CITY OF CAPE TOWN
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# WATER QUALITY OF RIVERS AND OPEN WATERBODIES IN THE CITY OF CAPE TOWN:

# STATUS AND HISTORICAL TRENDS, WITH A FOCUS ON THE PERIOD APRIL 2015 TO MARCH 2020

FINAL

AUGUST 2020

**TECHNICAL REPORT**


**PREPARED BY**

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Making progress possible. Together.

## FOREWORD

The City has committed itself, in its new Water Strategy, to become a Water Sensitive City by 2040. A Water Sensitive City is a city where rivers, canals and streams are accessible, inclusive and safe to use. The City is releasing this Technical Report on the quality of water in our watercourses, to promote transparency and as a spur to action to achieve this goal.

While some of our 20 river catchments are in a relatively good /near natural state, there are six catchments with particularly serious challenges. Overall, the data show that we have a long way to go to achieve our goal.

Where this report has revealed areas of concern, the City commits to full transparency around possible causes which need to be addressed from within the organization, however we request that residents always keep in mind the role they have to play, and take on their share of responsibility for ensuring the next report paints a more favourable picture. It is in all of our interests.

On the City's side, efforts to address water pollution are being intensified. We have drastically stepped up the upgrading of wastewater treatment works, assisted by loan funding, and are constantly working to reduce sewer overflows, improve solid waste collection/cleansing, and identify and prosecute offenders. Planning processes are also being revised to provide incentives for design features such as integration of stormwater with water reuse and conservation, reducing stormwater runoff and improving water quality through use of Sustainable Urban Drainage System best practises in developments which will contribute to the formation of attractive and safe Liveable Urban Waterways.

However, we can only achieve our goal in partnership with you, Cape Town's citizens. All of us, as citizens, contribute to the pollution of Cape Town's rivers, through our daily activities of keeping clean and through what we buy, throw away, and flush into the sewer or stormwater systems.

The expansion of wastewater treatment capacity and improvements in technology/design over the previous century have made a big impact in preventing ecological degradation, but often municipal wastewater treatment processes are handicapped by chemicals that people in our City illegally pour down the drain or flush down the toilet. Rainfall also washes pollutants from the urban environment into stormwater drains and into the rivers, including from sewers which have overflowed due to disposal of foreign objects. Irresponsible agricultural practices contribute nutrients such as phosphorus and nitrogen, encouraging aquatic plant growth and reducing the availability of oxygen for aquatic organisms. Ongoing land invasions can also create challenges, for instance by blocking the City's access to its infrastructure for maintenance and, in cases where invasions take place in floodplains, contributing to further degradation of our watercourses and wetlands.

These difficulties are ubiquitous throughout the world. While infrastructure upgrade programmes, stricter laws and enforcement, and improved incident responses are no doubt part of the solution, these on their own cannot be completely effective against the tidal wave of pollution generated by modern society. This is especially true in a developing country. Fostering a culture where Cape Town's communities feel a sense of collective ownership of and responsibility towards the wetlands, rivers and canals in their urban environment, and are aware of their role in properly managing this pollution, is arguably even more crucial in our efforts to restore our waterways to a state we can all be proud of.

As such, it is hoped that this report spurs civic organizations, businesses and the communities they represent to join the City to help us revolutionize the way residents think about the urban water cycle (natural surface water, potable water, sewage and stormwater systems), and assist with rehabilitating our rivers. We have already formed working relationships with a number of organizations linked to river health which are showing promising results in their efforts to care for waterways in their neighbourhoods. Much more of these initiatives are however necessary before we will be able to turn around water quality. Dumping into sewers, disposal of toxic chemicals into wastewater streams and polluting urban waterways should become taboo in the same way that littering is in most communities.

The City will continue to monitor and publish data on water quality in our waterways, so that we can measure progress towards our goal. We are committed to making this data more accessible to the public and more easily available to researchers. The recommendations made in this Technical Report on improvements to sampling processes (what is sampled, where, and when) will be implemented as appropriate and as resources allow. The significance of the data contained herein will be explained less technically in a summary document currently under development for release to the general public.

**Michael John Webster**

Executive Director Water and Waste

City of Cape Town

# EXECUTIVE SUMMARY

## E1 Introduction

### *E1.1 Background*

The quality of water in urban watercourses is perhaps one of the best indicators of the efficacy of a range of management activities in a city, reflecting the degree of containment of sources of contamination from both widespread land use and specific activities generating point source pollution streams. The implications of poor water quality can also be profound, cutting across a broad range of user sectors, including human health, sewer and stormwater infrastructure, tourism, recreation and biodiversity.

It is against this backdrop that the City of Cape Town ("the City") implements its inland water quality monitoring programme on a range of rivers and water bodies across the municipal area, with the City's Scientific Services Branch undertaking monthly water quality monitoring of rivers and wetlands/vleis of particular concern. This results in the generation of large volumes of data, requiring collation and analysis in order to provide meaningful information to City managers and other interested parties about the state of the City's watercourses, to inform management.

In 2020, the City contracted Liz Day Consulting (Pty) Ltd to prepare the 2019 Inland Water Quality Technical Report for inland aquatic ecosystems and estuaries (i.e. the current report), including an analysis of all historic water quality data collected up to the end of March 2020.

### *E1.2 Report structure*

The main body of the report was structured as follows:

- Section 1: General Introduction;
- Section 2: Background to the City's water quality monitoring programme and datasets; an outline of the proposed approach in this assessment, including the selection of variables for assessment in this study; setting of targets for different variables; an outline of analytical tools, methods, assumptions and basic interpretation guidelines;
- Section 3: Consideration of rainfall data from sites within the City, to illustrate rainfall seasonality and patterns in annual rainfall that might have some bearing on water quality in the City's watercourses;
- Section 4: Presentation of the assessment of long-term and current water quality data for river, stormwater and standing water sites across the City, presented at a sub-catchment level and discussed in terms of each of the key variables selected;
- Section 5: Presentation of water quality data pertaining to the condition of the key recreational vleis in the City, with regard to water quality risks to human health;
- Section 6: Summary of the main issues affecting water quality in each subcatchment;
- Section 7: Conclusions and recommendations for further monitoring;
- Appendices: These include a list of sites for which data have been accessed for this report; a brief review of the information used to inform decision-making around selection of variables and defining thresholds of acceptability; and detailed data tables showing summary (annual and seasonal) data for each of the key variables selected, for each site, for each year between April 2015 and March 2020. The CVs of the main report authors are included in the appendices.

| |
|---|
| This Executive Summary reflects on the most important findings and recommendations of this report only. The reader is referred to the main report for detailed analyses, graphs and explanations of important biological and chemical processes affecting and affected by water quality, and for discussion about individual watercourses and sites. |

### *E1.3 Overview of watercourses in the City of Cape Town*

The City lies in the Berg-Olifants Water Management Area, which extends north to include both the Berg and the Olifants River catchments, as well as the smaller natural catchments within the City's boundaries. The latter comprise the following, shown in **Figure E1**

- Diep River
- Eerste River
- Salt River
- Hout Bay (or Disa) River
- Lourens River
- Noordhoek Basin
- Sand River
- Silvermine River
- Sir Lowrys Pass River
- Sout River
- South Peninsula Rivers (this "catchment" in fact includes several discrete river catchments (e.g. Bokramspruit, Schusters and Else Rivers), grouped together in the City's stormwater system for ease of administration and referred to as such in this report).

In addition to the above natural river catchments, there are a number of areas where no rivers flowed under natural conditions. In these areas, which include the Cape Flats and parts of Atlantis, rainfall would rather have percolated through deep dune sands to the underlying aquifer, and seeped through to the coast in places. With catchment hardening associated with urbanization, such infiltration is no longer possible and instead, runoff is channelled or piped to coastal outlets or conveyed into other systems. Thus artificial catchment areas and in some cases "rivers" were created – e.g. the Little and Big Lotus Rivers, the Zeekoe canal and the Soet River. Areas where artificial rivers / open canals have been created, effectively resulting in new river catchment areas have been added to the above catchments, as follows:

- Zeekoe catchment - including the Big and Little Lotus Rivers, and Zeekoevlei outlet;
- Soet catchment.

Under natural conditions, at least twelve of these catchments would have culminated in estuaries or coastal lagoons, namely the Sout, Diep (which probably joined with the Salt River in its estuarine wetland reaches), Hout Bay, Wildevoelvlei, Bokramspruit, Schuster, Silvermine, Zandvlei, Eerste, Lourens and Sir Lowry's Pass River estuaries. Many of these estuaries today have lost all natural function, with their river outlets having been converted into concrete canals (e.g. the Salt and Sir Lowry's Pass Rivers) with none of the salt flux and tidal exchange necessary to meet the criteria for an estuary. Zandvlei and the Diep River Estuary are the only remaining systems that, despite significant levels of impact, particularly in terms of natural salinity, retain real estuarine functionality. The Eerste River Estuary has been severely impacted by large volumes of low salinity waste water discharges, and the Lourens River and Silvermine River estuaries have been impacted by urban development and (in the case of the former) significant upstream abstraction.

### *E1.4 The City of Cape Town's Inland Water Quality Monitoring Programme*

Today, the City's stormwater management system, which manages surface runoff across the City, includes:

- 16 630 kilometres of pipes and culverts;
- 890 detention ponds;
- 236 stormwater treatment wetlands;
- 1 910 kilometres of rivers and streams;
- 4164 "natural and semi natural" wetlands, including "vleis" and estuaries.

The City has collected various kinds of water quality data relating to its watercourses, with the data record in some cases going back to the late 1970's. This has generated an extensive historic database of sites that represent water quality in main rivers and stormwater or effluent outflows into watercourses, as well as key wetlands, dams and detention ponds: These amount to a total of 242 sites, made up of 13 canal sites; 7 artificial dam / impoundment sites; 2 detention ponds; 2 effluent outlet channels; 2 estuary sites, 158 river sites; 5 stormwater outlets and 53 vlei / standing water wetland sites.

Of this historical dataset, some 174 sites are currently monitored, with the City collecting water samples from these on a monthly basis, for analysis by the Scientific Services Branch at its water quality testing laboratories in Athlone.

The extensive Mitchell's Plain area, which is drained by stormwater pipes that discharge into the sea from coastal outlets, has no natural or artificial open channel system. It is however an important subcatchment, which generates large volumes of runoff from hardened urban areas. Two stormwater attenuation pond sample sites were thus included in this study to represent surface water quality in this subcatchment.

It should also be noted that not every catchment in the City is represented in the monitoring programme. Some catchments that are not considered problematic from a water quality perspective (e.g. minor rivers along the Atlantic seaboard); or which do not have significant river systems (e.g. the Atlantis subcatchment) or where natural rivers have been almost entirely piped into the stormwater system (e.g. the City Bowl) do not have any monitoring sites.

### *E1.5 Objective of the City's monitoring programme*

The City's water quality monitoring programme is structured around the collection of data that provide information about watercourses where water quality is a likely cause for concern. Thus many of the monitoring points are downstream of Waste Water Treatment Works (WWTW) effluent discharge points, and in river reaches in catchments where runoff is likely to be contaminated. Some sampling points are located in watercourses that are used for recreational purposes, and are thus used to provide information as to the fitness for use of these systems.

### *E1.6 Selection of water quality variables for analysis in this document*

Although the City monitors a number of physical, chemical and microbiological variables, only the following key variables were analysed in the report (abbreviations used in this report bracketed):

- pH;
- Electrical Conductivity (EC) – as a measure of salinity;
- Major nutrients – orthophosphate (PO4-P); total phosphorus (TotP); Total Inorganic Nitrogen (TIN) – these indicate issues such as eutrophication and the likelihood of algal blooms in standing water bodies;
- Un-ionised (or "free") ammonia nitrogen (NH3-N) – this can be toxic to aquatic organisms at even very low concentrations;
- Dissolved oxygen (DO) – this indicates organic pollution (when low) and is an essential component of healthy aquatic ecosystems;
- *Escherichia coli* bacteria (*E. coli*) – this is an indicator of the presence of faecal material from warm blooded animals and in urban areas can indicate sewage pollution;
- Microcystin toxins – this is a measure of the toxicity of a *Microcystis* algal bloom, to humans and other mammals (e.g. pets / livestock) that might drink or otherwise be exposed to it;
- Chlorophyll-*a* – this is a measure of nutrient enrichment and indicates plant (algal) productivity.

### *E1.7 Rainfall data*

Rainfall data were sourced from the most reliable accessible long-term rainfall datasets, and used to inform discussions around rainfall-related variability in water quality trends. The data showed a marked reduction in rainfall in the City over the period 2016 - 2018 with 2017 - 2018 being the year with the lowest rainfall during the 20-year period of analysis.

The data also confirmed that the assignment of seasons used in the project (October to March being summer and April to September being winter), very clearly also reflect a "dry season" (summer) and a "wet season" (winter) and could thus be used to aid interpretation of the results of the water quality data analyses.

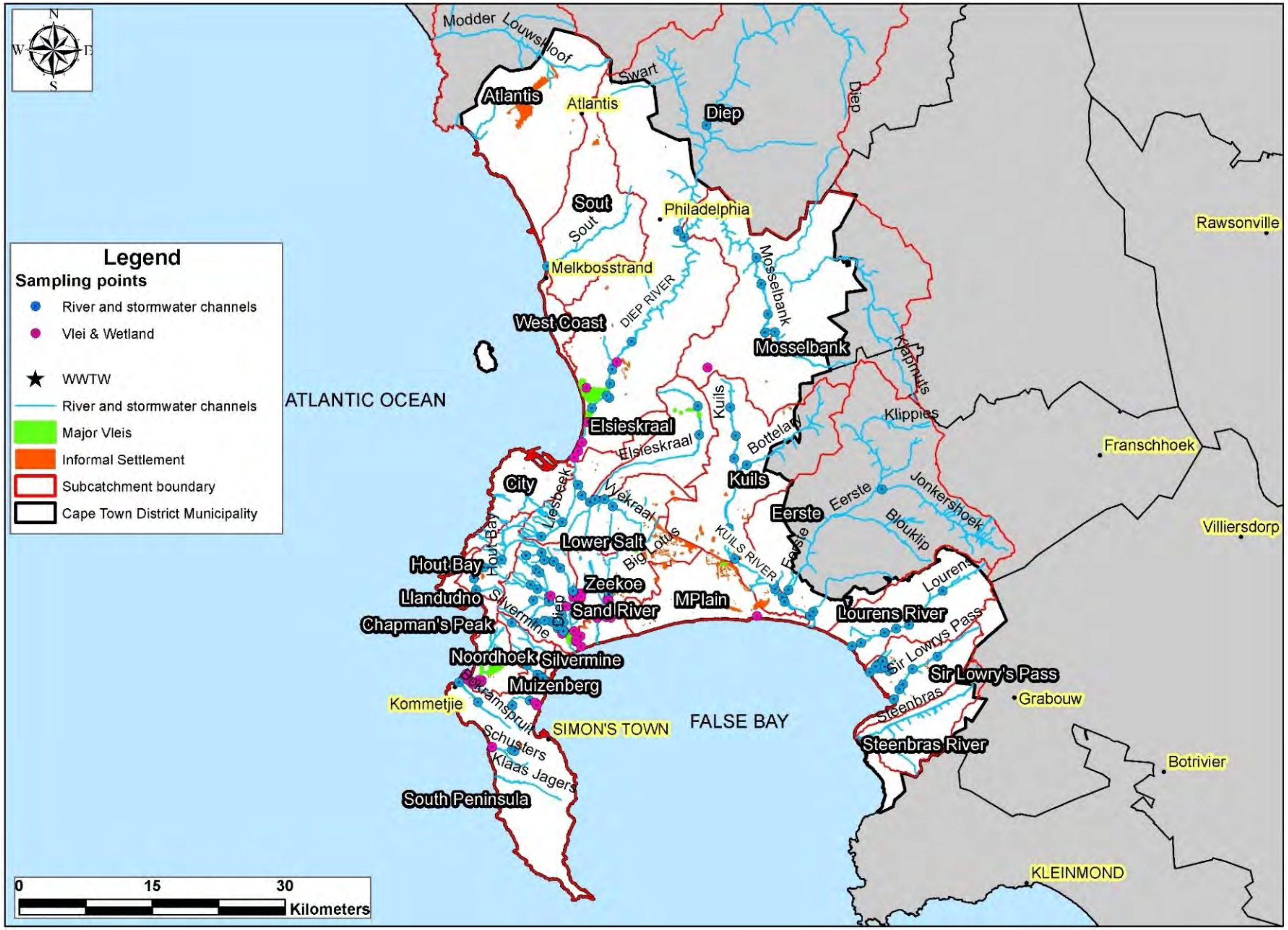


**Figure E1**
**Main rivers and major subcatchments in the City of Cape Town**

### *E1.8 Recommended thresholds to guide interpretation in this study*

In order to guide the interpretation of water quality data in a relatively simple and user-friendly manner, different ranges in concentration were identified for each selected water quality variable, and categorised, where possible, into between three and four water quality categories, ranging from Target (Incorporating "Good" and "Fair" categories, to "Poor" and then "Unacceptable". This categorical approach follows established national procedures commonly used in the assessment and reporting of inland water quality. Flowing water (i.e. river, canal and channel) systems are somewhat less sensitive to elevated nutrient concentrations than standing water systems (i.e. vleis, lakes and detention ponds). Thus the actual data ranges assigned to each category differed for some variables between these systems. **Tables E1** and **E2** present these ranges, which were based on national criteria and, where relevant, those used in the draft Berg Resource Quality Objectives study, which includes the City catchments.

Human health risk ratings for *Escherichia coli* (microbiological) data were also based on those used in the Berg Resource Quality Objectives study, adapted to identify examples of extreme exceedance of these thresholds (as developed by the City in routine reporting ), while microcystin toxin thresholds were based on WHO guidelines (see **Table E3 and E4**, respectively). The ratings include both standards for acceptable full contact recreation (i.e. swimming) and intermediate contact recreation (e.g. canoeing, sailing) for *E. coli.* Note that the City in fact does not recommend full contact use in any of its water bodies, other than designated swimming areas.

**Table E1**
**Rating ranges for water quality variables in City rivers**
Note: PO4-P = orthophosphate phosphorus; TIN=Total inorganic Nitrogen; DO=Dissolved oxygen; N:P= ratio of TIN:PO4-P; NH3-N = nitrogen in un-ionised ammonia. Note also that the terms "PO4-P", "NH3-N" are abbreviations and are not the full chemical notation for these ionic compounds.
See main report for dicussion of the various nutrient "trophic levels" – mesotrophic etc

<table>
<tr><th>City Water Quality Categories (CWQC)</th><th>Interpretation of CWQC</th><th>PO4-P mg/l</th><th>TIN mg/l</th><th>DO mg/l</th><th>N:P</th><th>NH3-N mg/l</th></tr>
<tr><td>GOOD</td><td rowspan="2">TARGET</td><td>≤ 0.025 (oligotrophic)</td><td>≤ 0.70 (oligotrophic - mesotrophic)</td><td rowspan="2">> 6</td><td rowspan="2">>25</td><td>≤ 0.044</td></tr>
<tr><td>FAIR</td><td>>0.025-- 0.075 (mesotrophic)</td><td>>0.70-1.75 (mesotrophic)</td><td>>0.044 -0.072</td></tr>
<tr><td>POOR</td><td>POOR</td><td>>0.075- 0.125 (eutrophic)</td><td>>1.75-3.00 (mesotrophic -eutrophic)</td><td>≥4 -6</td><td>10-25</td><td>>0.072-0.1</td></tr>
<tr><td>UNACCEPTABLE</td><td>UNACCEPTABLE</td><td>>0.125 (hypertrophic)</td><td>> 3.00 (eutrophic - concentrations > 10mg/L classified as hypertrophic)</td><td>< 4</td><td>< 10</td><td>>0.1</td></tr>
</table>

**Table E2**

**Rating ranges for water quality variables in City Vleis and Dams**

Note: $PO_4$-P = orthophosphate phosphorus; TIN=Total inorganic Nitrogen; DO=Dissolved oxygen; N:P= ratio of TIN:PO4P; $NH_3$-N = nitrogen in un-ionised ammonia; CHL-A= Chlorophyll-*a*. Note also that the terms "PO4-P", "NH3-N" are abbreviations and are not the full chemical notation for these ionic compounds.
See main report for dicussion of the various nutrient "trophic levels" – mesotrophic etc

| **City Water Quality Categories (CWQC)** | **Interpretation of CWQC** | **PO4-P** mg/l | **TIN** | **DO** mg/l | **N:P** | **NH3-N** mg/l | **RUNNING MEAN ANNUAL CHL-A** µg/l |
|---|---|---|---|---|---|---|---|
| **GOOD** | **TARGET** | ≤ 0.005 (oligotrophic) | ≤ 0.7 | > 6 | >25 | ≤ 0.044 | ≤ 10 |
| **FAIR** | | >0.005-- 0.015 (mesotrophic) | >0.7 -1 | | | >0.044 - 0.072 | >10 -20 |
| **POOR** | **POOR** | >0.015 - 0.025 (eutrophic) | >1.0-4.0 | ≥4 -6 | 10-25 | >0.072-0.1 | > 20 - 30 |
| **UNACCEPTABLE** | **UNACCEPTABLE** | >0.025 (hypertrophic) | > 4 | < 4 | <10 | >0.1 | > 30 |

**Table E3**

**Approach to assessment of microbial data (faecal coliforms including *Escherichia coli*)**

Note inclusion of Full Contact and Intermediate Contact thresholds and expansion of UNACCEPTABLE range to show different scales of pollution

| **Interpretation** | **[1]Faecal Coliform Count (*Including E. Coli)*[1]** |
|---|---|
| **TARGET FOR MAXIMUM ACCEPTABLE RISK FOR FULL CONTACT RECREATION** | **≤ 400 CFU/100 ml ** |
| **ACCEPTABLE RISK INTERMEDIATE CONTACT** | **≤ 2500 CFU/100 ml** |
| **TOLERABLE RISK - INTERMEDIATE CONTACT** | **> 2500-4000 CFU/100 ml** |
| **UNACCEPTABLE RISK - INTERMEDIATE CONTACT– LEVEL 1** | **> 4000 – 10 000 CFU/100 ml** |
| **UNACCEPTABLE RISK - INTERMEDIATE CONTACT– LEVEL 2** | **> 10 001 -100 000** |
| **UNACCEPTABLE RISK - INTERMEDIATE CONTACT– LEVEL 3** | **> 100 000** |

**Table E4**

**Water quality grades and corresponding threshold concentrations for microcystin toxins for inland waters adopted for this project.**

| **Interpretation** | **Microcystin Toxin Concentration** |
|---|---|
| **TARGET (ACCEPTABLE)** | **≤ 20 µg/L** |
| **MEDIUM RISK (UNACCEPTABLE)** | **>20- 30 µg/L** |
| **HIGH RISK (UNACCEPTABLE)** | **>30-40 µg/L** |
| **EXTREME RISK (UNACCEPTABLE)** | **>40 µg/L** |

# E2 Trajectories of change and current status of water quality in the City's watercourses

## *E2.1 Changes in salinity (Electrical conductivity)*

Electrical conductivity (EC) is a measure of the amount of dissolved inorganic ions (salts) in water (usually measured in mS/m), and thus also provides a measure of water salinity. Analysis of data showed that EC was higher in almost all of the assessed City's subcatchments than likely under natural conditions. The main reasons for raised EC were assumed to relate to inputs of sewage effluent, stormwater runoff from increasingly urbanised catchments and agricultural runoff from the more rural parts of the City (e.g. in the upper Elsieskraal and Mosselbank subcatchments).

Exceptions to this were the naturally brackish Sout River (and possibly certain naturally brackish sites within the Diep River catchment), which may if anything be getting slightly less saline over time, and sites within the Lourens and Hout Bay subcatchments (especially in the Lower River Zone) where EC values within the reference range are still recorded

These findings suggest that most river systems within the City have been in a highly modified state, at least in terms of their EC regime, for 35 years or more. This would have potentially major consequences for the biota in these systems, with shifts in plant and animal community structure (and the possible loss of more sensitive species) likely to have occurred compared to the natural reference state. Periods of drought would be likely to exacerbate such salinization, with lower inflows of rainfall and increased evapo-concentration of salts in water courses. This highlights the need for the identification and (less frequent) monitoring of minimally impacted sites within the City, which could then be protected as important refugia for more sensitive biota within an increasingly urbanized environment.

It should be noted that the above EC analyses exclude estuaries. However, it is known from other research that the City's major estuaries are affected by the opposite problem of reduced salinities, affecting their suitability as habitats for important estuarine species. The Eerste and Diep River estuaries are both impacted by inflows of treated effluent that is much less saline than natural. Controlled re-use of treated effluent to reduce inflows of water of much lower salinity could in part address this issue in these estuaries.

## *E2.2 Major nutrients (phosphorus and nitrogen)*

### *E2.2.1 General*

Plants require various nutrients for healthy growth (e.g. phosphorus, nitrogen, sulphur, magnesium, potassium and many others, often only required in extremely small amounts). Of these, nitrogen and phosphorus play a particularly important role in determining the rate of plant growth, and are often referred to as "growth limiting" nutrients, because of this. In freshwater ecosystems, phosphorus is in fact the real "growth limiting" nutrient, as some plants such as blue green algae (cyanophyte algae) are able to access nitrogen directly from the air.

Most nutrients are not toxic to aquatic environments, even in high concentrations. Exceptions to this in some circumstances include ammonia ($NH_3$), nitrite and nitrate (discussed later). In high concentrations, nutrients (and phosphorus in particular) do however trigger excessive growths of plants, changing aquatic ecosystem function and structure and triggering many management problems, from the need for invasive plant clearing to the risks of toxic algal blooms and fish kills due to low oxygen caused by the decomposition of aquatic plants.

Today, most if not all of the aquatic ecosystems in the City have been impacted by the receipt of additional nutrients, particularly phosphorus, mainly as a result of the following kinds of anthropogenic activities and inputs:

- Inputs of treated sewage effluent
- Runoff from catchment areas with high levels of backyard or informal settlements, subject to poor levels of sewage, solid waste and stormwater servicing

- Illegal discharges into the stormwater system in industrial and commercial areas (e.g. fertilizer factories; car washes; markets; informal butcheries and meat markets)
- Runoff from fertilized gardens and parks
- Runoff from agricultural areas within the City.

### *E2.2.2 Trophic state*

The nutrient (trophic) status of freshwater ecosystems allows them to be broadly classified into one of four trophic categories - oligotrophic, mesotrophic, eutrophic and hypertrophic –respectively associated with low, moderate, high and extremely high levels of nutrients (mainly phosphorus and nitrogen nutrients).

### *E2.2.3 Phosphorus enrichment*

Data analysis showed that phosphorus enrichment is a pervasive issue in most of the City's catchments, with only the Lourens and Silvermine River systems remaining largely within their Target range for this variable. Watercourses subject to receipt of treated effluent from WWTWs and runoff from poorly serviced settlements appear to be most affected.

The knock-on effects of such enrichment, which the data suggest is progressively increasing, was apparent in the high concentrations of phosphates in all of the standing water bodies assessed. Most samples fell well within the Unacceptable range indicative of hypertrophic systems, and many samples were more than two orders of magnitude beyond the threshold of Unacceptable. The water bodies where orthophosphate enrichment was least problematic, albeit still often in the hypertrophic range, comprised Princessvlei, Little Princessvlei, Die Oog, Glencairnvlei and the Elsieskraal Dams. These water bodies reflect subcatchments that are not subject to receipt of treated sewage effluent or characterized by substantial areas of informal or poorly serviced settlements;

### *E2.2.4 Nitrogen enrichment*

Analyses of total inorganic nitrogen (TIN) data suggested that nitrogen enrichment, although problematic, was a less prevailing concern in the City's subcatchments than was phosphorus enrichment.

Of the standing water bodies assessed, nitrogen enrichment was considered problematic only in Wildevoevlei and the Mew Way, Edith Stephens and Mitchell's Plain detention ponds, with TIN concentrations elsewhere generally falling within Acceptable limits. Nevertheless, the data also showed that standing water bodies (like the rivers / stormwater systems that feed them), were characterized by low N:P ratios, likely to promote blue-green algal dominance in many of these systems. The least affected systems comprised Zandvlei, Little Princessvlei and Princessvlei, and all systems were on a trajectory of increasing available phosphorus relative to nitrogen nutrients. This was considered likely to increase the tendency of standing water systems to being dominated by blue-green algae, and, under certain conditions, to give rise to blue-green algal blooms.

### *E2.2.5 Chlorophyll-a*

Chlorophyll-*a* is a pigment that occurs in green plants and is one of the primary pigments used in photosynthesis. In water quality assessments, it is used as a measure of algal growth – specifically, of phytoplankton abundance. Under conditions of nutrient enrichment, particularly of phosphorus, chlorophyll-*a* often increases, reflecting an increase in algal growth rates in response to increased nutrients. Interestingly, nutrient-enriched systems that are dominated by macrophytes (that is, more complex plants than single-celled or filamentous algae, such as pondweed or other aquatic plants) are less likely to be dominated by algae or give rise to algal bloom.

The report presented analyses of phytoplankton-sourced chlorophyll-*a* data from standing water bodies over the past five years that suggested that:

- Six out of the thirteen assessed standing water bodies had mean annual chlorophyll-a values that fell within the range of Acceptable conditions for this variable;

- The exceptions to this in the 2019 period were Princessvlei, Zeekoevlei, Rondevlei, Langevlei, Die Oog and Wildevoelvlei, for which mean annual concentrations lay in the Unacceptable range and, in the case of Wildevoelvlei, were over an order of magnitude beyond the Unacceptable threshold;

- Of the assessed systems, Rietvlei showed a significant decrease in mean chlorophyll-*a* over the 2019 period, compared to the previous four years. Nevertheless, even in 2019, chlorophyll-*a* concentrations from some samples still extended well into the Unacceptable range for this variable, suggesting occasional, probably localised and short-lived bloom periods in the vlei;

The report noted that severely elevated chlorophyll-*a* concentrations, indicative of bloom conditions, can have a range of implications for waterbody management. Not only do they contribute to the accumulation of nutrients at the bottom of the water body when the bloom dies, where decomposition can result in the formation of anoxic layers at times, and from where nutrients can periodically be released into the water column, but they can also be associated with odour and aesthetic problems. *Microcystis*, for example, which is the dominant Cyanophyte species in some of the City's water bodies, produces a distinctive foul smell under bloom conditions. The visible presence of green algal scums is also unpleasant, and persistent bloom conditions in water bodies can affect property value and the suitability of the water body for different kinds of recreational uses.

*E2.2.6 Ammonia toxicity*

In the aquatic environment two forms of ammonia can occur: harmless ammonium ions ($NH_4^+$) and toxic un-ionised ammonia ($NH_3$), with the relative proportion of each being controlled by pH and temperature. At pH >8, a significantly larger proportion of total ammonia ions are present in the un-ionised form, which may give rise to acute toxicity at concentrations as low as 0.1 mg N/L (DWAF 1996a). pH fluctuations can occur in aquatic ecosystems as a result of various factors, including high diurnal rates of photosynthesis (both natural and as a result of eutrophication), as well as resulting from activities such as construction, leading to runoff of alkaline cementitious waters.

Concentrations of un-ionised ammonia above Target levels would increase the risk of ammonia-toxicity in sensitive fauna – particularly fish. Particular attention should thus be paid to systems where pH levels are naturally high, or raised as a result of impacts such as construction, with pH >8 being a potential trigger for ammonia toxicity, when associated with elevated total ammonia concentrations. The development of low oxygen conditions would increase the availability of reduced nitrogen forms such as ammonia, rather than more stable nitrates. Oxygen levels are thus also an important consideration when assessing the threat posed to aquatic ecosystems by ammonia toxicity.

Analysis of data showed that sites representing river reaches where there was pronounced organic pollution and nutrient enrichment, often leading to, or coupled with low dissolved oxygen concentrations, were most likely to be vulnerable to elevated ammonia concentrations, which could further compromise the ecological health of systems that had already been impacted by nutrient enrichment and low oxygen.

More specifically, the data showed that in rivers / stormwater channels and canals:

- With the exception of the Silvermine and Hout Bay subcatchments, all of the monitored subcatchments had samples that at times went well over the Unacceptable thresholds;
- Samples from the Silvermine and Hout Bay subcatchments never exceeded the Acceptable range for NH3-N, reinforcing the importance of these systems and the Silvermine River system in particular as least-impacted river systems within the City.

With regard to vleis in these subcatchments:

- Most of these systems were probably not affected by ammonia toxicity;
- Nevertheless, median ammonia (NH3-N) concentrations at Wildevoelvlei and the Mitchell's Plain and

Mew Way detention ponds consistently fell within the acute toxicity range for this variable (i.e. Unacceptable). While this might not be problematic from an ecosystems perspective at the two detention ponds, which were not designed for ecological function, the implications for the natural (but clearly impacted) Wildevoelvlei system could have been more severe, and indicated a system in which natural ecological function was potentially highly threatened.

- All vleis / dams, with the exception of Glencairnvlei, Die Oog, Little Princessvlei and Princessvlei had periodic episodes of ammonia concentrations that lay well above the thresholds for acute toxicity, and these may have affected any remnant aquatic taxa that had sensitivity to ammonia. .

#### *E2.2.7 Escherichia coli contamination*

In inland watercourses, *Escherichia coli* measurements are used as the primary indicator of human health risk, particularly for recreational use of a waterbody. The report included a general assessment of *E. coli* data in all systems, followed by a more focused assessment of the implications of contamination of the City's main recreational water bodies.

The general assessment showed that, over the 2019 monitoring period, and with regard to river and stormwater systems:

- As expected, river and stormwater channels in the City were generally not fit for safe full contact recreational use (e.g. swimming and wading) – the Silvermine River was the only subcatchment where the 25$^{th}$ -75$^{th}$ percentile range fell entirely within the range of Acceptable for full contact recreational use, and even this subcatchment had periodic samples with *E. coli* concentrations well above the levels of Unacceptable for intermediate contact use. It is however noted that swimming in many urban watercourses worldwide is often not possible for a number of reasons and the City therefore generally also does not encourage swimming in its rivers;
- Overall, the data illustrated that all subcatchments were exposed to periodic high levels of *E. coli* contamination at times, possibly reflecting intermittent sewage leaks or overflows.

*E. coli* contamination in the standing water bodies (vleis and dams) that were assessed showed slightly different patterns to rivers in the respective subcatchments, reflecting the capacity of these open water systems for bacterial reduction as a result of an increased residence time, with resultant prolonged exposure to sunlight. Nevertheless, all the assessed water bodies showed periodic elevations in *E. coli* well above Target Full or Acceptable Intermediate Contact ranges, and their use for these purposes at times would therefore have been associated with high risk.

The report also raised concerns that there are areas in the City where standing water bodies are used for recreation by members of the public, but where there is no regular monitoring of human health risk (e.g. the Kuils River in the Khayelitsha Wetland Park area, where local communities participate in kayak polo games and training). Although this area has been subject to *ad hoc* assessment, the report recommended future routine monitoring of this (and any other similarly used) sites.

## E3 Current state of Recreational Areas (Vleis)

The report provided a more detailed analysis of human health risks and concerns associated with the following five main recreational waterbodies in the City, namely:

- Rietvlei;
- Milnerton Lagoon;
- Princessvlei;
- Zeekoevlei; and
- Zandvlei.

A range of watersports are known to take place in these waterbodies, such as rowing, paddling/canoeing, sailing, kite surfing, windsurfing, water-skiing, fishing, wading, and some swimming (mostly children splashing around in the shallows). The exception is Princessvlei, where watersports are not commonly practiced, but this vlei is a known baptism site.

Users of recreational waters in the City are potentially exposed to a number of human health risks. Those considered in the current water quality assessment were those associated with:

- Exposure to waters contaminated with human faecal material (considered here in terms of microbial indicator data – *E. coli*);
- Exposure to toxins produced by Cyanophytes (also called blue green algae) (considered here in terms of microcystin toxin data).

Based on analysis of *E. coli* and microcystin toxin data for the past five years, the report concluded that, of the five main recreational vleis / water bodies considered, most had generally been in a condition conducive to at least intermediate contact recreation. However, Milnerton Lagoon had been subject to periodic and at times prolonged contamination by *E. coli*, indicative of exposure to untreated sewage. Rietvlei itself, which like most of the assessed urban vleis was found to be hypertrophic with regards to phosphate, was vulnerable to periodic blue-green algal blooms, some of which had resulted in the production of microcystin toxins at concentrations likely to pose extreme risks to recreational users in contact with this water body.

A focus on measures to reduce sources of nutrient enrichment into all of the recreational water bodies was strongly recommended. Addressing upstream sources of untreated sewage into Milnerton Lagoon in particular was also strongly recommended, if this waterbody is to be used safely for recreational purposes.

## E4 Monitoring recommendations

The report noted three areas where additional monitoring might play a useful role, namely:

1. *Addressing concerns around human health issues in watercourses used for recreation*

It was recommended that:

- Certain of the reaches of the Kuils River and detention pond areas through the Khayelitsha Wetland Park area should be monitored routinely, at least for *E. coli*, as these reaches are used by local communities for kayak polo games and training;
- Two additional routine water quality monitoring points should be added to Rietvlei – one in the north western corner of the vlei, near where the Bayside Canal enters the system, and the other in the southern part of the water body;
- Measures to track and address apparent declining water quality in the Bayside Canal entering Rietvlei should also be considered.

2. *Including monitoring of Enterococci in routine analyses*

   Routine measurement of Enterococci concentrations in waterbodies that are used for contact recreation within the City was recommended, as part of the City's ongoing water quality monitoring programme. This would bring the City in line with international approaches and guidelines that now focus on Intestinal Enterococci measurements, often alongside *E. coli* data. Alternatively, inclusion of faecal coliform data should be allowed for, as a minimum, to allow for more appropriate utilisation of existing guidelines.

3. *Ambient water quality monitoring to allow reporting on the "State of the City's watercourses"*

   It was noted that the current dataset focuses primarily on the monitoring of problem areas and thus potentially exaggerates the extent of pollution and gross contamination. A more holistic monitoring approach would potentially provide a less biased assessment of water quality in the City. It was thus also recommended that consideration be given to the periodic collection of generalised "ambient" water quality data, which could provide a more holistic picture of the general state or condition of watercourses throughout the City, rather than the focused assessment of problematic, pollution-prone systems considered in the present report. A five-yearly assessment of key water quality variables from samples collected at the same time of year from an expanded set of representative sites across the City was recommended as a tool for the City to track its progress in managing all of its watercourses, and to allow for important holistic "State of the City's watercourses" reporting.

Inclusion of heavy metal analyses from the lower river or estuarine outlets of each major City catchment was also recommended for inclusion in this programme, to highlight catchments in which heavy metal contamination is an issue, and where more stringent pollution tracking may be required.

## E5 Recommendations for future reporting

Regardless of whether or not the above additional monitoring recommendations are addressed, it was recommended that the City allow for ongoing reporting on the data generated by the water quality monitoring programme, in order to reflect the long-term trajectory of water quality in its monitored systems. This would allow the efficacy of the City's catchment management approaches to be tracked, and should improve accountability, with regards to the City's commitment to improving water quality and general catchment condition.

Ongoing internal reporting within the Catchment, Stormwater and River Management Branch of the City's Water and Sanitation Department is used to highlight immediate pollution issues and to drive management interventions. It was thus recommended that five-yearly reporting on overall catchment-scale water quality trajectories should be conducted going forward, particularly with regard to the phosphorus enrichment, which has been identified in this report as the key issue of concern in the City's watercourses. This reporting could be coupled with the recommended ambient water quality monitoring programme, but should in its own right focus on the degree to which the issues highlighted in this (and subsequent) reports have been addressed, over the preceding five year period.

## E6 Concluding summary

The data presented in the report make it clear that the biggest water quality issue afflicting most of the routinely monitored systems was elevated phosphorus, which drives eutrophic and hypertrophic conditions. Such conditions make receiving water bodies such as vleis vulnerable to excessive plant growth, requiring ongoing maintenance and at times posing human health risks as a result of the presence or risk of microcystin toxins.

The most likely main sources of phosphorus loading in the City's inner catchments comprise treated effluent from the City's numerous WWTWs, which discharge into several rivers; discharges of raw sewage from leaking or overflowing infrastructure, sometimes as the result of pump failure during load shedding; and the passage of water contaminated with sewage and other domestic waste (e.g. water from cooking, washing etc.) from informal settlements and other poorly serviced areas.

Such waste is also associated with significant bacterial contamination, posing a risk to people encountering this water, in the form of puddles and ditches in settlements; in stormwater channels; and in the receiving rivers and (to a lesser extent) vleis and dams. Levels of *E.coli* indicator organisms are therefore also a major water quality challenge in some parts of the City's monitored surface water systesm.

From the perspective of human health, primarily represented in the report by *E. coli* data, the analyses presented here suggest that the five main recreational water bodies in the City have generally been in a condition conducive to support at least intermediate contact recreation activities over the past five years, despite often high levels of *E. coli* in the rivers and channels that feed them. During summer, the probability of Zeekoevlei, Zandvlei and Princessvlei meeting even full contact standards is high (approaching 100% for Zeekoevlei and 80% for the other two systems), although water quality near the major point source river inflows deteriorates somewhat in winter in Zeekoevlei, largely as a result of inflows of polluted water from informal settlements upstream, and in Zandvlei.

The risk of occurrence of *E. coli* at Unacceptable levels is highest in Milnerton Lagoon, which has been subject to periodic and at times prolonged contamination by *E. coli*. This is indicative of exposure to untreated sewage, assumed to derive mainly from the large areas of informal and backyard-dominated settlement in the catchment upstream (e.g. Du Noon and Jo Slovo areas). Occasionally compromised final effluent discharged from the Potsdam WWTW will also influence water quality in the system, but operational and capital improvements are reportedly addressing this.

Data for Rietvlei, currently represented by a single routinely monitored site and occasional *ad hoc* samples, suggested by contrast that the probability of *E. coli* measurements being within the target for direct contact recreation is high (>80%) throughout the year and the probability that there is an Unacceptable risk for indirect contact recreation remains very low.

Of some concern is the fact that there are areas in the City where residents (including children) informally play, swim, paddle and possibly even wash clothing, cook and drink water from rivers, vleis and other wetlands not considered in this report, without any knowledge as to its fitness for such uses. Some of these water bodies are highly contaminated, and the route to addressing this issue must lie in improving the condition of the catchments draining into these systems, through the provision of basic sanitation and servicing. Raising awareness and instilling a sense of shared responsibility regarding the condition of Cape Town's waterways is also important.

The report also notes that not all of the City's watercourses are highly contaminated, and the monitoring data do show that there were a few rivers where water quality was impacted to a much lesser degree. These included the Silvermine and Lourens River systems. Other rivers such as the Sand Catchment rivers and Hout Bay River were moderately to highly contaminated only in their lower reaches, and usually as a result of the issues outlined above. It must also be stressed that the City's monitoring programme itself, while extensive and covering all the major catchments in the City of Cape Town, focuses mainly on areas faced with water quality challenges. This generates an unintended bias in the water quality database towards degraded sites exhibiting signs of pollution. There are undoubtedly also a number of aquatic ecosystems (including river reaches, open waterbodies and wetlands) within the City that have relatively good water quality, particularly for a major urban area, which are not currently monitored on a routine basis due to budgetary constraints and the need to prioritise monitoring and pollution abatement initiatives in problematic areas.

## ABBREVIATIONS

| | |
|---|---|
| CCT | City of Cape Town Municipality |
| cfu | Colony forming units |
| Chl-a | Chlorophyll-*a* |
| CSRM | Catchment, Stormwater and River Management (Branch of CCT) |
| DO | Dissolved oxygen |
| DWS | Department of Water and Sanitation (now the Department of Human Settlements, Water and Sanitation) |
| *E. coli* | *Escherichia coli* |
| EC | Electrical conductivity |
| LDC | Liz Day Consulting (Pty) Ltd |
| mS/m | Milli-Siemens per metre (unit of measurement for conductivity) |
| NH3-N | Nitrogen component in Ammonia $NH_3$ |
| NH4-N | Nitrogen component in total ammonia ($NH_3$ + $NH_4^+$-N) |
| NO3-N | Nitrogen component in nitrate salts |
| PO4-P | Phosphorus in orthosphosphate |
| RI | Return Interval |
| The City | City of Cape Town Municipality |
| RQOs | Resource Quality Objectives |
| TIN | Total inorganic nitrogen |
| Tot P | Total phosphorus |
| TSS | Total suspended solids |
| WQMR | Water Quality Management Region |
| WWTW | Waste Water Treatment Works |

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# 1 INTRODUCTION

## 1.1 Background

The City of Cape Town ("the City") incorporates numerous rivers and wetlands within its boundaries, including open water vlei systems as well as estuaries and coastal lakes. In order to inform management of these systems, the City's Scientific Services Branch undertakes monthly water quality monitoring of rivers and wetlands/vleis of particular concern. This results in the generation of large volumes of data, requiring collation and analysis in order to provide meaningful information to City managers and other interested parties about the state of the City's watercourses.

In 2020, the City contracted Liz Day Consulting (Pty) Ltd to prepare the 2019 Urban Environmental Water Quality Report for inland aquatic ecosystems and estuaries (i.e. the current report), including an analysis of all water quality data collected up to the end of March 2020.

## 1.2 Scope of Works

The Scope of Works for this project was outlined in the City's Request for Proposals for the project, which stipulated that the appointed consultants should compile a report on the water quality of the City's inland aquatic ecosystems (that is, selected rivers and vleis / open water wetlands and estuaries), which:

- Reviews the full historical record of water quality data for the City's watercourses, and provides comment on trends and trajectories in water quality;
- Provides a specific focus on the water quality of these systems over the past five years (up to March 2020);
- Includes all data, analyses and graphics in spreadsheet format.

## 1.3 Project Team

Liz Day Consulting (Pty) Ltd (LDC) is a private consulting company, specialising in river and wetland assessment, management and rehabilitation. The current project, carried out as an LDC consultancy, included the following team members:

- Dr Liz Day (LDC): project manager and water quality consultant;
- Mr Dean Ollis (Inland Waters Consultancy): water quality consultant;
- Mr Tumisho Ngobela (Inland Waters Consultancy): GIS mapping;
- Dr Nick Rivers-Moore (private consultant): water quality consultant and statistical advisor.

For the purposes of this report, reference to LDC includes acknowledgement of the full team of consultants listed above.

## 1.4 Audience

This report is intended to be accessible to a wide range of audiences, including people with both technical and non-technical / scientific backgrounds. Nevertheless, the data need to be presented in a scientifically defensible and rigorous manner, which means that some parts of the report are more technical than others. It is hoped that any difficulty in understanding this material, or limited time to go through it all in detail, is addressed in the summary sections at the end of each chapter, in the concluding sections and in the Executive Summary.

## 1.5 Types of aquatic systems included

This report considers water quality data for the City's <u>inland</u> and <u>estuarine</u> water quality monitoring sites only. It does not include data for any marine sites, and includes only a few examples of artificial stormwater detention or attenuation ponds, where these provide useful indications of water quality issues in some key catchments. The report also generally excludes *ad hoc* or once-off sites, for which only a few data points exist.

## 1.6 Limitations

The following limitations apply:

- Large amounts of water quality data are available in the City's database. Of necessity, this project needed to summarise these data to draw out significant patterns and highlight particular areas of interest. This report thus focuses on a few key variables only, and does not consider data relating to every one of the water quality variables monitored by the City;
- Conversely, not all variables of concern are necessarily included in the City's monitoring programme, and are not therefore covered in this report. Heavy metals for example are not routinely analysed for by the City, largely for budgetary reasons. Jackson et al (2009) have however noted significant concentrations of various heavy metals in the Diep and Eerste River estuaries, and other catchments might well be subject to similar issues;
- Although the City routinely collects phytoplankton samples for enumeration and identification of algal species, these data were not available in time to be included in this assessment;
- This report does not provide a synopsis of the ambient water quality in the rivers, canals and open waterbodies across the City because the analyses presented here are based exclusively on the sampling sites of particular concern that are routinely monitored by the Scientific Services Branch of the City;
- No responsibility is taken by LDC for the accuracy of water quality data, which have all been derived from samples collected and analysed at the City's Scientific Services Branch, in Athlone;
- LDC distances itself from the implications of any future decisions taken to access any waterbodies for recreational purposes, on the basis of the data and assessments outlined here. These all refer to the past condition of these waterbodies, and no undertakings regarding future water quality or risk to human health is intended.

## 1.7 Report structure

This report has been structured as follows:

- Section 1: General Introduction;
- Section 2: Background to the City's water quality monitoring programme and datasets; an outline of the proposed approach in this assessment, including the selection of variables for assessment in this study; setting of targets for different variables; an outline of analytical tools, methods, assumptions and basic interpretation guidelines;
- Section 3: Consideration of rainfall data from sites within the City, to illustrate rainfall seasonality and patterns in annual rainfall that might have some bearing on water quality in the City's watercourses;
- Section 4: Presentation of the assessment of long-term and current water quality data for river, stormwater and standing water sites across the City, presented at a sub-catchment level and discussed in terms of each of the key variables selected;
- Section 5: Presentation of water quality data pertaining to the condition of the key recreational vleis in the City, with regard to water quality risks to human health;
- Section 6: Summary of the main issues affecting water quality in each subcatchment;
- Section 7: Recommendations for further monitoring and Conclusions;
- Appendices: These include a list of sites for which data have been accessed for this report; a brief review of the information used to inform decision-making around selection of variables and defining thresholds of acceptability; and detailed data tables showing summary (annual and seasonal) data for each of the key variables selected, for each site, for each year between April 2015 and March 2020. Readers with a particular interest in water quality at a particular site can access more detailed site specific information in these tables. The appendices include the consultants' CVs.

## 1.8 Acknowledgements

This report was compiled with considerable input from Ms Candice Bouland, City of Cape Town, who is thanked for her time in collating available data, discussions around data presentation and assessment and her attention to detail.

Useful comments and feedback were also provided by the following officials from the City's Water and Sanitation Department; Water and Waste Directorate:

- Mr Richard Nell (Catchment, Stormwater & River Management Branch);
- Ms Sarah Rushmere (Communication and Stakeholder Engagement);
- Mr Gregg Oelofse (Coastal Management, Environmental Management Department);
- Mr Abdulla Parker (Catchment Stormwater and River Management Branch).

Scientific Services Branch is thanked for providing the datasets.

The Century City Property Owners' Association (CCPOA) is also thanked for making their rainfall data available for this study.

# 2 OVERVIEW AND CONTEXT

## 2.1 The importance of urban watercourses

Urban watercourses can play important roles in a city, and their condition can have significant indirect impacts on issues such as human health; property value; security; amenity opportunities; flood risk and maintenance and management costs such as litter and sediment removal. From an ecological perspective, urban watercourses can be of great importance, acting as corridors of relatively natural habitat through increasingly sterile urban landscapes and, in the City of Cape Town, connecting mountainous habitats with the coast. They also provide aquatic habitat and, in some areas, are of great biodiversity importance.

In the City of Cape Town, which lies in the heart of the Cape Fynbos Biome, some aquatic ecosystems are highly threatened, sometimes supporting species of plants and/or animals that occur in a restricted area within watercourse types in parts of the City and nowhere else in the world.

The Western Leopard Toad (*Sclerophrys pantherine)* is an endangered frog species, restricted to the south-western Cape region. Although it inhabits terrestrial areas for most of the year, it breeds in standing water ponds, wetlands and vleis, where its eggs hatch into tadpoles which remain in the ponds for a few months until they emerge as tiny toadlets.
The City includes a number of important breeding sites for this species.
(Photo: M. Burger)

*Erica verticillata,* a Cape Town endemic, was once abundant in seasonal wetlands with acid soils in parts of the Cape Flats. Largescale loss of wetlands as a result of agricultural and urban development led to its extinction in the wild by the mid 20th Century.
A few specimens were however located in various botanical gardens, and cloned for re-introduction to the few remaining areas of suitable habitat in the City.

## 2.2 Challenges in the management of urban watercourses

The sustainable management of any watercourse can be challenging, but is particularly so in urban environments, where many of the natural drivers of ecosystem function have changed fundamentally. Canalisation, water abstraction, impoundment, inflows of waste water effluent and other pollutants, loss of floodplains, invasion by alien plants and a general loss of natural biodiversity as a result of all of these factors compounded by largescale loss of terrestrial and aquatic natural habitat can all contribute to reduced ecosystem resilience (Wagner et al 2008). They also contribute to problems for human communities – including health, safety and aesthetic issues that might affect their recreational or aesthetic value, or make them more likely to harbour criminals. Such problems include an increased propensity for flooding, pollution, accumulation of sediments, and invasion by nuisance plant or animal species.

**What's a watercourse?**
The National Water Act (Act 36 of 1998) defines a "watercourse'' as -

(a) a river or spring;

(b) a natural channel in which water flows regularly or intermittently;

(c) a wetland, lake or dam into which, or from which, water flows; and

(d) any collection of water which the Minister may, by notice in the Gazette, declare to be watercourse, and a reference to a watercourse includes, where relevant, its bed and banks.

Addressing these challenges is often rendered more difficult by the fact that there may be competing objectives between different urban user groups. For example, the need to manage flood risk (e.g. by channel lining, diversion, removal of vegetation or construction and maintenance of attenuation ponds) may require interventions that affect biodiversity (e.g. loss of riverine habitat or wetland function).

Effective management can also be inhibited by management structures. Management activities within urban areas are typically divided into different local government departments with different line functions responsible for managing various aspects of the urban built environment. The City of Cape Town includes, amongst other departments, the Department of Water and Sanitation (responsible for the provision of drinking water, sewage, refuse and catchment, stormwater and river management services); the Department of Recreation and Parks (responsible for the management of parks, sport facilities, tidal and municipal swimming pools, beach amenities and public open spaces); the Department of Human Settlements (responsible for formal housing and informal settlements); the Department of Environmental Management (responsible for nature reserves (including some wetlands and rivers), biodiversity nodes and the coastal zone); and the Department of Transport (charged with the management of roads, network management and public transport). These various departments all potentially impact on the character of watercourses, which respond to activities across whole watersheds or catchments, and require an integrated approach that is often rendered difficult by the above separate City structures, as well as by legislation.

Legislation, although generally acknowledged in South Africa to be comprehensive and theoretically enabling of social and environmental sustainability, requires monitoring and enforcement, and in some cases may be rendered meaningless by low rates of compliance. Implementation of local government policies that seek to achieve effective integration across departments may moreover be hampered by funding constraints, resulting in inadequate management of domestic and industrial waste streams and runoff, which have direct consequences for urban watercourses. The City tries to address this issue, with its Catchment, Stormwater and River Management Branch working closely with other line departments having an interest in and influence on urban catchments, to achieve a more holistic management at a catchment scale. Partnerships with external parties and public interest groups are also recognised as important tools in the urban catchment management arena.

The quality of water in urban watercourses is perhaps one of the best indicators of the efficacy of a range of management activities in a city, reflecting the degree of containment of sources of contamination from both widespread land use and specific activities generating point source pollution streams. The implications of poor water quality can also be profound, cutting across a broad range of user sectors, including human health, sewer and stormwater infrastructure, tourism, recreation and biodiversity.

It is against this backdrop that the City of Cape Town implements its inland water quality monitoring programme on a range of rivers and water bodies across the Cape Town municipal area.

## 2.3 Consideration of land-use and major point-source inputs of pollution

One of the most profound impacts affecting water quality in Cape Town, as well as in many other urban cities, is the impact of waste, with treated and untreated sewage being particular causes of problems.

Under ideal conditions, domestic and industrial waste is conveyed to waste water treatment works, where it is treated to an acceptable standard and then either released back into the environment (usually into rivers or the sea), re-used in industry, as an irrigation supply or in some areas, treated further for human consumption. In practice, the management and treatment of human waste is often fraught with problems in many areas, particularly in developing countries, with key issues being:

- Informal settlements with inadequate or no sanitation, resulting in waste being discharged into roads or directly into the stormwater systems;
- The establishment of many informal settlements in marginal land considered unsuitable for housing – such land is often in low-lying areas, in or near to seasonally inundated wetlands. The disposal of waste from residents is thus often directly into these areas, resulting in rapid pollution and degradation of sometimes important seasonal wetlands;
- Repeated sewer leaks and overflows from aging infrastructure in dense urban areas – these are often older areas, where infrastructure is now failing;

- Overflows from sewers as a result of pump failure – multiple power outages in the City over the past few years as a result of power "load shedding", with waste again passing into the stormwater system;
- Poorly treated waste discharged from WWTWs into rivers, where they contribute to significant enrichment and often low levels of oxygen and elevated ammonia, affecting river habitat quality and downstream systems such as vleis and other wetlands – it should be noted that, without dilution by the receiving water body, even effluent that is treated to comply with legal standards (e.g. General Effluent Limits, as specified by the National Department of Human Settlement, Water and Sanitation (DHSWS)) is likely to contain high levels of nutrients, as well as ammonia, and could also lead to poorly oxygenated waters as a result of high levels of organic decomposition;
- Illegal connections in industrial or residential areas, allowing waste that should be discharged into sewers to be passed instead into the stormwater systems – a common source of pollution in many more affluent residential areas is the passage of water backwashed from swimming pools into streets or the stormwater system, where it can result in the formation of persistent toxins (e.g. chloramines);
- Poor levels of solid waste collection and high levels of illegal waste dumping, resulting in the accumulation of waste along roads and open spaces, from where plastics and organic waste can wash into the stormwater system.

**Backyard dwellings and water quality**

In addition to the impacts on human health and dignity associated with many backyard dwellings, they are also often a source of significant water quality impairment, as a result of inadequate servicing. Although usually located in areas with formal water and sanitation, backyard dwellers often do not have access to formal sanitation, with the result that domestic waste (both sewage and water used for washing, cooking etc) is disposed of either into the streets or directly into the stormwater system, from where it passes into detention ponds or rivers.

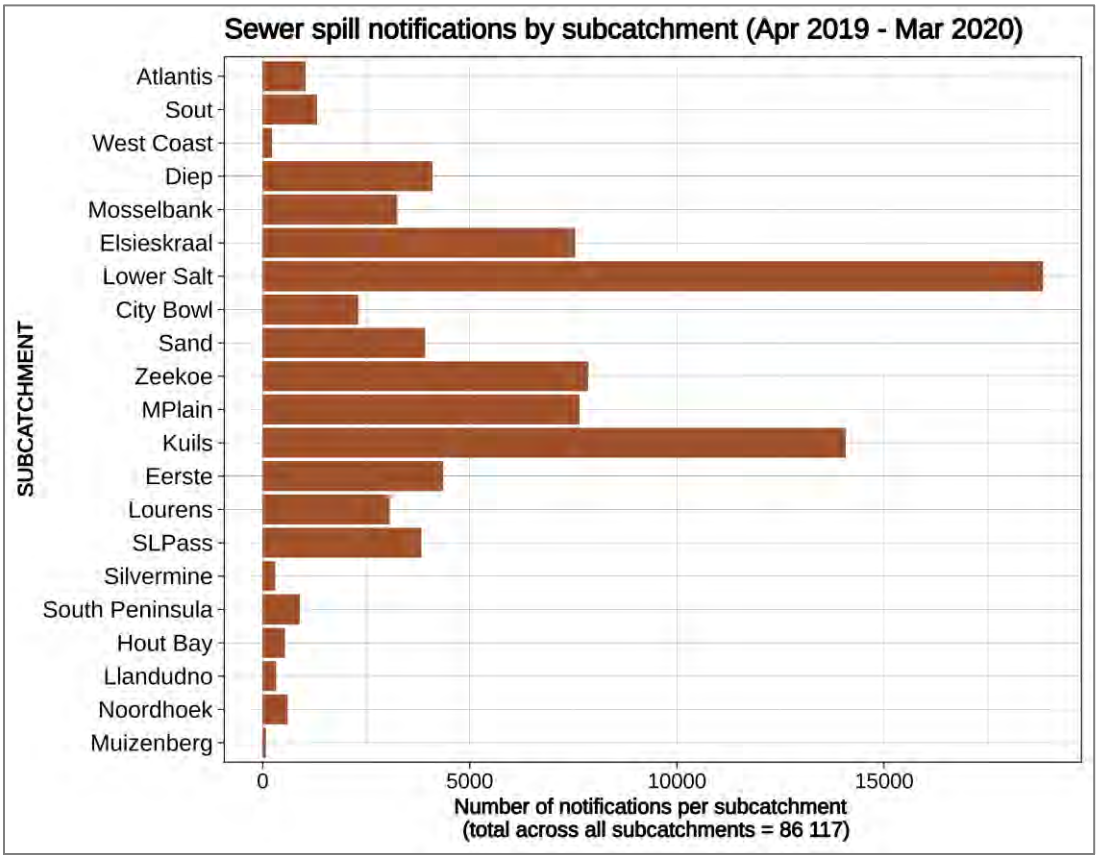
Even where toilets are available for backyard dwellers, bulk service design seldom caters for the sometimes three or four fold increase in actual resident numbers, as a result of backyard dwellings in addition to planned formal dwelling units. This means that sewers and pump stations are often inadequate for the additional volume of waste produced.

**Comment on sewage spill frequency in the City**

The figure below summarises data from the City, showing the frequency of sewer spills in the City, grouped in terms of the subcatchments around which the rest of this report revolves. The data suggest that the Lower Salt and Kuils subcatchments had by far the greatest frequency of reported sewage spills, followed by the Elsieskraal, Zeekoe, and Mitchell's Plain subcatchments. Since the Elsieskraal subcatchment feeds into the Lower Salt subcatchment, this catchment as a whole was subject to a substantial number of sewage spills. The Elsieskraal and Lower Salt subcatchments include many of the older urbanized areas of Cape Town, in which sewage infrastructure is also aging.

Subcatchments in which the lowest number of spills / overflows was reported were the Silvermine, South Peninsula, Hout Bay, Noordhoek, Atlantis, Sout, West Coast, Llandudno and Muizenberg subcatchments. Of these, the West Coast, Llandudno and Muizenberg subcatchments drain directly into the sea, and do not affect river systems.

The Mitchell's Plain subcatchment also drains to the sea, without any natural river systems, but includes a number of monitored stormwater attenuation ponds.




It should be noted that the data referenced here do not indicate volumes of sewage spilled or overflowing, or the time over which the spill occurred before being addressed. In addition, the data reflect only areas in which sewage spills were reported – in some areas, residents might be more vigilant in reporting problems than in others, and some reports might reflect relatively short-lived incidents versus major spills. In addition, repeat-reports of the same incident are also likely to cloud the data somewhat.

The locations of the subcatchments referred to in this box are described in more detail in Section 2.12.

## 2.4 What is water quality?

The concept of "water quality" considers the combined effects of the physical, chemical and biological attributes of a sample of water on a particular user. It is a measure of the condition of water relative to the requirements of one or more species, or to any human need or purpose - that is, its "fitness for use" for an intended purpose.

Water quality is usually interpreted with regard to standards or guidelines, developed around the specific effects of different aspects of water quality on a particular user group or purpose. These may include guidelines for human drinking water; domestic animal drinking water; irrigation water; recreational use of water (e.g. swimming or watersports) and guidelines as to the effects of different water quality ranges on aquatic plants and animals.

Considerations of water quality from a human health and/or ecological perspective requires an evaluation of a range of physical, chemical and biological attributes of the water. This often requires an integrated understanding of the interaction of these constituents, and water quality data should ideally be interpreted by people with expertise in the fields of freshwater ecology, microbiology and water chemistry, within the context of urban catchment landscapes and associated land-uses.

**Ambient water quality**

Ambient water quality refers to the quality of water in natural watercourses, as opposed to treated or piped water quality. The term is used to describe the state or condition of systems, derived from holistic monitoring of whole systems. By contrast, the current study has focused on water quality data collected from specific points, usually identified as problem areas, and thus do not provide an overall idea of ambient water quality in the City. In fact, because the focus of monitoring is on poorly performing systems, the water quality data assessed in this report to some extent arguably exaggerates the level of watercourse pollution in the City.

## 2.5 Purpose of water quality monitoring in urban watercourses

Water quality monitoring, if carefully structured and rigorously carried out, can provide valuable insights into the long-term trajectory of water quality in waterbodies, including rivers and lakes / vleis. This is important for informing decisions about the risk water quality may pose to different user groups (for example, are vleis generally fit for recreational uses such as swimming, rowing, sailing or canoeing?). It also provides information about the ecological health of these systems – an aspect that is important for understanding how ecologically sustainable they are in their current condition.

Water quality data can help to highlight which watercourses are prone to ongoing pollution, informing the need for further investigation to identify the causes of and possible solutions to these issues. The data can also 'red flag' sudden onsets of pollution, caused for example by sewage leaks or illegal discharges; provide evidence for compliance with licensing or permit conditions and inform water quality remediation efforts.

In cities such as Cape Town, where the urban watercourses discharge directly into the sea, urban water quality also has a very direct effect on the water quality of its coastal waters, affecting amongst other user groups the recreational value of its beaches and the viability of its near-shore fishing industry.

**What water quality monitoring can't do**

Remember that water quality monitoring only shows what the quality of water was like at the time of sampling and at the specific location where the sample was collected – it doesn't show what the water was like immediately before or afterwards – thus pollution plugs may be missed, or accidentally targeted by the timing of sampling. A long term monitoring programme undertaken for example at monthly or fortnightly intervals thus provides a general overview of water quality patterns and trends in the monitoring network.

It also only provides information about the constituents that were actually measured – there may be other kinds of pollutants in a water body as well.

The City also has a comprehensive coastal water quality monitoring programme. The recently published "Know your Coast 2019" report (http://www.capetown.gov.za/Explore%20and%20enjoy/nature-and-outdoors/our-precious-biodiversity/coastal-water-quality) provides an overview of coastal water quality around Cape Town's coastline.

## 2.6 Overview of watercourses in the City of Cape Town

The City lies in the Berg-Olifants Water Management Area, which extends north to include both the Berg and the Olifants River catchments, as well as many smaller catchments within the City's boundaries. The City itself includes numerous watercourses, which together drain 20 major catchment areas, shown in **Figure 2.1**.

Under more natural conditions, before the start of urban development in the Cape, most of the rivers in the City would have comprised <u>seasonal</u> rivers that flowed only in the wet season. Many of these would have been associated with wetlands, particularly where several watercourses converged, such as in the general region of today's Paarden Eiland, where the Diep, Black, Liesbeek and Salt Rivers once converged, forming expansive marshes (Brown and Magoba 2009).

Perennial rivers were those that rose in the mountains, with the main perennial systems being the Silvermine, Else, rivers off the Constantiaberg, Liesbeek, Lourens, Sir Lowry's Pass and Eerste River. Most of the rivers that flowed through the vast sandy Cape Flats, by contrast, were seasonal and often associated with groundwater-fed wetlands, which would have been inundated when the primary aquifer rose above the level of surrounding surface depressions. Today, the hydrology of many of these has been permanently altered by the receipt of urban stormwater runoff and treated sewage effluent, which has led to rivers such as the Black, Kuils and Mosselbank Rivers all becoming perennial, nutrient enriched systems. The need to drain water from areas with a high water table has led to the creation of formalized channels in areas once dominated by seasonal wetlands rather than channeled rivers – the Big and Little Lotus Rivers draining into Zeekoevlei are examples of this.

> Note that the Mitchell's Plain catchment shown in Figure 2.1 does not in fact (historically) include any natural watercourses, and water falling in this part of the Cape Flats probably infiltrated through the sand or formed shallow wetlands. Today it is largely developed, and runoff from the hardened urban surfaces is collected in large artificial detention ponds and conveyed to the sea through stormwater pipes and drains.
>
> The City Bowl (and adjacent Sea Point and Camps Bay areas) also do not include any remaining natural rivers . This is because most of the streams that drain off Table Mountain and the Twelve Apostles range have been piped underground, and pass into Table Bay and the coastline along the Atlantic seaboard as stormwater. This can affect coastal water quality, not considered here. The City's Biodiversity Park at Green Point Park makes use of some of this wasted water resource, which supplies its artificial wetlands and streams.

**Natural water quality**

Different watercourse types often have different water quality characteristics, with many standing-water wetlands or vleis being naturally more nutrient-enriched and possibly with higher salt contents than rivers, as a result of imports of nutrients from animals such as birds and the accumulation of plants over long periods of time.

Different river types themselves exhibit different water quality. Rountree and Wadeson (1999) classify rivers into distinct types, on the basis largely of geomorphology and gradient. Ollis et al (2013) provide a further approach to watercourse classification, and on the basis of this, the following broad river types are identified within the City, namely:

- **Mountain stream** reaches – flowing off steep mountain gradients, and tending to occur on the outskirts of the City and to lie outside of the urban edge;
- **Upper (or Cobble) foothill** reaches, which occur on the steep mountain foothills, and which, where they pass through the City's boundaries, tend to run mainly through farms, smallholdings or low-density residential areas and Nature Reserves;
- **Lower (or gravel) foothills** which, with a few exceptions run through highly developed urban areas, including residential suburbs, commercial and industrial zones;
- River reaches classified in the City's database as "transitional" but which are more accurately classified in terms of Ollis et al (2013) as **valley bottom wetlands**, and which dominate the naturally seasonal flat, low-lying Cape Flats area; and

- **Lowland rivers**, which meander across broad floodplains and generally pass into the estuarine zone of the river.

The City's rivers would have culminated in estuaries or lagoons under natural conditions, and Turpie and Clark (2007) list 10 estuaries within the City's boundaries, namely Rietvlei / the Diep River, Hout Bay, Wildevoelvlei, Bokramspruit, Schuster, Silvermine, Zandvlei, Eerste, Lourens and Sir Lowry's estuaries. The Sout and Salt systems would also have formed estuaries / coastal lagoons under natural conditions.

Many of these estuaries today have lost all natural function, with their river outlets having been converted into concrete canals (e.g. the Salt and Sir Lowry's Pass Rivers) with none of the salt flux and tidal exchange necessary to meet the criteria for an estuary. Zandvlei and the Diep River Estuary are the only remaining systems that, despite significant levels of impact, particularly in terms of natural salinity, retain real estuarine functionality. The Eerste River Estuary has been severely impacted by large volumes of low salinity waste water discharges, and the Lourens River and Silvermine River estuaries have been impacted by urban development and (in the case of the former) significant upstream abstraction.

At the same time, many of the naturally seasonal wetland pans or coastal lakes, which would have opened rarely, if ever, into the sea under natural circumstances (e.g. Wildevoelvlei and Zeekoevlei), have today been connected to the sea via artificial channels and canals, and have been classified in some studies as estuaries (e.g. DWS 2018).

Today, the City's stormwater management system, which manages surface runoff across the City, includes:

- [1]16 630 kilometres of pipes and culverts;
- 890 detention ponds;
- 236 stormwater treatment wetlands;
- 1 910 kilometres of rivers and streams;
- [2]4164 "natural and semi natural" wetlands, including 'vleis' and estuaries.

Such changes are representative of the significant changes that have occurred to watercourses as a result of urbanization and the multitude of challenges it poses to natural watercourse pattern and function. These reflect in water quality, and **the following sections focus on water quality as a measure of ecosystem condition, and the City's approach to monitoring of this important aspect**.

| **Examples of watercourse types in the City of Cape Town** | | | |
|---|---|---|---|
|  |  |  |  |
| Mountain stream: Window Stream | Foothills: Hout Bay River | Lowland River: Liesbeek River, Mowbray | Incised valley bottom wetland / "transitional" river -Diep River, Plumstead |

[1] Data from http://www.capetown.gov.za/family%20and%20home/transport-and-vehicles/road-safety/our-stormwater-system
[2] Data from City of Cape Town (2017) wetland layer

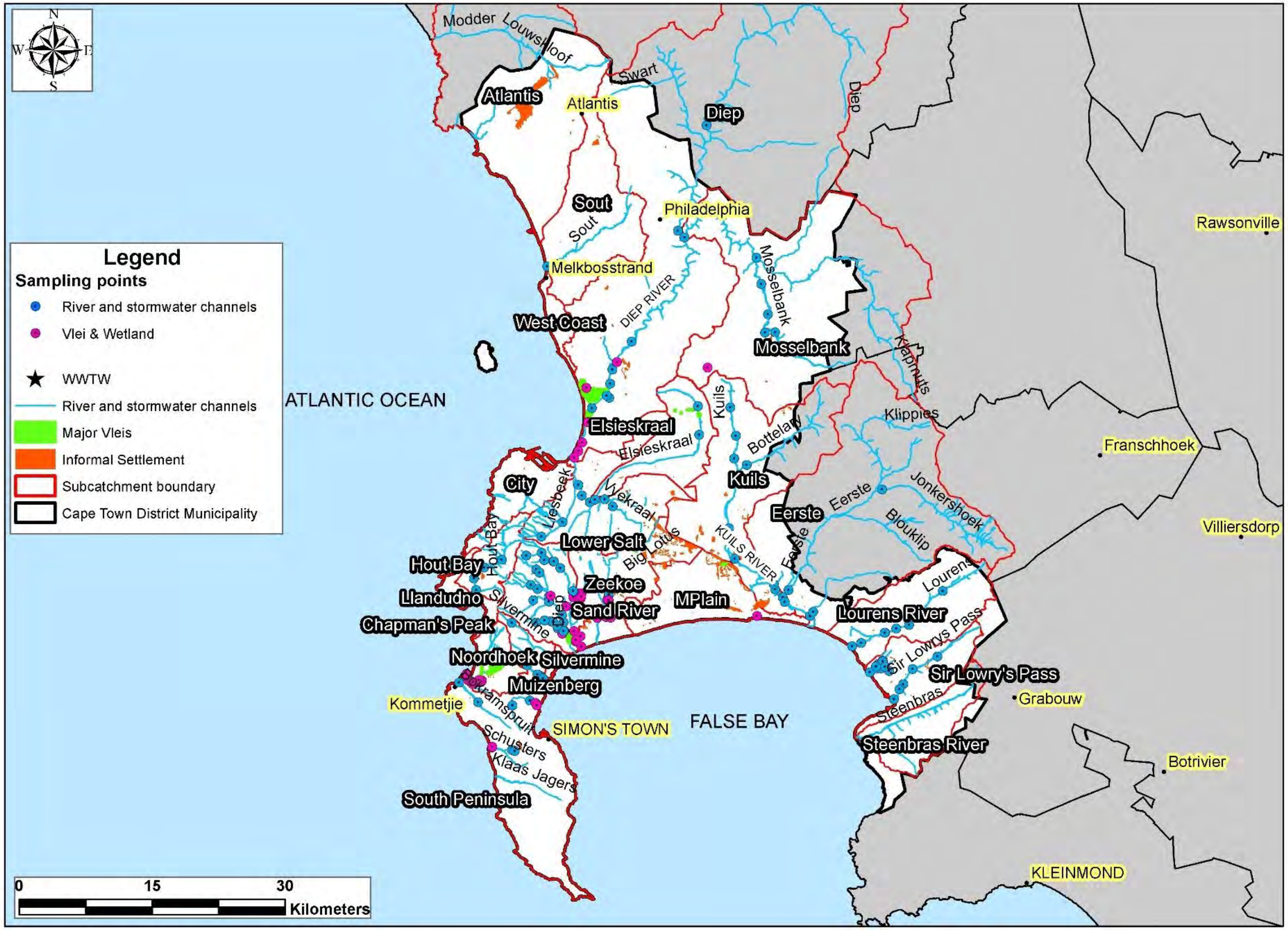



**Figure.2.1 Main rivers and major subcatchments in the City of Cape Town**

## 2.7 The City of Cape Town's Inland Water Quality Monitoring Programme

"Recreational water" is any body of water which is used for open water swimming or water sports such as kayaking, water skiing or sailing. Usually it means an inland body of fresh water such as a river, reservoir, lake or pond, but could also refer to coastal waters including estuaries and the open sea
**Https://watertreatmentservices.co.uk/water-treatment/recreational-water-quality-standards**

The City of Cape Town has collected various kinds of water quality data relating to its watercourses (main rivers and wetlands / vleis) - in some cases going back to the late 1970's. This has generated an extensive database of sites that represent water quality in main rivers and stormwater or effluent outflows into watercourses, as well as key wetlands, dams and detention ponds.

**Figure 2.2** shows the locations of all of the inland monitoring sites, both past and present, from which the City collects water quality samples, and which were utilised in this study, noting that sites for which only a few data points were available were excluded, as were minor wetland sites monitored infrequently for biodiversity rather than water quality imperatives.

The water quality sampling sites included in this report comprise a total of 242 sites, made up of 13 canal sites; 7 artificial dam / impoundment sites; 2 detention ponds; 2 effluent outlet channels; 2 estuary sites, 158 river sites; 5 stormwater outlets and 53 vlei / standing water wetland sites.

Of this historical dataset, some 174 sites are currently monitored, with the City collecting water samples from these on a monthly basis, for analysis by the Scientific Services Branch at its water quality testing laboratories in Athlone.

A range of chemical, algal and bacterial constituents are measured, and the data are interpreted and reported on by the City's Catchment, Stormwater and River Management Branch. **Appendix A** lists all of the water quality sampling sites used in this assessment, and shows the monitoring record (that is, the number of samples collected over time) at each.

## 2.8 Objective of the City's monitoring programme

The City's water quality monitoring programme has generally been structured around the collection of data that provide information regarding changes in the quality of watercourses where water quality is a likely cause for concern. Thus many of the monitoring points are downstream of WWTW effluent discharge points, and in river reaches in catchments where runoff is likely to be contaminated. Some sampling points are located in watercourses that are used for recreational purposes, and are thus used to provide information as to the fitness for use of these systems.

An important outcome of this approach is that, rather than being a structured programme that generates an overall understanding of the condition of all of the City's watercourses (that is, an understanding of ambient water quality), the data focus on problem areas and rather provide information about long-term trends and trajectories of water quality in these systems.

This is not necessarily a criticism of the monitoring programme, since it would be extremely expensive and logistically unfeasible to conduct full-scale long-term monitoring of all watercourses in the City. It is however an important point that should be borne in mind when considering the water quality data that are available.

## 2.9 Context in the Berg Resource Quality Objectives study

The City of Cape Town falls within the Berg-Olifants Water Management Area. In 2019, the Department of Water and Sanitation (DWS) produced a draft gazette outlining the proposed Water Resource Classification and Resource Quality Objectives (RQOs) for Priority (water) Resource Units in the Berg Catchment, along with a number of smaller catchments within the City of Cape Town Metropolitan Area, on the Cape Peninsula and along the West Coast (see Government Notice 655 of 10 May 2019). The resource classification and associated determination of RQOs is intended to inform management of water resources in the greater Berg catchment.

RQOs were based on meeting defined Target Ecological Categories (TECs) for each Integrated Unit of Analysis (IUA) (usually particular river reaches or specified estuaries). The TECs comprised hierarchical categories A to F, for the following components, namely:

- Water quantity (flow regime / hydroperiod);
- Water quality;
- Aquatic habitat;
- Aquatic biota.

**Appendix B** lists the Priority Resource Units included in the draft Gazette that fall within the boundary of the City of Cape Town. The following Priority Resource Units were selected within the City:

- Two river nodes in the Diep River, as well as the Diep River Estuary / Rietvlei
- Two river nodes in the Peninsula and Wildevoelvlei as an estuary node;
- One river node in the Cape Flats and Zandvlei
- Two river nodes in the Eerste catchment and the Eerste River estuary
- Three river nodes in the Sir Lowrys / Lourens catchment areas, as well as the Lourens Estuary, the Steenbras Reservoir and the Upper Steenbras Dam.

Note that the (draft) Water Resource Classification as presented in the draft Gazette relates only to rivers and estuaries, with wetland classification and RQOs not yet finalised.

## 2.10 Selection of water quality variables for analysis in this document

Although the City of Cape Town analyses a wide range of water quality variables, only those considered the most important general indicators of urban aquatic ecosystem health and human health risk were included in the current study. **Appendix C** outlines the considerations that led to the selection of these water quality variables, and includes a full list of the variables for which data are available.

The following variables (abbreviations used to refer to them in this report bracketed) have been included:

- pH
- Electrical Conductivity (EC) – as a measure of salinity
- Major nutrients – orthophosphate (PO4-P); total phosphorus (TotP); Total Inorganic Nitrogen (TIN) – these indicate issues such as eutrophication and the likelihood of algal blooms in standing water bodies;
- Un-ionised (or "free") ammonia nitrogen (NH3-N) – this can be toxic to aquatic organisms at even very low concentrations;
- Dissolved oxygen (DO) – this indicates organic pollution (when low) and is an essential component of healthy aquatic ecosystems;
- *Escherichia coli* bacteria (*E. coli*) – this is an indicator of the presence of faecal material from warm blooded animals and in urban areas can indicate sewage pollution;
- Microcystin toxins – this is a measure of the toxicity of a *Microcystis* algal bloom, to humans and other mammals (e.g. pets / livestock) that might drink or otherwise be exposed to it;
- Chlorophyll-*a* – this is a measure of nutrient enrichment and indicates plant (algal) productivity.

## 2.11 Recommended thresholds to guide interpretation in this study

In order to guide the interpretation of water quality data, in a relatively simple and user-friendly manner, different ranges in concentration were identified for each selected variable, and categorised, where possible, into between three and four water quality categories, ranging from Target (Incorporating "Good" and "Fair" categories, to "Poor" and then "Unacceptable" (see **Table 2.1**).

With regard to rating ranges for **ecosystem condition**, the categories used are compatible with Present Ecological State categories used nationally, and the thresholds used to define ranges per category are based on those used in the Berg Resource Quality Objectives study (Aurecon 2019) and/ or the DWAF (2008) and

DWAF (1996) water quality guidelines.

Ecosystem condition rating ranges differentiate between standing water bodies (in this case, the main recreational vleis and dams included in the City's inland monitoring programme) and flowing water systems (that is, rivers and selected stormwater channels or outlets), with different variables and sometimes concentrations applicable to different watercourse types, as shown in **Tables 2.2 and 2.3**.

With regards to pH and EC values, trends in these important characterizing variables were considered simply relative to established Reference Condition ranges, as identified by Dallas et al (1998) for the Water Quality Management Region into which the City falls.

**Human health risk ratings** for *Escherichia coli* data were also based on those used in the Berg Resource Quality Objectives study, adapted to identify examples of extreme exceedance of these thresholds (as developed by the City in routine reporting ), as shown in **Table 2.4**, while Microcystin toxin thresholds were based on those already included in the City's Recreational Use Water Quality Index (see **Table 2.5**).

The ratings include both full contact (i.e. swimming) and intermediate contact (e.g. canoeing, sailing) for *E. coli* – see **Appendix C** for a detailed discussion of this issue, as well as of the decision-making process around the selection of all of these thresholds and their derivations. The rated ranges (Target to Unacceptable) are referred to hereafter as **City Water Quality Categories** (CWQCs).

**Different rates for different states**

Note that the rating of water quality with regard to its level of risk to **human recreational users** is very different to the rating of water quality with regard to its **ecological condition**, which considers the degree to which water quality has changed from natural. For example, a salt pan frequented by numerous wading birds might rate very poorly from a human health perspective, as a result of high levels of salt and bacteria, but could rate in a near-natural condition ecologically, as a relatively un-impacted representative of the 'salt pan wetland' type.

Photo by Theo Stock

Water quality assessments from a human health perspective typically include measures or (in some cases) indicators of pollutants that could cause harm to humans, if ingested or in contact with human skin or body parts (e.g. eyes, ears etc). Water quality assessments that examine ecosystem function implications rather focus on variables that could contribute to toxicity to aquatic organisms or alternatively to changes in habitat quality or availability (e.g. as a result of excessive plant growth that alters habitat type)

**Table 2.1 Relationship between Present Ecological State (PES) water quality categories A-F and scores, showing % deviation from natural conditions, as defined in DWAF (2008) for river Water Quality Resource Directed Measures, as well as the rating categories used in the present assessment ("City Water Quality Categories"), and the Ideal – Unacceptable categories used in DWAF (2011) and the Berg RQOs**

| This project: | | DWS Ecological Categories (PES) / RDM terminology | PES% score range | DWAF (2011) |
|---|---|---|---|---|
| City Water Quality Categories | Interpretation of City Water Quality Categories | | | |
| GOOD | TARGET | **A**: Natural / no change | 90-100% | Ideal |
| | | **B**: Largely natural, with few modifications / small change | 80-89% | |
| FAIR | | **C**: Moderately modified / moderate change | 60-79% | Acceptable |
| POOR | BELOW TARGET | **D**: Largely modified / large change | 40-59% | Tolerable |
| UNACCEPTABLE | UNACCEPTABLE | **E**: Seriously modified / serious change | 20-39% | Unacceptable |
| | | **F**: Critically modified / extreme change | 0-19% | |

**Table 2.2 Rating ranges for variables considered in this assessment of water quality in City rivers**

Note: PO4-P = orthophosphate phosphorus; TIN=Total inorganic Nitrogen; DO=Dissolved oxygen; N:P= ratio of TIN:PO4-P; NH3-N = nitrogen in un-ionised ammonia. Note also that the terms "PO4-P", "NH3-N" are abbreviations and are not the full chemical notation for these ionic compounds

| City Water Quality Categories (CWQC) | Interpretation of CWQC | PO4-P mg/l | TIN mg/l | DO mg/l | N:P | NH3-N mg/l |
|---|---|---|---|---|---|---|
| GOOD | TARGET | ≤ 0.025 (oligotrophic) | ≤ 0.70 (oligotrophic - mesotrophic) | > 6 | >25 | ≤ 0.044 |
| FAIR | | >0.025-- 0.075 (mesotrophic) | >0.70-1.75 (mesotrophic) | | | >0.044 - 0.072 |
| POOR | POOR | >0.075- 0.125 (eutrophic) | >1.75-3.00 (mesotrophic -eutrophic) | ≥4 -6 | 10-25 | >0.072-0.1 |
| UNACCEPTABLE | UNACCEPTABLE | >0.125 (hypertrophic) | > 3.00 (eutrophic - concentrations > 10mg/L classified as hypertrophic) | < 4 | < 10 | >0.1 |

**Table 2.3 Rating ranges for variables considered in this assessment of water quality in City Vleis and Dams**

Note: $PO_4$-P = orthophosphate phosphorus; TIN=Total inorganic Nitrogen; DO=Dissolved oxygen; N:P= ratio of TIN:PO4P; $NH_3$-N = nitrogen in un-ionised ammonia; CHL-A= Chlorophyll-*a*. Note also that the terms "PO4-P", "NH3-N" are abbreviations and are not the full chemical notation for these ionic compounds

| City Water Quality Categories (CWQC) | Interpretation of CWQC | PO4-P mg/l | TIN | DO mg/l | N:P | NH3-N mg/l | RUNNING MEAN ANNUAL CHL-A µg/l |
|---|---|---|---|---|---|---|---|
| GOOD | TARGET | ≤ 0.005 (oligotrophic) | ≤ 0.7 | > 6 | >25 | ≤ 0.044 | ≤ 10 |
| FAIR | | >0.005-- 0.015 (mesotrophic) | >0.7 -1 | | | >0.044 - 0.072 | >10 -20 |
| POOR | POOR | >0.015 - 0.025 (eutrophic) | >1.0-4.0 | ≥4 -6 | 10-25 | >0.072-0.1 | > 20 - 30 |
| UNACCEPTABLE | UNACCEPTABLE | >0.025 (hypertrophic) | > 4 | < 4 | <10 | >0.1 | > 30 |

**Table 2.4 Approach to assessment of microbial data (faecal coliforms including *Escherichia coli*)**
See Appendix C for derivation of threshold values.
Note inclusion of Full Contact and Intermediate Contact thresholds and expansion of UNACCEPTABLE range to show different scales of pollution

| Interpretation | [1]Faecal Coliform Count (*Including E. Coli)*[1] |
|---|---|
| TARGET FOR MAXIMUM ACCEPTABLE RISK FOR FULL CONTACT RECREATION | ≤ 400 CFU/100 ML \ |
| ACCEPTABLE RISK INTERMEDIATE CONTACT | 1 001-2500 CFU/100 ML |
| TOLERABLE RISK - INTERMEDIATE CONTACT | > 2500-4000 CFU/100 ML |
| UNACCEPTABLE RISK - INTERMEDIATE CONTACT– LEVEL 1 | > 4000 – 10 000 CFU/100 ML |
| UNACCEPTABLE RISK - INTERMEDIATE CONTACT– LEVEL 2 | > 10 001 -100 000 |
| UNACCEPTABLE RISK - INTERMEDIATE CONTACT– LEVEL 3 | > 100 000 |

[1]The concentrations of bacteria in water is usually expressed as numbers of colony-forming units (cfu) per 100 ml, which is a measure of the number of viable cells in a particular sample, where a colony represents an aggregate of cells derived from a single progenitor cell

**Table 2.5 Water quality grades and corresponding threshold concentrations for microcystin toxins for inland waters adopted for this project. Guideline levels are based on those published by the WHO (2003)**
See Appendix C for derivation of threshold values.

| Interpretation | Microcystin Toxin Concentration |
|---|---|
| TARGET (ACCEPTABLE) | ≤ 20 µg/L |
| MEDIUM RISK (UNACCEPTABLE) | >20- 30 µg/L |
| HIGH RISK (UNACCEPTABLE) | >30-40 µg/L |
| EXTREME RISK (UNACCEPTABLE) | >40 µg/L |

## 2.12 Data analysis

### *2.12.1 Sampling sites included used in the analyses*

Only sites in the City's routine monthly monitoring network have been included in this assessment. *Ad hoc* samples have been excluded.

It should be noted that the number of sites monitored in the City has increased substantially over time, with monitoring at some sites having ceased, while additional sites have been added, presumably as a result of new water quality problems / concerns being noted in these reaches. Accordingly, it is perhaps relevant to stress again that the placement of sample sites in problematic areas to track or manage pollution inherently creates a bias suggestive that ambient water quality in the City is universally impaired when this may not be necessarily the case (see Section 2.8).

**Figure 2.2** presents a graphical summary of changes in the number of samples collected from different subcatchments over the monitoring record, while **Figure 2.3** shows how the number of sites that are monitored has increased over time. **Table 2.6** presents the same data in table form, for ease of reference.

These data have an important implication for the interpretation of some of the figures and summary data presented elsewhere in this report. Summary data presenting changes in the percentage of sites falling within different rated categories ("Target", "Poor" or "Unacceptable") must be interpreted in the context of changing site and sample numbers, and an emphasis in site selection on sites representing river reaches where water quality issues have been identified.

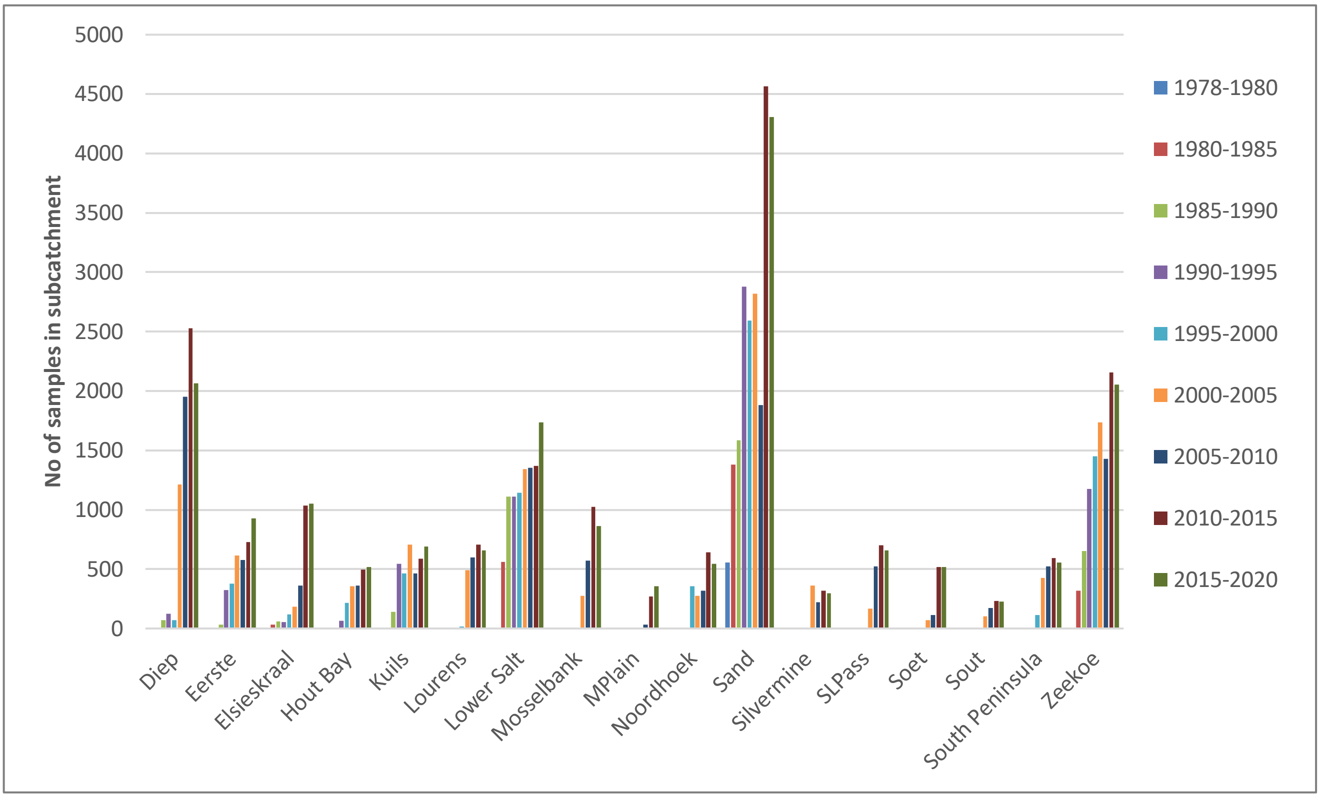



**Figure 2.2 Changes in number of samples collected from sites in different subcatchments over time**

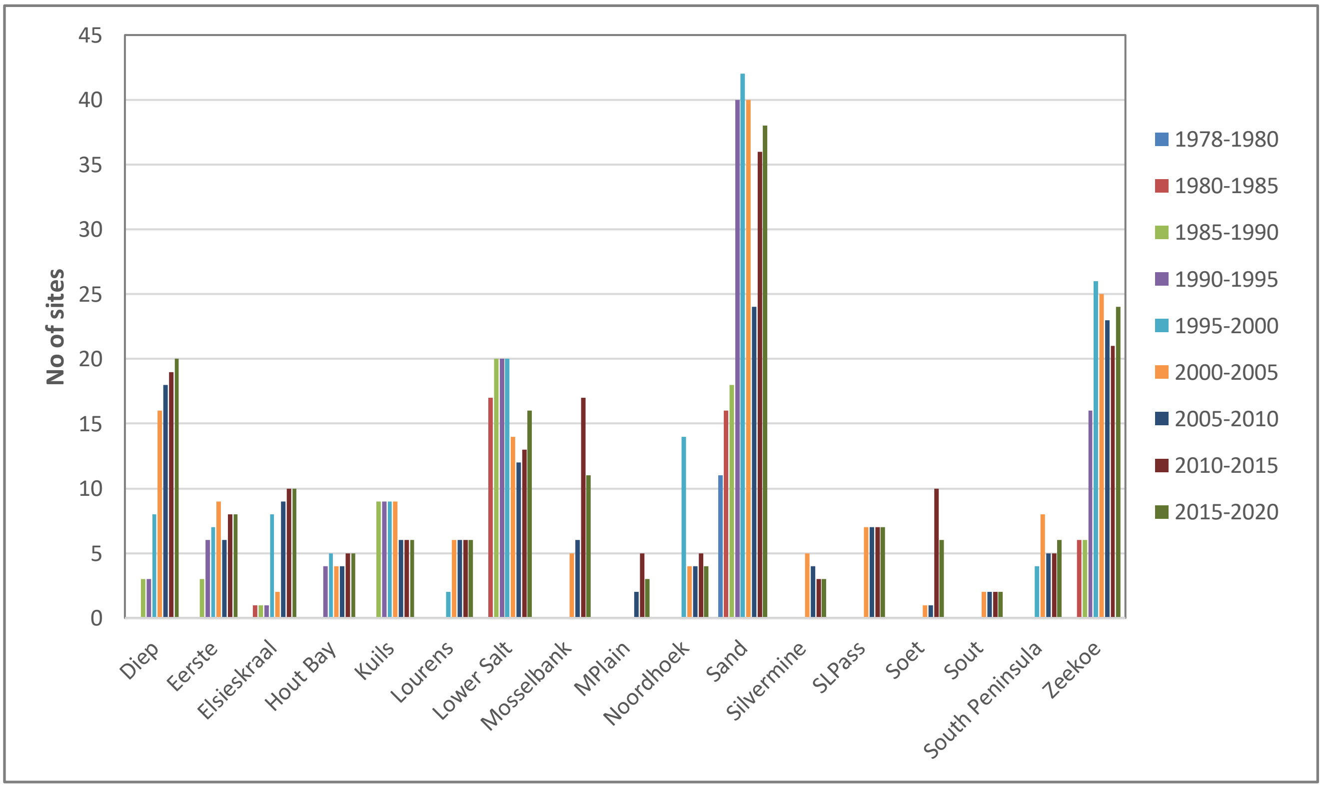



**Figure 2.3 Changes in number of sites at which samples are collected in different subcatchments over time**

The locations of all monitoring sites referred to in this report are shown in **Figure 2.4**. See Appendix A for more detailed descriptions of site locations and characteristics.

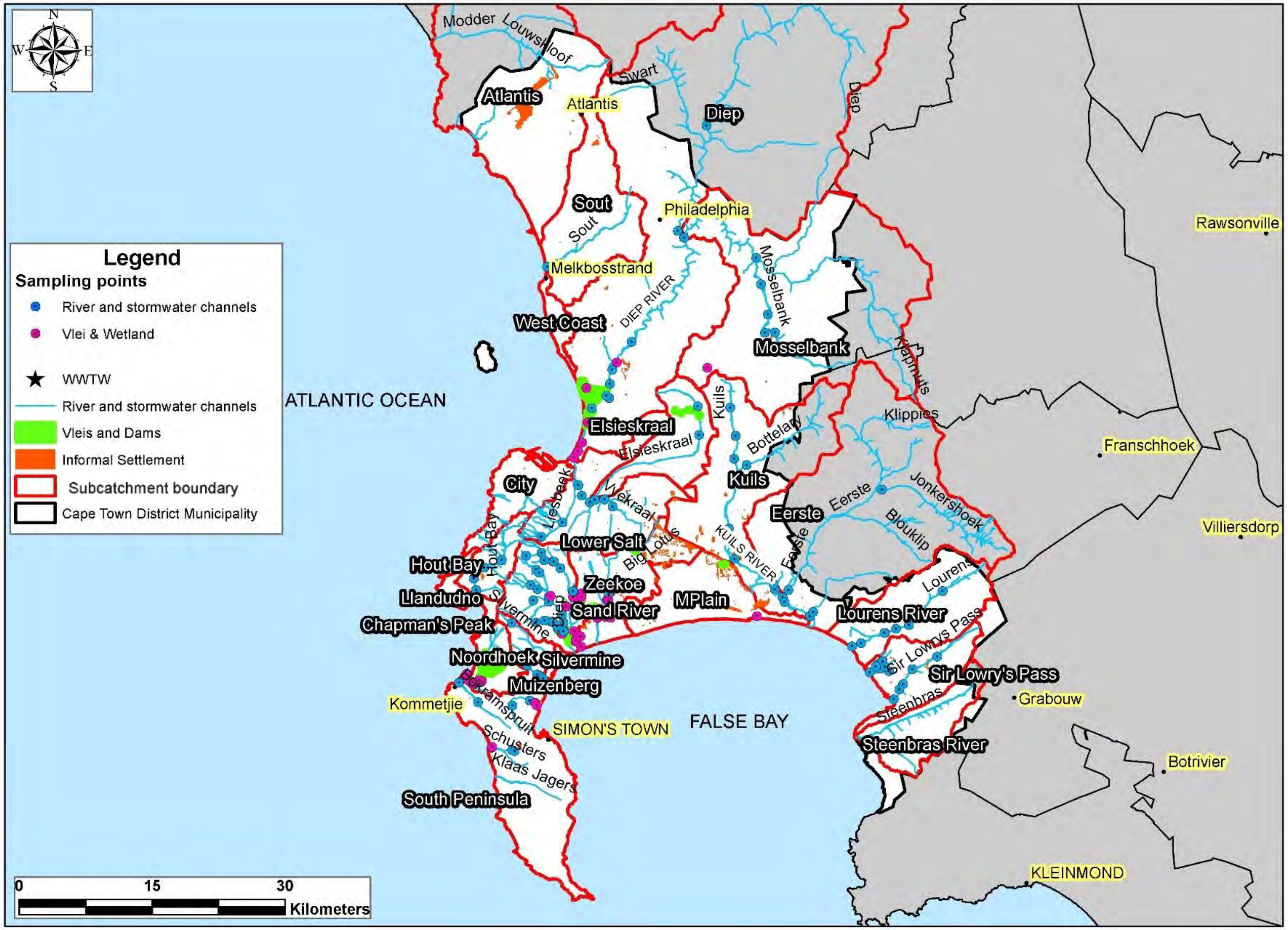



**Figure 2.4 City subcatchments showing river / stormwater channel and standing water (vlei and dam) water quality sampling point locations**

**Table 2.6 Changes in number of sample points in different subcatchments over time**

| SITE | 1978-1980 | 1980-1985 | 1985-1990 | 1990-1995 | 1995-2000 | 2000-2005 | 2005-2010 | 2010-2015 | 2015-2020 |
|---|---|---|---|---|---|---|---|---|---|
| Diep | | | 3 | 3 | 8 | 16 | 18 | 19 | 20 |
| Eerste | | | 3 | 6 | 7 | 9 | 6 | 8 | 8 |
| Elsieskraal | | 1 | 1 | 1 | 8 | 2 | 9 | 10 | 10 |
| Hout Bay | | | | 4 | 5 | 4 | 4 | 5 | 5 |
| Kuils | | | 9 | 9 | 9 | 9 | 6 | 6 | 6 |
| Lourens | | | | | 2 | 6 | 6 | 6 | 6 |
| Lower Salt | | 17 | 20 | 20 | 20 | 14 | 12 | 13 | 16 |
| Mosselbank | | | | | | 5 | 6 | 17 | 11 |
| MPlain | | | | | | | 2 | 5 | 3 |
| Noordhoek | | | | | 14 | 4 | 4 | 5 | 4 |
| Sand | 11 | 16 | 18 | 40 | 42 | 40 | 24 | 36 | 38 |
| Silvermine | | | | | | 5 | 4 | 3 | 3 |
| SLPass | | | | | | 7 | 7 | 7 | 7 |
| Soet | | | | | | 1 | 1 | 10 | 6 |
| Sout | | | | | | 2 | 2 | 2 | 2 |
| South Peninsula | | | | | 4 | 8 | 5 | 5 | 6 |
| Zeekoe | | 6 | 6 | 16 | 26 | 25 | 23 | 21 | 24 |

### *2.12.2 Taking seasonal variability into account*

A number of water quality variables are subject to significant seasonal variability, largely related to differences in rainfall between the wet and dry seasons. An attempt has thus been made to explicitly take seasonal variability into account in the current assessment by assigning one of two seasons to the data, as follows:

- Winter (typically the "wet season" in Cape Town) = April to September
- Summer (typically the "dry season" in Cape Town) = October to March

These seasons were based on the four seasons assigned by Dallas *et al*. (1998) in the development of regional guidelines for water quality assessment in South Africa, with the "winter" referred to here, starting mid-way through the Dallas *et al.* autumn season (i.e. April) and "summer" starting mid-way through the Dallas et al spring season.

Each sampling record in the dataset was pre-assigned to one of the two above-mentioned seasons before conducting the data analyses. The dataset used in the report concludes in March 2020 (end of dry season).

### *2.12.3 Spatial groupings of data*

Sites within the water quality dataset were classified in terms of subcatchment, using the areas identified in **Figure 2.1**. The assignment of different sites to subcatchments is indicated in the sites table in Appendix A. The subcatchments used as the basis for data analysis are as listed below, noting however that in some cases, the “subcatchments” comprise whole river catchments (e.g. Hout Bay River), while in others the main catchments have been split into different subcatchments (e.g. Mosselbank and (lower) Diep subcatchments of the Diep River). Other “subcatchments” in fact comprise a number of different river systems in adjacent catchments, considered sufficiently similar in terms of landuse to warrant lumping together by area (e.g. South Peninsula, comprising the Else, Bokramspruit and Schusters rivers). This was done to reduce the total number of subcatchments in this report to more manageable numbers. The groupings were as follows for catchments and subcatchments with water quality data:

- Diep
    - Mosselbank
    - Diep

- Eerste
    - Kuils (to Baden Powell Drive)
    - Lower Kuils and Eerste
- Salt
    - Lower Salt
    - Elsieskraal
- Hout Bay
- Lourens
- Mosselbank
- Mitchell's Plain (Mplain)
- Noordhoek
- Sand
- Silvermine
- Sir Lowrys Pass (SLPass)
- Soet
- Sout
- South Peninsula
- Zeekoe

Note that of these systems, the Mitchell’s Plain subcatchment does not include any natural river systems. Rainfall in this part of the Cape Flats would, under natural circumstances, have percolated through the deep dune sands to the underlying aquifer, and seeped through to the coast in places. In a development context, this is however an important subcatchment, which generates large volumes of runoff from hardened urban areas. Two stormwater attenuation pond sample sites have been used to represent water quality in this subcatchment, runoff from which is also represented in a number of coastal sample sites, which include stormwater outlets onto the False Bay beach. The coastal sites are not considered here, as water quality data from these sites have already been assessed in the City’s “Know your Coast 2019” coastal report.

It should also be noted that not every catchment in the City is represented in the monitoring programme. Some catchments that are not considered problematic from a water quality perspective; or which do not have significant river systems (e.g. the Atlantis subcatchment) or where natural rivers have been entirely piped into the stormwater system (e.g. the City Bowl) do not have any monitoring sites.

### *2.12.4 Analysis of historical (long-term) data*

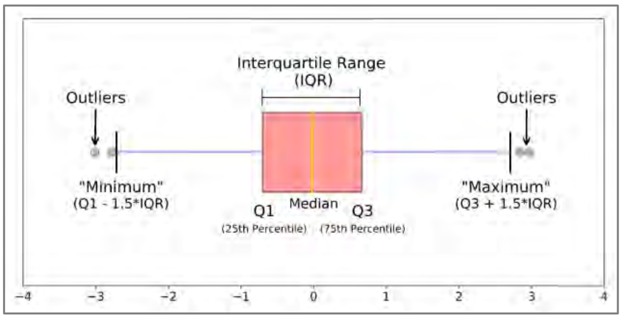
The following types of analysis were performed on the data, for the selected variables, separated according to watercourse type (standing water (vleis, dams and detention ponds) and flowing water (rivers, stormwater channels and estuaries)):

- Data were grouped into five-year time periods, with each period beginning in April of the first block and ending in March of the fifth year;
- For each five-year period (and for each season separately), the percentage of samples falling within the target range for the particular water quality parameter was calculated, as well as the percentages of samples falling into the “Target”, "Poor" and "Unacceptable" interpretation categories (see **Tables 2.2-2.4**), and presented as stacked bar graph summaries;

- Box and whisker plots (also known as boxplots) were produced, summarising these data by subcatchment, and showing summer and winter variation;

**Boxplot interpretation guide**

The figure below indicates how to interpret the box plots used in this report, with the yellow line in this figure indicating the median value, within a "box" representing the interquartile range – that is, the range between the 25th and 75th percentiles. The "whiskers" of the box indicate maximum and minimum values within 1.5 times the interquartile range added to the 75th percentile and subtracted from the 25th percentile, respectively. Outliers are shown as individual dots on either side of this range.




- The data were described in terms of each major variable considered, drawing attention to subcatchments of particular interest.

Exceptions to the above treatment of data were EC and pH datasets, which were treated as follows (see **Appendix C** for a reasoned discussion of this issue):

- Boxplots were compiled for both EC and pH, comparing the distribution of measured values in each subcatchment;
- In addition, separate time series graphs of the average EC and pH in each subcatchment were produced. Site data for each variable were extracted separately using a spreadsheet pivot table, and grouped/ filtered by subcatchment. Only river sites were considered ([3]dams, vleis and estuaries were excluded). Date stamps were not consistent - in general, data represented monthly readings, but there were numerous exceptions where multiple readings were taken within specific months or time periods. Consequently, all data were standardized to the 1st of each month, with means/medians calculated for multiple records within a month. Since pH values represent a logarithmic scale, raw values were first transformed using the inverse of a natural logarithm (exp), and then reconverted to pH values post-manipulation using the natural logarithm.
- Since EC data were not normally distributed, median monthly EC values per subcatchment were used for the time series graphs. Summary values for each subcatchment were derived using medians and 5th/95th percentile values. Conversely, due to the data transformations that were undertaken, mean monthly values per sub-catchment were used for the pH time series graphs, and their standard deviations used for the summary range.
- For the boxplots and the time series graphs, for both pH and EC, separate plots were produced for Upper River and Lower River sites in each subcatchment, in recognition of the importance of differentiating between the natural conditions of upper river zones (Headwater Stream, Mountain Stream, Upper Foothills) and lower river zones (Lower Foothills, Lowland Floodplain Rivers) in terms of these water quality parameters.
- The EC and pH data recorded in the subcatchments of the City over the time period of analysis (1980-

[3] Estuaries were excluded because their salinity should be markedly different from river salinity and subject to tidal fluctuation, too complex to be picked up in the limited estuarine monitoring sites and beyond the scope of this project. Standing water bodies were excluded because of their usually artificial nature

2019), as represented on the boxplots and time series graphs of averaged data, were compared against "reference values" that have been established by Dallas *et al*. (1998) for the Water Quality Management Region that the City falls within. This was done by plotting "background panels" on the graphs (shaded green), showing the mean/median reference range. In line with the DWAF (1996) water quality guidelines for aquatic ecosystems in relation to EC and pH, the "reference range" was taken as the upper and lower medians plus/minus 15% in the case of EC, and as the upper and lower mean values plus/minus one pH unit in the case of pH. For Upper River sites, the upper limit of the range was derived from the mean/median for the Mountain Stream Zone and the lower limit from the mean/median for the Upper Foothill Zone. In the case of Lower River Sites, the upper limit was derived from the mean/median for the Lower Foothill Zone (termed "Transitional" by Dallas *et al*. 1998) and the lower limit from the mean/median for the Lowland Floodplain River Zone.

**[Time series graphs presented in Appendix D and E]**

### *2.12.5 Analysis of current data*

For the purposes of this report, "current" data were defined as the last year of the monitoring record – that is, April 2019 to March 2020, and treated as follows:

- Date nomenclature: the annual sample period comprises the period from 1 April to 31 March in any given cycle, and is given the YEAR identity at the start of the period. Thus data for the period 1 April 2019 to 31 March 2020 are referred to as the **2019** dataset;
- Seasons were allocated as described in Section 2.10.2;
- Subcatchments were used as the unit of analysis, as already described;
- Sites were analysed separately according to watercourse type (standing water (vleis, dams and detention ponds) and flowing water (rivers and stormwater channels);
- Estuaries were classified as to whether they were standing water or flowing systems – e.g. water quality data for the Diep River Estuary / Milnerton lagoon were classified as from a flowing water system, and included, while Zandvlei was classified as a standing water system – note that these classifications applied only to water quality variables such as DO, PO4-P, TIN, N:P rations and *E. coli* concentrations, the interpretation of which did not differ between estuarine and freshwater systems. Assessments of salinity, measured as Electrical Conductivity (EC), did however distinguish between estuaries and other aquatic ecosystems;
- Median annual and seasonal data were calculated for the current year, and compared against the combined year sets 2015 to 2018 for all key variables, except *E. coli* and Chlorophyll-*a,* for which geometric and arithmetic mean data were calculated, respectively;
- Boxplots were developed for each of the selected data, and presented for discussion, comparing the current (2019) dataset with data from the past four years (2015 – 2018) – these data are presented relative to the CWQC interpretation categories for aquatic ecosystem health and human health (*E. coli*) of **Tables 2.2 – 2.4**;
- Data showing <u>change</u> in median annual and seasonal data per variable between 2019 data and the 2015-2018 dataset were plotted on GIS maps for each subcatchment, with the maps depicting current state (2019) in terms of CWQC categories Target to Unacceptable, with a symbol indicating degree of change in median data, compared to the 2015-2018 period. Significant "Change" was determined as an increase or decrease of 25% or more, compared to the 2015-2018 dataset;
- Median data per site per variable (mean data for *E. coli* and Chlorophyll-*a*) were also presented (**Appendix G**), with data colour-coded for ease of reference as to its CWQC category.

### *2.12.6 Assessment of the current state of water quality in terms of human health risks at major recreational (vlei) sites*

For the assessment of the current state of water quality within the City, the last five years of available data were used, and the same seasonal cycles and year nomenclature were used as presented in Section 2.10.2.

Data focused on the main recreational vleis / water bodies in the City, namely:

- Princessvlei
- Zeekoevlei
- Rietvlei
- Milnerton lagoon
- Zandvlei.

Assessment of human health risk at each water body entailed an analysis of the percentage of samples that exceeded the target value for safe intermediate contact recreation in terms of *E. coli* and Cyanophyte toxin concentrations (see Section 2.9 for an explanation of the relevant criteria).

Because of its implications in predicting how likely a system is to be prone to algal blooms, Chlorophyll-a data were also considered in this section, for recreational water bodies only.

*E. coli* data were analysed using all of the data generated across the assessment period, and separating the data into summer and winter seasons.

Analysis of *E. coli* data had the objective of calculating the probability of exceedance of each threshold condition (Target, Tolerable and Unacceptable as per **Table 2.4**) for *E. coli* density at each site. The method used is a date-independent method that is based on the number of records for each site. Data were assigned a rank order (i.e. 1 = first record, n = last record), then sorted from smallest to largest values with rank orders also sorted. Spreadsheet Visual Basic macros were used to calculate Spearman's rank orders and their sums. Based on these, return intervals were calculated using the % rank using the total number of records. Return interval curves were then plotted. The probability of exceedance of a given threshold was the inverse of the first return interval above the 1000 counts/100ml.

### *2.12.7 Consideration of rainfall patterns*

In order to aid in the interpretation of water quality results, rainfall datasets (that is, precipitation measurements) from selected rain gauging stations located within the City were analysed, as outlined below.

The short-term rainfall analyses completed for the current project involved the use of monthly rainfall data from 23 rain gauging stations, spread across the City (see list in **Table 2.7**). The main aim of these analyses was to gain an understanding of the spatial variability in rainfall between different sub-catchments within the City. Due to some stations having incomplete datasets, this analysis utilised data spanning the period April 2016 to March 2019 only. Notwithstanding this limitation, the rainfall data that were obtained from the City of Cape Town provide a rough indication of the spatial (and temporal) variability in rainfall across the study area for the April 2016 to March 2019 time period.

**Table 2.7 List of City rain gauging stations used in the rainfall analyses, indicating which subcatchment each station is located within**

| Station | Description | Catchment | Subcatchment |
|---|---|---|---|
| ATLA17AR | Atlantis WWTW | Atlantis | Atlantis |
| CITY11BR | Molteno Reservoir | City Bowl | City Bowl |
| DIEP05ER | Table Mountain | | |
| DIEP01AS | Rietvlei: Blaauwberg | Diep | Diep |
| KRAA01RS | Kraaifontein Roads Depot | | Mosselbank |
| EERS02AR | Klein Welmoed: Stellenbosch | Eerste / Kuils | Eerste |
| LOUR06BRS | Vergelegen Farm: Entrance | Lourens | Lourens |
| KHAY01RS | Khayalitsha Roads Depot | M-Plain | M-Plain |
| NORH08BR | Noordhoek Forestry Station | Noordhoek | Noordhoek |
| WILD08AR | WildevoelVlei WWTW | | |
| ELSI03CR | Tygerberg Reservoir | Salt | Elsieskraal |
| ELSI03XS | Howard Centre: Pinelands | | |
| ELSI03BR | Dagbreek Reservoir | | |
| ELSI03DR | Goodwood Bowling Greens | | |
| ELSI03ER | Pinelands Roads Depot | | |
| ELSI03AR | Maastricht Farm | | |
| VYGE03GR | Athlone WWTW 01 | | Lower Salt |
| LIES03FR | Newlands Reservoir | | |
| DIEP05CR | Wynberg Reservoir | Sand | Sand |
| DIEP05BR | Southfield Roads Depot | | |
| KEYS05FR | Tokai Forest | | |
| DIEP05AR | Kendal Water Works Depot | | |
| SPEN13AR | Simons Town | South Peninsula | South Peninsula |

In order to provide some understanding of longer term rainfall patterns over the full monitoring period considered in this report (i.e. 1980 to 2020), data from the above gauging stations were supplemented with data from a rain gauging station at Paardevlei (Somerset West). This dataset, originally compiled by AECI, contained monthly rainfall figures from July 1905 to August 2015. For the current study, data were extracted for the April 1980 to March 2015 period. Unfortunately, given the length of the data record, rainfall monitoring was discontinued at this site in 2015, after the City purchased the site from Paardevlei Properties. There are thus no data for the period April 2015 to March 2020 for this site.

In order to try to fill this gap, monthly rainfall data were also obtained from a rain gauge at Intaka Island (Century City), for the period January 1996 to March 2020. This rain gauge is managed by the Century City Property Owners' Association (CCPOA). For the current study, data were extracted from this dataset for the 20-year time period from April 2000 to March 2020.

For all the rainfall analyses, monthly rainfall figures were grouped into "hydrological years" (April to March), as opposed to calendar years, and into "winter" (April to September) and "summer" (October to March) using the seasonal categorisation explained in Section 2.12. The Paardevlei and Intaka Island datasets were also grouped into 5-year time periods, as was done for the historical water quality analyses in the current report. For the City's 2016 - 2019 dataset, rain gauging stations were grouped into sub-catchments for some of the analyses. It should be noted that the Paardevlei rain gauging station is located within the Lourens River catchment, while the Intaka Island rain gauge is located within the Diep River catchment.

The following summaries were produced from the three rainfall datasets:

- Paardevlei and Intaka Island gauging stations:
    - Total annual rainfall for each year, compared against the mean annual average over the period of analysis (1980 - 2015 for Paardevlei and 2000 - 2020 for Intaka Island);
    - Mean annual rainfall (and standard deviation) per 5-year period; and
    - Mean monthly rainfall (and standard deviation) by season per 5-year period;
- City gauging stations:
    - Total annual rainfall for each year, compared against the mean annual average across all gauging stations per year;
    - Mean annual rainfall (and standard deviation) across all gauging stations per year;
    - Mean annual rainfall (and standard deviation) per sub-catchment, compared against the mean annual average across all gauging stations per year and against the Paardevlei 1980 - 2015 long-term annual average;
    - Mean monthly rainfall (and standard deviation) by season across all gauging stations per year; and
    - Mean monthly rainfall (and standard deviation) by season and year per subcatchment with "winter" averages.

# 3 RAINFALL PATTERNS

## 3.1 Annual rainfall

The mean annual rainfall at Paardevlei over the 35-year period of analysis (1980 - 2015) was just under 600 mm (see **Figure 3.1**). There were five particularly "wet" years with >700mm cumulative annual rainfall during this period (in 1984 - 85, 2001 - 02, 2007 - 08, 2012 - 13 and 2013 - 14), and six "dry" years with <500mm cumulative annual rainfall (in 1994 - 95, 2000 - 01, 2003 - 04, 2010 - 11, 2011 - 12 and 2014 - 15).

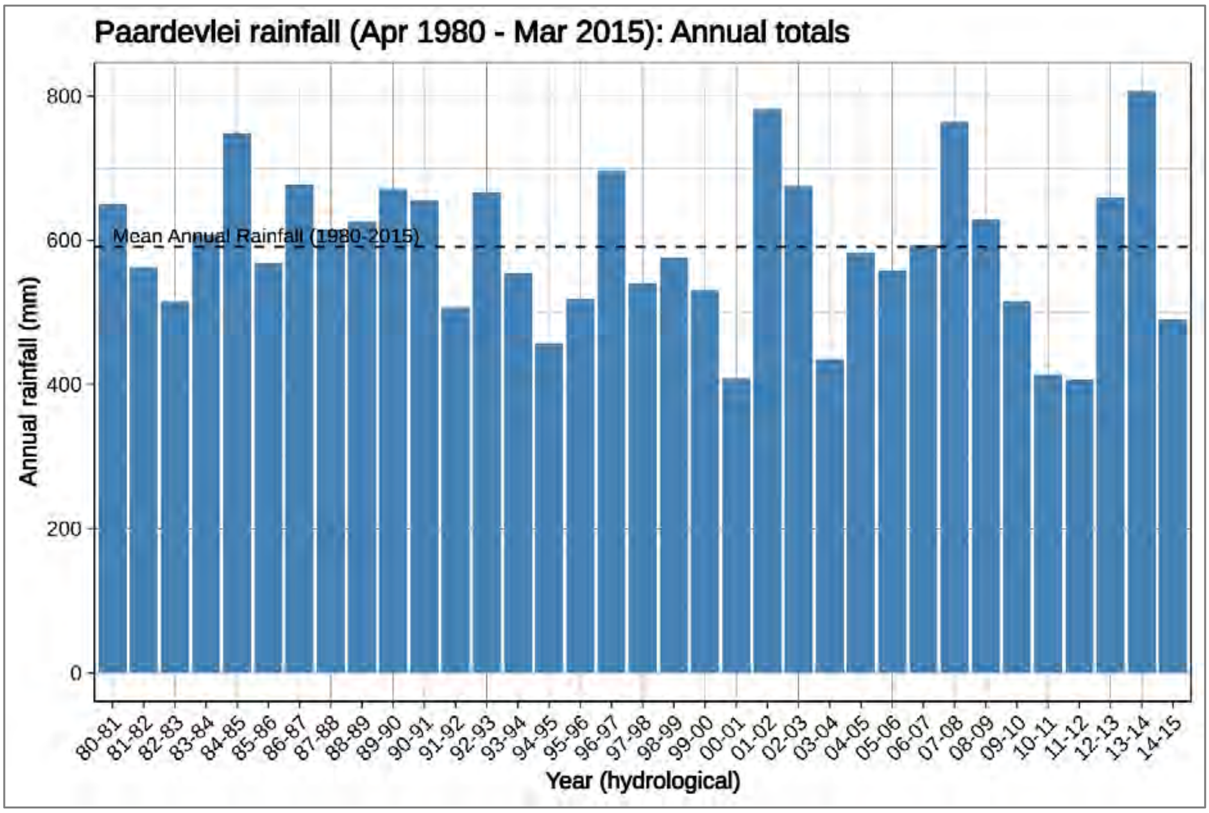



**Figure 3.1 Total annual rainfall at Paardevlei (1980 - 2015), showing mean annual rainfall over this period**

Interrogation of the mean annual rainfall per 5-year period at Paardevlei (see **Figure 3.2**) shows that the wetter periods in the last 35 years, on average, were in 1980 - 85, 1985 - 90 and 2005 - 2010. During these 5-year periods, the mean annual rainfall and the range of values (as represented by the spread of the standard deviation) were slightly higher than the other 5-year periods. Periods with the highest levels of variability (standard deviation > 100 mm per annum) were 2000 - 2005 and 2010 - 2015.

**Date nomenclature**

Note that the annual sample period comprises the period from 1 April to 31 March in any given cycle, and is given the **year identity at the start of the period**. Thus data for the period 1 April 2019 to 31 March 2020 is referred to as the 2019 dataset. Section 2.12 for more details.

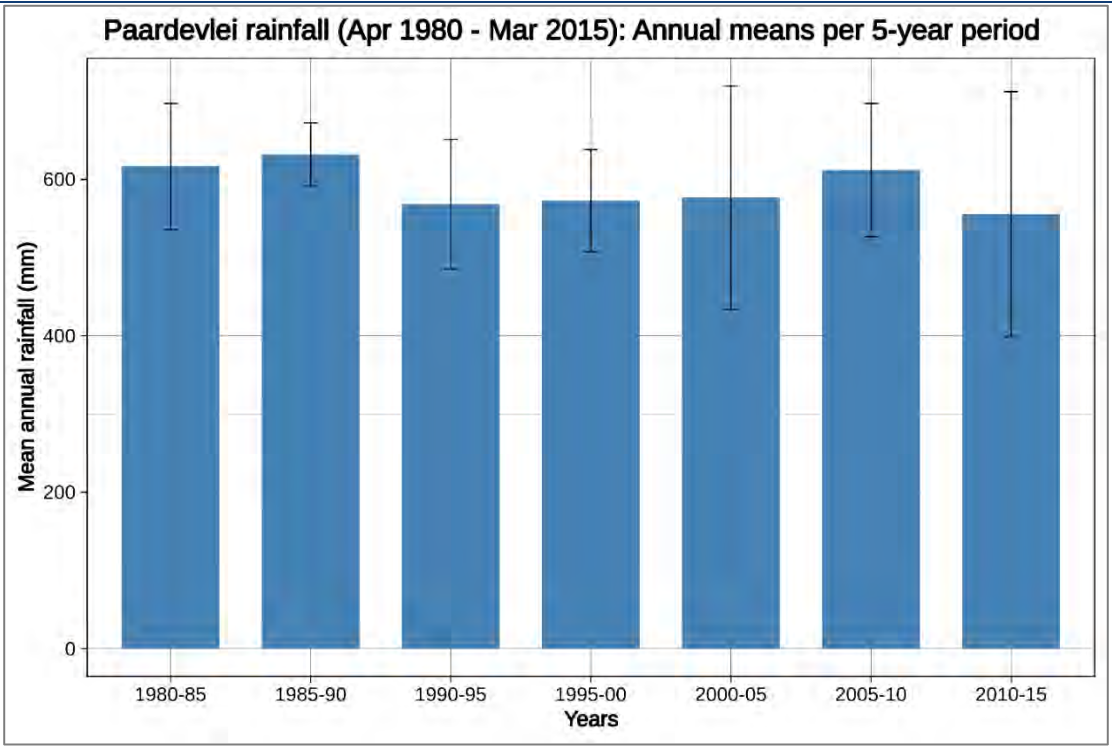



**Figure 3.2 Mean annual rainfall (and standard deviation) for each 5-year period between 1980 and 2015 at Paardevlei**

The mean annual rainfall at Intaka Island over the 20-year period of analysis (2000 - 2020), calculated to be 588.6 mm, was slightly lower than the long-term average at Paardevlei (just under 600 mm per annum), largely owing to the low annual rainfall totals recorded between 2014 - 15 and 2017 - 18 (see **Figure 3.3**) when no further measurements were taken at Paardevlei. There were five particularly "wet" years with >700mm cumulative annual rainfall at Intaka Island during this period (in 2001 - 02, 2004 - 05, 2005 - 06, 2012 - 13 and 2013 - 14), and nine "dry" years with ~500 mm or less of cumulative annual rainfall (in 2000 - 01, 2008 - 09, 2010 - 11, 2011 - 12 and all the years from 2014 - 15 to the end of the period of analysis with the exception of 2018 - 19). In general, the cumulative annual rainfall at Intaka Island was higher than or at least similar to that at Paardevlei for the same year, with significant exceptions being the years 2007 - 08 and 2008 - 09 when relatively high total annual rainfall figures were recorded at Paardevlei coinciding with 150 to 200 mm less rainfall being recorded cumulatively at Intaka Island. Another significant difference between the annual rainfall totals recorded during the same time period at Paardevlei and Intaka Island was in 2004 - 05 and 2005 - 06, when particularly high cumulative annual rainfall figures (>800 mm per annum) were recorded at Intaka Island near the centre of the City versus relatively low figures (<600 mm per annum) at Paardevlei, which lies in the eastern part of the City.

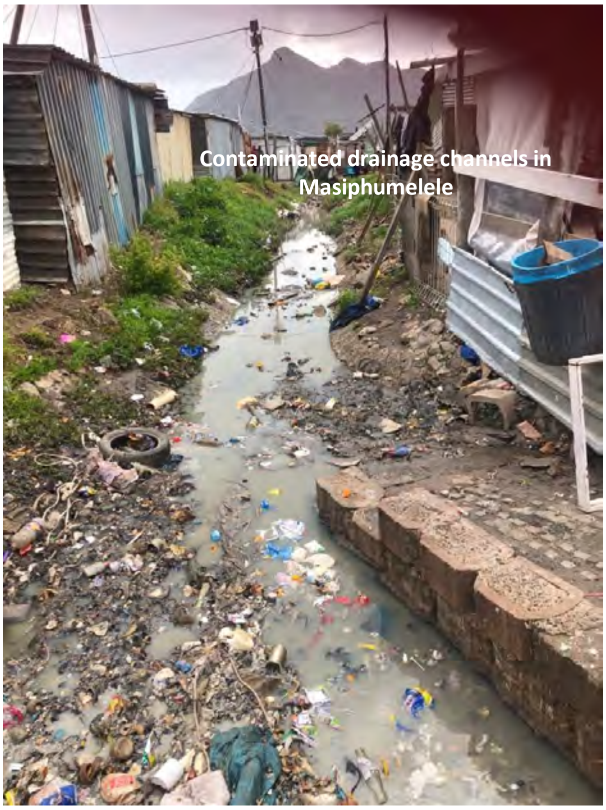
The graph of mean annual rainfall per 5-year period at Intaka Island (see **Figure 3.4**) shows that the wettest period at that gauging station in the last 20 years was in 2000 - 2005 and highlights the dry (and less variable) conditions experienced in 2015 - 20 when the mean annual rainfall was less than 450 mm. The variability in mean annual rainfall (represented by the standard deviation) was significantly greater at Intaka Island (>200 mm, except for 2015 - 20) than it was at Paardevlei over the same 5-year periods.

**Drought, floods and water quality**

Periods of drought can be linked to reduced water quality in urban rivers and wetlands, as the pollutant load tends to remain the same while dilution by rainfall is reduced.

Rainfall events can have varying effects on water quality in urban areas, depending on catchment characteristics. In well-serviced areas, where runoff entering the stormwater system includes only pollutants associated with normal urban activities (e.g. runoff from well-maintained roads and parking areas), then rainfall events usually result in improved wet season water quality in watercourses, as a result of dilution, after an initial "first flush" of pollutants. This entails increased concentrations of contaminants entering watercourses after a prolonged dry period, when accumulated pollutants are washed off the catchment, whereafter the catchment is much cleaner and produces much lower pollutant loading in subsequent events.


The exception to this is in poorly or unserviced areas, where stormwater includes grey and even black water, and high levels of waste build up in drainage channels and streets on a daily basis. Cerfonteyn and Day (2011) found that in such catchments, there is often no wet season reduction in pollutant concentration, with larger storms simply washing greater loads of pollutants into the system, and pollutant accumulation rate being greater than wash off rate.



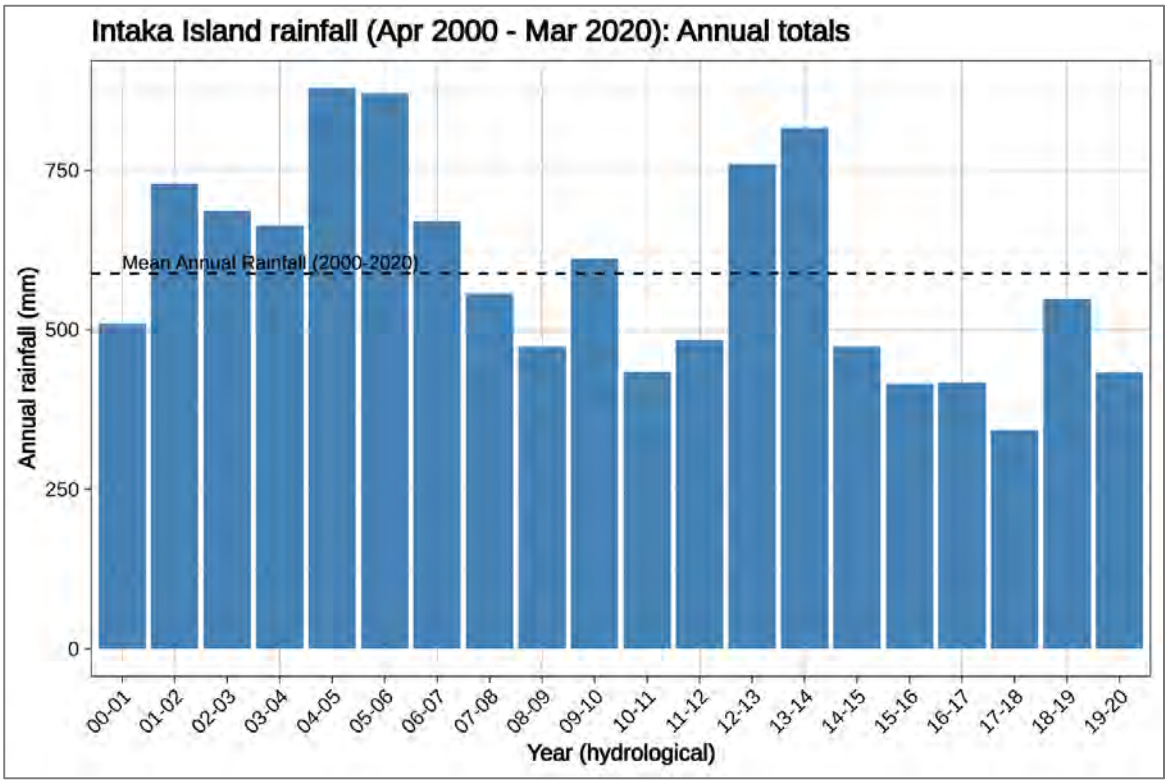



**Figure 3.3 Total annual rainfall at Intaka Island (2000 - 2020), showing mean annual rainfall over this period**

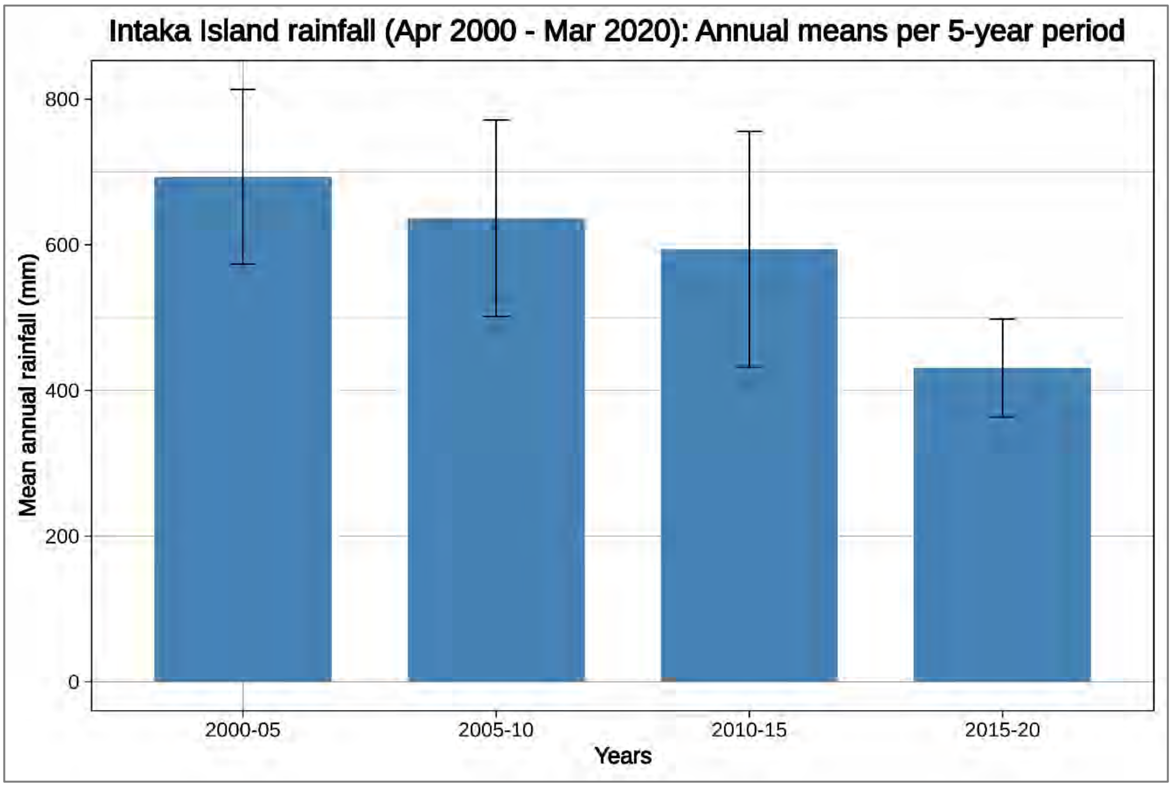



**Figure 3.4 Mean annual rainfall (and standard deviation) for each 5-year period between 2000 and 2020 at Intaka Island**

The graph of total annual rainfall at the selected CCT rain gauging stations for the 2016 - 2019 period (**Figure 3.5**) shows that there was a significant amount of variability between gauging stations across the City in each year. At all the rain stations significantly less rain was consistently recorded for 2017 compared to 2016 and 2018, with a mean annual rainfall across all stations of less than 320 mm in 2017 versus approximately 450 mm in the preceding and following years. Similarly, 2017 was the year with the lowest rainfall during the 20-year period of analysis (2000 - 2020) at Intaka Island, with less than 400 mm of cumulative rainfall recorded over the year. This pattern is also shown very clearly in the graph of mean annual rainfall (and standard deviation) per year across the CCT gauging stations (**Figure 3.6**), confirming that 2017 was a particularly dry year across all parts of the City.

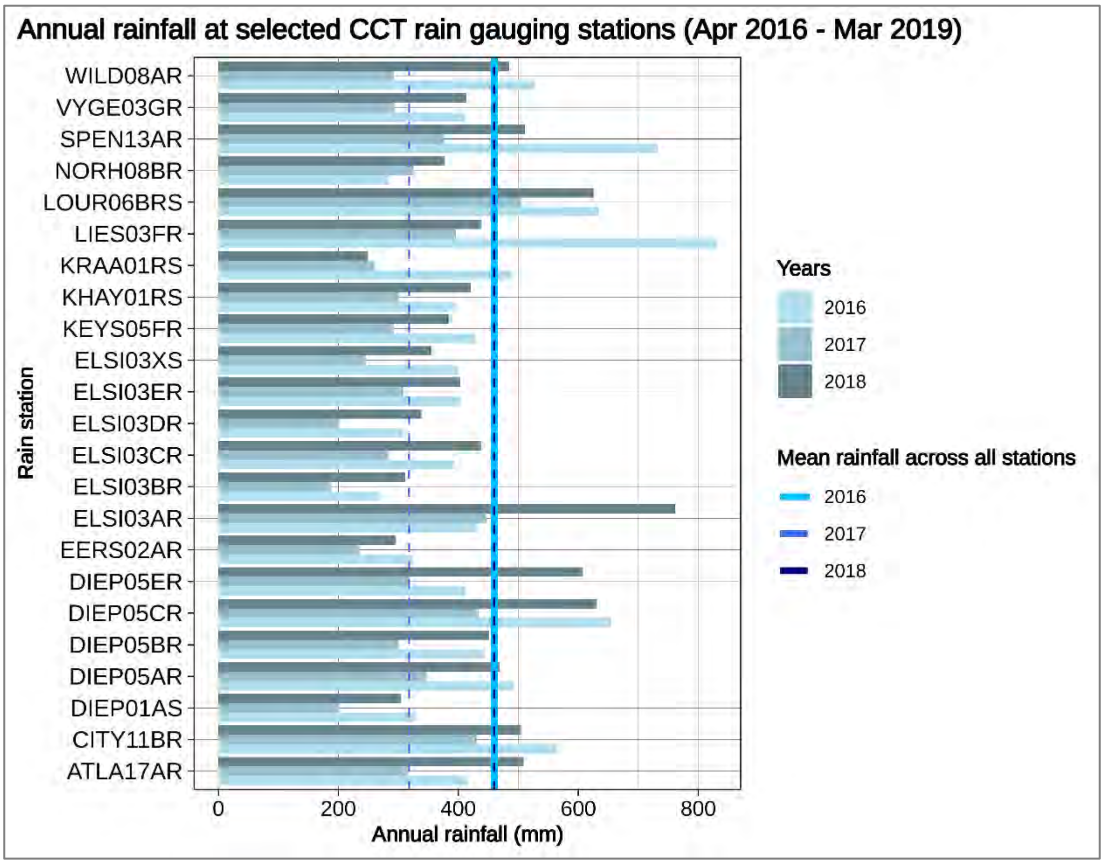



**Figure 3.5 Average Total Annual Rainfall (2016 - 2018) at each CCT rain gauging station that was selected for the rainfall analyses, showing the mean annual rainfall across all stations for each year (note that the mean annual rainfall was very similar in 2016 and 2018, so the two lines for these years are on top of each other)**

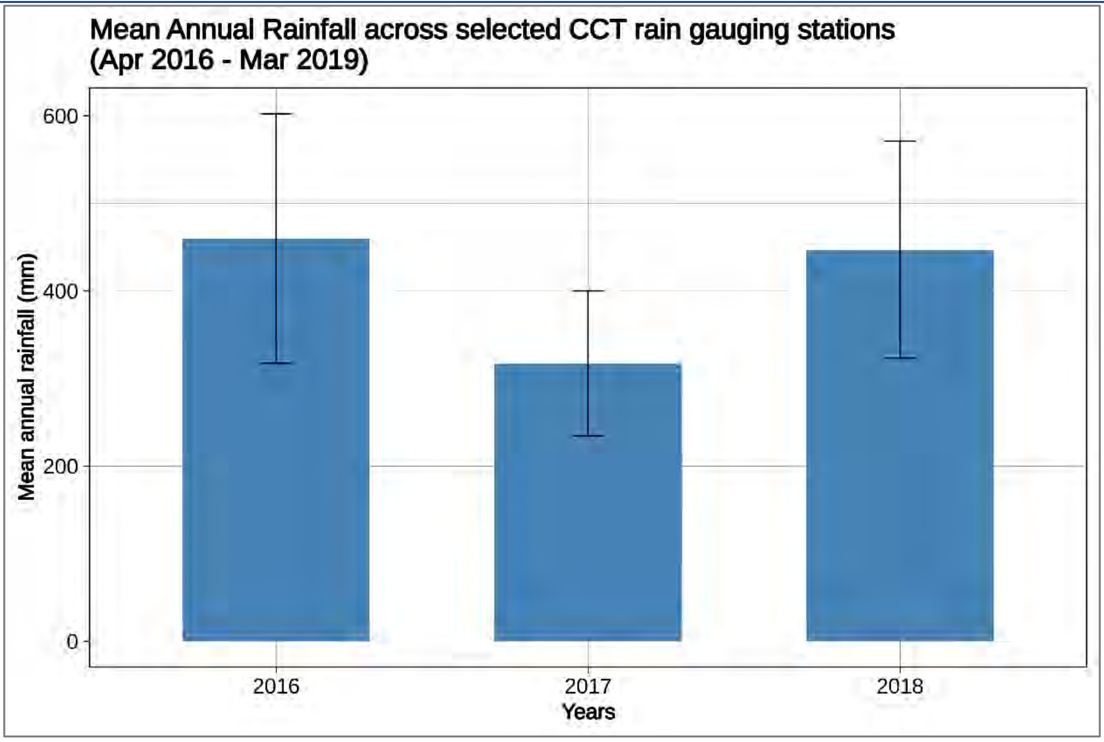



**Figure 3.6 Mean annual rainfall (and standard deviation) per year across all CCT rain gauging stations that were selected for the rainfall analyses (2016 - 2018)**

The same pattern is evident at a sub-catchment level (see graph of mean annual rainfall by sub-catchment in **Figure 3.7**), except for the Mosselbank River sub-catchment where the annual rainfall (represented by one gauging station, KRAA01RS - see **Table 2.7**) was similar in 2017 and 2018. The reason for the discrepancy in the Mosselbank River sub-catchment may well have to do with erroneous data, with rainfall amounts of zero recorded at this gauging station in November and December 2018, when most other rainfall stations across the City recorded some rainfall. Comparing the mean annual rainfall per year in each sub-catchment against the mean annual rainfall calculated per year for all stations across the City (shown as horizontal lines in **Figure 3.7**) indicates that sub-catchments with some rain stations in more mountainous areas (i.e. Lourens River, City Bowl, Sand River and South Peninsula) tend to have above-average rainfall, whereas sub-catchments in the lowlands (e.g. Eerste River, Diep River, Noordhoek and Mitchells Plain) tend to be below-average.

Most of the annual averages from 2016 to 2018 at a sub-catchment scale were below the long-term (1980 - 2015) annual average rainfall figure derived from the Paardevlei gauging station (represented by a dashed purple line in **Figure 3.7**), reflecting the drought conditions in the City during this time period. Exceptions to this pattern (namely the Salt, South Peninsula and Lourens sub-catchments in 2016, and the City Bowl and Lourens River sub-catchments in 2018) are related to sub-catchments with rain gauging stations in more mountainous areas that tend to have above-average rainfall, as discussed above.

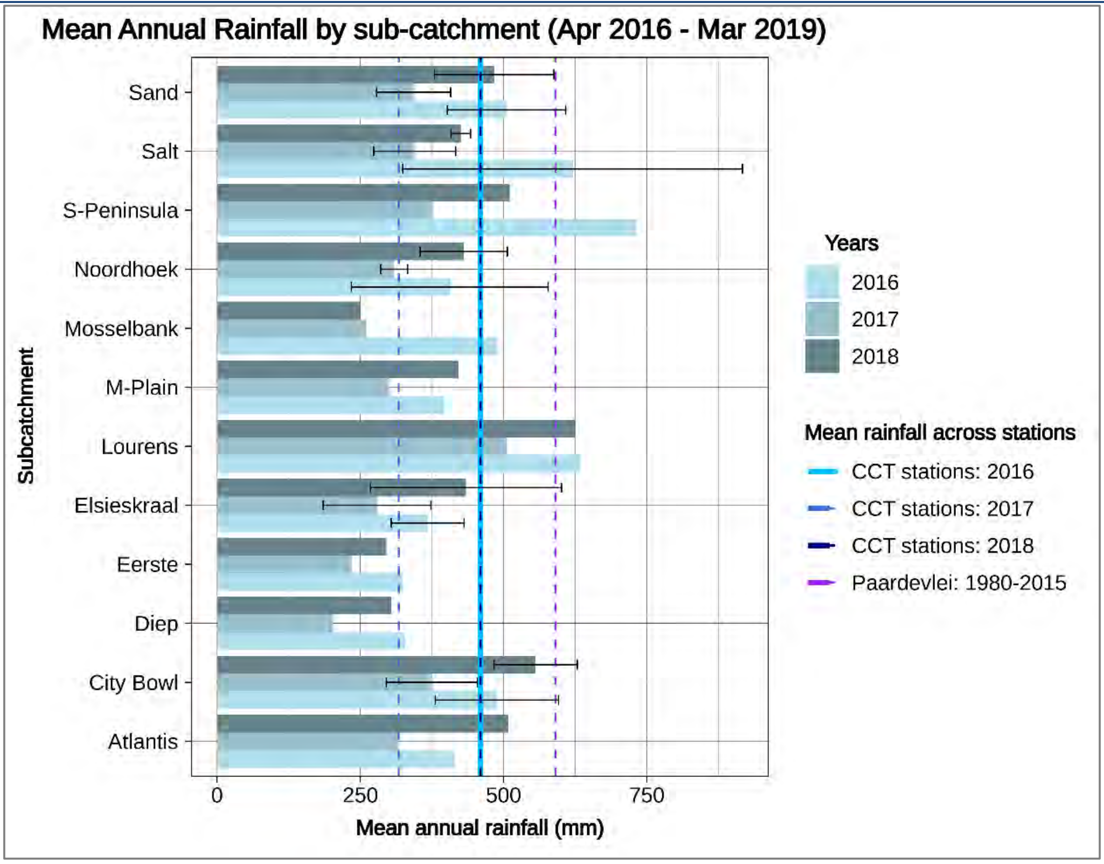



**Figure 3.7 Mean annual rainfall (and standard deviation, where relevant) per year for each subcatchment within which CCT gauging station data were obtained (2016-2018), plotted against the mean annual rainfall across all CCT stations each year and the long-term (1980-2015) mean annual rainfall at Paardevlei (note that the mean annual rainfall across CCT stations was very similar in 2016 and 2018, so the two lines for these years are on top of each other)**

## 3.2 Monthly rainfall by season

The analyses of mean monthly rainfall per season, for the long-term datasets from Paardevlei (**Figure 3.8**) and Intaka Island (**Figure 3.9**) and for the short-term CCT gauging station data from April 2016 – March 2019 (**Figure 3.10**), show that the summer rainfall is significantly lower than the winter rainfall. This confirms that the seasons, as classified for the current project, very clearly reflect a "dry season" (summer) and a "wet season" (winter) and can thus be used to aid interpretation of the results of the water quality data analyses. The monthly rainfall graphs also show that, for all three datasets, there was significant variability in monthly rainfall during both summer and winter, with the standard deviation for the respective time periods of analysis being of a similar magnitude to the monthly mean in most cases.

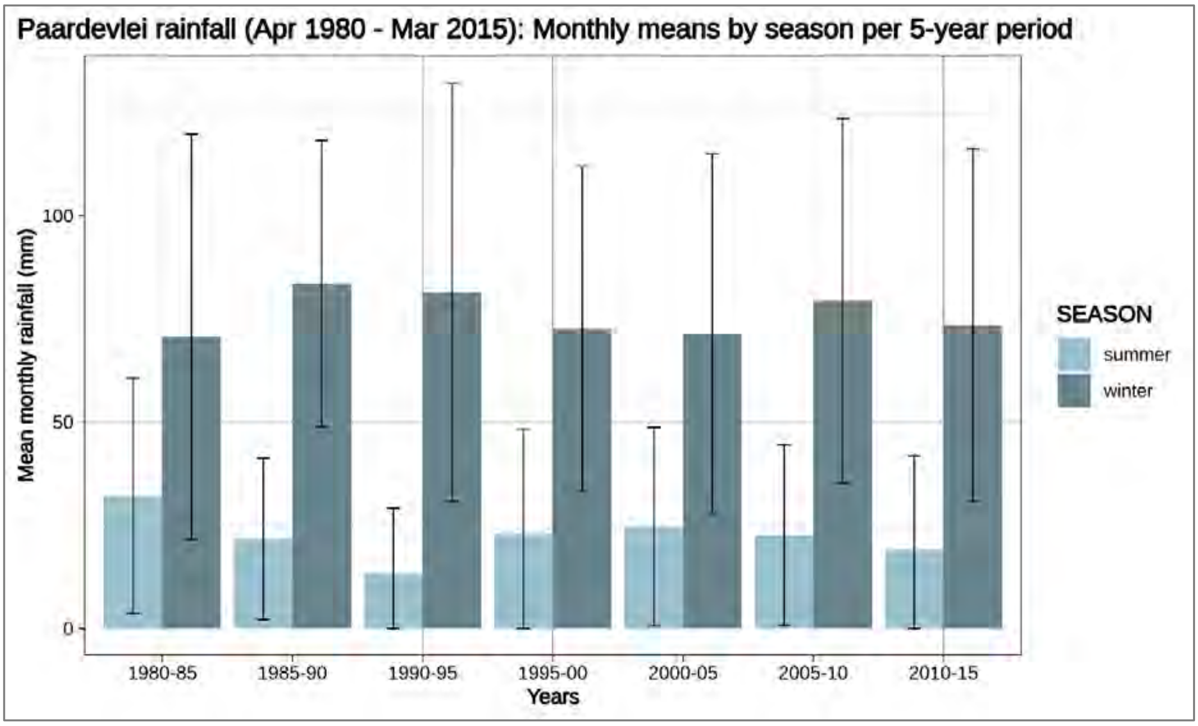



**Figure 3.8 Mean monthly rainfall (and standard deviation) at Paardevlei during summer and winter for each 5-year period between 1980 and 2015**

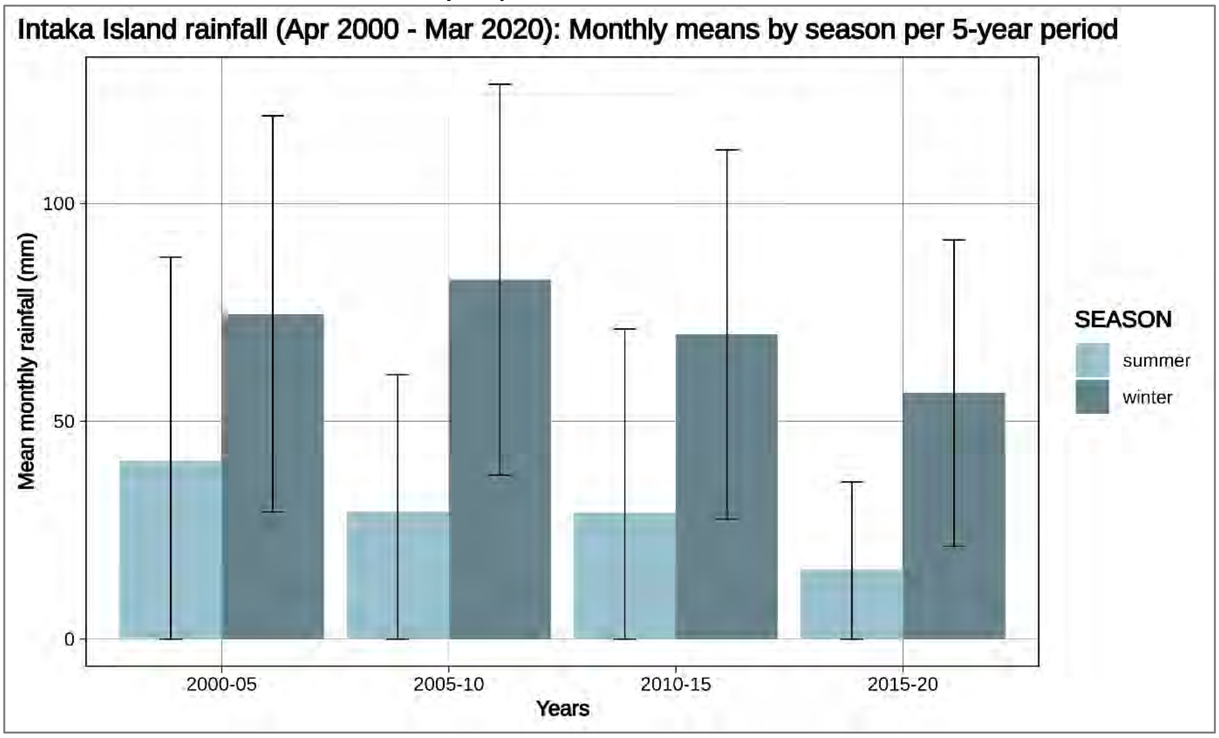



**Figure 3.9 Mean monthly rainfall (and standard deviation) at Intaka Island during summer and winter for each 5-year period between 2000 and 2020**

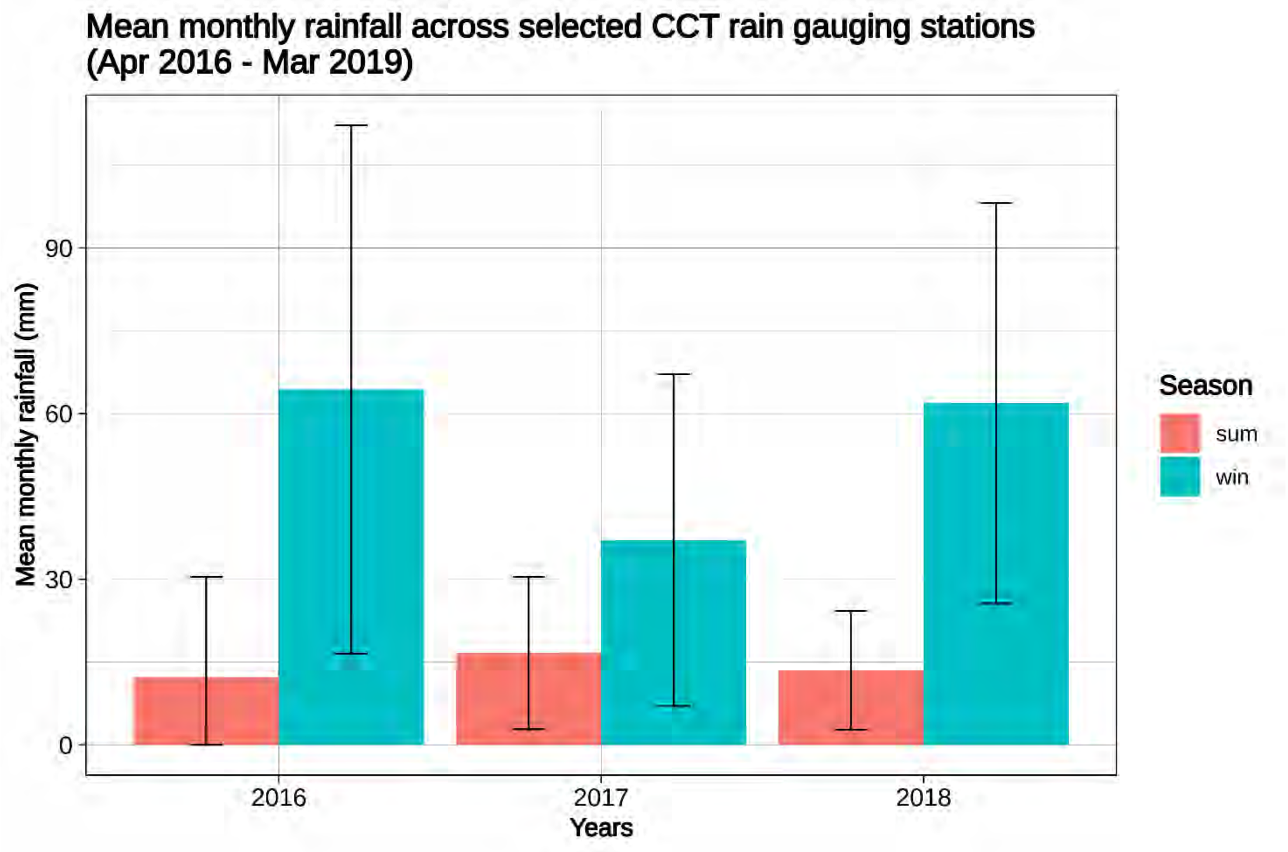



**Figure 3.10 Mean monthly rainfall (and standard deviation) across all selected CCT gauging stations during summer and winter for each year from 2016 to 2018**

When comparing the mean monthly rainfall (and standard deviation) figures by season and year for each subcatchment in the 2016 - 2018 time period with the monthly averages for winter (**Figure 3.11**), it is evident that the only subcatchments with monthly rainfall averages above the long-term (1980 - 2015) winter average for Paardevlei were those which have some rain gauging stations located in more mountainous areas (namely the City Bowl, Lourens River, Salt River and South Peninsula sub-catchments). These sub-catchments were also the ones where the mean monthly rainfall during winter was typically greater than the average monthly rainfall during winter across all sub-catchments for the respective year.

The monthly rainfall averages were as follows:

Winter 2016 (CCT stations) = 64.4 mm per month
Winter 2017 (CCT stations) = 37.1 mm per month
Winter 2018 (CCT stations) = 61.9 mm per month
Long-term winter average at Paardevlei (1980 - 2015) = 76.1 mm

These figures highlight how low the winter rainfall was across the City during the peak of the drought in 2017, at less than half of the long-term (35-year) average from 1980 - 2015 at Paardevlei.

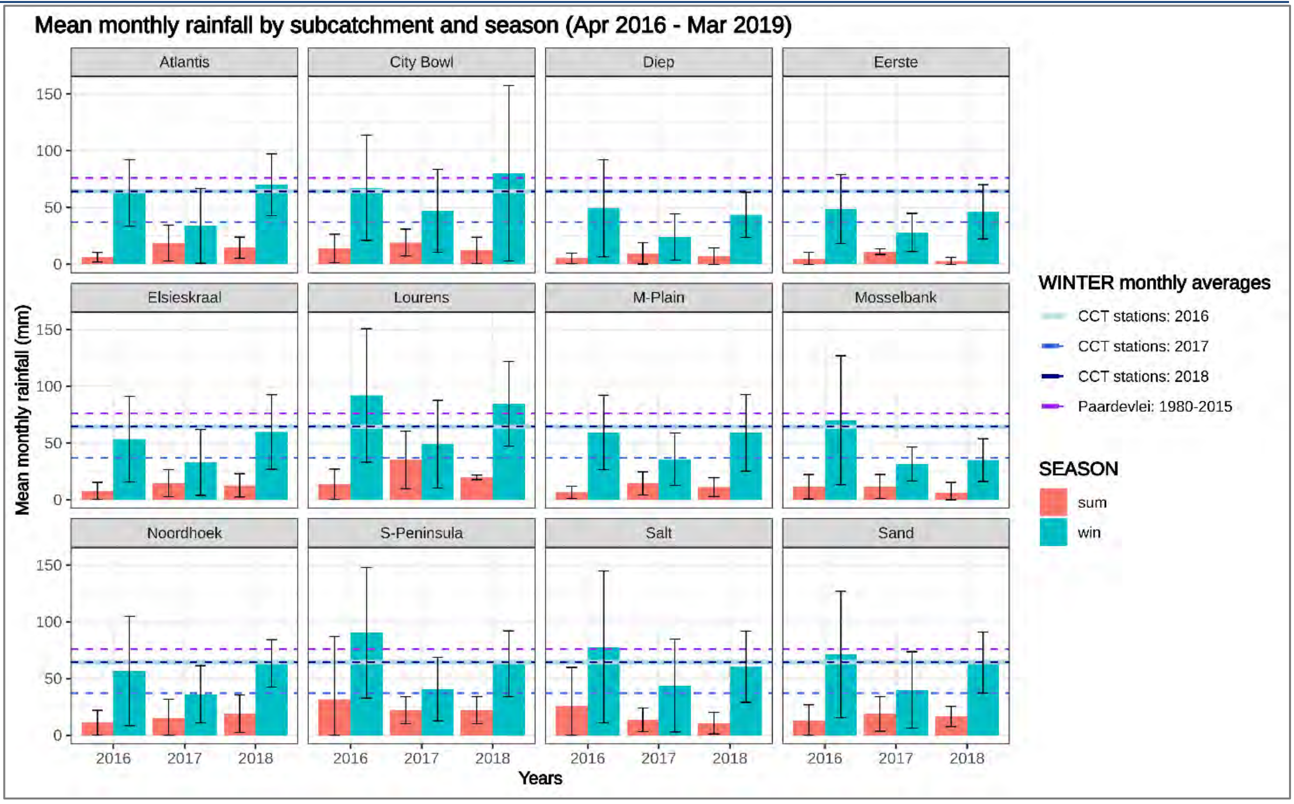



**Figure 3.11 Mean monthly rainfall (and standard deviation) per season and year for each subcatchment within which CCT gauging station data were obtained (2016 - 2018), plotted against mean monthly rainfall during winter across all CCT stations each year and the long-term (1980 - 2015) mean monthly rainfall during winter at Paardevlei (note that the mean annual rainfall across CCT stations was very similar in 2016 and 2018, so the two lines for these years are on top of each other)**

# 4 TRAJECTORIES OF CHANGE AND CURRENT STATUS OF WATER QUALITY IN THE CITY'S WATERCOURSES

## 4.1 Changes in salinity (Electrical conductivity)

### *4.1.1 Relevance*

Electrical conductivity (EC) is a measure of the amount of dissolved inorganic ions (salts) in water (usually measured in mS/m), and thus also provides a measure of water salinity. EC levels above 450 mS/m are usually indicative of brackish conditions, although the following habitats can be broadly defined:

- freshwater systems (EC < 450 mS/m);
- brackish systems (EC 450 mS/m – 2000 mS/m);
- saline systems (EC 2000 mS/m to 6 000 mS/m: note that seawater EC is in the order of around 5 400 mS/m); and
- hypersaline systems (> 6 000 mS/m).

Anthropogenic activities such as discharging saline industrial effluent, return of large quantities of sewage effluent, clear-felling, irrigation and water re-use often lead to increases in EC in watercourses (Dallas and Day 2004). Alternatively, inputs of fresh water (that is, water with a low salinity / low EC) into naturally saline inland aquatic ecosystems such as salt pans and estuaries or rivers draining shale-dominated catchments can, on the other hand, lead to decreases in EC relative to the natural reference range for that system. Activities that can decrease salinity in naturally saline systems include sewage effluent discharges, stormwater runoff or irrigation return-flows.

Significant changes in the EC regime of an inland aquatic ecosystem can lead to changes in the characteristics of floral and faunal communities associated with these ecosystems.

**Ecological effects of reduced salinities**

Freshening of the Diep River estuary as a result of long-term inflows of treated effluent from the Potsdam WWTW has largely contributed to the disappearance of the sand prawn *Kraussillichirus kraussi* from the estuary. This species provided an essential food source for estuarine fish as well as marine fish species, which used the estuary as a nursery. Its disappearance has implications for the West Coast fishery.

Photo by George Branch

Another effect of reduced salinities can be seen in many rivers and wetlands of Cape Town, where *Typha capensis* bulrush has expanded and in some cases taken over whole wetland areas, as a result of the combined effects of low salinities, increased nutrients and a raised water table.

### *4.1.2 Reference conditions*

Under natural conditions, the EC of inland aquatic ecosystems in the City of Cape Town would have been determined primarily by the geology of the surrounding catchment and climate. Areas dominated by Table Mountain Group sandstone geology and/or higher rainfall to evaporation ratios would have been characterized by inland aquatic ecosystems that are less saline than those in areas dominated by shale geology or marine sands and/or lower rainfall to evaporation ratios. This results in the natural reference range of EC values typically being significantly lower at upland sites than it is at lowland sites, as reflected in the "reference conditions" derived by Dallas *et al*. (1998) for river systems in the Southern and Western Coast Water Quality Management Region (**Table 4.1.1**). The reference data show that EC values recorded at minimally impacted Mountain Stream and Upper Foothill sites were significantly different from those recorded at minimally impacted Lower Foothill and Lowland River sites. Median values varied from 3.0 mS/m at Mountain Stream sites to 21.0 mS/m at Lowland River sites.

**Table 4.1.1 Median, mean, standard deviation (SD), minimum and maximum conductivity values (mS/m) for each longitudinal river zone within the Southern and Western Coast WQMR (extracted from Dallas *et al*. 1998)**

| LONGITUDINAL ZONE | MEDIAN | MEAN ± SD | MINIMUM | MAXIMUM | N |
|---|---|---|---|---|---|
| Mountain stream | 3.0 | 3.6 ± 2.5 | 0.9 | 21.5 | 113 (33) |
| Upper foothill | 3.1 | 3.8 ± 2.1 | 1.5 | 11.2 | 79 (23) |
| Lower foothill | 9.6 | 10.8 ± 6.6 | 2.6 | 47.9 | 60 (16) |
| Lowland river | 21.0 | 39.0 ± 25.5 | 4.5 | 107 | 43 (10) |

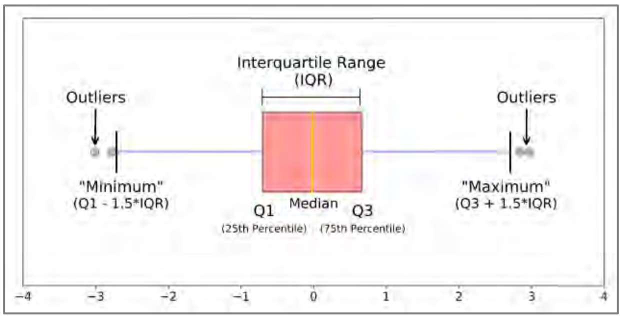
It should be noted that values outside of the reference ranges listed above can occur in natural systems where localised geology and climate (and/or other natural factors, such as the influence of salt-laden marine winds along the coast) override the regional pattern. For example, some lowland rivers in the drier northern portions of the City of Cape Town (e.g. the Sout River in Melkbosstrand, and sections of the Diep and Mosselbank Rivers) are naturally brackish (with EC levels much higher than the natural range for the WQMR given above) due to low rainfall, the presence of shale-dominated geology and marine influences.

### *4.1.3 Trajectory of change*

Due to a lack of "reference" data for the typical EC values of minimally impacted standing water systems in the City, the analysis of changes in EC was restricted to the City's river dataset for the current report (excluding estuarine sites which have highly variable natural salinity regimes due to marine influence / tidal inflows). Boxplots showing the distribution of EC values in each subcatchment are presented for Upper River and Lower River sites, respectively, in **Figures 4.1.1** and **4.1.2**. The boxplots include a shaded "band" in the background, showing the relevant "reference range". As explained previously, the lower limit of the reference band in the case of Upper River sites is the median for the Mountain Stream Zone (taken from **Table 4.1.1**) minus 15%, while the upper limit is the median for the Upper Foothill Zone plus 15%. For the Lower River graph (**Figure 4.1.2**), the limits of the reference band are the medians for the Lowland River Zone and the Lower Foothills Zone, plus/minus 15% respectively.

**Boxplot interpretation guide**

The figure below indicates how to interpret the box plots used in this report, with the yellow line in this figure indicating the median value, within a "box" representing the interquartile range – that is, the range between the 25th and 75th percentiles. The "whiskers" of the box indicate maximum and minimum values within 1.5 times the interquartile range added to the 75th percentile and subtracted from the 25th percentile, respectively. Outliers are shown as individual dots on either side of this range.



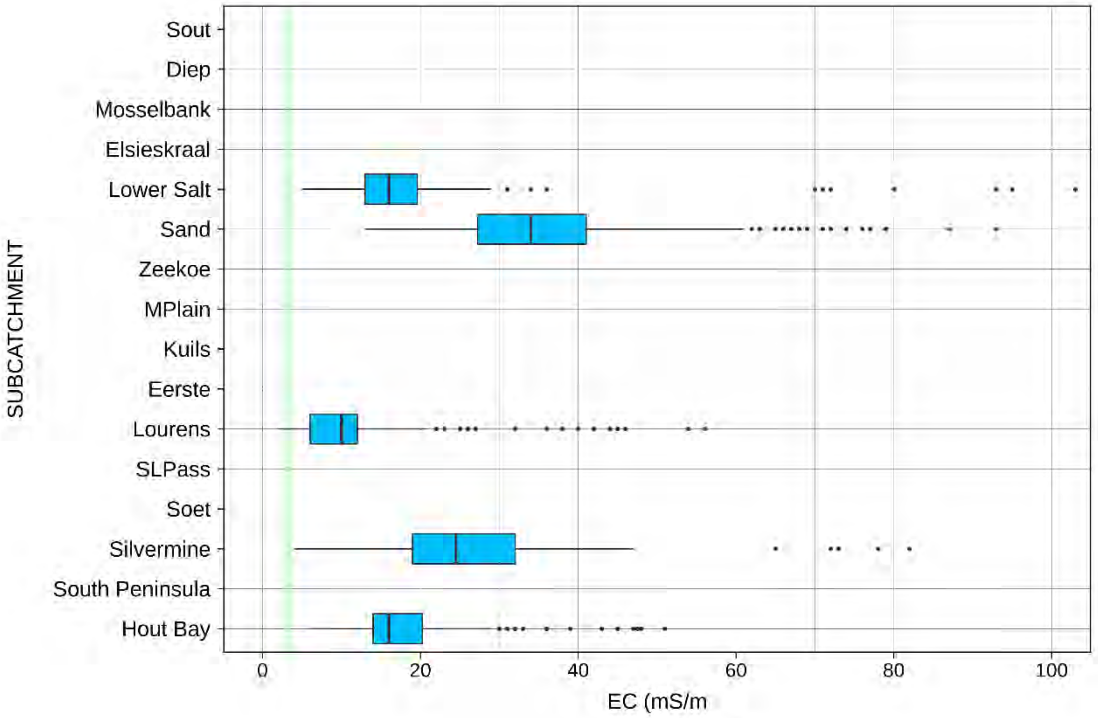



**Figure 4.1.1 Boxplots showing distribution of EC values recorded at UPPER RIVER sites in each subcatchment over the full time period of analysis (1980-2019/20), in comparison to the relevant "reference range" (green-shaded band in background of plot)**

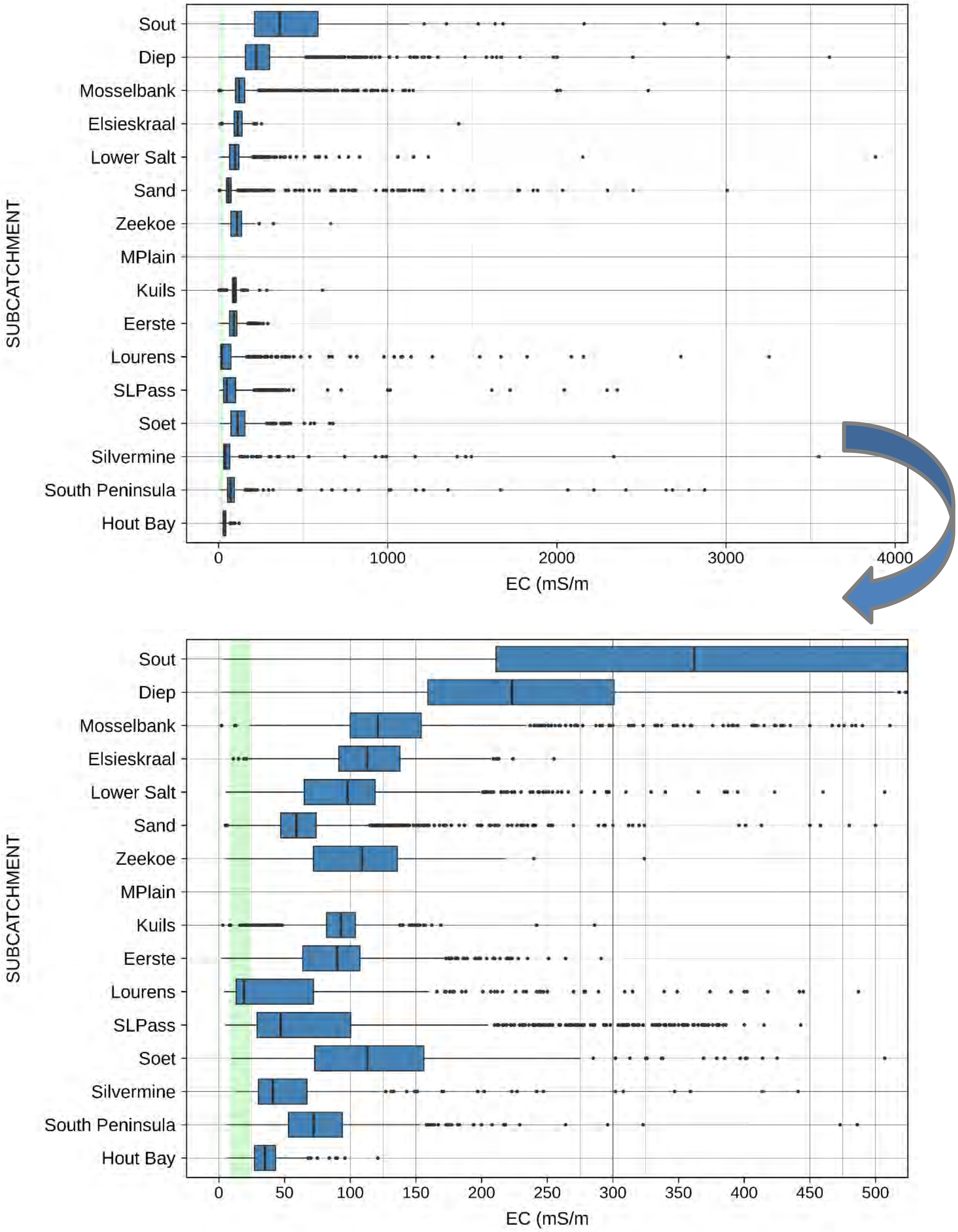



**Figure 4.1.2 Boxplots showing distribution of EC values recorded at LOWER RIVER sites in each subcatchment over the full time period of analysis (1980-2019/20) , in comparison to the relevant "reference range" (green-shaded band in background of plot). Note: above two graphs are the same but plotted on different EC scales on the y-axis.**

The boxplots of EC values over the full time period of analysis reveal that river systems in all of the subcatchments have been subject to an elevation in EC values relative to the presumed natural reference state since at least the 1980's, with the exception of the Lower River Zone of the Lourens River subcatchment. The main reasons for this presumably relate to inputs of sewage effluent, stormwater runoff from increasingly urbanised catchments and agricultural runoff from the more rural parts of the City (e.g. in the Elsieskraal subcatchment) going back to before routine monitoring of water quality was undertaken by the City. It is important to note, however, that the Sout River, and possibly some of the sites within the Diep River subcatchment, are presumably naturally brackish (EC > 450 mS/m), especially in the Lower River zones. As such, the elevated EC values in these systems relative to the regional reference conditions, especially the lower Sout River, are not indicative of impacts.

The EC time-series graphs in **Appendix D**, plotted using the monthly median EC in each subcatchment, support the above-mentioned conclusion that EC values in most of the subcatchments in the City have been raised above the natural reference range since the start of the time period of analysis, with the exception of Lower River sites in the Lourens and Hout Bay subcatchments. The $R^2$ value associated with the linear trend lines on the EC graphs in Appendix D was very low for all of the plots, being less than 0.1 in most cases. The only subcatchments with a trend line with an $R^2$ value >0.1 were the Elsieskraal (0.23) and the Sout (0.34), both of which indicated a downward trend for Lower River sites over the 1980-2019/20 time period, but the strength of the trend was still very low ($R^2 < 0.5$) so one should be cautious about drawing conclusions from these trendlines.

### *4.1.4 Current state (2019-2020)*

The analysis of the change in EC at river sampling sites across the City over the 1980-2019/20 time period (above) suggests that most the sites have been elevated above the relevant reference ranges for EC since the start of the period of analysis. Exceptions to this were the naturally brackish Sout River (and possibly certain naturally brackish sites within the Diep River catchment), which may if anything be getting slightly less saline over time, and sites within the Lourens and Hout Bay subcatchments (especially in the Lower River Zone) where EC values within the reference range are still recorded. These conclusions are also applicable to the current state (2019-20) of the river systems within the City, as no significant trends were detected for the change in EC values over time within any of the subcatchments.

### *4.1.5 Implications*

One of the main implications of the findings presented above in terms of EC is that very few, if any, of the water quality sampling sites for rivers that are being monitored in the City can be considered to be "reference sites". Possible exceptions are some of the sites along the Sout, Lourens and Hout Bay Rivers. This means that there are no "control sites" to act as a baseline for the City's monitoring programme, the addition of which should be given consideration for less frequent (e.g. every five years) baseline monitoring. Another implication of the findings presented above is that it suggests that most river systems within the City have been in a highly modified state, at least in terms of the EC regime, for 35 years or more. This would have potentially major consequences for the biota in these systems, with shifts in the community structure (and the possible loss of more sensitive species) likely to have occurred compared to the natural reference state. Periods of drought would be likely to exacerbate such salinization, with lower inflows of rainfall and increased evapoconcentration of flows. Again, this highlights the need for the identification and implementation of (less frequent) monitoring of minimally impacted sites within the City, which could then be protected as important refugia for more sensitive biota within an increasingly urbanized environment. This issue is addressed in more detail in Section 6.

It should be noted that the above analyses exclude estuaries. However, it is known from other research (e.g. Peak Practice (2008) and Turpie and Clark 2007) that the City's major estuaries are affected by the opposite problem of reduced salinities, affecting their suitability as habitats for important estuarine species. The Eerste and Diep River estuaries are both impacted by inflows of treated effluent that is much less saline than natural. Controlled re-use of treated effluent could in part address this issue.

## 4.2 Changes in pH

### *4.2.1 Relevance*

Acidity and alkalinity (expressed as pH) are measures of the amount of hydrogen ions in the water. Neutral pH is 7, with waters becoming increasingly acidic as the scale decreases from 7 to 1, and increasingly alkaline as the scale increases from 7 to 14. Most fresh waters are relatively well buffered (that is, they remain relatively stable) and more or less neutral, with pH ranging around 6-8. Very dilute waters, in which the major ions are sodium and chloride (i.e. NaCl-dominated waters) are poorly buffered because they contain virtually no bicarbonate or carbonate ions, which account for the buffering. If they drain catchments containing certain types of vegetation (e.g. fynbos, some forest types), the pH may naturally drop as low as 3.9 owing to the influence of organic acids (e.g. humic and fulvic acids and other polyphenol-rich compounds) leaching from the vegetation (Dallas and Day 2004).

pH influences a wide range of ecological and chemical processes. Of particular relevance to aquatic ecosystem assessment is the influence of pH on the availability and toxicity of heavy metals and other substances, such as ammonia and aluminium. . Since the adsorptive properties of large molecules and particulate matter in water depend on their surface charges, alterations in pH can also affect adsorption rates of phosphates and certain heavy metals.

It is important to note that, because it is measured on a logarithmic scale, small changes in pH can have a significant impact on aquatic biota, especially when pushed beyond the natural reference range of values for a particular region and/or aquatic ecosystem type.

**Ammonia toxicity and pH**

Ammonia exists in two forms, namely an un-ionized form ($NH_3$), often referred to a free ammonia, and as ammonium ions ($NH_4^+$). Of these, the former can be toxic to aquatic organisms at very low concentrations. The proportion of either form that exists in water at any time depends on temperature, salinity and, in particular, pH. At pH >8, a significantly larger proportion of total ammonia is present in the un-ionised form ($NH_3$), which may give rise to acute toxicity at concentrations as low as 0.1 mg N/L (DWAF 1996a) (see Section 4.6)

### *4.2.2 Reference conditions*

Most of the naturally-occurring water in the Cape Town area would have been sodium chloride dominated, in terms of its ionic constituency. This is because much of the City's water drains through ancient, well-leached marine-derived Table Mountain Group sandstone and shale formations located relatively close to the sea. This results in aquatic ecosystems that are typically poorly buffered and, in the areas dominated by fynbos vegetation and non-alkaline soils, would naturally have had characteristically low pH values (possibly <4). In particular, rivers and other aquatic ecosystems dominated by fynbos vegetation and flowing through upland areas away from the sandy coastline would have had particularly low pH values under natural conditions. Closer to the sandy portions of the coastline, and in the Cape Flats where alkaline soils (from broken down marine shell fragments) become more dominant, pH levels would be naturally higher, tending towards neutral and slightly to highly alkaline.

Overall, this results in the natural reference range of pH values typically being significantly lower at upland sites than it is at lowland sites (as in the case of EC), as reflected in the "reference conditions" derived by Dallas *et al*. (1998) for river systems in the Southern and Western Coast Water Quality Management Region (**Table 4.2.1**). The reference data show that pH values recorded at minimally impacted Mountain Stream and Upper Foothill sites were significantly different from those recorded at minimally impacted Lower Foothill and Lowland River sites. Mean values (and standard deviation) varied from 5.5 ± 0.9 at Mountain Stream sites to 7.3 ± 0.4 at Lowland River sites.

**Table 4.2.1 Median, mean, standard deviation (SD), minimum and maximum pH values for each longitudinal river zone within the Southern and Western Coast WQMR (extracted from Dallas *et al*. 1998)**

| LONGITUDINAL ZONE | MEDIAN | MEAN ± SD | MINIMUM | MAXIMUM | N |
|---|---|---|---|---|---|
| Mountain stream | 5.5 | 5.5 ±0.9 | 3.6 | 7.9 | 127 (37) |
| Upper foothill | 6.0 | 5.8 ±0.8 | 4.0 | 7.2 | 83 (25) |
| Lower foothill | 6.5 | 6.5 ±0.8 | 4.3 | 8.9 | 64(19) |
| Lowland | 7.3 | 7.3 ±0.4 | 6.5 | 8.5 | 44(11) |

### *4.2.3 Trajectory of change*

As in the case of EC, due to a lack of "reference" data for the typical pH values of minimally impacted standing water systems in the City, the analysis of changes in pH was also restricted to the City's river dataset for the current report (excluding estuarine sites). Boxplots showing the distribution of pH values in each subcatchment are presented for Upper River and Lower River sites, respectively, in **Figures 4.2.1** and **4.2.2**. The boxplots include a shaded "band" in the background, showing the relevant "reference range". As explained previously, the lower limit of the reference band in the case of Upper River sites is the mean for the Mountain Stream Zone (taken from **Table 4.1.1**) minus 1 pH unit, while the upper limit is the mean for the Upper Foothill Zone plus 1 pH unit. For the Lower River graph (**Figure 4.1.2**), the limits of the reference band are the means for the Lowland River Zone and the Lower Foothills Zone, plus/minus 1 pH unit respectively.

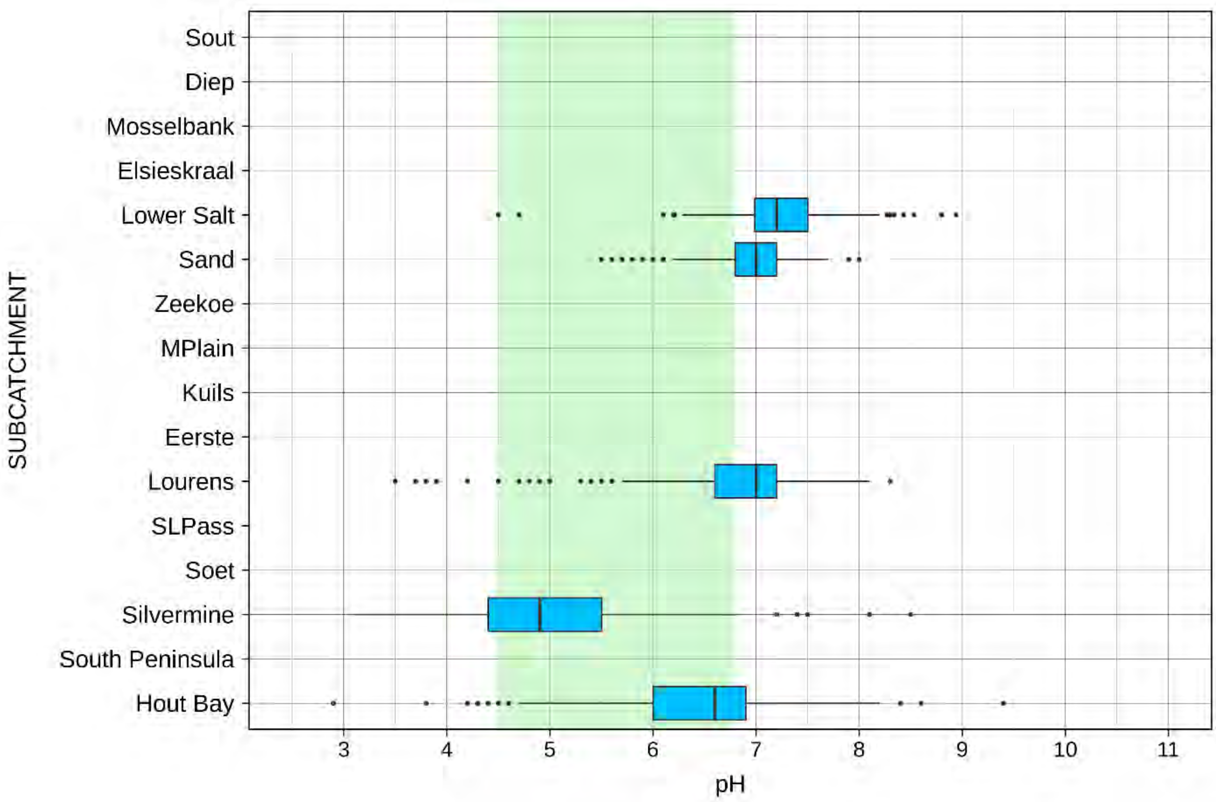



**Figure 4.2.1 Boxplots showing distribution of pH values recorded at UPPER RIVER sites in each subcatchment over the full time period of analysis (1980-2019/20), in comparison to the relevant "reference range" (green-shaded band in background of plot)**

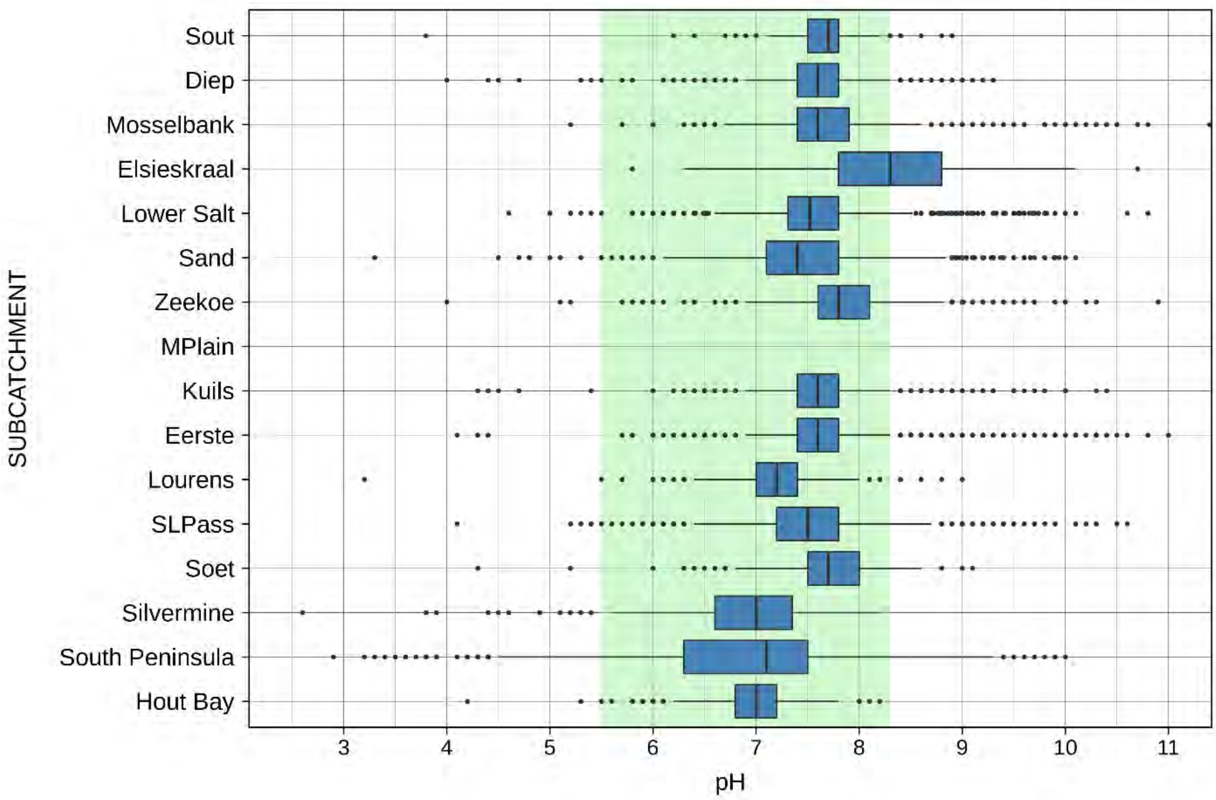



**Figure 4.2.2 Boxplots showing distribution of pH values recorded at LOWER RIVER sites in each subcatchment over the full time period of analysis (1980-2019/20), in comparison to the relevant "reference range" (green-shaded band in background of plot)**

The boxplots of pH values over the full time period of analysis reveal that Upper River systems in the Lower Salt and Sand subcatchments have been subject to an elevation in pH relative to the presumed natural reference state since at least the 1980's (with the "boxes" of the boxplots sitting outside the reference band), while Upper River pH values recorded in the Lourens River subcatchment also fall mostly outside the reference range but there are a greater proportion of samples within the reference range for this subcatchment (**Figure 4.2.1**). The pH values recorded from Upper River sites in the Silvermine and Hout Bay subcatchments fall mostly within the reference range. The majority of pH values recorded in Lower River systems in all subcatchments over the full time period of analysis, on the other hand, fell within the "reference range" for Lower River Zones (**Figure 4.2.2**), with the exception of the Elsieskraal subcatchment (where the upper quartile of the boxplot extends beyond the reference range). A possible reason for this exception is the natural occurrence of renosterveld vegetation in the Elsieskraal subcatchment, which is characterized by lower levels of acidity than true fynbos vegetation, and the fact that the middle to lower reaches of the system run through the Cape Flats, which is characteristically alkaline. Another possible reason, or contributing factor, for the more significant deviation from "reference conditions" in the case of the Elsieskraal subcatchment is that many of the rivers in the lower reaches of this subcatchment consist of concrete canals, which means that the systems tend to be dominated by rainwater and flows off hardened surfaces.

The pH time-series graphs in **Appendix E**, plotted using the (transformed) monthly mean pH in each subcatchment, support the above-mentioned conclusion that pH values in the Upper River zones that have been monitored within the City have been elevated above the natural reference range since the start of the time period of analysis in most subcatchments, with the exception of the Silvermine and possibly Hout Bay subcatchments. In the majority of subcatchments, the mean pH values for Lower River sites remained within the reference range for most of the time period of analysis (1980-2020), but relatively frequent and longer-lasting "spikes" of elevated values (approaching and exceeding 10) were recorded in the Mosselbank subcatchment (especially before 2013) and in the Elsieskraal subcatchment. Other subcatchments with sporadic "spikes" of elevated mean pH values at Lower River sites included the Lower Salt (especially between 1995 and 2007), Sand (mostly before 2005), Zeekoe (mostly before 1997), Kuils (especially since 2013, but just above the reference range) and Eerste (mostly between 1997 and 2013). The mean pH values at Lower River sites in the rest of the subcatchments (i.e. Sout, Diep, Lourens, Sir Lowry's Pass, Soet, Silvermine, South Peninsula and Hout Bay) were mostly within the reference range throughout the period of analysis.

The $R^2$ value associated with the linear trend lines on the pH graphs in Appendix E was very low for all of the plots, being less than or equal to 0.15 in all cases. This means there are no significant trends in pH change over the time period of analysis (1980-2020) for any of the subcatchments in the City.

Subcatchments with historically higher pH values that approach or exceed 8 are the Elsieskraal, Soet and Zeekoe subcatchments (see **Figure 4.2.2**). These are, therefore, subcatchments where there is a greater risk of ammonia toxicity, even with relatively low levels of ammonia.

### *4.2.4 Current state (2019-2020)*

The analysis of pH values recorded at river sampling sites across the City over the 1980-2019/20 time period (above) suggests that most of the Lower River sites have been within the relevant reference range for pH since the start of the period of analysis. The main exception to this was the Elsieskraal subcatchment, where the natural range of pH values could be higher due to soil and vegetation characteristics. The pH values recorded at Upper River sites in some of the subcatchments (Lower Salt and Sand, in particular) have, however, been elevated above the natural reference range over a large portion of the period of analysis.

Overall, it can be concluded from the analyses above that the current state of river systems in the City, in terms of pH, is that the natural pH regime does not appear to have been significantly altered from the natural reference state in the Lower River Zones, except for sporadic and generally short-lived "spikes" of elevated values in most subcatchments at times, while elevated pH values are prevalent in the Upper River Zones of certain subcatchments. Limited sampling has, however, been conducted at Upper River sites.

### *4.2.5 Implications*

The main implication of the findings presented above is that changes in pH are not of major concern for the river ecosystems that have been monitored in the City up until this point in time. Elevated pH values, resulting in an increase in the risk of ammonia toxicity risk also does not appear to be a pervasive problem to date, with high pH values approaching or exceeding 9 typically only being recorded sporadically for short periods of time in the Lower River zone of most subcatchments. As in the case of EC, however, a better understanding of the true situation would be gained by including minimally impacted "reference" or "control" sites in the City's water quality monitoring programme.

Elevated pH may however be more problematic in some of the standing water bodies not considered in this section. This is because many of these systems are nutrient enriched and as a result, their plant communities are dominated by algae. High rates of photosynthesis by day remove carbon dioxide from the water, and this can raise pH. At night, when only respiration occurs and releases carbon dioxide into the water, pH may drop again. In water bodies with high ammonia concentrations, these diurnal changes in pH can result in periods of ammonia toxicity, by day. This issue is discussed in more detail in subsequent sections.

## 4.3 Major nutrients (phosphorus and nitrogen)

### *4.3.1 Role of nutrients in aquatic ecosystems*

Plants require various nutrients for healthy growth (e.g. phosphorus, nitrogen, sulphur, magnesium, potassium and many others, often only required in extremely small amounts). Of these, nitrogen and phosphorus play a particularly important role in determining the rate of plant growth, and are often referred to as "growth limiting" nutrients, because of this. In freshwater ecosystems, phosphorus is in fact the real "growth limiting" nutrient, as some plants such as blue green algae (Cyanophyta) are able to access nitrogen directly from the air.

Most nutrients are not toxic to aquatic environments, even in high concentrations. Exceptions to this include ammonia ($NH_3$), nitrite and nitrate, in some circumstances, and these issues are discussed later in Section 4.6. In high concentrations nutrients (and phosphorus in particular) do however trigger excessive growths of plants, changing aquatic ecosystem function and structure and triggering many management problems, from the need for invasive plant clearing to the risks of toxic algal blooms and fish kills from low oxygen as a result of the decomposition of aquatic plants.

**What is an algal bloom ?**

An algal bloom is a rapid increase in the population of phytoplankton (single celled algae floating or suspended in the water column), often resulting in changes to the colour of the water and sometimes causing thick surface scums. It is usually caused by excessive phosphorus availability, and in standing water systems often coincides with warm calm conditions.

Photo: Characteristic green of a microcystis (blue green algae) bloom at Zeekoevlei

### *4.3.2 Reference conditions*

Under natural conditions, the upper reaches of the City's rivers would have been naturally low in nutrients, especially those that passed through catchments dominated by ancient well-leached and thus nutrient poor Table Mountain Sandstones. With distance downstream, even natural rivers tend to accumulate low levels of nutrients, as they are exposed to larger areas of catchment and the receipt of inputs from grazers, natural vegetation and birds.

Many wetlands are likely to have been more nutrient enriched – particularly those that were not linked to channeled outflows, and thus accumulated organics from plant material over time, as well as nutrients and salts (through evapo-concentration). Shallow seasonally inundated wetlands used as feeding areas by birds could become highly nutrient-enriched over time, supporting rich "soups" of invertebrates.

Today, most if not all of the aquatic ecosystems in the City have been impacted by the receipt of additional nutrients, particularly phosphorus, mainly as a result of the following kinds of activities and inputs:

- Inputs of treated sewage effluent
- Runoff from catchment areas with high levels of backyard or informal settlements, subject to poor levels of sewage and stormwater servicing
- Illegal discharges into the stormwater system in industrial and commercial areas (e.g. fertilizer factories; car washes; markets; informal butcheries and meat markets)
- Runoff from fertilized gardens and parks
- Runoff from agricultural areas within the City.

**What are "grey water" discharges?**

Grey water is the wastewater generated in households or other buildings from waste streams without faecal contamination. That is, all waste water streams except for the wastewater from toilets – these may include sinks, showers, baths, washing machines or dishwashers. In poorly serviced areas, discharges from residences often include faecal waste, and are thus termed "black water" discharges.

While the City's stormwater management systems can be designed to treat grey water, they are not designed for effective treatment of black water, which should be treated in WWTWs.

### *4.3.3 Trophic state*

The nutrient (trophic) status of freshwater ecosystems allows them to be broadly classified into one of four trophic categories - oligotrophic, mesotrophic, eutrophic and hypertrophic –respectively associated with low, moderate, high and extremely high levels of nutrients (mainly phosphorus and nitrogen nutrients).

In standing water bodies such as vleis, these conditions can translate into the following broad habitat types, where:

- **oligotrophic** water bodies typically have clear waters and a rocky or sandy shoreline. Both planktonic and rooted plant growth are sparse
- **mesotrophic** water bodies represent intermediate trophic states between oligotrophic and eutrophic, and often share characteristics between the other two
- **eutrophic** water bodies are typically shallow with a soft, silty bottom. Rooted plant growth is abundant along the shores and out into the lake, and algal blooms are not unusual. Water clarity is usually poor. If deep enough to thermally stratify, the bottom waters are often devoid of or low in oxygen.
- **hypertrophic** water bodies may have similar habitat types to eutrophic systems, but bottom level anoxia is more common and the systems are prone to blooms of blue-green as well as green algae.

**Appendix F** presents the range of nitrogen and phosphorus concentrations associated with different trophic states in South African freshwater ecosystems. These are also indicated in **Tables 2.2** and **2.3**, in relation to the threshold ranges used there. Flowing water (i.e. river) systems are somewhat less sensitive to elevated nutrient concentrations than standing water systems, and this is reflected in higher threshold concentrations for rivers than for standing water systems.

**Nutrient links to fish kills**

Periodically, many of the City's vleis (and other water bodies) experience so called "fish kills", when numbers of dead fish occur in parts of the water body. This is sometimes accompanied by other fish gulping at the water surface.

The cause of these fish kills is usually linked to excessive nutrients, resulting in rapid algal growth. Algae has a short life cycle and high rates of turnover, with the result that in bloom conditions, dead algae sink to the base of the vlei, where they decompose. Decomposition requires oxygen, and if large numbers volumes of algae (and other plant material) is decomposing, it can result in conditions where the bottom layer of the water body is anoxic, killing fish and other aquatic organisms that rely on dissolved oxygen. Such events often follow warm calm conditions, when decomposition is faster, and moreover when warm water contains less dissolved oxygen anyway. Other factors such as outbreaks of diseases like the koi herpes virus that affect carp, or toxic pollutants are less common causes of fish kills.

### *4.3.4 Phosphorus enrichment*

This section focuses on patterns of **phosphorus** enrichment in the City's waterbodies. Because of their different sensitivities and responses to phosphorus enrichment, and the different thresholds of concern allocated to them, phosphorus data for flowing water (i.e. rivers and stormwater channels) and standing water (i.e. main dams and vleis) systems have been analysed separately.

### *A History of change*

**Figures 4.3.1** and **4.3.2** present patterns in orthophosphate (PO4-P) enrichment in rivers / stormwater channels and standing water bodies respectively. The data have been presented as the percentage of samples from sites in each subcatchment that meet Target conditions for this variable, versus those falling within Poor and Unacceptable categories, representing eutrophic and hypertrophic conditions respectively. The caveat outlined in Sections 2.8 and 2.12.1 should however be noted – over time, there has been an increase in the number of monitored sites, and an emphasis on sites with known water quality problems.

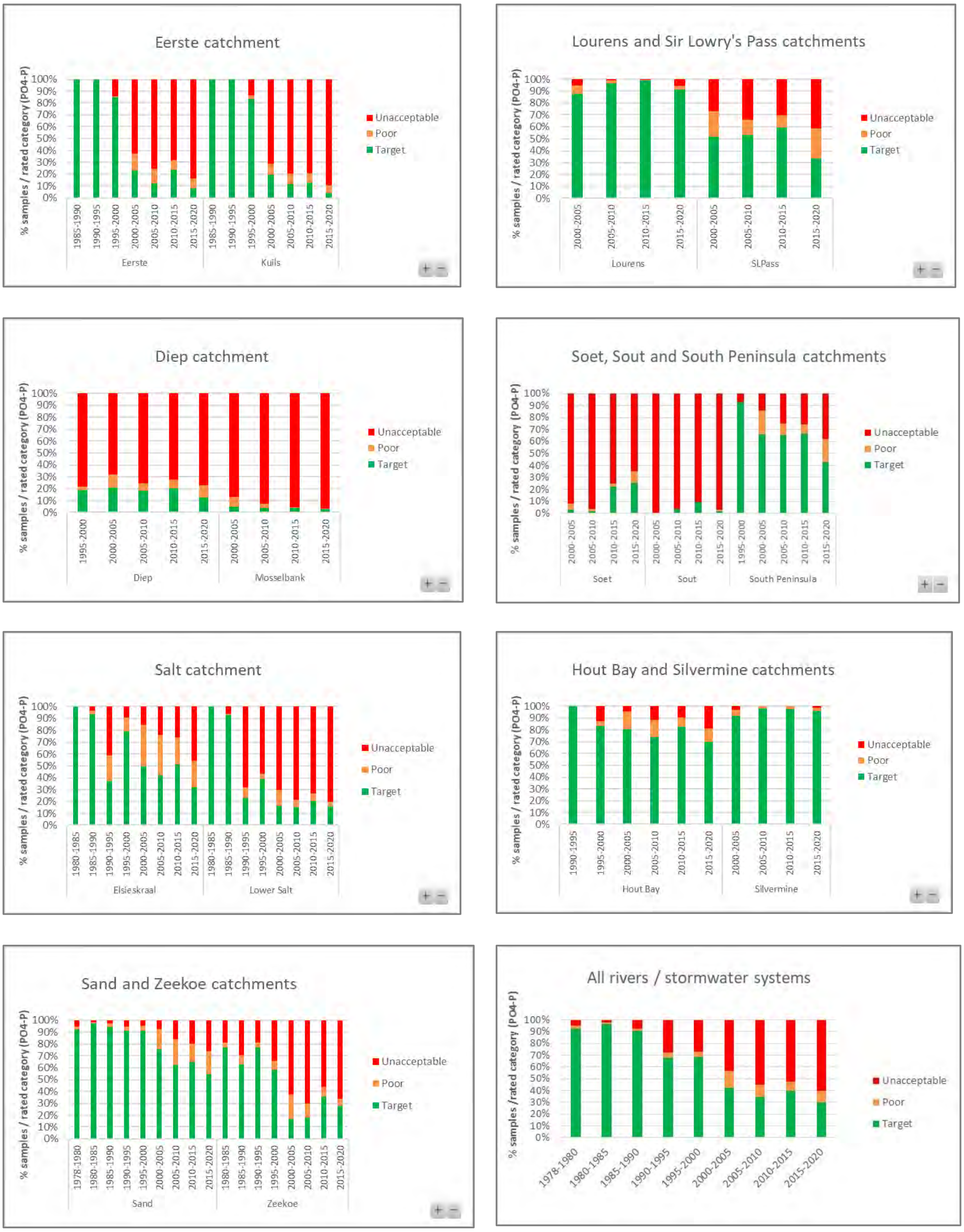



**Figure 4.3.1 Percentage of orthophosphate (PO4-P) samples from <u>river sites</u> in each subcatchment falling within each rated category for this variable. Thresholds as defined in Table 2.2. Subcatchments as shown in Figure 2.1**

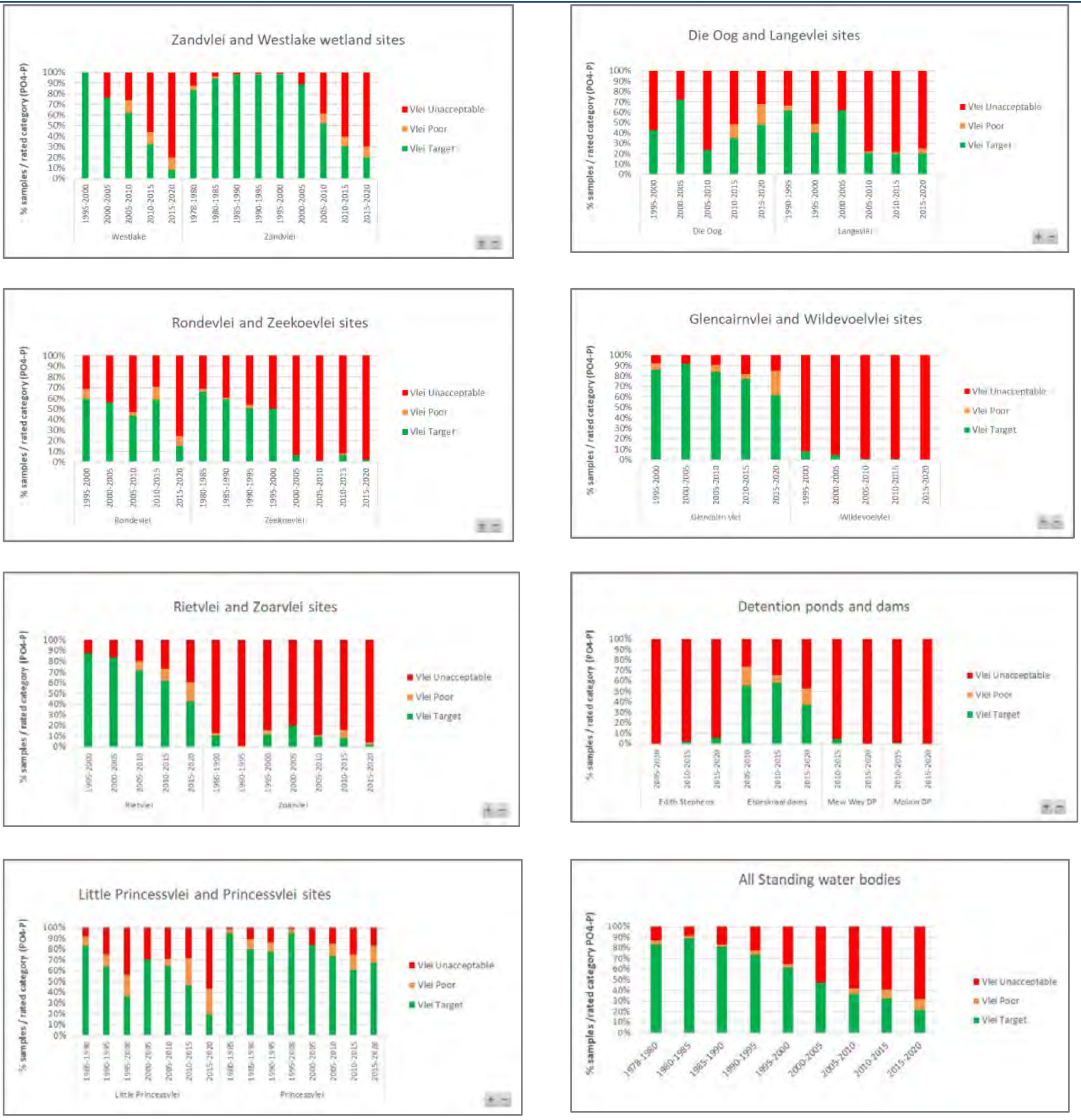



**Figure 4.3.2 Percentage of orthophosphate (PO4-P) samples from standing water sites in each subcatchment falling within each rated category for this variable.**

**Thresholds as defined in Table 2.3. Subcatchments as shown in Figure 2.1**

The data shown in these figures do however suggest that:

- There has been a marked increase in the number of samples showing phosphorus enrichment in all subcatchments, with the exception only of the Lourens, Silvermine and Soet River subcatchments;
- Samples in the Lourens and Silvermine subcatchments generally fell within the Target range for PO4-P, representing rivers in an oligotrophic to mesotrophic condition;
- While phosphorus enrichment in the Soet River system was generally in the Unacceptable range, some sites monitored over the past 10 years fell within the Target range for PO4-P, suggesting some improvement in this variable. This is likely to be a real improvement, as the same range of sites were monitored over time in this system;
- The Mosselbank and (lower) [4]Diep River subcatchments showed a history of phosphorus enrichment, which further increased over the past five years in both subcatchments. Treated and untreated sewage effluent as well as runoff from agricultural areas (livestock feedlots and fertilized fields) are the most likely contributors of phosphorus to these systems;
- The Sout system also showed a history of significant phosphorus enrichment – given that both assessed sites lie downstream of the Melkbosstrand WWTW, this is however to be expected;
- The Lourens, Hout Bay, Silvermine and Sand River subcatchments generally had a high proportion of sites within the Target range for orthophosphate – but all show a pattern of increasing numbers of samples that are within the Poor or Unacceptable ranges;
- The Eerste and Kuils subcatchments also showed a significant increase over time in the proportion of sites where water is in Poor or Unacceptable condition, suggesting increased nutrient enrichment, possibly associated with poor performance from WWTWs in the area and/or an expansion in informal settlement in the lower catchment.
- In the Salt River catchment, the Elsieskraal subcatchment was generally less enriched than the Lower Salt subcatchment, but both subcatchments nevertheless showed high levels of enrichment among sampled sites;
- The Zeekoe catchment also reflected a marked increase in the proportion of sites in the Poor and Unacceptable category for orthophosphate over the monitoring record. Some improvement over the past 10 years was however noted.

**Forms of Phosphorus**

Phosphorus occurs in both inorganic and organic forms, and may be present in water as particulate or dissolved species. Orthophosphate species $H_2PO_4$ and $HPO_4^{-2}$ are the only forms of soluble inorganic phosphorus that can be utilised directly by biota (DWAF 1996a). Total phosphorus (TP) is a measure of all the chemical species of phosphorus present in the water column. It includes dissolved forms, insoluble particulate forms and phosphorus already incorporated into phytoplankton (Malan and Day 2005). Total phosphorus is considered useful for determining trophic status, because it represents all the phosphorus potentially available for incorporation into active biomass.

Phosphorus is reactive under oxidizing conditions, forming relatively insoluble compounds with cations (e.g. Al, Fe) and precipitating out of water. Low oxygen conditions may cause the release of phosphorus back into the water column (DWAF 1996a).

On the basis of the above analysis of historical data, phosphorus enrichment (measured as orthophosphate phosphorus) of rivers and stormwater channels appears to be a significant and progressive concern in most of the City’s subcatchments. Many of these systems pass into vleis and in-channel dams, and add to phosphorus loading of these systems on an ongoing basis, as well as into the marine systems into which they ultimately discharge.

Not surprisingly therefore, the patterns of orthophosphate enrichment evident in river and stormwater systems is also reflected in standing water bodies in the same subcatchments. The following trends are

[4] note that this includes sites in the Diep River itself, as well as Milnerton Lagoon, and monitored inflows into the main channel

indicated by the graphs shown in **Figure 4.3.2**:

- Orthophosphate enrichment has generally increased in standing water bodies as a whole over the data record (see graph for "All standing water bodies"), with a marked movement towards eutrophic and hypertrophic states (as defined in **Table 2.3** for standing water bodies);
- The only standing water body for which a trend of increasing orthophosphate was not displayed consistently was the small suburban wetland Die Oog, in the Sand catchment. Although hypertrophic conditions dominated in this system up to the end of 2010, a marked improvement in the number of samples that were better than Unacceptable occurred thereafter. This reflects the positive results of a rehabilitation intervention embarked on around this time (C. Bouland, City of Cape Town, pers. comm.), when the system was dredged to remove black nutrient-enriched muds; exotic fish (with a known impact in terms of stirring up of bottom muds and thus increasing turbidity) were removed; and a large bird roosting tree was removed, with the result that ibis and egrets left the wetland, thus reducing sources of bird guano into the waterbody;
- Of the selected water bodies, Glencairnvlei and Princessvlei showed the lowest levels of orthophosphate enrichment, with a high proportion of samples being within Target, and thus within the Oligotrophic to Mesotrophic trophic range. This suggests that these water bodies would be least prone to algal blooms;
- Marked enrichment of Westlake, Zandvlei, Langevlei, Zeekoevlei, Westlake and Little Princessvlei has occurred over the monitoring record, with most samples measured from these systems over the past 10 to 15 years lying within the Unacceptable (hypertrophic) range. Of interest is the fact that there appears to have been little direct impact of the imposition of an annual wet season draw-down of water levels in Zeekoevlei, commencing in 1999. The subsequent construction of a cutoff drain to divert subsurface flows from the nearby WWTW away from Zeekoevlei and into the downstream Zeekoe channel in 2008 may reflect in the increased percentage of samples meeting Target conditions in the 2010-2015 period;
- Wildevoelvlei, Zoarvlei, and the Mew Way, Mitchell's Plain and Edith Stephens detention ponds all showed fairly consistent levels of long-term severe nutrient enrichment (Unacceptable) throughout the monitoring record, whereas the dams in the upper Elsieskraal catchment, although generally also on a trajectory of increasing phosphate enrichment, still included substantial numbers of samples within the Target or Poor ranges.

A more detailed analysis that allows for the influence of different sites within subcatchments to be considered is provided in the following section.
Note that the inclusion of detention ponds (e.g. Mitchell's Plain) in the analysis presented here is intended only to reflect the impact of catchment scale landuse on these waterbodies. An understanding of water quality in these systems is also important, in light of the fact that many detention ponds in the vicinity of high density informal settlements are utilized by local residents (mainly children) for swimming.

***B Current state (April 2019 to March 2020)***

**Figures 4.3.3 – 4.3.4** present boxplots of median orthophosphate data over the most recent monitoring year (referred to as the 2019 dataset) compared to data from the previous four year period (2015-2018 datasets), for river/ stormwater channels and dams / vleis respectively.

**Figures 4.3.5 – 4.3.6** present the same data, separated into summer and winter seasons.

**Figure 4.3.7** comprises a set of maps, one per catchment, which illustrate the performance of individual sites in the 2019 period, by comparing median annual orthophosphate concentrations in 2019 with the 2015-2018 median. These figures allow differentiation of the scale of phosphorus enrichment at different sites, as opposed to the previous section, which merely described whether subcatchments fell into Target, Poor or Unacceptable categories, but did not illustrate different degrees of non-compliance.

With regard to **river and stormwater systems**, the data illustrate the same broad trends discussed in the previous section, with the following specific aspects being noted:

- Based on **Figure 4.3.3**, it is evident that the Sout, Diep, Mosselbank, Lower Salt, Zeekoe, Kuils, Eerste, Mitchell's Plain and Soet River subcatchments were the worst performing with regard to phosphorus enrichment, with median values and interquartile range extending orders of magnitude beyond the target threshold for this variable, and outliers indicating samples that significantly exceed even these ranges;
- The Elsieskraal, Sir Lowry's Pass and South Peninsula subcatchments showed orthophosphate enrichment that was generally in the Unacceptable Range, but substantially lower than that of the above poor-performing subcatchments;
- The Sand, Lourens and Hout Bay subcatchments showed lower levels of orthophosphate enrichment, with median values within the Poor rather than Unacceptable range, albeit with large numbers of samples extending into the Unacceptable Range, and at times showing significant enrichment two or more orders of magnitude beyond the Unacceptable threshold. Of these, the Hout Bay system is the only one affected by runoff from poorly serviced informal settlements, affecting water quality in its lower reaches;
- The Silvermine subcatchment was by far the best-performing subcatchment, with most samples lying within the target range, and only a few extending into the range for Poor and Unacceptable;
- Over the 2019 period, median orthophosphate concentrations <u>increased</u> compared to the previous four years in the Soet, Zeekoe, Kuils, South Peninsula, Lower Salt and Diep subcatchments, illustrating deterioration in water quality - in the case of the Soet subcatchment, this change was nevertheless in the context of a long-term improvement in the condition of some sites, as reflected in the previous section;
- Subcatchments showing an improvement in orthophosphate enrichment over the past year were the Sout, Mitchell's Plain, Eerste, Sir Lowry's Pass and Hout Bay subcatchments;
- Strong seasonal differences were observed in the Sout, Mitchell's Plain, Eerste and Diep subcatchments, with summer water samples being generally more enriched than winter samples (**Figure 4.3.5**). This probably reflects winter dilution as a result of rainfall, and downstream nutrient loading is assumed to remain fairly similar
- No strong seasonal differences were noted in the Lower Salt, Mosselbank, Kuils, Zeekoe or Soet subcatchments. With the exception of the Soet, these systems are all impacted by inflows of treated effluent, which is less likely to be influenced by seasonality. The Soet is a small system that does not have a natural river channel and is almost entirely comprised of a constructed network of stormwater channels, which is subject to ongoing inflows of polluted grey water and sewage water discharged from Informal and poorly serviced settlements in its catchment, as well as from flows from the upstream Heritage Park area and its subcatchment;

Box plots for **Vleis and Dams / standing water areas** (**Figures 4.3.4** and **4.3.6**) reflect the influence of catchment scale orthophosphate enrichment on these standing water systems, noting that in most cases, unlike in the rivers, accumulation of phosphorus over time is likely, as a result of limited options for flushing. The following main issues are evident from the data:

- All of the assessed water bodies were enriched with regard to orthophosphates, and most samples fell well within the Unacceptable range of hypertrophic systems, with many samples more than two orders of magnitude beyond the threshold of Unacceptable;
- Wildevoelvlei showed by far the greatest levels of orthophosphate enrichment, reflecting inputs from both a large WWTW and an extensive area of poorly serviced informal settlement upstream. Such conditions make this system highly prone to algal blooms – discussed in Section 4.5;
- Rietvlei, Zeekoevlei and Zoarvlei were also well within the range for hypertrophic systems, albeit generally considerably less enriched than the systems described above. While inflows into Zoarvlei

are affected primarily by runoff from the industrial areas of Paarden Eiland, Zeekoevlei receives runoff influenced by its passage through large areas of informal and backyard settlement in the Gugulethu, Philippi and Grassy Park areas, as well as agricultural runoff from the Philippi Horticultural area and urban inflows from Grassy Park, Pelican Park and Lotus River;

- The smaller water bodies of Langevlei and Rondevlei, with relatively smaller subcatchments, albeit through highly urbanized catchments with high levels of street waste and dumping, showed lower levels of orthophosphate enrichment than neighbouring Zeekoevlei;
- Westlake Wetland and Zandvlei showed some improvement in phosphate enrichment over the 2019 period, with less episodic high levels of orthophosphate at Zandvlei than over the 2015-2018 period, but remained in the hypertrophic / Unacceptable range;
- The water bodies where orthophosphate enrichment was least problematic, albeit still in the hypertrophic range, comprised Princessvlei, Little Princessvlei, Die Oog, Glencairnvlei and the Elsieskraal Dams. This finding reflects subcatchments that are not subject to receipt of treated sewage effluent or characterized by substantial areas of informal or poorly serviced settlements;

> Note that the data described here reflect only orthophosphate concentrations in vleis and dams. That is, the source of this nutrient that is immediately available for biological uptake. Other sources of phosphate include particulate forms, in decomposing algal and other plant material, as well as phosphorus in bottom sediments, which can be released by turbulence or low oxygen conditions.

- Interestingly, strong seasonal variation in orthophosphate concentrations was evident only in the Wildevoelvlei system, and then only in the 2019 period, when Wildevoelvlei exhibited particularly elevated phosphate concentrations in the winter – these were not matched by elevated *E. coli* concentrations, and could reflect the influence of surface "wash", when organic contaminants accumulating in stormwater channels and surface areas of the poorly serviced and highly polluted Masiphumelele informal settlement are washed into the vlei as a result of high rainfall. The system also receives phosphorus from permanent inflows of treated effluent;
- The Edith Stephens, Mew Way, and Mitchell's Plain detention ponds all showed a broadly similar range of enrichment, reflecting highly compromised catchments, subject to runoff from poorly extensive areas of poorly serviced informal and/or backyard settlements – the Edith Stephens pond receives overflows from the Big Lotus River, which itself is highly polluted, reflecting a poorly serviced upstream catchment.

Median data shown in the mapped subcatchments of **Figure 4.3.7** provide a spatial perspective to the data described above, and in particular illustrate:

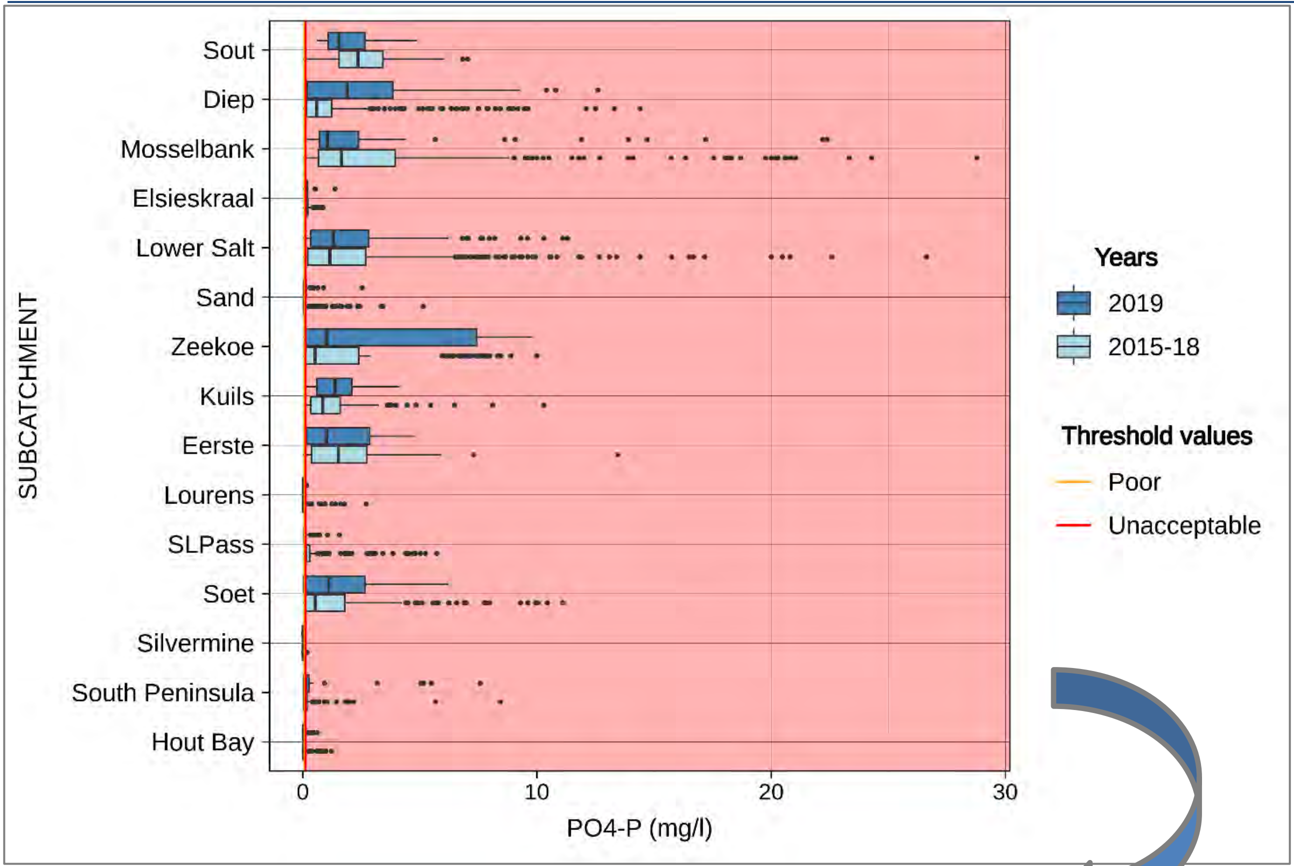
- An apparent correlation between the proximity of WWTWs and poorly serviced informal settlements, and water in an Unacceptable condition with regards to orthophosphates, in all catchments where these landuses occur (Sout, Diep, Mosselbank, Eerste, Kuils, Soet, Lower Salt, Mitchell's Plain, Zeekoe and Wildevoelvlei), with the exception of the Hout Bay and Sir Lowry's Pass systems, where phosphorus enrichment downstream of the informal settlement and WWTW respectively resulted in Poor rather than Unacceptable conditions for this variable;
- Subcatchments that did not appear to have been influenced by significant point source inflows of orthophosphate include the Silvermine and Lourens subcatchments only, although the maps indicate that parts of the Sand, Sir Lowrys Pass, Hout Bay and Schusters Rivers were also in a relatively unimpacted condition with regards to this nutrient.

Further detail relating to median orthophosphate concentrations at different sites over the past five years can be obtained from the rated tables in **Appendix G**.

**Implications:**

The data presented in this section indicate that phosphorus enrichment is a pervasive issue in most of the City's catchments. The effect of this is apparent in the high concentrations of phosphates in all of the open water bodies assessed in this report, and with the scale of enrichment reflecting catchment activities – particularly the influence of WWTW effluent releases and runoff from poorly serviced settlements. The cost of landuse and activities leading to phosphorus enrichment is likely to be reflected in management requirements, such as ongoing clearing of plants from nutrient enriched waterbodies to prevent flooding; loss of recreational value associated with water bodies prone to algal blooms and invasion by plants such as water hyacinth and reeds; and periodic fish kills associated with anoxic waters as a result of high rates of plant decomposition. These issues are discussed further in Section 5, with specific regard to the City's recreational vleis.

**I**



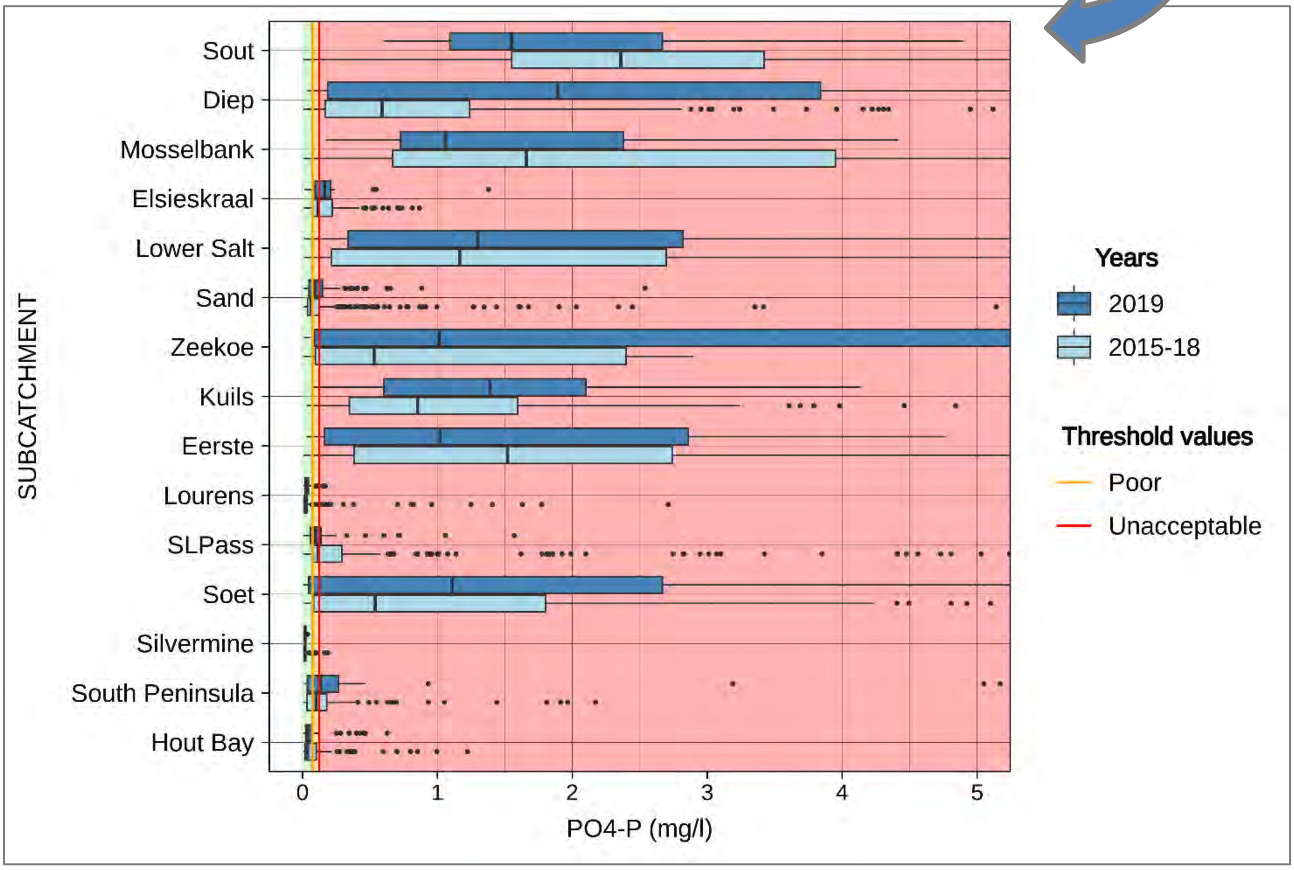




**Figure 4.3.3 Comparison of current (April 2019 to March 2020) PO4-P data with data from the previous 4 year record. Rivers and stormwater systems.**

Box plot: line shows median value, "box" shows interquartile range; "whiskers" indicate maximum and minimum values; dots indicate outliers. Top graph shows all data; bottom graph has been scaled to 5 mg P /L only.
Shading illustrates position in rated thresholds. Legend needs to include green for Target level

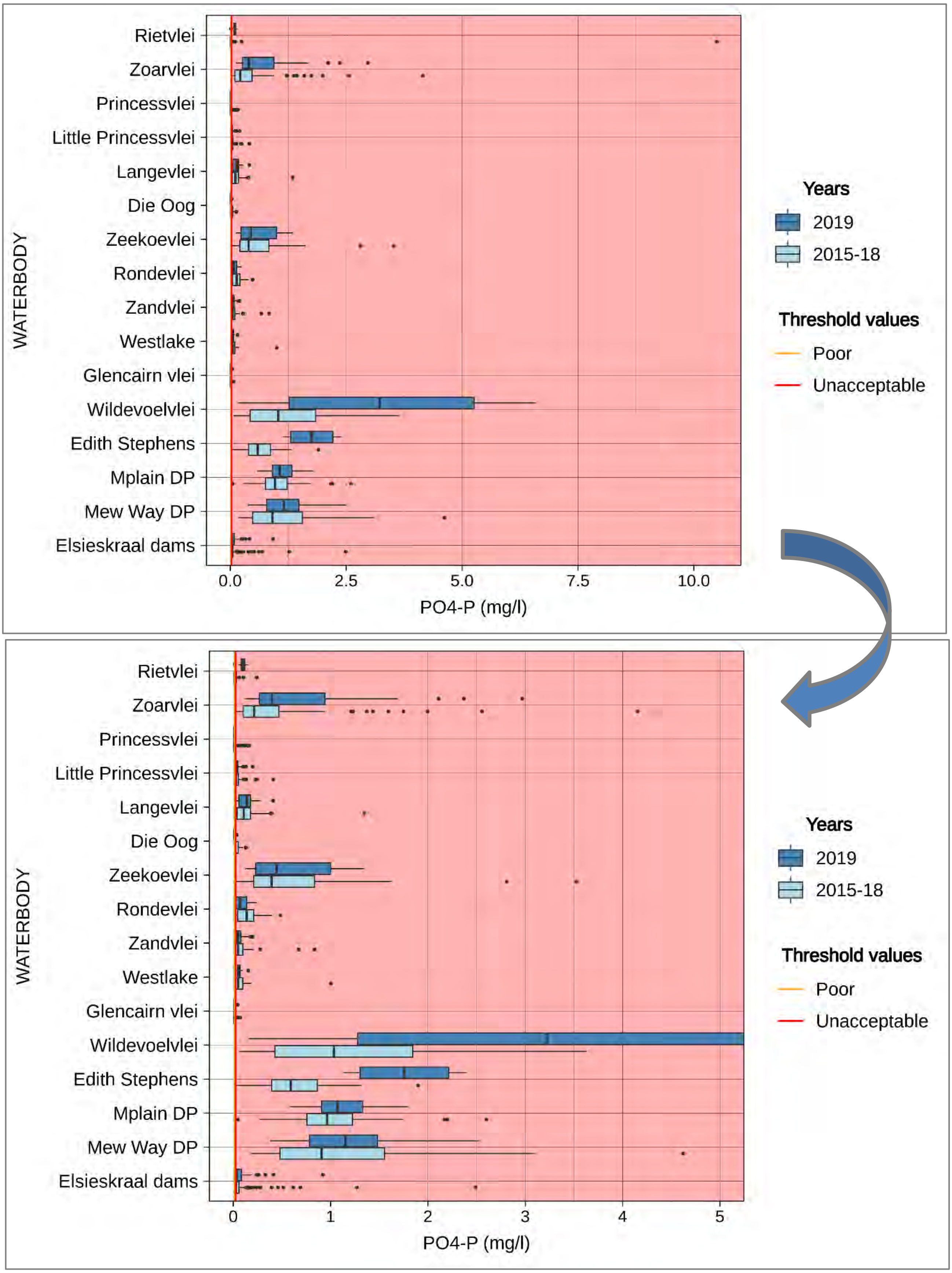



**Figure 4.3.4 Comparison of current (April 2019 to March 2020) PO4-P data with data from the previous 4 year record. Vleis and Dams**

Box plot: line shows median value, "box" shows interquartile range; "whiskers" indicate maximum and minimum values; dots indicate outliers. Top graph shows all data; bottom graph has been scaled to 5 mg P /L only.
Shading illustrates position in rated thresholds.

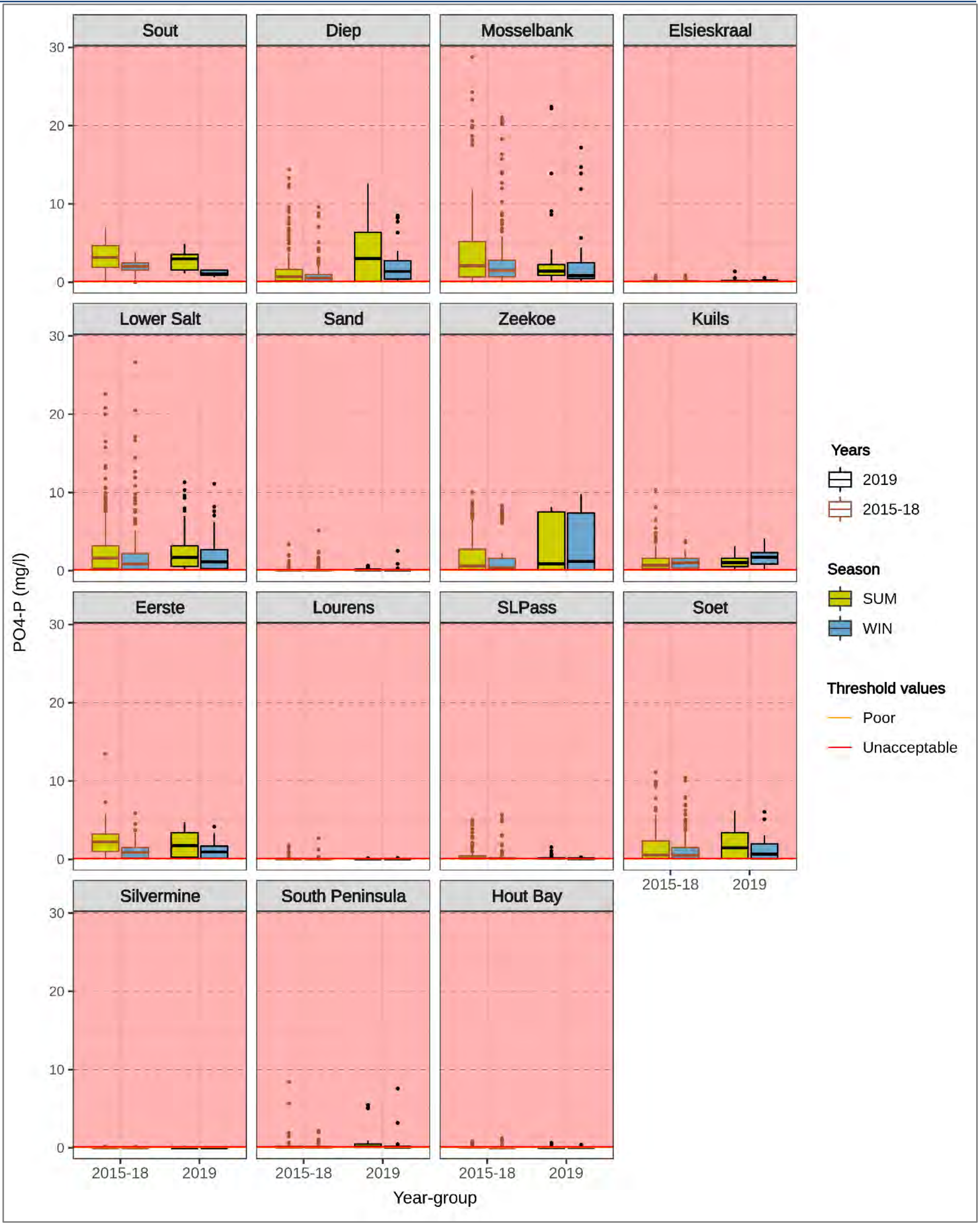



**Figure 4.3.5 Comparison of current (April 2019 to March 2020) PO4-P data with data from the previous 4 year record, showing seasonal variability. Rivers and stormwater systems**

Box plot: line shows median value, "box" shows interquartile range; "whiskers" indicate maximum and minimum values; dots indicate outliers. Shading illustrates position in rated thresholds.

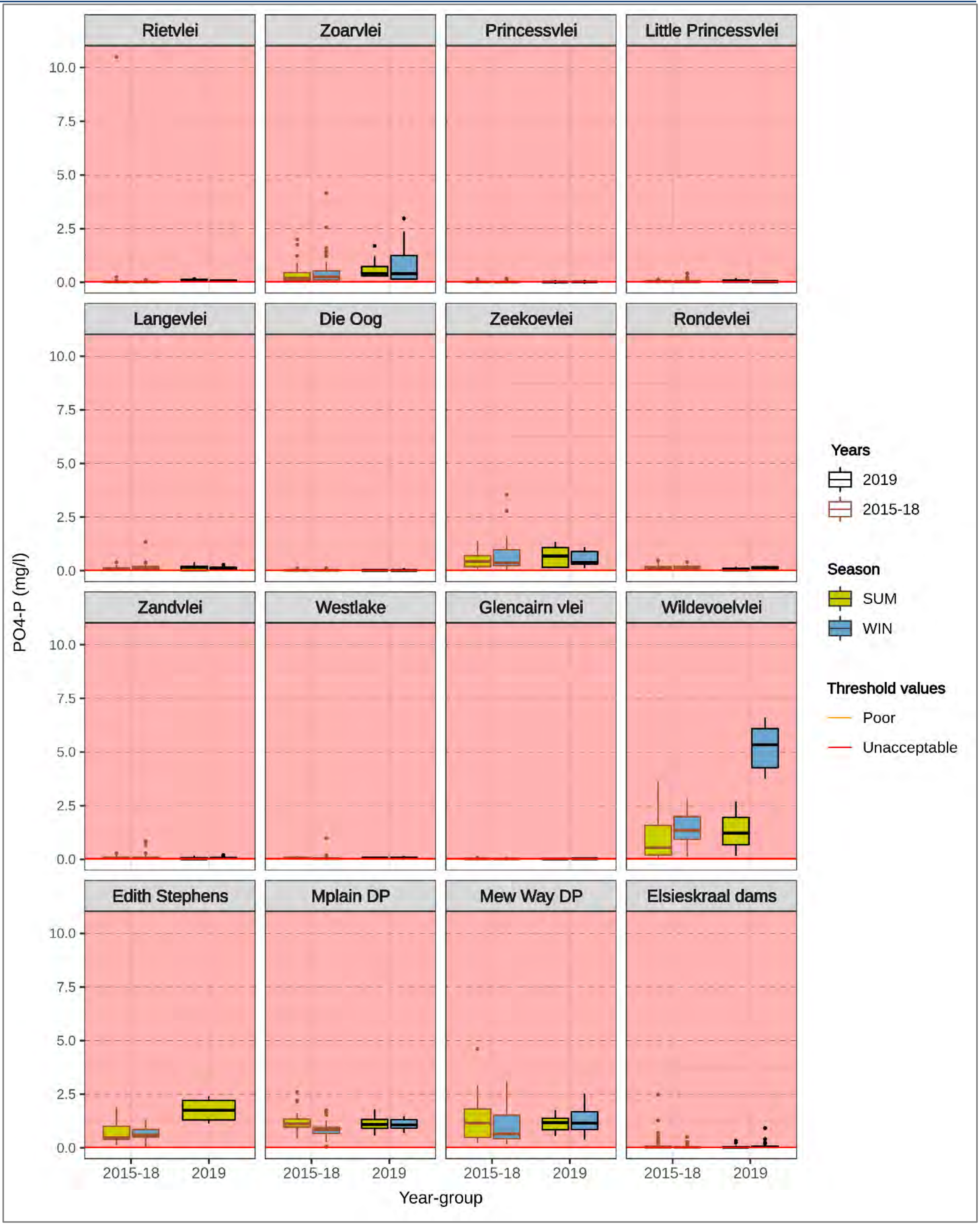



**Figure 4.3.6 Comparison of current (April 2019 to March 2020) PO4-P data with data from the previous 4 year record, showing seasonal variability. Vleis and Dams**

Box plot: line shows median value, "box" shows interquartile range; "whiskers" indicate maximum and minimum values; dots indicate outliers. Shading illustrates position in rated thresholds.

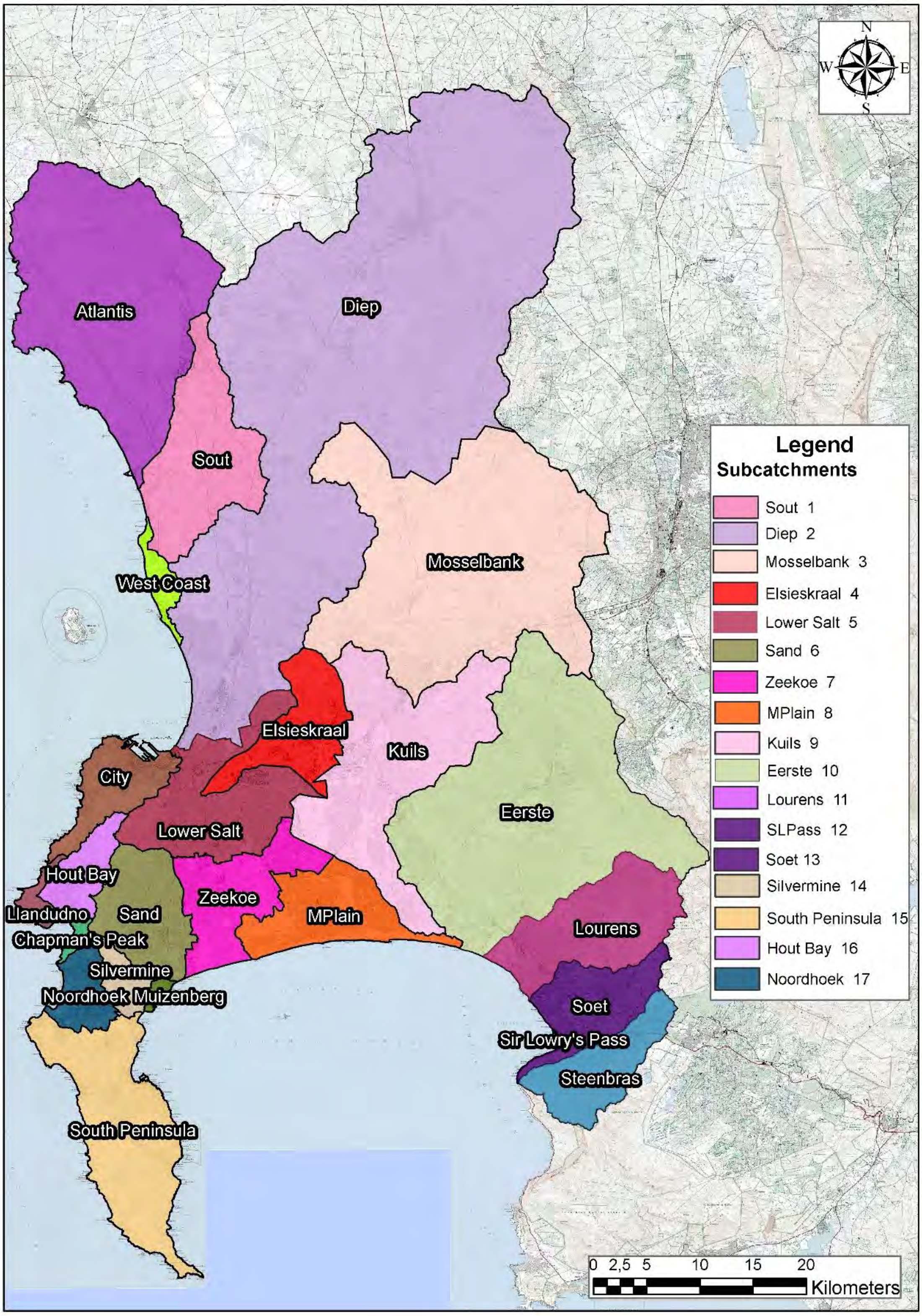
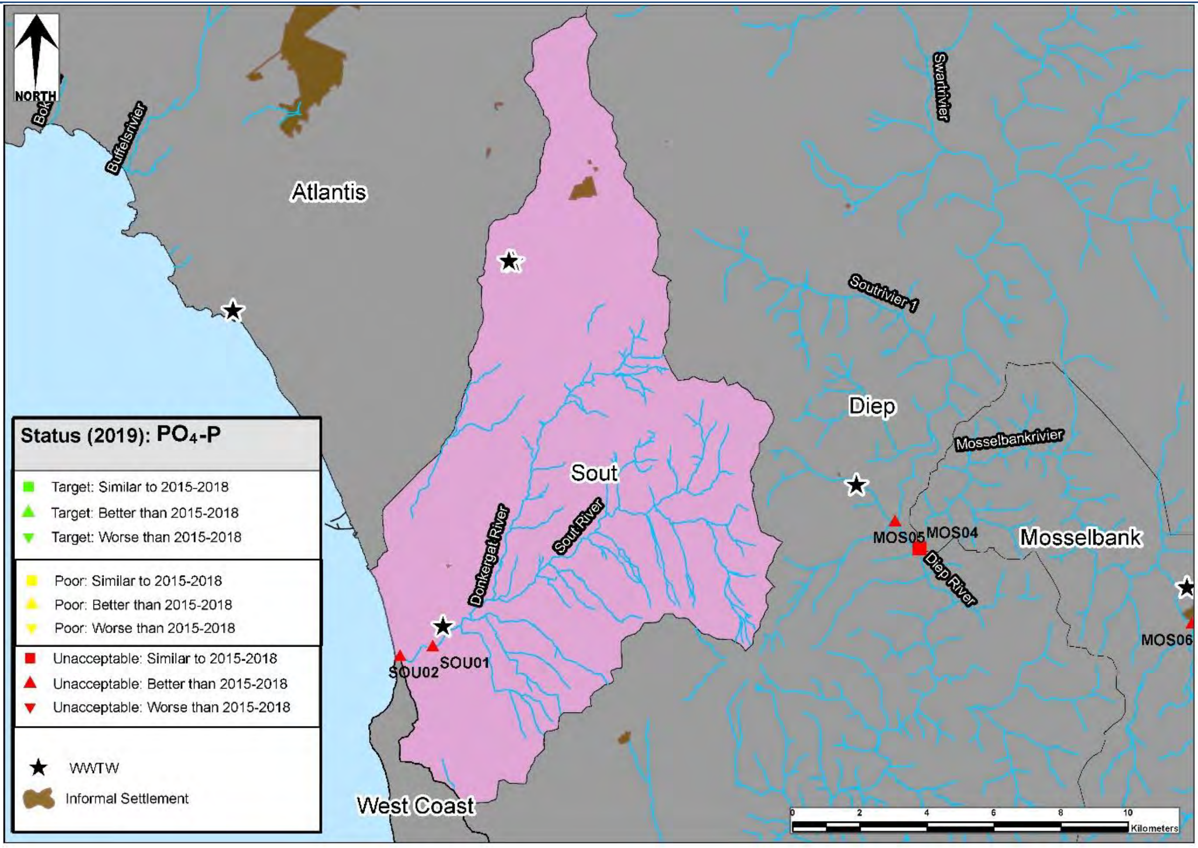



**Figure 4.3.7 Median annual orthophosphate (PO4-P) concentrations, presented as a range of maps per subcatchment. Data coded as to level of change compared to previous 4 year median dataset. Subcatchments presented in numbered order as shown in this map. See following maps for actual data.**



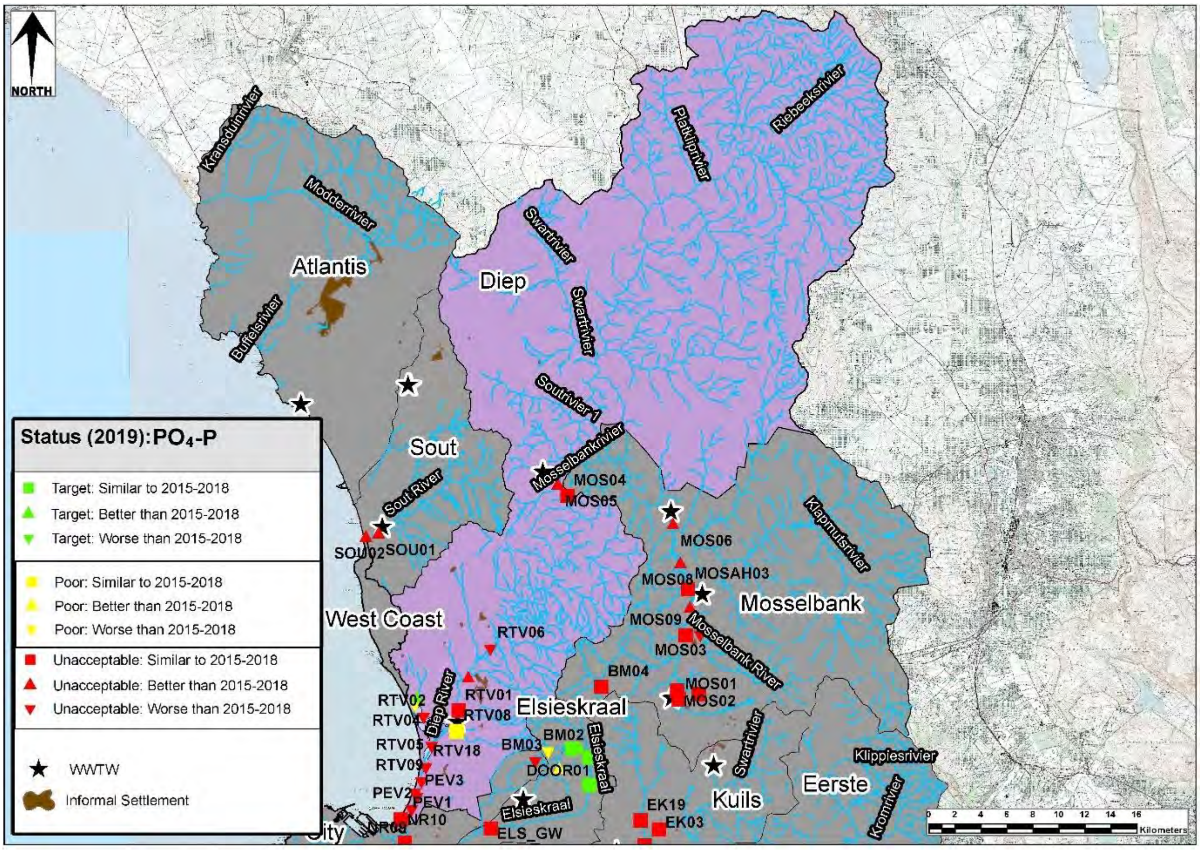




**Figure 4.3.7 (CONTD) Median annual phosphate (PO4-P) concentrations, presented per subcatchment. Data coded as to level of change compared to previous 4 year median data. Subcatchments presented in numbered order in first map.**

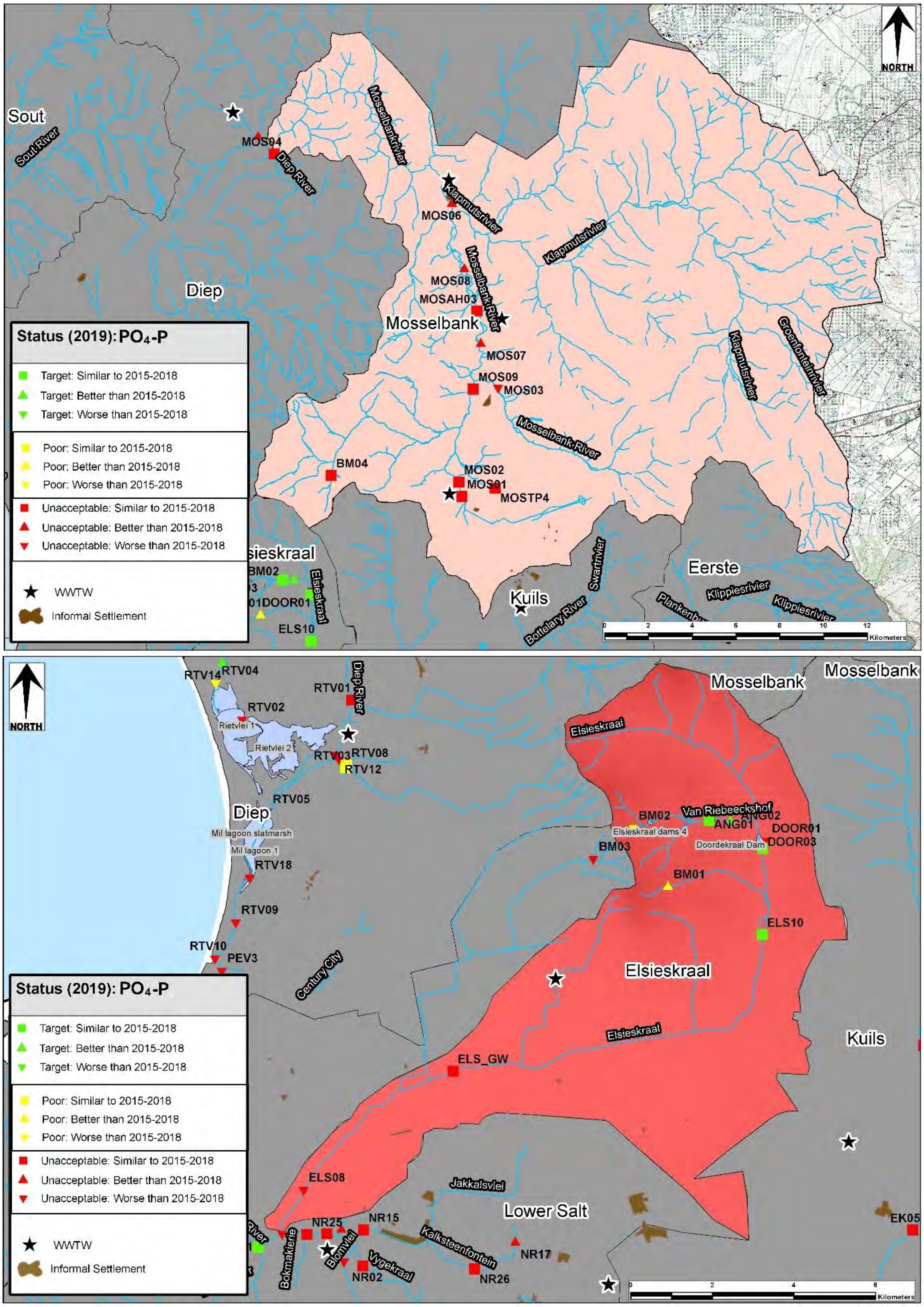
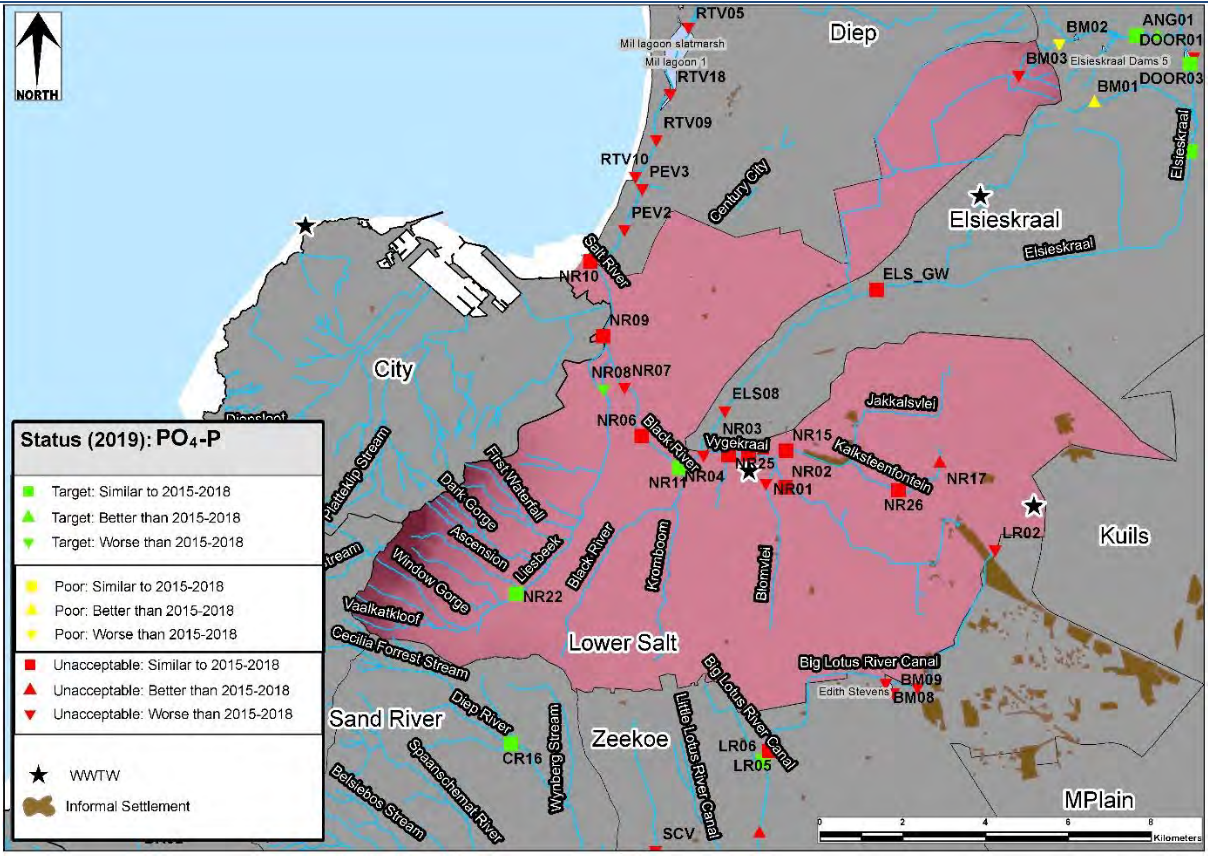



**Figure 4.3.7 (CONTD) Median annual phosphate (PO4-P) concentrations, presented per subcatchment. Data coded as to level of change compared to previous 4 year median data. Subcatchments presented in numbered order in first map.**



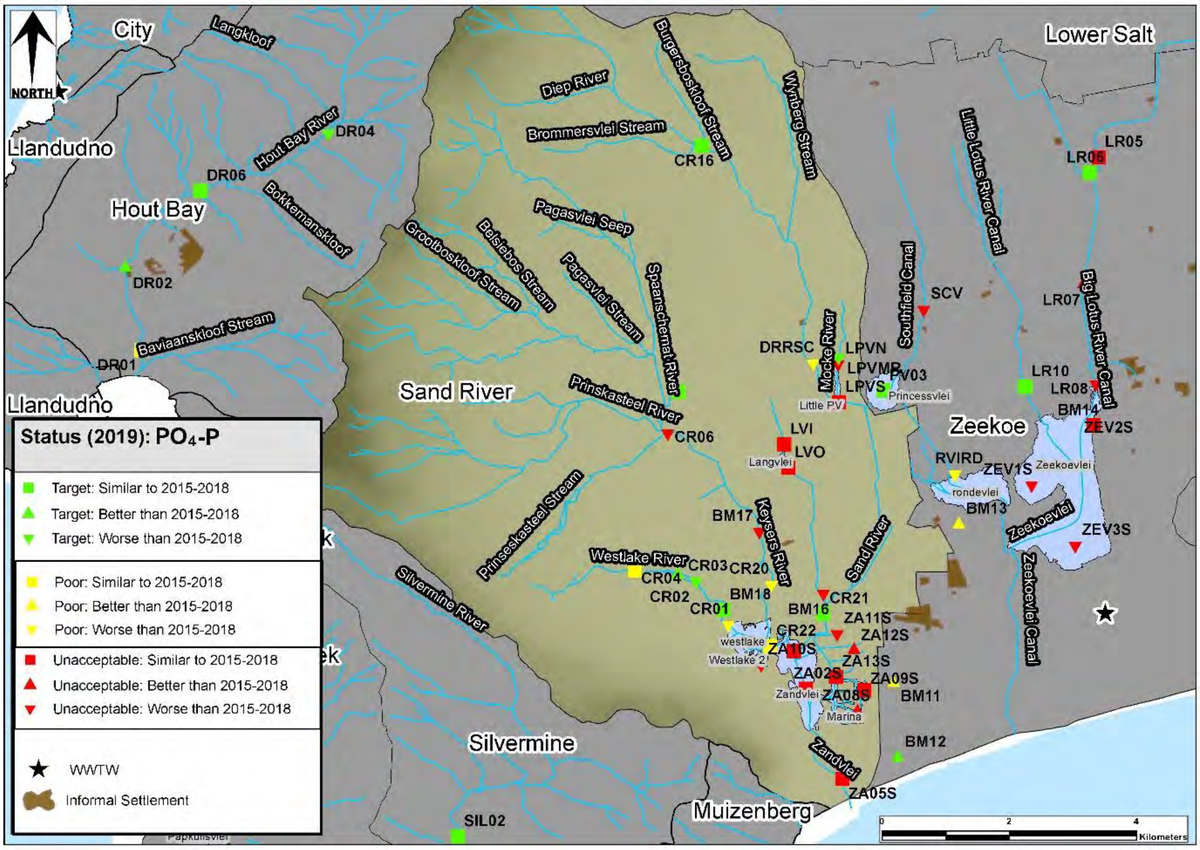
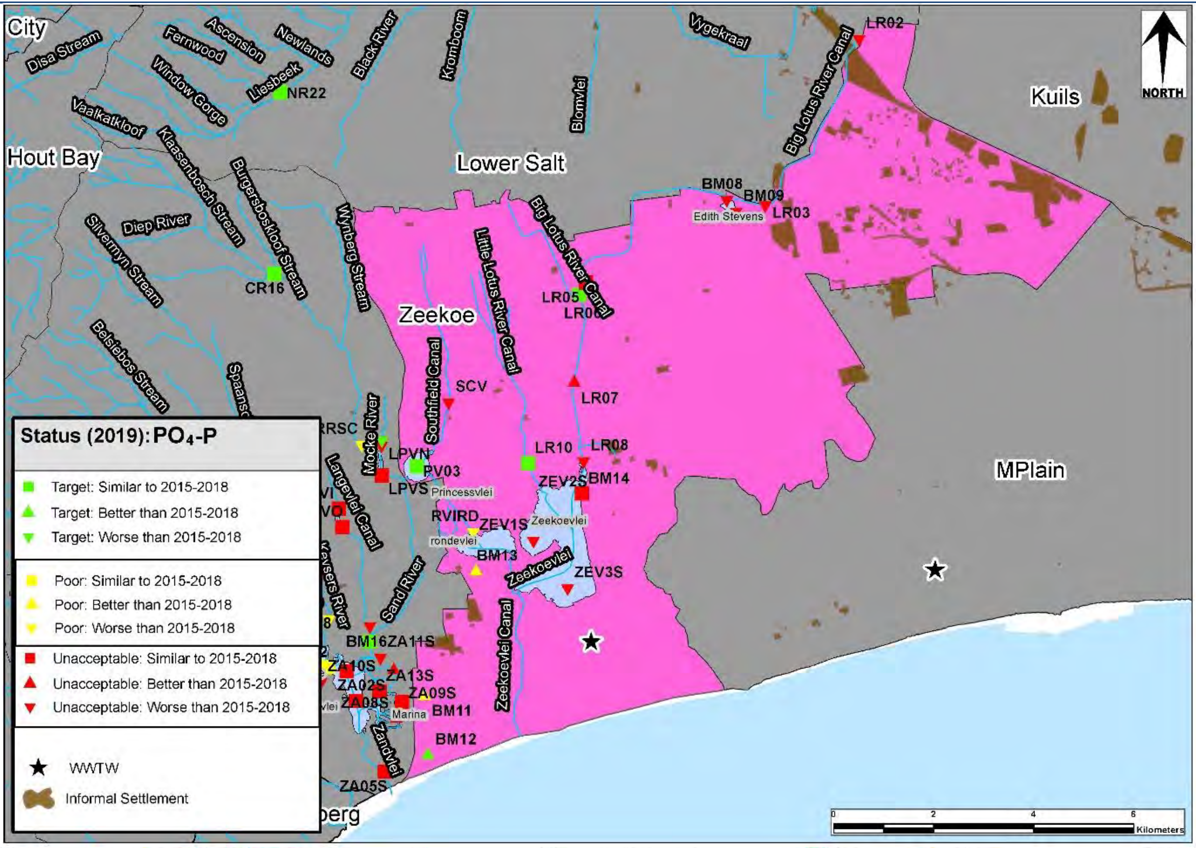




**Figure 4.3.7 (CONTD) Median annual phosphate (PO4-P) concentrations, presented per subcatchment. Data coded as to level of change compared to previous 4 year median data. Subcatchments presented in numbered order in first map.**



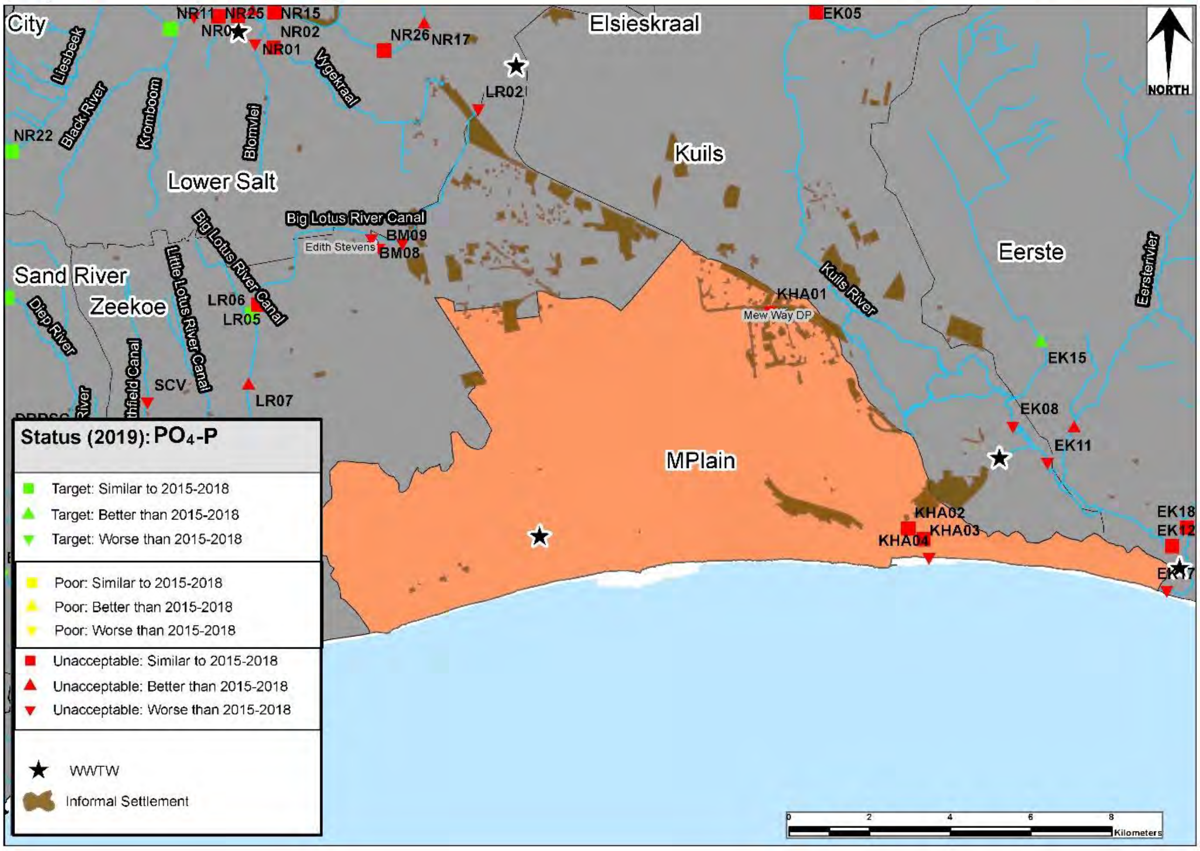


**Figure 4.3.7 (CONTD) Median annual phosphate (PO4-P) concentrations, presented per subcatchment. Data coded as to level of change compared to previous 4 year median data. Subcatchments presented in numbered order in first map.**

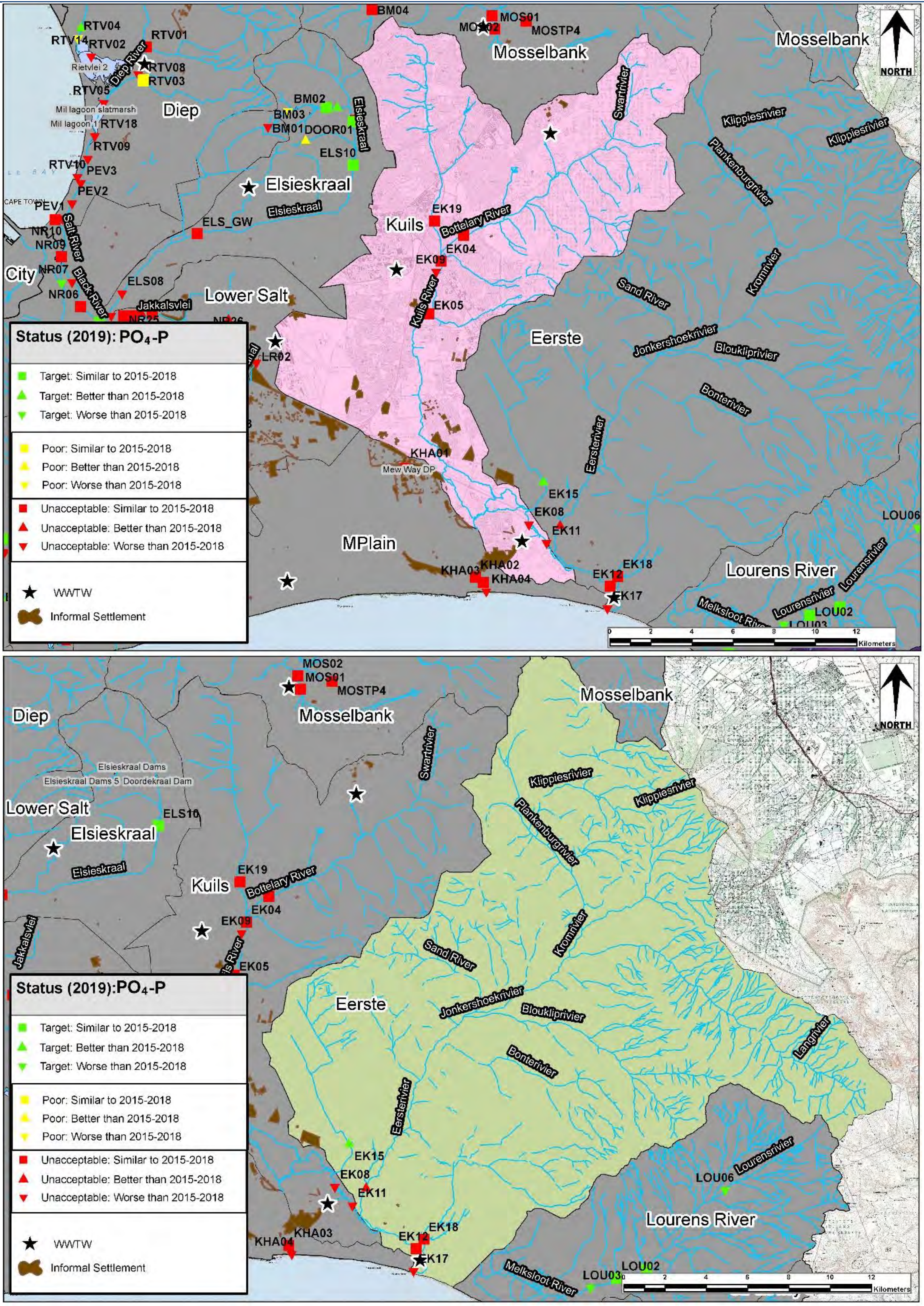
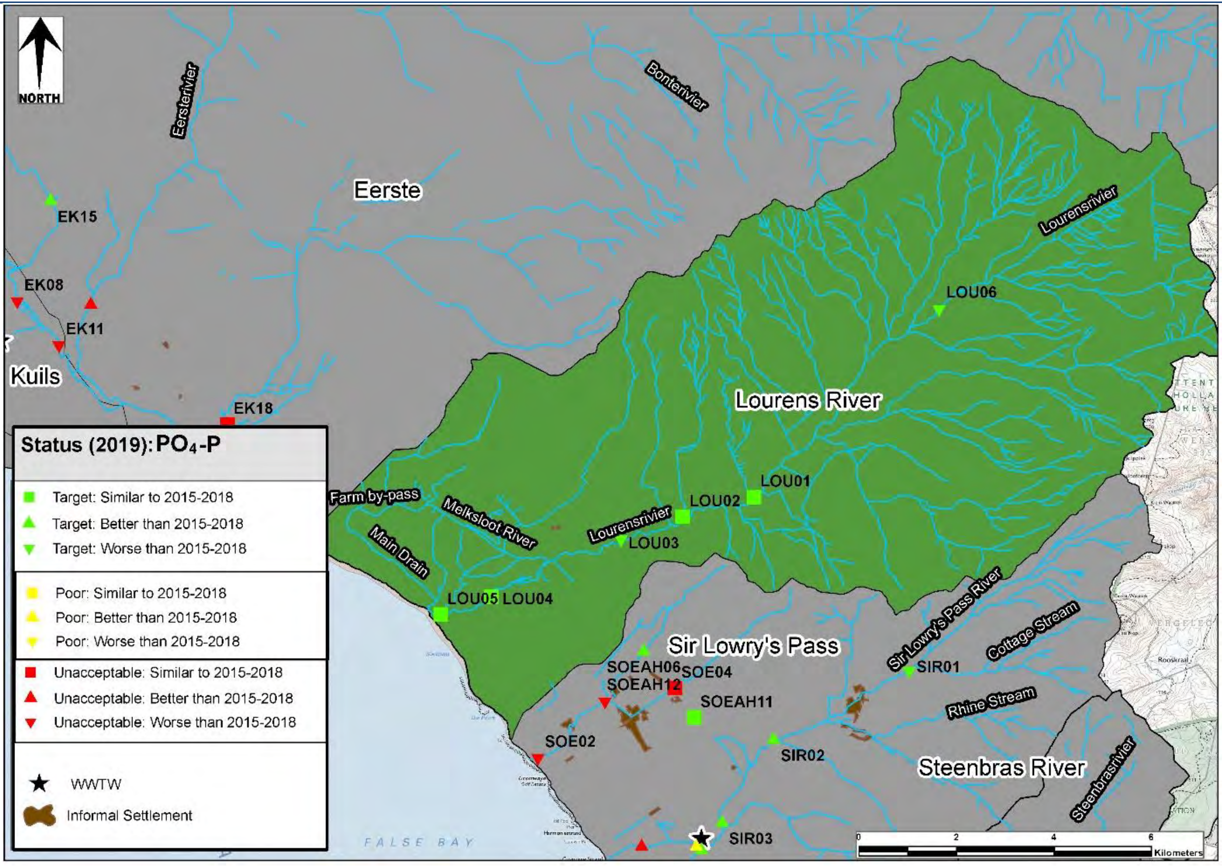



**Figure 4.3.7 (CONTD) Median annual phosphate (PO4-P) concentrations, presented per subcatchment. Data coded as to level of change compared to previous 4 year median data. Subcatchments presented in numbered order in first map.**



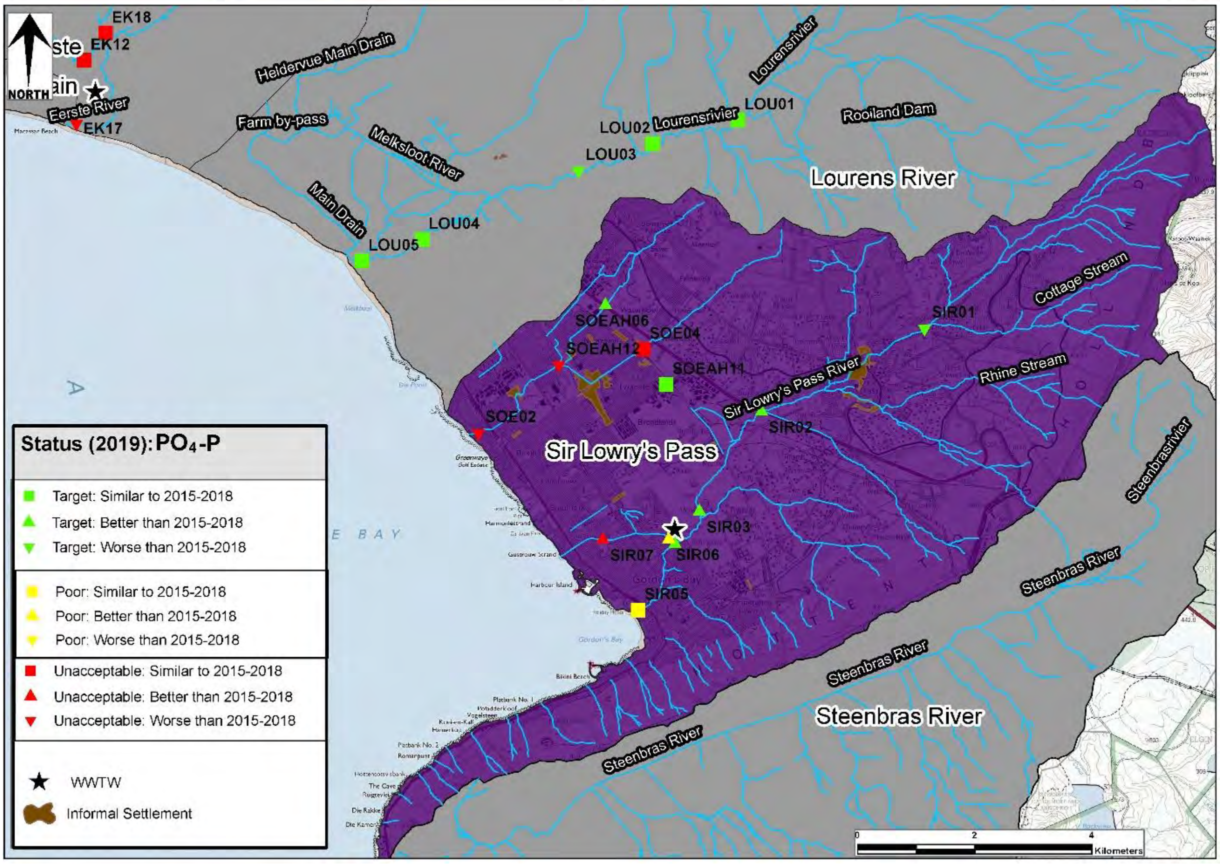




**Figure 4.3.7 (CONTD) Median annual phosphate (PO4-P) concentrations, presented per subcatchment. Data coded as to level of change compared to previous 4 year median data. Subcatchments presented in numbered order in first map.**

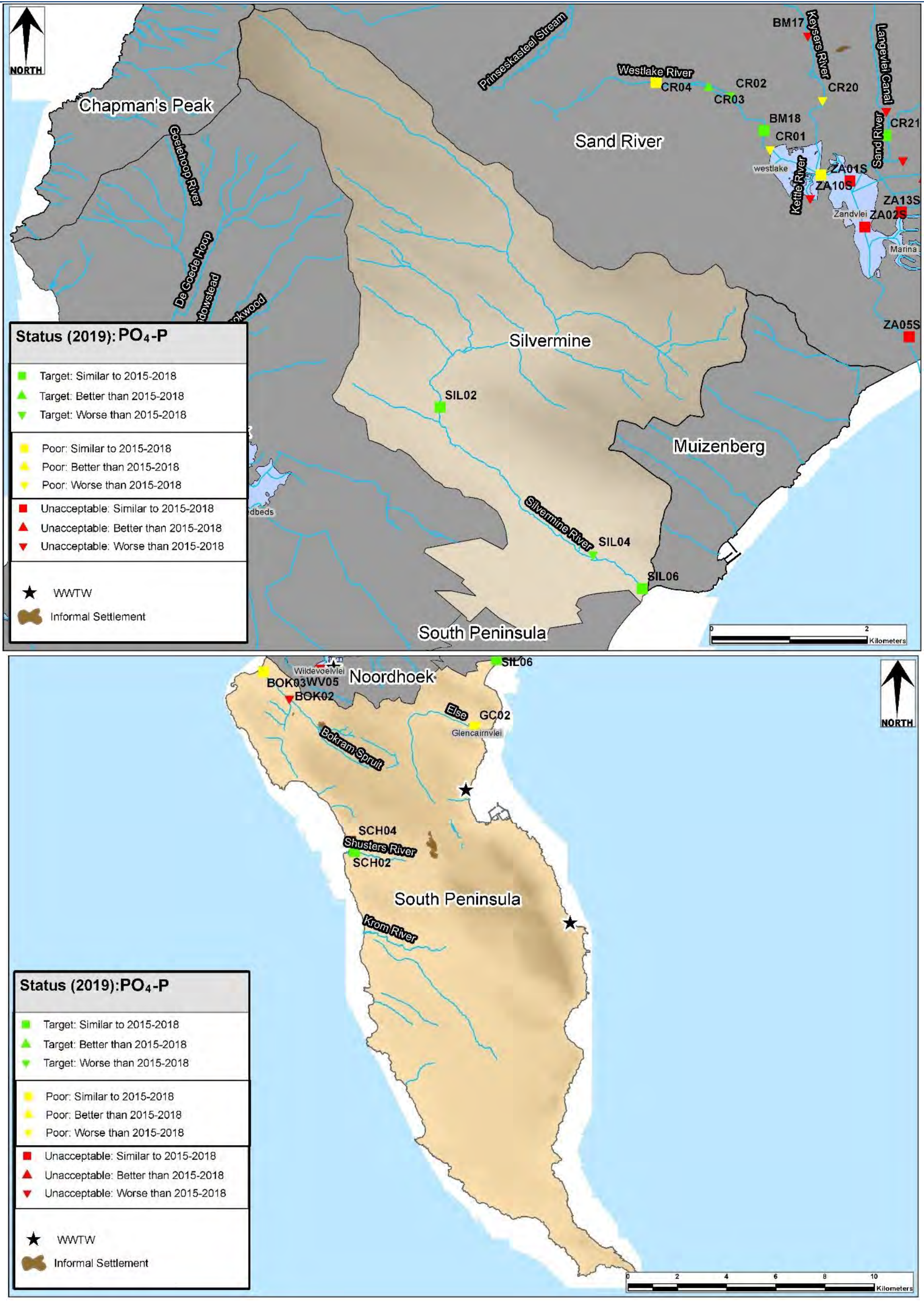



**Figure 4.3.7 (CONTD) Median annual phosphate (PO4-P) concentrations, presented per subcatchment. Data coded as to level of change compared to previous 4 year median data. Subcatchments presented in numbered order in first map.**

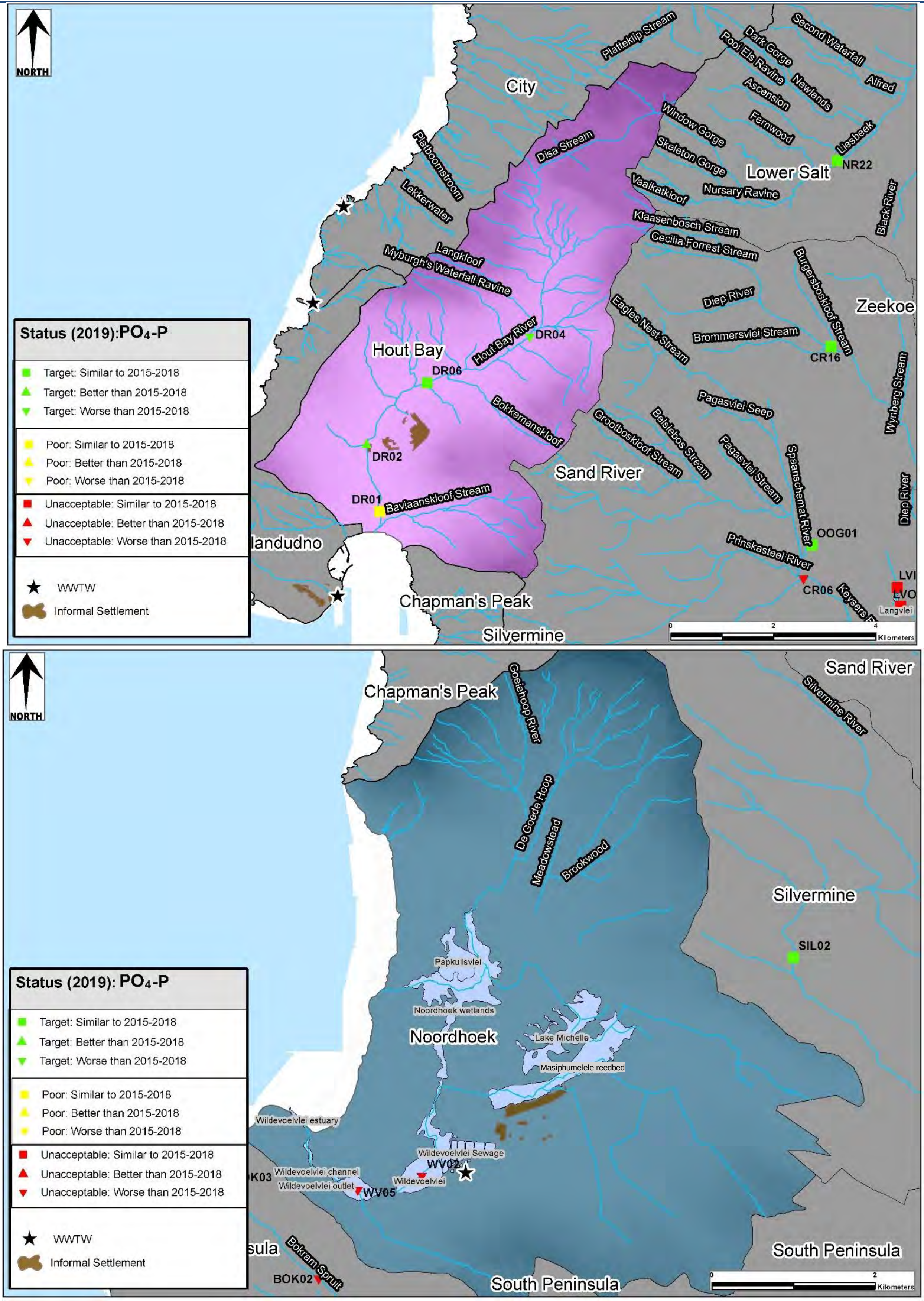



**Figure 4.3.7 (CONTD) Median annual phosphate (PO4-P) concentrations, presented per subcatchment. Data coded as to level of change compared to previous 4 year median data. Subcatchments presented in numbered order in first map.**

### *4.3.5 Nitrogen enrichment*

### *A History of change*

**Figures 4.3.8** and **4.3.9** present patterns in Total Inorganic Nitrogen (TIN) in rivers / stormwater channels and standing water bodies respectively, as a measure of enrichment of nitrogen nutrients. The data represent total available nitrogen in these systems, and were calculated by addition of the concentrations of nitrate- and nitrite nitrogen, as well as total ammonia nitrogen ($NH_4$-N). The long-term data have been presented as the percentage of samples from sites in each subcatchment that meet Target conditions for this variable, versus those falling within Poor and Unacceptable categories, representing eutrophic and hypertrophic conditions respectively.

**Figure 4.3.10** by contrast considers the ratio of TIN to orthophosphate phosphorus (N:P) in different systems. These are again represented in regard to thresholds of change in **Tables 2.2 and 2.3** and are considered in this report because they provide an indication of the degree to which excessive phosphate is the problem in the system, versus nitrogen enrichment. Aquatic ecosystems that have low N:P ratios (that is, too much phosphorus relative to nitrogen) are more likely to be prone to dominance by plants able to extract nitrogen from the air. These include Cyanophyte algae (also known as blue-green algae).

The **river and stormwater** data in **Figures 4.3.8** and **4.3.10** suggest:

- Nitrogen enrichment, although problematic, is a less prevailing concern in the City's catchments than is phosphorus enrichment (see Section 4.4.4);
- The Silvermine River subcatchment shows a history of low nitrogen enrichment, which has remained within the Target range throughout the monitoring period;
- The Hout Bay, Sout, Sand, South Peninsula, Lourens and Sir Lowry's Pass subcatchments all showed relatively high levels of samples falling within the Acceptable range for this variable (i.e. within Target or Poor ranges), with the Hout Bay and Lourens Rivers showing improving compliance over the historical record while systems in the Sand, Sout and South Peninsula subcatchments deteriorated somewhat over this period, reflecting additional nitrogen nutrient sources;
- Subcatchments in which nitrogen enrichment was a significant concern comprised the Eerste, Kuils, Diep, Mosselbank, Lower Salt, Zeekoe and Soet, and in these, all but the Kuils, Diep and Mosselbank subcatchments showed a trend of gradual deterioration with regard to this nutrient over the monitoring record;
- With regard to N:P ratios however, the data in **Figure 4.3.10** shows that generally throughout the City's subcatchments, including the least-impacted Silvermine River subcatchment, rivers and stormwater systems have excess of phosphorus compared to nitrogen, and this is likely to increase the tendency of standing water systems to exhibiting dominance by blue-green algae. This is particularly the case in Zeekoevlei and Wildevoelvlei which usually have year round dominance by this algal group. Other systems such as Princessvlei, Rondevlei and Langevlei occasionally have seasonal blooms of blue-green algae;
- The worst performing subcatchment was Mitchell's Plain, with 100% Unacceptable samples throughout the record, reflecting contaminated water largely emanating from parts of Mitchell's Plain and Khayelitsha which enter the constructed stormwater system – <u>it is reiterated that Mitchell's Plain does not include any natural rivers, and detention pond water quality data are included for this subcatchment simply as a gauge of catchment condition.</u>

The **vlei and dam** data in **Figures 4.3.9** and **4.3.11** suggest that:

- With the exception of the Mew Way, Edith Stephens and Mitchell's Plain detention ponds, and Wildevoelvlei, nitrogen enrichment of these water bodies is not excessive, and most of the time thorough the historical record, TIN concentrations have falling within Acceptable limits, with no trajectory of change in any system, other than Zandvlei, in which nitrogen enrichment has decreased over the past 10 years;

- **Figure 4.3.11** suggests however that standing water bodies are, like the rivers / stormwater systems that feed them, characterized by low N:P ratios, likely to promote blue-green algal dominance in many. The least affected systems comprised Zandvlei, Little Princessvlei and Princessvlei, and all systems have been on a trajectory of increasing available phosphorus relative to nitrogen nutrients.

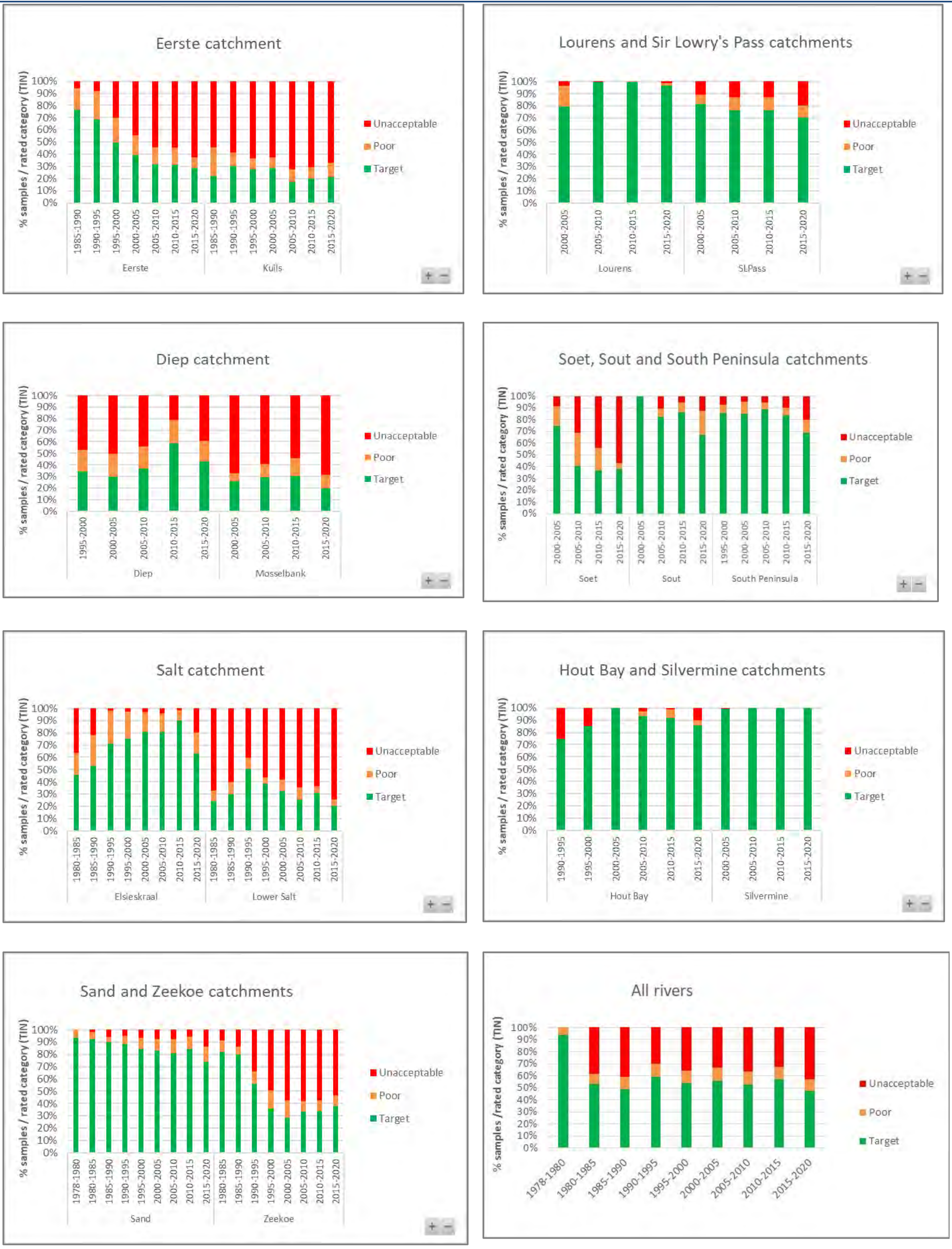



**Figure 4.3.8 Percentage of Total Inorganic Nitrogen (TIN) samples from river / stormwater channel sites in each subcatchment falling within each rated category for this variable. Thresholds as defined in Table 2.2. Subcatchments as shown in Figure 2.1**


**Figure 4.3.9 Percentage of Total Inorganic Nitrogen (TIN) samples from vlei and dam sites in each subcatchment falling within each rated category for this variable.**
**Thresholds as defined in Table 2.2. Subcatchments as shown in Figure 2.1**

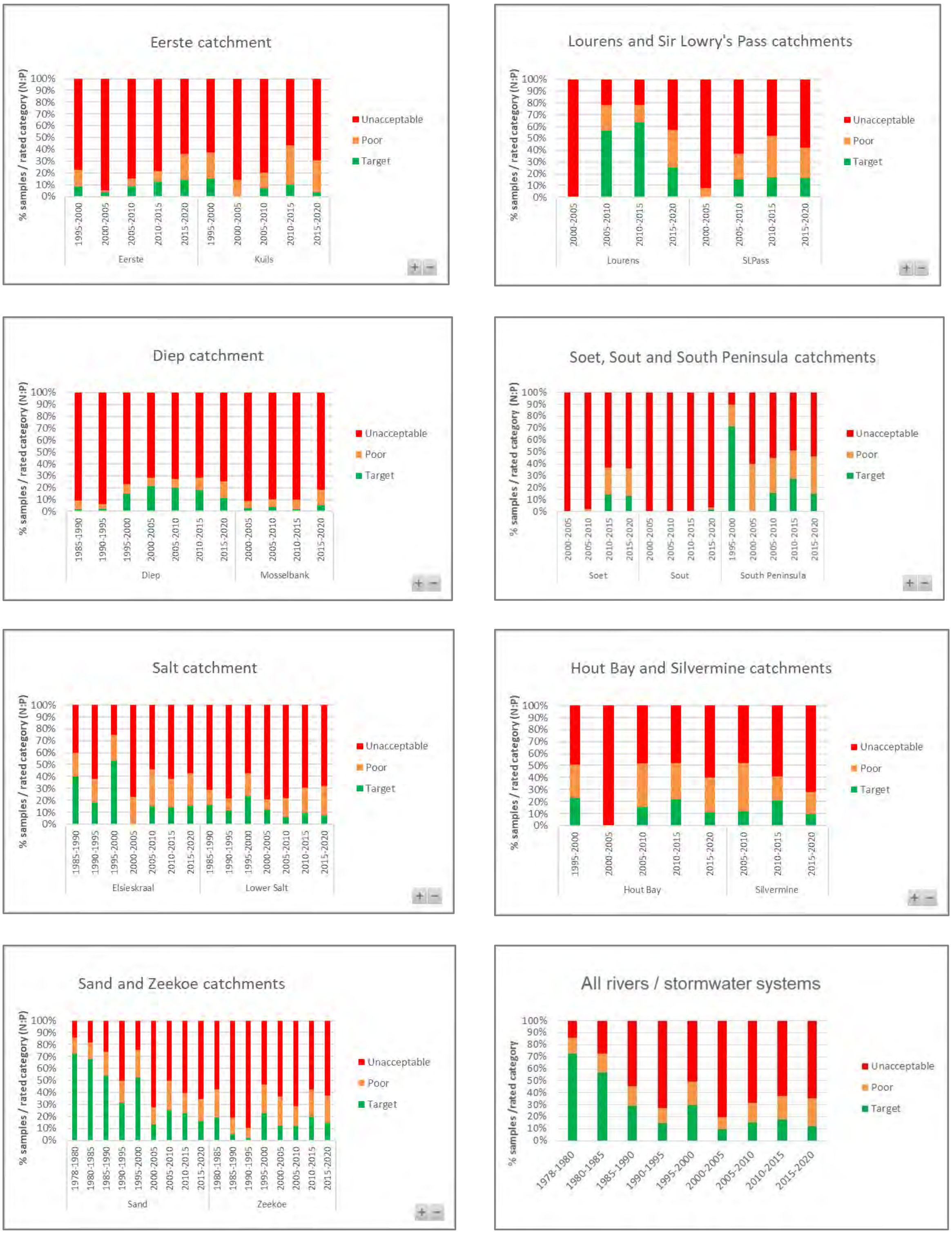



**Figure 4.3.10 Percentage of samples from RIVER sites in each subcatchment where N:P ratios fall within rated categories. Subcatchments as shown in Figure 2.1**

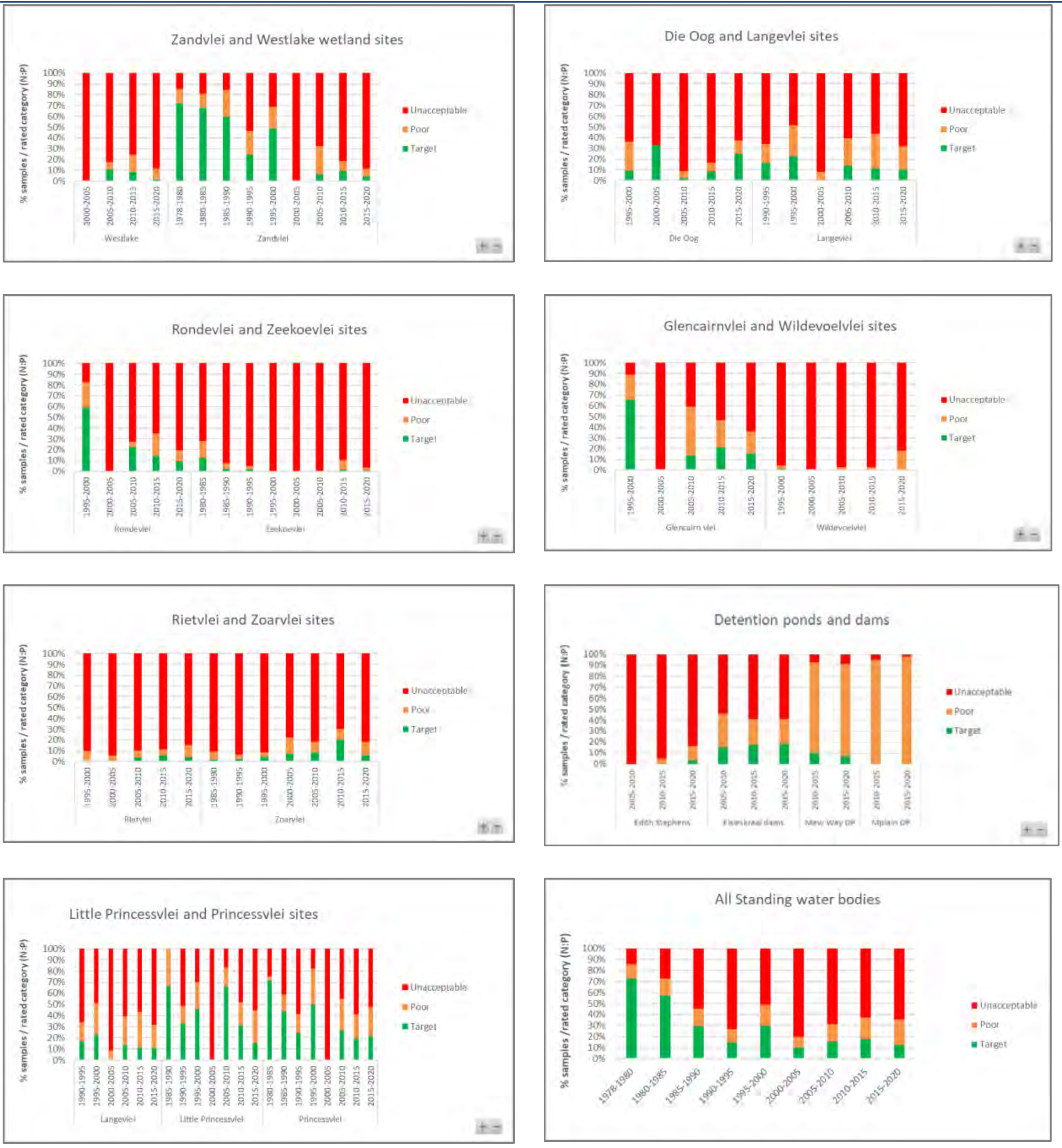



**Figure 4.3.11 Percentage of samples from Standing Water sites in each subcatchment where N:P ratios fall within rated categories.**

### *B Nitrogen enrichment: Current state (April 2019 to March 2020)*

**Figure 4.3.12** presents boxplots of median Total Inorganic Nitrogen (TIN) data over the most recent monitoring year (referred to as the 2019 dataset) compared to data from the previous four year period (2015-2018 datasets), for river/ stormwater channels and dams / vleis.

**Figures 4.3.13** and **4.3.14** present the same data, separated into summer and winter seasons, again for river/ stormwater channels and dams / vleis, respectively. **Figure 4.3.15** presents boxplots for vlei/dam sites, showing ratios of TIN to PO4-P (N:P) in these systems, comparing median ratios over the past year (2019) to the previous 4 years data (2015-2018).

Finally, **Figure 4.3.16** comprises a set of maps, one per subcatchment, which illustrate the performance of individual sites in the 2019 period, by comparing median N:P ratios in 2019 with the 2015-2018 median.

These figures allow differentiation of the scale of excessive orthophosphate enrichment, relative to nitrogen, which can be used as a measure of risk of different standing water bodies being dominated by blue-green algae.

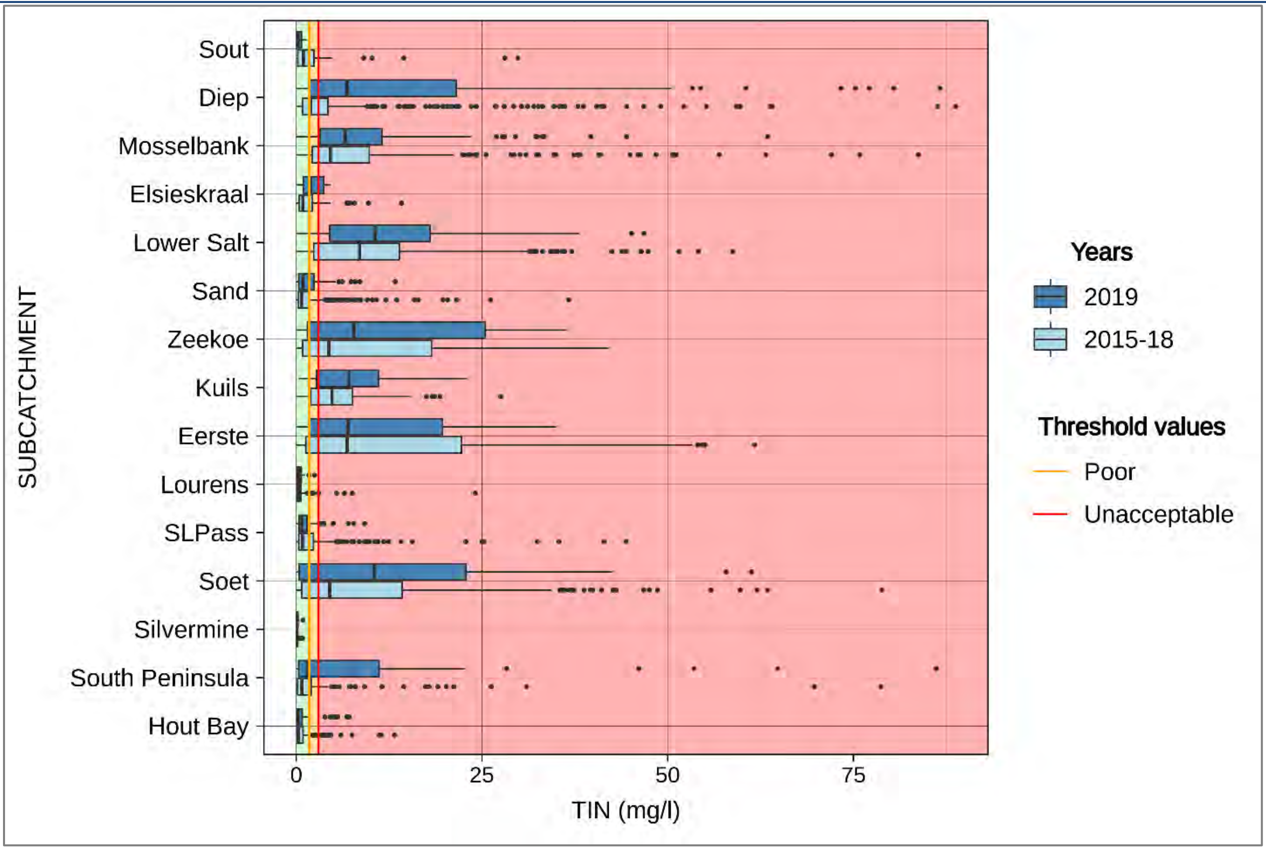
With regard to **river and stormwater systems**, the data illustrate the same broad trends discussed in the previous section, with the following specific aspects being noted:

- The subcatchment with the highest median TIN concentrations was Mitchell's Plain, with median concentrations well above the threshold levels for Acceptable for this variable;
- Median concentrations and the bulk of samples for the Diep, Mosselbank, Lower Salt, Zeekoe, Kuils, Eerste, Soet and South Peninsula subcatchments also all fell within the Unacceptable range for TIN, with a wide scatter of outlier samples for the Diep, Mosselbank, Soet, South Peninsula and Lower Salt subcatchments;
- The Sout, Elsieskraal, Sand, Lourens, Sir Lowry's Pass, Hout Bay and Silvermine subcatchments all had median values throughout the last five years within the Target or Poor range – that is, better than "Unacceptable". The Sir Lowry's Pass system was however characterized by high scatter well into the Unacceptable range;
- The Silvermine subcatchment was least affected by nitrogen enrichment over the past five years, with most samples lying within target concentrations;
- Median TIN concentrations increased in the Diep, Mosselbank, Lower Salt, Zeekoe, Kuils and Soet subcatchments, indicating increased nutrient enrichment in these subcatchments;
- No subcatchments showed a reduction in median TIN concentrations over this time;
- With regards to seasonal variation in TIN concentration, the Diep, Eerste, Soet and South Peninsula subcatchments showed strong seasonal trends in median TIN concentration, with TIN being highest in summer, presumably as a result of evapo-concentration of this nutrient, as well as the effects of sewage overflows linked to load shedding effects on pump stations in some catchments, over the 2019 summer period (see Section 2.3 for a more detailed discussion of this issue).

With regard to **vleis and dams**, the data illustrate the following key points:

- Samples from most of the assessed waterbodies fell within Acceptable levels (i.e. Target or Poor) with regard to TIN concentrations;
- Exceptions to this comprised Wildevoelvlei, the Mew Way detention pond and the Mitchell's Plain stormwater outlet, which fell mainly within the "Unacceptable" range;
- Samples showing significant elevation beyond Acceptable levels included the Edith Stephens detention pond, as well as Zeekoevlei, and Zoarvlei In the 2015-2018 period;
- When N:P ratios are considered, only samples from Die Oog had median values within the Target range for this variable, while samples from Rietvlei, Zoarvlei, Zeekoevlei, Rondevlei, Zandvlei, Westlake wetlands, Wildevoelvlei and the Edith Stephens detention pond all lay well within the range of Unacceptable, suggesting a high risk of dominance of these systems by blue-green algae.

Median N:P data shown in the mapped subcatchments of **Figure 4.3.16** provide a spatial perspective to the data described above, and highlight the fact that although TIN concentrations are not the primary concern in the City subcatchments, from the perspective of nutrient enrichment, the fact that phosphorus concentrations are generally so high means that most subcatchments have high vulnerability to the proliferation of blue-green algae in standing water systems. These systems tend to be more vulnerable to algal blooms than flowing water systems (i.e. rivers) because algae are able to accumulate in standing water conditions, and their nutrient t uptake is more efficient.



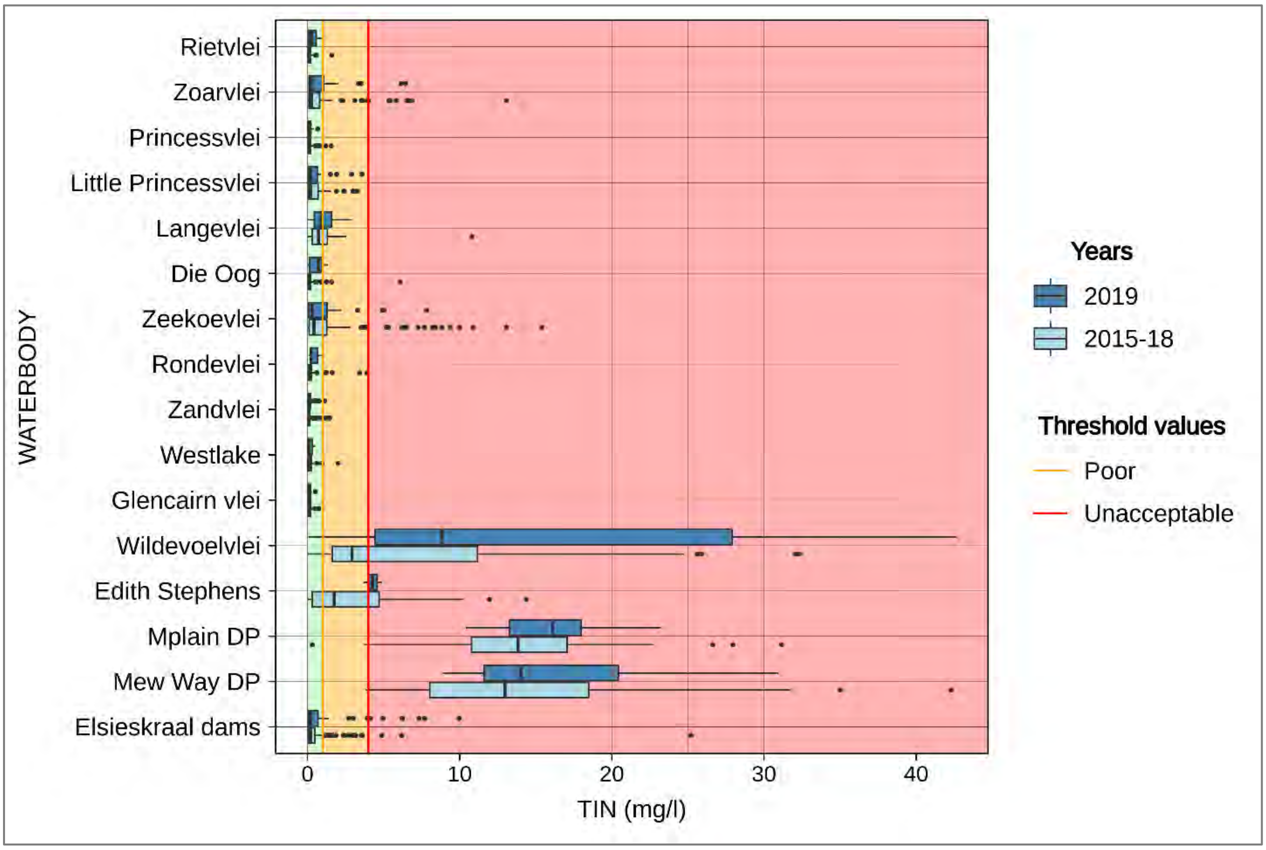




**Figure 4.3.12 Comparison of current (April 2019 to March 2020) Total Inorganic Nitrogen (TIN) data with data from the previous 4 year record, showing seasonal variability.**
**Top: Rivers and stormwater systems; Bottom: Vleis and Dams.**

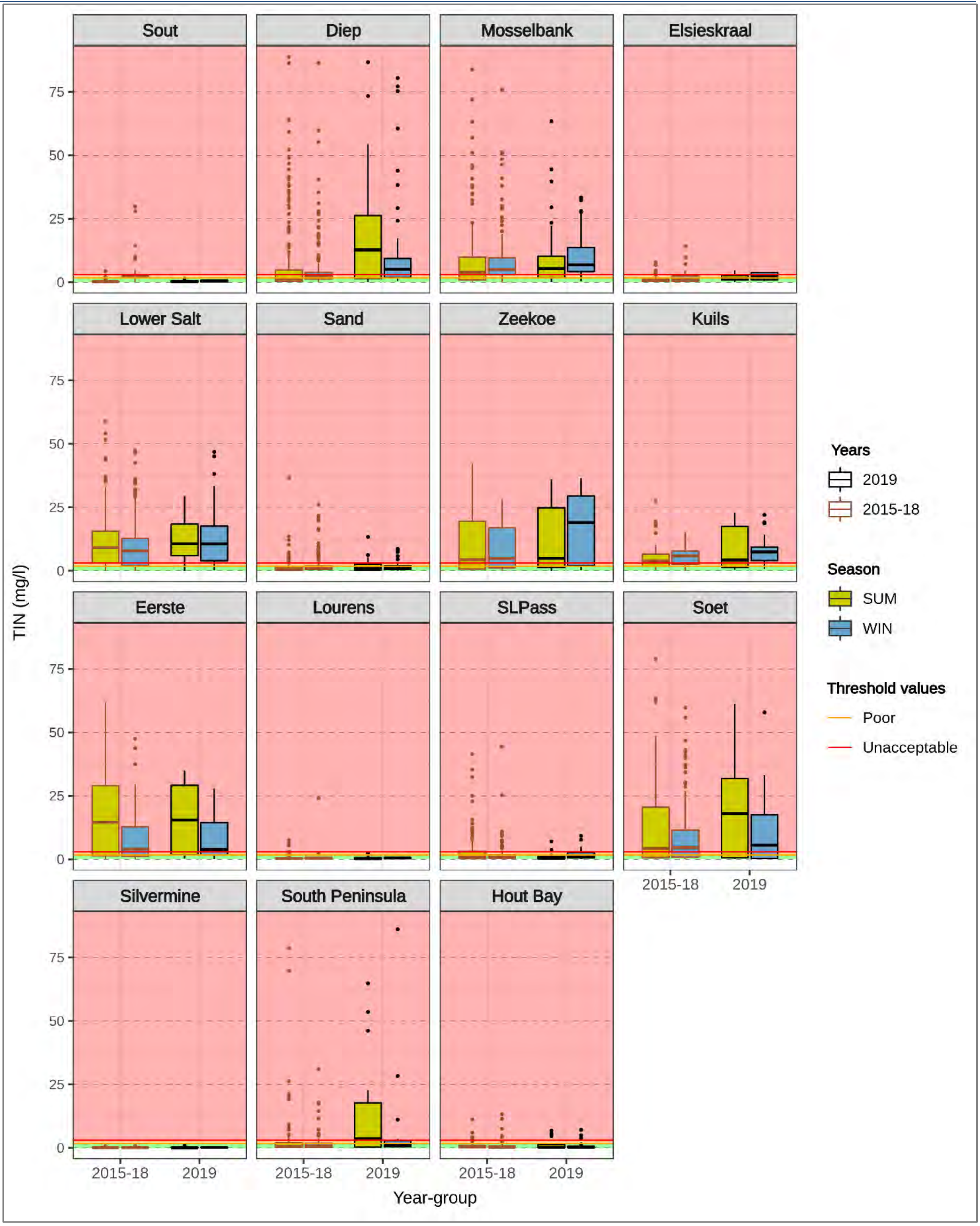



**Figure 4.3.13 Comparison of current (April 2019 to March 2020) Total Inorganic Nitrogen (TIN) data with data from the previous 4 year record, showing seasonal variability. Rivers and stormwater systems**

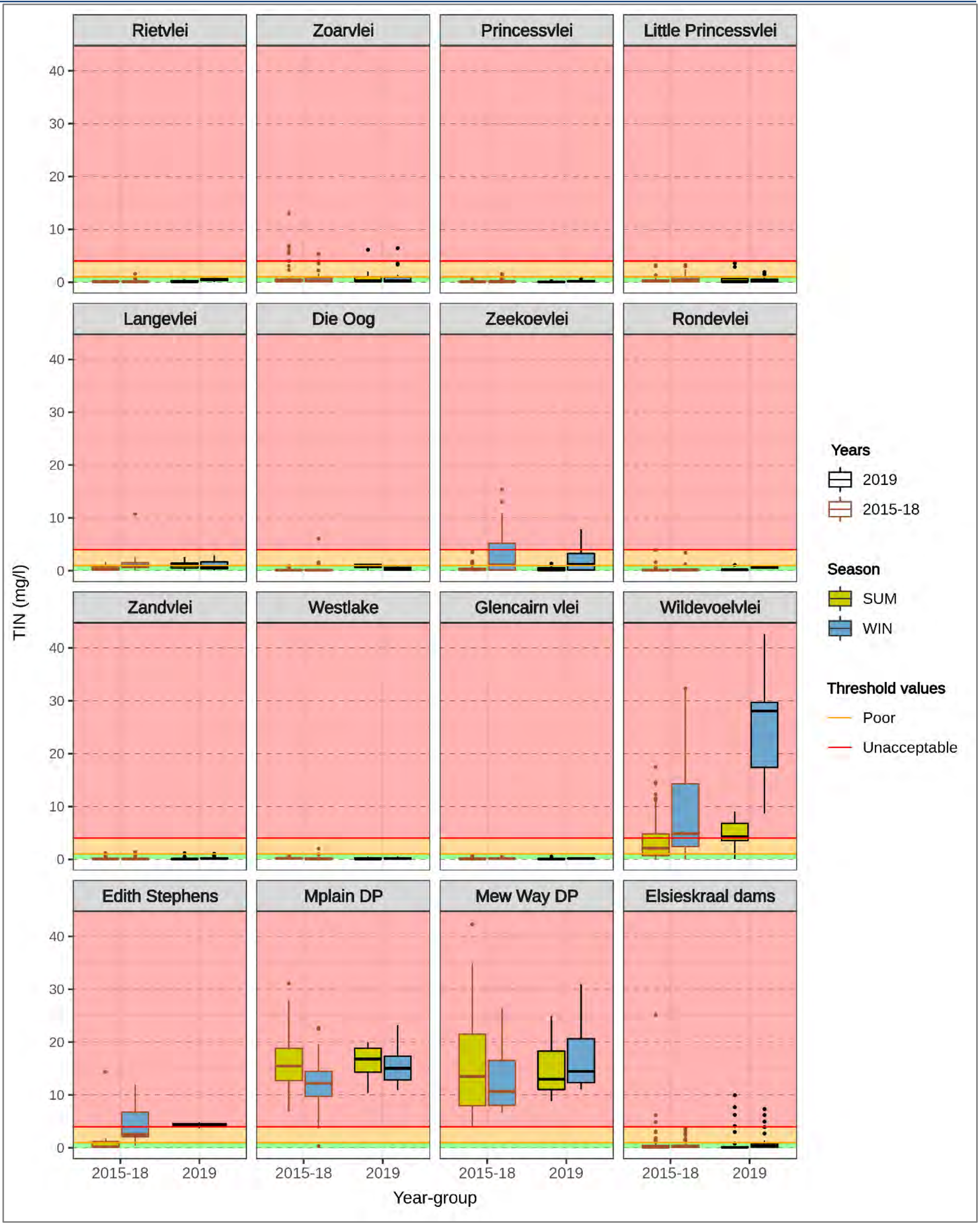



**Figure 4.3.14 Comparison of current (April 2019 to March 2020) Total Inorganic Nitrogen (TIN) data with data from the previous 4 year record, showing seasonal variability. Vleis and dams.**

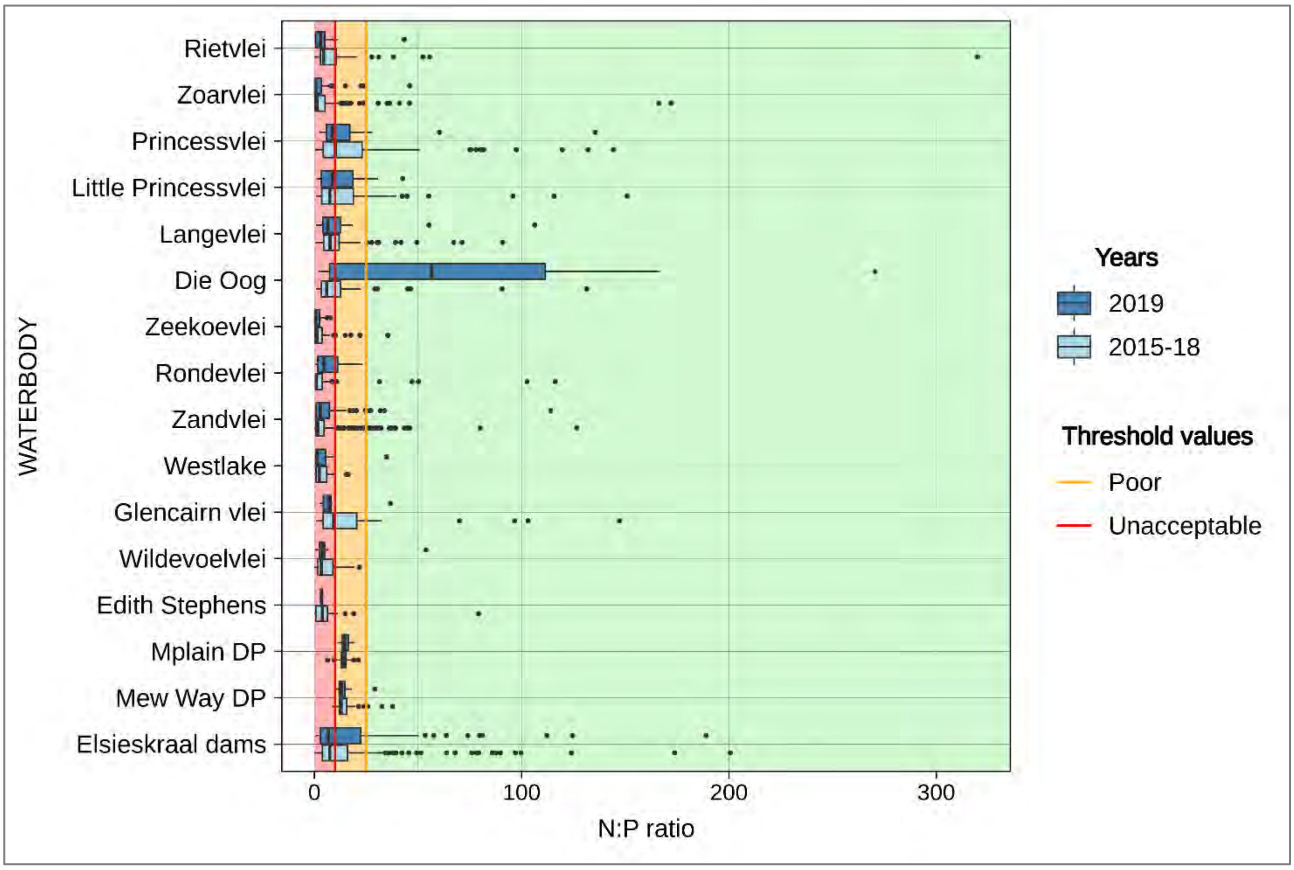



**Figure 4.3.15 Comparison of ratios of TIN to PO4-P in current (April 2019 to March 2020) year with data from the previous 4 year record. Vlei and dam systems**

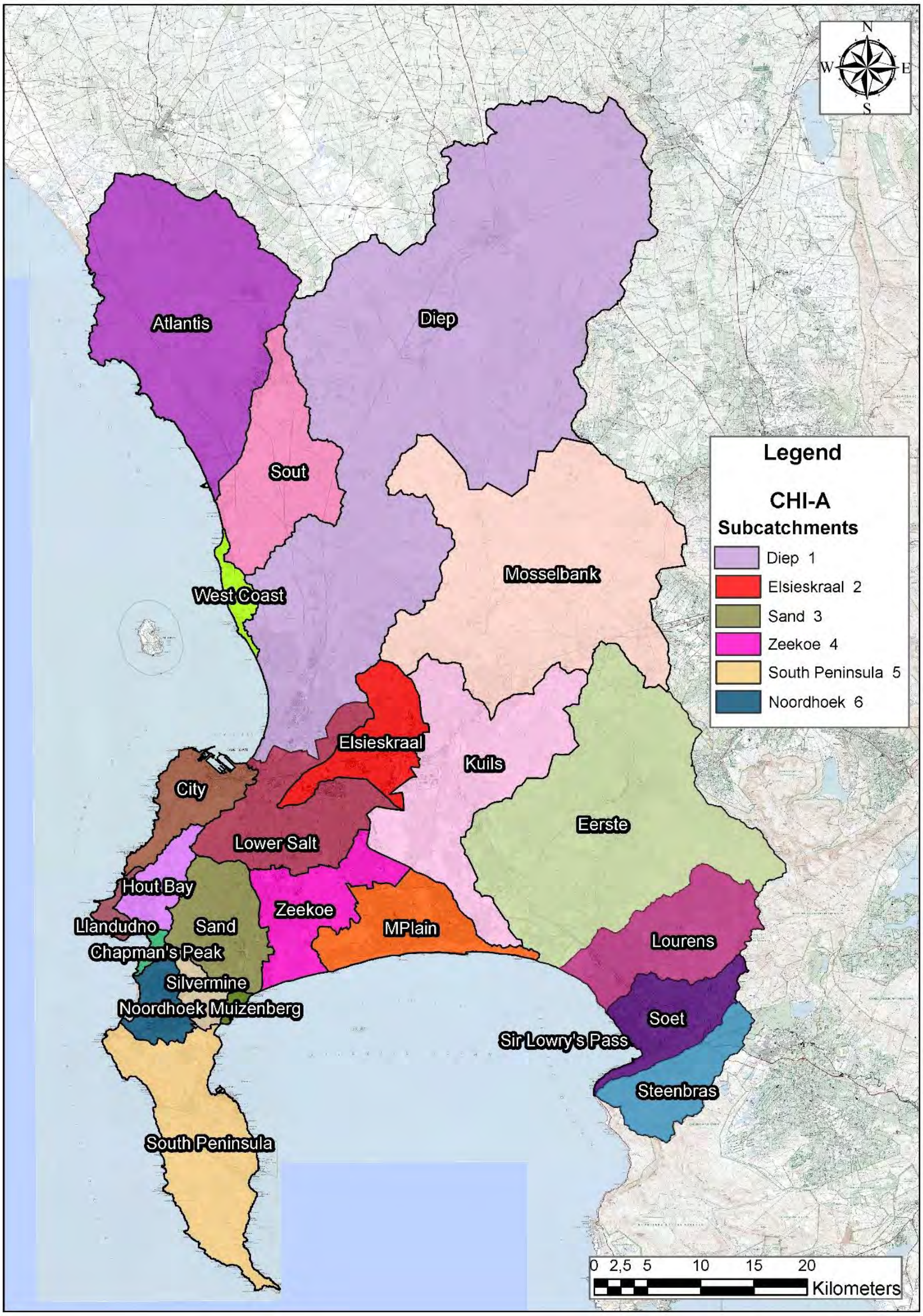
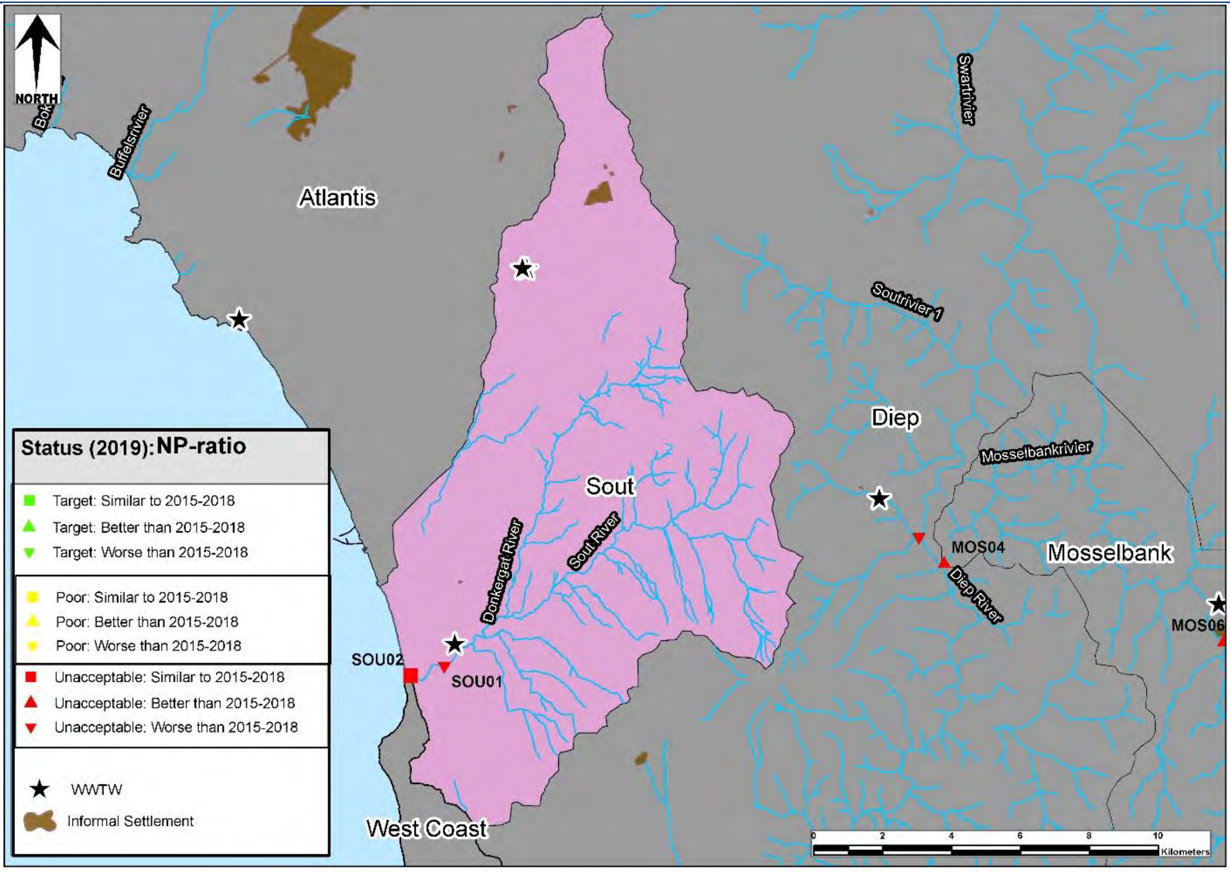



**Figure 4.3.16 Median Ratio of Total Inorganic Nitrogen (TIN) to PO4-P concentration, presented as a range of maps per subcatchment. Data coded as to level of change compared to previous 4 year median dataset. Subcatchments presented in numbered order as shown in this map. See following maps for actual data.Data coded as to level of change in 2019 dataset compared to previous 4 year median data. Top figure shows order of presentation of subcatchment maps.**



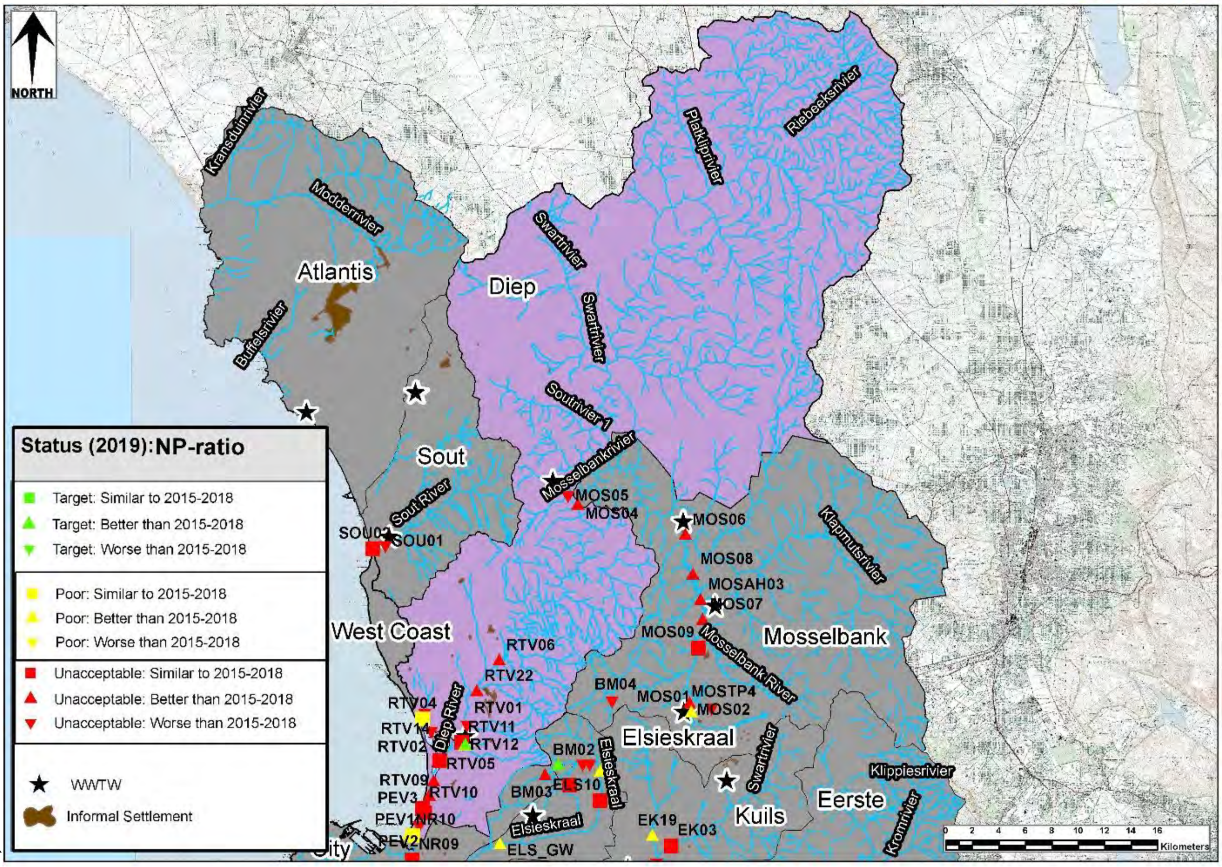
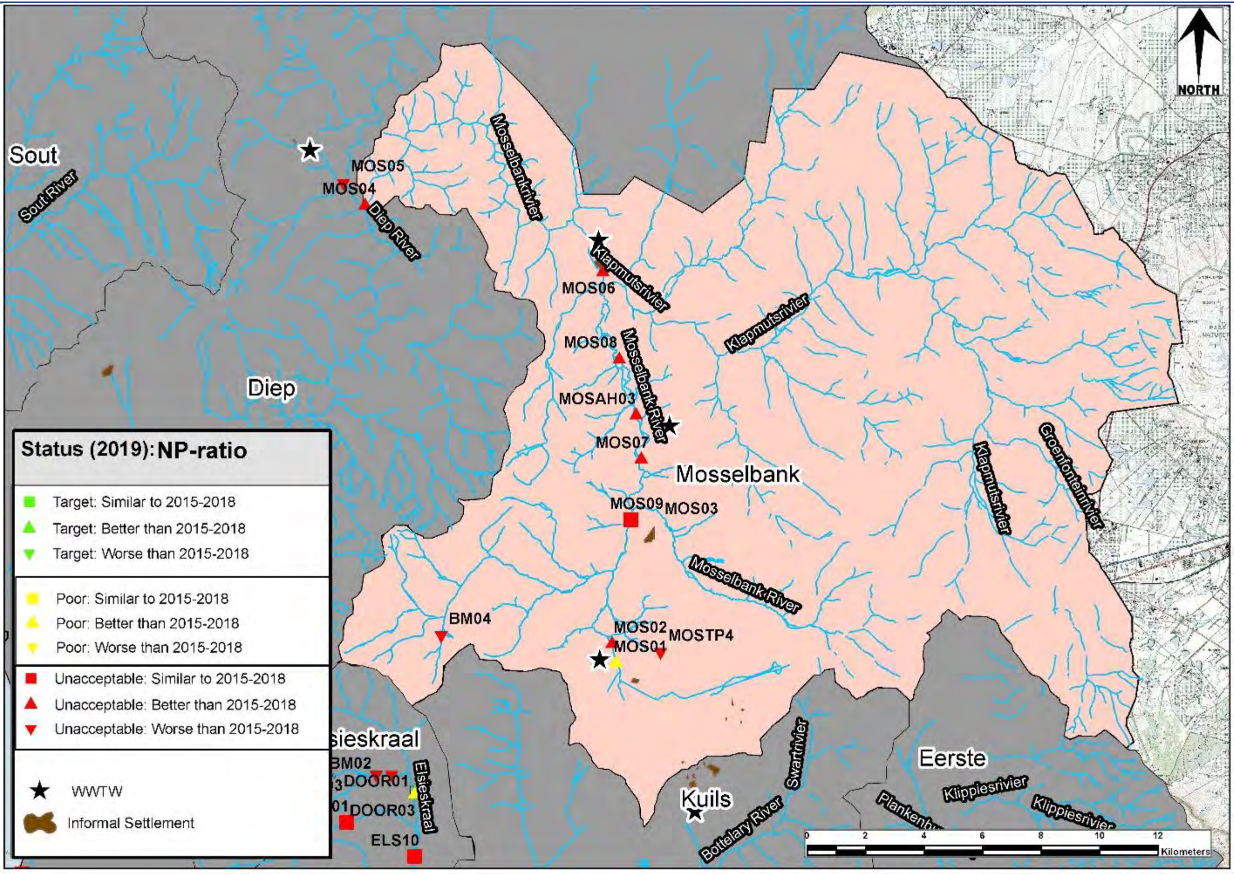




**Figure 4.3.16 (CONTD) Median Ratio of Total Inorganic Nitrogen (TIN) to PO4-P concentration (N:P), presented per subcatchment. Data coded as to level of change in 2019 dataset compared to previous 4 year median data. First figure shows order of presentation of subcatchment maps**



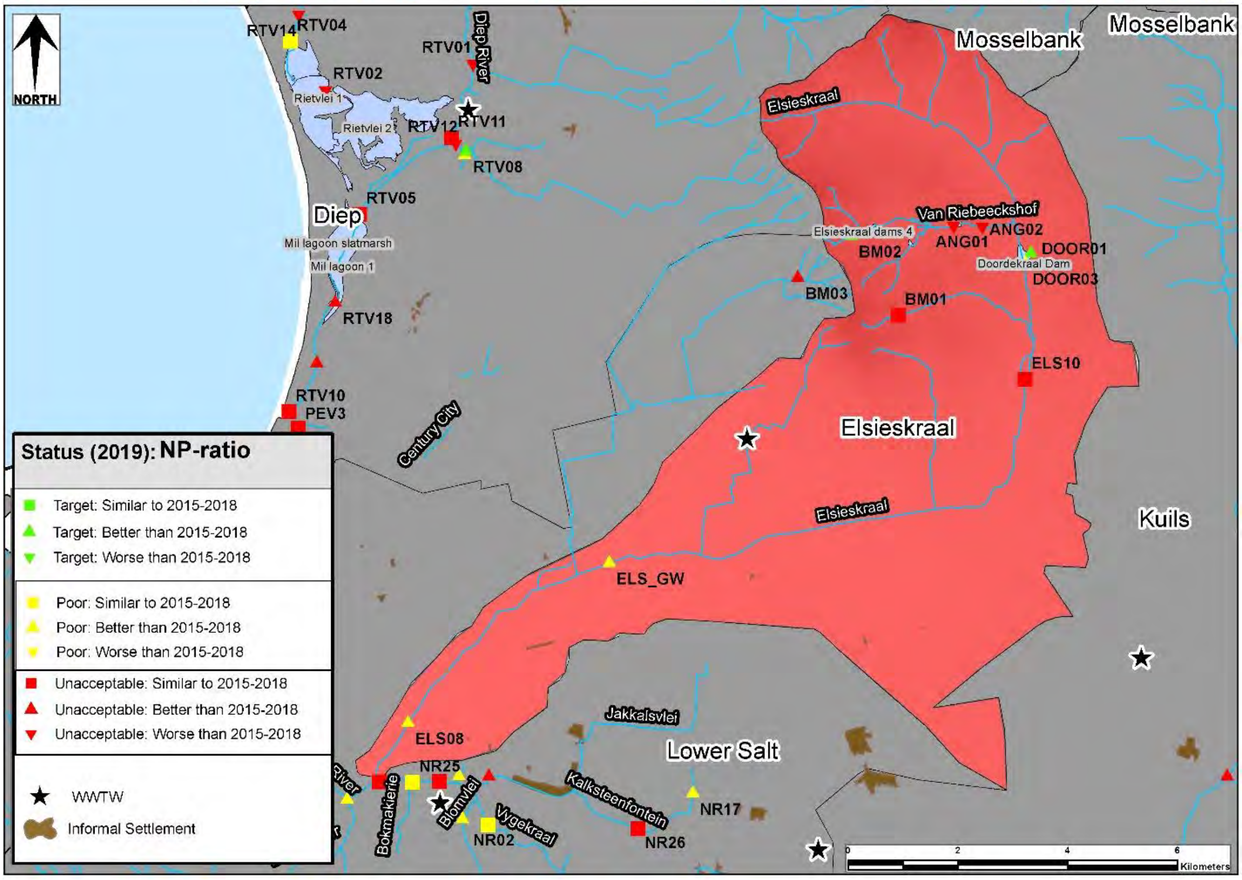




**Figure 4.3.16 (CONTD) Median Ratio of Total Inorganic Nitrogen (TIN) to PO4-P concentration (N:P), presented per subcatchment. Data coded as to level of change in 2019 dataset compared to previous 4 year median data. First figure shows order of presentation of subcatchment maps**

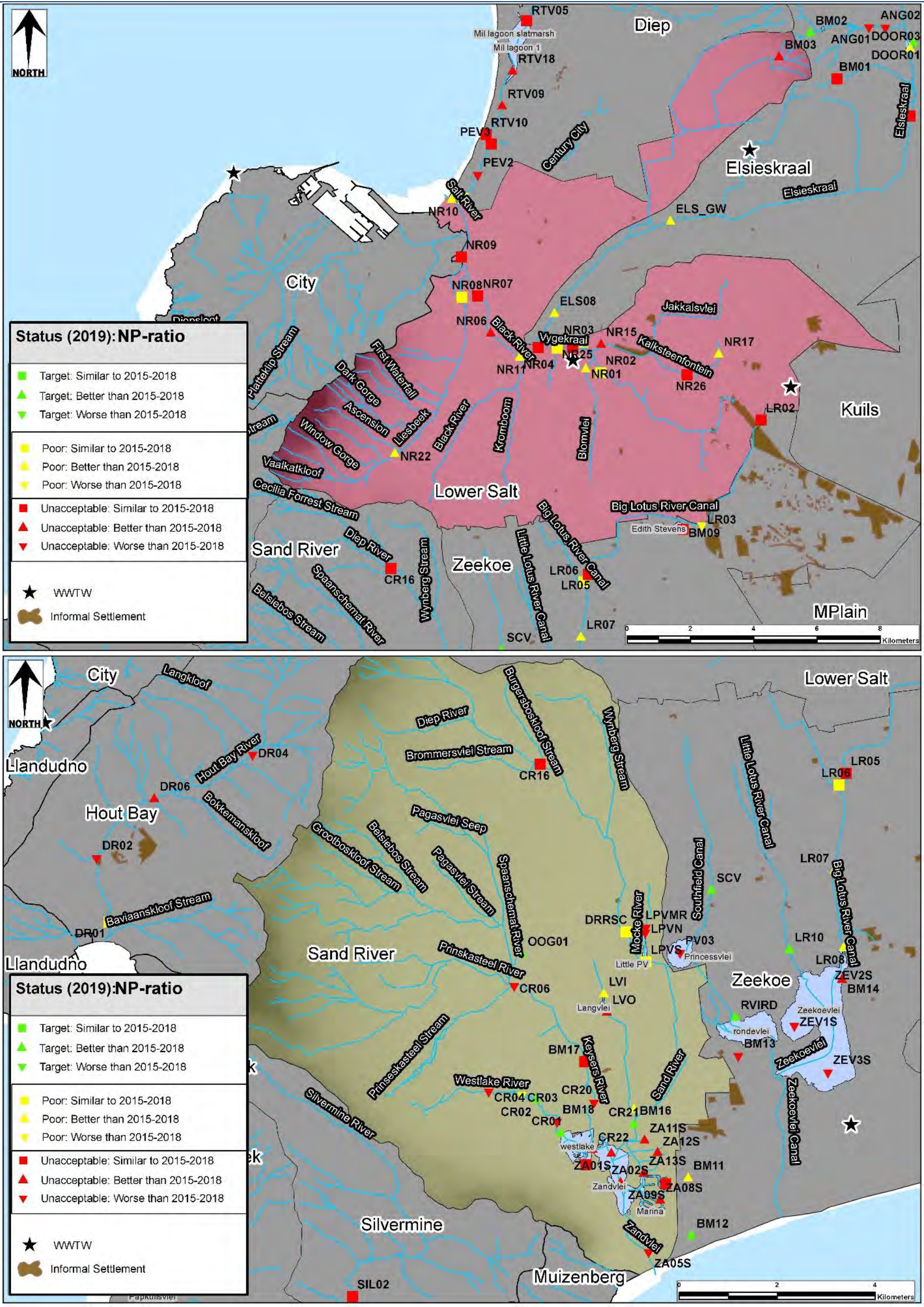



**Figure 4.3.16 (CONTD) Median Ratio of Total Inorganic Nitrogen (TIN) to PO4-P concentration (N:P), presented per subcatchment. Data coded as to level of change in 2019 dataset compared to previous 4 year median data. First figure shows order of presentation of subcatchment maps**

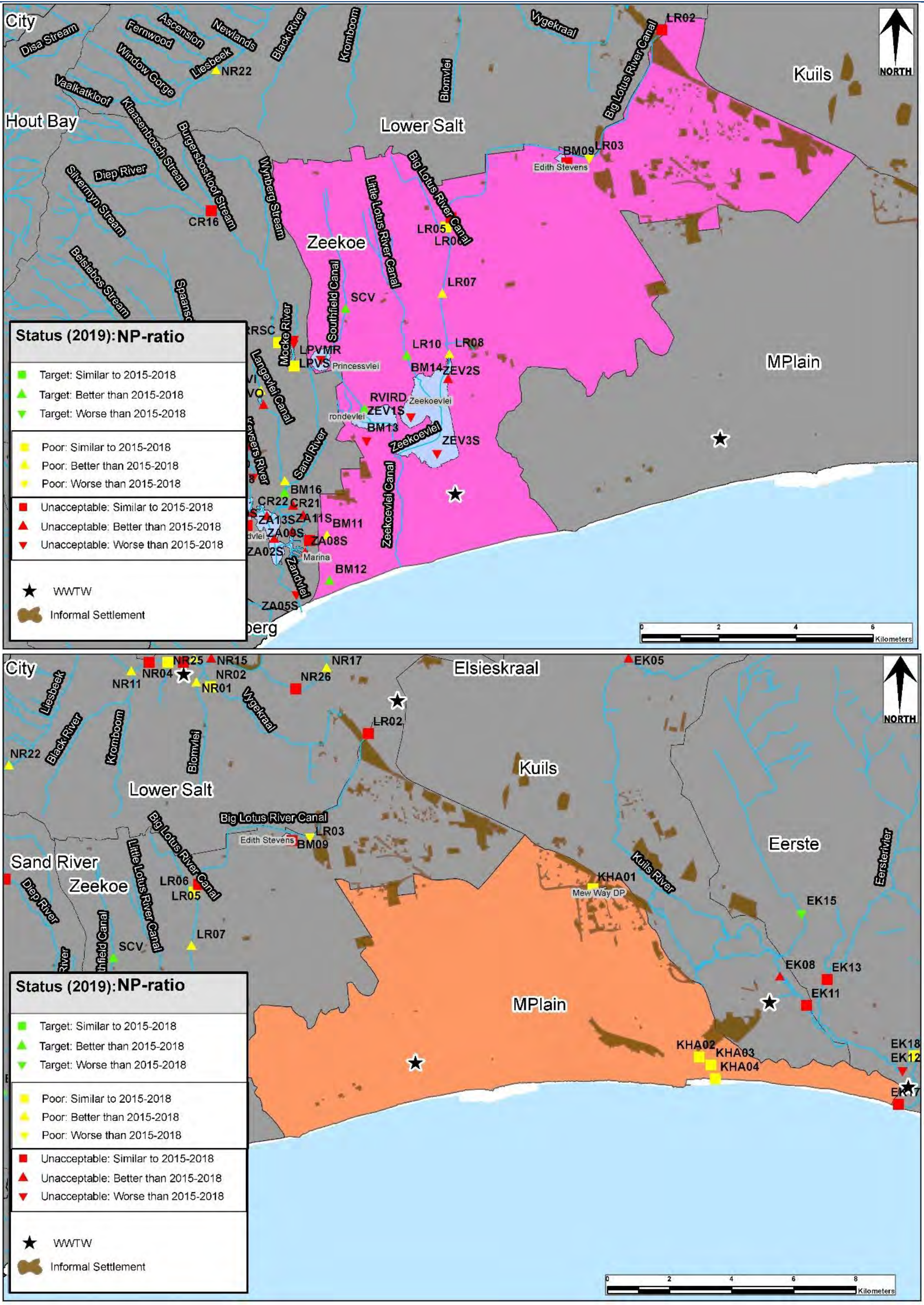
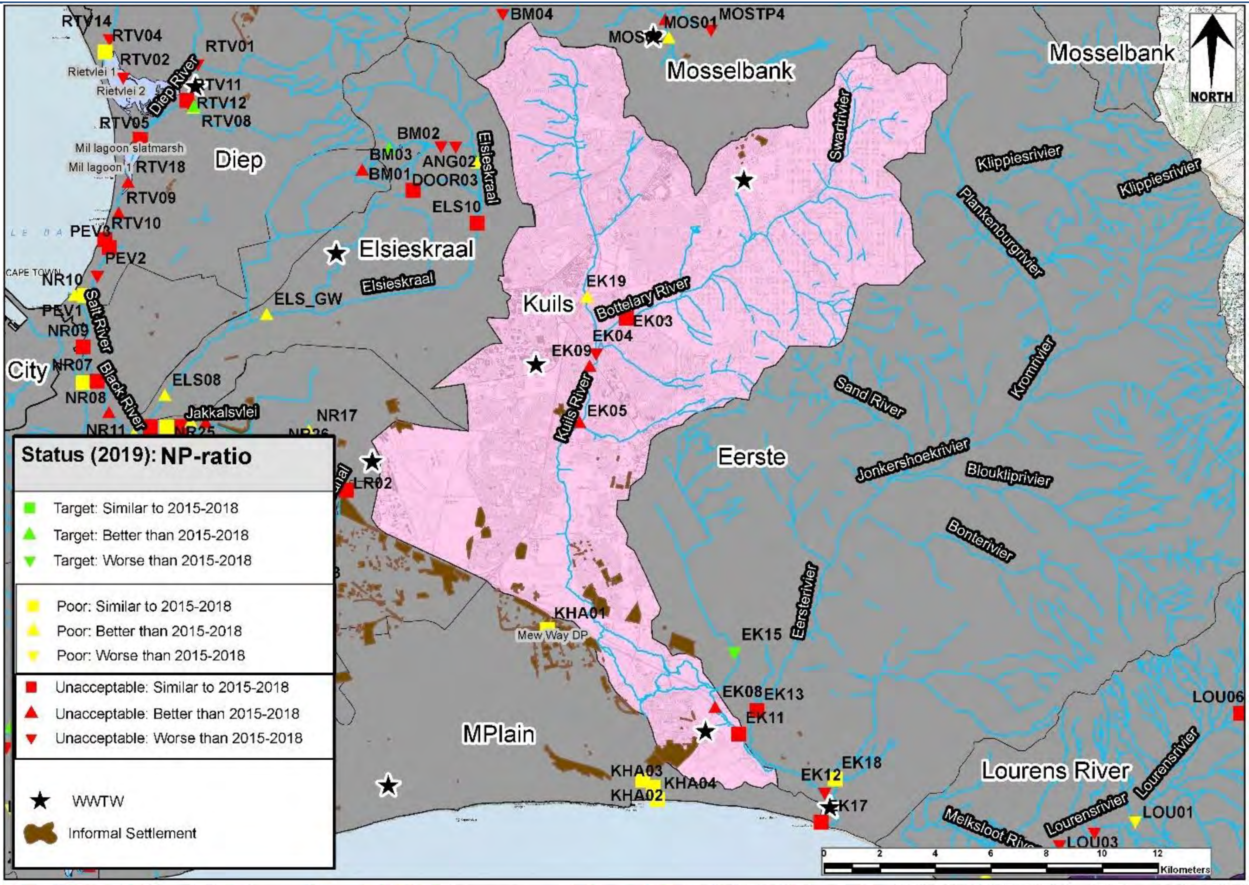



**Figure 4.3.16 (CONTD) Median Ratio of Total Inorganic Nitrogen (TIN) to PO4-P concentration (N:P), presented per subcatchment. Data coded as to level of change in 2019 dataset compared to previous 4 year median data. First figure shows order of presentation of subcatchment maps**



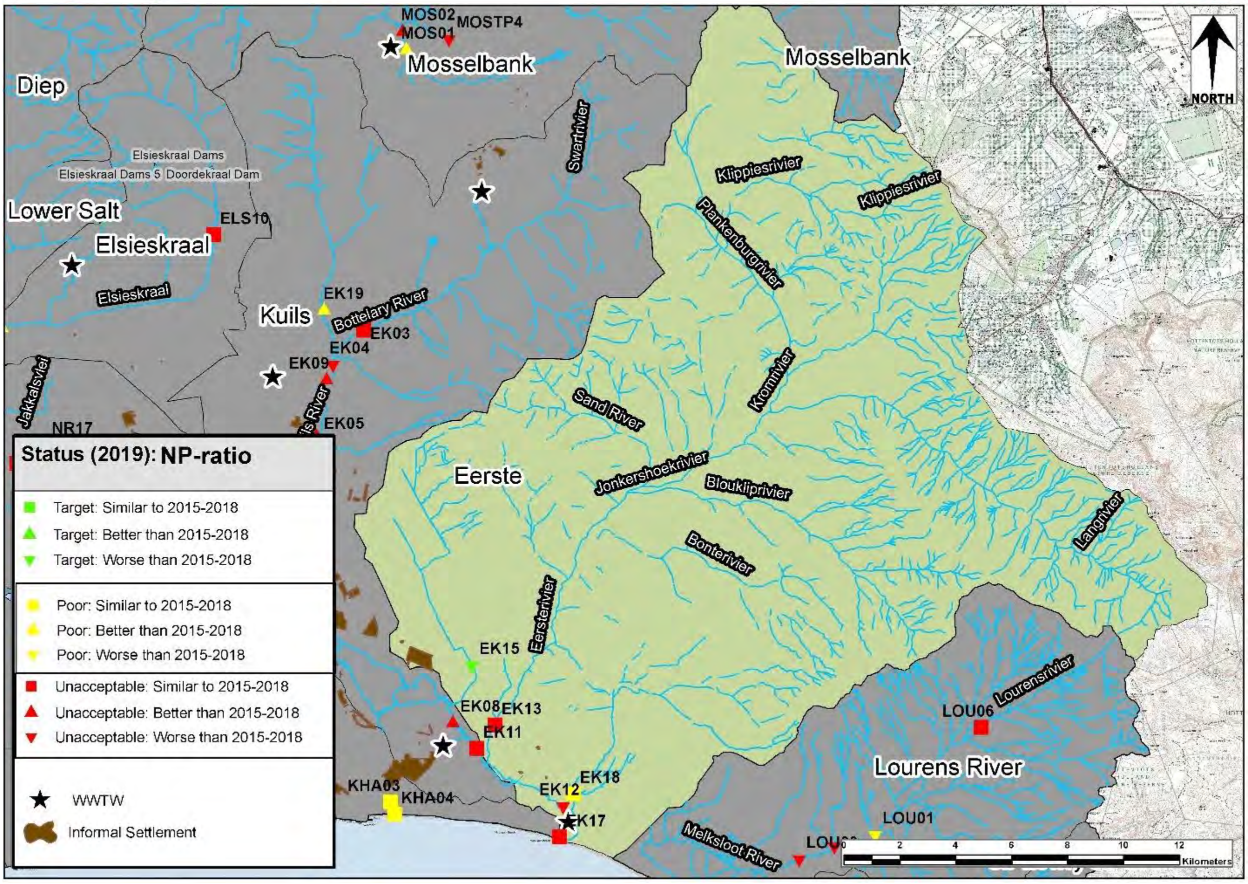




**Figure 4.3.16 (CONTD) Median Ratio of Total Inorganic Nitrogen (TIN) to PO4-P concentration (N:P), presented per subcatchment. Data coded as to level of change in 2019 dataset compared to previous 4 year median data. First figure shows order of presentation of subcatchment maps**

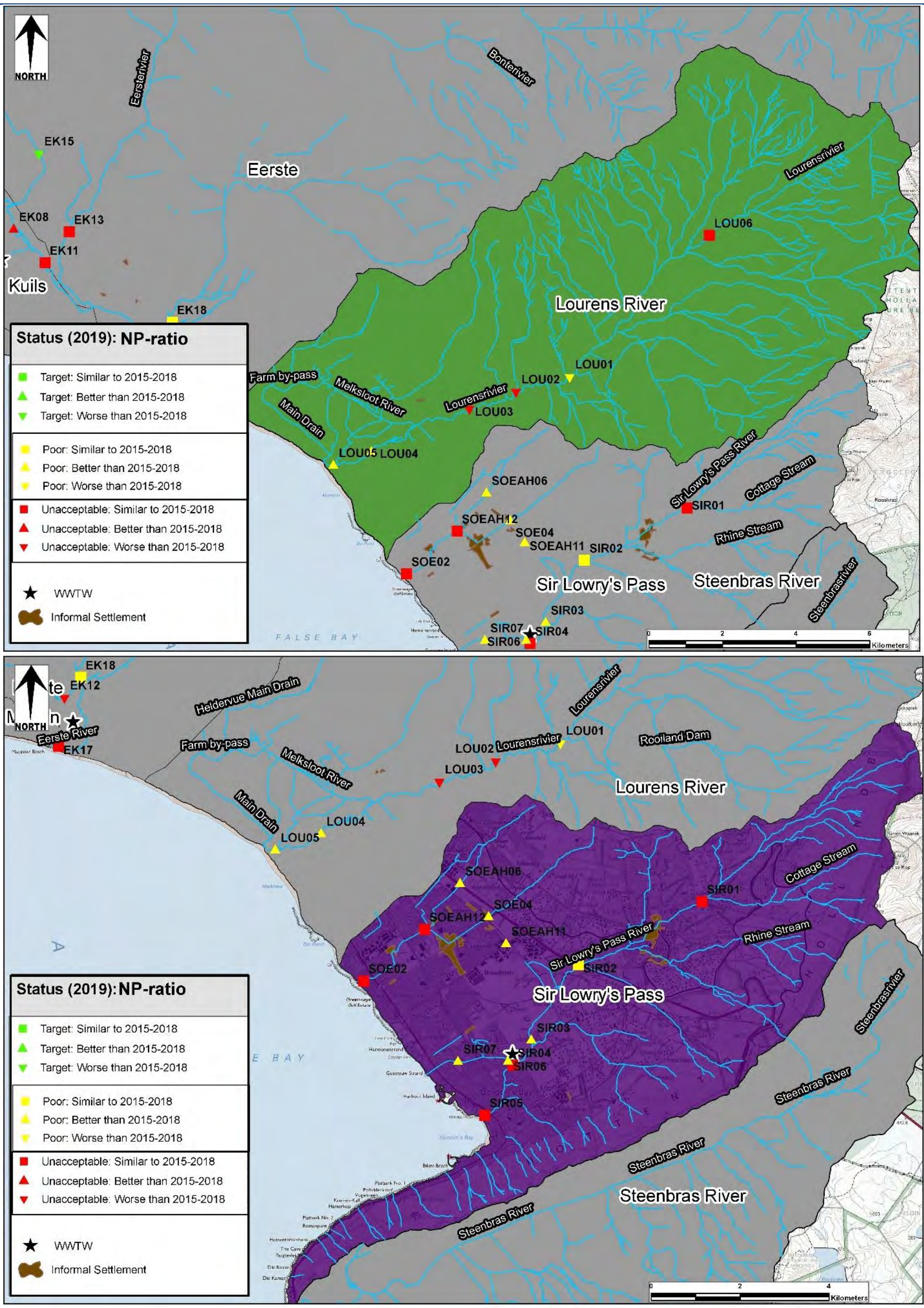
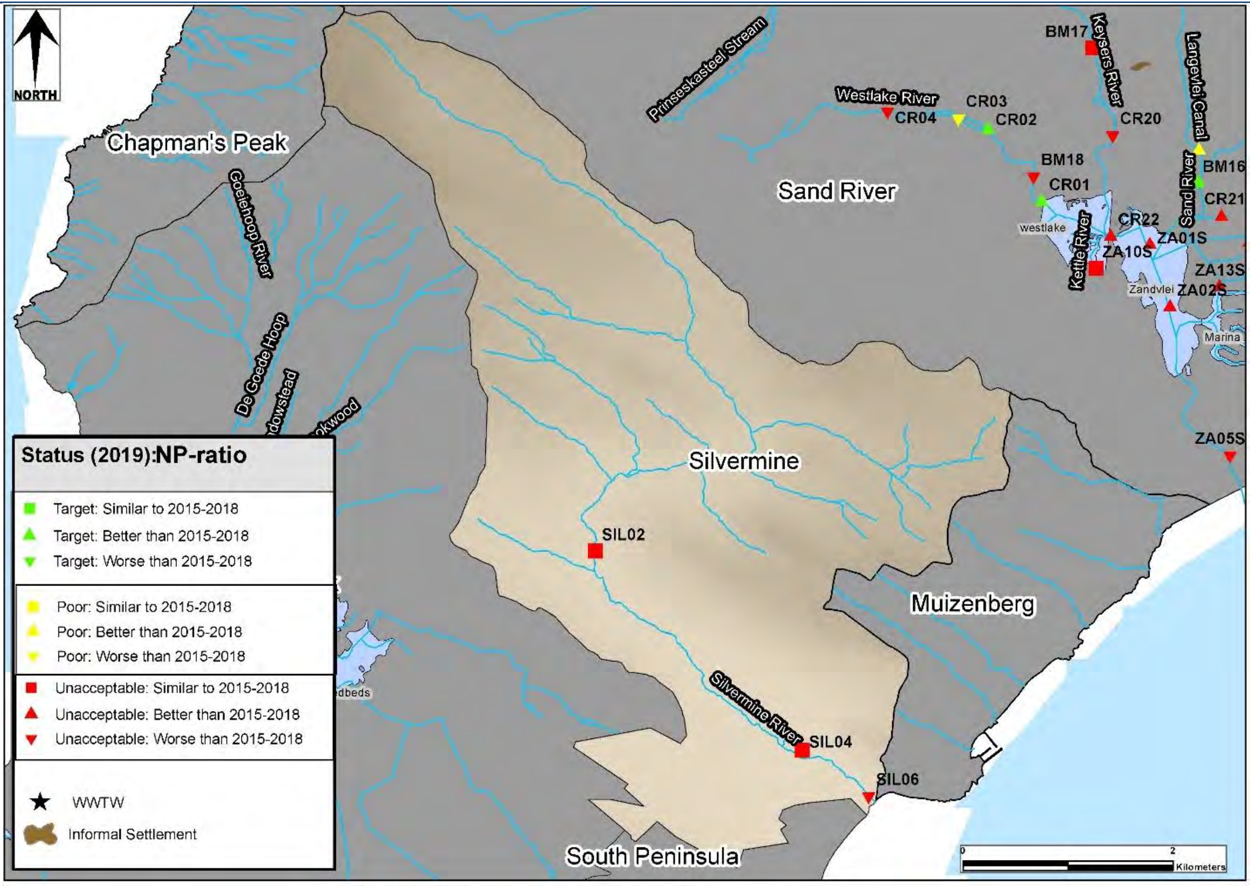



**Figure 4.3.16 (CONTD) Median Ratio of Total Inorganic Nitrogen (TIN) to PO4-P concentration (N:P), presented per subcatchment. Data coded as to level of change in 2019 dataset compared to previous 4 year median data. First figure shows order of presentation of subcatchment maps**



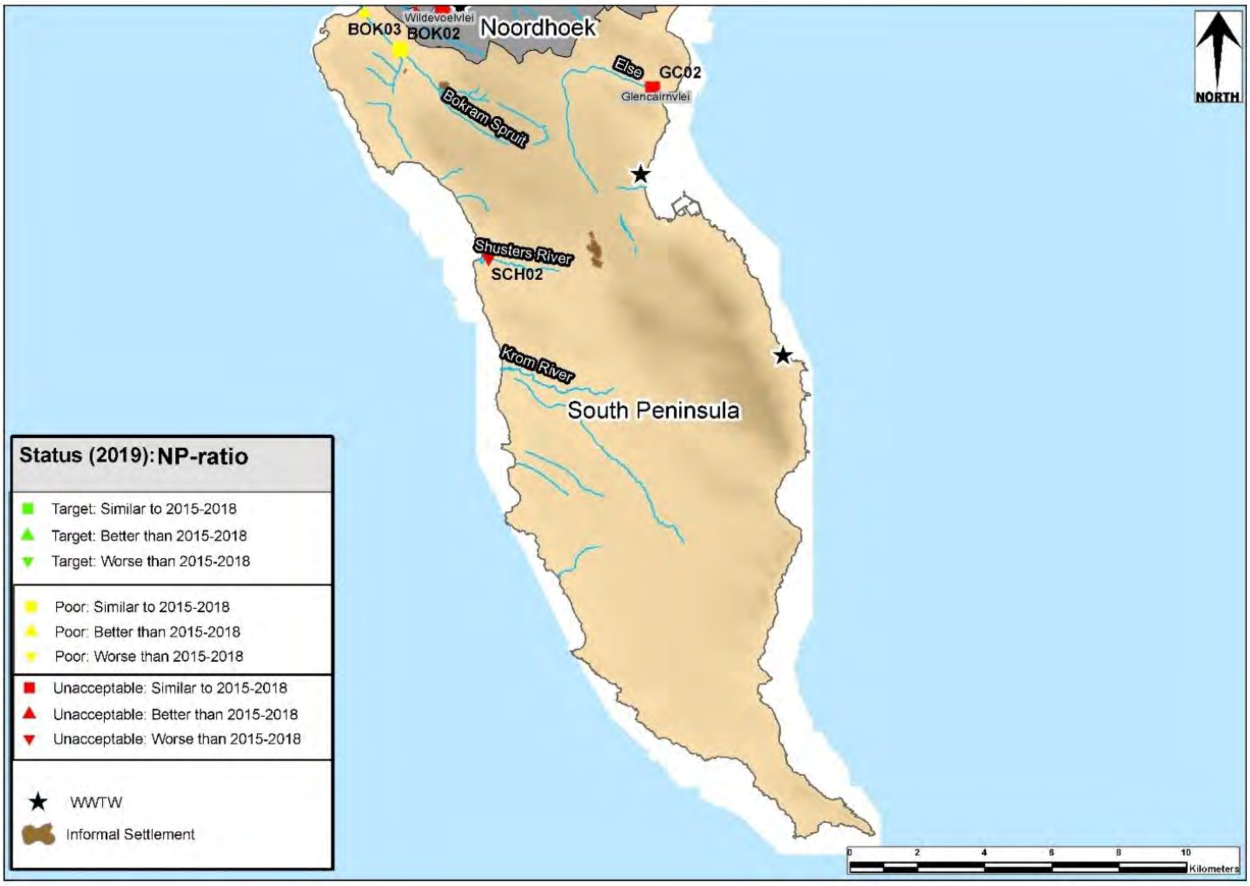
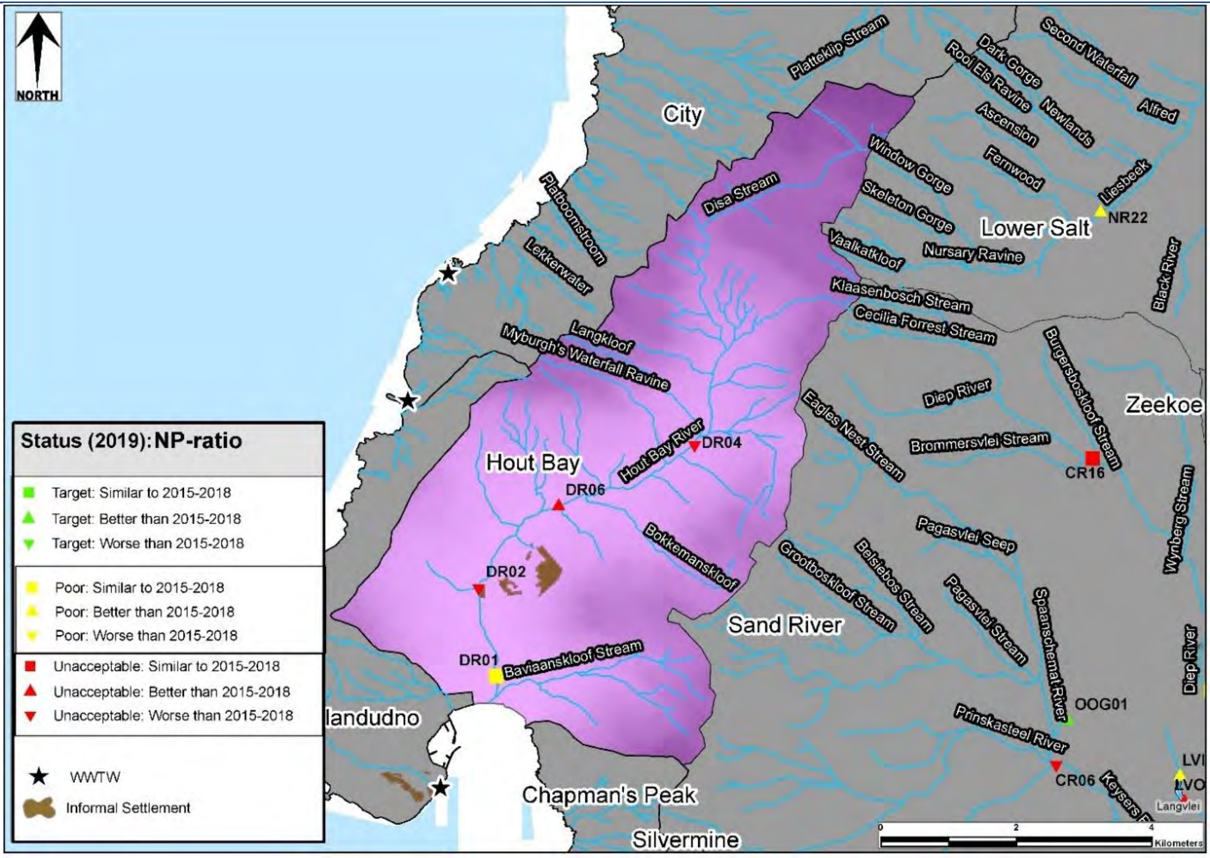




**Figure 4.3.16 (CONTD) Median Ratio of Total Inorganic Nitrogen (TIN) to PO4-P concentration (N:P), presented per subcatchment. Data coded as to level of change in 2019 dataset compared to previous 4 year median data. First figure shows order of presentation of subcatchment maps**



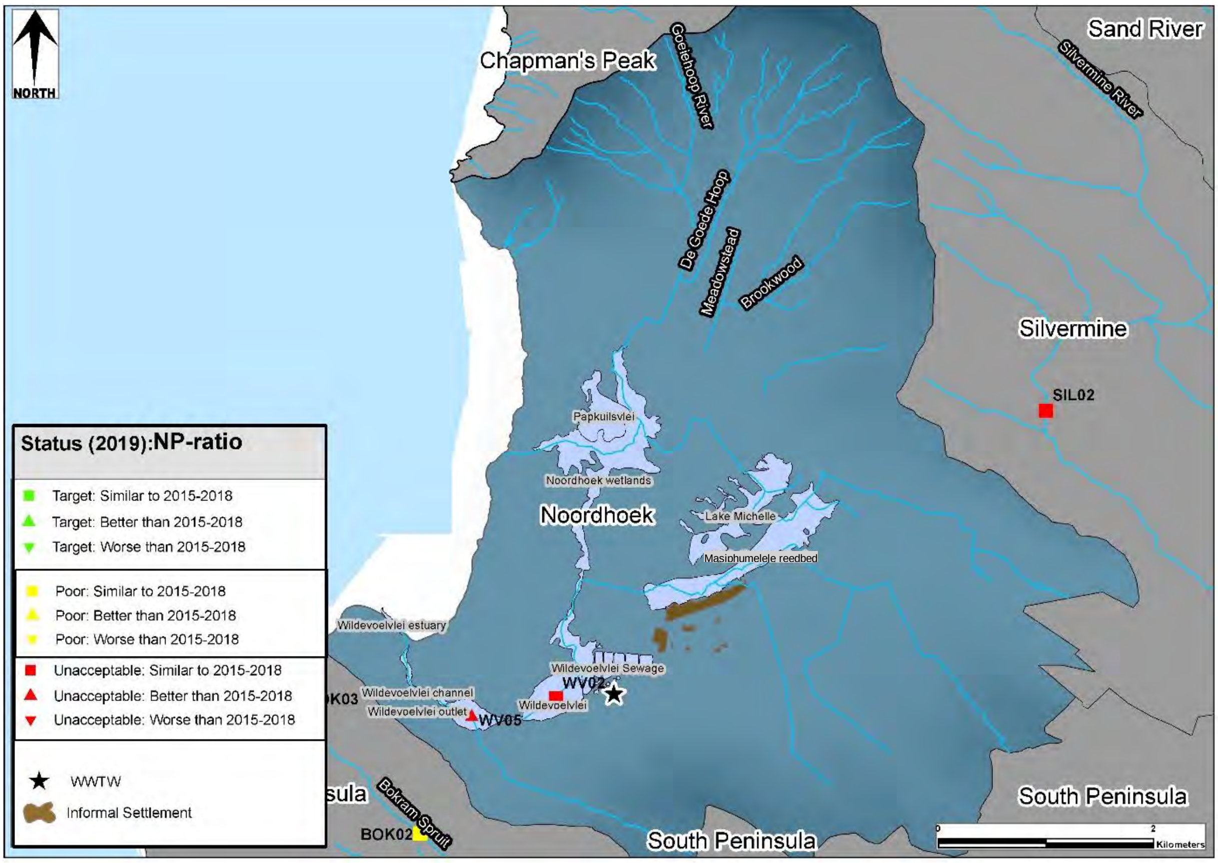




**Figure 4.3.16 (CONTD) Median Ratio of Total Inorganic Nitrogen (TIN) to PO4-P concentration (N:P), presented per subcatchment. Data coded as to level of change in 2019 dataset compared to previous 4 year median data. First figure shows order of presentation of subcatchment maps**

## 4.4 Chlorophyll-a

### *4.4.1 Relevance in water quality monitoring*

Chlorophyll-*a* is a pigment that occurs in green plants and is one of the primary pigments used in photosynthesis. In water quality assessments, it is used as a measure of algal growth – specifically, of phytoplankton abundance. Under conditions of nutrient enrichment, particularly of phosphorus, chlorophyll-*a* often increases, reflecting an increase in algal growth rates in response to increased nutrients. Interestingly, nutrient-enriched systems that are dominated by macrophytes (that is, more complex plants than single-celled or filamentous algae, such as pondweed or other plants) are less likely to be dominated by algae or give rise to algal blooms.

> **What is phytoplankton ?**
>
> Phytoplankton comprises microscopic single-celled algae, including diatoms, which occur in the water column

The City monitors chlorophyll-*a* in many of its standing water systems. This section considers these data from the perspective of its value as an indicator of ecosystem health, in the context already described in Section 4.4 where nutrient data suggest that the City's standing water bodies tend on the whole to be phosphate-enriched.

### *4.4.2 Current state (April 2019 to March 2020)*

The box plots in **Figure 4.4.1** summarise mean chlorophyll-*a* concentrations, as well as range and outliers for selected standing water systems in the City.

**Figure 4.4.2** shows the same data, presented in terms of season. Note that Detention Ponds (e.g. Mitchell's Plain, Edith Stephens and Mew Way Detention Ponds) are not monitored for this variable.

The maps in **Figure 4.4.3** provide an illustration of change in the 2019 values for this variable at different sites, compared with the 2015-2018 period. The figures suggest:

- Six out of the thirteen assessed standing water bodies had mean annual chlorophyll-*a* values that fell within the range of Acceptable conditions for this variable – that is, ≤ 30 μg/l (see **Table 2.3**);
- The exceptions to this in the 2019 period were Princessvlei, Zeekoevlei, Rondevlei, Langevlei, Die Oog and Wildevoelvlei, for which mean annual concentrations lay in the Unacceptable range and, in the case of Wildevoelvlei, were over an order of magnitude beyond the Unacceptable threshold;
- This said, the number of outlier samples in Zeekoevlei that showed extremely high chlorophyll-*a* concentrations was much lower in the 2019 period, presumably indicating reduced episodes of localised blooms;
- Of the assessed systems, Rietvlei showed a significant decrease in mean chlorophyll-*a* over the 2019 period,

> The sudden growth and subsequent die-back or simple turnover of phytoplankton blooms can have significant negative ecological impacts when they are associated with the creation of anoxic conditions as a result of decomposition. Anoxia can result in fish deaths and promote release of phosphorus from sediments.
>
> Strong daily changes in dissolved oxygen concentrations can occur in water bodies with high algal populations. This is because by day, the algae produce oxygen through photosynthesis, but at night, in the absence of photosynthesis, can have very high demands for oxygen for respiration, sometimes resulting in drastic reductions in dissolved oxygen overnight.
>
> Blooms of blue-green algae (cyanophytes) are usually associated with very high nutrient concentrations. In large concentrations, they form thick, unsightly scums, which may be odorous and at times can produce toxins that cause skin irritations on contact with water or vomiting, acute gastroenteritis and impaired liver function if ingested (DWAF 2006b).
>
> DWAF (2006b) note that all forms of excessive algal growth may interfere with the use of a water body for recreational purposes.

compared to the previous four years. Nevertheless, even in 2019, chlorophyll-*a* concentrations from some samples still extended well into the Unacceptable range for this variable, suggesting occasional, probably localised and short-lived bloom periods in the vlei;

- Generally, the data displayed in **Figure 4.4.2** do not show strong seasonal relationships in chlorophyll-a concentrations, with the exception of Wildevoelvlei in the 2015-2018 period, where winter concentrations were lower than in summer. This pattern would be expected at more sites, as algal production is generally lower during the colder months;

- The spatial presentation of changes in mean chlorophyll-a concentrations and the status of different sites with regard to this variable, as shown in the maps in **Figure 4.4.3**, confirm the status of Wildevoelvlei, Rondevlei, Die Oog, Zeekoevlei and Princessvlei as in an Unacceptable condition, while samples in Zandvlei and Glencairnvlei were within Acceptable limits (Target or Poor).

### *4.4.3 Implications*

Severely elevated chlorophyll-*a* concentrations, indicative of bloom conditions, can have a range of implications for waterbody management. Not only do they contribute to the accumulation of nutrients at the bottom of the water body when the bloom dies, where decomposition can result in the formation of anoxic layers at times, and from where nutrients can periodically be released into the water column, but they can also be associated with odour and aesthetic problems. *Microcystis*, for example, which is the dominant Cyanophyte species in some of the City's water bodies, produces a distinctive foul smell under bloom conditions. The visible presence of green algal scums is also unpleasant, and persistent bloom conditions in water bodies can affect property value and the suitability of the water body for different kinds of recreational uses. This issue is discussed in Section 5.

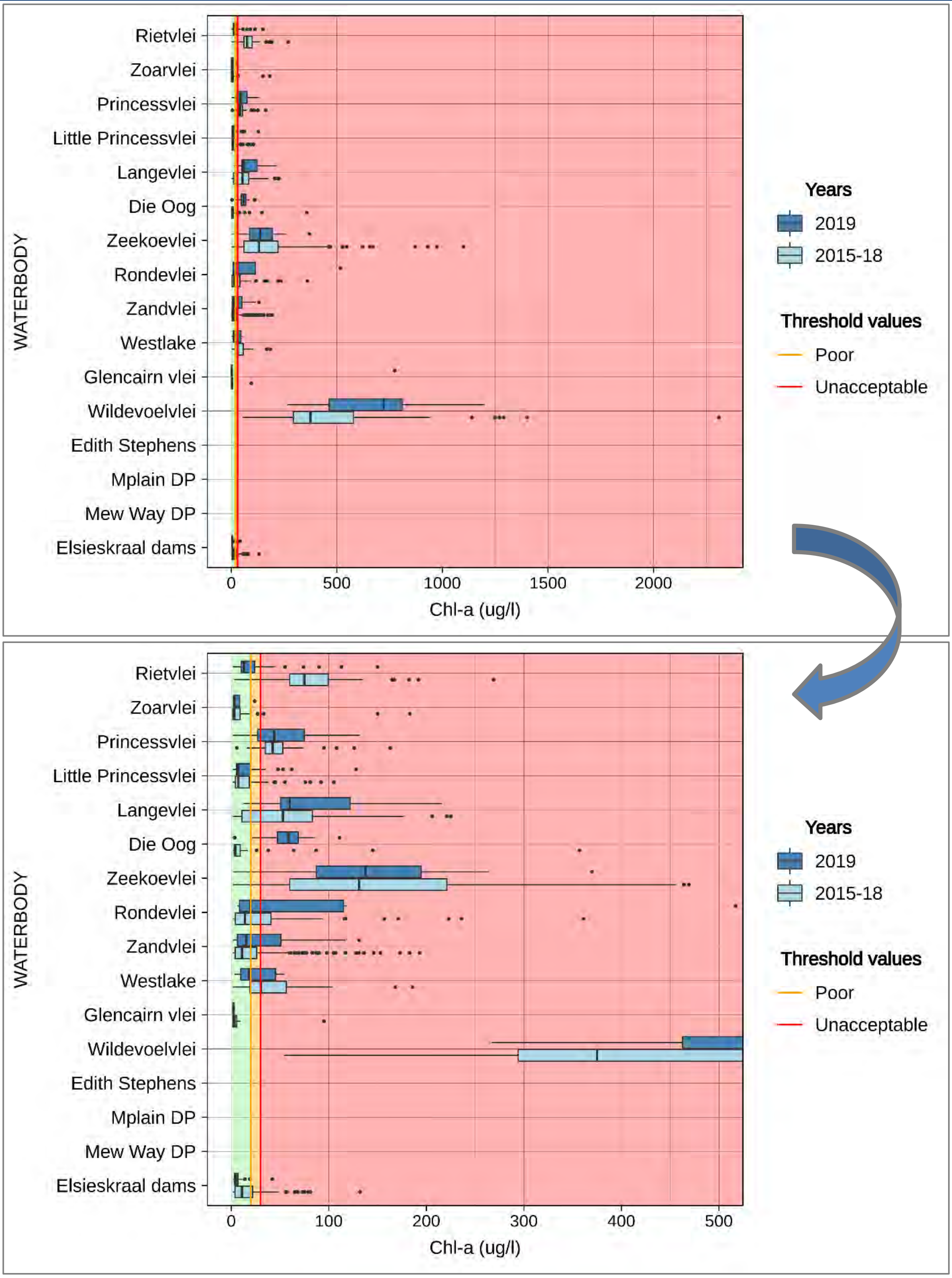



**Figure 4.4.1 Comparison of current (April 2019 to March 2020) Chlorophyll-*a* data with data from the previous 4 year record. Vleis and dams only**

Box plot: line shows mean value, "box" shows interquartile range; "whiskers" indicate maximum and minimum values; dots indicate outliers. Top graph shows all data; bottom graph has been scaled to 500 µg /L only. Shading illustrates position in rated thresholds – green band indicates target conditions.

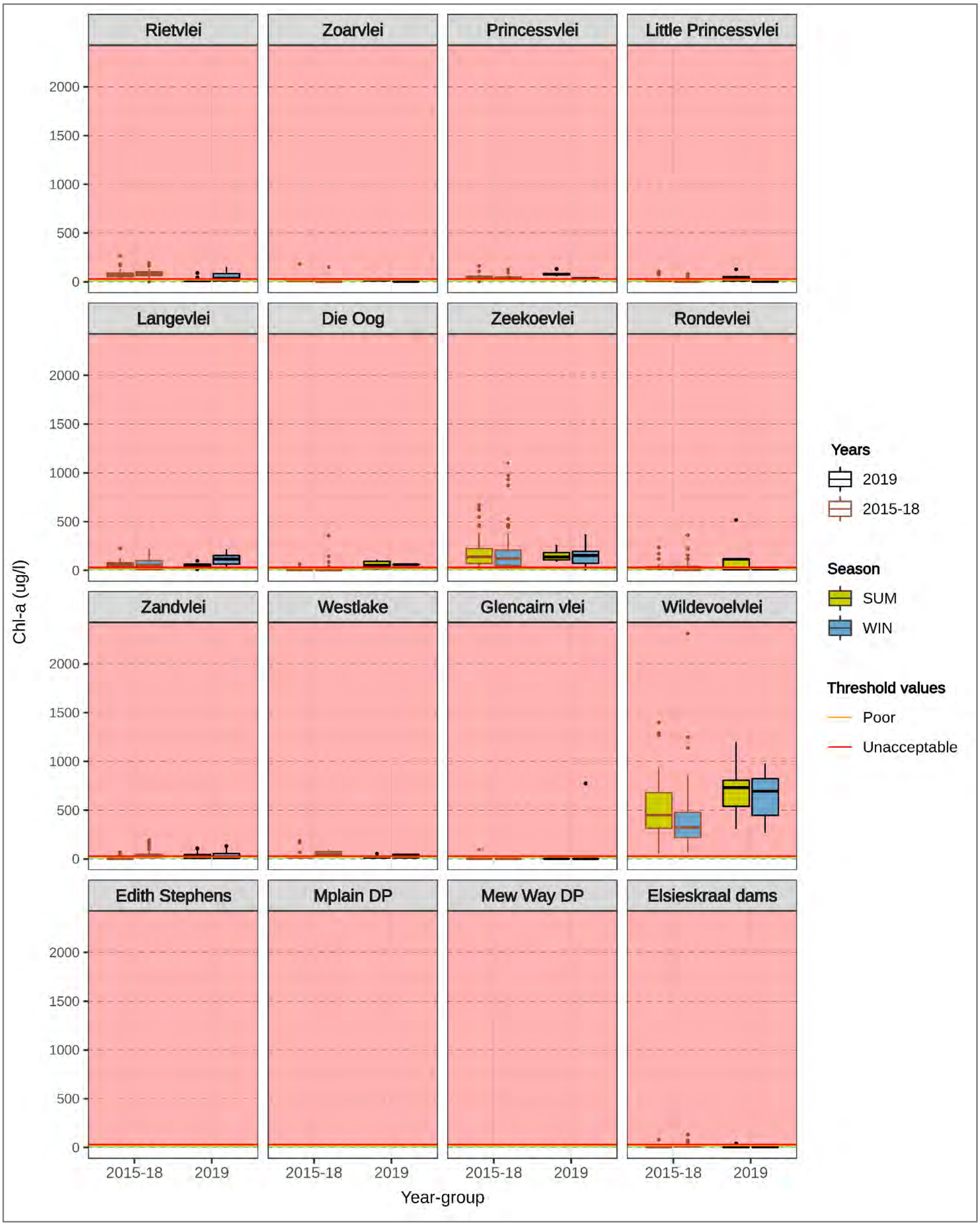



**Figure 4.4.2 Comparison of current (April 2019 to March 2020) Chlorophylll-*a* data with data from the previous 4 year record, showing seasonal variability.**

Box plot: line shows mean value, "box" shows interquartile range; "whiskers" indicate maximum and minimum values; dots indicate outliers. Top graph shows all data; bottom graph has been scaled to 500 µg /L only.
Shading illustrates position in rated thresholds

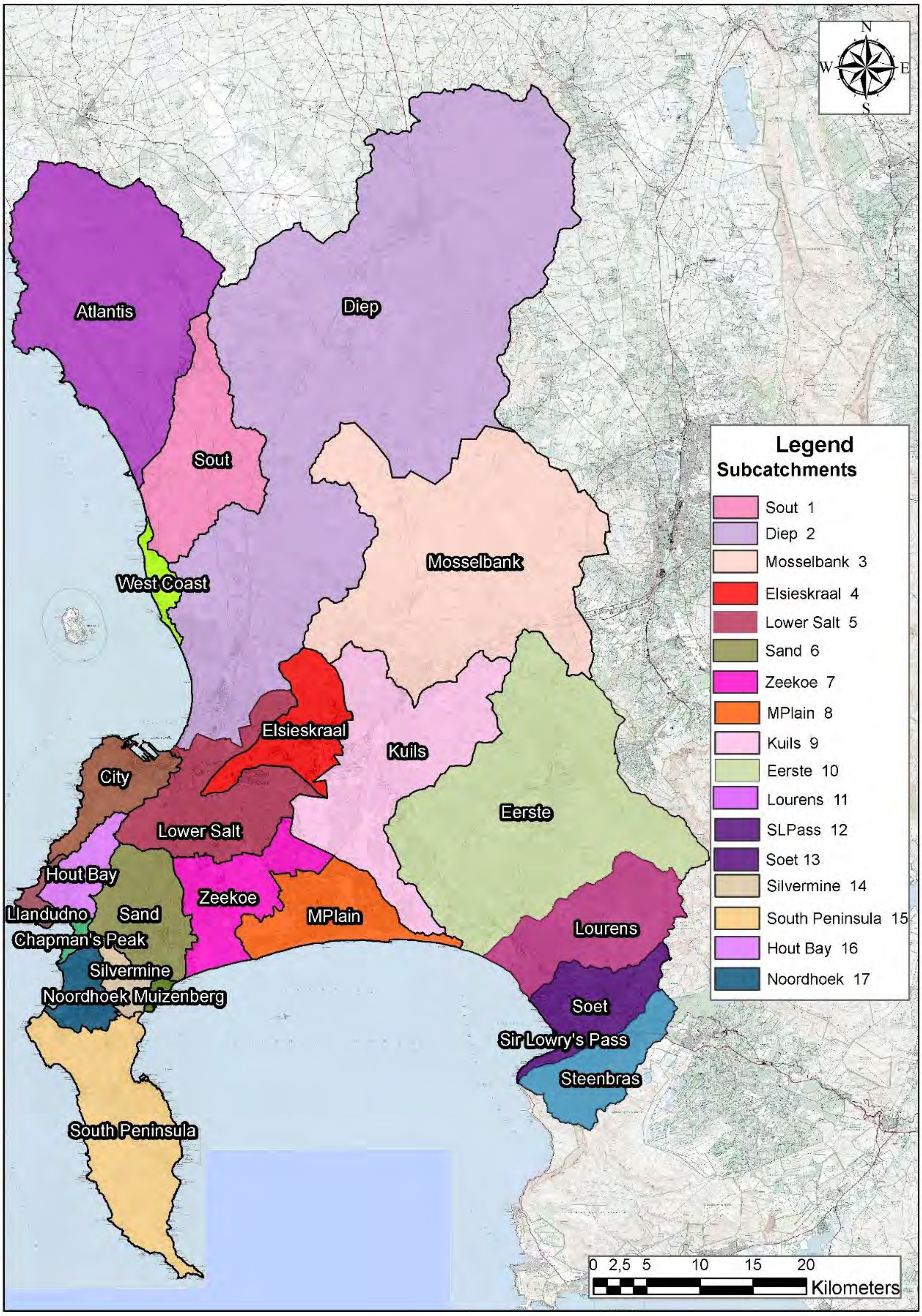
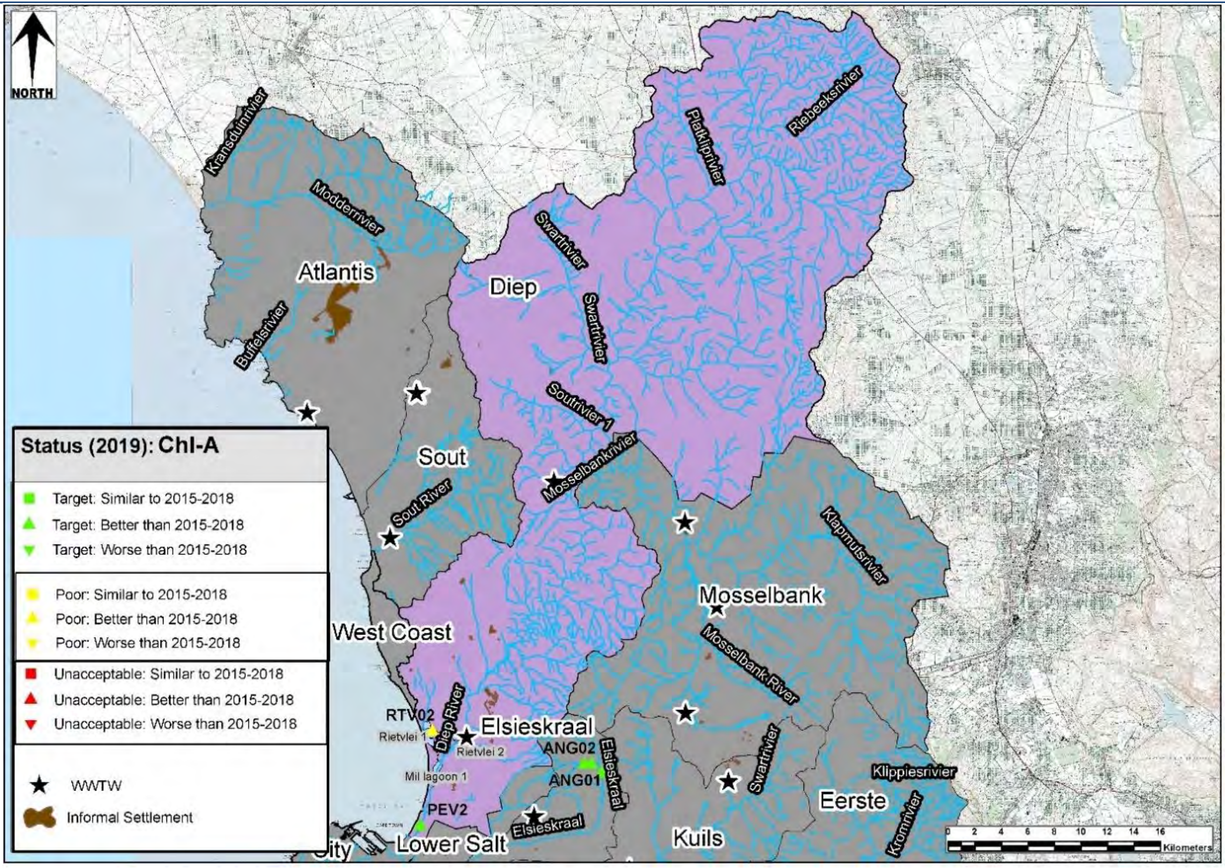



**Figure 4.4.3 Mean annual Chlorophyll-*a* concentrations, presented as a range of maps per subcatchment. Data coded as to level of change compared to previous 4 year median dataset. Subcatchments presented in numbered order as shown in this map. See following maps for actual data.**



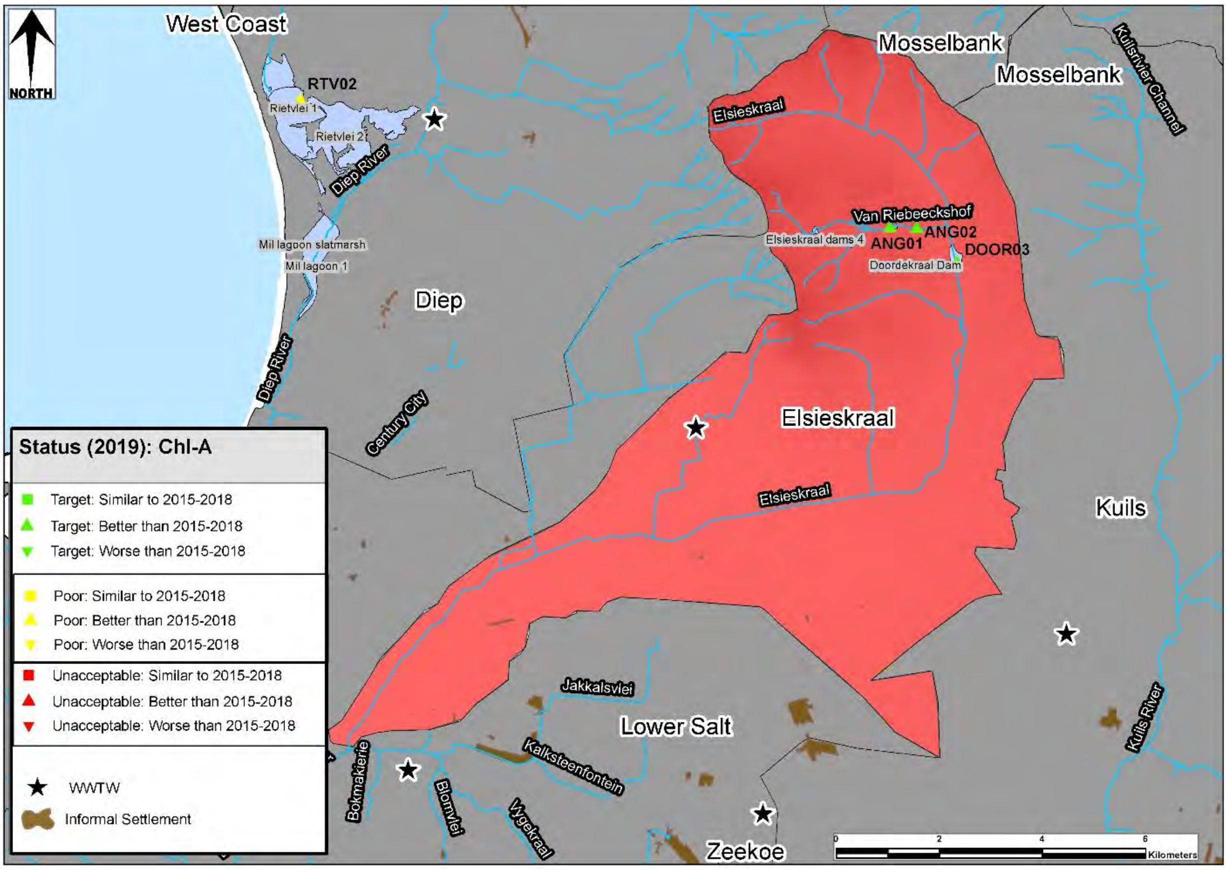
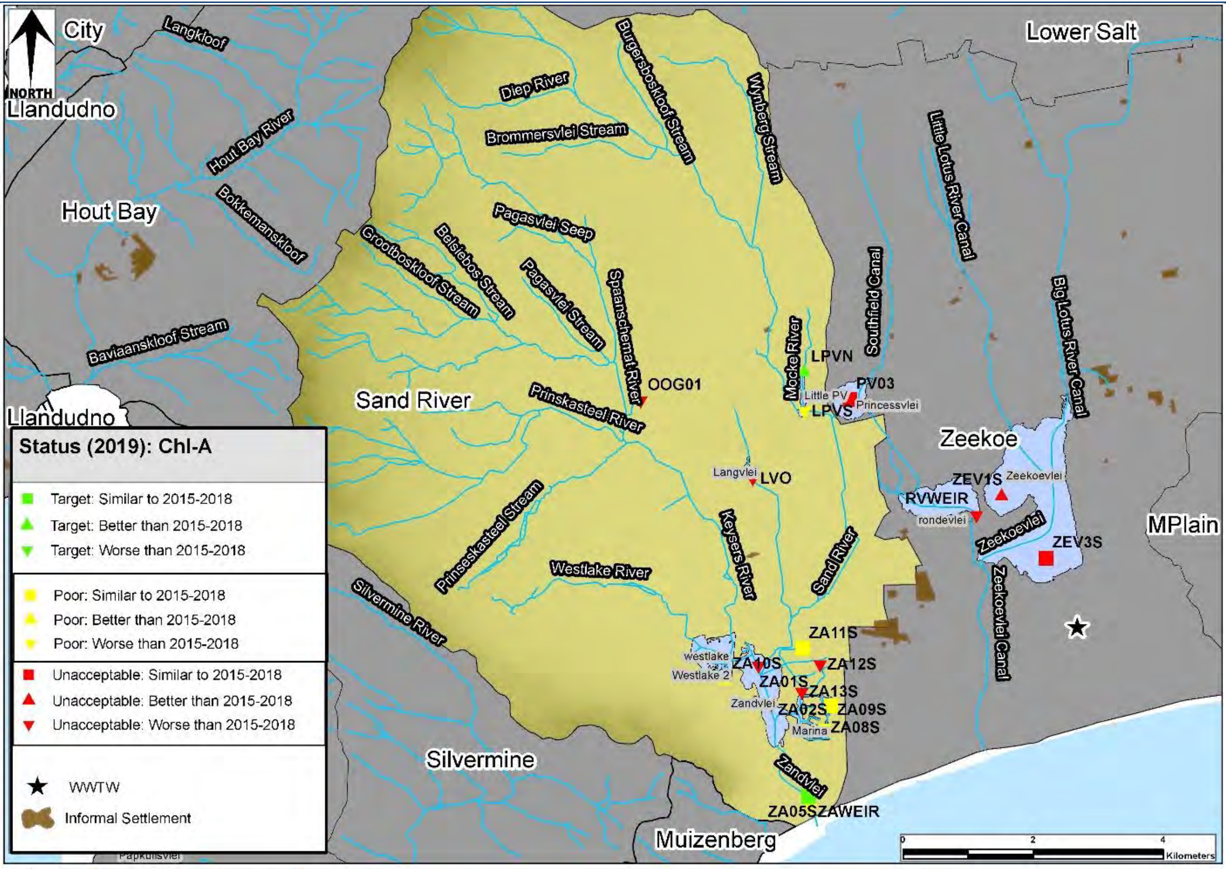




**Figure 4.4.3 (CONTD) Mean annual Chlorophyll-*a* concentrations, presented per subcatchment. Data coded as to level of change compared to previous 4 year median data. Subcatchments presented in numbered order in first map**



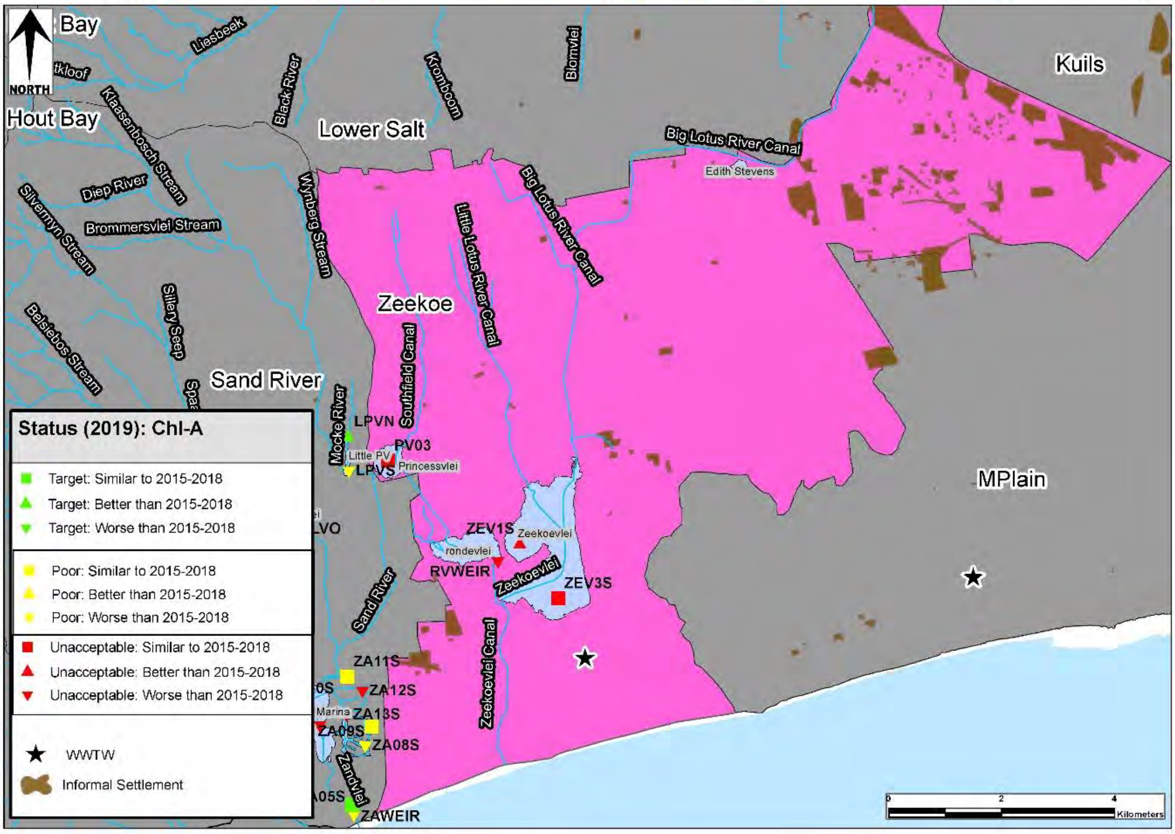
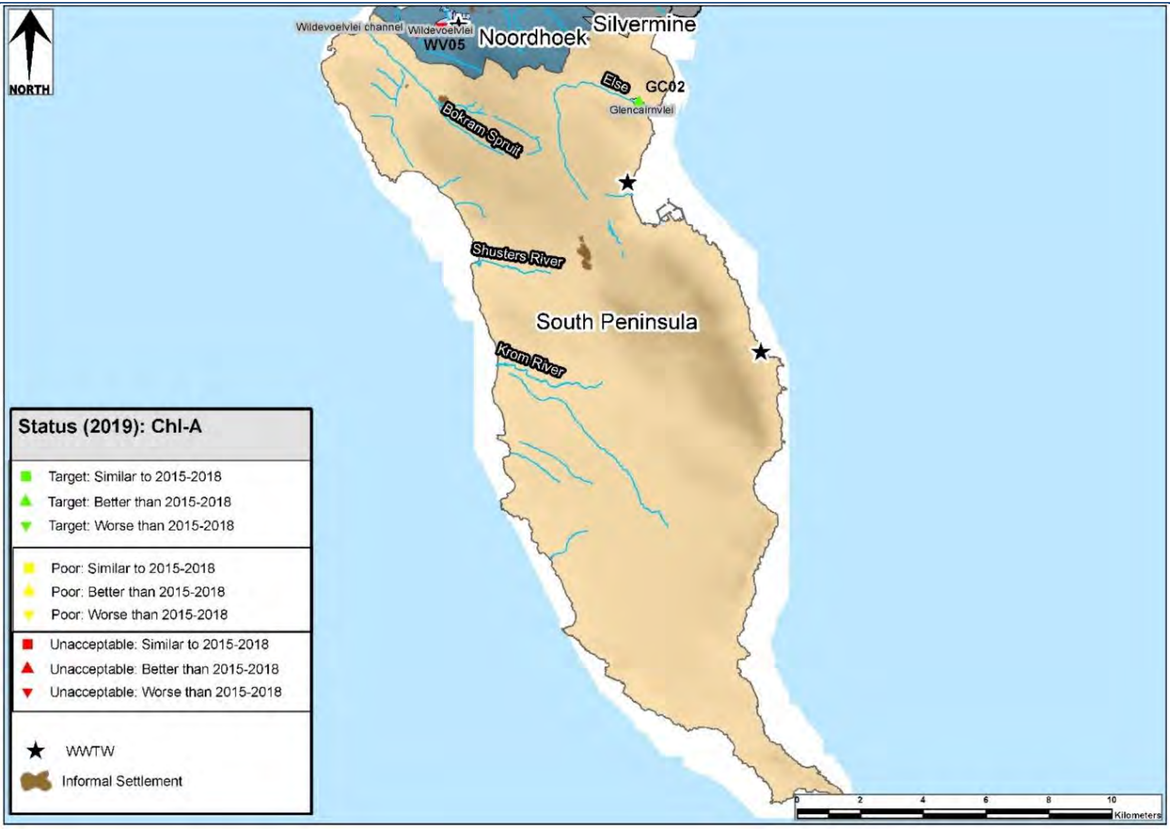




**Figure 4.4.3 (CONTD) Mean annual Chlorophyll-*a* concentrations, presented per subcatchment. Data coded as to level of change compared to previous 4 year median data. Subcatchments presented in numbered order in first map**



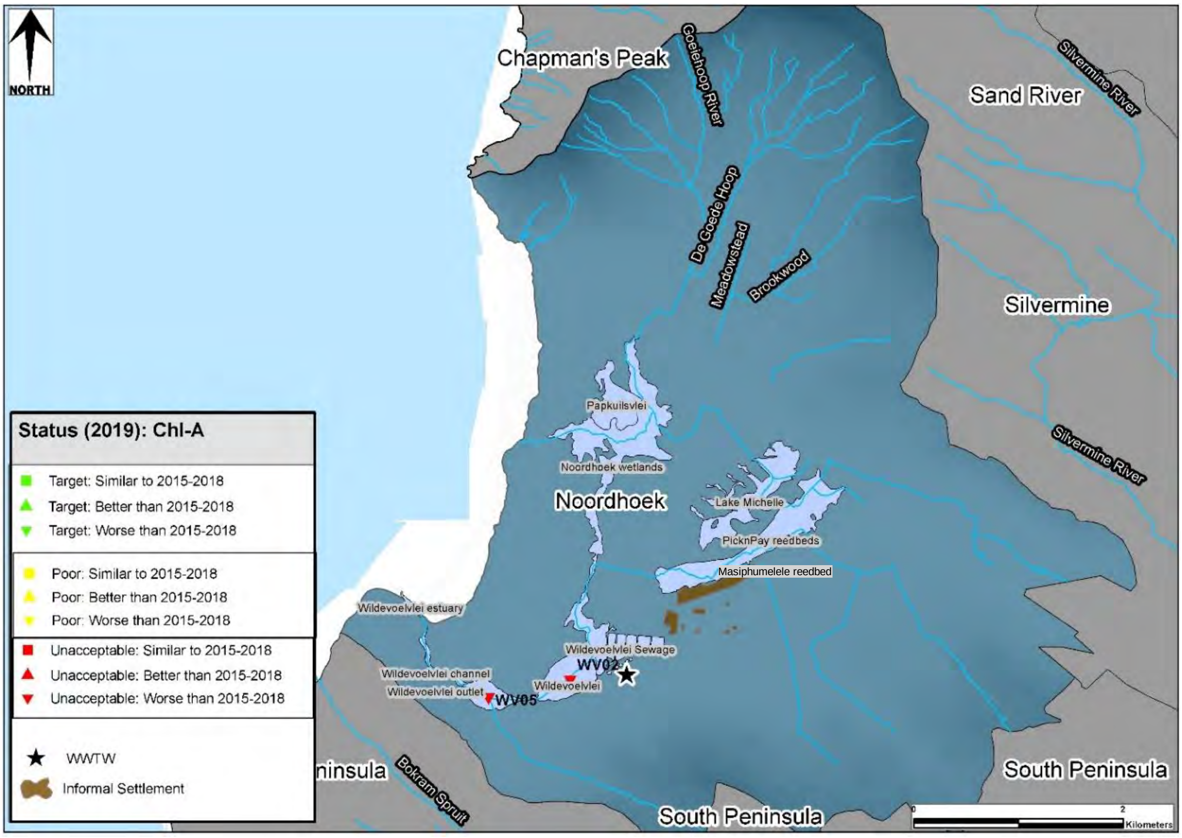




**FIGURE 4.4.3 (CONTD) Mean annual Chlorophyll-*a* concentrations, presented per subcatchment. Data coded as to level of change compared to previous 4 year median data. Subcatchments presented in numbered order in first map**

## 4.5 Dissolved oxygen

### *4.5.1 Relevance in water quality monitoring*

Oxygen is critical for the respiration of all aerobic organisms and, in aquatic ecosystems, adequate supplies of dissolved oxygen are needed for the survival of all non-air-breathing organisms. In aquatic ecosystems, it is sourced from atmospheric oxygen which dissolves in water, particularly if there is turbulent flow or wind-generated waves. It is also generated by submerged aquatic plants and algae during photosynthesis.

Low oxygen availability, particularly if combined with high temperature, can compound stress impacts on aquatic organisms, and can increase the toxicity of toxic substances such as various heavy metals (e.g. zinc, lead, copper) as well as sulphides and ammonia (DWAF1996a). In conditions where dissolved oxygen is limited, important nutrient cycling may be retarded – for example, oxidation of ammonia ($NH_3$) to Nitrite ($NO_2^-$) and then Nitrate ($NO_3^-$) may occur only very slowly, resulting in the accumulation of potentially toxic ammonia. This is an important issue in system that are already compromised with nitrogen-rich organic pollution (e.g. sewage or livestock waste), which is associated with high oxygen demand.

In standing water bodies (e.g. vleis and dams), oxygen concentrations are also important in determining phosphorus release from sediments – at low oxygen concentrations, phosphorus can be released as biologically available phosphates, contributing to ongoing cycles of increased plant productivity (Cooke *et al*. 2005).

Dissolved oxygen concentrations vary with temperature and salinity. Diel variation in photosynthesis means that concentrations of dissolved oxygen also vary on a daily basis, with the highest concentrations occurring in mid-afternoon, and lowest concentrations usually occurring near dawn. This means that the measurement of dissolved oxygen in water quality monitoring programmes needs to be carried out at the same time of day, if data between sites or over time are to be comparable. Since the City's sampling programme follows a strict order of sampling, it is assumed that samples are indeed collected at approximately the same time in each sampling cycle.

**Oxygen in vleis and dams**

In shallow standing water systems, dissolved oxygen concentrations can be reduced by:

- re-suspension of anoxic sediments as a result of wind-induced turbulence
- the presence of oxidisable organic matter (e.g. decaying plant matter)
- high concentrations of suspended material
- large algal populations with high nocturnal oxygen demand (compared to diurnal production of oxygen through photosynthesis).

While clearly exposure to water with very low dissolved oxygen concentrations can trigger immediate death for some non-air breathing organisms, DWAF (1996a) suggests that continuous exposure to water with sub-optimal concentrations may also be very harmful to aquatic organisms, including impacts on fish fecundity and/or mortality.

### *4.5.2 Dissolved oxygen as a water quality issue in City water bodies*

In this section, dissolved oxygen is considered from the perspective of the degree to which dissolved oxygen concentrations are likely to have contributed to aquatic ecosystem degradation over time. The next section considers ammonia toxicity as an issue in City water bodies, and dissolved oxygen concentrations have a direct bearing on this issue as well. **Figures 4.5.1** and **4.5.2** present data for dissolved oxygen concentrations in terms of the percentage of samples per subcatchment that met or did not meet the minimum thresholds of ecological acceptability – that is, a threshold of 4 mg/l, below which DWAF (1996) suggests acute effects of oxygen scarcity would be expected, if such conditions persisted for a day or more. The figures suggest:

- All of the subcatchments in the City have been affected at times by low levels of dissolved oxygen that fell below the acute effect (that is – lethal effects) of DWAF (1996) and within the Unacceptable category included in Tables 2.2 and 2.3 for this variable.

- The stormwater outlets in the Mitchell's Plain and Soet subcatchments generally showed very low levels of DO – this is consistent with water that is mostly piped through urban areas;
- The number of measurements in the Eerste subcatchment that fell into the Unacceptable range increased over the monitoring record, suggesting deteriorating ecological conditions in this system – this would be consistent with increased organic loading;
- Kuils subcatchment DO measurements also showed an increase in those falling within the Unacceptable range, although to a lesser extent than the Eerste system;
- DO concentrations in both the Diep and Mosselbank subcatchments is frequently highly compromised, with large numbers of measurements in the Unacceptable range. This said, DO concentrations have improved in the Diep subcatchment since 2000, with fewer measurements in the Unacceptable range;
- Broadly similar proportions of Unacceptable DO measurements were found in the Lower Salt and Zeekoe subcatchments, with measurements of concern in the Lower Salt mainly derived from the Black River and other slow flowing river reaches, also affected by organic inputs in the form of treated and untreated sewage waste; parts of the subcatchment that include the Liesbeek River showed less impacted DO concentrations;
- The Hout Bay system showed persistently low concentrations of DO in the early parts of the data record, but subsequently the proportion of measurements deemed Unacceptable decreased substantially, suggesting an improvement in ecosystem condition at some sites;
- DO concentrations in the Sand system always included a number of measurements suggesting poor ecosystem condition with regard to this variable. This said, the number of measurements in the Unacceptable range has reduced over time, and some of these measurements are likely to represent low flow in summer, when DO would be expected to be low under natural conditions;
- The Lourens, South Peninsula and Silvermine subcatchments had the lowest proportion of samples falling into the Unacceptable range, but nevertheless even these generally least-impacted aquatic ecosystems still had episodes throughout the data record when DO concentrations were low enough to be of significant concern.

Generally, low gradient rivers (gravel foothills and lowland rivers) might be expected at times to show low oxygen concentration, particularly in summer, when temperatures rise, and if they are nutrient enriched. Standing water systems are however still more vulnerable to the development of low oxygen or even anoxic conditions, because there is little flow to create turbulence; because nutrients accumulate in these systems; and because plant detritus sinks to the bottom of these system, and its decomposition requires oxygen. In this context, the data for vleis and dams in **Figure 4.5.2** suggest:

- The hypertrophic Zoarvlei system showed a high frequency of low oxygen conditions, likely to trigger ecosystem effects such as fish kills;
- Rondevlei and Little Princessvlei are both periodically affected by low oxygen conditions, consistent with small relatively sheltered systems with a high availability of nutrients;
- After very low levels of DO in the 1995-2000 data period, concentrations of this variable increased significantly in Rietvlei in subsequent years, with data showing generally high DO levels – occasional fish die-offs in the vlei over this period highlight the variability of DO on a daily basis, and the fact that short-term reductions below critical levels can have acute consequences. The deeper waters of

Rietvlei are also prone to deep water oxygen depletion as a result of organic decomposition, particularly in warm conditions, as they are unlikely to be oxygenated by wind-driven turbulence on the surface. Nevertheless, water quality data for this system generally show relatively low levels of nutrient enrichment, consistent with DO at levels that are not likely to be problematic;

- Zeekoevlei showed surprisingly few samples with low DO, given its catchment characteristics and the fact that the vlei is highly nutrient enriched. However, the water body is subject to high levels of wind-induced waves, which would increase surface oxygen concentrations, as would photosynthetic production by algae;

- The Edith Stephens, Mew Way and Mitchell's Plain detention ponds have all been characterized by low dissolved oxygen concentrations – although none of these systems are intended to be managed as thriving aquatic ecosystems, low oxygen also affects the efficiency of stormwater amelioration, and water passing out of these systems is likely to remain in a poor condition.

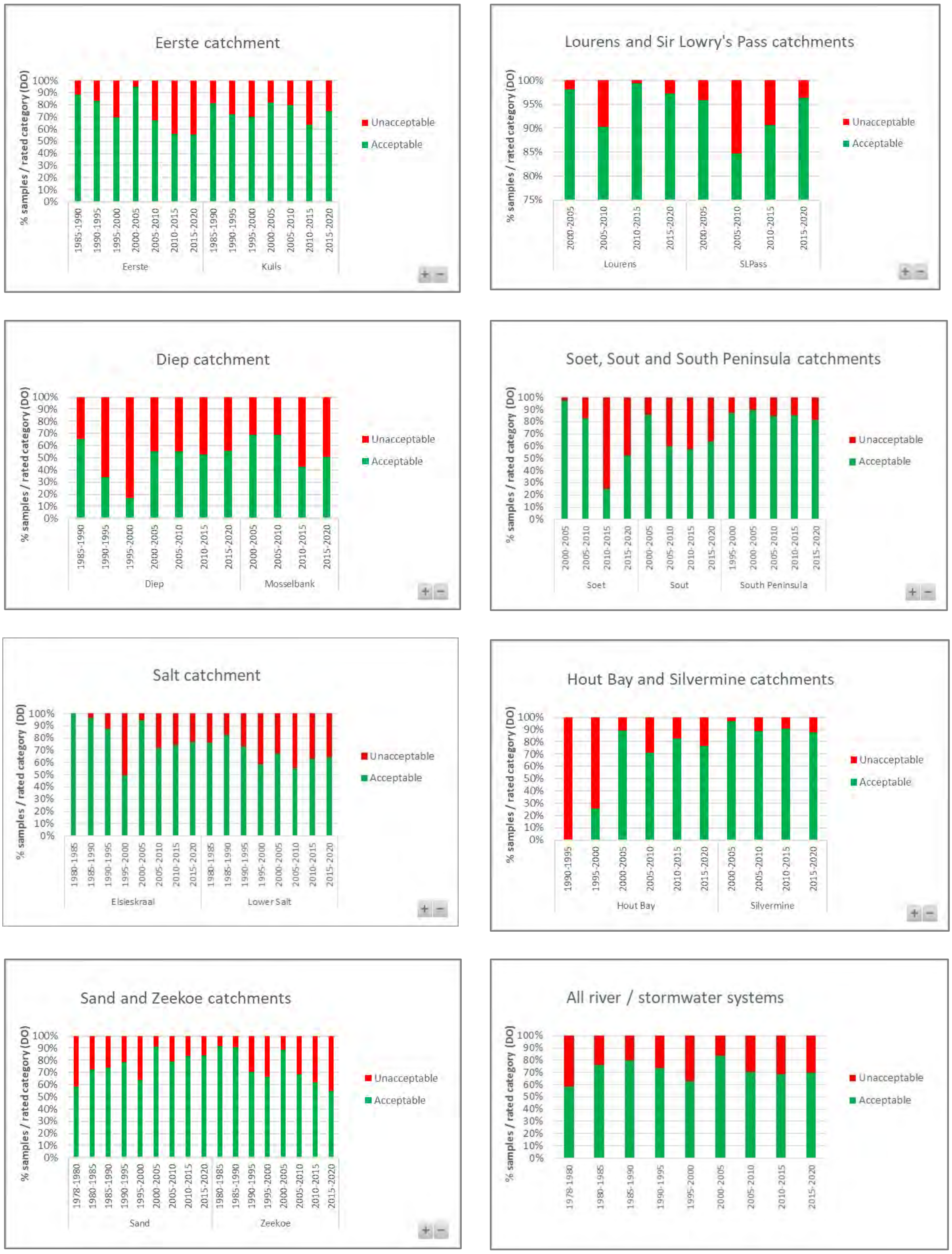



**Figure 4.5.1 Percentage of Dissolved Oxygen (DO) samples from river and stormwater channel sites in each subcatchment falling within each rated category for this variable.**

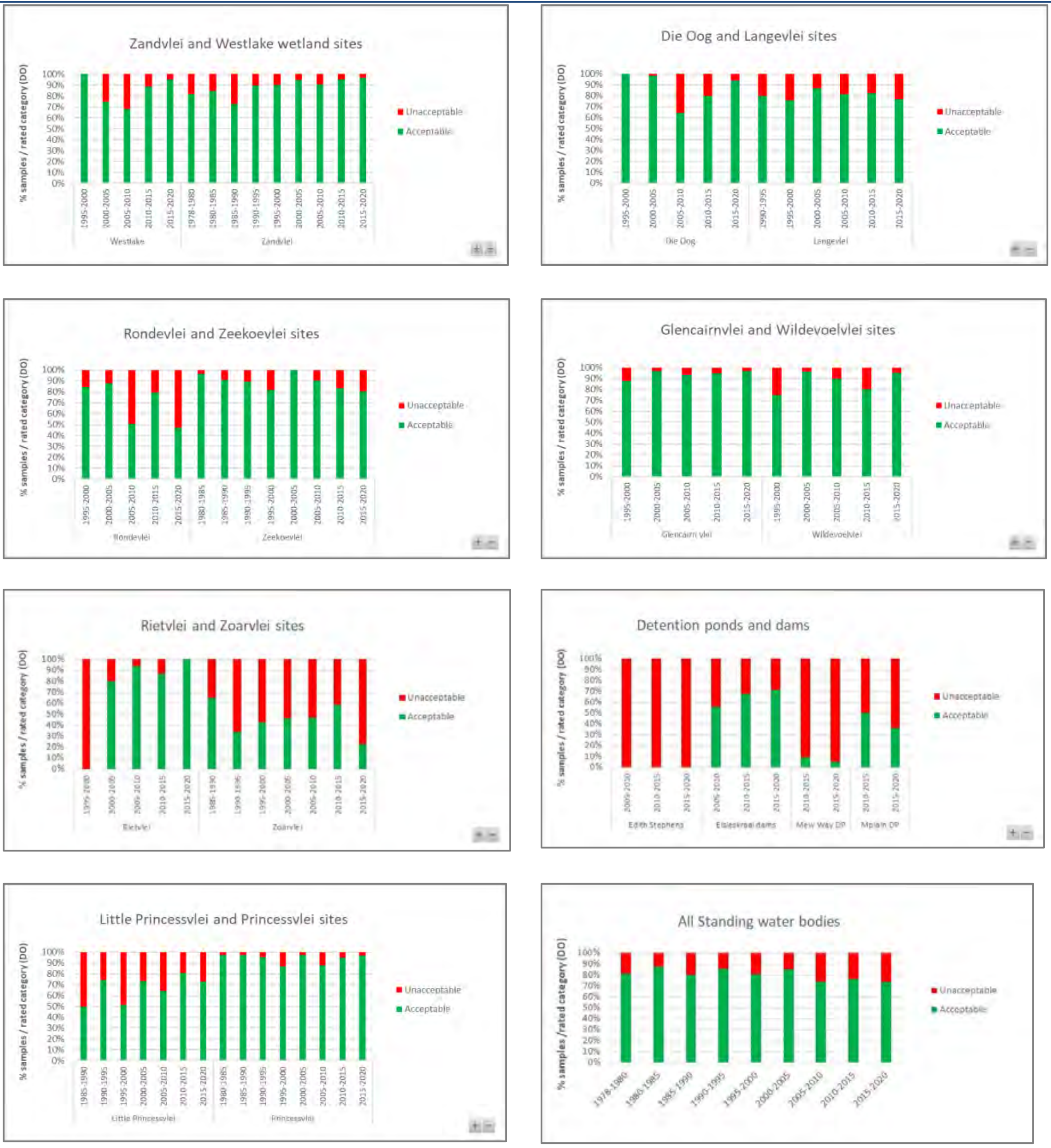



**Figure 4.5.2 Percentage of Dissolved Oxygen (DO) samples from vlei and dam sites in each subcatchment falling within each rated category for this variable.**

## 4.6 Ammonia toxicity

### *4.6.1 Relevance in water quality monitoring*

In the aquatic environment two forms of ammonia can occur: harmless ammonium ions ($NH_4^+$) and toxic un-ionised ammonia ($NH_3$), and the relative proportion of each is controlled by pH and temperature. The City measures "total ammonia nitrogen", and calculates the proportion of this that is likely to be in the toxic ammonia form, taking into account pH, EC and temperature. At pH >8, a significantly larger proportion of total ammonia ions are present in the un-ionised form, which may give rise to acute toxicity at concentrations as low as 0.1 mg N/L (DWAF 1996a). pH fluctuations can occur in aquatic ecosystems as a result of various factors, including high diurnal rates of photosynthesis (both natural and as a result of eutrophication), as well as resulting from activities such as construction, leading to runoff of alkaline cementitious waters (see Section 4.2).

Concentrations of un-ionised ammonia above Target levels (see **Tables 2.2 and 2.3**) would increase the risk of ammonia-toxicity in sensitive fauna – particularly fish. Particular attention should be paid to systems where pH levels are naturally high, or raised as a result of impacts such as construction, with pH >8 being a potential trigger for ammonia toxicity, when associated with elevated total ammonia concentrations. The development of low oxygen conditions would increase the availability of reduced nitrogen forms such as ammonia, rather than more stable nitrates. Oxygen levels are thus also an important consideration when assessing the threat posed to aquatic ecosystems by ammonia toxicity.

Prolonged exposure to ammonia at chronic toxicity levels (Poor level in **Tables 2.2 and 2.3**) could affect aquatic organism fecundity, general health and resilience, while exposure to ammonia at elevated levels associated with acute toxicity (Unacceptable level in **Tables 2.2 and 2.3**) could result in the death of more sensitive organisms.

### *4.6.2 Trajectories and Current state (April 2019 to March 2020)*

The box plots in **Figure 4.6.1** summarise median ammonia nitrogen (NH3-N) concentrations, as well as providing range and outliers for river / stormwater and selected vlei / dam sites in the City. The maps in **Figure 4.6.2** provide an illustration of change in the 2019 values for this variable at different sites, compared with the 2015-2018 period. The figures suggest:

- Median ammonia NH3-N concentrations in rivers and stormwater channels in the Diep, Lower Salt, Zeekoe, Eerste, Soet and Mitchell's Plain subcatchments were always in the Unacceptable range – that is, associated with Acute Toxicity effects to aquatic organisms. This means that only the most pollution tolerant, hardy aquatic organisms would be able to survive in these systems;
- With the exception of the Silvermine and Hout Bay subcatchments, all of the monitored subcatchments had samples that at times went well over the Unacceptable thresholds, and could have resulted in die-off of any sensitive fauna that still occurred there;
- Samples from the Silvermine and Hout Bay subcatchments never exceeded the Acceptable range for NH3-N, reinforcing the importance of these systems and the Silvermine River system in particular as least-impacted river systems within the City.

With regard to vleis in these subcatchments:

- Ammonia toxicity does not appear to have been a significant issue affecting these systems;
- Nevertheless, median NH3-N concentrations at Wildevoelvlei and the Mitchell's Plain and Mew Way detention ponds consistently fell within the acute toxicity range for this variable (i.e. Unacceptable). While this might not be problematic from an ecosystems perspective at the two detention ponds, which were not designed for ecological function, the implications for the natural (but clearly

impacted) Wildevoelvlei system are more severe, and indicate a system in which natural ecological function is highly threatened. This system lies in proximity to a breeding hotspot for (endangered) Western Leopard Toads, and such toxicity issues have wide-ranging implications;

- All vleis / dams, with the exception of Glencairnvlei, Die Oog, Little Princessvlei and Princessvlei had periodic episodes of ammonia concentrations that lay well above the thresholds for acute toxicity, and these could have eliminated any remnant aquatic taxa that have sensitivity to ammonia.

#### *4.6.3 Implications*

Sites representing river reaches where there is pronounced organic pollution and nutrient enrichment, often leading to, or coupled with low dissolved oxygen concentrations, are likely to be vulnerable to elevated ammonia concentrations, which could further compromise the ecological health of systems that have already been impacted by nutrient enrichment and low oxygen.

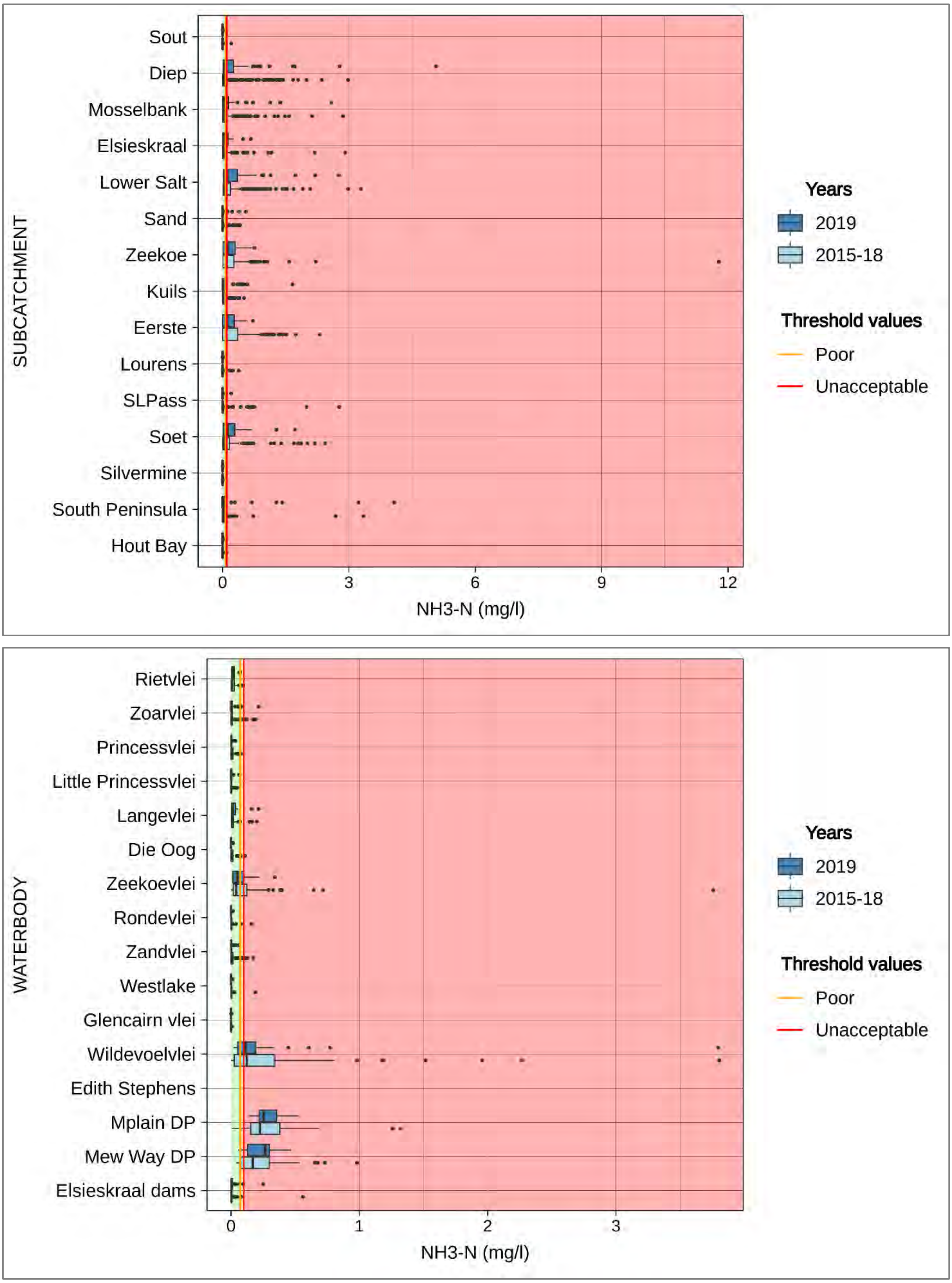



**Figure 4.6.1 Comparison of current (April 2019 to March 2020) NH3-N data with data from the previous 4 year record. Include green target level in threshold legend**

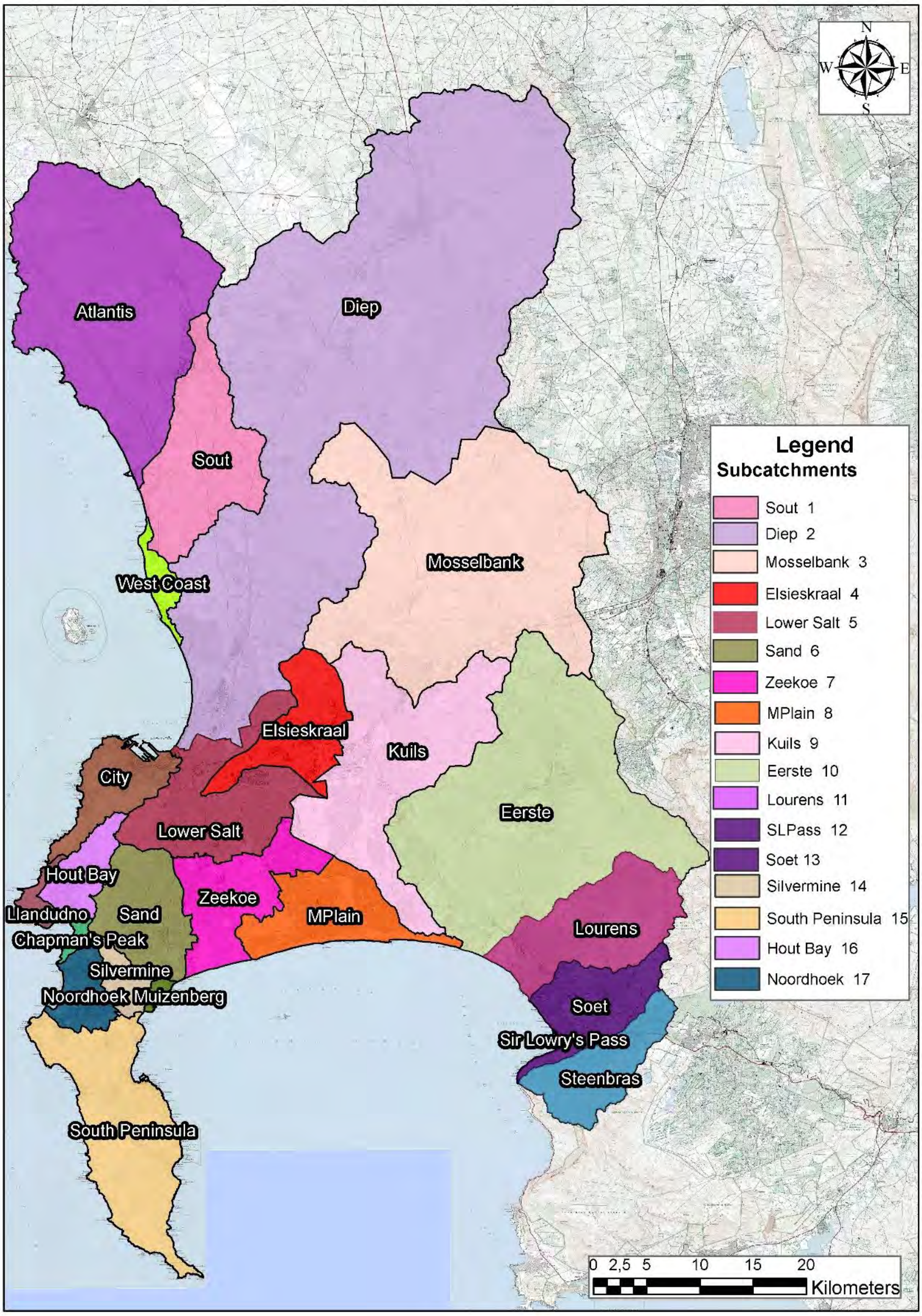
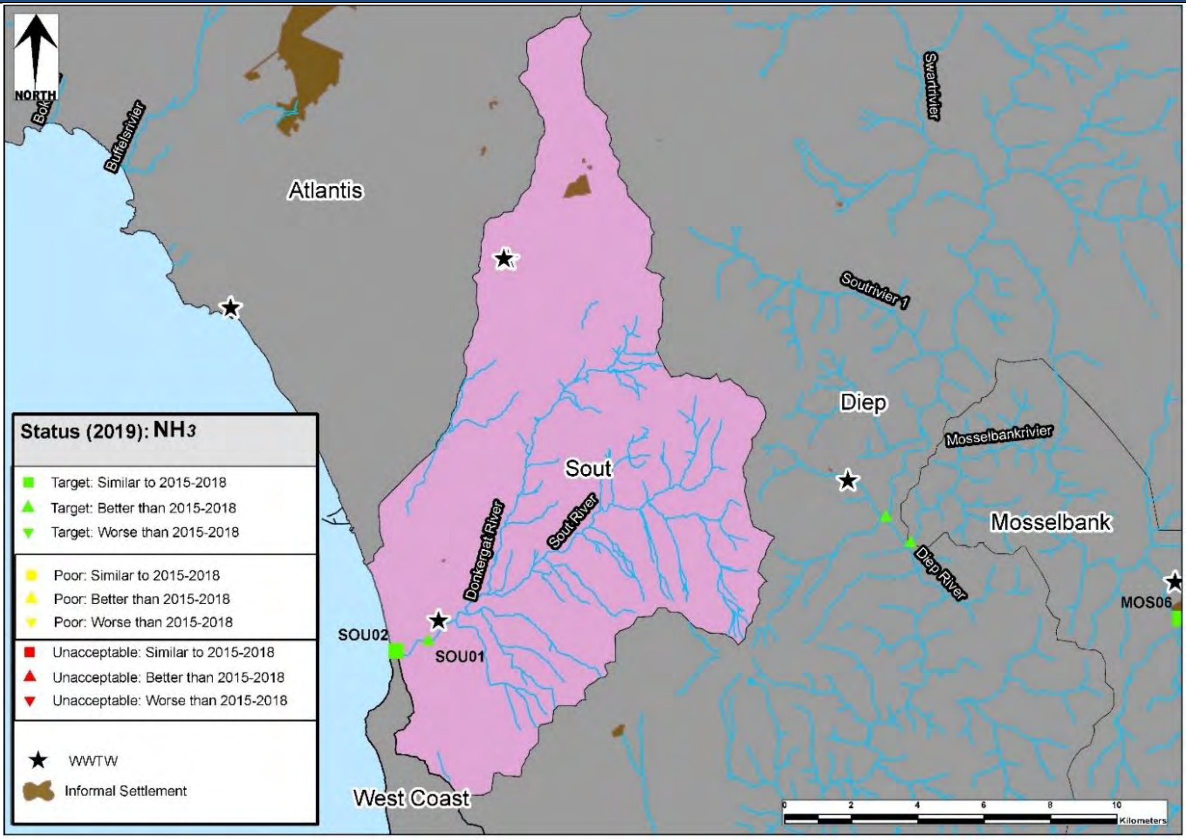



**Figure 4.6.2 Median annual NH3-N concentrations, presented presented as a range of maps per subcatchment. Data coded as to level of change compared to previous 4 year median dataset. Subcatchments presented in numbered order as shown in this map. See following maps for actual data.**



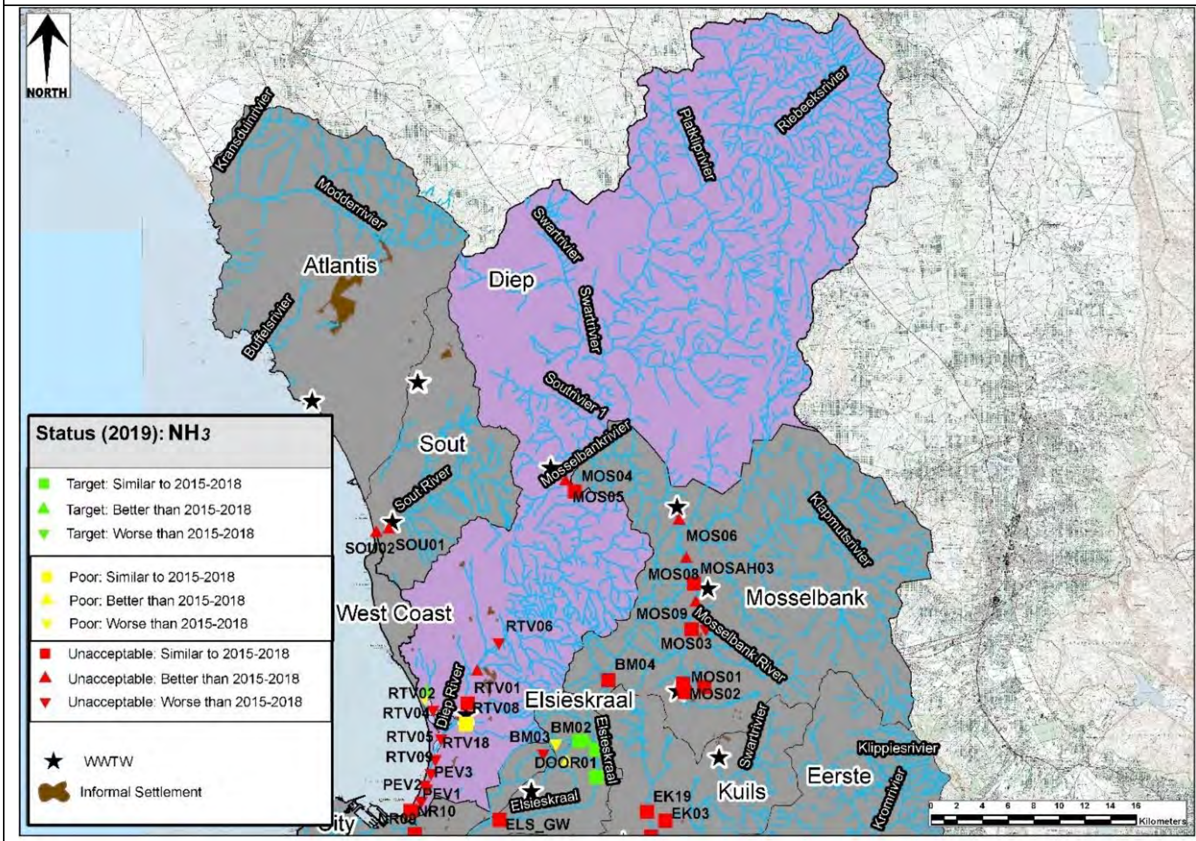




**Figure 4.6.2 CONTD Median annual NH3-N concentrations, presented per subcatchment. Data coded as to level of change in 2019 dataset compared to previous 4 year median data. First figure shows order of presentation of subcatchment maps**

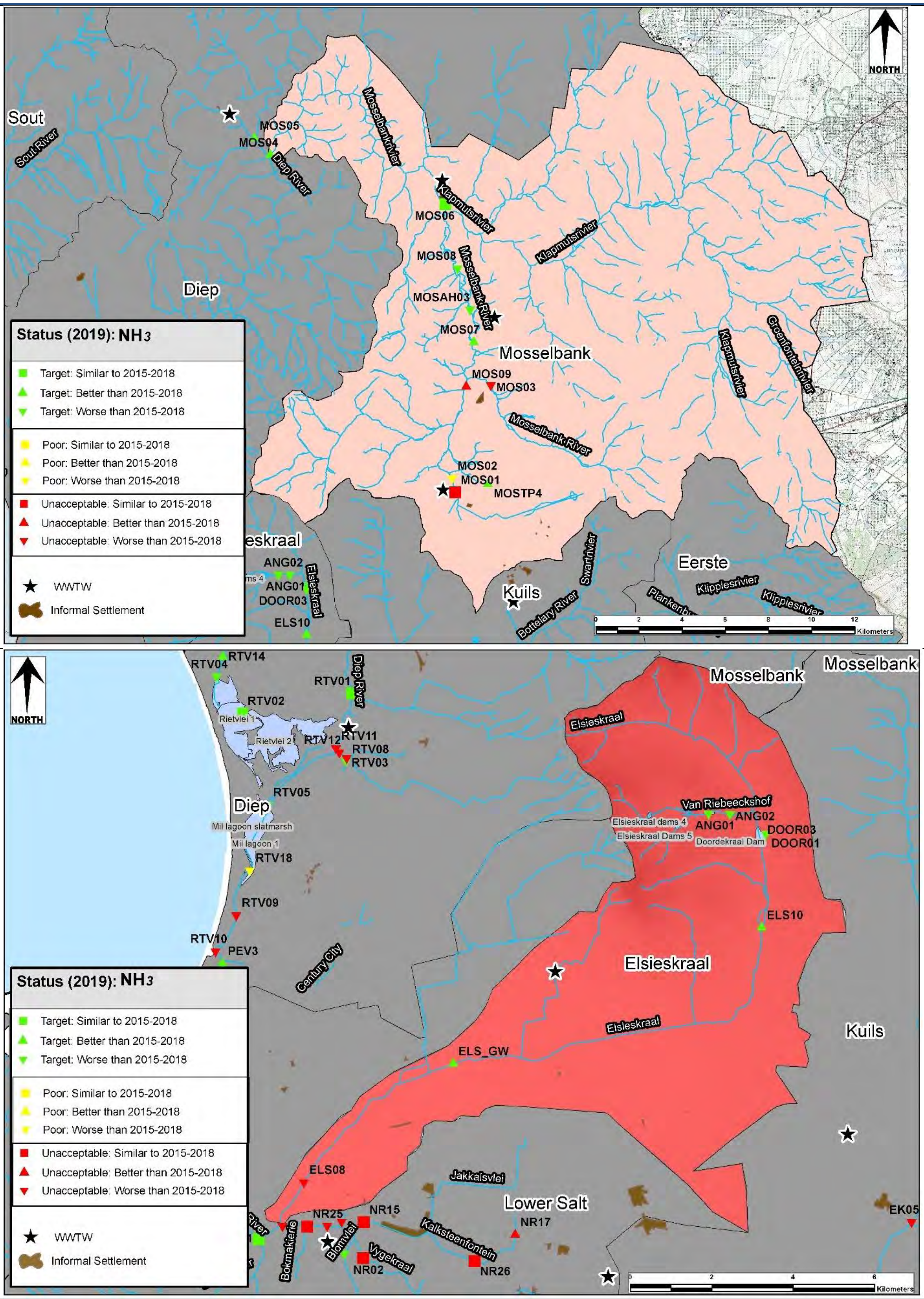
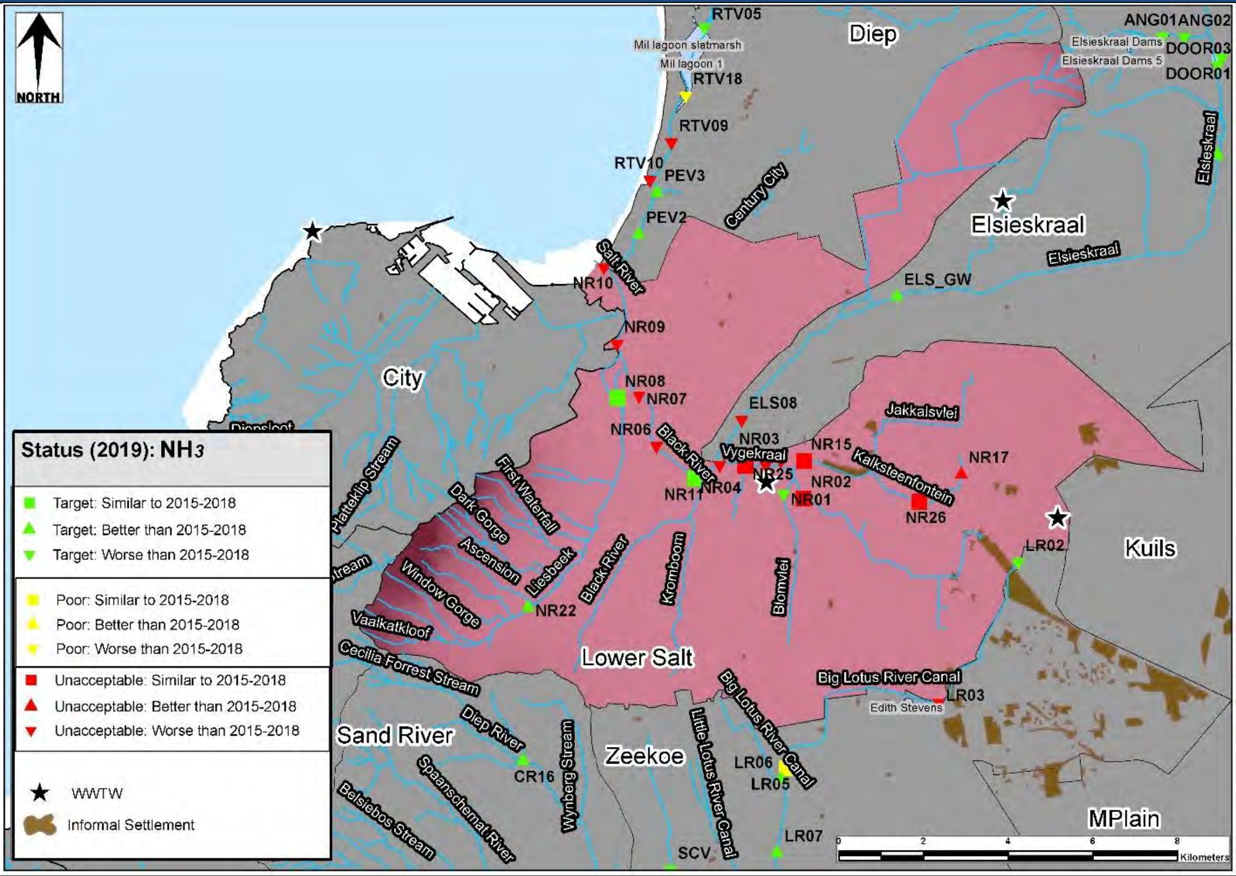



**Figure 4.6.2 CONTD Median annual NH3-N concentrations, presented per subcatchment. Data coded as to level of change in 2019 dataset compared to previous 4 year median data. First figure shows order of presentation of subcatchment maps**



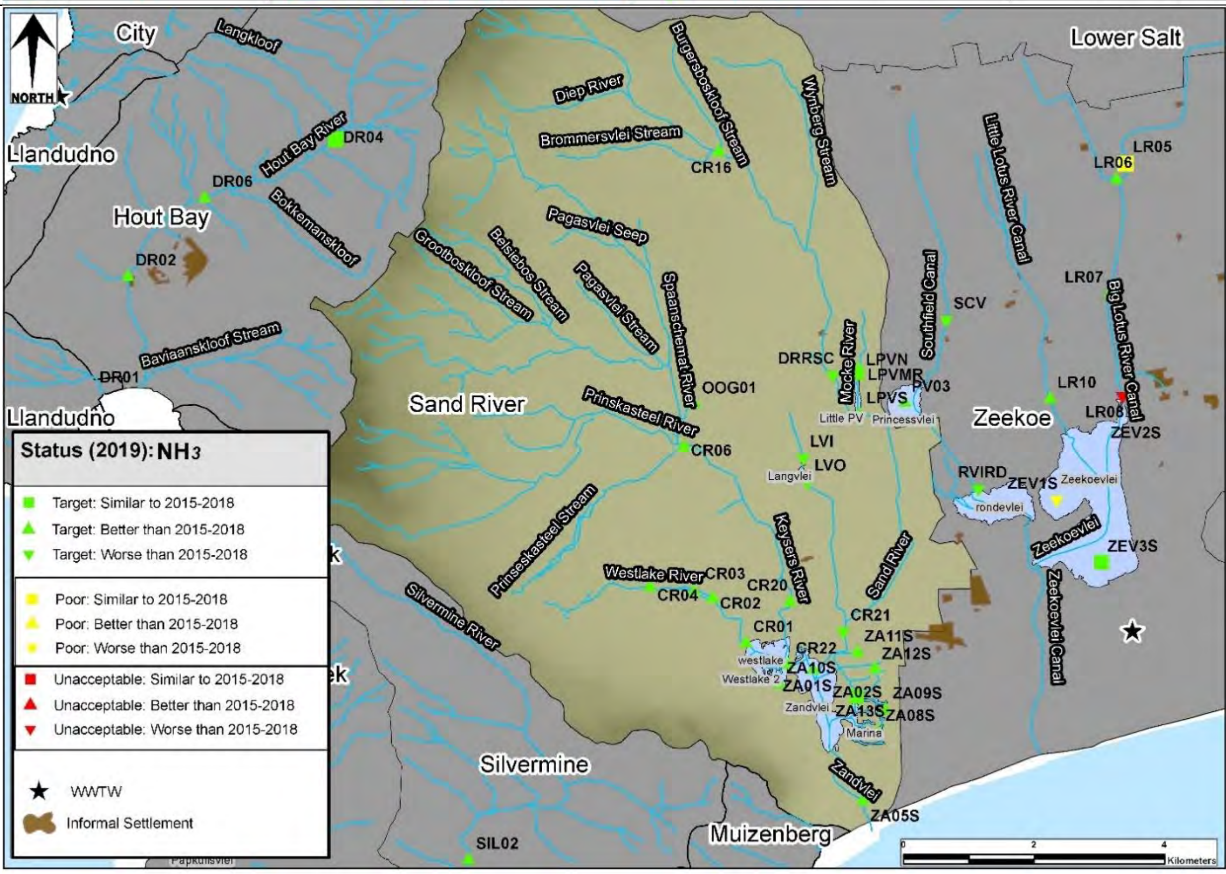
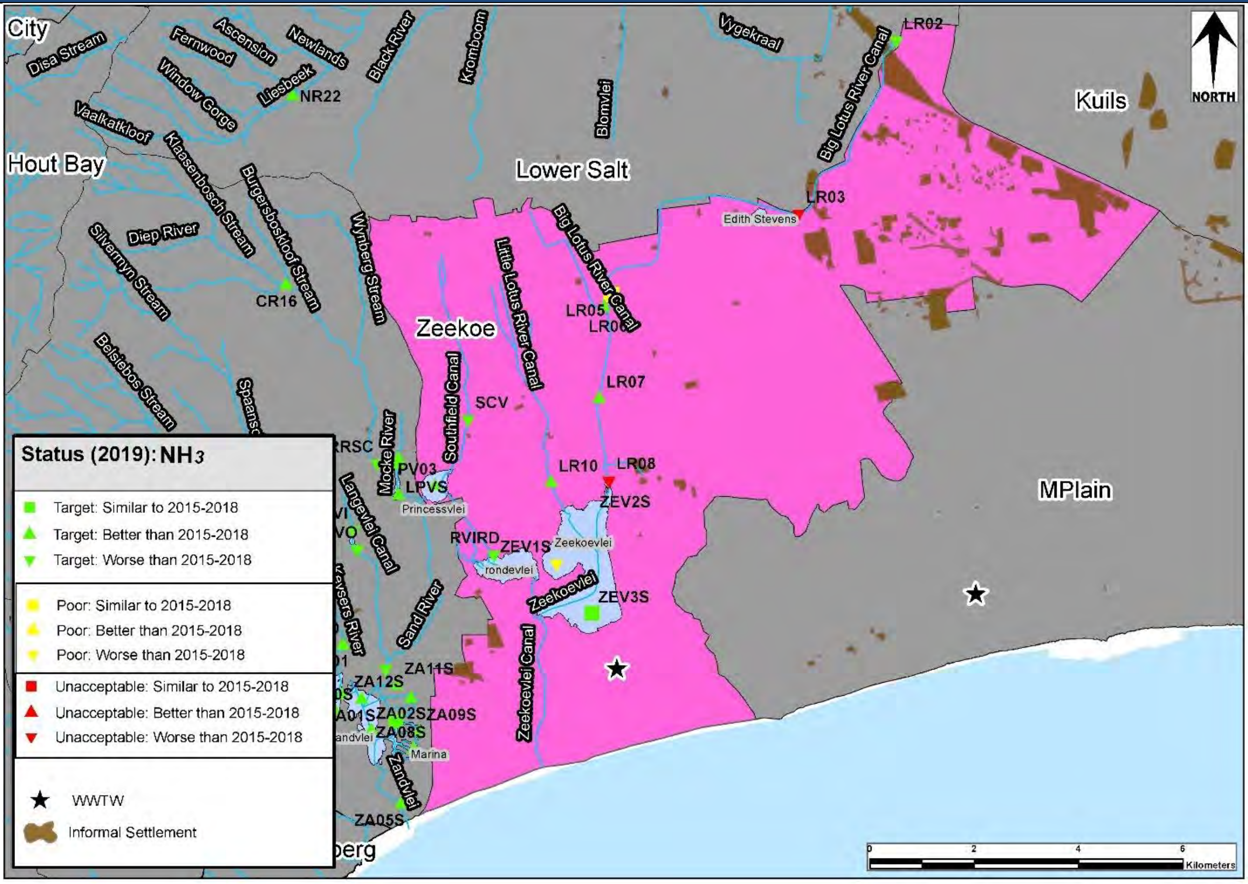




**Figure 4.6.2 CONTD Median annual NH3-N concentrations, presented per subcatchment. Data coded as to level of change in 2019 dataset compared to previous 4 year median data. First figure shows order of presentation of subcatchment maps**



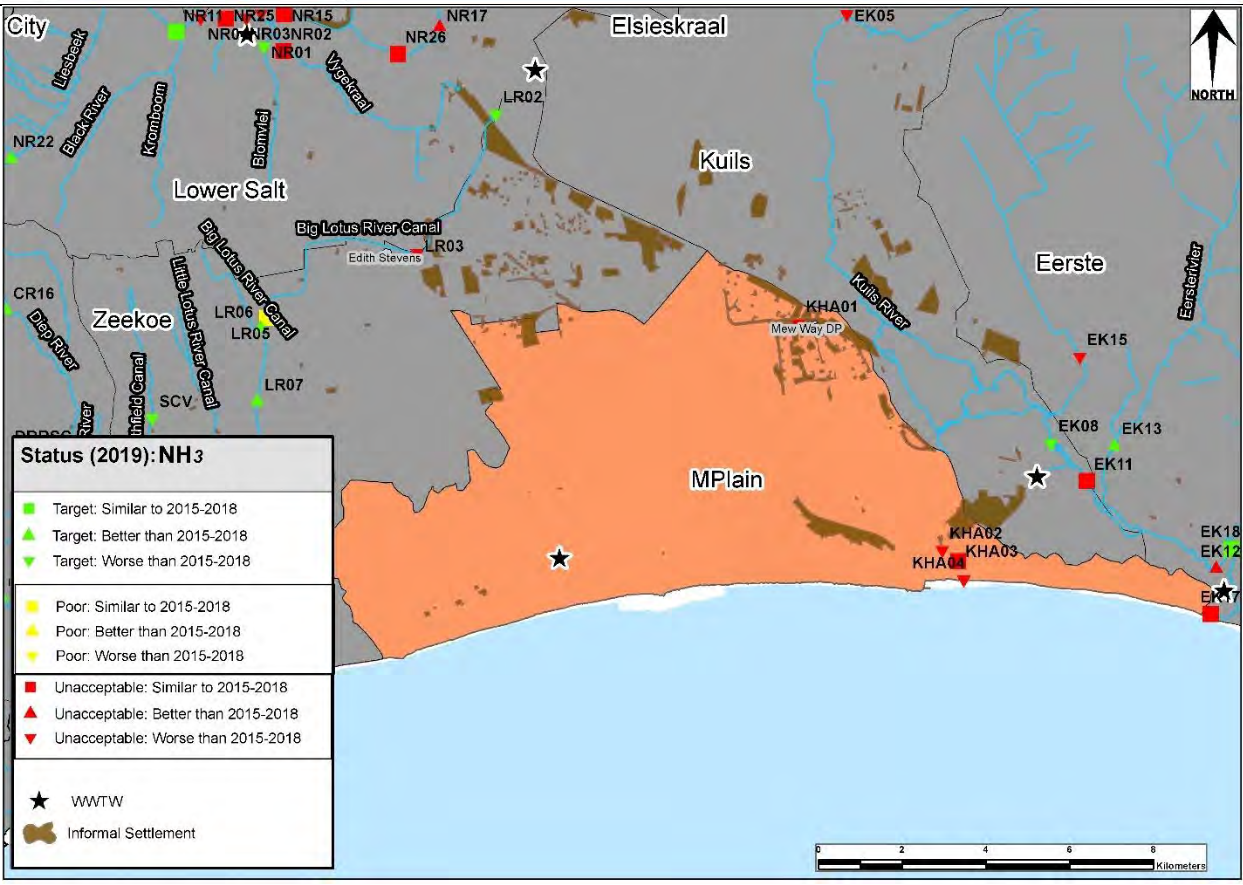




**Figure 4.6.2 CONTD Median annual NH3-N concentrations, presented per subcatchment. Data coded as to level of change in 2019 dataset compared to previous 4 year median data. First figure shows order of presentation of subcatchment maps**

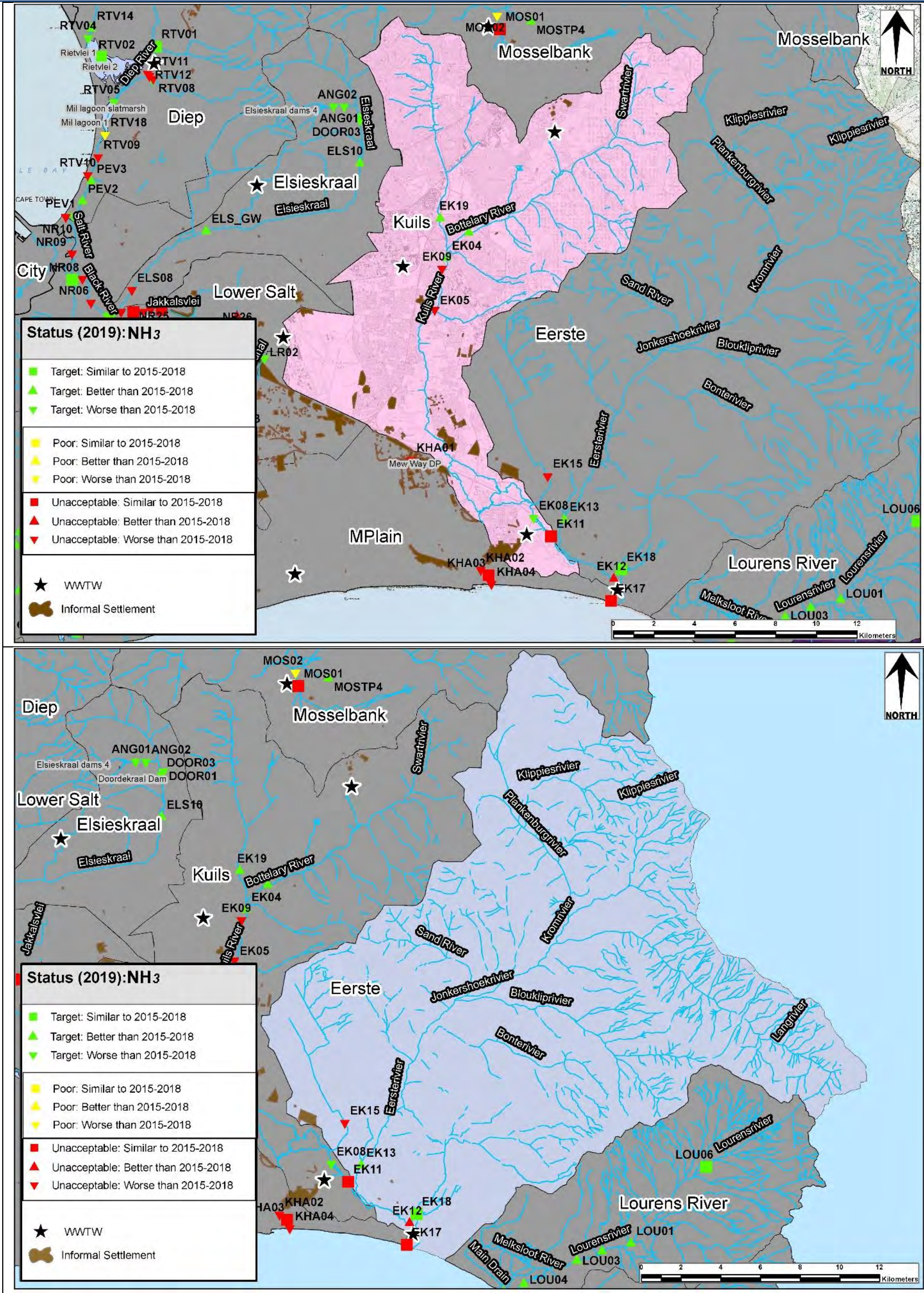



**Figure 4.6.2 CONTD Median annual NH3-N concentrations, presented per subcatchment. Data coded as to level of change in 2019 dataset compared to previous 4 year median data. First figure shows order of presentation of subcatchment maps**

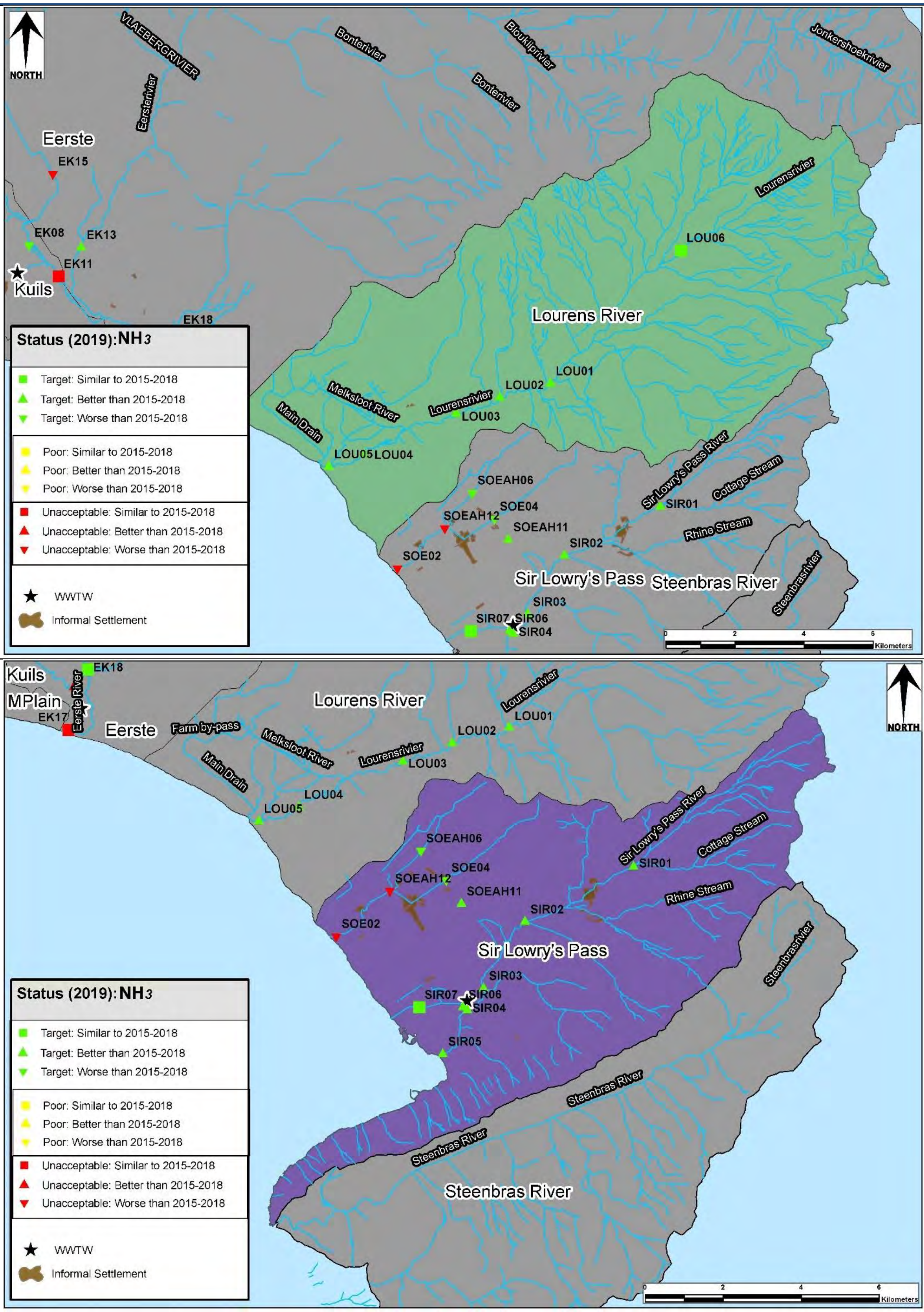
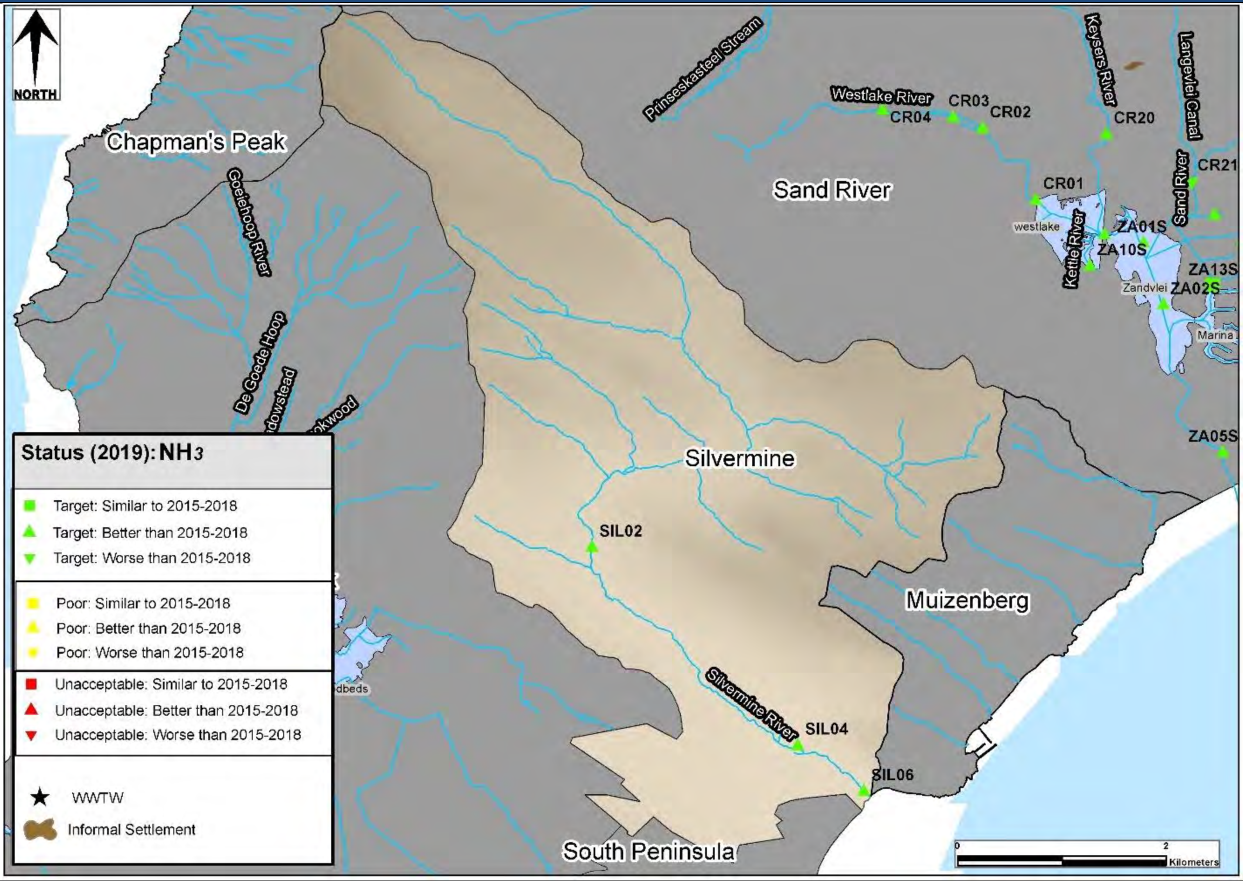



**Figure 4.6.2 CONTD Median annual NH3-N concentrations, presented per subcatchment. Data coded as to level of change in 2019 dataset compared to previous 4 year median data. First figure shows order of presentation of subcatchment maps**



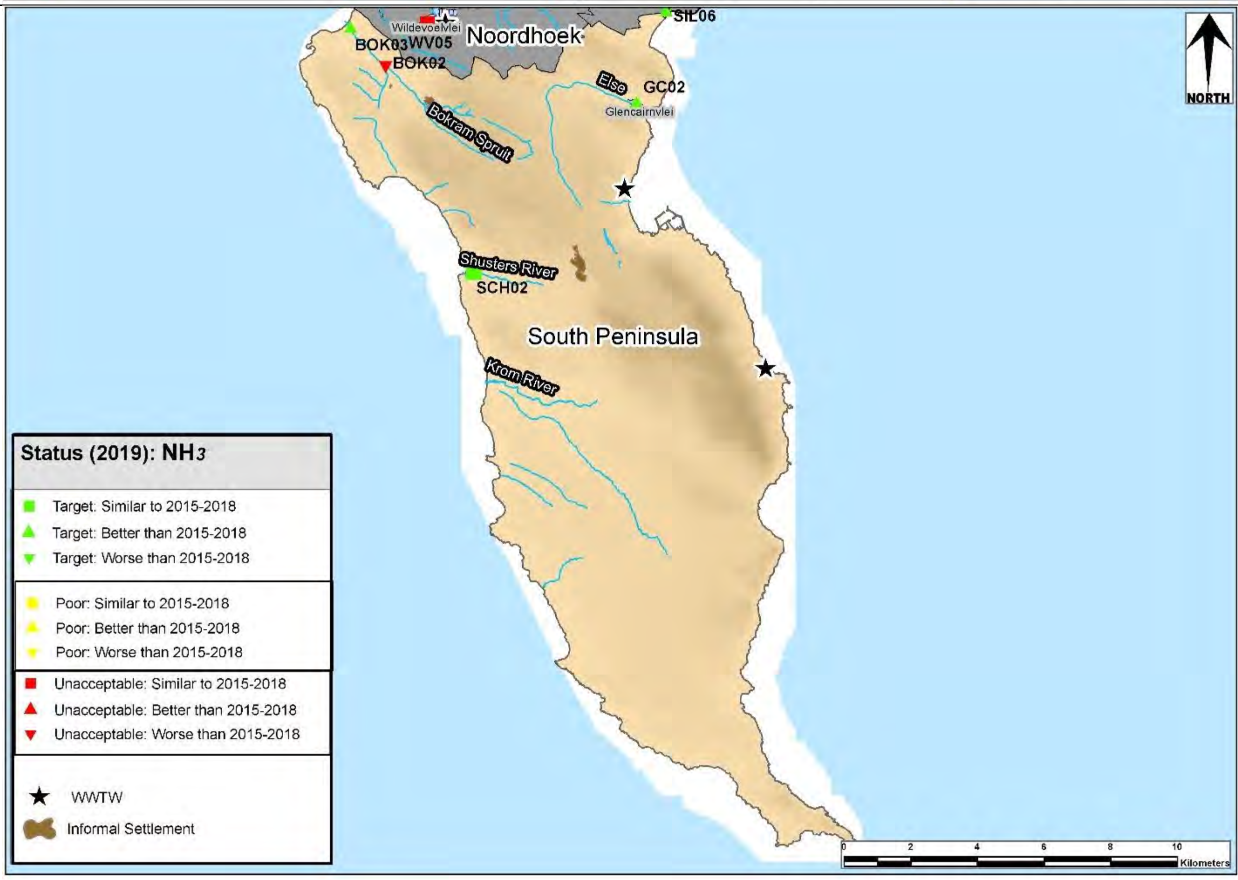
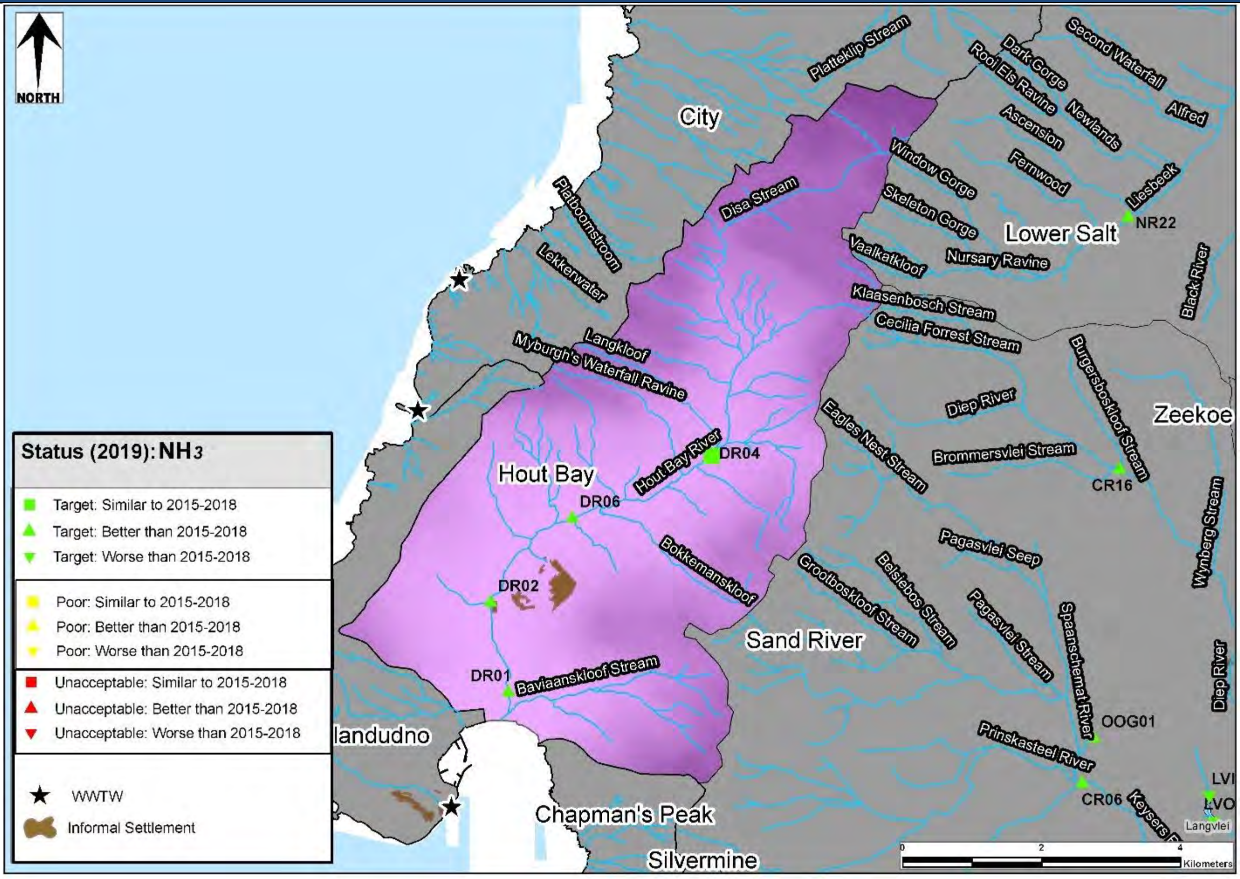




**Figure 4.6.2 CONTD Median annual NH3-N concentrations, presented per subcatchment. Data coded as to level of change in 2019 dataset compared to previous 4 year median data. First figure shows order of presentation of subcatchment maps**



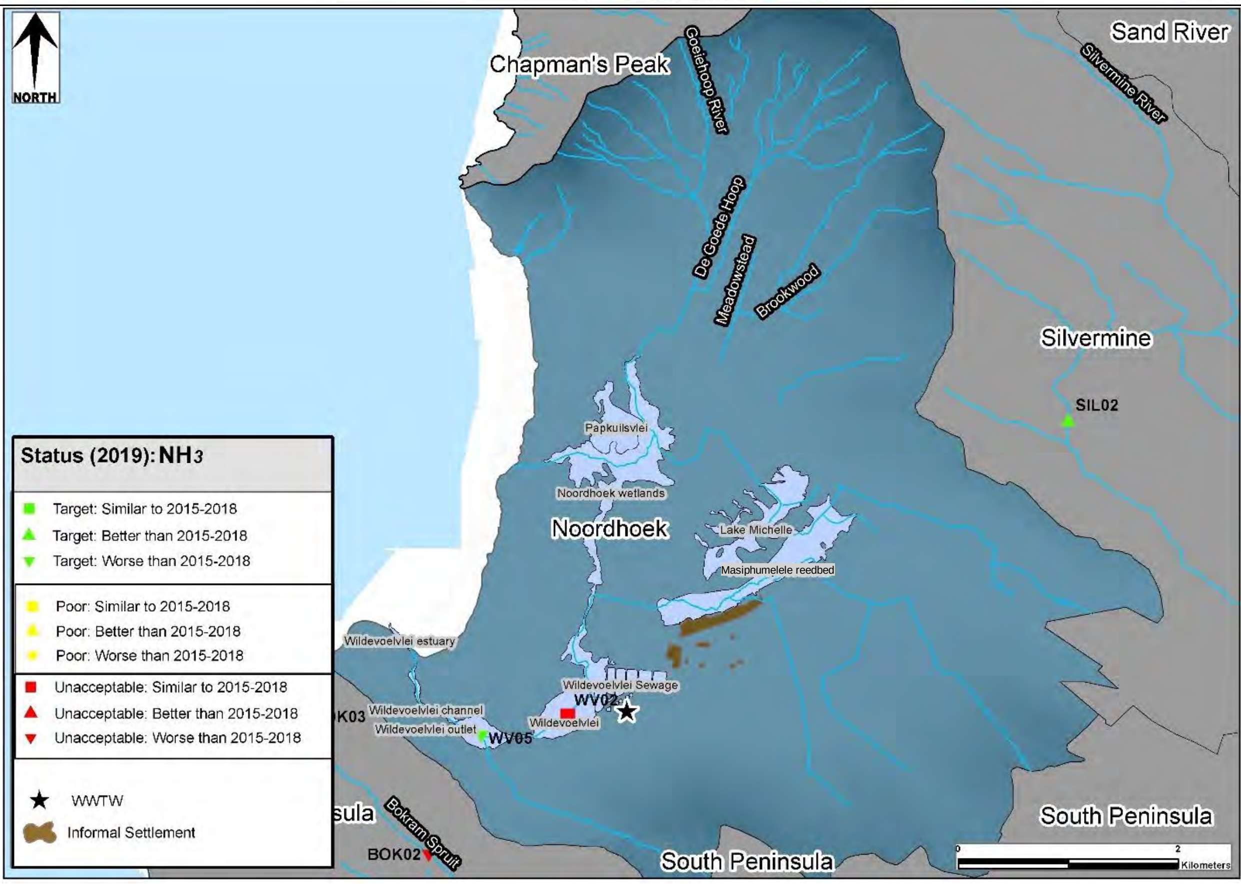




**Figure 4.6.2 CONTD Median annual NH3-N concentrations, presented per subcatchment. Data coded as to level of change in 2019 dataset compared to previous 4 year median data. First figure shows order of presentation of subcatchment maps**

## 4.7 *Escherichia coli* contamination

### *4.7.1 Relevance*

*E. coli* measurements are used primarily as an indicator of human health risk, particularly for drinking or recreational use of a waterbody. Consideration of this parameter is, therefore, of most relevance to the established recreational vlei systems in the City of Cape Town where a range of watersports and/or other water-based activities are known to take place (i.e. Zandvlei, Zeekoevlei, Rietvlei, Milnerton Lagoon and Princessvlei, as dealt with in **Section 5.2**). The current section has been included in this report to evaluate the potential recreational fitness-for-use of rivers and vlei systems within the City that are <u>not</u> known to be major / established recreational waterbodies.

> ***Escherichia coli*** (abbreviated *E. coli*) is a species of faecal coliform bacteria that is commonly found in the lower intestine of warm-blooded organisms (birds and mammals). Most *E. coli* strains are harmless, but some can cause serious food poisoning in humans. Their presence in the water is used as an "indicator" of faecal contamination of avian or mammalian origin, and therefore are indicative of other pathogens that *may* be present in faeces.

### *4.7.2 Risk levels*

The recreational risk ratings applied in the current assessment include *E. coli* thresholds for both full contact (i.e. swimming) and intermediate contact (e.g. canoeing, sailing), as explained in Section 2.8 (see **Table 2.8.4**). Ranges are provided for "Target" (acceptable risk), "Poor" (tolerable risk) and "Unacceptable" (high risk). Three levels of "Unacceptable" are provided for, to aid in the identification of areas where there is extreme exceedance of the high-risk threshold for *E. coli.*

> **Context of "risk"**
>
> It is <u>estimated</u> that at least 2400 *E. coli* organisms need to be ingested by a person (man, woman or child) in order for 50% of those ingesting the water to develop a subsequent (usually gastrointestinal) infection as a direct result of ingesting the contaminated water. To put this in perspective, and taking in to account the different size of an average mouthful for an average man (35.2ml), woman (26.3 ml) and child (9.3 ml), the number of mouthfuls of water that each of these individuals would have to swallow in order to incur a 50% level of risk of contracting an infectious disease as a direct result of the ingestion of the contaminated water is shown for the water quality threshold levels in the table below (Source: PDNA 2011).

### *4.7.3 Historical trajectory of change*

**Figures 4.7.1** and **4.7.2** present the percentage of samples in each of the above-mentioned risk categories for recreational use for each 5-year period for which *E. coli* data were recorded in each subcatchment, in rivers / stormwater channels and standing water bodies respectively. No data were available prior to 1990 in any subcatchment, with *E. coli* data specifically only being recorded from 1995 or later in most subcatchments (with the exception of the Sand and Zeekoe subcatchments).

The long-term summary of **river and stormwater** data in **Figure 4.7.1** suggest:

- There has been a high degree of variability between subcatchments throughout the monitoring time span;
- The Lourens, Sout and Silvermine River subcatchments all have a history of low levels of *E. coli* contamination, with 90% or more of the samples in most five-year periods having been in the acceptable or tolerable risk categories;
- The Diep, Mosselbank, Sir Lowry's Pass and Sand River subcatchments, and the Elsieskraal subcatchment with the exception of 2000-2005, also have a history of relatively low levels of *E. coli* contamination, with 60-70% of the samples (or more) in the acceptable or tolerable risk categories in each five-year period;

- Subcatchments in which *E. coli* contamination has been a significant and ongoing concern were the Kuils and Lower Salt, where less than 40% of the samples were in the acceptable or tolerable risk categories for most five-year periods (with the exception of the Lower Salt subcatchment in 2010-2015 where 45-50% of the samples were in the tolerable to acceptable range);
- The only trends that are apparent from the data are a deterioration in the Hout Bay River subcatchment from 2000 onwards and an improvement in the Zeekoe subcatchment from 2005 onwards.

The long-term summary of **vlei and dam** data in **Figures 4.7.2** suggests that:

- The Rietvlei, Westlake, Zandvlei, Rondevlei, Die Oog, Wildevoelvlei and Princessvlei waterbodies, as well as Zeekoevlei in all 5-year periods except 2005-2010, and Glencairnvlei in all 5-year periods except 2015-2020, all have a history of low levels of *E. coli* contamination, with 90% or more of the samples in most five-year periods having been in or close to the acceptable or tolerable risk categories;
- The worst performing waterbodies were the Mew Way and Mitchell's Plain detention ponds, where 95 to 100% of the samples in all years of sampling have been in the Unacceptable category – this is not surprising, given that their water is sourced wholly from runoff from highly urbanized areas, parts of which are subject to high levels of waste accumulation;
- On the whole, there were lower levels of *E. coli* contamination and less variability between standing waterbodies, compared with river systems in different subcatchments (compare bottom-right summary graphs in **Figures 4.7.1 and 4.7.2**).

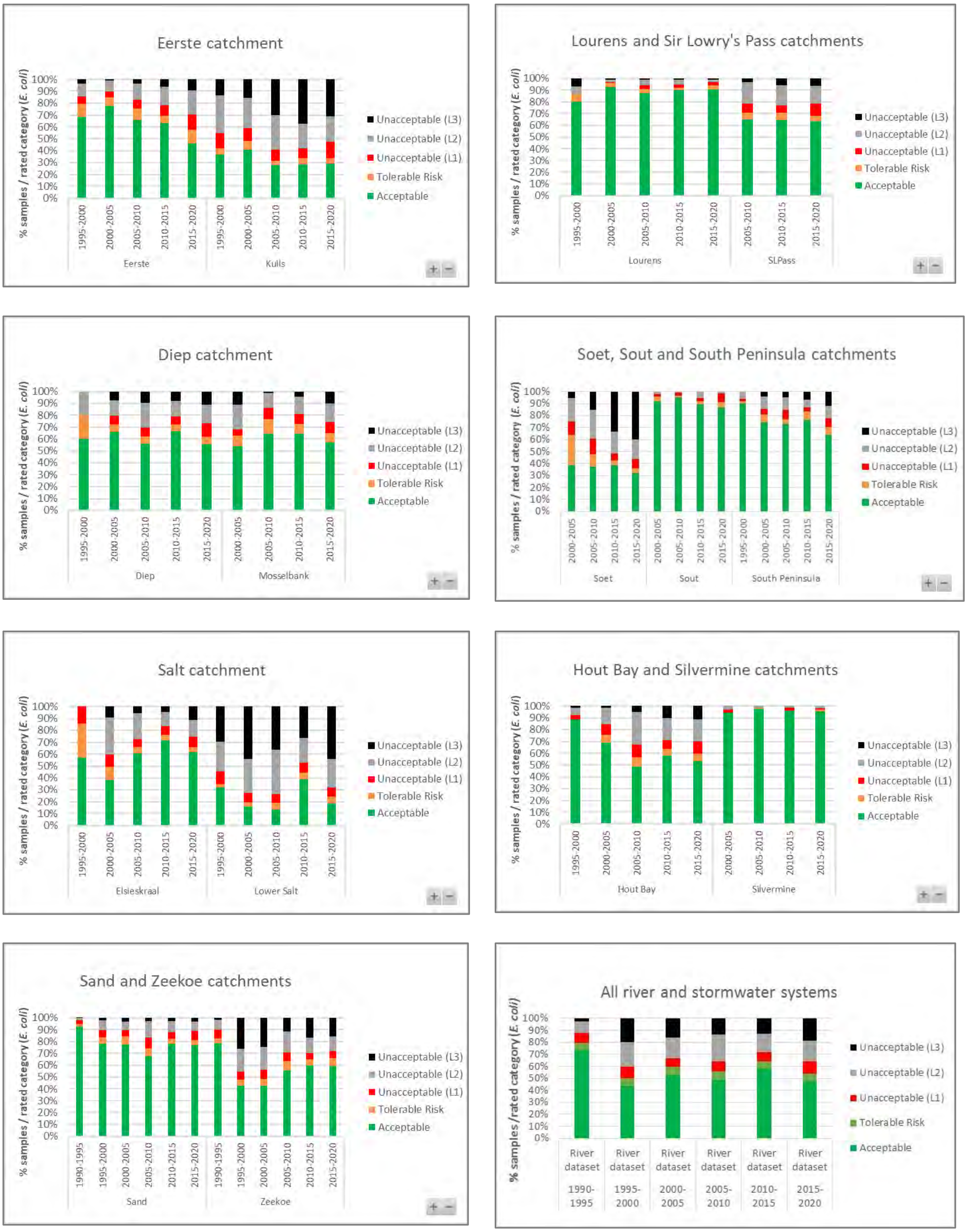



**Figure 4.7.1 Percentage of *E. coli* samples from river / stormwater channel sites in each subcatchment falling within each rated category for this variable. Last (bottom right) graph provides a summary for all river / stormwater sites. Thresholds as defined in Table 2.8.4. Subcatchments as shown in Figure 2.1**

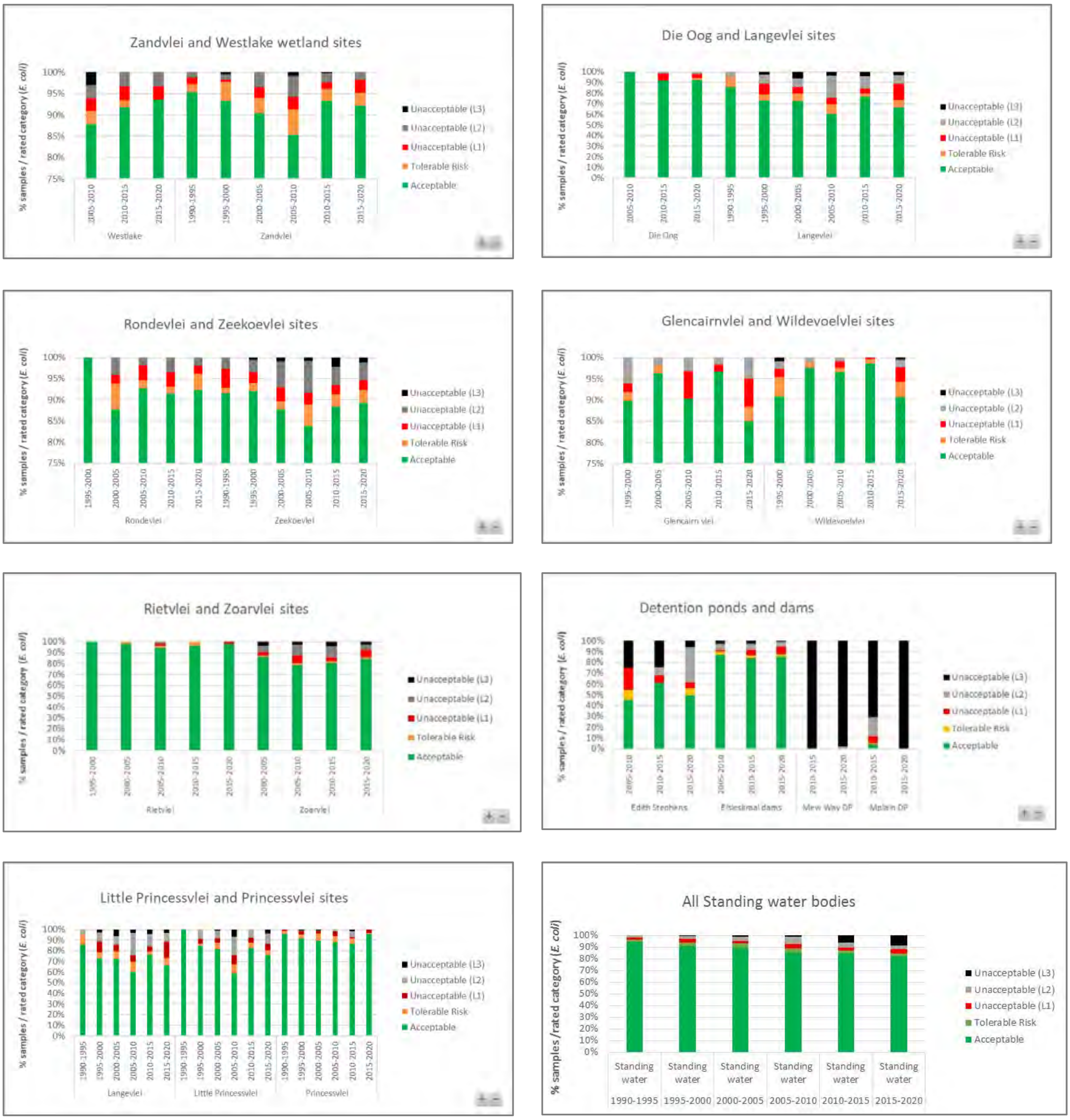



**Figure 4.7.2 Percentage of *E. coli* samples from vlei / dam sites in each subcatchment falling within each rated category for this variable. Last (bottom right) graph provides a summary for all standing waterbody sites. Thresholds as defined in Table 2.8.4. Subcatchments as shown in Figure 2.1**

### *4.7.4 Current state (April 2019 – March 2020)*

**Figures 4.7.3** presents boxplots of *E. coli* data over the most recent monitoring year (referred to as the 2019 dataset) compared to data from the previous four-year period (2015-2018 datasets), for river/ stormwater channels and dams / vleis respectively.

**Figures 4.7.4 – 4.7.5** present the same data, separated into summer and winter seasons.

**Figure 4.7.6** comprises a set of maps, one per catchment, which illustrate the performance of individual sites in the 2019 period, by comparing annual geometric mean *E. coli* concentrations for 2019 with the 2015-2018 geometric mean.

With regard to **river and stormwater systems**, the data illustrate the same broad trends discussed in the previous section, with the following specific aspects being noted:

- River and stormwater channels in the City were generally not fit for safe full contact recreational use (e.g. swimming and wading) – the Silvermine River was the only subcatchment where the 25$^{th}$ -75$^{th}$ percentile fell entirely within the range of Acceptable for full contact recreational use, and even this subcatchment had periodic samples with *E. coli* concentrations well above the levels of Unacceptable for intermediate contact use;
- Of all the subcatchments, the Silvermine, Lourens and Sout River were least-impacted over the 2015-2018 and 2019 monitoring periods, with median and 25$^{th}$ -75$^{th}$ percentile data (i.e. the boxes of the boxplots) all within the Target for safe intermediate contact recreational use. Neither the Lourens nor the Silvermine River have informal settlements or WWTW discharges within their catchments. The Sout River, by contrast, receives treated effluent from the Melkbosstrand WWTW upstream of the sampling sites, and the data suggest high efficacy of these works at least in terms of *E. coli* treatment (possibly facilitated by the naturally high salinity levels in the Sout River system, which would assist with the die-off of some bacteria, such as *E. coli*);
- Subcatchments of concern, where median *E. coli* values lay well within the Unacceptable range for intermediate contact recreation, and the 75% percentile extended far further into the Unacceptable range, comprised the Lower Salt, Soet and Elsieskraal subcatchments throughout the monitoring period, the Kuils in the 2015-2018 period, and the Diep in the 2019 period. These subcatchments lie in highly urbanized areas, with the Lower Salt including inflows from WWTWs as well as poorly serviced informal and backyard settlements; the Elsieskraal in its reaches through Bellville being affected by areas of inner city homelessness (Day 2020); the Soet passing through areas with high rates of informal settlement and the Diep including treated effluent from the Potsdam WWTW, as well as runoff from poorly serviced dense informal settlements such as Du Noon and Jo Slovo settlements upstream (Cerfonteyn and Day 2011). Consideration of the relevant maps in **Figure 4.7.6** suggests that the upper reaches of the Elsieskraal subcatchment are relatively uncontaminated by *E. coli*; and the Liesbeek River reaches of the Lower Salt subcatchment have the least affected monitoring sites in this subcatchment (albeit still in a Poor condition);
- Subcatchments that showed problematic but generally lower levels of *E. coli* contamination, with the 75$^{th}$ percentile ranging between Poor and the lower end of Unacceptable, were the Mosselbank, Diep (2015 – 2018 data), Sand, Zeekoe, Eerste, Sir Lowry's Pass, South Peninsula and Hout Bay subcatchments. The maps in **Figure 4.7.6** clearly illustrate the effect of runoff from the Imizamo Yethu informal settlement on *E. coli* concentrations in the Hout Bay subcatchment, with the downstream site showing Unacceptable mean *E. coli* concentrations in 2019, compared with upstream sites still within Target ranges. Low-flow stormwater from the Imizamo Yethu settlement is diverted to sewer – but clearly volumes of contaminated greywater runoff still pass into the river system, affecting water quality as far as the beach;

- In the South Peninsula subcatchment, the Schusters and Else Rivers showed mean annual *E. coli* concentrations in 2019 of Target and Poor, respectively, while the Bokramspruit sites (downstream of Ocean View with some backyard dwellers and poor servicing) were well within the range of Unacceptable (see relevant map in **Figure 4.7.6**);
- The stormwater and river channels of the Zeekoe subcatchment, by contrast, were almost all in the Unacceptable range, indicating a subcatchment where poor sanitation and poor servicing seem to be prevalent;
- Overall, the data shown in **Figure 4.7.3** also illustrate that all subcatchments were exposed to periodic high levels of *E. coli* contamination, possibly reflecting intermittent sewage leaks or overflows (see Section 2.3).
- Analysis of seasonal data shown in **Figure 4.7.4** did not show any clear trends, although there was some tendency for Winter samples in the Hout Bay, Sir Lowry's Pass and Zeekoe subcatchments to be slightly higher than those in summer, possibly reflecting surface wash events during rainfall, when contaminated channels and surfaces are flushed into the river system as a contaminated plug.

**Caution**

It should be remembered that *E. coli* is used as an indicator of contamination of waters by faecal material from warm blooded animals. Even if *E. coli* has died off as a result of exposure to sunlight, other health risks derived from faeces may remain in the water, including nematode eggs and cysts, other parasites, protists and bacteria.

*E. coli* contamination in the standing water bodies (vleis and dams) that were assessed showed slightly different patterns to rivers in the respective subcatchments, reflecting the capacity of these open water systems for bacterial reduction with exposure to sunlight in standing waters (as already indicated in the compliance data presented in Section 4.7.3). The boxplot data, shown in **Figures 4.7.3** to **4.7.5**, and the site-specific data for 2019 presented on the subcatchment-scale maps in **Figure 4.7.6**, suggest:

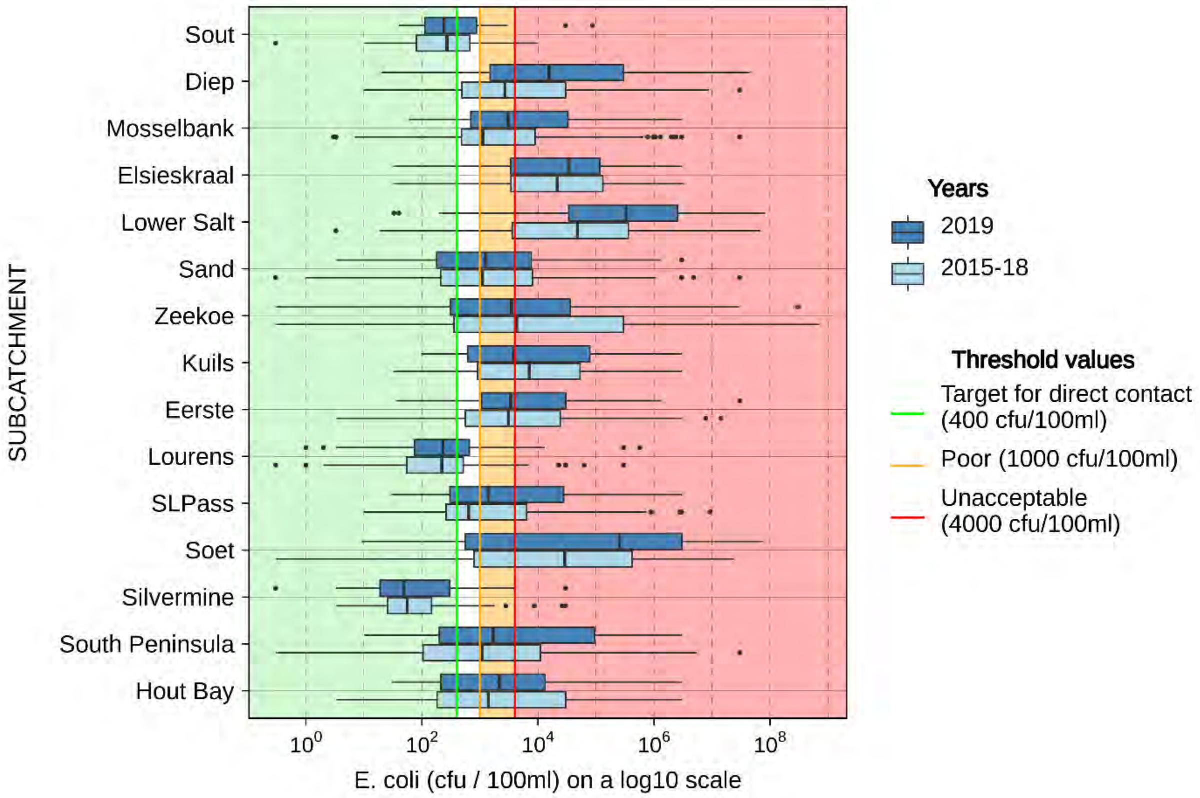
- Generally, the open waterbodies that were assessed are subject to less contamination by *E. coli* than rivers in the City, with median and at least 75$^{th}$ percentile values lying with Target ranges for full contact recreation in Rietvlei, Princessvlei, Zeekoevlei, Rondevlei, Westlake wetlands, and Wildevoelvlei;
- Median and up to 75$^{th}$ percentile values for Die Oog, Zoarvlei, Zandvlei, the Elsieskraal dams and Edith Stephens detention pond (2019) were elevated compared to the systems listed above, but still lay within the Acceptable range for Intermediate contact recreation (i.e. Poor to Target);
- Waterbodies subject to greater levels of *E. coli* contamination comprised Langevlei and Glencairnvlei in 2019, and Edith Stephens detention pond in the 2015-2018 period – samples from these systems fell more frequently within the Unacceptable range for intermediate contact recreation;
- The most polluted systems comprised the Mitchell's Plain and Mew Way detention ponds, where samples were always far into the Unacceptable range for intermediate contact recreation. This reflects contaminated stormwater runoff from the Mitchell's Plain subcatchment, which has no rivers and is characterized by high levels of poorly serviced informal settlements;
- The above patterns notwithstanding, it must be stressed that all the assessed water bodies showed periodic elevations in *E. coli* well above Target Full or Acceptable Intermediate Contact ranges, and their use for these purposes at times would have been associated with high risk;
- With regard to seasonality (see **Figure 4.7.5**):
    - Rietvlei, Zoarvlei, Princessvlei, the Elsieskraal dams, Zeekoevlei, Zandvlei and Edith Stephens detention pond (2015-18) all showed clear increases in *E. coli* in winter compared to summer. This could reflect increased catchment-scale runoff into these systems in the wet season. In the case of Zeekoevlei, which is partially drained for parts of winter and attracts large numbers of wading birds as a result, this could also reflect increased bird inputs, although it

can also be argued that the outlet weir is open for much of winter during draw-down, so residence time is shorter, and dilution of inflowing pollution plugs is less, leading to higher winter concentrations;

  - No marked differences were noted between summer and winter median *E. coli* values or the interquartile range for the other open waterbodies that were assessed.

- Of some concern is the fact that there are areas in the City where standing water bodies are used for recreation by members of the public, but where there is no regular monitoring of human health risk. An example of this is the use of a section of the Kuils River in the Khayelitsha Wetland Park area, where local communities participate in kayak polo games and training. Given that the lower reaches of the Kuils River do appear to be associated at times with significant *E. coli* contamination, consideration should be given to periodic ongoing monitoring in the actual area used for this sport, by adding this location to the existing water quality monitoring sites on the Kuils system.

The following section (Section 5) provides a more in-depth look at *E. coli* contamination and other issues affecting the recreational use of the City's main recreational vleis.



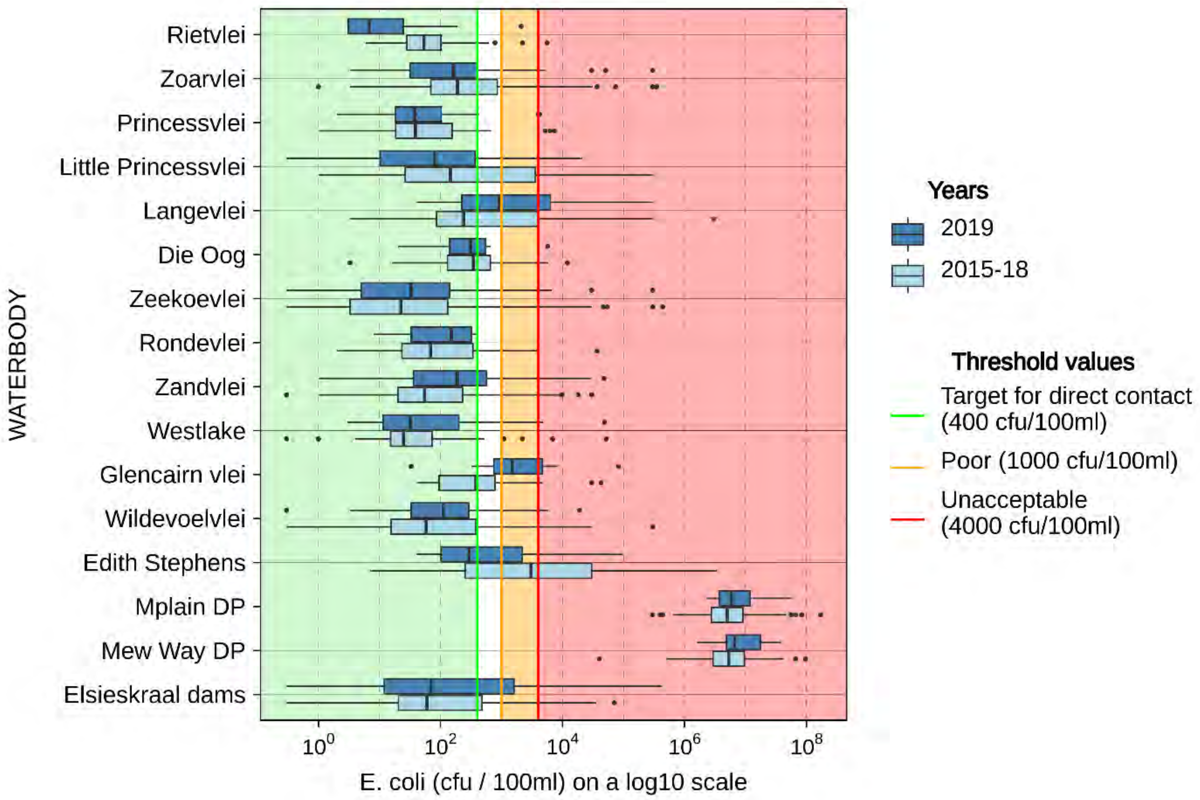




**Figure 4.7.3 Comparison of current (April 2019 to March 2020) *E. coli* data with data from the previous 4 year record per subcatchment, plotted against the thresholds for different levels of risk.**

**Top: Rivers and stormwater systems; Bottom: Vleis and Dams.**

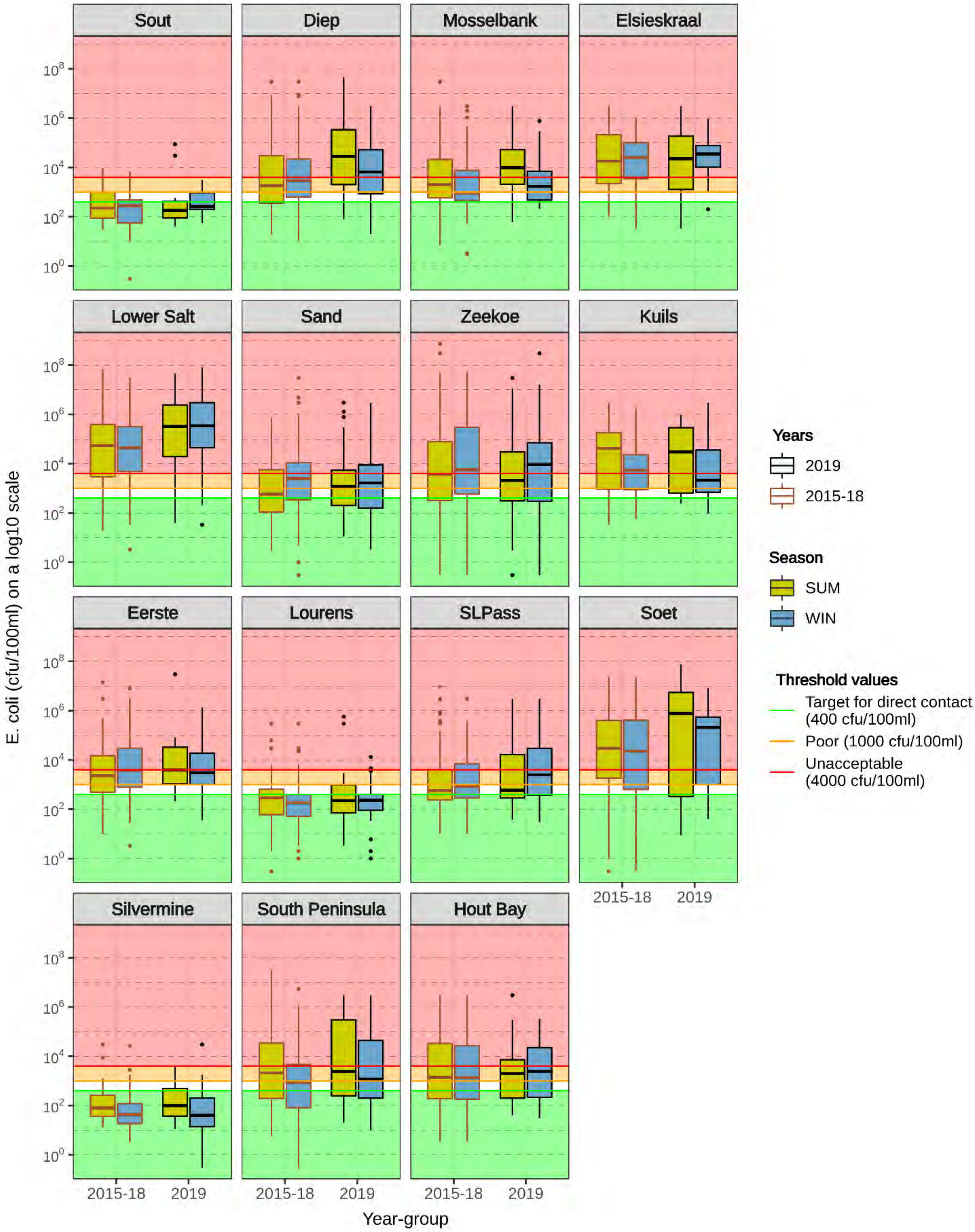



**Figure 4.7.4 Comparison of current (April 2019 to March 2020) *E. coli* data with data from the previous 4 year record per subcatchment showing seasonal variability, plotted against the thresholds for different levels of risk. Rivers and stormwater channels.**

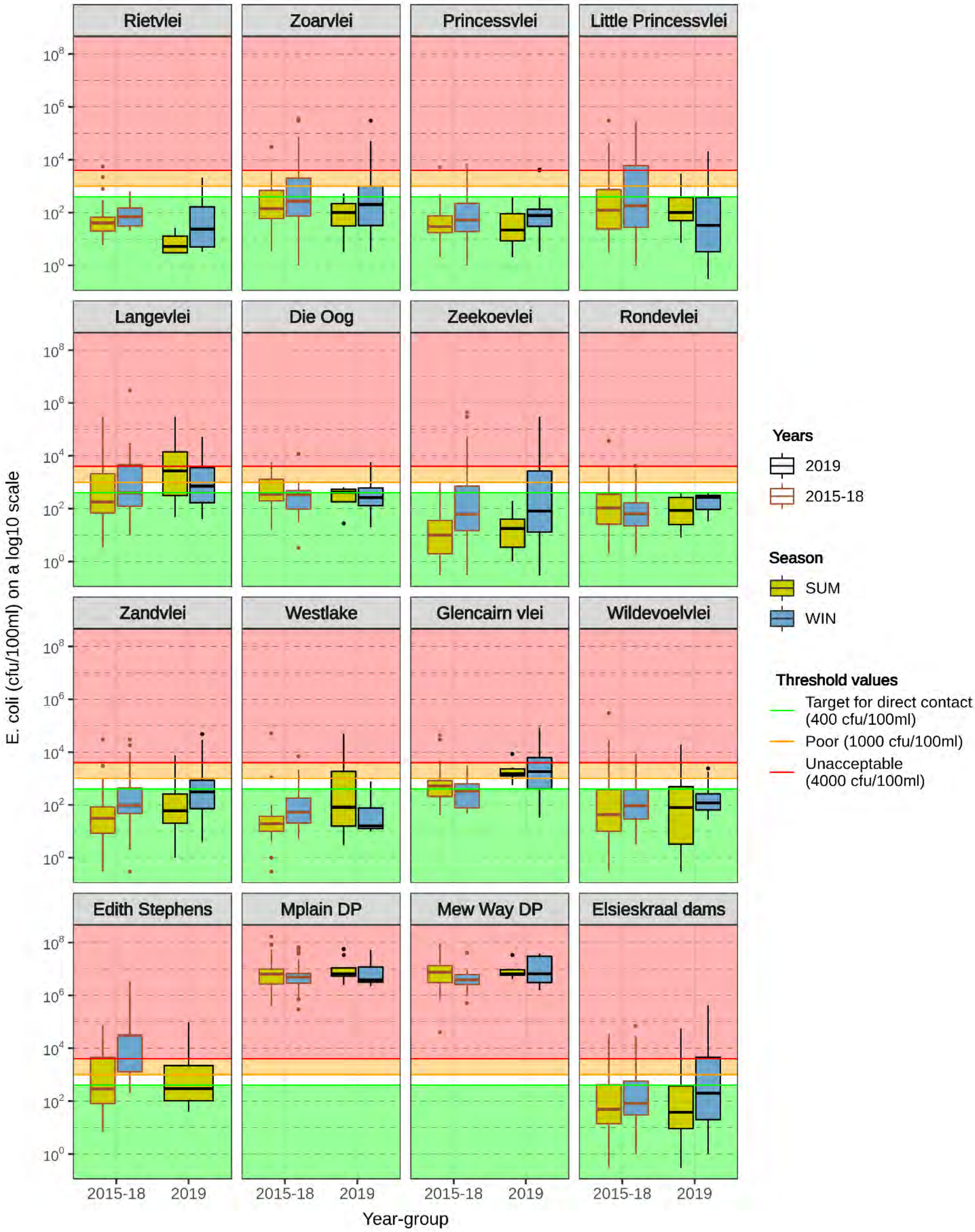



**Figure 4.7.5 Comparison of current (April 2019 to March 2020) *E. coli* data with data from the previous 4 year record per subcatchment showing seasonal variability, plotted against the thresholds for different levels of risk. Vleis and dams.**

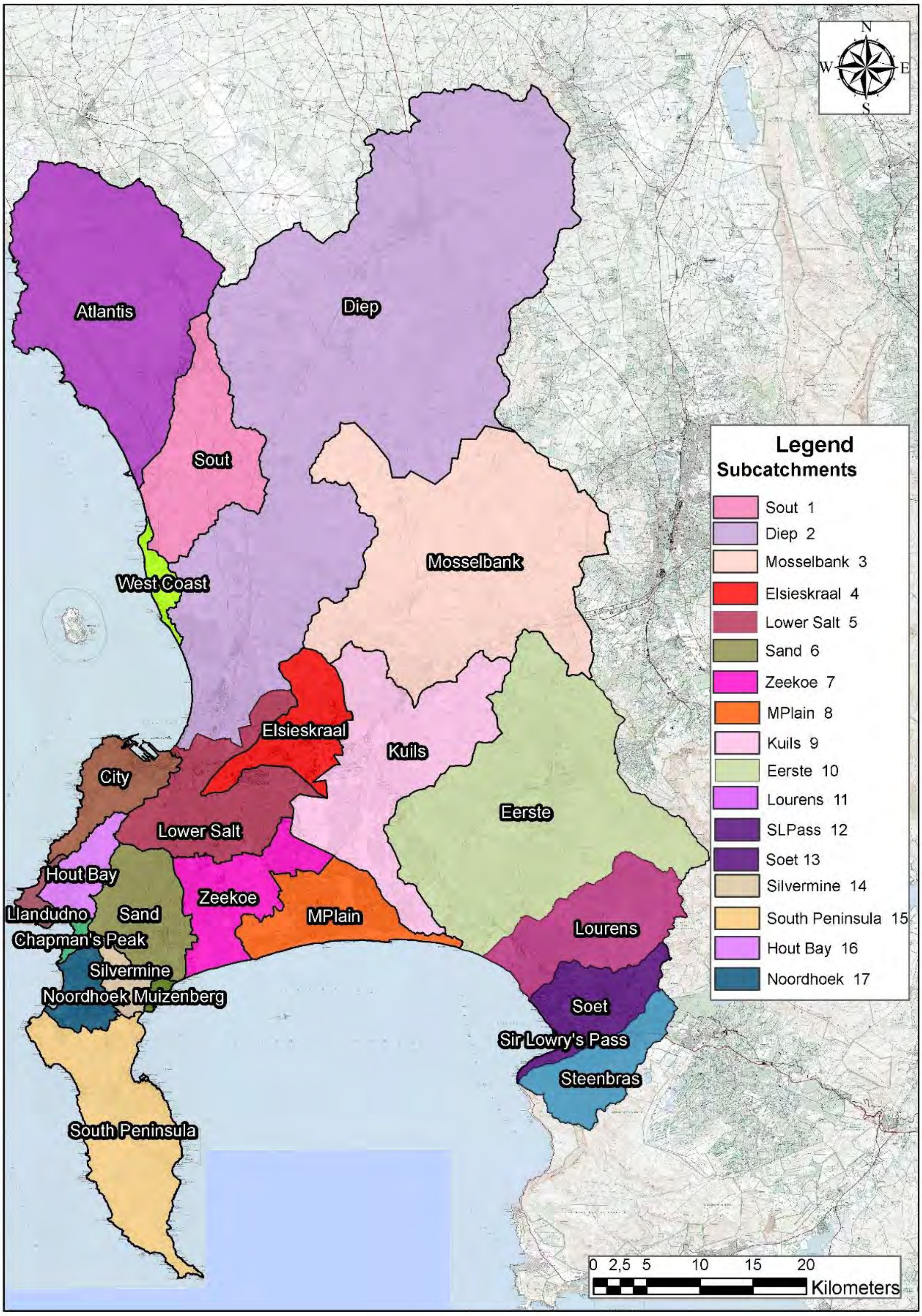
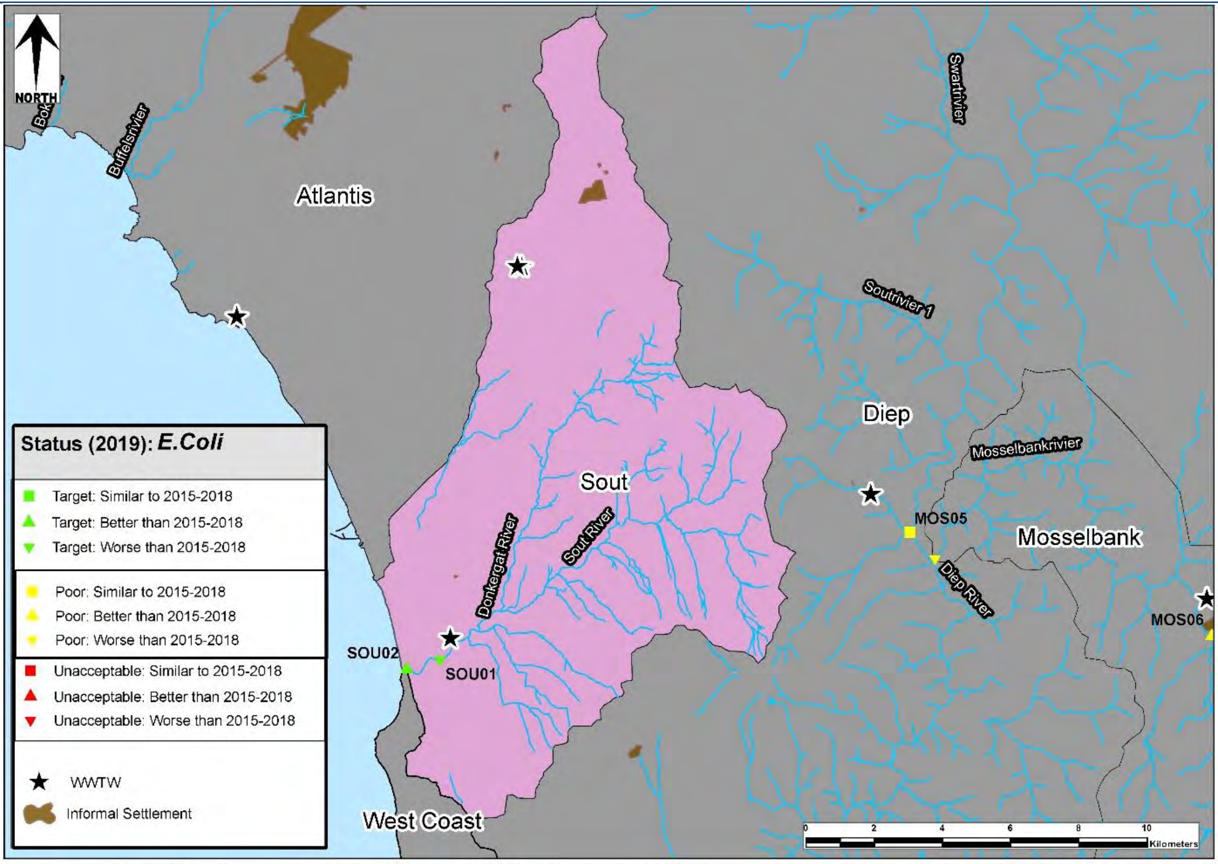



**Figure 4.7.6 Colour-coded categorisation of mean annual *E. coli* densities for each sampling site in 2019, presented presented as a range of maps per subcatchment. Data coded as to level of change compared to previous 4 year median dataset. Subcatchments presented in numbered order as shown in this map. See following maps for actual data.**



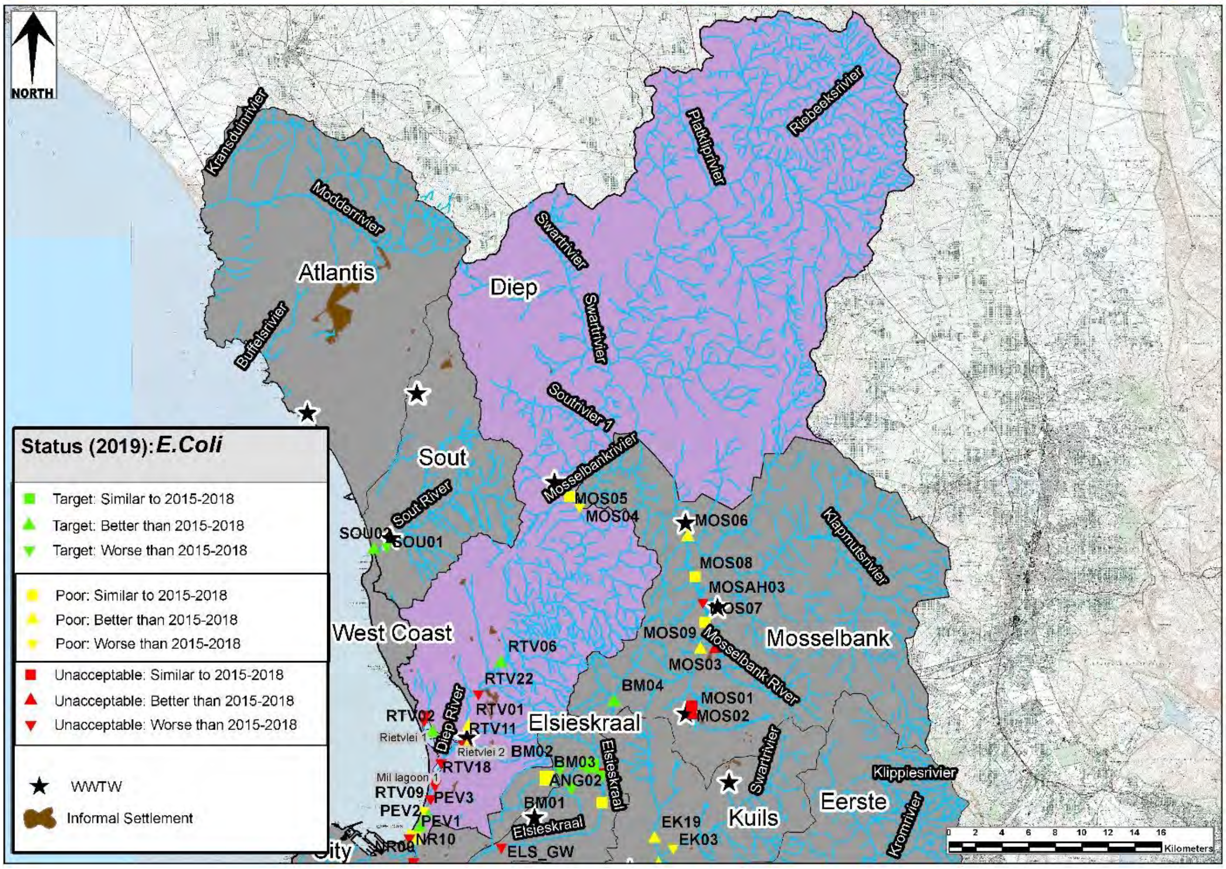




**Figure 4.7.6 (CONTD) Colour-coded categorisation of mean annual *E. coli* densities for each sampling site in 2019, presented per subcatchment. Symbols indicate trajectory of change compared to median for previous 4 years. Subcatchments presented in the order shown in the top map.**

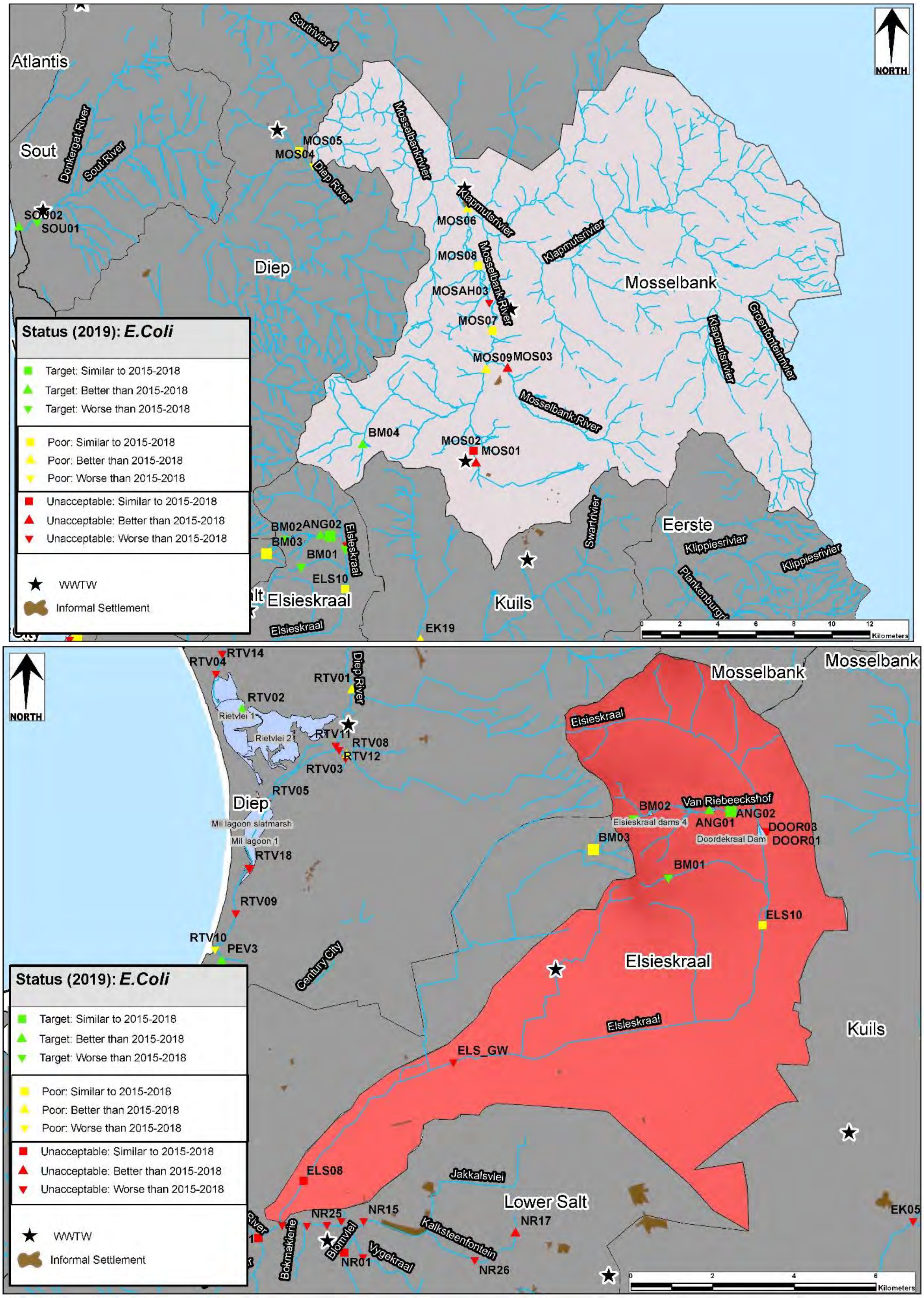



**Figure 4.7.6 (CONTD) Colour-coded categorisation of mean annual *E. coli* densities for each sampling site in 2019, presented per subcatchment. Symbols indicate trajectory of change compared to median for previous 4 years. Subcatchments presented in the order shown in the top map.**

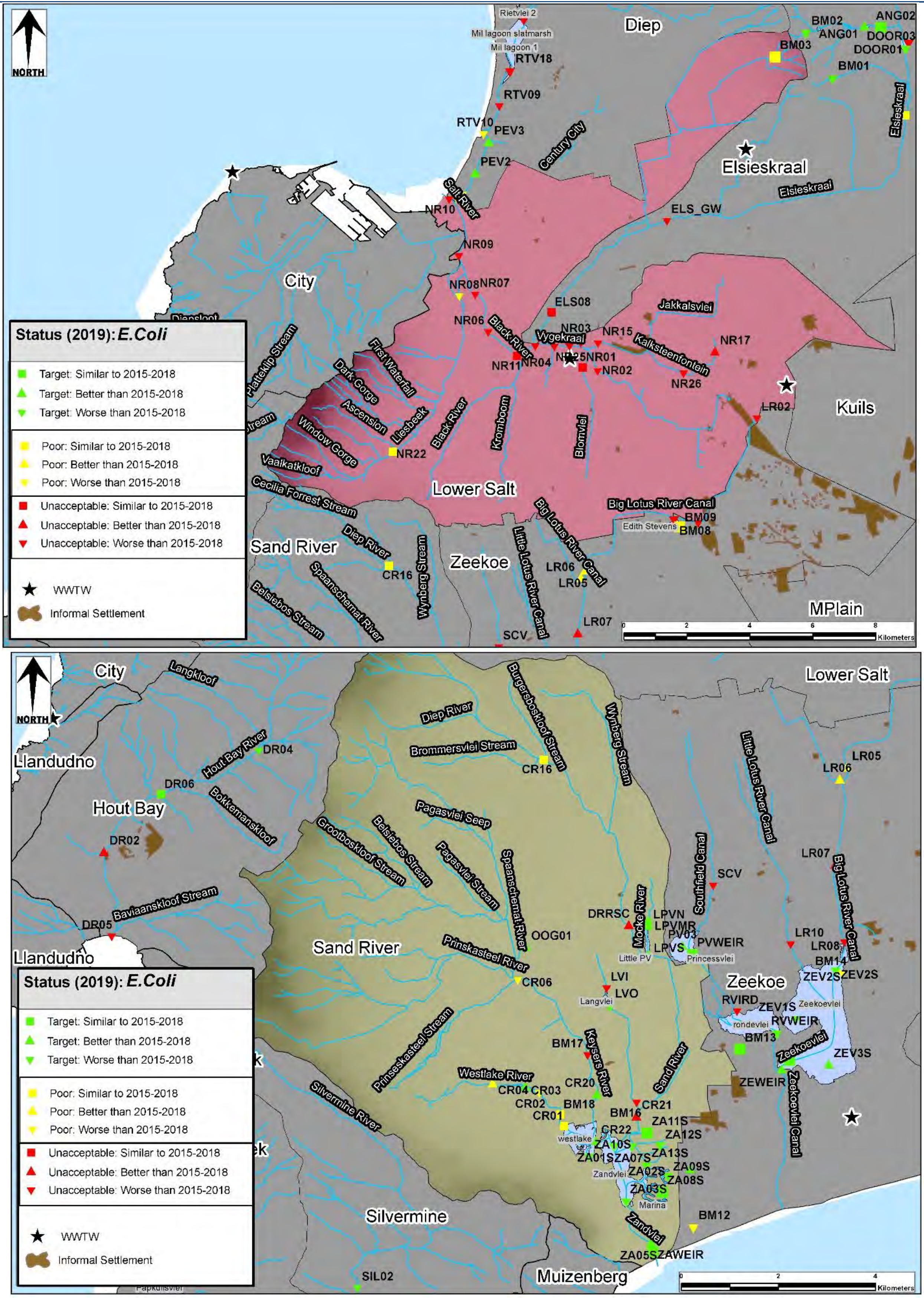



**Figure 4.7.6 (CONTD) Colour-coded categorisation of mean annual *E. coli* densities for each sampling site in 2019, presented per subcatchment. Symbols indicate trajectory of change compared to median for previous 4 years. Subcatchments presented in the order shown in the top map.**

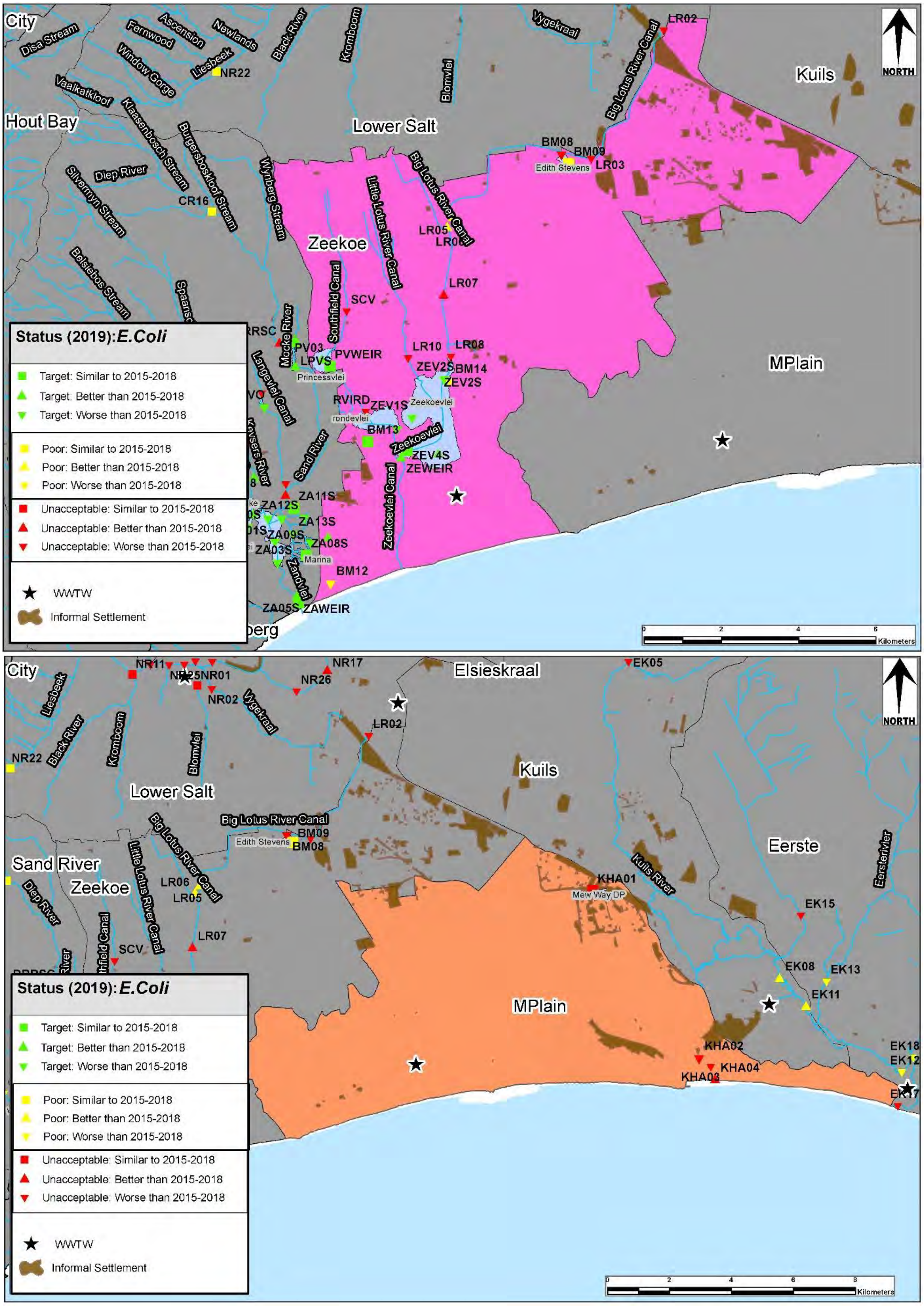



**Figure 4.7.6 (CONTD) Colour-coded categorisation of mean annual *E. coli* densities for each sampling site in 2019, presented per subcatchment. Symbols indicate trajectory of change compared to median for previous 4 years. Subcatchments presented in the order shown in the top map.**

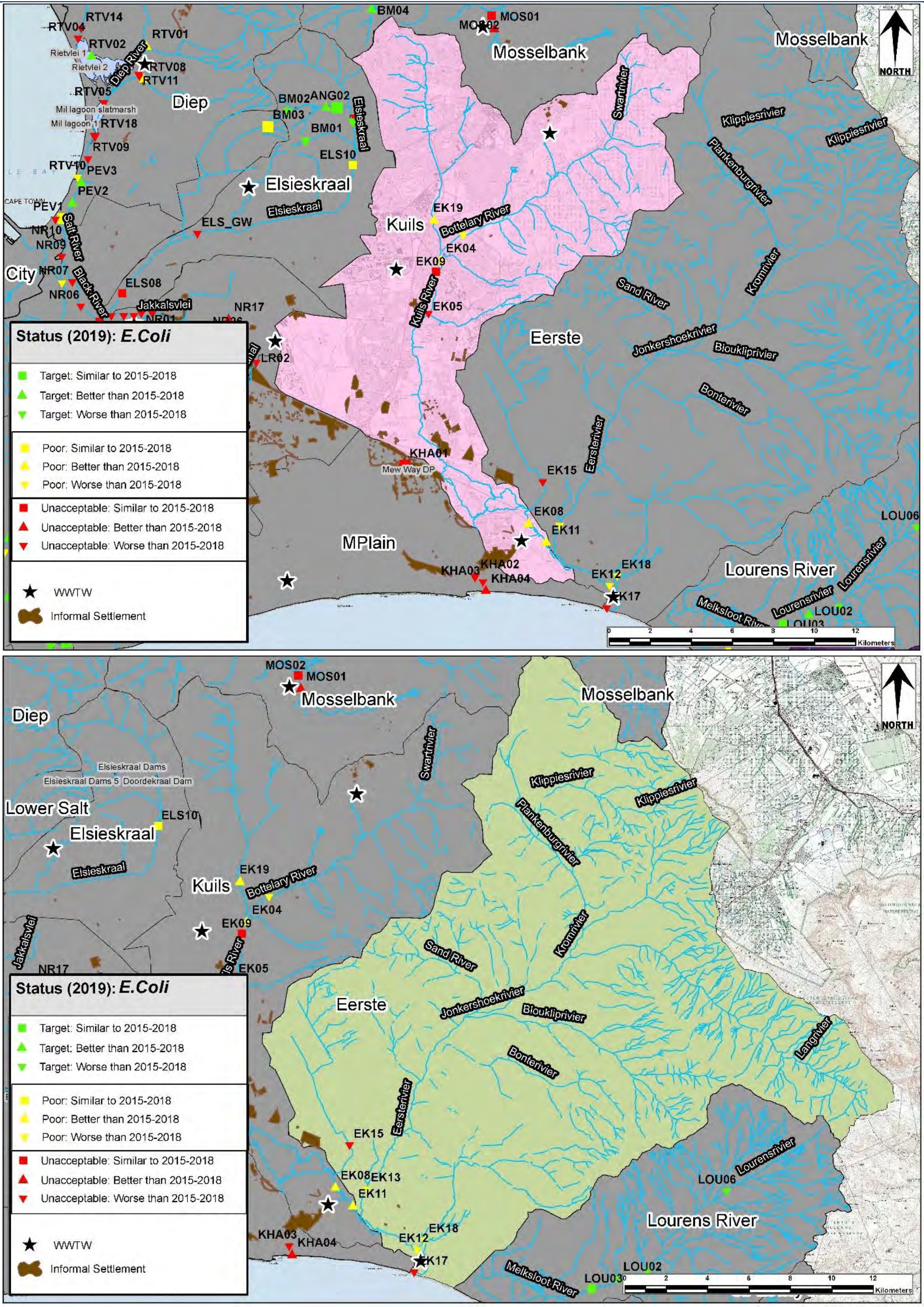



**Figure 4.7.6 (CONTD) Colour-coded categorisation of mean annual *E. coli* densities for each sampling site in 2019, presented per subcatchment. Symbols indicate trajectory of change compared to median for previous 4 years. Subcatchments presented in the order shown in the top map.**

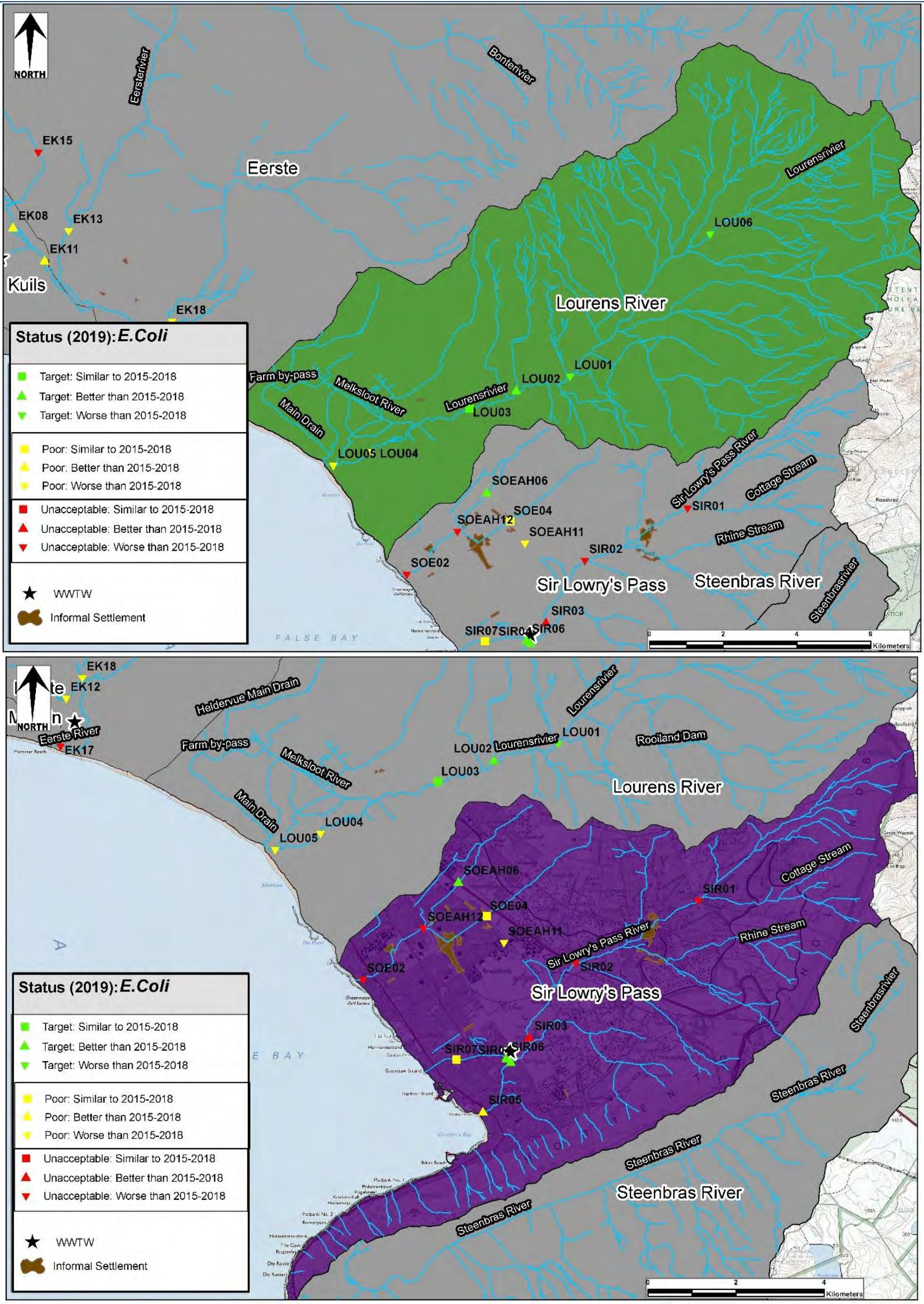
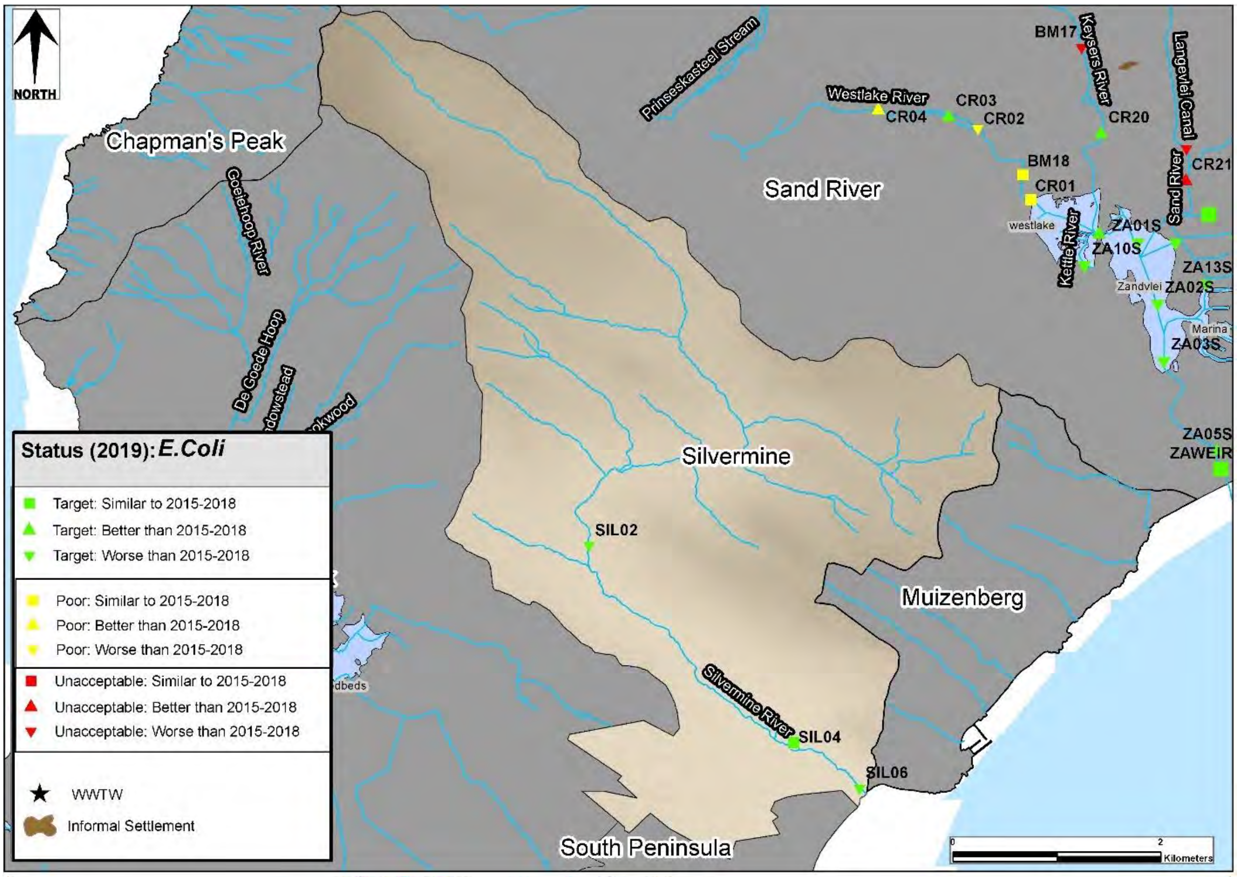



**Figure 4.7.6 (CONTD) Colour-coded categorisation of mean annual *E. coli* densities for each sampling site in 2019, presented per subcatchment. Symbols indicate trajectory of change compared to median for previous 4 years. Subcatchments presented in the order shown in the top map.**



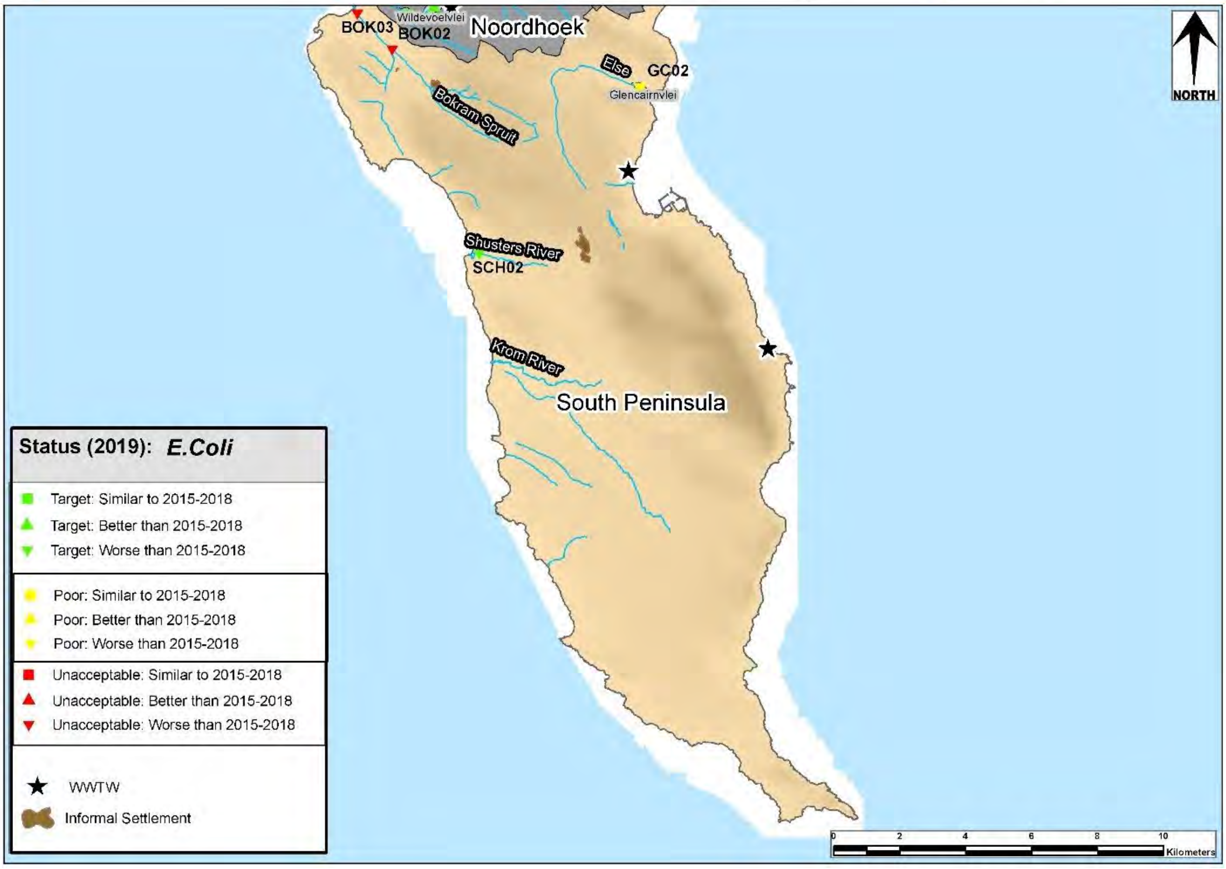




**Figure 4.7.6 (CONTD) Colour-coded categorisation of mean annual *E. coli* densities for each sampling site in 2019, presented per subcatchment. Symbols indicate trajectory of change compared to median for previous 4 years. Subcatchments presented in the order shown in the top map.**

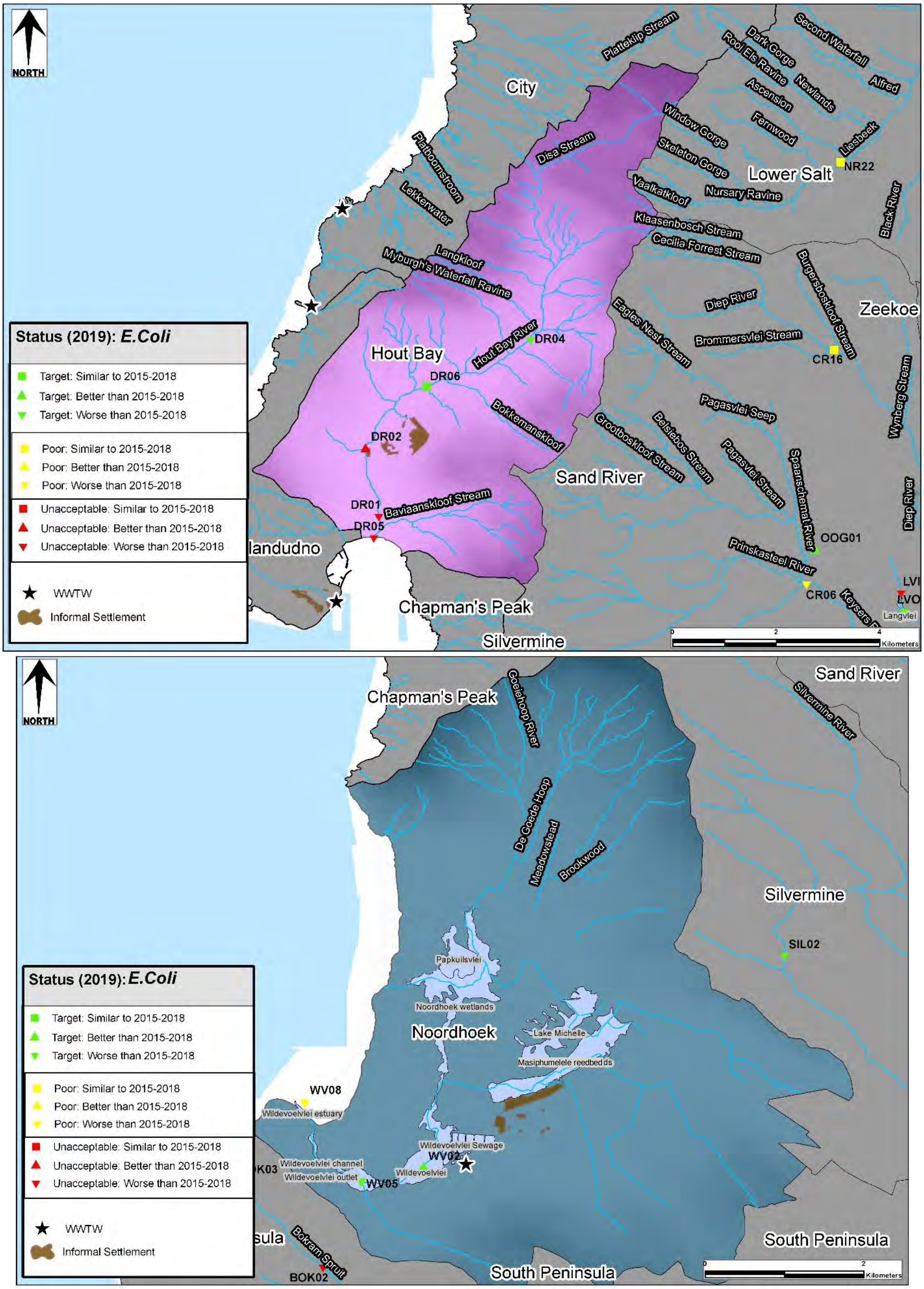



**Figure 4.7.6 (CONTD) Colour-coded categorisation of mean annual *E. coli* densities for each sampling site in 2019, presented per subcatchment. Symbols indicate trajectory of change compared to median for previous 4 years. Subcatchments presented in the order shown in the top map.**

# 5 CURRENT STATE OF RECREATIONAL AREAS (VLEIS)

This chapter has been included to deal specifically with the current state of the established recreational vlei systems in the City of Cape Town from a human health risk perspective. The five main recreational waterbodies that have been considered (as identified in consultation with the City of Cape Town) are as follows:

- Rietvlei;
- Milnerton Lagoon;
- Princessvlei;
- Zeekoevlei; and
- Zandvlei.

A range of watersports are known to take place in these waterbodies, such as rowing, paddling/canoeing, sailing, kite surfing, windsurfing, water-skiing, fishing, wading, and some swimming (mostly children splashing around in the shallows). The exception is Princessvlei, where watersports are not commonly practiced, but this vlei is a known baptism site.

Note that sites in Milnerton lagoon have been included with other "flowing water" (i.e. river, canal or channel) sites in the Diep subcatchment in previous sections of this report, but have been separated out in this section, since this section of the watercourse is a popular recreational area.

## 5.1 Overview of human health risks

Users of recreational waters in the City are potentially exposed to a number of human health risks. Those considered in this water quality assessment are those associated with:

- Exposure to waters contaminated with human faecal material (considered here in terms of microbial indicator data – *E. coli*);

- Exposure to toxins produced by Cyanophytes (also called blue green algae) (considered here in terms of microcystin toxin data).

There are also clearly many other sources of risk to humans who come in contact with urban watercourses, including drowning; entanglement with water weeds or plants; litter and solid waste issues, which are not considered directly in this report. Some of these issues are however indirectly or directly associated with water quality (e.g. eutrophic or hypertrophic systems that encourage high rates of plant growth and nuisance plants in particular).

It is also recognised that in some areas, residents including children informally play, swim, paddle and potentially even wash clothing, cook and drink water from rivers, vleis and other wetlands not considered in this section, without any recourse to its fitness for such uses.

This report focuses on assessment of water quality from the perspective of its fitness to the most reasonable management objective – that of intermediate contact, and it is noted that the City does not recommend that swimming or diving should take place in any urban river, vlei or dam.

**Defining recreational user groups**

Guidelines for inland waters are scaled to take account of different levels of risk associated with different types of recreational activity. The South African guidelines identify three recreational user groups, with different risk profiles, namely full-contact, intermediate-contact and non-contact recreation.

Full contact recreation is defined as full-body water contact, and includes full immersion activities such as swimming and diving. Distinguishing features of this user group include the extent of water contact (repeated and / or lengthy immersion is common and hence the probability of ingesting water is high), the age group of users (swimmers often include large numbers of children, who are more susceptible to a number of health effects, particularly infectious diseases) and the health status of users (people are inclined to swim even when they are not completely healthy, making them more susceptible to health effects).

Intermediate contact recreation is considered to include all forms of contact recreation excluding those listed under full contact recreation. This category thus includes some activities which involve a high degree of water contact (e.g. water skiing, wading and wind-surfing) as well as those which involve relatively little water contact (e.g. canoeing and angling). The major distinguishing features of the high contact activities in this class from full contact recreation are the degree of water contact (full immersion is likely to occur only occasionally and among novices of a water sport in respect of the latter category), the age of users (water sports such as water skiing and windsurfing are usually practised by adults rather than by young children), and health status of users (strenuous water sports are generally practised by water users in a fairly good state of health).

The final category, non-contact recreation, includes all forms of recreation which do not involve direct contact with water such as picnicking and hiking alongside water bodies, and scenic appreciation of water by those residing or holidaying on the shores of a water body. These activities are primarily concerned with the scenic and aesthetic appreciation of water; no water contact occurs with the water, thus public health effects associated with water quality are of little relevance to this group of users.

## 5.2 *Escherichia coli* contamination

This section of the report deals specifically with the level of *E. coli* contamination in the five main "recreational vleis" in the City (as listed above) in terms of the risk of full and intermediate contact recreational use of these systems. A detailed analysis is provided for these known major recreational waterbodies, to supplement the broad-scale assessment of *E. coli* contamination in inland water ecosystems across the City already presented in Section 4.7. The focus here is on the assessment of risk in terms of recreational use, through the compilation of "return interval curves" and (from these) determination of the probability of risk in each recreational vlei (as explained in Section 2.10.6). Probabilities were derived for the likelihood of *E. coli* levels being within the target for direct contact recreation (i.e. <400 cfu/100ml) and in exceedance of the threshold of acceptability for intermediate contact recreation (i.e. >4000 cfu/100ml). Consideration was also given to seasonal differences in the probability of risk. These detailed analyses were restricted to the most recent five years (2015-2019).

The results of the detailed analyses are presented in **Figures 5.2.1 to 5.2.8**, with the results for Rietvlei (which only has one routine monitoring site) and Milnerton Lagoon presented together. For each of the five main recreational vleis, the return interval (RI) curves and derived probabilities of meeting target or exceeding the threshold for unacceptable risk for recreational use are presented, first for all data from the time period of analysis (2015-2019) and then for each season (summer and winter).

Overall, the results show very clearly that, of the five waterbodies that were considered, the probability of the *E. coli* levels being in exceedance of the threshold of unacceptability for intermediate contact recreation is greatest at Milnerton Lagoon. At most sites on this waterbody (with the exception of RTV10), the probability of exceeding the threshold for unacceptable risk was calculated to be 40-50%. At RTV10, the situation appears to be significantly better in summer (<10% probability) than it is in winter (>50% probability), with the overall probability of exceeding the threshold for unacceptable risk of intermediate contact recreation dropping to 30-40% at this site.. Sampling point RTV02 on Rietvlei is the only site on these two systems where the probability of *E. coli* measurements being within the target for direct contact recreation remains high (>80%) throughout the year and the probability of exceeding the threshold of unacceptable risk for intermediate contact recreation remains very low. This sampling point is located at the pier in the watersport area of the vlei.

At both sampling points on Princessvlei, the derived probability of being within the target for full contact recreation is very high (>80%) throughout the year and the probability of *E. coli* levels being above the unacceptable threshold for intermediate contact recreation was calculated to be consistently low (<5%). The situation is slightly worse in winter than it is in summer (as can be seen from the return interval curves on **Figure 5.2.6**, which remain to the left of the vertical line for the target in summer).

At Zeekoevlei, a strong seasonal pattern was evident, with the situation being worse in winter than it is in summer. Here, the derived probability of meeting the target for full contact recreation was calculated to be approaching 100% in summer, while in winter this probability decreases to 50-80% at most sampling points. In winter, the estimated probability of exceedances of the unacceptable threshold for intermediate contact recreation approached 35% at ZEV2S, which is located in the northern section of the vlei near the more polluted inflowing rivers, and 15% at ZEV3S near the southern shoreline (with the calculated probabilities of exceeding the threshold remaining below 5% at other sampling points on the vlei).

**RI curves and probability**

The return interval (RI) curves show the frequency (i.e. number of records) for which *E. coli* measurements of a particular value were recorded over the period considered in the analysis. The fewer high values there are in a dataset, the quicker the RI curve turns up towards the end-point (total number of records over the period of analysis). Conversely, the more high values there are in a dataset, the further along the x-axis the RI curve reaches the end-point.

The probabilities of a particular measurement being recorded have been derived from the RI curve. This was done by looking up the number of measurements recorded for a particular threshold value (i.e. the frequency of occurrence) and expressing this as a percentage of the total number of records in the dataset. This percentage then represents the probability of occurrence for that particular value (e.g. *E. coli* densities of 400 or 4000 cfu/100ml).

A seasonal pattern was also observed at Zandvlei, with the situation being worse in winter than it is in summer. This is more obvious from the return interval curves than it is from the probability estimates (see graphs in **Figure 5.2.10**). Here, the probability of meeting the target for full contact recreation is >80% at all ten sampling points on the vlei in summer, while in winter the probability of exceeding the *E. coli* threshold for intermediate contact recreation approaches 10-15% at some of the sampling points. This is due to the influence of poorer quality water in the inflowing rivers due to winter catchment wash-off factors.

As noted previously, it is important to be aware of the limitations of determining the risk of using a waterbody for intermediate contact recreation on the basis of *E. coli* data. There is a possibility that the risk could be under-estimated when basing the assessment on *E. coli* data as opposed to faecal coliform data. Internationally, there is a move towards the use of Enterococci data for assessing the risk of recreational use of inland and coastal waterbodies, often in concert with *E. coli* data.

Consideration should thus be given to the routine collection of Enterococci measurements from the waterbodies that are used for contact recreation within the City, as part of the City's ongoing water quality monitoring programme. This would bring the City in line with international approaches and guidelines that focus on Intestinal Enterococci measurements. Alternatively, inclusion of faecal coliform data should be allowed for, as a minimum, to allow for more appropriate utilisation of existing guidelines.

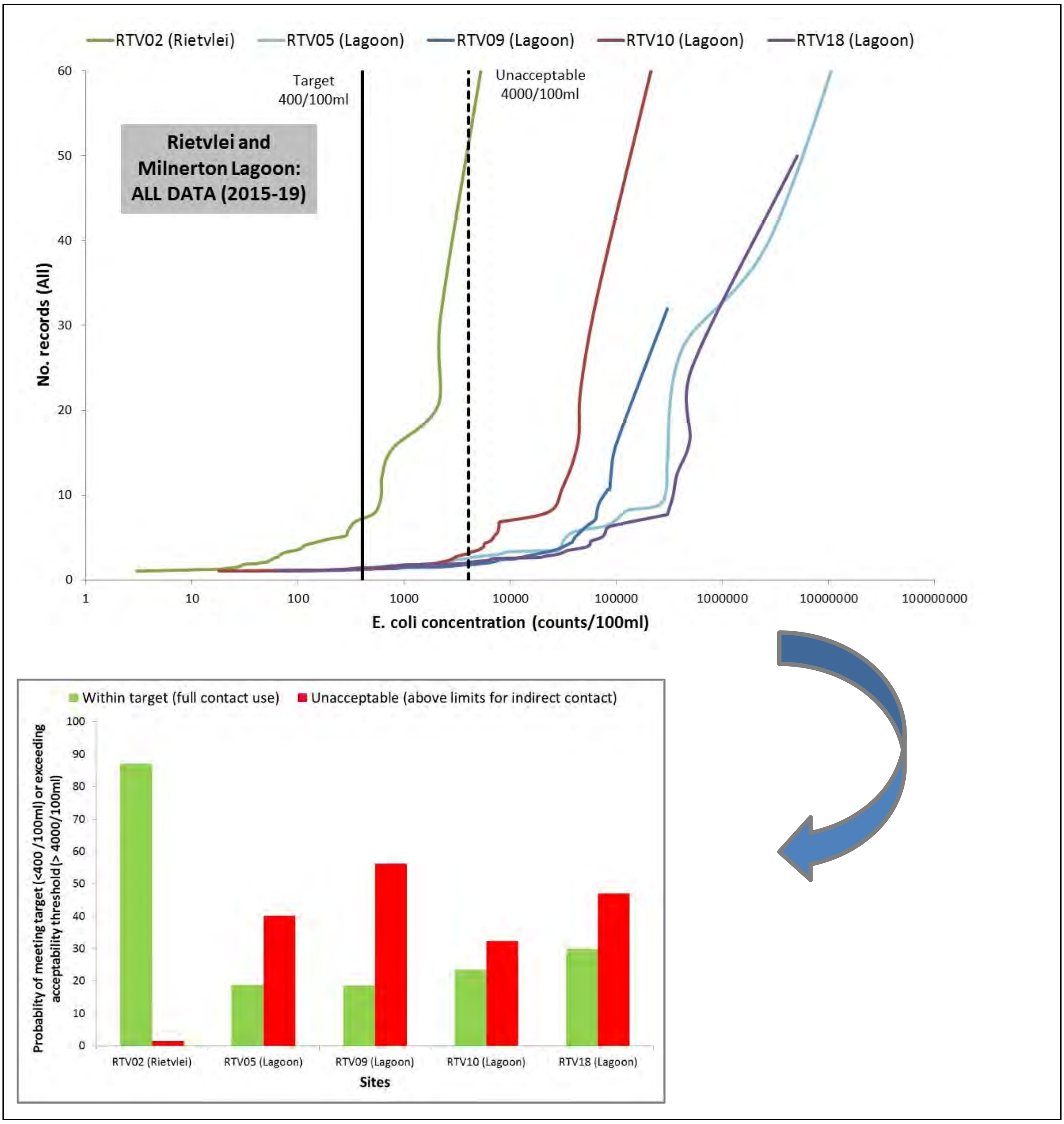



**Figure 4.7.7 Return interval curves for 2015-2019 *E. coli* measurements at sampling sites on Rietvlei and Milnerton Lagoon (all seasons), plotted in relation to the target for full contact recreation and the threshold of unacceptable risk for intermediate contact recreation. Accompanying bar graph shows the probability of meeting target or exceeding the risk threshold (as derived from the return interval data).**

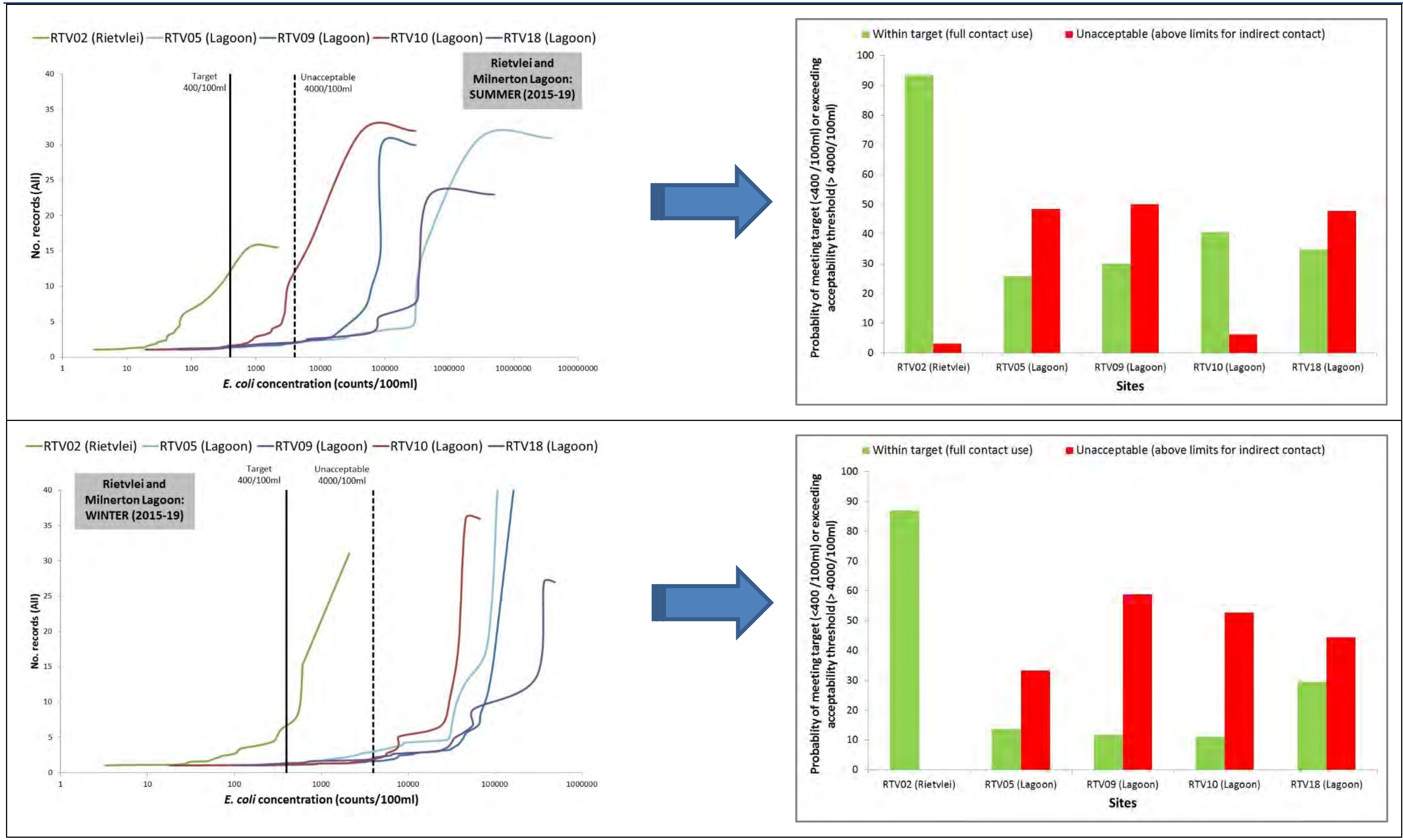



**Figure 4.7.8 Return interval curves for summer and winter *E. coli* measurements at sampling sites on Rietvlei and Milnerton Lagoon (2015-2019), plotted in relation to the target for full contact recreation and the threshold of unacceptable risk for intermediate contact recreation. Accompanying bar graph shows the probability of meeting target or exceeding the risk threshold in each season (as derived from the return interval data).**

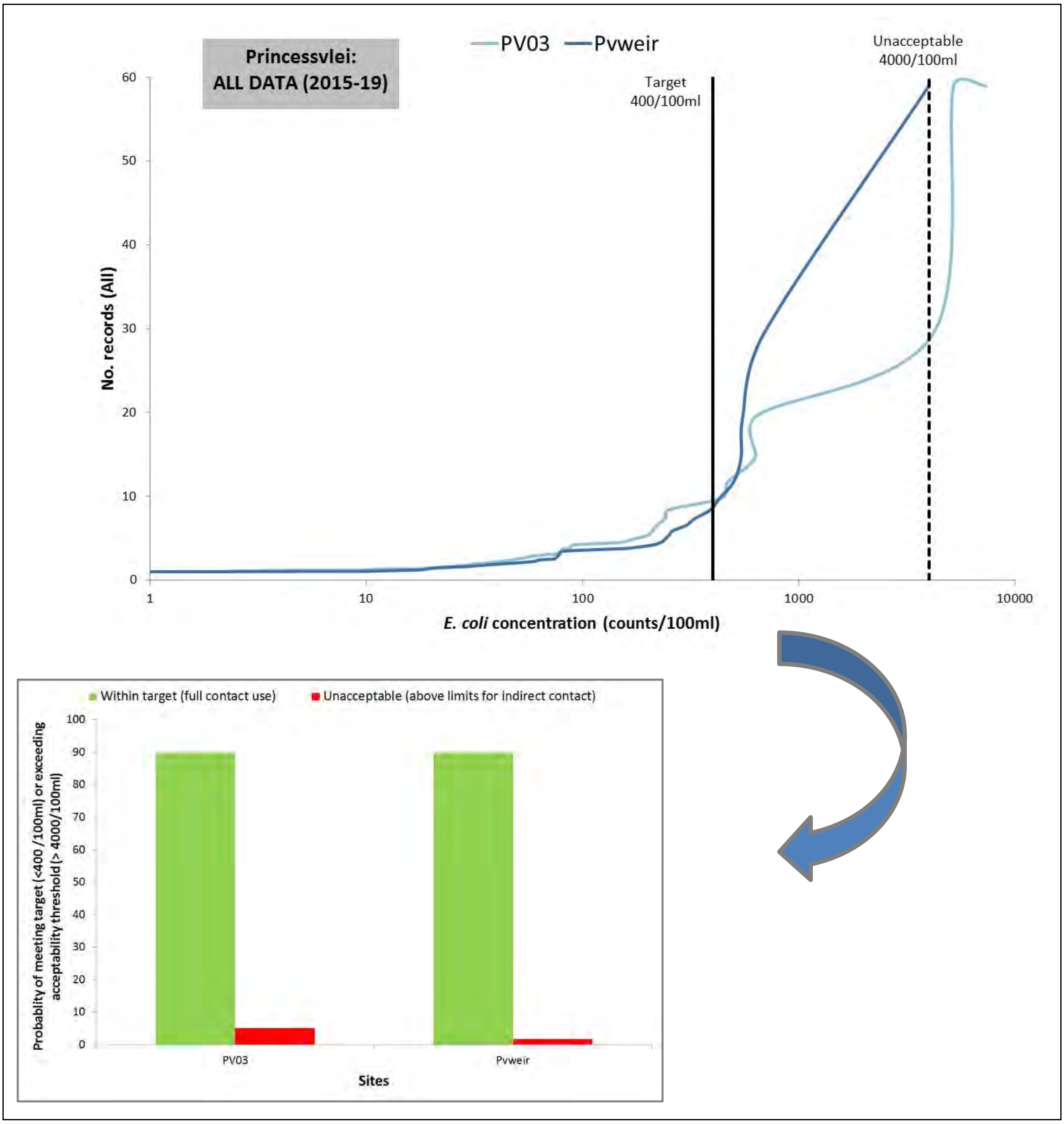



**Figure 4.7.3 Return interval curves for 2015-2019 E. coli measurements at sampling sites on Princessvlei (all seasons), plotted in relation to the target for full contact recreation and the threshold of unacceptable risk for intermediate contact recreation. Accompanying bar graph shows the probability of meeting target or exceeding the risk threshold (as derived from the return interval data).**

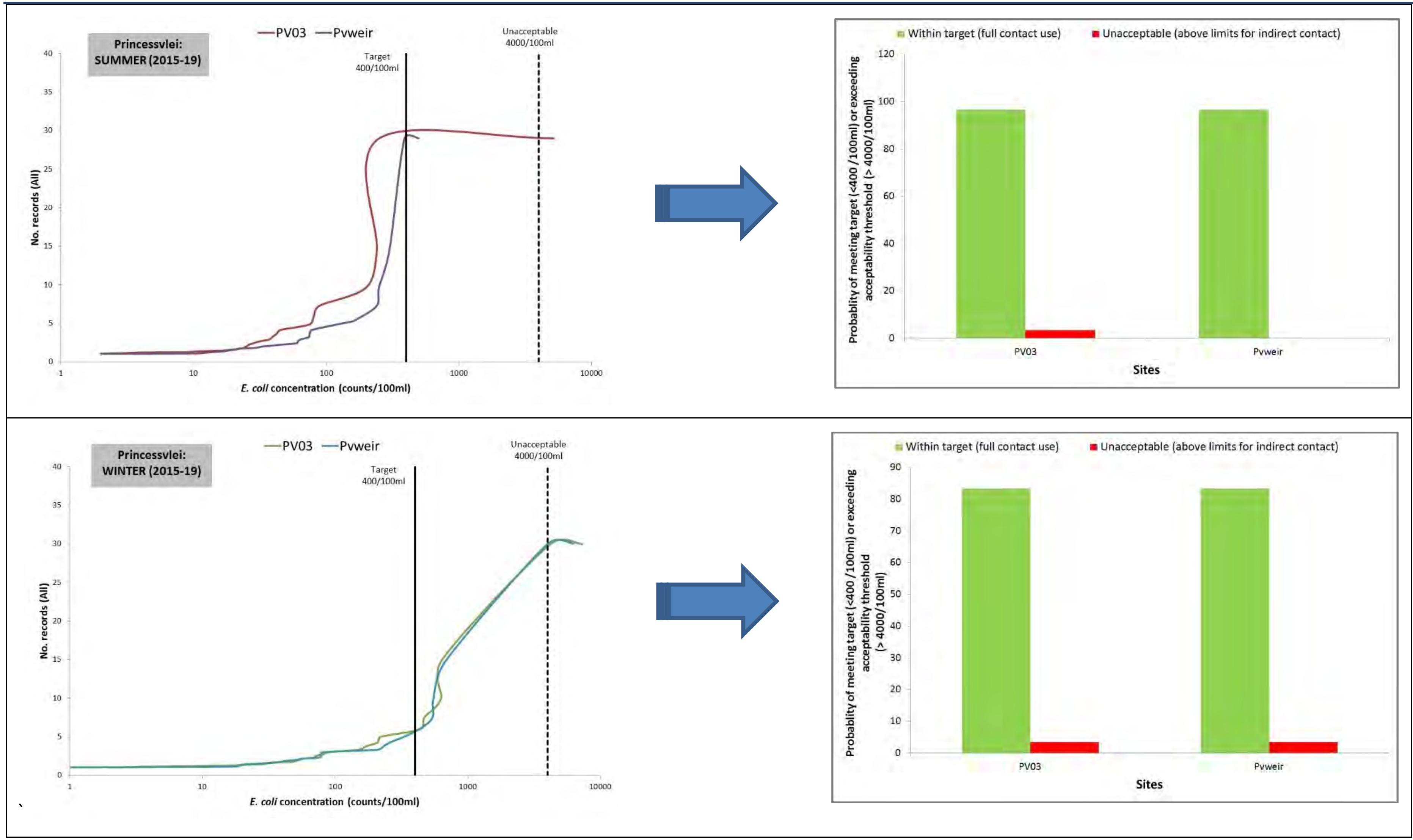



**Figure 4.7.4 Return interval curves for summer and winter E. coli measurements at sampling sites on Princessvlei (2015-2019), plotted in relation to the target for full contact recreation and the threshold of unacceptable risk for intermediate contact recreation. Accompanying bar graph shows the probability of meeting target or exceeding the risk threshold in each season (as derived from the return interval data).**

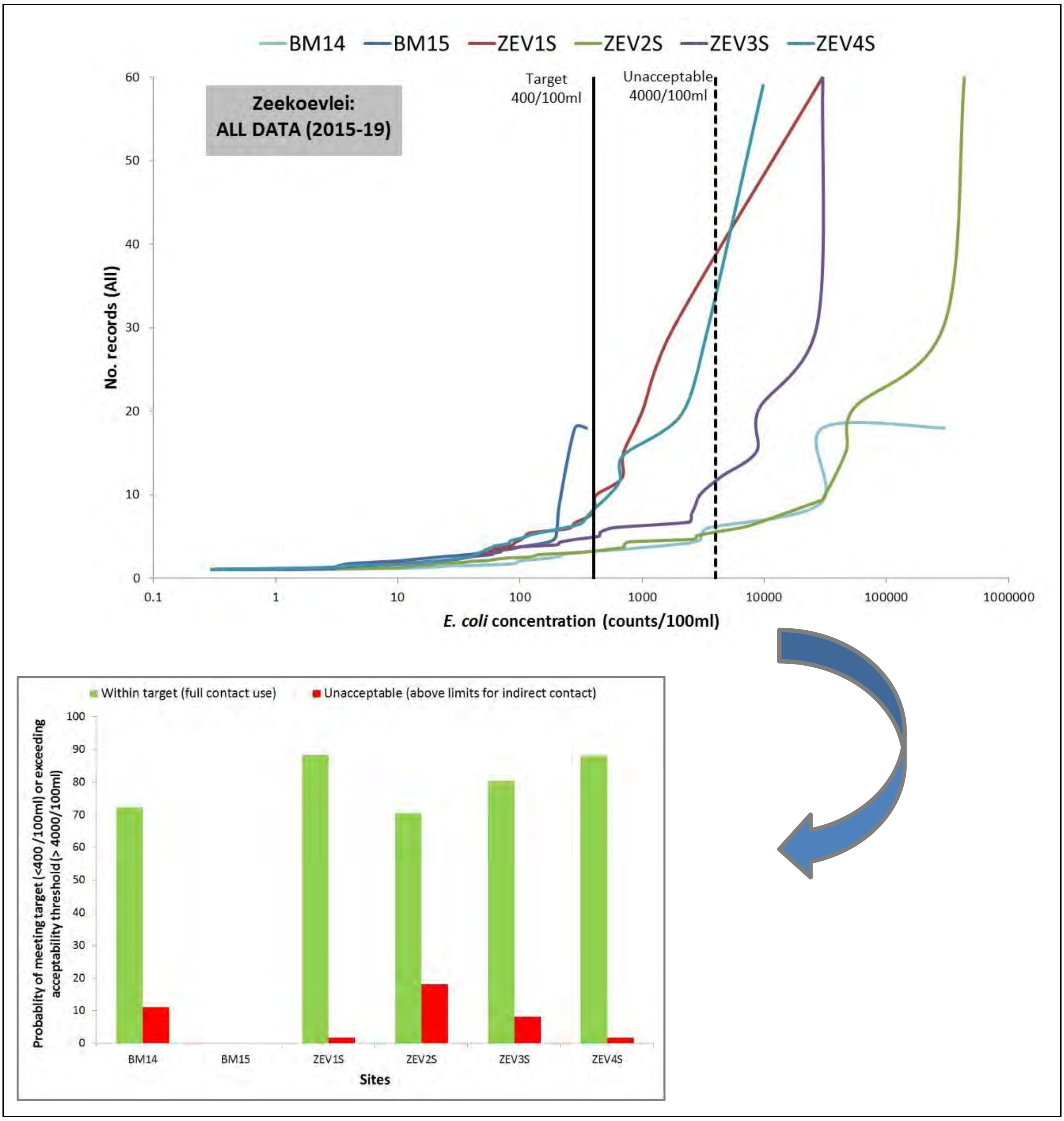



**Figure 4.7.5 Return interval curves for 2015-2019 E. coli measurements at sampling sites on Zeekoevlei (all seasons), plotted in relation to the target for full contact recreation and the threshold of unacceptable risk for intermediate contact recreation. Accompanying bar graph shows the probability of meeting target or exceeding the risk threshold (as derived from the return interval data).**

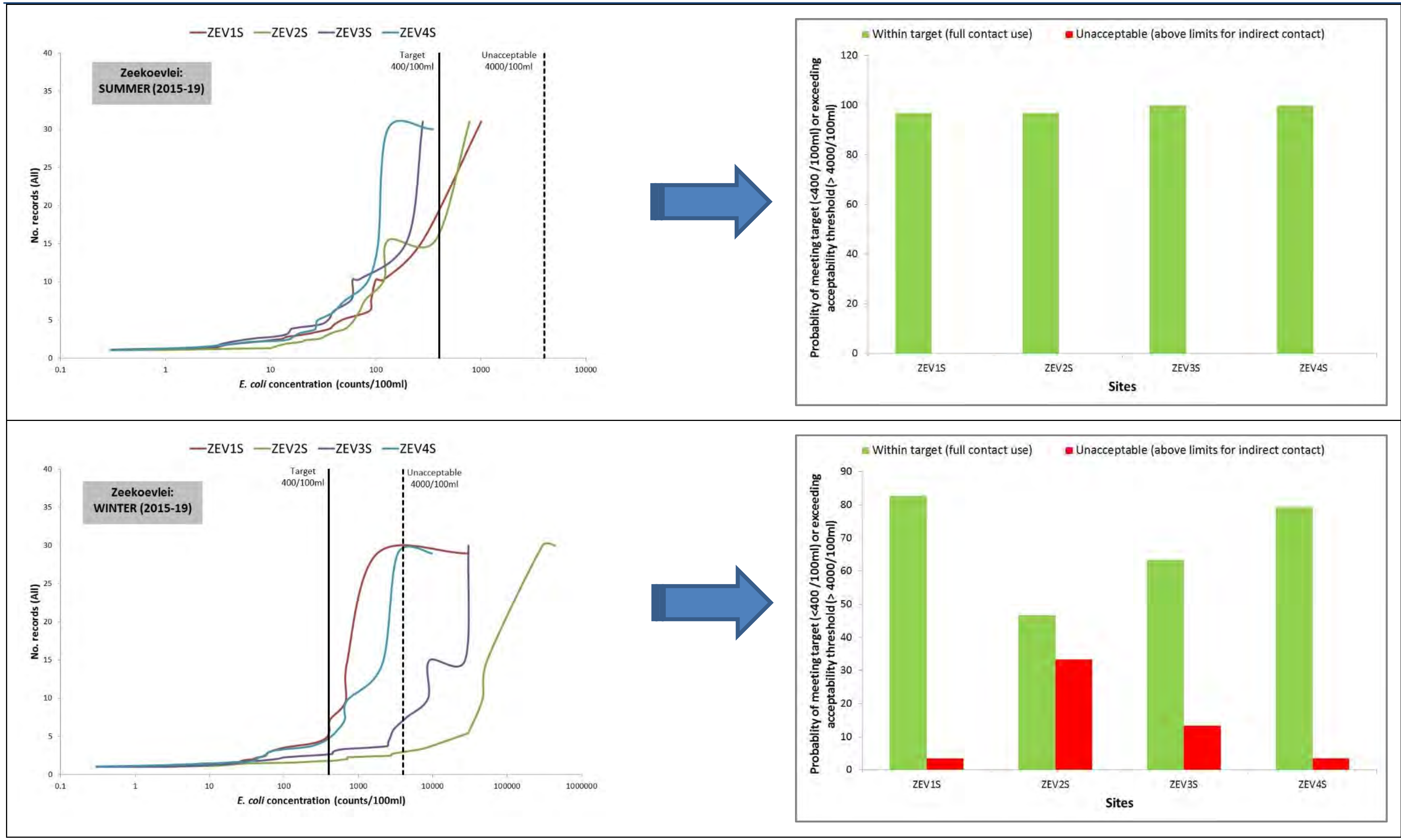



**Figure 4.7.6 Return interval curves for summer and winter E. coli measurements at sampling sites on Zeekoevlei (2015-2019), plotted in relation to the target for full contact recreation and the threshold of unacceptable risk for intermediate contact recreation. Accompanying bar graph shows the probability of meeting target or exceeding the risk threshold in each season (as derived from the return interval data).**

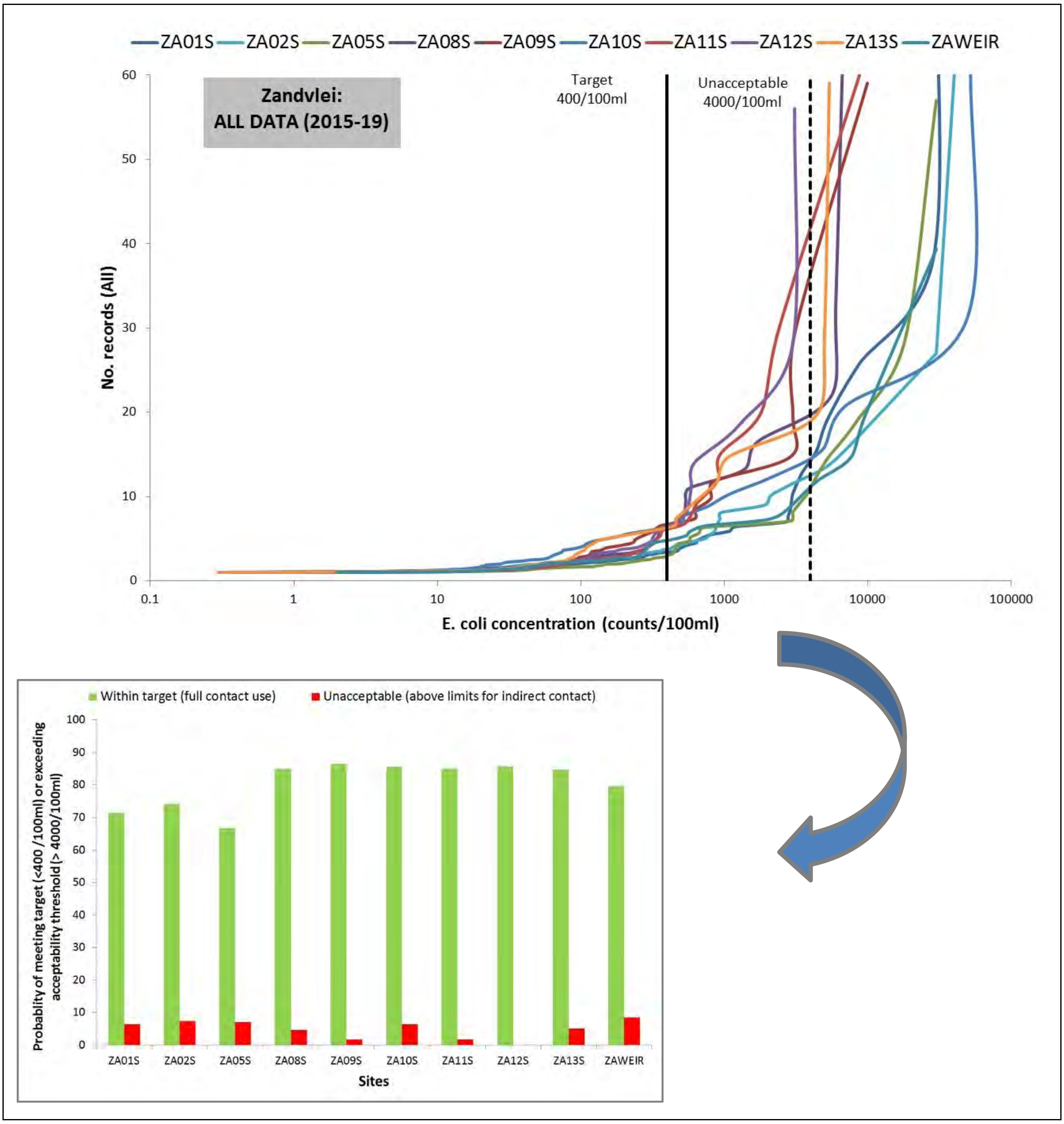



**Figure 4.7.7 Return interval curves for 2015-2019 E. coli measurements at sampling sites on Zandvlei (all seasons) and Westlake wetland (ZA05), plotted in relation to the target for full contact recreation and the threshold of unacceptable risk for intermediate contact recreation. Accompanying bar graph shows the probability of meeting target or exceeding the risk threshold (as derived from the return interval data).**

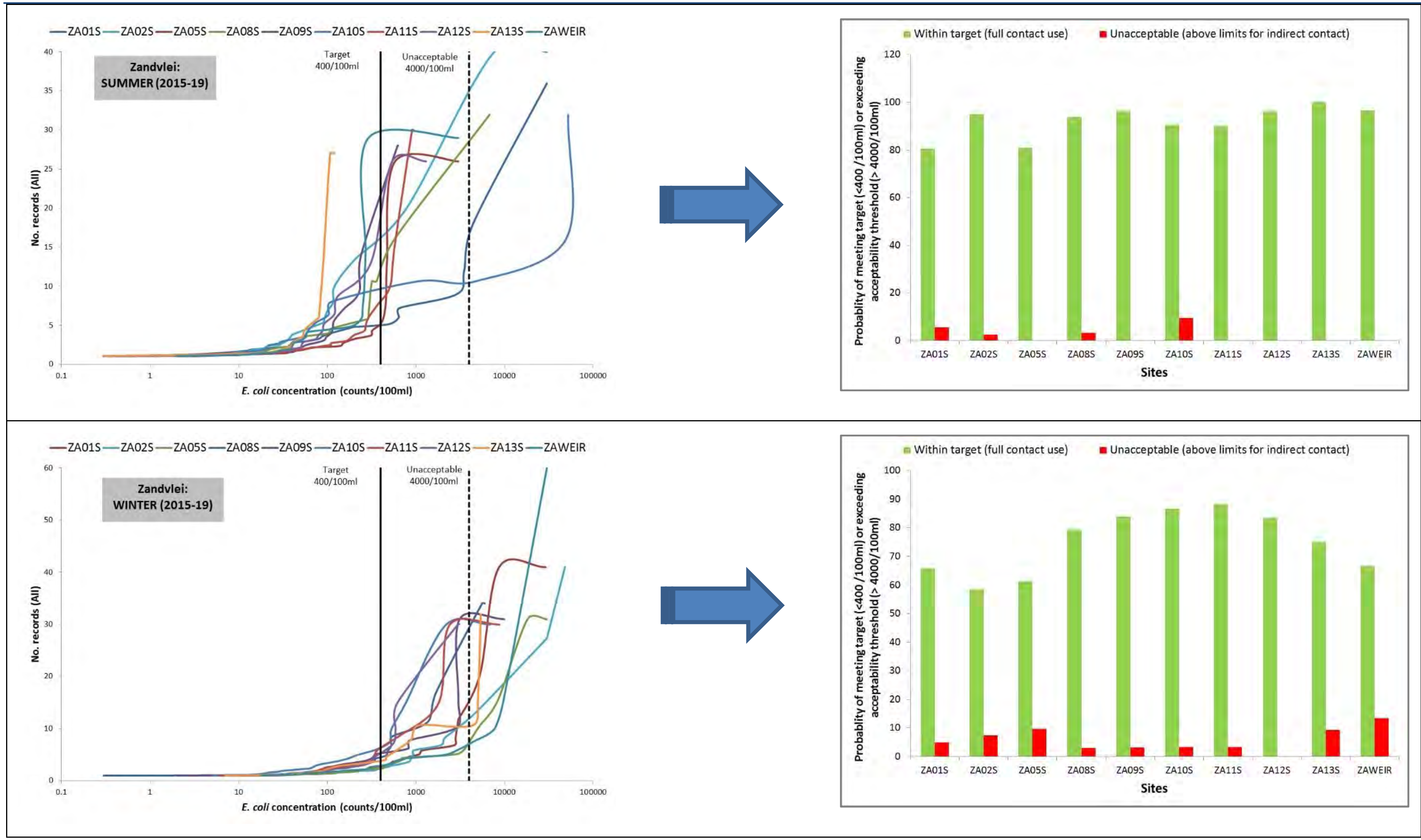



**Figure 4.7.8 Return interval curves for summer and winter E. coli measurements at sampling sites on Zandvlei (2015-2019), plotted in relation to the target for full contact recreation and the threshold of unacceptable risk for intermediate contact recreation. Accompanying bar graph shows the probability of meeting target or exceeding the risk threshold in each season (as derived from the return interval data).**

## 5.3 Microcystin toxicity risk

### *5.3.1 Relevance*

Cyanobacteria (or blue-green algae) are a common and naturally occurring component of most recreational water environments (WHO 2003). They are of potential public health concern because some types may under certain circumstances produce toxins that can have a harmful effect on recreational water users.

Since Microcystin testing is expensive, it is not routinely included in the City's water quality tests, but is instead undertaken when blue-green [5]algal cell counts are > 20 000 cells/ml.

> **Microcystin toxin effects on humans**
>
> Many cyanobacteria species produce a group of toxins known as microcystins, some of which are toxic. Upon ingestion, toxic microcystins are actively absorbed by fish, birds and mammals.
>
> Depending on the level of exposure, cyanobacterial blooms and their cyanotoxins can result in a wide range of symptoms in humans , including fever, headaches, muscle and joint pain, blisters, stomach cramps, diarrhoea, vomiting, mouth ulcers, and allergic reactions. Such effects can occur within minutes to days after exposure. In severe cases, seizures, liver failure, respiratory arrest, and (rarely) death may occur. The cyanotoxins include neurotoxins (affect the nervous system), hepatotoxins (affect the liver), and dermatoxins (affect the skin). However, there have been new studies of effects in other systems, including haematological, kidney, cardiac, reproductive, and gastrointestinal effects. There is also some evidence that long-term exposure to low levels of microcystins may the growth of tumours (Kubickova et al 2019).

### *5.3.2 Prevalence in recreational vleis*

**Figure 5.3.1** summarises the results of all Microcystin tests carried out on the City's main recreational vleis, including Wildevoelvlei for interest, since this non-recreational vlei has a history of excessive nutrient enrichment (Section 4.3) and moreover has in the past been the subject of major interventions to address persistent blue-green algal blooms.

The data show that, despite many of the vleis being prone at times to high levels of chlorophyll-*a*, and possible bloom conditions, the number of times that microcystin toxins were identified in these waterbodies was relatively seldom, with only samples from Rietvlei and Wildevoelvlei showing microcystin toxin concentrations of concern, in the period from 2010 onwards when Microcystin toxin testing became a regular response to blue-green algal blooms. This suggests a significant improvement in Zeekoevlei's water quality over time, with that system suffering frequent blue-green algal blooms and periods of Microcystin toxicity prior in the early 2000s.

> Several types of cyanobacteria have gas-filled cavities that allow them to float to the surface or to different levels below the surface, depending on light conditions and nutrient levels. This can cause the cyanobacteria to concentrate on the water surface, causing a pea-soup appearance.

Samples from Rietvlei were in the range associated with Extreme Risk in 2016, 2017 and 2019, with an additional episode of elevated toxins at Medium Risk in 2019. Since this vlei is a popular recreational waterbody, such episodes would have been of significant health risk to recreational uses exposed to the water. Measures to limit risk such as temporarily restricting access to the Rietvlei waterbody have been instituted by the City but were often met with opposition from certain user groups who disagreed that the water quality posed a potential health risk to users.

Wildevoelvlei showed periodic Microcystin levels that were high enough to be of concern in the event that this system was used recreationally, in 2009, 2010 and 2017. As this vlei receives treated effluent from the adjacent WWTW, recreational use contact with the water body is not advised and residents of the shoreline residential estate only partake in non-contact activities such as walking and bird watching..

[5] Note that algal cell count and identification data were not available in time for inclusion in this report

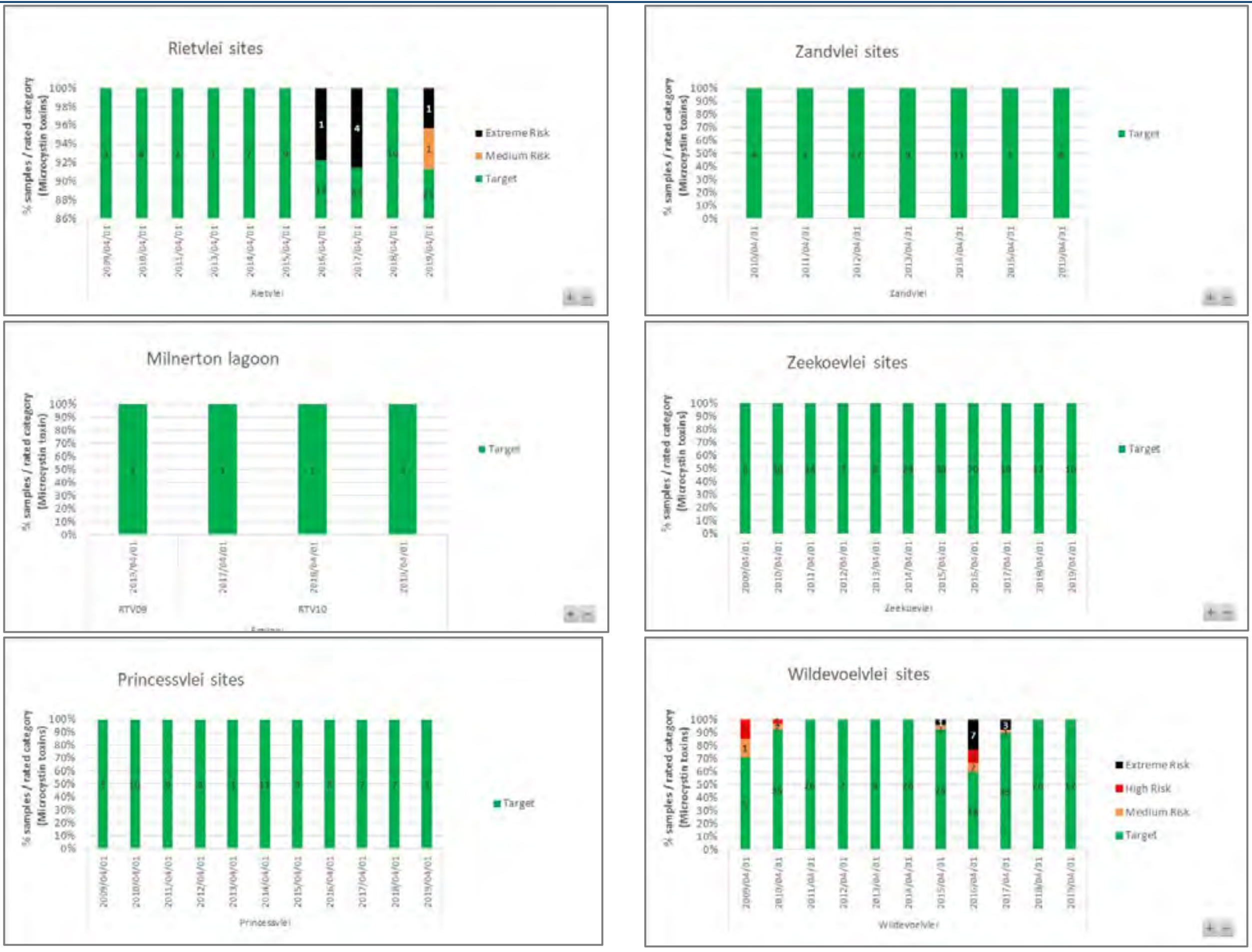



**Figure 5.3.1 Compliance rating for recreational water bodies tested for Microcystin toxins. Samples rated as per Table 2.5. Numbers show test numbers.**

## 5.4 Summary

Of the five main recreational vleis / water bodies, most have generally been in a condition conducive to intermediate contact recreation over the past five years. However, Milnerton Lagoon has been subject to periodic and at times prolonged contamination by *E. coli*, indicative of exposure to untreated sewage. Rietvlei itself, which like most of the assessed urban vleis is hypertrophic with regards to phosphate, is vulnerable to periodic blue-green algal blooms. Some of these blooms have resulted in the production of microcystin toxins at concentrations likely to pose extreme risks to recreational users in contact with this water body.

A focus on measures to reduce sources of nutrient enrichment into all of the recreational water bodies is strongly recommended. Addressing upstream sources of untreated sewage into Milnerton Lagoon in particular is strongly recommended if this waterbody is to be used safely for recreational purposes.

# 6 SUMMARY OF SUBCATCHMENT WATER QUALITY CHARACTERISTICS

This section provides a tabulated summary of general water quality changes and the main issues affecting water quality in each subcatchment for which water quality data were available for this study.

The information in this table has been distilled from the data presented and described in the previous sections of this report.

The locations of each of the subcatchments are indicated again in **Figure 6.1**, for ease of reference.

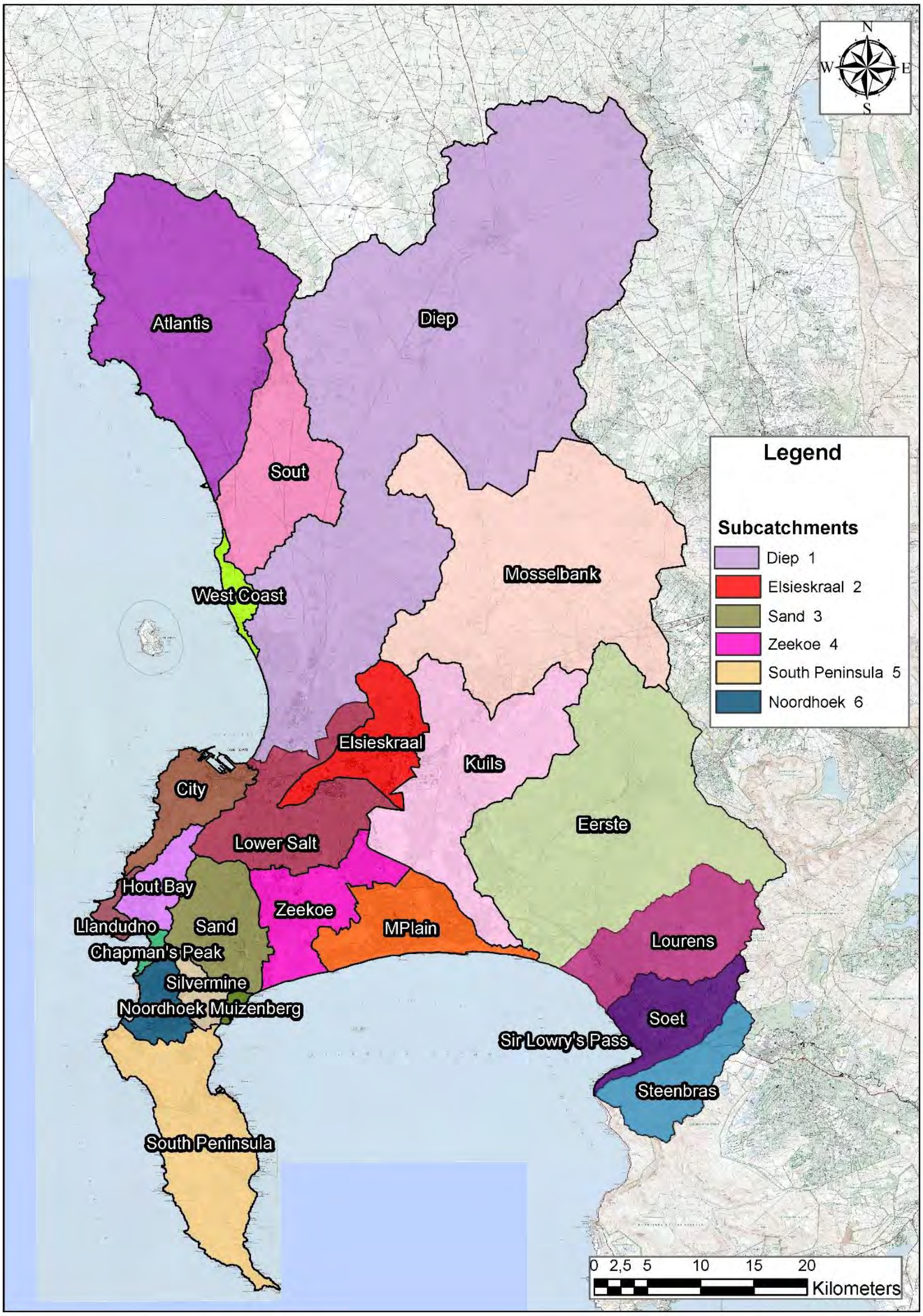



**Figure 6.1 Subcatchments in the City of Cape Town – note that water quality data are not available for all of these areas. See Table 6.1 for a summary of the water quality characeristics of each**

**Table 6.1 Summary of general water quality changes and the main issues affecting water quality in each subcatchment**

| CATCHMENT | SUB-CATCHMENT | Main rivers/canals and monitored open waterbodies*^ | Main parameter/s of concern | Description of main issues at monitoring sites | Main likely source/s of the issues |
|---|---|---|---|---|---|
| **Atlantis** | - | Silwerstroom [no major open waterbodies] | [none measured] | [no routine WQ monitoring points in this catchment] | [no routine WQ monitoring points in this catchment] |
| **Sout** | - | Rivers & canals: Sout River, Donkergat River | EC | Possible trend of decreasing salinity over time. | Irrigation return flows; Melkbosstrand WWTW discharge into lower Sout River. |
| | | | PO4-P | History of significant phosphate enrichment, currently among the worst-performing catchments with respect to this variable. | |
| | | [no major open waterbodies] | [none measured] | [n/a] | [n/a] |
| **West Coast** | - | [no major rivers or waterbodies] | [none measured] | [no routine WQ monitoring points in this catchment] | [no routine WQ monitoring points in this catchment] |
| **Diep** | **Diep** | Rivers & canals: Milnerton Lagoon*, Diep River, Soutrivier, Swartrivier, Platkliprivier, Riebeeksrivier | PO4-P | History of phosphorus enrichment, which has further deteriorated in the lower reaches of the Diep River (including the Milnerton Lagoon sites) over the past five years. Currently among the worst-performing subcatchments with respect to this variable. | Potsdam WWTW discharge into Lower Diep River / Milnerton Lagoon system; Presence of poorly serviced informal settlements in the subcatchment (e.g. Du Noon and Joe Slovo); Runoff from agricultural areas (livestock feedlots and fertilized fields). |
| | | | TIN | Nitrogen enrichment of river systems, historically and in recent years, with a significant increase in the most recent year of monitoring. | |
| | | | NH3-N | Median NH3 concentrations in rivers and stormwater channels of this subcatchment consistently in the Unacceptable range and thus associated with Acute Toxicity effects to aquatic organisms. | |

| CATCHMENT | SUB-CATCHMENT | Main rivers/canals and monitored open waterbodies*^ | Main parameter/s of concern | Description of main issues at monitoring sites | Main likely source/s of the issues |
|---|---|---|---|---|---|
| | | | DO | Relatively large proportion of DO measurements in the Unacceptable range, suggesting compromised river systems (with increased organic loading), but DO concentrations have improved in this subcatchment since 2000 (with fewer measurements in the Unacceptable range). | |
| | | | *E. coli* | Majority of *E. coli* values recorded in the most recent year of monitoring (2019) lay well within the Unacceptable range for intermediate contact recreation.<br>One of the most significantly impaired catchments from a human health perspective, with high levels of faecal contamination.<br>Of the five recreational waterbodies that were considered, Milnerton Lagoon has the greatest probability of *E. coli* levels being in exceedance of the threshold of unacceptability for intermediate contact recreation, based on the last 5 years of data. | |
| | | Waterbodies: Zoarvlei, Rietvlei* | PO4-P;<br>N:P ratio | Phosphate levels in Rietvlei and even more so in Zoarvlei were well within the range for hypertrophic systems (i.e. Unacceptable). | Inflows into Zoarvlei are affected primarily by runoff from the industrial area of Paarden Eiland;<br>Rietvlei is affected primarily by long-term inputs from the nutrient-enriched Bayside Canal and presumably by runoff from the surrounding catchment area that is periodically contaminated by sewage overflows. |
| | | | DO (Zoarvlei) | High frequency of low oxygen conditions recorded in Zoarvlei, which is likely to trigger ecosystem effects such as fish kills.<br>After very low levels of DO in the 1995-2000 period, concentrations increased significantly in Rietvlei in subsequent years, with data | |

| CATCHMENT | SUB-CATCHMENT | Main rivers/canals and monitored open waterbodies*^ | Main parameter/s of concern | Description of main issues at monitoring sites | Main likely source/s of the issues |
|---|---|---|---|---|---|
| | | | | showing generally high DO levels that are not likely to be problematic. | |
| | | | Chl-a & Microcystin (Rietvlei) | Mean annual concentrations of Chl-a were within the Unacceptable range in Rietvlei during 2015-18 (but not in 2019).<br>Some of the periodic blue-green algal blooms in Rietvlei since 2010 have resulted in the production of microcystin toxins at concentrations likely to pose extreme risks to recreational users in contact with this water body. | |
| | **Mosselbank** | Rivers & canals: Mosselbank River, Maastricht Canal, Klapmutsrivier, Kalbaskraal River, Groenfontein-rivier | pH | History of relatively frequent and prolonged "spikes" of elevated pH (approaching and exceeding 10). | Possibly related to transformation of natural vegetation, agricultural runoff, canalisation of rivers (e.g. Maastrecht Canal) and WWTW discharges. |
| | | | PO4-P | History of phosphorus enrichment, which has further deteriorated over the past five years. Currently among the worst-performing subcatchments with respect to this variable. | WWTW discharges into Mosselbank River; Presence of poorly serviced informal settlements and backyard dwellings in formal settlements such as Fisantekraal; Runoff from agricultural areas (livestock feedlots and fertilized fields). |
| | | | TIN | Nitrogen enrichment of river systems, historically and in recent years, with a significant increase in the most recent year of monitoring. | |
| | | | DO | Relatively large proportion of DO measurements in the Unacceptable range, suggesting compromised river systems (with increased organic loading) in the subcatchment. | |
| | | | *E. coli* | Majority of *E. coli* measurements recorded at river sites in this subcatchments in the past 5 | |

| CATCHMENT | SUB-CATCHMENT | Main rivers/canals and monitored open waterbodies*^ | Main parameter/s of concern | Description of main issues at monitoring sites | Main likely source/s of the issues |
|---|---|---|---|---|---|
| | | | | years fell in the Poor to lower end of Unacceptable categories for intermediate contact recreation. | |
| | | Waterbodies: Uitkamp wetland^ | [no summary] | [n/a] | [n/a] |
| **Salt** | **Elsieskraal** | Rivers & canals: Elsieskraal River, Vanriebeeckshof River | EC | Possible trend of decreasing salinity over time. | Inputs of relative fresh water (e.g. from irrigation return flows and urban runoff). |
| | | | pH | History of relatively frequent and prolonged “spikes” of elevated pH (approaching and exceeding 10). | Possibly related to transformation of natural vegetation, agricultural runoff, and canalisation of rivers (e.g. lower reaches of Elsieskraal River). |
| | | | PO4-P | High levels of phosphate enrichment among sampled river sites historically, to a greater extent than sites in the Lower Salt River subcatchment.<br>Slightly better performance than sites in the Lower Salt subcatchment over the last 5 years, but with phosphate concentrations still generally in the Unacceptable range. | Increasingly urbanised subcatchment, with the river reaches through Bellville being affected by areas of inner-city homelessness, but not subject to receipt of treated sewage effluent or characterized by substantial areas of informal or poorly serviced settlements. |
| | | | *E. coli* | Majority of *E. coli* values recorded throughout the last 5 years lay well within the Unacceptable range for intermediate contact recreation. | |
| | | Waterbodies: Elsieskraal dams (Fynbos Dam, Angelier Park lower dam, Welgemoed Dam, Kanonberg Dam, Plattekloof | PO4-P;<br>N:P ratio | Elsieskraal dams among the monitored waterbodies in the City where orthophosphate enrichment has been least problematic in recent years, albeit still in the hypertrophic range. | Runoff from agricultural and urban residential areas. |

| CATCHMENT | SUB-CATCHMENT | Main rivers/canals and monitored open waterbodies*^ | Main parameter/s of concern | Description of main issues at monitoring sites | Main likely source/s of the issues |
|---|---|---|---|---|---|
| | | Dam, Doordekraal Dam) | | | |
| | **Lower Salt** | Rivers & canals: Salt River Canal, Black River, Liesbeek River, streams of eastern slopes of Table Mtn Vygekraal River, Kromboom Canal, Blomvlei Canal, Jakkalsvlei Canal, Bokmakierie Canal, Langa Canal, Kalksteenfontein Canal, Nyanga Canal | PO4-P | High levels of phosphate enrichment among sampled river sites historically, but to less degree than sites in the Elsieskraal subcatchment.<br>Currently among the worst-performing subcatchments with respect to this variable. | Athlone WWTW discharge into Black River; Presence of poorly serviced informal settlements and backyard dwellers in the subcatchment. |
| | | | TIN | Nitrogen enrichment of river systems, historically and in recent years, with a long-term trend of gradual increase with regard to this nutrient over the monitoring record and a significant increase in the most recent year of monitoring. | |
| | | | NH3-N | Median NH3 concentrations in rivers and stormwater channels of this subcatchment consistently in the Unacceptable range and thus associated with Acute Toxicity effects to aquatic organisms. | |
| | | | DO | Relatively high proportion of river measurements in this subcatchment (approaching and exceeding 40%) consistently in the Unacceptable range for DO concentration, mainly in the Black River and other slow flowing river reaches.<br>Parts of the subcatchment that include the Liesbeek River showed less impacted DO concentrations. | |
| | | | *E. coli* | *E. coli* contamination has been a significant and ongoing concern over the full monitoring | |

| CATCHMENT | SUB-CATCHMENT | Main rivers/canals and monitored open waterbodies*^ | Main parameter/s of concern | Description of main issues at monitoring sites | Main likely source/s of the issues |
|---|---|---|---|---|---|
| | | | | period in this subcatchment, with a relatively high proportion of samples from rivers and stormwater channels consistently in the Unacceptable range. | |
| | | [no major open waterbodies] | [none measured] | [n/a] | [n/a] |
| **City Bowl** | - | Platteklip Stream [no major open waterbodies] | [none measured] | [no routine WQ monitoring points in this catchment] | [no routine WQ monitoring points in this catchment] |
| **Sand** | - | Rivers & canals: Zandvlei outlet channel, Sand River, Keysers River, Westlake River, Prinskasteel River, Prinskasteel Stream, Spaanschemat River, Grootboschkloof River, Pagasvlei Stream, Mocke River, Diep River, Brommersvlei Stream, Burgersboskloof Stream, Wynberg Stream, Southfield Canal | PO4-P | Increasing proportion of samples from river sites in Poor and Unacceptable ranges for phosphate concentration over time. | Highly urbanized catchment with high levels of street waste and dumping in certain parts, but not subject to receipt of treated sewage effluent or characterized by substantial areas of informal settlements. |
| | | | DO | Proportion of DO measurements in Poor category consistently relatively high for rivers of this catchment, but the number of measurements in the Unacceptable range has reduced significantly over time suggesting an improvement in recent years. | |
| | | | *E. coli* | Majority of *E. coli* measurements recorded at river sites in this subcatchments in the past 5 years fell in the Poor to lower end of Unacceptable categories for intermediate contact recreation. | |
| | | Waterbodies: Langevlei, Princessvlei*, Little Princessvlei, Die Oog, | PO4-P; N:P ratio | Marked phosphate enrichment of Zandvlei, Langevlei, Little Princessvlei and Westlake wetland has occurred historically over the monitoring record, with most samples | |

| CATCHMENT | SUB-CATCHMENT | Main rivers/canals and monitored open waterbodies*^ | Main parameter/s of concern | Description of main issues at monitoring sites | Main likely source/s of the issues |
|---|---|---|---|---|---|
| | | Zandvlei*, Westlake wetland, Psoralea Park wetland^ | | measured from these systems over the past 10 to 15 years lying within the Unacceptable (hypertrophic) range.<br>Princessvlei, Little Princessvlei and Die Oog are among the main waterbodies in the City where orthophosphate enrichment has been least problematic in recent years, albeit still in the hypertrophic range.<br>When N:P ratios are considered, only samples from Die Oog had median values within the Target range for this variable. | |
| | | | Chl-a | Mean annual concentrations of Chl-a were, during the last 5 years, within the Unacceptable range in Langevlei and Princessvlei, and in Die Oog during 2019. | |
| | | | DO (Little Princessvlei) | Little Princessvlei periodically affected by low oxygen conditions. | Small, relatively sheltered system with a high availability of nutrients. |
| | | | *E. coli* (Langevlei, winter in Zandvlei) | Majority of *E. coli* measurements from Langevlei in 2019 were within the Poor and Unacceptable ranges for intermediate contact recreation.<br>In Zandvlei, the probability of exceeding the *E. coli* threshold for indirect contact recreation approaches 10-15% at some of the sampling points in winter (which is still relatively low). | Runoff from the surrounding increasingly urbanised catchment areas, with poorly serviced backyard dwellings present in certain portions of the catchment. |
| **Muizenberg** | - | [no major rivers or waterbodies] | [none measured] | [no routine WQ monitoring points in this catchment] | [no routine WQ monitoring points in this catchment] |
| **Zeekoe** | - | Rivers & canals: Big Lotus River Canal, | PO4-P | Marked increase in the proportion of river sites in the Poor and Unacceptable category | ▪ WWTW discharge into Zeekoe outlet canal; |

| CATCHMENT | SUB-CATCHMENT | Main rivers/canals and monitored open waterbodies*^ | Main parameter/s of concern | Description of main issues at monitoring sites | Main likely source/s of the issues |
|---|---|---|---|---|---|
| | | Little Lotus River Canal, Zeekoe outlet channel | | for phosphate over the monitoring record, but with some improvement over the past 10 years.<br>Currently among the worst-performing subcatchments with respect to this variable. | ▪ Presence of relatively large areas of poorly serviced informal and backyard settlements in the Gugulethu, Philippi and Grassy Park areas;<br>▪ Runoff from highly urbanized areas with high levels of street waste and dumping;<br>▪ Agricultural runoff from the Philippi Horticultural Area;<br>▪ Improvements in WQ over the past 10 years presumably reflect management interventions such as the construction of a cutoff drain to divert subsurface flows from the nearby WWTW, into the downstream Zeekoe channel. |
| | | | TIN | Nitrogen enrichment of river systems, historically and in recent years, with a long-term trend of gradual increase with regard to this nutrient over the monitoring record and a significant increase in the most recent year of monitoring. | |
| | | | NH3-N | Median NH3 concentrations in rivers and stormwater channels of this subcatchment consistently in the Unacceptable range and thus associated with Acute Toxicity effects to aquatic organisms. | |
| | | | DO | Relatively high proportion of river measurements (approaching and exceeding 40%) consistently in the Unacceptable range for DO concentration in this subcatchment. | |
| | | | *E. coli* | Majority of *E. coli* measurements recorded at river sites in this subcatchments in the past 5 years fell in the Poor and Unacceptable categories for intermediate contact recreation. | |
| | | Waterbodies: Edith Stephens detention ponds, Zeekoevlei*, | PO4-P;<br>N:P ratio | Phosphate levels in Zeekoevlei and Edith Stephens DP were well within the range for hypertrophic systems (i.e. Unacceptable). | |

| CATCHMENT | SUB-CATCHMENT | Main rivers/canals and monitored open waterbodies*^ | Main parameter/s of concern | Description of main issues at monitoring sites | Main likely source/s of the issues |
|---|---|---|---|---|---|
| | | Rondevlei, Moddervlei^, Costa da Gama wetland^ | | Smaller waterbody of Rondevlei, with relatively smaller catchment area, showed lower levels of phosphate enrichment. | |
| | | | TIN (Edith Stephens DP) | Nitrogen enrichment of Edith Stephens detention ponds historically, but not so much in the most recent year of monitoring (2019). | |
| | | | Chl-a (Zeekoevlei) | Mean annual concentrations of Chl-a were, during the last 5 years, within the Unacceptable range in Zeekoevlei. | |
| | | | DO (Rondevlei, Edith Stephens DP) | Rondevlei periodically affected by low oxygen conditions.<br>Edith Stephens detention ponds have been characterized by consistently low dissolved oxygen concentrations. | Small, relatively sheltered systems with a high availability of nutrients. |
| | | | *E. coli* (Mostly Edith Stephens DP; during winter to some degree at Zeekoevlei) | In the Edith Stephens detention ponds, up to and exceeding 40% of the samples in all years of sampling have been in the Unacceptable category for *E. coli*.<br>Majority of *E. coli* measurements from Edith Stephens in 2015-18 period were within the Poor and Unacceptable ranges for intermediate contact recreation.<br>In winter, the estimated probability of exceedances of the unacceptable threshold for indirect contact recreation is relatively high (~35%) at sampling point ZEV2S on Zeekoevlei (based on the last 5 years of data). | Polluted runoff from the surrounding catchment;<br>Polluted inflowing rivers in the case of the northern portions of Zeekoevlei (near sampling point ZEV2S). |
| **Mitchell's Plain** | - | MPlain DP<br>[no rivers] | PO4-P;<br>N:P ratio | Mitchell's Plain detention pond showed a very high level of phosphate enrichment. | Presence of WWTWs in the subcatchment; |

| CATCHMENT | SUB-CATCHMENT | Main rivers/canals and monitored open waterbodies*^ | Main parameter/s of concern | Description of main issues at monitoring sites | Main likely source/s of the issues |
|---|---|---|---|---|---|
| | | | TIN | Extreme nitrogen enrichment of Mitchell's Plain detention pond, historically and in recent years. | Contaminated stormwater runoff from the subcatchment, which has no rivers and is characterized by high levels of poorly serviced informal settlements. |
| | | | NH3-N | Median NH3 concentrations in Mitchell's Plain detention pond consistently in the Unacceptable range and thus associated with Acute Toxicity effects to aquatic organisms. | |
| | | | DO | Mitchell's Plain detention pond has been characterized by consistently low dissolved oxygen concentrations. | |
| | | | *E. coli* | In the Mitchell's Plain detention pond, 95 to 100% of the samples in all years of sampling have been in the Unacceptable category for *E. coli*.<br>In the last 5 years, the Mitchell's Plain detention pond was among the most polluted of the monitored open waterbodies in the City in terms of *E. coli* contamination, with samples always far into the Unacceptable range for intermediate contact recreation. | |
| **Eerste/Kuils** | **Kuils** | Rivers & canals: Kuils River, Bottelary River | PO4-P | Significant increase over time in the proportion of river sites where water is in Poor or Unacceptable condition in terms of PO4-P.<br>Currently among the worst-performing subcatchments with respect to this variable. | Multiple WWTW discharges Into Kuils River;<br>Presence of large areas of poorly serviced informal settlements in the subcatchment. |
| | | | TIN | Nitrogen enrichment of river systems, historically and in recent years, with a | |

| CATCHMENT | SUB-CATCHMENT | Main rivers/canals and monitored open waterbodies*^ | Main parameter/s of concern | Description of main issues at monitoring sites | Main likely source/s of the issues |
|---|---|---|---|---|---|
| | | | | significant increase in the most recent year of monitoring. | |
| | | | DO | Long-term increase in proportion of DO measurements falling into the Unacceptable range over the monitoring record. | |
| | | | *E. coli* | *E. coli* contamination has been a significant and ongoing concern over the full monitoring period in this subcatchment, with a relatively high proportion of river and stormwater channel samples consistently in the Unacceptable range. | |
| | | Waterbodies: Mew Way DP | PO4-P;<br>N:P ratio | The Mew Way detention pond showed a very high level of phosphate enrichment. | |
| | | | TIN | Nitrogen enrichment of Mew Way detention pond, historically and in recent years. | |
| | | | NH3-N | Median NH3 concentrations in Mew Way detention pond consistently in the Unacceptable range and thus associated with Acute Toxicity effects to aquatic organisms. | |
| | | | DO | Mew Way detention pond has been characterized by consistently low dissolved oxygen concentrations, although to a lesser extent than the Eerste subcatchment. | |
| | | | *E. coli* | In the Mew Way detention pond, 95 to 100% of the samples in all years of sampling have been in the Unacceptable category *for E. coli*. In the last 5 years, the Mew Way detention pond was among the most polluted of the monitored open waterbodies in the City in | |

| CATCHMENT | SUB-CATCHMENT | Main rivers/canals and monitored open waterbodies*^ | Main parameter/s of concern | Description of main issues at monitoring sites | Main likely source/s of the issues |
|---|---|---|---|---|---|
| | | | | terms of *E. coli* contamination, with samples always far into the Unacceptable range for intermediate contact recreation. | |
| | **Eerste** | Rivers & canals: Eerste River, Lower Kuils River (sites EK08 & EK11), Kleinvlei Canal, Moddergatspruit | PO4-P | Significant increase over time in the proportion of river sites where water is in Poor or Unacceptable condition in terms of PO4-P.<br>Currently among the worst-performing subcatchments with respect to this variable. | WWTW discharges into Eerste River; Presence of poorly serviced informal settlements in the subcatchment. |
| | | | TIN | Nitrogen enrichment of river systems, historically and in recent years, with a long-term trend of gradual increase with regard to this nutrient over the monitoring record. | |
| | | | NH3-N | Median NH3 concentrations in rivers and stormwater channels of this subcatchment consistently in the Unacceptable range and thus associated with Acute Toxicity effects to aquatic organisms. | |
| | | | DO | Long-term increase in proportion of DO measurements falling into the Unacceptable range over the monitoring record. | |
| | | | *E. coli* | Majority of *E. coli* measurements recorded at river sites in this subcatchments in the past 5 years fell in the Poor to lower end of Unacceptable categories for intermediate contact recreation. | |
| | | [no major open waterbodies] | [none measured] | [n/a] | [n/a] |

| CATCHMENT | SUB-CATCHMENT | Main rivers/canals and monitored open waterbodies*^ | Main parameter/s of concern | Description of main issues at monitoring sites | Main likely source/s of the issues |
|---|---|---|---|---|---|
| **Lourens** | - | Rivers & canals: Lourens River, Melksloot | PO4-P | Increasing proportion of samples from river sites in Poor and Unacceptable ranges for phosphate over time, despite upper reaches of Lourens River being one of the least-impacted sections of river monitored in the City. | Runoff from agricultural and urban residential areas. |
| | | [no major open waterbodies] | [none measured] | [n/a] | [n/a] |
| **Sir Lowry's Pass** | **Sir Lowry's Pass** | Sir Lowry's Pass River [no major open waterbodies] | PO4-P | Slightly better performance than sites in the Soet River subcatchment over the last 5 years, but with phosphate concentrations still generally in the Unacceptable range. | Presence of poorly serviced informal settlements in the subcatchment. |
| | | | TIN | Median TIN values, historically and in the last five years, generally within the Target or Poor range but characterized by a high degree of scatter well into the Unacceptable range. | |
| | | | *E. coli* | Majority of *E. coli* measurements recorded at river sites in this subcatchments in the past 5 years fell in the Poor to lower end of Unacceptable categories for intermediate contact recreation. | |
| | **Soet** | Soet River [no major open waterbodies] | PO4-P | Phosphorus enrichment generally in the Unacceptable range, but some river sites monitored over the past 10 years fell within the Target range for PO4 -P, suggesting some long-term improvement in this variable. Currently (in 2019-2020), however, among the worst-performing subcatchments with respect to this variable. | The Soet is a small system that does not have a natural river channel and is almost entirely comprised of a constructed network of stormwater channels, which is subject to ongoing inflows of polluted grey water and sewage water discharged from Informal and poorly serviced settlements in its catchment, as well as from flows |

| CATCHMENT | SUB-CATCHMENT | Main rivers/canals and monitored open waterbodies*^ | Main parameter/s of concern | Description of main issues at monitoring sites | Main likely source/s of the issues |
|---|---|---|---|---|---|
| | | | TIN | Nitrogen enrichment of river systems, historically and in recent years, with a long-term trend of gradual increase with regard to this nutrient over the monitoring record and a significant increase in the most recent year of monitoring. | from the upstream Heritage Park area and its subcatchment. |
| | | | NH3-N | Median NH3 concentrations in rivers and stormwater channels of this subcatchment consistently in the Unacceptable range and thus associated with Acute Toxicity effects to aquatic organisms. | |
| | | | DO | Large proportion (40-75%) of DO measurements in the Unacceptable range in recent years (since 2010). | |
| | | | *E. coli* | Majority of *E. coli* values recorded throughout the last 5 years lay well within the Unacceptable range for intermediate contact recreation. | |
| **Steenbras** | - | Steenbras River [no major open waterbodies] | [none measured] | [no routine WQ monitoring points in this catchment] | [no routine WQ monitoring points in this catchment] |
| **South Peninsula** | - | Rivers & canals: Boramspruit, Schusters River, Elsies River | PO4-P | Phosphate concentrations in the Unacceptable range consistently at a number of sites in the past 5 years (e.g. along the Bokramspruit). | Increasingly urbanised catchment, but not subject to receipt of treated sewage effluent or characterized by substantial areas of informal or poorly serviced settlements (except for parts of Ocean View).<br>Bokramspruit sites are located downstream of Ocean View, which is |

| CATCHMENT | SUB-CATCHMENT | Main rivers/canals and monitored open waterbodies*^ | Main parameter/s of concern | Description of main issues at monitoring sites | Main likely source/s of the issues |
|---|---|---|---|---|---|
| | | | | | characterised by backyard dwellers and poor servicing. |
| | | | TIN | Nitrogen enrichment of certain rivers sites in this catchment in the most recent year of monitoring (2019), mostly along the Bokramspruit. | |
| | | | *E. coli* | Majority of *E. coli* measurements recorded at river sites in this subcatchments in the past 5 years fell in the Poor to lower end of Unacceptable categories for intermediate contact recreation.<br>In this subcatchment, the Schusters and Else Rivers showed mean annual *E. coli* concentrations in 2019 of Target and Poor, respectively, while the Bokramspruit sites were well within the range of Unacceptable. | |
| | | Waterbodies: Glencairnvlei, Schusters wetland^ | PO4-P;<br>N:P ratio | Glencairnvlei is among the main waterbodies in the City where orthophosphate enrichment has been least problematic in recent years, albeit still in the hypertrophic range. | Increasingly urbanised catchment, but not subject to receipt of treated sewage effluent or characterized by substantial areas of informal or poorly serviced settlements. |
| | | | *E. coli* | Majority of *E. coli* measurements from Glencairnvlei in 2019 were within the Poor and Unacceptable ranges for intermediate contact recreation. | |
| **Silvermine** | - | Silvermine River [no major open waterbodies] | PO4-P | Increasing proportion of samples from river sites in Poor and Unacceptable ranges for phosphate concentration over time, despite the upper and middle reaches of the | Runoff from urban residential areas and Westlake Golf Course in lower reaches of the Silvermine River. |

| CATCHMENT | SUB-CATCHMENT | Main rivers/canals and monitored open waterbodies*^ | Main parameter/s of concern | Description of main issues at monitoring sites | Main likely source/s of the issues |
|---|---|---|---|---|---|
| | | | | Silvermine River being amongst the least-impacted sections of river that are monitored in the City. | |
| **Noordhoek** | - | Rivers & canals: Brookwood Stream, De Goede Hoop Stream | [none measured] | [n/a] | [n/a] |
| | | Waterbodies: Wildevoelvlei | PO4-P; N:P ratio | Wildevoelvlei showed by far the greatest levels of phosphate enrichment of all open waterbodies in the City, making this system highly prone to algal blooms. | Inputs into Wildevoelvlei from both a large WWTW and (sporadically) an extensive area of poorly serviced informal settlement. |
| | | | TIN | Nitrogen enrichment of Wildevoelvlei, historically and in recent years. | |
| | | | NH3-N | Median NH3 concentrations in Wildevoelvlei consistently in the Unacceptable range and thus associated with Acute Toxicity effects to aquatic organisms. | |
| | | | Chl-a | Mean annual concentrations of Chl-a were, during the last 5 years, over an order of magnitude above the Unacceptable threshold in Wildevolevlei. | |
| | | | Microcystin | In the last ten years, Wildevoelvlei showed periodic Microcystin levels that were high enough to be of concern in the event that this system was used recreationally. | |
| **Chapman's Peak** | **-** | [no major rivers or waterbodies] | [none measured] | [no routine WQ monitoring points in this catchment] | [no routine WQ monitoring points in this catchment] |
| **Hout Bay** | **-** | Rivers & canals: Hout Bay River, | PO4-P | Increasing proportion of samples from river sites in Poor and Unacceptable ranges for | |

| CATCHMENT | SUB-CATCHMENT | Main rivers/canals and monitored open waterbodies*^ | Main parameter/s of concern | Description of main issues at monitoring sites | Main likely source/s of the issues |
|---|---|---|---|---|---|
| | | Baviaanskloof Stream, Bokkemanskloof Stream | | phosphate concentration over time, despite upper reaches of Hout Bay River being one of the least-impacted sections of river that are monitored in the City. | Presence of poorly serviced Imizamo Yeth informal settlement in middle to lower reaches of the subcatchment. |
| | | | DO | Proportion of DO measurements in the Unacceptable range was high in the past but has reduced significantly over time for river sites in this subcatchment, with an especially marked improvement since 2000. | |
| | | | *E. coli* | The Hout Bay River site downstream of the Imizamo Yethu informal settlement site was in the Unacceptable category for intermediate contact recreation in 2019 based on mean *E. coli* concentrations, compared with upstream sites in this subcatchment that fell within Target ranges. | |
| | | [no major open waterbodies] | [none measured] | [n/a] | [n/a] |
| **Llandudno** | - | [no major rivers or waterbodies] | [none measured] | [no routine WQ monitoring points in this catchment] | [no routine WQ monitoring points in this catchment] |

* Recognised "recreational vlei" waterbodies marked with asterisks

# Summarised results were not produced for open waterbodies in the City's database that are of insignificant size and/or for which there was a relatively sparse monitoring record. These included Uitkamp wetland (Mosselbank subcatchment), Psoralea Park wetland (Sand catchment), Moddervlei and Costa da Gama wetland (Zeekoe catchment), and Schusters wetland (South Peninsula catchment).

# 7 CONCLUSIONS

## 7.1 Overview of findings

This report has considered the City's watercourses from the perspective of a number of key water quality variables, which are critical indicators of aquatic ecosystem condition, particularly in urban areas. The data make it clear that the biggest water quality issue afflicting most of the routinely monitored systems is elevated phosphorus, which drives eutrophic and hypertrophic conditions. Such conditions make receiving water bodies such as vleis vulnerable to excessive plant growth, requiring ongoing maintenance and at times posing human health risks as a result of the presence or risk of microcystin toxins.

The report is largely descriptive with regard to identifying causal factors for phosphorus enrichment, and the most likely source areas are correlative rather than identified through systematic pollution tracking. Nevertheless, the most likely main sources of phosphorus loading in the City's inner catchments comprise the receipt of treated effluent from the City's numerous WWTWs, which discharge into several rivers; discharges of raw sewage from leaking or overflowing infrastructure, sometimes as the result of pump failure during load shedding; and the passage of water contaminated with sewage and other domestic waste (e.g. water from cooking, washing etc.) from informal settlements and other poorly serviced areas. Such waste is also associated with significant bacterial contamination, posing a risk to people encountering this water, in the form of puddles and ditches in settlements; in stormwater channels; and in the receiving rivers and (to a lesser extent) vleis and dams.

It is possible that, over time, WWTW effluent volumes discharged into the receiving aquatic environment will decrease as a result of the City's encouragement of effluent re-use. The problem of contamination of water as a result of inadequate servicing in some areas will, however, remain an issue until increased attention is paid to the improvement of servicing of informal settlements with regard to sewage management, solid waste removal, and stormwater treatment and conveyance. The costs of not providing such servicing at an appropriate scale play out not only in terms of human health and dignity in the affected areas, but also in terms of compromised ecosystems and significant management costs entailed in reactive and symptomatic management of issues such as:

- Invasive aquatic plant management;
- Emergency closure of recreational water bodies in response to algal blooms;
- Litter and solid waste removal;
- Management and removal of invasive reeds, water hyacinth and other plants that encroach into nutrient-enriched and often shallowing water bodies;
- Costs for dredging and removal of organic sludges; and
- Interventions such as cut-off drains and low flow diversions for the re-direction of proportions of contaminated stormwater into sewers.

This said, it is noted that not all of the City's watercourses are highly contaminated, and the monitoring data do show that there are a few rivers where water quality is impacted to a much lesser degree. These include the Silvermine and Lourens River systems. Other rivers such as the Sand Catchment rivers and Hout Bay River are moderately to highly contaminated only in their lower reaches, and usually as a result of the issues outlined above. It must also be stressed that the City's monitoring programme itself, while extensive and covering all the major catchments in the City of Cape Town, focuses mainly on areas faced with water quality challenges. This generates an unintended bias in the water quality database towards degraded sites exhibiting signs of pollution. There are undoubtedly also a number of aquatic ecosystems (including river reaches, open waterbodies and wetlands) within the City that have relatively good water quality, particularly for a major urban area, which are not currently monitored on a routine basis due to budgetary constraints and the need to prioritise monitoring and pollution abatement initiatives in problematic areas.

Of possible concern with regards to the future quality of even the currently relatively uncontaminated river systems is, however, the increasing trend for new developments in the City to seek to manage sewage generated on site through so-called "package plants", which treat low volumes of sewage effluent to specified standards. This is probably a response to the fact that in some areas development rates accelerate ahead of municipal infrastructure upgrade programs and thus compromise the capacity of some WWTWs. It is also in part an indirect effect of the recent drought in Cape Town, with on-site effluent treatment allowing treated effluent to be used for landscape irrigation, but with any excess (particularly in winter) being discharged into rivers. Although such effluent might well meet national effluent standards, it does mean that some rivers or river reaches that are not currently impacted by the elevated nutrients, salts and sometimes bacteria inevitably associated with treated effluent, may increasingly and insidiously be affected.

From the perspective of human health, represented in this report by *E. coli* data, the analyses presented here suggest that the five main recreational water bodies in the City have generally been in a condition conducive to support at least intermediate contact recreation activities over the past five years, despite often high levels of *E. coli* in the rivers and channels that feed them. During summer, the probability of Zeekoevlei, Zandvlei and Princessvlei meeting even full contact standards is high (approaching 100% for Zeekoevlei and 80% for the other two systems), although water quality near the major point source river inflows deteriorates somewhat in winter in Zeekoevlei, largely as a result of inflows of polluted water from informal settlements upstream, and in Zandvlei.

The risk of occurrence of *E. coli* at Unacceptable levels is highest in Milnerton Lagoon, which has been subject to periodic and at times prolonged contamination by *E. coli*. This is indicative of exposure to untreated sewage, assumed to derive mainly from the large areas of informal and backyard-dominated settlement in the catchment upstream (e.g. Du Noon and Jo Slovo areas). Occasionally compromised final effluent discharged from the Potsdam WWTW will also influence water quality in the system, but operational and capital improvements are reportedly addressing this.

Data for Rietvlei, currently represented by a single routinely monitored site and occasional *ad hoc* samples, suggested by contrast that the probability of *E. coli* measurements being within the target for direct contact recreation is high (>80%) throughout the year and the probability that there is an Unacceptable risk for indirect contact recreation remains very low.

Rietvlei, like most of the assessed urban vleis, is hypertrophic (that is, extremely enriched) with regards to phosphate, and vulnerable to periodic blue-green algal blooms. These blooms can result in the production of microcystin toxins (usually in summer to late autumn) that can pose risks to recreational users in contact with the water bodies. Rietvlei experienced such conditions in 2016, 2017, and 2019. Such transient episodes could have been of significant health risk to recreational users exposed to the water, and the City therefore imposed precautionary measures to limit risk such as temporarily restricting access to the Rietvlei waterbody. It is of interest that Rietvlei was, however, the only waterbody with microcystin toxin present in concentrations of concern from 2010 onwards, when microcystin toxin testing became a regular response to blue-green algal blooms. None of the other systems showed microcystin toxins in concentrations of concern This at least suggests a significant improvement in Zeekoevlei's water quality over time, with that system suffering frequent blue-green algal blooms and periods of microcystin toxicity prior in the early 2000s. Blue-green algal blooms and associated toxicity are less pervasive in Princessvlei and Zandvlei.

Of some concern is the fact that there are areas in the City where residents (including children) informally play, swim, paddle and possibly even wash clothing, cook and drink water from rivers, vleis and other wetlands not considered in this report, without any knowledge as to its fitness for such uses. Some of these water bodies are highly contaminated, and the route to addressing this issue must lie in improving the condition of the catchments draining into these systems, through the provision of basic sanitation and servicing. Raising awareness and instilling a sense of shared responsibility regarding the condition of Cape Town's waterways is also important.

## 7.2 Monitoring recommendations

Ongoing water quality monitoring and analysis of data are essential tools to inform City managers as to where to focus attention with regard to implementing pollution abatement measures and identifying areas with high human health risks. It is important that such data also enter the academic, public and political arenas, to drive constructive, collaborative discussion about how and where to implement remediation measures.

Three areas where additional monitoring might play a useful role are outlined below.

1. *Addressing concerns around human health issues in watercourses used for recreation*

It is recommended that certain of the reaches of the Kuils River and detention pond areas through the Khayelitsha Wetland Park area should be monitored routinely, at least for *E. coli*, as these reaches are used by local communities for kayak polo games and training. The City has undertaken some preliminary *ad hoc* sampling in this area and ascertained that microbial water quality is relatively good which is encouraging.

It is also recommended that two additional routine water quality monitoring points should be added to Rietvlei – one in the north western corner of the vlei, near where the Bayside Canal enters the system, and the other in the southern part of the water body. Measures to track and address apparent declining water quality in the Bayside Canal and its contribution to water quality in Rietvlei are also worth considering.

2. *Including monitoring of Enterococci in routine analyses*

Consideration should be given to the routine measurement of Enterococci in samples from the waterbodies that are used for contact recreation within the City, as part of the City's ongoing water quality monitoring programme. This would bring the City in line with international approaches and guidelines that now focus on Intestinal Enterococci measurements, often alongside *E. coli* data. Alternatively, inclusion of faecal coliform data should be allowed for, as a minimum, to allow for more appropriate utilisation of existing guidelines.

3. *Ambient water quality monitoring to allow reporting on the "State of the City's watercourses"*

It is also recommended that consideration be given to the periodic collection of generalised "ambient" water quality data (see Sections 2.5 and 2.8), which could provide a more holistic picture of the general state or condition of watercourses throughout the City, rather than the focused assessment of problematic, pollution-prone systems considered in the present report. A five-yearly assessment of key water quality variables from samples collected at the same time of year (e.g. early spring) from the downstream node of all second or third order streams in the City, as well as all natural standing water wetlands above a particular threshold size, could provide such information. These assessments would serve as a valuable tool to track progress in managing its watercourses as a whole, and to allow for important holistic "State of the City's watercourses" reporting. The current dataset focuses primarily on the monitoring of problem areas and thus potentially exaggerates the extent of pollution and gross contamination. A more holistic monitoring approach would potentially provide a less biased assessment of water quality in the City.

It is recommended that consideration should be given to this proposed addition to the water quality monitoring programme, and a method for identifying representative sites on a City wide scale be sought, through appropriate consultation.

Inclusion of heavy metal analyses from the lower river or estuarine outlets of each major City catchment is also recommended for inclusion in this programme, to highlight catchments in which heavy metal contamination is an issue, and where more stringent pollution tracking may be required.

## 7.3 Recommendations for future reporting

Regardless of whether or not the above additional monitoring recommendations are addressed, it is recommended that the City allow for ongoing reporting on the data generated by the water quality monitoring programme, in order to reflect the long-term trajectory of water quality in its monitored systems. This would allow the efficacy of the City's catchment management approaches to be tracked, and should improve accountability, with regards to the City's commitment to improving water quality and general catchment condition.

Ongoing internal reporting within the Catchment, Stormwater and River Management Branch of the City's

Water and Sanitation Department is used to highlight immediate pollution issues and to drive management interventions. It is thus recommended that five-yearly reporting on overall catchment-scale water quality trajectories should be conducted going forward, particularly with regard to phosphorus enrichment, which has been identified in this report as the key issue of concern in the City's watercourses. This reporting could be coupled with the recommended ambient water quality monitoring programme, but should in its own right focus on the degree to which the issues highlighted in this (and subsequent) reports have been addressed, over the five year period.

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# APPENDICES

## APPENDIX A: LIST OF SITES INCLUDED IN THIS REPORT

**Table A1**

**City Sampling sites for which data have been included in this assessment**

**Table indicates number of records (that is, samples) per site over 5 year time periods**

| CATCHMENT | SUB-CATCHMENT | SITE | SITE LOCATION | TYPE | VLEI NAME | 1978-1980 | 1980-1985 | 1985-1990 | 1990-1995 | 1995-2000 | 2000-2005 | 2005-2010 | 2010-2015 | 2015-2020 | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diep | Diep | BM24 | Parklands stormwater outlet at Gie Rd | River dataset | | | | | | | | 3 | 4 | | 7 |
| | | MOS05 | Diep River u/s Mosselbank River confluence | River dataset | | | | | | | 46 | 111 | 114 | 88 | 359 |
| | | MOSAH09 | | River dataset | | | | | | | | | 14 | | 14 |
| | | PEV1 | Zoarvlei (south end) at corner of Vrystraat and Grey St | Standing water | Zoarvlei | | | 24 | 49 | 10 | 88 | 104 | 104 | 107 | 490 |
| | | PEV2 | Zoarvlei (centre) at Wemmys road footbridge | Standing water | Zoarvlei | | | 21 | 35 | 10 | 98 | 81 | 149 | 103 | 497 |
| | | PEV3 | Zoarvlei (north end) at Bancroft St | Standing water | Zoarvlei | | | 24 | 42 | 6 | 77 | 104 | 105 | 113 | 471 |
| | | RTV01 | Diep River at Blauwberg Road bridge | River dataset | | | | | | 9 | 117 | 106 | 103 | 103 | 438 |
| | | RTV02 | Near jetty at yacht club | Standing water | Rietvlei | | | | | 9 | 117 | 121 | 206 | 296 | 749 |
| | | RTV03 | Stormwater canal from Theo Marais Park (Montagu Gardens) | River dataset | | | | | | 9 | 117 | 116 | 123 | 112 | 481 |
| | | RTV04 | Stormwater channel from Bayside Mall (into Rietvlei) | River dataset | | | | | | 9 | 117 | 115 | 97 | 113 | 451 |
| | | RTV05 | Outlet from Rietvlei at Otto du Plessis Drive bridge | River dataset | Rietvlei | | | | | 9 | 117 | 265 | 453 | 139 | 983 |
| | | RTV06 | Diep River downstream of N7 road bridge | River dataset | | | | | | | 45 | 75 | 87 | 88 | 295 |
| | | RTV07 | | River dataset | | | | | | | 20 | 1 | 1 | | 22 |
| | | RTV08 | Duikersvlei Stream u/s of confluence with Theo Marais canal | River dataset | | | | | | | 79 | 110 | 124 | 108 | 421 |
| | | RTV09 | Diep River estuary at Woodbridge Island (Loxton Rd) | River dataset | | | | | | | 51 | 117 | 137 | 127 | 436 |
| | | RTV10 | Diep River estuary at mouth | River dataset | | | | | | | 40 | 103 | 137 | 139 | 423 |
| | | RTV11 | Diep River d/s of Potsdam WWTW | River dataset | | | | | | | 42 | 266 | 372 | 125 | 805 |
| | | RTV12 | Canal d/s confluence TM & Duikersvlei | River dataset | | | | | | | 40 | 115 | 114 | 98 | 371 |
| | | RTV14 | Stormwater channel next to Bayside Mall d/s of Blaauberg Rd | River dataset | | | | | | | | 36 | 85 | 16 | 137 |
| | | RTV18 | Rietvlei north of island opp Broad Rd | River dataset | | | | | | | | | | 96 | 96 |
| | | RTV19 | Ad hoc site near Bayside inflow | Standing water | Rietvlei | | | | | | | | | 8 | 8 |
| | | RTV21 | Ad hoc site near Bayside inflow | Standing water | Rietvlei | | | | | | | | | 24 | 24 |
| | | RTV22 | Railway bridge near container yard | River dataset | | | | | | | | | | 60 | 60 |
| | Mosselbank | MOS01 | Maastricht Canal u/s WWTW | River dataset | | | | | | | 70 | 113 | 120 | 119 | 424 |
| | | MOS02 | Maastricht Canal d/s WWTW | River dataset | | | | | | | 70 | 116 | 110 | 84 | 380 |
| | | MOS03 | Mosselbank trib d/s Fisantkraal | River dataset | | | | | | | 53 | 116 | 116 | 93 | 378 |
| | | MOS04 | Mosselbank River u/s Diep River confluence | River dataset | | | | | | | 44 | 114 | 114 | 108 | 380 |
| | | MOS06 | Mosselbank River nr Klipheuwel | River dataset | | | | | | | 36 | 100 | 88 | 72 | 296 |
| | | MOS07 | Mosselbank River u/s Fisantekraal WWTW | River dataset | | | | | | | | | 147 | 92 | 239 |
| | | MOS08 | Mosselbank River d/s Fisantekraal WWTW | River dataset | | | | | | | | | 143 | 115 | 260 |
| | | MOS09 | Mosselbank tributary d/s Fisantkraal settlement | River dataset | | | | | | | | | 5 | 83 | 90 |
| | | MOSAH02 | Mosselbank project sample off R302 on Gravel Rd to County Fair Broiler Farm W trib point | River dataset | | | | | | | | | 32 | | 32 |
| | | MOSAH03 | | River dataset | | | | | | | | | 28 | 30 | 58 |
| | | MOSAH04 | | River dataset | | | | | | | | | 31 | | 31 |
| | | MOSTP1 | | River dataset | | | | | | | | | 11 | | 11 |
| | | MOSTP2 | | River dataset | | | | | | | | | 10 | | 10 |
| | | MOSTP3 | | River dataset | | | | | | | | | 11 | | 11 |
| | | MOSTP4 | | River dataset | | | | | | | | | 15 | 32 | 47 |
| | | MOSTP5 | | River dataset | | | | | | | | | 7 | | 7 |
| Eerste | Eerste | EK08 | Kuils River d/s of Baden Powell Drive bridge | River dataset | | | | 16 | 65 | 65 | 113 | 113 | 122 | 189 | 685 |
| | | EK11 | Kuils River d/s of Zandvliet discharge (dirt road bridge) | River dataset | | | | 10 | 63 | 64 | 115 | 112 | 122 | 189 | 677 |
| | | EK12 | Eerste River u/s of Macassar WTW (d/s of Kuils confluence) | River dataset | | | | 8 | 65 | 60 | 69 | | | 26 | 230 |
| | | EK13 | Eerste River on N2 Freeway (u/s of Kuils confluence) | River dataset | | | | | 50 | 46 | 55 | 89 | 118 | 111 | 469 |
| | | EK14 | Eerste River in Stellenbosch near Dorp Street bridge | River dataset | | | | | 51 | 53 | 66 | | | | 170 |
| | | EK15 | Kleinvlei canal | River dataset | | | | | 29 | 41 | 58 | 89 | 118 | 113 | 448 |
| | | EK16 | Zandvliet WWTW Final discharge | River dataset | | | | | | 50 | 8 | | | 81 | 139 |
| | | EK17 | Eerste River estuary | River dataset | | | | | | | 54 | 86 | 117 | 114 | 373 |
| | | EK18 | Moddergatspruit River at Macassar Rd | River dataset | | | | | | | 78 | 89 | 108 | 104 | 379 |
| | | EK21 | Kleinvlei Canal access Film City Drive | River dataset | | | | | | | | | 12 | | 12 |
| | | EK22 | Kleinvlei Canal south of Stratford Ave | River dataset | | | | | | | | | 12 | | 12 |
| | Kuils | EK01 | | River dataset | | | | 12 | 48 | 47 | 59 | | | | 166 |
| | | EK02 | Kuils River at Old Paarl Rd | River dataset | | | | 16 | 59 | 48 | 64 | | | | 187 |
| | | EK03 | Bottelary River at Amandel Rd | River dataset | | | | 16 | 58 | 48 | 113 | 115 | 117 | 112 | 579 |
| | | EK04 | Kuils River at Carinus street bridge | River dataset | | | | 16 | 64 | 59 | 65 | | 32 | 116 | 354 |
| | | EK05 | Kuils River in canal u/s of Stellenbosch Arterial Rd | River dataset | | | | 16 | 58 | 61 | 114 | 113 | 119 | 114 | 595 |
| | | EK06 | Kuils River d/s of Hindle Rd bridge | River dataset | | | | 16 | 65 | 61 | 69 | 4 | | | 215 |
| | | EK07 | Kuils River u/s of Old N2 / Faure Rd bridge | River dataset | | | | 16 | 64 | 62 | 66 | 4 | | | 212 |
| | | EK09 | Kuils River d/s Belville WWTW discharge at Rietvlei Rd | River dataset | | | | 16 | 64 | 58 | 115 | 115 | 121 | 117 | 608 |
| | | EK10 | | River dataset | | | | 16 | 65 | 21 | | | | | 102 |
| | | EK19 | Kuils River d/s R300 off old bridge | River dataset | | | | | | | 41 | 112 | 118 | 114 | 385 |
| | | KHA01 | Pond in Site C on Mew Way | Standing water | Mew Way DP | | | | | | | | 83 | 115 | 198 |
| HBay | Hout Bay | DR01 | Hout Bay River at Princess St | River dataset | | | | | 16 | 65 | 69 | 67 | 121 | 118 | 458 |
| | | DR02 | | River dataset | | | | | 16 | 65 | 116 | 118 | 119 | 115 | 551 |
| | | DR03 | Pond overflow from World of Birds to stormwater channel | River dataset | | | | | 15 | 19 | | | | | 34 |
| | | DR04 | Hout Bay River at Longkloof Rd | River dataset | | | | | 16 | 65 | 116 | 116 | 121 | 114 | 548 |
| | | DR05 | | River dataset | | | | | | 3 | 55 | 59 | 56 | 60 | 234 |
| | | DR06 | Disa River at Bethal Rd | River dataset | | | | | | | | | 80 | 111 | 191 |
| Lourens | Lourens | LOU01 | Lourens River at Vergelegen Estate | River dataset | | | | | | 8 | 99 | 116 | 116 | 118 | 459 |
| | | LOU02 | Lourens River in P.O.S., Hillcrest Rd | River dataset | | | | | | | 6 | 68 | 116 | 108 | 298 |
| | | LOU03 | Lourens River at Main Rd - Somerset West | River dataset | | | | | | 7 | 98 | 117 | 116 | 110 | 448 |
| | | LOU04 | Lourens River at Broadway Rd | River dataset | | | | | | | 68 | 67 | 115 | 92 | 342 |
| | | LOU05 | Lourens River on Beach Road | River dataset | | | | | | | 112 | 114 | 121 | 122 | 471 |
| | | LOU06 | Lourens River in Lourensford Estate at "Red Bridge" | River dataset | | | | | | | 109 | 114 | 120 | 110 | 453 |
| MPlain | MPlain | KHA02 | Canal inlet to detention pond near litter device | Standing water | Mplain DP | | | | | | | | 80 | 119 | 199 |
| | | KHA03 | Detention pond near outlet on Baden Powell Drive | River dataset | Mplain DP | | | | | | | | 81 | 118 | 199 |
| | | WV01 | SE side of EAST vlei nr stormwater outlet | Standing water | Wildevoelvlei | | | | | 11 | | | | | 11 |
| | | WV02 | Centre of EAST vlei | Standing water | Wildevoelvlei | | | | | 122 | 108 | 96 | 233 | 245 | 806 |
| | | WV03 | NW side of EAST vlei | Standing water | Wildevoelvlei | | | | | 6 | | | | | 6 |
| | | WV04 | SE side of WEST vlei | Standing water | Wildevoelvlei | | | | | 11 | | | | | 11 |
| | | WV05 | Centre of WEST vlei | Standing water | Wildevoelvlei | | | | | 105 | 108 | 91 | 150 | 146 | 602 |
| | | WV06 | NW side of WEST vlei | Standing water | Wildevoelvlei | | | | | 6 | | | | | 6 |

| CATCHMENT | SUB-CATCHMENT | SITE | SITE LOCATION | TYPE | VLEI NAME | 1978-1980 | 1980-1985 | 1985-1990 | 1990-1995 | 1995-2000 | 2000-2005 | 2005-2010 | 2010-2015 | 2015-2020 | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NHoek | Noordhoek | WV07 | | Standing water | Wildevoelvlei | | | | | 22 | 45 | 75 | 197 | | 339 |
| | | WV08 | Wildevoelvlei mouth to sea | Standing water | Wildevoelvlei | | | | | 12 | 13 | 56 | 62 | 78 | 221 |
| | | WV09 | Backshore of lagoon near old shipwreck | Standing water | Wildevoelvlei | | | | | | | | 1 | | 1 |
| | | WV10 | E end of EAST vlei nr WWTW outfall | Standing water | Wildevoelvlei | | | | | 11 | | | | | 11 |
| | | WV11 | W end of EAST vlei nr interconnecting channel | Standing water | Wildevoelvlei | | | | | 11 | | | | 76 | 87 |
| | | WV14 | S shore of EAST vlei | Standing water | Wildevoelvlei | | | | | 10 | | | | | 10 |
| | | WV15 | N shore of EAST vlei | Standing water | Wildevoelvlei | | | | | 9 | | | | | 9 |
| | | WV16 | S shore of WEST vlei | Standing water | Wildevoelvlei | | | | | 13 | | | | | 13 |
| | | WV17 | N shore of WEST vlei | Standing water | Wildevoelvlei | | | | | 9 | | | | | 9 |
| Salt | Elsieskraal | ANG01 | Angelier Park upper dam near Van Riebeekshof Rd | Standing water | Elsieskraal dams | | | | | | | 25 | 180 | 176 | 383 |
| | | ANG02 | Angelier Park lower dam near Van Riebeekshof Rd | Standing water | Elsieskraal dams | | | | | | | 25 | 185 | 162 | 372 |
| | | BM01 | Welgemoed Dam in Tygerberg Nature Reserve | Standing water | Elsieskraal dams | | | | | | | 19 | 41 | 38 | 98 |
| | | BM02 | Kanonberg Dam (Tygerberg NR) on trib of Elsieskraal | Standing water | Elsieskraal dams | | | | | | | 17 | 41 | 38 | 96 |
| | | BM03 | Plattekloof Dam at Meyboom Avenue in Plattekloof | Standing water | Elsieskraal dams | | | | | | | 17 | 33 | 22 | 72 |
| | | DOOR01 | Doordekraal Dam at large stormwater outlet on Angelier Stre* | Standing water | Elsieskraal dams | | | | | | | 27 | 118 | 112 | 259 |
| | | DOOR03 | Doordekraal Dam at south end next to dam wall | Standing water | Elsieskraal dams | | | | | | | 26 | 177 | 177 | 382 |
| | | ELS_GW | Elsieskraal River near Grandwest and Goodwood Station | River dataset | | | | | | | | | 29 | 112 | 141 |
| | | ELS01 | Elsieskraal River on Claredon Road | River dataset | | | | | | 10 | | | | | 10 |
| | | ELS02 | Elsieskraal River at Connaught Rd | River dataset | | | | | | 10 | | | | | 10 |
| | | ELS03 | Elsieskraal River on Coleman Road | River dataset | | | | | | 10 | | | | | 10 |
| | | ELS04 | Elsieskraal River on Chelsea Street | River dataset | | | | | | 10 | | | | | 10 |
| | | ELS05 | Elsieskraal River at end of Paul Kruger Rd | River dataset | | | | | | 10 | | | | | 10 |
| | | ELS06 | Elsieskraal River on Forest Drive Extension - Thornton | River dataset | | | | | | 10 | | | | | 10 |
| | | ELS07 | Elsieskraal River on Ringwood Drive | River dataset | | | | | | 10 | | | | | 10 |
| | | ELS08 | Elsieskraal River at Nightingale Way | River dataset | | | 33 | 60 | 56 | 47 | 114 | 106 | 118 | 122 | 656 |
| | | ELS10 | Elsieskraal at Carl Cronje Rd | River dataset | | | | | | | 68 | 99 | 112 | 93 | 372 |
| | Lower Salt | NR01 | Blomvlei Canal at Koodoo Street u/s of Vygekraal River conf* | River dataset | | | 33 | 60 | 56 | 64 | 118 | 114 | 111 | 113 | 669 |
| | | NR02 | Vygekraal River at Cornflower Street u/s of Blomvlei Canal * | River dataset | | | 33 | 60 | 56 | 64 | 117 | 116 | 114 | 112 | 672 |
| | | NR03 | Vygekraal River u/s of Athlone WTW | River dataset | | | 33 | 60 | 55 | 55 | 105 | 115 | 112 | 115 | 652 |
| | | NR04 | Vygekraal River d/s Athlone WTW | River dataset | | | 33 | 60 | 56 | 59 | 114 | 116 | 121 | 125 | 686 |
| | | NR06 | Black River at Raapenberg Road bridge | River dataset | | | 33 | 60 | 56 | 64 | 72 | 106 | 116 | 118 | 625 |
| | | NR07 | Black River on Footbridge to Alexandra Institute | River dataset | | | 33 | 60 | 56 | 62 | 74 | 104 | 80 | 112 | 581 |
| | | NR08 | Liesbeek River downstream of Lake weir opp. Hartleyvale | River dataset | | | 33 | 60 | 56 | 74 | 111 | 117 | 117 | 115 | 683 |
| | | NR09 | Salt River Canal at Voortrekker Road bridge | River dataset | | | 33 | 60 | 56 | 63 | 69 | 105 | 110 | 112 | 608 |
| | | NR10 | Salt River Canal at Marine Drive Bridge - Paarden Eiland | River dataset | | | 33 | 60 | 56 | 64 | 120 | 116 | 118 | 120 | 689 |
| | | NR11 | Black River in Rdbosch Golf Course | River dataset | | | 33 | 60 | 55 | 64 | 117 | 114 | 114 | 114 | 671 |
| | | NR12 | Liesbeek River on Sans Souci Rd | River dataset | | | 33 | 60 | 56 | 49 | | | | | 198 |
| | | NR13 | Liesbeek River - old canal next to River Club | River dataset | | | 33 | 60 | 56 | 39 | | | | | 188 |
| | | NR15 | Jakkalsvlei Canal at N2 | River dataset | | | 33 | 60 | 54 | 63 | 118 | 116 | 90 | 112 | 646 |
| | | NR16 | Langa Canal on N2 | River dataset | | | 33 | 60 | 53 | 60 | 114 | 115 | 112 | 112 | 659 |
| | | NR17 | Kalksteenfontein Canal nr Netreg Stn | River dataset | | | 33 | 60 | 56 | 65 | 24 | | | 114 | 352 |
| | | NR18 | Nyanga Canal at Duinefontein Road outside GF Jooste Hospital | River dataset | | | 33 | 60 | 56 | 39 | | | | | 188 |
| | | NR19 | Vygekraal River downstream of Elsieskraal but upstream of B* | River dataset | | | 33 | 60 | 55 | 40 | | | | | 188 |
| | | NR21 | Kalksteenfontein Canal near Borcherd's Quarry WWTW outfall | River dataset | | | | 36 | 56 | 27 | | | | | 119 |
| | | NR22 | | River dataset | | | | 26 | 56 | 77 | 71 | | 55 | 73 | 358 |
| | | NR23 | Liesbeek River on Winchester Rd - Kirstenbosch | River dataset | | | | 26 | 56 | 51 | | | | | 133 |
| | | NR25 | Vygekraal d/s of Athlone WWTW at Jan Smuts Drive | River dataset | | | | | | | | | | 51 | 51 |
| | | NR26 | Kalksteen Canal at corner Robert Subukwe and N2 | River dataset | | | | | | | | | | 118 | 120 |
| Sand | Sand | BM11 | | Standing water | Psoralea Park | | | | | | | 17 | 28 | 22 | 67 |
| Sand | | BM16 | Langevlei Canal at litter trap south of Military Road | River dataset | | | | | | | | 15 | 28 | 22 | 65 |
| | | BM17 | Keysers River at Keysers Road in industrial area | River dataset | | | | | | | | 15 | 28 | 21 | 64 |
| | | BM18 | Westlake River at Steenberg Rd near pumpstation | River dataset | | | | | | | | 15 | 28 | 22 | 65 |
| | | CR01 | Westlake River cnr Main and Chenel Roads | River dataset | | 52 | 111 | 115 | 167 | 116 | 115 | 115 | 122 | 94 | 1007 |
| | | CR02 | Westlake River at Orange St - Kirstenhof | River dataset | | | | | 12 | 39 | 70 | | 112 | 87 | 320 |
| | | CR03 | Westlake River Altenburg Rd - Kirstenhof | River dataset | | | | | 12 | 31 | 66 | | 112 | 86 | 307 |
| | | CR04 | Westlake River in Pollsmoor Prison grounds | River dataset | | | | | 12 | 29 | 62 | | 106 | 74 | 283 |
| | | CR05 | Westlake River at Steenberg Rd | River dataset | | | | | 12 | 35 | 50 | | 86 | 6 | 189 |
| | | CR06 | Prinskasteel River in greenbelt off Lismore Rd (close to M3) | River dataset | | | | | 12 | 39 | 105 | 115 | 105 | 110 | 486 |
| | | CR07 | Tributary of Prinskasteel River (just u/s of CR06) | River dataset | | | | | 12 | 39 | 68 | | | | 119 |
| | | CR08 | Prinskasteel at Orpen Rd | River dataset | | | | | 12 | 26 | 48 | | | | 86 |
| | | CR09 | Grootboschkloof River on Soetvlei Rd (where M3 runs paralle* | River dataset | | | | | 12 | 39 | 70 | | | | 121 |
| | | CR10 | Grootboschkloof on Spaanschemat River Rd | River dataset | | | | | 12 | 38 | 66 | | | | 116 |
| | | CR11 | Grootboschkloof on Klein Constantia (Hope of Constantia gat* | River dataset | | | | | 11 | 39 | 68 | | | | 118 |
| | | CR12 | Spaanschemat River on Constantia Main Road to Hout Bay | River dataset | | | | | 12 | 39 | 65 | | | | 116 |
| | | CR13 | Spaanschemat River on Gilmour Circle | River dataset | | | | | 12 | 39 | 63 | | | | 114 |
| | | CR14 | Diep River at Doordrift Road | River dataset | | | | | 12 | 39 | 68 | | | | 119 |
| | | CR15 | Diep River in Greenbelt off Alphen Drive (LHS of road) | River dataset | | | | | 12 | 30 | 56 | | | | 98 |
| | | CR16 | Diep River at Alphen Rd in canal d/s of CR15 | River dataset | | | | | 12 | 39 | 110 | 113 | 114 | 106 | 494 |
| | | CR17 | Diep River cnr Brommersvlei & Rathvelder Rds | River dataset | | | | | 11 | 27 | 54 | | | | 92 |
| | | CR18 | Diep River in dip on Hohenhort Drive | River dataset | | | | | 12 | 39 | 60 | | 10 | | 121 |
| | | CR19 | Diep River at T-junction Southern Cross & Rhodes Drive | River dataset | | | | | 9 | 36 | 38 | | | | 83 |
| | | CR20 | Keysers River at Military Rd | River dataset | | 52 | 111 | 116 | 162 | 103 | 108 | 113 | 123 | 118 | 1008 |
| | | CR21 | Sand River at Oudevlei Road (d/s conf Langvlei & Sand) | River dataset | | 52 | 110 | 117 | 132 | 86 | 110 | 114 | 125 | 126 | 974 |
| | | CR22 | Downstream of Westlake and Keysers River near railway line | River dataset | | | | | | | | | 105 | 112 | 217 |
| | | DRRSC | | River dataset | | | | | 81 | 111 | 115 | 116 | 118 | 110 | 651 |
| | | LPVMR | | River dataset | | | | | | | | | 86 | 110 | 196 |
| | | LPVN | Little Princessvlei - north | Standing water | Little Princessvlei | | | 5 | 89 | 82 | 74 | | 133 | 167 | 550 |
| | | LPVS | Little Princessvlei - south | Standing water | Little Princessvlei | | | 7 | 92 | 105 | 116 | 117 | 191 | 172 | 802 |
| | | LVI | Langevlei - canal at vlei inlet | River dataset | Langevlei | | | | 96 | 110 | 117 | 116 | 117 | 112 | 668 |
| | | LVO | Langevlei - vlei oulet | Standing water | Langevlei | | | | 97 | 110 | 119 | 117 | 192 | 186 | 823 |
| | | OOG01 | Die Oog at Midwood Avenue, Bergvliet | Standing water | Die Oog | | | | | 14 | 57 | 62 | 192 | 151 | 476 |
| | | PV01 | | Standing water | Princessvlei | | 19 | 66 | 111 | 96 | 28 | | | | 320 |

| CATCHMENT | SUB-CATCHMENT | SITE | SITE LOCATION | TYPE | VLEI NAME | 1978-1980 | 1980-1985 | 1985-1990 | 1990-1995 | 1995-2000 | 2000-2005 | 2005-2010 | 2010-2015 | 2015-2020 | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PV02 | | Standing water | Princessvlei | | 19 | 66 | 114 | 103 | 33 | | | | 335 |
| | | PV03 | Princessvlei - centre | Standing water | Princessvlei | | 19 | 66 | 115 | 106 | 113 | 115 | 224 | 212 | 970 |
| | | PV04 | | Standing water | Princessvlei | | 19 | 36 | 71 | 86 | 28 | | | | 240 |
| | | PVweir | Princessvlei near outlet weir | Standing water | Princessvlei | | | | 48 | 25 | 47 | 115 | 120 | 120 | 475 |
| | | SCV | Southfield Canal at Victoria Road | River dataset | | | 19 | 64 | 102 | 109 | 114 | 115 | 118 | 117 | 758 |
| | | ZA01S | Zandvlei - north, surface | Standing water | Zandvlei | 51 | 119 | 117 | 176 | 89 | 46 | 12 | 179 | 193 | 982 |
| | | ZA02S | Zandvlei - centre (opp Imperial Yacht Club), surface | Standing water | Zandvlei | 51 | 119 | 114 | 177 | 97 | 107 | 119 | 210 | 206 | 1202 |
| | | ZA03S | | Standing water | Zandvlei | 51 | 119 | 114 | 177 | 93 | 51 | 62 | 12 | 12 | 691 |
| | | ZA04S | | Standing water | Zandvlei | 50 | 119 | 118 | 108 | 43 | | 10 | | 1 | 449 |
| | | ZA05S | Outlet channel near Royal Road bridge, surface | Standing water | Zandvlei | 51 | 118 | 114 | 169 | 91 | 30 | 31 | 186 | 170 | 960 |
| | | ZA06S | South entrance to Marina da Gama canals, | Standing water | Zandvlei | 51 | 119 | 117 | 104 | 43 | | | | 1 | 435 |
| | | ZA07S | North entrance to Marina da Gama canals | Standing water | Zandvlei | 51 | 119 | 114 | 102 | 40 | | | | 6 | 432 |
| | | ZA08S | Marina da Gama canal near "The Anchorage", surface | Standing water | Zandvlei | 42 | 119 | 117 | 177 | 89 | 30 | | 180 | 189 | 945 |
| | | ZA09S | Marina da Gama canal, surface | Standing water | Zandvlei | | | | | | | | 175 | 174 | 349 |
| | | ZA10S | Westlake Wetland opposite Rutter Rd (old WLW) | Standing water | Westlake | | | | | 3 | 55 | 83 | 208 | 198 | 549 |
| | | ZA11S | Marina da Gama canal East Lake (old BM20), surface | Standing water | Zandvlei | | | | | | | | 171 | 180 | 351 |
| | | ZA12S | Marina da Gama canal Baalen Way (old BM22), surface | Standing water | Zandvlei | | | | | | | | 176 | 167 | 343 |
| | | ZA13S | Marina da Gama canal Park Island Bridge (old BM23), surface | Standing water | Zandvlei | | | | | | | | 170 | 173 | 343 |
| | | ZAweir | Zandvlei outlet channel at Rubble Weir, surface | Standing water | Zandvlei | | | | | | 21 | 59 | 177 | 176 | 435 |
| SLPass | SLPass | SIR01 | Sir Lowrys Pass River at Wedderwill Farm | River dataset | | | | | | | 36 | 92 | 110 | 107 | 345 |
| | | SIR02 | Sir Lowrys Pass River d/s N2 | River dataset | | | | | | | 25 | 85 | 112 | 107 | 329 |
| | | SIR03 | Sir Lowrys Pass River at Gustrouw Rd | River dataset | | | | | | | 22 | 74 | 106 | 85 | 287 |
| | | SIR04 | Sir Lowrys Pass River (original river channel) at Dolphin Rd | River dataset | | | | | | | 3 | 11 | 30 | 18 | 62 |
| | | SIR05 | Sir Lowrys Pass River (original river channel) Hendon Park | River dataset | | | | | | | 31 | 90 | 119 | 115 | 357 |
| | | SIR06 | Sir Lowrys Pass River d/s of WWTW (diversion canal) | River dataset | | | | | | | 19 | 81 | 110 | 108 | 320 |
| | | SIR07 | Sir Lowrys Pass River at Hibiscus Rd (diversion canal) | River dataset | | | | | | | 33 | 89 | 116 | 118 | 358 |
| | Soet | SOE02 | Soet River u/s of Greenways Rd | River dataset | | | | | | | 72 | 111 | 143 | 114 | 442 |
| | | SOE04 | Soet River below electric pylons south tributary | River dataset | | | | | | | | | 37 | 44 | 81 |
| | | SOEAH05 | In open channel nr ERF32524 SOUTHStormwater | River dataset | | | | | | | | | 43 | | 43 |
| | | SOEAH06 | In concrete channel in front of BP garage crn of N2 | River dataset | | | | | | | | | 49 | 105 | 154 |
| | | SOEAH07 | In open channel nr ERF15211 Morkels Cottage | River dataset | | | | | | | | | 41 | | 41 |
| | | SOEAH08 | In open channel nr ERF32524 EASTStormwater | River dataset | | | | | | | | | 44 | | 44 |
| | | SOEAH09 | At culvert inlet-cnr of Broadlands Blvd and Onverwacht | River dataset | | | | | | | | | 42 | | 42 |
| | | SOEAH10 | In open channel-ERF7810 next to Onverwacht Rd | River dataset | | | | | | | | | 58 | 78 | 136 |
| | | SOEAH11 | In open concrete channel cnr of Broadlands Road, | River dataset | | | | | | | | | 50 | 71 | 121 |
| | | SOEAH12 | Soet River in open channel near ERF32524 (Combined Channel 20 | River dataset | | | | | | | | | 10 | 106 | 118 |
| Smine | Silvermine | SIL01 | Downstream of Silvermine Dam | River dataset | | | | | | | 61 | 1 | | | 62 |
| | | SIL02 | Near Sunbird Environmental Centre -Silvermine Nature Reserve | River dataset | | | | | | | 106 | 113 | 113 | 114 | 446 |
| | | SIL03 | Silvermine River at top of Clovelly Country Club | River dataset | | | | | | | 50 | | | | 50 |
| | | SIL04 | Silvermine River a wooden bridge near Winkle Rd - Clovelly | River dataset | | | | | | | 87 | 105 | 92 | 68 | 352 |
| | | SIL05 | Silvermine River at footbridge on wetland near Clovelly Bea* | River dataset | | | | | | | 58 | | | | 58 |
| | | SIL06 | Silvermine River at Bridge on Main Rd, Clovelly | River dataset | | | | | | | | 4 | 115 | 116 | 237 |
| Sout | Sout | SOU01 | Sout River at R27 | River dataset | | | | | | | 33 | 64 | 114 | 108 | 319 |
| | | SOU02 | Sout River at Otto du Plessis Drive | River dataset | | | | | | | 68 | 108 | 116 | 119 | 413 |
| South Peninsula | South Peninsula | BOK02 | Bokramspruit River upstream of Slangkop Road | River dataset | | | | | | | 97 | 114 | 117 | 112 | 440 |
| | | BOK03 | Bokramspruit River a short distance d/s of Flamingo Rd | River dataset | | | | | | 1 | 94 | 114 | 112 | 104 | 425 |
| | | GC01 | Elsies River u/s of Glencairn vlei at Gordon's Camp bridge | River dataset | | | | | | 13 | | | | | 13 |
| | | GC02 | Glencairn vlei centre - at concrete berm | Standing water | Glencairn vlei | | | | | 79 | 114 | 124 | 184 | 180 | 683 |
| | | GC03 | Glencairn vlei at weir near road bridge | Standing water | Glencairn vlei | | | | | 19 | | | | | 19 |
| | | SCH01 | Schusters River at Main Road crossing | River dataset | | | | | | | 20 | | | 2 | 22 |
| | | SCH02 | Schusters River at Schusterskraal Reserve entrance | River dataset | | | | | | | 48 | 96 | 93 | 108 | 345 |
| | | SCH03 | Wetland adjacent to Schusters River | Standing water | Schusters wetland | | | | | | 19 | | | | 19 |
| | | SCH04 | Pound canal (stormwater) | River dataset | | | | | | | 22 | 73 | 86 | 49 | 230 |
| | | SCH05 | Tributary of Schusters at Main Road | River dataset | | | | | | | 10 | | | | 10 |
| Zeekoe | Zeekoe | BM08 | Edith Stephens Detention Pond near inlet from Lotus Canal | Standing water | Edith Stephens | | | | | | | 16 | 41 | 34 | 91 |
| | | BM09 | Edith Stephens Detention Pond near birdhide | Standing water | Edith Stephens | | | | | | | 16 | 40 | 34 | 90 |
| | | BM12 | Private Nature Reserve (Muizenberg East) | Standing water | Costa da Gama | | | | | | | 17 | 34 | 36 | 87 |
| | | BM13 | Eastern side of Moddervlei wetland at Rondevlei NR (near Gate C) | Standing water | Moddervlei | | | | | | | 17 | 34 | 33 | 84 |
| | | BM14 | Eastern shore of Zeekoevlei at end of 14th Avenue | Standing water | Zeekoevlei | | | | | | | 15 | 34 | 36 | 85 |
| | | LR01 | | River dataset | | | | | 18 | 22 | 28 | 1 | | | 69 |
| | | LR02 | Lotus River on (N2) 500m from Airport Approach Rd | River dataset | | | | | 15 | 35 | 64 | 91 | 109 | 114 | 428 |
| | | LR03 | Lotus River at corner Duinefontein and Lansdowne Roads | River dataset | | | | | 14 | 35 | 115 | 120 | 113 | 115 | 512 |
| | | LR04 | | River dataset | | | | | 19 | 34 | 67 | 1 | 9 | | 130 |
| | | LR05 | Lotus River at entrance to Council Depot on Old Strandfonte* | River dataset | | | | | 19 | 35 | 68 | 89 | 113 | 109 | 433 |
| | | LR06 | Woodlands Canal at New Ottery Road (near Ottery Hypermarket) | River dataset | | | | | 16 | 35 | 66 | 87 | 113 | 109 | 426 |
| | | LR07 | Lotus River at Klip Road | River dataset | | | | | 19 | 35 | 116 | 117 | 113 | 113 | 513 |
| | | LR08 | Lotus River at Fisherman's Walk bridge (just u/s of vlei bo* | River dataset | | | | | 19 | 35 | 117 | 118 | 122 | 124 | 537 |
| | | LR09 | | River dataset | | | | | 17 | 33 | 67 | 1 | | | 118 |
| | | LR10 | Little Lotus River at Eighth Avenue | River dataset | | | | | 17 | 33 | 116 | 116 | 119 | 122 | 525 |
| | | LR11 | Little Lotus River at Fifth Avenue Grassy Park | River dataset | | | 53 | 108 | 158 | 139 | 66 | | | | 528 |
| | | LR12 | Lotus River at Fifth Avenue - Grassy Park | River dataset | | | 53 | 108 | 164 | 145 | 65 | | | | 539 |
| | | LR13 | Big Lotus Canal at NY3A u/s of stormwater outlet | River dataset | | | | | | 39 | 29 | | | 1 | 69 |
| | | LR14 | | River dataset | | | | | | 38 | 29 | | | 1 | 68 |
| | | LR15 | Big Lotus Canal NY3 u/s of stormwater outlet | River dataset | | | | | | 39 | 29 | | | 1 | 69 |
| | | LR16 | | River dataset | | | | | | 37 | 29 | | | 1 | 67 |
| | | LR17 | | River dataset | | | | | | 39 | 30 | | | | 69 |
| | | LR18 | Big Lotus Canal at Springfield Rd Turfhill Estate | River dataset | | | | | | 36 | 31 | | | | 67 |
| | | RVIRD | Italian Rd canal leading to Rondevlei | River dataset | | | | | | 55 | 106 | 108 | 116 | 108 | 493 |
| | | RVPRD | Perth Rd canal leading to Rondevlei | River dataset | | | | | | 24 | | | | | 24 |
| | | RVweir | Rondevlei at weir | Standing water | Rondevlei | | | | | 62 | 99 | 110 | 189 | 162 | 622 |
| | | ZEV1S | Zeekoevlei Home Bay in front of Zeekoevlei Yacht Club | Standing water | Zeekoevlei | | 53 | 109 | 163 | 137 | 112 | 116 | 223 | 219 | 1136 |
| | | ZEV2S | | Standing water | Zeekoevlei | | 53 | 109 | 179 | 100 | 94 | 61 | 69 | 75 | 744 |

| CATCHMENT | SUB-CATCHMENT | SITE | SITE LOCATION | TYPE | VLEI NAME | 1978-1980 | 1980-1985 | 1985-1990 | 1990-1995 | 1995-2000 | 2000-2005 | 2005-2010 | 2010-2015 | 2015-2020 | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ZEV3S | Zeekoevlei in front of Cape Peninsula Aquatic Club | Standing water | Zeekoevlei | | 53 | 109 | 180 | 103 | 113 | 125 | 235 | 224 | 1148 |
| | | ZEV4S | | Standing water | Zeekoevlei | | 53 | 109 | 160 | 109 | 58 | 3 | 63 | 71 | 630 |
| | | ZEV5 | At cut-off drain outfall to Zeekoe outlet canal | River dataset | | | | | | | | 6 | 115 | 104 | 225 |
| | | ZEWEIR | At Zeekoevlei weir | Standing water | Zeekoevlei | | | | | 14 | 21 | 69 | 35 | 4 | 143 |
| **Grand Total** | | | | | | **554** | **2290** | **3646** | **6280** | **6917** | **11138** | **11425** | **18435** | **17991** | **78805** |

## APPENDIX B: LIST OF PRIORITY RESOURCES UNITS WITHIN THE CITY OF CAPE TOWN INCLUDED IN THE DRAFT BERG RIVER RQOs

**Table B1**

**List of priority Resources Units (river reaches) within the City of Cape Town included in the gazetted Berg RQOs**

Note that the (draft) Water Resource Classification in this table relates only to rivers and estuaries, with wetland classification and RQOs not yet finalised.

**Table B1: Summary of results of the prioritisation process for the Berg Catchment. After DWS (2018)**

| IUA | Prioritised Resource Units (RUs) for which detailed RQOs were developed | | | | |
|---|---|---|---|---|---|
| | **River Node** | **Estuary Name** | **Dam Name** | **Wetland Resource Units** | **Groundwater Resource Unit** |
| D8 Upper Berg | Bviii1<br>Bvii13<br>Biii3 | | Berg River Dam<br>Wemmershoek Dam | Strategic Water Source Wetlands_SEEP | G10A<br>G10B |
| D9 Middle Berg | Bvii5<br>Bviii11<br>Bvii3 | | | West Coast Shale Renosterveld FLOODPLAIN (Berg) | |
| C5 Berg Tributaries | Biii4<br>Bi1 | | | Strategic Water Source Wetlands_SEEP | G10E |
| B4 Lower Berg | Bvii12<br>Bvii6 | | Voëlvlei Dam<br>Misverstand Weir | Northwest Sandstone Fynbos SEEP (Boesmans River)<br>West Coast Shale Renosterveld FLOODPLAIN (Berg)<br>West Coast Shale Renosterveld DEPRESSION (Koekispan and Kiekoesvlei) | G10J<br>G21B |
| A1 Berg Estuary | | Berg (Groot) | | Southwestern Shale Fynbos UNCHANNELED VALLEY BOTTOM (Berg) | |
| A2 Langebaan | | Langebaan | | Salt marsh SEEP (Geelbek) | |
| A3 West Coast | | | | Southwest Sand Fynbos DEPRESSION (Yzerfontein) | G10L<br>G10M |
| D10 Diep | Bv1<br>Biv6 | Rietvlei/ Diep | | Southwest Sand Fynbos FLOODPLAIN (Rietvlei) and Dune Strandveld FLOODPLAIN (Rielvlei)<br>SEEP and DEPRESSION (Riverlands) | G21D |
| E11 Peninsula | Bviii6<br>Bvii20 | Wildevöelvlei | | Sand Fynbos DEPRESSION (Wildvoelvlei: open water)<br>Sand Fynbos DEPRESSION (Seasonal)<br>Sand Fynbos DEPRESSION (Pick n Pay Reedbeds)<br>Strategic Water Source Wetlands _FLAT | |
| E12 Cape Flats | Bvii7 | Zandvlei | | DEPRESSION (Zeekoeivlei main water body and seasonal wetlands)<br>DEPRESSION (Rondevlei main water body and seasonal wetlands)<br>FLOODPLAIN (Nooiensfontein)<br>DEPRESSION (Blouvlei)<br>DEPRESSION (Princessvlei)<br>DUNE SLACK (Phillipi: Denel) | G22C<br>G22D<br>G22E |
| D6 Eerste | Biii6<br>Biv8 | Eerste | | Strategic Water Source Wetlands_SEEP | |
| D7 Sir Lowry's | Bvii22<br>Bvii21<br>Bviii9 | Lourens | Steenbras Reservoir<br>Steenbras Upper Dam | Strategic Water Source Wetlands_SEEP | |
| **TOTAL** | **20** | **7** | **6** | **24** | **11** |

## APPENDIX C: SUMMARY OF APPROACH TO VARIABLE SELECTION AND SETTING OF THRESHOLDS OF CONCERN FOR SELECTED VARIABLES

This appendix presents the initial material and thinking behind the ultimate selection of threshold ranges for different variables, as well as the selection variables themselves and preliminary decisions around the treatment of data.

### C1 Selection of water quality variables for analysis in this document

**Table C1** lists the water quality variables that are routinely analysed for in the City of Cape Town's water quality monitoring programme. The table has been annotated as to the usefulness of inclusion of each of these variables in the current water quality assessment, noting that the primary objectives of this assessment are to provide a clear overview of the main water quality characteristics, concerns and trends of key watercourses in the City of Cape Town, and thus consideration of all variables for which data are available will not necessarily add value to the final product or improve its accessibility to a wide audience.

Note however that the rating of water quality with regard to its level of risk to **human recreational users** is very different to the rating of water quality with regard to its **ecological condition**, which considers the degree to which water quality has changed from "natural". For example, a salt pan frequented by numerous wading birds might rate very poorly from a human health perspective, as a result of high levels of salt and bacteria, but could rate in a near-natural condition ecologically, as a relatively un-impacted representative of the 'salt pan wetland' type. Water quality assessments from a human health perspective typically include measures or (in some cases) indicators of pollutants that could cause harm to humans, if ingested or in contact with human skin or body parts (e.g. eyes, ears etc). Water quality assessments that examine ecosystem function implications rather focus on variables that could contribute to toxicity to aquatic organisms or alternatively to changes in habitat quality or availability (e.g. as a result of excessive plant growth that alters habitat type).

**Table C1** also differentiates between variables that play a role in the broad characterization of watercourses in the City and their degree of change from natural or reference conditions, and those that are considered most useful from the perspective of highlighting the impacts of pollution or other causes of water quality change (e.g. changes in water inflows such as drought, abstraction or inter- or intra-catchment diversions).

**Table C1**
**Physical, chemical and biological water quality variables included in the City of Cape Town's routine inland water quality analyses, with those to be used in the current water quality assessment indicated.**
**Shaded blocks (river and vlei columns) indicate whether variable analysed in river and/ or vlei / standing water system samples**

| Variable | Recommended inclusion in assessments of: | | | Reason for inclusion: | |
|---|---|---|---|---|---|
| | Risk to human health | Ecosystem condition | | Variable allows system Characterization | Variable helps to identify level of Impact |
| | | Rivers | Vleis (standing water environments) | | |
| **Chemical constituents** | | | | | |
| (Total) ammonia nitrogen ($NH_4^+$-N) | | | YES | | |
| Free (unionized) Ammonia nitrogen ($NH_3$-N) | | YES | YES | | X |
| pH | | YES | YES | X | |
| Electrical Conductivity | | YES | YES | X | |

| Variable | Recommended inclusion in assessments of: | | | Reason for inclusion: | |
|---|---|---|---|---|---|
| | Risk to human health | Ecosystem condition | | Variable allows system Characterization | Variable helps to identify level of Impact |
| | | Rivers | Vleis (standing water environments) | | |
| Orthophosphate ($PO_4$-P) | | YES | YES | | X |
| Total phosphorus (TotP) | | | | | |
| Chemical Oxygen Demand (not regularly measured) | | | | | |
| Dissolved oxygen | | YES | YES | | X |
| Total Inorganic Nitrogen ("Inorganic nitrogen") | | YES | YES | | X |
| N:$PO_4$-P ratio | | | | | |
| Nitrite + Nitrate nitrogen (NOx-N) | | | | | |
| Oxygen saturation (DOPER) | | | | | |
| (Total) Suspended Solids (TSS) | | | | | |
| Total organic Nitrogen TON | | | | | |
| **Additional variables calculated** | | | | | |
| $PO_4$:TotP | | | YES | | X |
| TIN:$PO_4$-P | | | YES | | |
| **Bacteriological constituents** | | | | | |
| *Escherichia coli* | YES | | | | |
| **Algal constituents and toxins** | | | | | |
| Chlorophyll-*a* | | | YES | | X |
| Phaeophytin | | | | | |
| Microcystin toxin | YES | | YES | | X |
| **Additional variables calculated** | | | | | |
| Mean Annual Chl-*a* | | | YES | | X |

## C2 Data interpretation

Although a number of different guidelines exist for different water quality user groups, this project focuses on those that have been developed as guidelines for the interpretation of water quality data from the perspectives of **aquatic ecosystem health (condition)** and of **suitability for recreational use**.

These are considered separately in the following sections.

### *C2.1 Guidelines for interpretation of water quality from an ecological (aquatic ecosystem) perspective*

### *A Existing water quality guidelines*

The following guidelines have been considered in this report:

- DWAF 1996a: South African Water Quality Guidelines for Aquatic Ecosystems: This document provides threshold values for Acute and Chronic Toxicity for potentially toxic water quality constituents; target ranges (indicating concentration ranges of least concern) and trophic indicator ranges for major nutrients. The guidelines do not distinguish between lotic (flowing) and lentic (non flowing) systems (e.g. lakes / vleis);
- DWAF 2008: This document provides a guide to assessing the water quality component of the Ecological Reserve, or Ecological Water Requirements (EWR), for a Desktop, Rapid Level (III) and Intermediate or Comprehensive Reserve study for rivers. It includes Present Ecological State rating values A-F for most commonly measured water quality constituents – these are not differentiated regionally or with regard to river type. The report notes that pH rating values are not applicable to acid Western Cape streams and that Electrical Conductivity (EC) rating values should be adjusted in a linear manner where natural river salinity differs markedly from benchmarked reference conditions;
- DWAF 2011: This document uses "compliance" level data analyses to assess the percentage of sites rated as Unacceptable, Tolerable, Acceptable or Ideal for a number of water quality constituents from the perspective of the most stringent requirements in each case of Domestic, Basic Human Needs, Irrigation, Aquaculture, Industrial and Aquatic Ecosystem users. Aquatic ecosystem rating ranges were derived from DWAF (2008) but the document recommends adjustments in ranges for orthophosphate (PO4-P), for rivers, as opposed to dams;
- City of Cape Town Water Quality Index (Day and Clark 2012): This document presents rating ranges for a number of variables used in the development of an index for water quality assessment from an ecological perspective. The index used the rating ranges of DWAF (2008) for river nutrients and the eutrophication guidelines of DWAF (2002) for total phosphorus. Reference conditions for different river types were however determined as a project-specific output on a regional basis for EC and pH;
- DWS (2018): This document presents the Berg Classification and proposed RQOs as described in **Section 2.6**. Water quality categories A to F for different water quality variables in assessed rivers were derived from the following key sources (Mr N. Rossouw, Aurecon, water quality specialist in Berg RQO determination; pers. comm. to Liz Day):
- DWAF (1996) aquatic ecosystem guidelines
- DWAF (2008) methods for determining the Water Quality component of the Ecological Reserve
- DWAF (2011) recommendations for amendments to the trophic state ranges for nitrogen and phosphorus nutrients in rivers and lakes.

### *B Approach to setting rating ranges for the current assessment*

Since the City of Cape Town is included in the Berg Catchment and many of its systems have been assigned specific RQOs through the Berg Classification (see Section 6.2), it is important that the rating ranges and rating terminology used in the current assessment should align with these, and be readily referenceable to these gazetted requirements. This approach also ensures that any ecological categorisation of water quality for the City of Cape Town aligns to the categories of water quality condition employed at national level in South Africa and in particular to the methods for determining the water quality component of the Ecological Reserve for rivers. These methods, used in the Berg Classification of DWS (2018), are referred to as Resource Directed Measures (RDM) and assign river reaches or systems to a range of water quality categories, which are aligned to categories used in the assessments of Present Ecological State (PES).

The range of values included in these categories have been variously described as Natural to Poor or[6]Ideal to

[6] **Ideal** – the use of water is not affected in any way; 100% fit for use by all users at all times; desirable water quality (TWQR); **Acceptable** – slight to moderate problems encountered on a few occasions or for short periods of time; **Tolerable** – moderate to

Unacceptable (DWAF 2011), and ranked A to F. They can be semi-quantified in terms of percentage deviation from natural (reference) conditions, with 100% scores indicating completely natural conditions, and scores of 0 representing extreme (complete) change from natural conditions with respect to water quality (DWAF 2008). They are compared in **Table C2.**

The City's Water Quality Index was based on the use of Categories A – F, with an additional "z" Category representing extreme deviation beyond the lower threshold for Category F. While this categorisation allowed for fairly fine discrimination between categories, it proved cumbersome to implement across multiple sites and for a wide-ranging audience. As a result, it is recommended that a simpler approach, with fewer but still comparable categories thus being utilised in the current report. The rating scale included in **Table C2** has been adopted, comprising ratings of Good, Fair, Poor and Unacceptable, with the desired threshold (break point) being "Fair".

**Table C2**
**Relationship between Present Ecological State (PES) water quality categories A-F and scores, showing deviation from natural conditions, as defined in DWAF (2008) for water quality Resource Directed Measures, as well as the Rating categories used in the present assessment**

<table>
<tr><th colspan="2">This project:</th><th rowspan="2">DWS Ecological Categories (PES) / RDM terminology</th><th rowspan="2">PES% score range</th><th rowspan="2">DWAF (2011)</th></tr>
<tr><th>City Water Quality Categories</th><th>Interpretation of City Water Quality Categories</th></tr>
<tr><td rowspan="2">Good</td><td rowspan="3">TARGET</td><td>**A**: Natural / no change</td><td>90-100%</td><td rowspan="2">Ideal</td></tr>
<tr><td>**B**: Largely natural, with few modifications / small change</td><td>80-89%</td></tr>
<tr><td>Fair</td><td>**C**: Moderately modified / moderate change</td><td>60-79%</td><td>Acceptable</td></tr>
<tr><td>Poor</td><td>Poor</td><td>**D**: Largely modified / large change</td><td>40-59%</td><td>Tolerable</td></tr>
<tr><td rowspan="2">Unacceptable</td><td rowspan="2">Unacceptable</td><td>**E**: Seriously modified / serious change</td><td>20-39%</td><td rowspan="2">Unacceptable</td></tr>
<tr><td>**F**: Critically modified / extreme change</td><td>0-19%</td></tr>
</table>

### *B Recommended thresholds to guide interpretation in this study*

Rating ranges differentiate between standing water bodies (in this case, the main recreational vleis and dams included in the City's inland monitoring programme) and flowing water systems (that is, rivers), with different variables and sometimes concentrations applicable to different watercourse types, as identified in **Tables B3 and B4**.

severe problems are encountered; usually for a limited period only; and **Unacceptable** – water cannot be used for its intended use under normal circumstances at any time (DWAF 2006)

**Table C3**
**Rating ranges for variables considered in this assessment of water quality in City Rivers**

| City Water Quality Categories (CWQC) | Interpretation of CWQC | [7]PO4-P mg/l | [2]TIN mg/l | [8]DO mg/l | [3]NH3-N mg/l | [9]EC mS/m | [10]pH |
|---|---|---|---|---|---|---|---|
| GOOD | TARGET | ≤ 0.005 | ≤ 0.25 | > 6 | < 0.015 | | |
| | | >0.005-0.025 | >0.25-0.70 | | 0.015-0.044 | | |
| FAIR | | >0.025--0.075 | >0.70-1.75 | | >0.044 - 0.072 | | |
| POOR | POOR | >0.075-0.125 | >1.75-3.00 | ≥4 -6 | >0.072-0.1 | > 10- 15% change over 5 year seasonal mean | >5-10 % change or 0.5 -1 pH unit from 5 year seasonal mean |
| UNACCEPTABLE | UNACCEPTABLE | >0.125 | > 3.00 | < 4 | >0.1 | > 15% change over 5 year seasonal mean | >10 % change or >1 pH unit from 5 year seasonal mean |

**Table C4**
**Rating ranges for variables considered in this assessment of water quality in City Vleis and Dams**

| City Water Quality Categories (CWQC) | Interpretation of CWQC | [11]PO4-P mg/l | [12]TIN | [13]DO mg/l | [3]NH3-N mg/l | [14]pH | RUNNING MEAN ANNUAL CHL-A µg/l |
|---|---|---|---|---|---|---|---|
| GOOD | TARGET | ≤ 0.005 | ≤ 0.7 | > 6 | < 0.015 | | ≤ 5 |
| | | | | | 0.015-0.044 | | >5 - 10 |
| FAIR | | >0.005--0.015 | >0.7 -1 | | >0.044 - 0.072 | | >10 -20 |
| POOR | POOR | >0.015 - 0.025 | >1.0-4.0 | ≥4 -6 | >0.072-0.1 | >5-10 % change or 0.5 -1 pH unit from 5 year seasonal mean | > 20 - 30 |
| UNACCEPTABLE | UNACCEPTABLE | >0.025 | > 4 | < 4 | >0.1 | >10 % change or >1 pH unit from 5 year seasonal mean | > 30 |

[7] Based on DWAF (2011) and used in Berg RQOs (DWS 2018)
[8] Based on DWAF (2008) and used in Berg RQOs (DWS 2018)
[9] Based on DWAF (1996a) guideline – this range intended only to red flag possible change and not change from Reference Condition, for which ranges provided in Day and Clark (2012) per river type would be more suitable
[10] Based on DWAF (1996a) guideline (Target is < 5% or 0.5 pH unit change) – the range provided here is intended only to red flag possible change, and not change from Reference Condition, for which ranges provided in Day and Clark (2012) per river type would be more suitable
[11] Based on DWAF (2002) and used in Berg RQOs (DWS 2018)
[12] Based on DWAF (2002) and used in Berg RQOs (DWS 2018)
[13] Based on DWAF (1996a) guideline and used In Berg RQOs (DWS 2018)
[14] Based on DWAF (1996a) guideline (Target is < 5% or 0.5 pH unit change) – the range provided here is intended only to 'red flag' possible change, and not change from Reference Condition, for which ranges provided in Day and Clark (2012) per river type would be more suitable. Note that EC excluded from rated variables because waterbodies already substantially changed from natural, and are naturally highly variable

### *C2.2 Guidelines for interpretation of water quality risks to recreational users*

### *A Microbial indicators*

The most frequent adverse health outcome associated with exposure to water contaminated with faecal material is enteric illness (WHO 2003).

Historically, two different bacterial indicators have been used as a measure of the risk posed by the presence of pathogens in water - faecal coliforms and *Escherichia coli*, both typically reported as the number of organisms (or colony forming units / cfu ) present per 100 ml of water .

**Faecal coliforms** are a group of bacteria that include genera (such as *Escherichia*) that are able to survive in the guts of animals (including humans) and also occur in their faeces.

***Escherichia coli*** (abbreviated *E. coli*) is a species of faecal coliform bacteria that is commonly found in the lower intestine of warm-blooded organisms (birds and mammals). Most *E. coli* strains are harmless, but some can cause serious food poisoning in humans. Their presence in the water is used as an "indicator" of faecal contamination of avian or mammalian origin, and therefore are indicative of other pathogens that *may* be present in faeces.

While faecal coliforms (including *E. coli*) are still considered to be good indicators of the presence of other pathogens in freshwater, research over the last 10 years has shown that faecal coliforms tend to die off faster than other pathogens in seawater, and can result in an underestimate of the risk to beach bathers when only faecal coliform concentrations are monitored. As a result, microbial assessments of coastal waters has shifted to measurements of **intestinal Enterococci** as an indicator of public health risks. Worldwide, there has been a general shift to the use of intestinal Enterococci as a standard indicator of public health risks in inland recreational water bodies as well (WHO 2003; 2018;Australian Government National Health and Medical Research Council 2008), and while there are guidelines for the interpretation of *E. coli* in waters used for full contact recreation (e.g. EU ), most authorities who do consider intermediate contact uses now have begun to rely on intestinal Enterococci guidelines.

In South Africa, DWAF (1996b) provides guidelines for both Full Contact and Intermediate Contact recreational use. Of these, the former are based on non-exceedance of maximum ***E. coli*** concentrations, noting that there is "insufficient information for the development of criteria for *E. coli* in water used for intermediate contact recreation purposes" while the latter are based on non-exceedance of maximum **faecal coliform** bacteria concentrations.

The City's inland water quality historical database includes both faecal coliform and *E. coli* data. However, all current water microbial assessments include only *E. coli* data[15]. This means that evaluations of the implications of these data for human health must be carried out on the basis of *E. coli* concentrations alone. Accordingly, the City generally interprets the suitability of its inland waters for recreational purposes according to an adaptation of the intermediate contact South African Water Quality Guidelines for Recreational Use (DWAF 1996b) – see **Table C5**. A limitation of this guideline, when used with *E. coli* data alone, however, is that it potentially under-estimates risk, in that *E. coli* concentrations make up just one component of the total faecal bacterial count.

[15] This is due to an updated microbial analytical methodology (media change) where there is no longer a presumptive faecal coliform count followed by a confirmatory count for *E.coli.* Instead, the *E.coli* count is determined immediately after incubation (Scientific Services comment to C. Bouland).

**Table C5**
**Threshold grades included in the City's Recreational Index for inland waters (after Day and Clark 2012).**

| GRADE | FAECAL COLIFORM COUNT (INCLUDING *E. COLI*)[1] |
|---|---|
| TARGET | ≤ 1 000 CFU/100 ML |
| ACCEPTABLE | 1 001-2 000 CFU/100 ML |
| RISK | 2 001-4000 CFU/100 ML |
| UNACCEPTABLE | >4000 CFU/100 ML |

The concentrations of bacteria in water is usually expressed as numbers of colony-forming units (CFU) per 100 ml, which is a measure of the number of viable cells in a particular sample, where a colony represents an aggregate of cells derived from a single progenitor cell. In this report it is referred to more simply as counts per 100 ml.

The proposed RQOs developed and included in the draft gazette for the Berg Catchment (DWAF 2019) include both *E. coli* and faecal coliform bacteria in the development of pathogen RQOs, and use these data interchangeably with threshold limits provided for "*E. coli* / faecal coliforms". These thresholds outlined in Table C6 are very similar to those in Table C5 and, since it is planned that they will be gazetted, will form the basis for the assessment outlined in the present study.

**Table C6**
**Generic water quality limits for Recreational Use: Intermediate Contact**
**Faecal coliforms**
**Values extracted from DWAF (2006) as used in Berg RQOs**

| GRADE | FAECAL COLIFORM COUNT (INCLUDING *E. COLI*)[1] |
|---|---|
| TARGET (IDEAL) | ≤ 1 000 CFU/100 ML |
| ACCEPTABLE | 1 001-2 500 CFU/100 ML |
| TOLERABLE | 2 501-4000 CFU/100 ML |
| UNACCEPTABLE | >4000 CFU/100 ML |

In the present report, the following blended approach, summarised in **Table C7**, has been taken:

- The DWAF (2006) intermediate contact recreational limits have been used, with Acceptable being set at ≤ 2500 faecal coliform (including *E.coli*) counts per 100 ml – this corresponds to the Berg RQOs for Intermediate Contact Recreation;
- The DWAF (1996b) upper limit for full contact recreation (i.e. swimming) of [16]400 counts per 100 ml for ***E. coli*** are however included as an indicator target, if full contact recreational activities are considered.

[16] Note that WHO (2003) stipulates a maximum threshold of 575 *E. coli* counts per 100 ml for "infrequent" recreational use in freshwaters. This threshold equates to the intermediate use category referred to elsewhere in this report. Standards for Texas State in the USA (Texas Commission on Environmental Quality 2016) include a single limit for "secondary contact 1" recreation (i.e. activities including fishing, canoeing, kayaking, rafting, sailing, and motor-boating) of ≤630 counts per 100ml)

**Table C7**

**Approach to assessment of microbial data in this study, based on DWAF (1996b) and the Berg RQOs and applied to *E. coli* concentrations as per City of Cape Town R-WQI guidelines, with adjusted *E. coli* specific target for full contact recreation, as per DWAF (1996b)**

**Table below indicates additional ranges for E. coli beyond the "Unacceptable" threshold, to indicate very high levels of pollution in some cases.**

| GRADE | FAECAL COLIFORM COUNT (*INCLUDING E. COLI)*[1] |
|---|---|
| **TARGET FOR MAXIMUM ACCEPTABLE RISK FOR FULL CONTACT RECREATION** | **≤ 400 CFU/100 ML ** |
| **ACCEPTABLE RISK INTERMEDIATE CONTACT** | **1 001-2 500 CFU/100 ML** |
| **TOLERABLE RISK - INTERMEDIATE CONTACT** | **2 501-4000 CFU/100 ML** |
| **UNACCEPTABLE RISK - INTERMEDIATE CONTACT** | **>4000 CFU/100 ML** |

[1]The concentrations of bacteria in water is usually expressed as numbers of colony-forming units (CFU) per 100 ml, which is a measure of the number of viable cells in a particular sample, where a colony represents an aggregate of cells derived from a single progenitor cell

| "UNACCEPTABLE" CATEGORIES | INDICATIVE *E.COLI* RANGE (COUNT/100ML) | COMMENT / STRATEGIC MANAGEMENT RESPONSE |
|---|---|---|
| LEVEL 1 | **4001 – 10 000** | • WQ trends in this range may be reflective of general urban diffuse runoff rather than a major point source of pollution<br>• Address using stormwater / catchment management measures.<br>• Ensure sewer spill responses are adequate and timely.<br>• Continue to monitor to determine if additional pollution abatement intervention is necessary. |
| LEVEL 2 | **10 001 – 100 000** | • WQ trends in this high range are likely indicative of chronic pollution possibly from multiple source/s.<br>• If results are in this range for a single month / only during the rainy season it is possible that catchment wash-off (first flush) or surcharging sewers were causal factors.<br>• Transversal approach to pollution abatement is necessary.<br>• Extra budget may be required. |
| LEVEL 3 | **> 100 000** | • WQ trends in this extreme range likely indicate chronic ongoing pollution from multiple sources &/or extreme incidents.*<br>• Urgent management intervention to address the source/s of contamination.<br>• Transversal approach to pollution abatement is necessary.<br>• Significant funding likely to be required |

### *B Microcystin toxins*

Cyanobacteria (or blue-green algae) are a common and naturally occurring component of most recreational water environments (WHO 2003). They are of potential public health concern because some types may under certain circumstances produce toxins that can have a harmful effect on recreational water users.

The City of Cape Town also monitors its water bodies for microcystin toxins. The Recreational Water Quality Index (Day and Clark 2012) bases interpretation of these data on the WHO (2003) guidelines for full and intermediate contact recreation. These are outlined in **Table C8** and are used in the current assessment.

**Table C8**

**Water quality grades and corresponding threshold concentrations for Microcystin toxins for inland waters adopted for this project. Guideline levels are based on those published by the WHO (2003).**

| Interpretation | Microcystin Toxin Concentration |
|---|---|
| TARGET (ACCEPTABLE) | ≤ 20 µG/L |
| MEDIUM RISK (UNACCEPTABLE) | >20- 30 µG/L |
| HIGH RISK (UNACCEPTABLE) | >30-40 µG/L |
| EXTREME RISK (UNACCEPTABLE) | >40 µG/L |

## C3 Data analysis

### *C3.1 Information sources*

Key sources of information that were used to formulate the proposed approach to data analysis included:

- Conceptual Design Report for a National River Water Quality Assessment Programme (Harris *et al*. 1992);
- Statistical Methods in Water Resources (Helsel and Hirsch 2002);
- A Guide to Conduct Water Quality Catchment Assessment Studies: In support of the water quality management component of a Catchment Management Strategy (DWAF 2003);
- Resource Directed Management of Water Quality: Management Instruments. Volume 4.2: Guideline for Determining Resource Water Quality Objectives (RWQOs), Allocable Water Quality and the Stress of the Water Resource (Edition 2, DWAF 2006a);
- Resource Directed Management of Water Quality: Management Instruments. Volume 4.3: Guideline on Monitoring & Auditing for Resource Directed Management of Water Quality. (Edition 2, DWAF 2006b);
- WQ Manual for Ecological Reserve determinations (DWAF 2008) [in particular, the approach of using percentiles, e.g. 5th and 95th percentile, for interpretation of data];
- City Water Quality Index WQI documentation, particularly the "Review and evaluation of existing local and international water quality indices" (Anchor & FCG 2011).

### *C3.2 Dealing with values below detection limits*

The datasets that need to be analysed contain a number of entries where the values are recorded as being below the limit of detection for the relevant test. These are known as "censored data", and can present problems for statistical analyses . There are three main ways in which summary statistics can be estimated for censored data, namely simple substitution, distributional, and robust methods (Helsel & Hirsch 2002).

With simple substitution methods, a single value such as one-half the reporting limit is substituted for each less-than value. Summary statistics are then calculated using these substitute numbers along with the values above the reporting limit. Although they are widely used, simple substitution methods perform poorly in comparison to other procedures, especially for certain types of statistical analyses. Substitution of zero typically produces estimates of mean and median that are biased low, while substituting the reporting limit typically results in estimates above the true value. Results for the standard deviation and IQR, and for substituting one-half the reporting limit, have also been shown to be less desirable than alternative methods (Helsel & Hirsch 2002).

Distributional methods, in contrast, use the characteristics of an assumed distribution to estimate summary statistics. Data both below and above the reporting limit are assumed to follow a distribution such as the lognormal. Given a distribution, estimates of summary statistics are computed which best match the observed concentrations above the reporting limit and the percentage of data below the limit. Estimation methods include maximum-likelihood estimation (MLE) and probability plotting procedures. The problem is that, in practice, the distributions of environmental data are rarely if ever known, and may vary between constituents, time periods, and locations (Helsel & Hirsch 2002).

Robust methods combine *observed* data above the reporting limit with below-limit values extrapolated assuming a distributional shape, in order to compute estimates of summary statistics. This partially overcomes the problem of not knowing the true distribution of environmental data and it has thus been recommended that robust methods should be used to protect against the possibly large errors of distributional methods <u>when estimating the mean and standard deviation</u>. Either robust probability plot or distributional MLE procedures have, however, been shown to perform well for estimating the median and Interquartile Range (IQR). Use of these alternative methods of dealing with "below detection limit" entries, rather than simple substitution methods, should substantially lower estimation errors when generating summary statistics for environmental data (Helsel & Hirsch 2002).

Notwithstanding the above-mentioned shortcomings of simple substitution methods, compared to alternative procedures that could be used to deal with values below the detection limit, it is important to note that the problems are far less pervasive with bigger datasets where only a very small proportion of the entries are below the reporting limit/s, especially when using non-parametric statistics. For example, as highlighted by Helsel & Hirsch (2002), when less than 50% of the data are below the reporting limit, the sample median is known, and when less than 25% of the data are censored, the sample IQR is known. Some information is even available about percentiles when even larger amounts of data lie below the reporting threshold. This is, however, not the case for deriving sample estimates of the mean and standard deviation (Helsel & Hirsch 2002), which means that more caution is required with the use of simple substitution methods of censored datasets where parametric statistical analyses are to be carried out.

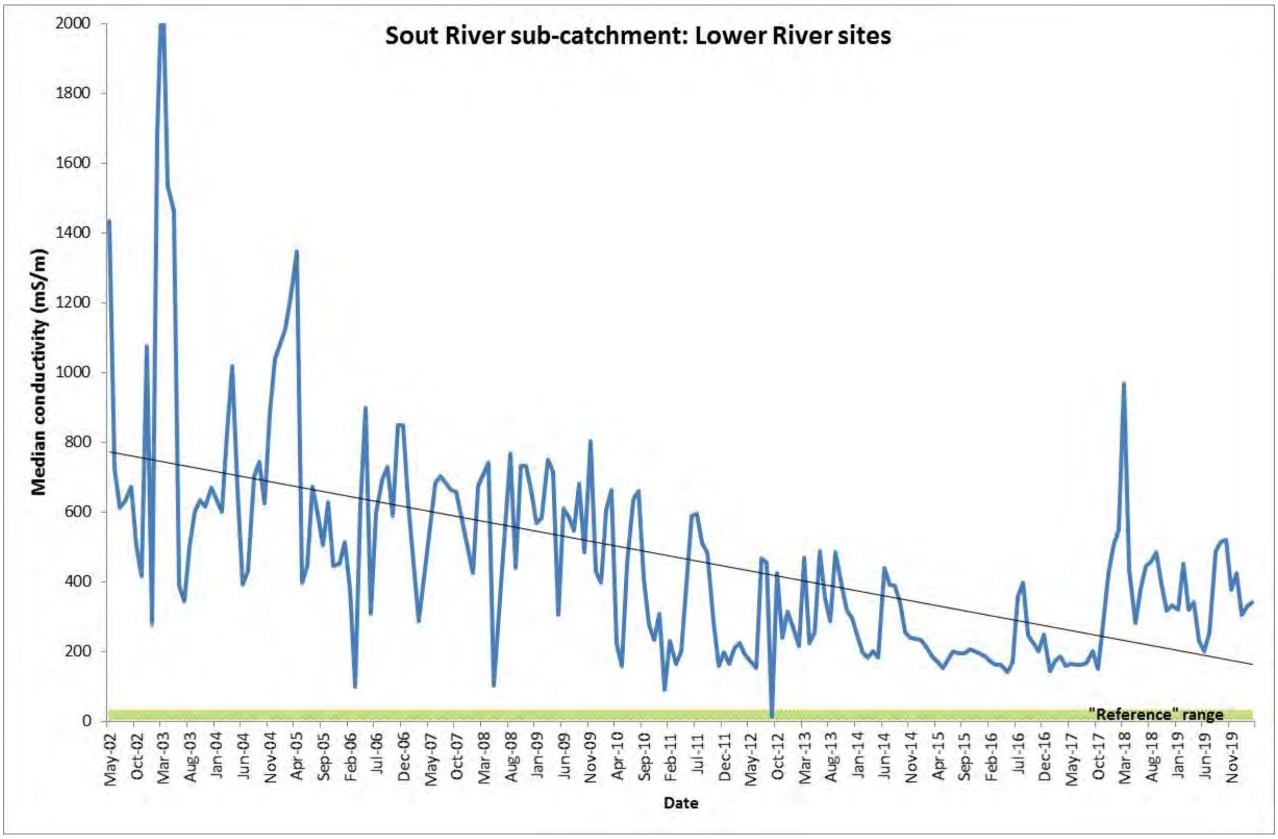
Many of the variables for which analyses are to be carried out in the current project are not normally distributed, implying that non-parametric statistics will be used for most analyses, and the percentage of entries that have been recorded as below the detection limit is very low. It is thus assumed that the use of simple substitution for entries recorded as below the detection limit is justifiable in this situation because it is unlikely to result in significant errors. With this being the case, the following standardised protocol of the City's Scientific Services Branch for the substitution of values recorded as less than (<) or greater than (>) was adopted:

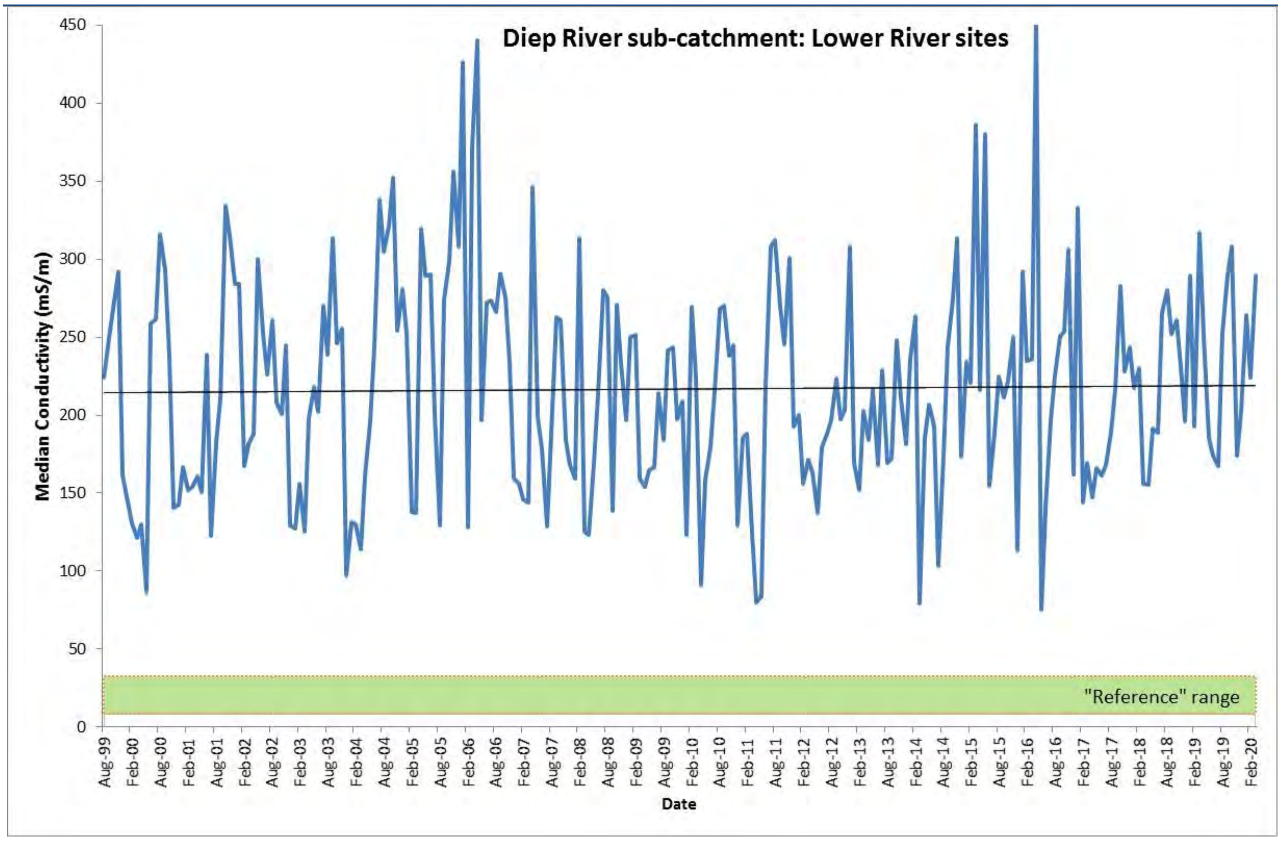
- *Chemical data:* When carrying out statistical calculations or plotting chemical values less than the limit of detection, a value of one half of the detection limit is substituted [i.e. divide < values by two]. This aligns with the recommendation of Harris et al. (1992) in their report on the conceptual design of a national river water quality assessment programme for South Africa;

- *Bacteriological data:* For counts below the limit of detection, a substituted value of one third the limit is used, while for those above the upper limit, 3 times that limit is used [i.e. divide < values by 3 or multiply > values by 3].

In addition to the above-mentioned protocol for values out of the range of detection, all entries in the datasets with measured values recorded as “og”, “ns’, “nr” or nulls were excluded from the analyses. This is also part of the standardised protocol developed by the Scientific Services Branch, the City’s laboratory that undertakes sample collection and analysis.

## APPENDIX D: EC TIME SERIES GRAPHS




Diep River sub-catchment: Lower River sites
Median Conductivity (mS/m)
Date
"Reference" range
0
50
100
150
200
250
300
350
400
450
Aug-99
Feb-00
Aug-00
Feb-01
Aug-01
Feb-02
Aug-02
Feb-03
Aug-03
Feb-04
Aug-04
Feb-05
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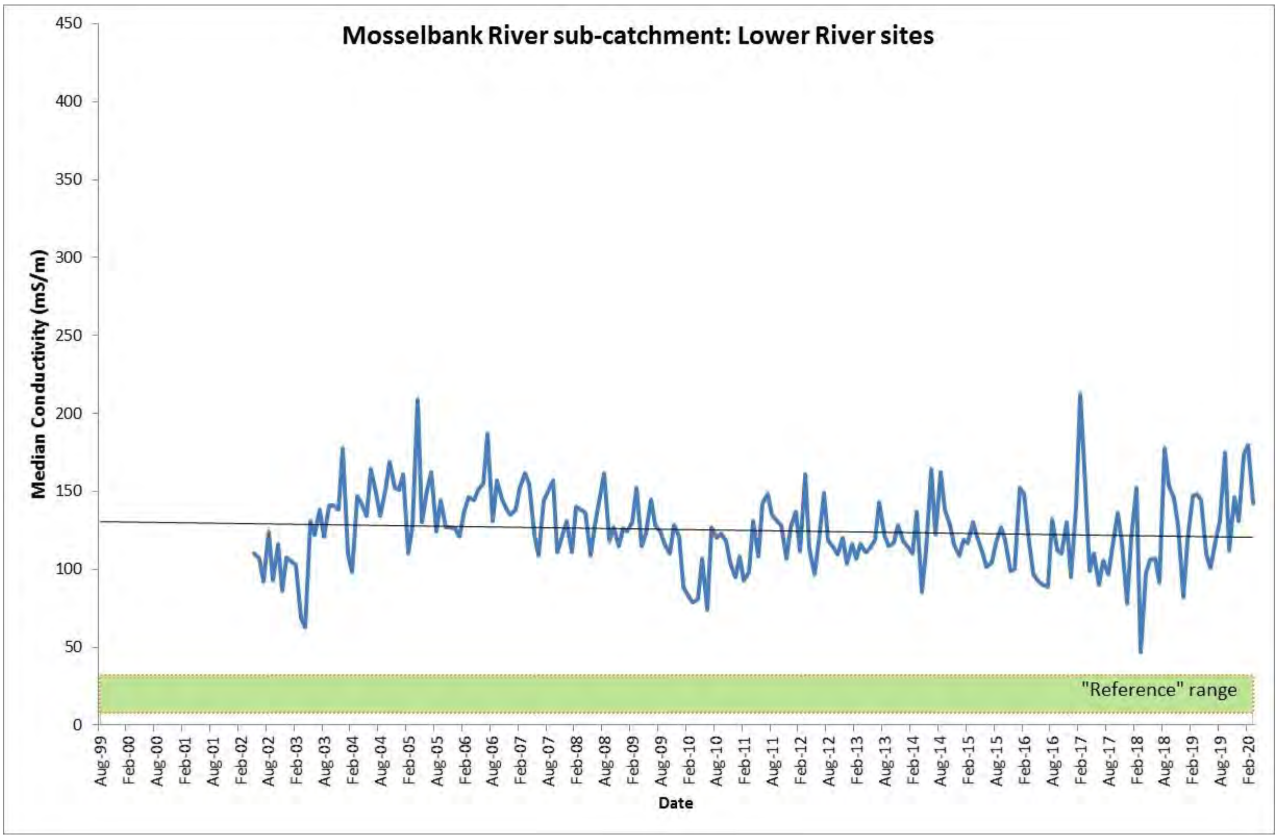
Feb-20


Mosselbank River sub-catchment: Lower River sites
Median Conductivity (mS/m)
Date
"Reference" range
0
50
100
150
200
250
300
350
400
450
Aug-99
Feb-00
Aug-00
Feb-01
Aug-01
Feb-02
Aug-02
Feb-03
Aug-03
Feb-04
Aug-04
Feb-05
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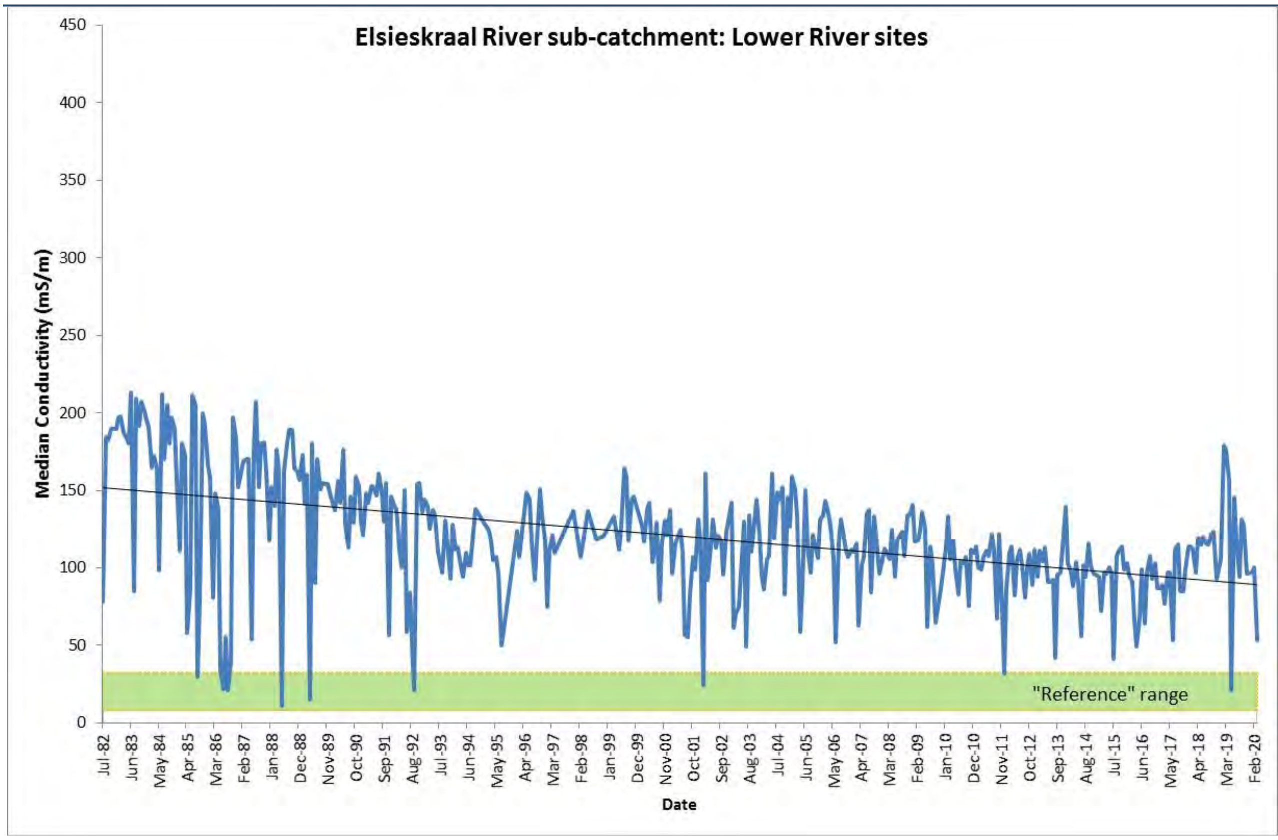
Elsieskraal River sub-catchment: Lower River sites
Median Conductivity (mS/m)
450
400
350
300
250
200
150
100
50
0
"Reference" range
Jul-82
Jun-83
May-84
Apr-85
Mar-86
Feb-87
Jan-88
Dec-88
Nov-89
Oct-90
Sep-91
Aug-92
Jul-93
Jun-94
May-95
Apr-96
Mar-97
Feb-98
Jan-99
Dec-99
Nov-00
Oct-01
Sep-02
Aug-03
Jul-04
Jun-05
May-06
Apr-07
Mar-08
Feb-09
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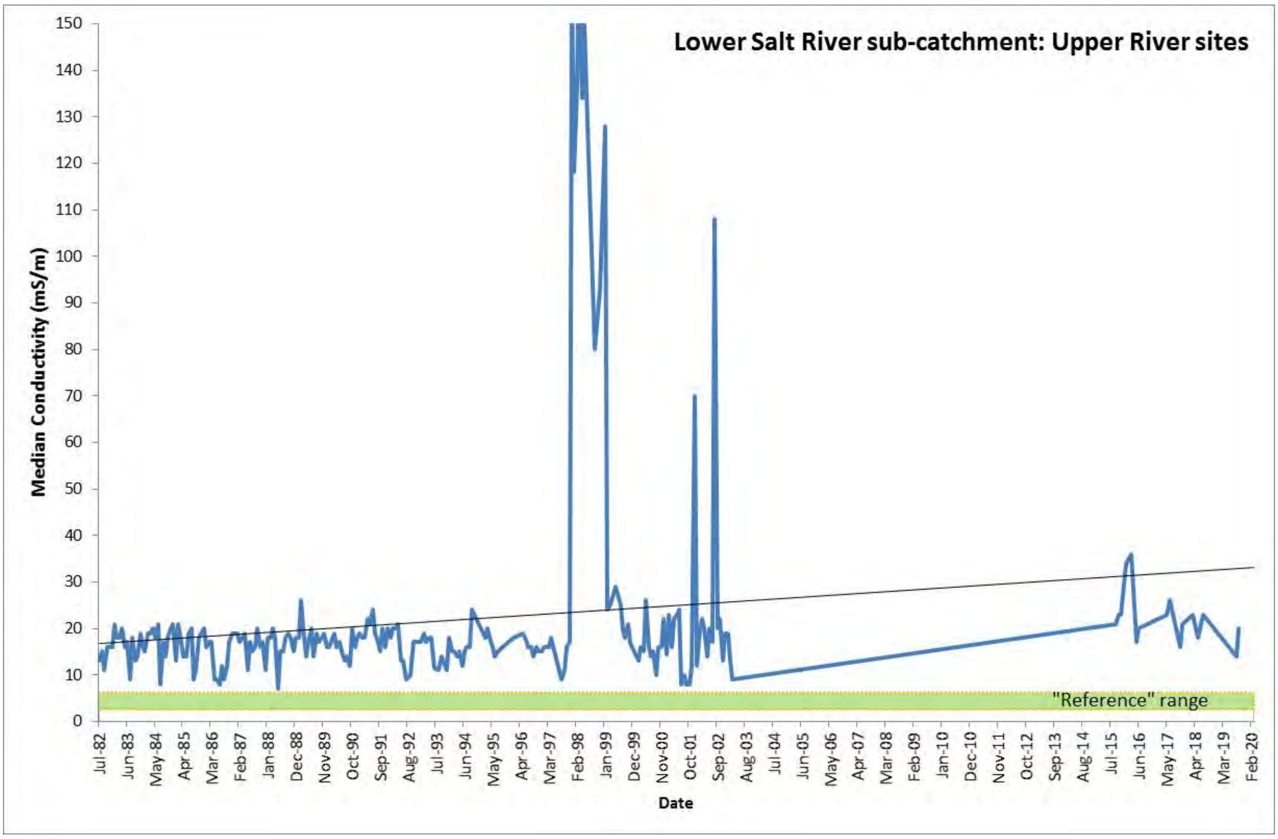
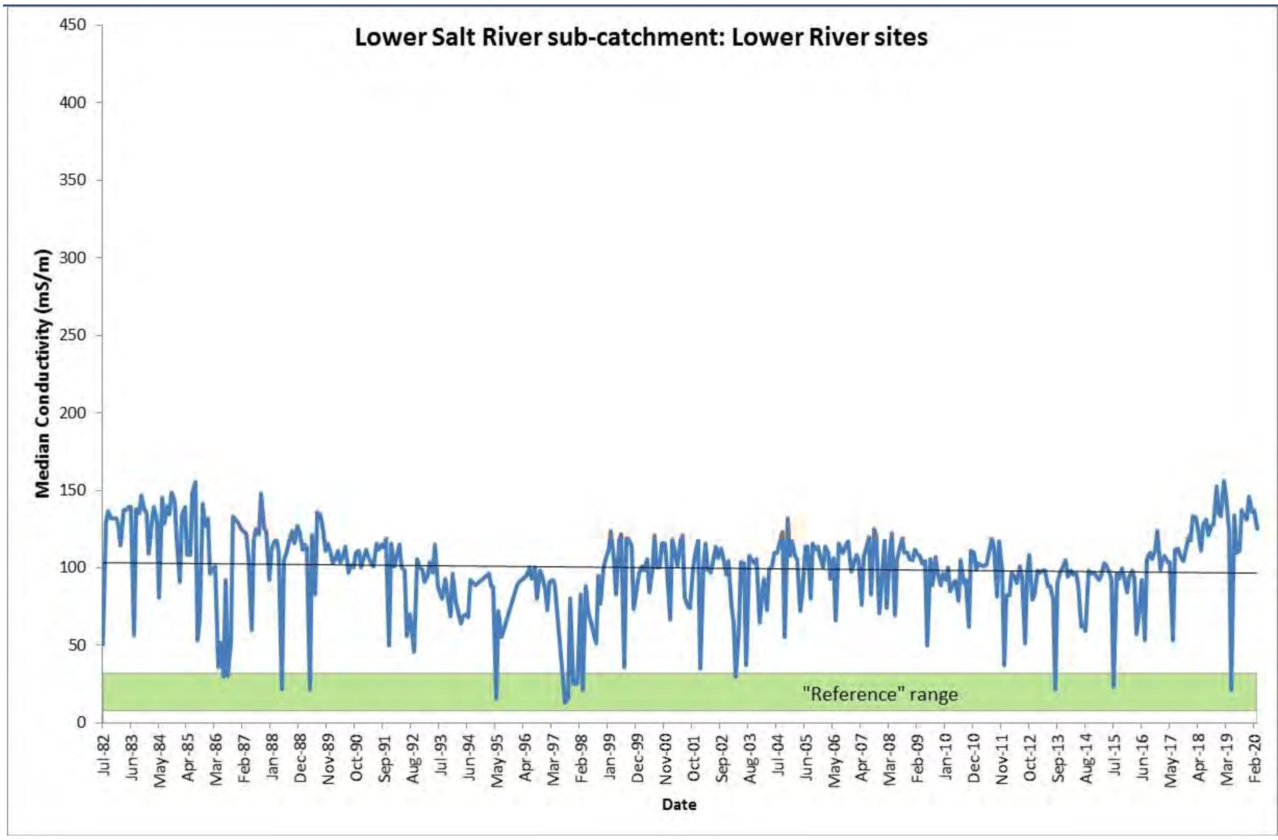
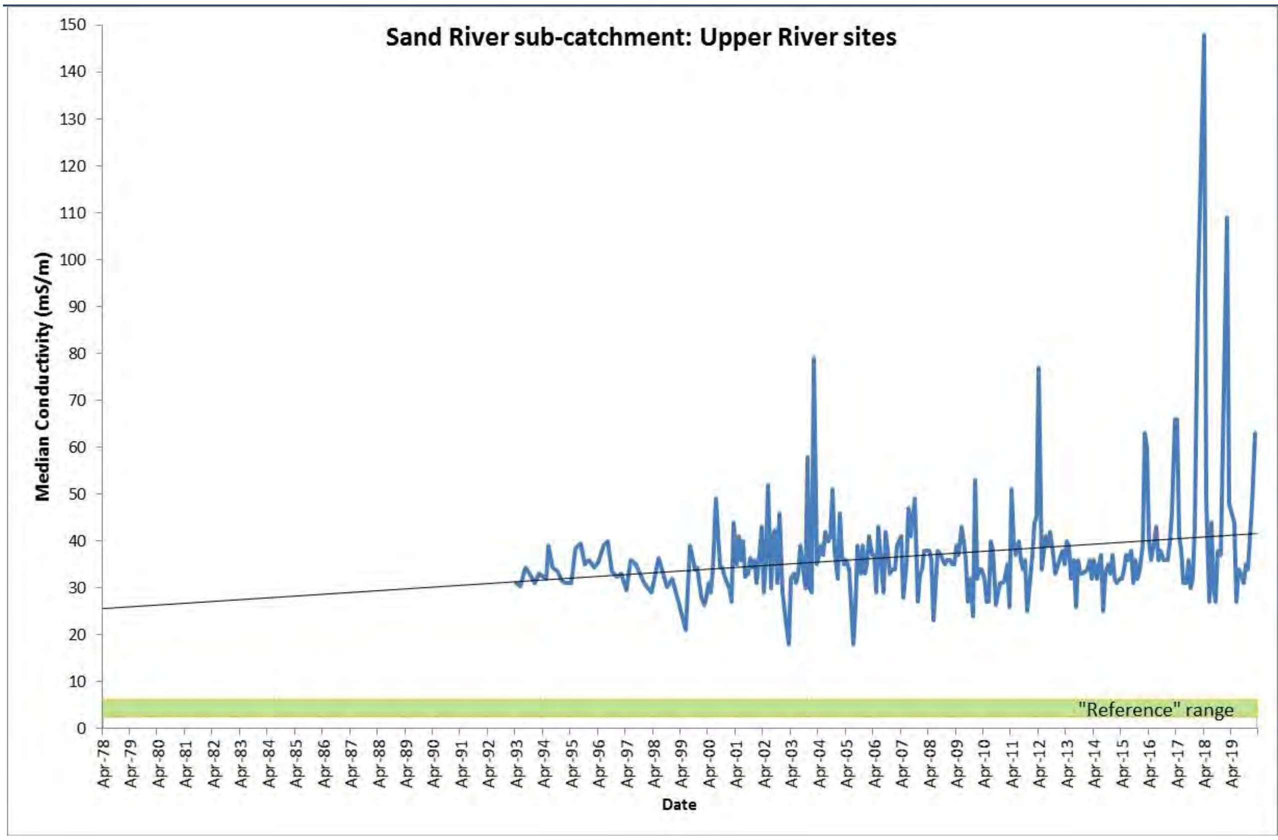
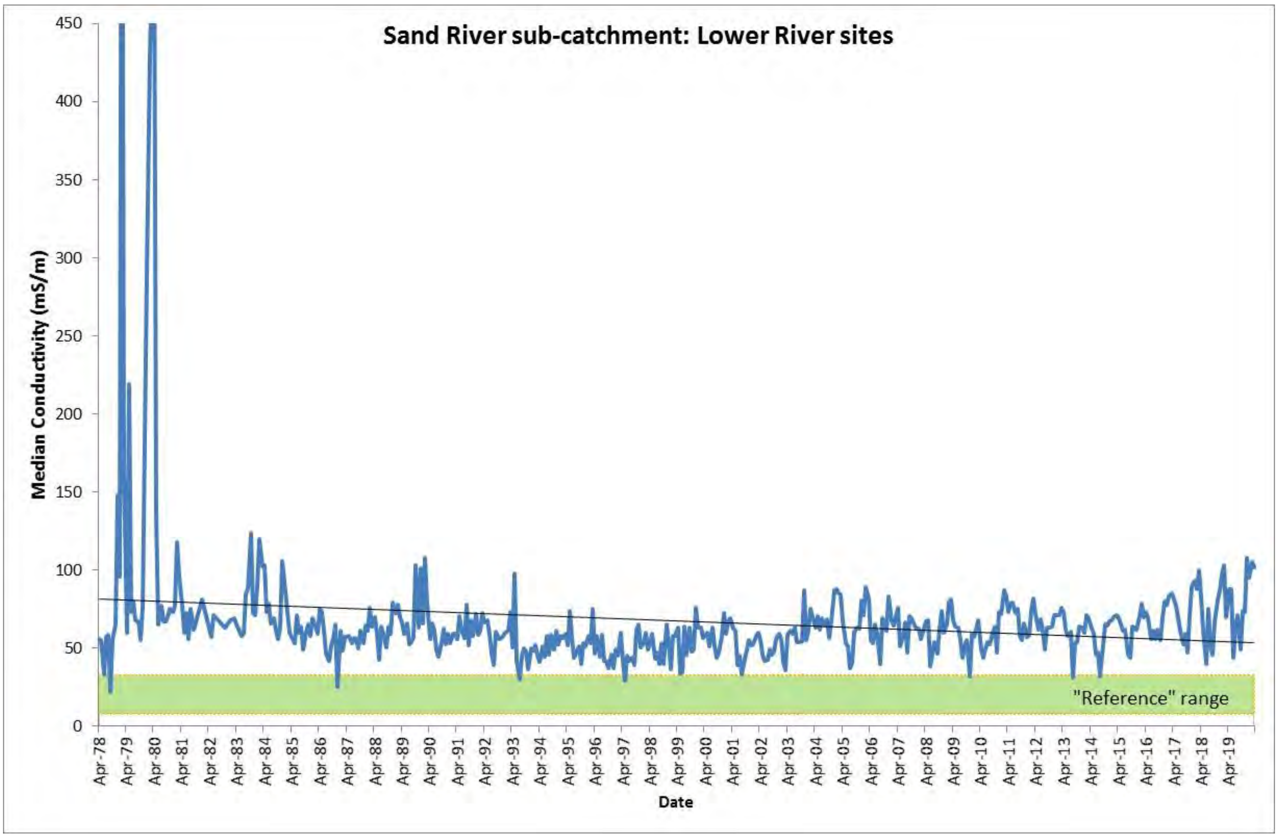
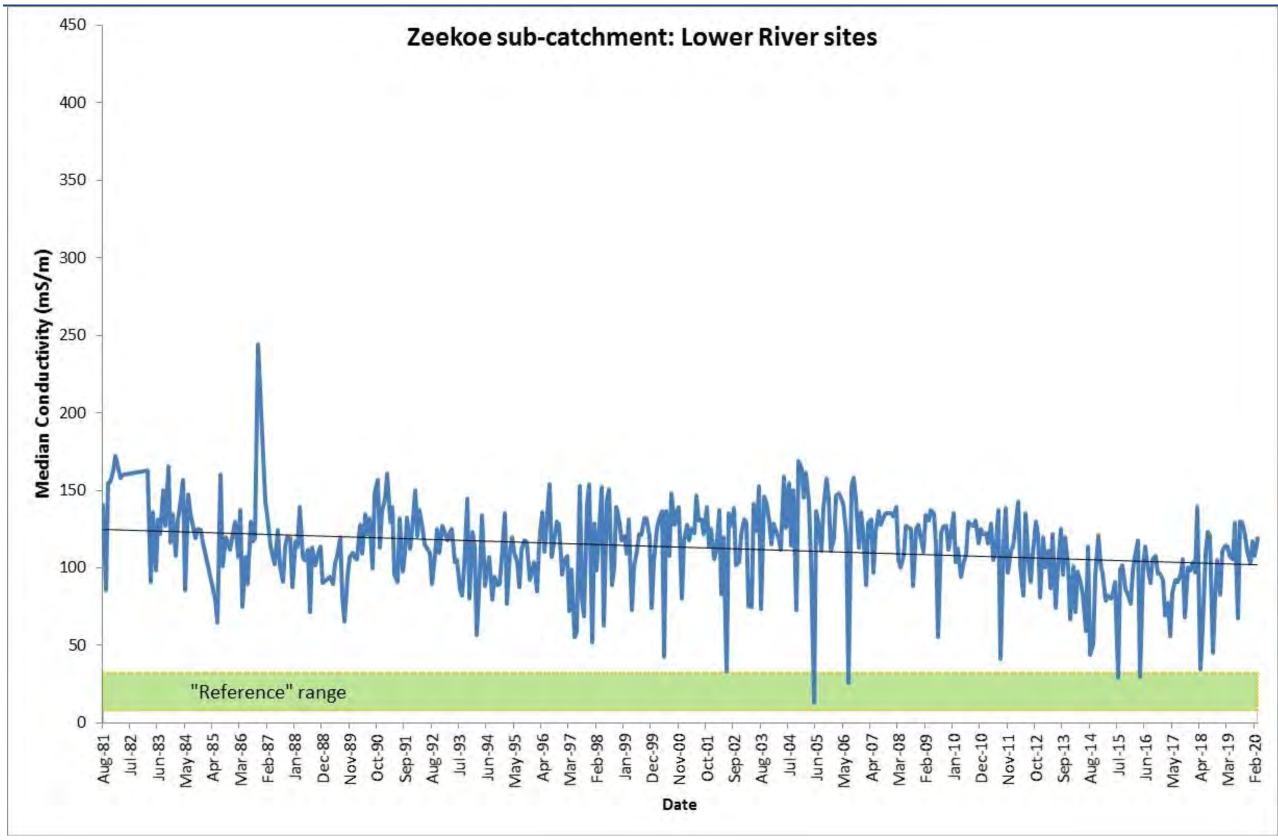
Apr-18
Mar-19
Feb-20
Date

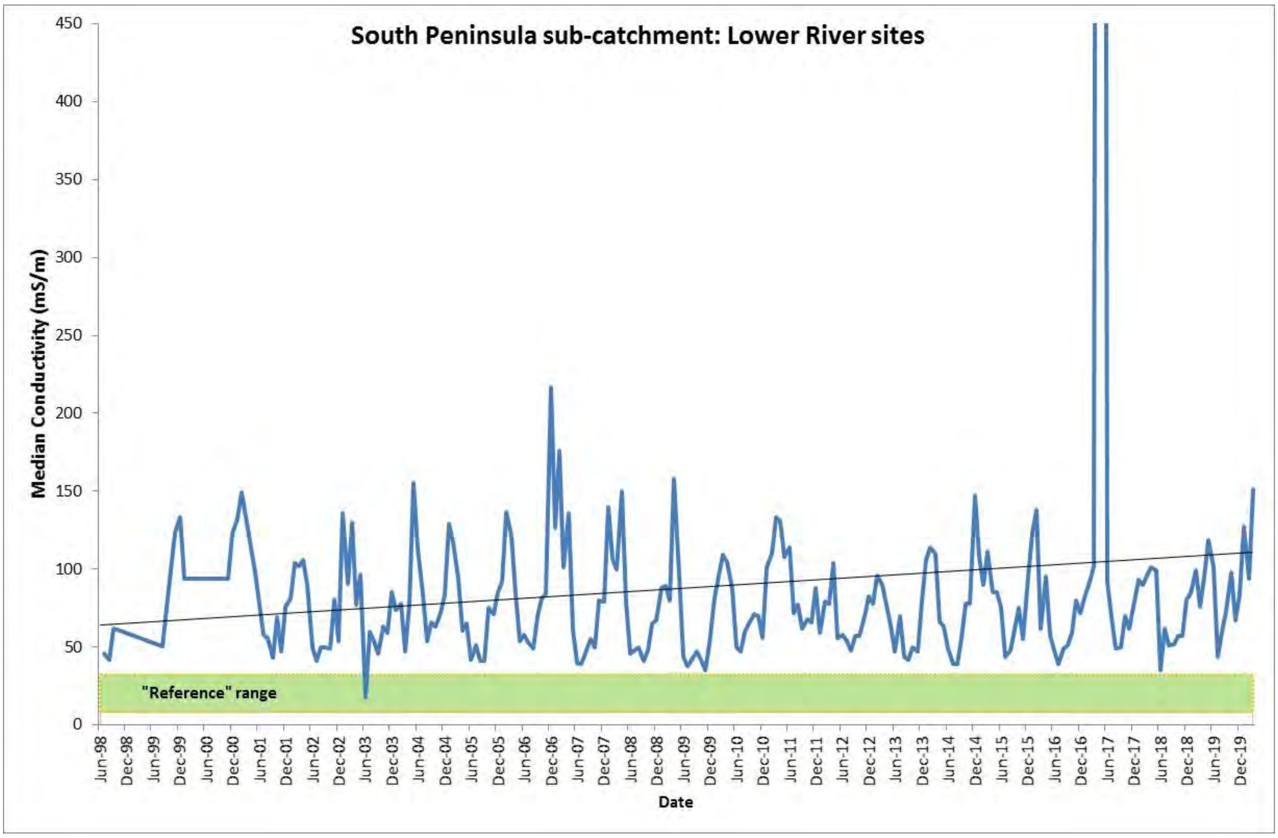

Lower Salt River sub-catchment: Upper River sites
Median Conductivity (mS/m)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
"Reference" range
Jul-82
Jun-83
May-84
Apr-85
Mar-86
Feb-87
Jan-88
Dec-88
Nov-89
Oct-90
Sep-91
Aug-92
Jul-93
Jun-94
May-95
Apr-96
Mar-97
Feb-98
Jan-99
Dec-99
Nov-00
Oct-01
Sep-02
Aug-03
Jul-04
Jun-05
May-06
Apr-07
Mar-08
Feb-09
Jan-10
Dec-10
Nov-11
Oct-12
Sep-13
Aug-14
Jul-15
Jun-16
May-17
Apr-18
Mar-19
Feb-20
Date

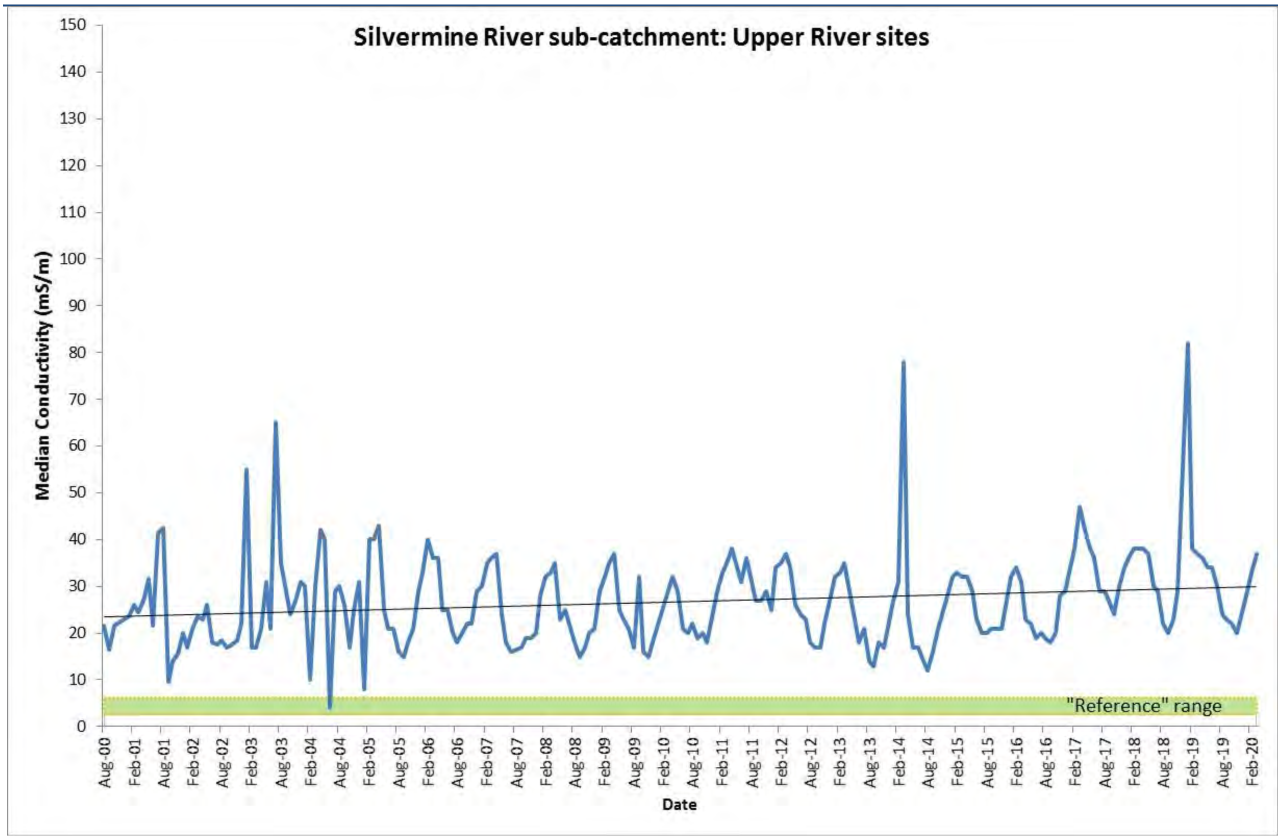

Lower Salt River sub-catchment: Lower River sites
Median Conductivity (mS/m)
450
400
350
300
250
200
150
100
50
0
"Reference" range
Jul-82
Jun-83
May-84
Apr-85
Mar-86
Feb-87
Jan-88
Dec-88
Nov-89
Oct-90
Sep-91
Aug-92
Jul-93
Jun-94
May-95
Apr-96
Mar-97
Feb-98
Jan-99
Dec-99
Nov-00
Oct-01
Sep-02
Aug-03
Jul-04
Jun-05
May-06
Apr-07
Mar-08
Feb-09
Jan-10
Dec-10
Nov-11
Oct-12
Sep-13
Aug-14
Jul-15
Jun-16
May-17
Apr-18
Mar-19
Feb-20
Date

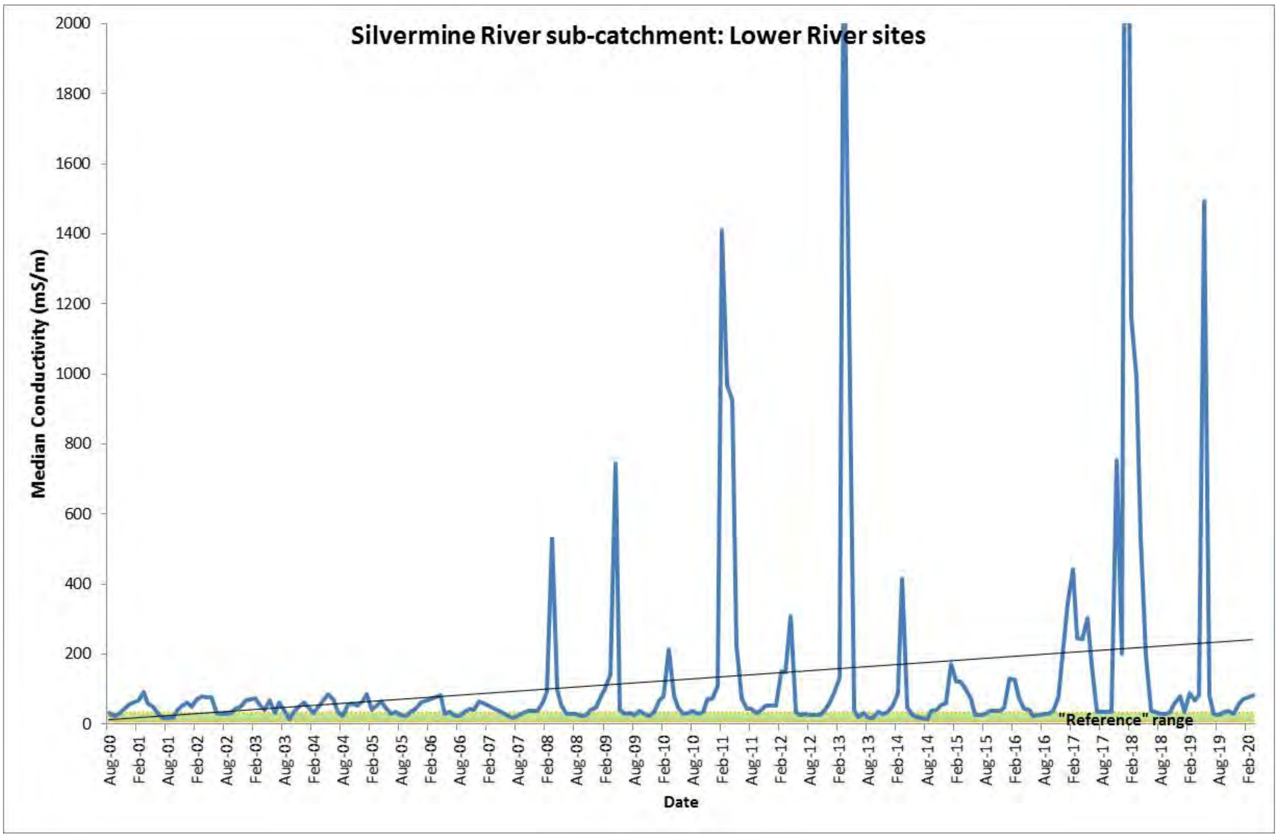

Sand River sub-catchment: Upper River sites
Median Conductivity (mS/m)
"Reference" range
Date

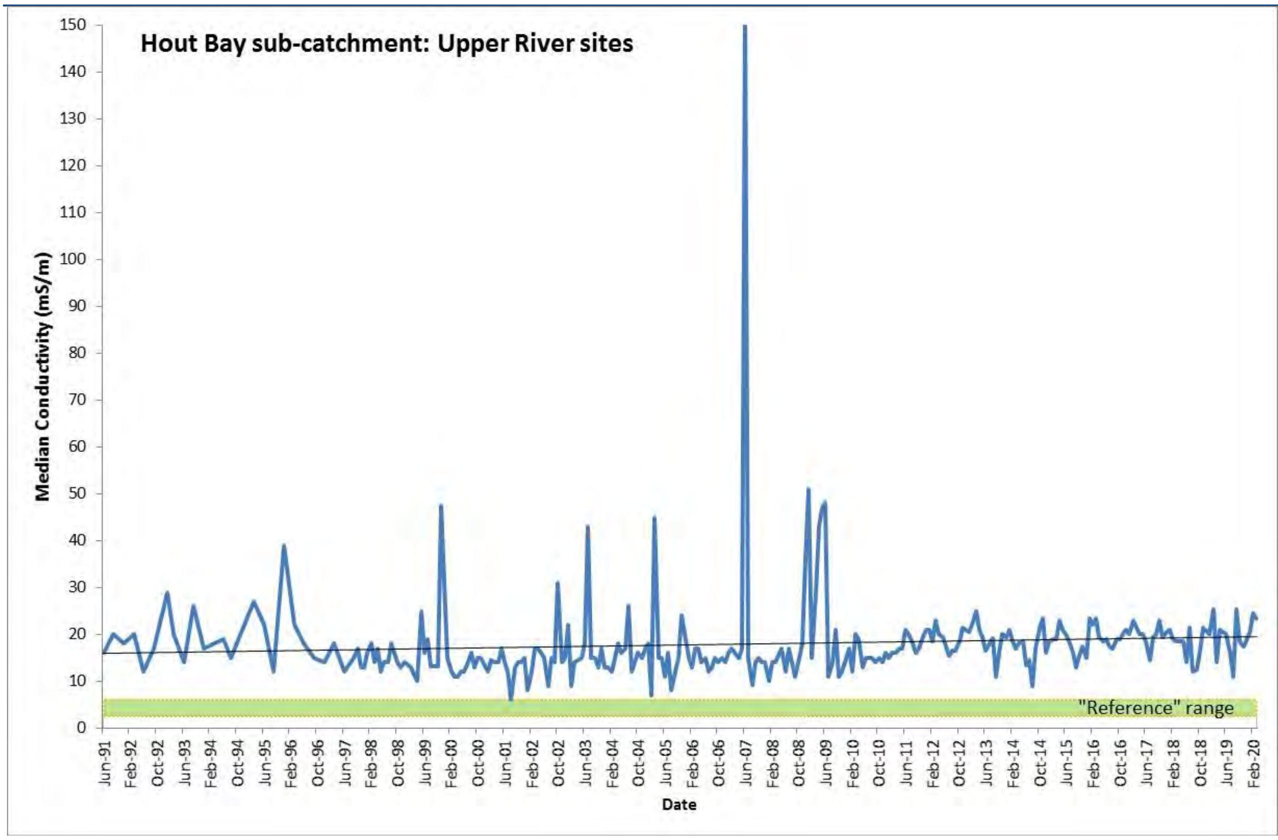

Sand River sub-catchment: Lower River sites
Median Conductivity (mS/m)
"Reference" range
Date

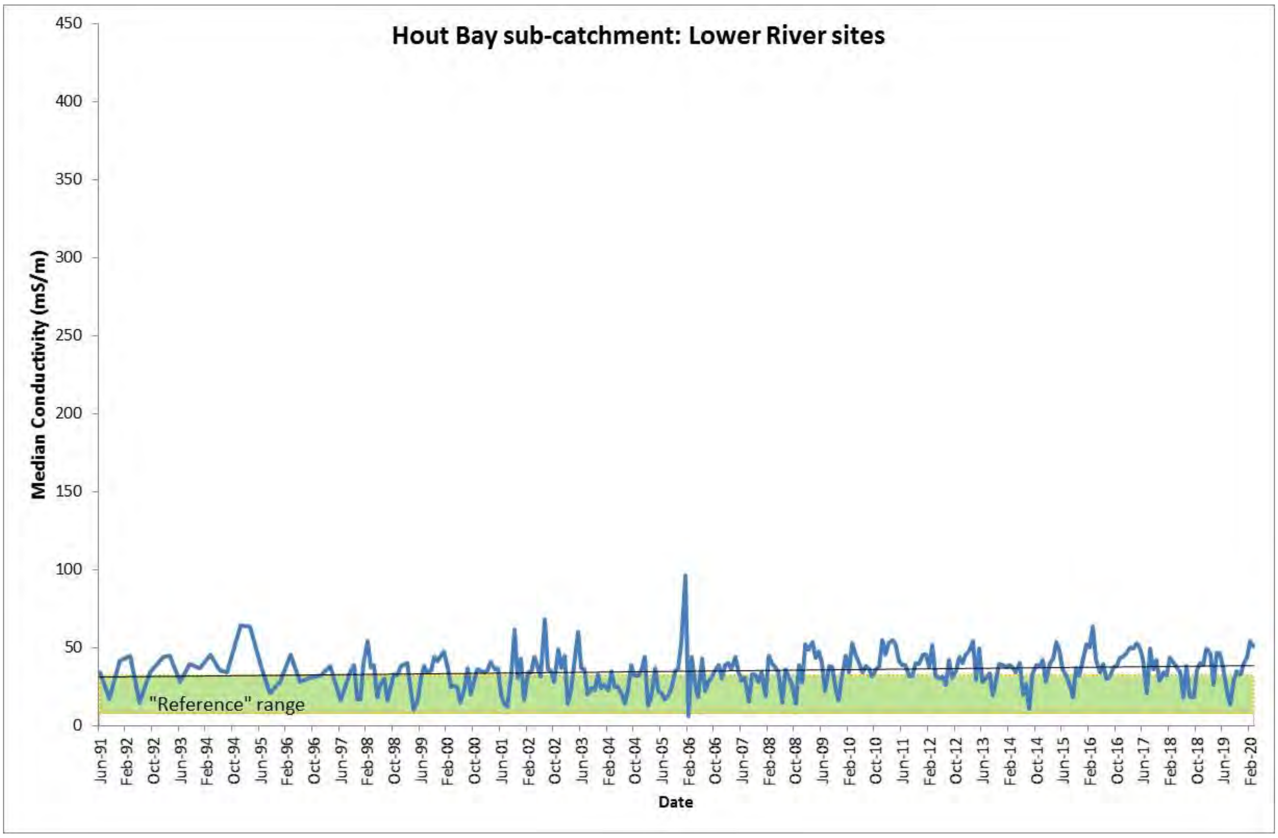

Zeekoe sub-catchment: Lower River sites
Median Conductivity (mS/m)
450
400
350
300
250
200
150
100
50
0
"Reference" range
Aug-81 Jul-82 Jun-83 May-84 Apr-85 Mar-86 Feb-87 Jan-88 Dec-88 Nov-89 Oct-90 Sep-91 Aug-92 Jul-93 Jun-94 May-95 Apr-96 Mar-97 Feb-98 Jan-99 Dec-99 Nov-00 Oct-01 Sep-02 Aug-03 Jul-04 Jun-05 May-06 Apr-07 Mar-08 Feb-09 Jan-10 Dec-10 Nov-11 Oct-12 Sep-13 Aug-14 Jul-15 Jun-16 May-17 Apr-18 Mar-19 Feb-20
Date

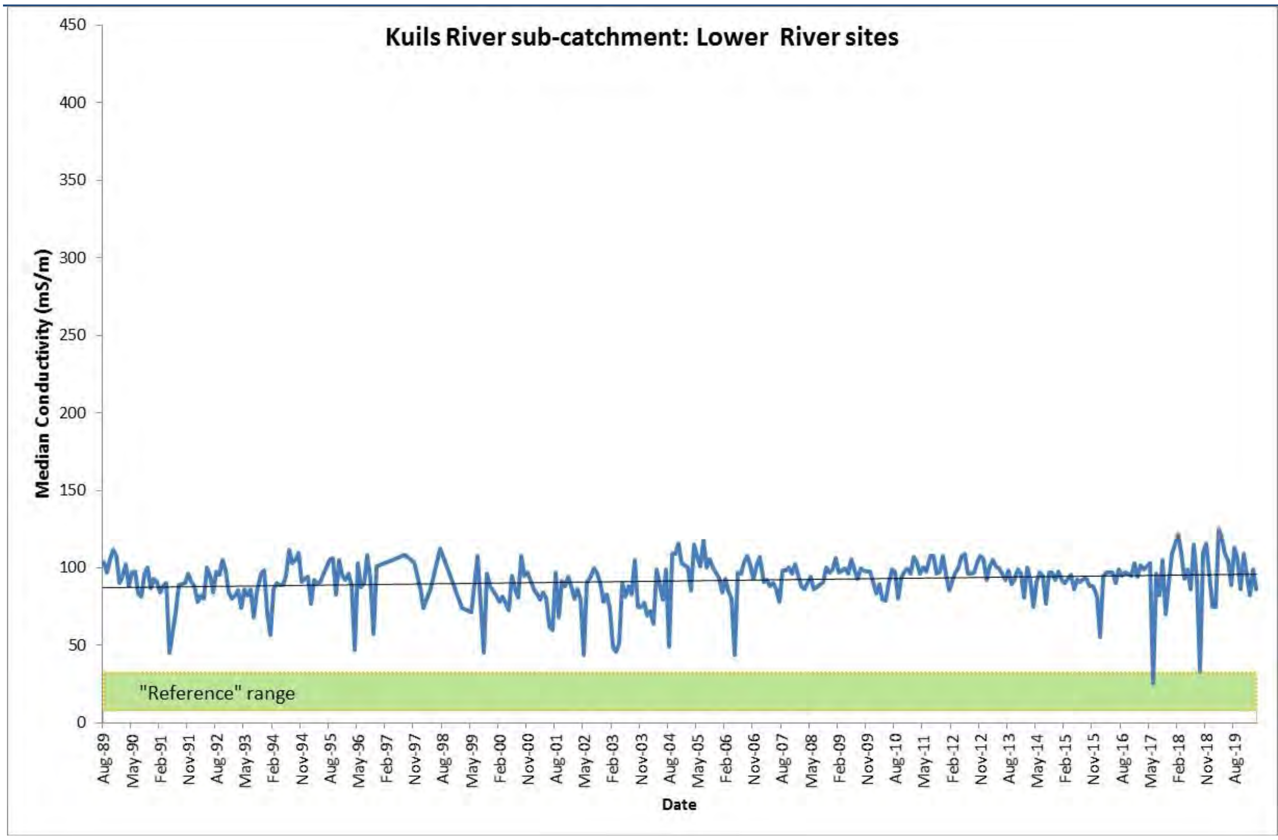

South Peninsula sub-catchment: Lower River sites
Median Conductivity (mS/m)
450
400
350
300
250
200
150
100
50
0
"Reference" range
Jun-98 Dec-98 Jun-99 Dec-99 Jun-00 Dec-00 Jun-01 Dec-01 Jun-02 Dec-02 Jun-03 Dec-03 Jun-04 Dec-04 Jun-05 Dec-05 Jun-06 Dec-06 Jun-07 Dec-07 Jun-08 Dec-08 Jun-09 Dec-09 Jun-10 Dec-10 Jun-11 Dec-11 Jun-12 Dec-12 Jun-13 Dec-13 Jun-14 Dec-14 Jun-15 Dec-15 Jun-16 Dec-16 Jun-17 Dec-17 Jun-18 Dec-18 Jun-19 Dec-19
Date

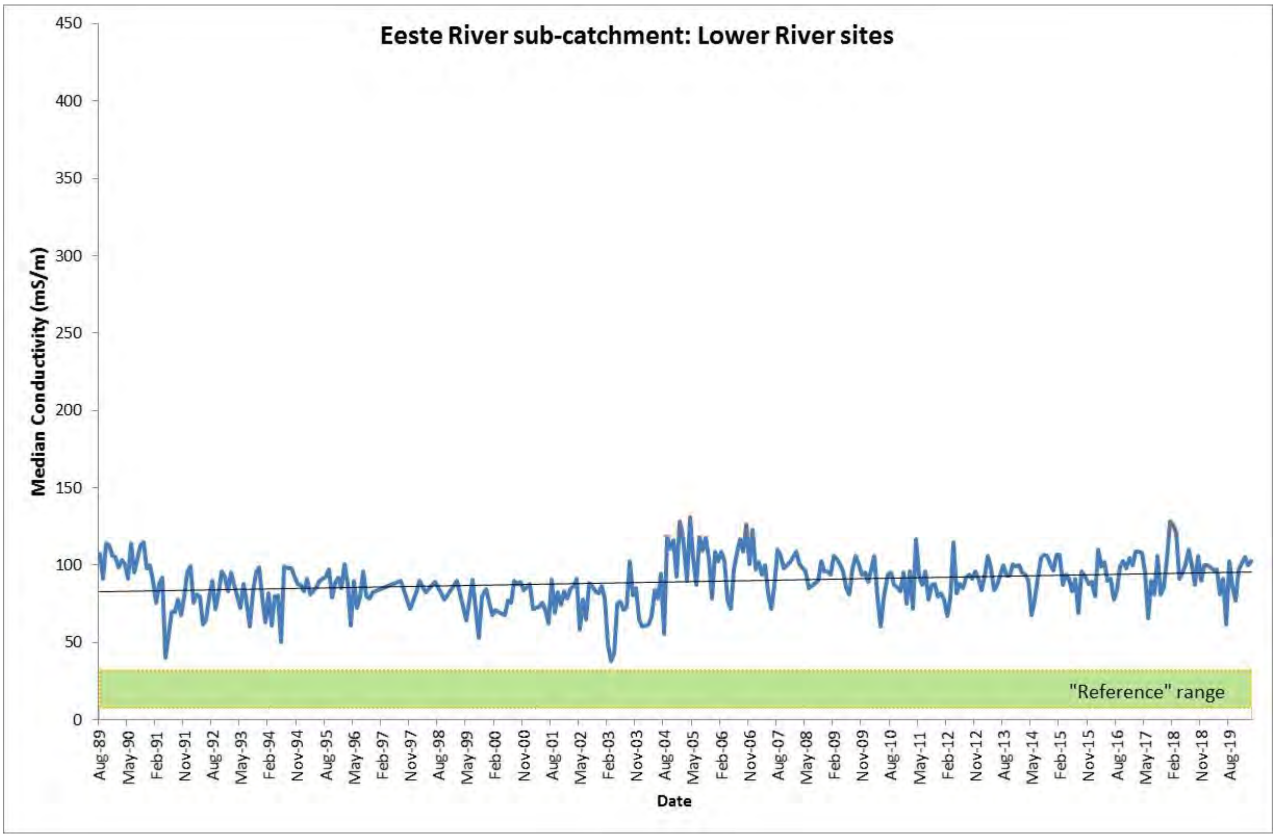

Silvermine River sub-catchment: Upper River sites
Median Conductivity (mS/m)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
"Reference" range
Aug-00
Feb-01
Aug-01
Feb-02
Aug-02
Feb-03
Aug-03
Feb-04
Aug-04
Feb-05
Aug-05
Feb-06
Aug-06
Feb-07
Aug-07
Feb-08
Aug-08
Feb-09
Aug-09
Feb-10
Aug-10
Feb-11
Aug-11
Feb-12
Aug-12
Feb-13
Aug-13
Feb-14
Aug-14
Feb-15
Aug-15
Feb-16
Aug-16
Feb-17
Aug-17
Feb-18
Aug-18
Feb-19
Aug-19
Feb-20
Date

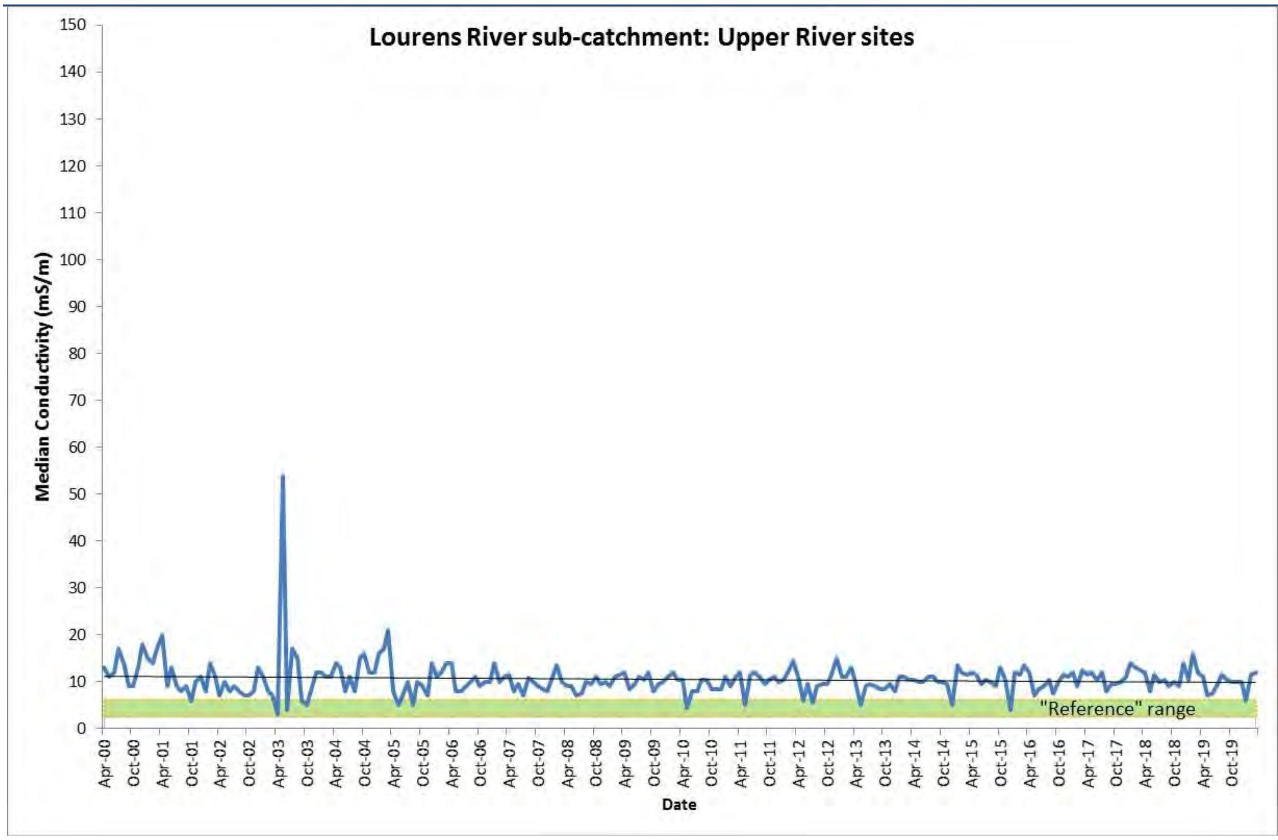

Silvermine River sub-catchment: Lower River sites
Median Conductivity (mS/m)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
"Reference" range
Aug-00
Feb-01
Aug-01
Feb-02
Aug-02
Feb-03
Aug-03
Feb-04
Aug-04
Feb-05
Aug-05
Feb-06
Aug-06
Feb-07
Aug-07
Feb-08
Aug-08
Feb-09
Aug-09
Feb-10
Aug-10
Feb-11
Aug-11
Feb-12
Aug-12
Feb-13
Aug-13
Feb-14
Aug-14
Feb-15
Aug-15
Feb-16
Aug-16
Feb-17
Aug-17
Feb-18
Aug-18
Feb-19
Aug-19
Feb-20
Date

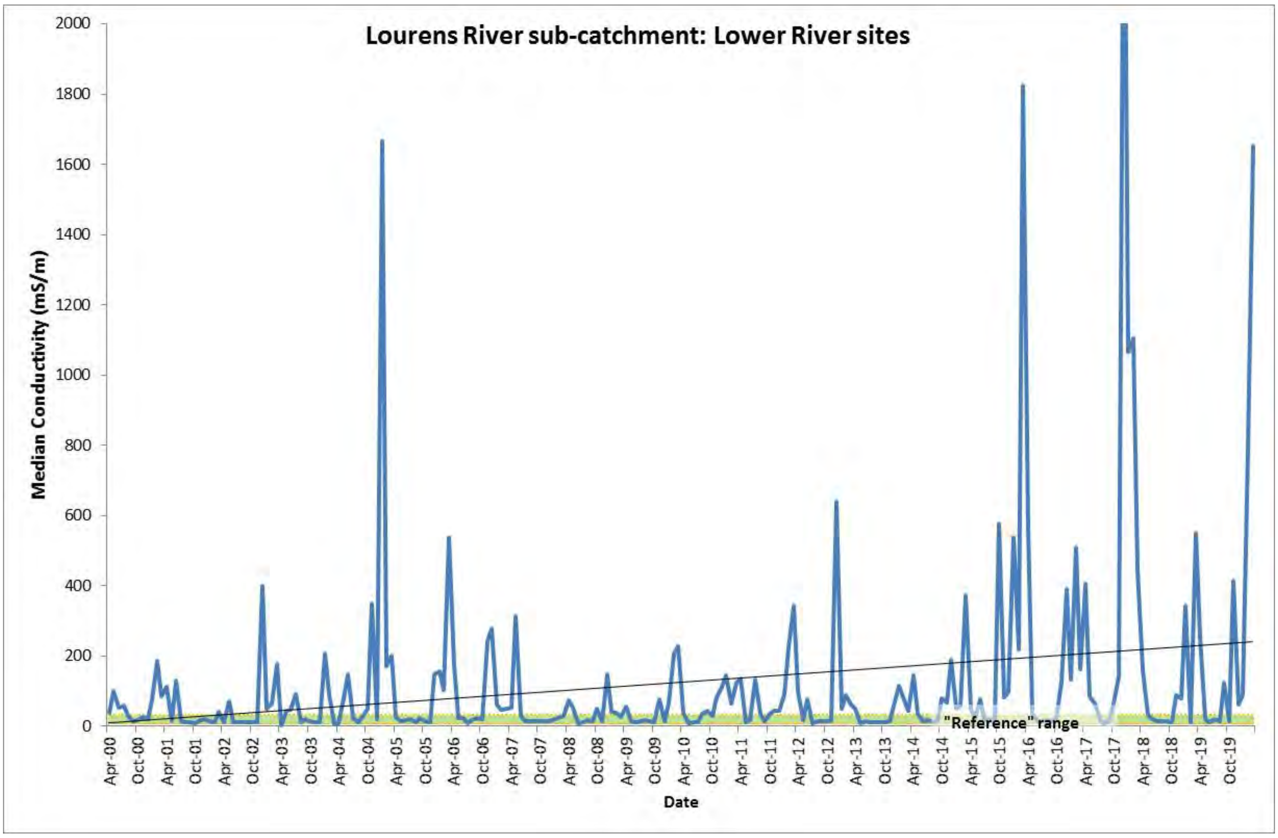

Hout Bay sub-catchment: Upper River sites
Median Conductivity (mS/m)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
"Reference" range
Jun-91 Feb-92 Oct-92 Jun-93 Feb-94 Oct-94 Jun-95 Feb-96 Oct-96 Jun-97 Feb-98 Oct-98 Jun-99 Feb-00 Oct-00 Jun-01 Feb-02 Oct-02 Jun-03 Feb-04 Oct-04 Jun-05 Feb-06 Oct-06 Jun-07 Feb-08 Oct-08 Jun-09 Feb-10 Oct-10 Jun-11 Feb-12 Oct-12 Jun-13 Feb-14 Oct-14 Jun-15 Feb-16 Oct-16 Jun-17 Feb-18 Oct-18 Jun-19 Feb-20
Date

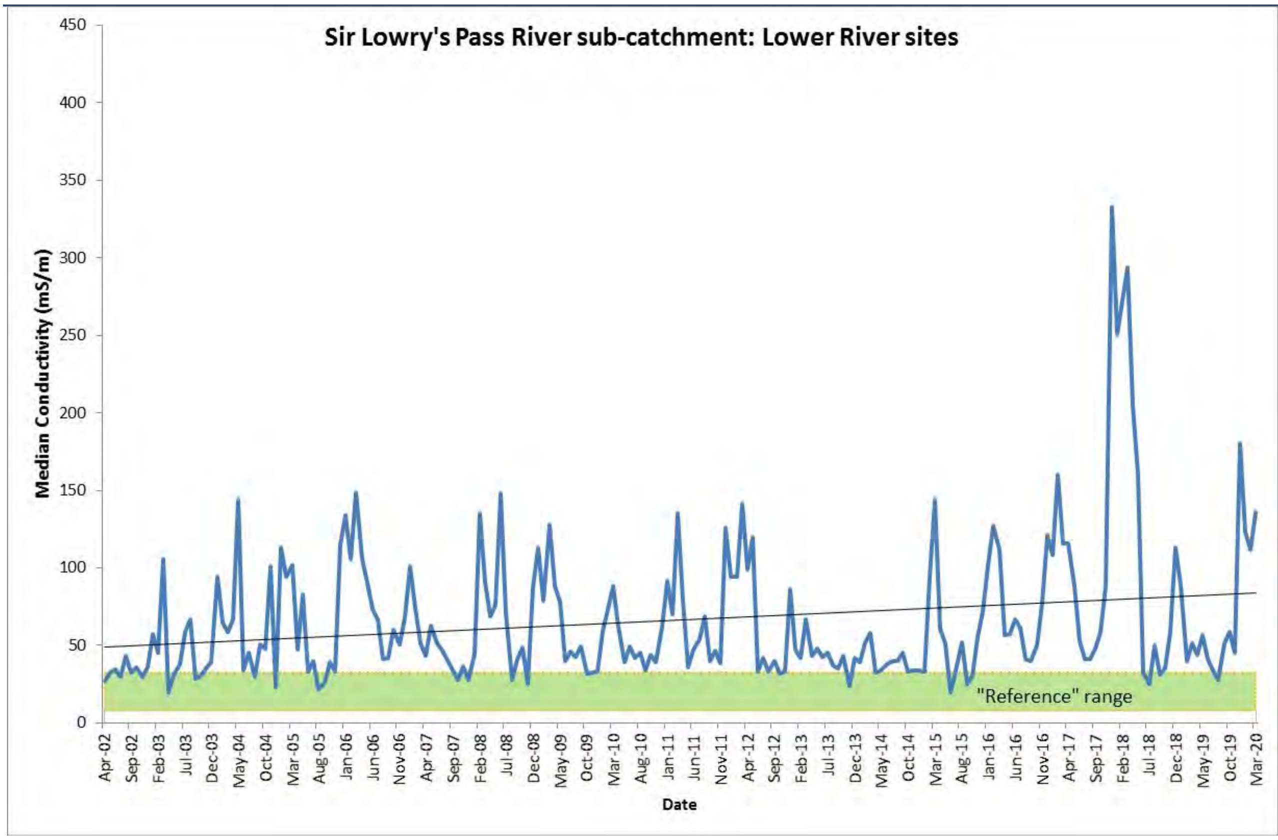

Hout Bay sub-catchment: Lower River sites
Median Conductivity (mS/m)
450
400
350
300
250
200
150
100
50
0
"Reference" range
Jun-91 Feb-92 Oct-92 Jun-93 Feb-94 Oct-94 Jun-95 Feb-96 Oct-96 Jun-97 Feb-98 Oct-98 Jun-99 Feb-00 Oct-00 Jun-01 Feb-02 Oct-02 Jun-03 Feb-04 Oct-04 Jun-05 Feb-06 Oct-06 Jun-07 Feb-08 Oct-08 Jun-09 Feb-10 Oct-10 Jun-11 Feb-12 Oct-12 Jun-13 Feb-14 Oct-14 Jun-15 Feb-16 Oct-16 Jun-17 Feb-18 Oct-18 Jun-19 Feb-20
Date

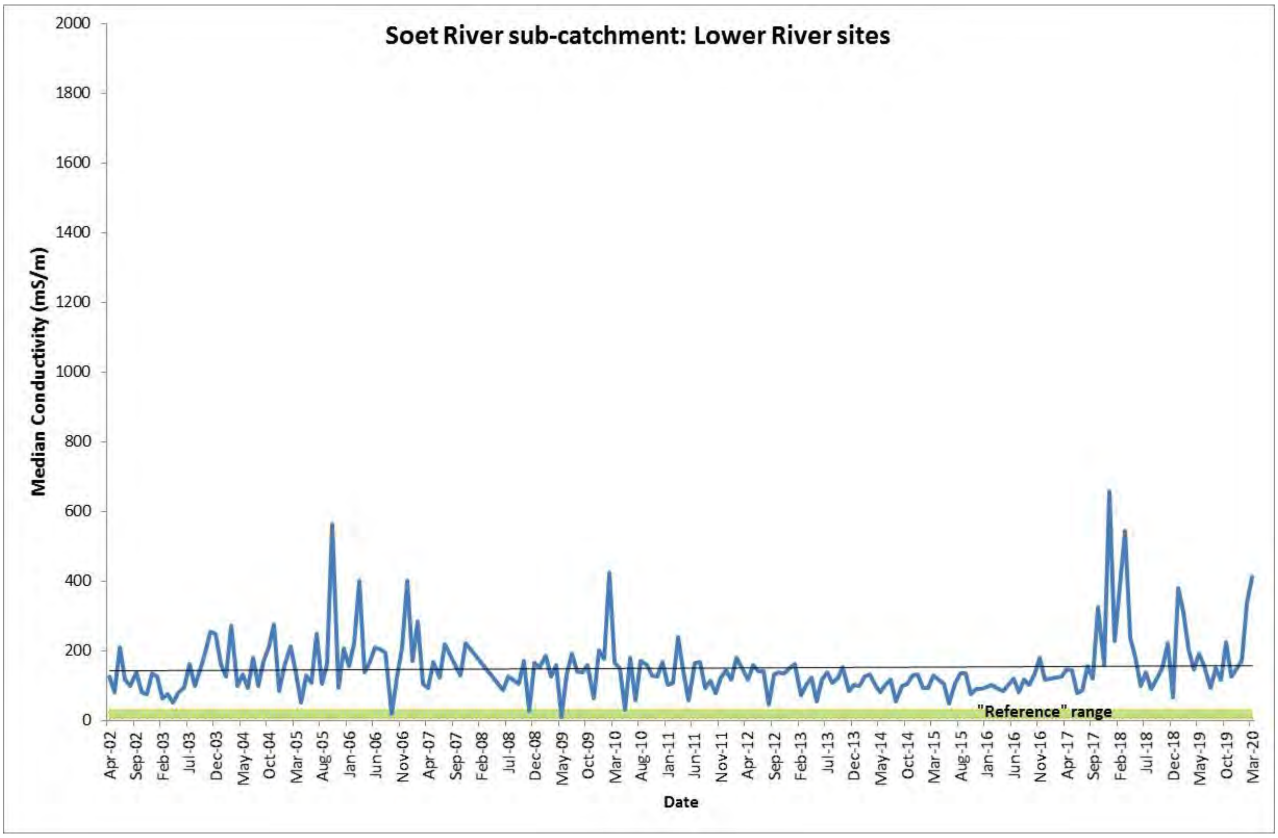

Kuils River sub-catchment: Lower River sites
Median Conductivity (mS/m)
450
400
350
300
250
200
150
100
50
0
"Reference" range
Aug-89
May-90
Feb-91
Nov-91
Aug-92
May-93
Feb-94
Nov-94
Aug-95
May-96
Feb-97
Nov-97
Aug-98
May-99
Feb-00
Nov-00
Aug-01
May-02
Feb-03
Nov-03
Aug-04
May-05
Feb-06
Nov-06
Aug-07
May-08
Feb-09
Nov-09
Aug-10
May-11
Feb-12
Nov-12
Aug-13
May-14
Feb-15
Nov-15
Aug-16
May-17
Feb-18
Nov-18
Aug-19
Date


Eeste River sub-catchment: Lower River sites
Median Conductivity (mS/m)
450
400
350
300
250
200
150
100
50
0
"Reference" range
Aug-89
May-90
Feb-91
Nov-91
Aug-92
May-93
Feb-94
Nov-94
Aug-95
May-96
Feb-97
Nov-97
Aug-98
May-99
Feb-00
Nov-00
Aug-01
May-02
Feb-03
Nov-03
Aug-04
May-05
Feb-06
Nov-06
Aug-07
May-08
Feb-09
Nov-09
Aug-10
May-11
Feb-12
Nov-12
Aug-13
May-14
Feb-15
Nov-15
Aug-16
May-17
Feb-18
Nov-18
Aug-19
Date

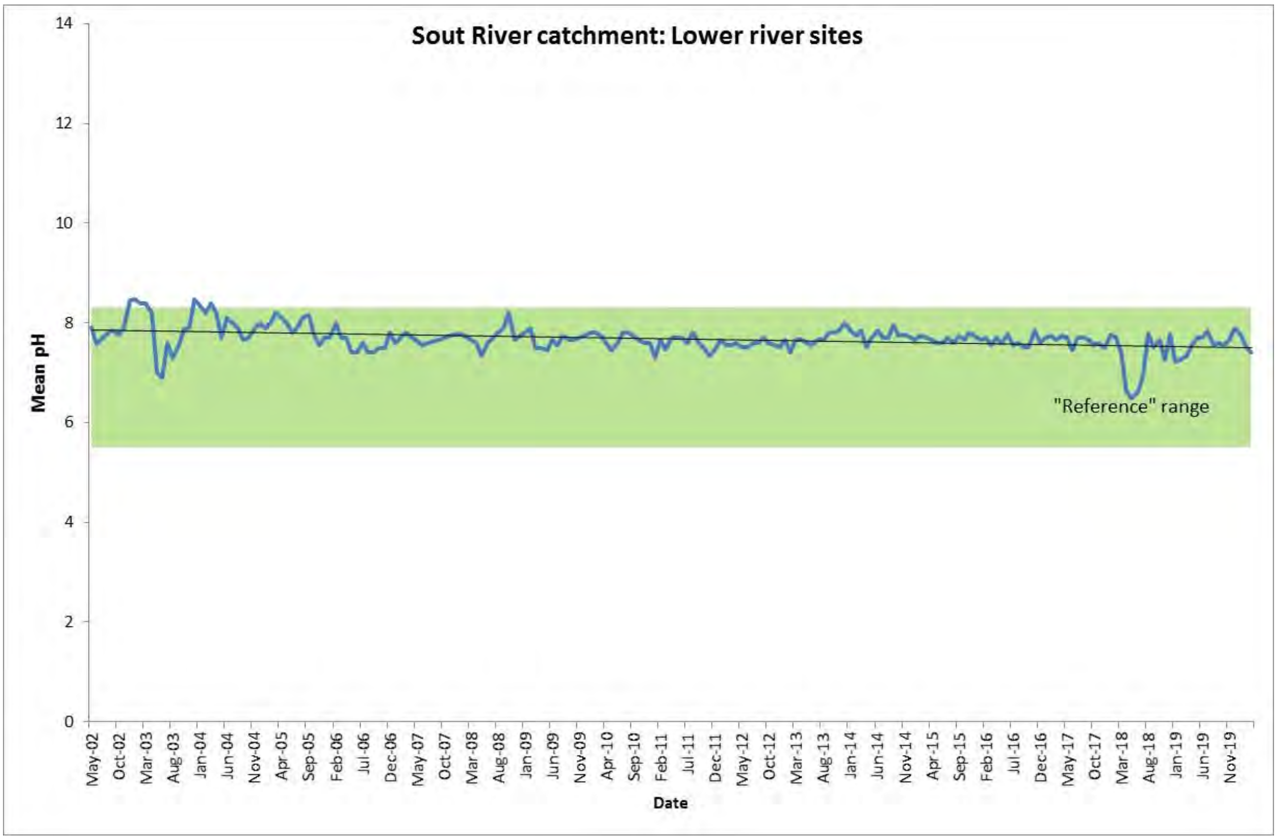

Lourens River sub-catchment: Upper River sites
Median Conductivity (mS/m)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
"Reference" range
Date

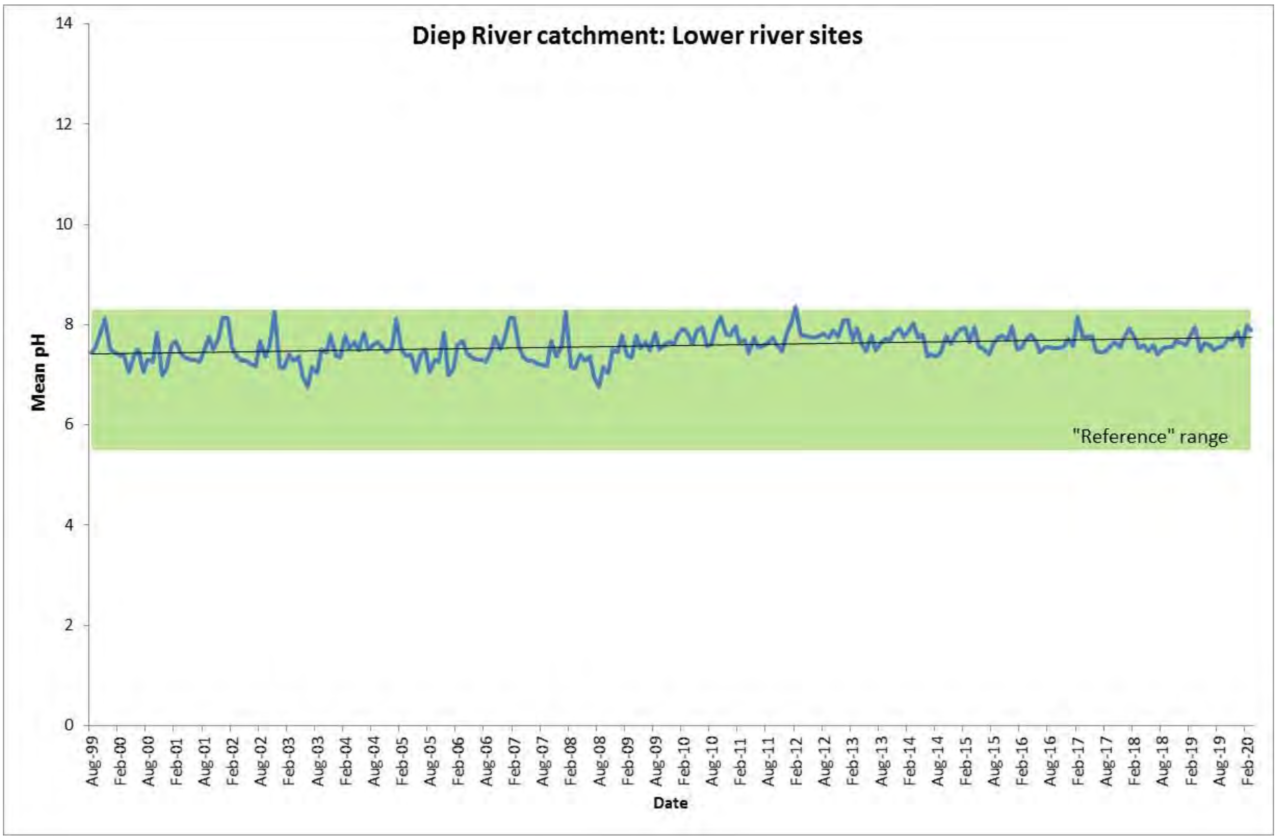

Lourens River sub-catchment: Lower River sites
Median Conductivity (mS/m)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
"Reference" range
Date

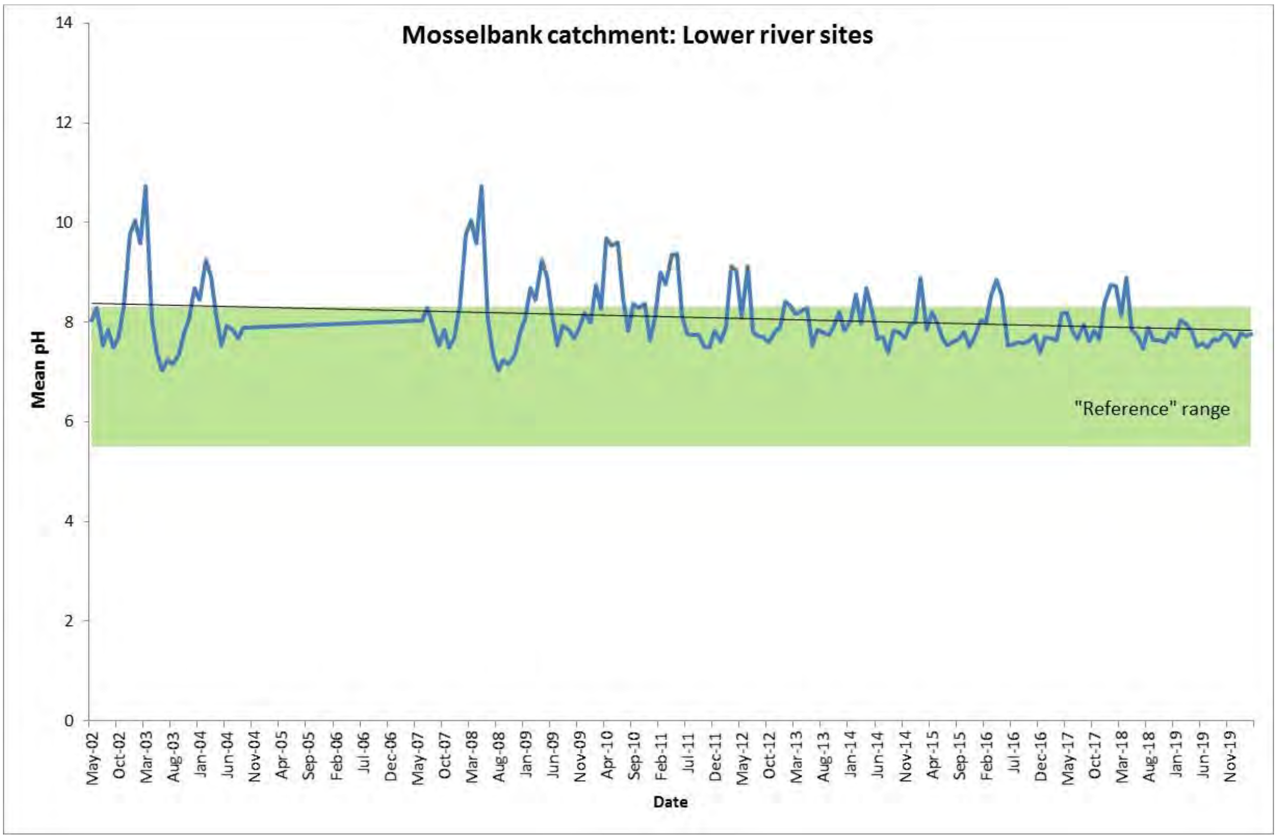

Sir Lowry's Pass River sub-catchment: Lower River sites
Median Conductivity (mS/m)
0
50
100
150
200
250
300
350
400
450
"Reference" range
Date

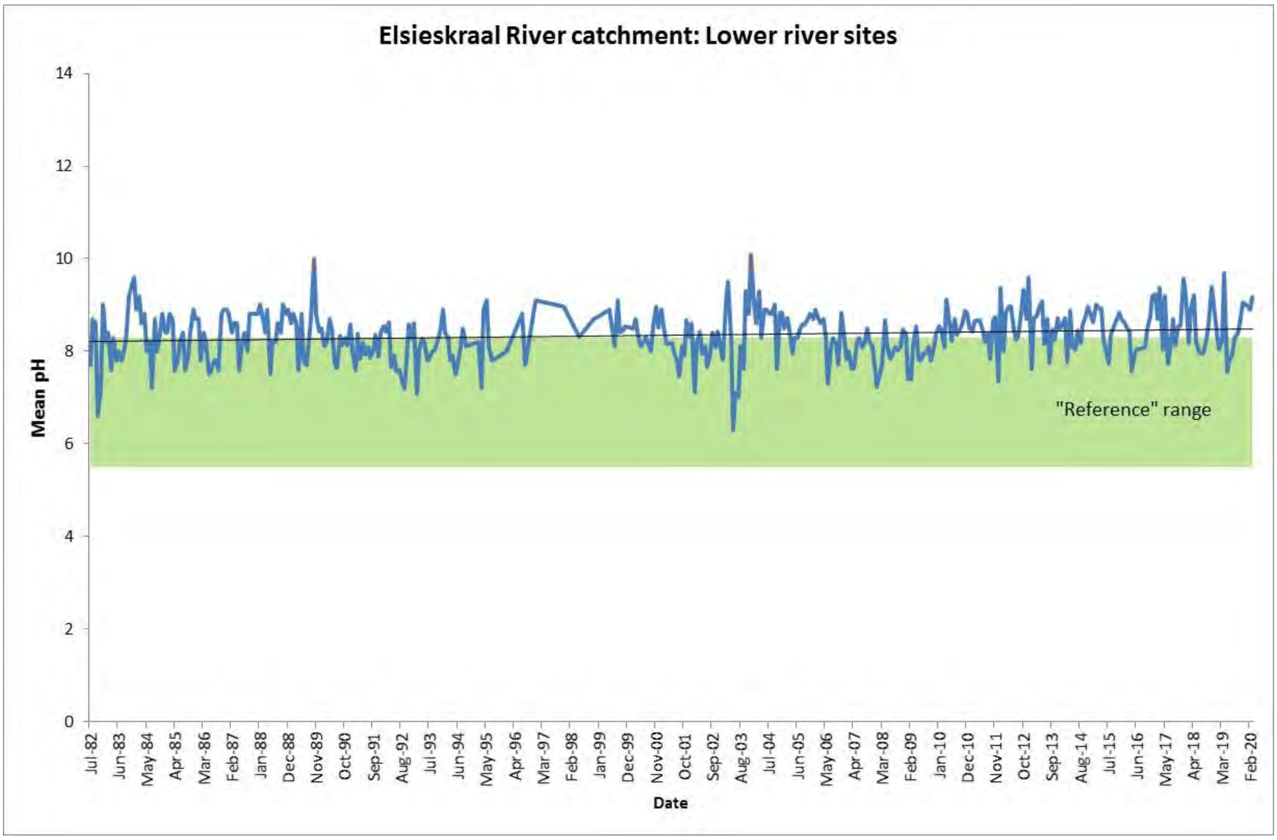

Soet River sub-catchment: Lower River sites
Median Conductivity (mS/m)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
"Reference" range
Date

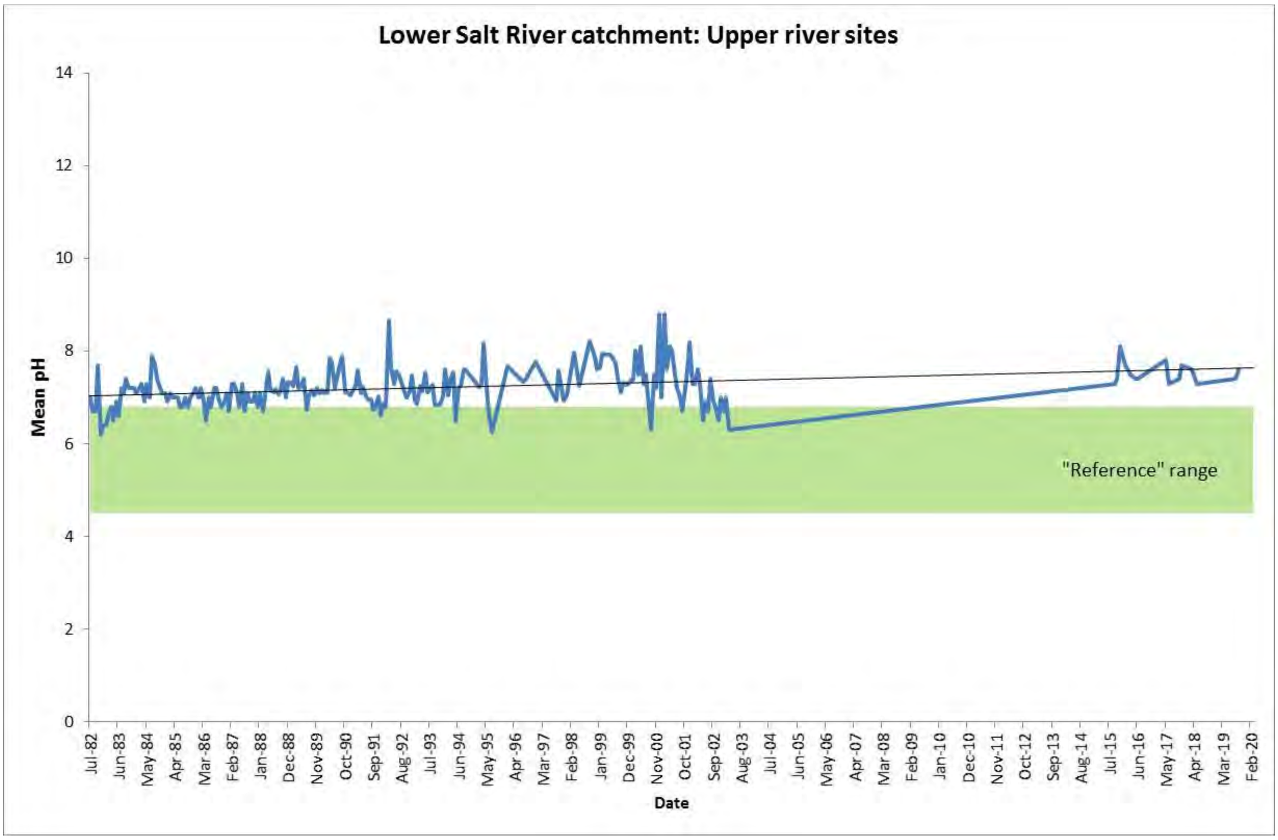
## APPENDIX E: PH TIME SERIES GRAPHS

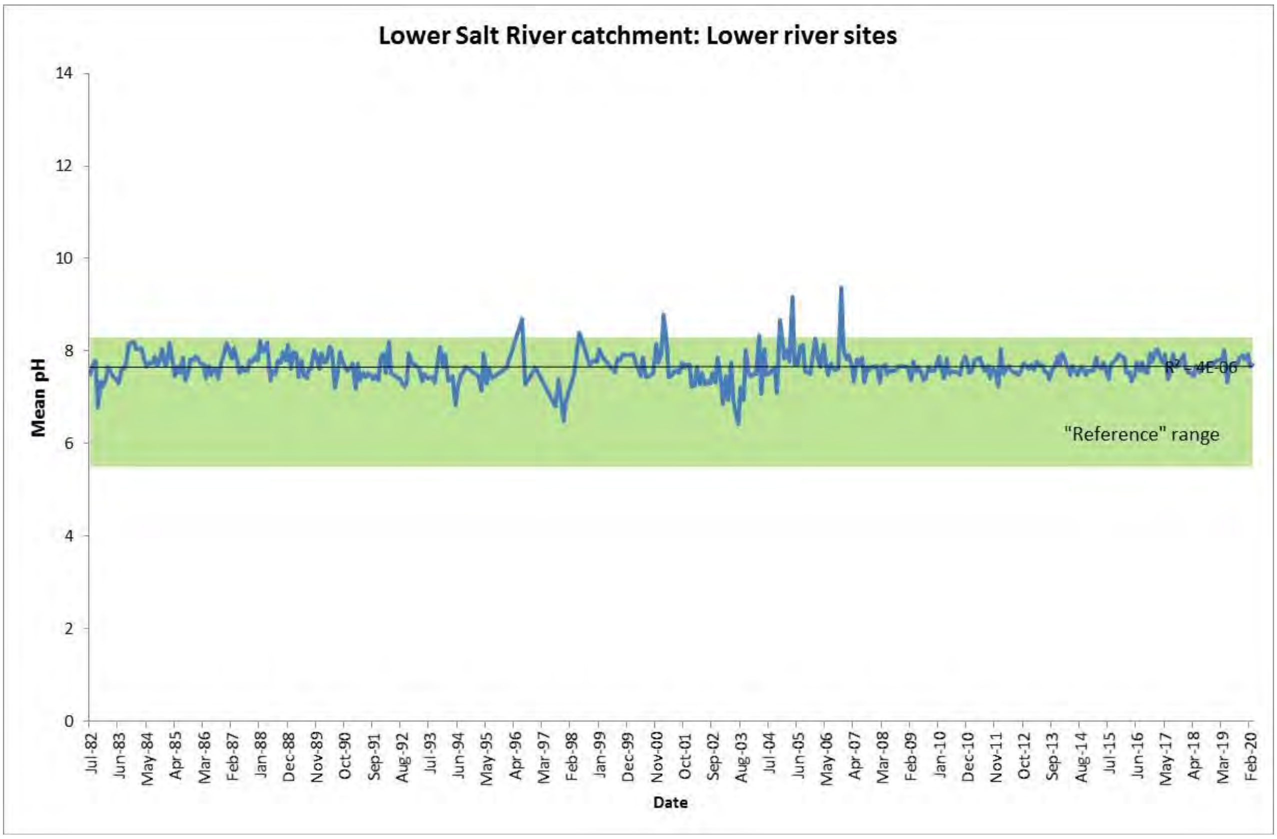


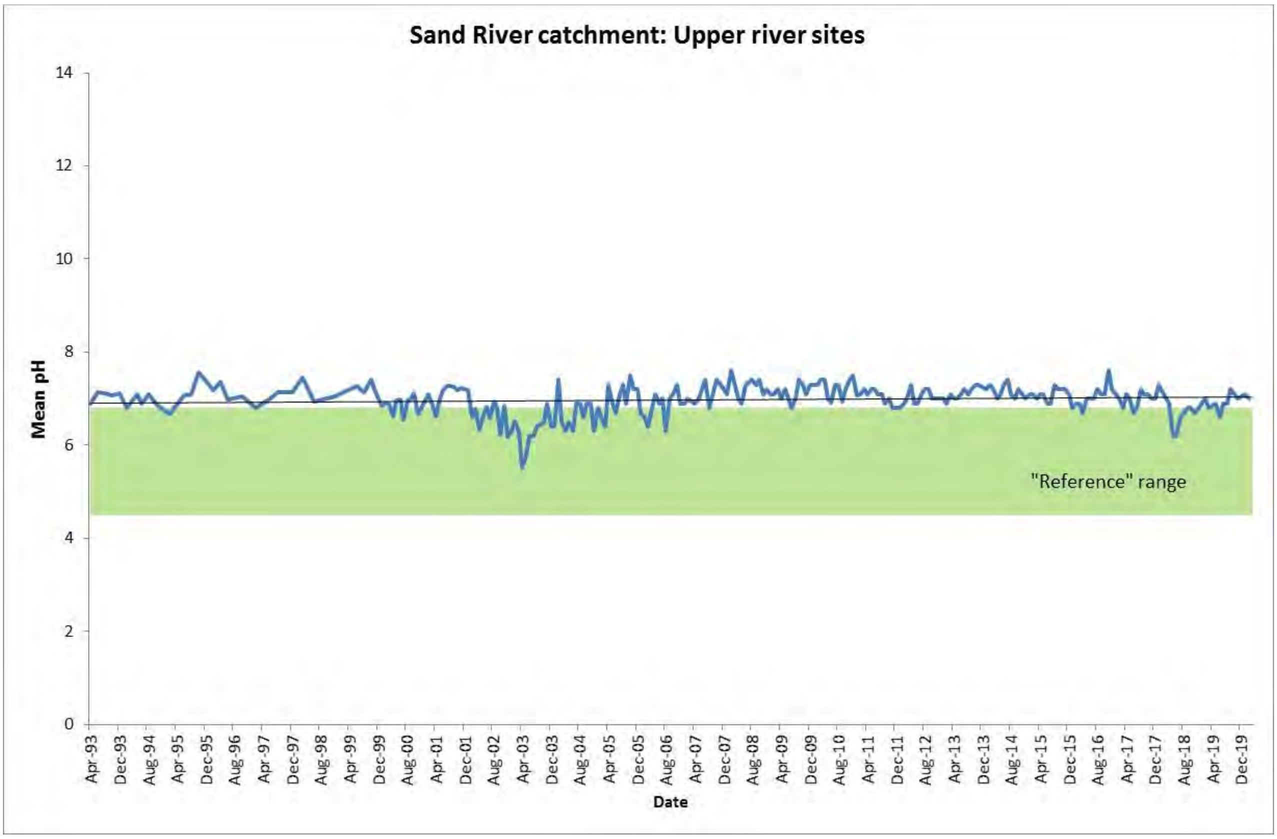



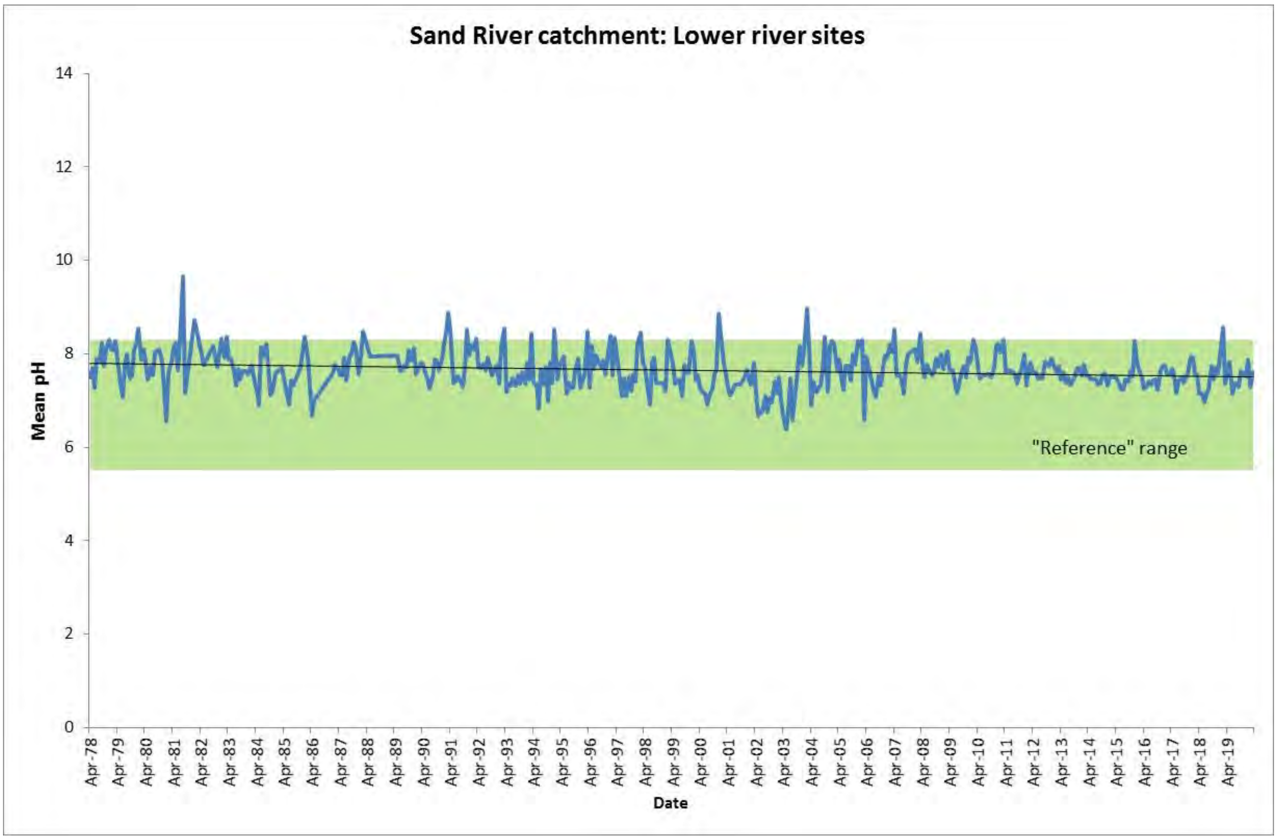

Mosselbank catchment: Lower river sites
Mean pH
Date
"Reference" range

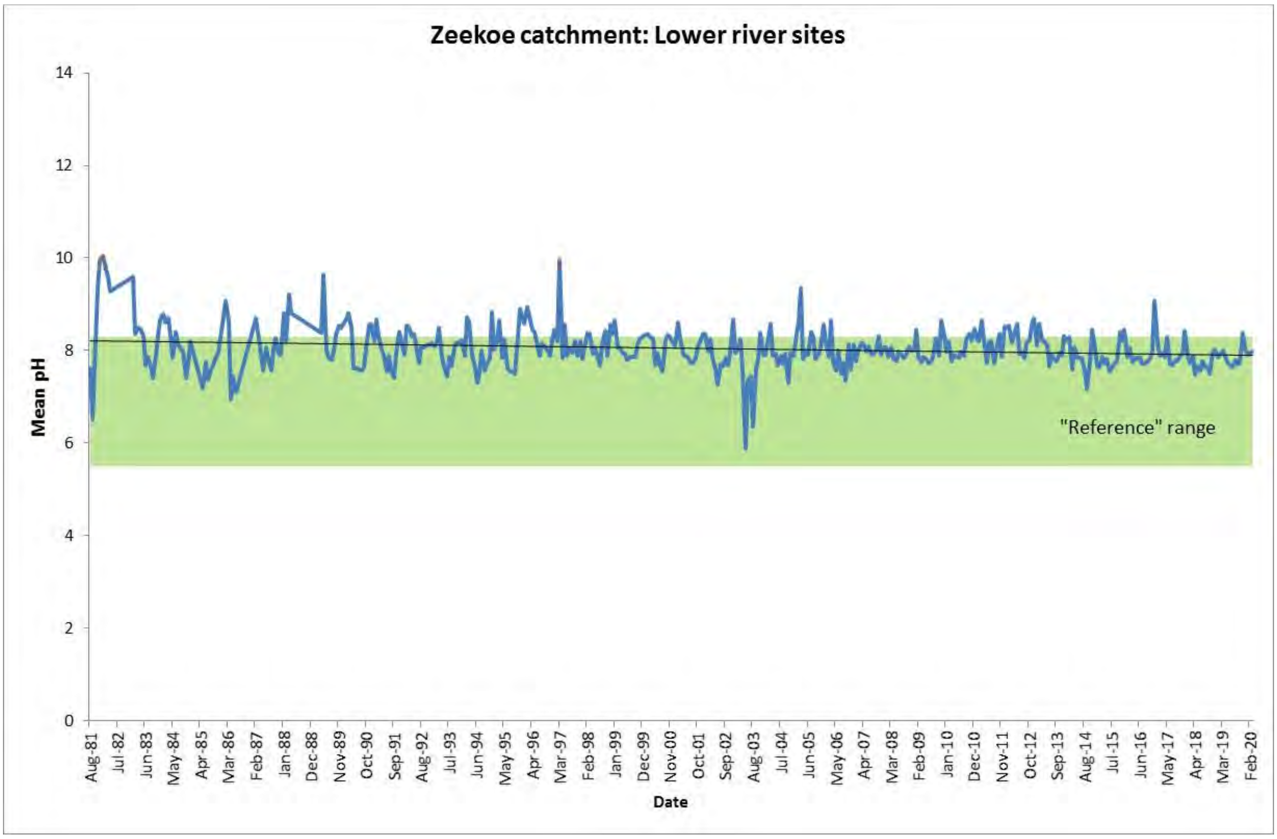

Elsieskraal River catchment: Lower river sites
Mean pH
Date
"Reference" range

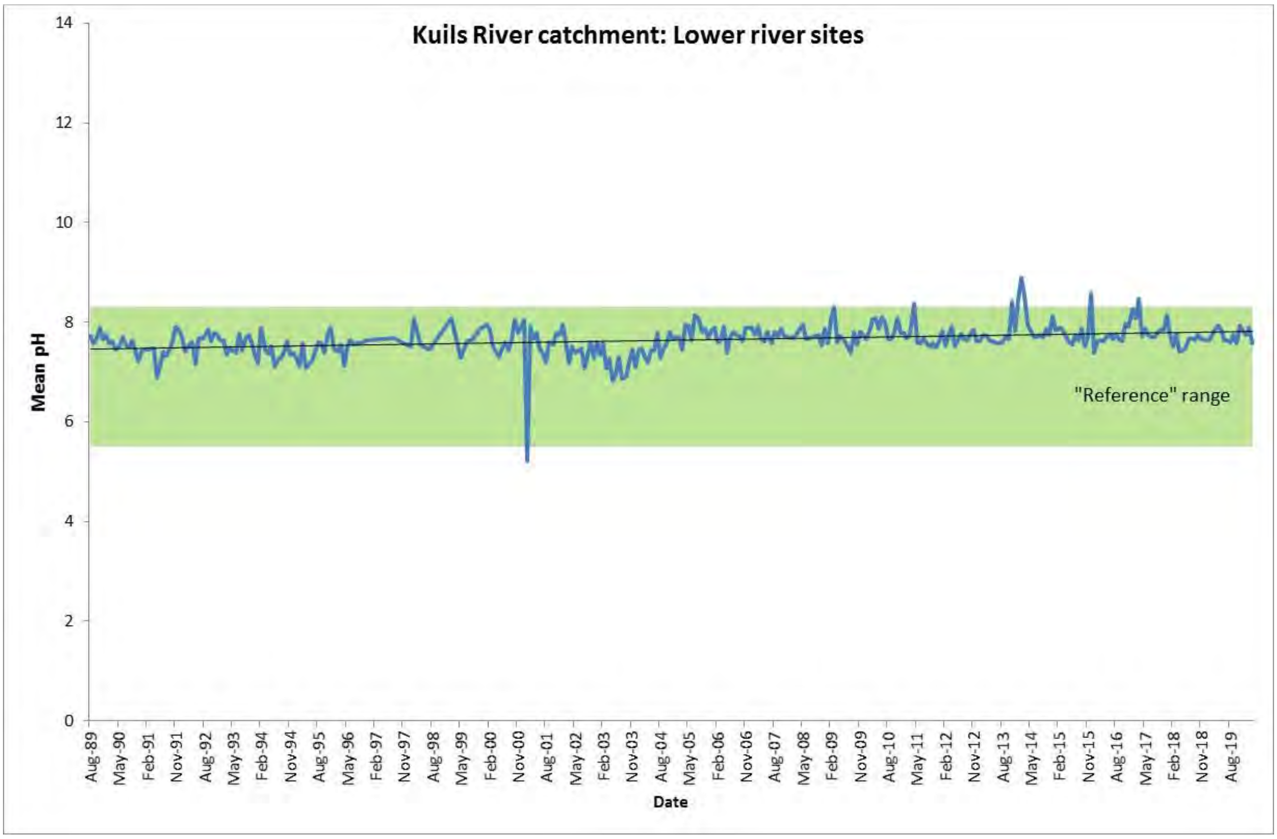

Lower Salt River catchment: Upper river sites
Mean pH
Date
"Reference" range

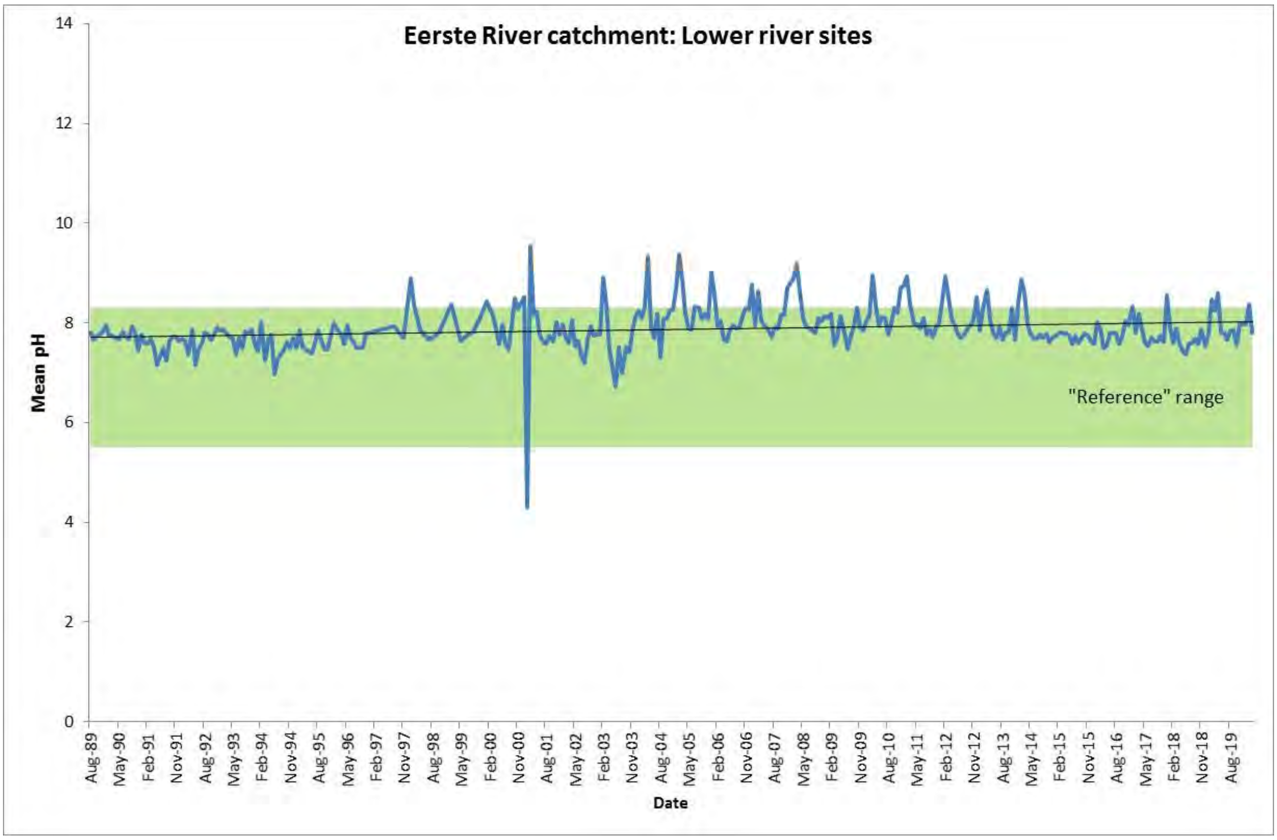

Lower Salt River catchment: Lower river sites
Mean pH
Date
"Reference" range

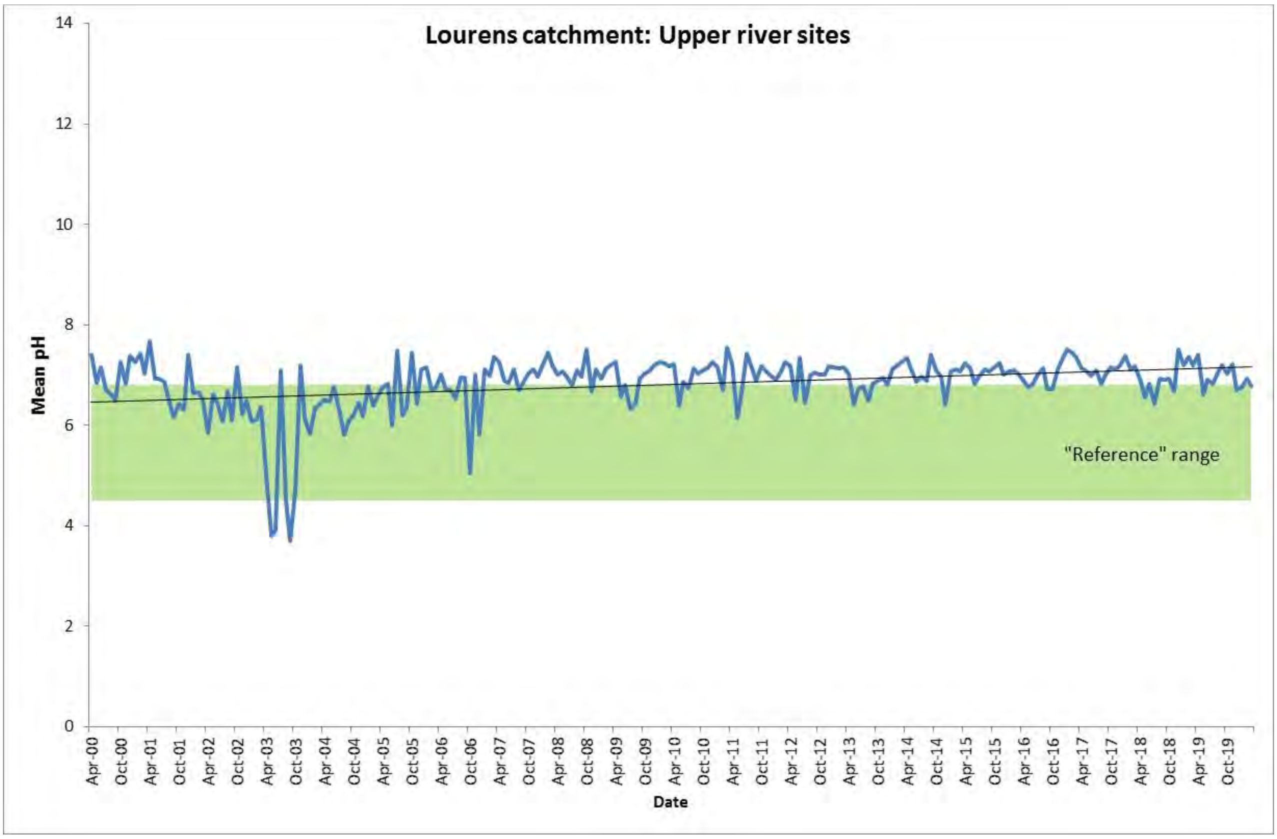

Sand River catchment: Upper river sites
Mean pH
Date
"Reference" range
0
2
4
6
8
10
12
14
Apr-93 Dec-93 Aug-94 Apr-95 Dec-95 Aug-96 Apr-97 Dec-97 Aug-98 Apr-99 Dec-99 Aug-00 Apr-01 Dec-01 Aug-02 Apr-03 Dec-03 Aug-04 Apr-05 Dec-05 Aug-06 Apr-07 Dec-07 Aug-08 Apr-09 Dec-09 Aug-10 Apr-11 Dec-11 Aug-12 Apr-13 Dec-13 Aug-14 Apr-15 Dec-15 Aug-16 Apr-17 Dec-17 Aug-18 Apr-19 Dec-19

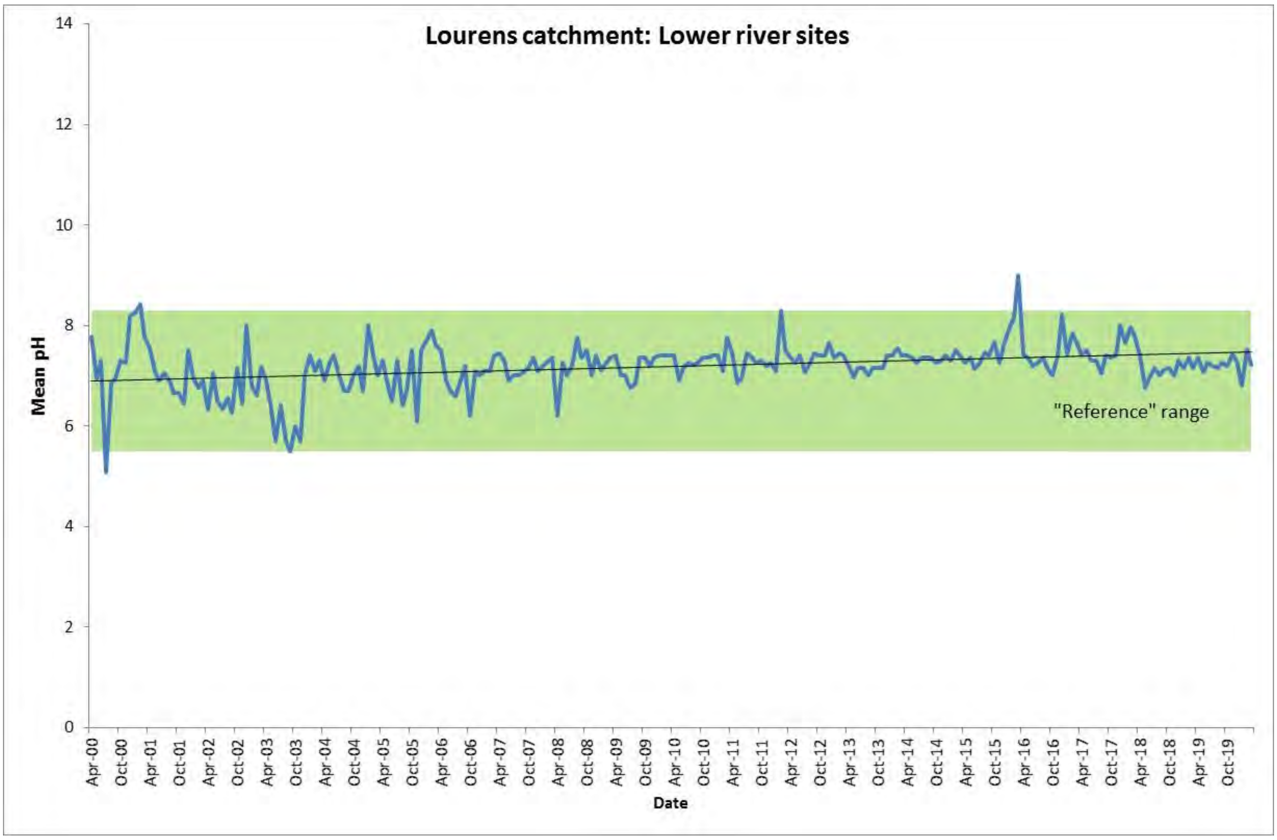

Sand River catchment: Lower river sites
Mean pH
Date
"Reference" range
0
2
4
6
8
10
12
14
Apr-78 Apr-79 Apr-80 Apr-81 Apr-82 Apr-83 Apr-84 Apr-85 Apr-86 Apr-87 Apr-88 Apr-89 Apr-90 Apr-91 Apr-92 Apr-93 Apr-94 Apr-95 Apr-96 Apr-97 Apr-98 Apr-99 Apr-00 Apr-01 Apr-02 Apr-03 Apr-04 Apr-05 Apr-06 Apr-07 Apr-08 Apr-09 Apr-10 Apr-11 Apr-12 Apr-13 Apr-14 Apr-15 Apr-16 Apr-17 Apr-18 Apr-19

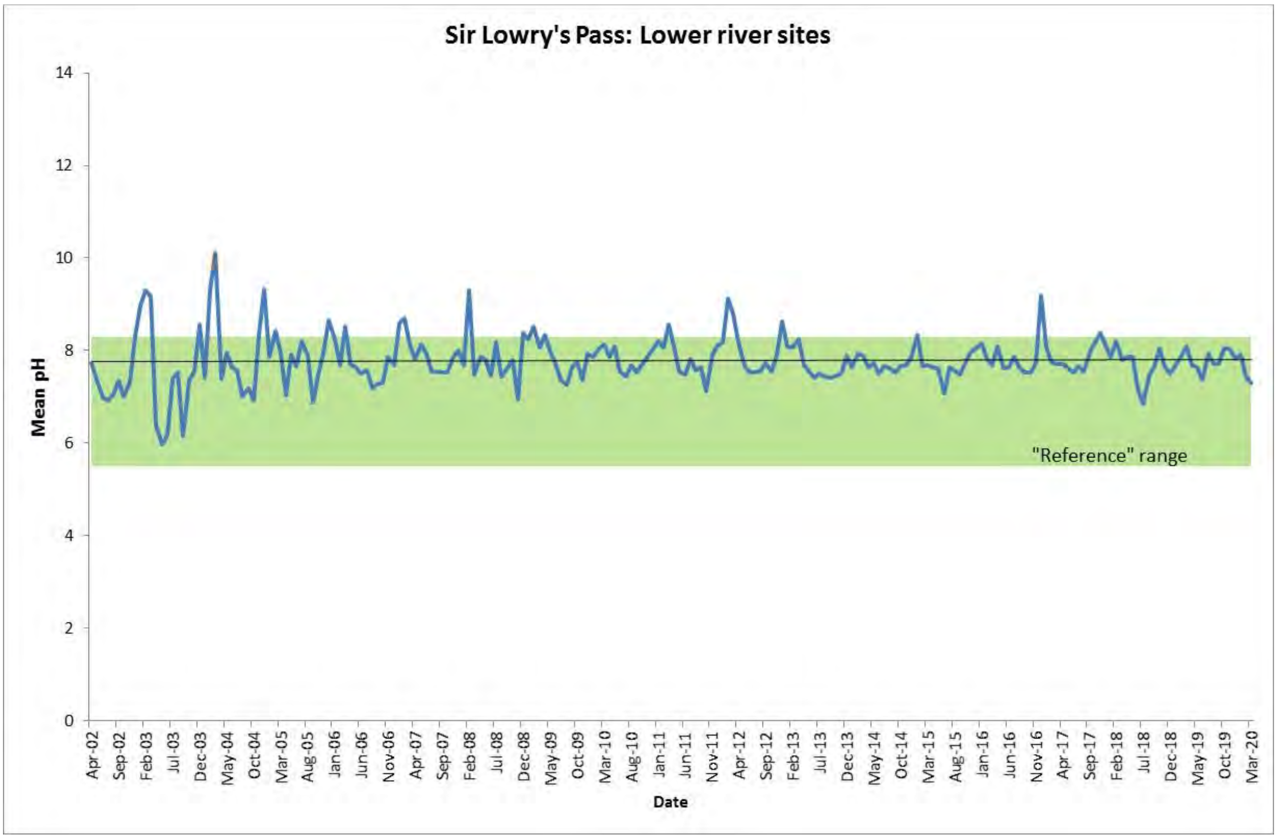

Zeekoe catchment: Lower river sites
Mean pH
Date
"Reference" range
14
12
10
8
6
4
2
0
Aug-81
Jul-82
Jun-83
May-84
Apr-85
Mar-86
Feb-87
Jan-88
Dec-88
Nov-89
Oct-90
Sep-91
Aug-92
Jul-93
Jun-94
May-95
Apr-96
Mar-97
Feb-98
Jan-99
Dec-99
Nov-00
Oct-01
Sep-02
Aug-03
Jul-04
Jun-05
May-06
Apr-07
Mar-08
Feb-09
Jan-10
Dec-10
Nov-11
Oct-12
Sep-13
Aug-14
Jul-15
Jun-16
May-17
Apr-18
Mar-19
Feb-20


Kuils River catchment: Lower river sites
Mean pH
"Reference" range
Date
0
2
4
6
8
10
12
14
Aug-89
May-90
Feb-91
Nov-91
Aug-92
May-93
Feb-94
Nov-94
Aug-95
May-96
Feb-97
Nov-97
Aug-98
May-99
Feb-00
Nov-00
Aug-01
May-02
Feb-03
Nov-03
Aug-04
May-05
Feb-06
Nov-06
Aug-07
May-08
Feb-09
Nov-09
Aug-10
May-11
Feb-12
Nov-12
Aug-13
May-14
Feb-15
Nov-15
Aug-16
May-17
Feb-18
Nov-18
Aug-19


Eerste River catchment: Lower river sites
Mean pH
"Reference" range
Date
0
2
4
6
8
10
12
14
Aug-89
May-90
Feb-91
Nov-91
Aug-92
May-93
Feb-94
Nov-94
Aug-95
May-96
Feb-97
Nov-97
Aug-98
May-99
Feb-00
Nov-00
Aug-01
May-02
Feb-03
Nov-03
Aug-04
May-05
Feb-06
Nov-06
Aug-07
May-08
Feb-09
Nov-09
Aug-10
May-11
Feb-12
Nov-12
Aug-13
May-14
Feb-15
Nov-15
Aug-16
May-17
Feb-18
Nov-18
Aug-19


Lourens catchment: Upper river sites
Mean pH
"Reference" range
Date
0
2
4
6
8
10
12
14
Apr-00
Oct-00
Apr-01
Oct-01
Apr-02
Oct-02
Apr-03
Oct-03
Apr-04
Oct-04
Apr-05
Oct-05
Apr-06
Oct-06
Apr-07
Oct-07
Apr-08
Oct-08
Apr-09
Oct-09
Apr-10
Oct-10
Apr-11
Oct-11
Apr-12
Oct-12
Apr-13
Oct-13
Apr-14
Oct-14
Apr-15
Oct-15
Apr-16
Oct-16
Apr-17
Oct-17
Apr-18
Oct-18
Apr-19
Oct-19


Lourens catchment: Lower river sites
Mean pH
"Reference" range
Date
0
2
4
6
8
10
12
14
Apr-00
Oct-00
Apr-01
Oct-01
Apr-02
Oct-02
Apr-03
Oct-03
Apr-04
Oct-04
Apr-05
Oct-05
Apr-06
Oct-06
Apr-07
Oct-07
Apr-08
Oct-08
Apr-09
Oct-09
Apr-10
Oct-10
Apr-11
Oct-11
Apr-12
Oct-12
Apr-13
Oct-13
Apr-14
Oct-14
Apr-15
Oct-15
Apr-16
Oct-16
Apr-17
Oct-17
Apr-18
Oct-18
Apr-19
Oct-19


Sir Lowry's Pass: Lower river sites
Mean pH
"Reference" range
Date
0
2
4
6
8
10
12
14
Apr-02
Sep-02
Feb-03
Jul-03
Dec-03
May-04
Oct-04
Mar-05
Aug-05
Jan-06
Jun-06
Nov-06
Apr-07
Sep-07
Feb-08
Jul-08
Dec-08
May-09
Oct-09
Mar-10
Aug-10
Jan-11
Jun-11
Nov-11
Apr-12
Sep-12
Feb-13
Jul-13
Dec-13
May-14
Oct-14
Mar-15
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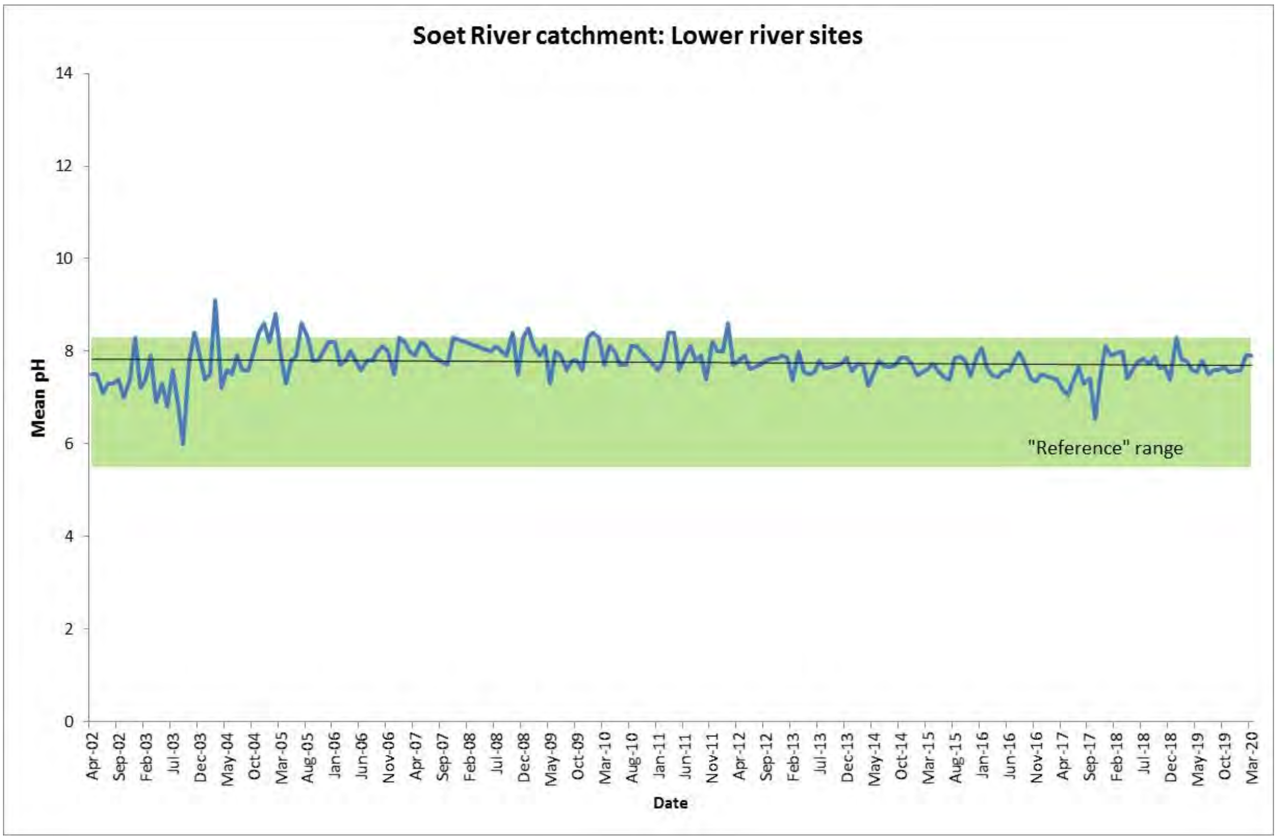
Feb-18
Jul-18
Dec-18
May-19
Oct-19
Mar-20


Soet River catchment: Lower river sites
Mean pH
"Reference" range
Date
0
2
4
6
8
10
12
14
Apr-02
Sep-02
Feb-03
Jul-03
Dec-03
May-04
Oct-04
Mar-05
Aug-05
Jan-06
Jun-06
Nov-06
Apr-07
Sep-07
Feb-08
Jul-08
Dec-08
May-09
Oct-09
Mar-10
Aug-10
Jan-11
Jun-11
Nov-11
Apr-12
Sep-12
Feb-13
Jul-13
Dec-13
May-14
Oct-14
Mar-15
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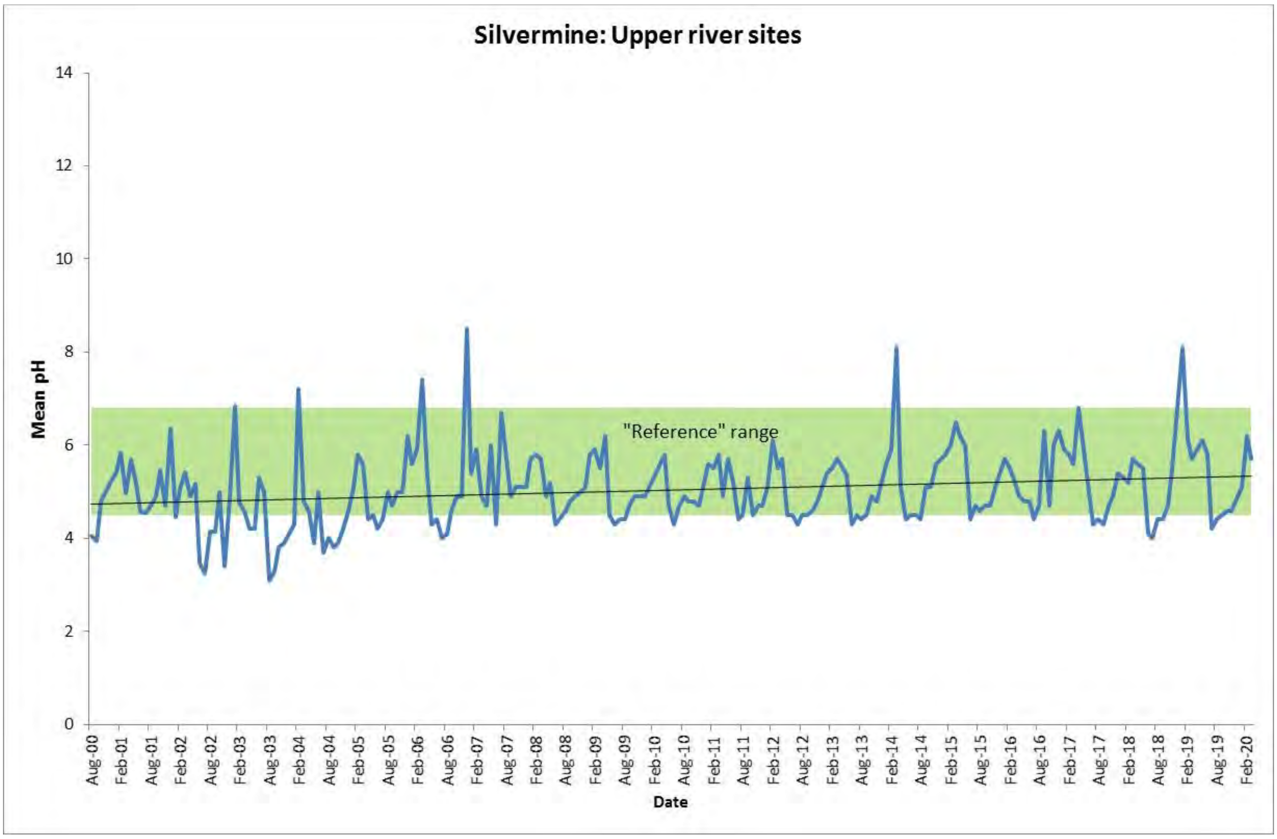
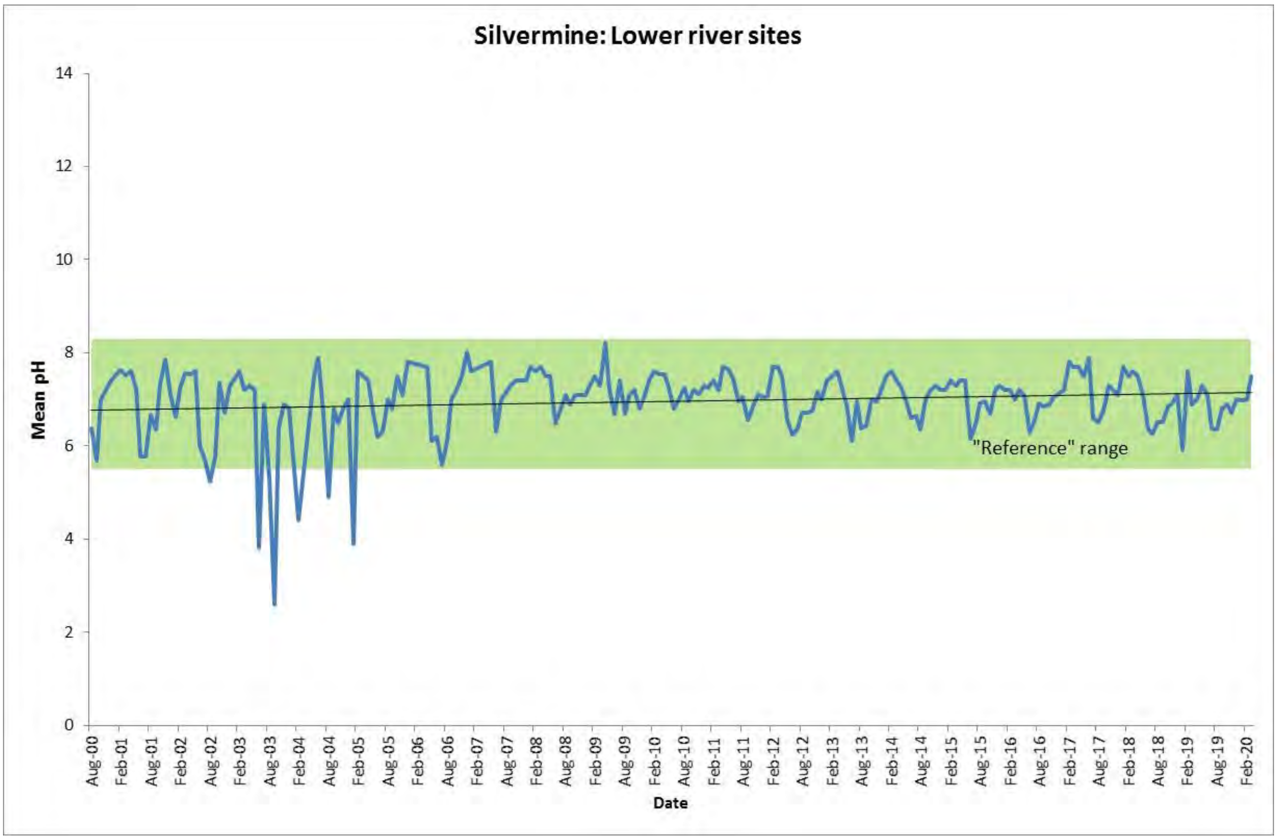
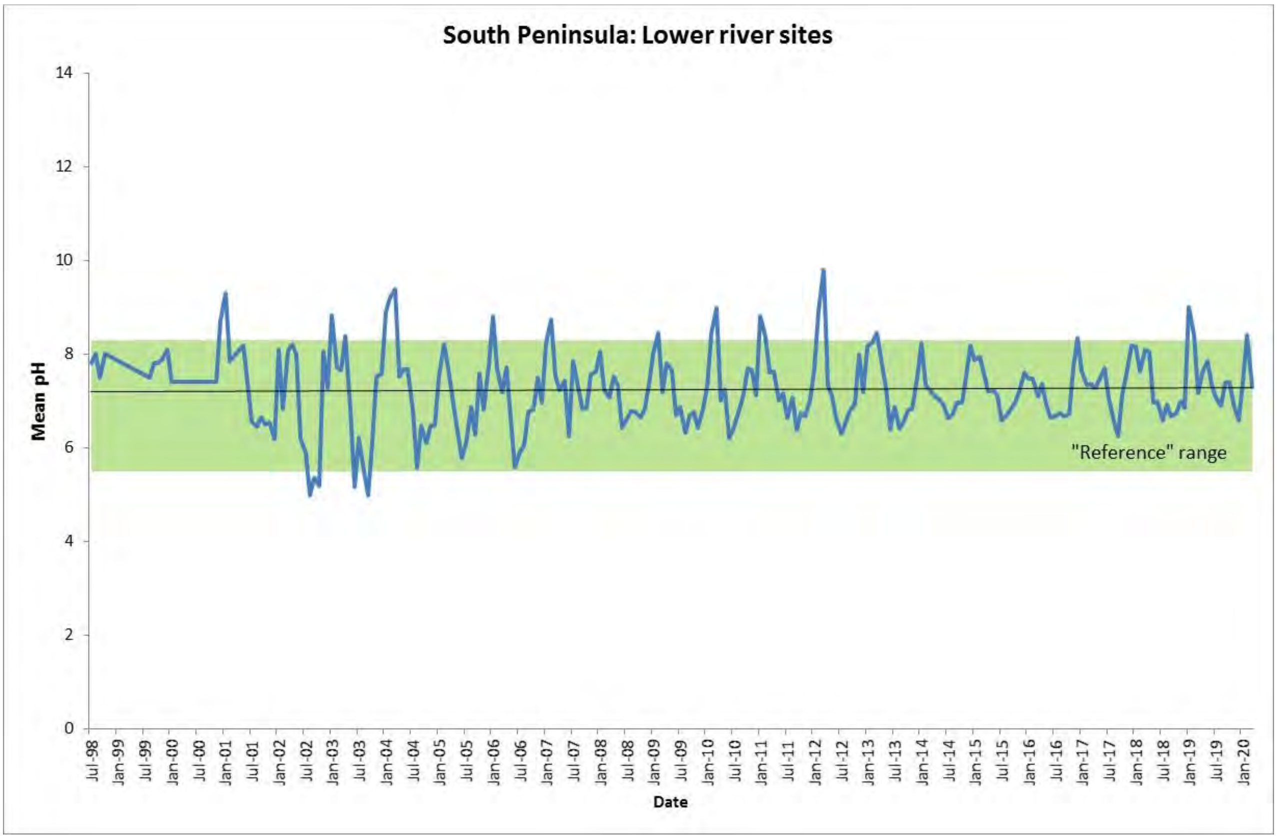
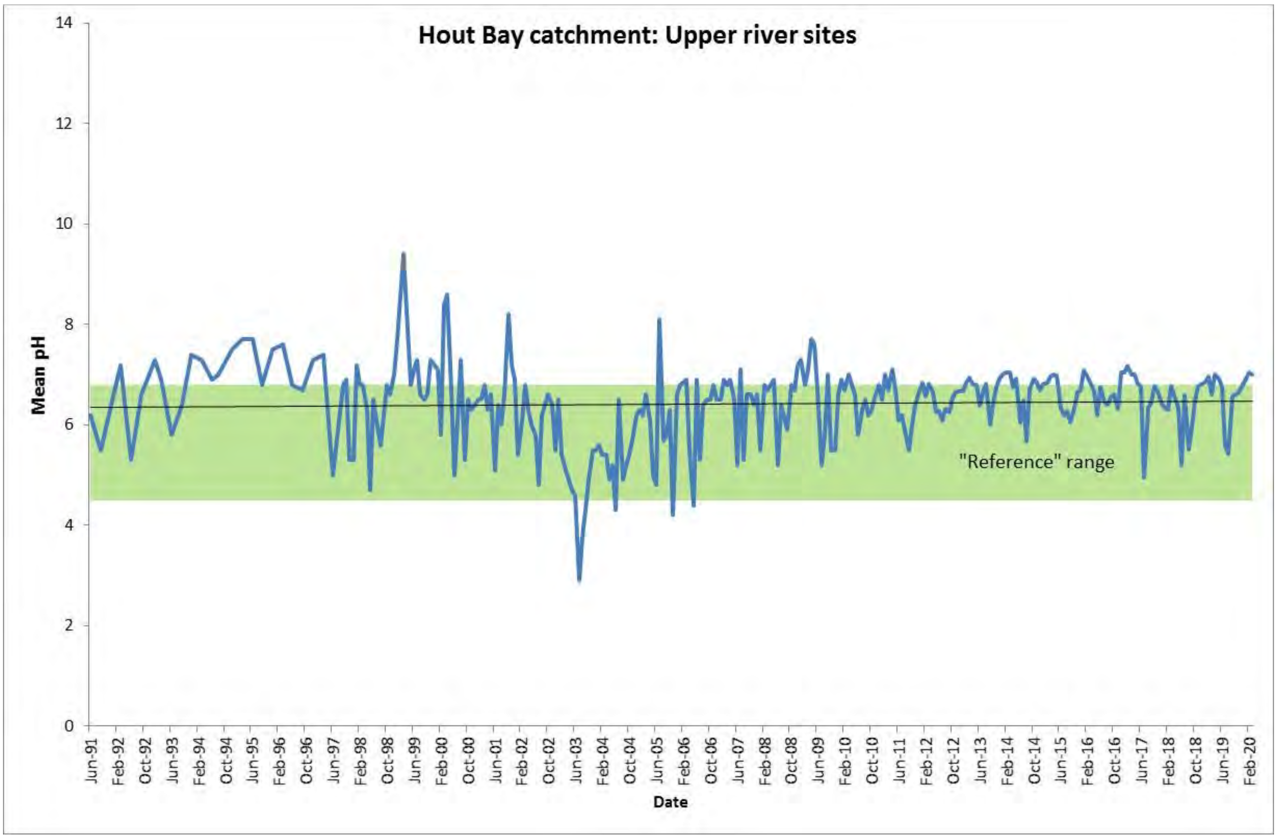
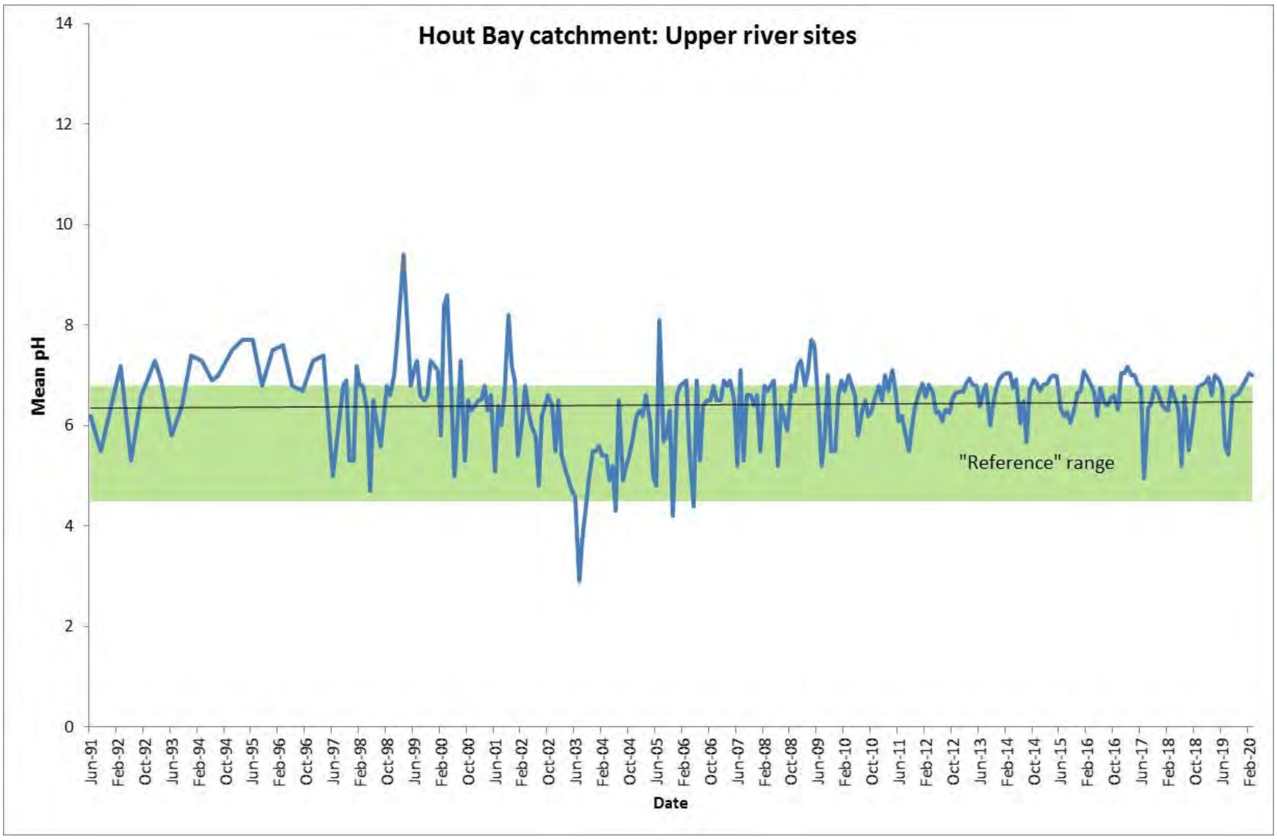
Sep-17
Feb-18
Jul-18
Dec-18
May-19
Oct-19
Mar-20


Silvermine: Upper river sites
Mean pH
Date
"Reference" range
0
2
4
6
8
10
12
14
Aug-00 Feb-01 Aug-01 Feb-02 Aug-02 Feb-03 Aug-03 Feb-04 Aug-04 Feb-05 Aug-05 Feb-06 Aug-06 Feb-07 Aug-07 Feb-08 Aug-08 Feb-09 Aug-09 Feb-10 Aug-10 Feb-11 Aug-11 Feb-12 Aug-12 Feb-13 Aug-13 Feb-14 Aug-14 Feb-15 Aug-15 Feb-16 Aug-16 Feb-17 Aug-17 Feb-18 Aug-18 Feb-19 Aug-19 Feb-20


Silvermine: Lower river sites
Mean pH
Date
"Reference" range
0
2
4
6
8
10
12
14
Aug-00 Feb-01 Aug-01 Feb-02 Aug-02 Feb-03 Aug-03 Feb-04 Aug-04 Feb-05 Aug-05 Feb-06 Aug-06 Feb-07 Aug-07 Feb-08 Aug-08 Feb-09 Aug-09 Feb-10 Aug-10 Feb-11 Aug-11 Feb-12 Aug-12 Feb-13 Aug-13 Feb-14 Aug-14 Feb-15 Aug-15 Feb-16 Aug-16 Feb-17 Aug-17 Feb-18 Aug-18 Feb-19 Aug-19 Feb-20


South Peninsula: Lower river sites
Mean pH
Date
"Reference" range
0
2
4
6
8
10
12
14
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Jan-01
Jul-01
Jan-02
Jul-02
Jan-03
Jul-03
Jan-04
Jul-04
Jan-05
Jul-05
Jan-06
Jul-06
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12
Jan-13
Jul-13
Jan-14
Jul-14
Jan-15
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20


Hout Bay catchment: Upper river sites
Mean pH
Date
"Reference" range
14
12
10
8
6
4
2
0
Jun-91 Feb-92 Oct-92 Jun-93 Feb-94 Oct-94 Jun-95 Feb-96 Oct-96 Jun-97 Feb-98 Oct-98 Jun-99 Feb-00 Oct-00 Jun-01 Feb-02 Oct-02 Jun-03 Feb-04 Oct-04 Jun-05 Feb-06 Oct-06 Jun-07 Feb-08 Oct-08 Jun-09 Feb-10 Oct-10 Jun-11 Feb-12 Oct-12 Jun-13 Feb-14 Oct-14 Jun-15 Feb-16 Oct-16 Jun-17 Feb-18 Oct-18 Jun-19 Feb-20


Hout Bay catchment: Upper river sites
Mean pH
Date
"Reference" range
14
12
10
8
6
4
2
0
Jun-91 Feb-92 Oct-92 Jun-93 Feb-94 Oct-94 Jun-95 Feb-96 Oct-96 Jun-97 Feb-98 Oct-98 Jun-99 Feb-00 Oct-00 Jun-01 Feb-02 Oct-02 Jun-03 Feb-04 Oct-04 Jun-05 Feb-06 Oct-06 Jun-07 Feb-08 Oct-08 Jun-09 Feb-10 Oct-10 Jun-11 Feb-12 Oct-12 Jun-13 Feb-14 Oct-14 Jun-15 Feb-16 Oct-16 Jun-17 Feb-18 Oct-18 Jun-19 Feb-20

## APPENDIX F: TROPHIC STATUS THRESHOLDS FOR NITROGEN AND PHOSPHORUS NUTRIENTS

**Table F1**

**Summary of ranges of phosphorus and/or nitrogen based nutrients associated with different trophic conditions in aquatic ecosystems. Nitrogen ranges from DWAF (1996a), as modified by Malan and Day (2005) and phosphorus ranges taken from DWAF (2002), with modifications suggested by Malan and Day (2005).**

| Trophic state | Effects | Average summer inorganic nitrogen concentrations (mg/l) | Average summer inorganic phosphorus concentrations (mg/l) |
|---|---|---|---|
| Oligotrophic | Moderate levels of species diversity; usually low productivity systems with rapid nutrient cycling; no nuisance growth of aquatic plants or the presence of blue-green algae | < 0.25 | < 0.015 |
| Mesotrophic | Usually high levels of species diversity; usually productive systems; nuisance growth of aquatic plants and blooms of blue-green algae; algal blooms seldom toxic | 0.25-2.5 | > 0.015-0.047 |
| Eutrophic | Usually low levels of species diversity; usually highly productive systems; nuisance growths of aquatic plants and blue-green algae, algal blooms may include species that are toxic to man, livestock and wildlife | 2.5-10 | >0.047-0.130 |
| Hypertrophic | Usually very low levels of species diversity; usually very highly productive systems; nuisance growths of aquatic plants and blue-green algae, algal blooms may include species that are toxic to man, livestock and wildlife | >10 | > 0.130 |

## APPENDIX G: TABLES OF RATED SITE DATA

Data rated and colour coded according to thresholds included in Tables 2.2 and 2.3

Sites as described in Table A1

## MEDIAN PHOSPHATE ($PO_4$-P) (mg P/L:

### RIVERS / STORMWATER

| SUBCATCHMENT | SITE | 2015 SUM | 2015 WIN | 2016 SUM | 2016 WIN | 2017 SUM | 2017 WIN | 2018 SUM | 2018 WIN | 2019 SUM | 2019 WIN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diep | MOS05 | 2.814 | 0.934 | 2.443 | 1.521 | 0.132 | 0.245 | 1.445 | 0.956 | 1.111 | 0.953 |
| | RTV01 | 0.448 | 1.042 | 2.026 | 0.863 | 0.420 | 1.169 | 0.853 | 1.006 | 1.020 | 0.995 |
| | RTV03 | 0.143 | 0.057 | 0.125 | 0.079 | 0.214 | 0.178 | 0.150 | 0.108 | 0.111 | 0.140 |
| | RTV04 | 0.072 | 0.058 | 0.070 | 0.064 | 0.249 | 0.082 | 0.090 | 0.082 | 0.051 | 0.151 |
| | RTV05 | 1.070 | 0.998 | 0.758 | 0.540 | 2.309 | 0.492 | 4.500 | 0.777 | 6.475 | 2.680 |
| | RTV06 | 0.453 | 1.458 | 1.724 | 1.074 | 1.285 | 0.725 | 2.920 | 1.142 | 3.350 | 1.570 |
| | RTV08 | 0.066 | 0.086 | 0.127 | 0.094 | 0.270 | 0.101 | 0.117 | 0.081 | 0.123 | 0.101 |
| | RTV09 | 0.543 | 0.827 | 0.575 | 0.591 | 1.685 | 0.578 | 2.495 | 0.640 | 5.960 | 2.790 |
| | RTV10 | 0.137 | 0.529 | 0.260 | 0.464 | 1.405 | 0.520 | 2.750 | 0.597 | 4.385 | 1.810 |
| | RTV11 | 0.884 | 1.320 | 0.959 | 0.864 | 2.076 | 0.461 | 1.770 | 1.182 | 7.290 | 3.640 |
| | RTV12 | 0.342 | 0.692 | 0.130 | 0.072 | 0.252 | 0.223 | 0.401 | 0.162 | 1.900 | 0.978 |
| | RTV14 | 2.810 | | 0.124 | 0.053 | | | | 0.026 | 0.068 | |
| | RTV22 | | | | | 5.460 | 0.851 | 5.230 | 1.982 | 4.050 | 5.130 |
| Eerste | EK08 | 1.596 | 0.896 | 1.949 | 1.315 | 2.015 | 0.890 | 2.610 | 1.129 | 3.530 | 1.550 |
| | EK11 | 1.862 | 1.230 | 2.150 | 1.652 | 2.892 | 1.314 | 3.310 | 1.310 | 3.000 | 2.125 |
| | EK12 | | | | | | | 1.960 | 0.605 | 2.930 | 1.270 |
| | EK13 | 2.824 | 0.654 | 2.924 | 0.899 | 1.104 | 1.524 | 0.730 | 0.370 | 0.595 | 0.305 |
| | EK15 | 0.078 | 0.232 | 0.046 | 0.074 | 0.080 | 0.104 | 0.094 | 0.035 | 0.043 | 0.089 |
| | EK16 | | | | | | | 2.980 | 0.497 | | |
| | EK17 | 2.912 | 2.131 | 2.791 | 2.088 | 3.692 | 2.096 | 2.390 | 1.330 | 2.800 | 1.050 |
| | EK18 | 0.138 | 0.109 | 0.128 | 0.121 | 0.125 | 0.106 | 1.130 | 0.198 | 0.151 | 0.128 |
| Elsieskraal | ELS_GW | 0.238 | 0.380 | 0.076 | 0.111 | 0.230 | 0.161 | 0.302 | 0.244 | 0.208 | 0.191 |
| | ELS08 | 0.088 | 0.118 | 0.062 | 0.159 | 0.079 | 0.095 | 0.140 | 0.142 | 0.101 | 0.177 |
| | ELS10 | 0.089 | 0.052 | 0.207 | 0.045 | 0.110 | 0.068 | 0.100 | 0.033 | 0.070 | 0.088 |
| Hout Bay | DR01 | 0.098 | 0.038 | 0.133 | 0.081 | 0.122 | 0.275 | 0.128 | 0.062 | 0.104 | 0.059 |
| | DR02 | 0.096 | 0.010 | 0.067 | 0.081 | 0.066 | 0.271 | 0.088 | 0.039 | 0.158 | 0.076 |
| | DR04 | 0.033 | 0.005 | 0.021 | 0.012 | 0.025 | 0.016 | 0.028 | 0.015 | 0.023 | 0.029 |
| | DR05 | | | | | 0.700 | | | | | |
| | DR06 | 0.036 | 0.005 | 0.022 | 0.016 | 0.030 | 0.024 | 0.029 | 0.018 | 0.021 | 0.034 |
| Kuils | EK03 | 0.709 | 1.472 | 0.566 | 2.042 | 1.050 | 1.749 | 1.140 | 1.131 | 1.360 | 1.995 |
| | EK04 | 0.318 | 0.798 | 0.147 | 1.143 | 0.323 | 0.685 | 0.412 | 0.540 | 0.654 | 1.145 |
| | EK05 | 0.520 | 0.888 | 1.266 | 1.927 | 2.097 | 1.195 | 2.030 | 0.966 | 1.610 | 1.950 |
| | EK09 | 0.670 | 1.108 | 1.796 | 2.025 | 2.335 | 1.330 | 1.770 | 1.029 | 2.010 | 2.470 |
| | EK19 | 0.188 | 0.122 | 0.115 | 0.118 | 0.180 | 0.180 | 0.577 | 0.091 | 0.232 | 0.116 |
| Lourens | LOU01 | 0.039 | 0.005 | 0.028 | 0.023 | 0.024 | 0.025 | 0.033 | 0.018 | 0.021 | 0.026 |
| | LOU02 | 0.041 | 0.005 | 0.018 | 0.024 | 0.028 | 0.026 | 0.031 | 0.024 | 0.017 | 0.029 |
| | LOU03 | 0.041 | 0.005 | 0.022 | 0.024 | 0.035 | 0.032 | 0.034 | 0.011 | 0.016 | 0.046 |
| | LOU04 | 0.034 | 0.005 | 0.013 | 0.022 | 0.021 | 0.027 | 0.034 | 0.012 | 0.019 | 0.028 |
| | LOU05 | 0.050 | 0.005 | 0.296 | 0.029 | 0.127 | 0.053 | 0.086 | 0.092 | 0.064 | 0.098 |
| | LOU06 | 0.051 | 0.005 | 0.075 | 0.017 | 0.030 | 0.076 | 0.031 | 0.015 | 0.024 | 0.050 |
| Lower Salt | NR01 | 0.054 | 0.165 | 0.039 | 0.143 | 0.180 | 0.154 | 0.120 | 0.206 | 0.226 | 0.247 |
| | NR02 | 0.559 | 0.324 | 0.871 | 0.378 | 1.290 | 0.833 | 0.666 | 0.525 | 1.190 | 0.470 |
| | NR03 | 2.794 | 2.270 | 4.627 | 1.882 | 1.880 | 2.774 | 6.520 | 3.400 | 4.450 | 3.305 |
| | NR04 | 1.769 | 1.122 | 2.147 | 0.939 | 1.930 | 1.960 | 2.315 | 1.868 | 2.615 | 2.395 |
| | NR06 | 1.775 | 2.003 | 2.019 | 1.023 | 2.355 | 1.656 | 2.160 | 1.109 | 2.260 | 1.800 |
| | NR07 | 1.925 | 0.917 | 1.455 | 0.926 | 2.540 | 1.814 | 2.390 | 1.336 | 2.020 | 1.980 |
| | NR08 | 0.020 | 0.059 | 0.032 | 0.039 | 0.045 | 0.043 | 0.042 | 0.030 | 0.028 | 0.059 |
| | NR09 | 1.743 | 0.841 | 1.173 | 0.814 | 3.000 | 1.732 | 2.420 | 1.035 | 1.630 | 1.490 |
| | NR10 | 1.615 | 0.825 | 1.405 | 0.449 | 2.670 | 1.752 | 2.205 | 0.826 | 1.320 | 1.410 |
| | NR11 | 0.036 | 0.065 | 0.044 | 0.098 | 0.089 | 0.094 | 0.102 | 0.041 | 0.067 | 0.104 |
| | NR15 | 3.564 | 1.741 | 5.037 | 2.984 | 3.925 | 3.847 | 2.250 | 4.703 | 7.970 | 4.330 |
| | NR16 | 0.109 | 0.546 | 0.567 | 0.044 | 1.970 | 0.805 | 2.950 | 1.798 | 1.280 | 0.307 |
| | NR17 | 0.324 | 0.471 | 0.392 | 0.233 | 2.080 | 1.034 | 0.440 | 0.400 | 0.546 | 0.619 |
| | NR22 | 0.053 | 0.208 | | 0.027 | 0.050 | 0.046 | | 0.018 | | 0.052 |
| | NR25 | | | | | 3.700 | | 3.170 | 1.240 | 4.940 | 2.220 |
| | NR26 | 4.487 | 4.083 | 6.868 | 3.668 | 4.280 | 4.830 | 9.635 | 6.810 | 5.735 | 5.600 |
| Mosselbank | MOS01 | 1.729 | 0.668 | 0.468 | 0.708 | 0.643 | 0.650 | 1.135 | 0.857 | 1.002 | 0.776 |
| | MOS02 | 1.324 | 0.152 | 1.008 | 0.661 | 1.020 | 0.501 | 1.780 | 0.916 | 1.190 | 0.751 |
| | MOS03 | 0.619 | 0.472 | 0.374 | 0.355 | 1.275 | 0.381 | 0.600 | 0.135 | 0.815 | 0.290 |
| | MOS04 | 0.192 | 1.894 | 0.182 | 1.502 | 0.462 | 0.984 | 0.597 | 0.984 | 1.150 | 0.932 |
| | MOS06 | 4.101 | 3.296 | 2.784 | 1.682 | 2.239 | 2.014 | 2.590 | 1.390 | 2.175 | 0.911 |
| | MOS07 | 6.514 | 2.230 | 7.694 | 2.133 | 5.130 | 2.015 | 3.025 | 0.438 | 1.610 | 0.596 |
| | MOS08 | 4.286 | 3.034 | 3.926 | 1.411 | 2.371 | 1.332 | 4.110 | 1.001 | 1.625 | 0.789 |
| | MOS09 | 19.084 | 12.941 | 23.408 | 15.222 | 20.383 | 20.391 | 15.100 | 5.447 | 18.050 | 13.900 |
| | MOSAH03 | | 2.308 | | 3.472 | | 1.112 | 5.570 | 5.142 | | 4.045 |
| | MOSTP4 | 9.035 | 5.405 | 7.773 | 4.133 | 4.353 | 5.105 | 5.490 | 3.080 | 4.210 | 3.060 |
| MPlain | KHA03 | 0.973 | 0.832 | 1.096 | 0.835 | 1.259 | 1.146 | 1.410 | 0.792 | 1.250 | 1.330 |
| | KHA04 | 0.970 | 0.799 | 1.138 | 0.819 | 1.268 | 1.148 | 1.405 | 0.870 | 1.285 | 1.225 |
| Sand | BM16 | 0.048 | 0.130 | 0.119 | | 0.150 | 0.033 | 0.016 | 0.154 | 0.374 | 0.037 |
| | BM17 | 0.244 | 0.050 | 0.017 | | 0.869 | 0.089 | 0.048 | 0.124 | 0.136 | 0.088 |
| | BM18 | 0.048 | 0.232 | 0.072 | | 0.235 | 0.063 | 0.053 | 0.288 | 0.071 | 0.081 |
| | CR01 | 0.027 | 0.072 | 0.028 | 0.036 | 0.086 | 0.045 | 0.100 | | 0.087 | 0.055 |
| | CR02 | 0.052 | 0.042 | 0.035 | 0.032 | 0.041 | 0.043 | 0.021 | 0.030 | 0.056 | 0.035 |
| | CR03 | 0.054 | 0.038 | 0.039 | 0.049 | 0.044 | 0.046 | 0.041 | 0.026 | 0.032 | 0.031 |
| | CR04 | 0.065 | 0.050 | 0.107 | 0.052 | 0.080 | 0.222 | | 0.892 | 0.125 | 0.111 |
| | CR05 | | | | | | 0.116 | | 0.057 | | |
| | CR06 | 0.129 | 0.166 | 0.523 | 0.077 | 0.914 | 0.177 | 0.388 | 0.137 | 0.170 | 0.251 |
| | CR16 | 0.069 | 0.050 | 0.048 | 0.044 | 0.054 | 0.046 | 0.054 | 0.016 | 0.049 | 0.055 |
| | CR20 | 0.051 | 0.140 | 0.043 | 0.065 | 0.184 | 0.068 | 0.070 | 0.106 | 0.112 | 0.094 |
| | CR21 | 0.028 | 0.092 | 0.032 | 0.041 | 0.028 | 0.106 | 0.027 | 0.045 | 0.059 | 0.045 |
| | CR22 | 0.082 | 0.102 | 0.067 | 0.065 | 0.145 | 0.112 | 0.081 | 0.110 | 0.124 | 0.092 |
| | DRRSC | 0.107 | 0.091 | 0.047 | 0.049 | 0.123 | 0.085 | 0.063 | 0.195 | 0.187 | 0.072 |
| | LPVMR | 0.046 | 0.025 | 0.057 | 0.076 | 0.015 | 0.024 | 0.023 | 0.045 | 0.054 | 0.028 |
| | LVI | 0.022 | 0.112 | 0.088 | 0.118 | 0.044 | 0.204 | 0.137 | 0.190 | 0.207 | 0.145 |
| | SCV | 0.126 | 0.093 | 0.137 | 0.169 | 0.057 | 0.122 | 0.075 | 0.803 | 0.097 | 0.230 |
| Silvermine | SIL02 | 0.027 | 0.005 | 0.014 | 0.016 | 0.019 | 0.036 | 0.019 | 0.015 | 0.017 | 0.025 |
| | SIL04 | 0.033 | 0.005 | 0.018 | 0.019 | 0.036 | 0.017 | 0.016 | 0.010 | 0.022 | 0.025 |
| | SIL06 | 0.021 | 0.005 | 0.017 | 0.017 | 0.015 | 0.016 | 0.035 | 0.022 | 0.015 | 0.020 |
| SLPass | SIR01 | 0.065 | 0.005 | 0.040 | 0.040 | 0.063 | 0.056 | 0.117 | 0.036 | 0.065 | 0.031 |
| | SIR02 | 0.080 | 0.276 | 0.116 | 0.069 | 0.237 | 0.101 | 0.188 | 0.132 | 0.048 | 0.091 |
| | SIR03 | 0.088 | 0.063 | 0.941 | 0.062 | 0.130 | 0.119 | 0.164 | 0.094 | 0.133 | 0.060 |
| | SIR04 | | 0.102 | | 0.082 | | | 0.118 | 0.079 | | 0.037 |
| | SIR05 | 0.124 | 0.050 | 0.097 | 0.123 | 0.104 | 0.096 | 0.106 | 0.087 | 0.111 | 0.111 |
| | SIR06 | 1.461 | 0.072 | 1.942 | 0.924 | 0.274 | 0.249 | 0.344 | 0.151 | 0.883 | 0.110 |
| | SIR07 | 1.829 | 0.399 | 1.732 | 0.847 | 0.388 | 0.231 | 0.268 | 0.130 | 0.250 | 0.107 |
| Soet | SOE02 | 0.558 | 0.640 | 1.952 | 0.626 | 2.823 | 1.887 | 1.690 | 0.716 | 3.410 | 2.215 |
| | SOE04 | 0.086 | 0.079 | 0.064 | 0.025 | 0.360 | 0.168 | 0.183 | 0.069 | 0.143 | |
| | SOEAH06 | 0.088 | 0.050 | 0.100 | 0.062 | 0.101 | 0.095 | 0.186 | 0.036 | 0.057 | 0.032 |
| | SOEAH10 | 2.242 | 2.289 | 5.706 | 2.612 | 2.131 | 6.335 | 6.250 | 2.872 | 4.440 | 6.060 |
| | SOEAH11 | 0.033 | 0.005 | 0.024 | 0.026 | 0.043 | 0.050 | 0.180 | 0.026 | 0.021 | 0.025 |
| | SOEAH12 | 0.837 | 0.560 | 2.246 | 0.579 | 2.034 | 1.816 | 1.290 | 0.427 | 2.075 | 1.081 |
| Sout | SOU01 | 3.045 | 2.073 | 4.999 | 1.963 | 3.322 | 2.842 | 0.370 | 0.906 | 3.570 | 1.030 |
| | SOU02 | 3.156 | 1.986 | 4.678 | 1.913 | 5.360 | 2.829 | 1.085 | 1.543 | 2.365 | 1.290 |
| South Peninsula | BOK02 | 0.539 | 0.158 | 0.100 | 0.136 | 0.110 | 0.038 | 0.084 | 0.202 | 5.050 | 0.148 |
| | BOK03 | 0.115 | 0.119 | 0.147 | 0.100 | 0.115 | 0.115 | 0.093 | 0.104 | 0.142 | 0.083 |
| | SCH01 | | | | 0.022 | | | | | | |
| | SCH02 | 0.050 | 0.005 | 0.029 | 0.023 | 0.042 | 0.019 | 0.020 | 0.021 | 0.027 | 0.028 |
| | SCH04 | 0.225 | 0.213 | 0.261 | 0.204 | 0.208 | 0.237 | 0.183 | 0.139 | 0.252 | 0.201 |
| Zeekoe | LR02 | 0.645 | 0.407 | 0.235 | 0.152 | 0.336 | 0.187 | 0.523 | 0.125 | 1.170 | 0.342 |
| | LR03 | 0.986 | 0.709 | 0.725 | 0.358 | 0.921 | 0.817 | 1.740 | 0.357 | 1.670 | 1.510 |
| | LR05 | 1.322 | 0.464 | 0.464 | 0.738 | 0.224 | 0.557 | 1.320 | 0.820 | 0.471 | 1.545 |
| | LR06 | 0.046 | 0.082 | 0.013 | 0.051 | 0.031 | 0.044 | 0.015 | 0.049 | 0.035 | 0.067 |
| | LR07 | 0.794 | 0.720 | 0.066 | 0.758 | 0.061 | 0.459 | 0.165 | 0.367 | 0.118 | 0.811 |
| | LR08 | 0.333 | 0.050 | 0.694 | 0.856 | 0.295 | 0.562 | 0.946 | 0.571 | 0.726 | 1.122 |
| | LR10 | 0.059 | 0.074 | 0.077 | 0.067 | 0.073 | 0.043 | 0.020 | 0.091 | 0.037 | 0.085 |
| | RVIRD | 0.125 | 0.049 | 0.034 | 0.024 | 0.068 | 0.025 | 0.138 | 0.186 | 0.069 | 0.048 |
| | ZEV5 | 7.065 | 7.101 | 6.299 | 7.214 | 6.720 | 6.428 | 5.450 | 7.881 | 7.830 | 9.040 |

### VLEIS / DAMS

| SUBCATCHMENT | SITE | 2015 SUM | 2015 WIN | 2016 SUM | 2016 WIN | 2017 SUM | 2017 WIN | 2018 SUM | 2018 WIN | 2019 SUM | 2019 WIN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diep | PEV1 | 0.050 | 0.082 | 0.040 | 0.076 | 0.270 | 0.068 | 0.387 | 0.176 | 0.330 | 0.141 |
| | PEV2 | 0.993 | 2.075 | 0.150 | 0.471 | 0.248 | 0.231 | 0.532 | 0.380 | 0.734 | 2.110 |
| | PEV3 | 0.234 | 0.322 | 0.125 | 0.161 | 0.317 | 0.419 | 0.488 | 0.404 | 0.349 | 0.400 |
| | RTV02 | 0.014 | 0.015 | 0.013 | 0.010 | 0.041 | 0.027 | 0.020 | 0.019 | 0.120 | 0.066 |
| | RTV18 | 0.726 | | 0.827 | 0.614 | 1.823 | 0.579 | 1.520 | 0.623 | 6.290 | 2.625 |
| Elsieskraal | ANG01 | 0.048 | 0.005 | 0.010 | 0.025 | 0.019 | 0.012 | 0.010 | 0.009 | 0.008 | 0.043 |
| | ANG02 | 0.048 | 0.025 | 0.013 | 0.025 | 0.042 | 0.023 | 0.019 | 0.022 | 0.011 | 0.038 |
| | BM01 | 0.089 | 0.028 | 0.054 | 0.084 | 0.063 | 0.056 | 0.048 | 0.031 | 0.021 | 0.088 |
| | BM02 | 0.017 | 0.005 | 0.043 | 0.018 | 0.069 | 0.016 | 0.056 | 0.009 | 0.045 | 0.030 |
| | BM03 | 0.020 | 0.050 | 0.022 | 0.090 | | 0.281 | 0.171 | 0.312 | 0.329 | 0.086 |
| | DOOR01 | 0.178 | 0.050 | 0.113 | 0.094 | 0.195 | 0.100 | 0.460 | 0.053 | 0.101 | 0.230 |
| | DOOR03 | 0.025 | 0.036 | 0.005 | 0.015 | 0.012 | 0.012 | 0.011 | 0.008 | 0.013 | 0.019 |
| Kuils | KHA01 | 0.763 | 0.820 | 0.487 | 0.474 | 1.312 | 1.236 | 1.760 | 0.405 | 1.175 | 1.155 |
| Mosselbank | BM04 | 0.047 | 0.096 | 0.076 | 0.068 | 0.113 | 0.104 | 0.012 | 0.075 | 0.027 | 0.092 |
| MPlain | KHA02 | 0.689 | 0.562 | 0.831 | 0.771 | 1.212 | 0.834 | 1.515 | 0.948 | 0.952 | 0.993 |
| Noordhoek | WV02 | 0.347 | 1.073 | 1.390 | 2.053 | 1.324 | 1.472 | 0.678 | 1.312 | 1.530 | 5.615 |
| | WV05 | 0.170 | 0.827 | | | 0.205 | | 0.443 | 1.071 | 1.029 | 4.710 |
| | WV11 | | | 0.938 | | 1.470 | 1.480 | | 0.753 | | 5.500 |
| Sand | BM11 | 0.013 | 0.057 | 0.016 | 0.050 | | 0.042 | 0.043 | 0.099 | 0.017 | 0.142 |
| | LPVN | 0.017 | 0.025 | 0.028 | 0.019 | 0.021 | 0.015 | 0.023 | 0.025 | 0.030 | 0.018 |
| | LPVS | 0.042 | 0.050 | 0.034 | 0.040 | 0.066 | 0.168 | 0.056 | 0.041 | 0.077 | 0.040 |
| | LVO | 0.048 | 0.113 | 0.034 | 0.061 | 0.055 | 0.156 | 0.081 | 0.105 | 0.131 | 0.100 |
| | OOG01 | 0.019 | 0.026 | 0.013 | 0.012 | 0.010 | 0.041 | 0.088 | 0.051 | 0.015 | 0.011 |
| | PV03 | 0.016 | 0.043 | 0.005 | 0.005 | 0.010 | 0.015 | 0.016 | 0.013 | 0.008 | 0.014 |
| | PVweir | 0.016 | 0.031 | 0.005 | 0.005 | 0.008 | 0.005 | 0.023 | 0.011 | 0.008 | 0.013 |
| | ZA01S | 0.089 | 0.065 | 0.067 | 0.016 | 0.036 | 0.120 | 0.066 | 0.069 | 0.005 | 0.077 |
| | ZA02S | 0.100 | 0.068 | 0.035 | 0.014 | 0.028 | 0.121 | 0.027 | 0.065 | 0.024 | 0.050 |
| | ZA03S | | | 0.106 | | | | | | 0.005 | |
| | ZA05S | 0.123 | 0.084 | 0.075 | 0.052 | 0.148 | 0.160 | 0.149 | 0.088 | 0.143 | 0.062 |
| | ZA08S | 0.074 | 0.050 | 0.060 | 0.012 | 0.051 | 0.047 | 0.016 | 0.011 | 0.017 | 0.046 |
| | ZA09S | 0.055 | 0.050 | 0.048 | 0.009 | 0.033 | 0.037 | 0.024 | 0.023 | 0.014 | 0.064 |
| | ZA10S | 0.046 | 0.022 | 0.082 | 0.013 | 0.101 | 0.062 | 0.069 | 0.072 | 0.057 | 0.053 |
| | ZA11S | 0.053 | 0.033 | 0.057 | 0.005 | 0.032 | 0.092 | 0.011 | 0.028 | 0.011 | 0.065 |
| | ZA12S | 0.078 | 0.080 | 0.031 | 0.022 | 0.031 | 0.055 | 0.015 | 0.043 | 0.012 | 0.045 |
| | ZA13S | 0.085 | 0.044 | 0.035 | 0.012 | 0.029 | 0.044 | 0.005 | 0.031 | 0.009 | 0.028 |
| | ZAweir | 0.125 | 0.071 | 0.074 | 0.043 | 0.117 | 0.163 | 0.143 | 0.101 | 0.140 | 0.054 |
| South Peninsula | GC02 | 0.021 | 0.013 | 0.008 | 0.014 | 0.013 | 0.012 | 0.013 | 0.013 | 0.013 | 0.025 |
| Zeekoe | BM08 | 0.699 | 0.776 | 0.433 | 0.359 | 0.437 | 0.298 | 1.900 | 1.089 | 1.880 | |
| | BM09 | 0.714 | 0.882 | 0.599 | 0.399 | 0.445 | 0.610 | 1.010 | 0.526 | 1.640 | |
| | BM12 | 0.008 | 0.032 | 0.005 | 0.008 | 0.023 | 0.017 | 0.028 | 0.023 | 0.013 | 0.005 |
| | BM13 | 0.028 | 0.046 | 0.066 | 0.093 | 0.086 | 0.112 | 0.076 | 0.120 | 0.053 | 0.017 |
| | BM14 | 0.360 | 0.209 | 0.685 | 0.743 | 0.451 | 0.466 | 0.643 | 0.397 | 0.564 | 1.000 |
| | RVweir | 0.050 | 0.187 | 0.019 | 0.118 | 0.171 | 0.173 | 0.137 | 0.182 | 0.034 | 0.139 |
| | ZEV1S | 0.209 | 0.132 | 0.721 | 1.181 | 0.264 | 0.260 | 0.415 | 0.220 | 0.685 | 0.391 |
| | ZEV2S | 0.816 | 0.351 | | 1.513 | | | | | | |
| | ZEV3S | 0.138 | 0.152 | 0.692 | 1.088 | 0.206 | 0.355 | 0.335 | 0.305 | 0.711 | 0.403 |
| | ZEV4S | 0.853 | | | 1.312 | | | | | | |

# MEDIAN DISSOLVED OXYGEN (mg/L)

## RIVERS / STORMWATER

| SUBCATCHMENT | SITE | 2015 SUM | 2015 WIN | 2016 SUM | 2016 WIN | 2017 SUM | 2017 WIN | 2018 SUM | 2018 WIN | 2019 SUM |
|---|---|---|---|---|---|---|---|---|---|---|
| Diep | MOS05 | 0.350 | 0.037 | 0.463 | 0.422 | 0.056 | 0.047 | 0.157 | 0.004 | 0.0 |
| Diep | RTV01 | 0.017 | 0.011 | 0.015 | 0.008 | 0.020 | 0.098 | 0.012 | 0.029 | 0.0 |
| Diep | RTV03 | 0.025 | 0.004 | 0.013 | 0.003 | 0.019 | 0.017 | 0.021 | 0.010 | 0.0 |
| Diep | RTV04 | 0.010 | 0.008 | 0.013 | 0.012 | 0.080 | 0.019 | 0.052 | 0.010 | 0.0 |
| Diep | RTV05 | 0.011 | 0.008 | 0.035 | 0.006 | 0.124 | 0.028 | 0.279 | 0.011 | 0.4 |
| Diep | RTV06 | 0.024 | 0.003 | 0.032 | 0.011 | 0.032 | 0.001 | 0.109 | 0.003 | 0.0 |
| Diep | RTV08 | 0.025 | 0.007 | 0.064 | 0.003 | 0.060 | 0.027 | 0.024 | 0.010 | 0.2 |
| Diep | RTV09 | 0.018 | 0.012 | 0.023 | 0.016 | 0.028 | 0.027 | 0.292 | 0.013 | 0.8 |
| Diep | RTV10 | 0.009 | 0.014 | 0.006 | 0.015 | 0.009 | 0.020 | 0.210 | 0.018 | 1.0 |
| Diep | RTV11 | 0.009 | 0.008 | 0.046 | 0.012 | 0.262 | 0.026 | 0.182 | 0.026 | 0.2 |
| Diep | RTV12 | 0.015 | 0.022 | 0.023 | 0.005 | 0.037 | 0.028 | 0.080 | 0.007 | 0.1 |
| Diep | RTV14 | 0.725 | | 0.027 | 0.010 | | | | | 0.0 |
| Diep | RTV22 | | | | | 1.042 | 0.005 | 1.168 | 0.087 | 0.1 |
| Eerste | EK08 | 0.005 | 0.003 | 0.002 | 0.002 | 0.006 | 0.003 | 0.008 | 0.002 | 0.1 |
| Eerste | EK11 | 0.361 | 0.127 | 0.531 | 0.156 | 0.287 | 0.206 | 0.415 | 0.147 | 0.4 |
| Eerste | EK12 | | | | | | | 0.527 | 0.082 | 0.3 |
| Eerste | EK13 | 0.217 | 0.014 | 0.312 | 0.024 | 0.003 | 0.020 | 0.002 | 0.001 | 0.0 |
| Eerste | EK15 | 0.074 | 0.056 | 0.084 | 0.032 | 0.098 | 0.016 | 0.171 | 0.032 | 0.2 |
| Eerste | EK16 | | | | | | | 1.074 | 0.538 | |
| Eerste | EK17 | 0.326 | 0.145 | 0.769 | 0.187 | 0.675 | 0.232 | 0.830 | 0.128 | 0.4 |
| Eerste | EK18 | 0.076 | 0.009 | 0.002 | 0.003 | 0.005 | 0.002 | 0.270 | 0.010 | 0.1 |
| Elsieskraal | ELS_GW | 0.123 | 0.324 | 0.017 | 0.015 | 0.360 | 0.007 | 0.371 | 0.067 | 0.1 |
| Elsieskraal | ELS08 | 0.046 | 0.028 | 0.044 | 0.010 | 0.023 | 0.005 | 0.314 | 0.063 | 0.1 |
| Elsieskraal | ELS10 | 0.006 | 0.003 | 0.009 | 0.007 | 0.001 | 0.005 | 0.008 | 0.001 | 0.0 |
| Hout Bay | DR01 | 0.014 | 0.007 | 0.007 | 0.002 | 0.006 | 0.016 | 0.005 | 0.002 | 0.0 |
| Hout Bay | DR02 | 0.002 | 0.004 | 0.003 | 0.004 | 0.007 | 0.004 | 0.003 | 0.001 | 0.0 |
| Hout Bay | DR04 | | 0.001 | | | 0.007 | | 0.001 | | 0.0 |
| Hout Bay | DR06 | | 0.005 | 0.002 | 0.001 | 0.001 | | 0.001 | | 0.0 |
| Kuils | EK03 | 0.002 | 0.001 | 0.001 | 0.002 | 0.001 | 0.010 | 0.001 | 0.001 | 0.0 |
| Kuils | EK04 | 0.007 | 0.003 | 0.004 | 0.004 | 0.006 | 0.008 | 0.042 | 0.003 | 0.0 |
| Kuils | EK05 | 0.026 | 0.041 | 0.257 | 0.076 | 0.179 | 0.020 | 0.074 | 0.013 | 0.4 |
| Kuils | EK09 | 0.021 | 0.047 | 0.082 | 0.067 | 0.122 | 0.023 | 0.076 | 0.020 | 0.2 |
| Kuils | EK19 | 0.002 | 0.003 | 0.007 | 0.001 | 0.011 | 0.011 | 0.044 | 0.004 | 0.0 |
| Lourens | LOU01 | 0.002 | 0.001 | 0.001 | | 0.001 | 0.001 | 0.001 | | 0.0 |
| Lourens | LOU02 | | 0.001 | 0.001 | | 0.002 | | 0.001 | | 0.0 |
| Lourens | LOU03 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.0 |
| Lourens | LOU04 | 0.001 | 0.002 | | 0.001 | 0.002 | 0.001 | 0.001 | | 0.0 |
| Lourens | LOU05 | 0.010 | 0.002 | 0.056 | 0.002 | 0.062 | 0.001 | 0.003 | 0.117 | 0.0 |
| Lourens | LOU06 | | | | | | | 0.401 | | 0.0 |
| Lower Salt | NR01 | 0.003 | 0.009 | 0.004 | 0.007 | 0.015 | 0.005 | 0.010 | 0.011 | 0.0 |
| Lower Salt | NR02 | 0.245 | 0.073 | 0.133 | 0.109 | 0.139 | 0.178 | 0.134 | 0.093 | 0.1 |
| Lower Salt | NR03 | 0.107 | 0.112 | 0.204 | 0.073 | 0.105 | 0.320 | 0.489 | 0.201 | 0.3 |
| Lower Salt | NR04 | 0.038 | 0.015 | 0.090 | 0.023 | 0.067 | 0.057 | 0.144 | 0.061 | 0.4 |
| Lower Salt | NR06 | 0.057 | 0.017 | 0.131 | 0.031 | 0.098 | 0.048 | 0.326 | 0.058 | 0.3 |
| Lower Salt | NR07 | 0.055 | 0.016 | 0.082 | 0.023 | 0.091 | 0.064 | 0.248 | 0.062 | 0.3 |
| Lower Salt | NR08 | 0.002 | 0.005 | 0.001 | 0.001 | 0.001 | 0.001 | 0.003 | 0.001 | 0.0 |
| Lower Salt | NR09 | 0.037 | 0.011 | 0.062 | 0.021 | 0.088 | 0.059 | 0.294 | 0.036 | 0.2 |
| Lower Salt | NR10 | 0.118 | 0.011 | 0.248 | 0.009 | 0.213 | 0.093 | 0.463 | 0.090 | 0.3 |
| Lower Salt | NR11 | 0.008 | 0.002 | 0.017 | 0.002 | 0.028 | 0.004 | 0.058 | 0.008 | 0.0 |
| Lower Salt | NR15 | 0.601 | 0.094 | 0.244 | 0.095 | 0.110 | 0.382 | 0.195 | 0.344 | 0.3 |
| Lower Salt | NR16 | 0.003 | 0.008 | 0.026 | 0.005 | 0.098 | 0.036 | 0.220 | 0.386 | 0.5 |
| Lower Salt | NR17 | 0.352 | 0.030 | 0.563 | 0.064 | 1.042 | 0.530 | 0.152 | 0.203 | 0.3 |
| Lower Salt | NR22 | 0.004 | | | 0.001 | 0.001 | 0.006 | | 0.002 | |
| Lower Salt | NR25 | | | | | 0.159 | | 0.097 | 0.099 | 0.4 |
| Lower Salt | NR26 | 0.237 | 0.106 | 0.590 | 0.209 | 0.070 | 0.440 | 0.720 | 0.443 | 0.3 |
| Mosselbank | MOS01 | 0.115 | 0.036 | 0.338 | 0.085 | 0.255 | 0.031 | 0.164 | 0.099 | 0.8 |
| Mosselbank | MOS02 | 0.025 | 0.004 | 0.015 | 0.016 | 0.075 | 0.018 | 0.103 | 0.057 | 0.1 |
| Mosselbank | MOS03 | 0.050 | 0.034 | 0.272 | 0.023 | 0.044 | 0.023 | 0.047 | 0.021 | 0.0 |
| Mosselbank | MOS04 | 0.002 | 0.008 | 0.009 | 0.004 | 0.003 | 0.003 | 0.009 | 0.004 | 0.2 |
| Mosselbank | MOS06 | 0.002 | 0.004 | 0.002 | 0.005 | 0.004 | 0.014 | 0.043 | 0.024 | 0.0 |
| Mosselbank | MOS07 | 0.043 | 0.012 | 0.014 | 0.022 | 0.012 | 0.096 | 0.008 | 0.004 | 0.0 |
| Mosselbank | MOS08 | 0.005 | 0.005 | 0.005 | 0.007 | 0.002 | 0.003 | 0.013 | 0.005 | 0.0 |
| Mosselbank | MOS09 | 1.085 | 0.172 | 0.976 | 0.223 | 0.417 | 0.265 | 0.637 | 0.078 | 0.4 |
| Mosselbank | MOSAH03 | | 0.071 | | 0.011 | | 0.005 | 0.032 | 0.013 | |
| Mosselbank | MOSTP4 | 0.334 | 0.045 | 0.138 | 0.046 | 0.030 | 0.089 | 0.005 | 0.005 | 0.0 |
| MPlain | KHA03 | 0.293 | 0.155 | 0.339 | 0.160 | 0.460 | 0.225 | 0.430 | 0.115 | 0.3 |
| MPlain | KHA04 | 0.290 | 0.138 | 0.334 | 0.153 | 0.629 | 0.275 | 0.464 | 0.193 | 0.4 |
| Sand | CR01 | 0.002 | 0.002 | 0.001 | 0.001 | 0.002 | 0.001 | 0.005 | | 0.0 |
| Sand | CR02 | 0.001 | 0.001 | 0.001 | 0.001 | 0.002 | 0.002 | 0.006 | 0.001 | 0.0 |
| Sand | CR03 | 0.004 | 0.005 | 0.004 | 0.002 | 0.003 | 0.005 | 0.011 | 0.003 | 0.0 |
| Sand | CR04 | 0.011 | 0.001 | 0.007 | 0.007 | 0.005 | 0.017 | | 0.033 | 0.0 |
| Sand | CR05 | | | | | | 0.001 | | 0.001 | 0.0 |
| Sand | CR06 | 0.002 | 0.004 | 0.002 | | 0.013 | 0.001 | 0.001 | 0.009 | 0.0 |
| Sand | CR16 | 0.002 | | 0.001 | 0.012 | 0.001 | 0.001 | 0.001 | 0.021 | 0.0 |
| Sand | CR20 | 0.001 | 0.070 | 0.001 | | 0.001 | 0.001 | 0.002 | 0.001 | 0.0 |
| Sand | CR21 | 0.007 | 0.004 | 0.006 | 0.004 | 0.010 | 0.011 | 0.024 | 0.008 | 0.0 |
| Sand | CR22 | 0.004 | 0.002 | 0.005 | 0.001 | 0.002 | 0.001 | 0.005 | 0.001 | 0.0 |
| Sand | DRRSC | 0.031 | 0.005 | 0.003 | 0.002 | 0.009 | 0.009 | 0.009 | 0.005 | 0.0 |
| Sand | LPVMR | 0.001 | 0.005 | 0.001 | | 0.001 | 0.002 | 0.001 | 0.001 | 0.0 |
| Sand | LVI | 0.008 | 0.015 | 0.020 | 0.004 | 0.009 | 0.003 | 0.015 | 0.002 | 0.0 |
| Sand | SCV | 0.025 | 0.002 | 0.031 | 0.004 | 0.006 | 0.013 | 0.056 | 0.318 | 0.0 |
| Silvermine | SIL02 | | | | | | | 0.005 | | 0.0 |
| Silvermine | SIL04 | 0.002 | 0.001 | | | 0.001 | | 0.001 | | 0.0 |
| Silvermine | SIL06 | 0.001 | 0.001 | 0.001 | 0.003 | 0.002 | 0.001 | 0.001 | 0.003 | 0.0 |
| SLPass | SIR01 | 0.001 | | 0.001 | | 0.001 | 0.001 | 0.001 | 0.002 | 0.0 |
| SLPass | SIR02 | 0.003 | 0.025 | 0.022 | 0.001 | 0.036 | 0.005 | 0.022 | 0.010 | 0.0 |
| SLPass | SIR03 | 0.005 | 0.001 | 0.024 | 0.002 | 0.023 | 0.007 | 0.019 | 0.004 | 0.0 |
| SLPass | SIR04 | | 0.003 | | 0.001 | | | 0.012 | 0.003 | |
| SLPass | SIR05 | 0.004 | 0.003 | 0.003 | 0.003 | 0.004 | 0.002 | 0.004 | 0.003 | 0.0 |
| SLPass | SIR06 | 0.010 | 0.007 | 0.014 | 0.001 | 0.003 | 0.097 | 0.014 | 0.004 | 0.0 |
| SLPass | SIR07 | 0.067 | 0.009 | 0.032 | 0.062 | 0.022 | 0.039 | 0.109 | 0.003 | 0.0 |
| Soet | SOE02 | 0.108 | 0.004 | 0.283 | 0.047 | 0.090 | 0.175 | 0.038 | 0.091 | 0.1 |
| Soet | SOE04 | 0.007 | 0.002 | | 0.008 | 0.004 | 0.018 | 0.017 | 0.004 | 0.0 |
| Soet | SOEAH06 | 0.004 | 0.004 | 0.003 | 0.003 | 0.001 | 0.001 | 0.030 | 0.002 | 0.0 |
| Soet | SOEAH10 | 0.279 | 0.070 | 0.130 | 0.164 | 0.245 | 0.046 | 0.451 | 0.300 | 0.0 |
| Soet | SOEAH11 | 0.004 | 0.053 | 0.019 | 0.007 | 0.005 | 0.010 | 0.024 | 0.005 | 0.0 |
| Soet | SOEAH12 | 0.174 | 0.022 | 0.180 | 0.051 | 0.442 | 0.111 | 0.209 | 0.081 | 0.2 |
| Sout | SOU01 | 0.003 | 0.014 | 0.003 | 0.006 | 0.014 | 0.001 | 0.002 | 0.001 | 0.0 |
| Sout | SOU02 | 0.001 | 0.001 | 0.004 | 0.002 | 0.002 | 0.062 | 0.001 | 0.011 | 0.0 |
| South Peninsula | BOK02 | 0.118 | 0.060 | 0.020 | 0.008 | 0.088 | 0.008 | 0.011 | 0.016 | 0.4 |
| South Peninsula | BOK03 | 0.022 | 0.003 | 0.019 | 0.030 | 0.001 | 0.005 | 0.002 | 0.003 | 0.0 |
| South Peninsula | SCH02 | 0.002 | | | 0.003 | | 0.012 | 0.001 | | 0.0 |
| South Peninsula | SCH04 | 0.002 | | 0.001 | 0.002 | | 0.003 | 0.001 | 0.001 | 0.0 |
| Zeekoe | LR02 | 0.013 | 0.004 | 0.008 | 0.012 | 0.012 | 0.002 | 0.011 | 0.009 | 0.0 |
| Zeekoe | LR03 | 0.102 | 0.321 | 0.090 | 0.212 | 0.216 | 0.286 | 0.162 | 0.097 | 0.4 |
| Zeekoe | LR05 | 0.354 | 0.093 | 0.318 | 0.128 | 0.011 | 0.079 | 0.248 | 0.111 | 0.0 |
| Zeekoe | LR06 | 0.006 | 0.002 | 0.024 | 0.001 | 0.002 | 0.002 | 0.006 | 0.031 | 0.0 |
| Zeekoe | LR07 | 0.561 | 0.022 | 0.012 | 0.152 | 0.013 | 0.054 | 0.044 | 0.929 | 0.0 |
| Zeekoe | LR08 | 0.182 | 0.010 | 0.049 | 0.158 | 0.043 | 0.311 | 0.151 | 0.087 | 0.4 |
| Zeekoe | LR10 | 0.025 | 0.005 | 0.059 | 0.008 | 0.043 | 0.004 | 0.002 | 0.004 | 0.0 |
| Zeekoe | RVIRD | 0.033 | 0.003 | 0.006 | 0.001 | 0.024 | 0.008 | 0.020 | 0.009 | 0.0 |
| Zeekoe | ZEV5 | 0.377 | 0.105 | 0.224 | 0.207 | 0.265 | 0.220 | 0.438 | 0.281 | 0.2 |

## VLEIS / DAMS

| SUBCATCHMENT | SITE | 2015 SUM | 2015 WIN | 2016 SUM | 2016 WIN | 2017 SUM | 2017 WIN | 2018 SUM | 2018 WIN | 2019 SUM | 2019 WIN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diep | PEV1 | 7.820 | 4.490 | 3.490 | 3.375 | 0.850 | 1.300 | 5.400 | 2.200 | 1.400 | 4.200 |
| | PEV2 | 3.410 | 2.035 | 0.905 | 1.300 | 2.900 | 2.131 | 0.800 | 2.450 | 3.600 | 2.300 |
| | PEV3 | 0.730 | 0.410 | 1.800 | 2.685 | 1.370 | 1.350 | 1.700 | 0.850 | 1.000 | 2.400 |
| | RTV02 | 9.275 | 8.845 | 10.320 | 3.650 | 9.800 | 10.665 | 10.000 | 9.350 | 8.400 | 9.700 |
| | RTV18 | 6.800 | | 6.680 | 3.010 | 5.500 | 3.300 | 4.000 | 3.600 | 0.600 | 2.040 |
| Elsieskraal | ANG01 | 6.335 | 7.440 | 7.065 | 7.515 | 7.200 | 5.960 | 8.900 | 7.220 | 7.800 | 8.450 |
| | ANG02 | 5.080 | 7.465 | 5.805 | 7.980 | 6.380 | 7.525 | 7.100 | 8.300 | 7.600 | 9.100 |
| | DOOR01 | 2.680 | 6.605 | 2.135 | 4.465 | 2.250 | 4.015 | 6.600 | 7.090 | 5.700 | 6.150 |
| | DOOR03 | 5.220 | 7.790 | 7.020 | 8.755 | 8.210 | 6.860 | 8.550 | 8.490 | 7.450 | 9.100 |
| Kuils | KHA01 | 0.540 | 1.580 | 0.880 | 1.700 | 0.095 | 1.920 | 0.400 | 2.000 | 0.600 | 1.550 |
| MPlain | KHA02 | 3.270 | 4.630 | 2.985 | 3.715 | 2.800 | 3.410 | 1.450 | 4.100 | 2.050 | 2.000 |
| Noordhoek | WV02 | 9.170 | 10.755 | 5.810 | 11.765 | 8.045 | 9.275 | 10.955 | 10.535 | 9.600 | 9.000 |
| | WV05 | 8.870 | 10.380 | | | 9.470 | | 9.495 | 10.530 | 9.790 | 9.400 |
| | WV11 | | | 5.300 | | 8.400 | 8.630 | 6.400 | | | 8.100 |
| Sand | LPVN | 5.450 | 7.290 | 6.640 | 7.310 | 6.000 | 8.470 | 7.170 | 8.320 | 7.400 | 9.310 |
| | LPVS | 2.860 | 6.670 | 5.035 | 3.780 | 2.395 | 5.830 | 7.160 | 4.195 | 1.400 | 4.230 |
| | LVO | 7.860 | 8.240 | 10.080 | 8.360 | 7.350 | 8.015 | 7.870 | 7.525 | 4.800 | 9.850 |
| | OOG01 | 8.545 | 7.975 | 8.045 | 8.700 | 6.000 | 8.420 | 8.290 | 8.160 | 6.525 | 8.160 |
| | PV03 | 8.405 | 9.165 | 9.570 | 9.120 | 8.550 | 10.105 | 8.900 | 8.925 | 10.335 | 10.215 |
| | PVweir | 8.710 | 9.405 | 9.330 | 9.770 | 9.125 | 9.950 | 9.480 | 10.000 | 10.570 | 10.420 |
| | ZA01S | 7.360 | 9.480 | 8.325 | 7.365 | 8.240 | 9.690 | 9.900 | 9.495 | 9.610 | 10.190 |
| | ZA02S | 6.500 | 8.475 | 7.080 | 8.740 | 8.420 | 8.750 | 9.050 | 9.135 | 9.980 | 10.260 |
| | ZA03S | | | 6.900 | | | | | | | |
| | ZA05S | 7.045 | 7.925 | 7.080 | 7.505 | 7.860 | 7.290 | 5.740 | 8.090 | 6.400 | 8.670 |
| | ZA08S | 6.215 | 11.100 | 9.700 | 9.135 | 9.510 | 9.195 | 10.660 | 9.765 | 8.870 | 9.035 |
| | ZA09S | 6.885 | 10.950 | 7.825 | 9.615 | 8.500 | 8.465 | 9.000 | 9.610 | 8.810 | 8.605 |
| | ZA10S | 7.365 | 8.625 | 6.560 | 8.095 | 7.990 | 6.985 | 6.710 | 5.615 | 7.085 | 8.825 |
| | ZA11S | 5.410 | 9.645 | 8.550 | 10.070 | 9.255 | 8.140 | 9.180 | 9.625 | 4.425 | 7.060 |
| | ZA12S | 6.490 | 9.440 | 6.915 | 7.670 | 8.400 | 9.385 | 8.600 | 9.340 | 8.620 | 10.260 |
| | ZA13S | 7.100 | 8.790 | 8.170 | 8.370 | 7.820 | 8.985 | 9.050 | 9.795 | 8.300 | 8.935 |
| | ZAweir | 6.480 | 8.580 | 7.530 | 7.645 | 6.685 | 7.485 | 5.160 | 7.675 | 8.015 | 8.545 |
| South Peninsula | GC02 | 5.520 | 7.610 | 6.455 | 7.730 | 6.450 | 6.930 | 6.850 | 7.500 | 6.405 | 7.450 |
| Zeekoe | RVweir | 3.000 | 4.300 | 3.225 | 5.085 | 3.140 | 5.410 | 1.800 | 3.100 | 3.200 | 7.200 |
| | ZEV1S | 8.400 | 9.450 | 7.560 | 4.700 | 9.195 | 10.435 | 10.525 | 9.405 | 9.650 | 10.410 |
| | ZEV2S | 10.090 | 3.910 | | 1.135 | | | | | | |
| | ZEV3S | 6.300 | 9.500 | 8.310 | 7.480 | 8.045 | 9.935 | 10.790 | 8.870 | 9.660 | 9.845 |
| | ZEV4S | 8.350 | | | 5.805 | | | | | | |

## MEDIAN NH3 (mg NL)

### RIVERS / STORMWATER

| SUBCATCHMENT | SITE | 2015 SUM | 2015 WIN | 2016 SUM | 2016 WIN | 2017 SUM | 2017 WIN | 2018 SUM | 2018 WIN | 2019 SUM | 2019 WIN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diep | MOS05 | 0.350 | 0.037 | 0.463 | 0.422 | 0.056 | 0.047 | 0.157 | 0.004 | 0.010 | 0.015 |
| | RTV01 | 0.017 | 0.011 | 0.015 | 0.008 | 0.020 | 0.098 | 0.012 | 0.029 | 0.015 | 0.016 |
| | RTV03 | 0.025 | 0.004 | 0.013 | 0.003 | 0.019 | 0.017 | 0.021 | 0.010 | 0.033 | 0.025 |
| | RTV04 | 0.010 | 0.008 | 0.013 | 0.012 | 0.080 | 0.019 | 0.052 | 0.010 | 0.041 | 0.033 |
| | RTV05 | 0.011 | 0.008 | 0.035 | 0.006 | 0.124 | 0.028 | 0.279 | 0.011 | 0.413 | 0.060 |
| | RTV06 | 0.024 | 0.003 | 0.032 | 0.011 | 0.032 | 0.001 | 0.108 | 0.007 | 0.005 | 0.002 |
| | RTV08 | 0.025 | 0.007 | 0.064 | 0.003 | 0.060 | 0.027 | 0.024 | 0.010 | 0.270 | 0.107 |
| | RTV09 | 0.018 | 0.012 | 0.023 | 0.016 | 0.028 | 0.027 | 0.292 | 0.013 | 0.854 | 0.067 |
| | RTV10 | 0.009 | 0.014 | 0.006 | 0.015 | 0.009 | 0.020 | 0.210 | 0.018 | 1.010 | 0.060 |
| | RTV11 | 0.009 | 0.008 | 0.046 | 0.012 | 0.262 | 0.026 | 0.182 | 0.026 | 0.221 | 0.128 |
| | RTV12 | 0.015 | 0.022 | 0.023 | 0.005 | 0.037 | 0.028 | 0.080 | 0.007 | 0.134 | 0.041 |
| | RTV14 | 0.725 | | 0.027 | 0.010 | | | | | 0.009 | |
| | RTV22 | | | | | 1.042 | 0.005 | 1.168 | 0.087 | 0.166 | 0.300 |
| Eerste | EK08 | 0.005 | 0.003 | 0.002 | 0.002 | 0.006 | 0.003 | 0.008 | 0.002 | 0.146 | 0.001 |
| | EK11 | 0.361 | 0.127 | 0.531 | 0.156 | 0.287 | 0.206 | 0.418 | 0.147 | 0.439 | 0.184 |
| | EK12 | | | | | | | 0.527 | 0.082 | 0.324 | 0.080 |
| | EK13 | 0.217 | 0.014 | 0.312 | 0.024 | 0.003 | 0.020 | 0.002 | 0.001 | 0.001 | 0.001 |
| | EK15 | 0.024 | 0.056 | 0.084 | 0.032 | 0.098 | 0.016 | 0.171 | 0.022 | 0.223 | 0.053 |
| | EK16 | | | | | | | 1.074 | 0.538 | | |
| | EK17 | 0.326 | 0.145 | 0.769 | 0.187 | 0.675 | 0.232 | 0.830 | 0.128 | 0.456 | 0.183 |
| | EK18 | 0.076 | 0.009 | 0.002 | 0.003 | 0.005 | 0.002 | 0.270 | 0.010 | 0.172 | 0.004 |
| Elsieskraal | ELS_GW | 0.123 | 0.124 | 0.017 | 0.015 | 0.160 | 0.007 | 0.321 | 0.067 | 0.160 | 0.024 |
| | ELS08 | 0.046 | 0.028 | 0.044 | 0.010 | 0.023 | 0.005 | 0.014 | 0.003 | 0.133 | 0.014 |
| | ELS10 | 0.006 | 0.003 | 0.009 | 0.007 | 0.001 | 0.005 | 0.008 | 0.001 | 0.007 | 0.002 |
| Hout Bay | DR01 | 0.014 | 0.007 | 0.007 | 0.002 | 0.006 | 0.016 | 0.005 | 0.002 | 0.003 | 0.001 |
| | DR02 | 0.002 | 0.004 | 0.003 | 0.004 | 0.007 | 0.004 | 0.001 | 0.001 | 0.005 | 0.001 |
| | DR04 | | 0.001 | | | 0.002 | | 0.001 | | 0.001 | 0.001 |
| | DR06 | | 0.005 | 0.002 | 0.001 | 0.001 | | 0.001 | | 0.001 | 0.001 |
| Kuils | EK03 | 0.002 | 0.003 | 0.001 | 0.002 | 0.001 | 0.010 | 0.001 | 0.001 | 0.001 | 0.001 |
| | EK04 | 0.007 | 0.003 | 0.004 | 0.004 | 0.006 | 0.008 | 0.042 | 0.002 | 0.034 | 0.001 |
| | EK05 | 0.026 | 0.041 | 0.257 | 0.076 | 0.179 | 0.020 | 0.074 | 0.013 | 0.478 | 0.080 |
| | EK09 | 0.021 | 0.047 | 0.082 | 0.067 | 0.122 | 0.023 | 0.076 | 0.020 | 0.278 | 0.068 |
| | EK19 | 0.002 | 0.003 | 0.007 | 0.003 | 0.011 | 0.011 | 0.044 | 0.004 | 0.003 | 0.002 |
| Lourens | LOU01 | 0.002 | 0.001 | 0.001 | | 0.001 | 0.001 | 0.001 | | 0.001 | 0.001 |
| | LOU02 | | 0.001 | 0.001 | | 0.002 | | 0.001 | | 0.001 | 0.001 |
| | LOU03 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| | LOU04 | 0.001 | 0.002 | | 0.001 | 0.002 | 0.001 | 0.001 | | 0.001 | 0.001 |
| | LOU05 | 0.010 | 0.002 | 0.056 | 0.002 | 0.063 | 0.001 | 0.003 | 0.112 | 0.005 | 0.001 |
| | LOU06 | | | | | | | 0.001 | | 0.001 | 0.001 |
| Lower Salt | NR01 | 0.003 | 0.009 | 0.004 | 0.007 | 0.015 | 0.009 | 0.010 | 0.013 | 0.030 | 0.011 |
| | NR02 | 0.241 | 0.073 | 0.124 | 0.109 | 0.139 | 0.179 | 0.134 | 0.093 | 0.129 | 0.106 |
| | NR03 | 0.107 | 0.112 | 0.204 | 0.073 | 0.160 | 0.320 | 0.689 | 0.201 | 0.325 | 0.189 |
| | NR04 | 0.038 | 0.015 | 0.090 | 0.023 | 0.067 | 0.037 | 0.148 | 0.061 | 0.419 | 0.055 |
| | NR06 | 0.037 | 0.017 | 0.111 | 0.031 | 0.098 | 0.048 | 0.226 | 0.058 | 0.385 | 0.041 |
| | NR07 | 0.055 | 0.016 | 0.082 | 0.024 | 0.091 | 0.064 | 0.240 | 0.062 | 0.228 | 0.065 |
| | NR08 | 0.002 | 0.005 | 0.001 | 0.003 | 0.002 | 0.001 | 0.003 | 0.001 | 0.003 | 0.002 |
| | NR09 | 0.037 | 0.013 | 0.082 | 0.023 | 0.088 | 0.059 | 0.294 | 0.038 | 0.286 | 0.121 |
| | NR10 | 0.115 | 0.011 | 0.248 | 0.009 | 0.213 | 0.093 | 0.483 | 0.090 | 0.368 | 0.081 |
| | NR11 | 0.008 | 0.002 | 0.017 | 0.002 | 0.028 | 0.004 | 0.058 | 0.008 | 0.023 | 0.004 |
| | NR15 | 0.601 | 0.094 | 0.244 | 0.095 | 0.110 | 0.382 | 0.195 | 0.344 | 0.159 | 0.197 |
| | NR16 | 0.003 | 0.008 | 0.026 | 0.005 | 0.098 | 0.036 | 0.220 | 0.186 | 0.140 | 0.095 |
| | NR17 | 0.352 | 0.020 | 0.561 | 0.064 | 1.041 | 0.330 | 0.153 | 0.201 | 0.368 | 0.175 |
| | NR22 | 0.004 | | | 0.001 | 0.001 | 0.006 | | 0.002 | | 0.001 |
| | NR25 | | | | | 0.151 | | 0.097 | 0.099 | 0.410 | 0.076 |
| | NR26 | 0.237 | 0.106 | 0.560 | 0.267 | 0.070 | 0.440 | 0.720 | 0.443 | 0.388 | 0.231 |
| Mosselbank | MOS01 | 0.115 | 0.036 | 0.148 | 0.085 | 0.755 | 0.031 | 0.164 | 0.099 | 0.468 | 0.128 |
| | MOS02 | 0.025 | 0.004 | 0.015 | 0.018 | 0.075 | 0.018 | 0.103 | 0.057 | 0.100 | 0.086 |
| | MOS03 | 0.050 | 0.034 | 0.272 | 0.023 | 0.044 | 0.023 | 0.047 | 0.021 | 0.084 | 0.029 |
| | MOS04 | 0.002 | 0.008 | 0.009 | 0.004 | 0.003 | 0.001 | 0.009 | 0.004 | 0.231 | 0.001 |
| | MOS06 | 0.002 | 0.004 | 0.002 | 0.005 | 0.004 | 0.014 | 0.043 | 0.024 | 0.006 | 0.004 |
| | MOS07 | 0.048 | 0.012 | 0.014 | 0.022 | 0.012 | 0.006 | 0.008 | 0.004 | 0.009 | 0.006 |
| | MOS08 | 0.005 | 0.005 | 0.005 | 0.007 | 0.002 | 0.001 | 0.013 | 0.005 | 0.005 | 0.003 |
| | MOS09 | 0.133 | 0.170 | 0.478 | 0.223 | 0.417 | 0.160 | 0.637 | 0.076 | 0.441 | 0.185 |
| | MOSAHO3 | | 0.071 | | 0.011 | | 0.005 | 0.032 | 0.013 | | 0.148 |
| | MOSTP4 | 0.394 | 0.045 | 0.138 | 0.046 | 0.030 | 0.089 | 0.005 | 0.005 | 0.009 | 0.001 |
| MPlain | KHA03 | 0.223 | 0.151 | 0.109 | 0.180 | 0.440 | 0.225 | 0.490 | 0.115 | 0.371 | 0.189 |
| | KHA04 | 0.293 | 0.138 | 0.144 | 0.153 | 0.878 | 0.275 | 0.464 | 0.186 | 0.410 | 0.245 |
| Sand | CR01 | 0.002 | 0.002 | 0.001 | 0.001 | 0.002 | 0.001 | 0.005 | | 0.001 | 0.001 |
| | CR02 | 0.001 | 0.001 | 0.001 | 0.001 | 0.002 | 0.002 | 0.006 | 0.001 | 0.001 | 0.001 |
| | CR03 | 0.004 | 0.005 | 0.004 | 0.002 | 0.003 | 0.005 | 0.011 | 0.003 | 0.003 | 0.003 |
| | CR04 | 0.011 | 0.001 | 0.007 | 0.007 | 0.005 | 0.017 | | 0.033 | 0.009 | 0.004 |
| | CR05 | | | | | | 0.001 | | 0.002 | | |
| | CR06 | 0.002 | 0.004 | 0.001 | | 0.013 | 0.001 | 0.001 | 0.009 | 0.001 | 0.001 |
| | CR16 | 0.002 | | 0.001 | 0.012 | 0.001 | 0.001 | 0.001 | 0.021 | 0.001 | 0.001 |
| | CR20 | 0.001 | 0.070 | 0.001 | | 0.001 | 0.001 | 0.002 | 0.001 | 0.001 | 0.001 |
| | CR21 | 0.007 | 0.004 | 0.006 | 0.004 | 0.010 | 0.011 | 0.024 | 0.006 | 0.027 | 0.009 |
| | CR22 | 0.004 | 0.002 | 0.005 | 0.001 | 0.002 | 0.001 | 0.005 | 0.001 | 0.001 | 0.001 |
| | DRRSC | 0.031 | 0.005 | 0.003 | 0.002 | 0.008 | 0.006 | 0.009 | 0.005 | 0.077 | 0.002 |
| | LPVMR | 0.001 | 0.005 | 0.001 | | 0.001 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 |
| | LVI | 0.008 | 0.015 | 0.020 | 0.004 | 0.009 | 0.016 | 0.015 | 0.002 | 0.031 | 0.013 |
| | SCV | 0.025 | 0.002 | 0.031 | 0.004 | 0.006 | 0.013 | 0.056 | 0.118 | 0.054 | 0.028 |
| Silvermine | SIL02 | | | | | | | 0.001 | | 0.001 | 0.001 |
| | SIL04 | 0.002 | 0.001 | | | 0.001 | | 0.001 | | 0.001 | 0.001 |
| | SIL06 | 0.001 | 0.001 | 0.001 | 0.002 | 0.002 | 0.001 | 0.001 | 0.003 | 0.001 | 0.001 |
| SLPass | SIR01 | 0.001 | | 0.003 | | 0.001 | 0.001 | 0.001 | 0.002 | 0.001 | 0.001 |
| | SIR02 | 0.003 | 0.025 | 0.022 | 0.001 | 0.036 | 0.005 | 0.022 | 0.010 | 0.002 | 0.004 |
| | SIR03 | 0.003 | 0.001 | 0.616 | 0.002 | 0.023 | 0.007 | 0.019 | 0.004 | 0.025 | 0.001 |
| | SIR04 | | 0.003 | | 0.001 | | | 0.012 | 0.006 | | 0.001 |
| | SIR05 | 0.004 | 0.003 | 0.002 | 0.003 | 0.004 | 0.002 | 0.004 | 0.003 | 0.001 | 0.001 |
| | SIR06 | 0.010 | 0.007 | 0.014 | 0.001 | 0.003 | 0.097 | 0.014 | 0.004 | 0.002 | 0.005 |
| | SIR07 | 0.007 | 0.009 | 0.032 | 0.003 | 0.021 | 0.039 | 0.109 | 0.003 | 0.009 | 0.013 |
| Soet | SOE02 | 0.105 | 0.041 | 0.243 | 0.047 | 0.590 | 0.175 | 1.098 | 0.091 | 0.521 | 0.263 |
| | SOE04 | 0.007 | 0.002 | | 0.008 | 0.004 | 0.018 | 0.017 | 0.004 | 0.074 | |
| | SOEAH0 | 0.004 | 0.004 | 0.003 | 0.003 | 0.005 | 0.001 | 0.020 | 0.002 | 0.002 | 0.002 |
| | SOEAH1 | 0.279 | 0.070 | 0.130 | 0.164 | 0.145 | 0.046 | 0.651 | 0.180 | 0.300 | 0.299 |
| | SOEAH1 | 0.004 | 0.059 | 0.018 | 0.007 | 0.005 | 0.010 | 0.024 | 0.005 | 0.005 | 0.001 |
| | SOEAH1 | 0.174 | 0.022 | 0.360 | 0.051 | 0.467 | 0.133 | 0.203 | 0.033 | 0.245 | 0.083 |
| Sout | SOU01 | 0.001 | 0.014 | 0.002 | 0.006 | 0.014 | 0.001 | 0.002 | 0.001 | 0.001 | 0.001 |
| | SOU02 | 0.003 | 0.001 | 0.004 | 0.002 | 0.002 | 0.002 | 0.001 | 0.011 | 0.001 | 0.001 |
| South Peninsula | BOK02 | 0.118 | 0.080 | 0.020 | 0.008 | 0.088 | 0.009 | 0.011 | 0.018 | 0.097 | 0.007 |
| | BOK03 | 0.022 | 0.002 | 0.015 | 0.030 | 0.001 | 0.005 | 0.002 | 0.003 | 0.040 | 0.001 |
| | SCH02 | 0.002 | | | 0.001 | | 0.012 | 0.001 | | 0.001 | 0.001 |
| | SCH04 | 0.002 | | 0.001 | 0.002 | | 0.003 | 0.001 | 0.001 | 0.016 | 0.001 |
| Zeekoe | LR02 | 0.013 | 0.004 | 0.008 | 0.012 | 0.012 | 0.002 | 0.011 | 0.008 | 0.006 | 0.017 |
| | LR03 | 0.602 | 0.221 | 0.606 | 0.212 | 0.710 | 0.286 | 0.662 | 0.097 | 0.663 | 0.354 |
| | LR05 | 0.358 | 0.093 | 0.103 | 0.178 | 0.011 | 0.079 | 0.249 | 0.111 | 0.020 | 0.279 |
| | LR06 | 0.006 | 0.002 | 0.024 | 0.001 | 0.003 | 0.002 | 0.006 | 0.002 | 0.002 | 0.002 |
| | LR07 | 0.561 | 0.021 | 0.012 | 0.192 | 0.013 | 0.056 | 0.044 | 0.028 | 0.009 | 0.143 |
| | LR08 | 0.163 | 0.010 | 0.069 | 0.158 | 0.041 | 0.103 | 0.111 | 0.047 | 0.128 | 0.192 |
| | LR10 | 0.025 | 0.005 | 0.059 | 0.005 | 0.033 | 0.004 | 0.003 | 0.004 | 0.044 | 0.010 |
| | RVIRD | 0.033 | 0.003 | 0.006 | 0.001 | 0.024 | 0.008 | 0.020 | 0.005 | 0.013 | 0.005 |
| | ZEV5 | 0.377 | 0.288 | 0.261 | 0.207 | 0.365 | 0.225 | 0.438 | 0.281 | 0.270 | 0.356 |

### VLEIS / DAMS

| SUBCATCHMENT | SITE | 2015 SUM | 2015 WIN | 2016 SUM | 2016 WIN | 2017 SUM | 2017 WIN | 2018 SUM | 2018 WIN | 2019 SUM | 2019 WIN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diep | PEV1 | 0.005 | 0.011 | 0.012 | 0.002 | 0.011 | 0.005 | 0.110 | 0.019 | 0.061 | 0.020 |
| | PEV2 | 0.030 | 0.002 | 0.001 | | 0.001 | 0.002 | 0.002 | 0.004 | 0.002 | 0.001 |
| | PEV3 | 0.003 | 0.011 | 0.001 | | 0.003 | 0.001 | 0.002 | 0.002 | 0.001 | 0.001 |
| | RTV02 | 0.019 | 0.002 | 0.005 | 0.017 | 0.016 | 0.006 | 0.023 | 0.008 | 0.026 | 0.011 |
| | RTV18 | 0.017 | | 0.040 | 0.014 | 0.058 | 0.032 | 0.023 | 0.009 | 0.182 | 0.037 |
| Elsieskraal | ANG01 | 0.002 | 0.001 | 0.006 | 0.004 | 0.003 | 0.001 | 0.006 | 0.004 | 0.009 | 0.001 |
| | ANG02 | 0.002 | 0.002 | 0.002 | 0.001 | 0.006 | 0.001 | 0.002 | 0.003 | 0.003 | 0.002 |
| | DOOR01 | 0.016 | 0.002 | 0.006 | 0.002 | 0.008 | 0.003 | 0.033 | 0.003 | 0.006 | 0.012 |
| | DOOR03 | 0.002 | 0.002 | 0.008 | 0.002 | 0.003 | 0.002 | 0.003 | 0.001 | 0.006 | 0.004 |
| Kuils | KHA01 | 0.258 | 0.098 | 0.115 | 0.123 | 0.280 | 0.230 | 0.379 | 0.059 | 0.278 | 0.198 |
| MPlain | KHA02 | 0.247 | 0.117 | 0.204 | 0.170 | 0.346 | 0.254 | 0.379 | 0.164 | 0.304 | 0.267 |
| Noordhoek | WV02 | 0.282 | 0.041 | 0.183 | 0.330 | 0.097 | 0.444 | 0.083 | 0.076 | 0.057 | 0.301 |
| | WV05 | 0.056 | 0.023 | | | 0.047 | | 0.098 | 0.040 | 0.044 | 0.155 |
| | WV11 | | | 0.679 | | 0.060 | 0.670 | | 0.028 | | 0.047 |
| Sand | LPVN | 0.012 | 0.023 | 0.003 | 0.001 | 0.015 | 0.004 | 0.003 | 0.002 | 0.004 | 0.001 |
| | LPVS | 0.002 | 0.002 | 0.002 | 0.001 | 0.002 | 0.007 | 0.002 | 0.003 | 0.002 | 0.001 |
| | LVO | 0.008 | 0.017 | 0.008 | 0.005 | 0.016 | 0.023 | 0.022 | 0.008 | 0.043 | 0.007 |
| | OOG01 | 0.046 | 0.003 | 0.002 | 0.003 | 0.005 | 0.004 | 0.003 | 0.004 | 0.006 | 0.001 |
| | PV03 | 0.033 | 0.001 | 0.005 | 0.004 | 0.018 | 0.005 | 0.003 | 0.005 | 0.003 | 0.001 |
| | PVweir | 0.007 | 0.001 | 0.006 | 0.001 | 0.015 | 0.009 | 0.003 | 0.002 | 0.005 | 0.001 |
| | ZA01S | 0.006 | 0.002 | 0.009 | 0.002 | 0.003 | 0.002 | 0.013 | 0.006 | 0.002 | 0.021 |
| | ZA02S | 0.004 | 0.001 | 0.010 | 0.003 | 0.008 | 0.015 | 0.009 | 0.004 | 0.001 | 0.002 |
| | ZA03S | | | 0.003 | | | | | | | |
| | ZA05S | 0.002 | 0.003 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.001 | 0.001 |
| | ZA08S | 0.004 | 0.002 | 0.011 | 0.006 | 0.027 | 0.003 | 0.034 | 0.008 | 0.003 | 0.003 |
| | ZA09S | 0.004 | 0.001 | 0.019 | 0.006 | 0.023 | 0.005 | 0.036 | 0.001 | 0.003 | 0.002 |
| | ZA10S | 0.004 | 0.001 | 0.002 | 0.005 | 0.005 | 0.003 | 0.009 | 0.002 | 0.002 | 0.001 |
| | ZA11S | 0.022 | 0.001 | 0.028 | 0.008 | 0.016 | 0.005 | 0.031 | 0.005 | 0.001 | 0.003 |
| | ZA12S | 0.013 | 0.003 | 0.005 | 0.005 | 0.006 | 0.002 | 0.016 | 0.007 | 0.002 | 0.003 |
| | ZA13S | 0.005 | 0.001 | 0.020 | 0.002 | 0.008 | 0.004 | 0.027 | 0.003 | 0.001 | 0.004 |
| | ZAweir | 0.001 | 0.001 | 0.002 | 0.001 | 0.004 | 0.002 | 0.002 | 0.006 | 0.001 | 0.001 |
| South Peninsula | GC02 | 0.001 | 0.002 | 0.001 | 0.006 | 0.003 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Zeekoe | RVweir | 0.004 | 0.003 | 0.005 | 0.002 | 0.004 | 0.001 | 0.001 | 0.003 | 0.002 | 0.001 |
| | ZEV1S | 0.079 | 0.009 | 0.027 | 0.176 | 0.035 | 0.015 | 0.064 | 0.026 | 0.040 | 0.070 |
| | ZEV2S | 0.134 | 0.017 | | 0.164 | | | | | | |
| | ZEV3S | 0.084 | 0.009 | 0.024 | 0.183 | 0.032 | 0.042 | 0.095 | 0.031 | 0.015 | 0.084 |
| | ZEV4S | 0.054 | | | 0.144 | | | | | | |

# MEDIAN TIN (mg N/L)

## RIVERS / STORMWATER

| SUBCATCHMENT | SITE | 2015 SUM | 2015 WIN | 2016 SUM | 2016 WIN | 2017 SUM | 2017 WIN | 2018 SUM | 2018 WIN | 2019 SUM | 2019 WIN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diep | MOS05 | 4.308 | 1.753 | 8.793 | 13.495 | 3.206 | 5.384 | 4.988 | 5.860 | 0.158 | 2.762 |
| | RTV01 | 0.551 | 1.440 | 1.097 | 1.438 | 4.692 | 8.790 | 0.396 | 3.169 | 1.750 | 1.736 |
| | RTV03 | 0.554 | 1.068 | 1.274 | 1.797 | 0.530 | 1.288 | 1.082 | 2.813 | 1.519 | 2.487 |
| | RTV04 | 0.392 | 0.802 | 1.251 | 1.284 | 2.130 | 1.687 | 2.459 | 1.746 | 1.457 | 3.729 |
| | RTV05 | 0.850 | 2.017 | 2.768 | 2.055 | 11.270 | 4.243 | 20.313 | 2.182 | 30.915 | 7.792 |
| | RTV06 | 0.158 | 1.297 | 0.205 | 1.858 | 0.170 | 1.644 | 2.102 | 1.862 | 0.391 | 1.893 |
| | RTV08 | 0.929 | 3.273 | 8.302 | 1.787 | 6.408 | 6.878 | 23.580 | 2.989 | 30.728 | 21.464 |
| | RTV09 | 0.232 | 1.943 | 0.588 | 2.166 | 0.649 | 1.751 | 5.968 | 1.527 | 26.697 | 6.034 |
| | RTV10 | 0.101 | 1.403 | 0.061 | 1.877 | 0.199 | 1.316 | 3.073 | 1.446 | 20.746 | 3.585 |
| | RTV11 | 1.139 | 2.357 | 3.532 | 2.806 | 22.659 | 4.675 | 11.802 | 3.998 | 26.124 | 22.303 |
| | RTV12 | 0.932 | 2.548 | 3.104 | 1.460 | 2.070 | 3.345 | 19.012 | 2.691 | 17.179 | 5.398 |
| | RTV14 | 24.875 | | 1.408 | 0.947 | | | | 3.141 | 0.514 | |
| | RTV22 | | | | | 46.810 | 2.516 | 59.225 | 12.690 | 11.551 | 38.300 |
| Eerste | EK08 | 0.434 | 0.441 | 0.305 | 0.997 | 0.777 | 0.899 | 1.035 | 1.179 | 15.025 | 1.554 |
| | EK11 | 20.245 | 11.447 | 23.391 | 11.617 | 24.765 | 16.505 | 27.883 | 12.730 | 30.917 | 15.890 |
| | EK12 | | | | | | | 27.133 | 8.835 | 28.584 | 8.829 |
| | EK13 | 19.054 | 5.158 | 17.437 | 6.768 | 2.504 | 7.334 | 3.637 | 1.816 | 1.261 | 1.727 |
| | EK15 | 1.568 | 4.049 | 2.689 | 3.112 | 3.091 | 2.424 | 1.222 | 3.474 | 1.874 | 3.774 |
| | EK16 | | | | | | | 50.332 | 46.633 | | |
| | EK17 | 24.597 | 14.587 | 29.416 | 16.806 | 33.637 | 22.007 | 31.252 | 12.878 | 33.803 | 17.232 |
| | EK18 | 2.967 | 0.742 | 1.709 | 0.859 | 0.974 | 0.936 | 21.148 | 2.621 | 10.959 | 1.299 |
| Elsieskraal | ELS_GW | 0.953 | 2.409 | 0.458 | 1.880 | 1.305 | 1.458 | 1.754 | 4.043 | 2.615 | 3.751 |
| | ELS08 | 0.383 | 0.584 | 0.266 | 1.926 | 0.960 | 0.838 | 3.037 | 3.530 | 1.585 | 1.978 |
| | ELS10 | 0.273 | 0.237 | 0.920 | 0.854 | 0.672 | 0.442 | 0.820 | 0.369 | 0.951 | 0.863 |
| Hout Bay | DR01 | 0.949 | 0.255 | 1.163 | 0.725 | 1.303 | 3.203 | 1.238 | 0.772 | 0.998 | 0.511 |
| | DR02 | 0.668 | 0.262 | 0.406 | 0.731 | 0.754 | 2.022 | 0.796 | 0.759 | 0.896 | 0.538 |
| | DR04 | 0.091 | 0.209 | 0.075 | 0.044 | 0.126 | 0.116 | 0.209 | 0.046 | 0.114 | 0.072 |
| | DR05 | | | | | 6.000 | | | | | |
| | DR06 | 0.044 | 0.206 | 0.125 | 0.116 | 0.162 | 0.093 | 0.185 | 0.133 | 0.158 | 0.136 |
| Kuils | EK03 | 3.784 | 9.814 | 5.207 | 9.602 | 3.549 | 7.358 | 2.754 | 7.283 | 4.120 | 9.275 |
| | EK04 | 1.596 | 5.923 | 0.662 | 5.580 | 2.351 | 3.415 | 1.384 | 3.983 | 0.675 | 5.872 |
| | EK05 | 4.152 | 7.893 | 7.905 | 7.891 | 6.037 | 6.644 | 5.186 | 4.624 | 17.785 | 20.316 |
| | EK09 | 4.506 | 8.623 | 7.820 | 8.127 | 9.064 | 6.086 | 6.740 | 5.002 | 18.741 | 7.976 |
| | EK19 | 1.074 | 1.239 | 1.012 | 1.384 | 1.691 | 1.506 | 2.367 | 1.497 | 1.167 | 2.083 |
| Lourens | LOU01 | 0.610 | 0.469 | 0.475 | 0.775 | 0.426 | 0.599 | 0.639 | 0.862 | 0.297 | 0.717 |
| | LOU02 | 0.335 | 0.392 | 0.261 | 0.610 | 0.414 | 0.480 | 0.535 | 0.753 | 0.143 | 0.591 |
| | LOU03 | 0.191 | 0.357 | 0.153 | 0.589 | 0.146 | 0.503 | 0.448 | 0.821 | 0.101 | 0.558 |
| | LOU04 | 0.146 | 0.401 | 0.083 | 0.547 | 0.373 | 0.587 | 0.525 | 0.622 | 0.142 | 0.540 |
| | LOU05 | 0.386 | 0.286 | 1.971 | 0.525 | 1.245 | 0.558 | 0.859 | 1.020 | 0.674 | 0.558 |
| | LOU06 | 0.074 | 0.068 | 0.054 | 0.075 | 0.074 | 0.224 | 0.129 | 0.060 | 0.096 | 0.113 |
| Lower Salt | NR01 | 0.676 | 1.949 | 0.449 | 2.447 | 1.780 | 1.412 | 1.235 | 3.337 | 2.532 | 3.866 |
| | NR02 | 6.472 | 6.527 | 6.477 | 7.399 | 7.353 | 11.022 | 8.175 | 9.758 | 7.566 | 8.920 |
| | NR03 | 6.882 | 8.652 | 9.879 | 8.202 | 11.485 | 16.009 | 19.114 | 17.421 | 9.462 | 15.436 |
| | NR04 | 10.753 | 10.231 | 15.379 | 12.612 | 18.630 | 14.594 | 21.269 | 19.737 | 22.920 | 15.459 |
| | NR06 | 9.810 | 8.157 | 11.786 | 10.150 | 13.957 | 11.356 | 19.985 | 14.142 | 17.929 | 22.861 |
| | NR07 | 9.693 | 8.673 | 11.907 | 8.880 | 13.805 | 11.619 | 17.392 | 15.957 | 16.510 | 13.263 |
| | NR08 | 0.523 | 0.705 | 0.211 | 0.472 | 0.341 | 0.375 | 0.770 | 0.645 | 0.302 | 0.608 |
| | NR09 | 8.151 | 7.686 | 9.462 | 7.935 | 11.281 | 8.994 | 18.596 | 11.880 | 13.692 | 10.657 |
| | NR10 | 6.907 | 7.684 | 9.128 | 4.553 | 10.092 | 9.039 | 12.995 | 12.258 | 8.661 | 11.522 |
| | NR11 | 0.183 | 0.588 | 0.193 | 1.251 | 0.849 | 0.969 | 1.032 | 2.511 | 0.740 | 1.808 |
| | NR15 | 12.920 | 5.060 | 11.278 | 11.112 | 12.114 | 24.112 | 20.625 | 28.818 | 14.929 | 20.835 |
| | NR16 | 0.500 | 0.384 | 2.667 | 0.715 | 8.472 | 3.409 | 12.950 | 10.395 | 9.804 | 6.921 |
| | NR17 | 4.740 | 7.250 | 6.015 | 4.508 | 20.712 | 12.915 | 9.986 | 10.752 | 9.906 | 10.536 |
| | NR22 | 0.068 | 0.244 | | 0.118 | 0.067 | 0.255 | | 0.290 | | 0.494 |
| | NR25 | | | | | 16.581 | | 18.858 | 18.290 | 22.232 | 16.560 |
| | NR26 | 16.250 | 8.702 | 20.104 | 14.191 | 17.771 | 29.816 | 26.331 | 24.960 | 15.219 | 23.947 |
| Mosselbank | MOS01 | 3.454 | 4.277 | 2.623 | 5.007 | 6.645 | 3.447 | 8.931 | 8.259 | 8.211 | 10.215 |
| | MOS02 | 3.338 | 0.447 | 4.555 | 4.333 | 3.935 | 3.191 | 7.594 | 10.344 | 8.268 | 9.542 |
| | MOS03 | 5.089 | 6.107 | 18.856 | 5.623 | 11.588 | 5.644 | 5.923 | 8.168 | 8.915 | 8.049 |
| | MOS04 | 0.070 | 2.393 | 0.119 | 3.737 | 0.133 | 0.995 | 0.247 | 2.398 | 3.177 | 1.862 |
| | MOS06 | 1.067 | 5.413 | 0.971 | 3.676 | 1.104 | 3.994 | 3.359 | 3.465 | 2.042 | 5.183 |
| | MOS07 | 9.699 | 5.767 | 7.646 | 7.419 | 3.617 | 3.197 | 2.437 | 6.318 | 1.515 | 4.867 |
| | MOS08 | 1.926 | 3.160 | 0.147 | 5.743 | 0.796 | 2.941 | 0.890 | 3.693 | 0.344 | 4.495 |
| | MOS09 | 45.856 | 25.929 | 51.476 | 31.807 | 33.091 | 37.931 | 26.384 | 10.664 | 25.824 | 28.094 |
| | MOSAH03 | | 0.945 | | 0.852 | | 0.981 | 1.061 | 3.822 | | 15.315 |
| | MOSTP4 | 30.935 | 12.565 | 12.705 | 11.741 | 6.892 | 11.628 | 5.125 | 9.270 | 44.471 | 30.044 |
| MPlain | KHA03 | 12.695 | 11.153 | 15.680 | 12.367 | 19.594 | 16.107 | 20.083 | 13.825 | 16.488 | 17.365 |
| | KHA04 | 12.700 | 11.433 | 15.823 | 11.750 | 19.698 | 17.301 | 19.551 | 14.025 | 18.476 | 17.121 |
| Sand | BM16 | 0.409 | 1.230 | 0.190 | | 0.904 | 0.932 | 0.036 | 0.986 | 5.305 | 2.384 |
| | BM17 | 0.496 | 0.099 | 1.208 | | 1.170 | 0.254 | 0.039 | 0.292 | 0.698 | 0.484 |
| | BM18 | 0.785 | 0.254 | 0.247 | | 0.475 | 0.216 | 0.085 | 0.098 | 0.084 | 0.949 |
| | CR01 | 0.268 | 1.316 | 0.195 | 1.881 | 0.652 | 1.496 | 0.683 | | 1.331 | 1.326 |
| | CR02 | 0.658 | 0.554 | 0.513 | 2.090 | 1.006 | 1.841 | 0.178 | 1.071 | 3.884 | 1.742 |
| | CR03 | 2.500 | 1.032 | 4.621 | 2.240 | 6.023 | 4.253 | 4.419 | 4.000 | 0.408 | 2.550 |
| | CR04 | 1.341 | 0.804 | 1.052 | 1.424 | 1.028 | 2.760 | | 9.327 | 0.910 | 1.812 |
| | CR05 | | | | | | 0.243 | | 0.475 | | |
| | CR06 | 0.291 | 0.637 | 0.107 | 0.472 | 2.768 | 0.404 | 0.194 | 1.327 | 0.585 | 0.392 |
| | CR16 | 0.692 | 0.623 | 0.676 | 0.546 | 0.497 | 0.509 | 0.480 | 0.600 | 0.478 | 0.338 |
| | CR20 | 0.093 | 0.682 | 0.067 | 0.455 | 0.197 | 0.447 | 0.235 | 0.705 | 0.120 | 0.305 |
| | CR21 | 0.567 | 1.543 | 1.154 | 1.693 | 0.409 | 1.285 | 1.229 | 1.292 | 2.220 | 1.756 |
| | CR22 | 0.132 | 1.096 | 0.030 | 0.580 | 0.085 | 0.403 | 0.220 | 0.613 | 0.115 | 0.618 |
| | DRRSC | 1.652 | 1.539 | 0.453 | 0.840 | 0.711 | 0.650 | 0.916 | 2.198 | 1.423 | 1.094 |
| | LPVMR | 0.095 | 0.279 | 0.061 | 0.102 | 0.130 | 0.177 | 0.090 | 0.194 | 0.168 | 0.086 |
| | LVI | 0.211 | 1.440 | 0.728 | 1.405 | 0.715 | 0.673 | 0.736 | 0.773 | 1.063 | 0.915 |
| | SCV | 2.681 | 2.729 | 3.013 | 4.430 | 2.706 | 4.910 | 6.273 | 14.210 | 4.541 | 6.591 |
| Silvermine | SIL02 | 0.074 | 0.147 | 0.075 | 0.049 | 0.187 | 0.166 | 0.129 | 0.112 | 0.066 | 0.173 |
| | SIL04 | 0.224 | 0.087 | 0.100 | 0.071 | 0.128 | 0.180 | 0.133 | 0.126 | 0.133 | 0.235 |
| | SIL06 | 0.062 | 0.033 | 0.062 | 0.040 | 0.158 | 0.133 | 0.092 | 0.132 | 0.066 | 0.143 |
| SLPass | SIR01 | 0.224 | 0.253 | 0.294 | 0.227 | 0.240 | 0.305 | 0.795 | 0.533 | 0.404 | 0.507 |
| | SIR02 | 0.288 | 0.386 | 1.498 | 0.678 | 2.829 | 0.859 | 3.203 | 2.107 | 0.586 | 1.436 |
| | SIR03 | 0.306 | 0.524 | 17.004 | 0.605 | 2.739 | 1.646 | 2.031 | 2.260 | 2.483 | 1.064 |
| | SIR04 | | 0.413 | | 0.070 | | | 1.873 | 1.399 | | 0.146 |
| | SIR05 | 0.468 | 0.567 | 0.554 | 0.644 | 0.203 | 0.398 | 1.194 | 0.661 | 0.487 | 0.661 |
| | SIR06 | 0.637 | 0.647 | 0.920 | 1.927 | 6.008 | 3.073 | 2.139 | 1.300 | 0.726 | 3.413 |
| | SIR07 | 2.738 | 1.309 | 0.772 | 2.515 | 4.116 | 2.960 | 1.116 | 1.581 | 0.332 | 3.200 |
| Soet | SOE02 | 2.748 | 4.663 | 11.598 | 4.575 | 20.524 | 11.223 | 14.552 | 6.341 | 31.825 | 17.490 |
| | SOE04 | 0.383 | 0.283 | 0.195 | 0.374 | 1.522 | 3.002 | 1.428 | 2.054 | 2.735 | |
| | SOEAH06 | 0.563 | 1.058 | 0.459 | 0.623 | 0.536 | 1.087 | 0.316 | 1.329 | 0.096 | 0.281 |
| | SOEAH10 | 23.820 | 17.140 | 38.755 | 20.909 | 19.041 | 38.503 | 47.525 | 25.485 | 45.849 | 57.877 |
| | SOEAH11 | 0.164 | 1.108 | 0.732 | 0.540 | 0.739 | 0.569 | 2.458 | 0.645 | 0.375 | 0.342 |
| | SOEAH12 | 9.202 | 4.527 | 20.638 | 6.123 | 23.398 | 13.168 | 15.457 | 6.649 | 22.087 | 10.766 |
| Sout | SOU01 | 0.339 | 2.225 | 0.317 | 2.503 | 0.721 | 2.130 | 0.303 | 3.908 | 0.155 | 0.660 |
| | SOU02 | 0.094 | 1.757 | 0.329 | 2.381 | 0.122 | 1.613 | 0.135 | 6.608 | 0.130 | 0.452 |
| South Peninsula | BOK02 | 7.161 | 1.039 | 0.995 | 1.998 | 0.964 | 1.444 | 1.077 | 1.915 | 46.326 | 2.391 |
| | BOK03 | 2.361 | 1.468 | 1.634 | 0.889 | 0.435 | 0.920 | 1.702 | 2.391 | 5.401 | 1.120 |
| | SCH01 | | | | 0.051 | | | | | | |
| | SCH02 | 0.111 | 0.094 | 0.121 | 0.067 | 0.173 | 0.141 | 0.154 | 0.228 | 0.093 | 0.147 |
| | SCH04 | 1.081 | 0.942 | 1.263 | 0.194 | 0.130 | 1.042 | 0.637 | 2.026 | 2.648 | 3.071 |
| Zeekoe | LR02 | 0.507 | 1.243 | 0.616 | 0.594 | 0.684 | 0.215 | 0.466 | 0.777 | 0.483 | 1.021 |
| | LR03 | 25.535 | 14.269 | 19.634 | 12.574 | 26.825 | 21.266 | 28.583 | 10.512 | 31.425 | 24.981 |
| | LR05 | 16.190 | 5.888 | 2.712 | 11.593 | 0.451 | 8.971 | 11.325 | 8.744 | 1.518 | 20.361 |
| | LR06 | 0.144 | 1.595 | 0.398 | 1.396 | 0.310 | 0.529 | 0.724 | 0.981 | 1.237 | 0.722 |
| | LR07 | 15.267 | 3.530 | 0.290 | 10.893 | 0.239 | 5.513 | 1.425 | 3.705 | 1.002 | 11.404 |
| | LR08 | 2.777 | 1.338 | 3.775 | 10.633 | 1.444 | 6.321 | 5.315 | 4.840 | 5.002 | 14.473 |
| | LR10 | 0.370 | 1.266 | 0.643 | 1.628 | 0.971 | 0.800 | 0.737 | 2.149 | 1.585 | 2.698 |
| | RVIRD | 4.491 | 0.383 | 3.757 | 1.453 | 3.744 | 1.047 | 4.393 | 1.035 | 5.745 | 3.506 |
| | ZEV5 | 21.830 | 21.093 | 18.369 | 21.518 | 19.725 | 17.503 | 29.294 | 26.709 | 24.930 | 33.345 |

## VLEIS / DAMS

| SUBCATCHMENT | SITE | 2015 SUM | 2015 WIN | 2016 SUM | 2016 WIN | 2017 SUM | 2017 WIN | 2018 SUM | 2018 WIN | 2019 SUM | 2019 WIN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diep | PEV1 | 0.170 | 1.132 | 0.945 | 0.742 | 0.447 | 0.751 | 5.835 | 2.627 | 1.605 | 2.357 |
| | PEV2 | 0.058 | 0.152 | 0.120 | 0.235 | 0.127 | 0.145 | 0.420 | 0.687 | 0.141 | 0.080 |
| | PEV3 | 0.488 | 0.167 | 0.105 | 0.070 | 0.340 | 0.099 | 0.110 | 0.219 | 0.168 | 0.232 |
| | RTV02 | 0.095 | 0.037 | 0.043 | 0.186 | 0.153 | 0.067 | 0.157 | 0.228 | 0.225 | 0.474 |
| | RTV18 | 0.968 | | 1.672 | 2.930 | 1.732 | 2.902 | 0.846 | 1.636 | 24.472 | 6.331 |
| Elsieskraal | ANG01 | 0.055 | 0.161 | 0.082 | 0.267 | 0.083 | 0.148 | 0.128 | 0.215 | 0.055 | 0.191 |
| | ANG02 | 0.073 | 0.232 | 0.077 | 0.235 | 0.286 | 0.207 | 0.168 | 0.150 | 0.120 | 0.240 |
| | BM01 | 0.053 | 0.018 | 0.206 | 0.045 | 1.982 | 0.179 | 0.066 | 0.151 | 0.051 | 0.382 |
| | BM02 | 0.044 | 0.240 | 0.082 | 0.065 | 0.269 | 0.066 | 0.116 | 0.780 | 0.044 | 0.498 |
| | BM03 | 0.145 | 0.309 | 0.225 | 0.139 | | 0.576 | 0.066 | 0.634 | 0.815 | 0.386 |
| | DOOR01 | 0.918 | 0.556 | 1.274 | 1.492 | 1.260 | 0.768 | 3.058 | 2.694 | 5.192 | 4.452 |
| | DOOR03 | 0.053 | 0.115 | 0.067 | 0.169 | 0.098 | 0.178 | 0.128 | 0.117 | 0.058 | 0.146 |
| Kuils | KHA01 | 9.995 | 11.643 | 7.264 | 7.974 | 14.949 | 13.562 | 19.689 | 10.725 | 12.988 | 14.485 |
| Mosselbank | BM04 | 0.212 | 0.387 | 6.581 | 0.132 | 0.795 | 0.268 | 0.040 | 0.514 | 0.058 | 0.168 |
| MPlain | KHA02 | 11.354 | 7.945 | 11.465 | 10.425 | 15.713 | 13.413 | 19.303 | 14.638 | 13.966 | 13.302 |
| Noordhoek | WV02 | 2.020 | 2.509 | 8.611 | 12.886 | 3.568 | 20.992 | 1.312 | 3.339 | 5.417 | 28.293 |
| | WV05 | 0.080 | 2.354 | | | 0.298 | | 1.512 | 2.322 | 3.680 | 19.790 |
| | WV11 | | | 3.104 | | 1.927 | 20.971 | | 1.846 | | 30.087 |
| Sand | BM11 | 0.082 | 0.040 | 0.047 | 0.063 | | 0.190 | 0.082 | 0.673 | 0.225 | 0.086 |
| | LPVN | 0.059 | 0.237 | 0.051 | 0.060 | 0.122 | 0.140 | 0.127 | 0.082 | 0.063 | 0.084 |
| | LPVS | 0.478 | 1.314 | 0.273 | 0.613 | 0.552 | 1.140 | 0.522 | 2.147 | 0.646 | 0.686 |
| | LVO | 0.208 | 1.292 | 0.261 | 0.613 | 0.235 | 0.919 | 0.667 | 0.827 | 0.839 | 0.368 |
| | OOG01 | 0.073 | 0.084 | 0.097 | 0.054 | 0.180 | 0.156 | 0.617 | 1.229 | 1.040 | 0.365 |
| | PV03 | 0.125 | 0.069 | 0.048 | 0.072 | 0.156 | 0.310 | 0.164 | 0.143 | 0.048 | 0.208 |
| | PVweir | 0.065 | 0.030 | 0.085 | 0.044 | 0.137 | 0.282 | 0.110 | 0.166 | 0.081 | 0.151 |
| | ZA01S | 0.078 | 0.030 | 0.117 | 0.033 | 0.069 | 0.083 | 0.092 | 0.244 | 0.110 | 0.381 |
| | ZA02S | 0.046 | 0.030 | 0.128 | 0.083 | 0.077 | 0.092 | 0.139 | 0.064 | 0.098 | 0.327 |
| | ZA03S | | | 0.074 | | | | | | 0.171 | |
| | ZA05S | 0.052 | 0.053 | 0.091 | 0.216 | 0.040 | 0.113 | 0.104 | 0.085 | 0.073 | 0.122 |
| | ZA08S | 0.047 | 0.038 | 0.063 | 0.111 | 0.090 | 0.078 | 0.086 | 0.072 | 0.057 | 0.129 |
| | ZA09S | 0.054 | 0.030 | 0.069 | 0.044 | 0.092 | 0.088 | 0.142 | 0.049 | 0.065 | 0.138 |
| | ZA10S | 0.052 | 0.030 | 0.148 | 0.035 | 0.134 | 0.174 | 0.221 | 0.117 | 0.070 | 0.152 |
| | ZA11S | 0.125 | 0.030 | 0.066 | 0.057 | 0.061 | 0.117 | 0.088 | 0.050 | 0.053 | 0.168 |
| | ZA12S | 0.072 | 0.048 | 0.058 | 0.061 | 0.061 | 0.085 | 0.101 | 0.159 | 0.060 | 0.175 |
| | ZA13S | 0.041 | 0.030 | 0.055 | 0.068 | 0.062 | 0.080 | 0.090 | 0.052 | 0.068 | 0.159 |
| | ZAweir | 0.060 | 0.066 | 0.084 | 0.161 | 0.114 | 0.062 | 0.077 | 0.191 | 0.078 | 0.114 |
| South Peninsula | GC02 | 0.076 | 0.135 | 0.066 | 0.134 | 0.136 | 0.116 | 0.292 | 0.178 | 0.060 | 0.151 |
| Zeekoe | BM08 | 0.196 | 9.948 | 0.513 | 1.889 | 0.670 | 1.354 | 14.386 | 6.057 | 3.691 | |
| | BM09 | 0.230 | 4.387 | 0.133 | 2.227 | 0.708 | 7.002 | 1.865 | 4.165 | 4.876 | |
| | BM12 | 0.082 | 2.828 | 0.295 | 0.068 | 0.233 | 0.278 | 0.186 | 0.145 | 0.192 | 0.223 |
| | BM13 | 0.646 | 0.051 | 0.969 | 4.173 | 0.685 | 1.772 | 0.168 | 0.267 | 0.225 | 0.074 |
| | BM14 | 0.191 | 1.913 | 0.285 | 5.081 | 0.350 | 4.740 | 0.161 | 0.694 | 0.163 | 7.827 |
| | RVweir | 0.097 | 0.112 | 0.233 | 0.072 | 0.169 | 0.157 | 0.086 | 0.317 | 0.201 | 0.658 |
| | ZEV1S | 0.442 | 0.584 | 0.128 | 5.103 | 0.132 | 0.138 | 0.326 | 0.422 | 0.171 | 0.732 |
| | ZEV2S | 0.895 | 1.235 | | 13.140 | | | | | | |
| | ZEV3S | 0.325 | 0.088 | 0.073 | 5.181 | 0.143 | 0.560 | 0.209 | 1.338 | 0.335 | 1.505 |
| | ZEV4S | 0.653 | | | 6.299 | | | | | | |

# AVERAGE E. COLI (cfu/ 100 ml)

## RIVERS / STORMWATER

| SUBCATCHMENT | SITE | 2015 SUM | 2015 WIN | 2016 SUM | 2016 WIN | 2017 SUM | 2017 WIN | 2018 SUM | 2018 WIN | 2019 SUM | 2019 WIN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diep | MOS05 | 656 | 50727 | 18000 | 503128 | 2895 | 6464 | 908 | 96235 | 75975 | 7305 |
| | RTV01 | 20072 | 2130 | 1700 | 2119 | 300 | 51983 | 16094 | 157314 | 2294 | 400 |
| | RTV03 | 657530 | 27932 | 242100 | 11935 | 63560 | 103570 | 68948 | 11462 | 2063533 | 252450 |
| | RTV04 | 17133 | 59967 | 520317 | 59729 | 257033 | 118267 | 285067 | 612600 | 1026500 | 680733 |
| | RTV05 | 51178 | 26294 | 5089 | 6711 | 89494 | 10978 | 108708 | 626 | 10650000 | 22420 |
| | RTV06 | 376 | 1085 | 391 | 5883 | 339 | 373 | 780 | 3395 | 727 | 353 |
| | RTV08 | 11244 | 750 | 1366 | 16079 | 300 | 5620 | 15938 | 1182 | 12824 | 320 |
| | RTV09 | 12677 | 90640 | 18433 | 27126 | 32433 | 20222 | 7657 | 1784 | 56868 | 32700 |
| | RTV10 | 1632 | 14518 | 8104 | 10285 | 1042 | 9933 | 1167 | 4412 | 51177 | 10471 |
| | RTV11 | 60232 | 25463 | 57860 | 2780 | 24590 | 5543 | 20013 | 22800 | 729920 | 137333 |
| | RTV12 | 19850 | 692287 | 106633 | 16673 | 64100 | 16025 | 174450 | 18300 | 13400000 | 94175 |
| | RTV14 | 410000 | | 300 | 18087 | | | | | 23400 | |
| | RTV22 | | | | | 7771667 | 6017614 | 735820 | 2772357 | 1213333 | 1353729 |
| Eerste | EK08 | 100368 | 2565 | 1264 | 1861 | 29025 | 7230 | 29593 | 17134 | 6614 | 1038 |
| | EK11 | 106293 | 68900 | 84155 | 2270 | 32167 | 14050 | 19471 | 26686 | 21660 | 2442 |
| | EK12 | | | | | | | 6000 | 850 | 5360 | 2200 |
| | EK13 | 6050 | 1120 | 690 | 3369 | 540 | 1897 | 764 | 6346 | 846 | 2608 |
| | EK15 | 127420 | 30150 | 72198 | 144867 | 2997000 | 166917 | 682980 | 1949833 | 6023880 | 444500 |
| | EK16 | | | | | | | 2362 | 440 | | |
| | EK17 | 24500 | 41683 | 88050 | 22383 | 52867 | 17950 | 65800 | 30883 | 51840 | 17580 |
| | EK18 | 62152 | 1915 | 63002 | 5464 | 2148 | 60533 | 1484 | 9563 | 27095 | 5024 |
| Elsieskraal | ELS_GW | 234600 | 318733 | 107620 | 160400 | 300183 | 50950 | 923040 | 170700 | 162500 | 161500 |
| | ELS08 | 72517 | 113244 | 33814 | 65406 | 289250 | 84589 | 982400 | 220000 | 637447 | 207200 |
| | ELS10 | 26364 | 838 | 10298 | 95435 | 1513 | 3240 | 856 | 568 | 643 | 11050 |
| Hout Bay | DR01 | 165967 | 11947 | 29263 | 43450 | 106333 | 646333 | 165233 | 26687 | 553867 | 73189 |
| | DR02 | 609567 | 2710 | 9846 | 48422 | 146150 | 180820 | 591293 | 33400 | 1052000 | 113233 |
| | DR04 | 156 | 112 | 112 | 145 | 101 | 71 | 179 | 4466 | 230 | 405 |
| | DR05 | 24170 | 7150 | 8084 | 11696 | 38271 | 62990 | 62174 | 5736 | 51403 | 9853 |
| | DR06 | 864 | 333 | 880 | 437 | 365 | 335 | 804 | 1720 | 174 | 1402 |
| Kuils | EK03 | 12696 | 1168 | 168 | 334 | 584 | 1457 | 400 | 7903 | 192716 | 2283 |
| | EK04 | 85517 | 2181 | 2318 | 2683 | 148940 | 22067 | 88180 | 14862 | 13028 | 1268 |
| | EK05 | 179000 | 3980 | 249517 | 32967 | 490833 | 125900 | 193400 | 361833 | 378800 | 1031283 |
| | EK09 | 302667 | 11518 | 19198 | 19867 | 712217 | 63733 | 122067 | 166783 | 237800 | 35617 |
| | EK19 | 218607 | 3075 | 28563 | 3921 | 69783 | 12233 | 705340 | 17550 | 10406 | 51122 |
| Lourens | LOU01 | 182 | 225 | 220 | 116 | 175 | 122 | 80 | 39 | 113 | 358 |
| | LOU02 | 326 | 265 | 364 | 554 | 869 | 367 | 229 | 148 | 370 | 207 |
| | LOU03 | 1944 | 445 | 480 | 188 | 346 | 750 | 1230 | 152 | 346 | 2155 |
| | LOU04 | 443 | 3660 | 7200 | 1874 | 500 | 387 | 1550 | 738 | 1108 | 630 |
| | LOU05 | 997 | 44034 | 16333 | 5869 | 717 | 4838 | 52350 | 637 | 146017 | 2059 |
| | LOU06 | 24 | 66 | 22 | 14 | 268 | 9 | 13 | 27 | 28 | 34 |
| Lower Salt | NR01 | 2924000 | 1050550 | 2132000 | 761500 | 717000 | 70500 | 217160 | 1078286 | 1423400 | 986500 |
| | NR02 | 31200 | 309533 | 42820 | 302283 | 247500 | 405317 | 152380 | 542183 | 7669800 | 1071500 |
| | NR03 | 945000 | 62807 | 944500 | 302167 | 2350000 | 1115000 | 3478333 | 735571 | 3382667 | 7726667 |
| | NR04 | 16950 | 28534 | 208500 | 162735 | 34733 | 85417 | 582667 | 4407486 | 1069556 | 1558167 |
| | NR06 | 5397 | 116775 | 36317 | 41867 | 196750 | 81327 | 752000 | 295529 | 1173600 | 1361667 |
| | NR07 | 1238 | 18317 | 6067 | 32673 | 227267 | 67050 | 228625 | 170429 | 742000 | 948333 |
| | NR08 | 813 | 5153 | 315 | 27362 | 1468 | 3125 | 9866 | 1447 | 1842 | 2905 |
| | NR09 | 310 | 13542 | 7143 | 44307 | 45650 | 72062 | 20480 | 119267 | 103560 | 148017 |
| | NR10 | 8707 | 27470 | 6110 | 49223 | 20617 | 69217 | 91983 | 77350 | 102900 | 223067 |
| | NR11 | 50812 | 29294 | 2568 | 17583 | 85333 | 25735 | 77060 | 505463 | 78325 | 24483 |
| | NR15 | 3550000 | 799056 | 3972000 | 3716633 | 2031667 | 1786667 | 28936000 | 1471667 | 3174000 | 11178333 |
| | NR16 | 114400 | 55494 | 732000 | 177006 | 9955000 | 412667 | 8264000 | 2716333 | 16680000 | 19945000 |
| | NR17 | 5720650 | 1625000 | 259300 | 1136583 | 910833 | 2031133 | 796400 | 1669167 | 1241300 | 375672 |
| | NR22 | 13576 | 563 | 1338 | 13858 | 1135 | 1260 | 530 | 843 | 956 | 55640 |
| | NR25 | | | 11000 | 36200 | 325000 | | 676267 | 698200 | 1538000 | 2888333 |
| | NR26 | 224167 | 331800 | 783000 | 241650 | 1583333 | 1685000 | 5636333 | 404556 | 1673000 | 3261667 |
| Mosselbank | MOS01 | 14733 | 256052 | 61267 | 103349 | 1474000 | 57767 | 5307167 | 527833 | 956000 | 81430 |
| | MOS02 | 2100 | 36000 | 580 | 51857 | 803333 | 26475 | 1026167 | 603833 | 674800 | 179917 |
| | MOS03 | 945 | 8708 | 730 | 3330 | 12467 | 3352 | 105193 | 7337 | 77675 | 13324 |
| | MOS04 | 224 | 367 | 162 | 5967 | 490 | 288 | 378 | 3280 | 12196 | 1310 |
| | MOS06 | 1657 | 2253 | 480 | 5954 | 1105 | 8668 | 860 | 16382 | 1795 | 1165 |
| | MOS07 | 2075 | 2175 | 1650 | 1024 | 4433 | 244 | 13590 | 2526 | 12433 | 3268 |
| | MOS08 | 1462 | 4058 | 1315 | 2913 | 1256 | 605 | 68725 | 6898 | 22568 | 1560 |
| | MOS09 | 9907 | 11200 | 1860 | 10467 | 738 | 11142 | 36000 | 7663 | 14225 | 648 |
| | MOSAH03 | | 454 | | 13430 | | 382 | 682 | 160725 | | 95600 |
| MPlain | KHA03 | 7026667 | 4446667 | 2805000 | 19768333 | 10600000 | 3520000 | 3390000 | 5340000 | 9916667 | 8566667 |
| | KHA04 | 54271667 | 4526667 | 3241667 | 13445000 | 4433333 | 7860000 | 4383333 | 6980000 | 3670000 | 12686667 |
| Sand | BM16 | 6940 | 4360 | 84 | | 100 | 23300 | 9930 | 67000 | 79000 | 500 |
| | BM17 | 35575 | 470 | 44 | | 88000 | 150017 | 100 | 88000 | 72000 | 300 |
| | BM18 | 64030 | 140 | 890 | | 68000 | 450 | 80 | 2700 | 2600 | 300 |
| | CR01 | 1042 | 26253 | 79 | 427 | 657 | 3493 | 1405 | | 718 | 5262 |
| | CR02 | 133 | 4367 | 134 | 624 | 5997 | 2337 | 20 | 1016 | 1480 | 1026 |
| | CR03 | 294 | 3427 | 536 | 1069 | 5946 | 1127 | 890 | 743 | 447 | 533 |
| | CR04 | 115000 | 28850 | 58077 | 19627 | 29000 | 176663 | | 2285000 | 3200 | 6400 |
| | CR05 | | | | | | 1300 | | 178 | | |
| | CR06 | 5549 | 1443 | 324 | 422 | 318 | 5820 | 235 | 1012 | 790 | 2577 |
| | CR16 | 5900 | 3617 | 1820 | 8063 | 1083 | 3175 | 14305 | 53122 | 750583 | 13536 |
| | CR20 | 328 | 5664 | 771 | 625 | 1023 | 10168 | 17754 | 5972 | 152 | 895 |
| | CR21 | 12711 | 41183 | 11145 | 10150 | 5647 | 34233 | 24929 | 1099060 | 3267 | 20817 |
| | CR22 | 184 | 19625 | 61 | 292 | 1177 | 490 | 3013 | 392 | 130 | 747 |
| | DRRSC | 157380 | 54250 | 232900 | 136133 | 34900 | 145500 | 71720 | 183422 | 210900 | 566300 |
| | LPVMR | 162 | 223 | 84 | 40 | 352 | 1233 | 3852 | 5408 | 834 | 29 |
| | LVI | 5071 | 1837 | 60741 | 5172 | 2928 | 501897 | 5756 | 9640 | 114120 | 15533 |
| | SCV | 14300 | 21080 | 13665 | 10367 | 5115 | 79650 | 75020 | 1106683 | 312600 | 68000 |
| Silvermine | SIL02 | 45 | 41 | 41 | 47 | 46 | 37 | 159 | 73 | 129 | 42 |
| | SIL04 | 447 | 260 | 69 | 147 | 315 | 34 | 155 | 202 | 1223 | 66 |
| | SIL06 | 189 | 154 | 278 | 212 | 1740 | 4911 | 3296 | 451 | 956 | 5455 |
| SLPass | SIR01 | 138 | 170 | 201 | 276 | 370 | 6383 | 22160 | 1968 | 52680 | 24450 |
| | SIR02 | 2122 | 5152 | 9180 | 1835 | 794000 | 19967 | 2038860 | 1014500 | 602654 | 144167 |
| | SIR03 | 887 | 5688 | 218283 | 1424 | 18650 | 579483 | 639932 | 1007533 | 37500 | 510300 |
| | SIR04 | | 2900 | | 110 | | | 21517 | 43000 | | 247 |
| | SIR05 | 374 | 10963 | 51952 | 17668 | 553 | 3600 | 67360 | 10878 | 368 | 11674 |
| | SIR06 | 2098 | 10967 | 261 | 368 | 826 | 1180 | 18008 | 2157 | 538 | 917 |
| | SIR07 | 650 | 3597 | 516 | 393 | 2008 | 438 | 9420 | 7337 | 13728 | 1718 |
| Soet | SOE02 | 12135 | 165733 | 28520 | 18708 | 139317 | 565167 | 1146367 | 1444500 | 1301600 | 335667 |
| | SOE04 | 160500 | 8780 | 50000 | 2110 | 119000 | 26267 | 16450 | 3425 | 5850 | |
| | SOEAH06 | 368 | 15368 | 4518 | 274 | 7403 | 6151 | 6946 | 1356 | 39 | 478 |
| | SOEAH10 | 990000 | 1706333 | 1446667 | 404000 | 1580000 | 3560000 | 467000 | 1635000 | 34990000 | 600000 |
| | SOEAH11 | 1260 | 105 | 1105 | 1134 | 1321 | 522 | 15000 | 4933 | 333 | 5800 |
| | SOEAH12 | 788960 | 106700 | 334083 | 769833 | 9533333 | 3275000 | 3608000 | 5253333 | 21616667 | 4630000 |
| Sout | SOU01 | 73 | 113 | 78 | 454 | 381 | 123 | 516 | 119 | 17468 | 170 |
| | SOU02 | 4820 | 2478 | 1765 | 2277 | 933 | 319 | 795 | 990 | 5743 | 1347 |
| South Peninsula | BOK02 | 6303333 | 279520 | 528500 | 1029250 | 103250 | 65966 | 24860 | 199167 | 904680 | 602900 |
| | BOK03 | 60157 | 22280 | 15942 | 3218 | 60928 | 355 | 42280 | 300518 | 612244 | 14906 |
| | SCH01 | | | | 5200 | | | | | | |
| | SCH02 | 622 | 476 | 3280 | 4524 | 56 | 16 | 2135 | 887 | 578 | 121 |
| | SCH04 | 3943 | 340 | 53 | 264 | 460 | 55 | 80 | 301 | 60 | 175 |
| Zeekoe | LR02 | 12633 | 1153 | 7054 | 7335 | 28938 | 8050 | 122120 | 6805 | 88200 | 7352 |
| | LR03 | 165814286 | 9780000 | 5188000 | 2875000 | 65066667 | 4078333 | 10860000 | 6774273 | 11440000 | 55033333 |
| | LR05 | 6058833 | 345908 | 143587 | 1049333 | 880960 | 1343760 | 6060727 | 1690833 | 12247 | 564006 |
| | LR06 | 12300 | 2994 | 22100 | 7750 | 5488 | 3073 | 61820 | 10280 | 2030 | 7107 |
| | LR07 | 639333 | 168489 | 22840 | 452167 | 337117 | 557400 | 1650420 | 5440167 | 22220 | 560583 |
| | LR08 | 240996 | 15087 | 53096 | 1317857 | 71240 | 579733 | 1090883 | 619967 | 10435 | 2500883 |
| | LR10 | 74417 | 16260 | 18365 | 30300 | 42683 | 16733 | 19750 | 19933 | 11539 | 71733 |
| | LR13 | | 490000 | | | | | | | | |
| | LR14 | | 14100000 | | | | | | | | |
| | LR15 | | 1320000 | | | | | | | | |
| | LR16 | | 1430000 | | | | | | | | |
| | RVIRD | 69858 | 45912 | 1548 | 45778 | 8543 | 4374 | 10840 | 55788 | 3488 | 11867 |
| | ZEV5 | 13 | 1 | 3 | 13 | 15 | 5342 | 2 | 8 | 6 | 4 |

## VLEIS / DAMS

| SUBCATCHMENT | VLEI NAME | SITE | 2015 SUM | 2015 WIN | 2016 SUM | 2016 WIN | 2017 SUM | 2017 WIN | 2018 SUM | 2018 WIN | 2019 SUM | 2019 WIN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diep | Rietvlei | RTV02 | 76 | 144 | 52 | 40 | 622 | 196 | 955 | 415 | 14 | 402 |
| | | RTV18 | 1398600 | | 952 | 116390 | 63292 | 60282 | 8700 | 6017 | 158333 | 16875 |
| | Zoarvlei | PEV1 | 54 | 8530 | 965 | 6863 | 1652 | 72348 | 6377 | 52663 | 102 | 63800 |
| | | PEV2 | 264 | 3093 | 65 | 919 | 71 | 7658 | 110 | 253 | 128 | 1148 |
| | | PEV3 | 948 | 337 | 596 | 737 | 351 | 1224 | 265 | 126 | 187 | 67 |
| Elsieskraal | Elsieskraal da | ANG01 | 61 | 612 | 48 | 264 | 62 | 885 | 37 | 964 | 310 | 1668 |
| | | ANG02 | 260 | 735 | 161 | 136 | 93 | 137 | 67 | 352 | 79 | 1030 |
| | | BM01 | 44 | 63 | 18 | 43 | 67 | 26 | 11 | 14 | 135 | 19 |
| | | BM02 | 31 | 76 | 34 | 44 | 1062 | 11 | 46 | 31 | 1300 | 305 |
| | | BM03 | 72 | 97 | 910 | 910 | | 7 | 6700 | 2417 | 120 | 1600 |
| | | DOOR01 | 7082 | 2854 | 8373 | 1474 | 38185 | 18493 | 14200 | 2746 | 15598 | 129335 |
| | | DOOR03 | 246 | 438 | 112 | 54 | 15 | 31 | 73 | 144 | 20 | 6000 |
| Kuils | Mew Way DP | KHA01 | 24423333 | 10050000 | 14200000 | 3402000 | 21666667 | 10833333 | 5623333 | 3722000 | 11183333 | 15860000 |
| Mosselbank | Uitkamp | BM04 | 4785 | 257 | 26 | 80 | 300 | 111 | 92 | 741 | 40 | 119 |
| MPlain | Mplain DP | KHA02 | 66356667 | 3703333 | 16250000 | 15193333 | 19850000 | 15771429 | 6733333 | 8500000 | 23233333 | 18616667 |
| Noordhoek | Wildevoelvlei | WV02 | 8 | 895 | 60 | 186 | 1238 | 104 | 4284 | 1146 | 58 | 489 |
| | | WV05 | 11 | 284 | | | 10009 | | 10 | 104 | 37 | 103 |
| | | WV08 | 50105 | 300 | 1434 | 396 | 1708 | 574 | 1681 | 2076 | 5584 | 549 |
| | | WV11 | | | 77 | | 70 | 89 | | 56 | | 200 |
| Sand | Die Oog | OOG01 | 547 | 2251 | 1783 | 172 | 1210 | 339 | 757 | 570 | 387 | 1563 |
| | Langevlei | LVO | 935 | 207 | 168 | 777 | 2395 | 2628 | 5079 | 3422 | 6003 | 468 |
| | Little Princess | LPVN | 47 | 27 | 167 | 78 | 51 | 644 | 89 | 110 | 291 | 11 |
| | | LPVS | 62727 | 11490 | 673 | 3823 | 62135 | 60162 | 8085 | 70117 | 658 | 4130 |
| | Princessvlei | PV03 | 60 | 1261 | 20 | 37 | 314 | 262 | 11 | 224 | 67 | 740 |
| | | PVweir | 80 | 1107 | 71 | 38 | 91 | 258 | 116 | 201 | 97 | 773 |
| | Psoralea Park | BM11 | 3100 | 8 | 460 | 217 | | 6900 | 1400 | 24046 | 3 | 10 |
| | Westlake | ZA10S | 13 | 1560 | 41 | 77 | 6514 | 195 | 209 | 40 | 8897 | 158 |
| | Zandvlei | ZA01S | 16 | 727 | 16 | 112 | 22 | 1632 | 3426 | 1034 | 1136 | 2812 |
| | | ZA02S | 49 | 587 | 14 | 440 | 12 | 5921 | 3384 | 3594 | 725 | 4015 |
| | | ZA03S | | | 31 | | | | 16 | 290 | 30 | |
| | | ZA04S | | | | | | | | | | 820 |
| | | ZA05S | 117 | 5183 | 629 | 1054 | 170 | 1281 | 228 | 3157 | 295 | 1442 |
| | | ZA06S | | | | | | | | | 30 | |
| | | ZA07S | | | | | | | 160 | | 352 | 170 |
| | | ZA08S | 220 | 128 | 73 | 596 | 109 | 244 | 12 | 583 | 1003 | 508 |
| | | ZA09S | 109 | 579 | 146 | 214 | 28 | 132 | 30 | 1474 | 187 | 1164 |
| | | ZA11S | 985 | 139 | 234 | 1013 | 14 | 493 | 40 | 219 | 248 | 388 |
| | | ZA12S | 77 | 172 | 45 | 179 | 130 | 225 | 24 | 207 | 351 | 1095 |
| | | ZA13S | 56 | 148 | 35 | 898 | 23 | 898 | 22 | 257 | 60 | 928 |
| | | ZAweir | 26 | 5141 | 523 | 1797 | 29 | 1392 | 133 | 5392 | 127 | 1578 |
| South Peninsula | Glencairn vlei | GC02 | 1192 | 692 | 899 | 1387 | 381 | 138 | 12432 | 142 | 2643 | 15879 |
| Zeekoe | Costa da Gam | BM12 | 20 | 490 | 7 | 50 | 16 | 15 | 69 | 18 | 9925 | 70 |
| | Edith Stepher | BM08 | 15167 | 3200000 | 6080 | 2550 | 142 | 30500 | 74000 | 30000 | 48570 | |
| | | BM09 | 2604 | 15170 | 75 | 255 | 230 | 49000 | 70 | 15130 | 330 | |
| | Moddervlei | BM13 | 40 | 890 | 40 | 997 | 50 | 7 | 33 | 3 | 50 | 60 |
| | Rondevlei | RVweir | 6484 | 818 | 809 | 127 | 102 | 827 | 119 | 16 | 158 | 231 |
| | Zeekoevlei | BM14 | 12 | 1495 | 4 | 16700 | 125 | 14905 | 200 | 83 | 70 | 300000 |
| | | ZEV1S | 20 | 6987 | 2 | 105 | 67 | 503 | 105 | 91 | 35 | 66 |
| | | ZEV2S | 87 | 52216 | 143 | 73563 | 36 | 26955 | 19 | 5030 | 38 | 7238 |
| | | ZEV3S | 15 | 7213 | 6 | 718 | 67 | 2379 | 17 | 5050 | 38 | 1027 |
| | | ZEV4S | 16 | 1782 | 9 | 65 | 80 | 445 | 39 | 83 | 7 | 784 |
| | | ZEWEIR | | | | | | | | 40 | 26 | |