are emphasised are those of data transfer, data quality and data models (Rowley, 1993:42).

GIS users comprise professionals from a great many disciplines such as geography, hydrology, geohydrology, engineering, landscape architecture, surveying etc. (Parent and Church, 1989:9) and even though they may not be primarily concerned with the quality of graphics derived from data and information manipulation and analysis, they should be aware of the implications of how this is to be represented on a resultant map (Fischer and Lindenberg, 1989:1433). Buttenfield and Mackaness and Burrough warn that when perceptual analysis and decisions are based on graphical representations, the graphics should not belie true spatial patterns (Buttenfield and Mackaness, 1991:437 and Burrough, 1986:76). A new need has therefore arisen for cartographic design principles.

The use of computers to replicate previously used technology like pen and drafting tables has contributed greatly to the lack of attention by GIS vendors and software architects to perceptually sound graphic defaults and good principles of graphic design (Buttenfield and Mackaness, 1991:430). This is not due to the lack of documentation on the limitations of the perception of colour for example, or on size and visual clustering or visual complexity (Buttenfield and Mackaness, 1991:430).

GIS vendors and graphics research analysts are at pains to point out that GIS systems can offer capabilities to manipulate and analyze spatial data in a way which could not be done previously and that GIS is not "just a pretty mapmaker" (Smith, 1994:44). This is indeed true, but GIS software packages should compensate for the visual estimation of size, value, and colour and incorporate this into graphic defaults to ensure that there is a minimum of bias in the use of GIS graphics when displaying geo-referenced information (Buttenfield and Mackaness, 1991:437).

4

CARTOGRAPHIC GIS STANDARDS

The approach to the standardization of graphic representations for output generated by the departmental GIS was to a large extent user-driven. From the outset it was realised that these standards needed to be versatile to accommodate the many applications for which GIS is used in the department. (See 2.1.1) These standards apply to hard copy map output only.

4.1 CARTOGRAPHIC APPROACH

The communication approach to cartography was, due to its emphasis on the use of maps, the most suited approach in terms of the mapping problems experienced at the DWAF. The actual map making steps have been illustrated in Figure 3.1. For each level of transformation depicted in this figure, different requirements for cartographic standards apply. Standards devised or set for a final map would need to take more cartographic variables into account than, for example, standards which were set at the map topic level. Designing standards for final maps for all the applications at the department, (see 2.1.1) would not only have been inflexible and tedious but also cumbersome to use. The level of flexibility therefore decreases as map transformations progress. Standards had to be related to a stage between the data base level and the final map.

At each level of transformation, different cartographic variables play a role in the transformation process. These variables are:

- information content and date of content;
- map scale;
- priority of element (eg. background or main topic); and
- geographical extent.

As the transformation process progresses these variables become 'fixed'. See Table 4.1.

Transformation Process	Information Content	Map Scale	Priority	Geographical Area/Extent
Map Theme				
Encoding				
Map Layout				
Map Composition				
Map Production				

Variable Flexible

Variable Fixed

Table 4.1. Second level transformations in the communication approach to cartography, and the variables that influence them.
(Source: Compiled by the author from Robinson *et al.*, 1984:16.)

At the data base level, it is at its most flexible. At the map theme level, the content and date of information are selected. At the symbolisation or encoding level, map scale and the priority of features are determined. When the map layout is planned the geographical extent of the map is determined and at the map compilation and production stages the output medium will be determined.

In view of this, departmental standards were designed at the symbolisation or encoding level where information content, priority of elements and map scale are fixed. General rules for map layout also formed part of the project. This approach enabled the application of cartographic standards without loosing the appropriate degree of flexibility which was desirable for effective map compilation at the department.

4.2 PROCEDURE FOLLOWED TO ESTABLISH CARTOGRAPHIC STANDARDS

Based on the above, the departmental procedure which was followed to compile standards for map output was divided into five phases. These phases are summarised in Table 4.2.

PHASE	TRANSFORMATION PROCESS
PHASE 1	Identify themes and features
PHASE 2	Identify mapping scales
PHASE 3	Design cartographic encoding of features
PHASE 4	Draw up technical specifications of encoding
PHASE 5	Generate digital map symbols
PHASE 6	Identify general rules for map content and composition

Table 4.2. Phases in designing cartographic standards for GIS hard copy output at the DWAF.
(Source: Modified by the author from Wolfer 1992:4.)

In Phases 1 and 2, the identification of themes and related features, their classification as well as the mapping scale were considered. These phases were almost entirely reliant on input from GIS users. Phases 3 and 4, the encoding, technical specification and digital generation of map symbols required input from users as well as professional cartographic input. Phase 5, general rules for map layout and composition, required cartographic input only.

Map generalisation was not isolated as a separate step in the above mentioned transformations. This was done because map generalisation plays a role in each step of the map making process.

4.3 CARTOGRAPHIC STANDARDS

4.3.1 MAP SCALE

Map scale determines which feature will be considered for graphic display. A departmental survey was done to determine which map scales were used most often. Fourteen scales were identified. (See Table 4.3).

1	2	3	4
SCALE RANGE NO.	POPULAR SCALES	SCALE RANGE BOUNDARIES	SCALE FACTOR
		1: 5 000	
7	1: 5 000		
	1: 7 000		
	1: 10 000		
		1: 13 000	2.6
6	1: 15 000		
	1: 20 000		
	1: 25 000		
		1: 33 000	2.5
5	1: 50 000		
	1: 75 000		
		1: 83 000	2.5
4	1: 100 000		
	1: 150 000		
		1: 183 000	2.2
3	1: 200 000		
	1: 250 000		
		1: 433 000	2.3
2	1: 500 000		
	1:1 000 000		
		1:1 082 000	
1	<1:1 000 000		

Table 4.3. Scale ranges identified for the standardisation of cartographic output. (Source: Wolfer, 1992:3.)

It would have been impractical to design mapping standards for each of these scales listed in the second column and such a specification would have excluded the use of other intermediate map scales. The scales were grouped and seven scale ranges were identified. The groups were selected in such a way that the incremental scale factor between different ranges was on average 2.4. The values have been listed in Column 4 of Table 4.3.

4.3.2 MAP THEMES AND FEATURES

Users of the GIS at the department were consulted to identify the range of themes and geographical features which were most commonly used. The outcome of this survey has been summarised in Section 2, Table 2.1 of this report. A comprehensive list of geographical features which were identified and which are associated with the identified themes are given in Appendix A.The identification of themes and geographical features is however an ongoing one. An extract from this Appendix, listing only features for the hydrology map theme are given in Table 4.4.

ENVIRONMENT	THEME	FEATURE
SCIENTIFIC AND NATURAL	HYDROLOGY	Catchment area
		Sub-catchment area
		Hydrological zone
		River
		Flow gauging station
		Flood zone
		Run-off zone
		Pan
		Wetland
		Lake
		Dam
		Spring
		Borehole
		Estuary
		Sedimentation
		Water quality

Table 4.4. Features identified for hydrological mapping.
(Source: Wolfer, 1992 :5.)

4.3.3 CARTOGRAPHIC ENCODING

The features listed in Appendix A were then classified in terms of map scale, output parameters, feature class and potential values.

4.3.3.1 CLASSIFICATION OF FEATURES

a) **Output parameters**

Features needed to be classified and prioritized in terms of whether they would be represented on colour maps (C), in monochrome (M), whether they would be used as background information (B) or whether they could be displayed in all three ways (A). This information was obtained from users. For the hydrology theme, which has been classified and prioritised in Table 4.5, it was deemed necessary to be able to display information in all three ways.

b) **Feature classification**

All geographical features needed to be classified in terms of the feature type (point, line and polygon) which would be required to represent these features in graphical form. This is a scale dependent variable.

c) **Potential values**

A list of potential values for each feature type needed to be determined. Features could have a potential value which would fall on either a nominal (N), ordinal (O), interval (I) or ratio (R) scale. These potential values were determined in consultation with GIS users. These values have been listed in Column 3 of Table 4.5 .

i) Nominal scale values.

All features having values on the nominal scale, have more than one value but there is no hierarchy between values. There is thus a qualitative distinction between values (Cooper, 1993:193). Springs are a good example of this. Springs are classified as being perennial or non-perennial. A sub-classification includes whether they yield fresh water or brackish water.

ii) Ordinal scale values.

Values on an ordinal scale have a qualitative hierarchy (Cooper, 1993:193). An example of such values would be the primary, secondary, tertiary and quaternary catchment areas which are distinguished at the DWAF.

iii) Interval scale.

Values on an interval scale of measurement have an exact numerical value so that the difference between any two items on a scale are known (Cooper, 1993:192). An example of such values are those allocated to water occurrence in terms of geohydrology. Water occurrence is classified into productivity classes of high, moderate, low and very low. Each of the classes have a definite quantifiable limit.

iv) Ratio scale.

Values on the ratio scale are based on absolute values and would, for example, include a classification based on ^{0}K (Kelvin temperature scale). No such potential values were identified.

An example of how this was done for the hydrology theme is given in Table 4.5. Once again only those features related to the hydrology theme have been indicated as an example.

1	2							3		
FEATURE	SCALE RANGE AND OUTPUT PARAMETERS							FEATURE TYPE AND SCALE OF MEASUREMENT		
	1	2	3	4	5	6	7	Polygon	Line	Point
Catchment	A	A	A	A	A	A	A	N	N	
Sub-catchment			A	A	A	A	A	O	O	
Hydrological zone	A	A	A	A	A	A	A	N	N	
River	A	A	A	A	A	A	A		N	
Flow gauging station	A	A	A	A	A	A	A			N
Flood zone				A	A	A	A	N	N	
Run-off zone	A	A	A	A	A	A	A	N	N	
Pan			A	A	A	A	A	N	N	
Wetland			A	A	A	A	A	N	N	
Lake			A	A	A	A	A	N	N	
Dam			A	A	A	A	A	N	N	
Spring			A	A	A	A	A			N
Borehole			A	A	A	A	A			N

A = Colour, monochrome and as background information.
N = Nominal Values.
O = Ordinal Values.

Table 4.5. Classification of features identified for hydrological mapping. (Source: Wolfer, 1992:5.)

4.3.3.2 TECHNICAL SPECIFICATION OF MAP SYMBOLS

Before the map symbols identified in Table 4.5 could be digitally generated, technical specifications, specifying line thicknesses and type, colours and marker symbols depicting point features needed to be specified.The following was taken into account when technical specifications were drawn up for the map symbols.

a) Compatibility with existing conventions

Compatibility with existing conventions as used by the Chief Directorate of Surveys and Land Information for topographic mapping needed to be taken into account for all base map features. From a thematic mapping point of view topographical or locational information is important in terms of background or base map information.

b) Cartographic correctness and consistency

Symbols for a particular geographical feature needed to be displayed at different scales by a symbol with similar characteristics (e.g. similar colour allocation needed to be used for pipes of comparable capacity).

The six graphic elements, size, value, spacing, colour, orientation and shape, were taken into account when designing the technical specifications for map symbols. The positional element was purposefully omitted as it has a lower priority as far as thematic mapping is concerned (Taylor, 1983:7).

c) Enlargement and reduction

Maps produced by the department for reports were mainly on A4 and A3-sized paper. Symbols needed to be designed in such a way that they could be used for more than one scale within a scale range.

d) Compatibility of output parameters

Compatibility of colour, black and white and background symbolisation on maps needed to be taken into account. In some cases, such as hydrology and geohydrology in particular, colour maps were regarded by the users as being of a higher priority than monochrome mapping.

e) Production technology

The limitations of plotting facilities and printing media needed to be taken into account. All map symbols were designed to ultimately comply to requirements for printing technology. The interim output devices are however inkjet, electrostatic and thermal wax plotters. This did have an influence on the choice of graphic elements such as value and colour.

Colours produced by the electrostatic plotter vary enormously depending on humidity and the quality of the ink. This leads to inconsistencies in the actual output. Brighter colours than those that would normally be used for printing purposes need to be selected for this plotter in order to distinguish between different values of a colour.

Examples of the technical specifications for the representation of the hydrological wetland feature (polygons with nominal scale values), rivers (lines which have nominal scale values) and springs (points with nominal scale values) are shown in Tables 4.6, 4.7 and 4.8.

SCALE RANGE	SYMBOL	COLOUR	MONOCHROME	BACKGROUND
1-2	ARC/INFO Shadeset Template.Shd 1032	100% Cyan	100% Black	80% Black
3-5		100% Cyan	100% Black	80% Black
6-7		100% Cyan	100% Black	80% Black

Table 4.6 Technical specification for digital wetland map symbols.
(Source: Jonck, 1992:25.)

The wetland map symbol is an area symbol consisting of a colour 'hatching'. An existing ARC/INFO symbol was used in this case.

SCALE RANGE	FEATURE RIVER	PRIORITY	LINE	COLOUR	FILL
1 - 4	Perennial	Colour	0,5 mm	100% Cyan	20% Cyan
		Monochrome	0,5 mm	100% Black	20% Cyan
		Background	0,5 mm	80% Black	20% Black
5 - 7	Non-perennial	Colour	0,25 mm	100% Cyan	None
		Monochrome	0,25 mm	100% Black	None
		Background	0,25 mm	80% Black	None

Table 4.7 Technical specifications for digital river map symbols.
(Source:Jonck, 1992 :23.)

Users identified the need to depict perennial and non-perennial rivers in colour, monochrome and as background information. Rivers could be depicted as a single line (perennial) and a dashed line (non-perennial). Line thickness as well as the length of the dash and gap between dashes needed to be specified. At scales 1 - 4, however, rivers can be indicated by a double line (each line will depict a river bank). Here the colour of the fill (colouring to be used between the lines) needed to be specified in addition to the colour of the line.

SCALE RANGE	FEATURE	SYMBOL	COLOUR	MONOCHROME	BACKGROUND
1-7	Perennial		100% Cyan	100% Black	80% Black
	Non-Perennial		100% Cyan	100% Black	80% Black

Table 4.8 Technical specification for digital fresh water spring symbols.
(Source: Jonck, 1992:27.)

Springs were to be identified at all scale ranges by the same symbol. This symbol could, with the aid of ARC/INFO software, be scaled according to the scale factor given in Table 4.3.

4.3.3.3 GENERATION OF DIGITAL MAP SYMBOLS

All specified map symbols were created in a digital format. Examples of the symbols created for the hydrology map theme and for which the technical specifications have been enclosed as examples, are shown in Figures 4.1, 4.2 and 4.3.

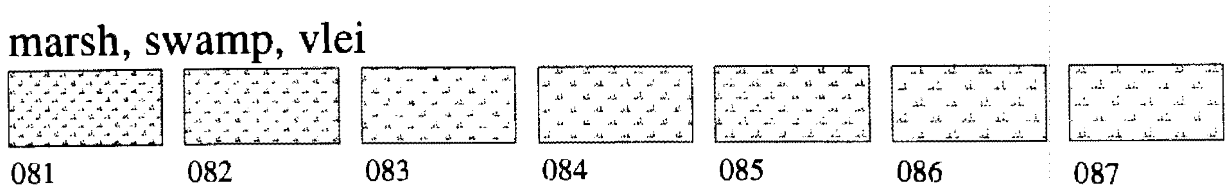


Fig. 4.1. Wetland map symbols.
(Source: BASEMAP.SHD file, DWAF.)

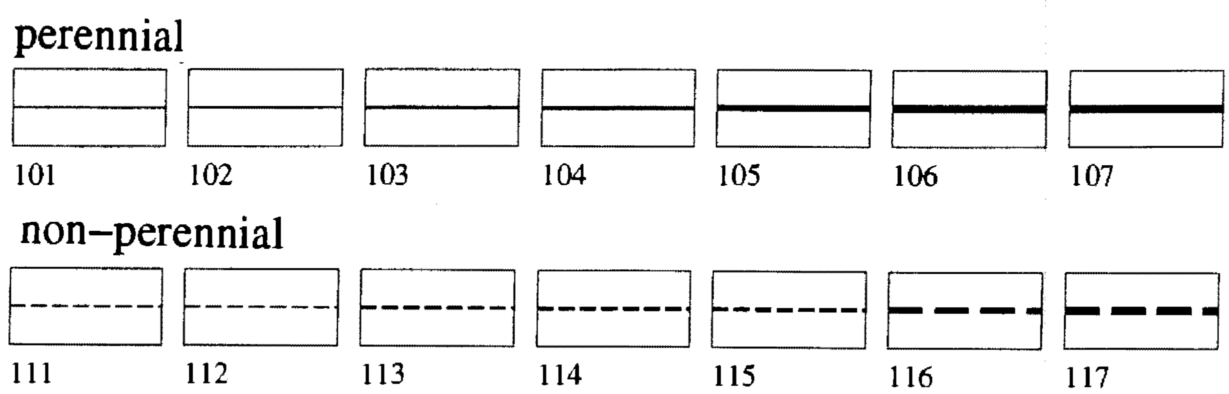


Fig. 4.2. Perennial and non-perennial river map symbols.
(Source:BASEMAP.LIN file, DWAF.)

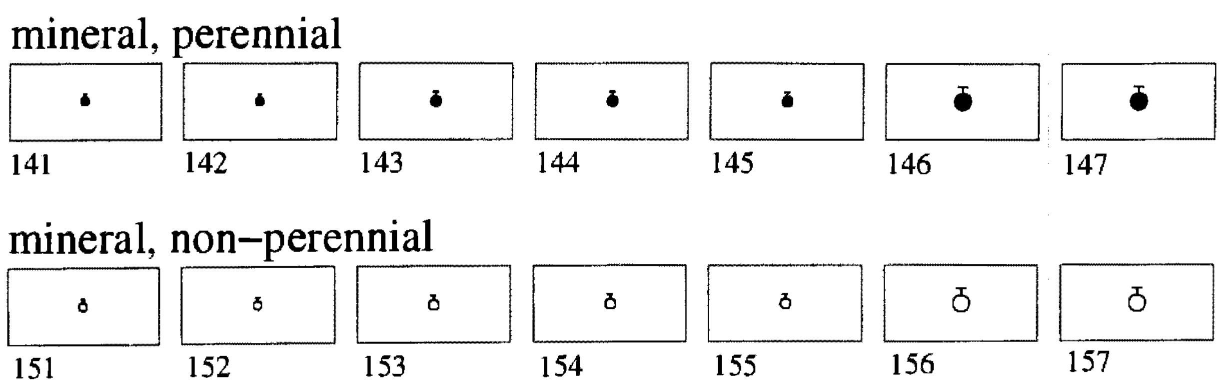


Fig 4.3. Fresh water spring map symbols.
(Source: BASEMAP.MRK file, DWAF.)

4.3.3.4 USE OF MAP SYMBOLS

The standard gives the following general rules for using digital map symbols:

a) features must be big enough for either colour or hatching to be discernable. If this is not the case a larger map scale will need to be used or the digital data will need to be generalised (Jonck *et al.*, 1994:17);

b) a general rule which can be kept in mind is that the larger an area, the lighter the colour or the coarser the hatching should be (Jonck *et al.*, 1994:17);

c) text and base map information must be visible despite the use of colour to shade an area (Jonck *et al.*, 1994:17);

d) the graphic density of information should be proportional to the real world situation (Jonck *et al.*, 1994:17); and

e) if generalisation is applied, this should apply in an equal measure to all features or objects shown on a map (Jonck *et al.*, 1994:17).

4.3.4 MAP CONTENT

4.3.4.1 ORIENTATION OF MAPPED AREA

These guidelines were specifically aimed at problems such as those pointed out in Figure 2.3. It is specifically mentioned that the following orientation features should appear on all thematic maps:

- Towns;
- Roads and/or railways; and
- Surrounding information such as coastlines, international boundaries etc. (Jonck *et al.*, 1994:5). This is specifically aimed at preventing "island"-like maps such as is depicted in Figures 2.1 and 2.2.

4.3.4.2 MAP REFERENCE

The positioning of the map reference is predetermined by the map templates referred to in 4.3.5.1. The standards make specific reference to the fact that all mapped features should be explained in the map reference, that feature types (points, lines, areas) should be grouped and that both graphics (symbols) and type should be properly aligned (Jonck *et al.*, 1994:5). It is also specified that line features symbols should not be enclosed in boxes or be drawn as a zig-zag line (as in Figure 2.3). See Figure 4.4 for an example of a map reference.

4.3.4.3 LOGOS

It is mentioned that logos should be placed in the map reference area and that they should be grouped. The size of a logo placed on a map will depend on the physical size of the map. If reduced to such an extent that they become illegible the logo design needs to be simplified (Jonck *et al.*, 1994:6).

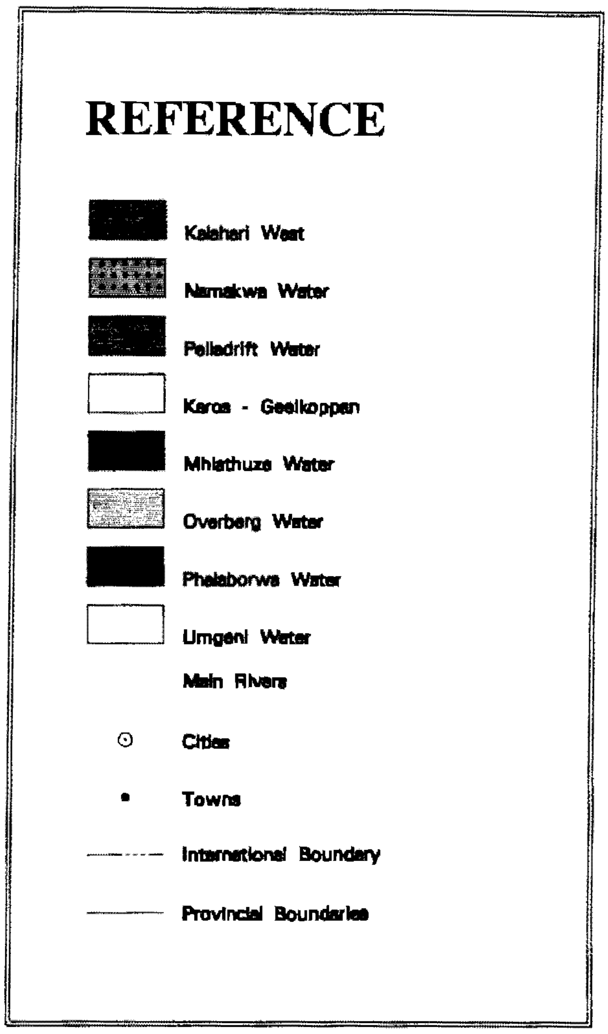


Fig. 4.4. Map reference compiled according to the guidelines given in the departmental cartographic standards.
(Source: DWAF Map Archives.)

4.3.4.4 COORDINATES

Geographical coordinates, the standard states, should be indicated on the map frame (See Figure 4.5) and not as crosses within the mapped area as is shown in Figures 2.1 and 2.2 (Jonck *et al.*, 1994:10).

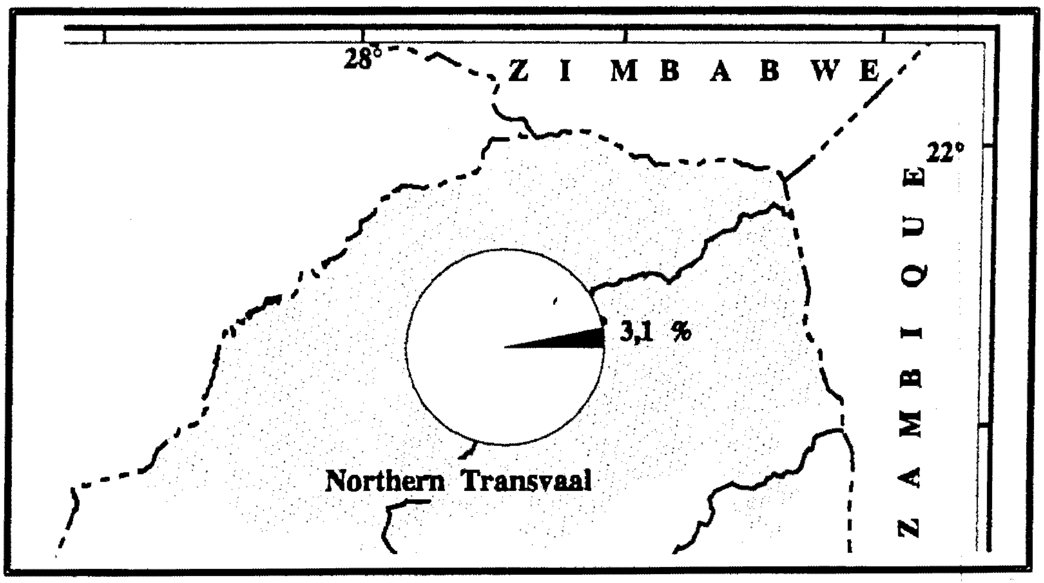


Fig. 4.5. Method by which the cartographic standards specify that geographical coordinates should be indicated on maps.
(Source: DWAF Map Archives.)

4.3.4.5 SCALE LINES AND DIAGRAMS

The DWAF standard specifies that both a scale line or scale diagram and a scale numeral, indicating a proportional scale, should be part of all maps and that the scale line numerals should have intervals of five. Subsections should be indicated on the scale line or diagram. An example of the DWAF recommendation in this regard is depicted in Figure 4.6.

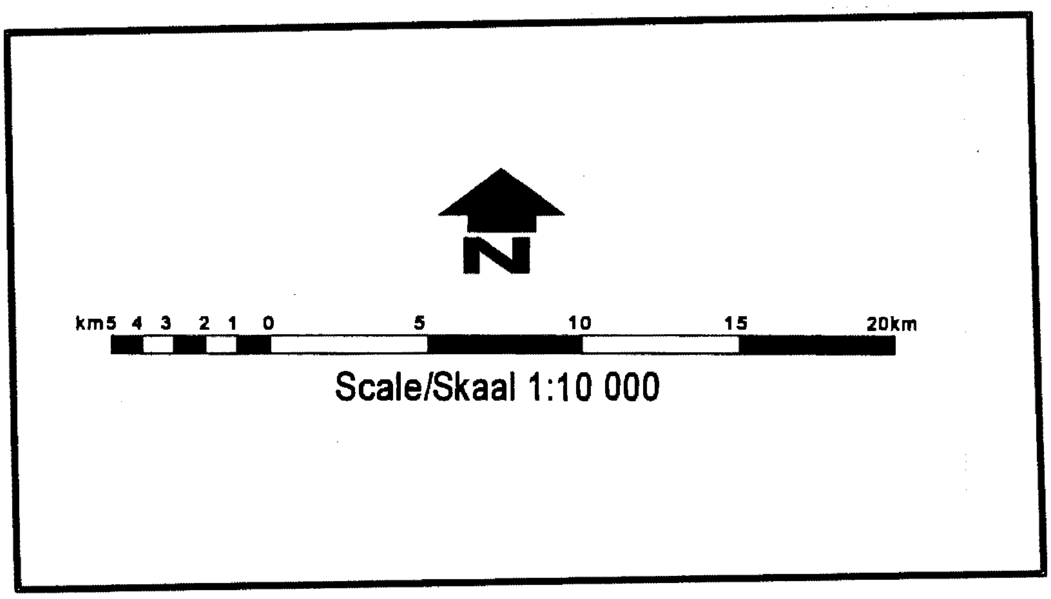


Fig. 4.6. Specifications for the construction of scale lines.
(Source: Jonck *et al.*, 1994:10.)

4.3.4.6 NORTH ARROW

The standard states that the size of north arrows, like those of logos will depend on the map size. The north arrow should however be placed above the scale bar, as is indicated in Figure 4.6 and both should be positioned in the main map area in a position where no other information is shown.

4.3.4.7 ADDITIONAL INFORMATION

The standard specifies that the following information should also appear on maps:

- Publishing date;
- Name of map compiler;
- Reference number;
- Projection and projection parameters;
- Information sources; and
- Map number or reference number.

4.3.5 MAP COMPOSITION

Due to the problems experienced with poor map layout by the various operators and other organisations which compile digital maps for, or on behalf of, the department (see Figures 2.1, 2.2 and 2.3), it was decided to include a list of general rules for map layout. It needs to be kept in mind that these guidelines were intended for GIS users who are cartographically illiterate and who are not aware of even the most basic map users requirements.

4.3.5.1 MAP TEMPLATES

Templates for A4, A3, A1 and A0-sized maps were generated. For both A4 and A3-sized maps a portrait and landscape template was made.

4.3.5.2 MAP TITLE

Positioning of the map title was guided by the map template. General rules regarding typographical considerations are given. These include for example that map titles should always be in heavier type than other text on a map and that map title length determines actual letter size (Jonck *et al.*, 1994:4).

4.3.5.3 MAP PLACEMENT

In the standard, particular mention is made of north/south orientation. It is clearly stated that the actual orientation of a mapped area will depend on the shape of the area. Orientation should however preferably be such that north will be at the top of a page. If this is not possible, the mapped area should be rotated, but then it is essential to indicate north with a north arrow (Jonck *et al.*, 1994:4).

4.3.5.4 MAP EXTENT

It is specifically mentioned that surrounding information should be extended to the neat line of a map (Jonck *et al.*, 1994:5). This was specified to prevent the kind of problem experienced, for example, with Figures 2.1 and 2.2.

4.3.5.5 INDEX MAPS

The standard clearly states that index maps should be clearly separated from main maps, that labelling should be sparse but sufficient to orientate the map user and that the index map must have its own north arrow and scale bar (Jonck *et al.*, 1994:8).

4.3.5.6 INSET MAPS

A layout of a map with inset maps is schematically shown in Figure 4.7 below. This kind of map layout is seldom used at the department for A4 or A3-sized maps more commonly associated with A1 and A0-sized maps.

The standard states that inset maps must have the same orientation as the main map and that each inset map must have a north arrow, scale line and map title (Jonck *et al.*, 1994:8). It is also stated that the key or map reference to such maps should be included in the map reference of the main map and that there should be an indication of the location of the inset maps with respect to the main map (Jonck *et al.*, 1994:8).

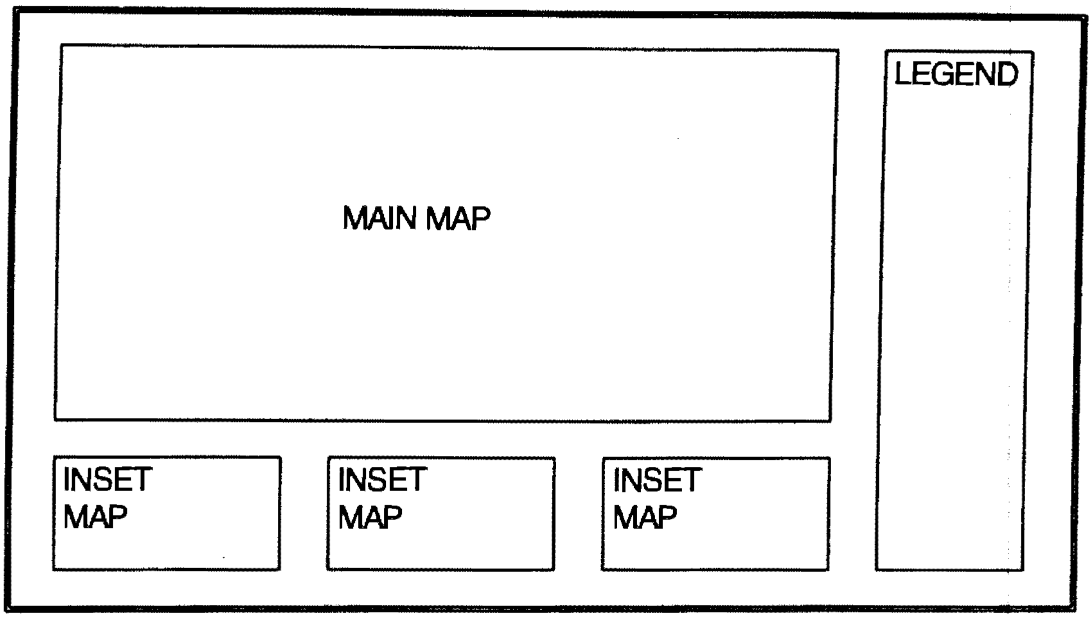


Fig. 4.7. Schematic layout of a map with inset maps.
(Source: Jonck *et al.*, 1994:8.)

4.3.5.7 TYPOGRAPHIC DESIGN

As a general rule, no text should overlap with other information.

a) Text size

It is stated that text size will depend on the size of the object which is being mapped and that minimum text size is 1.3 millimetre (Jonck *et al.*, 1994:13).

b) Text font, colour and case

The following is specified:

i) Water features

All text pertaining to water features should be in cyan and in cursive. Upper and lower case is used in all instances except for ocean names which are written in upper case only (Jonck *et al.*, 1994:13).

ii) Towns

All town names should be printed in black. Important towns are indicated with capital letters only and other towns by the use of upper and lower case lettering (Jonck *et al.*, 1994:13).

iii) Mountain ranges are indicated in capitals using only brown lettering.

It is clearly stated that the same font can be used throughout with changes only in the use of cursive (italic), upper and lower case and colour as indicated above (Jonck *et al.*, 1994:13).

c) Text placement

Names of features with a fixed location should be positioned first. A town's location is, for example, fixed and its name should be positioned before that of a mountain which can then be positioned to suit the available space. In general, lettering should be written across the map from left to right, if not possible the guidelines in Figure 4.8. below should be followed.

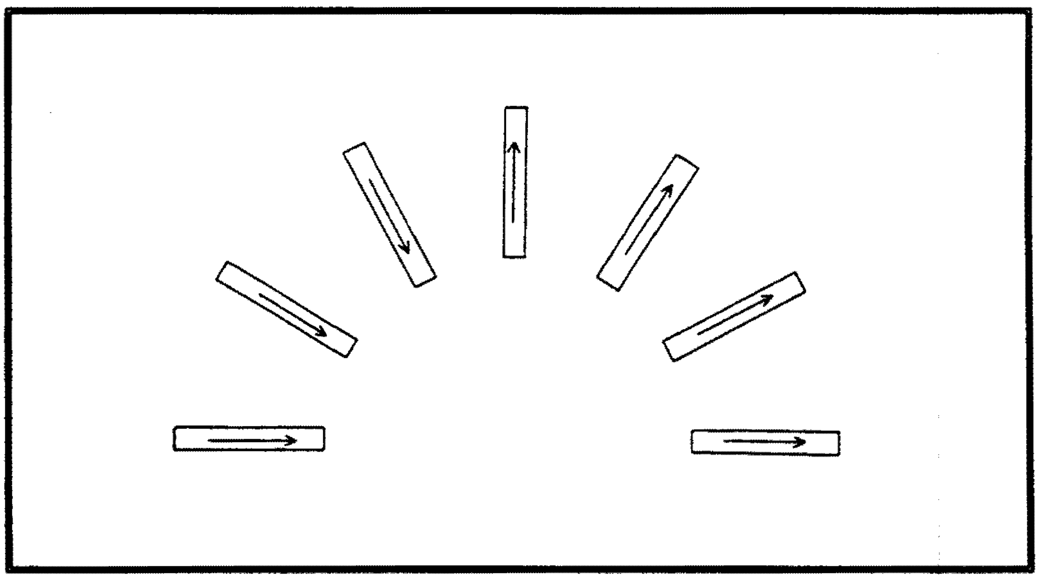


Fig. 4.8. General guidelines for positioning of text.
(Source: Jonck *et al.*, 1994:12.)

Point or fixed features

The guidelines indicated in Figure. 4.9 should be followed.

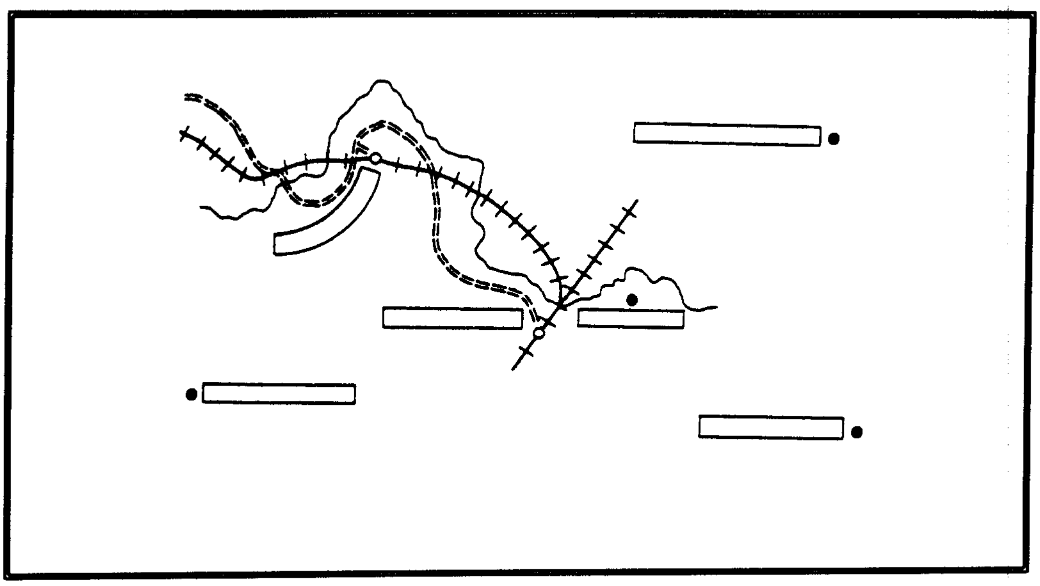


Fig. 4.9. Guidelines for name placement of point features. (Source: Jonck *et al.*, 1994:14.)

Linear Features

The guidelines in Figure 4.10 should be followed.

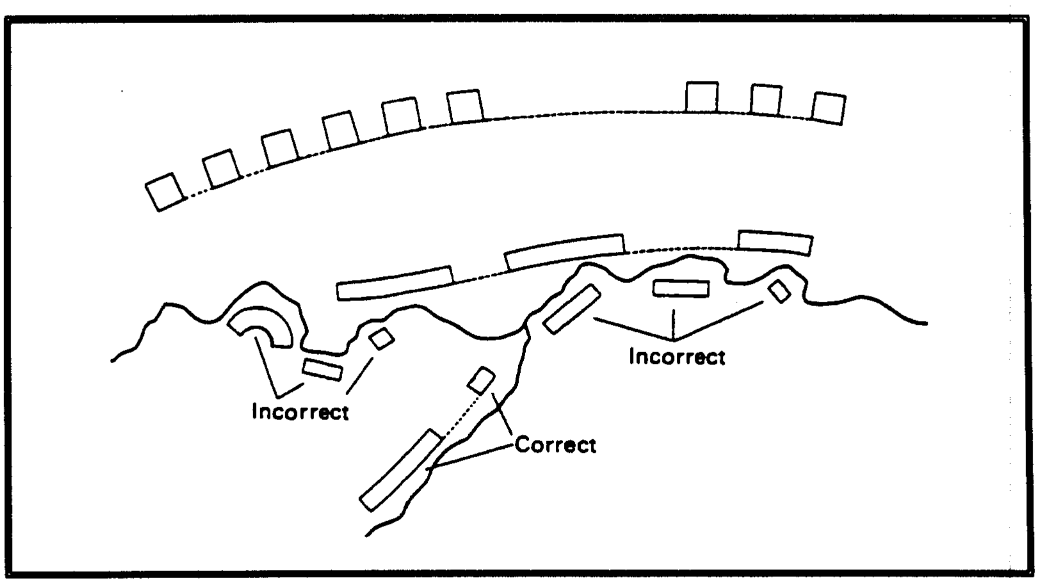


Fig. 4.10. Guidelines for the placement of text for linear features. (Source: Jonck *et al.*, 1994:15.)

Areal features

Text indicating areal features should preferably be placed within the area in question. If this is not possible, the area should be treated as a point feature and the same rules as those indicated in Figure 4.11 will apply. If an area is long and irregular in shape, text may follow the general direction of the feature. General guidelines are indicated in Figure 4.11.

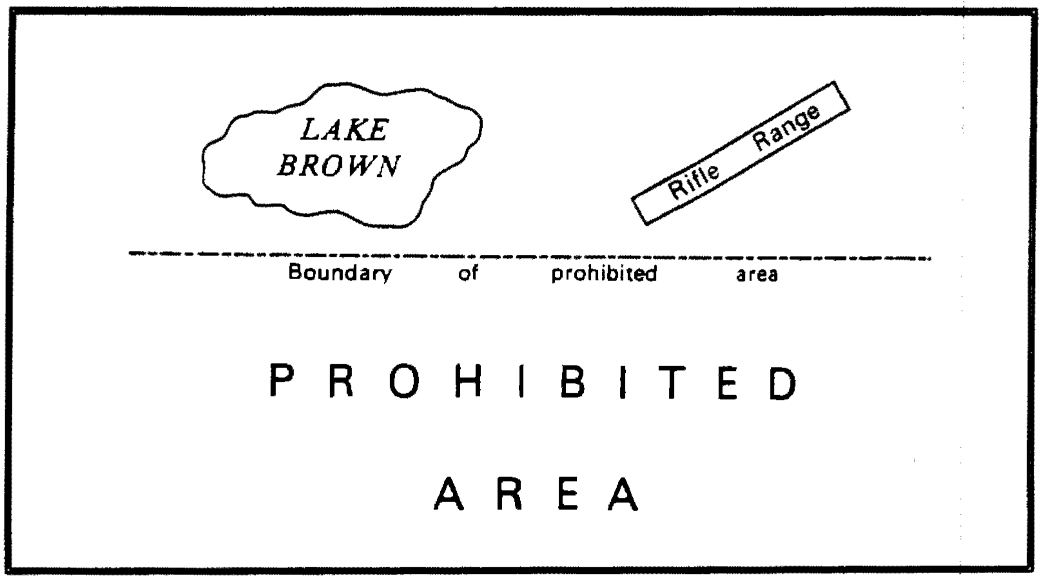


Fig. 4.11. Guidelines for the placement of text pertaining to areal features on a map.
(Source: Jonck *et al.*, 1994:16.)

4.3.5.8 MAP PROJECTIONS

The guidelines for map projections contained in the DWAF presentation standards are the following:

a) If the area being mapped covers less than two degrees of longitude the Gauss Conform projection is to be used regardless of scale (Jonck *et al.*, 1994:20).

b) If the area being mapped covers more than two degrees and less than six degrees of longitude the Lambert Conform Conic projection is to be used. This applies to all mapping scales. The standard meridian is then that line of longitude which lies at the centre of the area being mapped (Jonck *et al.*, 1994:20).

c) If the area being mapped covers more than six degrees of longitude the Albers Equal Area Conic projection with two standard parallels should be used. The standard meridian is then that line of longitude which lies at the centre of the area being mapped (Jonck *et al.*, 1994:20). The standard gives no further guidelines or indication of how the standard parallels are to be selected.

d) If the whole of South Africa is mapped the following projection parameters will apply:

Central meridian :	24^0 East.
Standard parallels:	19^0 and 27^0 South.

4.4 IMPLEMENTATION OF STANDARDS

The draft document compiled by Jonck *et al.* in 1994 is used by map making operators as a users guide or manual. It contains explanations of the general rules and guidelines discussed above as well as hard copy examples of all digital symbols.

All 'symbol set' files were structured as 'Markerset', 'Lineset', 'Shadeset' and 'Textset' files. Each file was divided into two units. In the first unit, symbol numbers range from 001 to 499, these symbols being all scale dependent. The first two digits indicate the feature, 08, for example, indicates a marsh, swamp or vlei, (See Figure 4.1) and the third digit represents the scale range number (See Table 4.3). Symbol numbers 500 to 999 in the same file relate to symbols that are not scale dependent and all three digits refer to a specific unique symbol.

5

DATA COLLECTION, FINDINGS AND ANALYSIS

The cartographic standards adopted by the department, were implemented in the data management section during July 1994 and thereafter in the data processing section during May 1995. Although maps are made by consultants on behalf of the department as well as at departmental regional offices, only maps that were actually compiled at head office, where the implementation has been limited, could be considered for evaluation.

The purpose of the data collection, was to evaluate how and to what degree the adoption of these standards improved graphic communication to decision makers. Maps made while using these standards were the unit of analysis. These maps were evaluated in terms of the cartographic design principles identified by Robinson *et al.* (1994), Wood (1992), Dent (1990) and Freeman (1991) as being of importance in the communication of graphic information (See Section 2).

The success of such standards depend not only on the standards or the maps that are produced according to these standards, but also on their implementation. With the hitherto limited implementation, implementation problems, or instances where the standards have not been applied fully, also played a role. Maps in the sample were also evaluated in terms of the standards to identify implementation-related problems.

5.1 DATA COLLECTION

5.1.1 POPULATION OF THE DATA

5.1.1.1 TOTAL NUMBER OF GIS MAPS GENERATED FROM 1 JULY 1992 TO 31 JUNE 1995.

Although GIS was implemented in the department in 1987, and a colour electrostatic plotter acquired in 1989, a record of maps which were produced with GIS technology has only been kept since 1992. The number of maps made in the years that followed are represented in Figure 5.1.

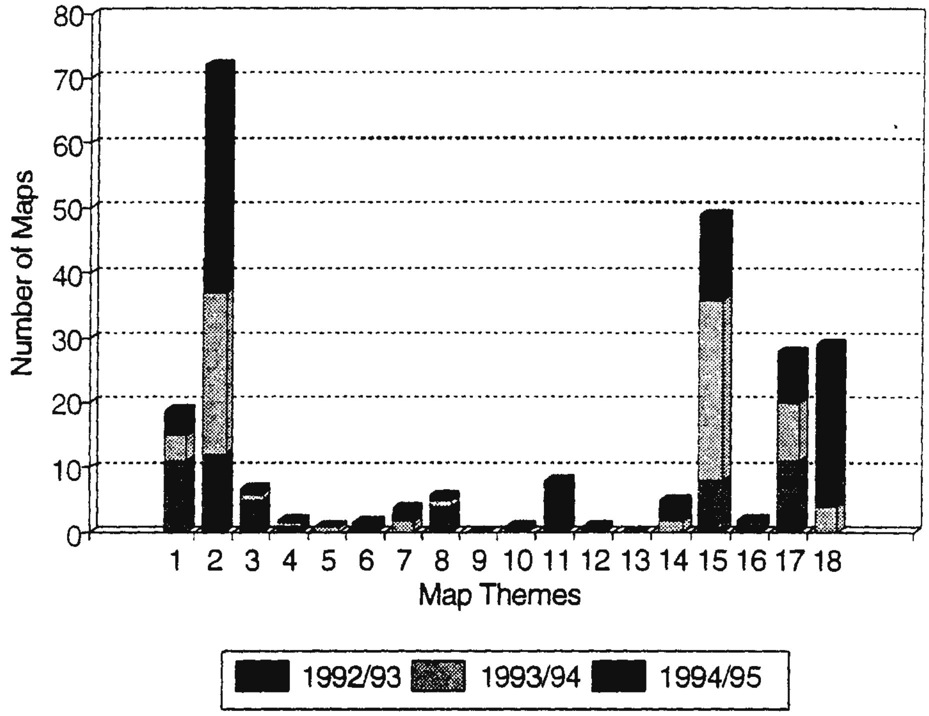


Fig. 5.1. Number of hard copy maps produced by GIS technology at the DWAF from 1 July 1992 to 31 June 1995.
(Source; Compiled by the author from records which are kept by the Projects Office, DWAF.)

Map themes represented in columns:

1. Geohydrology
2. Hydrology
3. Meteorology
4. Geomorphology
5. Geology
6. Pedology
7. Vegetation
8. Distribution Network
9. Structures
10. Agriculture
11. Forestry
12. Conservation
13. Industrial
14. Recreation
15. Administrative
16. Cadastral
17. Social Statistical
18. Water Management

The number of GIS-generated maps virtually doubled in the three years that records were kept. The 55 thematic map types produced in 1992/93 increased to 103 by 1994/95. The themes of these maps varied greatly from year to year and no maps representing the industrial or structures themes were made at head office during this time. On the other hand, no water management maps were made in 1992/93 but 25 maps on this theme were made in 1994/95.

It needs to be kept in mind that the Government of National Unity, which has been in power in South Africa since 1994, have brought about many policy changes within government. Decision makers needed to make water resource related decisions which differ from those made previously. This is reflected in the themes for which thematic maps were made. In 1993/94, great emphasis was placed on reviewing provincial and other administrative boundaries. During this period the department made 28 types of administrative maps in comparison with only 8 which were produced in the previous year. The need to take hydrological aspects into account when deciding on these boundaries have also been reflected in an increase in hydrological maps. Maps on this theme increased from 12 in 1992/1993 to 25 in 1993/1994. During the 1994/95 period, great emphasis was placed on planning to provide all South African citizens with potable water and sanitation. This is again reflected in the increase of maps made for the water management theme from 4 in 1993/94 to 25 in 1994/95.

Thematic maps made at the department often represent a single feature or a very limited selection of features for a specific theme. Under the hydrology map theme, for example, maps representing catchment boundaries, sediment yield, run-off etc. were made. (See Appendix A for map features identified for each map theme in 1992).

5.1.1.2 THEMATIC GIS-GENERATED MAPS MADE AFTER THE IMPLEMENTATION OF CARTOGRAPHIC STANDARDS

Due to the limited implementation of the standards, not all maps produced from 1 July 1994 to 31 June 1995 were in fact made using the cartographic standards. The map themes and associated number of maps made with these standards, are listed below.

Map theme	Number of maps
Geohydrology	2*
Geology	1
Hydrology	4
Meteorology	1
Geology	1
Vegetation	2
Distribution Network	1
Recreation	2
Administrative	4
Social Statistical	8
Water Management	22
TOTAL	48

* The geohydrology maps mentioned here are A3 and A4-sized maps and are not part of the National Geohydrology map series. This series has not been included in this report. The standards considered here are applicable to a wider range of map themes.

The general trends in terms of variation in map themes which were discussed in conjunction with Figure 5.1 are also applicable here. Most maps, namely 22, were made on the water management theme. The number is however deceptive in that 18 of these maps indicate the location of individual water boards only with no other detail.

All maps made at the department after the implementation of the standards were coloured maps. No evaluation of monochrome maps was therefore possible.

5.1.2 SAMPLING

The characteristics of the population discussed in 5.1.1 eliminated the possibility of a statistically based sampling method. To compare maps made prior to the implementation of these standards with maps made after the implementation of the standards, all maps made with the standards needed to be considered. These maps had however to be compared with previously made maps on the same sub-theme. This proved to be particularly troublesome in terms of social statistical maps. Only 20 maps for which comparable previously made maps could be located in the DWAF map archives could be identified. The actual map titles are listed in Appendix B. A summary of this list in terms of main map theme only is given below.

Map theme	Number of map pairs
Geohydrology	1
Hydrology	4
Meteorology	1
Geology	1
Vegetation	1
Distribution Network	1
Recreation	1
Administrative	3
Social Statistical	3
Water Management	4
TOTAL	20

5.1.3 EVALUATION METHODOLOGY

5.1.3.1 CARTOGRAPHIC DESIGN PRINCIPLES

Each map in the sample listed, needed to be evaluated in terms of the five recognised cartographic design principles (See 3.6) to enable the author to validate the minor propositions discussed in Section 2.4.

For the purpose of such an evaluation an evaluation sheet was compiled (See Appendix C). This evaluation sheet was used to evaluate each map listed in Appendix B individually. The data collected in this way was tabulated on a computer spreadsheet. The data on standardised maps was then compared with data collected on non-standardised maps.

Where applicable, frequency distribution histograms have been compiled. All meaningful statistical analysis is based on normal distributions. Due to the limited range of values, (in most instances four or five values only), the statistically accepted methods of normalising skewed distributions were inappropriate. Meaningful comparison between samples is also dependent on comparing samples of the same size. The number of map symbols contained in standardised and non-standardised data sets differed greatly. The only basis on which a comparison could be made was by way of percentages.

5.1.3.2 EVALUATION OF IMPLEMENTATION

To be able to evaluate the Major Proposition given in Section 2.4, the findings obtained by means of the methods outlined above needed to be compared with the standards as contained in Jonck *et al.* (1994).

5.1.3.3 USER PERCEPTIONS

The definition cited for cartography in Section 3.2.1 which states that it could be regarded as an art, science and skill may well also apply to the profession of architecture and graphic art. The further qualification, that cartography graphically communicates information distinguishes it from architecture but not from graphic art.

Occupants of buildings, and viewers of organisational logos or letterheads (as an example of graphic art) do, if asked about their feelings regarding the design of a building, logo or letterhead do, provided that all other things are equal, only comment in the sense that they either like it or not. This also applies to cartography. When confronted by two maps of the same theme users either respond by saying they "like" this one better than that one. These views are entirely subjective and not in any way based on any knowledge of what constitutes good design principles. The aesthetical appeal of maps vary between users and is dependent on the nature and level of training of users. User perceptions, were for this reason, not considered.

5.2 FINDINGS AND ANALYSIS

5.2.1 CLARITY AND LEGIBILITY

5.2.1.1 DIFFERENTIATION BETWEEN MAP SYMBOLS

The map symbols discussed here are only those symbols which are related to the theme of the map. Symbols which have been used for base map information are discussed separately under Hierarchical Organisation. (See 5.2.3). Map symbols that depict or are related to the map theme need to differ from each other by two graphic elements to be clear and legible (Robinson *et al.*, 1984:147). Examples of how this can be achieved are shown in Figure 5.2.

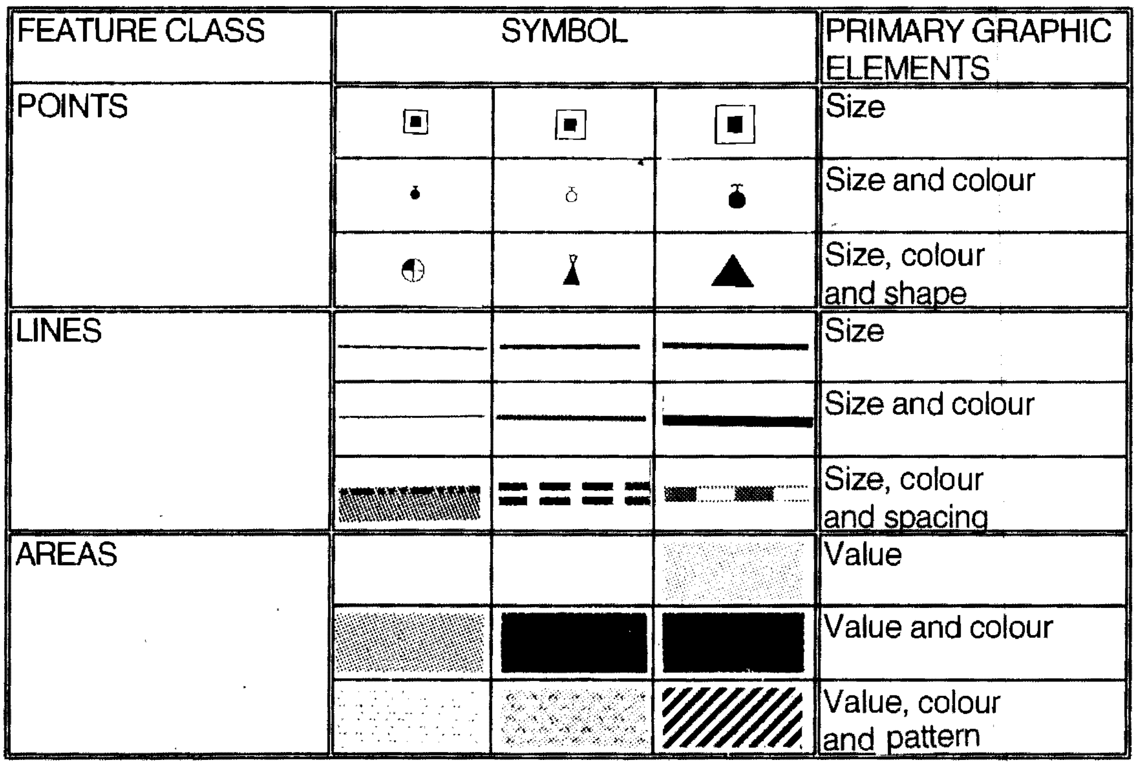


Fig. 5.2. Examples of how point, line and areal symbols can be differentiated from each other by using primary graphic elements.
(Source: Compiled by the author from map symbols contained in Jonck *et al.*, 1994.)

In Figure 5.2, point, line and areal symbols which are differentiated from each other in terms of one, two and three primary graphic elements are shown. The graphic element of pattern mentioned above, refers to the use of the graphic elements of shape, spacing and orientation when applied collectively to the use of markings to distinguish between areal symbols.

The frequency of use of different numbers of graphic elements to distinguish between thematic map symbols is summarised in the histogram in Figure 5.3.

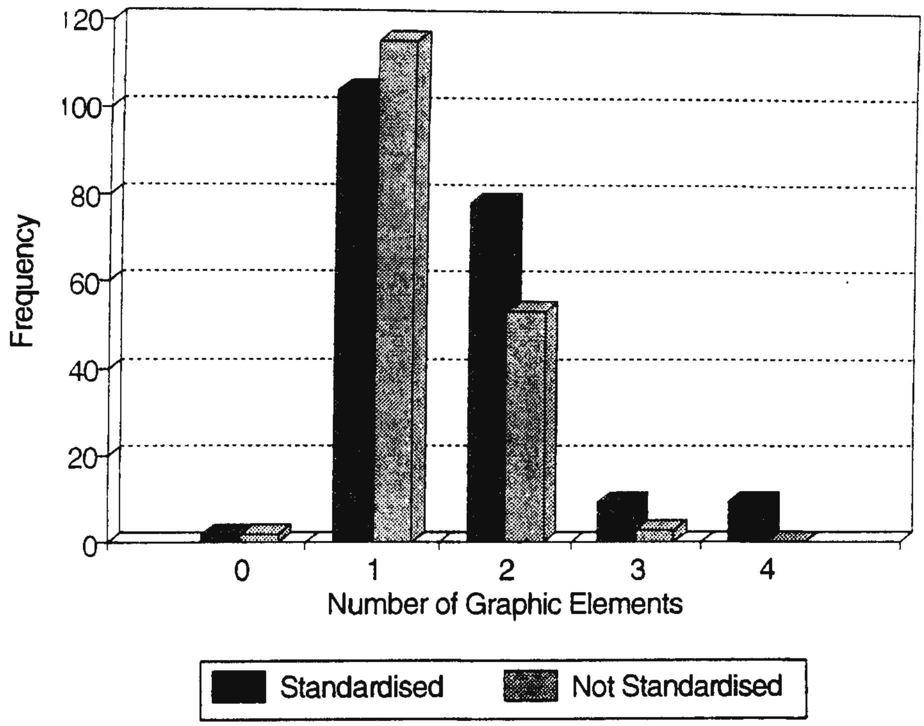


Fig. 5.3. Frequency distribution of the number of graphic elements used to distinguish between thematic map symbols. (Source: Compiled by the author.)

The standardised sample consisted of 202 symbols and the non-standardised sample of 173 symbols. To facilitate comparison, the percentage of symbols that are differentiated by means of differing numbers of graphic elements have been listed below.

Number of graphic elements	Standardised	Not standardised
No graphic elements	1%	1%
One graphic element	52%	67%
Two graphic elements	38%	31%
Three graphic elements	4,5%	1%
Four graphic elements	4.5%	0%

The percentage of thematic map symbols which differed from each other by two graphic elements had thus increased by 7%. Over 50% of standardised maps however differed only in terms of one graphic element.

EVALUATION IN TERMS OF DEPARTMENTAL STANDARDS

A comparison of the percentages of the number of graphic elements by which the 194 map symbols contained in Jonck *et al.* differed from each other is given below.

Number of graphic elements	Percentage of symbols
No graphic elements	11
One graphic element	50.5%
Two graphic elements	33%
Three graphic elements	5%
Four graphic elements	0,5%

A graphic comparison between the sample and the total population of standardised map symbols in terms of the number of graphic elements used to differentiate between individual map symbols is given in Figure 5.4.

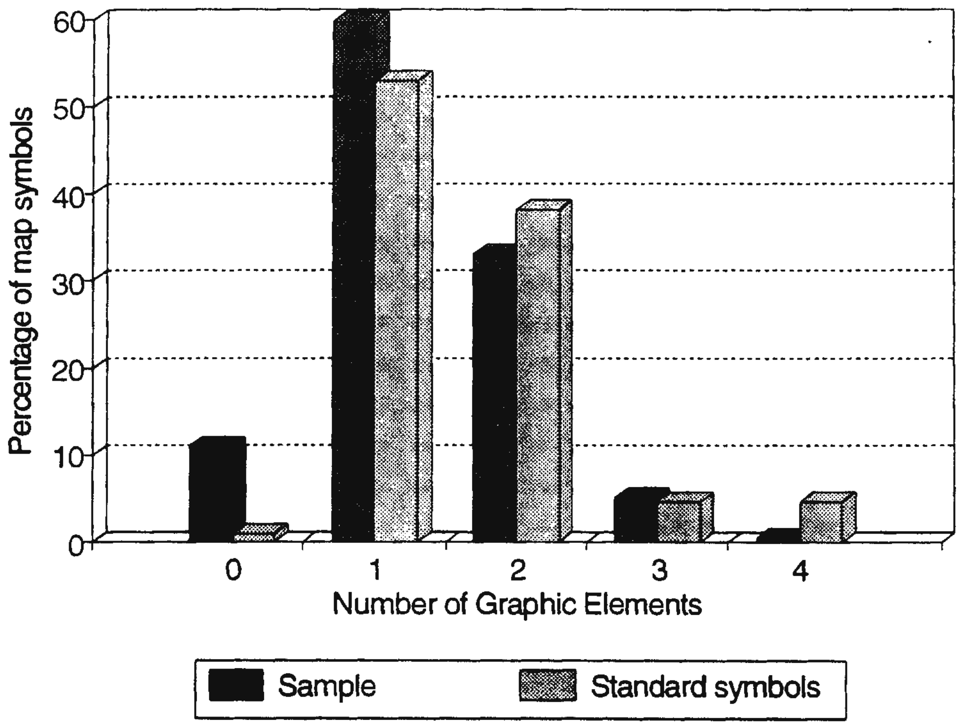


Fig. 5.4. Frequency distribution of the number of graphic elements by which map symbols in the sample and standardised map symbols differed from each other. (Source: Compiled by the author.)

The number of graphic elements used to differentiate between symbols on standardised maps closely reflected the number of graphic elements used to differentiate between symbols which were used in the standards. This indicated that the specified symbols had been correctly used.

5.2.1.2 SYMBOL SIZE

All map symbols in the sample and in Jonck *et al.* (1994) complied with the minimum size determined by Robinson *et al.* (1984:142) and were visible.

5.2.1.3 DELINEATION

Good delineation of map symbols play an important role in the clarity and legibility of a map. This aspect has not been considered as this is, in the case of digital mapping, a function of the output device, the capabilities of which do not fall within the scope of this report.

5.2.1.4 MAP REFERENCE OR KEY

Figure 5.5 depicts the frequency of use of variables that influence the clarity and legibility of map references on both standardised and non-standardised maps. The variables which are represented in Columns 1 to 4 are listed below the figure.

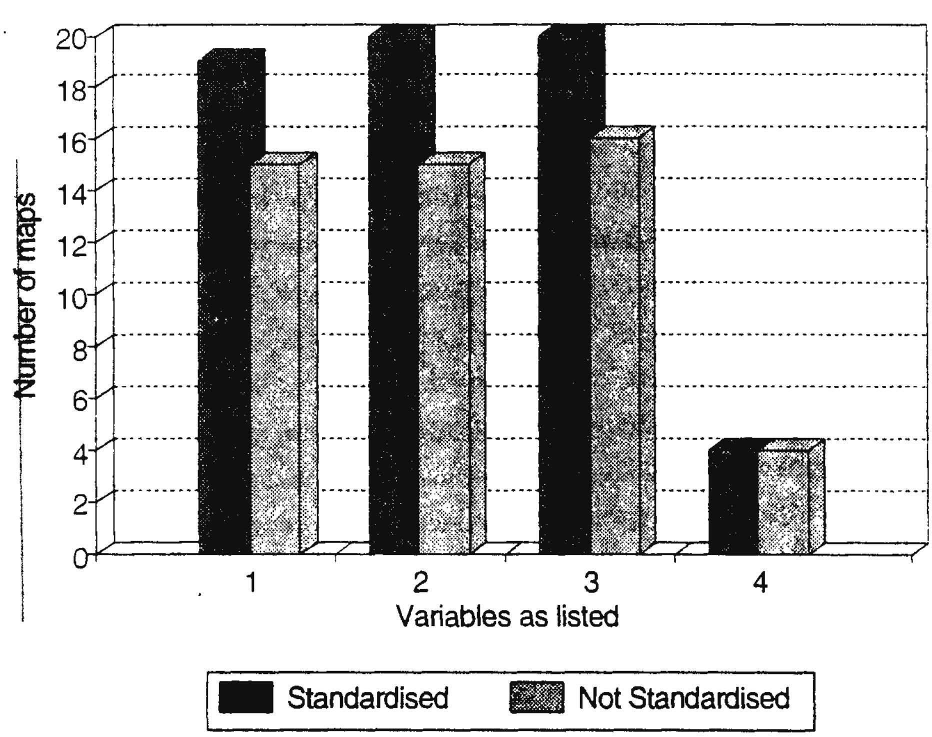


Fig. 5.5. Comparison of clarity and legibility of map references of standardised and non-standardised maps.
(Source: Compiled by the author.)

Column 1: Number of maps where the map symbols on the map reference are of the same size as those on the actual map (Robinson *et al.*, 1984:159).

Column 2: The number of maps where map symbols depicting quantities have been arranged in an order from either high to low or low to high (Robinson *et al.*, 1984:159).

Column 3: The number of map references where map symbols have been grouped according to feature class, eg., areas, lines and points (Robinson *et al.*, 1984:159).

Column 4: The number of map references which contained a full summary of all map symbols which are not self explanatory (Robinson *et al.*, 1984:159).

As far as representing map symbols in the reference, in the same size as that in which they are depicted on the map is concerned, standardisation effected a 25% improvement. Only one of the standardised maps in the sample did not comply with this requirement.

On all standardised maps contained in the sample, map symbols were grouped from either high to low or vica versa and all were grouped according to feature class. This represented an improvement of 25% and 20% respectively for the variables in Columns 2 and 3.

There had however not been any improvement in the completeness of the map references in terms of symbols that were self-explanatory. Only 20% of both standardised and non-standardised map references complied with this requirement.

Two non-standardised maps had no map reference at all. The overall clarity and legibility of standardised maps had collectively improved by 17.5% in terms of the variables that were used for this evaluation.

EVALUATION IN TERMS OF COMPLIANCE WITH THE DEPARTMENTAL STANDARDS.

All four criteria used for the above evaluation are mentioned in the standards. Had implementation therefore been entirely successful all standardised maps would have complied fully with these criteria.

5.2.1.3 TEXT

Text placement had only been evaluated in terms of the general rules outlined by Imhof (1961) and summarised by Freeman in 1991 (Freeman, 1991:447) (See 3.8). The findings of this evaluation are summarised in Figure 5.6. The variables represented by Columns 1 to 6 have been listed below the figure.

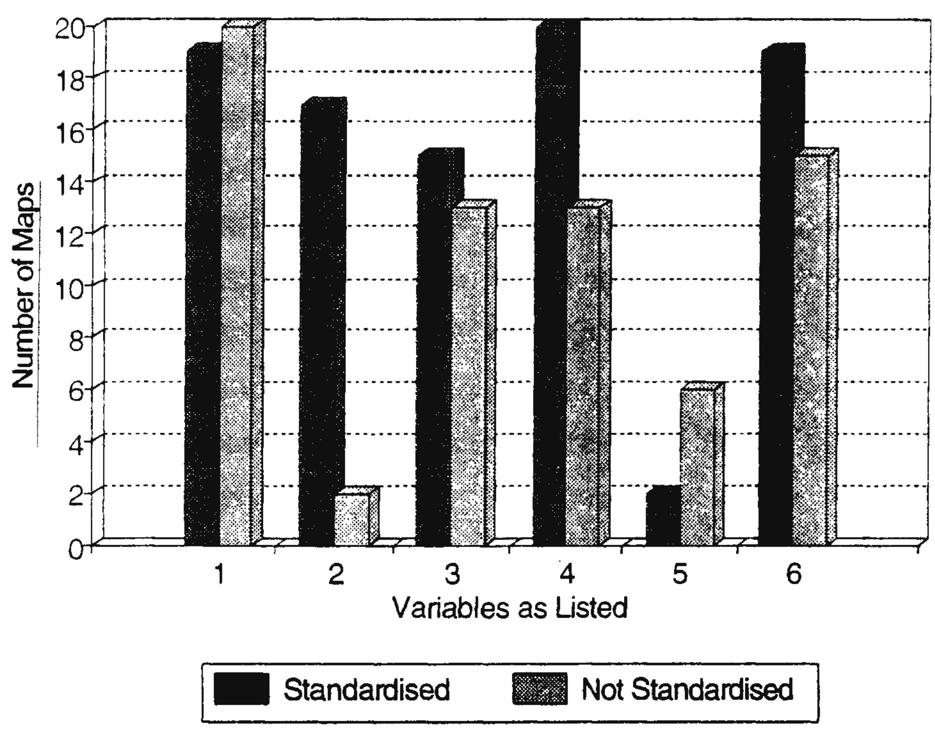


Fig. 5.6. Comparison of clarity and legibility of text on standardised and non-standardised maps.
(Source: Compiled by the author.)

Column 1: Text overlap (Freeman, 1991:447).
Column 2: Feature overlap (Freeman, 1991:447).
Column 3: Whether the text did in fact follow the shape of the feature it pertained to (Freeman, 1991:447).
Column 4: Whether the text was generally in a left to right direction.
Column 5: The unambiguous association with the feature it identifies (Freeman, 1991:447).
Column 6: Text appears natural and not contrived (Freeman, 1991:447).

One map, in the sample of standardised maps had text overlapping other text. This was not evident on any of the non-standardised maps. One non-standardised map had no text on the map itself. There had however been an 85% improvement in cases concerning text overlapping underlying features when standardisation was implemented. Also text followed the shape of features more closely such as rivers. There had been a 15% improvement in this regard. The general notion of having text written in a left to right direction had improved from 65% to 100%. There had been a 20% improvement in terms of the association of text with the relevant feature as well as in the natural appearance of text. There had been an overall improvement of 33,75% in the clarity and legibility of text on maps.

COMPLIANCE WITH DEPARTMENTAL STANDARDS

Here again all variables used for the above evaluation were incorporated in the departmental cartographic standards (See 4.3.5.7). Had the implementation been fully successful, all standardised maps would have complied with these requirements.

5.2.1.6 ADDITIONAL MAP INFORMATION

A list of all additional map information which actually appeared on maps produced by the department was made. These included the following:

- map title (Column 1);
- scale diagram or proportional scale (Column 2);
- north arrow (Column 3);
- logo (Column 4);
- date (Column 5);
- source of data (Column 6);
- name of map compiler (Column 7);
- map reference number (Column 8);
- figure number (Column 9); and
- projection name and parameters (Column 10).

The number of maps in the sample that actually contained this information was then determined and is represented in the histogram in Figure 5.7.

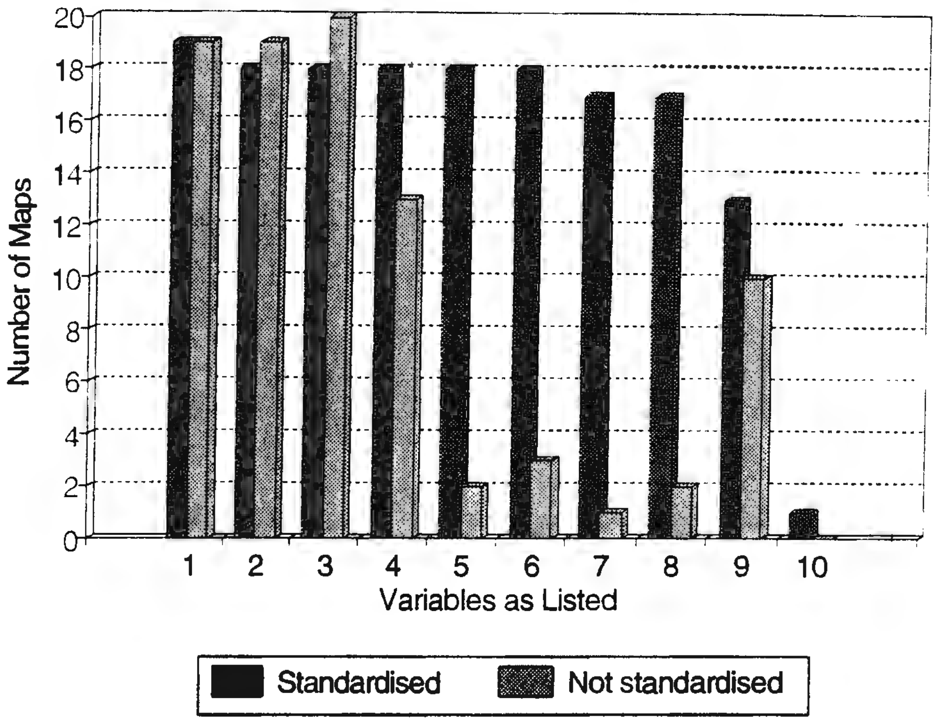


Fig. 5.7. Frequency of use of additional map elements.
(Source: Compiled by the author.)

Standardised maps had, overall, 35% more additional information items than non-standardised maps.

From a comparison between those items listed in the departmental standards (See 4.3.4.7) and those listed in Section 3.6.6, it appears that the only item not appearing on the departmental list is that of copyright.

COMPLIANCE WITH DEPARTMENTAL STANDARDS

Had the implementation been entirely successful all standardised maps would have complied with the variables given. The standards do not include an item on copyright.

5.2.2 FIGURE-GROUND

5.2.2.1 FAMILIARITY OF MAPPED AREA

A map user can be familiarised with the mapped area if there is an indication of the location of the area by using geographical coordinates, by showing the area that surrounds the mapped area or by indicating known towns, roads or rivers. These three variables were used to determine whether the use of the standards had in fact improved in communicating familiarity of a mapped area to decision makers. The results of the evaluation of maps in the sample are summarised in Figure 5.8.

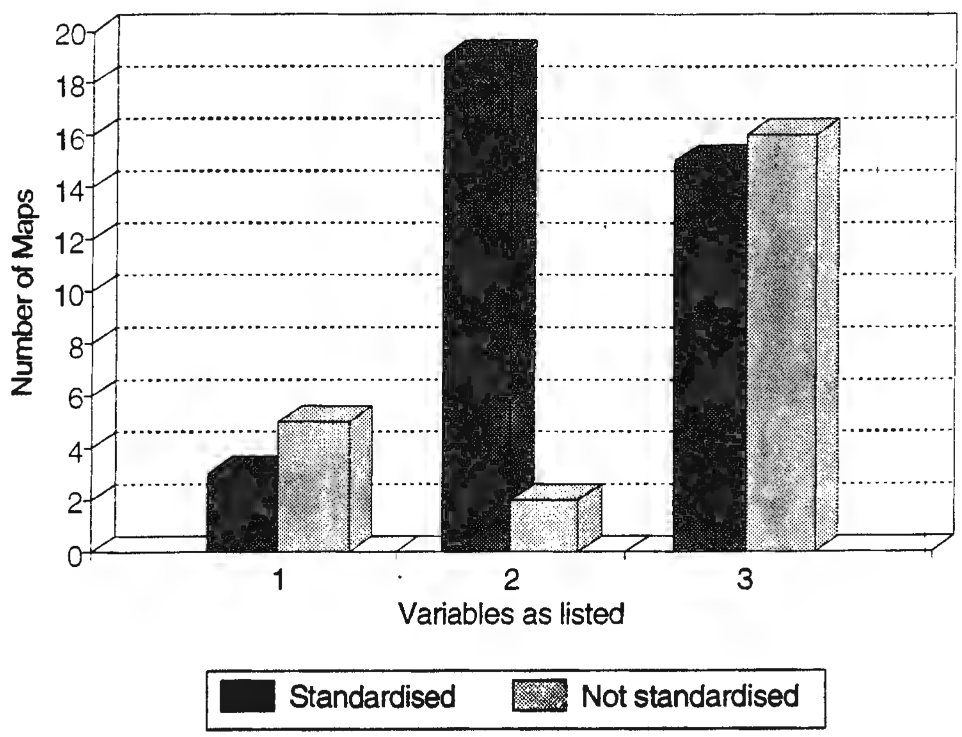


Fig. 5.8. Comparison of variables used to familiarise map users of standardised and non-standardised maps with the mapped area. (Source: Compiled by the author.)

Column 1: Indicates which maps had geographical coordinates on the map border (Robinson et al, 1984:150).

Column 2: Surrounding information.

Column 3: Base map information such as an indication of main roads, rivers and towns.

Despite the method used to familiarise the user with the mapped area there had been an overall improvement of 25% in additional information to facilitate orientation. From the histogram it is clear that the preferred method for standardised maps was that of indicating what areas surround the mapped area or figure (See Column 3).

COMPLIANCE TO DEPARTMENTAL STANDARDS

Apart from an indication of geographical coordinates, no further specification regarding familiarising the map users with the area which is being mapped is contained in the departmental standards. The standards do however clearly state that corner graticule intersections are not acceptable as a way to indicate location, 15% of non-standardised maps did in fact have such marks.

5.2.2.2 DIFFERENTIATION OF MAPPED AREA

The variables which can be used to differentiate between the figure and the ground and which have been discussed in Section 3.6.2 were used to evaluate the maps in the sample. The frequency with which these variables, which are represented in Columns 1 to 7 and which are listed below were used, has been summarised in Figure 5.9.

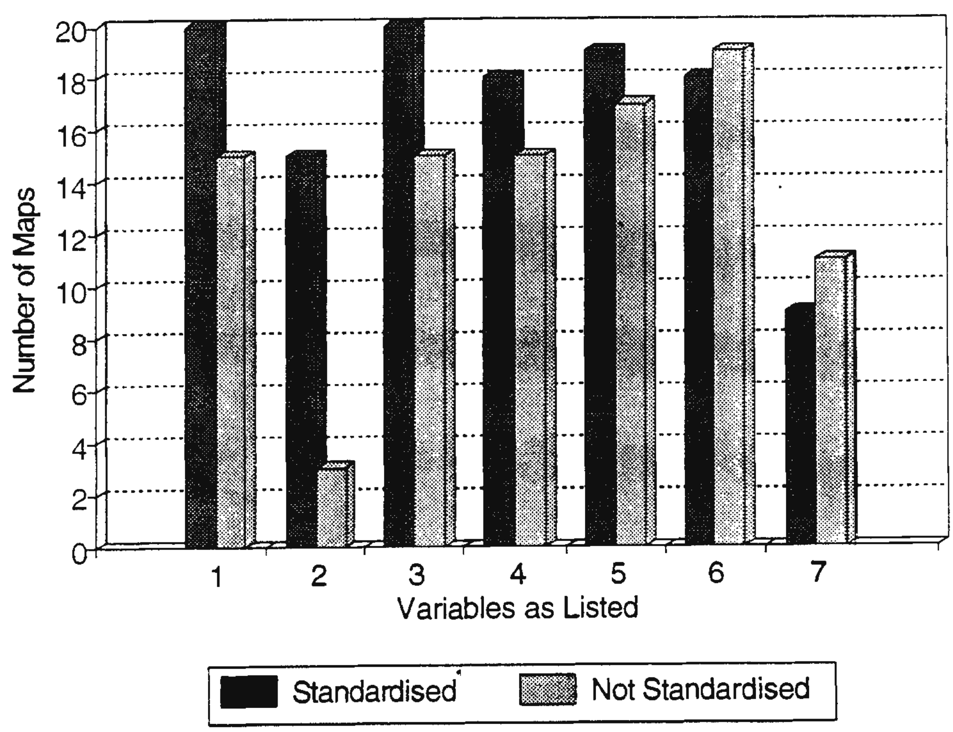


Fig. 5.9. Frequency of use of variables to differentiate between figure and ground. (Source: Compiled by the author.)

Column 1: The number of maps in the sample where a line symbol was used to differentiate between figure and ground (Wood, 1992:438).

Column 2:	Use of an areal symbol to distinguish between figure and ground (Wood, 1992:438 and Dent, 1990:330).
Column 3:	Closed form, (Figure enclosed) (Robinson *et al.*, 1984:150).
Column 4:	Good Contour (Figure well defined) (Robinson *et al.*, 1984:150).
Column 5:	Brightness of mapped area (Robinson *et al.*, 1984:150).
Column 6:	Figure distinguished by articulation (Robinson *et al.*, 1984:150, and Wood 1992:438).
Column 7:	Placement of the mapped area with respect to the optical centre of the mapped area (Wood, 1992:439).

After standardisation there had been an increase of 25% in the use of a line symbol and closed form to improve differentiation and a 15% increase in good contour to further the same aim. Brightness as a means to differentiation had improved by 10%. Articulation of the figure and the placement of the figure in terms of the optical centre as a means to distinguish between figure and ground had decreased by 5% and 10% respectively. An overall improvement of 10% was evident.

EVALUATION IN TERMS OF STANDARDS

This aspect is not specifically addressed in the standards as such. It is however affected by the standards for encoding.

5.2.2.3 MAP PROJECTIONS

Only one of the standardised maps in the sample indicated projection type and parameters. No evaluation in terms of this variable could therefore be made. Requirements for projections and the need to specify them together with the parameters used are addressed in the standards (See 4.3.5.8). Implementation problems therefore exist in this area.

5.2.2.4 FIGURE:GROUND RATIO

The frequency distribution of figure:ground ratios in the sample have been summarised in Figure 5.10. The calculation of the total area that the map occupied included the area occupied by the map title and reference or legend if these had not been visually separated by means of a line. The columns in this figure represent ratio classes which have been listed below this figure.

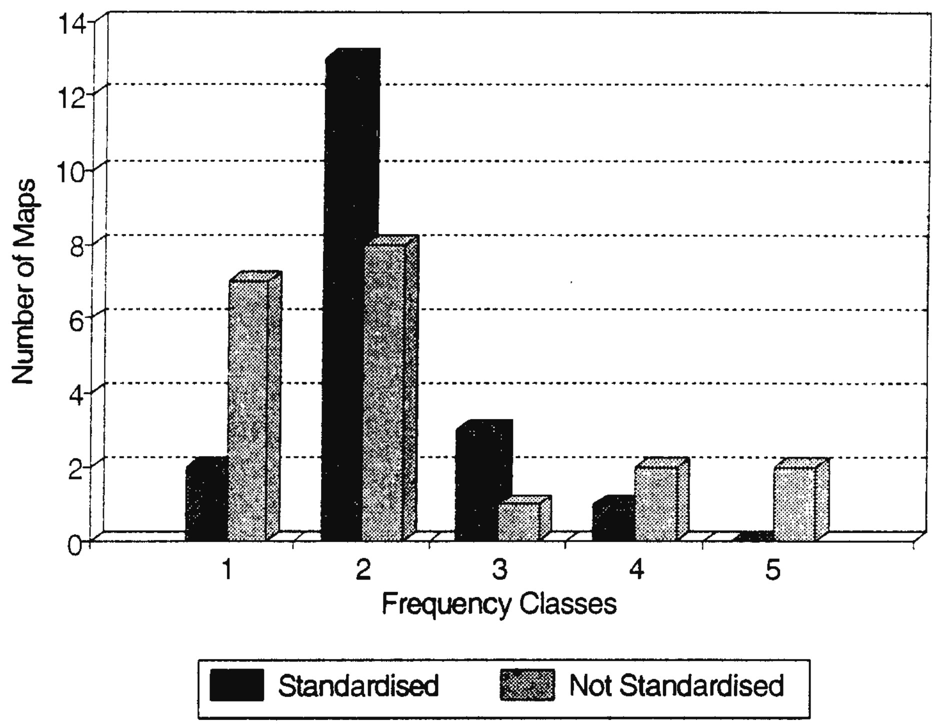


Fig. 5.10. Frequency distribution of figure:ground ratios.
(Source: Compiled by the author.)

Column 1:	1:0.0 to 0.9
Column 2:	1:1.0 to 1.9
Column 3:	1:2.0 to 2.9
Column 4:	1:3.0 to 3.9
Column 5:	1:4.0 to 4.9

Robinson *et al.* specify that the ideal ratio between figure and ground should fall within a range of 1:1.5 to 1:1.4 (Robinson *et al.*, 1984:151). If the ratio is less than 1:1.5 confusion between figure and ground occurs easily (Robinson *et al.*, 1984:151). From the distribution summarised above 30% of all standardised maps fall within this range and 25% of non-standardised maps complied. There had been a 5% improvement in this ratio. To assist with further statistically-based comparison the following was calculated:

	Standardised	Non-standardised
Arithmetic mean	1:2.13	1:1.50
Mean deviation	1:1.04	1:1.94
Standard deviation	1:1.02	1:1.39
Coefficient of variation	47.87%	92.76%
Range	1:0.87 to 1:5.69	1:0.002 to 1:4.625

Neither range falls within the range specified by Robinson *et al.* (1984). The arithmetic mean of neither data set falls within the range either. Both distributions are positively skew. This is confirmed by the large values of the coefficient of variation. All further calculations which are based on the characteristics of normal curves will therefore be irrelevant.

COMPLIANCE WITH THE DEPARTMENTAL STANDARDS

No standard was set for a figure:ground ratio.

5.2.3 HIERARCHICAL ORGANISATION

Maps made at the department are all thematic in nature. Base map symbols which do appear on departmental maps, are of a lower hierarchy than thematic map symbols (Wood, 1992:437). The number of graphic elements with which base map symbols differed from each other have been summarised in Figure 5.11.

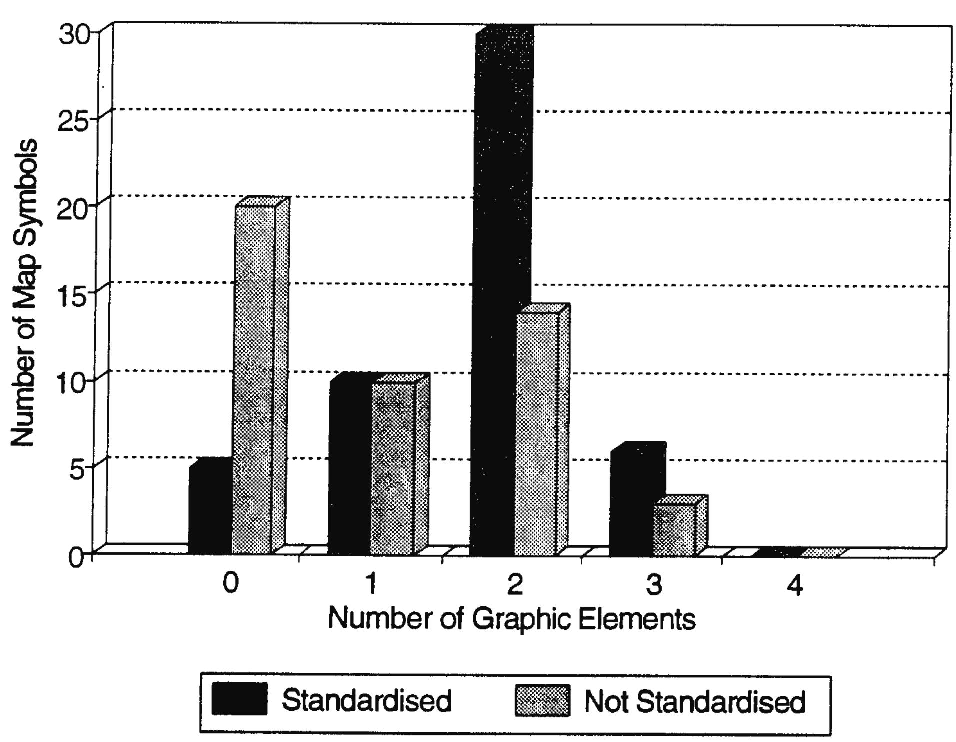


Fig. 5.11. Frequency of the number of graphic elements by which base map symbols differed from each other.
(Source: Compiled by the author.)

The standardised sample consisted of 51 and the non-standardised sample of 47 base map symbols. To facilitate comparison a percentage comparison can be made between the two sample data sets.

Occurrence	Standardised	Non-standardised
No graphic elements	10%	42%
One graphic element	20%	21%
Two graphic elements	59%	30%
Three graphic elements	11%	7%
Four graphic elements	0%	0%

For standardised maps the larger part of the symbols differed from other symbols by two graphic elements. The very large percentage, 42% of symbols of non-standardised maps that are differentiated by no graphic elements is partly due to the fact that most non-standardised maps do not have areal symbols which distinguish the figure and ground. Standardisation effected an overall improvement of 58% in the number of base map symbols that differed from other symbols. Base map symbols are of a lower hierarchical order than thematic map symbols and only need to to be differentiated by one graphic element. Standardisation had not improved this aspect of cartographic design.

The number of graphic elements used to distinguish between base map symbols and the background against which they were mapped has been summarised in Figure 5.12 below.

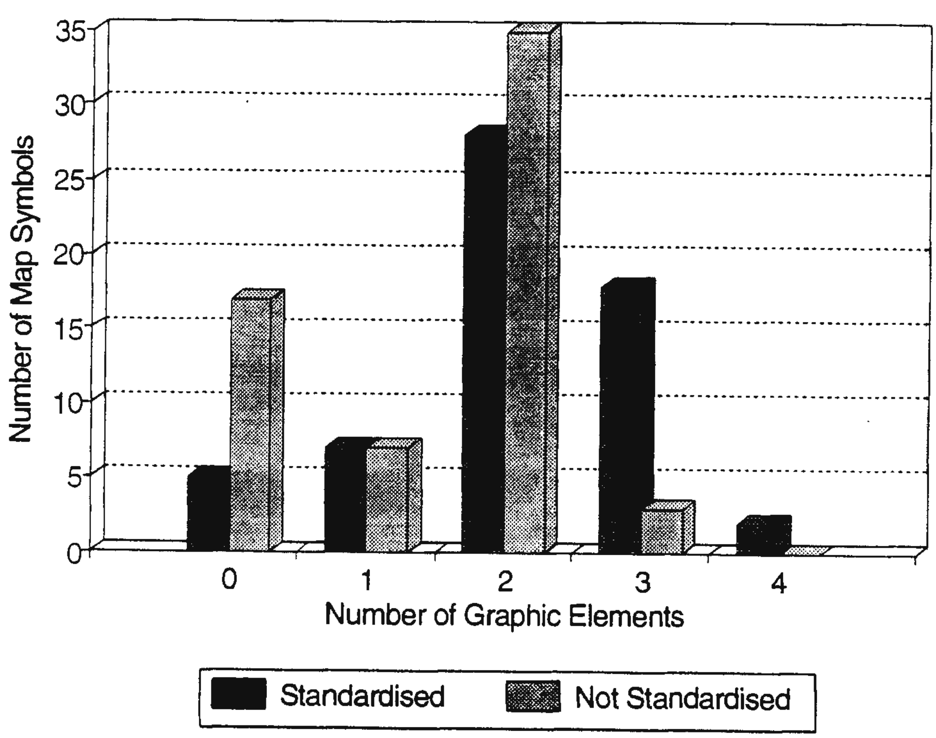


Fig. 5.12. Frequency of use of the number of graphic elements by which base map symbols differed from the background.
(Source: Compiled by the author.)

As in previous cases a percentage comparison between values facilitates the drawing of conclusions as the sample sizes differed by 13 symbols.

Occurrence	Standardised	Non-standardised
No graphic elements	9%	28%
One graphic element	12%	10%
Two graphic elements	46%	57%
Three graphic elements	30%	5%
Four graphic elements	4%	0%

Most base map symbols in both standardised and non-standardised samples differed from the background by two graphic elements. As these symbols are of a a lower hierarchical order than thematic map symbols they need to differ by only one graphic element. In this respect there had only been an improvement of 1% after standardisation.

COMPLIANCE WITH DEPARTMENTAL STANDARDS

The departmental symbol sets make no distinction between base and thematic map symbols. This had been the original intention but it had not been implemented. The number of graphic elements by which all symbols in Jonck *et al.* differed has been discussed in 5.2.1.1

5.2.4 VISUAL CONTRAST

The frequency of use of the number of graphic elements to distinguish between thematic map symbols or marks on a map and the background against which they are displayed on the map has been summarised as a frequency distribution histogram. As with the design concept of clarity and legibility, Robinson *et al.* stated that to achieve the desired visual contrast between map symbols and the background against which they were used, map symbols needed to differ by two graphic elements with the mapped background (Robinson *et al.*, 1984:147).

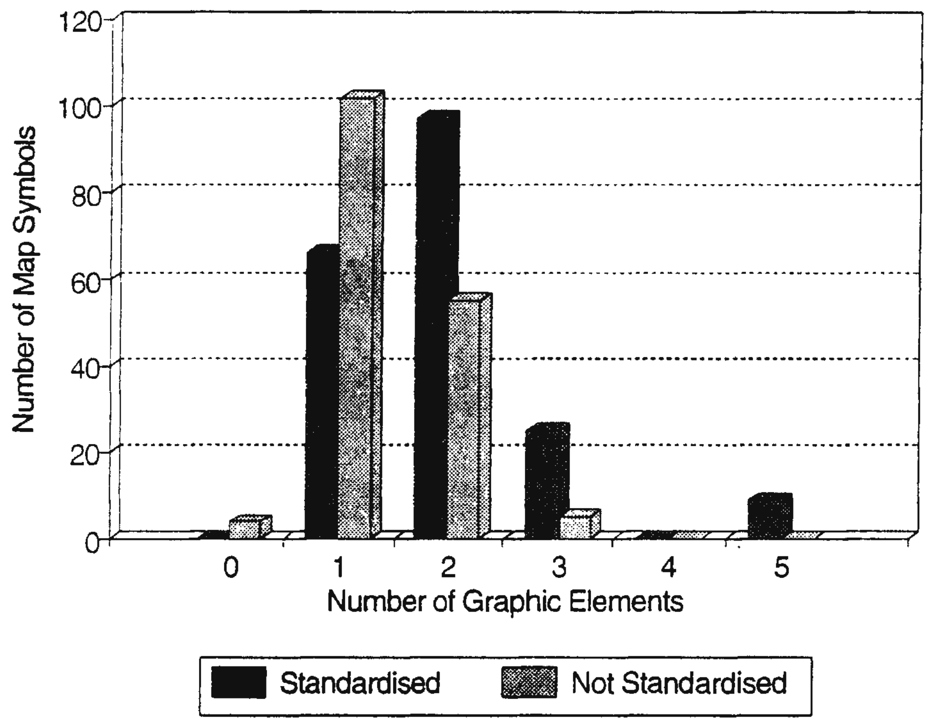


Fig. 5.13. Frequency of use of the number of graphic elements to distinguish between thematic map symbols and their background. (Source: Compiled by the author.)

The standardised sample consisted of 197 and the non-standardised sample of 166 map symbols. A percentage comparison between the number of graphic elements used is given below:

Number of graphic elements	Standardised	Non-Standardised
No graphic elements	0%	2%
One graphic element	33.5%	62%
Two graphic elements	49%	33%
Three graphic elements	13%	3%
Four graphic elements	0%	0%
Five graphic Elements	4.5%	0%

For standardised maps, 49% of all symbols complied to Robinson's requirement of differing by two graphic elements. This represented an overall improvement of 16%.

COMPLIANCE WITH DEPARTMENTAL STANDARDS

The number of graphic elements used to differentiate between map symbols in Jonck *et al.* have been discussed in 5.2.1.1.

5.2.5 VISUAL BALANCE

5.2.5.1 MAP LAYOUT

The evaluation of the visual balance of maps in the sample is represented in Figure 5.14. The variables which were used for the evaluation and which are represented by Columns 1 to 3 are listed below.

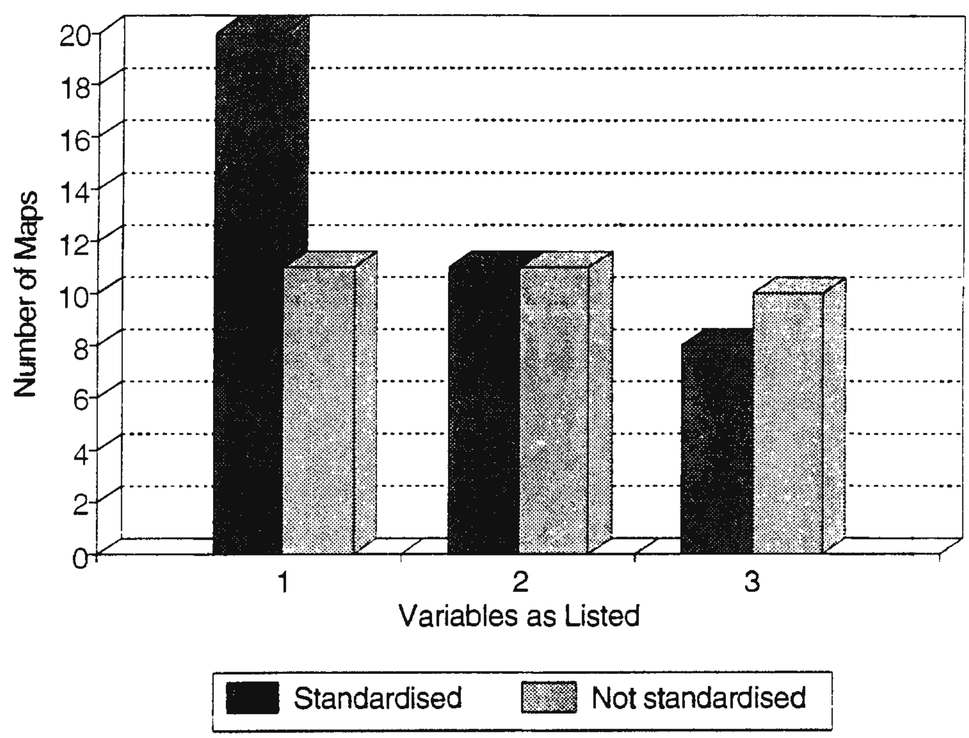


Fig. 5.14. Frequency of compliance to variables that influence the visual balance of maps.
(Source: Compiled by the author.)

Column 1: Logical positioning of the mapped area (Robinson *et al.*, 1984:147).
Column 2: Placing of mapped area with respect to the optical centre (Robinson *et al.*, 1984:147).
Column 3: The visual weighting of the map with respect to the optical centre of the map sheet (Robinson *et al.*, 1984:147).

The logical positioning of the mapped area had improved by 45% after standardisation. Placing with respect to the optical centre had remained unchanged and the visual weighting with respect to the optical centre had, after standardisation deteriorated by 10%. There was however an overall improvement of 11,5%.

COMPLIANCE WITH DEPARTMENTAL STANDARDS

No specific requirement exists in the standards for visual balance. The standardised templates, and their proportion do however influence the visual balance of the map layout.

5.2.5.2 PROPORTION OF MAPPED AREA

Robinson *et al.* (1984:149) are of the opinion that the most desirable proportion of the actual rectangle in which a map is placed should be 3:5 or 1:1.6. The actual proportions of mapped areas for standardised and non-standardised maps are summarised in Figure 5.15. The columns represent proportional classes which have been listed below the figure.

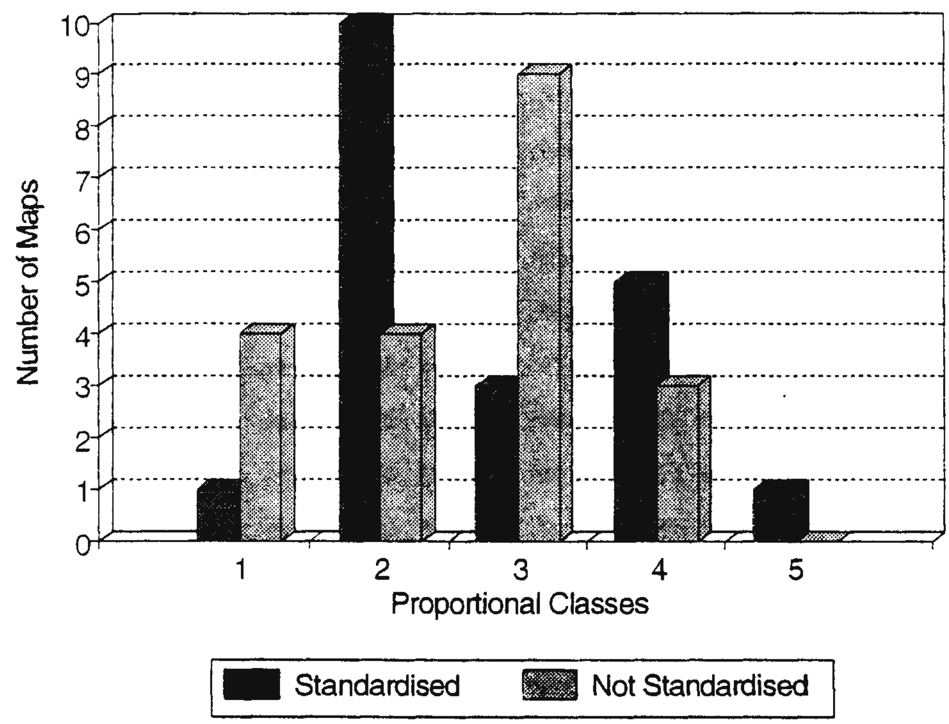


Fig. 5.15. Frequency distribution of proportion of mapping rectangle.
(Source: Compiled by the author.)

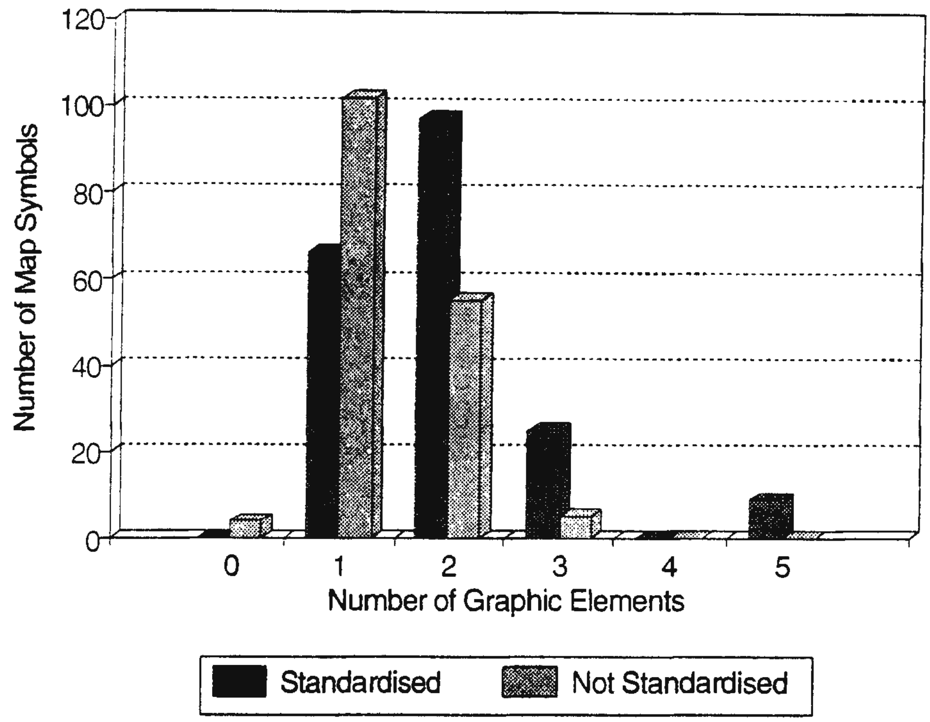


Fig. 5.13. Frequency of use of the number of graphic elements to distinguish between thematic map symbols and their background. (Source: Compiled by the author.)

The standardised sample consisted of 197 and the non-standardised sample of 166 map symbols. A percentage comparison between the number of graphic elements used is given below:

Number of graphic elements	Standardised	Non-Standardised
No graphic elements	0%	2%
One graphic element	33.5%	62%
Two graphic elements	49%	33%
Three graphic elements	13%	3%
Four graphic elements	0%	0%
Five graphic Elements	4.5%	0%

For standardised maps, 49% of all symbols complied to Robinson's requirement of differing by two graphic elements. This represented an overall improvement of 16%.

COMPLIANCE WITH DEPARTMENTAL STANDARDS

The number of graphic elements used to differentiate between map symbols in Jonck *et al.* have been discussed in 5.2.1.1.

5.2.5 VISUAL BALANCE

5.2.5.1 MAP LAYOUT

The evaluation of the visual balance of maps in the sample is represented in Figure 5.14. The variables which were used for the evaluation and which are represented by Columns 1 to 3 are listed below.

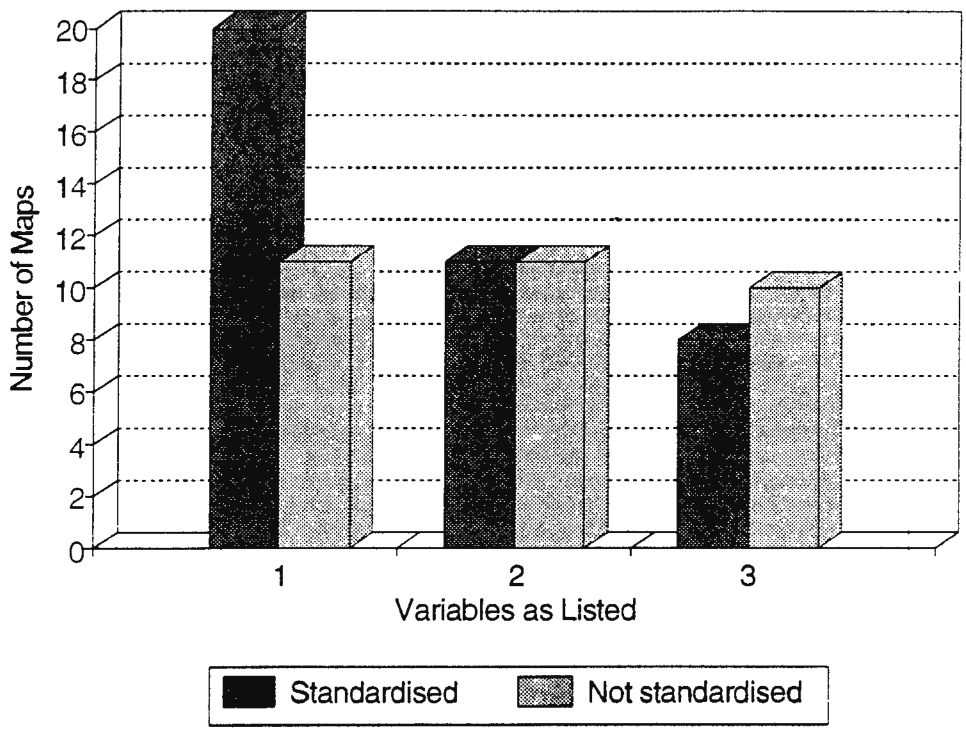


Fig. 5.14. Frequency of compliance to variables that influence the visual balance of maps.
(Source: Compiled by the author.)

Column 1: Logical positioning of the mapped area (Robinson *et al.*, 1984:147).

Column 2: Placing of mapped area with respect to the optical centre (Robinson *et al.*, 1984:147).

Column 3: The visual weighting of the map with respect to the optical centre of the map sheet (Robinson *et al.*, 1984:147).

The logical positioning of the mapped area had improved by 45% after standardisation. Placing with respect to the optical centre had remained unchanged and the visual weighting with respect to the optical centre had, after standardisation deteriorated by 10%. There was however an overall improvement of 11,5%.

COMPLIANCE WITH DEPARTMENTAL STANDARDS

No specific requirement exists in the standards for visual balance. The standardised templates, and their proportion do however influence the visual balance of the map layout.

5.2.5.2 PROPORTION OF MAPPED AREA

Robinson *et al.* (1984:149) are of the opinion that the most desirable proportion of the actual rectangle in which a map is placed should be 3:5 or 1:1.6. The actual proportions of mapped areas for standardised and non-standardised maps are summarised in Figure 5.15. The columns represent proportional classes which have been listed below the figure.

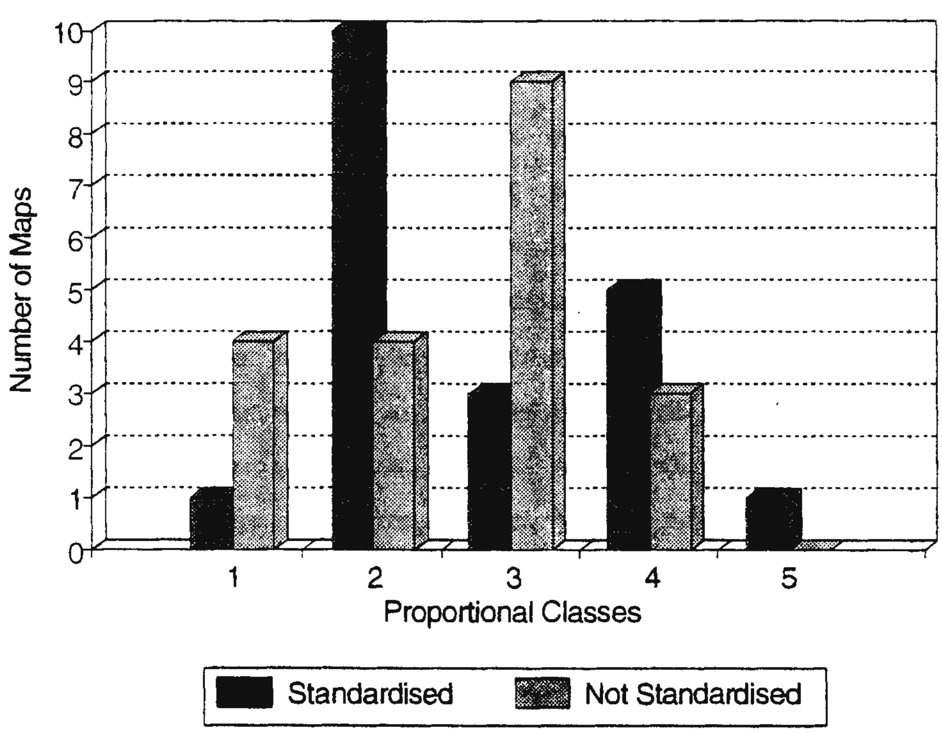


Fig. 5.15. Frequency distribution of proportion of mapping rectangle.
(Source: Compiled by the author.)

The columns represent the following proportional classes:

Column 1:	1:1.0 to 1:1.19
Column 2:	1:1.2 to 1:1.39
Column 3:	1:1.4 to 1:1.59
Column 4:	1:1.6 to 1:1.79
Column 5:	1:1.8 to 1:1.99

Further statistical comparison can be facilitated by comparing the arithmetic mean, mean deviation, standard deviation and coefficient of variation as well as the ranges within which the values lie for both data sets.

	Standardised maps	Non-standardised maps
Arithmetic mean	1:1.36	1:1.37
Mean deviation	0.039	0.067
Standard deviation	0.19	0.26
Coefficient of variation	14.67%	18.92%
Range	1:1.1 to 1:1,76	1:107 to 1;1.76

The arithmetic mean of both data sets is well below Robinson's requirement. The standard deviation and coefficient of variation indicates that there was greater deviation around the arithmetic mean for values in the non-standardised data set. Three standardised maps and one non-standardised map complied. This represented an overall improvement of 5%.

COMPLIANCE WITH DEPARTMENTAL STANDARDS

The proportion of standardised maps are predetermined by the standardised map templates. Only one of these templates complied with Robinson's requirements.

5.3 VERIFICATION OF PROPOSITIONS

The findings discussed above have been summarised in Table 5.1.

CARTOGRAPHIC DESIGN PRINCIPLES	IMPROVEMENT
CLARITY AND LEGIBILITY	
Differentiation between symbols Clarity of map reference Typography Additional information	7% 17.5% 33.5% 35%
FIGURE-GROUND	
Familiarity Articulation of figure Map projection Figure-ground ratio	25% 10% 5% 5%
HIERARCHICAL ORGANISATION	1%
VISUAL CONTRAST	16%
VISUAL BALANCE	
Map layout Proportion of mapped area	11.5% 10%

Table 5.1. Summary of findings of evaluation of sample of maps.
(Source: Compiled by the author.)

The left column lists the cartographic design principles and the right column the percentages by which maps in the sample had improved in terms of these principles.

The Major Proposition, namely that **the implementation of cartographic standards at the Department of Water Affairs and Forestry for GIS hard copy map output has improved the graphic communication of geo-referenced information**, cannot be validated as a whole and has been broken down into minor propositions (see 2.4.2). Each of these need to be either accepted or rejected before the major proposition can be validated.

5.3.1 MINOR PROPOSITIONS

5.3.1.1 MINOR PROPOSITION ONE

The first minor proposition states that the standardisation of **encoding** has improved the graphic communication of information on GIS-generated hard copy map output.

As can be seen in Table 5.1, encoding or standardisation of map symbols has contributed towards an improvement of the **clarity and legibility** of maps. Encoding has also played a role in the differentiation between **figure and ground** in that the delineation of figure as opposed to ground improved after standardisation. Encoding also played a major role in the improvement of the **hierarchical organisation** of map information as well as the improved **visual contrast** between map symbols and the background against which they were mapped.

Minor proposition one can therefore be accepted as valid.

5.3.1.2 MINOR PROPOSITION TWO

The second minor proposition states that the standardisation of **map content** has improved the graphic communication of geo-referenced information to decision makers on maps that are produced by the departmental GIS.

Table 5.1 clearly indicates that the contribution made by the legend, and additional information to maps after standardisation made a considerable contribution to the added **clarity and legibility** of standardised maps. As far as the distinction between **figure and ground** is concerned, standardisation of map content contributed to making the mapped area more familiar to the map user by the addition of surrounding information and the indication of the geographical location of a mapped area.

This proposition can therefore also be accepted as being correct.

5.3.1.3 MINOR PROPOSITION THREE

Minor proposition three states that the standardisation of **map composition** by the department has improved the graphic communication of geo-referenced information on hard copy maps produced by the departmental GIS.

Table 5.1 indicates that the standardisation of those aspects pertaining to typographical design improved the **clarity and legibility** of maps. **Visual balance** of standardised maps also improved in terms of layout and proportion of the mapped area.

This proposition can therefore also be accepted as being correct.

5.3.2 MAJOR PROPOSITION

There had been an overall improvement in terms of graphic design principles of 14.7%. The major proposition which states that the implementation of cartographic standards at the DWAF has improved the communication of geo-referenced information on hard copy maps output by the departmental GIS can therefore be accepted as being valid.

6

RECOMMENDATIONS

The implementation of cartographic standards at the DWAF has improved the communication of graphic information. The improvement was however of varying degree due to both implementation problems and shortcomings in the standards as such. The latter is discussed and recommendations are made in the first half of this section of the report. In the second half of this section implementation problems are pointed out and recommendations made to improve implementation.

6.1 STANDARDS

From the findings given in Section 5 of this report, the standards need to be reviewed with respect to improving the following.

6.1.1 CLARITY AND LEGIBILITY OF ENCODING

As mentioned in 5.2.1.1, and graphically illustrated in Figure 5.4, 50.5% of map symbols in Jonck *et al.* differ from each other by one graphic element only. Robinson *et al.* (1984:147) clearly state that for map symbols to be clear and legible, a differentiation by way of two graphic elements is preferred. In fact, twenty one (11%) of the 194 map symbols contained in this document do not differ from each other in any way at all. It is unlikely that all the symbols designed thus far will ever be used on one map, but the maps produced when applying these standards, reflected the above, in that on the 20 maps in the sample, 52% of the map symbols differed from each other by one graphic element only.

It is therefore recommended that the standardised symbols be reviewed with a view to the requirements for clarity and legibility as recommended by Robinson *et al.* It is well recognised that different plotting devices influence both the colour and the value of map symbols. To determine the influence of this constraint on map symbols contained in the sample a further investigation into the variables used to distinguish between map symbols is warranted.

6.1.1.1 FREQUENCY OF USE OF VARIABLES USED TO DIFFERENTIATE BETWEEN MAP SYMBOLS

The actual variables used to differentiate between map symbols in **Jonck** *et al.* (1994), have been summarised in histogram form below.

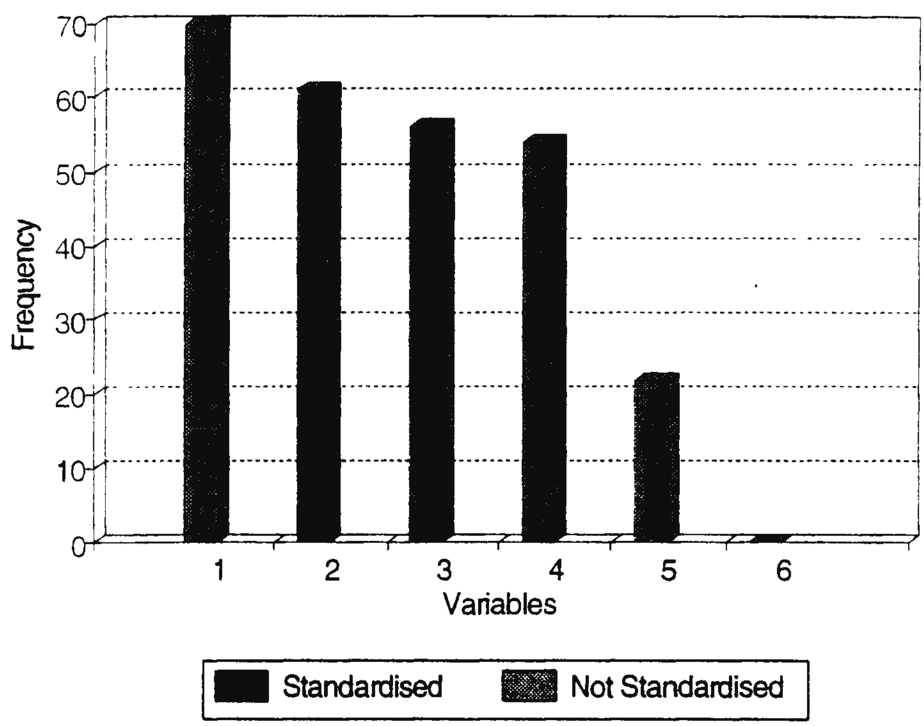


Fig. 6.1. Frequency of use of different variables to distinguish between map symbols.
(Source: Compiled by the author.)

Column 1: Colour.
Column 2: Value.
Column 3: Size.
Column 4: Shape.
Column 5: Spacing.
Column 6: Orientation.

A further comparison can be made by comparing the percentages of occurrence of use of the different graphic elements.

Graphic element	Symbol set
Colour	27%
Value	23%
Size	21%
Shape	20%
Spacing	8%
Orientation	0%

Colour and value were jointly used to differentiate between symbols for 50% of occurrences. The department has several colour output devices which include an electrostatic plotter, inkjet plotters and thermal wax plotters. The colour output from these different types of plotters as well as from plotters of the same type but from different manufacturers vary. Colour and value are not only affected by the plotting device itself but also by humidity as well as the type of paper used. This is illustrated by Figures 6.2 and 6.3 which depict the waterboards in South Africa and have been plotted on an inkjet and thermal wax plotter respectively.

If symbols are to be consistently clear and legible, symbol sets which contain colour symbols need to be designed for individual plotting devices.

6.1.2 HIERARCHICAL ORGANISATION OF BASE MAP INFORMATION

In the symbol sets designed and created by the department, no distinction is made between base map and thematic symbols. The effect of this is clearly illustrated in Figure 6.4. Here both thematic and base map symbols differ by one graphic element, namely colour, only. Apart from confusion in terms of the hierarchical organisation of information being mapped, this can lead to confusion between figure and ground.

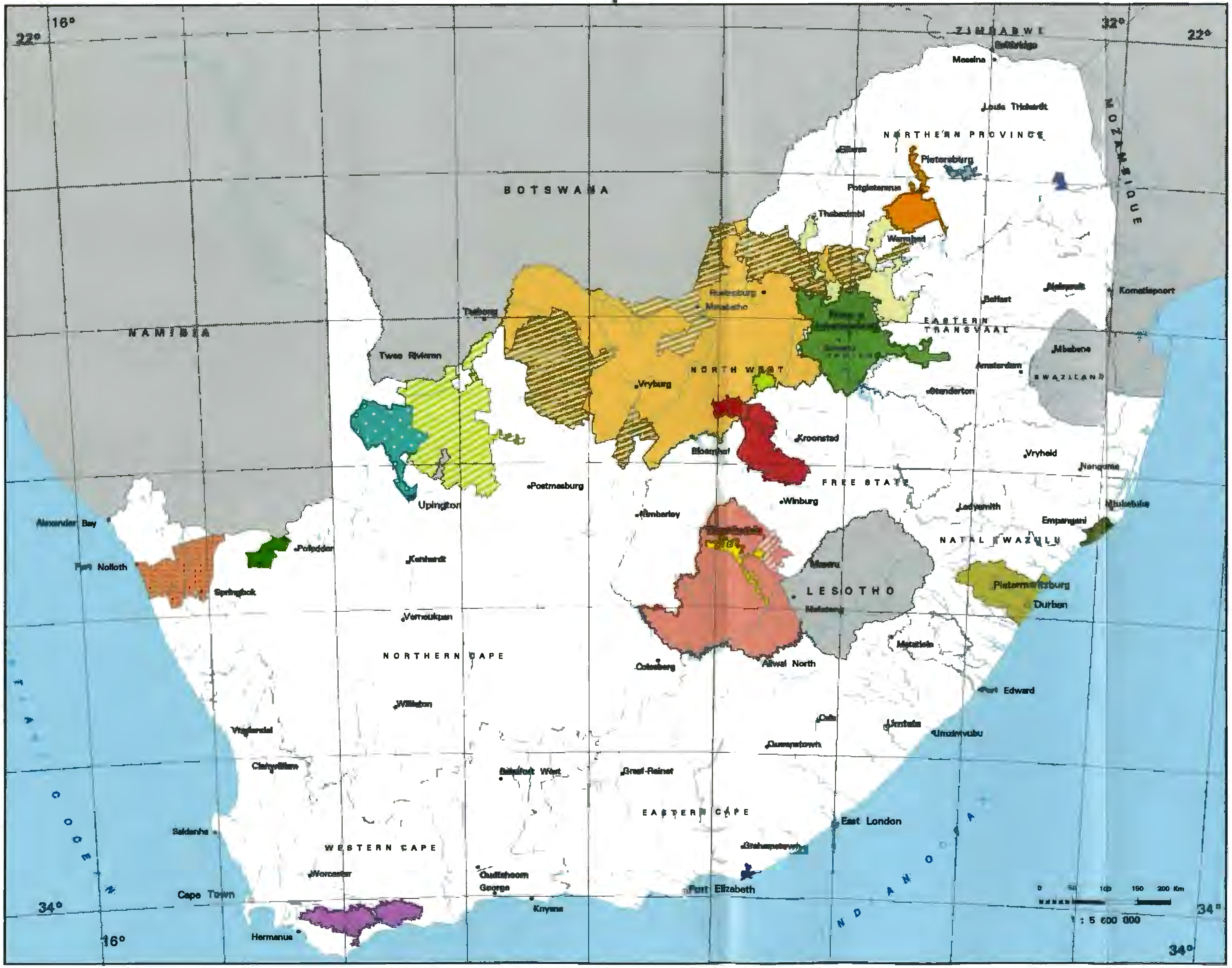
A distinctive set of symbols for base map information will need to be designed separately.

NOTE:

The titles to Figures 6.2 to 6.5 have been indicated on their preceding pages. This has been done as it would be contrary to the aim of this report to alter maps which have been compiled by operators.

Fig. 6.2. Map of the waterboards of South Africa which has been plotted by an inkjet plotter.
(Source: DWAF Map Archives.)

Waterboards of the Republic of South Africa



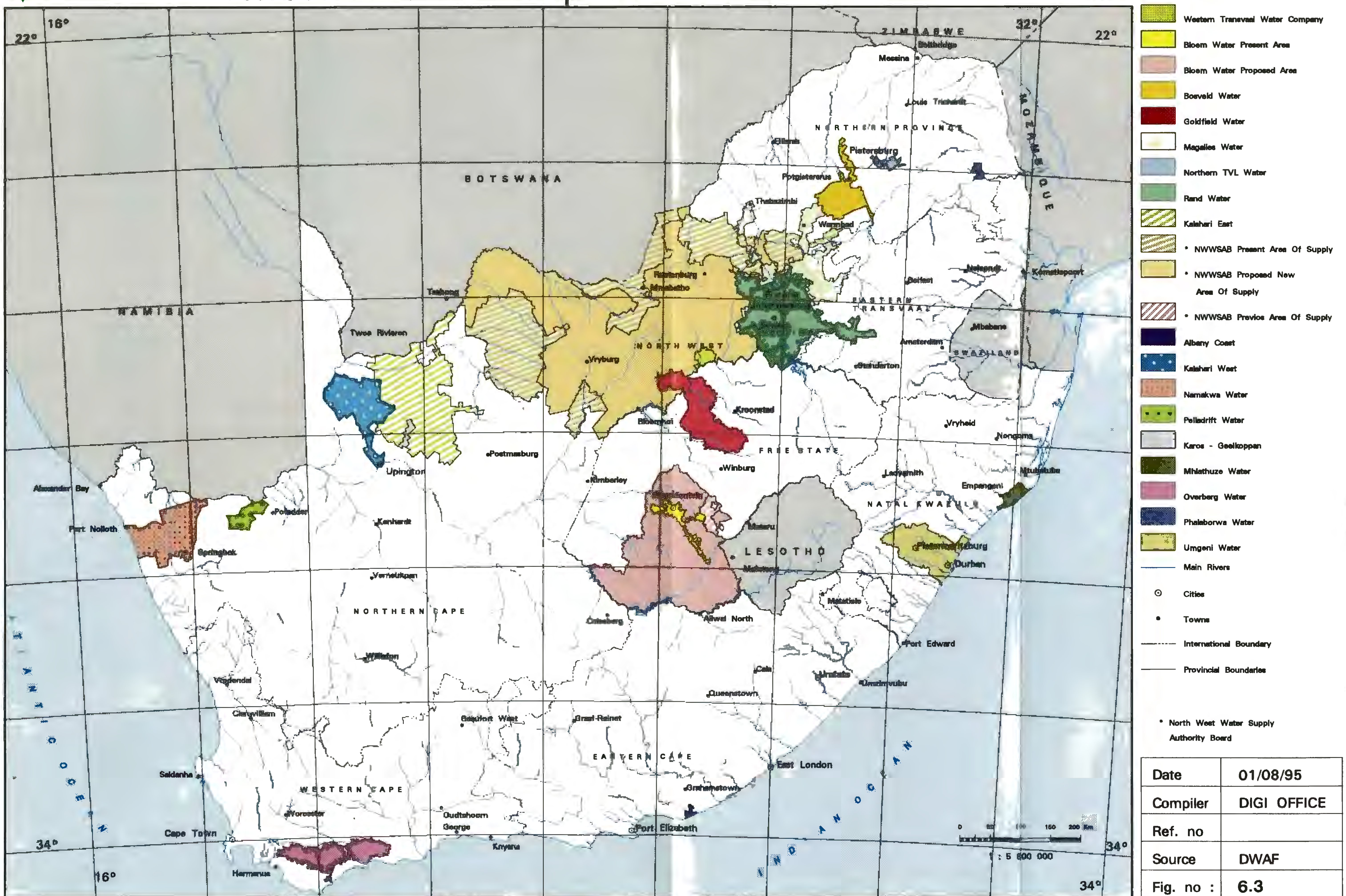
- Western Transvaal Water Company
- Bloem Water Present Area
- Bloem Water Proposed Area
- Bosveld Water
- Goldfield Water
- Magalies Water
- Northern TVL Water
- Rand Water
- Kalahari East
- * NWWSAB Present Area Of Supply
- * NWWSAB Proposed New Area Of Supply
- * NWWSAB Previos Area Of Supply
- Albany Coast
- Kalahari West
- Namakwa Water
- Pelladrift Water
- Karoo - Gcelkoppan
- Mhlathuze Water
- Overberg Water
- Phalaborwa Water
- Umgeni Water
- Main Rivers
- Cities
- Towns
- International Boundary
- Provincial Boundaries

* North West Water Supply Authority Board

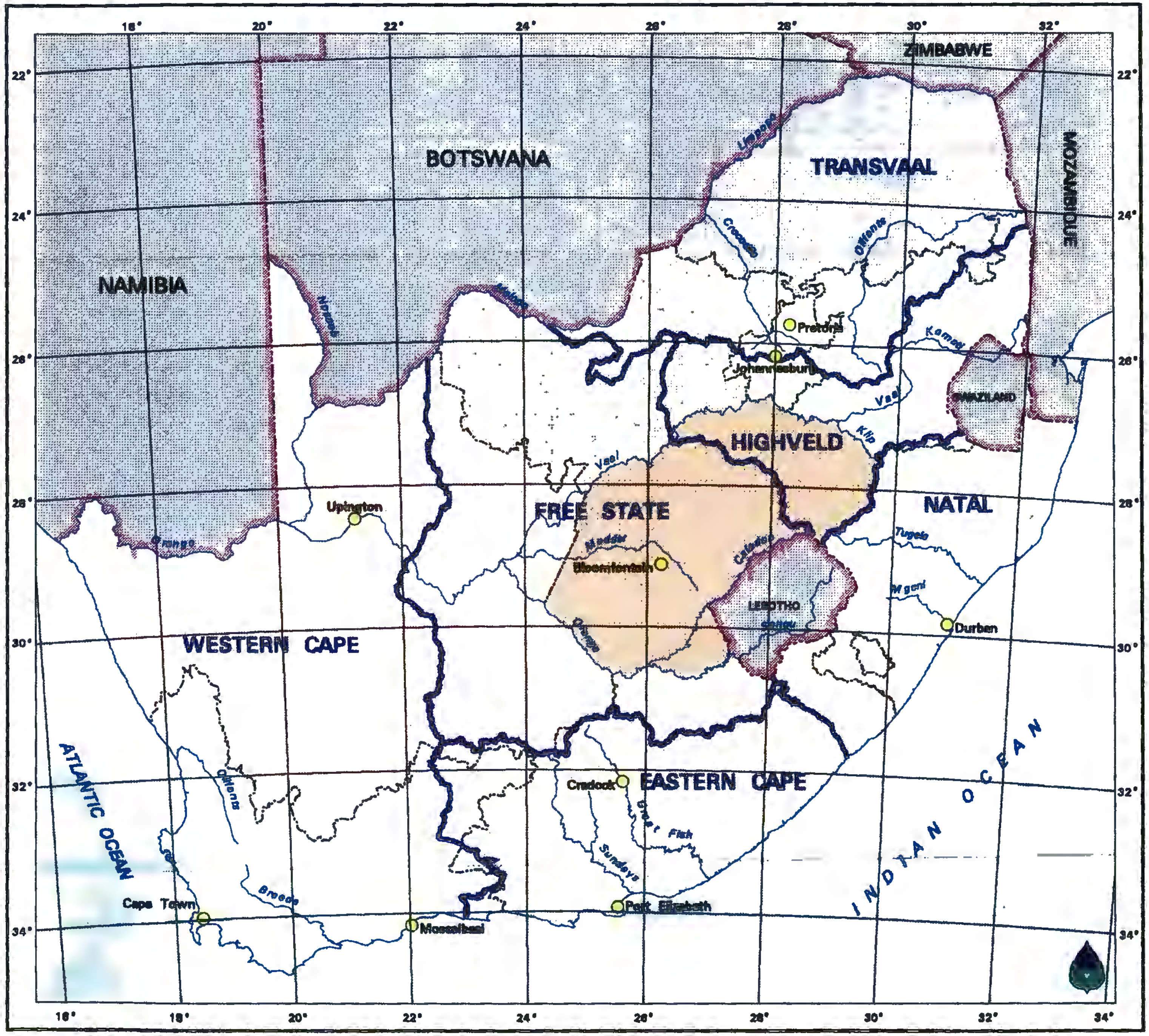
Date	01/08/95
Compiler	DIGI OFFICE
Ref. no	
Source	DWAF
Fig. no :	6.2

Fig. 6.4. An example of how the use of a single graphic element, namely colour, to differentiate between map symbols, leads to confusion of the hierarchical organisation of information on a map.
(Source: DWAF Map Archives.)

Waterboards of the Republic of South Africa



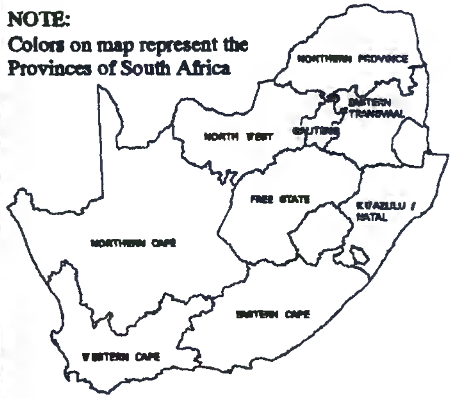
Date	01/08/95
Compiler	DIGI OFFICE
Ref. no	
Source	DWAF
Fig. no :	6.3



REGIONAL BOUNDARIES OF THE DEPARTMENT OF WATER AFFAIRS AND FORESTRY

- Regional Boundaries
- Rivers
- International Boundaries
- Provincial Boundaries
- Towns

NOTE:
Colors on map represent the Provinces of South Africa



100 0 300 km

Date	August 1995
Compiler	ISUS – Paul de Sousa
Ref. no	/db/paul/t18295
Projection	Albers
Source	DWAF

6.1.3 MAP PROJECTIONS

The requirements for map projections which are contained in the standards are inadequate. No consideration has been given to

- the shape of the area which is being mapped; and
- the purpose for which a map is being made.

The standards themselves address only the map extent of the area which is being mapped (See 4.3.5.8). The standards need to be reviewed and more detail should be given regarding projection parameters such as standard parallels. ARC/INFO software supports many projections. The standards should include suggestions or guidelines in terms of projections for maps which are made for specific purposes. These should include:

- Distribution maps; and
- Maps used for routing or navigation.

6.1.4 FIGURE:GROUND RATIO

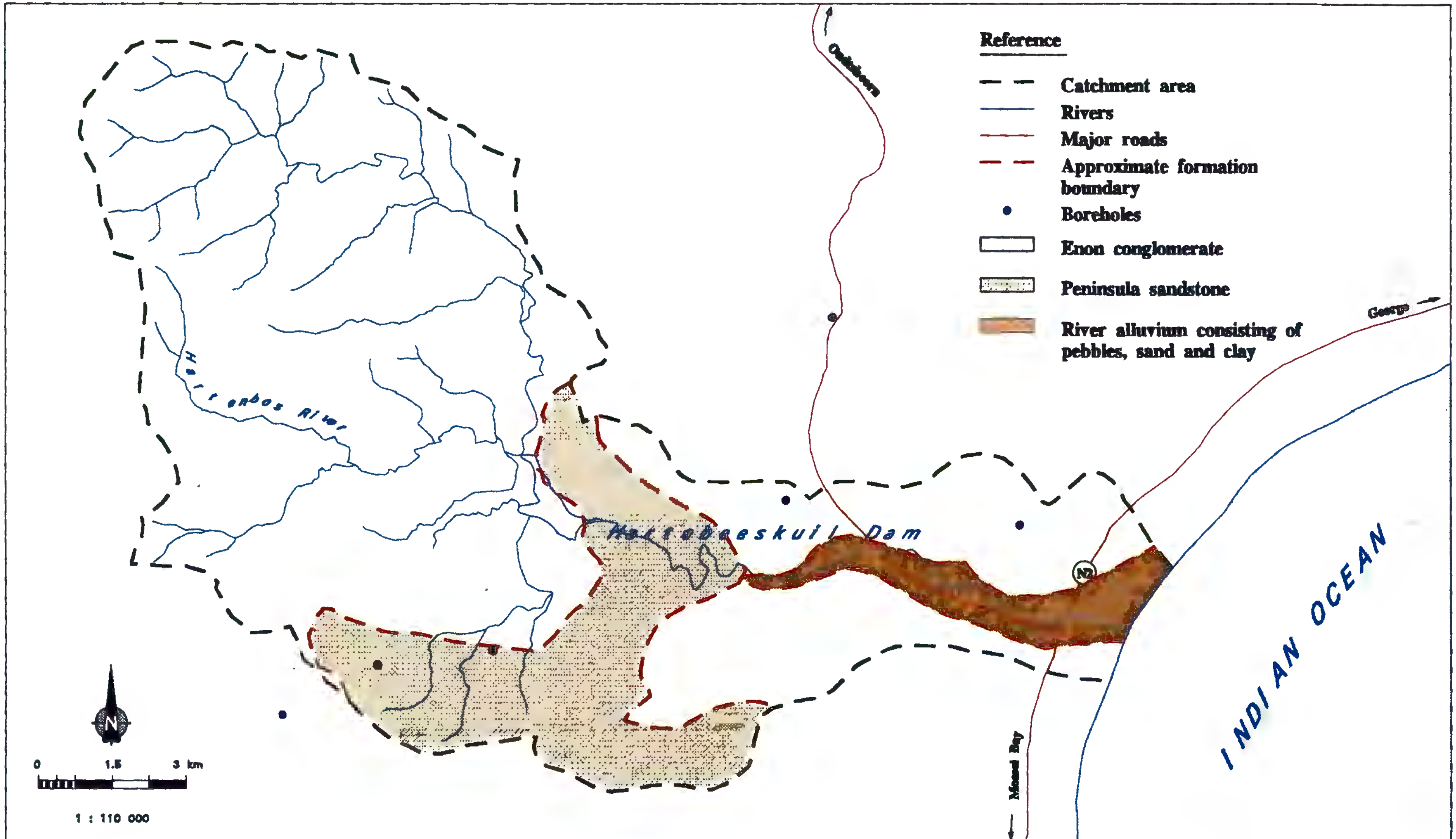
Figure:ground ratios have not been addressed by the standards. In theory this ratio should fall within a range of 1:1.4 to 1:1.5. In practice this ratio is influenced by the shape and size of the area being mapped.

This ratio is to a very large extent unique to each individual map. An awareness can however be created by making map making operators aware of this issue.

6.1.5 PLACING OF FIGURE WITH RESPECT TO OPTICAL CENTRE OF IMAGE AREA

The standards make no reference with respect to the placing of the mapped area within the image area. This aspect is however also unique to a specific map and is influenced by the geographical shape of the area which is mapped. This is illustrated in Figure 6.5. This is also influenced by the map projection which is used (Wood, 1992:436). An awareness of this can be created by including guidelines in this regard in a revised edition of Jonck *et al.* which operators regard as a users guide.

Fig. 6.5. Influence of the geographical shape of an area which is mapped on the placement of the area in relation to the optical centre of the image area. (Source: DWAF Map Archives.)



Geology of the Hartenbos River catchment area | **Fig. 6.5**

6.1.6 MAP LAYOUT AND PROPORTION OF MAPPED AREA

The map layout and proportion of the rectangle in which a map is drawn has, since implementation of the standards been largely dictated by the map templates used by operators. All except one of the map templates therefore need to be reviewed and the requirements layed down by Robinson *et al.* need to be adhered to. The placing of the figure also plays a role here and the recommendations contained in 6.1.5 could contribute to improving this aspect of cartographic design.

6.1.7 ADDITIONAL MAP ELEMENTS

A copyright statement has not been included in the section on additional information in Jonck *et al.* This needs to be addressed. The department uses a considerable amount of data which is obtained from other sources and this aspect therefore requires urgent attention.

6.1.8 TEXT PLACEMENT

The guidelines given for the placement of text for linear features, see Figure 4.10, is ambiguous and needs to be reviewed. Confusion exists concerning the placement of text above the linear feature in this figure.

6.2 IMPLEMENTATION

Implementation-related problems are highlighted by the limited improvement which was effected with respect to the

- application of rules for typographic design;
- addition of extra information;
- familiarising the map reader, or user, with the area that has been mapped; and
- delineation of the figure as opposed to the ground.

The following are recommendations on how implementation can be improved without enforcing these standards in an authoritarian way.

6.2.1 WORKING GROUP MEETINGS

Standards need to be accepted by the user community to be successful (Cooper, 1993:96). The user community in this case consists of the computer operators who use the standards to produce departmental maps. Operators therefore need to feel that the standards 'belong' to them and they must be informed of the purpose of these standards. To further this aim a monthly workshop should be convened by the departmental digital cartographer. Active participation by users should be encouraged at such a workshop and the following should be included in the programme:

6.2.1.1 PURPOSE OF THE STANDARDS

It needs to be explained that the purpose of the standards are to improve graphic communication to decision makers within the department. The importance of this must be emphasised and the positive role that operators can play in this process needs to stressed.

6.2.1.2 REVISION OF DRAFT PRESENTATION STANDARDS

In Section 6.1, recommendations have been made on how the standards can be improved. Operators should be given an opportunity to state what their needs are and indicate which aspects of the guide are unclear to them. Problems that are currently being experienced should be put to them and suggestions invited as to how to improve the standards set in Jonck *et al.*

Operators can also be asked to submit suggested new map templates as only one of the standardised templates have the correct proportions.

6.2.1.3 AUTOMATION AND IMPLEMENTATION

Implementation problems need to be discussed and pointed out, because perhaps they could be solved by automation. Operators can assist here in not only making suggestions, but by getting involved in the actual writing of the required computer routines.

6.2.1.4 MAP PROJECTIONS

The monthly workshop can also be used as a forum for training. Expert speakers could from time to time be invited to give short presentations. Operators have no knowledge of map projections and in addition to changes in the users' document itself, map projections need to be explained to them.

6.2.2 MONTHLY AWARD

A " Map of the Month" award should be made. Such a map, can be prominently displayed on a notice board together with the operators name. The reasons why a particular map has been given the award, should be explained at the monthly cartographic workshop.

6.2.3 DEVELOPMENT OF AN EXPERT SYSTEM

The effectiveness of the implementation of these standards could be enhanced by the development of an expert system Expert systems are software systems that encapsulate the knowledge and/or skill of human specialists and perform tasks accordingly. In such systems human knowledge is represented by rules which take the form of 'IF' (condition) and 'THEN' (action) statements (Roth, 1991:42).

In this case such rules could be applied to the following:

- the selection of map symbols;
- the choice of map projection;
- the placement of text; and
- cartographic generalisation.

The development of such a system requires the gathering of knowledge from the human expert, in this case the cartographer. The standards which have been developed already contribute to this requirement. The knowledge gained in this way will then need to be structured, represented and the required computer coding will need to be done. Knowledge of the latter three aspects is very specialised and consequently also costly (Roth, 1991:42).

7

CONCLUSION

The cartographic or presentation standards adopted and implemented by the department, were designed for use by all map makers who use GIS technology to compile maps on behalf of the department. They were specifically focused on the production of thematic maps not associated with any particular map series. The purpose of these standards was to improve comparability between maps made for the same theme, but with differing geographical extent and to assist GIS computer operators who have no knowledge of cartographic design concepts or principles to communicate effectively.

All maps are to a certain degree unique, and thematic mapping in particular invites the map maker to design or use map symbols that are unique to that specific map (Liebenberg, 1986:60). Operators are further tempted by the large number of map symbols that are part and parcel of commercial GIS software packages and are therefore prone to experimentation. This has led to the production of some notoriously poor maps at the department.

The emergence of computer technology for mapping and other geographically related purposes, has focused cartographic research on the technology of map making. The design aspects have been temporarily cast aside (Wood, 1992:436). Computer and GIS technology has also given operators the technical capability to make maps.

In an attempt to emphasise the analytical capabilities of GIS software, references are also being made, in journals in particular, to the fact that such software packages are not merely "pretty mapmakers" (Smith, 1994:44). This is indeed so, but most decision makers are not hands-on GIS users and the maps produced by GIS, after manipulation and analysis of geo-referenced data, are the only means of communicating information generated by such systems to decision makers. This aspect was well recognised when GIS was implemented in the department in 1987 (Olivier *et al.*, 1990:1473).

The problem associated with the cartographic quality of maps which are produced from GIS is further hampered in South Africa by the lack of availability of trained cartographers. Cartographers are trained at only one institution. These cartographers all have a technical training and are not recognised by the professional users of GIS as co-professionals. This exacerbates the problem in that their views are not sought on improving the cartographic quality of maps output by GIS.

The implementation of cartographic standards at the DWAF has contributed, to a varying degree, to an increase in effectiveness of the communication of geo-referenced information, generated by the departmental GIS, to decision makers. Due to the limited implementation of the standards only coloured maps could be evaluated.

Despite this limitation, the standards set for encoding, map content and map composition have improved the clarity and legibility of maps, the hierarchical organisation of map information, the distinction between figure and ground, visual contrast and the visual balance of maps. There are however certain areas which need to receive further attention. Certain aspects of the standards such as the proportion of the map templates used, the placing of the mapped area with respect to the optical centre of the image area, encoding of base map symbols and map projections in particular, need to be reviewed and revised.

Certain problems also exist with the actual implementation of these standards. Operators need to be made to feel that the standards belong to them and they need to be encouraged to use them. This cannot be achieved in an authoritarian way. Many aspects of these standards can be further automated. This will not only aid the implementation of the standards but will also contribute to the efficiency with which maps are made. Operators should be actively involved in this process and in this way be made to feel that they are making a contribution to improving graphic communication to departmental decision makers.

Despite the problems which still exist, the improvement in graphic communication has not gone by unnoticed in the department. All users have expressed their approval of the newly made maps. The digital cartographer employed by the department has also been approached by professionals to assist them in improving the cartographic quality of maps that they produce. The implementation has thus increased the professional standing of cartographers in the department and has highlighted the importance of excellence of cartographic design in graphic communication.

GLOSSARY

Algorithm A process or a set of rules which govern a calculation (Sykes, 1984:22).

Base map information Fundamental information used as a base on which additional information of a specialised nature is compiled (Cooper, 1993:184).

Cartographic encoding Representing features in an abstract way with the aid of certain marks on a two dimensional surface (Adapted from Robinson *et al.*, 1984:145).

Cartographic generalisation The process by which the amount of information shown on maps is reduced when the scale of a map is reduced (Cooper, 1993:200).

Chart A chart is a map which is used as a working document and has not been made merely as a representation of the distribution of phenomenon. A navigational chart, for example, is used to plot a course (Liebenberg, 1986:4).

Coefficient of variation A variability index where variability is indicated by dividing the standard deviation with the arithmetic mean and expressing this value as a percentage (Gregory, 1963:43).

Compilation The preparation of a new or revised map (Adapted from Robinson *et al.*, 1984:518).

Coordinate A coordinate is a linear or angular quantity which designates the position that a point occupies in a given reference frame or system (Cooper, 1993:191).

Data analysis The process of extracting information from data (Cooper, 1993:183).

Data base A store of digital information which is organised in such a way that selective extraction is possible (Robinson *et al.*, 1984:518).

Digital	The computer representation of a quantity by a number code (Adapted from Robinson *et al.*, 1984:519).
Digitize	Converting an analog measurement of a physical variable into a discreet numerical value in a digital form (Cooper, 1993:195).
Ellipsoid	A "symmetrical surface" which is used as a "best fit of the total geoid". The ellipsoid provides the reference surface for planimetric coordinates (Adapted from Cooper, 1993:224).
Feature	An identifiable set of one or more objects in the real world with a defined set of characteristics.
Geo-referenced	Positionally-referenced to latitude and longitude.
Global positioning system	The global positioning system is a satellite-based locational system (Cooper, 1993:201).
Graticule	The graticule is the geographical grid or network of intersecting lines of latitude and longitude inscribed on the surface of the earth for the purpose of fixing the location of surface features (Strahler and Strahler, 1978:7).
Hard copy	A physical map or graphic presentation which has some degree of permanence (Robinson *et al.* 1984:520).
Hue	Hue is a complex visual perception which is commonly used for the term "colour" (Robinson *et al.*, 1984:142).
Hydrology	A collective term for all water related variables that influence water related processes on land.
Interval scale	A scale of measurement which assigns a value to items in such a way that the difference between any two items is known (Cooper, 1993:192).
Isopleth	An isopleth is an imaginary line joining points of equal value or quantity. Derived from the Greek *isos* meaning equal and *plethis* which means fullness of quantity (Strahler and Strahler, 1978:24).

Latitude	The latitude of a point on the ellipsoid is defined as the angular distance between the point and the plane of the equator of the ellipsoid (Cooper, 1993:207).
Layout	The plan or design of the arrangement of map elements on a sheet of paper.
Longitude	The longitude of a point on the ellipsoid is the angular distance between a meridian and plane through the point and a defined meridian which is usually the Greenwich Meridian (Cooper, 1993:207).
Map projection	A system whereby location on the curved surface of the earth is displayed on a two dimensional surface using a set of rules (Goodchild and Kemp, 1991:27-3).
Map projection parameters	The function which defines the one-to-one mapping of points and/or lines of latitude and longitude between the reference surface and the projection surface (Cooper, 1993:218).
Map scale	The ratio between a distance on a map, graphics screen or any other display device or medium displaying a map and the corresponding distance on the surface of the earth (Cooper, 1993:221).
Map symbol	Distinctive marks created and arranged to form a visual representation of phenomena (Robinson *et al.*, 1984:137).
Meridian	A line of longitude. Derived from the Latin *meridianus*. Adopted by Ptolemy as all places situated on the same line of longitude experience midday at the same time (Liebenberg, 1986:15).
Minutes	Each degree of latitude and longitude is divided into sixty equal parts or sections called minutes. This is derived from the Latin *minutiae primus* meaning first small parts (Liebenberg, 1986:15).
Neat line	Line separating the body of a map from the map margin (Robinson *et al.*, 1984:522).

Nominal scale A measuring scale that is used to distinguish between features on the basis of their intrinsic character according to some qualitative consideration (Cooper, 1993:193).

Ordinal scale A scale of measurement where a distinction is based on rank according to some quantitative measure. Only rank is involved, i.e. the order of variables from lowest to highest. There is no distinction in terms of a numerical value (Cooper, 1993:193).

Orientation This refers to the directional arrangement of marks on a map (Robinson *et al.*, 1984:142).

Plotter A computer peripheral for producing graphics on paper or film. The distinction between plotters and printers are becoming increasingly vague as such devices can be capable of producing both text and graphics (Cooper, 1993:217).

Polygon A plane figure consisting of vertices or points connected by lines. The region which is enclosed by these lines is known as a polygon (Adapted from Cooper, 1993:217).

Proposition An expression in language or sign of something that could be either true or false.

Ratio scale This is a measuring scale where there is a true zero point. The scale allows for the calculation of precise differences so that measurements retain the same ratio to one another (Cooper, 1993:193).

Remote sensing The recording, interpretation, measurement and analysis of electromagnetic radiation to obtain information about the earth by means of non-contact systems (Adapted from Davis and Simonett, 1991:192).

Scale factor The quantity used in scaling by which the quantities which are being altered are multiplied or divided to bring them within the desired limits (Cooper, 1993:221).

Seconds Each minute of a degree of latitude or longitude is divided into sixty equal sections called seconds. This is derived from the Latin *minutae secundae* meaning second small parts (Liebenberg, 1986:15).

Shape — This is a graphic characteristic provided by the appearance of a regular form such as a circle, outline of an irregular form or the contour of a linear feature (Robinson *et al.* 1984:142).

Software — The programs, procedures and routines that are associated with a computer data processing system (Adapted from Cooper, 1993:222).

Source document — A document that provides data for input into a data processing system (Standards Committee for the National Land Information System, 1990:A-10).

Spacing — This refers to the arrangement of component marks on a map (Robinson *et al.*, 1984:142).

Spatial data — Data that has a position in a multi-dimensional space (Cooper, 1993:193).

Standard deviation — The square root of the average of the squares of the deviations from the arithmetic mean (Gregory, 1963:24).

Symbol — A mark or character used to represent a feature or object (Adapted from Robinson *et al.*, 1984:145).

Template — A pattern which governs the assembly of data (Cooper, 1993:227).

Value — Value refers to the lightness or brightness of a colour (Robinson *et al.*, 1984:142).

Variable — A quantity which can take on any of the numbers of a set (Robinson *et al.*, 1984:527).

Visualisation — This is the process of representing information synoptically for the purpose of recognising, communicating and interpreting pattern and structure (Buttenfield and Mackaness, 1991:432).

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APPENDIX A

MAPPING THEMES AND FEATURES IDENTIFIED AT THE DEPARTMENT IN 1992

(Source: Wolfer, 1992:5 - 7.)

ENVIRONMENT	THEME	FEATURE
SCIENTIFIC AND NATURAL	Geohydrology	Ground Water Occurence Lithology Water Feature Groundwater Suitability Recharge Index Depth of Rest Water Electrical Conductivity Geological Boundary Fault Dyke Flow Direction of Groundwater Springs Boreholes
	Hydrology	Catchment Area Sub-Catchment Area Hydrological Zone River Flow Gauging Station Flood Zone Runoff Zone Pan Wetland Dam Spring Borehole Estuary Sedimentation Water Quality
	Geology	Lithology Structure
	Meteorology	Temperature Gauge Humidity Gauge Evaporation Gauge Rainfall Gauge Isoheyts Isotherms Climatic Zones Temperature Zone Rainfall Zone Evaporation Zone
	Geomorphology	Contour Slope Aspect Eroded area
	Pedology	Sediment Production Zone Sediment Yield Soil Type

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SCIENTIFIC AND NATURAL	Geohydrology	Ground Water Occurence Lithology Water Feature Groundwater Suitability Recharge Index Depth of Rest Water Electrical Conductivity Geological Boundary Fault Dyke Flow Direction of Groundwater Springs Boreholes
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	Pedology	Sediment Production Zone Sediment Yield Soil Type

APPENDIX B

TITLES OF MAPS IN THE SAMPLE USED FOR DATA COLLECTION AND ANALYSIS

(Source: Compiled by the author.)

MAP	THEME	TITLE
1A	Geohydrology	Groundwater Resources of South Africa
1B		Groundwater Classification System
2A	Geology	Geology of the Hartenbos Catchment Area
2B		Regionale Geologie van die Tolwe Gebied
3A	Hydrology	Major Dams in the Lower Kei, Mbashe and Qora Basins
3B		Major Dams in the Olifants River Basin
4A		Basins in the Eastern Cape Province
4B		Drainage Basins in the Northern Transvaal
5A		Sediment Dynamics of the Hartenbosch River Mouth
5B		Sediment Yield Elandsdraai Dam
6A		Flow Gauging Stations in the Former Ciskei
6B		Flow Gauging Stations in the Mgeni Catchment
7A	Meteorology	Mean Annual Rainfall in the RSA
7B		Rainfall in the Olifants River Basin
8A	Vegetation	Vegetation in the Swart Vlei Estuary
8B		Vegetation at the Vygeboomdam
9A	Distribution	Water Reticulation in the Highveld Region
9B	Network	Reticulation Lesotho Highland Water Project : Phase I
10A	Recreation	Zoning at the Grootdraai Dam
10B		Zoning at the Braam Raubenheimer Dam
11A	Administrative	Locality Map Eastern Cape
11B		Locality Map Upper Kei Basin
12A		Provincial Boundaries of the RSA
12B		Provincial Boundaries of the RSA
13A		Boundaries of the Former Transkei and Ciskei
13B		Boundaries of the TBVC States
14A	Social	Availability of Water for Human Consumption
14B	Statistical	Water Use: Olifants River Basin
15A		Population Distribution in the RSA
15B		Population Distribution in the Olifants River Basin
16A		Dominant Languages in the RSA
16B		Dominant Languages
17A	Water	Magalies Water Board
17B	Management	Goldfields Water Board
18A		Water Boards in the Northwest Province
18B		Water Boards in the Northern Cape
19A		Water Boards in the RSA
19B		Water Boards in the RSA
20A		Irrigation Potential in the RSA
20B		Irrigation Potential in the Olifants River Basin

A: Standardised Maps
B: Non-Standardised Maps

APPENDIX C

MAP EVALUATION SHEET

(Source: Compiled by the author.)

MAP TITLE:		REF. NO	
MAP THEME		CHECKED	

1.	CLARITY AND LEGIBILITY														
1.1	ENCODING: GRAPHIC ELEMENTS USED TO DIFFERENTIATE BETWEEN THEMATIC SYMBOLS														
	MAP SYMBOL TYPE AND NUMBER														
	Size														
	Colour														
	Value														
	Shape														
	Spacing														
	Orientation														

1.2	MAP REFERENCE OR KEY		
	Number of symbols on map		
	Number on reference		
	Same size	Yes	No
	Range high to low, or	Yes	No
	Low to high	Yes	No
	Grouped	Yes	No

1.3	TEXT					
	Text overlapping text	Yes	No	Shape of feature	Yes	No
	Text overlapping features	Yes	No	Left to right	Yes	No

2.	FIGURE GROUND					
2.1	FAMILIARITY					
	Corner graticule intersections	Yes	No	Surrounding information	Yes	No
	Co-ordinates on border	Yes	No	Base Map information	Yes	No

2.2	DELINEATION					
	Line symbol	Yes	No	Brightness	Yes	No
	Areal symbol	Yes	No	Articulation	Yes	No
	Closed form	Yes	No	Placement with respect to the		
	Good contour	Yes	No	optical center	Yes	No

2.3	FIGURE-GROUND RATIO	

3	HIERARCHICAL ORGANISATION														
3.1	ENCODING: GRAPHIC ELEMENTS USED TO DIFFERENTIATE BETWEEN BASE MAP SYMBOLS														
	MAP SYMBOL TYPE AND NUMBER														
	Size														
	Colour														
	Value														
	Shape														
	Spacing														
	Orientation														

3.2	ENCODING: GRAPHIC ELEMENTS USED TO DIFFERENTIATE BETWEEN BASE MAP SYMBOLS AND THEIR BACKGROUND														
	MAP SYMBOL TYPE AND NUMBER														
	Size														
	Colour														
	Value														
	Shape														
	Spacing														
	Orientation														

4.	VISUAL CONTRAST ENCODING														
	GRAPHIC ELEMENTS USED TO DIFFERENTIATE BETWEEN THEMATIC SYMBOLS AND THEIR BACKGROUND														
	MAP SYMBOL TYPE AND NUMBER														
	Size														
	Colour														
	Value														
	Shape														
	Spacing														
	Orientation														

5.	VISUAL BALANCE		
	Logical Positioning	Yes	No
	Placement at optical centre	Yes	No
	Visual weighting at optical center	Yes	No
	PROPORTION OF MAPPED AREA		

6	ADDITIONAL MAP ELEMENTS					
	MAP PROJECTION					
	CLASS:			ASPECT:		
	Location considered	Yes	No	Shape of area	Yes	No
	Geographic extent	Yes	No	Purpose	Yes	No