Chapter 8
Establishing South Africa's Current Water Quality Risk Areas

South Africa developed its National Water Policy underpinned by integrated water resource management. International good practice was recommended and followed which resulted in the decentralisation of water management and the establishment of water management institutions which are based on hydrological instead of political boundaries. Nineteen Water Management Areas (WMA) were established with envisaged establishment of a Catchment Management Agency (CMA) for each. This was subsequently decreased to nine as concerns were raised regarding the capacity of the country to manage and support 19 CMAs.

For the purpose of this book, water quality data of selected physical, chemical and biological water quality parameters were obtained from Department of Water and Sanitation: Resource Quality Services Department which were consequently structured, validated and analysed. Four risk categories were developed to classify and establish water quality risk areas for each WMA.

8.1 Brief Background to South Africa's Water Management Areas

South Africa developed its National Water Policy for South Africa (1997) and the National Water Act (Act 36 of 1998) through extensive public participation as well as international expertise and advice, underpinned by integrated water resource management. This resulted in the recommendation to follow international good practice through the decentralisation of water management and the establishment of water management institutions which are based on hydrological instead of political boundaries. The country proceeded to develop the National Water Resource Strategy in 2004 which led to the development of 19 Water Management Areas (WMAs) as well as the envisaged establishment of a Catchment Management Agency (CMA) for each (DWS 2016). Concerns were raised regarding the capacity of the country to

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manage and support 19 CMAs and a decision was consequently made to reduce the number to nine (Fig. 8.1).

The development of CMAs was drawn from international experience which identifies multiple key drivers for catchment-based management of water resources. The main needs identified for the establishment of CMAs included:

- Achieving integrated management of a catchment;
- Facilitating stakeholder participation in decision-making and management of water resources; and
- Separating policy and national strategy functions of the Ministry/Department and the operational functions of the CMA.

It should be noted that these WMA boundaries do not correlate with South Africa's administrative boundaries. Factors that were taken into consideration were institutional efficiency, the financial self-sufficiency of the water consumers, the centres or locations of economic activity, social development patterns, the distribution of water resource infrastructures, and lastly, the centres of water-related expertise for future assistance (DWAF 2004).

The DWS has however recently announced that it is aiming to dissolve or merge the nine CMAs into a single CMA however this is still being considered and under discussion.

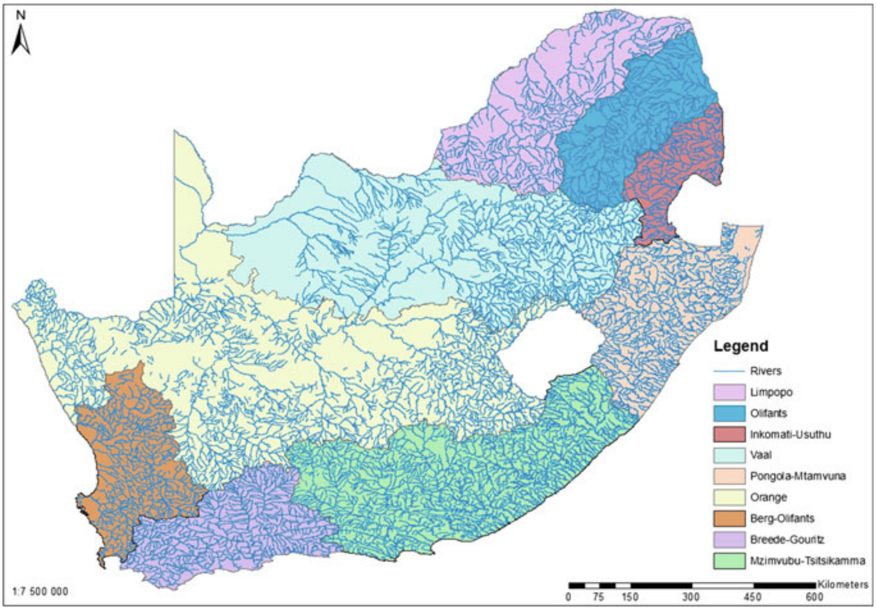

Fig. 8.1 South Africa's nine WMAs (RSA 2016)

8.2 Establishing South Africa's Water Quality Risk Areas

For the purpose of this book, water quality data were collected for the nine WMAs which were established in 2016. Water quality data were collected for the period of July 2011–June 2017 from the DWS: Resource Quality Services. Water quality data were still grouped under the previous 19 WMAs and were consequently consolidated and grouped into the nine WMAs. The types of water quality sampling stations included

- Dams/barrages;
- Rivers;
- Springs/eyes;
- Wetlands;
- Estuaries/lagoons; and
- Wastewater treatment works (WWTWs).

Collected water quality data were structured and validated. The water quality data obtained from the water quality sampling points were measured monthly, weekly and, in some cases, daily throughout the year, but at no scheduled time and on no fixed day or week. An overall average for the mentioned period was calculated for each of the water quality parameters used at each station.

Some sampling stations were excluded due to inadequate data recordings. Sampling stations were therefore excluded in the case of the station having recorded less than four measurements within a year. Some water quality sampling stations were also not included in this research due the station having measured less than four parameters with less than four recorded measurements within a year. The "Four by Four" (4 × 4) rule was therefore followed as recommended by the Canadian Council of Ministers for the Environment. This rule ensures that only sampling stations that regularly monitor the relevant parameter are included and eliminates stations that have only three monitoring phases per year. The evaluation was therefore limited to these sampling stations which had adequate replication in an attempt to ensure high quality data and representation.

A total of 2,438 water quality sample stations were included in the evaluation in terms of physical and chemical water quality parameters. Only 318 water sample stations measured *Chlorophyll a* and 1,619 water quality sample stations measured *Faecal coliform* levels (Figs. 8.2, 8.3 and 8.4).

In terms of water quality parameters, there is no single parameter that can be used to describe the overall water quality for any water body. A wide variety of water quality parameters can and should be used to obtain a holistic and accurate view of a water body's water quality in terms of environmental and human health (UNEP 2007). Water quality parameters were selected according to the following rules:

- The water quality parameter needs to have available national water quality indices or guidelines.
- The water quality parameter must have been commonly measured and reported by the DWS water quality sampling stations.

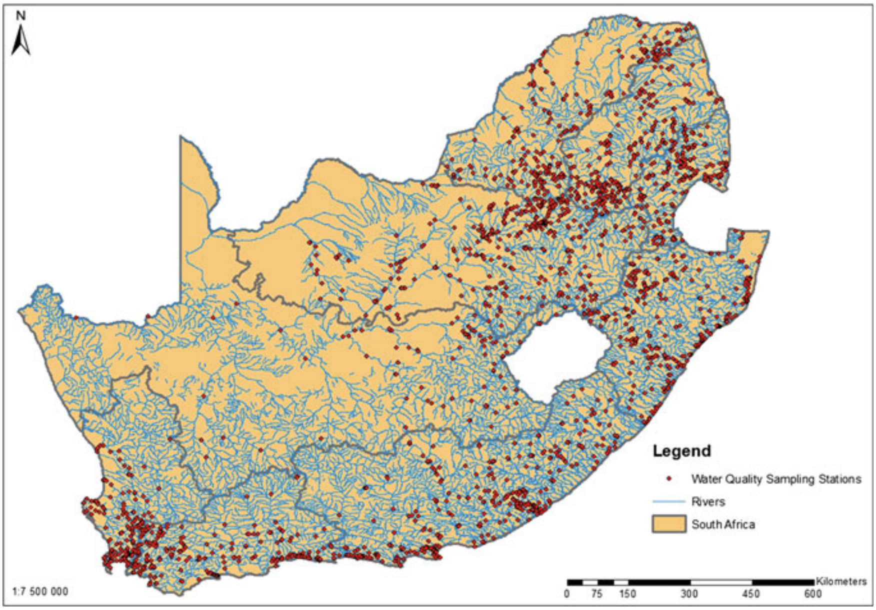

Fig. 8.2 Evaluated physical and chemical water quality parameter sample stations

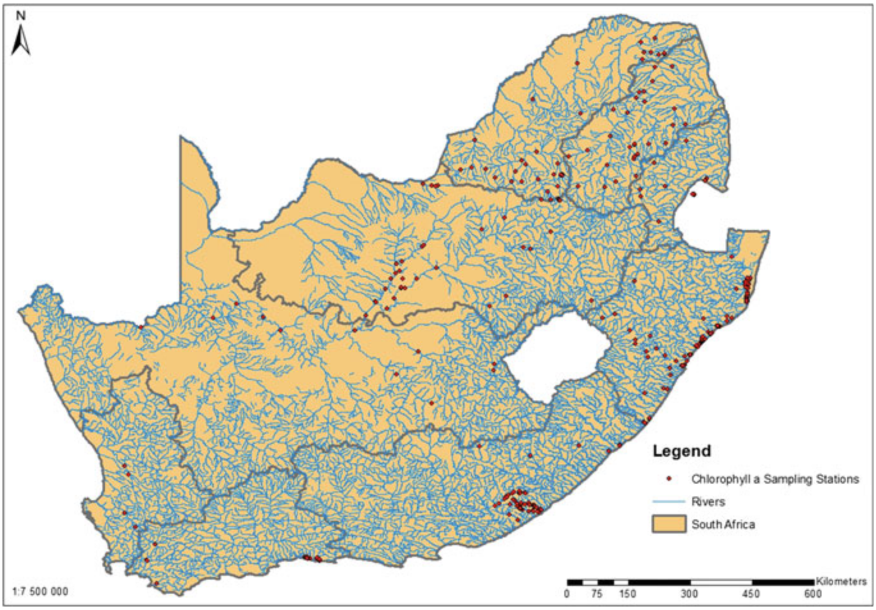

Fig. 8.3 Evaluated *Chlorophyll a* sample stations

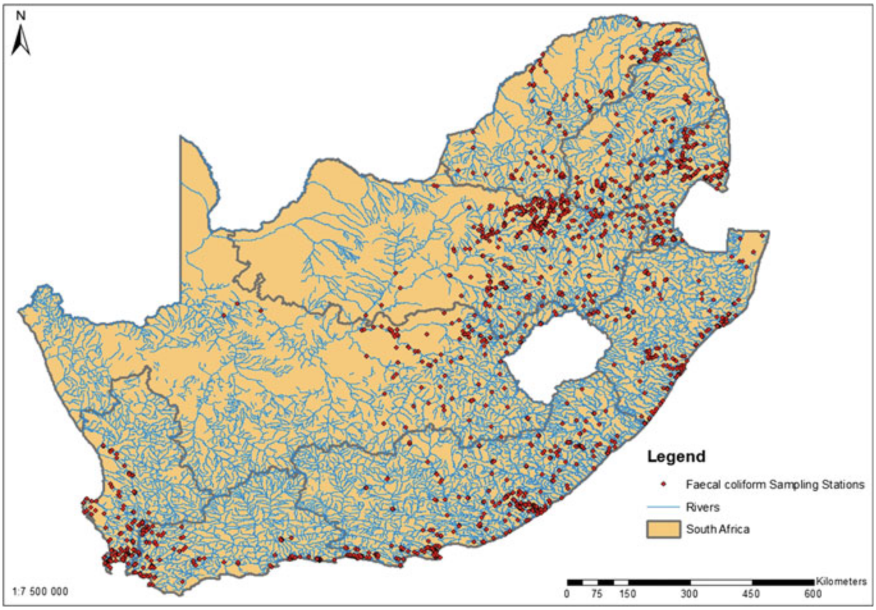

Fig. 8.4 Evaluated *Faecal coliform* sample stations

- The water quality parameter needs to have a representation percentage of a minimum of 80% (50% in the case of biological parameters).
- Water quality parameters which are characterised by the occurrence or measurement of non-detectable values needs to be excluded due to the possibility of bias.

South Africa's National DWS water quality guidelines for the following water uses were used for the selected water quality parameters:

- Domestic use,
- Aquatic Ecosystems,
- Irrigation, and
- Industrial use.

Subsequently a total of 11 water quality parameters[1] were selected included the following:

- *Physical parameters*: pH and Electrical Conductivity (EC);
- *Chemical parameters*: Calcium, Chloride, Sodium, Ammonia (NH_4), Nitrates (NO_3), Phosphate (PO_4) and Sulphate (SO_4); and
- *Biological/Microbiological parameters*: *Chlorophyll a* and *Faecal coliform*.

All of the selected water quality parameters had relevant domestic use water quality guidelines. In terms of the other water use water quality guidelines, not all

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[1] For reference, the water quality guidelines and standards for each of the identified water quality parameters are listed in Appendix.

of the selected water quality parameters had a guideline. Only chloride, ammonia, nitrate and phosphate had applicable water quality guidelines in terms of Aquatic ecosystems. pH, EC, chloride, sodium, ammonia and nitrates had applicable water quality guidelines for irrigation use and lastly pH, EC, chloride and sulphate had applicable water quality guidelines in terms of industrial use.

In terms of Microbiological/Biological water quality parameters the following water quality standards were used as not all of the mentioned water uses have guidelines. Domestic use and aquatic ecosystems water quality guidelines were used for *Chlorophyll a*, and domestic use and irrigation water quality guidelines were used for *Faecal coliform*.

To ultimately establish water quality risk areas, for the purpose of this book, four risk categories were developed. These risk categories included the following:

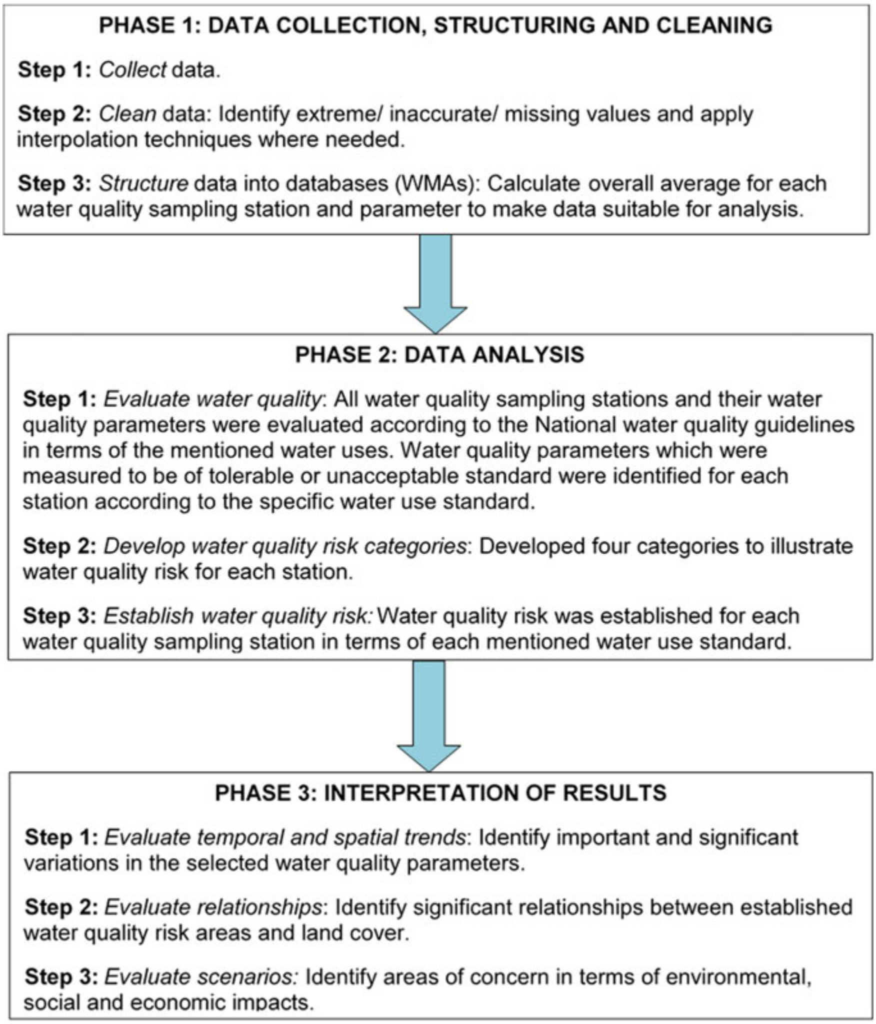
- 0—No-Risk Area (All water quality parameters are of ideal to acceptable standard);
- 1—Low-Risk Area (One or two water quality parameters are of tolerable to unacceptable standard);
- 2—Medium-Risk Area (Potential Future Risk Area—50% of water quality parameters are of tolerable to unacceptable standard); and
- 3—High-Risk Area (Majority >80% of water quality parameters are of tolerable to unacceptable standard).

The most up to date land cover dataset (2013/2014) were also obtained from South African National Biodiversity Institute (SANBI) to assist in establishing main causes for the established water quality risk areas and possible consequences thereof.

To ultimately achieve the establishment of South Africa's water quality risk areas, the research procedure was differentiated into three phases. These phases, with their main steps or actions, are presented in Fig. 8.5.

Some shortcomings in the water quality data were identified and included the following. Some water sampling stations contained some gaps and inconsistencies in the form of missing values or extreme values. Linear interpolation was used to reprocess the data in order to fill in some of the missing parts in the data. Table 8.1 presents the important sources of uncertainty concerning water quality data. Not all of these uncertainties as listed in table were applicable or relevant. Instrument errors were found to have been relevant as extreme values were present. These measurements were consequently identified as extreme values, were removed and replaced by an interpolated value. Furthermore, the variation in sampling frequency was also identified as an uncertainty as the sampling frequency differed between some water quality sampling stations. This uncertainty was addressed by structuring the data in a uniform way through the calculation of an overall average.

Some missing values were present in this data range. These gaps or missing values could be attributed to the following. First, the instruments used for measuring the quality of the water could break down or become faulty and could therefore register inaccurate measurements. It proved to be a lengthy process to repair the instruments as in most cases parts needed to be ordered from overseas. Much time passed before these parts arrived in the country and could be installed.



PHASE 1: DATA COLLECTION, STRUCTURING AND CLEANING

Step 1: *Collect* data.

Step 2: *Clean* data: Identify extreme/ inaccurate/ missing values and apply interpolation techniques where needed.

Step 3: *Structure* data into databases (WMAs): Calculate overall average for each water quality sampling station and parameter to make data suitable for analysis.

PHASE 2: DATA ANALYSIS

Step 1: *Evaluate water quality*: All water quality sampling stations and their water quality parameters were evaluated according to the National water quality guidelines in terms of the mentioned water uses. Water quality parameters which were measured to be of tolerable or unacceptable standard were identified for each station according to the specific water use standard.

Step 2: *Develop water quality risk categories*: Developed four categories to illustrate water quality risk for each station.

Step 3: *Establish water quality risk:* Water quality risk was established for each water quality sampling station in terms of each mentioned water use standard.

PHASE 3: INTERPRETATION OF RESULTS

Step 1: *Evaluate temporal and spatial trends*: Identify important and significant variations in the selected water quality parameters.

Step 2: *Evaluate relationships*: Identify significant relationships between established water quality risk areas and land cover.

Step 3: *Evaluate scenarios:* Identify areas of concern in terms of environmental, social and economic impacts.

Fig. 8.5 Phases in the research procedure and their main actions

As a result of the complexities of the data, a heuristic approach was used in addition to the above-mentioned statistical approaches, with the main focus being on assessing the outcome of the linear interpolation, which had been completed. This approach was also necessary for data reflecting unrealistic values. An example illustrating the application of incorrect data can be quoted in the case of pH values of 17 and 18 that were measured at some water quality sampling points, all of which were clearly incorrect. Interpolation was required in such cases and consequently carried out.

Table 8.1 Most important uncertainties in water quality data (van Loon et al. 2005; Rode and Suhr 2007)

Field instruments	Sampling location	Representative sampling	Laboratory analysis	Load calculation
Instrument errors	Mixing of large tributaries	High spatial variation within cross section	Sampling conservation	Sampling frequency
Instrument calibration errors	Point source inputs	High temporal variation (due to point source inputs and flood events)	Sample transport	Sampling period
	Impoundments and dead zones	Sampling volume	Instrument errors	Choice of extrapolation method
		Sampling duration	Laboratory-induced uncertainties	

Lastly, the method used in the collection and chemical analysis of the water quality samples could also be regarded as a shortcoming. According to Davies and Day (1998), this type of chemical analysis is unsatisfactory as, although it provides accurate measurements in terms of the quantity of the selected individual substances present in the water body, it only takes the water that flows past a specific point into account at the time of collection. Thus, although these water quality samples were collected throughout a 24-h period in order to calculate the average monthly readings for the specific water quality parameter, the data were still only collected once a month and represented by a single average value (Davies and Day 1998).

Davies and Day (1998) concluded that such readings may be subjective to a particular degree of inaccuracy as variations within these measured concentrations of the selected water quality parameter can fluctuate significantly over the period of a month.

Shortcomings were also identified regarding the use of national land cover data. These included possible inaccuracies. A logical error test was consequently completed through the completion of a sensitivity analysis to establish whether significant errors were present. Very few errors were, however, identified through this testing process. Errors were corrected when necessary. Mixed classes or classification structure is also a recognised limitation of land use data. Mixed classes or classification structure was not a limitation due to the use of a hierarchical classification design namely the "Standard Land Cover Classification Scheme for Remote Sensing Applications in South Africa" (Burrough 1990; Liou et al. 2004; Longley et al. 2005).

Lastly, the land cover dataset is but a single "snapshot" of a period in time. Owing to the dynamic nature of the land cover and land use, this issue also needs to be taken into account when identifying patterns and making conclusions.

The nine WMAs have been divided into regions and three chapters. Chapter 9, the northern region which includes the Limpopo, Olifants and the Inkomati-Usuthu WMAs. Chapter 10, the central region, which includes the Vaal, Pongola-Mtamvuna and Orange WMAs and lastly Chap. 11, the southern region, which includes the Berg-Olifants, Breede-Gouritz and Mzimvubu-Tsitsikamma WMAs.

These chapters will give a brief overview for each WMA in terms of its main characteristics as well as the location and amount of water quality sampling points. This will be followed by the evaluation of water quality risk areas based on the mentioned national water quality guidelines, i.e. domestic use, aquatic ecosystems, irrigation as well as industrial use in terms of the selected physical and chemical water quality parameters. Each WMA will also be evaluated in terms of establishing main risk areas for *Chlorophyll a* according to domestic use and aquatic ecosystem water quality standards and *Faecal coliform* according to domestic use and irrigation water quality standards. The main water quality issues will also be discussed for each of the WMAs. The results for each of the nine WMAs now follow in the following three chapters through detailed discussions and evaluations.

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