CITY OF CAPE TOWN
ISIXEKO SASEKAPA
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CITY OF CAPE TOWN INLAND WATER QUALITY REPORT
FOR THE PERIOD OCTOBER 2021 TO SEPTEMBER 2023
(2022 AND 2023 REPORTING PERIODS)



FINAL

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TECHNICAL REPORT

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READER GUIDE

Not everyone will have the time or inclination to read through all of the details of water quality analyses and interpretation that are presented in this report, and which are necessary to inform the contents of the summary overview report.

Those interested in particular aspects of water quality and not wanting to read the report in detail should refer to the following Reader Guide to navigate the report more quickly:

- **Section 2** where **Figure 2.1** shows the locations of all of the sub-catchments included in the CCT's area and referred to throughout this report;
- **Section 3** where **Section 3.7** provides an explanation of the water quality categories that are used in this report and **Section 3.8** explains how data were treated / analysed;
- **Section 4** for a discussion of rainfall data;
- **Section 5**, where the colour-coded compliance graphs give a quick visual overview of which sub-catchments or listed vleis and other standing water areas had water quality that generally met or failed to meet Target criteria. These graphs are presented towards the end of each of the subsections on phosphate and nitrogen enrichment; ammonia; dissolved oxygen; chlorophyll-*a* and *E. coli*;
- **Section 6** for discussions around the condition of the City's main recreational vleis, and their condition with regard to human health;
- **Section 7** for a brief overview of some of CCT's current and planned programmes to address water quality in the City and/or improve other aspects of watercourse condition;
- **Section 8** focuses on the CCT's Priority Catchments, and provides brief, illustrated descriptions of the main factors affecting water quality in these catchments. Most usefully in this section are maps showing each priority catchment (and the surrounding area) with the locations of routine water sampling points in the map colour coded to represent the water quality category assigned to annual data for three key variables, namely phosphate (as PO4-P), ammonia (as NH_3) and *E. coli*;
- **Section 9** summarises the main findings and recommendations of the report as a whole;
- **Appendix A** presents a table showing the locations and site codes for all of the sample points, in their different sub-catchments;
- **Appendix B** provides an explanation of the derivation of the thresholds that were used in the analyses of ecosystem condition and human health risk from recreational use of waterbodies.
- **Appendix C** presents summary annual data for key water quality variables for each sub-catchment and sample point. The former have been colour coded for ease of interpretation and allow readers to look up data relating to particular monitoring points of interest.
- **Appendix D** presents boxplots of annual data for the variables considered in this report, comparing sub-catchments for flowing water systems and individual vlei systems for standing waterbodies.
- **Appendix E** provides an evaluation of the salinities recorded in the two estuarine vleis in the City (i.e. Milnerton Lagoon and Zandvlei) against the Berg RQOs for salinity.

EXECUTIVE SUMMARY OF THE TECHNICAL REPORT

E1 CONTEXT

E1.1 Background

The City of Cape Town (CCT) is responsible for the management of numerous waterbodies within its municipal boundaries, including rivers, wetlands, open water vlei systems, estuaries and coastal lakes. Regular reporting on the results of water quality sampling is required in order to inform both City managers and other interested parties / members of the public about the state of the City's watercourses. In 2020, the CCT commissioned its first independent Inland Water Quality Report (Day *et al*. 2020). The current report is the third such report.

This report considers water quality data for Cape Town's inland and estuarine water quality monitoring sites, as well as coastal stormwater outlets. 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 key catchments. The report also excludes water quality data from ad hoc or once-off sites, for which only a few data points exist, as well as data generated as part of investigations into specific water quality issues in localised parts of the City (e.g. following particular pollution events). The report focuses on water quality data for the period October 2021 to September 2023. In order to give these data context, they are analysed against a backdrop of data going back to October 2019.

E1.2 City catchments and Stormwater Planning Regions

The City's numerous watercourses drain 17 major catchment areas, as shown in **Figure E1**. Some of these areas in fact include a number of relatively small catchments, which are grouped together for management purposes. Three catchments are significantly larger than others, namely the Diep, Eerste and Salt River catchments. For the purposes of this report, these catchments have been further divided into 'paired sub-catchments' (the Diep and Mosselbank; Kuils and Eerste; Elsieskraal and Lower Salt Sub-catchments). These are also shown in **Figure E1**, and all of the delineated areas in that figure are referred to as 'sub-catchments' in the current report. It should be noted that a large proportion of the Diep, Mosselbank and Eerste sub-catchments lie outside of the CCT boundary.

While Cape Town's rivers and other watercourses lie within catchments, defined by topography and separated by watersheds, the CCT manages them through so-called Stormwater Planning Regions. There are four such regions, comprising a Northern, Southern, Eastern, Central and Western region. Each region has a separate manager, responsible for stormwater management across the whole region. The delineations of the regions do not take any account of the 17 major river sub-catchments, but in many cases cut through sub-catchments, assigning sections of a river and its tributaries in some cases to two or even three different managers. This means that effectively it is difficult to manage stormwater and its associated water quality issues from a catchment perspective.

E1.3 The CCT's priority sub-catchment areas

Seven priority sub-catchment areas have been identified by the CCT for focused interventions, intended to improve river and wetland ecosystem function, and through this, an improvement in water quality. The priority sub-catchments are:

- The Lower Diep River (upstream of Milnerton Lagoon)
- The Sir Lowry's Pass and Soet River
- The Lower Salt River
- The Kuils / Eerste Rivers
- The Hout Bay River
- The Big and Little Lotus Rivers (within the Zeekoe catchment)
- The Sand catchment (upstream of Zandvlei).

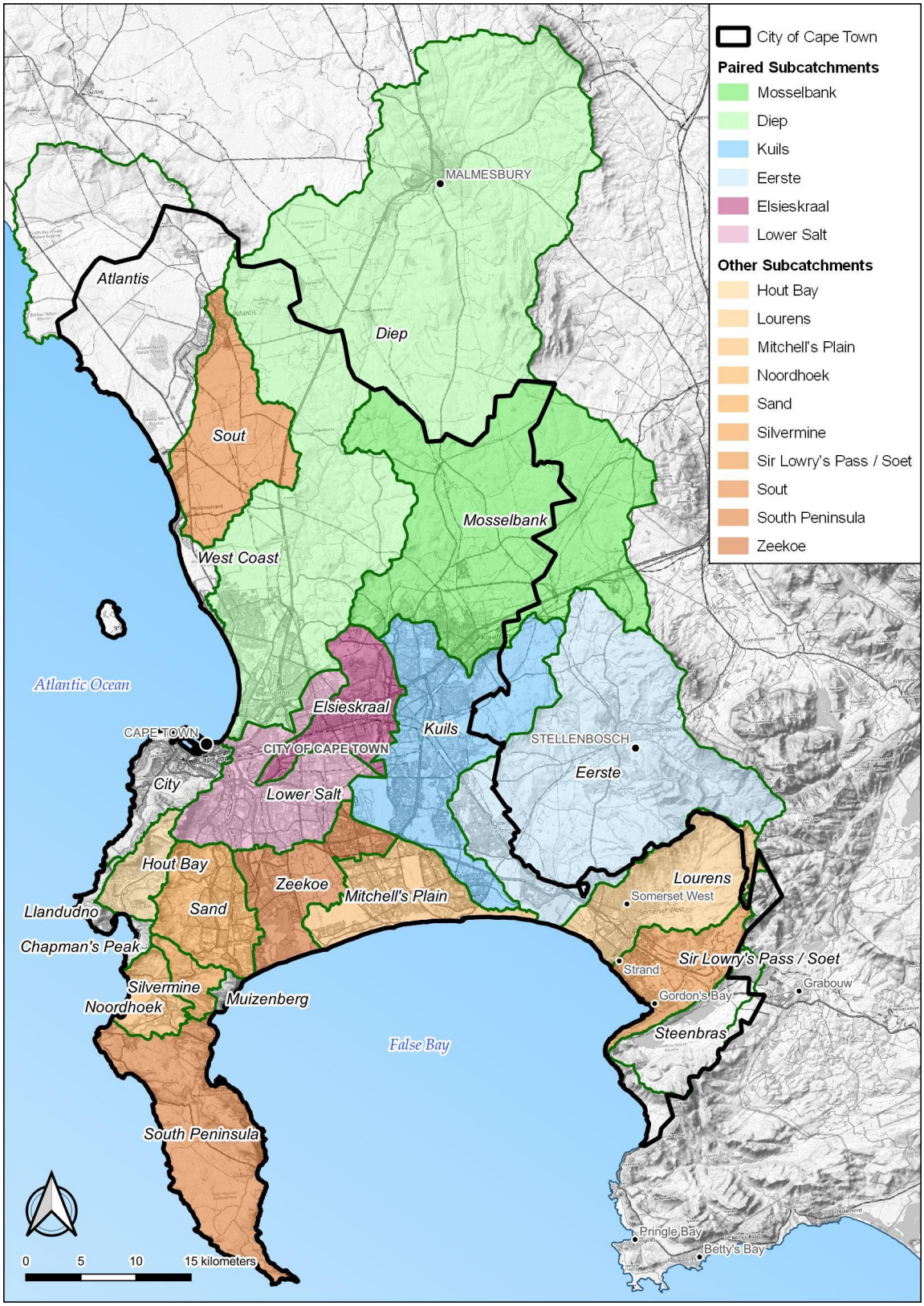


Figure E.1
Sub-catchments used for the CCT Inland Water Quality Report.

The priority sub-catchments also form the focus of three major CCT programmes, namely the CCT's

Water Quality Improvement Programme (WQIP); the Liveable Urban Waterways (LUW) Programme and the Mayor's Priority Programme (MPP) on Sanitation and Inland Water Quality.

E1.4 Monitoring points in the CCT's Inland Water Quality Monitoring Programme

To date, the CCT's water quality monitoring programme has been designed to monitor changes in watercourses where water quality is likely to be a cause for concern. Many of the monitoring points are therefore 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 religious rituals (e.g. baptisms) and/or recreational purposes (e.g. sailing, rowing, kayaking). Water quality data for such systems 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 Cape Town's watercourses, the data collected by the CCT to date focus on problem areas, and provide information about long-term trends and trajectories of water quality in these systems. This means that water quality data over-emphasize problem areas, and do not provide an over-arching view of water quality in the City's rivers and wetlands as a whole. This issue has been considered by the CSRM, and additional monitoring sites, intended to provide a more holistic overview of water quality in the City's watercourses, will be added during the course of 2024.

The present report considers only data from routine water quality sampling. **Figure E2** shows the locations of all the current inland routine monitoring points utilised in this study, including sampling points located at major stormwater outfalls along the coast. All sites are sampled monthly, with samples being analysed for basic water chemistry variables and microbiology (*E. coli*). In addition, recreational vleis (Rietvlei, Milnerton Lagoon, Zeekoevlei, Princessvlei and Zandvlei) are sampled roughly twice monthly for *E. coli*.

E1.4 Water quality variables considered in this report

Although the CCT 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 are assessed in the Inland Water Quality Report, as determined in Day *et al*. (2020). The following variables have been included (abbreviations used to refer to them in this report are shown in brackets):

- Major nutrients
    - Phosphorus in orthophosphates (PO4-P)
    - Phosphorus in total phosphorus (Tot-P)
    - Total Inorganic Nitrogen (TIN)
- Un-ionised (or 'free') ammonia (NH_3)
- Dissolved oxygen (DO)
- *Escherichia coli* bacteria (*E. coli*)
- Microcystin concentrations
- Chlorophyll-*a* (Chl-*a*)
- pH as an indicator of ammonia toxicity risk
- Electrical conductivity (EC) as a measure of salinity, specifically for vlei systems in the City that were delineated as estuaries in the Berg RQO study.

The following additional water quality variables were obtained by calculation from existing data:

- Total Inorganic Nitrogen (TIN) – through addition of NH4-N and (NO3+NO2)-N
- NH4:TIN – the ratio of NH4-N:TIN
- TIN: PO4P – as a ratio of TIN to PO4-P
- PO4-P:Total phosphorus (PO4-P:TotP), expressed as a ratio.

E1.5 Water quality thresholds to guide data interpretation

Tables E1 and E2 outline the ranges in concentrations of key water quality variables used to guide data interpretation in this report, with regard to their implications for aquatic ecosystem condition. The ranges and thresholds distinguish between flowing water systems (rivers, channels and canals) and open water systems (dams, vleis, detention ponds and coastal lakes).

Two changes in water quality thresholds have been introduced into the present report, in discussion with the CSRM, as follows:

- Free ammonia ranges have been amended, to reflect more accurate ecological thresholds than those included in the RQOs. Specifically, the Present Ecological State (PES) Category A and B ("Good") and Category C ("Fair") thresholds (all "Acceptable") were decreased from ≤ 0.044 mg/L to ≤ 0.007 mg/L and from 0.072 mg/L to ≤ 0.015 mg/L, respectively. This change is in line with the DWAF (1996) guidelines for target and chronic toxicity thresholds, respectively.
- Whereas the 2020 and the 2023 water quality reports used orthophosphate concentrations as a measure of both flowing and standing water phosphorus enrichment, the present report rather uses total phosphorus concentrations to measure standing water phosphorus enrichment, using the values provided by DWAF (2002) and reiterated in DWAF (2011) guidelines for lakes and dams. Total phosphorus (TP) is a measure of all the forms of phosphorus, dissolved or particulate, that are found in a sample. By contrast, orthophosphate phosphorus is a measure of the soluble, inorganic portion of total phosphorus that is biologically available to be taken up by plants. The 2020 RQOs for dams in the Berg catchment erroneously use the same orthophosphate phosphorus thresholds for dams and rivers. The use of total phosphorus concentrations is a more useful measure for standing water systems such as vleis, lakes and dams (Cooke *et al*. 2005).

Tables E3 and E4 present the thresholds used to determine risks to human health on the basis of monitoring of two key variables, namely *E. coli* bacteria (an indicator of exposure to raw sewage and other faecal sources from warm-blooded animals) and microcystin toxins, which can be associated with cyanobacteria (also called blue-green algae). Concentrations of these variables are evaluated with respect to the level of risk they pose to people undertaking 'intermediate contact' recreational activities, such as canoeing, kayaking, fishing, sailing, rowing, kite-boarding and wind-surfing.

It should be noted that, whereas the CCT previously also monitored *Enterococci* bacteria counts in vlei water samples, these analyses were discontinued in the 2022/2023 monitoring periods, despite recommendations for their continuance and expansion of monitoring sites made in Day *et al*. (2023).

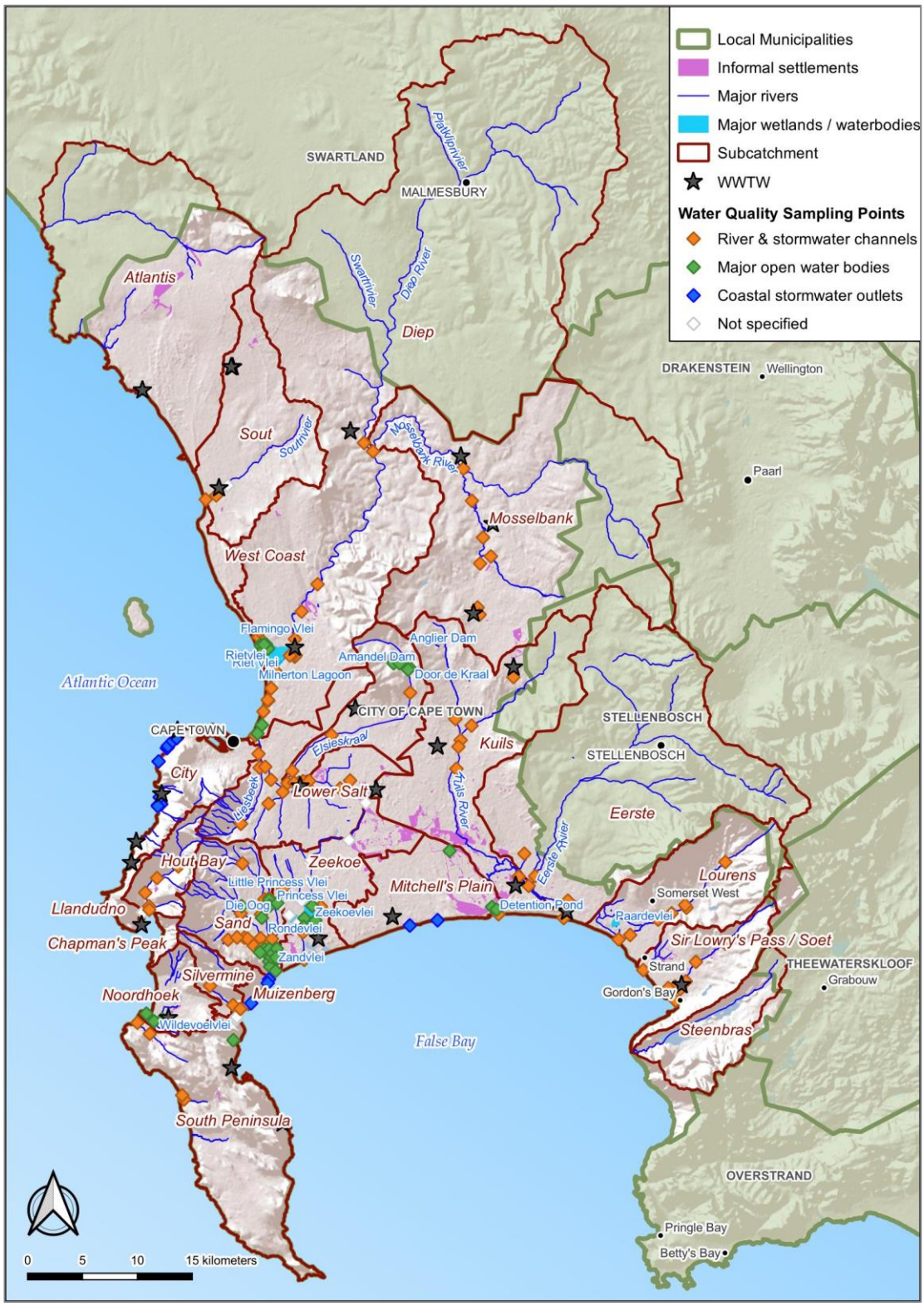


Figure E.2
Sample locations for the CCT water quality monitoring programme, showing river and stormwater channels/canals, standing water (vlei and dam), and coastal stormwater pipeline sampling points.

Table E1
Rating ranges for variables considered in this assessment of water quality in rivers.
Note: PO4-P = phosphate phosphorus; TIN=Total inorganic nitrogen; DO=Dissolved oxygen; N:P= ratio of TIN:PO4-P; NH_3 = un-ionised ammonia. Note also that the terms 'PO4-P', 'N:P' are abbreviations and are not the full chemical notation for these variables

City Water Quality Categories	Interpretation of City WQ Categories	PO4-P mg P/l	TIN mg N/l	DO mg/l	N:P	NH_3 mg/l
GOOD	TARGET	≤ 0.015 (oligotrophic)	≤ 0.70 (oligotrophic - mesotrophic)	>7	>25	≤ 0.007
FAIR		> 0.015 - 0.025 (mesotrophic)	>0.70-1.00 (mesotrophic)	>6-7		> 0.007 - 0.015
POOR	POOR	> 0.025- 0.125 (eutrophic)	>1.00 -4.00 (mesotrophic - eutrophic)	>4 -6	10-25	> 0.015-0.1 (chronic toxicity)
UNACCEPTABLE	UNACCEPTABLE	> 0.125 (hypertrophic)	> 4.00 (eutrophic - concentrations > 10mg/L classified as hypertrophic)	≤ 4	< 10	> 0.1 (acute toxicity)

Table E2
Rating ranges for variables considered in this assessment of water quality in vleis and dams.
Note: TP= total phosphorus; TIN=Total inorganic nitrogen; DO=Dissolved oxygen; N:P= ratio of TIN:PO4P; NH_3 = un-ionised ammonia; Chl-*a*= Chlorophyll-*a*. Note also that the terms 'PO4-P', 'TIN' etc are abbreviations and are not the full chemical notation for these variables

City Water Quality Categories	Interpretation of City WQ Categories	TOTAL PHOSPHORUS mg P/l	TIN mg N/l	DO mg/l	N:P	NH_3 mg/l	MEAN ANNUAL CHL-A µg/l
GOOD	TARGET	≤ 0.015 (oligotrophic)	≤ 0.7	> 7	>25	≤ 0.007	≤ 5
							>5 - 10
FAIR		> 0.015 – 0.047 (mesotrophic)	>0.7 -1	>6-7		> 0.007 - 0.015	>10 -20
POOR	POOR	>0.047 - 0.130 (eutrophic)	>1.0-4.0	>4 -6	10-25	> 0.015-0.1 (chronic toxicity)	> 20 - 30
UNACCEPTABLE	UNACCEPTABLE	>0.130 (hypertrophic)	> 4	≤ 4	<10	> 0.1 (acute toxicity)	> 30

Table E3
Approach to assessment of microbial data (faecal coliforms including escherichia coli).
Note inclusion of Full Contact and Intermediate Contact thresholds

Interpretation	Inland systems Faecal Coliform Count (*including E. coli)*
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	> 2 500 – 4 000 cfu/100 ml
UNACCEPTABLE Risk – intermediate contact	> 4 000 cfu/100 ml

Table E4
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 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

E1.6 Reporting periods and seasonality considered in this report

Water quality reporting for previous inland water quality reports (Day *et al*. 2020, 2023) was based on annual cycles between April of one year through to March of the following year, covering the ecosystem cycle between autumn and late summer. In the present report, and going forwards with the inland water quality reporting, the annual reporting cycle has been changed to reflect so-called hydrological periods, extending from October of one year to end of September of the following year. This change has been instituted to allow for timeous reporting on water quality in any annual cycle, before the end of the CCT's financial year in June. The new cycle aligns well with the summer / winter seasons already incorporated into data assessments (as explained below) and is thus not considered problematic from the perspective of scientific rigour in reporting.

The annual reporting period used in this report comprises the period from 1 October to 30 September in any given cycle and is given the YEAR identity of the end of the period. Data for the period 1 October 2022 to 30 September 2023 are accordingly referred to as the 2023 dataset. The Scope of Works for the present report requires a focus on water quality data for the 2022 and 2023 reporting periods (1 October 2021 to 30 September 2023). In order to be able to report meaningfully on at least short- to medium-term water quality trajectories, data for the (new) 2022 and 2023 reporting periods are, however, assessed in the light of data over a five-year period. Thus, the report includes data from 1 October 2018 through until 30 September 2023.

The concentrations of a number of water quality variables measured in rivers, vleis and other wetlands undergo significant seasonal variability, largely related to differences in rainfall and temperature between the wet and dry seasons. An attempt has thus been made to 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.

E2 CURRENT STATE AND TRAJECTORIES OF CHANGE IN WATER QUALITY IN CAPE TOWN'S MAJOR WATERCOURSES

E2.1 Rainfall patterns

Analyses of rainfall data were included to provide background understanding of rainfall patterns in different catchments of the City, both over the current reporting period and to get context over a longer-term period (e.g., whether it was a drought year). The analyses were based on the records of CCT-managed rainfall gauges with reliable datasets for the reporting periods and those of the rain gauge at Intaka Island at Century City.

The annual rainfall recorded at Intaka Island in Reporting Years 2021 and 2022 was significantly below the 20-year average, at <500 mm per annum, but for the main focal year for the current report (i.e., Reporting Year 2023) the annual rainfall (almost 750 mm) was well above the long-term average.

At most of the rain stations across the City, significantly more rain was recorded for Reporting Year 2023 compared with the other years.

A similar pattern of month-to-month fluctuations in rainfall, typically peaking in the winter months of June to August, was evident in the bar graphs of total monthly rainfall at the selected CCT-operated rain-gauging stations over the October 2018 to September 2023 period. These graphs show that particularly high rainfall was recorded at most gauging stations in June and, especially, September 2023, with a daily maximum rainfall of 50-150 mm (indicative of a flood event) having been recorded at many stations during September 2023.

E2.2 Major nutrients (phosphorus and nitrogen)

The nutrient (or '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).

The key take-away points from the assessment of nutrient data were as follows:

- In terms of phosphorus concentrations:
    - Phosphate data continue (as noted in the 2020 and 2023 Inland Water Quality Reports) to indicate that ortho-phosphate enrichment remains an issue of great concern, affecting most of Cape Town's monitored rivers and other stormwater systems, which over the 2022 and 2023 reporting periods lay generally well within the hypertrophic (Unacceptable) range for this variable. Although median PO4-P concentrations reduced in many catchments over the 2023 reporting period, the proportion of samples within an Acceptable range reduced by almost half, and just under 80% of samples fell within the Unacceptable range. Since many of these nutrient-enriched rivers feed into the City's vleis and dams, the impacts of river phosphorus enrichment are passed on to, and magnified within, these standing water bodies;
    - The Silvermine, Lourens and Hout Bay Sub-catchments continued to be the best-performing catchments among monitored systems in the City, but nevertheless all showed a decrease in the proportion of samples in an Acceptable condition for PO4-P over the 2023 reporting period;
    - Overall, total phosphorus data show that all of the City's standing water systems were highly nutrient-enriched, with water quality lying within either the range for Poor (eutrophic) or Unacceptable (hypertrophic) conditions throughout the three reporting periods considered here. These data reflect inflows from significantly more polluted rivers and stormwater systems, which load standing water bodies with nutrients that accumulate over time, in the water bodies themselves, as well as in bottom sediments and living plant material.

- TIN data showed that:
    - While phosphorus is considered more problematic than nitrogen in driving ecosystem responses to eutrophication (e.g. rapid plant growth including algae and reeds), nitrogen enrichment was also at levels of concern in many parts of Cape Town's watercourses over the 2022 and 2023 reporting periods, with > 55% of water quality samples from routinely monitored sites rated Unacceptable with regard to their TIN concentrations;
    - By contrast to the above, over 60% of samples from most of the monitored standing water systems (vleis and dams) fell within the Target range for this variable, with some systems performing much better - exceptions comprised Zeekoevlei, Langevlei,, Wildevoelvlei and the Mew Way and Mitchell's Plain detention ponds;
    - These results show that excessive TIN concentrations were considerably less problematic in standing water systems than in rivers and stormwater channels, and this is assumed to reflect dilution by a larger water body but, more importantly, the ecological impacts of extended residence time, which allows nitrogen uptake, sedimentation and de-nitrification (to produce N2 gas) through anaerobic processes.
- With respect to N:P ratios:
    - Generally, standing water bodies were characterised by low N:P ratios, in the range most likely for these systems to be dominated by blue-green algae rather than rooted plants or other less problematic algal groups;
    - In particular, very low (and thus problematic) N:P ratios were evident in Wildevoelvlei, the Mew Way and Mitchell's Plain detention ponds, Zeekoevlei, Rondevlei and Zoarvlei (in the 2023 reporting period), suggesting that all of these systems were likely to be affected at least at times by blue-green algal growth.
- The ratio of TIN that comprises total ammoniacal nitrogen (NH4-N) is also an important measure considered in this report. That is because total ammoniacal nitrogen includes a proportion of un-ionised ammonia (NH_3), which can be toxic to some aquatic biota at relatively low concentrations. Hence its dominance in TIN can reflect problems in ecosystem health (or condition). Generally, less-nutrient enriched rivers had lower NH4-N:TIN ratios, suggesting that where TIN loads are lower, more efficient nitrification takes place. Even high proportions of total ammoniacal nitrogen in such systems would still be likely to comprise very low NH_3 concentrations, which would be unlikely to be below toxic thresholds;
- The above findings highlight how catchment condition reflects in river (and vlei) water quality, with the least developed catchments having the least impacted water quality while catchments subject to the accumulation of solid waste, treated and untreated sewage inflows and other sources of contaminated stormwater including fertilisers, are characterized by impacted river (and vlei) waters.

E2.3 Chlorophyll-*a*

The main findings in terms of algal productivity, as reflected in chlorophyll-*a* measurements recorded for the selection of standing water bodies in Cape Town during the reporting periods under consideration, were:

- The most problematic systems, where the risk of algal blooms would have been high during the reporting periods being considered, were Zeekoevlei, Princessvlei, Wildevoelvlei and Langevlei (although there was a noticeable improvement in the situation at Wildevoelvlei in Reporting Year 2023);
- High levels of non-compliance were recorded for Rietvlei in Reporting Years 2022 and 2023 (with <25% of the samples within the Target range for Chl-*a*);
- Relatively high levels of non-compliance were recorded for Zoarvlei and Die Oog in Reporting Year 2023, with a significant decrease in the level of compliance from Reporting Year 2022,

especially during winter;

- The least problematic system in terms of algal production was Glencairnvlei, which is characterised by relatively low nutrient inputs and where >90% of the samples had Chl-*a* measurements within the Target range during all three reporting periods;
- Consistently good conditions (with close to or more than 80% compliance in terms of the Target range for Chl-*a*) were recorded for Zoarvlei and the Elsieskraal dams in the 2019-2021 and 2022 reporting periods, and at Die Oog in Reporting Year 2022, but there was a significant reduction in the level of compliance (to 40-60%) within all of these waterbodies during Reporting Year 2023.

E2.4 Dissolved oxygen

The dissolved oxygen (DO) data assessed in this report suggest that extremely low DO concentrations in the Unacceptable category were not as pervasive a problem as elevated nutrient concentrations in the CCT during the reporting periods. There are systems, however, which were characterised by low DO concentrations, either consistently or intermittently – these were generally rivers or channels, where water quality was typically more impacted than most of the large vleis / standing water systems.

The main findings with respect to dissolved oxygen levels in the monitored water bodies across the City were as follows:

- The level of non-compliance in relation to the Target range of values for DO concentrations was more problematic for the monitored flowing water sites than it was for standing water sites, but this could be at least partly the result of many of the flowing system sites being purposefully located immediately downstream of known pollution sources;
- For flowing systems, the results are indicative of a generally bad state of water quality at the monitored sites within the City, with 40% or more of the DO measurements collected over the five-year period from Reporting Year 2019 to 2023 consistently being reflective of Poor to Unacceptable conditions, although there was an overall improvement from the 2022 to the 2023 reporting period;
- The worst-performing sub-catchments with respect to DO compliance in flowing systems were the Lower Salt and the Soet for all three reporting periods, the Eerste in the 2019-2021 reporting period, and the Zeekoe in both the 2019-2021 and the 2022 reporting periods;
- Conditions in the Soet sub-catchment were particularly bad in Reporting Year 2022, with >60% of the samples from flowing systems falling within the Unacceptable category and no samples in the Target range;
- For the most recent year of analysis (Reporting Year 2023), the conditions in terms of DO concentrations improved significantly compared to previous reporting periods for flowing water systems in the Diep, Eerste, Kuils, Sout, Zeekoe, Hout Bay, Silvermine and South Peninsula sub-catchments;
- The least problematic sub-catchments in terms of DO compliance at monitored flowing water sites were, unsurprisingly, the more rural Elsieskraal sub-catchment and the Lourens, SL Pass and Silvermine sub-catchments containing less impacted upper river sites, as well as the Kuils and Hout Bay sub-catchments in the most recent Reporting Year 2023;
- For river and stormwater channel sites, there was a tendency for conditions to be worse (lower DO concentrations) in summer compared to winter, and for the range of variability to be greater during summer than in winter, although exceptions to this latter tendency were observed in certain sub-catchments which receive WWTW inflows and/or or stormwater inflows that are contaminated with sewage input including the Lower Salt, Sir Lowry's Pass, Mosselbank and Zeekoe sub-catchments;
- The grouped results for standing water systems show a trajectory of some improvement in terms of DO compliance from one reporting period to the next, for the three reporting periods that

were considered, with the most significant improvements in terms of recorded DO concentrations compared to the previous reporting period/s observed at Rondevlei and Glencairnvlei in Reporting Year 2023, at Zeekoevlei, Westlake and Langevlei in Reporting Year 2022 (although for Langevlei, the situation deteriorated in Reporting Year 2023), and at Zandvlei in both Reporting Years 2022 and 2023;

- High DO levels within the Target range were recorded in all or most (>90%) of the samples collected at Rietvlei and Princessvlei during all three reporting periods, at Westlake in Reporting Year 2022, at Glencairnvlei in Reporting Year 2023, and at Zandvlei in Reporting Years 2022 and 2023;
- High DO levels were also prevalent (with 80-90% of the samples within the Target range) at Zandvlei and Wildevoelvlei in the 2019-2021 reporting period, Die Oog in the 2019-2021 and 2022 reporting periods, Westlake in the 2019-2021 and 2023 reporting periods, Langevlei in Reporting Year 2022, and at Zeekoevlei in Reporting Years 2022 and 2023;
- The worst-performing standing waterbody in terms of DO compliance was the Mew Way detention pond, where >80% of the samples collected during all three reporting periods were in the Unacceptable category;
- Low to very low DO levels were also prevalent at Zoarvlei and the Mitchell's Plain detention ponds during all three reporting periods, at Rondevlei during the 2019-2021 and 2022 reporting periods, and at Wildevoelvlei in Reporting Year 2022;
- The seasonal patterns observed for DO concentrations in flowing water systems were not as consistently or strongly apparent in the data for the vlei, dam and detention pond sites, although there were small seasonal differences in some cases.

E2.5 Ammonia toxicity

The main findings with respect to the potential for toxic conditions for aquatic fauna in monitored aquatic ecosystems across the City resulting from elevated levels of un-ionised ammonia were:

- Potentially toxic conditions associated with elevated NH_3 concentrations were more prevalent in flowing water systems than they were for standing water systems, partly attributable to the dilution effect of large standing water bodies;
- There were a number of sub-catchments for which ammonia toxicity was not a major issue of concern for monitored flowing water systems during the reporting periods under consideration, namely the Lourens, Sout, Hout Bay and Silvermine sub-catchments, as well as (to a slightly less degree) the Sir Lowry's Pass and Sand sub-catchments;
- There were also number of monitored standing water systems for which ammonia toxicity was not an issue of concern), namely Glencairnvlei, Little Princessvlei, Princess Vlei and the Elsieskraal dams during all three reporting periods, as well as at Rondevlei and Die Oog during the 2019-2021 and 2022 reporting periods, at Rietvlei in Reporting Year 2022, Zoarvlei in Reporting Years 2022 and 2023, and at Zandvlei in Reporting Year 2023;
- Reasonably good conditions in terms of the risk of ammonia toxicity were also recorded at Westlake in all three reporting periods, and at Rietvlei in the 2019-2021 and 2023 reporting periods, Zoarvlei in the 2019-2021 reporting period, Zandvlei in the 2019-2021 and 2022 reporting periods, and Langevlei in Reporting Year 2022;
- The situation deteriorated in Reporting Year 2023 at Rondevlei, Die Oog and Langevlei, with a significant increase in the proportion of samples in the Poor and/or Unacceptable categories (indicative of potential chronic to acute ammonia toxicity) compared to the previous reporting period/s;
- The most problematic sub-catchment in terms of the potential for ammonia toxicity within flowing water systems was the Soet, where >75% of the samples collected in all three reporting periods had NH_3 concentrations in the Unacceptable category;

- The potential for ammonia toxicity was also prevalent in the Lower Salt and Zeekoe sub-catchments during all three reporting periods;
- Other problematic sub-catchments included the Eerste sub-catchment in all three reporting periods, the Diep sub-catchment in Reporting Years 2022 and 2023, the Mosselbank sub-catchment in the 2019-2021 reporting period, and the Elsieskraal sub-catchment in the 2019-2021 and 2022 reporting periods;
- The most problematic standing water systems during the reporting periods under consideration were Wildevoelvlei and the Mitchells Plain and Mew Way detention ponds, where recorded NH_3 concentrations were in the Poor and Unacceptable categories (indicating chronic to acute toxicity) for 100% or close to 100% of the samples;
- Potentially toxic conditions in terms of NH_3 concentrations were also often present in Zeekoevlei during all three reporting periods;
- There was generally a greater range of values in recorded un-ionised ammonia levels in summer compared to winter, for all watercourses (flowing and standing water systems) that did not have very high levels of compliance in terms of the Target range for NH_3 concentrations, and the median NH_3 concentration was generally higher in summer, indicating a greater risk of toxic conditions than in winter;
- The only problematic sub-catchment in terms of ammonia toxicity at flowing water sites that was characterised by elevated pH values indicative of an increased risk of ammonia toxicity was the Eliseskraal sub-catchment, suggesting that the ammonia toxicity problems in the other sub-catchments (including the particularly problematic Soet) are being driven by excessively high ammonia concentrations and not elevated pH values;
- There was a relatively high risk of ammonia toxicity as a result of median pH values >8 in the Rietvlei, Langevlei, Zeekoevlei and Zandvlei standing water bodies during all three reporting periods, and in Princessvlei during the 2019-2021 and 2022 reporting periods, the Westlake Wetland during Reporting Year 2022 and Wildevoelvlei during the 2019-2021 reporting period.

E2.6 *Escherichia coli* bacterial counts as an indicator of sewage contamination

Escherichia coli measurements are used primarily as an indicator of human health risk, particularly for drinking or recreational use of a waterbody. The recreational risk ratings applied in the current assessment thus include *E. coli* thresholds for intermediate contact (e.g. canoeing, sailing, paddling), with ranges provided for 'Target' (acceptable risk), 'Poor' (tolerable risk) and 'Unacceptable' (high risk). The *E. coli* data, however, also highlight point-sources of pollution into watercourses, where elevated *E. coli* is an indicator of contamination from untreated sewage.

Sources of sewage contamination in Cape Town's sub-catchments include:

- Periodic sewer blockages and manhole overflows that enter the stormwater system and thus pass into watercourses (blockages result variously from poor solid waste management, overflows as a result of stormwater ingress, vandalism, aging infrastructure, and increasing sewage volumes generated from rapidly expanding, largely informal settlements);
- Overflows from sewage pump stations (or from low-lying manholes downstream of pump stations) as a result of blockages, pump station failure and from load-shedding power outages – unless diverted back into the sewerage system by pumping or other means, such waste finds its way into the stormwater system and thence into the City's watercourses;
- Contaminated stormwater runoff from poorly serviced informal settlements, where sewage is disposed of into canals and stormwater drains for want of alternative disposal options or because access to options to dispose of waste to sewers is unsafe (e.g. at night) or unhygienic (because of a build-up of solid waste and/or faecal waste);
- Runoff from urban areas with high levels of homeless people without alternative waste disposal options;

- Illegal connections of sewers into stormwater systems;
- Previously-designed sewer overflows into stormwater systems;
- Inputs from wildlife (baboons and birds);
- Input from livestock (e.g. feedlots in agricultural areas in and draining into rivers or other watercourses);
- Runoff from pavements, parks etc. accessed by domestic animals (e.g. dogs) – this is however likely to be a relatively minor input in most areas.

Key take-away points from the analyses of *E.coli* data were as follows (noting that reliable *E. coli* data were not available for the 2021 and 2022 reporting periods):

- The proportion of river samples rated as Unacceptable from a human risk perspective increased over the assessed reporting periods (2019, 2020 and 2023), with data showing increases from 49% Unacceptable (2019 dataset) to 59% in the 2023 dataset – related impacts such as an increased frequency of load-shedding, with its effects on sewage pump stations and WWTWs, as well as burgeoning poorly serviced informal settlements in many sub-catchments, are likely to have contributed to these increases;
- The most poorly-performing sub-catchments was the Soet (90 – 100 % Unacceptable samples), reflecting a stormwater system fed almost entirely by grey- and black-water inflows from informal settlements;
- The Silvermine and the Lourens River catchments were least impacted by *E. coli* (and by assumption, raw sewage), with > 80% of samples lying within the Acceptable range, and explaining in part their generally low levels of nutrient enrichment and elevated ecosystem condition (as shown also by DO and NH_3 data). Nevertheless, even these generally cleaner sub-catchments were impacted at least at times by sources of sewage;
- Standing water systems (vleis, dams, detention ponds) typically showed lower *E. coli* concentrations and performed better in terms of compliance data than do the rivers feeding into them. This is attributed mainly to extended retention time within standing water bodies (especially the large vleis), allowing exposure of *E. coli* to UV light in sunlight (which kills these bacteria) and dilution of point-source inflows in large water bodies;
- All of the routinely monitored open-water systems in the City, with the exception of the Mew Way and Mitchell's Plain detention ponds, showed relatively low levels of sewage pollution as measured by *E. coli* counts, with > 60% of samples in all systems lying within the Acceptable range for *E. coli* during the 2023 reporting period;
- The markedly worst-performing Mew Way and Mitchell's Plain detention ponds (100% of samples were rated Unacceptable throughout all of the assessed reporting periods) were unsurprising, given that these ponds are fed by black- and grey-water discharges from poorly serviced urban areas, where even formal residential areas are prone to frequent manhole and pump station overflows of raw sewage;
- It must be stressed that *E. coli* is used in the CCT's monitoring programme as an indicator of sewage contamination but, even if these bacteria are killed by UV light, the nutrients associated with decomposing organic waste and various pathogens also associated with sewage would still remain within the affected water bodies, where they would be expected to result in various short- to long-term impacts on the fitness for use of the system for both human use and aquatic ecosystems;
- The 2020 Inland Water Quality Report recommended that intestinal enterococci should be monitored in inland water bodies. This was based on a recommendation in WHO (2003) and was reiterated in WHO (2021). However, enterococci monitoring has been excluded from the SSB's monitoring programme post 2022. The implications of this are that the SSB's inland water quality monitoring programme becomes progressively out-dated compared with global standards and

(more importantly), outside of *E. coli* analyses, no alternative data are available with which to assess the magnitude and associated human health risks of sewage pollution into water bodies. This is particularly important, given the recent (2021-2022) history of the SSB's poor laboratory performance with regard to *E. coli* analyses. It is thus recommended that enterococci analyses should be provided for, along with *E. coli* analyses, at least in recreational water bodies.

E2.7 Other sewage contamination indicators

Although informal settlements, as well as any areas with unserviced back-yard settlements, contribute permanent streams of raw sewage into watercourses, usually by way of formal or informal stormwater systems, by far the greatest loading of sewage-associated pollutants into the City's watercourses, as a result of the sheer volumes generated, are assumed to stem from the formal sewage reticulation and treatment systems.

The main findings in terms of the quality of inflows of treated effluent from Cape Town's (inland) WWTWs were as follows:

- *E. coli* data showed that only five of the CCT's WWTWs consistently produced effluent within the General Limits for this variable, with most of the other WWTWs producing effluent with E. coli counts several orders of magnitude higher;
- COD data, which are probably the most useful for highlighting the magnitude of downstream chemical risk to aquatic ecosystems, indicate that the most poorly performing WWTWs in this regard feed into the following aquatic ecosystems:
    - Diep River estuary and Milnerton Lagoon (Potsdam WWTW)
    - Black River and Salt River canal (Athlone and Borcherd's Quarry WWTW)
    - Wildevoelvlei (Wildevoelvlei WWTW)
    - Zeekoe canal (Cape Flats WWTW)
    - Mosselbank River (and lower Diep River) (Klipheuwel WWTW) – note however that the effluent volume from this system was relatively low, so downstream loading was not marked)
    - Eerste River estuary (Macassar WWTW)
- Of the above, the impacts of the Potsdam WWTW on the downstream systems are considered most significant, having contributed largely to the collapse of this estuary and its once-important nursery for juvenile fish (Rose *et al*. 2023). Similarly, the Macassar WWTW - the effects of which are multiplied by inflows from the Bellville, Scottsdene and Zandvliet WWTWs upstream in the catchment - has contributed to the severe degradation of the Eerste River estuary;
- Although the Cape Flats, Athlone and Borcherd's Quarry WWTWs essentially now feed into canalised artefacts of urban drainage, these systems nevertheless play important roles in Cape Town's urban society and poor effluent quality both actively detracts from the value of the areas through which they pass, and has significant ecological costs;
- Improved performance in some WWTWs was apparent in both loading and effluent quality data but, despite these improvements, the downstream impacts of many of these WWTWs are significant;
- It is important to note that high concentrations of phosphorus in effluent from all WWTWs were apparent in final effluent data, despite compliance (in some cases) with regulated General Limits.

With respect to pump station failures (which typically result in overflows of raw sewage into stormwater systems), 338 incidents were reported by the CCT across the City in the 2022 reporting period (data for the full 2023 reporting year were not available). The main causes of pump station failure over the 2022 reporting period were reported as follows:

- By far the most prevalent causes of damage were reported as pump tripping and electrical

failures (both 23%) and mechanical failure (17%);

- Load shedding was the factor that accounted for the fourth highest number of pump station overflows (9 %);
- The data suggest that theft accounted for only 1% of pump station failures.

With respect to the frequency of pump station overflows per sub-catchment, along with the reported magnitude of each incident, the main findings (differentiated per sub-catchment) were as follows:

- Overflows rated as Catastrophic occurred twice over the 2022 reporting period, in the Zeekoe sub-catchment (Retreat main pump station, Lavender Hill area) and in the Sand sub-catchment (Raapkraal pump station), with data indicating that these events lasted in excess of 24 hours (up to 48 hours) so it is assumed that they contributed significantly to the pollution of downstream watercourses – in the case of the Raapkraal pump station, in particular, to pollution of the Westlake Wetlands and Zandvlei estuary;
- Sub-catchments impacted by Major sewage overflows comprised (in order of number of events) the Sand, Zeekoe, Diep and Lower Salt;
- Of concern is the fact that the Silvermine sub-catchment was also impacted by at least three major sewage spills – this sub-catchment is generally the most natural and least impacted of all of the City's catchment areas, and would be expected to show high sensitivity to such events;
- All sub-catchments were exposed to pump station overflows at least at times, with those most exposed comprising the Diep, Lower Salt, City bowl, Kuils, Mosselbank, Sand and Zeekoe sub-catchments;
- All of the above, excluding the City Bowl and Mosselbank sub-catchments are included in the Mayoral Priority Programme for water quality improvement, and the data presented here highlight the importance of addressing pump station overflows in these problem sub-catchments, if water quality improvements are to be achieved.

Another measure of sewage spill frequency in Cape Town is provided by records of reporting on sewage spills by members of the public, through submission of the CCT's C3 reporting forms. These data indicate that, over the 2022-2023 reporting periods:

- The hotspots for sewage overflows, based on reported incidents, lay in the Lower Salt sub-catchment, with the Bonteheuwel, Ruytewacht, Kewtown and Manenberg areas being worst affected;
- Of the above, areas with the most intense levels of sewage overflows are those with high levels of informal settlement and/or backyard dwellings and where the sub-catchments themselves are characterised by an accumulation of solid waste that is likely to contribute to the frequency of sewer blockage, along with an increased likelihood of vandalism of sewers and pump stations as a result of a range of socio-economic and other issues;
- A caveat to the use of the C3 report data is, however, that the original data source does 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 also reflect relatively short-lived incidents versus major spills.

E3 CURRENT STATE OF RECREATIONAL WATERS

This section was included in the report to deal specifically with the current state of established recreational waterbodies in Cape Town from the perspective of the risk, if any, that they pose to human health. Five main waterbodies have been considered, namely:

- Rietvlei
- Milnerton Lagoon
- Princessvlei
- Zeekoevlei
- Zandvlei

With the exception of Princessvlei, these vleis and estuaries are used for various water sport activities, including sailing, kayaking, canoeing, fishing, kite-boarding, skiing, wind-surfing, rowing and fishing. Princessvlei is not used for water sports. It is however used periodically for baptism ceremonies, requiring full immersion. All of these activities expose users to some level of health risk if water quality is compromised.

Assessment of human health risk at each waterbody entailed an analysis of the percentage of samples that exceeded the target value for safe intermediate contact recreation in terms of *E. coli*, and microcystin concentrations. The latter is a toxin produced at times by *Microcystis* algae under bloom conditions. All the assessments assume intermediate contact use only – that is, excluding swimming.

The main findings from the *E. coli* data analyses for recreational water bodies were as follows (bearing in mind that *E. coli* data for the 2021 and 2022 reporting periods were not used, given issues around the reliability of these data):

- *Escherichia coli* data suggest that all of the CCT's recreational water bodies periodically posed risks to human health during the 2023 reporting period, but (with the exception of Milnerton Lagoon) were largely in an Acceptable condition, conducive to their recreational use;
- Milnerton Lagoon was mostly in an Unacceptable condition, and its use for recreation would have posed likely risks to human health most of the time;
- Data for the standing water vleis (i.e. excluding Milnerton Lagoon) generally showed much lower *E. coli* concentrations than in (or near to) in-flowing waters, highlighting the effect of extended detention time, associated exposure to sunlight, and dilution within a larger water body, on *E. coli* counts;
- Sample points in Milnerton Lagoon were all rated as Unacceptable, with the main sources of raw sewage assumed to stem from the catchment between Blaauwberg Bridge and Otto Du Plessis Drive, including overflows from the Koeberg and other sewage pump stations, overflows from the Potsdam WWTW, and inflows of polluted stormwater from poorly serviced informal settlements, unmanaged urban areas (e.g. Phoenix and Jo Slovo Park) and backyard dwellings.

The key findings from the analyses of health risks in the five main recreational water bodies based on microcystin concentrations were as follows:

- All five of the City's recreational water bodies have been impacted by high levels of phosphate enrichment, likely to promote high levels of plant productivity, which in some cases result in algal blooms, some of which are associated with microcystin toxins;
- Although blue-green algal blooms were clearly present on numerous occasions over the 2022 and 2023 reporting periods, the only vlei in which microcystin toxins were recorded at concentrations of concern was Zeekoevlei;
- This means that, excluding Zeekoevlei, and despite periodic blue-green algal blooms, Cape Town's recreational water bodies were assumed to be relatively safe for human use over the 2022

and 2023 reporting periods, from the perspective of exposure during intermediate contact use to microcystin toxins in water from these systems;

- Of all of the City's recreational vleis, Zeekoevlei was most affected by algal blooms over the 2022 and 2023 reporting periods, reflecting ongoing nutrient enrichment of this vlei from external sources, exacerbated by the build-up of organic sediments within the vlei, which provide an ongoing source of additional phosphate nutrients, facilitated by low dissolved oxygen availability.

E4 WATER QUALITY IN PRIORITY CATCHMENTS ADDRESSED BY THE CCT'S WATER QUALITY IMPROVEMENT PROGRAMMES

The priority sub-catchments that were given focussed consideration in this report were the following (see map of sub-catchments in **Figure E1**):

- The Lower Diep River (upstream of Milnerton Lagoon) (Central and Northern Stormwater Management Regions);
- The Sir Lowry's Pass and Soet River (Eastern Stormwater Management Region);
- The Lower Salt River (Northern and Central Stormwater Management Regions);
- The Kuils / Eerste Rivers (Eastern Stormwater Management Region);
- The Hout Bay River (Southern Stormwater Management Region);
- The Big and Little Lotus Rivers (within the Zeekoe catchment) (Southern Stormwater Management Region); and
- The Sand catchment (upstream of Zandvlei) (Southern Stormwater Management Region).

For each of the priority sub-catchments, a catchment overview is provided, followed by information on the major sources of pollution in the sub-catchment, the water quality status within the sub-catchment in terms of current state and trajectory of change, and the focus areas of the CCT's water quality interventions within the sub-catchment. Then, for each priority sub-catchment, an indication is given of the major challenges in implementing the interventions in the sub-catchment and recommendations are provided for going forward.

The following key points emerged from the discussions about the priority sub-catchments:

- All of the CCT's priority catchments include runoff from informal settlements with poor access to sewerage systems. This means that water quality in stormwater systems is in many areas compromised, to levels where standard application of SUDS and other stormwater quality polishing / improvement approaches are unlikely to be effective – the Sand Sub-catchment is the exception to this, but even this includes small areas of informal settlement and some suburbs with extensive backyard dwellers.
- In areas not subject to high levels of sewage-impacted stormwater, the CCT is encouraged to implement or require implementation of SUDS-type interventions and implement pollution tracking when water quality deterioration is detected. These measures will help to maintain the current relatively good status of water quality in these sub-catchments. These sub-catchments comprise:
    - The Silvermine Sub-catchment
    - The Lourens Sub-catchment
    - Hout Bay (upper Sub-catchment)
    - The South Peninsula Sub-catchment; and
    - The Liesbeek River and its tributaries within the Lower Salt Sub-catchment.
- The accumulation of solid waste is also rife in many areas of the City, particularly in low-income areas. This waste passes readily into stormwater systems, from where it is costly to remove. It also

blocks or is used to block sewers and pump stations, resulting in added watercourse pollution. Addressing this issue through significantly ramped-up solid waste collection is strongly recommended.

- Halting of the planned implementation of four of six of LUW projects, all within the Sand catchment, has been questioned in this report. In the less-polluted Sand catchment in particular, their implementation might well have given rise to measurable water quality improvements as a result of catchment-scale interventions, carried out in combination with pollution abatement strategies such as sewer and pump station upgrades and repairs.
- The CCT's current stormwater management system results in some catchments extending across two or more Stormwater Planning Regions. This means that, in some cases, river catchments are managed by two or more catchment planners, making integration of projects and responsibilities difficult, and accountability for catchment condition unwieldly.
- Similarly, sewage reticulation activities are also not carried out on a (river) catchment basis. This again means that efforts in one part of a reticulation zone may be negated by a lack of co-ordination with upstream managers, or different strategies and level of effort in different areas.

E5 CONCLUSIONS AND RECOMMENDATIONS

Overall, analyses of water quality data and other complementary datasets highlighted the fact that, from an ecological perspective, **by far the most pervasive and problematic water quality issue almost throughout the CCT's monitored rivers and other watercourses was (and remains) phosphate enrichment**. Although median phosphorus concentrations reduced in many catchments over the 2023 reporting period, the proportion of samples within an Acceptable range reduced by almost half, with just under 80% of samples lying within the Unacceptable range. Phosphate data indicate that phosphorus enrichment negatively affects most of Cape Town's monitored rivers and other stormwater systems. Since many of these nutrient-enriched rivers feed into the City's vleis and dams, the impacts of river phosphorus enrichment are passed on to, and are magnified within, these standing water bodies.

The main drivers of the aquatic ecosystem degradation, and phosphate enrichment in particular, that persisted and, in some cases, worsened in the City's sub-catchments over the current reporting periods, revolved primarily around a number of issues, most of which do not relate to stormwater flows and their effects on rivers and wetlands, but relate rather to inflows of sewage and solid waste from various sources. The **key sources of pollution** were identified as follows:

- Inflows of treated effluent from WWTWs across the City result at best (if licensing requirements are met) in permanent flows of nutrient-enriched effluent into sometimes seasonal or small river systems, and downstream vleis or estuaries. However, not all (or even most) of the CCT's 17 inland discharging WWTWs meet General Effluent Limits.
- Episodic overflows from sewage pump stations and surcharging manholes result in overflows that pass either directly into watercourses or enter them via the stormwater system.
- Runoff from informal settlements and housing areas with high levels of backyard dwelling and/or where there is poor attention paid to maintenance of existing infrastructure result in permanent, generally low level but highly contaminated waste streams passing out of informal settlements and into the City's watercourses.
- Accumulations of large volumes of solid waste and illegal dumping of waste that characterise many areas of the City's open spaces, roadways and pavements. Much of this waste enters watercourses, where it may contribute harmful pollutants to aquatic ecosystems (e.g. cans containing oil and other waste; old nappies and other organic waste) or block stormwater drains and channels. When solid waste is disposed of into the sewer system, it can block sewers and clog pumps at sewage pump stations. This issue stems largely from inadequate solid waste collection, compared with the volume of waste generated.

There are many other activities and landuses that contribute to cumulative water quality degradation in the City. The above are considered by far the most significant, and unless they can be addressed or their impacts mitigated, there is little likelihood that the CCT will be able to effect meaningful and measurable improvement in water quality in most of its managed sub-catchments.

E5.1 Key recommendations from this report

Upfront it must be stated that until the pervasive issues of pollution from WWTWs and informal settlements can be addressed, it is unlikely that there will be a significant turn-around in water quality in many areas. Notwithstanding this proviso, the current report highlights the key interventions and/or activities that stem from the assessments that were completed, providing specific recommendations in relation to:

- Addressing pollution from major WWTWs;
- Addressing pollution from informal settlements and suburbs with high levels of backyard settlement;
- Addressing sewage overflows from pump station failure;
- Reducing the passage of solid waste into stormwater systems and watercourses;
- Making changes in stormwater and sewerage reticulation management structures;
- Fast-tracking implementation of PASAPs and TAPs;
- Changing targets for interpreting sewage contamination in water quality data;
- Conservation of existing sub-catchments in relatively good condition;
- Conservation of remnant floodplains and their wetland;
- Prioritisation of LUW programme implementation;
- Changes to the CCT's water quality monitoring programme in terms of sampling sites and water quality variables;
- Reporting water quality data;
- Water quality data availability;
- The need to link water quality data to pollution control interventions;
- Improvements in data quality or data availability from other CCT datasets; and
- Capturing spill data per catchment.

In addition to the above, specific recommendations have been provided to improve inland water quality reporting going forward. One of the key recommendations made here, in order to simplify water quality reporting, and make its outputs more accessible to wider non-technical audiences, is the use of the CCT's Water Quality Indices. In this regard, it is strongly recommended that the CCT updates its (2013) Ecological and Recreational Use Water Quality Indices, and use these in annual reporting instead of the current format. The Indices output a single rating per water sample (A-F), which is based on consideration of the concentrations and condition thresholds of the full range of variables considered individually here.

Water quality in Cape Town's watercourses is not determined solely by the CCT's interventions. Residents also need to play a role in reducing sources of pollution into watercourses. This report includes ten priority steps that local residents can take which, if carried out by sufficient numbers, could lead to measurable improvements in water quality in aquatic ecosystems in at least some sub-catchments.

ACRONYMS

BMB	Biodiversity Management Branch
CBD	Central Business District
CCPOA	Century City Property Owners' Association
CCT	City of Cape Town Metropolitan Municipality
CFF	C40 Cities Finance Facility
cfu	Colony forming units
Chl-a	Chlorophyll-*a*
COD	Chemical Oxygen Demand
CSRM	Catchment, Stormwater and River Management (Branch of CCT)
CWQC	City Water Quality Categories
DEA	Department of Environmental Affairs
DEADP	(Western Cape) Department of Environmental Affairs and Development Planning
DO	Dissolved oxygen
DWAF	Department of Water Affairs and Forestry (now DWS)
DWS	Department of Water and Sanitation
EFZ	Estuarine Functional Zone
E. coli	*Escherichia coli*
EC	Electrical conductivity
FLR	Friends of the Liesbeek River
FBNR	False Bay Nature Reserve
FOZR	Friends of Zeekoevlei and Rondevlei
GI	Green Infrastructure
GN	Government Notice
HBRCF	Hout Bay River Catchment Forum
IUA	Integrated Unit of Analysis
LDC	Liz Day Consulting (Pty) Ltd
LUW	Liveable Urban Waterways (programme)
mamsl	metres above mean sea level
MAC	Milnerton Aquatic Club
MCC	Milnerton Canoe Club
Mplain	Mitchell's Plain
MPP	Mayoral Priority Programme
mS/m	milli-Siemens per metre (unit of measurement for conductivity)
NbS	Nature-based Solution
NH3	Abbreviation used in this report for free ammonia (NH_3)
NH4-N	Abbreviation used in this report for nitrogen in total ammonia (NH_3 + NH_4^+)N

NO3-N	Abbreviation used in this report for nitrogen in nitrate salts
PASAPs	Pollution Abatement Strategy and Action Plan
PES	Present Ecological State
pH	Potential of hydrogen (a measure of how acidic or basic a substance is)
PO4-P	Abbreviation used in this report for phosphorus in phosphate
RQOs	Resource Quality Objectives
SABS	South African Bureau of Standards
SLPass	Sir Lowry's Pass
SSB	Scientific Services Branch (of the CCT)
SUDS	Sustainable Urban Drainage Systems
TAPs	Transversal Action Plans
TECs	Target Ecological Category
TIN	Total inorganic nitrogen
ToR	Terms of Reference
Tot P	Total phosphorus
TSS	Total suspended solids
UNESCO	United Nations Educational, Scientific and Cultural Organisation
W&SD	Water and Sanitation Department (CCT)
WHO	World Health Organisation
WQIP	Water Quality Improvement Programme
WQMR	Water Quality Management Region
WTP	Water Treatment Plant
WWTW	Waste Water Treatment Works

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1 PREFACE AND INTRODUCTION

1.1 Background

The City of Cape Town (CCT) is responsible for the management of numerous rivers and wetlands, including open water vlei systems, estuaries and coastal lakes, within its municipal boundaries. These are referred to together as 'inland waters', largely in line with the South African classification system for aquatic ecosystems (Ollis et al. 2013).

The CCT has monitored the quality of water in these water bodies since the early 1980s, and its water quality database includes data from both long-term, routine monitoring points and those generated from *ad hoc* or project-specific monitoring.

Regular reporting on the results of water quality sampling is required in order to inform both City managers and other interested parties / members of the public about the state of the City's watercourses. The CCT's Catchment, Stormwater and River Management Branch (CSRM) thus provides ongoing internal reporting on inland water quality to various City branches and departments. In addition, an independent overview of all water quality data for routine sites, dating back to 1982, was undertaken in 2020 (Day et al 2020), followed by a report on the City's inland water quality data, outlining river and wetland conditions and trajectories over the 2020 / 2021 reporting period (Day et al 2023). In December 2023, Lukhozi Consulting Engineers ("Lukhozi") was appointed by the CCT, through its term tender (Contract 194C/2020/21-CSRM), to prepare the 2022 / 2023 Inland Water Quality Report, including an analysis of water quality data collected between October 2021 and end of September 2023. These data were to be assessed in the context of the medium-term trajectory of water quality over the past five years (i.e. as far back as October 2018).

Given LDC's previous involvement in the compilation of the CCT's inland water quality reports, Lukhozi subcontracted LDC to compile the 2023 report.

1.2 Scope of Works

The CCT's Scope of Works for this project stipulated that the appointed consultants should compile a report on the water quality of Cape Town's waterways that:

- Follows the same format as the 2021/2022 Inland Water Quality Report (i.e., Day et al. 2023);
- Utilises the same thresholds for interpretation of water quality data that were established in the 2020 Inland Water Quality Report (Day et al 2020) and included in the 2021/2022 report;
- Analyses water quality data for a five-year period up until end of September 2023, with a particular focus on the two-year period between October 2021 and September 2023;
- Is scientifically defendable in its analyses and data interpretation and presentation;
- Uses language that is readily accessible by a wide-ranging and largely non-technical / non-scientific audience;
- Includes reporting on progress made in key CCT programmes that have a bearing on water quality in inland waters;
- Includes all data, analyses and graphics in spreadsheet format for subsequent use by the CCT.

1.3 Project Team

Lukhozi is a private consulting engineering company, which has sub-contracted the present project to Liz Day Consulting (Pty) Ltd (LDC). LDC is a private consulting company, specialising in river and wetland assessment, management and rehabilitation.

The current project included the following team members:

- Lukhozi team:
  - Mr James Lochner
  - Ms Natalie Ritsch
- LDC team:
  - Dr Liz Day (LDC): project manager and water quality consultant
  - Mr Dean Ollis (Inland Waters Consultancy): water quality consultant
  - Mr Ian Wilson (Spatial Mapping Solutions), providing GIS input and producing all GIS-based maps
  - Mr Michael Day (R-analyses and graphics production).

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

1.4 Client team

Input into this report was also guided by the CCT's team from the Catchment Stormwater and River Management (CSRM) Branch, comprising:

- Ms Nicole Garcia
- Mr Fahad Aziz
- Mr Richard Nell.

1.5 Audience

This report is intended to be accessible to a wide range of audiences, including people with both technical and non-technical / non-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, in the Executive Summary and in the non-technical Summary Report that is being produced as an accompaniment to this technical report.

1.6 Types of aquatic systems included

This report considers water quality data for Cape Town's inland and estuarine water quality monitoring sites, as well as for a number of coastal stormwater outlets. 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 key catchments. The report also excludes water quality data from *ad hoc* or once-off sites, for which only a few data points exist, as well as data generated as part of investigations into specific water quality issues in localised parts of the City (e.g. following particular pollution events).

1.7 Limitations

The following limitations should be borne in mind when reading this report:

- Large amounts of water quality data are available in the CCT's database. Of necessity, this project needs to summarise these data to draw out significant patterns and highlight particular areas of interest. The 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 CCT;

- Conversely, not all variables of concern are necessarily included in the CCT's monitoring programme and are not therefore covered in this report. Heavy metals, for example, are not routinely analysed by CCT, largely for budgetary reasons. Jackson et al. (2009) and Infinity & CCT (2022) 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 (see also Day et al. 2022 for comment on heavy metals in the Zeekoe catchment);
- Although the CCT routinely collects phytoplankton samples for enumeration and identification of algal species, these data were not included in this assessment;
- This report does not provide a synopsis of the ambient water quality in the rivers, canals, and open water bodies across CCT because the analyses presented here are based exclusively on the sampling sites of particular concern that are routinely monitored by the Scientific Services Branch (SSB) of the CCT – aquatic systems that are not affected by pollution issues have, to date, generally not been monitored[1];
- 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 CCT's SSB, in Athlone;
- LDC distances itself from the implications of any future decisions taken to access any water bodies for recreational purposes, on the basis of the data and assessments outlined here. These all refer to the past condition of these water bodies, and no undertakings regarding future water quality or risk to human health is intended.

1.8 Report structure

This report has been structured as follows:

- **Section 1**: Preface and general introduction;
- **Section 2**: Background information on water quality, an introduction to the CCT's managed river catchments and stormwater regions, and a brief summary of the main findings and recommendations of the previous Inland Water Quality Report;
- **Section 3**: Introduction to the CCT's routine water quality monitoring programme and datasets; description of the water quality variables considered in this report; the water quality thresholds used to determine water quality classes and to set targets; an outline of data analysis and presentation approaches used in this report;
- **Section 4**: Consideration of rainfall data from sites within the CCT, to illustrate rainfall seasonality and patterns in annual rainfall that might have some bearing on water quality in Cape Town's watercourses;
- **Section 5**: Presentation of the assessment of long-term and current water quality data for river, stormwater and standing water sites across CCT, presented at a sub-catchment level, and discussed in terms of each of the key variables selected. This section includes compliance-type graphs and summary boxplots for all of the kay variables included;
- **Section 6**: Presentation of water quality data pertaining to the condition of the key recreational vleis in the CCT, with regard to water quality risks to human health. This section focuses on variables with a direct bearing on human health during recreational activities, hence: *E. coli*, enterococci, and microcystin toxin data;
- **Section 7**: An overview of the key programmes established by the CCT in an effort to address water quality issues in particular;
- **Section 8:** A summary of water quality conditions and concerns in the CCT's seven priority

[1] At the time of compilation of this report, the CCT's CSRM branch had engaged with the SSB to identify additional monitoring sites in the City, that would allow for more balanced reporting on ambient water quality across all of the City's watercourses, without the current bias towards monitoring of problem areas. These data should be reflected in the 2024 water quality report.

catchments, including comment on measures undertaken in each to try to address these;

- **Section 9:** Summary of key issues, with recommendations 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 define water quality thresholds of acceptability; detailed data tables, showing summary annual data for each of the key variables selected, for each site, for each year between October 2021 and September 2023; and the full statistical boxplots for variables presented in **Section 5**. Readers with a particular interest in water quality at a particular site can access more detailed site specific information in these tables.

1.9 Acknowledgements

Useful comments and feedback and ongoing input into the project were provided by the following officials from the CCT's CSRM Branch: Water and Sanitation Department; Water and Waste Directorate:

- Mr Michael Killick
- Mr Richard Nell
- Ms Nicole Garcia
- Mr Fahad Aziz
- Stormwater Planning Region managers and their teams:
    - Mr Abdulla Parker
    - Mr Ben De Wet
    - Mr Johann Terblanche and
    - Mr Gerhardt Muller.

The Scientific Services Branch is thanked for providing the datasets, and for comments regarding the collection and analysis of water quality samples. In particular, comment from Mr Robert Siebritz and Dr Swastika Surujlal-Naicker is appreciated.

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

2 WATER QUALITY IN AN URBAN CONTEXT

2.1 Cape Town's watercourses

Extensive natural watercourses as well as artificial stormwater channels, canals, pipelines and detention ponds occur in Cape Town's urban areas, and together form part of the City's stormwater system, which is managed by the CCT. These include:

- 16 630 km of pipes and culverts[2]
- 890 detention ponds
- 236 stormwater treatment wetlands
- 1 880 km of natural rivers and streams[3]
- Around 567 km of lined and unlined open channels and canals
- 4 164 'natural and semi natural' wetlands, including 'vleis' and estuaries[4].

Box 2.1
What is 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.

The 'extent of a watercourse' (i.e. that area that is considered in the legislation) is further defined in Government Notice (GN) 4167 of 2023 as the area within the 1:100 year floodline of the watercourse, or the delineated riparian area, whichever is the larger.

The CCT also considers the river floodplain as the area below the 1:100 year floodline – this has relevance to the application of its policy for development in flood-prone areas, which requires new developments to be set back from rivers and their floodplains and its stormwater quality policy, which regulates the treatment of runoff from new developments, into watercourses.

2.2 Water course classification

The City's watercourses range from rivers, through wetlands and coastal lakes, to estuaries, as well as artificial or highly modified dams and vleis. Natural water quality can vary widely between different systems. So when assessing water quality data, it is important to understand which watercourses are being assessed.

In South Africa, a classification system (Ollis et al 2013) has been developed, to allow different watercourse types to be distinguished from each other. This system is a hierarchical one, which distinguishes first between marine, estuarine and inland systems, and then further categorises inland systems, in terms of different types of rivers and wetland. The present report deals only with **inland** and **estuarine** ecosystems. These are discussed and illustrated briefly below.

2.2.1 Inland systems

There are three broad types of inland systems, namely:

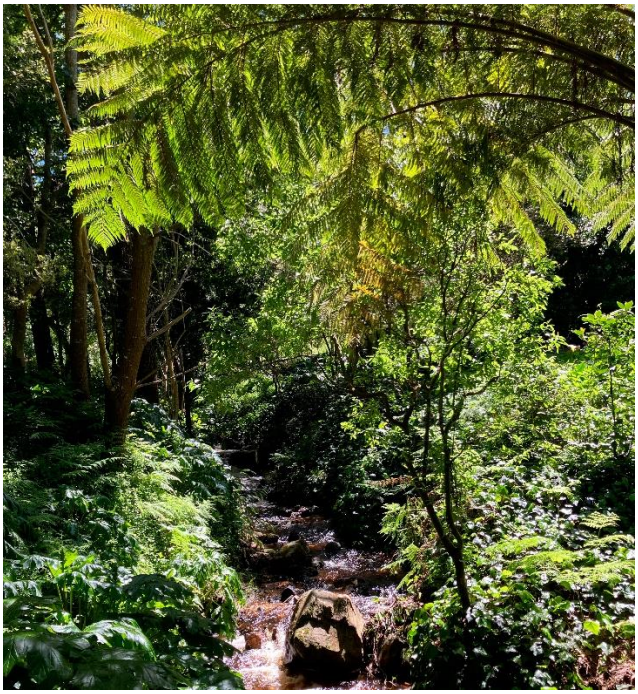
- **Rivers**, which are flowing water systems, where water is concentrated in distinct channels. Five river types can be identified within Cape Town's water bodies:
    - **Mountain stream** reaches flowing off steep mountain gradients, and tending to occur on the outskirts of CCT and to lie outside of the urban edge – many of these are perennial systems, fed by extensive aquifers;
    - **Upper (or Cobble) foothill** reaches, which occur on the steep mountain foothills, and which, where they pass through the CCT'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 – these tend

[2] Data from http://www.capetown.gov.za/family%20and%20home/transport-and-vehicles/road-safety/our-stormwater-system
[3] Data kindly supplied by Ms Kristin Botes, City of Cape Town
[4] Data from CCT wetland layer

to be highly impacted by urban land-use;

- River reaches classified in the CCT'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 – most of these have been channelised, and have lost all or most of their wetland characteristics; and
- **Lowland rivers**, which meander across broad floodplains and generally pass into the estuarine zone of the river. These systems have been highly impacted by urban land-use (e.g. they have been canalized or channelized to reduce their floodplain extent) and many floodplains have been developed over.

Table 2.1
Examples of river types in Cape Town.



Mountain stream (Diep River, Constantia)



Transitional stream through Noordhoek wetlands area



Cobble foothills
(Hout Bay River)



Gravel foothills
Liesbeek sub-catchments (Photo: CCT)



Valley-bottom wetland / 'wetland transitional' stream
Channelised and partially diverted Keysers River



Lowland River
(bermed Eerste River)



Remnant floodplain wetlands on the Eerste River



Flooded floodplain wetlands
(Eerste River – following September 2023 floods)

- **Open water bodies,** which are permanently inundated water bodies where standing water is the main habitat – open water bodies with water greater than 2 m in depth are also called lake (or limnetic) systems;
- **Wetlands,** which are characterised by permanently, seasonally or temporarily saturated soils, sometimes covered with shallow water and vegetated with plants that are adapted to life in saturated soils or standing water.

Of the above inland systems, **this report considers only rivers, artificial stormwater channels and canals** that are comparable to 'rivers' in their various forms; and the main 'open water' bodies that are routinely monitored by the CCT. The latter include both natural and artificial water bodies (e.g. stormwater detention ponds).

In addition, there are artificial stormwater canals and channels, as well as piped stormwater outlets into marine area – these are included with the river (i.e., flowing water) systems for the purposes of this report.

2.2.2 *Estuaries*

Before urbanisation, Cape Town's rivers all ultimately passed into the sea via estuaries or coastal lagoons. There are 10 estuaries within the CCT's boundaries, namely the Diep River (Milnerton Lagoon), Hout Bay, Wildevoelvlei, Bokramspruit, Schuster, Silvermine, Zandvlei, Eerste, Lourens and Sir Lowry's Pass estuaries. The Sout and Salt systems would also have formed estuaries / coastal lagoons under natural conditions, but these have long lost all natural estuarine function as a result of upstream changes including canalisation up to the seashore.

Most of city's estuaries have been highly modified, their river outlets having been converted into concrete canals (e.g. the Salt and Sir Lowry's Pass Rivers), and with none of the salt flux and tidal exchange necessary to meet the criteria for an estuary. At the time of this report, Zandvlei was the only remaining system that, despite significant levels of impact, retained real estuarine functionality (see **Section 6**). The Eerste River Estuary has been severely impacted by large volumes of low salinity wastewater discharges; the Diep River Estuary (Milnerton Lagoon) has been heavily polluted by ongoing inflows of treated and untreated sewage, including from the Potsdam WWTW (Rose et al

Box 2.2
Open water bodies

Rietvlei, Zeekoevlei, Princessvlei, Little Princessvlei, Langevlei and Wildevoelvlei are all lake-like open water bodies. Of these, Rietvlei and Zeekoevlei have both been artificially modified to provide near-permanent standing water for recreational purposes, and water levels in Princessvlei are also managed by an artificial weir.



View of Rietvlei

Box 2.3
What is an estuary ?

Estuaries are legally defined as '*a body of surface water—(a) that is permanently or periodically open to the sea; (b) in which a rise and fall of the water level as a result of the tides is measurable at spring tides when the body of surface water is open to the sea; or (c) in respect of which the salinity is higher than fresh water as a result of the influence of the sea, and where there is a salinity gradient between the tidal reach and the mouth of the body of surface water*" (definition from The National Environmental Management: Integrated Coastal Management Act (Act 24 of 2008 (as amended 2015)).

Many of Cape Town's natural estuaries no longer meet the above criteria.



Photo: **Eerste River estuary**

2023); and the Lourens River and Silvermine River estuaries have also been impacted by urban development and (in the case of the former) significant upstream abstraction.

Other naturally seasonal coastal lakes, which opened periodically to the sea during particularly wet periods (e.g. Rondevlei and Zeekoevlei) have today been connected to the sea via artificial channels and canals (Brown and Magoba 2009. These channeled outlets do not, however, have any estuarine function.

In this report, Milnerton Lagoon (downstream of Otto Du Plessis Drive) and Zandvlei have been treated as functional estuaries. The other estuaries are either not routinely monitored at their outlets or their outlets are too altered to be expected to have any estuarine characteristics.

2.3 The ecological importance of urban watercourses

From an ecological perspective, urban watercourses can act as corridors of relatively natural habitat through increasingly sterile urban landscapes and, in Cape Town's case, they also connect mountainous habitats with the coast. They also provide aquatic habitat and, in some areas, are of great biodiversity importance. The CityCity lies in the heart of the Cape Fynbos Biome, and some of its aquatic ecosystems, support species of plants and/or animals that occur in a restricted area and nowhere else in the world.



The Western Leopard Toad (*Sclerophrys pantherina*) 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)



***Aponogeton angustifolius* (Cape pondweed) is a Western Cape endemic wetland plant species that occurs in watercourses that dry out in summer. It is threatened by habitat loss, with many seasonal wetlands within urban areas in particular being infilled or changed to permanently wetted systems as a result of urban drainage**
(Photo: T. Stock)

2.4 Urban watercourses and waste

Urban watercourses can play important roles in a city, and their overarching 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. For example, while properties in proximity to well-managed watercourses in good condition may benefit from enhanced property value, those in proximity to watercourses that are in poor condition, subject to litter, odour or aquatic plant invasion (including algal growth in standing water bodies), are likely to experience a decline in property value (de Wit et al. 2009).

Among the most profound issues affecting water quality in Cape Town, as well as in many other urban centers, is the impact of waste. Treated and untreated sewage waste that enters Cape Town's watercourses is a particular cause of problems.

Under ideal conditions, domestic and industrial waste is conveyed to waste water treatment works (WWTWs), 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 or for irrigation; or, in some areas, treated further for human consumption. In practice, however, the management and treatment of human waste is often fraught with problems, particularly in developing countries. Key issues relevant to waste management in Cape Town are:

- Informal settlements and back-yard dwellings with inadequate or no sanitation, resulting in sewage waste as well as so-called "grey water" discharges, comprising waste water from cooking and washing, being discharged into roads or directly into stormwater systems – high densities of human populations in both informal settlements and backyard dwellings make this a major water quality (and human health) issue;
- 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, sometimes caused by power outages due to 'load-shedding' or the illegal dumping of foreign objects into the sewage system;
- Poorly treated effluent discharged from WWTWs into rivers, contributing 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. Without dilution by the receiving waterbody, even effluent that is treated to comply with legal standards (e.g. General Effluent Limits, as specified by the National Department of Water and Sanitation (DWS)), 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 back-washed 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 (e.g. from used nappies, offal and other waste sources) can wash into the stormwater system.



Litter accumulating along the edges of watercourses in Cape Town



Polluted industrial inflows into the Diep River



Solid waste and raw sewage threaten human health and downstream wetlands in the Masiphumelele informal settlement



Polluted point-source inflows of sewage and grey water from unserviced settlements in the Big Lotus River catchment

2.5 City catchments

Cape Town lies within the Berg River catchment, which forms part of the Berg-Olifants Water Management Area. The City's numerous watercourses drain 17 major catchment areas, shown in **Figure 2.1** (including the City Bowl). Some of these areas in fact include a number of relatively small catchments, which are lumped together for management purposes. These include the 'South Peninsula' catchment, comprising several discrete river systems such as the Bokramspruit River, the Schusters River and the Noordhoek Wetlands; and the Sir Lowry's Pass River system, which includes the hydrologically separate but adjacent Soet River system, itself almost wholly an artefact of stormwater management.

It should be noted that the City Bowl and adjacent Sea Point and Camps Bay areas do not have any remaining natural rivers. Both natural and artificial drainage is diverted into underground systems, which can nevertheless affect coastal water quality if polluted. These catchments are reflected in this report in data for coastal stormwater outlets only.

By contrast, the Mitchell's Plain catchment, shown in **Figure 2.1**, would not have included any natural rivers prior to urbanisation. Rainwater falling in this part of the Cape Flats probably infiltrated through the sand or formed shallow, largely isolated wetlands. Today, however, the area is highly urbanised, and runoff from the hardened surfaces is collected in large artificial detention ponds and conveyed to the sea through stormwater pipes and drains.

Other catchments (Atlantis, Steenbras, Llandudno, Chapmans Peak and Muizenberg catchments) do not have major rivers and do not currently include any monitoring points. These catchments have not been color-coded in **Figure 2.1** and are not referenced further in this report, although clearly activities in these catchments, as in all catchments, have an impact on the quality of water entering the coastal zone.

Three catchments are significantly larger than others, namely the Diep, Eerste and Salt catchments. For the purposes of this report, these catchments have been further divided into sub-catchments (the Diep and Mosselbank; the Kuils and Eerste; Elsieskraal and the Lower Salt Sub-catchments). These sub-catchments are shown in **Figure 2.1**, and all of the delineated areas in that figure are hereafter referred to as 'sub-catchments'. These might, as already outlined, include several minor

discrete river systems and their catchments (e.g. the South Peninsula Sub-catchment); an entire river catchment (e.g. the Hout Bay Catchment), or a discrete portion of a large catchment (e.g. the Kuils Sub-catchment of the Eerste River Catchment). It should also be noted that a large proportion of the Diep, Mosselbank and Eerste River Sub-catchments in fact lie outside of the CCT's boundary.

The (small) Soet and adjacent Sir Lowry's Pass River Sub-catchments are managed by the CCT as one unit and referred to as the Sir Lowry's Pass / Soet Sub-catchment.

2.6 CCT's priority sub-catchment areas

Seven priority sub-catchment areas have been identified by the CCT for focused interventions, intended to improve river and wetland ecosystem function, and through this, an improvement in water quality. The priority sub-catchments are:

- The Lower Diep River (upstream of Milnerton Lagoon)
- The Sir Lowry's Pass and Soet River
- The Lower Salt River
- The Kuils / Eerste Rivers
- The Hout Bay River
- The Big and Little Lotus Rivers (within the Zeekoe catchment)
- The Sand catchment (upstream of Zandvlei.

The above priority sub-catchments also form the focus of three major CCT programmes, namely the CCT's Water Quality Improvement Programme (WQIP); the Liveable Urban Waterways (LUW) Programme and the Mayor's Priority Programme (MPP) on Sanitation and Inland Water Quality.

Progress in these three programmes, with particular regard to interventions aimed at improving water quality within the priority sub-catchment areas, is reported on in **Section 7**, and the condition and trajectory of water quality in each of the priority sub-catchments is considered in **Section 8**.

2.7 Stormwater management regions

While Cape Town's rivers and other watercourses lie within catchments, defined by topography and separated by watersheds, the CCT manages them through so-called Stormwater Planning Regions. There are four such regions, comprising a Northern, Southern, Eastern, Central and Western region (see **Figure 2.2**). Each region has a separate manager, responsible for stormwater management across the whole region. The delineations of the regions do not take any account of the 17 major river sub-catchments, but in many cases cut through sub-catchments, assigning sections of a river and its tributaries in some cases to two or even three different managers. This means that effectively it is difficult to manage stormwater and its associated water quality issues from a catchment perspective, which would be a more logical starting point.

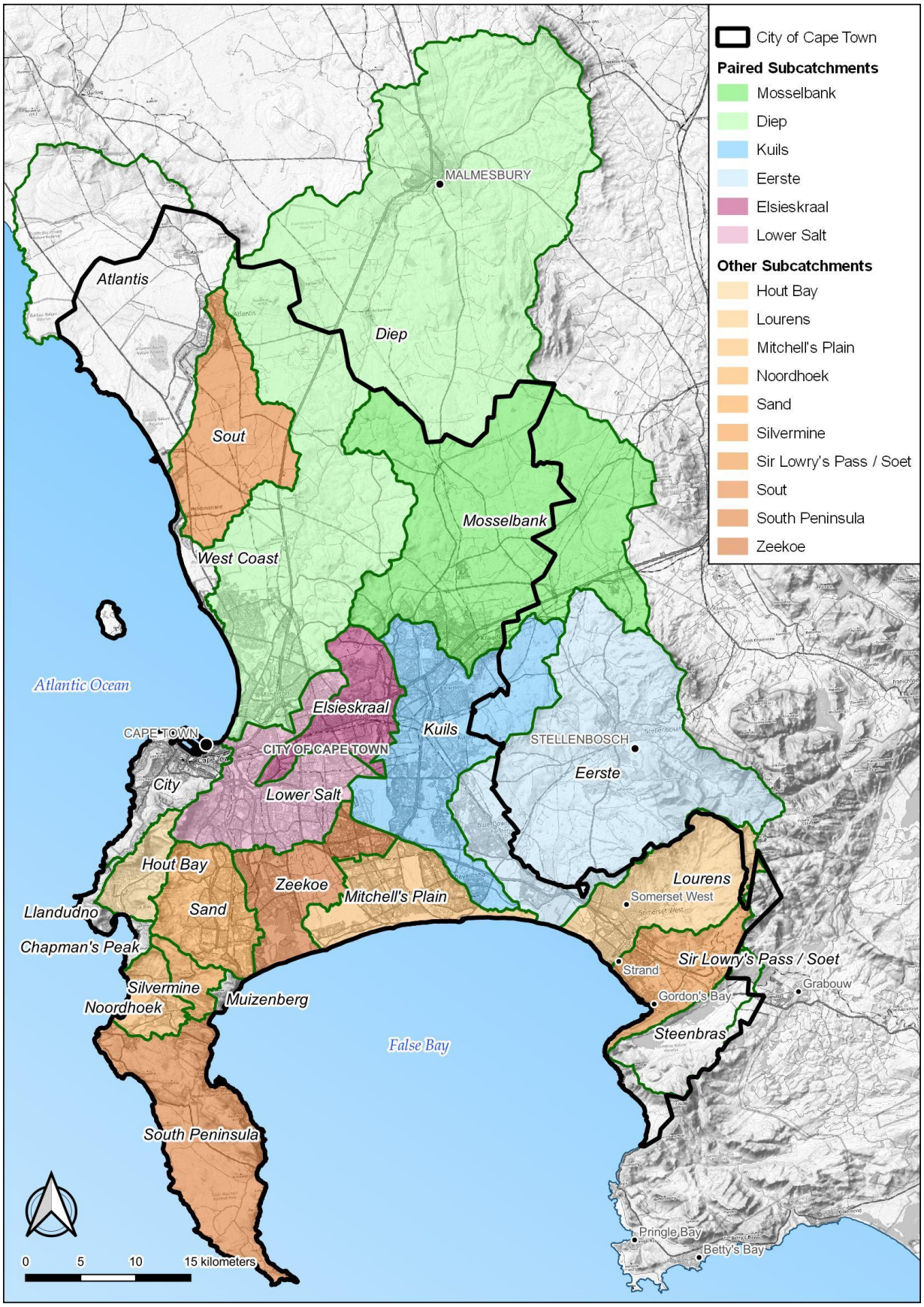


Figure 2.1
Cape Town's major sub-catchments and watercourses

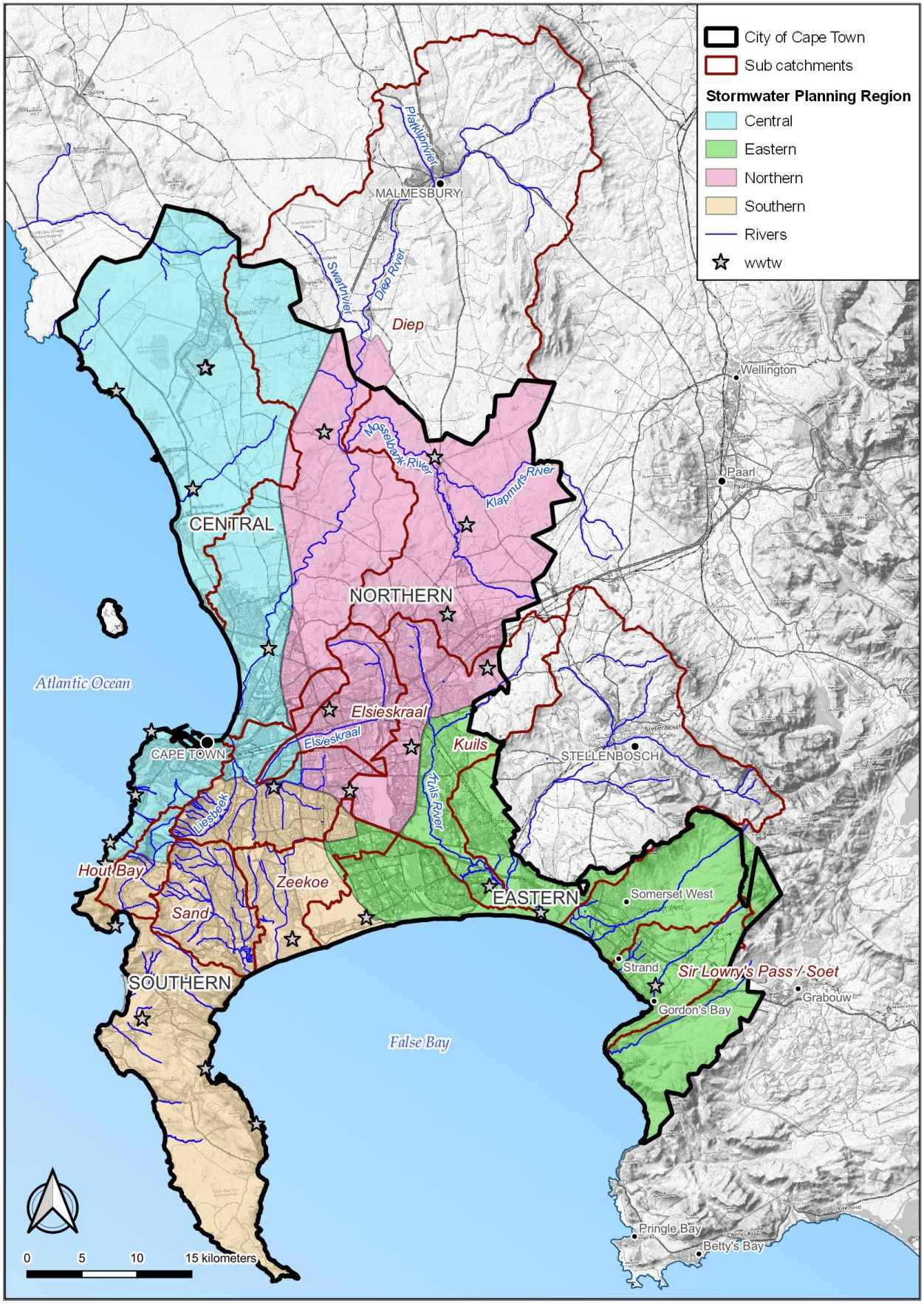


Figure 2.2
Relationship between the CCT's stormwater planning regions and Cape Town's river catchments.

2.8 Key findings and recommendations of the previous (2023) Inland Water Quality Report

The previous Inland Water Quality Report (Day et al. 2023) concluded with the following broad findings and recommendations:

- Discharges of variously treated effluent from the City's WWTWs contribute substantially to watercourse degradation. Many WWTWs were dysfunctional and/or poorly performing as a result of sewage inflows exceeding their design capacity and/or because of a history or poor maintenance and delayed upgrades. The report recommended that:
    - Upgrades to WWTWs should be prioritised
    - Rehabilitation of wetlands / watercourses impacted by years of WWTW discharges should take place (e.g. Milnerton Lagoon)
    - Attention should be paid to fast-tracking mechanisms for the procurement of pumps and other equipment required to effect repairs or remediation of contaminated areas
    - CSRM should include final effluent water quality and discharge volumes from all WWTWs in its data base, to allow for more integrated interpretation of water quality data in receiving water bodies
- Pollution from informal settlements and suburbs with high levels of backyard settlement needs to be addressed with urgency, as does the rapid and uncontrolled expansion of informal settlements in many areas of the City;
- Sewage overflows from pump station failure needs to be addresses – the report noted that the main reasons for pump station overflows over the CCT's 2020/2021 financial year were rooted in mechanical and equipment failure, rather than load-shedding;
- The passage of solid waste into stormwater systems and watercourses must be reduced – the report recommended upscaling solid waste collection in the City to reduce the high levels of waste that accumulate in many areas as well as the introduction of pro-active measures to improve waste management in solid waste hotspots.
- Changes in stormwater and sewerage reticulation management structures were recommended, to allow for catchment-based stormwater and sewage reticulation management, rather than the present system of regional management across multiple but incomplete catchments;
- Fast-tracking implementation of PASAPs was recommended, as well as the compilation of additional PASAPs for other key pollution hotspots, including the lower Kuils River, the upper Sir Lowry's Pass River, the upper Sand River through Retreat and the Diep River sub-catchments;
- A focus of effort on maintaining existing sub-catchments that are in relatively good condition – the report identified some sub-catchments and portions of sub-catchments that were in a generally good condition and recommended that these should be safeguarded, with high attention paid to addressing sources of periodic pollutant inflows into these systems to ensure that these sub-catchments remain in a relatively good condition within the CCT boundaries (identified sub-catchments comprised the Silvermine, Lourens, (upper) Hout Bay, South Peninsula and Sand sub-catchments;
- Inclusion of the Sand catchment as a priority catchment on the basis of the high ecological importance of the catchment; its vulnerability to frequent sewage overflows and pump station failures; and the high levels of recreational use of the Zandvlei estuary and its

associated wetlands;

- Conducting a study to assess the real socio-economic costs of vlei / estuary closure as a result of poor water quality (this recommendation stemmed from the extended closure of three of the City's recreational vleis in 2021/ 2022, on the basis of their water quality data. Profound economic and social implications for businesses and users dependent on access to these water bodies were assumed, but never quantified);
- Changes to the CCT's water quality monitoring programme, as follows:

- Inclusion of additional water quality monitoring sites in the Khayelitsha Wetland Park, at a representative site for the water bodies utilised by the Khayelitsha Canoe Club and downstream of all WWTW effluent outfalls into rivers or channels;
- Monitoring of the following additional water quality variables is recommended:
    - Chloramine and COD in receiving waters downstream of WWTWs;
    - Heavy metal analyses at the downstream ends of all catchments, with heavy metals to be determined with regard to sub-catchment land use characteristics.
    - Enterococci testing at all sites currently tested for *E. coli,* with a view ultimately to moving from *E. coli* to enterococci testing as well as for improving confidence in / double-checking *E. coli* data.
- Measures to improve confidence in E. coli data (e.g. submitting replicate data to other accredited laboratories for data verification);
- Standardisation of reporting on *E. coli* and other bacteriological data, so that data can be analysed statistically without being confounded by poor dilution effort, resulting in multiple samples reported as "> x cfu/100 ml", where x may be orders of magnitude below actual counts;
- Water quality monitoring data that indicate pollution of the City's watercourses must be followed up by active pollution tracking and interventions;
- Improvement in the rainfall data collection, collation and recording was recommended;
- Measurement of flow regime in main watercourses was recommended, to allow calculation of pollution loading into downstream systems and associated prioritisation of pollution abatement measures;
- Recommendations for interventions by all city residents to reduce their own contribution of pollution to our watercourses.

3 APPROACHES TO WATER QUALITY MONITORING, DATA ANALYSIS AND INTERPRETATION[5]

3.1 What is water quality?

The term 'water quality' refers to 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'.

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. Guidelines may focus on water quality criteria for human drinking water; aquaculture; industrial use; domestic animal drinking water; irrigation water; recreational use of water (e.g. swimming or watersports); and guidelines as to the effects of different concentrations of different water quality variables on aquatic plants and animals.

Since assessing water quality from a human health and/or ecological perspective requires data representing a range of physical, chemical, and biological attributes, people with expertise in the fields of freshwater ecology, water chemistry and microbiology should ideally be tasked with interpreting the data.

Box 3.1

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. At present, the CCT's Inland Water Quality reports focus 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 CCT. In fact, because the focus of monitoring is on poorly performing systems, the water quality data assessed in this report arguably exaggerate the level of watercourse pollution in CCT.

It is, however, reasonable that water quality monitoring effort should focus on problem areas, **provided that such effort is accompanied by focused pollution abatement efforts.**

Note that in future, the CSRM plans to include sampling points across a wider range of sites, including those that are not in perceived problem areas.



Clean stream in Cape Town – photo courtesy CCT

3.2 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 water bodies, including rivers and lakes/vleis. This is important for informing decisions about the risks that exposure to water 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 and, where long-term data are available, can provide an indication of the trajectory of different ecosystems – that is, whether their condition is improving or deteriorating over time. Such information can and should be used to inform planning around the need for engineering or other interventions to address deterioration in any watercourses. They can also be used to assist catchment managers in strategic planning around where to focus efforts to achieve maximum returns.

[5] While most of this report has been updated entirely to reflect new thinking, data and interpretation since the 2023 report of Day et al. (2023), this section has been edited only where necessary, to reflect minor changes, but essentially the assessment and reporting methodologies outlined here remain (as a specific requirement of the Terms of Reference for this contract) as per those of the 2023 approach.

Water quality data can also 'red flag' sudden onsets of pollution (caused, for example, by sewage leaks or illegal discharges); inform pollution-tracking efforts along watercourses; and provide evidence for compliance with licensing or permit conditions.

3.3 The CCT's Inland Water Quality Monitoring Programme

The CCT's water quality database goes back to the late 1970s for at least some monitoring points along its main rivers and wetlands/vleis. The 2020 Inland Water Quality Report (Day et al 2020) analysed and discussed the full historical record of water quality data included in this extensive database.

The present report deals only with data generated from water quality monitoring over the past five years. These monitoring points are located in main rivers and stormwater outflows into watercourses, as well as key wetlands, dams, detention ponds and stormwater outflows into the marine environment.

The CCT differentiates between water quality data from its routine sampling programme, reflecting data from samples collected from the same monitoring points on a regular, long-term basis; *ad hoc* samples, collected to inform specific once-off or short-term questions around pollution type, magnitude or sources in particular watercourses; and project-specific data, collected as part of specific programmes such as for pollution tracking or to inform stormwater master planning.

The present report considers only data from **routine** water quality sampling.

Figure 3.1 shows the locations of all the current inland routine monitoring points utilised in this study, including sampling points located at major stormwater outfalls along the coast.

A range of chemical, algal and bacterial constituents are measured from water samples collected at these sites, and the data are interpreted and reported on by the CCT's Catchment, Stormwater and River Management (CSRM) Branch.

Box 3.2
Public access to water quality data

Following years of agitation from concerned members of the public and various organisations regarding their need to access the CCT's water quality data to allow for independent data evaluation and comment, the CCT announced in April 2022 that these data would be available for public download from its data portal [https://odp-CCTegis.opendata.arcgis.com/documents/inland-water-quality/about]. These data include most but not all of the monitored water quality variables from inland and estuary systems.

Box 3.3
Limitations of water quality data

Water quality data show only what the quality of water was like at the time of sampling and at the specific location where the sample was collected. It cannot be used to infer future water quality (for example whether a waterbody is fit for swimming a day or even an hour after sampling, or to show what it was like immediately before sampling. 'Plugs' of pollution, for example, may be missed, or accidentally targeted by the timing of sampling. Furthermore, where watercourses are seriously contaminated, point-source pollution streams may be difficult to identify, because of the high level of general contamination.

It also only provides information about the constituents that were actually measured – there may also be other kinds of pollutants in the water. For example, CCT's routine water quality monitoring does not include analyses of heavy metals, hydrocarbons, or contaminants of emerging concern (CECs).

Note that this report reflects only water chemistry and microbiological data, and not algal data, other than microcystin toxin data.

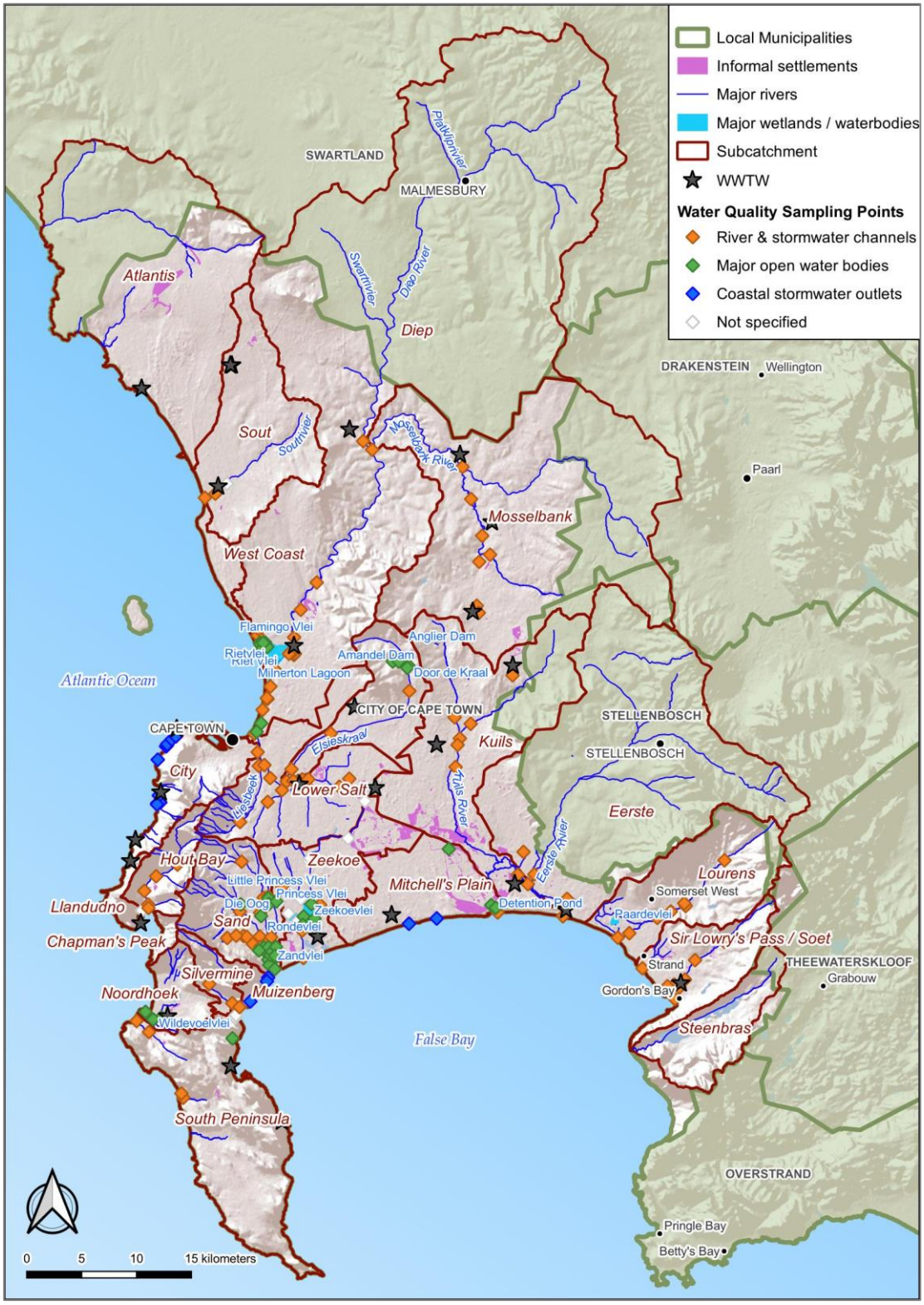


Figure 3.1
City sub-catchments, showing water quality sampling point locations on river and stormwater channels and canals; standing water systems (vleis and dams); and coastal stormwater pipeline outlets.

3.4 Objectives of the CCT's water quality monitoring programme

To date, the CCT's water quality monitoring programme has been designed to monitor changes in watercourses where water quality is likely to be a cause for concern. Many of the monitoring points are therefore 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 religious rituals (e.g. baptisms) and/or recreational purposes (e.g. sailing, rowing and kayaking). Water quality data for such systems 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 Cape Town's watercourses, the data collected by the CCT to date focus on problem areas, and provide information about long-term trends and trajectories of water quality in these systems.

This means that water quality data over-emphasize problem areas, and do not provide an over-arching view of water quality in the City's rivers and wetlands as a whole. This issue has been considered by the CSRM, and additional sites, intended to provide a more holistic overview of water quality in the City's watercourses, will be monitored during the course of 2024 and going forwards, and should be reflected in the 2024 or 2025 inland water quality reports (Ms N. Garcia, CSRM, pers. comm.).

3.5 Context in the Berg Resource Quality Objectives study

Cape Town falls within the Berg-Olifants Water Management Area. In 2020, the Department of Water and Sanitation (DWS) published a 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 Cape Town Metropolitan Area, on the Cape Peninsula and along the West Coast (see Government Notice 1179 of 6 November 2020). The following Priority Resource Units fall within the CCT's boundaries:

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

The resource classification and associated determination of RQOs are intended to inform management of water resources in the greater Berg catchment. The gazetted 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:

- Water quantity (flow regime/hydroperiod)

Box 3.4

RQOs and Estuaries

The Berg Water Resource Classification system assigned Resource Quality Objectives to river and estuary systems in the Berg Water Management Area, including those in CCT. It is important to note that this study defined estuaries as <u>all areas below 5 m above mean sea level (mamsl)</u>. This area in fact relates to the legislated Estuarine Functional Zone (EFZ). It is based on Listing Notice 3 of Government Notice (GN) 324 of 2017, which defines an EFZ as '*the area in and around an estuary which includes the open water area, estuarine habitat (such as sand and mudflats, rock and plant communities) and the surrounding floodplain area, as defined by the area below the 5 m topographical contour (referenced from the indicative mean sea level)*'.

Under this definition, many non-estuarine watercourses such as Langevlei, Rondevlei and Zeekoevlei have been classified as estuarine, and assigned estuarine rather than Inland standing water RQOs.

- Water quality
- Aquatic habitat and
- Aquatic biota.

The water quality categories used in the present Inland Water Quality Reports are generally compatible with those of the Berg RQOs, although there are some differences in the classification of estuaries between the two (see **Box 3.4** above), and orthophosphate and free ammonia ranges have been amended in this report, to reflect more accurate ecological thresholds than those included in the RQOs (these issues are unpacked in more detail in **Section 3.7**).

For the vlei systems within the City that have been delineated as estuaries in the Berg RQO study, an assessment of compliance with the RQOs that were set for salinity has been included in the current report (**Appendix E**).

Note that the Water Resource Classification as presented in the gazette relates only to rivers and estuaries, with the classification of wetlands and the associated setting of wetland RQOs not yet having been finalised.

3.6 Water quality variables considered in this report

Although the CCT 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 are assessed in the Inland Water Quality Report, as determined in Day et al. (2020). The following variables have been included (abbreviations used to refer to them in this report are shown in brackets – note that, with the exception of un-ionised ammonia (NH_3) these abbreviations are not intended to be in scientific notation):

- Major nutrients
    - Phosphorus in orthophosphates (PO4-P)
    - Phosphorus in total phosphorus (Tot-P)
    - Total Inorganic Nitrogen (TIN)
- Un-ionised (or 'free') ammonia (NH_3)
- Dissolved oxygen (DO)
- *Escherichia coli* bacteria *(E. coli*)
- Microcystin concentrations
- Chlorophyll-*a* (Chl-*a*)
- pH as an indicator of ammonia toxicity risk; and
- Electrical conductivity (EC) as a measure of salinity, specifically for vlei systems in the City that were delineated as estuaries in the Berg RQO study.

3.7 Water quality thresholds to guide data interpretation

3.7.1 Thresholds to interpret ecosystem condition with regards to water quality

Tables 3.1 and **3.2** outline the ranges in concentrations of key water quality variables considered in this report, with regard to their implications for **ecosystem condition**. The criteria used to derive these (currently nationally acceptable) thesholds are outlined in **Appendix B** along with the link between these categories and the various terminologies used in different DWS reporting (e.g. DWS (2008) A-F categories and DWAF (2011) Ideal – Unacceptable descriptors).

The ranges and thresholds distinguish between **flowing water systems** (rivers, channels and canals) and **open water systems** (dams, vleis, detention ponds and coastal lakes). The rationale behind these thresholds is also outlined in **Appendix B**, after Day et al. (2020).

3.7.2 Changes in water quality thresholds for aquatic ecosystem assessments in the present report

Two changes in water quality thresholds have been introduced into the present report, in discussion with the CSRM. These are as follows:

- Free ammonia ranges have been amended to reflect more accurate ecological thresholds than those included in the RQOs. Specifically, the Present Ecological State (PES) Category A and B ("GOOD") and Category C ("Fair") thresholds (all "Acceptable") were decreased from ≤ 0.044 mg/L to ≤ 0.007 mg/L and from 0.072 mg/L to ≤ 0.015 mg/L, respectively. This change is in line with the DWAF (1996) guidelines for target and chronic toxicity thresholds, respectively. Since DWAF (2008) also references DWAF (1996) as the source of toxicity thresholds, it is assumed that the values used in DWAF (2008) for Categories A-D (rating classes 0-3) were entered erroneously.
- Whereas the 2020 and the 2023 water quality reports used orthophosphate concentrations as a measure of both flowing and standing water phosphorus enrichment, the present report rather uses [6]**total phosphorus** concentrations to measure standing water phosphorus enrichment, using the values provided by DWAF (2002) and reiterated in DWAF (2011) guidelines for lakes and dams. The 2020 RQOs for dams in the Berg catchment erroneously use the same orthophosphate phosphorus thresholds for dams and rivers. The use of total phosphorus concentrations is a more useful measure for standing water systems such as vleis, lakes and dams (Cooke et al 2005).

Table 3.1
Rating ranges for variables considered in this assessment of water quality in Cape Town's rivers.
See Appendix B for derivation of threshold values.
Note: PO4-P= phosphate phosphorus; TIN=Total inorganic Nitrogen; DO=Dissolved oxygen; N:P= ratio of TIN:PO4-P; NH3 = un-ionised ammonia. Note also that the terms 'PO4-P', 'TIN' are abbreviations and are not the full chemical notation for these variables.

City Water Quality Categories (CWQC)	Interpretation of CWQC	PO4-P Mg P/l	TIN Mg N/l	DO mg/l	N:P	NH_3 mg/l
GOOD	TARGET	≤ 0.015 (oligotrophic)	≤ 0.70 (oligotrophic - mesotrophic)	>7	>25	≤ 0.007
FAIR		> 0.015 - 0.025 (mesotrophic)	>0.70-1.00 (mesotrophic)	>6-7		> 0.007 - 0.015
POOR	POOR	> 0.025- 0.125 (eutrophic)	>1.00 -4.00 (mesotrophic - eutrophic)	>4 -6	10-25	> 0.015-0.1 (chronic toxicity)
UNACCEPTABLE	UNACCEPTABLE	> 0.125 (hypertrophic)	> 4.00 (eutrophic - concentrations > 10mg/L classified as hypertrophic)	≤ 4	< 10	> 0.1 (acute toxicity)

[6] Total phosphorus (TP) is a measure of all the forms of phosphorus, dissolved or particulate, that are found in a sample. By contrast, orthophosphate phosphorus is a measure of the soluble, inorganic) portion of total phosphorus. This form is the biologically available component that is taken up by plants.

Table 3.2
Rating ranges for variables considered in this assessment of water quality in cape town's vleis and dams.
See **Appendix B** for derivation of threshold values.
Note: TP= total phosphorus; TIN=Total inorganic Nitrogen; DO=Dissolved oxygen; N:P= ratio of TIN:PO4P; NH3 = un-ionised ammonia; CHL-A= Chlorophyll-*a*. Note also that the terms 'PO4-P', 'TIN' etc are abbreviations and are not the full chemical notation for these variables.

City Water Quality Categories (CWQC)	Interpretation of CWQC	TOTAL PHOSPHORUS mg P/l	TIN mg N/l	DO mg/l	N:P	NH_3 mg/l	RUNNING MEAN ANNUAL CHL-A µg/l
GOOD	TARGET	≤ 0.015 (oligotrophic)	≤ 0.7	> 7	>25	≤ 0.007	≤ 5
							>5 - 10
FAIR		> 0.015 – 0.047 (mesotrophic)	>0.7 -1	>6-7		> 0.007 - 0.015	>10 -20
POOR	POOR	>0.047 - 0.130 (eutrophic)	>1.0-4.0	>4 -6	10-25	> 0.015-0.1 (chronic toxicity)	> 20 - 30
UNACCEPTABLE	UNACCEPTABLE	>0.130 (hypertrophic)	> 4	≤ 4	<10	> 0.1 (acute toxicity)	> 30

3.7.3 Thresholds to interpret water quality risks to human health

Tables 3.3 and **3.4** present the thresholds used to determine risks to human health on the basis of monitoring of two key variables, namely *Escherichia coli* bacteria (an indicator of exposure to raw sewage and other faecal sources from warm-blooded animals (i.e. birds and mammals)) and microcystin toxins, which can be associated with cyanobacteria (also called blue-green algae).

Concentrations of all of these are evaluated with respect to the level of risk they pose to people undertaking 'intermediate contact' recreational activities, such as canoeing, kayaking, fishing, sailing, rowing, kite-boarding and wind-surfing.

Although people undertaking such activities are likely to come into contact with and possibly ingest some water, they are less at risk than people undertaking 'full-contact' recreational activities (e.g. swimming).

Box 3.1
Interpreting human health guidelines

WHO (2021) guidelines for management of water quality in recreational water bodies stress important points, namely that most generic guideline values are derived from studies involving healthy adult recreational water users. They may not apply to children, the elderly or people who are immunocompromised, who may have lower immunity and might require a greater degree of protection. In addition, risks are also likely to be greater in areas with higher carriage rates or prevalence of diseases that could be transmitted through recreational water contact.

These warnings are particularly relevant to many low-income and particularly informal settlement areas in Cape Town, where people's immune systems may be compromised by chronic exposure to pathogens and poor nutrition and limited access to basic health

Note that the CCT does not manage any of its water bodies with the target of their being fit for full contact rereation. This is not considered a realistic target under the present circumstances.

The criteria used to derive these thesholds are outlined in **Appendix B.**

It must also be noted that, whereas the CCT previously (see Day et al 2023) also monitored Enterococci bacteria counts in vlei water samples, these analyses were discontinued in the 2022/ 2023 monitoirng periods, despite reccommendations for their continuance and expansion of

monitoring sites made in Day et al (2023).

Table 3.3
Approach to the interpretation of microbial data (faecal coliforms including *Escherichia coli*).
See **Appendix B** for derivation of threshold values.
Note the inclusion of Full Contact AND Intermediate Contact thresholds, as well as the expansion of the UNACCEPTABLE range, to show different scales of pollution. This expanded scale was not used in the present report, as a result of issues of reporting on ">" values, as discussed in Section 3.8.10.

Interpretation	Inland systems [1] Faecal Coliform Count (including *E. coli*)[1]
TARGET FOR MAXIMUM ACCEPTABLE RISK FOR FULL CONTACT RECREATION	≤ 400 [2]cfu/100 ml
ACCEPTABLE RISK INTERMEDIATE CONTACT	1 001 – 2 500 cfu/100 ml
TOLERABLE RISK - INTERMEDIATE CONTACT	> 2 500 – 4 000 cfu/100 ml
UNACCEPTABLE RISK - INTERMEDIATE CONTACT– LEVEL 1	> 4 000 – 10 000 cfu/100 ml
UNACCEPTABLE RISK - INTERMEDIATE CONTACT– LEVEL 2	> 10 001 - 100 000 cfu/100 ml
UNACCEPTABLE RISK - INTERMEDIATE CONTACT– LEVEL 3	> 100 000 cfu/100 ml

[1] DWAF (1996) uses faecal coliform bacteria to provide target ranges and risk thresholds for intermediate recreational use. The report acknowledges that *Escherichia coli* bacteria are a preferred indicator of faecal pollution, but notes that many smaller laboratories do not have facilities for these analyses. The report further notes that *E. coli* may comprise up to 97% of coliform bacteria in human faeces. In the present assessment, the CCT's SSB analyses its water samples for *E. coli* bacteria.
[2] 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 3.4
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). Note that WHO (2021) provides an updated GV Recreation (GVRECREATION) Threshold of 24 ug/L for microcystins, below which recreational water use should be within acceptable risk limits. This suggests that the Medium Risk values in the table below are slightly conservative. See **Appendix B** for derivation of threshold values.

Interpretation	Microcystin 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

3.8 Data analysis

3.8.1 Sampling sites included in the analyses

The CCT currently collects routine water quality data from 162 inland monitoring sites. An additional 19 stormwater outlets into coastal areas are also included in the Inland Water Quality Monitoring Programme. In the present report, 192 inland water quality monitoring points are in fact referenced in total – the additional sites listed include detention ponds in the Mitchell's Plain catchment, where there are no natural rivers and monitoring sites in the Rietvlei recreational water body.

Only sites in the CCT's routine monitoring network have been included in this assessment. All sites are sampled monthly, with samples being analysed for basic water chemistry variables and microbiology (*E. coli*). In addition, recreational vleis (Rietvlei, Milnerton Lagoon, Zeekoevlei, Princessvlei and Zandvlei) are sampled roughly twice monthly for *E. coli* (see **Figure 3.1** for details of sample point locations).

These inland monitoring sites include sites in the City's canals, main recreational dams and vleis, major rivers and estuaries, detention ponds and stormwater outlets.

Figures 3.2 and 3.3 respectively graphically summarise the different monitoring point types and the distribution of sampling points per catchment / sub-catchment. These data show that most monitoring points are located in the City's rivers, followed by vleis, and that the largest number of routine monitoring points are located in the Sand Catchment (38); followed by the Diep (27); the Zeekoe (25); and the Lower Salt Sub-catchment (17).

Listings of the actual locations of each monitoring point in each sub-catchment are provided in **Appendix A**.

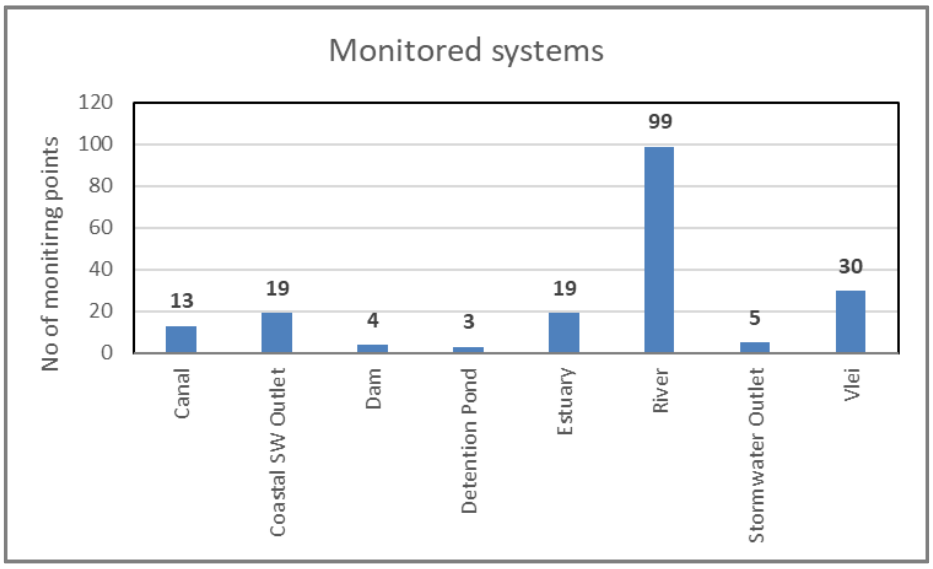


Figure 3.2
Summary of types and numbers of sample points for which data have been included in the present report.

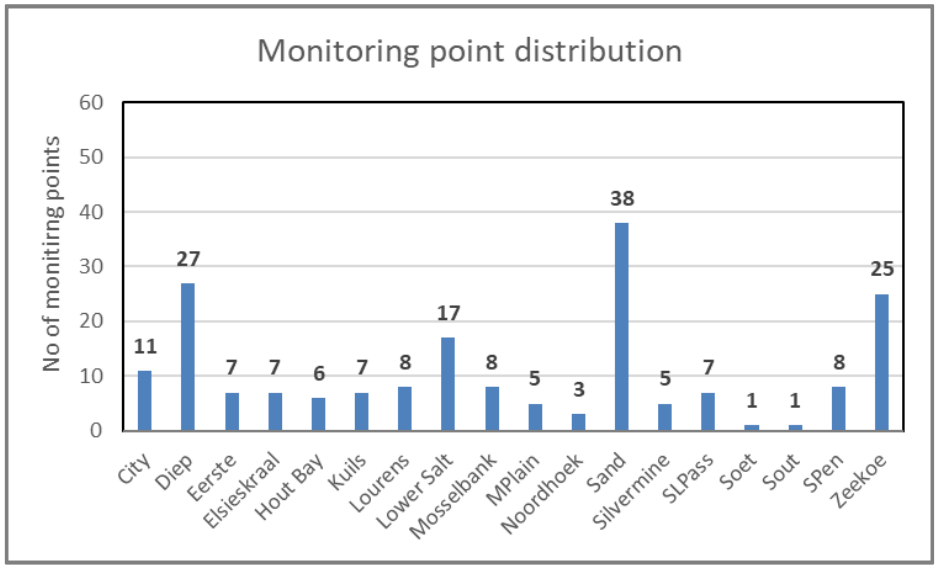


Figure 3.3
Summary of numbers of sites in each sub-catchment for which data have been included in this report.

3.8.2 Dealing with seasonal variability

The concentrations of a number of water quality variables measured in rivers, vleis and other wetlands undergo significant seasonal variability, largely related to differences in rainfall and

temperature between the wet and dry seasons. An attempt has thus been made to 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.

The assignment of different months to these seasons was 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 September 2023 (end of the wet season).

3.8.3 Spatial groupings of data

Sites within the water quality dataset were classified into sub-catchments and catchments, as per the areas identified in **Figure 3.1**. The sub-catchments used as the basis for data analysis are as listed below, noting that in some cases they in fact comprise whole river catchments (e.g. Hout Bay River), while in others the main catchments have been split into different sub-catchments (e.g. Mosselbank and (lower) Diep sub-catchments of the Diep River). Other 'sub-catchments' comprise a number of different river systems in adjacent catchments, considered sufficiently similar in terms of land use 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 sub-catchments in this report to more manageable numbers.

The groupings for catchments and sub-catchments that have been used to present water quality data in this report are as follows:

- Cape Town City Bowl
- Diep
    - Mosselbank
    - Lower Diep
- Eerste
    - Kuils
    - Eerste from the Kuils River confluence
- Salt
    - Elsieskraal
    - Lower Salt
- Hout Bay
- Lourens
- Mitchell's Plain (MPlain)
- Noordhoek
- Sand
- Silvermine
- Sir Lowrys Pass (SLPass)
    - Sir Lowrys Pass (SLPass)
- Soet
- Sout
- South Peninsula
- Zeekoe.

Note that, of these systems, the Mitchell's Plain sub-catchment does not include any natural river systems, but generates large volumes of runoff from hardened urban areas. Two stormwater attenuation pond sample sites have been used to represent water quality in this sub-catchment, runoff from which is also represented in a number of coastal sample sites, which include stormwater

outlets onto the beaches of False Bay.

It should also be noted that not every catchment in Cape Town 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 Sub-catchment), or where natural rivers have been almost entirely piped into the stormwater system (e.g. City Bowl rivers) do not currently have monitoring sites, other than at their coastal stormwater outfall sites.

3.8.4 Calculations to provide additional water quality variables

The following additional water quality variables were obtained for analysis in this report, by calculation from existing data:

- Total Inorganic Nitrogen (TIN) – through addition of NH4-N and (NO3+NO2)-N
- NH4:TIN – the ratio of NH4-N:TIN
- TIN: PO4P – as a ratio of TIN to PO4-P
- PO4-P:Total phosphorus (PO4-P:TotP), expressed as a ratio (note that in some cases this ratio exceeded 1, suggesting analytical error / inaccuracy, and in such cases the data were excluded.

3.8.5 Changes in annual reporting cycles in this report

Previous Inland water quality reports (Day et al 2020 and Day et al 2023) based water quality reporting on annual cycles between April of one year through to March of the following year. These cycles covered ecosystem cycle between autumn and late summer.

In the present report, and going forwards with the Inland water quality reporting, the annual reporting cycle has been changed to reflect so-called hydrological periods, extending from October of one year to end of September of the following year. This change has been instituted to allow for timeous reporting on water quality in any annual cycle, before the end of the CCT's financial year in June. The new cycle aligns well with the summer / winter seasons already incorporated into data assessments (see Section 3.8.2) and is thus not considered problematic from the perspective of scientific rigour in reporting.

3.8.6 Reporting cycle nomenclature

The annual reporting period used in this report comprises the period from 1 October to 30 September in any given cycle and is given the YEAR identity of the **end** of the period. Data for the period 1 October 2022 to 30 September 2023 are accordingly referred to as the **2023** dataset. These annual cycles are different to those referenced in previous Inland water quality reports, as outlined in Section 3.8.5.

3.8.7 Time series considered in this report

The Scope of Works for the present report requires a focus on water quality data for the **2022 and 2023 reporting periods** (1 October 2021 to 30 September 2023).

In order to be able to report meaningfully on at least short- to medium-term water quality trajectories, data for the (new) 2022 and 2023 reporting periods are, however, assessed in the light of data over a five-year period. **Thus, the report includes data from 1 October 2018 through until 30 September 2023**.

Going forwards, it is this team's understanding that the CCT's Inland Water Quality Report will be generated on an annual basis and will assess data from the last reporting period against the previous four years' of data on a rolling basis.

3.8.8 Treatment of unreliable E. coli data

Between April 2021 and January 2022, the CCT's Scientific Services Branch (SSB) reported *E. coli* data that appeared out of sync with observed conditions in many water bodies, and led to the closure of

Rietvlei, Zeekoevlei and Zandvlei, over various periods. Following testing of replicate water samples at independent laboratories, it was noted that there was a serious discrepancy in results, with *E. coli* concentrations being over-reported in SSB data. This was confirmed in independent testing carried out in both Rietvlei and Zeekoevlei.

An investigation into the SSB processes was carried out by SABS in May 2022. This investigation concluded that the Hicrome MTEC agar that SSB had started using in April 2021 was problematic, in that it allowed the growth of both *E. coli* and another faecal coliform bacteria, *Klebsiella pneumoniae*, which has a similar colony form. This made differentiation of the two difficult, leading to inaccurate reporting (Memorandum from SSB to CSRM, 7 February 2023).

As a result of the above findings, the SSB has switched analytical methods, and now uses the Colilert system for *E. coli* analysis.

Given these issues, the *E. coli* data for the period April 2021 to at least May 2022 could not be used for this report. These data span large portions of both the 2021 and 2022 Reporting Periods for this report. As a result, no *E. coli* data are included for either of these reporting periods.

3.8.9 Treatment of data below detection limits

Reporting on the results of laboratory analyses of water samples for different variables are subject to the limits of detection and limits of quantification of different analytical techniques. These data are reported as "< x", where x-=the limit of detection and/or quantification. By convention, such data are analysed in water quality reporting as 0.5 x the reported limit – thus a value reported as <0.5 would be reflected in the dataset as 0.25.

This issue has however created problems in the present reporting cycle, with regard to two different variables, namely orthophosphate and total phosphorus data. Up until January 2022, SSB's limits of detection were reported as < 0.01 mg P/l for both these variables. With effect from January 2023, however, the analytical equipment used by SSB for both these analyses ceased functioning, and the laboratory has outsourced both sets of analysis to date. The data since January 2023 have been subject to detection limits of < 0.1 mg P/L. This is an order of magnitude increase in the detectable concentrations of phosphorus. If the 50% reporting rule is used, and the data are analysed as 0.05 mg P/L, they lie within the "Target" range for rivers / flowing systems but within the "Poor" (or eutrophic) range for vleis / dams / standing water systems. This has implications for tracking the trajectory of concentrations of this critical nutrient in the City's water bodies, as high detection limits may mask improvements in some systems, and will not indicate significant deterioration in others.

Analysis of data for the 2023 reporting period showed that 11.4% of orthophosphate data (395 out of 3457 data points) were reported as < 0.1 mg P/l; while 14% of total phosphorus data (91 out of a total of 650 data points) were reported as < 0.1 mg P/l.

This is an important issue that must be addressed by the SSB.

3.8.10 Treatment of data reported as greater than specified limits

Another data issue that arose in both the present (2022/2023) reporting and the previous (2020/2021) reporting periods is that regarding the reporting of *E. coli* data by SSB. The data include a number of samples that, for reasons of under-dilution cannot be assigned actual numbers of *E. coli* colony forming units, but which are rather reported as '>x' (where x= the level of resolution that has been attained by the laboratory for that sample).

While this method of reporting is normal laboratory practice, over the 2020 reporting period for which *E. coli* data are assumed to be reliable, as well as the 2023 reporting period, there was a marked increase in the reporting of samples as '>' values that were either still below the Unacceptable threshold for this variable, or above the lower threshold, but within relatively low concentrations for known highly polluted scenarios. For example, reporting at >24 196 cfus for samples in a system where *E. coli* counts frequently exceed 1 000 000 cfus does not allow for pollution tracking or for detection of areas where pollution appears to be greater and closer to source. Such practices also make meaningful statistics difficult.

The CCT's SSB has noted that its laboratory routinely conducts dilutions of up to 10^4 of water samples. Where such dilution is insufficient to result in an absolute value, the laboratory reports it as ">x". A limitation on the laboratory's ability to run further dilutions on such samples is that laboratory best practice for *E. coli* analyses requires the analysis of water samples within 6 hours of sample collection (comment from Ms Millicent Julius, SSB, CCT), and greater than 24 hours would have elapsed since sample collection if analyses were to be repeated. Recommendations in this regard have been included in **Section 9** of this report.

For this reason, *E. coli* data were analysed only in terms of Compliance-type reporting of the percentage of samples falling within different categories of acceptability, and were not analysed statistically with regard to their arithmetic mean or other statistical measures.

In addition:

- Data reported as '>' any number below the Unacceptable threshold were automatically rated as Unacceptable;
- Similarly, (less frequent) reporting as '<' any number within the Unacceptable range was also rated Unacceptable. This is a risk-averse strategy to deal with data uncertainty and could result in some over-estimation of Unacceptable data.

Figure 3.4 presents a summary of the number of data points reported as '>' and '<', excluding those in the 2021 and 2022 reporting years, which have already been excluded from the dataset. Only 5% of all data reported in the 2017-2019 (three-year) period were thus reported, while 14.6% of data in the 2020 reporting year alone were affected. Data for samples reported on as '>' for levels below ten million cfu/100 ml at least were considered problematic, as they do little to assist in pollution tracking or catchment-scale interpretation.

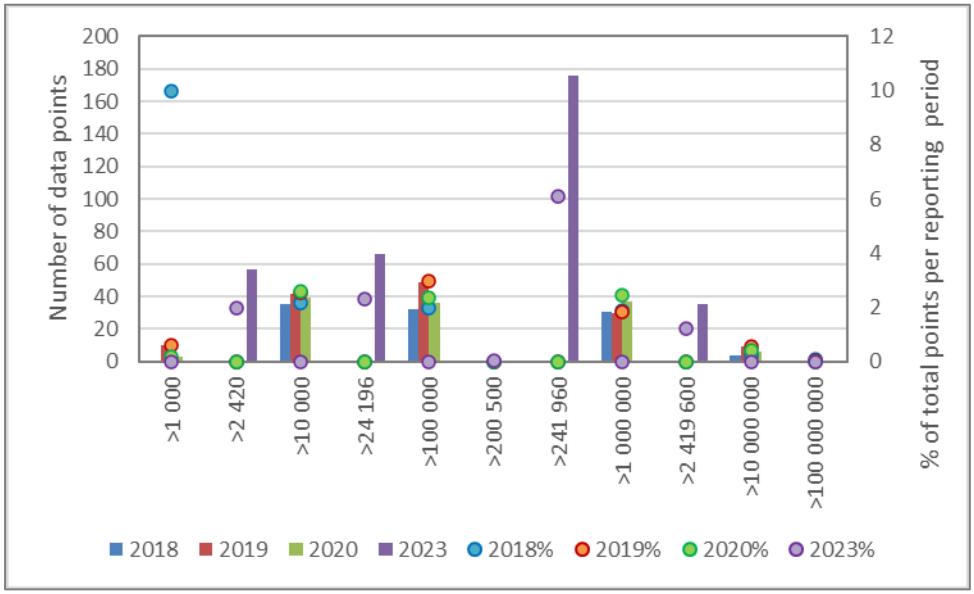


Figure 3.4
Frequency histogram showing numbers and percentages of *E. coli* data reported on as '>x', categorised by reporting year. Data for 2021 and 2022 reporting periods excluded.

3.8.11 Data categorisation

- Seasons were allocated as described in **Section 3.8.2**;
- Sub-catchments were used as the unit of analysis, as already described;
- Sites were analysed separately according to watercourse type, i.e., standing water (vleis, dams and detention ponds) and flowing water (rivers and stormwater channels/ coastal stormwater outlets);
- Functional estuaries[7] 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, 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 and N:P ratios, the interpretation of which did not differ between estuarine and freshwater systems. *E. coli* assessments did, however, distinguish between estuaries and other aquatic ecosystems since different standards are applicable to estuarine and freshwater systems.

3.8.12 Analysis of data for the current reporting period

For the purposes of this report, the 'current' reporting period is defined as the last two years of the monitoring record – that is, October 2021 to September 2023 - and the data from this period have been treated as follows:

- In order to provide broad summaries of 'performance' (that is, the proportion of data for each selected key variable from monitoring points across each sub-catchment over any specified reporting period), compliance-type graphs were created, plotting the percentage of data falling into each of the Target, Poor and Unacceptable categories listed in **Tables 3.1-3.3** for ecological variables, *E. coli* and microcystin toxicity. In this regard:
    - In the case of *E. coli* data, the CCT has set itself a 'target' that at least 60% of samples in any catchment should meet the defined Target thresholds. *E. coli* compliance graphs thus also show this 60% threshold – **Section 5.5.5** provides comment on this practice;
    - Boxplots were developed for all of the selected data, and presented for discussion, comparing the current (2022 and 2023) datasets (separately) with data from the previous three years (2019 – 2021) – these data are presented relative to the interpretation categories for aquatic ecosystem health and human health (*E. coli*) shown in **Tables 3.1 – 3.3;**
- Median annual data per site per variable (note that geometric mean data were provided for *E. coli* and arithmetic mean data were provided for Chlorophyll-a) are also presented in table form (**Appendix C**), with data colour-coded for ease of reference as to its water quality category;
- Truncated summary boxplot data are presented in **Section 5** for ease of reference – the full boxplot datasets including outliers is presented in **Appendix D**.

Box 3.5 provides an explanation of the interpretation of boxplots as a guide to readers unfamiliar with this form of data presentation.

[7] Note that the DWS (2018) classification of all areas below the 5 mamsl contour line as estuarine was not considered in this assessment, and only systems known to comply with the legal definition of an estuary (see **Section 2.2.2**) were assessed using Estuarine rather than Inland thresholds for *E. coli*

Box 3.5

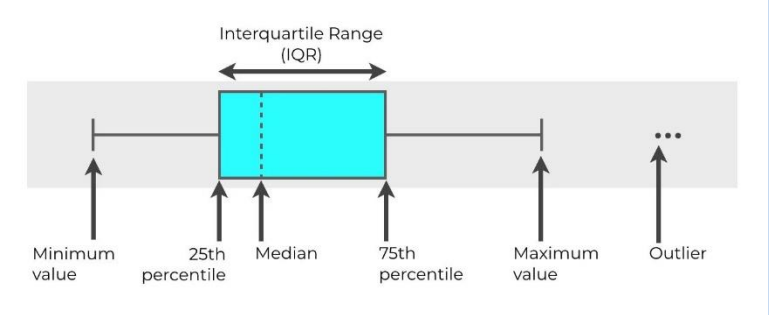
Explanation of boxplots, also known as box-and-whisker plots

A boxplot, or box-and-whisker diagram, is a standardised type of graph for visually depicting the central tendency and variability of a dataset, as well as the distribution (or skewness) of the data and the presence of outliers. It does this by dividing the range of a dataset into quarters, or quartiles, with each quartile containing 25% of the data points. There are thus the same number of data points in each quartile. A boxplot typically consists of three parts: a box (usually split into two portions), a set of lines perpendicular to the box ('whiskers') and point markers beyond the whiskers depicting outliers, as shown in the diagram below. Sometimes, the full range of a dataset is shown as part of the whiskers, in which case there will be no outliers.

The box represents the range of values from the first/lower quartile (Q1 = 25th percentile) of a dataset to the third/upper quartile (Q3 = 75th percentile), with the middle value in the dataset (Q2 = median or 50th percentile) indicated by a line dividing the box into two quartiles. The box thus shows the range of values within which the central half (50%) of the data points of a dataset fall, extending from Q1 to Q3 and known as the Inter-quartile Range (IQR).

The whiskers of a boxplot extend outwards from ends of the box, which represent the lower and upper quartiles (Q1 and Q3, respectively), to the minimum and maximum values of the dataset. For a boxplot, the minimum and maximum values are typically derived from the IQR (i.e., Q3-Q1) to set a boundary beyond which any observations would be considered outliers. The maximum is taken as the largest observed value of a dataset that falls within 1.5 times the IQR added to Q3, while the minimum is taken as the smallest observed value falling within 1.5 times the IQR subtracted from Q1. The whiskers either simply terminate at the minimum and maximum values or short lines are drawn perpendicular to the whiskers at these points (as in the diagram below). It is important to remember that, even though 1.5 times the IQR is the same for both sides of the box, the whisker lengths are often unequal because the whiskers must end at an observed data point. In some cases, the minimum (and boundary of the lower whisker) is simply taken as the smallest observed value of the data set, and the maximum (boundary of the upper whisker) as the largest observed value of the data set.

All data points outside the boundary of the whiskers (i.e., less than the derived minimum or greater than the derived maximum values) are considered to be outliers. Outliers are plotted as individual data points on the boxplot.



3.8.13 Assessment of the current state of water quality in terms of human health risks at major recreational sites

For the assessment of the current state of Cape Town's inland water quality, the last five reporting years of available data (2019 – 2023 Reporting Periods) were used, and the same seasonal cycles and year nomenclature were used as presented in **Sections 3.8.5 – 3.8.7)**.

Data focused on Cape Town's main recreational vleis / water bodies, namely:

- Princessvlei
- Zeekoevlei
- Rietvlei

- Milnerton lagoon
- Zandvlei.

Although inclusion of a section of the lower Kuils River from which the Khayelitsha Canoe Club operates was also proposed, there are no sample points that adequately reflect water quality in this area.

Assessment of human health risk at each waterbody entailed an analysis of the percentage of samples that exceeded the target value for safe intermediate contact recreation in terms of *E. coli,* and microcystin concentrations (see **Sections 3.6 and 3.7** for an explanation of the relevant criteria).

E. coli data for the 2021 and 2022 reporting period were not used, given issues around the reliability of these data (see **Section 3.8.8**).

3.8.14 Assessment of the trajectory of water quality in priority sub-catchments

- Median annual and seasonal data were calculated separately for the two current reporting years (2022 and 2023) and compared against the combined year sets for the 2018 to 2021 reporting periods for all key variables, except chlorophyll-*a* and *E. coli* data. Arithmetic mean data were calculated for the former, while geometric mean data were calculated for *E. coli* data, using the Hazen Method as recommended by WHO (2021), and interpreted as per **Table 3.5**;
- Data showing changes in annual and seasonal data per variable between 2022 data and 2023 datasets were plotted on GIS maps, with a map produced per Priority sub-catchment;
    - The maps were produced for the water quality variables believed to be most indicative of catchment quality – PO4-P; NH3; DO and *E. coli*;
    - The mapped data were colour-coded per site for each variable considered, using the thresholds for Target to Unacceptable, as shown in **Tables 3.1-3.4;**
    - In order to provide an indication of trajectory of change, data points were also coded to indicate improvement, degradation, or no real change. Significant 'change' was determined as **an increase or decrease of 25% or more, compared to the previous dataset;**
    - In the case of *E. coli* data, for which data from the 2021 and 2022 datasets were considered unreliable, no trajectory data have been produced. Note that the *E. coli* data shown in the maps are presented as geometric means, rather than median values, this being the more appropriate way of treating these data (see **Box 3.6**);
    - Total phosphorus data were also not available for the 2023 reporting period (see **Section 3.8.15**), and no trajectory data were therefore plotted for these data either;
    - Data for which no trajectory could be calculated (i.e. total phosphorus (vleis) and *E. coli*) were coded in maps simply with regard to their condition (i.e. Target to Unacceptable and Acceptable to Unacceptable ratings, respectively).

3.8.15 Missing total phosphorus data

No analyses of total phosphorus were carried out by the SSB with effect from January 2023, as a result of equipment failure. The SSB's analytical equipment requires replacement, and at the time of writing of this report, such replacement had not yet taken place (summarised comment from Ms A. Smith, SSB, to CSRM; February 2024).

Box 3.6

Geometric versus arithmetic means

The Geometric Mean (GM) is a type of average, which is often used as a measure of central tendency for bacteria concentrations and other datasets with a large range of variability. While the arithmetic mean finds the average by summing the values and dividing by the number of observations, the GM finds the average by multiplying and then taking a root of the product. The GM is mathematically defined as the **n^{th} root of the product of n numbers**, with the following formula:

$$\sqrt[n]{X_1 X_2 \dots X_n}$$

GM =

Where:

X = the values of a variable; and
n = the number of values in the dataset.

What this formula means is that the values are multiplied by one another, and then the nth root is calculated, where n is the number of values in the dataset. This is the same as taking the average of the logarithmic values of a dataset and converting this back to a base 10 number, which implies that the geometric mean (sometimes referred to as the log mean) is really a log-transformation of a dataset.

The GM tends to dampen the effect of very high or low values to a greater degree than the arithmetic mean. It is always less than the arithmetic mean, except where all the values of the dataset are the same, in which case the two means are equal.

If the variable of interest has a log-normal distribution, the GM is the same as the median for that dataset (Vogel 2020), although random differences can be expected in practice, depending on the number of samples and the sampling frequency (DWAF 1996). It is important to be aware that **the GM is extremely sensitive to both the underlying distribution of a dataset and its skewness, as well as differences in sample size** (Vogel 2020). This measure should thus be used with caution when comparing datasets that have significantly different sample sizes.

4 RAINFALL PATTERNS IN CAPE TOWN

4.1 Rationale for assessing rainfall

Rainfall data are included to provide background understanding of rainfall patterns in different catchments of the City, both over the current reporting period and to get context over a longer-term period (e.g., whether it was a drought year). Tight correlations of rainfall events with individual sample point data is not, however, possible because sample collection is not (and is not intended to) align with rainfall events.

4.2 Approach

Daily rainfall data were provided by the CSRM for 38 rain-gauging stations across Cape Town, spanning the period October 2018 to September 2023 (i.e., Reporting Years 2019 through to 2023). Unfortunately, the dataset provided had numerous 'no data' entries for most of the stations during the relevant reporting periods. In the end, the rainfall analyses completed for the current project involved the use of rainfall data from only ten official CCT rain-gauging stations with no missing data (or only one 'no data' entry during a period when no or very little rainfall was recorded at other rain-gauging stations). The ten stations that were selected are spread across seven of the CCT's catchments (see list in **Table 4.1** and map in **Figure 4.1**).

Additional monthly rainfall data for the five-year period of analysis (Reporting Years 2019 through to 2023) were obtained for a rain-gauging station at the Rondevlei section of False Bay Nature Reserve (in the Zeekoe catchment). To gain a better understanding of the rainfall patterns in the study area during the time period of analysis in relation to longer term trends, a reliable long-term dataset for a rain-gauging station at Intaka Island (Century City, located within the Diep catchment) was also obtained. For the current study, 20 years of rainfall data were extracted from this additional dataset for the period October 2003 to September 2023.

Table 4.1
List of rain-gauging stations used in the rainfall analyses, indicating which catchment and sub-catchment each station is located within [official CSRM rain stations in bold].

Rain station	Description	Catchment	Sub-catchment
ATLA17AR	Atlantis WWTW	Sout	[n/a]
INTAKA	Intaka Island, Century City	Diep	Diep
ELSI03CR	Tygerberg Reservoir	Salt	Elsieskraal
ELSI03ER	Pinelands Roads Depot		
VYGE03GR	Athlone WWTW		Lower Salt
DIEP05CR	Wynberg Reservoir	Sand	[n/a]
KEYS05FR	Tokai Forest		
RONDEVLEI	Rondevlei Section of FB Nature Reserve	Zeekoe	[n/a]
KHAY01RS	Khayelitsha Roads Depot	M-Plain	[n/a]
SPEN13AR	Brooklyn WTP, Red Hill, Simonstown	South Peninsula	[n/a]
LOUR06BRS	Vergelegen Farm, Somerset West	Lourens	[n/a]
LOUR06DR			

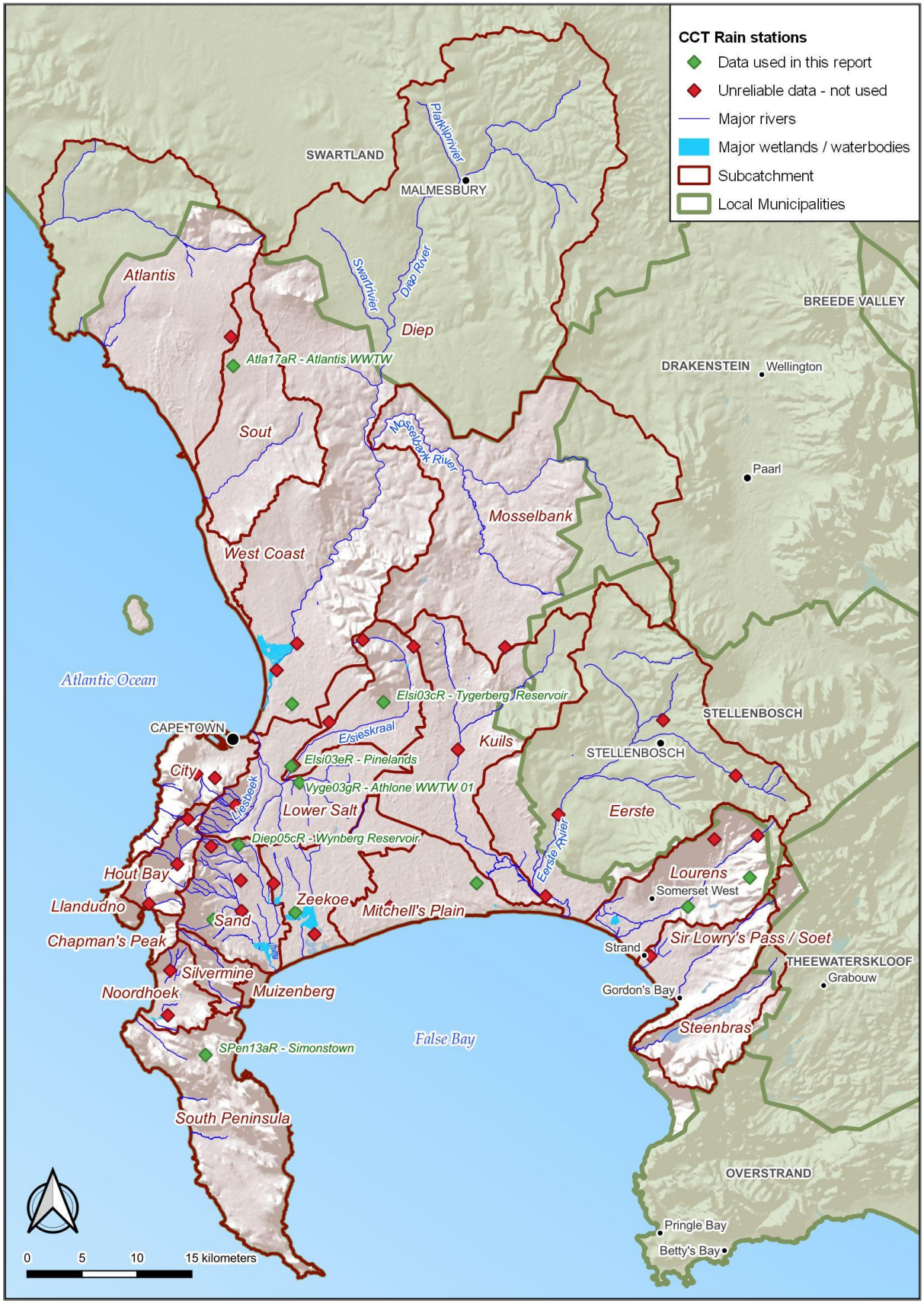


Figure 4.1
Map of rain-gauging stations that were used for the rainfall analyses, in relation to sub-catchments

For the rainfall analyses, monthly rainfall totals were derived from daily rainfall figures, except for the Rondevlei and Intaka rain stations where monthly rainfall totals were provided. The monthly totals were grouped into 'hydrological years' or 'reporting years' (October to September), as opposed to calendar years, and into 'summer' (October to March) and 'winter' (April to September) seasons using the seasonal categorisation explained previously (see **Section 3.8.2**). Rain-gauging stations were grouped into catchments/sub-catchments for some of the analyses.

The following summaries were produced from the two rainfall datasets:

- Intaka Island gauging station (long-term dataset):
    - Total annual rainfall for each year, compared against the mean annual rainfall over the October 2003 – September 2023 period; and
    - Total seasonal rainfall per reporting year, compared against the mean annual rainfall values over the summer and winter seasons for the 20-year period.
- CCT gauging stations:
    - Monthly rainfall at each of the 10 CSRM stations for the October 2018 – September 2023 reporting period, plotted together with maximum daily rainfall per month [the Rondevlei gauging station was excluded from this plot because daily rainfall data weren't available];
    - Total annual rainfall at each station (including Rondevlei) for each reporting year (2019-2023), grouped by sub-catchment, compared against the mean annual rainfall at Intaka Island over the 20-year period;
    - Mean annual rainfall (and standard deviation) across all gauging stations (including Rondevlei) per reporting year for the five-year reporting period (2019-2023), compared against the 20-year mean annual rainfall at Intaka Island; and
    - Total seasonal rainfall per reporting year at each of the 11 stations (including Rondevlei) for the five-year reporting period, compared against the 20-year mean winter rainfall at Intaka Island.

The rainfall patterns are discussed separately, below, for the 20-year period preceding the end of the current reporting period (i.e., September 2023), based on the Intaka Island dataset (**Section 4.3**), and for the five-year period up to the end of the current reporting period, based on the CCT's rain-gauge data (**Section 4.4**). The long-term average, derived from the 20-year Intaka Island dataset, is shown as a point of comparison in some of the analyses for the recent five-year period.

4.3 Intaka Island 20-year dataset

The mean annual rainfall at Intaka Island over the 20-year period of analysis (Oct 2003 – Sep 2023) was 592.3 mm (see **Figure 4.2**). The recent dry years of 2015, 2017 and 2019, with less ≤350 mm per annum, are clearly visible on the bar graph. Going back further, the previous dry period (with <400 mm of annual rainfall), was a much shorter spell in Reporting Year 2011. The annual rainfall recorded at Intaka Island in Reporting Years 2021 and 2022 was still significantly below the 20-year average, at <500 mm per annum, but for the main focal year for the current report (i.e., Reporting Year 2023) the annual rainfall (almost 750 mm) was well above the long-term average. Previous wet periods in the last 20 years (with >750 mm of rain per annum) were observed in the Intaka Island rainfall records for Reporting Years 2013 and 2004-2005.

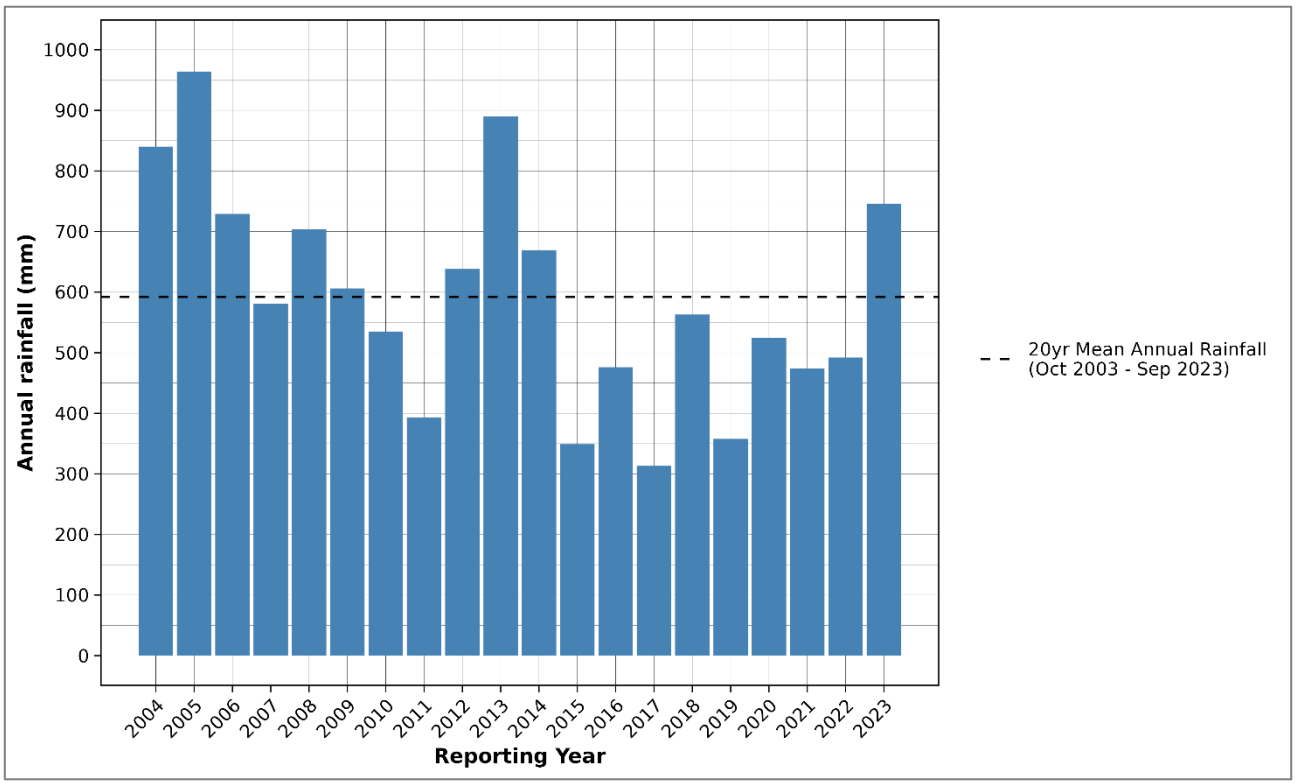


Figure 4.2
Total annual rainfall at Intaka island for the 20-year period Oct 2003 – Sep 2023, showing the mean annual rainfall over this period.

Interrogation of the total rainfall per season for each year over the last 20 years at Intaka Island (see **Figure 4.3**) shows that the total winter rainfall during Reporting Years 2017, 2019 and 2021, at less than 300 mm, was significantly less than the long-term (20-year) winter average of 414 mm. Total winter rainfall was slightly higher in Reporting Years 2020 and 2022, at 300-350 mm, but still below the long-term winter average. During Reporting Years 2018 and 2023, however, the winter rainfall total was above the seasonal average at >450mm. Prior to this, above-average winter rainfall was recorded at Intaka Island in Reporting Years 2012-2014, 2008, and 2004-2006. Total summer rainfall was well below-average during Reporting Years 2015-2019, increasing to average levels (~180 mm per summer) in Reporting Years 2020-2022, and rising significantly above the long-term summer average in Reporting Year 2023 when close to 300 mm of rainfall was recorded at Intaka Island over the summer months of October 2022 to March 2023.

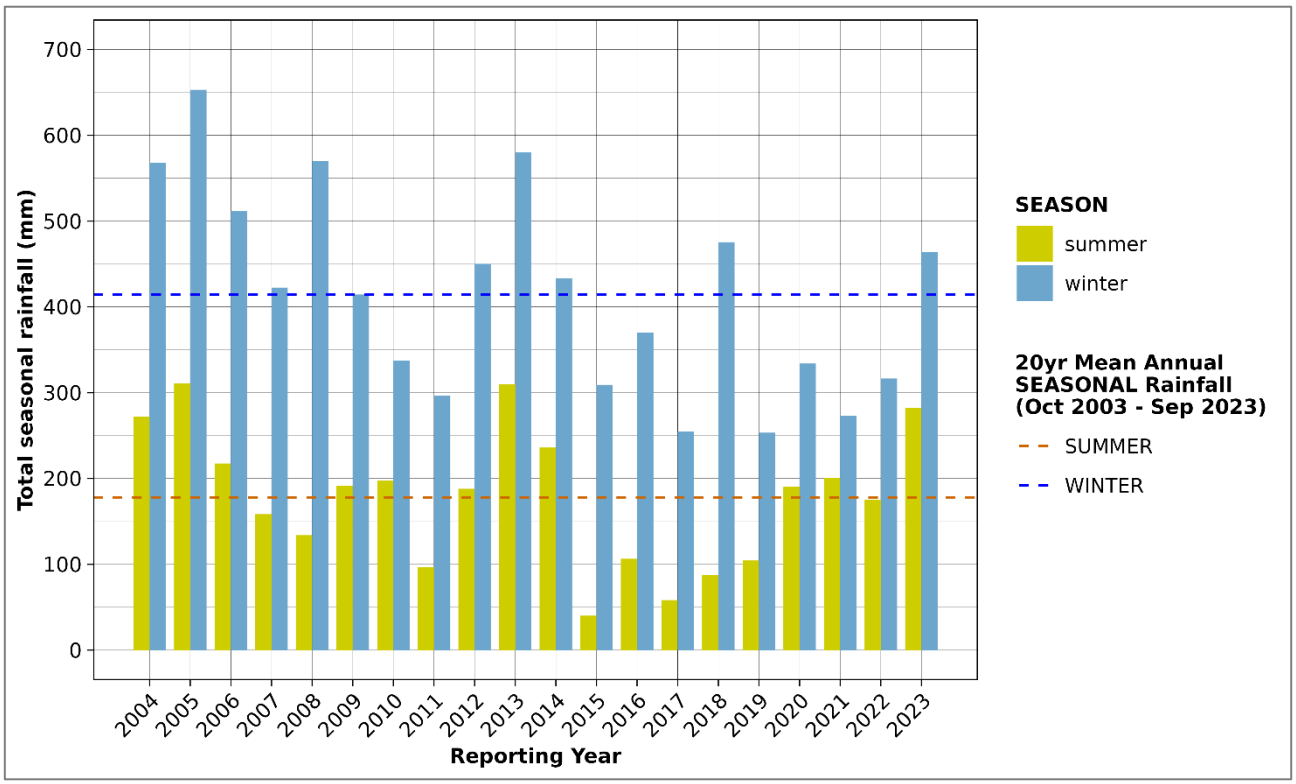


Figure 4.3
Total summer and winter rainfall at Intaka Island for each reporting year between 2004 and 2023, in relation to mean annual summer and winter rainfall for the full 20-year period.

4.4 Five-year period (Apr 2017- Mar 2022) at the CCT's rain-gauging stations

The graph of total annual rainfall at the CCT's rain-gauging stations for the 2019-2023 period (**Figure 4.4**) shows that there was a significant amount of variability between gauging stations across Cape Town in each year, with the highest cumulative rainfall for each year typically being recorded at rain stations LOUR06DR and LOUR06BRS (in the upper reaches of the Lourens catchment), and DIEP05AR and KEYS05FR (in the Sand catchment). At most of the rain stations across the City, significantly more rain was recorded for Reporting Year 2023 compared with the other years, with the only exceptions being rain stations ELSI03CR, KHAY01RS and RONDEVLEI (where the total rainfall in Reporting Year 2023 was not significantly higher than the other years in the period of analysis). This pattern is also shown very clearly in the graph of mean annual rainfall (and standard deviation) per year across all gauging stations (**Figure 4.5**), confirming that Reporting Year 2023 was a particularly wet year across all parts of Cape Town. For Reporting Years 2019 to 2022, but especially 2019 and 2022, the mean annual rainfall across all CCT rainfall stations included in the analysis was below the long-term (20-year) MAP of just under 600 mm derived from the Intaka Island dataset.

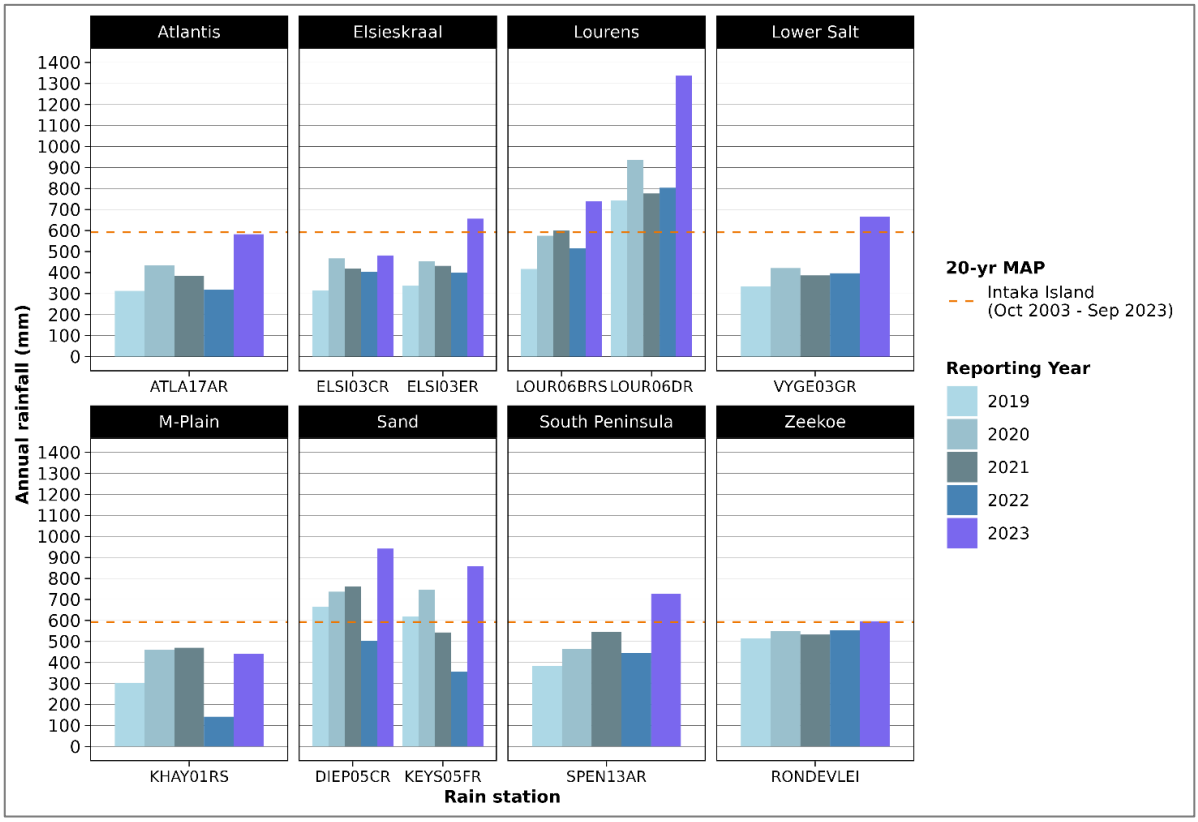


Figure 4.4
Total annual rainfall (Reporting Years 2019-2023) at each of the CCT rain-gauging stations that were selected for the rainfall analyses, grouped by sub-catchment, showing the long-term (20-year) map at Intaka Island.

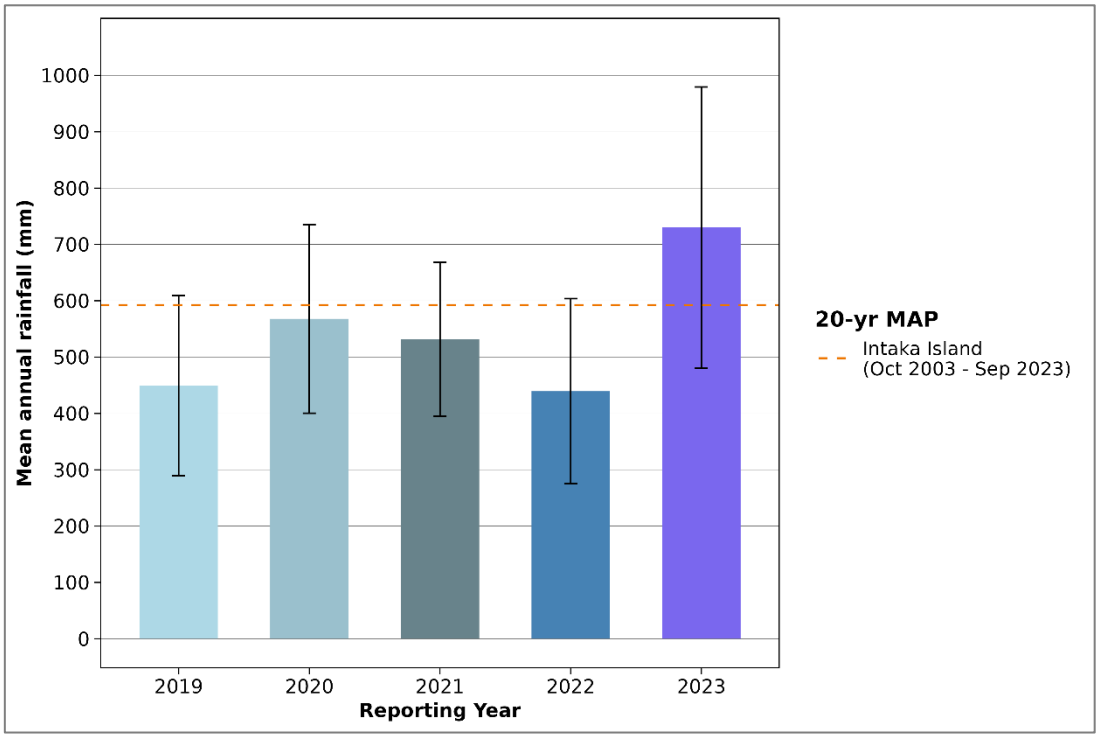


Figure 4.5
Mean annual rainfall (and standard deviation) per year across all of the CCT rain-gauging stations that were selected for the rainfall analyses (Reporting Years 2019-2023).

The similar pattern of month-to-month fluctuations in rainfall, typically peaking in the winter months of June to August, is evident in the bar graphs of total monthly rainfall at the selected CCT-operated rain-gauging stations over the October 2018 to September 2023 period (see **Figure 4.6**). These graphs show that particularly high rainfall was recorded at most gauging stations in June and, especially, September 2023, with a daily maximum rainfall of 50-150 mm (indicative of a flood event) having been recorded at many stations during September 2023. Especially high rainfall was recorded at DIEP05CR in June 2023 (close to 350 mm for the month) and at LOUR06DR in September 2023 (~300 mm for the month, with a daily maximum of 110 mm recorded on 24/09/2023).



Figure 4.6
Total monthly rainfall (bars) and maximum daily rainfall per month (red dots) at each of the CCT-operated rain-gauging stations that were selected for the rainfall analyses (reporting years 2019-2023), indicating the sub-catchment (in brackets behind the station name).

The analysis of total rainfall per season per Reporting Year at each of the selected CCT-operated rain-gauging stations, for the five-year period from October 2019 to September 2023 (**Figure 4.7**), shows that the summer rainfall is significantly lower than the winter rainfall at all stations, as was the case for the Intaka Island 20-year dataset (**Figure 4.3**). 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.

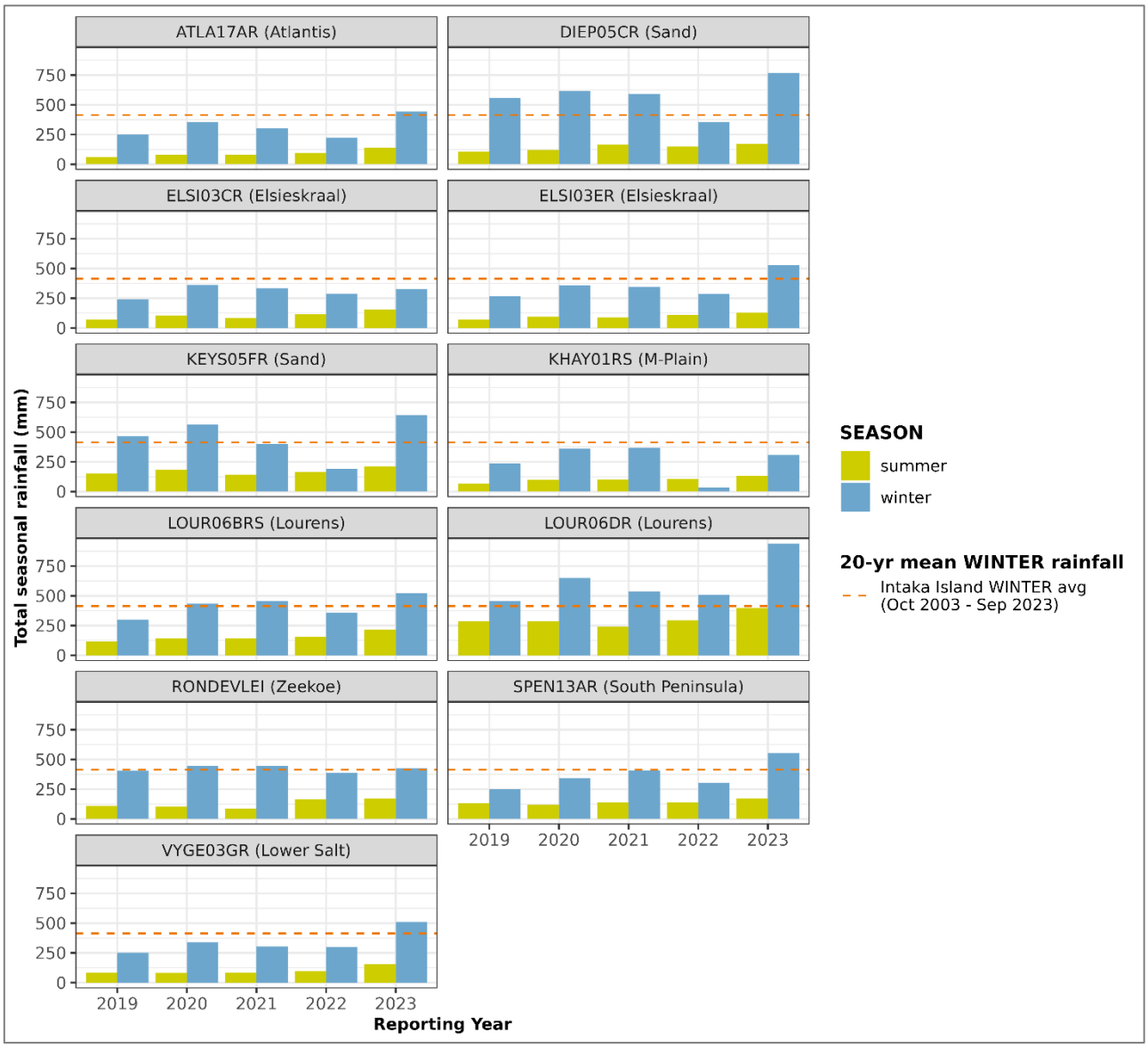


Figure 4.7
Total rainfall per season at the CCT rain-gauging stations for each reporting year from 2019 to 2023, compared with the 20-year mean winter rainfall figure derived from the Intaka Island dataset.

The graphs of total rainfall by season for the selected CCT gauging stations (in **Figure 4.7**) also show that, with the exception of gauging stations ELSI03CR (in the Elsieskraal sub-catchment), KHAY01RS (in the M-Plain catchment) and RONDEVLEI (in the Zeekoe catchment), the winter rainfall in Reporting Year 2023 was generally greater than the other 4 years of the period of analysis and above the long-term (20-year) mean winter rainfall of 414 mm recorded at Intaka Island. On the other hand, at most of the gauging stations the winter rainfall totals recorded during Reporting Years 2019 and 2022 were typically the lowest for the 5-year period of analysis. Total summer rainfall was generally significantly lower than the winter total at most of the selected rain gauging stations during most of the reporting years. Exceptions to this pattern were recorded at KEYS05FR and KHAY01RS in Reporting Year 2022, when the total summer rainfall was similar to or even greater than the total winter rainfall. It should also be noted that the total summer rainfall was anomalously high at LOUR06DR (in the upper Lourens catchment), compared to the winter totals at the same station and compared to the summer totals at all the other gauging stations that were considered.

5 CURRENT STATE AND TRAJECTORIES OF CHANGE IN WATER QUALITY IN CAPE TOWN'S MAJOR WATERCOURSES

5.1 Major nutrients (phosphorus and nitrogen)

5.1.1 Role of nutrients

All ecosystems require nutrients to support growth. In aquatic ecosystems, the major nutrients are phosphorus and nitrogen, which occur in various forms. These two nutrients play a particularly important role in determining the rate of plant growth, and so are sometimes referred to as 'growth-limiting' nutrients. In freshwater ecosystems, phosphorus is the main growth limiting nutrient, as some plants can access sufficient nitrogen from the air for growth. Other nutrients are also important for healthy growth, and these include sulphur, magnesium, potassium, calcium, iron, and many others, often required only in very small amounts.

This section deals only with phosphorus and nitrogen nutrients, which play a major role in determining aquatic ecosystem condition.

5.1.2 Forms of phosphorus and nitrogen in aquatic ecosystems

Both phosphorus and nitrogen occur in various forms in aquatic ecosystems, some of which are available for uptake by plants.

Phosphorus, for example, occurs in both inorganic and organic forms, and may be present in water as particulate or dissolved species. Phosphate species ($H_2PO_4^-$ and HPO_4^{-2}) are the only forms of soluble inorganic phosphorus that can be utilised directly by plants (DWAF 1996a). In this report they are referred to generally as phosphates, and with regard to data that reflect the concentration of phosphorus in phosphate only, as the abbreviation PO4-P.

Total phosphorus (Tot-P) 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 or other fine particulate organic material (Malan and Day 2005). Total phosphorus is useful for understanding the nutrient (or trophic) status of aquatic ecosystems 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^{3+} (aluminium), Fe^{3+}/ Fe^{2+} (iron), which precipitate out of the water, into bottom sediments. By contrast, low-oxygen conditions may cause the release of phosphorus back into the water column (DWAF 1996a).

In aquatic ecosystems, **nitrogen** occurs both as organic nitrogen and as inorganic nitrogen, in the form of nitrate (NO_3^-) and nitrite (NO_2^-) ions, as well as total ammonia, comprising ionised (NH_4^+) and un-ionised (NH_3) forms. Un-ionised (or 'free') ammonia can be toxic to some aquatic organisms, even at very low concentrations (DWAF 1996a and DWAF 2008). This aspect is discussed in **Section 5.4**.

The present chapter / section focuses on the role and availability of inorganic nitrogen as a nutrient, available as NO_3^- and NH_4^+ for plant uptake.

5.1.3 The effects of nutrient enrichment on aquatic ecosystems

In inland aquatic ecosystems, high concentrations of nutrients, and phosphate in particular, promote rapid plant growth. This growth may be in the form of rooted plants such as reeds and sedges in shallow areas of watercourses, vleis and lakes; floating or rooted plants in the water column or on the water surface; or algae, suspended in the water column, floating on the water surface as scums or algal mats, or attached to the surfaces of rocks or other substrate, as filamentous algae.

Rooted plants such as pondweed play important roles in aquatic ecosystems, as they both take up nutrients and store them in plant tissue, and oxygenate the water column, through photosynthesis.

Such plants do, however, rely on light penetration for photosynthesis to take place. In deep waters, or where aquatic weeds or algae inhibit light penetration, they may not have access to sufficient light. Under such conditions, with high phosphate concentrations providing an abundance of nutrients, there may be a shift in plant type, with phytoplankton and/or floating aquatic macrophyte plants dominating the system instead. Blue-green algae (or cyanobacteria) often prevail in these circumstances, in part because they are able to access nitrogen from the air, in response to high phosphate availability.

As algal cells die off and fall to the lake or vlei floor, they start to decompose. Decomposition requires oxygen – and if abundant nutrients have promoted **eutrophic to hypertrophic** conditions (see Section 5.1.4), then the oxygen demands of decomposition may be very high. This is often particularly the case in summer, when warm temperatures promote decomposition and algal growth, and when dissolved oxygen concentrations are in any case lower, because of temperature.



Photo 5.1.1
The CCT's False Bay Nature Reserve officials remove invasive water hyacinth from Zeekoevlei and other inland water bodies
(Photo S. Jacobs)

Under such conditions, or when there are additional inflows of organic enrichment (e.g. raw sewage), oxygen demand may well exceed oxygen supply, resulting in anoxic or low-oxygen conditions, which may result in sudden fish die-off and the deaths of other aquatic organisms that depend on the availability of dissolved oxygen in the water column.

In the Western Cape, floating non-algal aquatic plants are all alien to this area, and likely to proliferate under conditions of elevated nutrients. The most problematic floating plant species include water hyacinth (*Pontaderia crassipes*), duck weed (*Lemna gibba*) and water hornwart (*Ceratophyllum demersum)*. These can create serious management problems. Water hyacinth in particular blocks channels and open water bodies, leading to flooding and affecting their suitability for recreational uses such as sailing, rowing, and kayaking. Control of water hyacinth in the Western Cape is primarily by physical removal, which is a costly, ongoing exercise.

5.1.4 Categorising nutrient levels as trophic states

The nutrient (or '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) (see **Box 5.1**).

In standing water bodies such as vleis or lakes, 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 dissolved oxygen concentrations;
- **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. During the day, shallow warm waters may also at times be hyperoxic, as a result of very high rates of photosynthesis by algae.

Appendix B presents the range of nitrogen and phosphorus concentrations associated with different trophic states in South African freshwater ecosystems. These are also indicated in **Tables 3.1** and **3.2**, in relation to the threshold ranges used there.

5.1.5 Sources of nutrients

The main sources of nutrients into Cape Town's watercourses are as follows:

- Inputs of treated sewage effluent from any of the CCT's 16 WWTWs that discharge treated effluent into inland watercourses or estuaries. These discharges do not always meet licensing conditions, and even if they do so, the volumes of effluent discharged, compared to the volumes of river water, mean that they still give rise to significant nutrient enrichment downstream. This is particularly likely in summer, when treated effluent makes up the entire run-of-river flow in some naturally seasonal systems (e.g. the Black, Kuils and Mosselbank Rivers and Milnerton Lagoon) – see Section 5.5 for discussion of WWTW outflows;
- Overflows from sewage pump stations and/or low-lying sewer manholes into the stormwater system as a result of load-shedding or sewer line blockage – see Section 5.5 for data and more detailed discussion around these issues;
- Runoff from catchment areas with high levels of backyard or informal settlements, subject to poor levels of sewage and stormwater servicing and often large populations;

Box 5.1

Nutrients under natural conditions

Under natural (or 'reference') conditions, prior to human-induced change, the upper reaches of Cape Town'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 the catchment and its runoff.

By contrast, even under pre-development conditions, wetlands would probably have been more nutrient enriched than rivers – particularly those wetlands that were not linked to channeled outflows, and thus accumulated plant material over time. 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 severely impacted by the receipt of additional nutrients, particularly phosphorus.

- Illegal discharges of nutrient-enriched water into the stormwater system in industrial and commercial areas (e.g. fertiliser factories; car washes; markets; informal butcheries and meat markets);
- Runoff from fertilised gardens and parks;
- Runoff from agricultural areas (e.g. Philippi Horticultural Area);
- Runoff, irrigation seepage or direct discharges from so-called sewage package plants used to treat sewage effluent on a small scale (usually on private developments);
- Recycling of decomposing sediments from bottom waters in lakes and dams, as a result of low-oxygen conditions that cause re-activation of phosphorus; and also, as a result of stirring up of sediments from wind- or boat-induced wave action.

5.1.6 Phosphorus enrichment of Cape Town's watercourses

In this report, orthophosphate (PO4-P) data are assessed for rivers, while total phosphorus (Tot-P) data are assessed for vleis / dams. This is a change in reporting of this nutrient, as outlined in Section 3.7.2. These data are presented in this report in the forms of:

- Compliance-type data, showing the percentage of river / stormwater ('flowing' water) samples in each sub-catchment (**Figure 5.1.1**) and in major vleis / dams (**Figure 5.1.2**) that met Target conditions for this nutrient, versus the percentage of samples falling within the range for Poor or

Unacceptable concentrations. Target concentrations imply mesotrophic to oligotrophic conditions with regards to this nutrient (see **Tables 3.1 and 3.2, Section 5.1.4** and **Appendix B**), while Unacceptable concentrations suggest hypertrophic conditions;

- Boxplots presenting summary statistical data – these are shown as seasonal plots in **Figures 5.1.3** and **5.1.4** for flowing water systems (PO4-P) and vleis / dams (Tot-P) respectively, and as annual median values (without seasonal distinctions in **Appendix D** (**Figures D1.1** and **D1.2**);
- Median annual concentrations of these variables at a catchment scale, for rivers, and for individual vleis /dams, in **Table 5.1.1**;
- Median annual concentrations of these variables at individual monitoring points in each sub-catchment are provided in **Appendix C**, as well as (for priority catchments), in the maps in **Section 8**.

The data suggest that:

- For **rivers / flowing water systems**:
    - Phosphate concentrations were elevated well above Unacceptable thresholds in most sub-catchments, with all sub-catchments other than Sir Lowry's Pass showing an increase in the proportion of samples rated as Unacceptable over the 2023 reporting period, compared with 2022 and the previous three years, and/or a decrease in the proportion of samples rated as Acceptable. This is a serious finding and suggests that nutrient enrichment in Cape Town's rivers and stormwater systems is on a concerning and deteriorating trajectory;
    - Summary data for all samples over the selected reporting periods (see **Figure 5.1.1** - bottom right hand graph) show that just under 80% of the City's samples fell within the Unacceptable range over all three assed periods (2019-2021, 2022 and 2023), but the proportion that were Acceptable fell from just over 6% for the previous two reporting periods, to just 2.8% in 2023;
    - The worst-performing sub-catchments, characterized by permanent non-compliance in analysed samples, comprised the Mosselbank, Sout and Soet systems;
    - These were followed by the Eerste and Kuils systems, where a small proportion (<5%) of samples fell within the Poor range, and the rest were in the Unacceptable range;
    - The lower Diep, Lower Salt and Elsieskraal sub-catchments also showed poor compliance, followed by the Zeekoe catchment, all reflecting sub-catchments impacted by inflows from areas with extensive, poorly serviced informal settlements; inflows from variously performing WWTWs; and (in the case of the Mosselbank and Zeekoe systems, likely inflows from agricultural areas, including fertilized lands, livestock feed-lots and manure stock-piles;
    - Better performing catchments comprised the Sand Sub-catchment (which nevertheless showed a decrease in the percentage of both Acceptable and Poor samples over the 2023 reporting period) and the Sir Lowry's Pass and South Peninsula Sub-catchments;
    - The best performing catchments comprised the Lourens, Hout Bay and Silvermine Sub-catchments. Of great concern is however the fact that the percentage of Acceptable samples dropped by some 25% in the Silvermine Sub-catchment over the 2023 reporting period, to 40% compliance only, while the proportion of Acceptable samples in the previously high-performing Lourens Sub-catchment fell by nearly 50% to just 24%;
    - Increased phosphate concentrations in the Silvermine Sub-catchment is attributed at least in part to the impacts of periodic pump station failure affecting the Silvermine Wetland, the effects of which are exacerbated by upstream abstraction (comments from Stormwater Planning Region management team to Liz Day).
    - Phosphate enrichment in the Hout Bay Sub-catchment also increased substantially over

the reporting period, with an increase in Unacceptable and Poor samples and a decrease in Acceptable samples.

Seasonal data, shown as boxplots in **Figure 5.1.3,** provide further insights into patterns of phosphate pollution in Cape Town's watercourses. This is in part because the data indicate not only the levels of data compliance with specified targets, but also the magnitude of non-compliance. These data show that:

- Samples from the Lower Diep, Lower Salt, Mosselbank, Sout, Soet, Eerste and Kuils River Sub-catchments were consistently many times greater than the Unacceptable threshold for this nutrient, with summer concentrations in the Sout Sub-catchment, for example, over the 2023 reporting period being at times over two orders of magnitude higher than this threshold;
- The Sout Sub-catchment in particular appears to have been affected by a marked increase in phosphate enrichment over the past two reporting periods, compared with median concentrations over the 2019-2021 reporting periods. It is assumed that this reflects a deterioration in performance at the Melkbosstrand WWTW – this is considered in **Section 5.6.2**;
- The Elsieskraal, Hout Bay, Sir Lowry's Pass and South Peninsula systems were by contrast characterized by markedly lower median phosphate concentrations compared to the worst performing catchments, albeit still generally above the Unacceptable threshold, with outliers extending well above this range. These are catchments where relatively minor interventions might be considered that would substantially reduce nutrient enrichment, compared with the large-scale pollution affecting the systems listed above;
- The best performing catchments monitored were the Lourens and Silvermine systems, with markedly lower phosphate concentrations than other catchments throughout the year – these data reflect catchments with generally low levels of urban settlement, little to no informal or backyard settlements, an absence of WWTW inflows, and extensive mountain catchments that receive high quality runoff;
- Nevertheless, median annual phosphate concentrations increased in the Silvermine Sub-catchment in the 2023 reporting period (see **Table 5.1.1**), potentially indicating the influence of increased laboratory detection limits for this variable (see Section 3.8.9), but also a real increase in measured nutrients above these limits;
- The Lourens and Silvermine Sub-catchments were followed by the Sand, Sir Lowry's Pass, Hout Bay and Elsieskraal Sub-catchments, the data for all of which showed relatively low median and interquartile ranges phosphate concentration, marred by episodic high concentrations, assumed to reflect inflows of pollutants such as sewage, associated with pump station or sewer manhole overflows in parts of the catchment, as well as point-source inflows from permanently contaminated parts of the catchment (e.g. Sir Lowry's Pass Village and Imizamo Yethu settlement (Hout Bay);
- Generally, the seasonal data in **Figure 5.1.3** showed, as would be expected, that median summer phosphate concentrations were always higher than winter concentrations, reflecting evapo-concentration in rivers, as well as the fact that, in many systems, the only water flowing in the rivers derived from treated or untreated sewage effluent, "grey" water from unserviced households and illegal discharges into the stormwater system;
- Although performance data (**Figure 5.1.1**) showed an overall deterioration in water quality in most catchments, as measured by phosphorus enrichment (that is, more samples fell within the Unacceptable Range over the 2023 period than previously), the box-plot data show that in fact, during winter, median concentrations in the 2023 reporting period were always lower, and often significantly lower, than those of the 2022 reporting period. This points to some improvement in wet season water quality,

although not to any level that is picked up by compliance reporting, and thus also not to any level that would reflect in ecological change.

- The exception to the above (improvement) was the Zeekoe Sub-catchment, where interquartile (3rd quartile) data for the 2023 winter period were substantially higher than over any other period, reflecting continuously elevated discharges into this system, with the wet season of 2023 potentially having simply contributed to nutrient concentrations by washing in contamination from the broader catchment, during rainfall and particularly flood events. Elsewhere, lower phosphate concentrations in rivers in the 2023 reporting period are assumed to reflect generally higher rainfall over this period, as noted in Section 4;
- Summary data without seasonal distinctions presented in **Appendix D** (**Figure D1.1**) show a high degree of scatter in phosphate concentrations within sub-catchments, pointing to both episodic point-source driven pollution as well as a range of water courses in different condition within the sub-catchments, with some more prone to receipt of severely contaminated water at times than others – the Hout Bay River for example has relatively unenriched water quality in its upper reaches, only deteriorating significantly in its lower reaches, which are impacted primarily by runoff from large informal settlements. These details are unpacked in Section 8, for each of the CCT's Priority Sub-catchments;

Overall, phosphate data continue (as noted in the 2020 and 2023 Inland Water Quality Reports) to indicate that phosphorus enrichment remains an issue of great concern, affecting most of Cape Town's monitored rivers and other stormwater systems, which over the 2022 and 2023 reporting periods lay generally well within the hypertrophic (Unacceptable) range for this variable. Although median phosphorus concentrations reduced in many catchments over the 2023 reporting period, the proportion of samples within an Acceptable range reduced by almost half, with just under 80% of samples lying within the Unacceptable range. Since many of these nutrient-enriched rivers feed into the City's vleis and dams, the impacts of river phosphorus enrichment is passed on to, and magnified within these standing water bodies.

The Silvermine, Lourens and Hout Bay Sub-catchments continued to be the best-performing catchments among monitored systems in the City, but nevertheless all showed a decrease in the proportion of samples in an Acceptable condition over the 2023 reporting period.

A pronounced increase in phosphate enrichment has characterised the Sout Sub-catchment over the past two reporting periods, presumably indicating decreased performance in the WWTW in that catchment.

- **For standing water systems (vleis, dams, detention ponds)**, for which [8]total phosphorus data are shown in **Figures 5.1.2** and **5.1.4**, the available data (see Section 3.8.15 for discussion of missing data from January 2024) show that:
    - All of the City's routinely monitored standing water sites were phosphorus-enriched, with water quality lying within either the range for Poor (eutrophic) or for Unacceptable (hypertrophic) conditions throughout the three reporting periods considered here (**Figure 5.1.2**);
    - The least-enriched water bodies over all three reporting periods assessed in this report were Glencairn Vlei, followed by the two monitored Elsieskraal River dams (Doordekraal and Angelier Park dams). Monitoring data showed that measured phosphorus concentrations within the latter were always in the eutrophic but never hypertrophic range, reflecting an urban waterbody with a history of previous enrichment by treated sewage effluent, now long-discontinued, and with extensive reeds and other aquatic plants that are assumed to play an important role in effecting nutrient uptake and or

[8] Note that this report uses total phosphorus as a measure of trophic state and general phosphorus enrichment in standing water systems – this differs from previous Inland Water Quality reports, but is considered a more ecologically useful way of reporting on the nutrient status of lakes and dams

binding to soil / root masses. The Elsieskraal dam data showed an increasing frequency of elevated phosphorus within the hypertrophic (Unacceptable) range in samples over the past two reporting periods (2022 and 2023) compared to the previous three years of data. This is assumed to link to an increased frequency in pumpstation failure over the past two years, as a result of load-shedding and other issues (see **Section 5.6.3**);

- Little Princessvlei data also suggested phosphorus enrichment largely within the range of eutrophic rather than hypertrophic conditions, with some improvement noted in the 2022 reporting period, but with the proportion of Unacceptable samples reducing in 2023;
- Both Die Oog (a small wetland system in the Sand Sub-catchment) and Zandvlei itself, showed improvement in eutrophication levels, with a reduced proportion of hypertrophic samples (< 25%) in the 2023 reporting period compared to previous assessed periods;
- The worst performing water bodies, with measured phosphorus concentrations always within the hypertrophic range, comprised the long-term enriched Zeekoevlei, Zoarvlei, and Wildevoelvlei, as well as the artificial stormwater ponds (Mew Way (Kuils River sub-catchment) and Mitchell's Plain detention ponds), with permanent inflows of polluted black- and grey water passing into these areas from poorly serviced urban catchments;
- Systems showing deterioration over the assessment period comprised Rietvlei (also referred to as the Flamingo Vlei waterbody (Rose et al 2023), for which all samples in the 2022 and 2023 periods fell within the Unacceptable range, compared with < 85% in the 2019-2021 period, as well as Westlake wetlands and Langevlei, the latter of which showed an increase (to 100%) in samples within the Unacceptable range;
- More positively, wetlands showing reduced total phosphorus concentrations comprised Princessvlei (at least compared with 2022, but not with 2019-2021); Rondevlei and Zandvlei. The latter has been the subject of concerted management efforts, including attention to managing links to the sea, and at a catchment level, with a particular focus on reducing the impact of sewage overflows (see Section 8), and this may also reflect in decreased phosphorus concentrations in this important system;

Seasonal data, shown as boxplots in **Figure 5.1.4,** as well as median data without seasonal distinctions, shown in Appendix D (**Figure D1.2**) provide further insights into patterns of phosphorus pollution in Cape Town's standing water bodies. Again, these graphs are useful because they reflect the magnitude of non-compliance, although it must be noted that Tot-P data were missing for winter 2023, as a result of laboratory problems (see Section 3.8.15) and in fact, even summer data reflect only data for early summer in the 2023 reporting period (October to December 2022). The available data show that:

- By far the highest levels of consistent phosphorus enrichment in standing water bodies over the 2019-2021, 2022 and 2023 reporting periods, based on median data and inter-quartile ranges, occurred in Wildevoelvlei, followed .by the Mew Way and Mitchell's Plain detention ponds, Zeekoevlei and Zoarvlei – such hypertrophic conditions are likely to be linked to excessive plant growth including algae, invasive alien plants such as water hyacinth (*Pontaderia crassipes*) and reeds in these systems;
- Median total phosphorus concentrations increased in Wildevoelvlei over the 2023 reporting period compared with 2022, as well as in Zeekoevlei, the Mitchell's Plain detention ponds and the Elsieskraal Sub-catchment dams 2023 reporting periods – these data must however be interpreted with caution, as they are missing winter data – with winter phosphorus concentrations typically being lower than in summer, as a result of rainfall and groundwater dilutions in many systems;
- Despite the above, improvements (i.e. reductions) in median total phosphorus concentrations were evident in the 2023 reporting period for Rietvlei; Zoarvlei; Princessvlei; Die Oog; Rondevlei; Zandvlei; Mew Way detention ponds, albeit not at levels that would reflect in any change in trophic state or associated reduced requirement for management effort (reed or floating aquatic removal or dredging of accumulated

organic sludges). The least-enriched water bodies comprised Glencairn Vlei, Zandvlei (in 2023), Die Oog, Little Princessvlei and Princessvlei, both of which showed median and interquartile range data that lay below and/or just above hypertrophic (Unacceptable) thresholds for this nutrient;

- The above were followed by Rietvlei, Rondevlei, Westlake wetlands and the Elsieskraal River dams, then the much more significantly enriched Langevlei, Zoarvlei and Zeekoevlei; and finally the most enriched Mew Way and Michell's Plain detention ponds and Wildevoelvlei;
- The above rough groupings of water bodies can be used to inform management decisions about where minor interventions might bring about major ecosystem changes (e.g. associated with decreases management requirements, if a system can move into a lower trophic threshold – candidate systems for such interventions would potentially thus comprise:
  - Glencairn Vlei, Zandvlei, Die Oog, Little Princessvlei and Princessvlei; and then, more challengingly:
  - Rietvlei, Rondevlei, Westlake wetlands and the Elsieskraal River dams; then (associated with major catchment scale effort:
  - Langevlei, Zoarvlei and Zeekoevlei; and finally, but least likely to achieve measurable change:
  - The Mew Way and Michell's Plain detention ponds and Wildevoelvlei.

Overall, total phosphorus data show that all of the City's standing water systems are highly nutrient-enriched, reflecting inflows from significantly more polluted rivers and stormwater systems, which load standing water bodies with nutrients that accumulate over time, in the water bodies themselves, as well as in bottom sediments and living plant material.

Note that maps showing rated annual median phosphate concentrations at all sample points in the priority catchment areas can be accessed in **Section 8**.

Table 5.1.1
Summary median data for reporting periods 2022 and 2023 – total phosphorus, orthophosphate (PO4-P), TIN and NH4-N:TIN data only, showing sub-catchments and vlei names.

TYPE	SUBCATCHMENT	VLEI NAME	2022 Reporting Year				2023 Reporting Year			
			Tot-P (mg/L)	PO4-P (mg P/L)	TIN (mg N/L	NH4:TIN (%)	Tot-P (mg/L)	PO4-P (mg P/L)	TIN (mg N/L)	NH4:TIN
River dataset	Diep		1.854	2.554	9.783	93.0	3.871	1.5	5.761	79.3
	Eerste		2.1065	2.3	9.8	88.5	2.56	1.726	9.4335	82.9
	Elsieskraal		0.459	0.208	1.932	50.8	0.196	0.1775	2.095	42.1
	Hout Bay		0.051	0.032	0.22325	50.5	0.0925	0.05	0.472	71.2
	Kuils		2.276	1.9	7.3	56.2	2.727	1.6	9.2	61.8
	Lourens		0.051	0.019	0.3995	15.6	0.051	0.041	0.3744	12.0
	Lower Salt		2.511	3.318	12.922	88.3	3.7295	2.123	13.988	86.5
	Mosselbank		2.032	1.305	5.472	71.3	4.041	1.2	3.5	51.5
	MPlain		1.949	1.472	16.205	99.8	2.241	1.191	12.015	97.8
	Sand		0.217	0.075	0.4955	59.8	0.356	0.182	0.884	71.0
	Silvermine		0.051	0.018	0.132	34.1	0.051	0.0325	0.0876	47.7
	SLPass		0.132	0.12	1.0624	20.1	0.153	0.1	0.8	39.5
	Soet		3.2675	2.67	25.519	99.6	3.437	2.445	20.7185	99.2
	Sout		7.559	6.7	1.7	65.0	7.9975	6.108	2.4	67.6
	South Peninsula		0.386	0.246	2.07	75.9	0.203	0.167	2.268	69.3
Standing water	Diep	Rietvlei	0.211	0.14	0.073	44.6	0.178	0.057	0.16	49.2
		Zoarvlei	0.4535	0.1845	0.4665	70.3	0.4225	0.234	0.4365	64.8
	Elsieskraal	Elsieskraal dams	0.051	0.0165	0.15365	38.0	0.051	0.05	0.159	43.5
	Kuils	Mew Way DP	2.225	1.8975	16.517	99.7	2.055	1.151	12.064	96.9
	MPlain	Mplain DP	1.884	1.4455	15.02	99.7	2.047	0.998	11.529	94.4
	Noordhoek	Wildevoelvlei	7.2755	5.031	40.0355	99.6	7.9005	4.3265	26.5945	98.2
	Sand	Die Oog	0.051	0.0165	0.1007	65.8	0.051	0.05	0.5475	83.3
		Langevlei	0.184	0.046	0.444	34.4	0.345	0.134	1.1095	48.4
		Little Princessvlei	0.051	0.012	0.20695	44.0	0.1165	0.05	0.4462	49.4
		Princessvlei	0.1935	0.0105	0.11075	17.0	0.1525	0.017	0.11265	34.2
		Westlake	0.1965	0.0965	0.371	73.4	0.1895	0.055	0.392	50.6
		Zandvlei	0.138	0.044	0.11105	65.3	0.113	0.05	0.147	69.7
	South Peninsula	Glencairn vlei	0.051	0.0095	0.0717	37.4	0.051	0.014	0.1671	18.7
	Zeekoe	Rondevlei	0.249	0.076	0.1985	53.9	0.134	0.101	0.7415	53.3
		Zeekoevlei	1.09	0.59	1.026	52.9	1.063	0.483	0.86	56.9

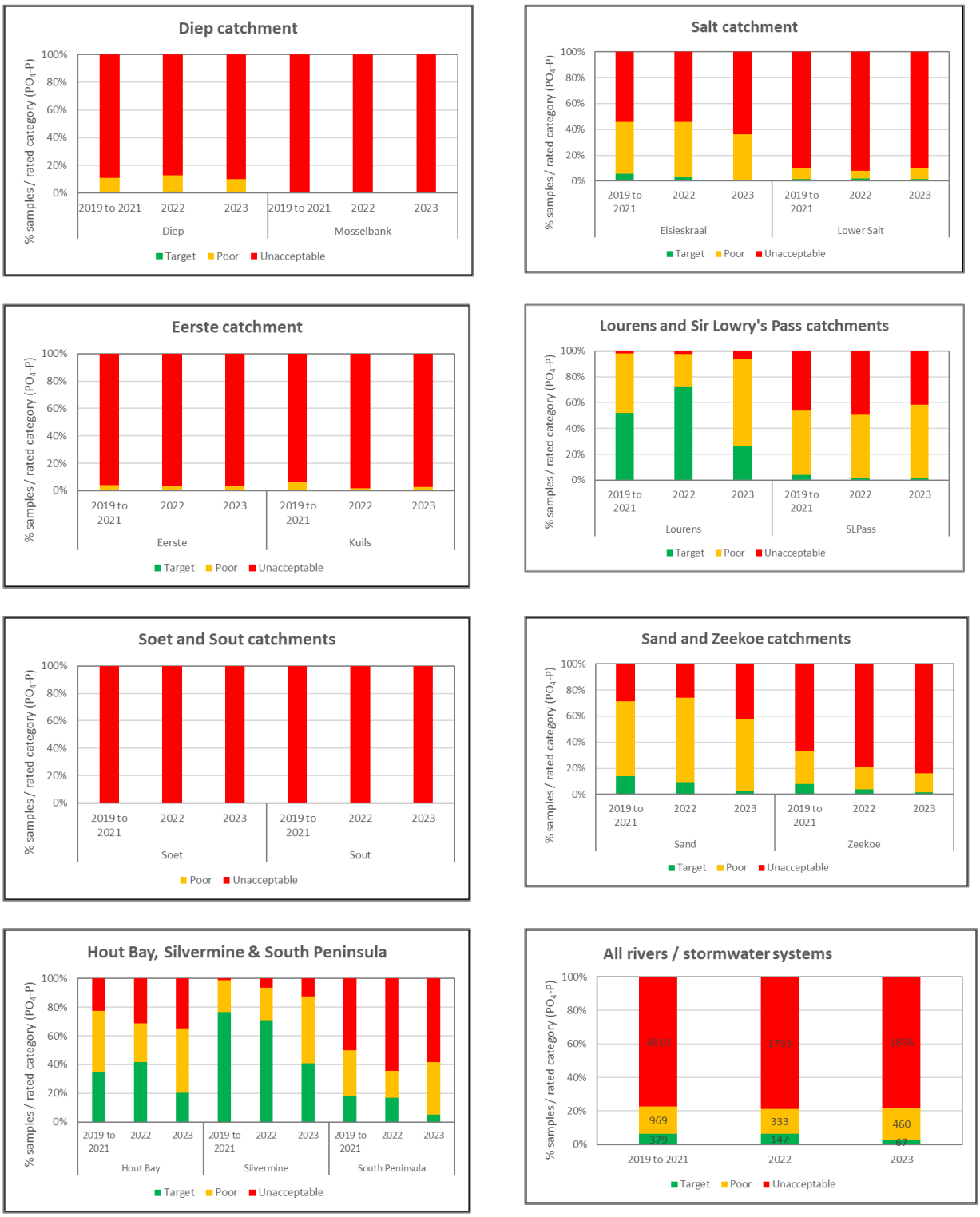


Figure 5.1.1
Percentage of phosphate (PO4-P) samples falling within each rated category for this variable, per sub-catchment. Thresholds for rated categories as defined in Table 3.1. Data presented for river / 'flowing' water monitoring points. Sub-catchments as shown in Figure 2.1. Total number of samples considered shown in bars in bottom right plot ('all rivers / stormwater systems').

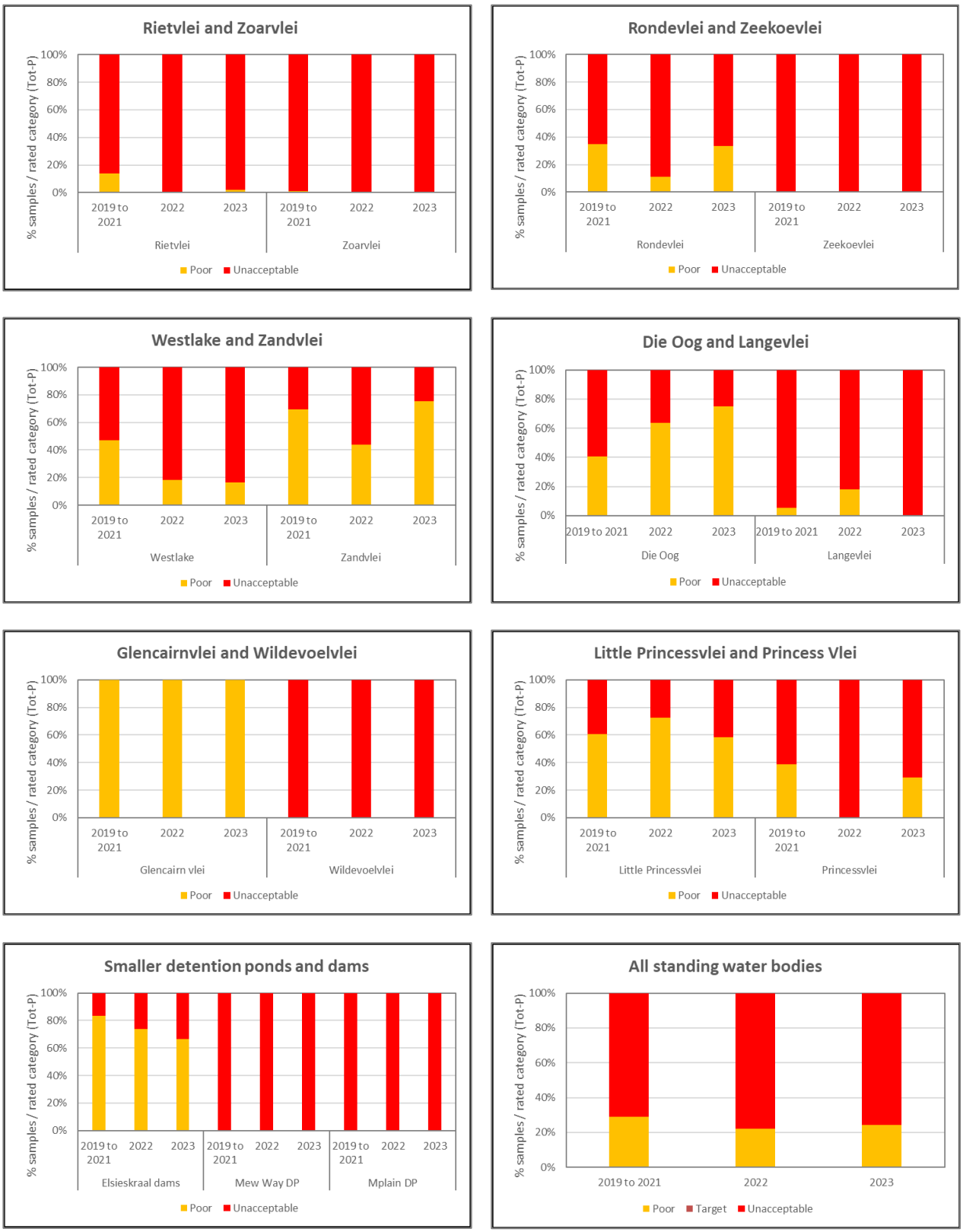


Figure 5.1.2
Percentage of total phosphorus (Tot-P) samples falling within each rated category for this variable, per monitored standing water system

Thresholds for rated categories as defined in Table 3.2. Data for sample points in standing water bodies / vleis and detention ponds. Total number of samples considered shown in bars in bottom right plot ('all standing water bodies'). Note: Total Phosphorus data missing from January 2023.

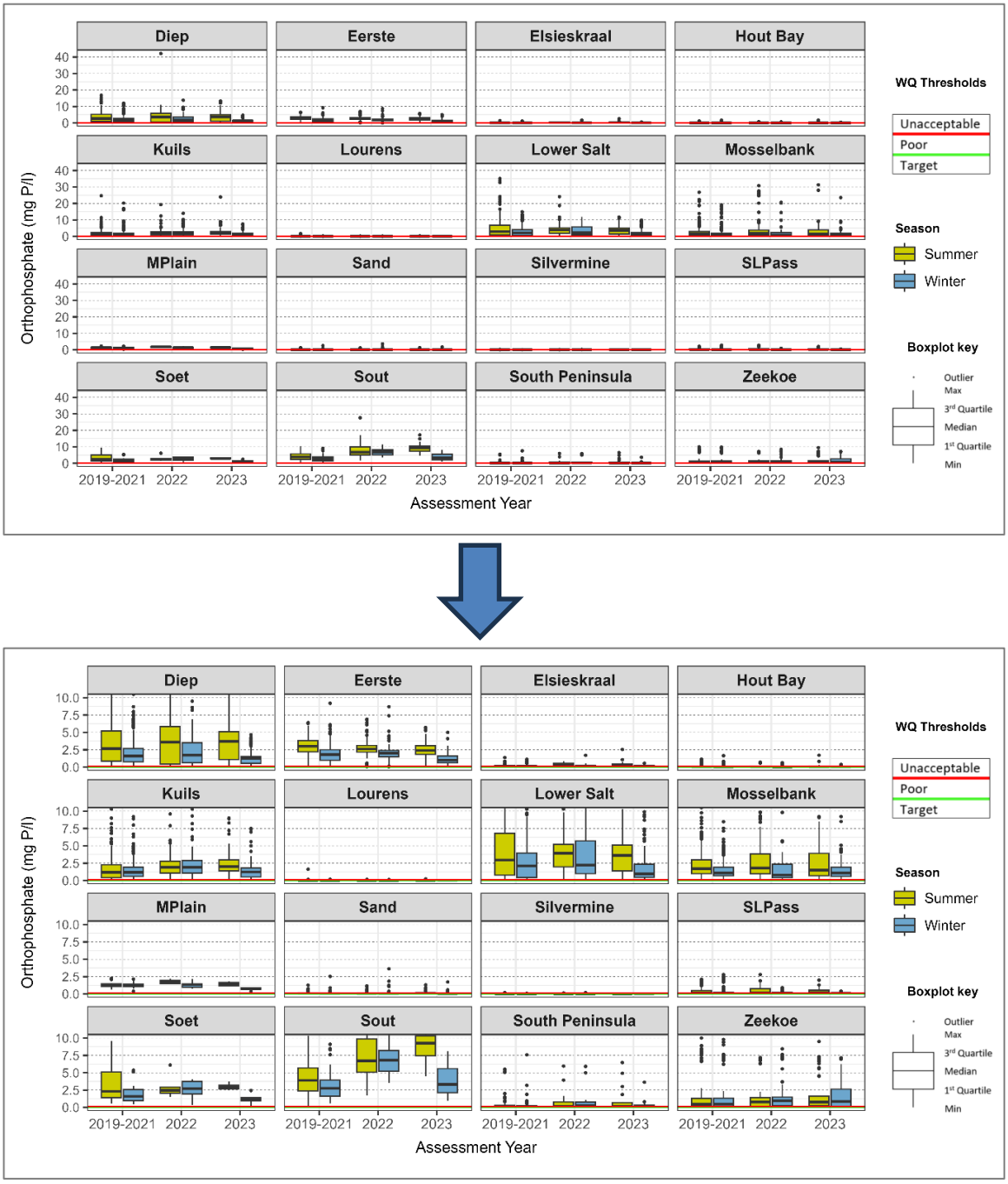


Figure 5.1.3
Comparison of phosphate (PO4-P) data for flowing systems (rivers and stormwater channels) from the 2023 and 2022 reporting periods, with those from the previous three years (2019 to 2021) combined.
Sub-catchment extent as shown in Figure 2.1. Data analysed as summer and winter datasets. Marked thresholds as per Table 3.1. Bottom figure (arrowed) shows same data at different scale.

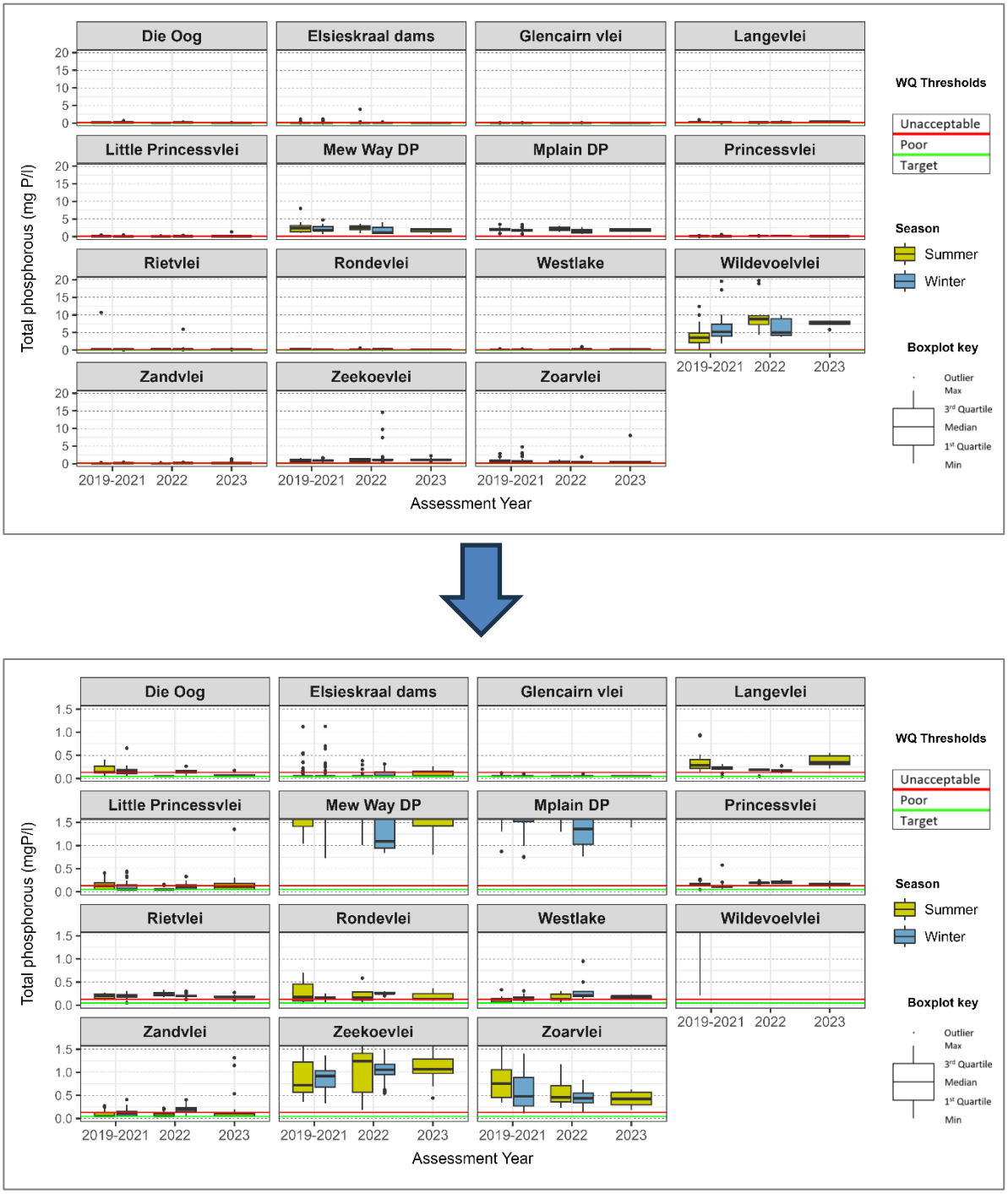


Figure 5.1.4
Comparison of total phosphorus (Tot-P) data for flowing systems (rivers and stormwater channels) from the 2023 and 2022 reporting periods, with those from the previous three years (2019 to 2021) combined. Sub-catchment extent as shown in Figure 2.1. Data analysed as summer and winter datasets. Marked thresholds as per Table 3.2. Bottom figure (arrowed) shows same data at different scale. Note missing Tot-P data from January 2023 (hence no winter 2023 data).

5.1.7 Nitrogen enrichment in Cape Town's watercourses

As for the previous section, nitrogen enrichment data (reported on as Total Inorganic Nitrogen (TIN)) are presented as both compliance-type data (the proportion of samples in various categories that fall within the Target range for this variable, or are rated as 'Poor' or 'Unacceptable', using the criteria listed in **Tables 3.1 and 3.2**), and as boxplots, which show statistical data for all analysed watercourse groups and categories, allowing consideration of the magnitude of TIN concentrations. These data are again presented separately for flowing water systems (rivers and stormwater channels) (**Figures 5.1.5 and 5.1.7**, as well as **Figure D1.3** in **Appendix D**) and for standing water systems (vleis, dams and detention ponds) (**Figures 5.1.6 and 5.1.8**, as well as **Figure D1.4** in **Appendix D**).

- The data show that, as for previously assessed data (i.e. Day et al 2020 and Day et al 2023), nitrogen enrichment is generally less problematic in Cape Town's waters than is phosphorus, and TIN data for rivers and stormwater channels, and in particular, standing water bodies (vleis and dams), all showed much higher proportions of samples within the Target range for this variable (**Figures 5.1.5 and 5.1.6**). Nevertheless, the data do indicate that at least in some sub-catchments, nitrogen enrichment was at ecologically problematic levels at least at times, while other catchments were better performing throughout the year, as is described in the following sections;
- For **rivers / flowing water systems**:
    - Compliance data showed relatively little change in TIN over the 2023 and 2022 reporting periods, compared with the 2019-2021 period, with slight decreases in the proportion of samples rated as within Target concentrations in the Eerste and Kuils sub-catchments, and slightly increased proportion of Unacceptable samples in the Zeekoe, Eerste and Lower Salt sub-catchments over the past two reporting periods. Small improvements (i.e. increased proportion of samples within the Target Range) were apparent in data for the Lourens, Mosselbank and Sir Lowry's Pass sub-catchments;
    - The best-performing catchments with very low levels of nitrogen enrichment, comprised the Silvermine and Lourens River Sub-catchments, with 100% of samples lying within the Target range for TIN over the 2023 and 2023 reporting periods;
    - Other well-performing catchments were the Hout Bay and Sand Sub-catchments, with over 50% of samples within Target range and <10% rated as Unacceptable;
    - The Sout Sub-catchment showed consistent results with < 50% of samples within Target and most samples rated Poor to Unacceptable – samples in this catchment are all collected downstream of the WWTW inflow, and elevated TIN is expected;
    - The worst performing catchments were the Soet Sub-catchment (100% Unacceptable in 2023 and 2019-2021 reporting periods, albeit with slight improvement in 2022); followed by (in improving order) the Lower Salt, Kuils and Eerste, Zeekoe, Diep and then the Mosselbank sub-catchments;
    - The above poorly-performing catchments are all characterised to greater or lesser extents by areas with high levels of solid waste accumulating from informal and backyard settlement settlements and/or poorly serviced areas with high levels of gangs and crime that inhibit service delivery (see Section 8); and treated and/or untreated sewage inflows, with characteristically high nitrogen content, often in the form of ammonia nitrogen;
    - Overall, the data showed that, for the 2022 and 2023 reporting periods, > 55% of water quality samples from routinely monitored sites were rated Unacceptable with regard to their TIN concentrations. This indicates that, while phosphorus is considered more problematic than nitrogen in driving ecosystems responses to eutrophication (e.g. rapid plant growth including algae and reeds), nitrogen enrichment is also at levels of concern in many parts of Cape Town's watercourses;
    - Seasonal TIN data, shown as boxplots in **Figure 5.1.7**, and annual boxplots analysed without seasonal differentiation **(Figure D1.3 in Appendix D)** for routinely monitored

sample sites, allow more quantitative interpretation of TIN data, and indicate that:

- Median summer TIN concentrations and inter-quartile ranges were generally higher in all sub-catchments than in winter, reflecting high levels of polluted dry-weather flows from some areas as well as treated sewage effluent, constituting the full run of river flows in summer in naturally seasonal river systems (e.g. the Diep, Mosselbank, Kuils, Lower Salt, Sout and Zeekoe sub-catchments;
- Of all assessed sub-catchments, the Zeekoe Sub-catchment was the only one that consistently did not show strong seasonal variation in TIN, suggesting perennial inflows of similarly enriched water, from a catchment where increased loading as a result of wet season wash-off from a dirty catchment appears to offset the dilution effect of rainfall in the wet season. This catchment includes extensive agricultural areas, and wet season (e.g. spring) fertilization of lands might help to explain seasonal TIN concentrations;
- The sub-catchment characterized by the highest concentrations of TIN in the 2022 and 2023 reporting periods comprised the Diep sub-catchment, with particularly high summer TIN concentrations, likely to stem primarily from inflows from the Potsdam WWTW and from blackwater flows from the Jo Slovo settlement, via the Erika Road stormwater outlet – these pollution sources were highlighted in Rose et al (2023) but were markedly reduced in the 2023 wet season;
- Other sub-catchments characterized by elevated TIN comprised the Lower Salt, Mosselbank, Zeekoe, Kuils and Mitchell's Plain sub-catchments;
- Generally low levels of TIN characterised the Elsieskraal, Hout Bay, Sand, Sir Lowry's Pass, Sout and South Peninsula sub-catchments, marred by periodic spikes, presumed to reflect episodic sewage overflows, often associated with load-shedding and/or pump station and manhole blockages or failure;
- The Silvermine and Lourens sub-catchments were characterized by consistently low concentrations of TIN, within the Target range, as already indicated by Compliance data;
- Of interest was the marked decrease in TIN concentrations in the Soet sub-catchment in winter 2023, compared to previous years data. This may reflect some effort in catchment clean-up prior to wet season runoff; the possible impacts of the large June and September 2023 floods in achieving dilution in many sub-catchments; but also potentially the impact of aeration of the river in its reaches just upstream of the sampling site in this catchment (see Section 8 for details);
- Summary annual data presented in Figure D1.2 (Appendix D) show a major increase in TIN concentrations in many samples in the Diep Sub-catchment in 2023 compared to previous years, and confirms that the sub-catchments that were most enriched (samples usually above Unacceptable thresholds) comprised the Diep, Soet, Lower Salt, Zeekoe, Kuils and Eerste;
- Sub-catchments where river water was less compromised by nitrogen enrichment and generally within Target or Poor ranges, comprised (in improving order) the Sout, South Peninsula, Elsieskraal, Sand, Sir Lowry's Pass, Hout Bay, Lourens and Silvermine sub-catchments, of which the latter two were never had samples above Unacceptable thresholds;
- Data included in **Figures 5.1.10 and Figure D1.4** (Appendix D) show the ratio of TIN that comprises total ammoniacal nitrogen (NH4-N) in any sample. Since total ammoniacal nitrogen includes a proportion of un-ionised ammonia (NH_3), which can be toxic to some aquatic biota at relatively low concentrations (see DWAF 1996), its dominance in TIN can reflect ecological problems. The data NH4-N:TIN ratios for rivers (expressed as fraction of 1) indicate that:

- Total ammonia comprised >50% of TIN in most sub-catchments;
- Generally less-nutrient enriched rivers had lower NH4-N;TIN ratios, suggesting that where TIN loads are lower, more efficient nitrification takes place (that is, the aerobic processing of ammonia, to nitrites and then nitrates). Even high proportions of ammonia nitrogen in such systems would still be likely to comprise very low concentrations, that would be unlikely to be within toxic thresholds;
- Sub-catchments for which the inter-quartile range for NH4-N:TIN was less than 75% comprised the Sand, Sir Lowry's Pass, Lourens and Silvermine systems, while the highest ratios were found in the Soet River, where most of the (already high) inorganic nitrogen load was in the form of total ammonia, and likely to be highly toxic to aquatic biota, affecting both plant and animal diversity and health;

▪ The South Peninsula grouping of rivers across multiple small catchments has shown increasing deterioration with regard to TIN over the past few years of sample analysis. Re-analysis of these data as separate discrete sub-catchments is recommended in future reporting, to allow for particularly problematic land-uses in this broad and diverse part of the City to be identified.

The above findings again highlight how catchment condition reflects in river water quality, with the least developed catchments having the least impacted water quality while catchments subject to the accumulation of solid waste, treated and untreated sewage inflows and other sources of contaminated stormwater including fertilisers, are characterized by impacted river waters.

- **For standing water systems (vleis, dams, detention ponds)**, shown in **Figures 5.1.6, 5.1.8** and (for ratios of total ammonia nitrogen to TIN) **Figure 5.1.9**, the data suggest that nitrogen enrichment was less problematic in these systems than in the flowing water systems, with the following more specific observations applying:
  - Over 60% of samples from most of the monitored standing water systems fell within the Target range for this variable, with some systems performing much better (Zandvlei, Glencairn Vlei, Rietvlei and Die Oog all showed in excess of 80% of samples within Target range - exceptions comprised Zeekoevlei, Langevlei, Wildevoelvlei and the Mew Way and Mitchell's Plain detention ponds;
  - These results show that excessive TIN concentrations were considerably less problematic in standing water systems than in rivers and stormwater channels, and this is assumed to reflect dilution by a larger water body but, more importantly, the ecological impact of extended residence time, which allows nitrogen uptake, sedimentation and de-nitrification (to produce N2 gas) through anaerobic processes;
  - Systems showing consistently problematic nitrogen enrichment were Wildevoelvlei and the Mew Way and Mitchell's Plain detention ponds, 95% of which were above Unacceptable thresholds;
  - Data showing the ratio of TIN comprising total ammoniacal nitrogen (NH4-N:TIN), shown in **Figures 5.1.10 and D1.5** (Appendix D), show that vleis / dams where these ratios were below 75% comprised the least-nutrient enriched systems (Princessvlei, Glencairn Vlei, the Elsieskraal River dams, Langevlei, Little Princessvlei (outside of 2022) and Rietvlei (other than in the 2023 reporting period) – these systems are assumed to be those in which nitrification processes are able to shift the load of (potentially toxic under certain conditions) ammoniacal nitrogen, formed in the decay of organic material, to nitrite and then nitrate nitrogen, through oxidation;
  - Sites impacted by increased nitrogen enrichment comprised Wildevoelvlei (no Acceptable samples in 2022 and 2023), Little Princessvlei and Princessvlei (reduced number of Acceptable samples in 2023), Langevlei and Westlake wetlands (reduced

proportion of Target samples in 20923),

- **Seasonal** TIN data, shown as boxplots in **Figure 5.1.8** for routinely monitored sample sites**,** again allow more quantitative interpretation of TIN data, and indicate that:
  - Median TIN data for standing water courses only exceeded Target thresholds at Wildevoelvlei and at the Mitchell's Plain and Mew Way detention ponds;
  - At these three water bodies, TIN was significantly in excess of the threshold for Unacceptable conditions, suggesting significant nitrogen enrichment;
  - The detention ponds function primarily in winter, and thus the summer seasonal data are of little value in these graphs, although they do indicate that the ponds have limited to no importance as wetland habitats in an urban environment;
  - **Figures 5.1.10 and Figure D1.5** (Appendix D) indicate that TIN in the Mitchell's Plain and Mew Way detention ponds as well as Wildevoelvlei (2023 data) consisted primarily of total ammonia rather than oxidized nitrites or nitrates – oxygenation of all of these water bodies would be beneficial in increasing nitrification and thus the oxidation of ammonia to nitrite and nitrate, from where denitrification (transformation of nitrate-nitrogen into nitrogen gas) would be more efficient.

5.1.8 Implications of nitrogen-to-phosphorus ratios

Finally, the ratios of nitrogen (as TIN) to phosphorus (as PO4-P) data are presented in **Figure 5.1.10** for standing water bodies only (as individual vleis, dams and detention ponds). These ratios are considered important, because they provide some hint of likely ecosystem responses to different degrees of nutrient enrichment. Aquatic ecosystems that have low N:P ratios (that is, a lot of biologically available phosphorus, compared with nitrogen availability) are more likely to be dominated by plants that are able to extract nitrogen from the air, rather than relying on nitrogen in dissolved compounds in the water. The most common of such plants include cyanophyte (or 'blue-green') algae.

N:P data are presented here only for standing water bodies, where these relationships are more likely to exist than in flowing rivers and stormwater systems, where relatively high flow rates mean that algal growth is often not an issue as a result of low uptake rates in flowing conditions.

The data suggest that:

- Generally, standing water bodies were characterised by low N:P ratios, in the range most likely for these systems to be dominated by blue-green algae rather than rooted plants or other less problematic algal groups;
- In particular, low ratios well below Target values were evident in Wildevoelvlei, the Mew Way and Mitchell's Plain detention ponds, Zeekoevlei, Rondevlei and Zoarvlei (in the 2023 reporting period), suggesting that all of these systems are likely to be affected at least at times by blue-green algal growth. This is discussed further in **Section 6**;
- Generally, N:P ratios improved in winter data, when phosphate concentrations reduced as a result of rainfall and groundwater dilution. However, such seasonal changes would be unlikely to drive reduced algal growths, given that temperature and light would already be factors limiting algal growth.

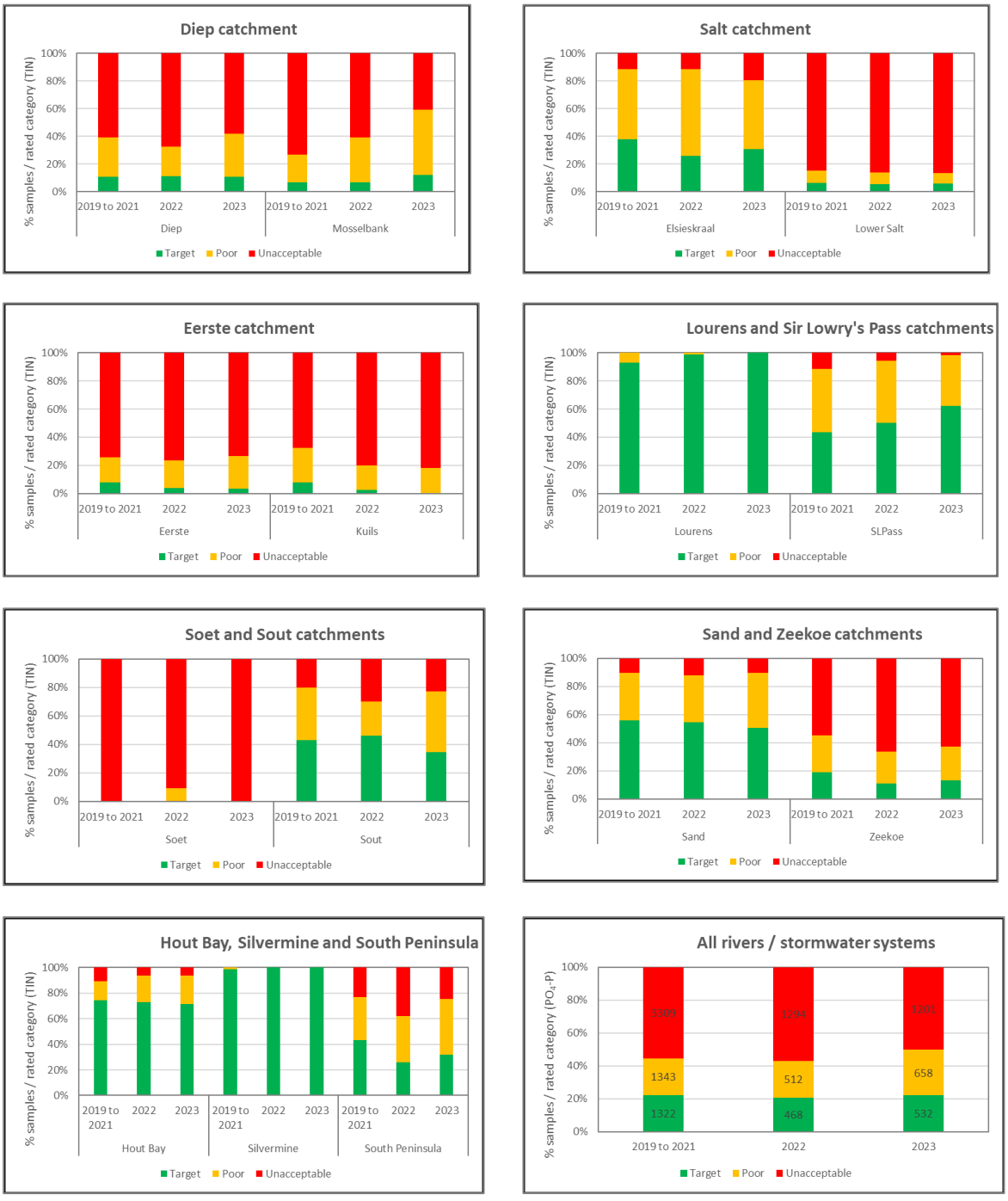


Figure 5.1.5
Percentage of Total Inorganic Nitrogen (TIN) samples falling within each rated category for this variable, per sub-catchment. Thresholds for rated categories as defined in Table 3.2. Data for river / 'flowing' water monitoring points in each sub-catchment. Sub-catchments as shown in Figure 2.1. Total number of samples considered shown in bars in bottom right plot ('All rivers / stormwater systems').



Figure 5.1.6
Percentage of Total Inorganic Nitrogen (TIN) samples falling within each rated category for this variable, per monitored standing water system.
Thresholds for rated categories as defined in Table 3.3. Data for sample points in standing water bodies / vleis and detention ponds. Total number of samples considered shown in bars in bottom right plot ('All standing water bodies').

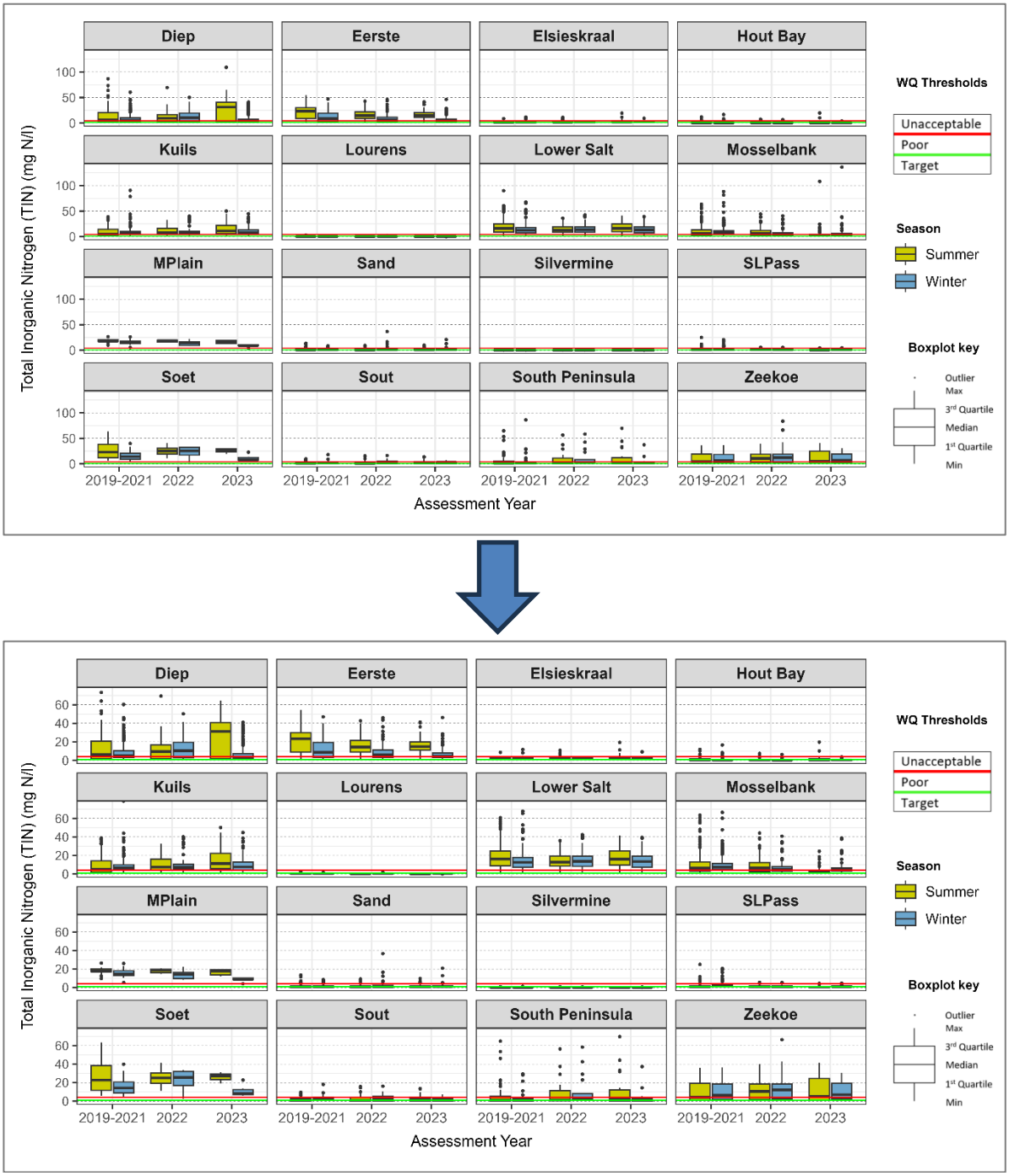


Figure 5.1.7
Comparison of Total Inorganic Nitrogen (TIN) data for flowing systems (rivers and stormwater channels) from the 2023 and 2022 reporting periods, with those from the previous three years (2019 to 2021) combined. Sub-catchment extent as shown in Figure 2.1. Data analysed as summer and winter datasets. Marked thresholds as per Table 3.1. Bottom figure (arrowed) shows same data at different scale.

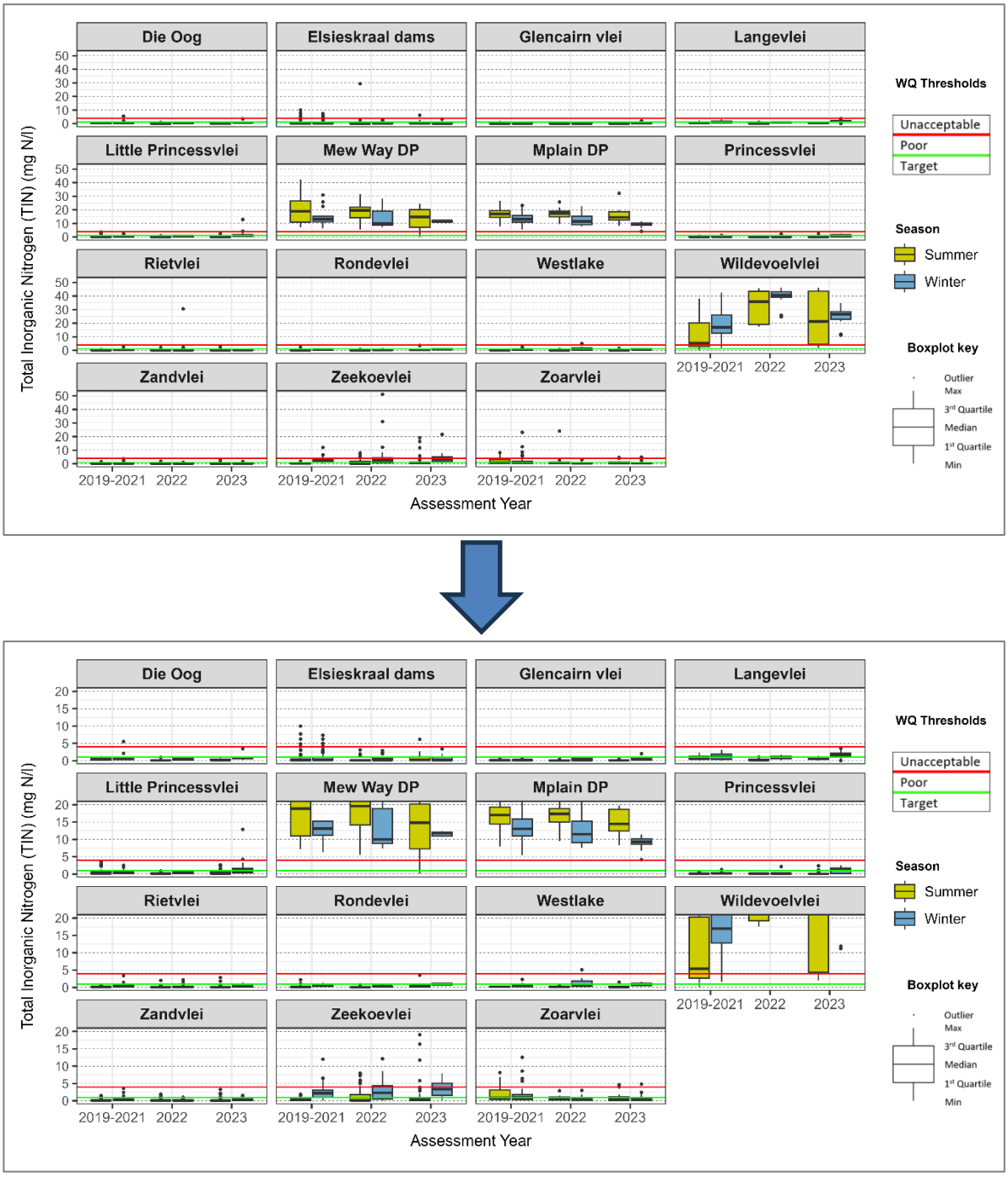
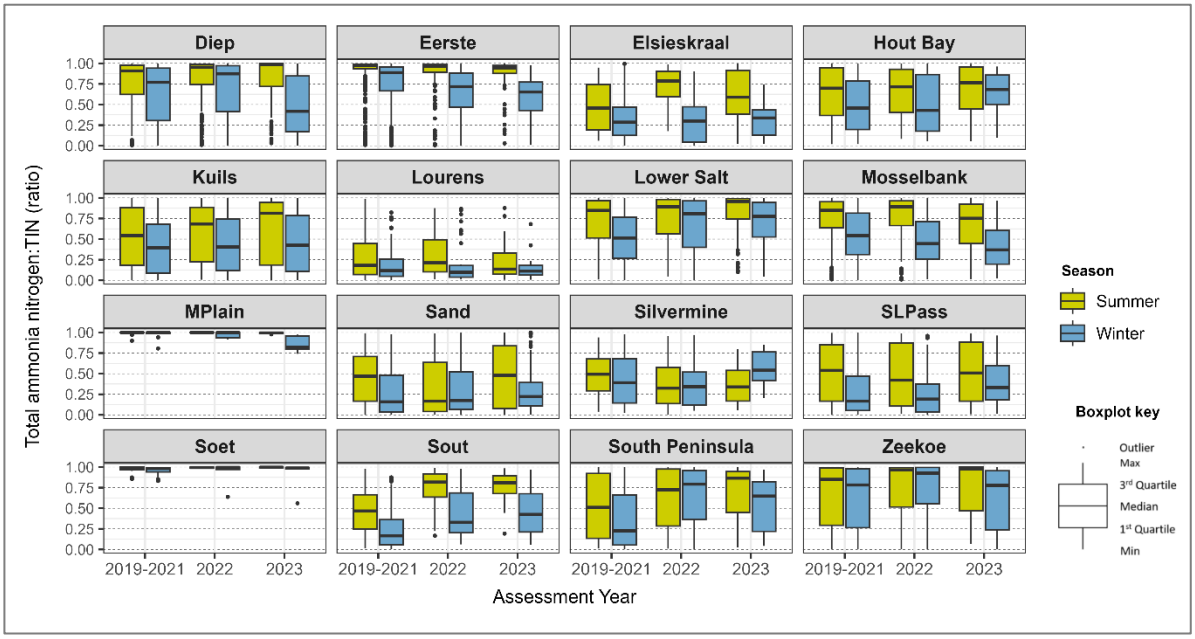


Figure 5.1.8
Comparison of Total Inorganic Nitrogen (TIN) data for standing water systems (vleis and dams) from the 2023 and 2022 reporting periods, with those from the previous three years (2019 to 2021) combined. Sub-catchment extent as shown in Figure 2.1. Data analysed as summer and winter datasets. Marked thresholds as per Table 3.1. Bottom figure (arrowed) shows same data at different scale.



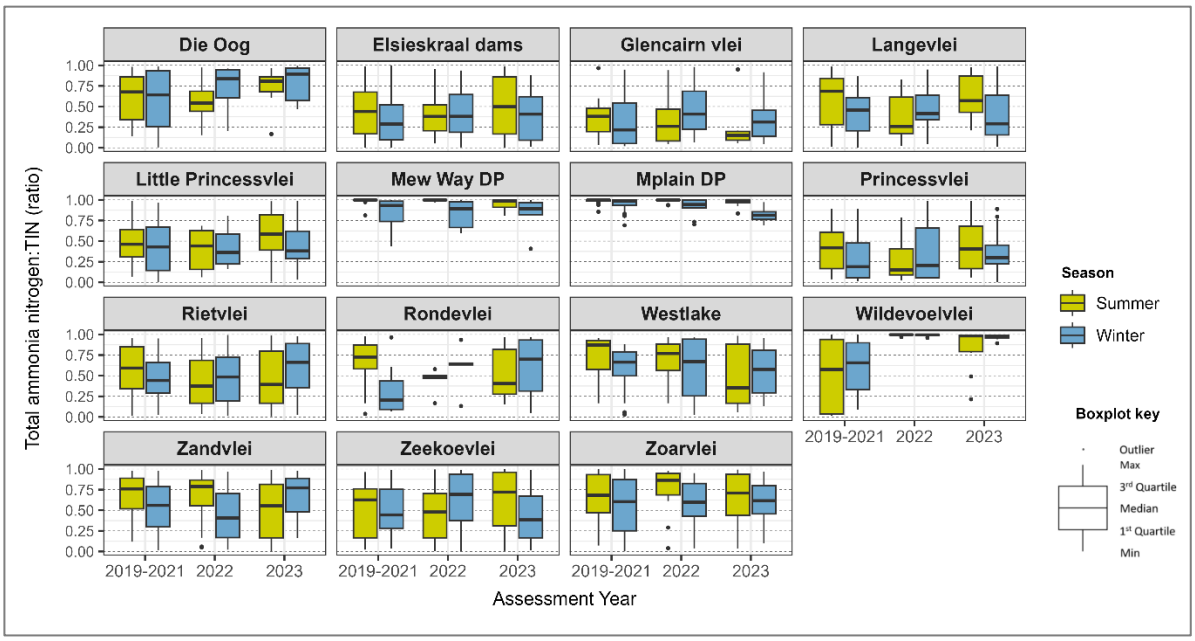


Figure 5.1.9
Ratio of total ammoniacal nitrogen (NH4-N) to Total Inorganic Nitrogen (TIN) data for flowing water systems (top graphs) and standing water systems (vleis and dams) (bottom graphs) from the 2023 and 2022 reporting periods, with those from the previous three years (2019 to 2021) combined. Sub-catchment extent as shown in Figure 2.1. Data analysed as summer and winter datasets.

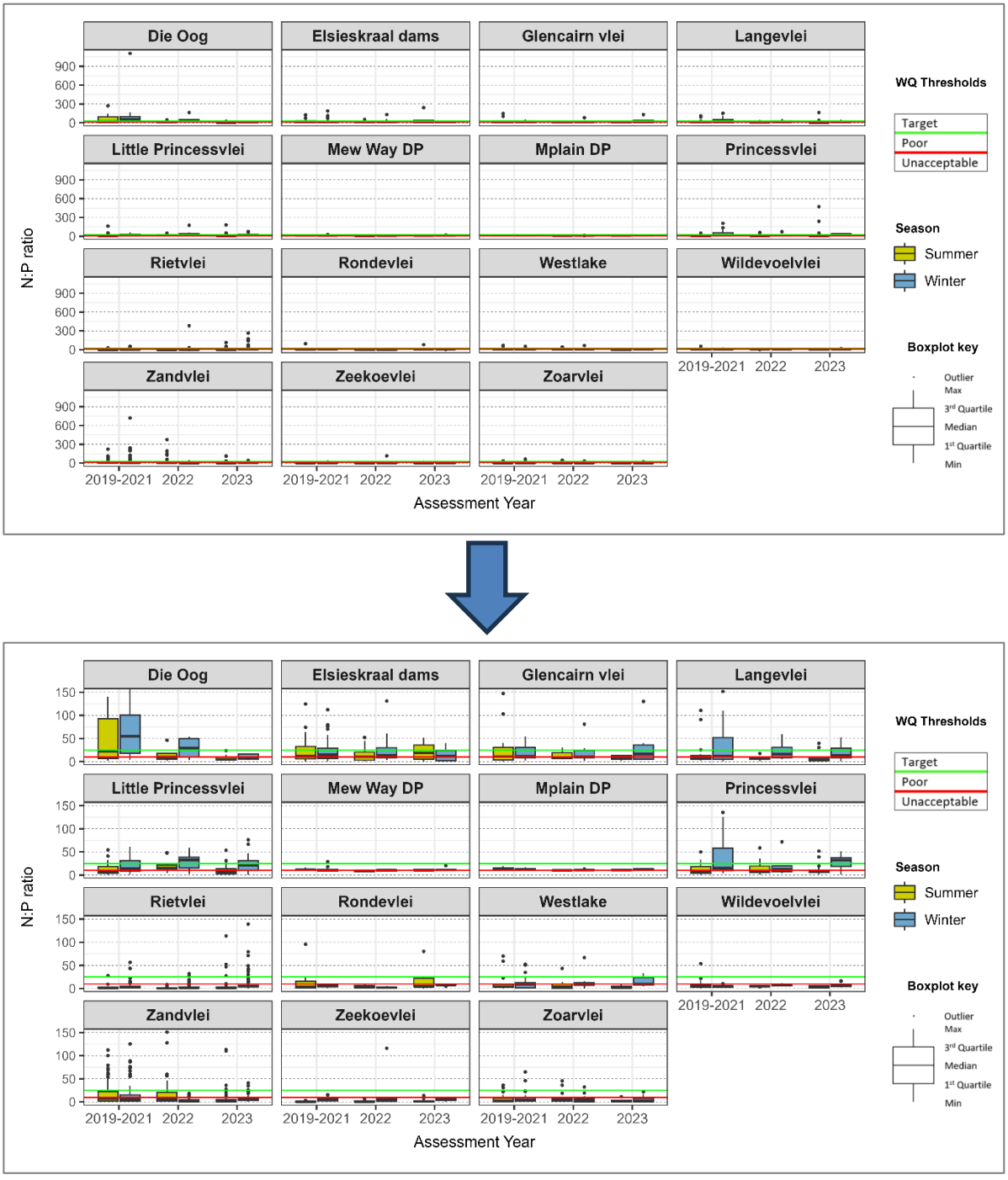


Figure 5.1.10
Comparison of ratios of Total Inorganic Nitrogen (TIN) to phosphate phosphorus (PO4-P) for standing water systems (vleis, dams and detention ponds) from the 2021 reporting period, with those from 2020 and the previous three years (2017 to 2019) combined. Data analysed as summer and winter datasets. Marked thresholds as per Table 3.2. Closer view (reduced y-axis) shown in bottom hand figure.

5.1.9 Key take-away points from assessment of nutrient data

- Phosphate data continue (as noted in the 2020 and 2023 Inland Water Quality Reports) to indicate that phosphorus enrichment remains an issue of great concern, affecting most of Cape Town's monitored rivers and other stormwater systems, which over the 2022 and 2023 reporting periods lay generally well within the hypertrophic (Unacceptable) range for this variable. Although median phosphorus concentrations reduced in many catchments over the 2023 reporting period, the proportion of samples within an Acceptable range reduced by almost half, and just under 80% of samples fell within the Unacceptable range. Since many of these nutrient-enriched rivers feed into the City's vleis and dams, the impacts of river phosphorus enrichment is passed on to, and magnified within these standing water bodies.
- The Silvermine, Lourens and Hout Bay Sub-catchments continued to be the best-performing catchments among monitored systems in the City, but nevertheless all showed a decrease in the proportion of samples in an Acceptable condition over the 2023 reporting period;
- Overall, total phosphorus data show that all of the City's standing water systems were highly nutrient-enriched, with water quality lying within either the range for Poor (eutrophic) or for Unacceptable (hypertrophic) conditions throughout the three reporting periods considered here. These data reflect inflows from significantly more polluted rivers and stormwater systems, which load standing water bodies with nutrients that accumulate over time, in the water bodies themselves, as well as in bottom sediments and living plant material;
- TIN data for these systems showed that
    - While phosphorus is considered more problematic than nitrogen in driving ecosystem responses to eutrophication (e.g. rapid plant growth including algae and reeds), nitrogen enrichment was also at levels of concern in many parts of Cape Town's watercourses over the 2022 and 2023 reporting periods - > 55% of water quality samples from routinely monitored sites were rated Unacceptable with regard to their TIN concentrations;
    - By contrast to the above, over 60% of samples from most of the monitored standing water systems (vleis and dams) fell within the Target range for this variable, with some systems performing much better - exceptions comprised Zeekoevlei, Langevlei,, Wildevoelvlei and the Mew Way and Mitchell's Plain detention ponds;
    - These results show that excessive TIN concentrations were considerably less problematic in standing water systems than in rivers and stormwater channels, and this is assumed to reflect dilution by a larger water body but, more importantly, the ecological impacts of extended residence time, which allows nitrogen uptake, sedimentation and de-nitrification (to produce N2 gas) through anaerobic processes;
- Generally, standing water bodies were however also characterised by low N:P ratios, in the range most likely for these systems to be dominated by blue-green algae rather than rooted plants or other less problematic algal groups;
- In particular, very low (and thus problematic) N:P ratios were evident in Wildevoelvlei, the Mew Way and Mitchell's Plain detention ponds, Zeekoevlei, Rondevlei and Zoarvlei (in the 2023 reporting period) , suggesting that all of these systems were likely to be affected at least at times by blue-green algal growth;
- The ratio of TIN that comprises total ammoniacal nitrogen (NH4-N) is also an important measure considered in this report. That is because total ammoniacal nitrogen includes a proportion of un-ionised ammonia (NH_3), which can be toxic to some aquatic biota at relatively low concentrations. Hence its dominance in TIN can reflect problems in ecosystem health (or condition). Generally less-nutrient enriched rivers had lower NH4-N;TIN ratios, suggesting that where TIN loads are lower, more efficient nitrification takes place. Even high proportions of total ammoniacal nitrogen in such systems would still be likely to comprise very low NH_3 concentrations, which would be unlikely to be below toxic thresholds;

- The above findings highlight how catchment condition reflects in river water quality, with the least developed catchments having the least impacted water quality while catchments subject to the accumulation of solid waste, treated and untreated sewage inflows and other sources of contaminated stormwater including fertilisers, are characterized by impacted river waters.

5.2 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.

The CCT 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.

5.2.1 Relevance in water quality monitoring

Under conditions of nutrient enrichment, particularly of phosphorus, chlorophyll-*a* often increases, reflecting an increase in algal growth rates in response to increased nutrients. If nutrient-enriched systems are dominated by macrophytes (that is, more complex plants than single-celled or filamentous algae, such as pondweed or other plants), they are less likely to be dominated by algae or give rise to algal blooms.

The sudden growth and subsequent die-back or simple turnover of phytoplankton blooms can have significant negative ecological impacts, as bloom decomposition may create anoxic conditions that may result in fish deaths. Anoxia also promotes the release of phosphorus from sediments, as well as hydrogen sulphide in the case of estuaries.

Blooms of blue-green algae (also called cyanobacteria or 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).

Severely elevated chlorophyll-*a* concentrations, indicative of bloom conditions, have a range of implications for waterbody management. Not only do they contribute to the accumulation of nutrients, organic sludges (requiring periodic dredging) and low-oxygen water in bottom waters, but they can also be associated with odour and aesthetic problems. *Microcystis*, for example, which is the dominant blue-green algal species in some of Cape Town'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 waterbody for different kinds of recreational uses. This issue is discussed in **Section 6**.

5.2.2 Current state and recent trajectory of change

Chlorophyll-*a* (Chl-*a*) data for standing water bodies are presented primarily as compliance-type graphs, showing the proportion of samples from the reporting years under consideration that fall within the Target range, or are rated as 'Poor' or 'Unacceptable', according to the toxicity criteria listed in **Tables 3.1 and 3.2**. In addition, the data are summarised in the form of boxplots (explained in **Box 3.5**). Seasonal boxplots are shown in this section, while the annual boxplots are provided in **Appendix D**.

Box 5.2

Note that mean annual Chl-*a* concentrations at individual monitoring points in each waterbody can be seen in **Appendix C,** as well as (for priority catchments) in the maps in **Section 8.**

The compliance graphs for Chl-*a* concentrations in **standing water systems** (at vlei, dam and detention pond sites) (**Figure 5.2.1**) indicate that:

- Considering all the data from standing water systems together (graph in bottom right panel), it can be seen that there was a decrease of approximately 20% in the proportion of samples within the Target range for Chl-*a* (i.e., <20 µg/L) in Reporting Years 2022 and 2023, from close to 60% compliance in the 2019-2021 reporting period;
- The least problematic system was Glencairnvlei, where >90% of the samples had Chl-*a* readings within the Target range for all three reporting periods;
- Consistently good conditions (with close to or more than 80% compliance in terms of the Target

range for Chl-*a*) were recorded for Zoarvlei and the Elsieskraal dams in the 2019-2021 and 2022 reporting periods (reducing to just over 40% and 60% compliance, respectively, in Reporting Year 2023), and at Die Oog in Reporting Year 2022 (up from ~25% compliance in 2019-2021 but reducing to ~40% in Reporting Year 2023);

- Relatively high levels of compliance (≥60% in Target category for Chl-*a*) were recorded for Little Princessvlei in all three reporting periods, and at Rietvlei and Rondevlei in the 2019-2021 reporting period (reducing to less than 30% compliance in Reporting Years 2022 and 2023 in the case of Rietvlei, and ~50% in the case of Rondevlei);
- Moderate levels of compliance (≥50% in Target category for Chl-*a*) were recorded for Westlake wetland and Zandvlei in all three reporting periods;
- The most problematic systems in Reporting Years 2022 and 2023 were Zeekoevlei and Princessvlei, where 85 to 100% of the samples that were collected fell into the Unacceptable category for Chl-*a* (i.e., >30 µg/L), suggesting that the risk of algal blooms would have been particularly high in these water bodies during the 2022 and 2023 reporting periods (in the 2019-2021 reporting period, the situation was similar for Zeekoevlei but slightly better for Princessvlei with just under 80% of the Chl-*a* measurements in the Unacceptable category);
- The situation at Langevlei was also problematic, especially in Reporting Year 2023 and the 2019-2021 reporting period when 70 to 80% of the samples were in the Unacceptable category for Chl-*a*, with an improvement in Reporting Year 2022 when just under 60% of the samples were in the Unacceptable category;
- At Wildevoelvlei, the situation improved significantly in Reporting Year 2023 but was still problematic with just over 60% of the samples in the Unacceptable category for Chl-*a*, compared to the 2019-2021 and 2022 reporting periods when >80% of the samples had measurements in the Unacceptable category.

The seasonal boxplots for Chl-*a* in **Figure 5.2.2** (and the annual boxplots in **Appendix D**) provide the following additional insight in relation to the potential for algal blooms in standing water bodies during the reporting periods under consideration:

- The only systems with Chl-*a* levels consistently below the threshold for Unacceptable during all three reporting periods (as indicated by the inter-quartile ranges on the annual and seasonal boxplots) were Glencairnvlei and the Elsieskraal dams, as well as Zoarvlei in the 2019-2021 reporting period (but not in Reporting Years 2022 and 2023 when the upper end of the inter-quartile range extended beyond the Unaccepatble threshold value for Chl-*a* during summer and both seasons, respectively);
- During all three reporting periods, the range of Chl-*a* values recorded in both summer and winter was greatest at Wildevoelvlei and Zeekoevlei, followed by Langevlei, compared to the other monitored water bodies, as shown by longer boxes and whiskers on the respective boxplots;
- No clear seasonal patterns were observed, which was somewhat surprising because algal production is generally lower during the colder winter months and should result in mostly lower Chl-*a* measurements compared to those recorded in summer.

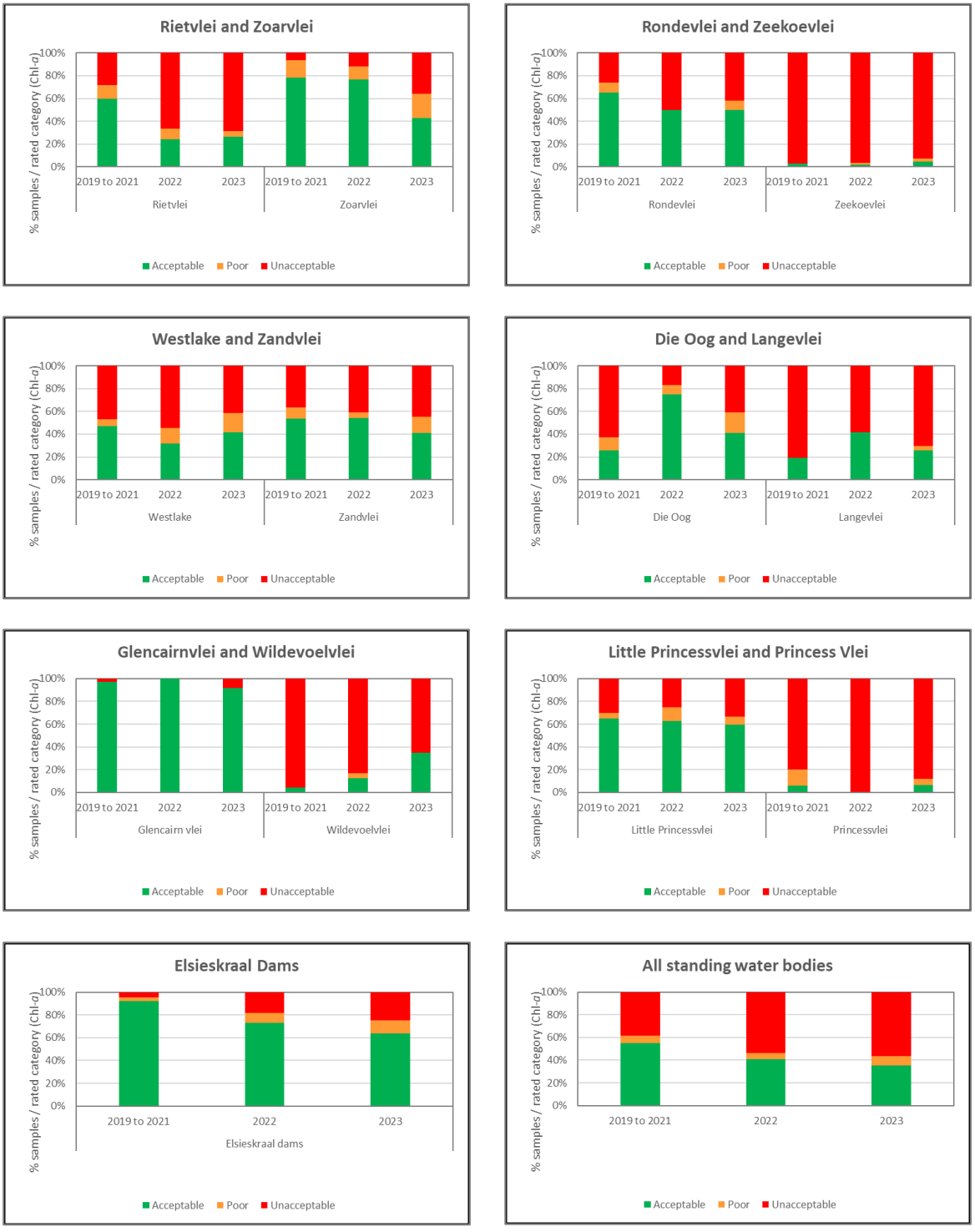


Figure 5.2.1
Percentage of Chlorophyll-*a* (Chl-*a*) samples falling within each rated category for this variable, per monitored standing water system. Thresholds for rated categories as defined in Table 3.2. Data for sample points in standing water bodies / vleis and detention ponds. Total number of samples considered shown in bars in bottom right plot ('All standing water bodies').

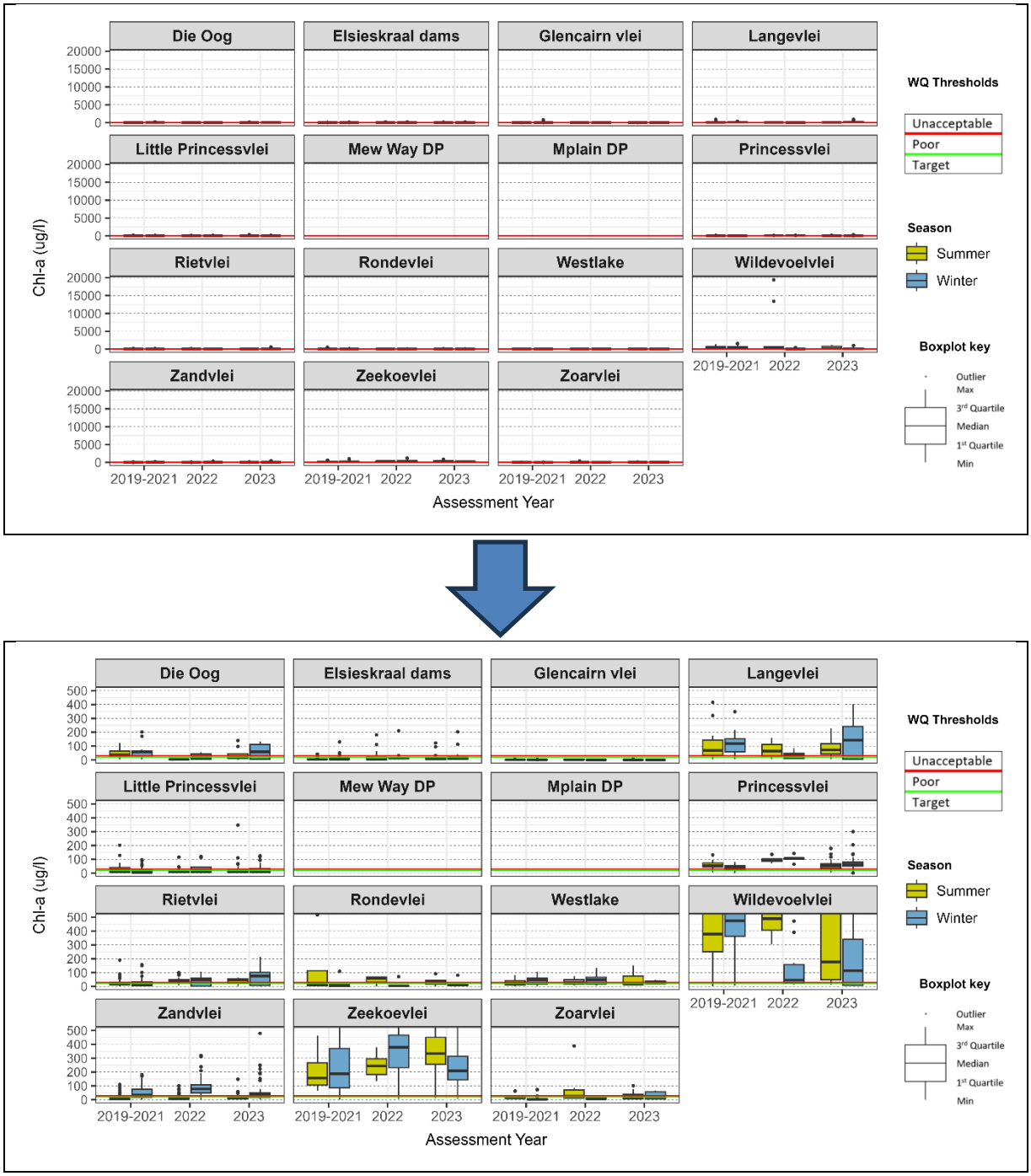


Figure 5.2.2
Comparison of Chlorophyll-a data for standing water systems (vleis, dams and detention ponds) from the 2023 reporting period with those from 2022 and the previous three years (2019 to 2021) combined. Data analysed as summer and winter datasets. Marked thresholds as per Table 3.2. Bottom figure (arrowed) shows same data at different scale. Note that there are no data for Mew Way DP and Mplain DP.

5.2.3 Key take-away points from assessment of Chlorophyll-a data

The main findings in terms of algal productivity, as reflected in chlorophyll-*a* measurements recorded for the selection of standing water bodies in Cape Town during the reporting periods under consideration, were:

- The most problematic systems, where the risk of algal blooms would have been high during the reporting periods being considered, were Zeekoevlei, Princessvlei, Wildevoelvlei and Langevlei (although there was a noticeable improvement in the situation at Wildevoelvlei in Reporting Year 2023);
- High levels of non-compliance were recorded for Rietvlei in Reporting Years 2022 and 2023 (with <25% of the samples within the Target range for Chl-*a*);
- Relatively high levels of non-compliance were recorded for Zoarvlei and Die Oog in Reporting Year 2023, with a significant decrease in the level of compliance from Reporting Year 2022, especially during winter;
- The least problematic system in terms of algal production was Glencairnvlei, which is characterised by relatively low nutrient inputs and where >90% of the samples had Chl-*a* measurements within the Target range during all three reporting periods;
- Consistently good conditions (with close to or more than 80% compliance in terms of the Target range for Chl-*a*) were recorded for Zoarvlei and the Elsieskraal dams in the 2019-2021 and 2022 reporting periods, and at Die Oog in Reporting Year 2022, but there was a significant reduction in the level of compliance (to 40-60%) within all of these waterbodies during Reporting Year 2023.

5.3 Dissolved oxygen

5.3.1 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 impacts on aquatic organisms, and can increase the toxicity of certain toxic substances such as various heavy metals (e.g., zinc, lead, copper) as well as sulphides and ammonia (DWAF 1996a). 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 un-ionised ammonia. This is especially problematic for aquatic systems that are polluted with nitrogen-rich contaminants such as sewage. 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/conductivity. Variations in photosynthesis through the day 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. Consequently, the measurement of dissolved oxygen in water quality monitoring programmes should be carried out at the same time of day if data between sites or over time are to be comparable. Since the CCT'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.

Box 5.3

Dissolved oxygen in open water bodies

In shallow standing water systems, dissolved oxygen concentrations can be reduced (i.e. made worse) 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, especially phytoplankton.

Exposure to water with very low dissolved oxygen concentrations can trigger immediate death for some non-air-breathing organisms, as in the case of some fish kill incidents. Continuous exposure to water with non-lethal but sub-optimal concentrations may also be very harmful to aquatic organisms, including impacts on fish fecundity and/or mortality (DWAF 1996a).

5.3.2 Current state and recent trajectory of change

In this section, dissolved oxygen is considered from the perspective of the degree to which suppressed dissolved oxygen concentrations are likely to have contributed to aquatic ecosystem degradation at sampling sites. The next section (**Section 5.4**) considers ammonia toxicity as a potential issue in Cape Town's water bodies. Total ammonia concentrations are directly affected by dissolved oxygen concentrations. This is because, with low DO availability, nitrification processes are slow to non-existent, and decomposing organic nitrogen remains as total ammonia nitrogen and does not oxidise readily to nitrites or nitrates.

Figures 5.3.1 and **5.3.2** present data for dissolved oxygen concentrations in terms of the percentage of samples per sub-catchment and standing waterbody, respectively, that met or did not meet the minimum threshold of ecological acceptability – that is, a threshold concentration 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 graphs also show the percentage of samples that were in the target range for dissolved oxygen concentration (i.e. >6 mg/l), as well as the remaining percentage of samples considered to be representative of poor conditions in terms of dissolved oxygen (i.e.

concentrations of 4-6 mg/l).

The graphs for river and stormwater channel sites (**Figure 5.3.1**), grouped by sub-catchment, indicate that:

- Taking all the data for flowing systems in all the monitored sub-catchments across Cape Town together (bottom right panel in **Figure 5.3.1**), the proportion of sampling sites with DO measurements within the Target category remained at 50-55% through the 2019-2021 and 2022 reporting periods, increasing to just over 60% in Reporting Year 2023, indicative of an improving but sub-optimal situation with respect to DO levels in flowing systems across Cape Town, with 40% or more of the measurements collected over the five-year period of analysis consistently being reflective of Poor to Unacceptable conditions;
- The conditions in the most recent year of analysis (Reporting Year 2023) improved significantly compared to previous reporting periods, in terms of DO, in the Diep, Eerste, Kuils, Sout, Zeekoe, Hout Bay, Silvermine and South Peninsula sub-catchments, where the proportion of samples in the Unacceptable category for DO concentrations decreased and the proportion within the Target category increased;
- No major deterioration in the situation with regard to DO compliance in flowing systems was recorded for any of the sub-catchments in Reporting Year 2023, compared to the previous reporting periods;
- The worst-performing sub-catchments with respect to DO compliance in flowing systems were the Lower Salt and the Soet, where >40% of the samples were in the Unacceptable category and <40% in the Target range for all three reporting periods;
- Similarly impacted conditions (> 40% of flowing water samples in the Unacceptable category for DO concentrations) were recorded in the Eerste sub-catchment in the 2019-2021 reporting period, and in the Zeekoe sub-catchment in both the 2019-2021 and the 2022 reporting periods;
- Conditions in the Soet sub-catchment were particularly bad in Reporting Year 2022, with >60% of the samples falling within the Unacceptable category and no samples in the Target range;
- Low to very low DO levels were also prevalent (with 50% or more of the samples falling into the Poor and Unacceptable categories combined) in the Diep sub-catchment in all three reporting periods, the Mosselbank sub-catchment in the 2019-2021 and 2022 reporting periods, and in the Eerste, Kuils, Sout and South Peninsula sub-catchments in Reporting Year 2022;
- High DO levels within the Target range (reflective of good conditions) were recorded in close to 80% or more of the samples collected from the Elsieskraal, Lourens and Sir Lowry's Pass sub-catchments during all three reporting periods, in the Kuils and Hout Bay sub-catchments in Reporting Year 2023, and in the Silvermine sub-catchment in Reporting Years 2022 and 2023 (with 100% compliance in this catchment during Reporting Year 2023);
- Relatively high proportions (60-75%) of the flowing-water samples were within the Target range for DO concentrations, with ≤25% of recorded measurements in the Unacceptable category, in the Sand sub-catchment during all three reporting periods, in the Eerste sub-catchment during Reporting Year 2023, in the Kuils and Silvermine sub-catchments during the 2019-2021 reporting period, and in the South Peninsula sub-catchment during the 2019-2021 and 2022 reporting periods.

Standing water bodies are generally more vulnerable to the development of low-oxygen or even anoxic conditions than riverine systems. The data for vleis, dams and detention ponds (graphs in **Figure 5.3.2**) indicate that:

- Considering the data for all the monitored standing water systems across CCT together (bottom right panel in **Figure 5.3.2**), the proportion of sampling sites with DO measurements within the Target category was significantly higher than that for flowing systems, at 70-85% for standing water sites versus ~50% to just over 60% for flowing water sites [These results are somewhat unexpected because standing water systems, which lack the turbulence created by flow, are

generally assumed to be less oxygenated than flowing systems. The results were, however, probably skewed by the large number of flowing water sites in the monitoring database that were selected specifically due to the presence of pollution problems (explained in **Sections 3.3 & 3.4**) and the presumed collection of water samples in standing water systems from near the water surface, as opposed to from deeper into the water column and closer to the bottom.];

- The grouped results for standing water systems show a trajectory of some improvement from one reporting period to the next, for the three reporting periods that were considered, with a slightly greater proportion of samples within the Target range for DO concentrations, and slightly lower proportions of samples in the Poor and Unacceptable categories, in each subsequent reporting period;
- With respect to individual standing water bodies, the most significant improvements in terms of recorded DO concentrations compared to the previous reporting period/s were observed at Rondevlei and Glencairnvlei in Reporting Year 2023, at Zeekoevlei, Westlake and Langevlei in Reporting Year 2022 (although for Langevlei, the situation deteriorated in Reporting Year 2023 back to similar levels as the 2019-2021 reporting period), and at Zandvlei in both Reporting Years 2022 and 2023;
- High DO levels within the Target range (reflective of good conditions) were recorded in all or most (>90%) of the samples collected at Rietvlei and Princessvlei during all three reporting periods, at Westlake in Reporting Year 2022, at Glencairnvlei in Reporting Year 2023, and at Zandvlei in Reporting Years 2022 and 2023;
- High DO levels were also prevalent (with 80-90% of the samples within the Target range) at Zandvlei and Wildevoelvlei in the 2019-2021 reporting period, Die Oog in the 2019-2021 and 2022 reporting periods, Westlake in the 2019-2021 and 2023 reporting periods, Langevlei in Reporting Year 2022, and at Zeekoevlei in Reporting Years 2022 and 2023;
- Reasonably good compliance, with 60-80% of the samples within the Target range for DO concentrations and <25% in the Unacceptable category, was recorded for Little Princessvlei and the Elsieskraal dams in all three reporting periods, Glencairnvlei in the 2019-2021 and 2022 reporting periods, Zeekoevlei in the 2019-2021 reporting period, and at Rondevlei, Die Oog and Wildevoelvlei in Reporting Year 2023;
- The worst-performing standing waterbody in terms of DO compliance was the Mew Way detention pond, where >80% of the samples collected during all three reporting periods were in the Unacceptable category, although the proportion of samples in the Target category did increase from near-zero in the previous reporting periods to just under 20% in Reporting Year 2023;
- Low to very low DO levels were also prevalent, with 40-60% of the samples in the Unacceptable category and <35% within the Target range, at Zoarvlei and the Mitchell's Plain detention ponds during all three reporting periods, at Rondevlei during the 2019-2021 and 2022 reporting periods, and at Wildevoelvlei in Reporting Year 2022.

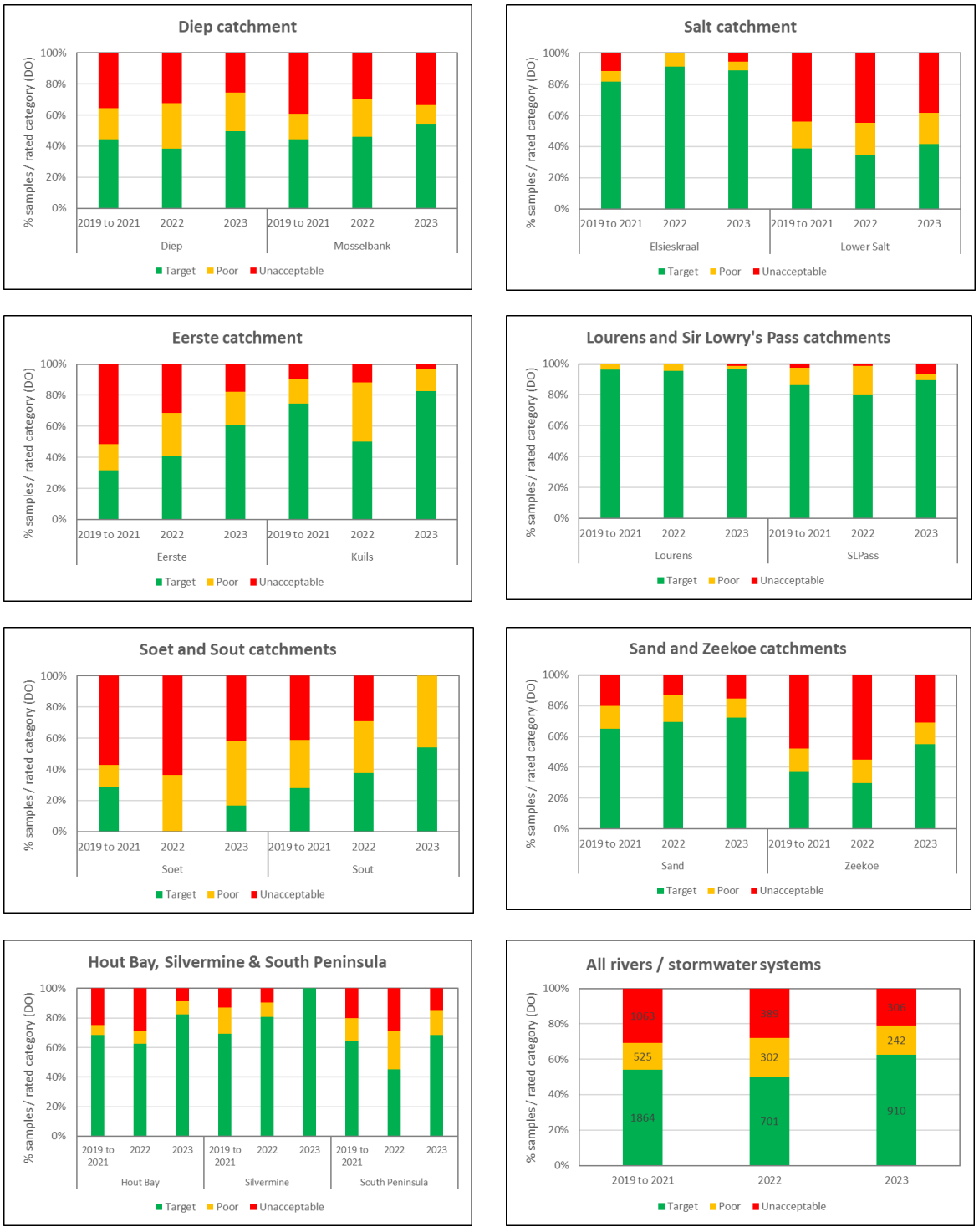


Figure 5.3.1
Percentage of Dissolved Oxygen (DO) falling within each rated category for this variable, per sub-catchment.
Thresholds for rated categories as defined in Table 3.1. Data for river / 'flowing' water monitoring points in each sub-catchment. Sub-catchments as shown in Figure 2.1. Total number of samples considered shown in bars in bottom right plot ('All rivers / stormwater systems').



Figure 5.3.2
Percentage of Dissolved Oxygen (DO) samples falling within each rated category for this variable, per monitored standing water system. Thresholds for rated categories as defined in Table 3.2. Data for sample points in standing water bodies / vleis and detention ponds. Total number of samples considered shown in bars in bottom right plot ('All standind water bodies).

Boxplots of DO data for Reporting Years 2022 and 2023 compared to data from the previous three-year period (2019-2021), separated into summer and winter seasons, are presented below for river / stormwater channels (**Figure 5.3.3**) and dams / vleis (**Figure 5.3.4**). These graphs show that, for river and stormwater channel sites, there was a tendency for conditions to be worse (lower DO concentrations) in summer compared to winter, as expected. There was also a tendency, at least over the three reporting periods analysed here, for the range of variability to be greater during summer than in winter at the sites representative of flowing systems. This was also to be expected due to the wider range of temperature fluctuations in flowing water systems during summer compared to winter. Exceptions to this latter tendency were, however, observed in certain sub-catchments (e.g., the Lower Salt and Sir Lowry's Pass sub-catchments for all three reporting periods, and the Mosselbank and Zeekoe sub-catchments for Reporting Years 2022 and 2023), where similar summer and winter inter-quartile ranges were recorded (or a wider range of values in winter compared to summer). Most of the sub-catchments where these exceptions were recorded receive significant WWTW inflows and/or stormwater inflows that are contaminated with sewage, which would regulate the flows and (to less extent) water temperatures in the systems, thus dampening seasonal DO variations.

The above-mentioned patterns, in terms of summer versus winter differences, are not as consistently or strongly apparent in the data for the vlei, dam and detention pond sites (**Figure 5.3.4** vs. **Figure 5.3.3**), although there are small seasonal differences in some cases. Possible reasons for this lack of strong seasonal variability include the following:

- Standing water systems are generally not exposed to strong seasonal variation (other than in Zeekoevlei and Rondevlei, which are both managed by seasonal draw-downs, with water levels in Zeekoevlei being drawn down in winter and those in Rondevlei being drawn down in summer);
- Standing water systems typically have a more stable temperature regime compared to flowing systems, due to a lack of flows and a deeper water column;
- The presence of a much greater volume of water with a larger surface area for standing water systems, exposed to atmospheric oxygen as well as wind-induced turbulence and mixing.

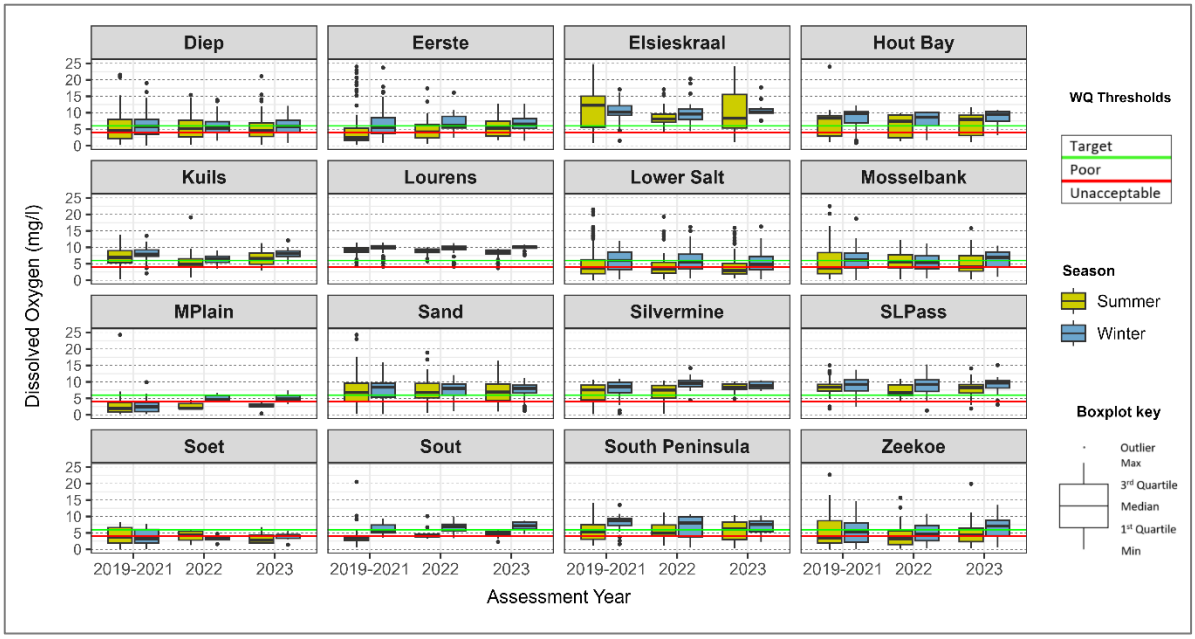


Figure 5.3.3
Comparison of dissolved oxygen for flowing systems (rivers and stormwater channels) from the 2023 reporting period, with those from 2022 and the previous three years (2019 to 2021) combined. Sub-catchments as shown in Figure 2.1. Data analysed as summer and winter datasets. Marked thresholds as per Table 3.1.

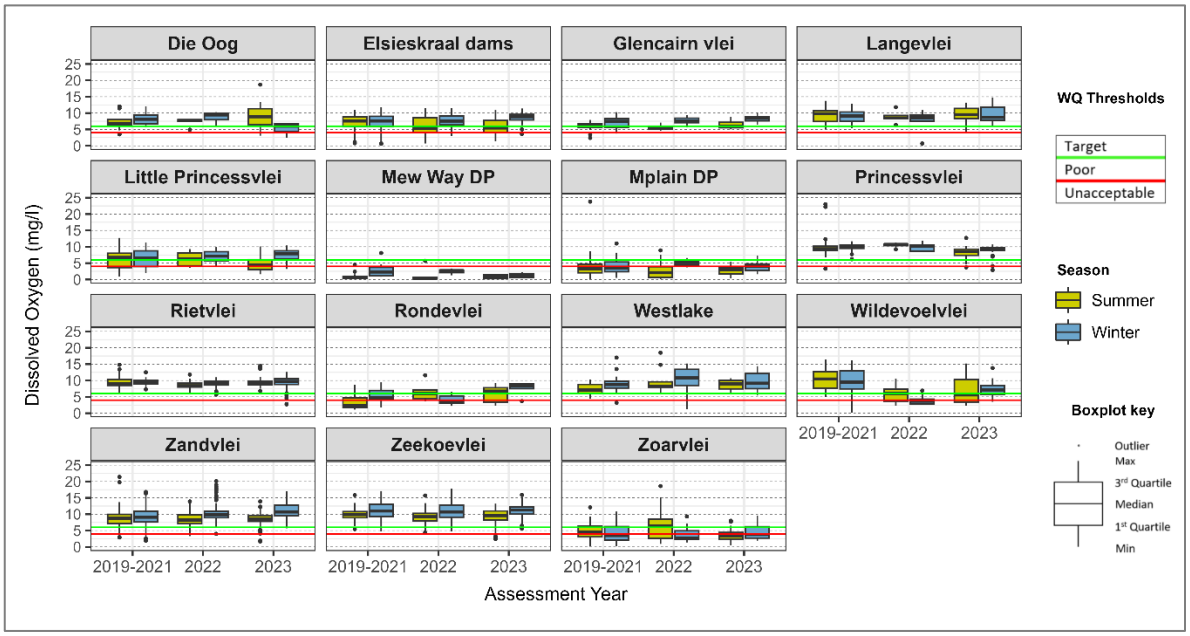


Figure 5.3.4
Comparison of dissolved oxygen for standing water systems (vleis, dams and detention ponds) from the 2023 reporting period, with those from 2022 and the previous three years (2019 to 2021) combined. Data analysed as summer and winter datasets. Marked thresholds as per Table 3.2.

5.3.3 Key take-away points from assessment of dissolved oxygen data

The main findings with respect to dissolved oxygen levels in the monitored water bodies across the City were as follows:

- The level of non-compliance in relation to the Target range of values for DO concentrations was more problematic for the monitored flowing water sites than it was for standing water sites, but this could be at least partly the result of many of the flowing system sites being purposefully located immediately downstream of known pollution sources;
- For flowing systems, the results are indicative of a generally poor state of water quality with respect to DO levels at the monitored sites within the City, with 40% or more of the measurements collected over the five-year period from Reporting Year 2019 to 2023 consistently being reflective of Poor to Unacceptable conditions, although there was an overall improvement from the 2022 to the 2023 reporting period;
- The worst-performing sub-catchments with respect to DO compliance in flowing systems were the Lower Salt and the Soet for all three reporting periods, the Eerste in the 2019-2021 reporting period, and the Zeekoe in both the 2019-2021 and the 2022 reporting periods;
- Conditions in the Soet sub-catchment were particularly bad in Reporting Year 2022, with >60% of the samples from flowing systems falling within the Unacceptable category and no samples in the Target range;
- For the most recent year of analysis (Reporting Year 2023), the conditions in terms of DO concentrations improved significantly compared to previous reporting periods for flowing water systems in the Diep, Eerste, Kuils, Sout, Zeekoe, Hout Bay, Silvermine and South Peninsula sub-catchments;
- The least problematic sub-catchments in terms of DO compliance at monitored flowing water sites were, unsurprisingly, the more rural Elsieskraal sub-catchment and the Lourens, Sir Lowry's Pass and Silvermine sub-catchments containing less impacted upper river sites, as well as the Kuils and Hout Bay sub-catchments in the most recent Reporting Year 2023;
- For river and stormwater channel sites, there was a tendency for conditions to be worse (lower DO concentrations) in summer compared to winter, and for the range of variability to be greater during summer than in winter, although exceptions to this latter tendency were observed in certain sub-catchments which receive WWTW inflows and/or or stormwater inflows that are contaminated with sewage input including the Lower Salt, Sir Lowry's Pass, Mosselbank and Zeekoe sub-catchments;
- The grouped results for standing water systems show a trajectory of some improvement in terms of DO compliance from one reporting period to the next, for the three reporting periods that were considered, with the most significant improvements in terms of recorded DO concentrations compared to the previous reporting period/s observed at Rondevlei and Glencairnvlei in Reporting Year 2023, at Zeekoevlei, Westlake and Langevlei in Reporting Year 2022 (although for Langevlei, the situation deteriorated in Reporting Year 2023), and at Zandvlei in both Reporting Years 2022 and 2023;
- High DO levels within the Target range were recorded in all or most (>90%) of the samples collected at Rietvlei and Princessvlei during all three reporting periods, at Westlake in Reporting Year 2022, at Glencairnvlei in Reporting Year 2023, and at Zandvlei in Reporting Years 2022 and 2023;
- High DO levels were also prevalent (with 80-90% of the samples within the Target range) at Zandvlei and Wildevoelvlei in the 2019-2021 reporting period, Die Oog in the 2019-2021 and 2022 reporting periods, Westlake in the 2019-2021 and 2023 reporting periods, Langevlei in Reporting Year 2022, and at Zeekoevlei in Reporting Years 2022 and 2023;

- The worst-performing standing waterbody in terms of DO compliance was the Mew Way detention pond, where >80% of the samples collected during all three reporting periods were in the Unacceptable category;
- Low to very low DO levels were also prevalentat Zoarvlei and the Mitchell's Plain detention ponds during all three reporting periods, at Rondevlei during the 2019-2021 and 2022 reporting periods, and at Wildevoelvlei in Reporting Year 2022;
- The seasonal patterns observed for DO concentrations in flowing water systems were not as consistently or strongly apparent in the data for the vlei, dam and detention pond sites, although there were small seasonal differences in some cases.

5.4 Ammonia toxicity

As explained in **Section 5.1.2**, inorganic nitrogen in aquatic ecosystems occurs in the form of nitrate and nitrite ions, and as total ammonia. There are two forms of ammonia, namely ionised ammonia ($NH4^+$), also known as ammonium, and un-ionised ammonia (NH_3). Un-ionised (or 'free') ammonia can be toxic to some aquatic organisms, even at very low concentrations (DWAF 1996a and DWAF 2008).

The present section focuses specifically on the potential for ammonia toxicity as a result of elevated un-ionised ammonia concentrations at the CCT's water quality sampling points, both in flowing and standing water systems.

5.4.1 Relevance in water quality monitoring

In an aquatic environment, the relative proportion of un-ionised ammonia to ammonium ions in water is controlled primarily by pH and temperature. The CCT measures the 'total ammonia nitrogen' concentration in a water sample and calculates the proportion of this that is likely to be in the potentially toxic un-ionised form, taking into account pH, temperature and EC (or salinity in estuarine waters). 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).

Concentrations of un-ionised ammonia above Target levels (see **Tables 3.1 and 3.2**) would increase the risk of ammonia toxicity in sensitive fauna, especially fish. The presence of low oxygen conditions would tend to 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 un-ionised ammonia at chronic toxicity levels (Poor category in **Tables 3.1 and 3.2**) could affect aquatic organism fecundity, general health and resilience, while exposure to elevated levels associated with acute toxicity (Unacceptable category in **Tables 3.1 and 3.2**) could result in the death of more sensitive organisms.

5.4.2 Current state and recent trajectory of change

Box 5.4

Note that median annual NH_3 concentrations at individual monitoring points in each sub-catchment can be seen in **Appendix C,** as well as (for priority catchments) in the maps in **Section 8.**

Un-ionised ammonia data (abbreviated hereafter as NH_3) are presented as compliance-type data, showing the proportion of samples from the reporting years under consideration that fall within the Target range compared to the proportions rated as 'Poor' and 'Unacceptable' (according to the toxicity criteria listed in **Tables 3.1 and 3.2**). In addition, the results are presented as boxplots, which show statistical data for all analysed watercourse groups and categories (as explained in **Box 3.5**).

These data are presented separately for flowing water systems (rivers and stormwater channels) and for standing water systems (vleis, dams and detention ponds). The compliance graphs and seasonal boxplots are shown in this section, while the annual boxplots are provided in **Appendix D**.

The compliance graphs for NH_3 concentrations at **river and stormwater channel sites** (**Figure 5.4.1**), grouped by sub-catchment, indicate that:

- Considering all flowing water sites across all sub-catchments together (graph in bottom right panel), only 40 to 50% of the samples had NH_3 concentrations within the Target range for all three reporting periods, with 25 to 30% in the Unacceptable category;
- There was a negligible risk of ammonia toxicity in the Lourens, Sout, Hout Bay and Silvermine sub-catchments in all three reporting periods, with 100% or close to 100% compliance in relation to the Target threshold for un-ionised ammonia in most cases (or at least near-zero results in the

Unacceptable category);

- There was also a relatively low risk of ammonia toxicity over all three reporting periods in the Sir Lowry's Pass and Sand sub-catchments, where close to or more than 80% of the samples had NH_3 concentrations lower than the Target threshold, with <10% in the Unacceptable category;
- The most problematic sub-catchment, in terms of the potential for ammonia toxicity in flowing water systems, was the Soet where >80% of the samples collected in the 2019-2021 and 2022 reporting periods had NH_3 concentrations in the Unacceptable category, improving slightly to ~75% in Reporting Year 2023;
- Potentially toxic conditions were very prevalent in the Lower Salt and Zeekoe sub-catchments in all three reporting periods, with NH_3 concentrations above the Target threshold (i.e., in the Poor and Unacceptable categories) recorded in 70% or more of the samples that were collected, but the situation was particularly problematic in these catchments during Reporting Years 2022 and 2023 when more than 50% of the samples were in the Unacceptable category (rising to 60 to 70% in the case of the Lower Salt sub-catchment);
- Ammonia toxicity was also an issue of concern in the Eerste sub-catchment in all three reporting periods, the Diep sub-catchment in Reporting Years 2022 and 2023, the Mosselbank sub-catchment in the 2019-2021 reporting period, and the Elsieskraal sub-catchment in the 2019-2021 and 2022 reporting periods, with NH_3 concentrations falling in the Unacceptable category for ~40% of the samples collected in these sub-catchments during those time periods, indicative of potential acute toxicity;
- In the Kuils sub-catchment during all three reporting periods, and in the Elsieskraal sub-catchment during Reporting Year 2023, approximately 40% of the samples that were collected had NH_3 concentrations within the Target range, with 20 to 30% of the samples in the Unacceptable category, implying that concentrations indicative of conditions conducive to chronic or acute ammonia toxicity were present close to 60% of the time in these two catchments during these periods;
- Approximately 20% of the samples were in the Unacceptable category in the South Peninsula catchment during all three reporting periods and in the Mosselbank sub-catchment during Reporting Year 2023, but <50% of the samples in the Mosselbank sub-catchment were in the Target range versus 60 to 75% in the South Peninsula catchment where the proportion of samples in the Poor category (indicative of chronic ammonia toxicity) was significantly less.

The compliance graphs for NH_3 concentrations in **standing water systems** (at vlei, dam and detention pond sites) (**Figure 5.4.2**) indicate that:

- Considering all the data from standing water systems together (graph in bottom right panel), ammonia toxicity was generally less of a problem for these systems than it was for flowing water systems, with >60% of the standing water samples from all three reporting periods being in the Target category and less than 20% in the Unacceptable category;
- There was ≥80% compliance in relation to the Target threshold for NH_3 at Glencairnvlei (100% compliance), Little Princessvlei, Princessvlei and the Elsieskraal dams during all three reporting periods, at Rondevlei and Die Oog during the 2019-2021 and 2022 reporting periods, and at Rietvlei in Reporting Year 2022, Zoarvlei in Reporting Years 2022 and 2023, and Zandvlei in Reporting Year 2023;
- The situation deteriorated in Reporting Year 2023 at Rondevlei and Die Oog, where the proportion of samples in the Poor category (indicative of potential chronic ammonia toxicity) increased from <10% in the previous reporting periods to 40-45%;
- There was ~60 to 75% compliance in relation to the Target threshold for NH_3 recorded at Westlake in all three reporting periods, and at Rietvlei in the 2019-2021 and 2023 reporting periods, Zoarvlei

in the 2019-2021 reporting period, Zandvlei in the 2019-2021 and 2022 reporting periods, and Langevlei in Reporting Year 2022;

- The situation at Langevlei deteriorated significantly in Reporting Year 2023, compared to the previous (2022) reporting period, with NH_3 concentrations above the Target threshold (indicative of a high risk of at least chronic ammonia toxicity) recorded for more than 50% of the samples collected from this waterbody during the 2023 reporting period (similar to the situation in the 2019-2021 reporting period);
- Potentially toxic conditions were particularly prevalent at Wildevoelvlei and at the Mitchell's Plain and Mew Way detention ponds during all three reporting periods, where recorded NH_3 concentrations were in the Poor and Unacceptable categories (indicating chronic to acute toxicity) for 100% or close to 100% of the samples;
- Potentially toxic conditions were often present in Zeekoevlei during all three reporting periods, with NH_3 concentrations in the Unacceptable category (indicative of a high risk of acute ammonia toxicity) recorded in 50 to 60% of the samples that were collected.

The seasonal boxplots for un-ionised ammonia in **Figure 5.4.3 and 5.4.4** (and the annual boxplots in **Appendix D**) provide the following additional insight in relation to the potential for ammonia toxicity:

- The range of recorded NH_3 values was noticeably greater in sub-catchments and standing water systems with lower levels of compliance, as shown by longer boxes (representing the inter-quartile range) and whiskers (representing the range, excluding outliers) on the boxplots, especially in summer;
- The risk of toxicity associated with high levels of un-ionised ammonia is clearly generally far greater in the monitored flowing water systems than it is in the monitored standing water systems, during both summer and winter, with the exception of the poorly performing standing water systems (i.e., Wildevoelvlei, Zeekoevlei and the artificial Mew Way and Mitchells Plain detention ponds);
- If the sub-catchments and standing water bodies with very high levels of compliance in terms of un-ionised ammonia are excluded, all the other flowing water sites and standing water sites showed a greater range of values in summer compared to winter, and generally higher median values (and thus more risk of non-compliance) in summer than in winter (the only exceptions being Wildevoelvlei in the 2019-2021 reporting period, and Zeekoevlei in the 2019-2021 and 2022 reporting periods). This is the expected pattern for ammonia toxicity, the risk of which increases at higher temperatures.

5.4.3 pH values and risk of ammonia toxicity at sampling points

As explained in **Section 5.4.1**, particular attention should be paid to raised pH levels because of the relationship between pH, water temperature and the ratio of ammonium ions to un-ionised ammonia (DWAF, 1996a). In the current report, as a rough guideline, pH >8 is considered to be a potential trigger for ammonia toxicity when associated with elevated total ammonia concentrations. Boxplots of the pH values recorded at CCT sampling sites during the three reporting periods considered in this report are presented in **Appendix C4**, with separate plots for the flowing water and standing water sites. It is important to note that the focus of the analysis here is to assess the degree of ammonia toxicity risk as a result of high pH values, and not the degree to which pH has been altered from the presumed natural reference range.

For **river and stormwater channel sites**, grouped by sub-catchment, the relevant boxplot of recorded pH values in **Appendix D** suggests the following in relation to the risk of ammonia toxicity:

- The Elsieskraal sub-catchment was the most at risk of ammonia toxicity, especially in the 2019-

2021 and 2022 reporting periods when median pH values of >8 were recorded (and the 3rd quartile was approaching 9), with less risk in Reporting Year 2023 when the median pH was just below 8 (and the 3rd quartile dropped to ~8.25);

- Maximum pH values approaching 11 were recorded in the Elsieskraal sub-catchment in the 2019-2021 reporting period, with the maximum values decreasing to 9.7 in Reporting Year 2022 and ~8.5 in Reporting Year 2023;
- The sub-catchments least at risk of ammonia toxicity because of low pH values were the Hout Bay and Silvermine sub-catchments, where median pH values were <7 (except for the Hout Bay sub-catchment in Reporting Year 2022, with a median pH just over 7), the 75th percentile (3rd quartile) was <7.25 and the maximum values were <8.2 (<7.5 in the case of the Hout Bay Sub-catchment);
- All other sub-catchments had median pH values ranging between 7.2 and 7.8, with the 75th percentile generally <8 (the only exception being the Mosselbank catchment in Reporting Year 2022, when the 75th percentile was ~8.1), suggesting a generally low risk of ammonia toxicity unless ammonia concentrations were exceedingly high and/or there were particularly warm water temperatures;
- Maximum pH values of >8.5, indicating intermittent spikes of high ammonia toxicity risk related to pH, were recorded in the Mosselbank and Sand sub-catchments for the 2019-2021 and 2022 reporting periods.

For **standing water (vlei and wetland) sites**, grouped by waterbody, the relevant boxplot of recorded pH values in **Appendix D** suggests the following in relation to the risk of ammonia toxicity:

- A greater proportion of the standing water sites had relatively high pH values, resulting in an increased risk of ammonia toxicity, compared to the flowing water sites;
- There was a relatively high risk of ammonia toxicity as a result of median pH values >8 in the Rietvlei, Langevlei, Zeekoevlei and Zandvlei water bodies during all three reporting periods, and in Princessvlei during the 2019-2021 and 2022 reporting periods, in the Westlake Wetland during Reporting Year 2022 and in Wildevoelvlei during the 2019-2021 reporting period;
- A relatively high risk was most prevalent at Rietvlei, Langevlei, Zeekoevlei and Zandvlei for all three reporting periods, and at Princessvlei during the 2019-2021 and 2022 reporting periods, at the Westlake Wetland in Reporting Year 2022 and at Wildevoelvlei in the 2019-2021 reporting period, with the 25th percentile (1st quartile) for recorded pH values approaching or exceeding 8 in all these cases;
- During the recent Reporting Years 2022 and 2023, maximum pH values ≥9, indicating periods of particularly high risk of ammonia toxicity, were recorded at Rietvlei (2023), Princessvlei (2022), Langevlei (2023), Die Oog (2023), Zeekoevlei (2022 and 2023), Zandvlei (2022 and 2023), and Westlake Wetland (2022).

5.4.4 Key take-away points from assessment of un-ionised ammonia data

The main findings with respect to the potential for toxic conditions for aquatic fauna in monitored aquatic ecosystems across the City resulting from elevated levels of un-ionised ammonia were:

- Potentially toxic conditions associated with elevated NH_3 concentrations were more prevalent in flowing water systems than they were for standing water systems, partly attributable to the dilution effect of large standing water bodies;
- There were a number of sub-catchments for which ammonia toxicity was not a major issue of concern for monitored flowing water systems during the reporting periods under consideration, namely the Lourens, Sout, Hout Bay and Silvermine sub-catchments, as well as (to a slightly less degree) the Sir Lowry's Pass and Sand sub-catchments;

- There were also number of monitored standing water systems for which ammonia toxicity was not an issue of concern), namely Glencairnvlei, Little Princessvlei, Princess Vlei and the Elsieskraal dams during all three reporting periods, as well as at Rondevlei and Die Oog during the 2019-2021 and 2022 reporting periods, at Rietvlei in Reporting Year 2022, Zoarvlei in Reporting Years 2022 and 2023, and at Zandvlei in Reporting Year 2023;
- Reasonably good conditions in terms of the risk of ammonia toxicity were also recorded at Westlake in all three reporting periods, and at Rietvlei in the 2019-2021 and 2023 reporting periods, Zoarvlei in the 2019-2021 reporting period, Zandvlei in the 2019-2021 and 2022 reporting periods, and Langevlei in Reporting Year 2022;
- The situation deteriorated in Reporting Year 2023 at Rondevlei, Die Oog and Langevlei, with a significant increase in the proportion of samples in the Poor and/or Unacceptable categories (indicative of potential chronic to acute ammonia toxicity) compared to the previous reporting period/s;
- The most problematic sub-catchment in terms of the potential for ammonia toxicity within flowing water systems was the Soet, where >75% of the samples collected in all three reporting periods had NH_3 concentrations in the Unacceptable category;
- The potential for ammonia toxicity was also prevalent in the Lower Salt and Zeekoe sub-catchments during all three reporting periods;
- Other problematic sub-catchments included the Eerste sub-catchment in all three reporting periods, the Diep sub-catchment in Reporting Years 2022 and 2023, the Mosselbank sub-catchment in the 2019-2021 reporting period, and the Elsieskraal sub-catchment in the 2019-2021 and 2022 reporting periods;
- The most problematic standing water systems during the reporting periods under consideration were Wildevoelvlei and the Mitchells Plain and Mew Way detention ponds, where recorded NH_3 concentrations were in the Poor and Unacceptable categories (indicating chronic to acute toxicity) for 100% or close to 100% of the samples;
- Potentially toxic conditions in terms of NH_3 concentrations were also often present in Zeekoevlei during all three reporting periods;
- There was generally a greater range of values in recorded un-ionised ammonia levels in summer compared to winter, for all watercourses (flowing and standing water systems) that did not have very high levels of compliance in terms of the Target range for NH_3 concentrations, and the median NH_3 concentration was generally higher in summer, indicating a greater risk of toxic conditions than in winter;
- The only problematic sub-catchment in terms of ammonia toxicity at flowing water sites that was characterised by elevated pH values indicative of an increased risk of ammonia toxicity was the Eliseskraal sub-catchment, suggesting that the ammonia toxicity problems in the other sub-catchments (including the particularly problematic Soet) are being driven by excessively high ammonia concentrations and not elevated pH values;
- There was a relatively high risk of ammonia toxicity as a result of median pH values >8 in the Rietvlei, Langevlei, Zeekoevlei and Zandvlei standing water bodies during all three reporting periods, and in Princessvlei during the 2019-2021 and 2022 reporting periods, the Westlake Wetland during Reporting Year 2022 and Wildevoelvlei during the 2019-2021 reporting period.

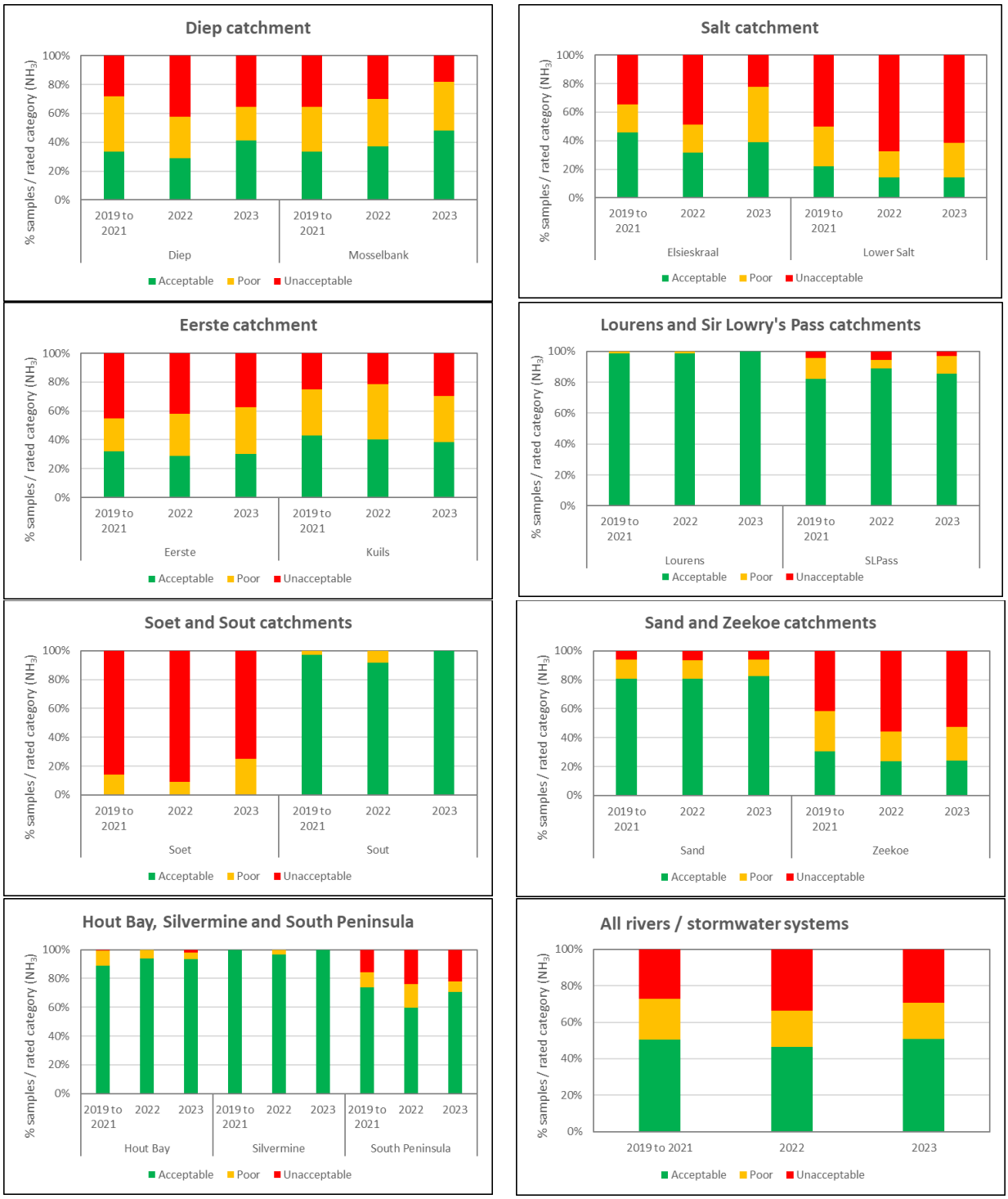


Figure 5.4.1
Percentage of un-ionised ammonia (NH_3) samples falling within each rated category for this variable, per sub-catchment. Data for river / 'flowing' water monitoring points in each sub-catchment. Thresholds for rated categories as defined in Table 3.1. Sub-catchments as shown in Figure 2.1.

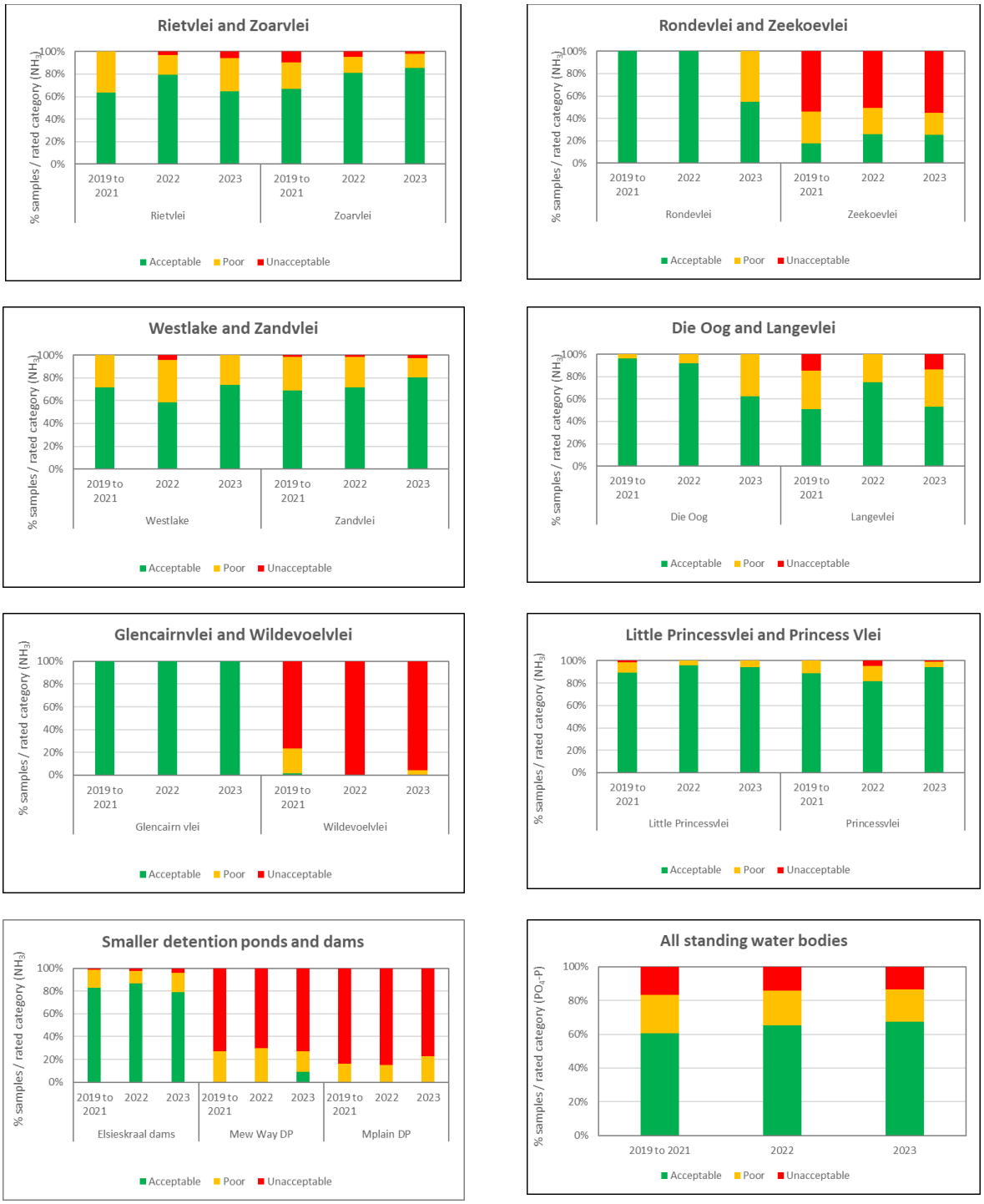


Figure 5.4.2
Percentage of un-ionised ammonia (NH_3) samples falling within each rated category for this variable, per monitored standing water system. Thresholds for rated categories as defined in Table 3.2. Data for sample points in standing water bodies / vleis and detention ponds.

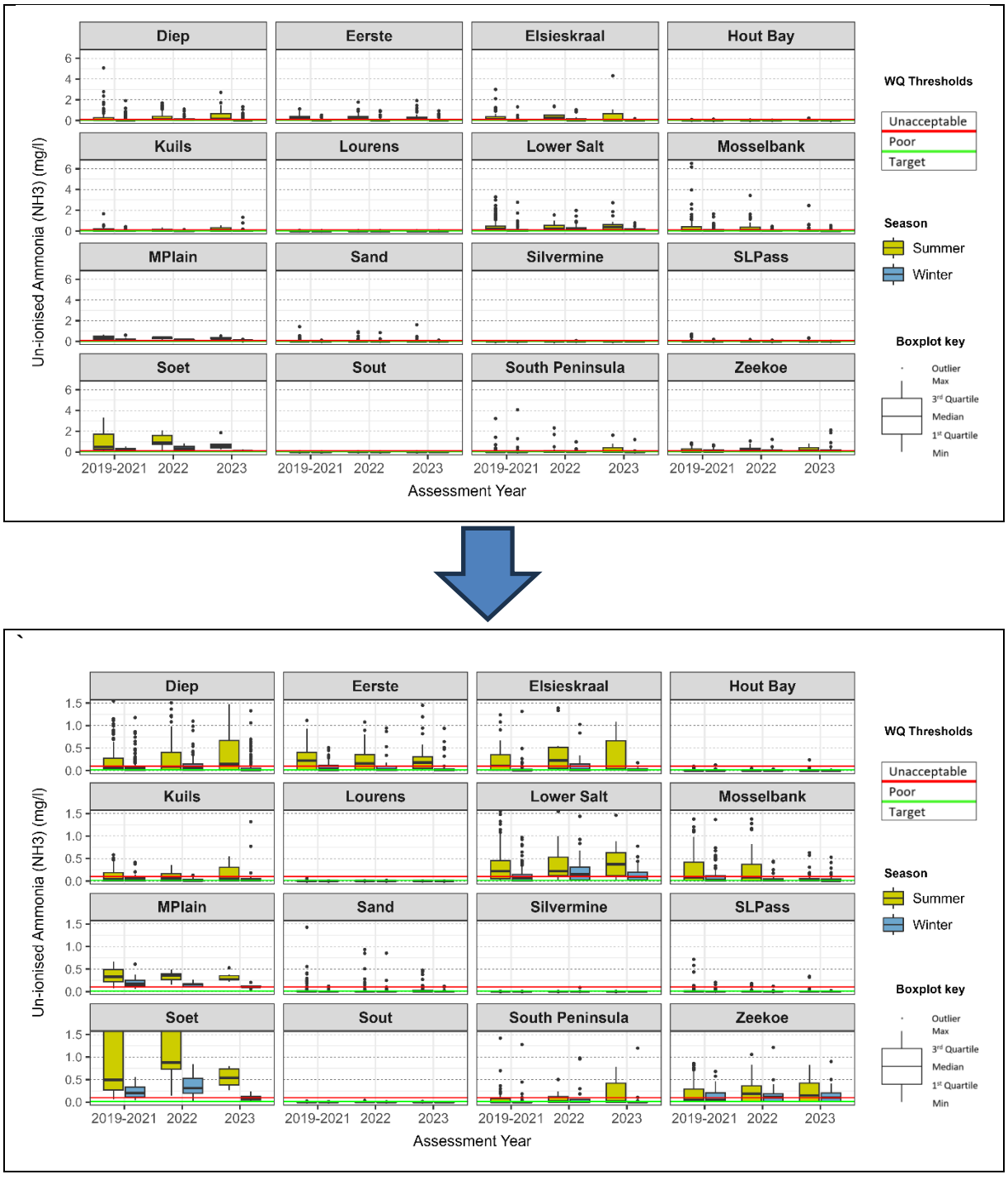


Figure 5.4.3
Comparison of un-ionised ammonia for flowing systems (rivers and stormwater channels) from the 2023 reporting period, with those from 2022 and the previous three years (2019 to 2021) combined. Data analysed as summer and winter datasets. Sub-catchments as shown in Figure 2.1. Marked thresholds as per Table 3.1. Bottom figure (arrowed) shows same data at different scale.

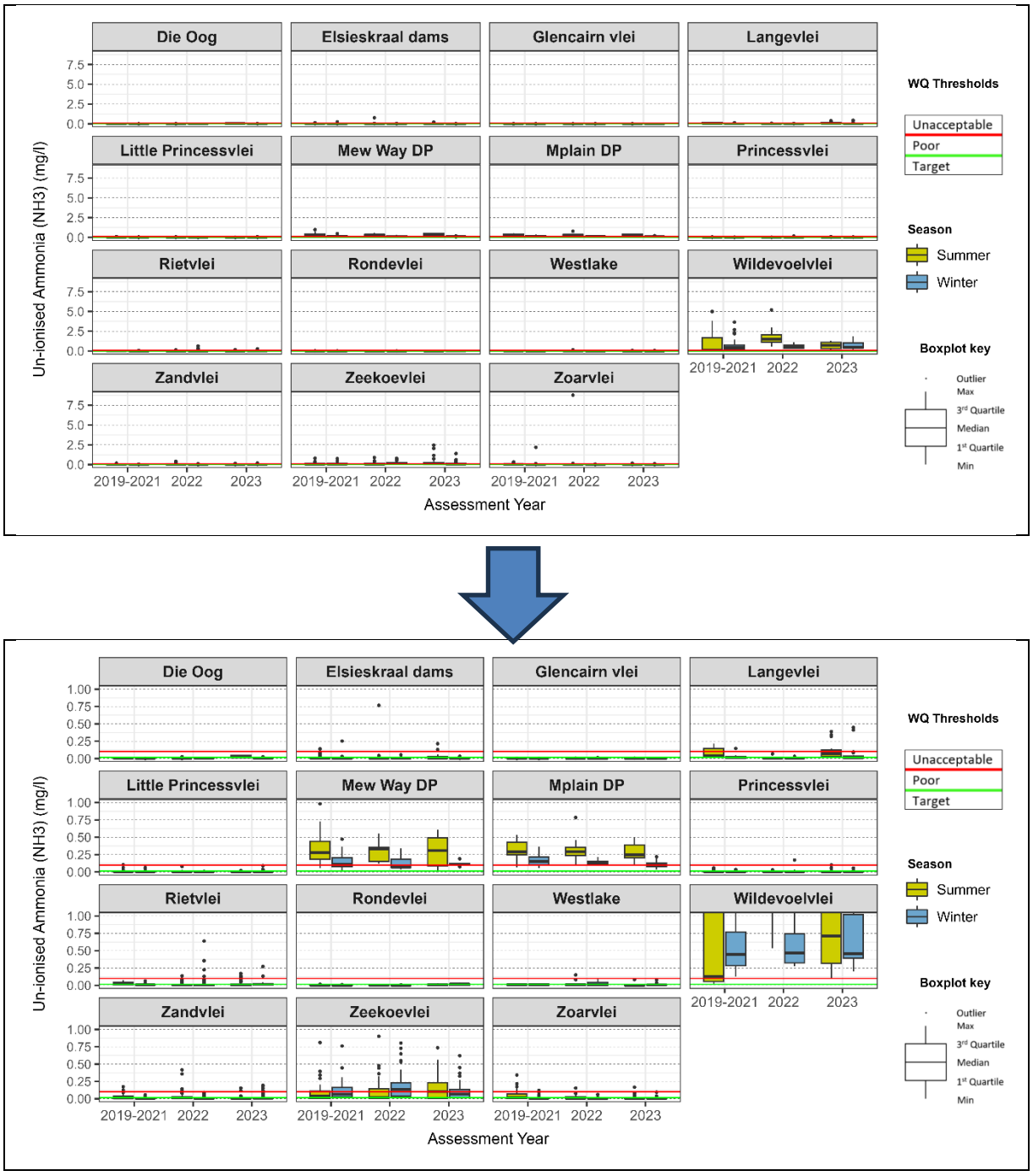


Figure 5.4.4
Comparison of un-ionised ammonia for standing water systems (vleis, dams and detention ponds) from the 2023 reporting period, with those from 2022 and the previous three years (2019 to 2021) combined. Data analysed as summer and winter datasets. Marked thresholds as per Table 3.2. Bottom figure (arrowed) shows same data at different scale.

5.5 *Escherichia coli* bacterial counts as an indicator of sewage contamination

5.5.1 Relevance

Escherichia 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 Cape Town's established recreational vlei systems, 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 well as the lower Kuils River, which is used by the Khayelitsha Canoe Club. This issue is dealt with extensively in Section 6.

Box 5.5

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.

The current section has however been included in this report to evaluate the potential recreational fitness-for-use of a broader array of rivers and vlei systems within Cape Town – not necessarily all major / established recreational water bodies. The data referenced here also highlights point-source pollution into watercourses, where elevated *E. coli* is an indicator of contamination from untreated sewage, either from overflows from manholes or sewage pump stations, or from inflows from poorly serviced backyard or informal settlements with inadequate access to sewer networks.

5.5.2 Risk levels

The recreational risk ratings applied in the current assessment include *E. coli* thresholds for intermediate contact (e.g. canoeing, sailing, paddling), as explained in Section 3.7.3 (see **Table 3.3**). Ranges are provided for 'Target' (acceptable risk), 'Poor' (tolerable risk) and 'Unacceptable' (high risk). Although **Table 3.3** also provides for an additional two levels of 'Unacceptable', to aid in the identification of areas where there is extreme exceedance of the high-risk threshold for *E. coli,* these were not applied in this assessment. This was due to issues with reporting of *E. coli* data, making tighter determinations difficult over the 2021 to 2023 reporting periods (see Section 3.8.10).

Reliable *E. coli* data were moreover not available for large parts of the 2021 and 2022 reporting periods (see Section 3.8.8), and these reporting periods have thus been omitted from this report.

5.5.3 Sources of sewage contamination based on E. coli data

Sources of sewage contamination in Cape Town's sub-catchments include:

- Periodic sewer blockages and manhole overflows that enter the stormwater system and thus pass into watercourses (Section 9 illustrates that blockages result variously from poor solid waste management (due to multiple factors), overflows as a result of stormwater ingress, vandalism, aging infrastructure (reflecting a history of poor maintenance effort), and increasing sewage volumes generated from rapidly expanding, largely informal settlements;
- Overflows from sewage pump stations (or from low-lying manholes downstream of pump stations) as a result of blockages, pump station failure and from load-shedding power outages

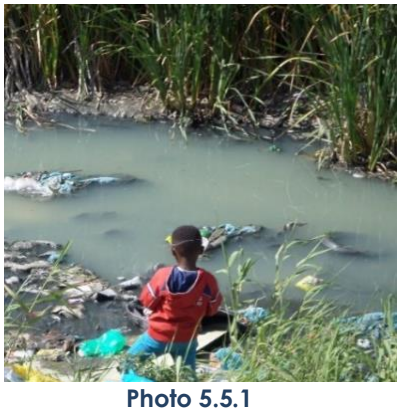


Photo 5.5.1
Children play in and near polluted stormwater ponds (Zeekoe sub-catchment)
(Photo courtesy Mr Thanduxolo Xokoza)

(**Photo 5.5.2**) – unless diverted back into the sewerage system by pumping or other means, such waste finds its way into the stormwater system and thence into the City's watercourses;

- Contaminated stormwater runoff from poorly serviced informal settlements, where sewage is disposed of into canals and stormwater drains for want of alternative disposal options or because access to options to dispose of waste to sewers is unsafe (e.g. at night) or unhygienic (because of a build-up of solid waste and/or faecal waste) (**Photo 5.5.3**);
- Runoff from urban areas with high levels of homeless people without alternative waste disposal options;
- Illegal connections of sewers into stormwater systems;
- Previously-designed sewer overflows into stormwater systems;
- Inputs from wildlife (baboons and birds);
- Input from livestock (e.g. feedlots in agricultural areas in and draining into rivers or other watercourses);
- Runoff from pavements, parks etc. accessed by domestic animals (e.g. dogs) – this is however likely to be a relatively minor input in most areas.

Major likely sources of sewage into the stormwater system are assessed in more detail in Section 5.6.



Photo 5.5.2
Sewage overflows into the Theo Marais channel, leading to the Milnerton Lagoon (Diep River Sub-catchment) as a result of prolonged failure of the Koeberg Pump Station (March 2024)

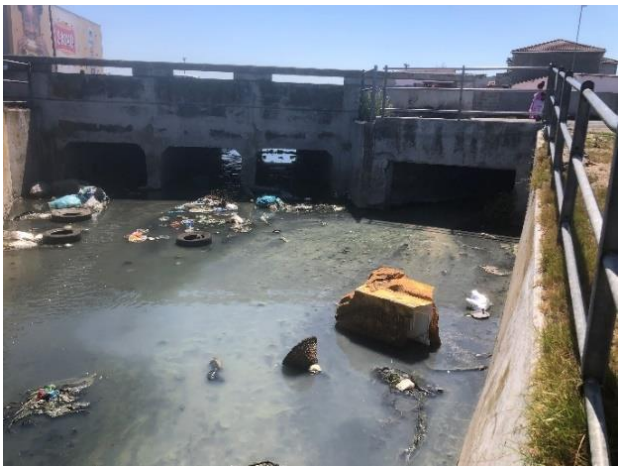


Photo 5.5.3
Polluted inflows from informal settlements and back-yard areas into the Big Lotus River, Gugulethu (Zeekoe Sub-catchment)

5.5.4 Assessment of available E. coli data

Figures 5.5.1 and **5.5.2** present the results of analyses of samples from routine water quality monitoring points in rivers/ stormwater channels and standing water systems (vleis / detention ponds etc.) respectively. The data are compared over the 2019-2020 and 2023 reporting periods only (see Sections 3.8.8 and 3.8.10). Data from the 2021 and 2022 reporting period have been excluded, as a result of unreliable laboratory analyses over this time, discussed in Section 3.8.8, affecting 4 and 8 months respectively of the annual datasets.

The assessed data suggest that (for the limited data period available):

- For **rivers / flowing water systems**:
    - The proportion of river samples that are rated as Unacceptable from a human risk perspective increased over the staggered time period considered here (2019, 2020 and

2023), with data showing increases from 49% Unacceptable (2019 dataset) to 59% in the 2023 dataset – related impacts such as an increased frequency of load-shedding, with its effects on sewage pump stations and WWTWs, as well as burgeoning poorly serviced informal settlements in many sub-catchments, are likely to have contributed to these increases;

- The most poorly-performing sub-catchment was the Soet (90 – 100 % Unacceptable samples, reflecting a stormwater system fed almost entirely by grey- and black-water inflows from informal settlements, possibly mitigated with distance downstream through the lowest section of the sub-catchment before the single sample point in this system, just upstream of the outlet to the sea);
- Samples from the Elsieskraal and Lower Salt River sub-catchments also showed high levels of pollution, with over 80% of samples rated as Unacceptable in both sub-catchments over the 2023 period, reflecting increased pollution levels in both catchments over the assessed reporting periods;
- 74% of samples from the City Sub-catchment (all stormwater outlets into the coastal areas) were in an Unacceptable condition, reflecting a highly urbanized area, with several large areas of post-Covid informality; areas characterized by other street dwellers; and mainly piped stormwater and underground rivers (**Photo 5.5.4**), with little to no exposure to sunlight before passing into the sea. This means that *E. coli* are likely to persist longer than in systems where exposure to sunlight results in die-off of these bacteria;



Photo 5.5.4
The Plattekloof River is passed under the City Bowl in covered, brick-lined culverts

- Most other sub-catchments were less-impacted by the concentration and/or frequency of sewage inflows (< 80% samples were Unacceptable but < 60% fell within the Acceptable risk range), and these included the Diep, Mosselbank, Eerste, Kuils, Hout Bay, South Peninsula, Sand and Zeekoe sub-catchments. Of these, all but the South Peninsula river samples showed an increase in the proportion of samples rated Unacceptable over the 2023 reporting period, reflecting generally higher levels of exposure to raw sewage across multiple areas of the City;
- The Sir Lowry's Pass catchment rivers showed lower levels of and frequency of sewage pollution than the above systems, with just over 60% of samples lying within the Acceptable range for *E. coli* and indeed, showing some improvement compared with data for the 2019 reporting period;
- The Sout sub-catchment also showed relatively low levels of pollution by raw sewage – this site lies downstream of the Melkbosstrand WWTW (and the Atlantis WWTW which feeds into a tributary of the Sout upstream), and a low frequency of elevated E. coli reflects both a very low frequency of informal settlements in the river catchment as well as assumed largely functional WWTW discharges, at least with regard to *E. coli* treatment (see Section 5.6 for a discussion of WWTWs);
- The Silvermine and the Lourens River catchments were least impacted by *E. coli* (and by assumption, raw sewage), with > 80% of samples lying within the Acceptable range, and explaining in part their generally low levels of nutrient enrichment and elevated ecosystem condition (as shown also by DO and NH_3 data). Nevertheless, even these

generally cleaner sub-catchments were impacted at least at times by sources of sewage;

It must be noted that the summary data reported on in this section assess data from (at least on the whole) from multiple sites across sub-catchments. A high proportion of samples rated Unacceptable might represent both a high frequency of sewage contamination throughout the catchment, or simply inflows from a few point-source areas, reflecting in a limited number of downstream sites. The Hout Bay River is an example of this scenario. Spatial variation of water quality within sub-catchments is however explored in more detail in the maps presented per priority sub-catchment in Section 8.

- **Standing water systems (vleis, dams, detention ponds)** typically have lower *E. coli* concentrations and perform better in terms of compliance data than do the rivers feeding into them. This is evidenced by much of the data shown in **Figure 5.1.2** . More specifically, these data suggest that, for the limited period of reliable data that can be drawn on here:
    - All of the routinely monitored open-water systems in the City, with the exception of the Mew Way and Mitchell's Plain detention ponds, showed relatively low levels of sewage pollution as measured by *E. coli* counts, with > 60% of samples in all systems lying within the Acceptable range for *E. coli* during the 2023 reporting period, and thus being considered of low risk for intermediate contact recreation;
    - Of the above, lesser-polluted systems, the 2023 reporting period showed that Rietvlei, followed by the small, urban Die Oog wetland had the lowest incidence of elevated E. coli counts to levels above Unacceptable Risk;
    - An increase in the proportion of samples within the Unacceptable range was recorded for samples from the 2023 reporting period, compared with 2020 samples, for the following water bodies: Zoarvlei, Rondevlei, Zeekoevlei, Die Oog, Little Princessvlei and Princessvlei;
    - Water bodies showing reduced proportions of Unacceptable samples over the same period were Westlake wetlands, Rietvlei, Langevlei, Glencairn Vlei, Widevoelvlei and the Elsieskraal dams;
    - Altogether, the data (bottom right hand graph in **Figure 5.5.2)** show very similar patterns in the proportion of open water samples impacted by *E. coli* to different rated levels, over the three reporting periods analysed, although the 2023 reporting period included a greatly increased total number of samples (± 250 % increase);
        - The markedly worst-performing Mew Way and Mitchell's Plain detention ponds (100% of samples were rated Unacceptable throughout all of the assessed reporting periods) were unsurprising, given that these ponds are fed by black- and grey-water discharges from poorly serviced urban areas, where even formal residential areas are prone to frequent manhole and pump station overflows of raw sewage (see Section 5.6).

The notably higher proportion of samples in monitored standing water bodies that fell within the Acceptable risk range, compared with rivers / other flowing water systems, is likely to reflect:

- Extended retention time within standing water bodies (especially the large vleis), allowing exposure of *E. coli to* ultra-violet (UV) light in sunlight (which kills these bacteria);
- Dilution of point-source inflows in large water bodies.

It must however be stressed that *E. coli* data are used in the CCT's monitoring programme as an indicator of sewage contamination. Even if these bacteria are killed by UV light, the nutrients, associated decomposing organic waste, and various pathogens also often found in sewage would still remain within the affected water bodies. Thus even where *E. coli* counts are low, these contaminants would still be expected to result in short- to long-term impacts on the fitness for use of the system for both human use and aquatic ecosystems.

5.5.5 CCT's E. coli targets

In the case of *E. coli* data, the CCT has set itself a 'target' that at least 60% of samples in any catchment should meet the defined Acceptable thresholds of ≤ cfu /100 ml (as per **Table 3.3**). *Escherichia coli* compliance graphs thus also show this 60% threshold as a dotted line across the data. The rationale for an additional 'target' for meeting minimum Acceptable standards from a human health perspective is, however, questioned in this report, as in previous Inland Water Quality Reports. The Target values, as defined in **Table 3.3**, indicate *E. coli* counts that would be considered 'safe' or of low / acceptable risk for uses engaging in intermediate contact recreational activities only – that is, with assumed low exposure to sewage-associated contaminants in the waterbody.

In practice, many waterbody users engaging in these relatively 'safe' activities are in fact already exposed to a greater degree of risk than what is implied by 'intermediate' recreational exposure. Sailing, rowing, kayaking, and kite-surfing, for example, are all popular sports engaged in within Cape Town's inland recreational water bodies. These all expose participants to full immersion at times in the water bodies.

The CCT's 60% target for meeting Acceptable risk levels seems counter-productive in this regard – **and a target of 100% for meeting Acceptable standards in Cape Town's recreational water bodies would be a strongly recommended way forward.**

The data described in the previous section indicate that, in the City's monitored rivers and stormwater channels, the 60% target was achieved in only four sub-catchments in the 2023 reporting period (Silvermine, Lourens, Sir Lowry's Pass and Sout River), while it was achieved in all standing water bodies but the Mew Way and Mitchell's Plain detention ponds, which have been flagged in this and previous Inland water quality reports as highly polluted artificial systems, fed by grey- and black-water effluent and runoff from extensive informal and backyard settlements as well as informal street-industries (e.g. abattoirs, raw and cooked food vending).

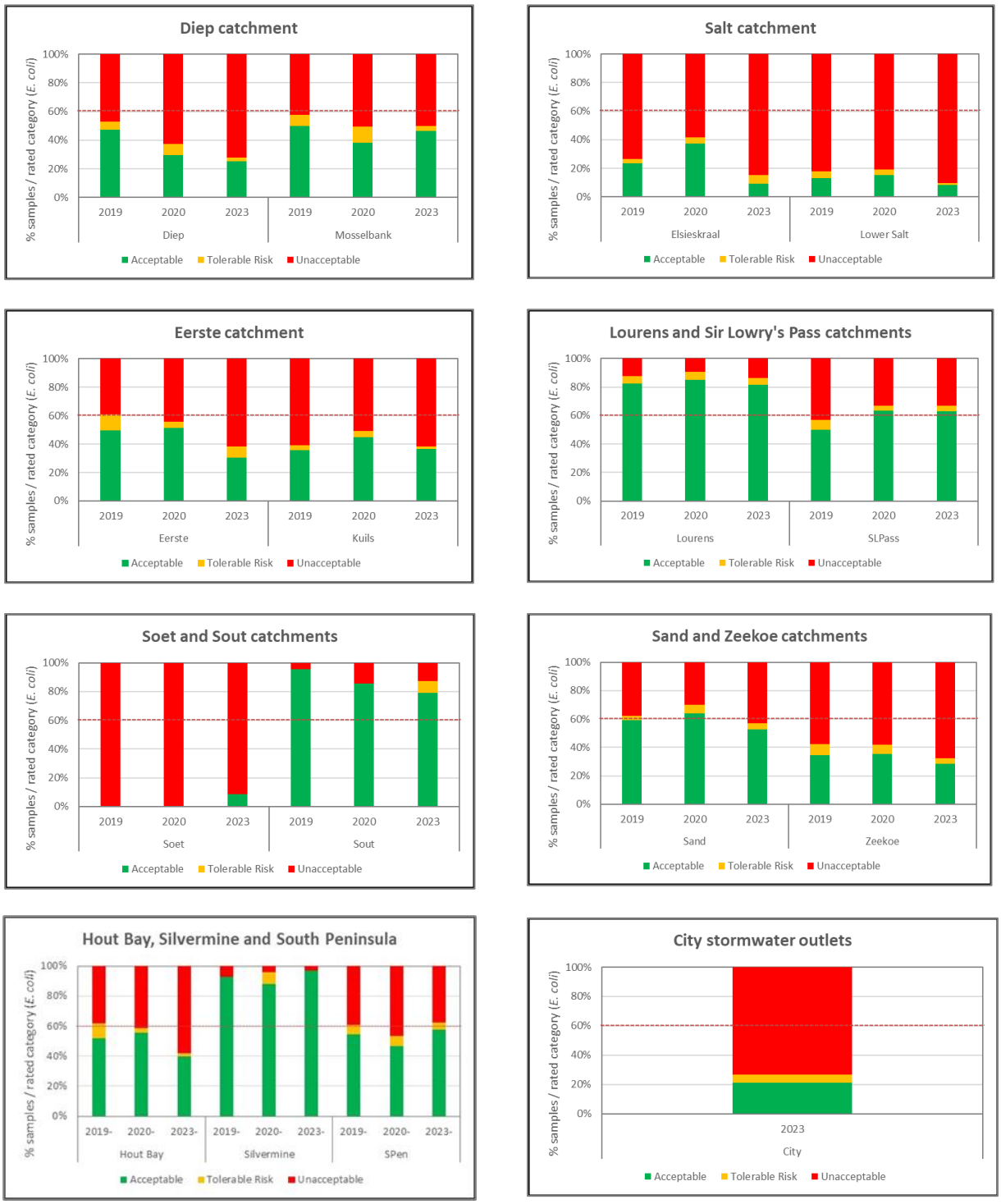


Figure 5.5.1
Percentage of Escherichia coli samples falling within each rated category for this variable, per sub-catchment. Thresholds for rated categories as defined in Table 3.4. Data for river / 'flowing' water monitoring points in each sub-catchment. Sub-catchments as shown in Figure 2.1. Note inclustion of City coastal stormwater outlets. Dotted red line indicates City's '60% Target' for meeting *E. coli* targets.

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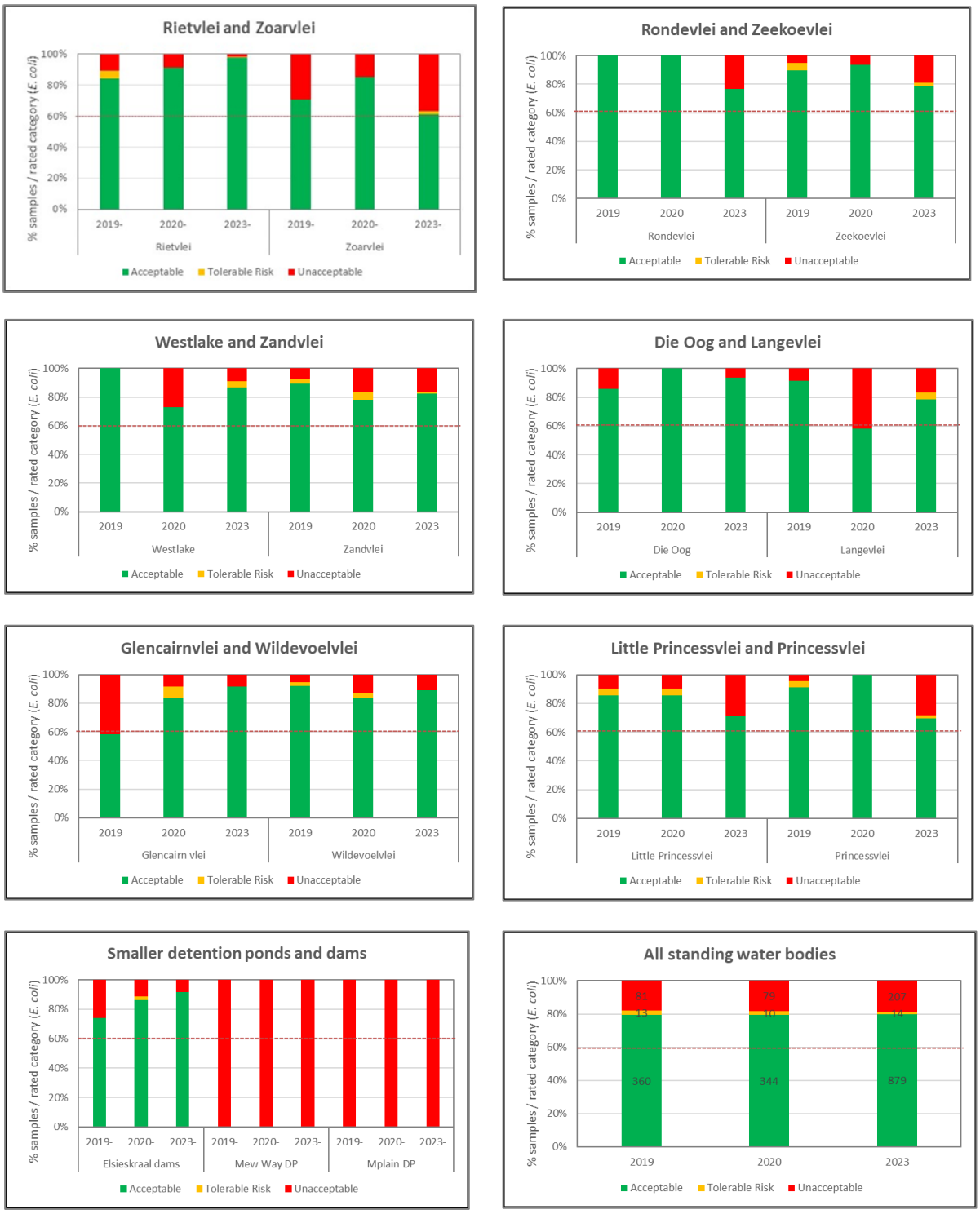


Figure 5.5.2
Percentage of *Escherichia coli* samples falling within each rated category for this variable. Thresholds for rated categories as defined in Table 3.4. Data for sample points in standing water bodies / vleis and detention ponds. Total number of samples considered shown in bars in bottom right plot ('All standing water bodies').

5.5.6 Intestinal enterococci data

The 2020 Inland Water Quality report recommended that intestinal enterococci should be monitored in inland water bodies. This was based on a recommendation in WHO (2003) and was reiterated in WHO (2021).

Although the SSB included intestinal enterococci monitoring in data used in the 2023 Inland Water Quality Report, this monitoring was subsequently discontinued. This appears to be a decision in part relating to the fact that most of the CCT's historical microbiological data base includes *E. coli* and not enterococci data; to the costs and other ramifications of attaining laboratory certification for these analyses; and to the costs of essential duplication of both datasets, over an extended period, to allow a switch from one methodology to another.

However, the opportunity costs of not including enterococci analysis with routine analysis of at least recreational water bodies are as follows:

- The SSB's inland water quality monitoring programme becomes progressively out-dated compared with global standards;
- There are no alternative datasets with which to assess the magnitude and associated human health risks of sewage pollution into water bodies – this is particularly important, given the recent (2021-2022) history of the SSB's poor laboratory performance with regard to *E. coli* analyses (see Section 3.8.8).

This report recommends that enterococci analyses should be provided for, along with *E. coli* analyses, at least in recreation water bodies.

5.5.7 Key take-away points

- The proportion of river samples rated as Unacceptable from a human risk perspective increased over the assessed reporting periods (2019, 2020 and 2023), with data showing increases from 49% Unacceptable (2019 dataset) to 59% in the 2023 dataset – related impacts such as an increased frequency of load-shedding, with its effects on sewage pump stations and WWTWs, as well as burgeoning poorly serviced informal settlements in many sub-catchments, are likely to have contributed to these increases;
- The most poorly-performing sub-catchments was the Soet (90 – 100 % Unacceptable samples, reflecting a stormwater system fed almost entirely by grey- and black-water inflows from informal settlements;
- The Silvermine and the Lourens River catchments were least impacted by *E. coli* (and by assumption, raw sewage), with > 80% of samples lying within the Acceptable range, and explaining in part their generally low levels of nutrient enrichment and elevated ecosystem condition (as shown also by DO and NH_3 data). Nevertheless, even these generally cleaner sub-catchments were impacted at least at times by sources of sewage;
- Standing water systems (vleis, dams, detention ponds) typically showed lower *E. coli* concentrations and performed better in terms of compliance data than do the rivers feeding into them. This is attributed mainly to extended retention time within standing water bodies (especially the large vleis), allowing exposure of *E. coli to* ultra-violet (UV) light in sunlight (which kills these bacteria) and dilution of point-source inflows in large water bodies.
- All of the routinely monitored open-water systems in the City, with the exception of the Mew Way and Mitchell's Plain detention ponds, showed relatively low levels of sewage pollution as measured by *E. coli* counts, with > 60% of samples in all systems lying within the Acceptable range for *E. coli* during the 2023 reporting period;
- The markedly worst-performing Mew Way and Mitchell's Plain detention ponds (100% of samples were rated Unacceptable throughout all of the assessed reporting periods) were unsurprising, given that these ponds are fed by black- and grey-water discharges from poorly serviced urban areas, where even formal residential areas are prone to frequent manhole and pump station overflows of raw sewage (see **Section 5.6**).

- It must be stressed that *E. coli* is used in the CCT's monitoring programme as an **indicator** of sewage contamination. Even if these bacteria are killed by UV light, the nutrients, associated decomposing organic waste, and various pathogens also associated with sewage would still remain within the affected water bodies, where they would be expected to result in various short- to long-term impacts on the fitness for use of the system for both human use and aquatic ecosystems. Water quality data for the Sout Sub-catchment illustrate this point. *E. coli* data for the single monitoring point on the river suggest that the river is in relatively good condition from a water quality perspective. The data in fact indicate rather that the upstream WWTW conducts effective disinfection of treated effluent – nutrient data presented in Section 5.1 indicate that the river is characterized by high concentrations of orthophosphate and ammoniacal nitrogen (NH4-N).
- The 2020 Inland Water Quality report recommended that intestinal enterococci should be monitored in inland water bodies. This was based on a recommendation in WHO (2003) and was reiterated in WHO (2021). However, enterococci monitoring has been excluded from the SSB's monitoring programme post 2022. The implications of this are that the SSB's inland water quality monitoring programme becomes progressively out-dated compared with global standards and (more importantly), outside of *E. coli* analyses, no alternative data are available with which to assess the magnitude and associated human health risks of sewage pollution into water bodies– this is particularly important, given the recent (2021-2022) history of the SSB's poor laboratory performance with regard to *E. coli* analyses. It is thus recommended that enterococci analyses should be provided for, along with *E. coli* analyses, at least in recreational water bodies.

5.6 Other indicators of sewage contamination

5.6.1 Overview

Nutrient enrichment, particularly by phosphorus nutrients, as well as issues of elevated (potentially toxic) ammonia and low dissolved oxygen in Cape Town's watercourses are serious issues that have been discussed in previous parts of this section. They all contribute to aquatic ecosystem degradation, and some (phosphorus nutrients in particular) contribute to excessive algal and other (often nuisance aquatic alien) plant growth.

Inflows of both treated and raw sewage into the City's watercourses are one of the main sources of phosphate nutrients into these systems, and also contribute to high ammonia concentrations and conditions of low dissolved oxygen - in some instances, anoxic conditions. This is because raw sewage includes organic material and high ammoniacal concentrations, the decomposition of all of which has a high oxygen demand. Poorly treated sewage can also have a high biological and chemical oxygen demand, resulting in water bodies with low dissolved oxygen for fish and other gilled fauna, and resulting also in the generation of toxic bi-products of anaerobic decomposition, including methane, ammonia and hydrogen sulphide.

Although informal settlements, as well as any areas with unserviced back-yard settlements, contribute permanent streams of raw sewage into watercourses, usually by way of formal or informal stormwater systems, by far the greatest loading of sewage-associated pollutants into the City's watercourses, as a result of the sheer volumes generated, are assumed to stem from the formal sewage reticulation and treatment systems.

The frequency of overflows from the former and the quality of effluent from the latter are explored in this section, in relation to water quality impacts in different sub-catchments within the City.

5.6.2 Inflows of treated effluent from Cape Town's (inland) WWTWs

5.6.2.1 Background

The CCT has 25 WWTWs, 17 of which pass effluent into inland aquatic ecosystems and are therefore considered in this report. The CCT is currently treating approximately 542 Ml/d of sewage across all of its plants (M. Killick. CCT -presentation of 15 March 2024 to the CCT's S80 Committee).

Both the quality and the quantity of effluent that is passed out of these WWTWs is governed, at least in theory if not always in practice, by a License issued by the national department of Water and Sanitation. Auditing of WWTW compliance is currently undertaken through the Green Drop Certification programmes, as well as through direct monitoring and reporting programmes, as stipulated in the conditions included in the various individual WWTW licenses.

In general, effluent quality from the CCT's WWTWs need to comply as a minimum with the DWS's General Effluent Limits, as listed in **Table 5.6.1** (taken from Government Notice No. 169 of 2013). Since the main focus of the present report is on inland water quality and not on WWTW compliance, only those water quality variables that are most relevant to the receiving environments (rivers, vleis, dams, estuaries and wetlands) are considered here, and this section in no way purports to be an audit on WWTW compliance.

The data presented here also need to be considered in the context of impacts on receiving watercourses. Even WWTW effluent discharges that are fully compliant with General Limits for effluents may exert major impacts on

Box 5.6

Prior to urbanisation, the Black River (Lower Salt Sub-catchment) was a naturally seasonal river, flowing only in the wet season and when the water table was high. Today, it is a perennial river, but its dry season (summer) flows comprise almost exclusively WWTW effluent and black- and grey water discharges from informal and backyard settlements without access to formal sewer networks. The river is plagued by growths of invasive water hyacinth, reeds and odorous organic sludges – all symptoms of its main water sources in summer.



aquatic ecosystems, where the volume of effluent discharged exceeds or dominates the volume of natural flows in the river or wetland at any time.

Table 5.6.1
General and special effluent limits as applicable to discharges from WWTWs into water resources in South Africa (Government Notice 169 of 2013: Revision Of General Authorisations in terms of Section 39 of the National Water Act (Act 36 of 1998)

SUBSTANCE/PARAMETER	GENERAL LIMIT	SPECIAL LIMIT
Faecal Coliforms (per 100 ml)	1000	0
Chemical Oxygen Demand (mg/l)	75 (i)	30(i)
pH	5,5-9,5	5,5-7,5
Ammonia (ionised and un-ionised) as Nitrogen (mg/l)	6	2
Nitrate/Nitrite as Nitrogen (mg/l)	15	1,5
Chlorine as Free Chlorine (mg/l)	0,25	0
Suspended Solids (mg/l)	25	10
Electrical Conductivity (mS/m)	70 mS/m above intake to a maximum of 150 mS/m	50 mS/m above background receiving water, to a maximum of 100 mS/m
Ortho-Phosphate as phosphorous (mg/l)	10	1 (median) and 2,5 (maximum)
Fluoride (mg/l)	1	1
Soap, oil or grease (mg/l)	2,5	0

SUBSTANCE/PARAMETER	GENERAL LIMIT	SPECIAL LIMIT
Dissolved Arsenic (mg/l)	0,02	0,01
Dissolved Cadm ium (mg/l)	0,005	0,001
Dissolved Chromium (VI) (mg/l)	0,05	0,02
Dissolved Copper (mg/l)	0,01	0,002
Dissolved Cyanide (mg/l)	0,02	0,01
Dissolved Iron (mg/l)	0,3	0,3
Dissolved Lead (mg/l)	0,01	0,006
Dissolved Manganese (mg/l)	0,1	0,1
Mercury and its compounds (mg/l)	0,005	0,001
Dissolved Selenium (mg/l)	0,02	0,02
Dissolved Zinc (mg/l)	0,1	0,04
Boron (mg/l)	1	0,5

5.6.2.2 Locations of inland WWTWs

Figure 5.6.1 shows the locations (and names) of the CCT's WWTWs, located in the following sub-catchments:

- Eerste Sub-catchment:
  - Zandvliet WWTW
  - Macassar WWTW
- Kuils Sub-catchment:
  - Scottsdene WWTW
  - Bellville WWTW
- Mosselbank Sub-catchment:
  - Klipheuwel WWTW
  - Kraaifontein WWTW
  - Fisantekraal WWTW
- Lower Diep Sub-catchment:
  - Potsdam WWTW

- Sout Sub-catchment:
  - Melkbosstrand WWTW
  - Wesfleur Industrial WWTW
  - Wesfleur Domestic WWTW
- Lower Salt Sub-catchment
  - Athlone WWTW ([9]note that sludge from this WWTW is at times piped to the Cape Flats WWTW, in the Zeekoe Sub-catchment)
  - Borcherd's Quarry WWTW
- South Peninsula Sub-catchments
  - Wildevoelvlei WWTW
- Zeekoe-Sub-catchment:
  - Cape Flats WWTW
- Mitchell's Plain Sub-catchment:
  - Mitchell's Plain WWTW
- Sir Lowry's Pass Sub-catchment:
  - Gordon's Bay WWTW

Of the above, final effluent (FE) data and daily effluent flows (for days on which water quality samples were collected) were provided by the CCT. Data for the Gordon's Bay WWTW were not however available within the timeframes of this project. Median daily effluent flows were calculated from these data as a coarse means of comparing effluent volumes between WWTWs. These are summarised in **Figure 5.6.2**.

Daily effluent loading was calculated from daily effluent flow data, and presented as time series graphs for each variable considered here, along with FE water quality data. Although data were provided to the LDC consultant team for multiple water quality variables, only key ones were considered in this report, namely *E. coli*, COD, total ammoniacal nitrogen (NH4—N) and orthophosphate phosphorus (PO4-P).

Given problems with laboratory analyses of *E. coli* over the 2021 and 2022 reporting periods, only data for the 2023 reporting period were assessed here.

Figures 5.6.3 to 5.6.6 show summary and time series data for water quality concentrations and loading for *E. coli*, COD, total ammoniacal nitrogen (NH4-N) and phosphates (PO4-P), over the 2022 and 2023 reporting periods. FE quality data are shown in relation to General Limits for the relevant variables plotted.

5.6.2.3 WWTW effluent quantity

Median daily effluent flow data summarised in **Figure 5.6.2** illustrate that:

- The largest treated effluent volumes passing into the City's inland watercourses and accounting for some 56% of total effluent came from (in order)
  - Cape Flats WWTW
  - Zandvliet WWTW
  - Athlone WWTW
- Potsdam, Bellville, Borcherd's Quarry and Mitchell's Plain WWTWs accounted for a further estimated 28% of total effluent;
- The remaining 16% of treated effluent came from eight smaller WWTWs, shown in the figure, all contributing relatively low effluent volumes into watercourses – the impact of final effluent on these watercourses is however determined by the quality of the effluent and the sensitivity and size (relative to effluent volume and pollutant loading) of the watercourse.

[9] Comment from Mr L. Abdullah (CSRM) to Liz Day

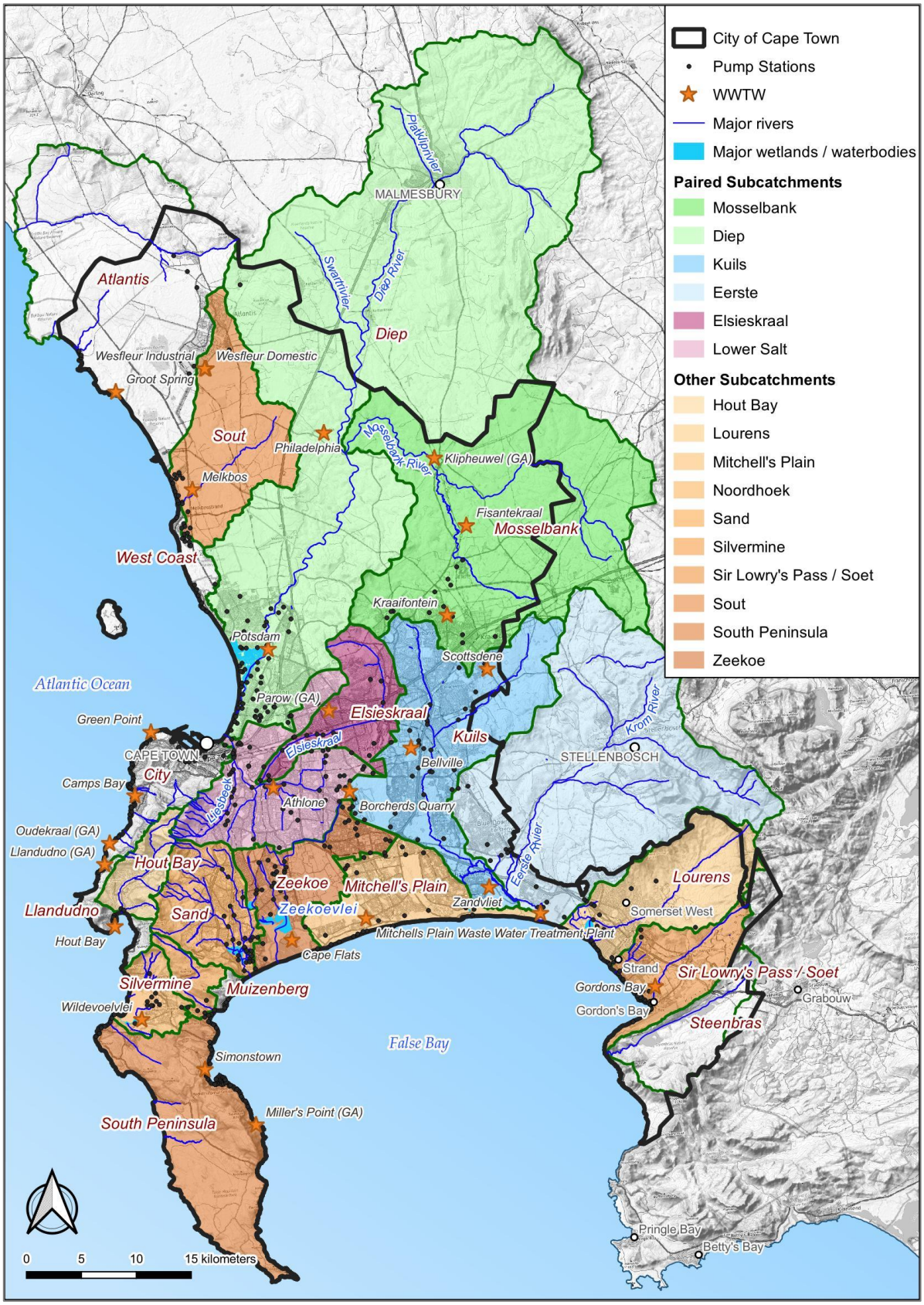


Figure 5.6.1
Map showing the locations of the City of Cape Town's WWTWs and sewage pump stations, in the context of different sub-catchments and their rivers and major wetlands.

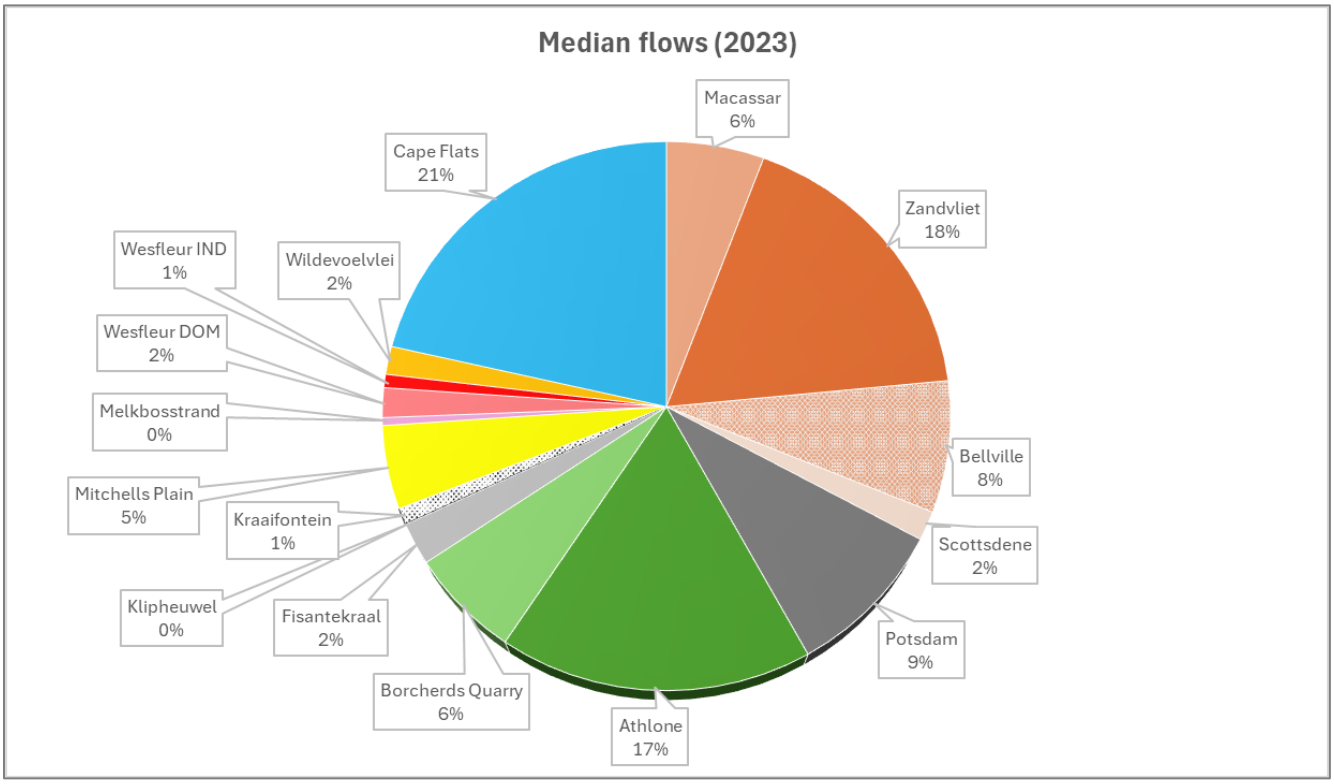


Figure 5.6.2
Comparison of median daily final effluent flows from the CCT's inland WWTWs (2023 reporting period).

5.6.2.4 Effluent quality and loading

Over the 2022 and 2023 reporting periods:

- ***Escherichia coli*** data (**Figure 5.6.3**) for final effluent suggest that:
    - Only five of the CCT's WWTWs generally produced effluent that had been treated to levels where *E. coli* had been effectively removed, to (generally) below the general limit of 1000 cfu/100 ml for this variable. These comprised: Fisantekraal, Kraaifontein, Melkbosstrand, Wesfleur Domestic, Wesfleur Industrial, the (up-graded by early 2023) Zandvliet and Potsdam WWTWs. Of these the latter was disinfecting final effluent by chlorination during much of the 2023 reporting period, as a result of high turbidities that made UV disinfection ineffective (Rose et al 2023). In itself, this practice is problematic, because, in ammonia-rich water, it produces chloramines, which are conservative (i.e. long-lasting), highly toxic chemicals that impact on downstream aquatic organisms;
    - Of the remaining WWTWs, all producing effluent with E. coli at concentrations often if not usually beyond the general limit, those where median concentrations were highest were Athlone, Cape Flats, Klipheuwel and Macassar, followed by Scottsdene, Bellville, Mitchell's Plain and Wildevoelvlei;
    - Data for the poorly performing WWTWs listed above showed interquartile ranges for *E. coli* from these WWTWs to be several orders of magnitude greater than general limits, and well within the range of Unacceptable risk for intermediate recreation.
    - Watercourses affected by such conditions comprise the Black River (Athlone), the Zeekoe canal (downstream of Zeekoevlei), the Mosselbank (and downstream Diep) Rivers, the Kuils River (affected by inflows from Bellville and Scottsdene WWTWs) and Wildevoelvlei itself;
    - Compliance-type data shown in **Figure 5.6.4** further highlight poor performance by most WWTWs over at least the 2023 reporting period, showing that:

- Only the Wesfleur Domestic and Fisantekraal WWTWs achieved 90% compliance or better for *E. coli* samples;
- The Melkbosstrand, Wesfleur Industrial/ Kraaifontein and the (upgraded) Zandvliet works achieved >80% compliance, although the Kraaifontein plant at times produced FE with counts well over one million cfu per 100 ml;
- Potsdam and Wildevoelvlei WWTWs achieved between 60 and 75% compliance;
- The remaining WWTWs achieved extremely poor levels of FE compliance, with the Cape Flats plant being the worst performing (0% compliance); followed by Athlone (<5%); Bellville, Klipheuwel and Macassar (<25%); Scottsdene and Mitchell's Plain (25-35%); and Borcherd's Quarry (55%).(

- Final effluent **COD data** (**Figure 5.6.5**) suggest that:
  - The Melkbosstrand, Wesfleur (Domestic), Fisantekraal, Kraaifontein and Zandvliet median COD concentrations lay below the general limits for COD in both reporting periods. Of these, the Zandvliet WWTW underwent major [10]upgrades, with hand-over completed in March 2023 (2023 reporting period);
  - WWTWs with median concentrations lying at or just above general limits comprised the Bellville, Scottsdene and Mitchell's Plain WWTWs;
  - WWTWs where both median concentrations and the interquartile ranges of COD concentrations exceeded general limits by a marked degree comprised (in increasing order for 2023 data) the Klipheuwel, Macassar, Borchard's Quarry, Cape Flats, Wildevoelvlei and Potsdam WWTWs;
  - Marked deterioration in median effluent quality was observable at the Macassar, Athlone, and Borcherd's Quarry works between the 2022 and 2023 reporting periods, while slight improvements were noted for the Klipheuwel, Wildevoelvlei and Cape Flats WWTWs over the same period;
  - Of the above worst-performing WWTWs, loading was greatest from the Athlone WWTW (into the Black River – Lower Salt Sub-catchment), followed by Potsdam and Cape Flats WWTWs (Diep and Zeekoe Sub-catchments respectively). These WWTWs are likely to have substantial impacts on downstream aquatic ecosystems – discharges of high volumes of poor quality effluent from Potsdam WWTW have in fact been cited as the main reason under-pinning the collapse of the Milnerton Lagoon estuarine ecosystem in 2022/ 2023, and the associated noxious hydrogen sulphide gases produced within the lagoon (Rose et al 2023);
  - WWTWs that produced effluent that lay closer to general limits, but was produced in large volumes also contributed (at least at times) high COD loadings into riverine systems. The most marked of these WWTWs comprised Borcherd's Quarry, Zandvliet, Macassar and Bellville WWTWs.

Box 5.7

Chemical Oxygen Demand (COD)

COD is a measure of the oxygen needed to oxidise the organic matter present in a quantity of water (that is, for decomposition). When COD is high, it can indicate low available oxygen for aquatic organisms such as fish and may correlate with high (potentially toxic) total ammonia and indicators of anaerobic conditions such as hydrogen sulphide gases.

- **Total ammoniacal nitrogen** data for WWTW final effluent (**Figure 5.6.6**) paint a slightly different picture to COD performance and show that:
  - The only WWTWs that generally produced effluent within (below) general limits were the Wesfleur Domestic, Fisantekraal, and Kraaifontein WWTWs, and loading of total ammonia into the receiving watercourses for these systems (Donkergat River in the Sout sub-catchment and the Mosselbank

[10] The CCT's media release for the March 2023 hand-over states that the plant's treatment capacity was upgraded from 72 to 90 million litres per day, with effluent quality improving due to cutting-edge membrane treatment technology, used on portions of the effluent stream

sub-catchment respectively) was also relatively low;

- By far the worst performing WWTW in terms of median and interquartile ranges for total ammoniacal nitrogen in the 2023 reporting period was Macassar (median concentrations > 20 times the general limit), followed by Wildevoelvlei, Cape Flats, Klipheuvel, Potsdam, Athlone, Bellville and Scottsdene WWTWs, all of which had median NH4-N concentrations above 20 mg N/L (> 10 times the general limit);
- The Mitchell's Plain and Borcherd's Quarry WWTWs also exceeded general limits, but by lower multiples while the Melkbosstrand and Wesfleur Industrial WWTWs produced effluent with total ammoniacal nitrogen usually relatively close to general limits.
- Of the above, loading calculations show that the greatest loads of ammoniacal nitrogen in the 2023 reporting period at least were produced by the Cape Flats WWTW, followed by Athlone, Macassar, Potsdam (varying loading through 2023), the (upgraded) Zandvliet (in the latter part of 2023);
- Marked improvements (median in 2023 fell below the interquartile range for 2022) in ammoniacal nitrogen concentrations were evident in data for the Macassar, Zandvliet, Wildevoelvlei and Cape Flats WWTWs between the 2022 and 2023 reporting periods, although these WWTWs still produced effluent many times greater than acute toxicity thresholds for aquatic ecosystems (as per DWAF 1996);
- WWTWs where function deteriorated markedly over this time comprised Bellville and Borcherd's Quarry, while a less significant increase in median concentrations from Potsdam WWTW are shown by loading data to encompass great fluctuation in effluent quality over the 2023 reporting period, with markedly reduced loading from around May 2023, when attention was paid to reducing treated effluent pollution from passage through contaminated maturation ponds;
- Bellville, Borcherd's Quarry, Scottsdene and Mitchell's Plain all produced marked but lower loads throughout the year.

Box 5.8

Total ammoniacal nitrogen (NH4-N)

The General Limit for total ammoniacal nitrogen is 2 mg/L (see Table 5.6.1). At an assumed pH of 8 and temperature of 20C, this would translate into free ammonia (NH_3) at a concentration of 0.076 mg/L – this is 5 times the chronic toxicity threshold for ammonia in aquatic ecosystems and just under the threshold of 0.01 mg/L for acute toxicity. Thus even WWTWs producing effluent at the general limit pose severe ecological risk to downstream aquatic ecosystems, especially in summer when effluent constitutes all or most of the effluent in naturally seasonal rivers.

- Final effluent **orthophosphate phosphorus (**PO4-P) data (**Figure 5.6.7**) suggest that:
  - WWTWs all met general limits all or nearly all the time over the 2022 and 2023 reporting periods – however, the general limit for this variable is very high from an ecological perspective – 10mg P/L. This is nearly an order of magnitude greater than the hypertrophic ("Unacceptable") thresholds for this variable of 0.125 and 0.130 mg P/L in rivers and standing water systems respectively;
  - WWTWs producing the highest loads into downstream systems comprised Cape Flats (by far the largest loads, usually > 50 kg/ day), followed by Athlone, Zandvliet (with loading generally decreasing over time in 2023, albeit with some major spikes), Borcherd's Quarry, Potsdam (with loads decreasing from mid-2023), Bellville and Mitchell's Plain.

5.6.2.5 Comments

The data presented in this section highlight the varying levels of function of WWTWs over the 2022 and 2023 reporting periods, and the variation in efficiency of different WWTWs in treating different chemical variables.

Escherichia coli data showed that only five of the CCT's WWTWs consistently produced effluent within general limits for *E. coli*, with most of the other WWTWs producing effluent with *E. coli* counts several orders of magnitude higher, and highlighting the risks posed by such effluent to downstream water users in contact with the water.

COD data are probably the most useful for highlighting the magnitude of downstream chemical risk to aquatic ecosystems. These data indicate that the most poorly performing WWTWs in this regard feed into the following river aquatic ecosystems:

- Diep River estuary and Milnerton Lagoon (Potsdam WWTW)
- Black River and Salt River canal (Athlone and Borcherd's Quarry WWTW)
- Wildevoelvlei (Wildevoelvlei WWTW)
- Zeekoe canal (Cape Flats WWTW)
- Mosselbank River (and lower Diep River) (Klipheuwel WWTW) – note however that the effluent volume from this system was relatively low, so downstream loading was not marked)
- Eerste River estuary (Macassar WWTW).

Of the above, the impacts of the Potsdam WWTW on the downstream systems are considered most significant, having contributed largely to the collapse of this estuary and its once-important nursery for juvenile fish (Rose et al 2023). Similarly, the Macassar WWTW, the effects of which are multiplied by inflows from the Bellville, Scottsdene and Zandvliet WWTWs upstream in the catchment) has contributed to the severe degradation of the Eerste River estuary.

Although the Cape Flats, Athlone and Borcherd's Quarry WWTWs essentially now feed into canalised artefacts of urban drainage, these systems nevertheless play important roles in Cape Town's urban society and poor effluent quality both actively detracts from the value of the areas through which they pass, and has significant ecological costs – for example, the potential for estuarine fish to migrate up the Zeekoe Canal is compromised by large volumes of effluent outflows, often of very poor quality. Similarly, the Black River accumulates organic sludges from upstream inflows of *inter alia* treated effluent, with CODs well above the capacity of this system to effect aerobic decomposition.

Improved performance in some WWTWs was apparent in both loading and effluent quality data, however, despite improvements, the downstream impacts of many of these WWTWs are significant.

Finally, it is noted that high concentrations of phosphorus in effluent from all WWTWs were apparent in final effluent data, despite compliance with regulated general limits.

5.6.2.6 Recommendations

It is recommended that measures to further reduce final effluent concentrations should be prioritised by the CCT for WWTWs that discharge into rivers that feed into important vleis, coastal lakes or estuaries, and contribute to algal and other plant blooms; and an increase in organic sludges from algal growth. A substantial effort to decrease treated effluent phosphorus concentrations to eutrophic levels or below should reduce both the ecological (and knock-on recreational and economic) costs of degraded aquatic ecosystems in urban areas, but also result in reduced management costs, in terms of clearing of invasive aquatic vegetation such as water hyacinth as well as reeds and the need for river and vlei dredging.

It is understood that the CCT is investigating the upgrade and other requirements of existing WWTWs across the City (see Section 7). It is recommended that prioritisation of such interventions take cognizance of the importance, sensitivity and restorability of receiving watercourses when determining which WWTWs to focus on for upgrades. WWTWs discharging into the Kuils, Eerste, Mosselbank and Diep Rivers in particular should be prioritized, as these river systems retain elements of natural aquatic ecosystem function and include important downstream estuaries and floodplain wetlands. This recommendation is not intended to imply that polluted discharges into other systems do not also result in major ecological and human health consequences. The recommendation is rather about prioritisation of effort.

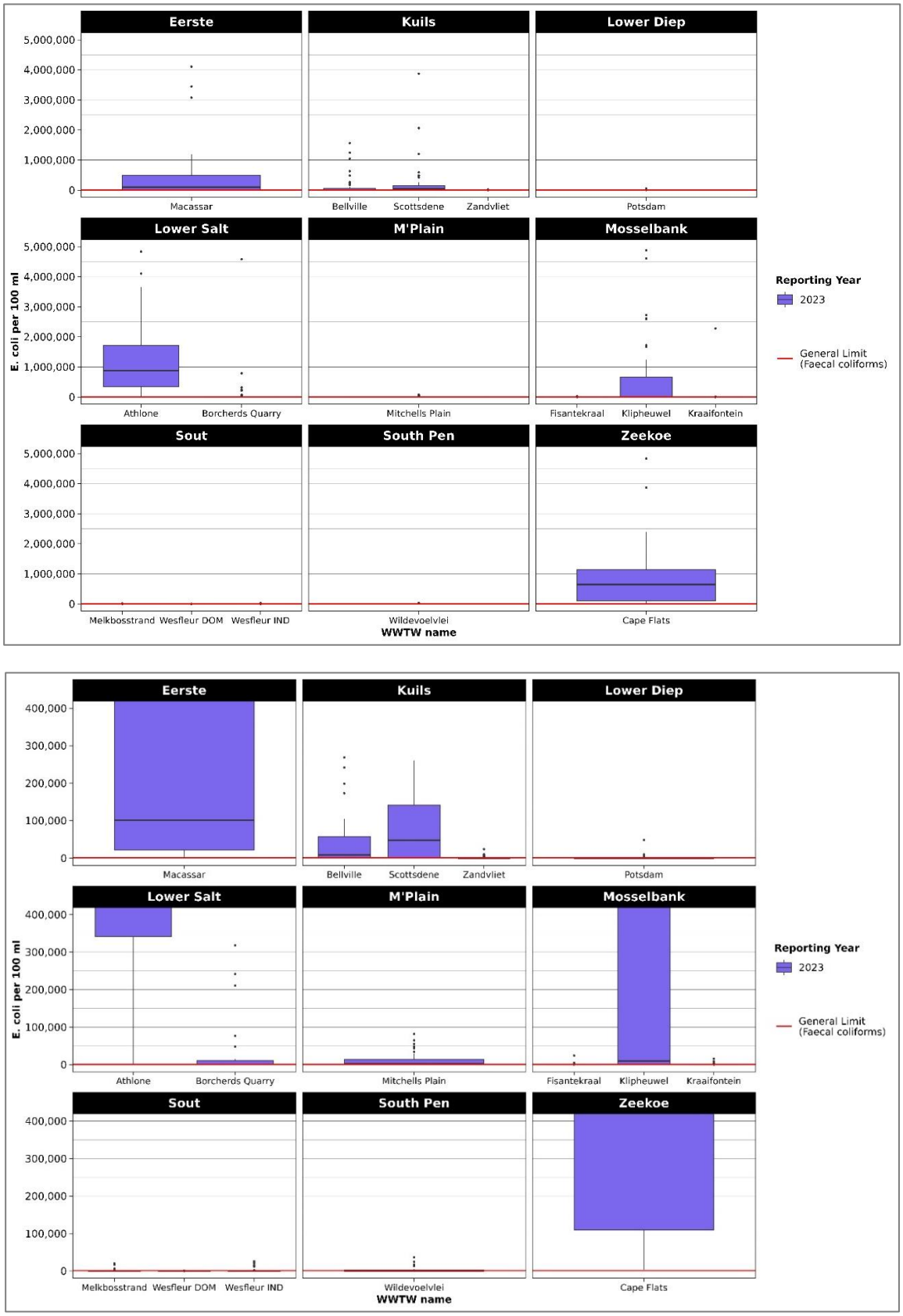


Figure 5.6.3
***Median Escherichia coli* concentrations and loading in effluent from WWTWs in Cape Town. Note difference in y-axis between graphs.**

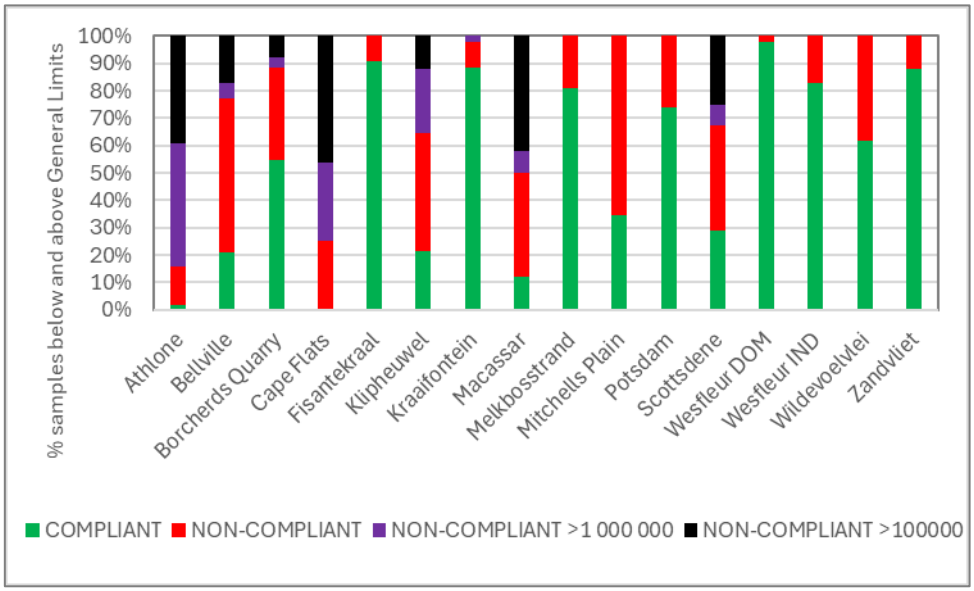
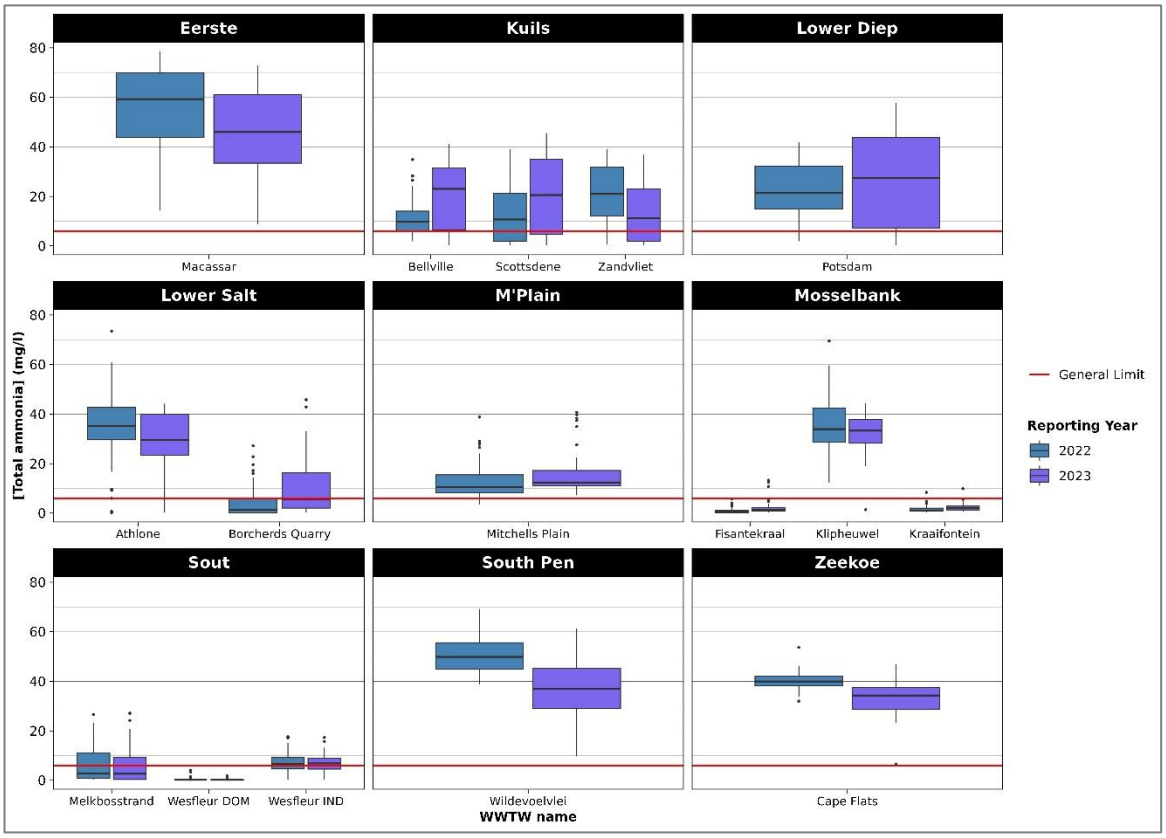


Figure 5.6.4
Proportion of *Escherichia coli* samples from each WWTW falling within or above General Effluent Limits (2023 reporting period)



Figure 5.6.5
Median Chemical Oxygen Demand (COD) concentrations and loading in effluent from WWTWs in Cape Town



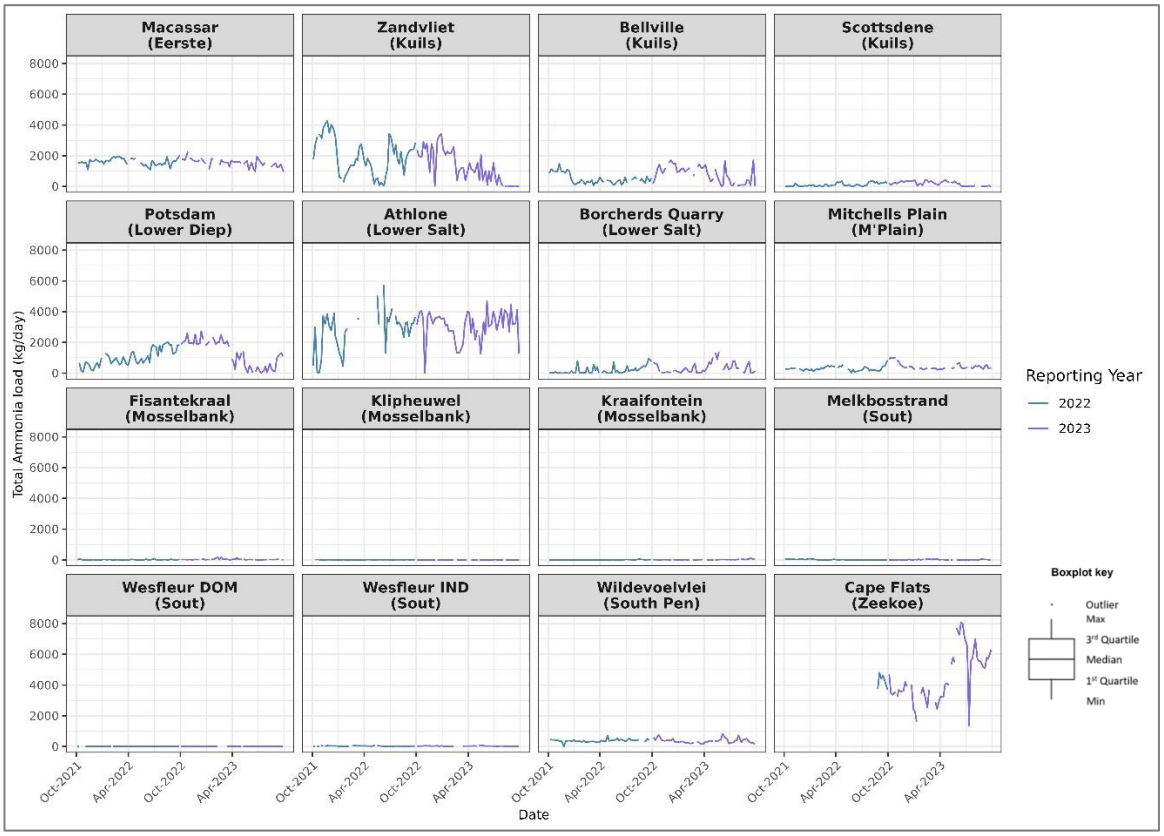
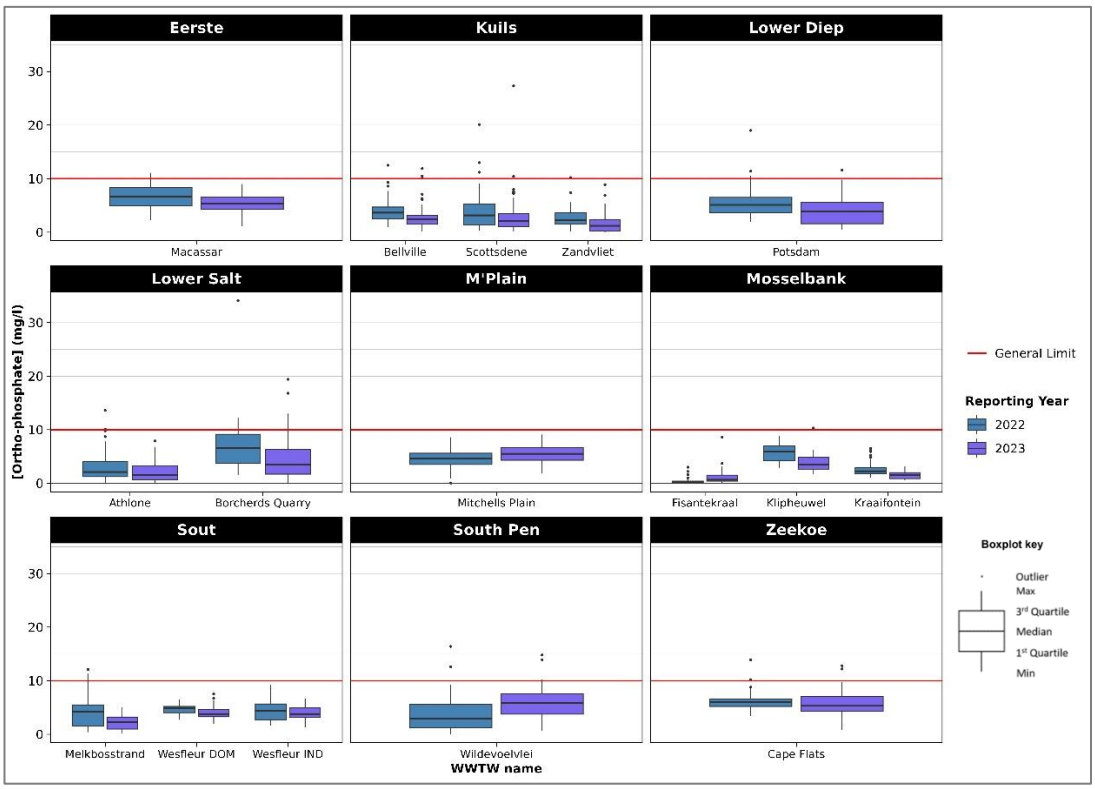


Figure 5.6.6
Median total ammonia concentrations (NH4-N) and loading in effluent from WWTWs in Cape Town



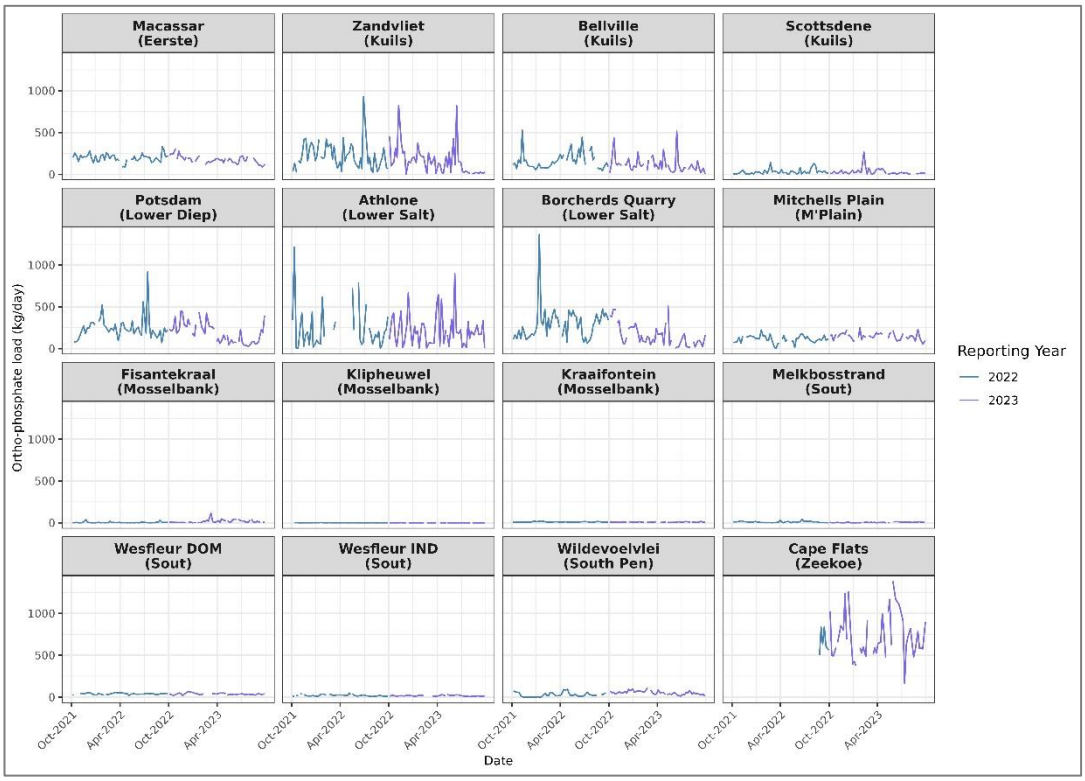


Figure 5.6.7
Median orthophosphate phosphorus (PO4-P) concentrations and loading in effluent from WWTWs in Cape Town

5.6.3 Pump station failures and associated overflows into stormwater systems

A major but episodic rather than perennial source of raw sewage into the City's catchments is from the sewer system, with overflows occurring from blocked or malfunctional pump stations; sewer manholes (because of sewer or pump station blockages); or as a result of sewer pipeline collapse /failure.

This section attempts to gauge the magnitude of these issues, and to identify which sub-catchments are most vulnerable, using CCT records of both pump station failures and the public reporting of sewage manhole overflow incidents (C3 reporting). Sewage spill data are further categorised by the CCT in terms of the magnitude and/or significance of impact of each spill incident, as shown in **Table 5.6.2.**

The collation and inclusion of matching spatial data in these records reflect an important and relatively new effort by the CCT to track pollution-related incidents, their locations and causes.

At the time of this report, data for pump station overflow events were available up until July 2023. In order to maintain consistency with the inland water quality report reporting periods, only data for the 2022 reporting period were included in this section, as data for the full 2023 reporting year (till September 2023) were not available.

5.6.3.1 Pump station breakdowns (associated with sewage overflows)

Figure 5.6.8 summarises the main causes of pump station failure over the 2022 reporting period. The figure indicates that of the 338 incidents reported on, city-wide:

- By far the most prevalent causes of damage were reported as pump tripping and electrical failures (both 23%) and mechanical failure (17%);
- Load shedding was the factor that accounted for the fourth highest number of pump station overflows (9 %);
- Mains supply faults, blockages / breakdowns as a result of rags and foreign objects including sand in the pump station wet wells, and generator failure accounted for 7%, 6% and 5% of break-downs respectively;
- Of interest is the fact that data suggest that theft accounted for only 1% of pump station failures.

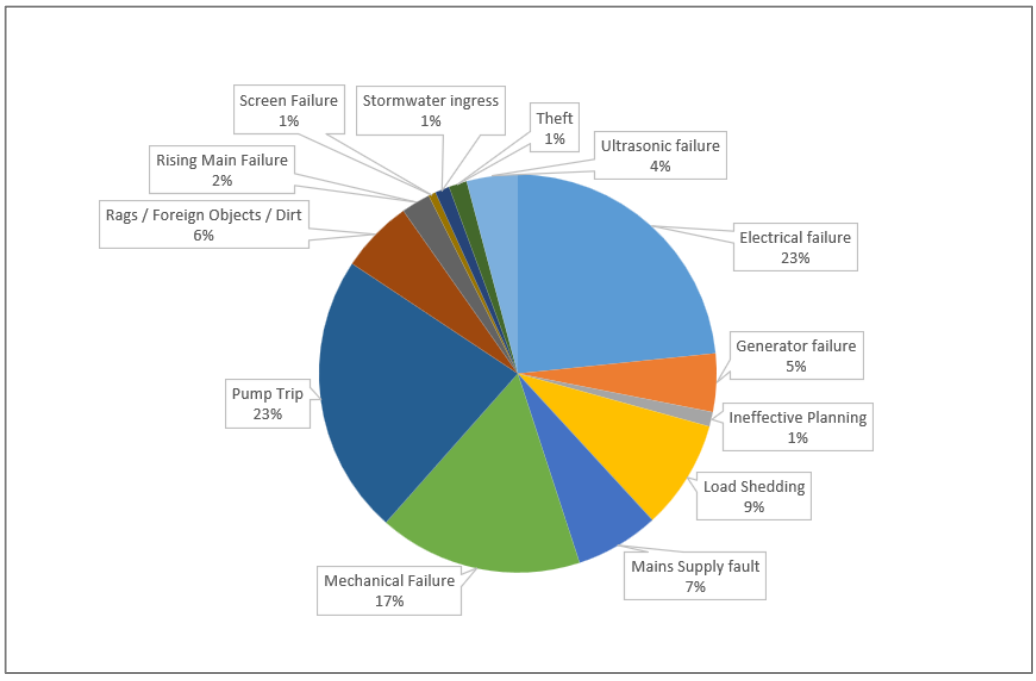


Figure 5.6.8
Contribution of different causes to sewage pump station overflows (2022 reporting period only). Data analysed from the CCT 2024 Director's Report.

Figures 5.6.9 and **5.6.10** respectively plot the frequency of pump station overflows per sub-catchment, along with their magnitude; and the causes of pump station overflow, differentiated per sub-catchment. These data suggest that:

- Overflows rated as Catastrophic occurred twice over the 2022 reporting period, in the Zeekoe sub-catchment (Retreat main pump station, Lavender Hill area) and in the Sand sub-catchment (Raapkraal pump station). Data indicate that these events lasted in excess of 24 hours (up to 48 hours) and it is assumed that they contributed significantly to the pollution of downstream watercourses – in the case of the Raapkraal sub station in particular, to pollution of the Westlake Wetlands and Zandvlei estuary;
- Sub-catchments impacted by Major sewage overflows comprised (in order of number of events) the Sand, Zeekoe, Diep and Lower Salt, with sub-catchments experiencing only one or two such events comprised the City, Eerste, Elsieskraal, Kuils and Mosselbank Sub-catchments;
- Of concern is the fact that the Silvermine sub-catchment was also impacted by at least three major sewage spills – this sub-catchment is generally the most natural and least impacted of all of the City's catchment areas, and would be expected to show high sensitivity to such events – 2023 *E. coli* data for this sub-catchment (Section 5.5) also show periods where water samples were rated Unacceptable, suggesting repeated (but probably infrequent) pump station failure in the following reporting period as well;
- All sub-catchments were exposed to pump station overflows at least at times, with those most exposed comprising the Diep, Lower Salt, City bowl, Kuils, Mosselbank, Sand and Zeekoe sub-catchments;
- All of the above, excluding the City bowl and Mosselbank sub-catchments are included in the Mayoral Priority Programme for water quality improvement (See Section 7), and the data presented here highlight the importance of addressing pump station overflows in these problem sub catchments, if water quality improvements are to be achieved.

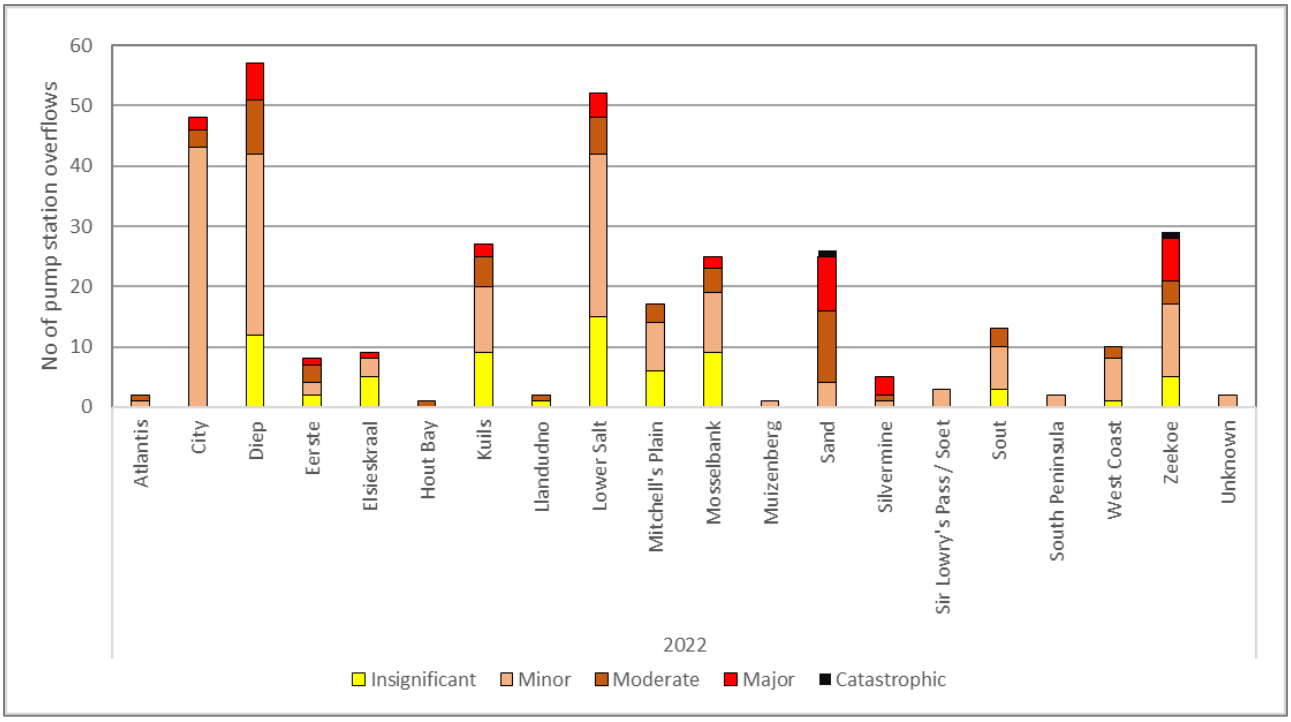


Figure 5.6.9
Number of reported pump station overflows in Cape Town's sub-catchments. Data for the period October 2021 to September 2022 (2022 Reporting Period). Data categorised as per Table 5.6.1.

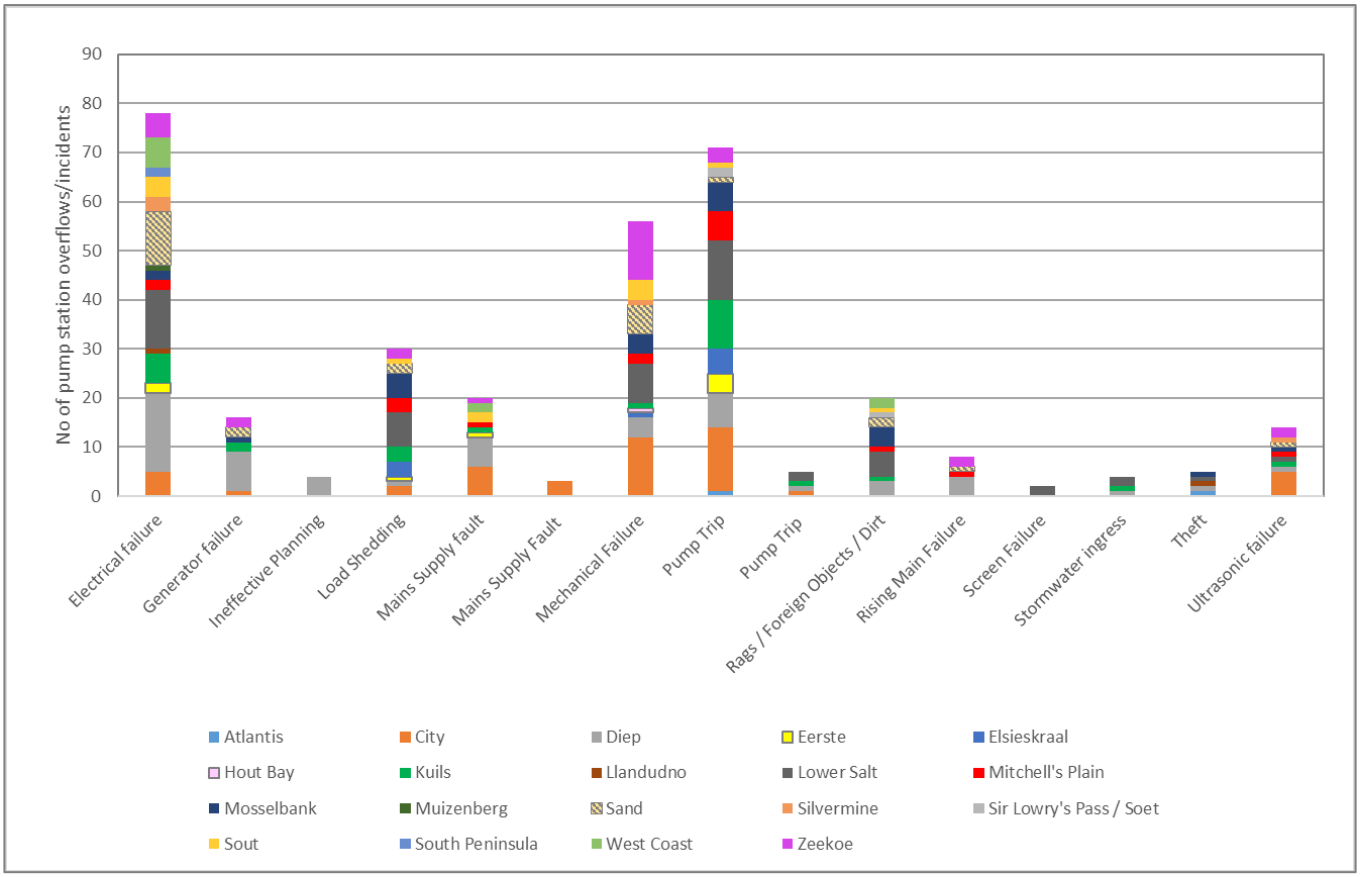


Figure 5.6.10
Logged causes of pump station sewage overflows, with data differentiated between sub-catchments. Data analysed for the 2022 reporting period only.

Figure 5.6.10 shows the results of analysis of pump station data from the perspective of the listed cause of each overflow, differentiating between sub-catchments. These data suggest that, of the most frequently impacted sub-catchments:

- Overflows in the Diep and Lower Salt sub-catchments stemmed mainly from various forms of electrical and mechanical failure (suggesting poor maintenance or systems operating over capacity), as well as (for the Diep Sub-catchment) stated "ineffective planning", which is assumed to revolve around issues such as securing replacement parts, diesel for generators etc. Theft played a relatively small role in this sub-catchment, while foreign objects including rags clearly also contributed to pump station failure at times, and reflects parts of the sub-catchment where communities live in poverty and where solid waste and other material is disposed of into stormwater and sewer systems;
- Most of the issues affecting pump station overflows in the City bowl area were also related mainly to electrical and mechanical failure, rather than to load-shedding, crime or foreign objects;



Photo 5.6.1
Protecting sewerage infrastructure froom theft and vandalism is increasingly important – this pump station is located in the Diep Sub-catchment

- Electrical failure (including pump tripping) and load shedding were the main drivers of sewage spills in the Kuils Sub-catchment;
- Load shedding, pump tripping, electrical failure and impacts of foreign objects into the wet wells were the main drivers of pump station overflows in the Mosselbank Sub-catchment;
- Again, electrical and mechanical failure drove pump failures in the Sand sub-catchment, with blockages as a result of foreign objects and load-shedding also contributing to the frequency of sewage spill events;
- In the Zeekoe sub-catchment, mechanical failure was responsible for most pump station overflows, followed by electrical failures (including pump tripping), failure on the rising main, and load shedding.

Table 5.6.2
Classification of Sewage Pollution Incidents. Classification supplied by the CCT.

Level	Classification	Description
1	**Minor** (No reporting)	The overflow **is/will be contained and not drain** to a local sensitive environment* and/or • Where the overflow reaches waters, the volume of sewage likely to enter the waterway may be insignificantly small with regard to the volume and flow of receiving waters or, • Where the overflow reaches land, it is contained in an area where public exposure is minimal given the maximum response time**.
2	**Moderate** (Responsible Person to report internally Alarm report and EIR)	The overflow **may not be contained and/or could drain** to a local sensitive environment* and/or • Where the overflow reaches waters, the volume of sewage likely to enter the water way is insignificant with regard to the volume and flow of receiving waters, or • Where the overflow reaches land or watercourse, it may travel to an area where public exposure is low within the maximum response time**.
3	**Major** (Responsible Person to report internally & externally – alarm report and 14 days EIR)	The overflow **is uncontrollable and likely to drain** to a local sensitive environment* and/or • Where the overflow reaches waters, the volume of sewage likely to enter the waterway is high with regard to the volume and flow of the receiving waters, or • Where the overflow reaches land or watercourse, the public exposure risk will be high given the maximum response time**.
4	**Catastrophic** (Responsible Person to report internally & externally – alarm report and 14 days EIR)	The overflow **drains to** a local sensitive environment* and • Where the overflow discharges to waters, the volume of sewage entering the water is very high with regard to the volume and flow of receiving waters, or • Where the overflow discharges to land or watercourse, the public exposure risk is very high given the maximum response time**.

*A sensitive environment includes:
- A drinking water catchment or domestic groundwater source, or
- Protected water bodies, ecological communities or conservation areas as defined by Local Government, National Conservation Authorities, or
- Waterways used for recreation (non-contact), or
- A recreational area or other area with high public exposure or associated health risk

**Maximum response time should be based on the length of time taken for the relevant official to detect the overflow or for the overflow to be reported, and the time taken for the relevant official to attend to the site and secure against public contact.
***Overflow = raw untreated overflow

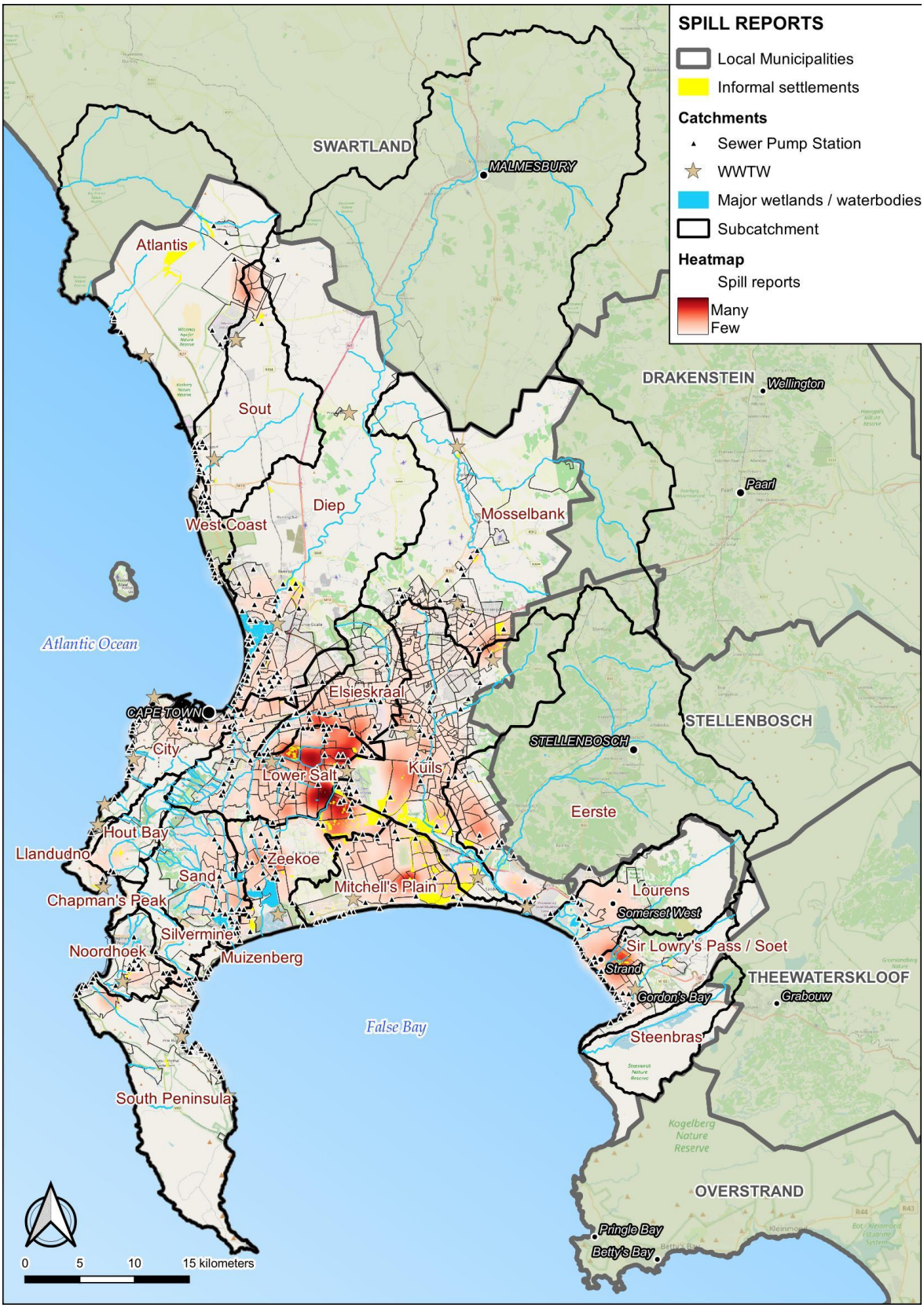


Figure 5.6.11
'Heat map' showing the number of C3 complaints filed for sewage spills in Cape Town over the 2022 and 2023 reporting periods (1 October 2021 to 30 September 2023)

5.6.4 Reported sewage overflows from manholes

Another measure of sewage spill frequency in Cape Town is provided by records of reporting on sewage spills by members of the public. This is done on-line using the CCT's C3 reporting forms. **Figure 5.6.11** provides a coarse spatial overview of the distribution of C3 data for the period. The data are presented as a 'heat map', which shows the intensity of C3 reporting in different areas of Cape Town. Repeated reporting of incidents were deleted from the dataset

These data indicate that, over the 2022-2023 reporting periods:

- The hotspots for sewage overflows, based on reported incidents, lay in the Lower Salt Sub-catchment, with the Bonteheuwel, Ruytewacht, Kewtown and Manenberg areas being worst affected;
- Other significantly affected sub-catchments included:
    - The Soet River portion of the Sir Lowry's Pass / Soet sub-catchment
    - Mitchell's Plain (particularly in the Portland Park, Eastridge, Tafelsig and Beacon Valley areas
    - The Zeekoe Sub-catchment – with particularly problematic areas in the Manenberg, Crossroads / Gugulethu areas; and (seemingly to a lesser reported extent) in the area immediately downstream of Gugulethu; along the Woodlands canal; and in the Parklands and Grassy Park areas;
    - The Kuils River, particularly in its Delft and Rotterdam areas
    - The Eerste River in its Faure and Macassar areas
    - The Mosselbank River in the Wallacedene and Belmont Park areas
    - The Diep River – low levels of reporting across most of the sub-catchment
    - The Sand sub-catchment – mostly in the Westlake area

Of the above, areas with the most intense levels of sewage overflows are those with high levels of informal settlement and/or backyard dwellings and where the sub-catchments themselves are characterised by an accumulation of solid waste that is likely to contribute to the frequency of sewer blockage, along with an increased likelihood of vandalism of sewers and pump stations as a result of a range of socio-economic and other issues.

A caveat to the data presented in **Figure 5.6.11** is however that the original data source does 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 also reflect relatively short-lived incidents versus major spills.

5.6.5 General comments

WWTW effluent of varying quality, often not complying with general effluent limits, and in general, far in excess of the nutrient and other pollutant loads that receiving water bodies can accept without impact; sewage overflows from pump stations, largely as a result of electrical and mechanical problems, exacerbated by issues of foreign material, not collected in debris screens; and overflowing sewers, as a result of pump station blockages ; sewer blockages; and sewer collapse have all contributed to the ongoing, serious pollution of Cape Town's watercourses over the current reporting periods (2022 and 2023 reporting periods).

Important comments and recommendations raised by consideration of the above include the following:

- Measures to further reduce final effluent concentrations should be seriously considered by the CCT for WWTWs that discharge into rivers that feed into important vleis, coastal lakes or estuaries; contribute to algal and other plant blooms; and an increase in organic sludges from algal growth;
- A substantial effort to decrease treated effluent orthophosphate concentrations to eutrophic levels or below should reduce both the ecological (and knock-on recreational and economic) costs of degraded aquatic ecosystems in urban areas, but also result in reduced management costs, in terms of clearing of invasive aquatic vegetation such as water hyacinth as well as reeds and the need for river and vlei dredging;

- Prioritisation of upgrades to existing WWTWs and new WWTWs across the City should take cognizance of the importance, sensitivity and restorability of receiving watercourses when determining which WWTWs to focus on for upgrades;
- Pump station overflows were, on the basis of data from CCT, linked primarily to electrical and mechanical failures as well as pump tripping. This suggests that increased pump station maintenance and management effort is required across most of the City's sub-catchments;
- Load-shedding was also a noted impact, and should be addressed to some extent by the CCT's introduction of back-up generators and invertors. Generator failure was however one of the noted issues linked with pump station overflows, and generator failure as a result of insufficient fuel is also likely to be a contributing issue;
- The ongoing passage of foreign material into pump stations is clearly an issue of concern – the CCT's plans to include sediment and solid waste traps upstream of pump stations in the future, where space allows, should address this issue to some extent. However, the passage of solid waste into the wet wells of pump stations during screen cleaning is clearly a risk inherent in many pump stations at present, and could be rectified through measures such as double screens, even in systems where there is not space for sediment and solid waste trapping upstream;
- Manhole overflows are due to both pump station blockages and sewer blockages or collapses – measures such as proactive sewer cleaning and re-lining as necessary may assist in reducing these events. It is however clear that a dramatically improved approach to solid waste management is required at a city-wide scale, to reduce knock-on impacts on sewerage systems and watercourse condition.

6 CURRENT STATE OF CAPE TOWN'S RECREATIONAL WATERS

6.1 Background

While vleis and standing water bodies in general have been discussed in Section 5, in relation to the key water quality variables assessed in that section, the present section has been included to deal specifically with the current state of Cape Town's established recreational water bodies from the perspective of the risk, if any, that they pose to human health. Five main water bodies have been considered (identified in consultation with the CCT):

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

With the exception of Princessvlei, these vleis and estuaries are used for various water sport activities, including sailing, kayaking, canoeing, fishing, kite-boarding, skiing, wind-surfing, rowing, and fishing. All of these activities expose users to some level of health risk if water quality is compromised.

Princessvlei is not used for water sports. It is however used periodically for baptism ceremonies, requiring full immersion.

6.2 Background ecological condition

Data already presented in Section 5 indicate that of the above five recreational water bodies, all have been impacted by high levels of phosphate enrichment, likely to promote high levels of plant productivity, in the form of emergent reeds, floating and rooted aquatic weeds, and filamentous and single-celled algae.

High total ammoniacal nitrogen concentrations with at times free ammonia at levels of concern (i.e. above acute toxicity thresholds / in the Unacceptable range) were frequent in Zeekoevlei's water samples in particular, and indicative of a build-up of organic material in lake sediments (Day et al 2022), contributing to low DO in the system at least at times. Rose et al (2023) noted very low (in places zero) DO in Milnerton lagoon, also associated with high loads of organic material (in this case, stemming mainly from the Potsdam WWTW and catchment sewage overflows), and resulting in anaerobic conditions in the estuary, characterised by the production of hydrogen sulphide and methane from decomposing bottom sediments.

By way of providing ecological context to the discussion around vlei water quality from a human health perspective, **Figures 6.2.1 – 6.2.4** present median annual data for the above recreational vleis, for orthophosphate phosphorus and dissolved oxygen, showing conditions at individual sites within the focus water bodies.

These figures illustrate the following broad patterns and issues, already discussed in Section 5:

- With the exception of parts of Zandvlei, all of the recreational vleis were in a hypertrophic (Unacceptable) condition with regard to phosphorus enrichment, making them productive systems, prone to rapid plant growth (reeds, aquatic weeds, algae) and thus requiring ongoing plant management;
- Parts of Zandvlei were characterized by slightly lower phosphorus enrichment, albeit still rated Poor and thus still likely to encourage plant growth;
- Dissolved oxygen concentrations (useful in this context as a measure of oxygen demand in nutrient-enriched waterbodies where decaying plant and other organic material builds up on vlei bottoms) was rated Unacceptable through most of Milnerton Lagoon – this watercourse has been profoundly impacted by ongoing receipt of poorly treated sewage effluent from Potsdam WWTW and other sewage sources (see Section 5.6), resulting in parts of the estuary switching to anaerobic conditions (Rose et al 2023);
- Dissolved oxygen concentrations were generally within Target range in all of the other recreational

waterbodies, with the exception of sites in Zandvlei close to areas known to be affected by periodic sewage overflows (CR22 and CR01);

- In the case of Zeekoevlei, these DO concentrations belie known low oxygen conditions in bottom waters, where deep organic sludges have accumulated (see Day et al 2022 and Day 2023). The DO data presented in **Figure 6.2.3** portray near-surface concentrations only.

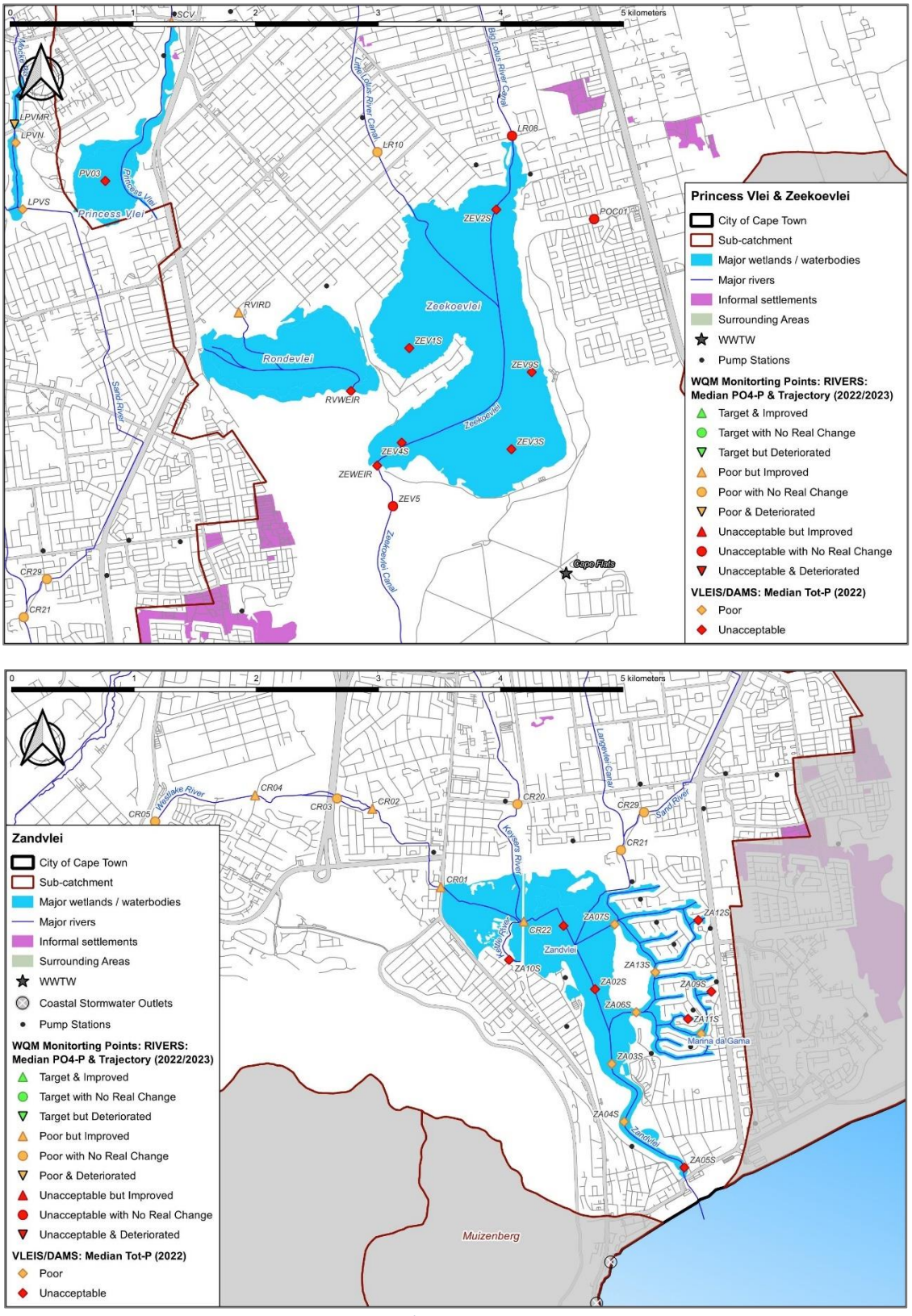


Figure.6.2.1
Median annual orthophosphate phosphorus (PO4-P) data for rivers passing into and from Princessvlei, Zeekoevlei and Zandvlei over the 2022 and 2023 reporting periods, showing trajectory per site (as described in Section 3.8.14).
Median annual total phosphorous concentrations for the vleis themselves are provided for 2022 only, due to missing total phosphrous data from January 2023 onwards.

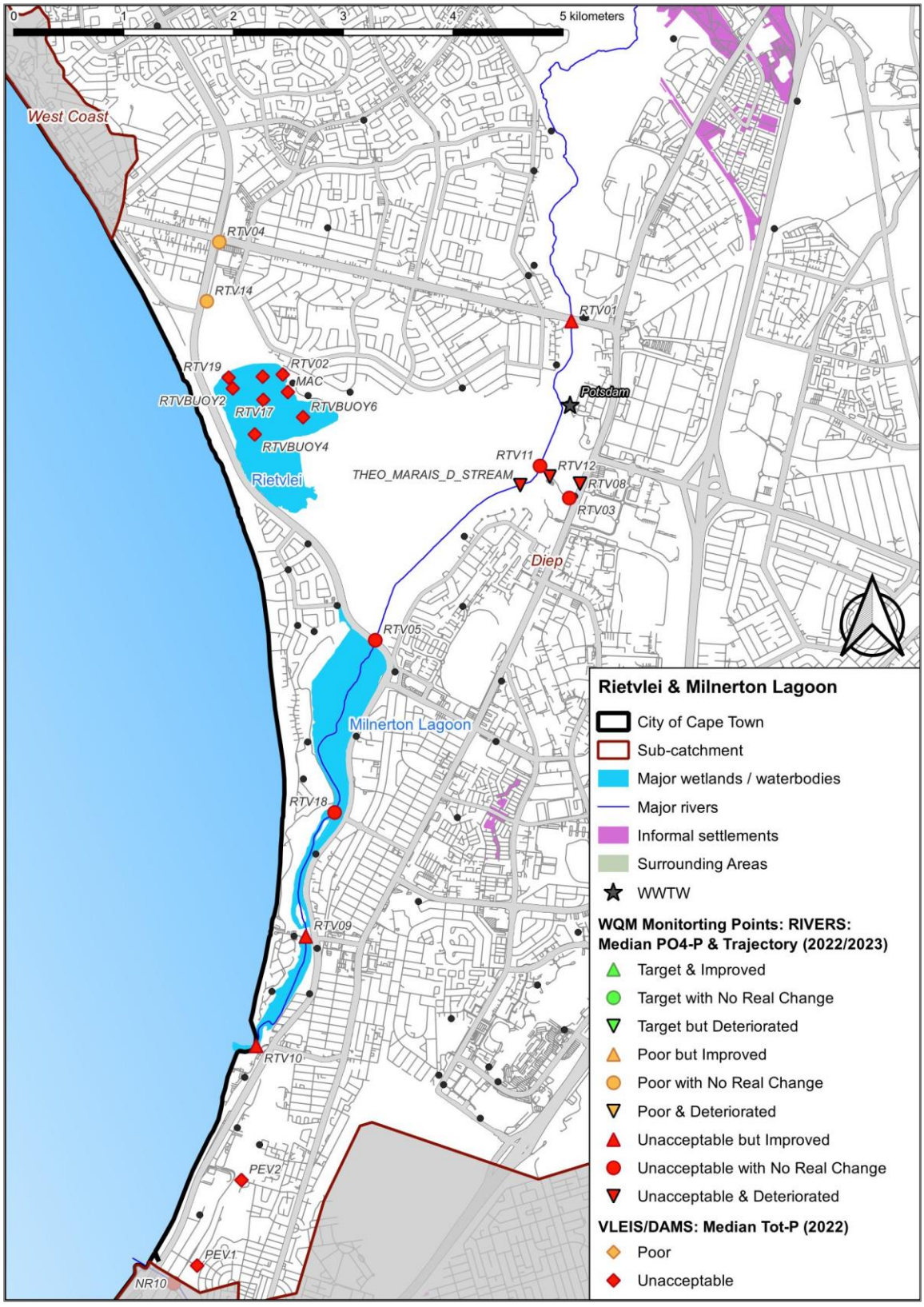


Figure 6.2.2
Median annual orthophosphate phosphorus (PO4-P) data for Milnerton Lagoon and Rietvlei over the 2022 and 2023 reporting periods, showing trajectory as described in Section 3.8.14. Median annual total Phosphorous concentrations for the vleis themselves are provided for 2022 only, due to missing total Phosphorous data from January 2023 onwards.

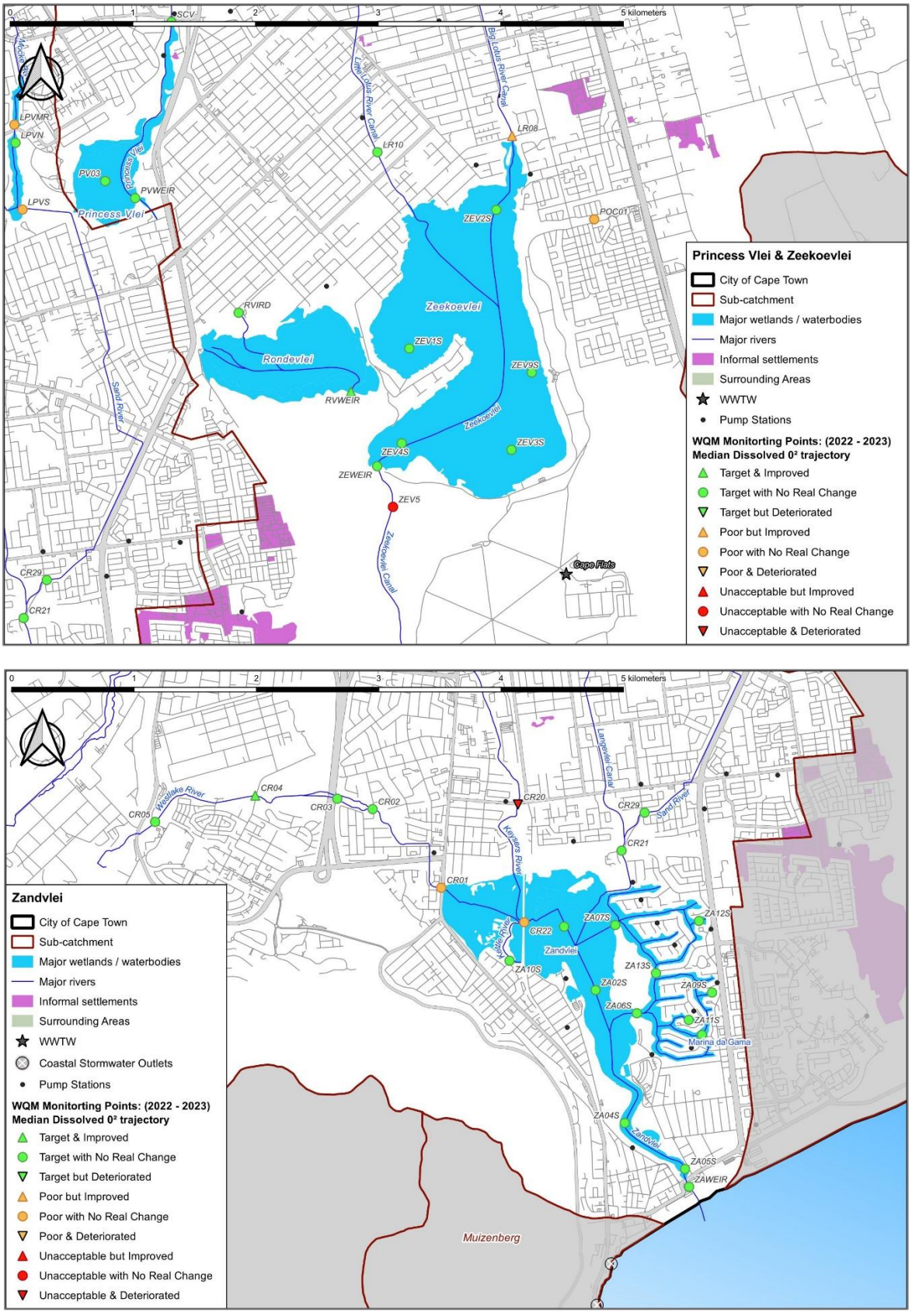


Figure 6.2.3
Median annual dissolved oxygen (DO) data for Princessvlei, Zeekoevlei and Zandvlei over the 2022 and 2023 reporting periods, showing trajectory as described in Section 3.8.14

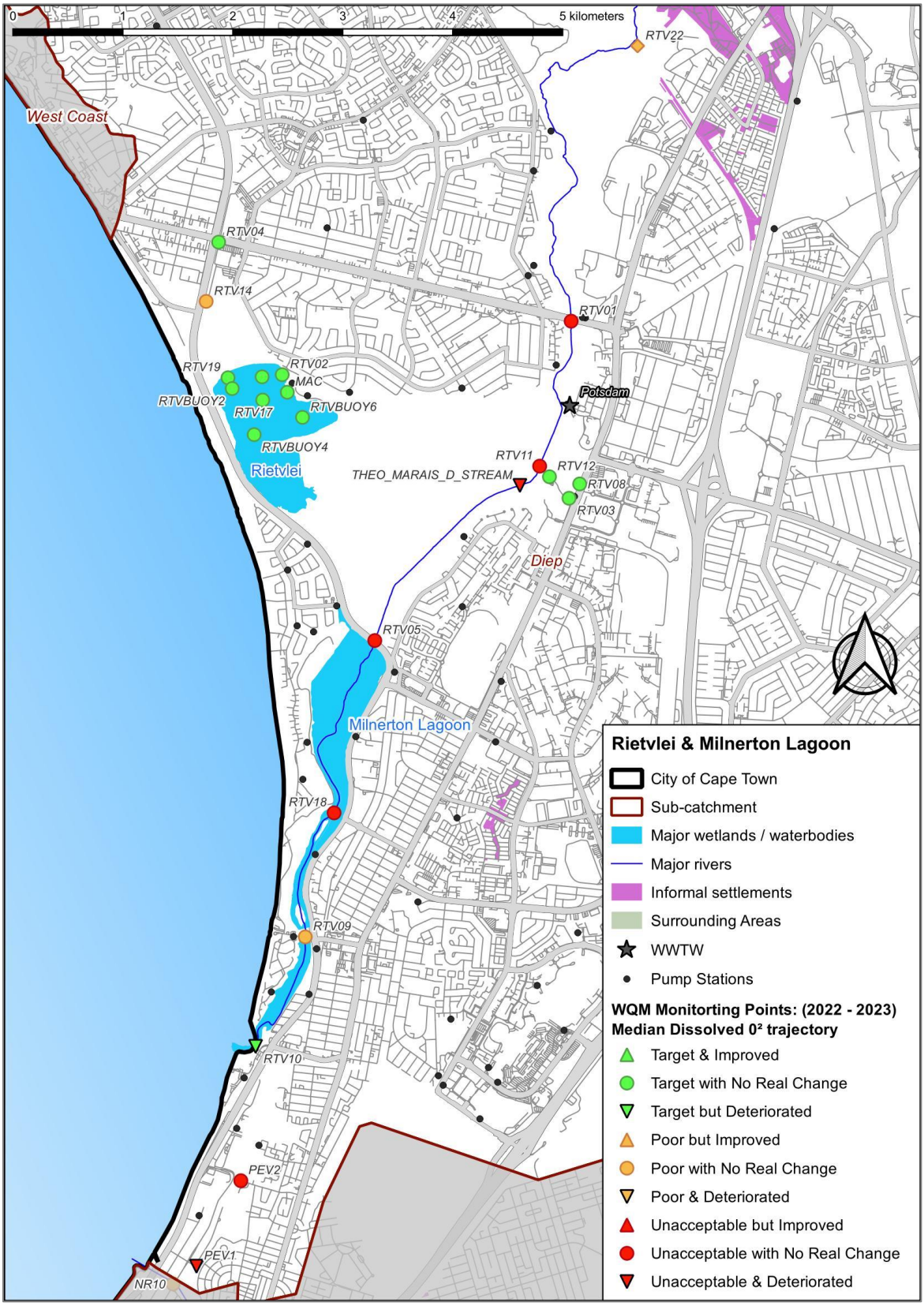


Figure 6.2.4
Median annual dissolved oxygen (DO) data for Milnerton Lagoon and Rietvlei over the 2022 and 2023 reporting periods, showing trajectory as described in Section 3.8.14.

6.3 Human health risk thresholds

The *E. coli* and microcystin toxin data presented here have been assessed with regard to the rated water quality thresholds presented in **Tables 3.3** and **3.4**.

It is however noted that the CCT does not purport to manage any of its inland water bodies for full contact recreation, but rather sets 'Target', 'Tolerable Risk' and 'Unacceptable' thresholds, **based on risks posed by intermediate contact only** (CCT 2023a).

What is intermediate contact recreational use?

CCT (2023) defines this as 'All forms of water based recreation but excluding full-body water contact activities such as swimming or diving. Intermediate contact activities may involve a high degree of water contact, such as water skiing, wind surfing and canoeing'. DEA (2012) does not distinguish between full contact and intermediate contact uses, but notes that exposure (and therefore risk) differs between activities.

Full-immersion baptism is short-term, and once-off, but nevertheless is arguably a full-contact use, rather than an intermediate contact use (see DWAF 1996).

The CCT does not endorse full-contact use of its inland water bodies.

6.4 Data used to assess risks to human health

The main focus of this section is on those water quality variables that relate directly to human health in the recreational vleis, rather than to ecosystem condition. These comprise indicators of sewage contamination (i.e. *E. coli*) and data reflecting concentrations of microcystin toxins, often associated with blue-green algal blooms. Unlike the presentation of data in Section 5, where Milnerton Lagoon water samples, for example, are including in the Diep River catchment with flowing systems rather than as an individual standing water system, the present section provides summary data for individual recreational systems.

6.5 Indicators of sewage contamination

6.5.1 *Escherichia coli*

6.5.1.1 Background

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 (generally < 1%) can cause significant diarrhoea and other illness (WHO 2021). The presence of *E. coli* in water is used as an indicator of faecal contamination of avian (bird) or mammalian origin, and therefore is indicative of other pathogens that *may* also be present in faeces. These include other bacteria, nematode cysts and viruses.

See **Sections 5.5 and 5.6** for *E. coli* data in the CCT water bodies as a whole and for discussion around issues with *E. coli* analysis and reporting.

6.5.1.2 *E. coli* data for recreational water bodies

Figure 6.4.1 presents the results of *E. coli* analyses for water samples from the recreational water bodies outlined in **Section 6.1**. These data were available for reporting periods 2019, 2020 and 2023 (see Section 3.8.8).

Note that the *E. coli* data have already been presented in **Section 5.5**, along with data for other open water bodies and rivers, while **Section 5.6** presents data and discussion around the main sources of *E. coli* in different sub-catchments over the present main reporting periods.

The data in **Figure 6.4.1** are presented as compliance graphs, showing separate summer and winter samples. The data show that:

- **Milnerton Lagoon** experienced high levels of faecal contamination over all three reporting periods considered, with an increased frequency of Unacceptable estuarine samples over the 2023 period. Since data for Potsdam WWTW (see Section 5.6.2) do not suggest high *E. coli* in treated effluent, the data in **Figure 6.4.1** highlighting the impacts of raw sewage inflows from the catchment, including informal settlements in the Dunoon, Doornbach, Jo Slovo, Phoenix and many other areas in the catchment, some

of which entered Milnerton Lagoon via point source inflows from the Erika Road stormwater outlet during and prior to the 2023 reporting period;

- The data for Milnerton Lagoon thus suggest that, for most of the 2023 reporting period, Milnerton Lagoon was not a safe waterbody for even intermediate recreational use;
- Although Day et al (2023) reported that winter *E. coli* concentrations were usually higher than in summer, reflecting increased wash-off from polluted catchments and increases in sewer surcharges during storm events, the Milnerton Lagoon data do not reflect strong seasonal patterns in the 2023 reporting period, suggesting near-continual inflows of polluted water from points sources including failed sewage pump stations (see Section 5.6.3);
- **Rietvlei** (also referred to as Flamingo Vlei in some documents (e.g. Rose et al 2022)) by contrast was seemingly exposed to raw sewage only occasionally, with samples showing in excess of 95% compliance in the 2023 reporting period. Extended detention time in the vlei (compared with the flowing Milnerton Lagoon) and exposure to a cleaner catchment, albeit still affected at times by overflows from pump-stations and sewer manholes;
- Rietvlei thus appears to have provided a relatively low-risk environment to recreational users, at least from the perspective of exposure to raw sewage;
- Both **Princessvlei** and **Zeekoevlei** were exposed to more frequent *E. coli* inflows during the 2023 reporting period than over previous periods for which data were available and analysed here, with 45% and 25% of samples from these two vleis, respectively, having *E. coli* at Unacceptable concentrations in winter 2023. Substantially better compliance was however evident during summer of the same reporting period;
- **Zandvlei** data showed 15-20% of samples were Unacceptable over winter and summer respectively in the 2023 reporting period, with these data indicating a recreational system threatened by sewage overflows, with pump stations such as the Raapenberg pump station, near Westlake, being a frequent offender.

Generally, the data suggest that all of the CCT's recreational water bodies periodically posed risks to human health during the 2023 reporting period, but were largely in an Acceptable condition, conducive to their recreational use. Milnerton Lagoon was however mostly in an Unacceptable condition, and its use for recreation would have posed likely risks to human health most of the time.

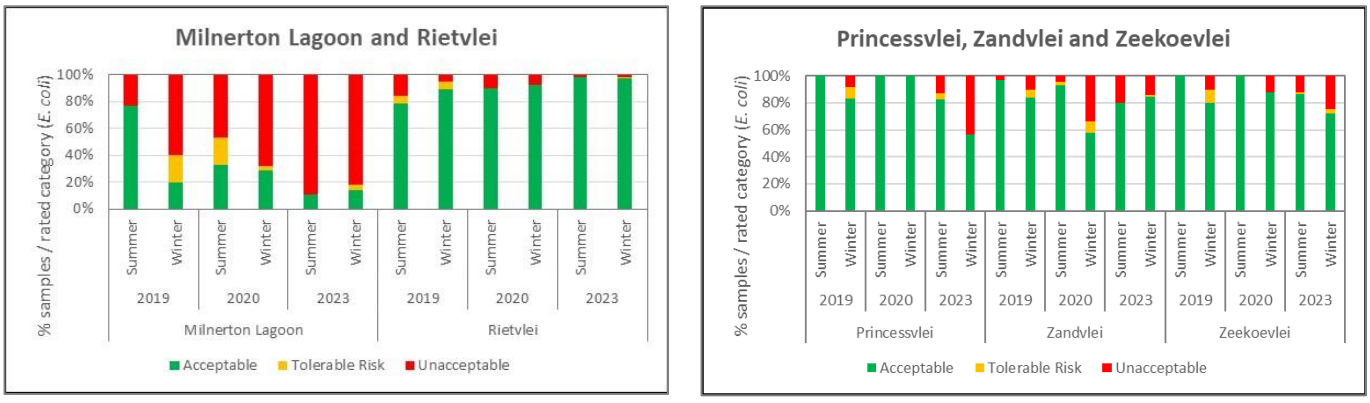


Figure 6.4.1
Percentage of *E. coli* samples falling within each rated category for this variable for each recreational waterbody.

6.5.2 E. coli by site

In order to provide some spatial information about *E. coli* concentrations in different parts of the main recreational vleis, geometric mean *E. coli* data for the 2020 reporting period have been colour coded, using the threshold data for E. coli provided in **Table 3.3** as a guide, and plotted as individual monitoring sites in **Figures 6.5.1** and **6.5.2**, which show Zandvlei, Zeekoevlei and Princessvlei; and Rietvlei and Milnerton Lagoon, respectively. It must be noted that geometric mean data for *E. coli*, while useful for showing broad trends, cannot be used to infer overall risks to human health, as they do not show events when *E. coli* was elevated above thresholds of concern, and moreover, are impacted by reporting issues around upper and lower limits of analysis (see Sections 3.8.8 and 3.8.9), with the result that geometric means may well under-estimate actual values, had they been more accurately calculated. Nevertheless, the data do allow spatial variation in *E. coli* data within and around the recreational wetlands to be considered.

The data highlight what the compliance data have already indicated, namely that:

- Princessvlei sites were generally in an Acceptable condition, albeit fed by more polluted water from the Southfield Canal (geometric mean rated as Unacceptable);
- Mean annual Zeekoevlei data were similarly within an Acceptable range across the vlei, other than in the upper vlei, near to the mouth of the highly polluted Big Lotus River, where mean *E. coli* concentrations were in the Unacceptable range, high-lighting the high level of risk associated with recreational use in this part of the vlei;
- Mean Zandvlei data were also within the Acceptable range across most of the estuarine wetland, other than at CR22 (a site downstream of the Westlake and Keysers River inflows, near the railway line, and presumed to be impacted by road runoff and periodic sewage manhole overflows;
- Data for watercourses flowing into Zandvlei highlight generally less polluted water entering from the Westlake and Keysers River systems, but more problematic water inflows from the Langvlei and Sand River systems to the north, both of which flow through at least some areas in their lower catchments where there are high levels of solid waste on street and in canals, and where associated sewer blockages and other impacts are likely to be more frequent;
- Monitored sample points in Rietvlei were all rated as within Target range – but the upstream catchment (Bayside channel) was clearly problematic and rated as Unacceptable;
- Sample points in Milnerton Lagoon were all rated as Unacceptable, and continued as Unacceptable upstream as far as Blaauwberg Bridge (RTV01), suggesting that the main sources of raw sewage stem from the catchment between Blaauwberg Bridge and Otto DU Plessis Drive. Data for inflowing canals such as the Theo Marais canal (RTV12) illustrate high levels of pollution with raw sewage, probably stemming mainly from overflows from the Koeberg Pump Station in this area, but also likely to reflect at least occasional overflows from the WWTW into this canal, prior to disinfection with chlorine at the WWTW outlet into the diversion channel upstream of the Theo Marais canal outlet;
- Water quality was rated as of high risk (Unacceptable) throughout the Milnerton Lagoon's reaches, including past the Milnerton Canoe Club, near Woodbridge Island (MCC).

It is however again reiterated that summary *E. coli* data are complicated, in that even using geometric means, the data include in some cases a wide range of values between spill and non-spill periods, and even those sites rated green (Target) in the figures provided may have experienced sewage spills at times.

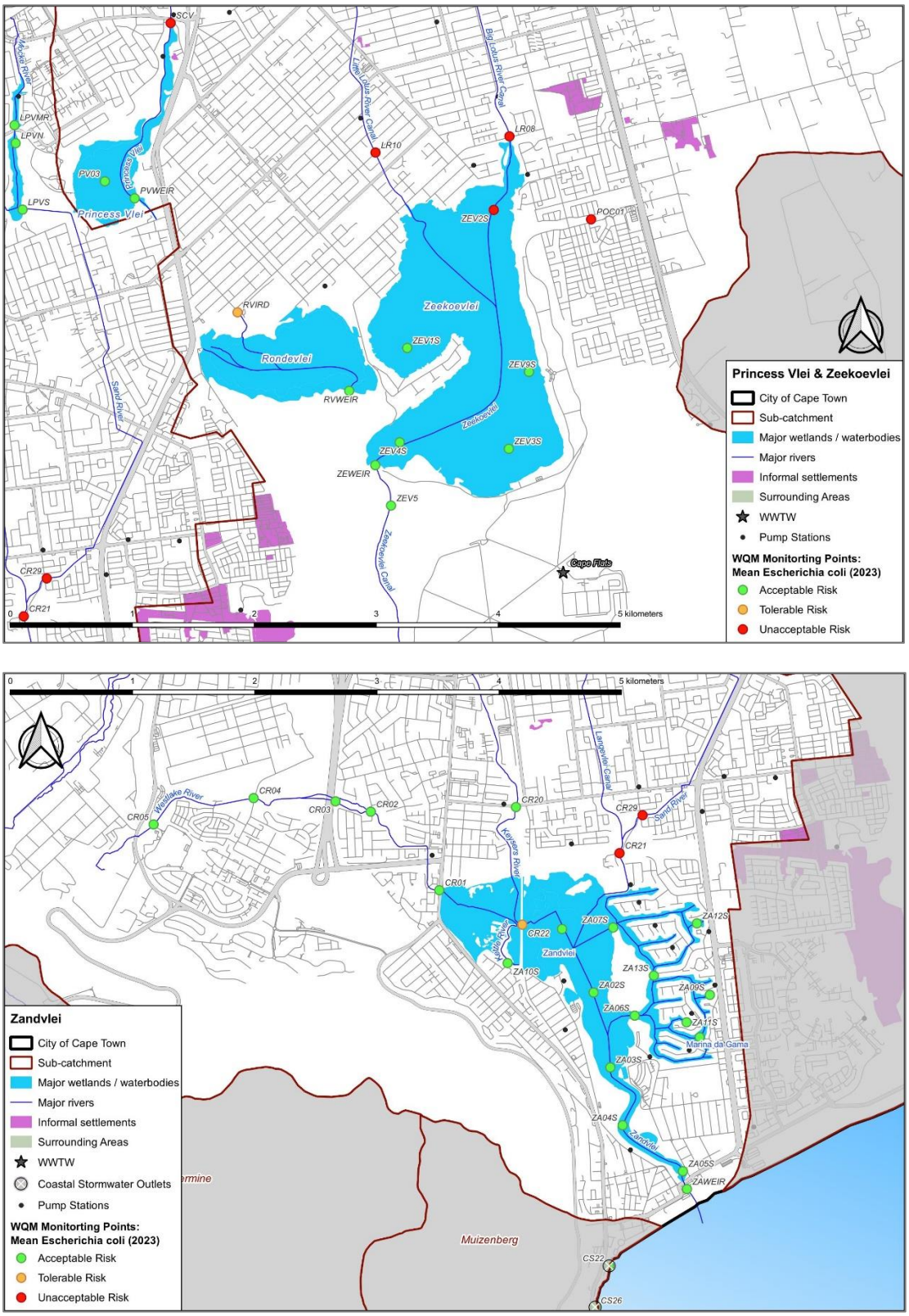


Figure 6.5.1
Geometric mean annual *E. coli* data, focusing on Princessvlei, Zeekoevlei and Zandvlei for the 2023 reporting period.

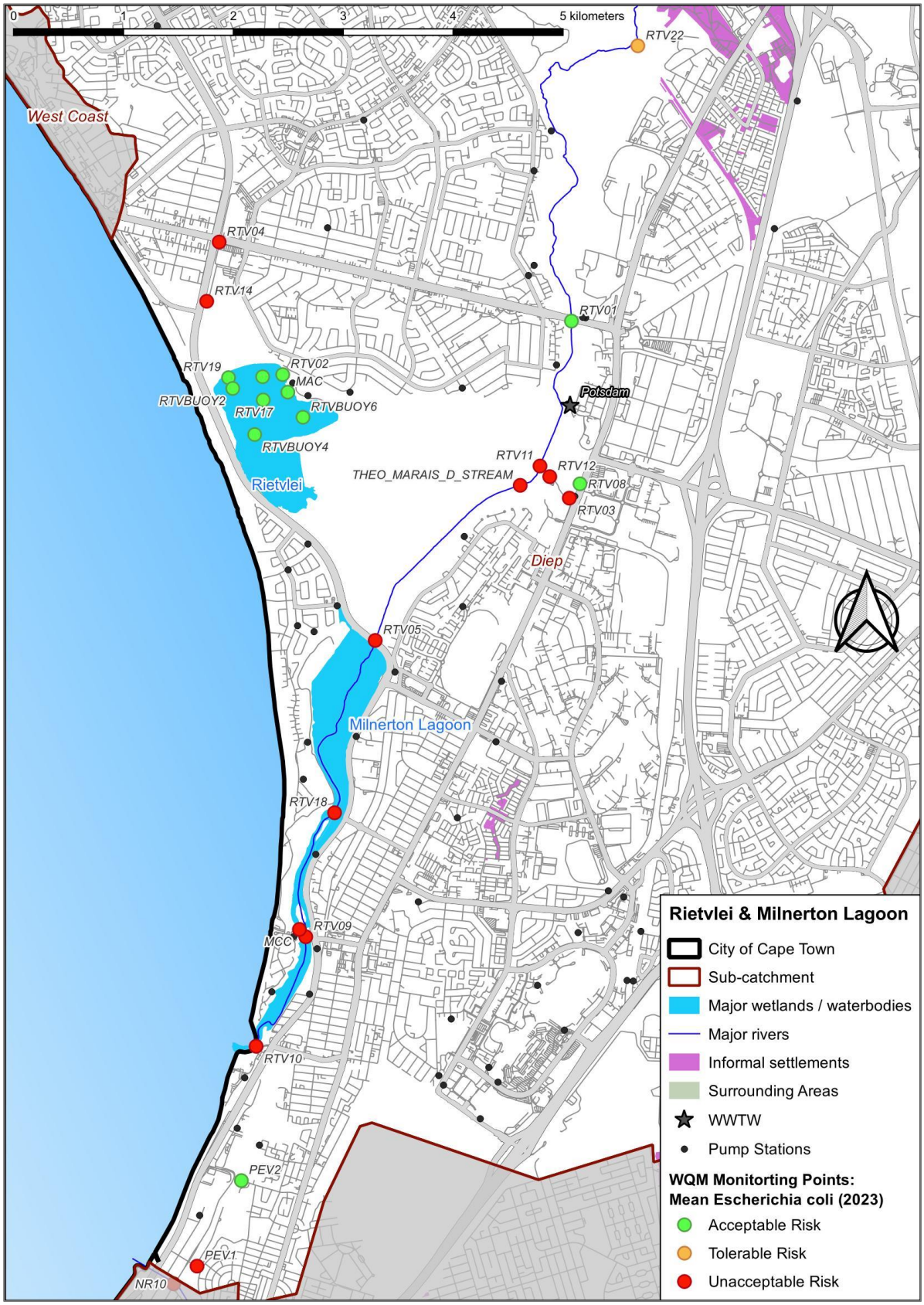


Figure 6.5.2
Geometric mean annual *E. coli* data, focusing on Milnerton Lagoon and Rietvlei.

6.6 Microcystin risks

6.6.1 *Background*

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 conditions, produce a group of secondary metabolites known as microcystins, some of which are toxic.

Since microcystin toxin testing is expensive, it is not routinely included in the CCT's water quality tests but is instead undertaken when blue-green algal blooms have been detected. A 'bloom' is defined by the SSB as a cell count> 20 000 cells/ml. However, when field evidence suggests that bloom conditions are obvious (e.g. blue-green algal slicks), microcystin tests are carried out immediately, without the delay necessitated by microscopic enumeration of algal cells.[11]

Blue-green algae – why the name ?

Blue-green algae (an algal division also referred to as cyanophytes or cyanobacteria) produce green surface scums under bloom conditions. The algal cells also contain a blue pigment (phycocyanin), which is mostly visible when algal cells, in bloom conditions, die and rupture, releasing the pigment into the water. This sometimes appears as if turquoise-coloured paint has been spilled into the water body (adapted from WHO 2021).

6.6.2 *Assessment of microcystin toxin data and sampling frequency*

Figure 6.6.1 presents the results of analyses of water samples from Cape Town's recreational water bodies for microcystin toxins.

The data show that, although blue-green algal blooms were clearly present on numerous occasions over the 2022 and 2023 reporting periods covered in this report, the only vlei in which microcystin toxins were recorded at concentrations of concern was Zeekoevlei.

This means that, excluding Zeekoevlei's waters, and despite periodic blue-green algal blooms, Cape Town's recreational watercourses were assumed to be relatively safe for human use over the 2022 and 2023 reporting periods, from the perspective of exposure during intermediate contact use to microcystin toxins in water from these systems.

Three samples analysed from Zeekoevlei in the 2022 reporting period (two in summer and one in winter) showed microcystin concentrations rated as of Medium Risk (summer 2022) and Extreme Risk (winter 2022). This means that recreational users of Zeekoevlei could have been exposed to at least periodic risk of exposure to microcystins. Note however that blue-green algal blooms in Zeekoevlei were localised over the reporting period, and certainly did not occur as blooms over the whole vlei, but generally comprised isolated blooms, usually confined to sheltered parts of the vlei (Liz Day pers. obs.). Nevertheless, the data are of concern, and are symptomatic of a system in a hypertrophic and deteriorating condition.

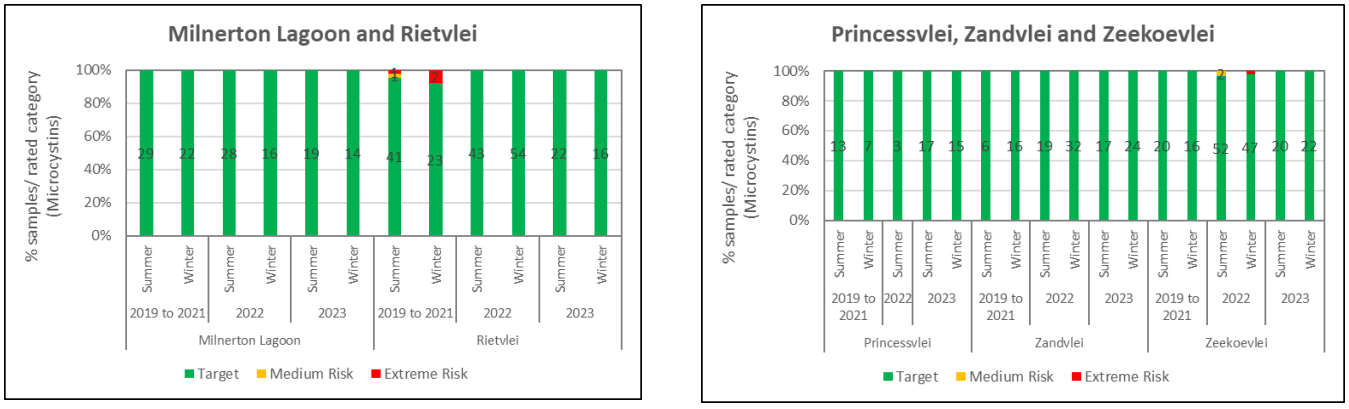


Figure 6.6.1
Percentage of microcystin samples falling within each rated category for this variable, per recreational vlei.
Thresholds for rated categories as defined in Table 3.4

[11] See Day et al (2023)

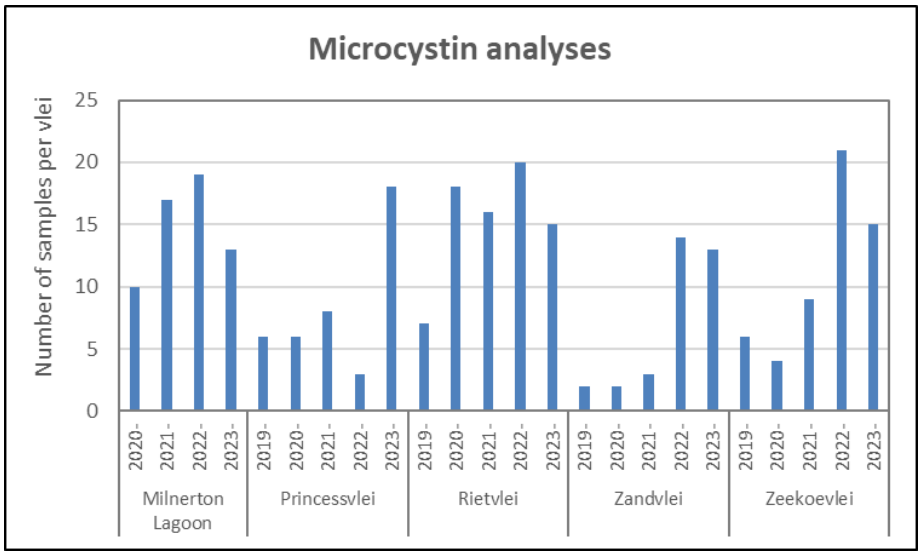


Figure 6.6.2
Number of samples analysed for the presence and concentration of microcystin toxins over the past five reporting periods. Note: Sample number calculated per date per vlei, and not total sample numbers per vlei per date.

Figure 6.6.2 presents a slightly different picture. This graph plots the frequency of sampling per vlei for analysis for the presence of microcystins, over the 2019-2021, 2022 and 2023 reporting periods. Since the trigger for microcystin analysis of any sample is the presence of visible blue-green algal blooms or algal count data indicating bloom conditions, the data can also be used as a gauge of blue-green algal bloom frequency, even where this is not accompanied by microcystins at toxic concentrations. These data are presented as vlei sampling frequency and not total samples per vlei, to prevent bias as a result of different numbers of samples being collected from different vleis.

On this basis it can therefore be loosely deduced that:

- Since the 2020 reporting period, **Rietvlei** has consistently experienced 15-20 algal blooms per year, highlighting the fact that the vlei is hypertrophic and thus prone to high plant productivity of some kind (see **Section 5.1.6**);
- Post 2020, **Milnerton Lagoon** has experienced a marked increase in the frequency of algal blooms, although the number decreased in 2023 – water quality data for Milnerton Lagoon do not however suggest that this decrease was due to reduced nutrient enrichment, and the data might instead reflect other factors such as higher rainfall and stormwater flushing during the course of 2023 (see **Section 4**);
- **Princessvlei** has, since the 2019 reporting period, generally experienced relatively low frequencies of algal blooms, with the exception of 2023, when bloom frequency increased markedly, presumably in response to increased sewage inflows, reflecting in elevated phosphorus availability, but also possibly influenced by activities such as clearing of water hyacinth, which is an invasive alien aquatic plant, that nevertheless takes up orthophosphates efficiently. Removal of this problem weed might have a secondary impact of reducing competition for algal productivity;
- Prior to the 2022 reporting period, data for **Zandvlei** showed relatively few algal bloom episodes. This situation changed in the 2022 and 2023 reporting periods, when a marked increase in the frequency of algal blooms was shown by monitoring data. It seems likely that these reflect increased nutrient inflows into the waterbody, via sewage overflows. It is however also possible that these changes also reflect a reported shift in macrophyte species dominance, from *Stuckenia pectinata* (pondweed, associated with fresh to mildly brackish conditions), to the estuarine species *Ruppia maritima*. The decline in *S. pectinata* has been associated with increased filamentous algal and phytoplankton blooms and it is possible that, if nutrient concentrations are not reduced, that this system will become algal rather than macrophyte dominated (Wright 2023);
- Of all of the City's recreational vleis, **Zeekoevlei** was most affected by algal blooms over the 2022 and

2023 reporting periods, reflecting ongoing nutrient enrichment of this vlei from external sources, exacerbated by the build-up of organic sediments within the vlei, which provide an ongoing source of additional phosphate nutrients, facilitated by low dissolved oxygen availability. Under such conditions, Zeekoevlei waters were able to support high levels of phytoplankton productivity. Blue-green algae are moreover able to access nitrogen through the air (Kadlec 2020) as well as from within the waterbody, so in conditions of elevated phosphate, they have a competitive advantage over many other plant taxa.

6.7 The Kuils River at the Khayelitsha Wetland Park

The Khayelitsha Canoe Club operates from the Khayelitsha Wetland Park, located on what is presumed to have been a backwater of the Kuils River, but is now a stormwater detention pond. The club's operations are hampered by ongoing land invasion into the wetland park as well as by invasion of open water bodies by water hyacinth. These plants are cleared manually by the Canoe Club members[12], and their rate of growth reflects the high levels of nutrient availability in the Kuils River sub-catchment, and phosphorus availability in particular, in its phosphate form. During the 2023 reporting period, Canoe Club members started an operation to convert water hyacinth into biochar, for possible commercial sale.

Canoeing or kayaking in these sections of the river, as well as water hyacinth clearing, exposes members of the club to potential health risks, stemming from exposure to inflows of raw sewage or other sources of pollution. Although the Kuils River main stem is monitored at the Baden Powell Bridge, this sample point is considered unrepresentative of conditions at the Khayelitsha Canoe Club venue itself, where water backs up in a ponded area and point source inflows from adjacent areas impact on local water quality.

Without data, the fitness of this waterbody for intermediate contact recreational use cannot be commented on. It is however recommended (as previously in Day et al (2023)), that the CCT create an additional routine monitoring point within the Khayelitsha Wetland Park in the reaches utilised by the canoe club, to provide some input into health risks imposed at different times by exposure to polluted waters.

6.8 Key take-away points

- ***Escherichia coli*** data suggest that all of the CCT's recreational water bodies periodically posed risks to human health during the 2023 reporting period, but were largely in an Acceptable condition, conducive to their recreational use;
    - Milnerton Lagoon was mostly in an Unacceptable condition, and its use for recreation would have posed likely risks to human health most of the time.
    - Data for the standing water vleis (i.e. excluding Milnerton Lagoon), generally showed much lower *E. coli* concentrations than in (or near to) in-flowing waters, highlighting the effect of extended detention time, associated exposure to sunlight, and dilution within a larger water body, on *E. coli* counts;
    - Sample points in Milnerton Lagoon were all rated as Unacceptable, with the main sources of raw sewage assumed to stem from the catchment between Blaauwberg Bridge and Otto DU Plessis Drive, including overflows from the Koeberg and other sewage pump stations, overflows from the Potsdam WWTW, and inflows of polluted stormwater from poorly serviced informal settlements, unmanaged urban areas (e.g. Phoenix and Jo Slovo Park) and backyard dwellings;
- All five of the City's recreational water bodies have been impacted by high levels of phosphate enrichment, likely to promote high levels of plant productivity, which in some cases result in **algal blooms**, some of which are associated with **microcystin toxins**;
    - Although blue-green algal blooms were clearly present on numerous occasions over the 2022 and 2023 reporting periods, the only vlei in which microcystin toxins were recorded at concentrations of concern was Zeekoevlei;
    - This means that, excluding Zeekoevlei's waters, and despite periodic blue-green algal blooms,

[12] Comment From Mr Siya Sopangisa (Khayelitsha Canoe Club) to Liz Day

Cape Town's recreational watercourses were assumed to be relatively safe for human use over the 2022 and 2023 reporting periods, from the perspective of exposure during intermediate contact use to microcystin toxins in water from these systems.

  - Of all of the City's recreational vleis, **Zeekoevlei** was most affected by algal blooms over the 2022 and 2023 reporting periods, reflecting ongoing nutrient enrichment of this vlei from external sources, exacerbated by the build-up of organic sediments within the vlei, which provide an ongoing source of additional phosphate nutrients, facilitated by low dissolved oxygen availability.

- Not included in the assessed recreational water bodies, by reason of a lack of water quality data, is a backwater area of the Kuils River in Khayelitsha, from where the **Khayelitsha Canoe Club** operates. The club's operations are hampered by ongoing land invasion into the wetland park as well as by invasion of open water bodies by water hyacinth, and poor water quality. This report recommends that the CCT create an additional routine monitoring point in the reaches of the Kuils River that are utilised by the canoe club, to provide some input into health risks imposed at different times by exposure to polluted waters.

7 CITY PROGRAMMES TO IMPROVE WATER QUALITY

7.1 Background

The CCT's 2020 water strategy commits the City to transition to a water-sensitive city by 2040 with diverse water resources and water infrastructure, making optimal use of stormwater and urban waterways for flood control, aquifer recharge, water reuse and recreation, according to sound ecological principles. It stated that this would be done through new incentives and regulatory mechanisms, as well as through the way the City invests in new infrastructure.

The overarching vision is that Cape Town will become a city that optimises and integrates the management of water resources to improve resilience, competitiveness, and liveability for the prosperity of its people. Achieving the vision will require a shift to water-sensitive urban design that encompasses all aspects of integrated urban water cycle management, including water supply, sewerage, and stormwater management, as well as protecting natural ecosystems.

Achieving and maintaining water quality that is fit for use is a critical part of achieving the CCT's vision, where "users" include domestic, industrial, agricultural and ecological uses, managed in a sustainable manner. Addressing the severe pollution that characterises many of Cape Town's watercourses and improving the ecological functioning and capacity of its watercourses to delivery ecosystem services, are all recognized by the CCT as critical early milestone on its path to a water-sensitive city.

Box 7.1

Cape Town as a Ramsar Wetland City

In 2022, the City of Cape Town became South Africa's first city to be accredited as a Ramsar Wetland City. This voluntary accreditation scheme was approved in 2015 at COP12, where Contracting Parties were invited to propose cities that are located close to Ramsar Sites or other significant wetlands for accreditation, providing they met specific criteria. The scheme was conceptualised in recognition of the importance of urban wetlands and the fact that more than 50% of the Earth's population now resides in cities, towns and urban settlements. It was developed to encourage cities to highlight and strengthen a positive relationship with wetlands through increased public awareness and participation in municipal planning and decision-making. It also promotes the conservation and wise use of wetlands, as well as sustainable socio-economic benefits for local people. The first batch of 18 Wetland Cities were recognised at COP13 in 2018, with another 25 recognised at COP14 in 2022.

Cape Town's status as a Ramsar City is in support of the False Bay Nature Reserve, located within the City's Zeekoe catchment, and designated in 2015 as South Africa's 22nd Wetland of International Importance under the Ramsar Convention.

7.2 The CCT's Water Quality Improvement Programme

In 2020, the CCT's Water and Sanitation Department (W&SD) developed a city-wide Water Quality Improvement Programme (WQIP), as a strategic intervention to allow integration of short-term priority responses to water quality problems, with a medium- and long-term programme, with the overall objective of progressively improving water quality in the City's rivers and water bodies.

The WQIP comprises a series of **Pollution Abatement Strategies & Action Plans** (PASAPs) that set out strategies to address pollution and poor water quality on a river catchment or sub-catchment basis. The PASAPs include detailed **Transversal Action Plans** (TAPs), which are supposed to outline short- to long-term interventions and projects across various directorates and work streams, aimed at achieving the PASAP objectives.

Development of the TAPs requires a clear understanding of the causes of pollution; relative significance of different pollution sources; the anticipated effects of planned interventions; and the costs and timeframes. They thus need to be compiled by Task Teams made up of key role players within the targeted catchments or sub-catchments. The TAPs include aspects such as monitoring of capital improvements at WWTW plants, infrastructure audits, improved sewer spill response times, pro-active maintenance of sewage infrastructure, river maintenance programme implementation, litter-boom, and river warden project partnerships, as well as engagement with catchment forums and other interest groups.

The WQIP has since been incorporated into and indeed underpins the Mayor's Priority Programme (MPP) on

Sanitation and Inland Water Quality, which was developed in 2022. Reporting on progress in the development and implementation of the PASAPs and their associated TAPs in different sub-catchments at the time of this report is thus included in Section 7.3.

7.3 The Mayor's Priority Programme on Sanitation and Inland Water Quality

7.3.1 Background

The Mayor's Priority Programme on Sanitation and Inland Water Quality (referred to in this report as the MMP, although it is noted that it in fact forms one of five other MPPs identified by the Executive Mayor and City Manager (see Box 7.1). The MPP under consideration here was developed against a backdrop of ongoing and increasing pollution of many of the City's watercourses; closure of three of the City's recreational vleis over several months of 2021 and 2022 as a result of extended suspected and/or actual pollution with raw sewage; poor public access to, and trust in, water quality data from the SSB; and a number of major pollution episodes, resulting in several Directives being issued to the CCT by the Western Cape's Department of Environmental Affairs and Development Planning (DEADP), in response to pollution of watercourses.

Box 7.2

Mayoral Priority Programmes

The Executive Mayor and City Manager have identified five priority programmes where additional resources have been allocated to ensure that progress is made during the current term of office. These five areas are broadly: sanitation, energy, land release, safety, and ease of doing business (City of Cape Town 2022).

The MPP was developed as a strategic programme, aimed at improving urban sanitation generally and through this and various other interventions, improving the quality and ecological condition of the City's inland watercourses. The WQIP and its associated PASAPs were integrated into the MPP as one of its five work streams (WS4 – Pollution of waterways).

The five work streams making up the MPP are shown in **Figure 7.1**, which lists sub-programmes under each work stream. Their effective and timeous implementation should allow the MPP to improve the quality of life of Cape Town's residents, reduce the impact of sewage spills and wastewater effluent on the environment, and improve reliability of infrastructure.

At the time of writing this report, a sixth work stream had been added to the MPP, dealing with solid waste management, although the sub-programmes under this work stream had not yet been defined. Given that solid waste is one of the most pervasive issues driving poor water quality, poor sanitation in urban slums and informal settlements, and blocking sewers, pump stations and stormwater systems, this addition to the MPP is strongly supported.

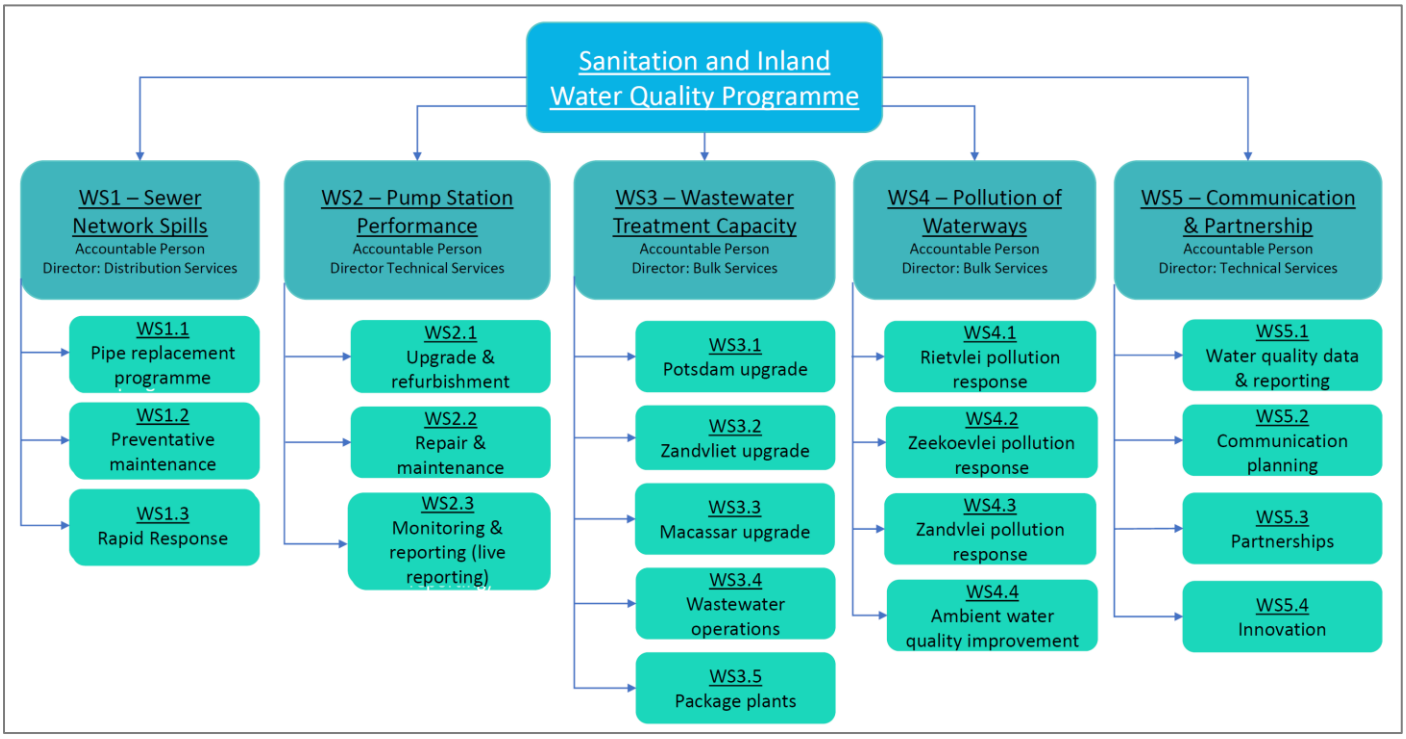


Figure 7.1
The Mayor's Priority Programme (MPP) on Sanitation and Inland Water Quality is structured around five Work Streams, each comprised of a number of sub-programmes.

7.3.2 The MPP work streams

More detail on the MPP's five Work Streams and their aims and focal areas is provided below.

- **Sewer Network Spills**: This Work Stream aims to reduce the frequency, duration, and impact of sewer network spills through preventative maintenance and a pipe replacement programme, as well as faster response in addressing such spills. Preventative maintenance involves pro-active cleaning of critical sewer networks, together with regular cleaning of pump station wet wells to reduce overflows. In addition, investigations to identify illegal connections between sewer and stormwater systems will be conducted to prevent both stormwater ingress into the sewer system and illegal discharge of sewage into the stormwater system.
- **Pump Station Performance**: This Work Stream will improve reliability and performance of pump stations, which have electrical-mechanical equipment that is subject to wear and tear, requires ongoing maintenance and has a life span limited to 10 to 15 years. The aim is to reduce the frequency and duration of spills from pump stations, and hence their impact on the environment and on the recreational use of Rietvlei, Zandvlei and Zeekoevlei. Apart from strategic interventions involving upgrades, refurbishment, repairs and maintenance, the Work Stream has a monitoring and reporting component that will improve near real-time monitoring via telemetry systems and a manned operational control room;
- **Wastewater Treatment Capacity**: This Work Stream will increase the capacity of the three WWTWs (Potsdam, Zandvliet and Macassar WWTW) currently constraining development in their respective catchment areas and will also bolster training for operators at all WWTWs. This should improve the overall quality of treated wastewater and reduce operational incidents that result in poor effluent quality. Furthermore, the viability of package plants in addressing capacity constraints will be investigated to provide guidance to the CCT on how to manage decentralised wastewater treatment to enable development.
- **Pollution of Waterways**: This Work Stream deals with addressing the causes of pollution of Cape Town's rivers and vleis, as well as short- and longer-term remediation measures to ensure that the vleis are managed and maintained in a healthy ecological state. The overall objective is to improve water quality

in the City's catchments and ensure that Rietvlei, Zandvlei and Zeekoevlei remain open for recreational use. The Kader Asmal Integrated Catchment Programme (a job creation and skills development programme) will be scaled up, and since it includes the appointment of river wardens, visibility on the river corridors will improve. Strategic interventions include canal and weir upgrades, deployment of litter booms, vlei dredging and weed removal, and review of estuary management plans, among others.

The WQIP underpinning this work stream focuses on six priority sub-catchments that have been identified as having significant water quality challenges, namely the Diep, Soet, Lower Salt, Eerste/Kuils, Hout Bay and the Big and Little Lotus River sub-catchments.

The Sand sub-catchment has been added to these priority sub-catchments, because of the high ecological and recreational value of the Zandvlei Estuary, and the promise the catchment is showing in improving watercourse condition, through management interventions (Day et al 2023).

- **Communication and Partnerships**: This Work Stream will facilitate the development and implementation of a programme to effectively communicate and partner with residents on issues related to environment pollution, including water quality, the causes of poor water quality, and community actions to improve water quality outcomes. Learning initiatives will be implemented and innovation supported to raise awareness within communities and to formulate solutions for pollution problems, including those emanating from diffuse sources. These activities will support a shift in communications by the City, with a focus on openness, acknowledgment of challenges and shortfalls in City operations, and the promotion of community stewardship. Existing forums and groups, such as Protected Area Advisory Committees, Friends groups and ratepayers associations, will be engaged with, and catchment forums established for the Sand, Zeekoe and Diep catchments.

7.3.3 Progress in the MPP work stream to date

The previous Inland Water Quality Report (Day et al 2023) described the MPP work streams and their aims and planned interventions, but the report was compiled too soon after the commencement of the MPP for useful reporting on its implementation.

Detailed quantification and costing of all of the measures that have been introduced and are being undertaken as part of the MPP at present lies beyond the scope of this report, and progress in each sub-programme is in any case reported on separately within the CCT's mayoral programmes. This section does however seek to list some of the areas where implementation of parts of the MPP appears to have made progress. Information provided in this section has been drawn largely from information provided by CCT officials from the CSRM, including discussions with the managers and their on-the-ground teams from the CCT's four Stormwater Planning Regions; discussions with other CSRM and Bulk Water Services officials, acknowledged in **Section 1.9;** and from presentations by various CCT officials to the CCT's Section 80 Committee on Water Quality and Wetlands and to the Section 79 Portfolio Committee - Spatial Planning and Environment (e.g. McDonald 2024 and Gerrans 2022 respectively).

Budgetary constraints are clearly a major consideration in achieving the combined goals of this MPP, with Killick (2024) noting the competing funding demands of the following programmes, at a time when the CCT is experiencing significant financial stress as a result of National Treasury budget cuts:

- The CCT's new Water Programme
- Refurbishment of existing Water Treatment Plants (WTPS)
- Sewage pump station upgrades
- Sewer network replacements
- Wastewater upgrades and capacity increases.

Subsequent City-wide budget cuts in early 2024 will exacerbate budget issues and are likely to impact on the delivery of many aspects of this MPP.

Killick (2024) notes however that, with regard to budget cuts in the WWTW:

- Budgets for key MPP projects (sewer pipe replacement and expansion) will be maintained;

- Budgets for critical pump station upgrades will remain untouched;
- Budgets for the Faure New Water Scheme (FNWS) and Cape Flats WWTW upgrades and proposed Biosolids Beneficiation Facilities have been moved to operating budgets and will be implemented as a Public/Private Partnership.

The main workstream sub-programmes and the key interventions that have been implemented to date are summarized in **Table 7.2**. Progress in implementation of these interventions is explored in Section 8 for each of the CCT's priority sub-catchments.

Table 7.2
Mayor's priority programme on sanitation and inland water quality. summary of main workstream sub-programmes and associated interventions that have been implemented by the CCT since its commencement in 2022.

Work stream focal area and sub-programmes	Progress	Additional comments and recommendations, drawn from project team experience and, mainly, from discussions with CCT officials including Stormwater Planning Region managers
WS1: Sewer Network spills		
Pipe replacement	Gerrans (2022) noted that a progressive increase of the replacement target to 100km/year over the next 2 years was proposed	Budget cuts (as of January 2024) may impact on the CCT's capacity to achieve its goals regarding pipe replacement and preventative maintenance
Preventative maintenance	Preventative maintenance of the sewer network is performed by cleaning sediment from the reticulation system proactively	
Rapid response	Sewer Incident Response Protocols (SIRP) have been developed – a generic SIRP is applicable for all incidents but individual ones are being developed for particularly problematic pump stations – e.g. the Raapkraal pump station SIRP (Sand sub-catchment) and the coastal sewage spill response protocol (see Colenbrander 2023)	Critical pump stations (those within or near sensitive areas and those prone to failure and still feeding ultimately into ecologically sensitive areas or those with high risk of human exposure to sewage) should be identified and SIRPs for identified critical pump stations and sewer lines should be prioritised – with time lines for their completion
WS2:Pump station performance		
Upgrade and Refurbishment	Seven pump stations identified for complete upgrade with budgets allocated (Gerrans 2022) Budget allocated for electrical, mechanical and security upgrades	Security costs are high CCT has committed to provision of generators or invertors at all pump stations – progress in this endeavour is not known and theft and vandalism remain major challenges, with provision of security being an increasing cost
Repairs and Maintenance	Gerrans (2022) noted that: • Various tender processes have been initiated to facilitate maintenance outsourcing, spares and equipment procurement; • Fleet acquisitions are required to deal with spills more efficiently with faster response times.	Data presented in Section 5.6.3 of this report show that pump station pump tripping and other electrical and mechanical failures accounted for 63% of sewage spills from pump stations in the 2022 reporting period. This suggests that there should be a strong focus on pro-active repairs and maintenance. Stormwater Planning Region managers note

Work stream focal area and sub-programmes	Progress	Additional comments and recommendations, drawn from project team experience and, mainly, from discussions with CCT officials including Stormwater Planning Region managers
	• Maintenance tracking is required	that in many areas, there are numerous pump station failures and poor reporting on these failures. This said, the CCT is now collating reporting data on pump station failures, locations, reasons for and magnitude of spills. Issues such as poor screening design (single screens only, which allow passage of solid waste into wet wells during maintenance periods) should be addressed. Procurement issues and limited pumps able to deal with overflowing pump stations (e.g. Koeberg pump station) and limited storage capacity for overflowed sewage from most pump stations remain serious impediments.
Monitoring and Reporting (Near Real Time)	Gerrans (2022) notes the need for an audit of existing telemetry related to PSs, the implementation of a peering agreement allowing telemetry data to be remotely accessible, the development of a PS performance dashboard and the implementation of a 24/7 control room monitoring PS performance and failures.	These interventions should be prioritised for critical pump stations (those within or near sensitive areas and those prone to failure and still feeding ultimately into ecologically sensitive areas or those with high risk of human exposure to sewage). Provision of expanded overflow capacity (above ground or sub-surface) should be explored for all critical pump stations. Stormwater Planning Region managers report poor telemetry across numerous pump stations.
WS3: Waste water treatment capacity		
Upgrading of Wastewater Treatment Works: Potsdam WWTW Zandvliet WWTW Macassar WWTW	Commencement of Potsdam WWTW upgrades in 2023 Completion and handover of Zandvliet WWTW upgrade in March 2023. Design and tender documents completed. Both Civil and Mechanical / Electrical Tenders to be advertised in March 2024 (Killick 2024)	WWTW upgrades are large and capital intensive and can take up to a decade or more (comment from Mr M. Killick, CCT: Director: Bulk Services - Water and Sanitation Directorate) Appeals on tender awards add additional delays (e.g. Potsdam WWTW)
Wastewater Operations	Commissioning of a WWTW *Status quo* / Strategic Evaluation Study: Killick (2024) noted that the study was commissioned by the CCT in June 2023 for all 26 WWTWs. The study/studies will provide recommendations for the following:	Killick (2024) notes that operations at WWTWs are particularly challenged by: - Load-shedding (Section - Historical underinvestment in WwTWs - Ingress into sewer networks – large volumes unaccounted-for

Work stream focal area and sub-programmes	Progress	Additional comments and recommendations, drawn from project team experience and, mainly, from discussions with CCT officials including Stormwater Planning Region managers
	Phase 1: *Status quo* of WWTWs Phase 2: Future Planning Phase 3: Licensing and Green Drop considerations and requirements Phases 1 & 2 are currently underway, with expected completion by end of June 2024. Phase 3 will start upon completion of Phases 1 and 2.	- Sewer mis-use, with large objects in sewers causing damage at WWTW inlets - Illegal discharges or dumped waste into sewers that either overwhelms screens / grit removal infrastructure or poisons the biology that effects the treatment process - The corrosive environment of the WWTWs - Liquid waste streams generated by informal settlements that need to be accounted for in plant upgrade programmes (This is being investigated by the CCT for the Lower Diep Sub-catchment: Dunoon/Doornbach areas). The present Inland Water Quality Report suggests that prioritisation of WWTW upgrades should also consider the level of ecological degradation and human health risk to downstream receiving environments – Section 5.6.2 of this report noted that WWTWs discharging into natural or semi-natural rivers, floodplains and estuaries should be accorded priority for upgrades that would improve water quality and (for naturally seasonal systems) allow for increased effluent re-use, to retain seasonal hydroperiod – such rivers (with WWTWs) comprise the Mosselbank River and its tributaries; the Diep River; the Kuils and Eerste Rivers; and the Sout River.
	Commissioning of a Waste Water Sludge Strategy Study to review W&SD's future regionalised sludge treatment and disposal approach. The study was commissioned early 2023 and completed February 2024. Its overall objective was to review future regionalised sludge treatment and disposal approach embarked on by the WW Branch in 2010:	Killick (2024) reported that the sludge study concluded that: - There was confirmation that the 'future' wastewater sludge strategy embarked on in 2010 by the (then) WW Branch (three regionalised Biosolids Beneficiation Facilities with anaerobic digestion, nutrient recovery and onsite electricity generation utilising biogas and disposal of digestate to land) is still the most feasible way forward for CCT's wastewater sludge treatment and disposal - - Historical and current delays in implementing the first regionalised biosolids beneficiation facility pose a risk regarding CCT's future Provincial and National regulations and legislation - The CCT should consider (among other

Work stream focal area and sub-programmes	Progress	Additional comments and recommendations, drawn from project team experience and, mainly, from discussions with CCT officials including Stormwater Planning Region managers
		recommendations) Public /Private Partnerships for regional facilities, however with reduced financial responsibility for the Private entity
Package WWT Plants	A Standard Operating Procedure has been developed and approved by the CCT	This Inland Water Quality study recommends that the use of Package WWT Plants be limited to watercourses that are already impacted by WWTW effluent or major discharges from informal settlements, and should not be considered in any development where discharge would be into rivers not yet impacted as such, also noting that although summer irrigation of landscaped areas may be away of disposing of effluent beneficially, the same is not true of winter (wet season) discharges.
WS4: Pollution of waterways		
Response to DEADP Directives regarding pollution of Rietvlei and Milnerton Lagoon, Zeekoevlei and Zandvlei	Assessment and rehabilitation plans were compiled to address the Zeekoevlei. Milnerton Lagoon, Rietvlei and Zandvlei Directives (Day et al 2022a and b); Rose et al (2023); Day et al 2023; Rose et al 2022)	Note that until upstream pollution sources of all of these vleis have been addressed, the responses to the DEADP Directives will achieve short-term remediation only (see Day et al 2022 and Rose et al 2023).
	Following the above: Budget was allocated for: Zandvlei - Zandvlei mouth caisson wall refurbishment and the Langevlei and Sand River canal upgrades (through the Liveable Urban Waterways Programme – see **Section 7.4**) Zeekoevlei - Lowering of the Zeekoevlei weir and fish ladder including EIA and WULA (this project is currently in it is detailed design phase, with construction provisionally planned for September 2025 ending EIA outcomes) Remediation plans for the vleis, including bathymetric surveys and recommendations for/ specifications around dredging of Rietvlei, Zandvlei and Zeekoevlei. Dredging of Zeekoevlei has been recommended and authorized by DWS; the EIA has been submitted for authorisation consideration. Dredging of Milnerton Lagoon was recommended as a temporary response	

Work stream focal area and sub-programmes	Progress	Additional comments and recommendations, drawn from project team experience and, mainly, from discussions with CCT officials including Stormwater Planning Region managers
	to high levels of pollution and anaerobic conditions creating noxious smells in the lagoon – budget cuts in early 2024 suggest that this dredging is unlikely to go ahead. A trial aeration project in the lagoon commenced in late 2023, as a short-term measure to treat odour problems. New weed harvesters were purchased for Zandvlei and Rietvlei to control aquatic weeds	
Ambient Water Quality Improvement Plan	Pollution Abatement Strategies and Action Plans (PASAPs) planned for the selected six priority catchments (Gerrans 2022). To date, PASAPs and TAPs have been compiled for: • The Hout Bay catchment (2023) • The Diep River (as part of the Diep River Estuary Management Plan) and the Soet River (both of these in response to Directives from the DEADP) • The Sand River sub-catchment(draft PASAP only, not available at the time of this study) • Draft Lower Salt and Zeekoe PASAPs - not available at the time of this study). A study on the Erica Road Outlet (Diep River catchment) – this study recommended (and has subsequently been implemented) diversion of polluted low-flows upstream of the Erica Road outlet, so as to pass them into the mains sewer upstream of Otto Du Plessis Drive / R27. Detailed designs have also been developed for the diversion of polluted low flows further upstream at the Milky Way pump station The following studies are required to inform planning: 1. A Low Flow diversion study across the City - Progress reported to date comprises. - Professional Service Provider's proposal to be reviewed - Phase 1B to commence in FY23/24 – subject to budget availability.	Roll-out of PASAPs and associated TAPs has been slow and should be accelerated. PASAP and TAP implementation is hampered by the complexity of implementing environments, involving multiple departments and directorates (affected assets variously belong to/ are managed by CSRM, Sewage Reticulation, Solid Waste, Human Settlements, Biodiversity, Parks and Recreation etc.) Stormwater Planning Region managers reported that issues such as crime, vandalism, extortion and highly polluted unsafe watercourses also hinder the effective implementation of TAPs, which is further hampered by a culture of unaccountability in some CCT departments.

Work stream focal area and sub-programmes	Progress	Additional comments and recommendations, drawn from project team experience and, mainly, from discussions with CCT officials including Stormwater Planning Region managers
	2. Identification of storm water infrastructure (e.g. ponds, dams, etc.) and floodplains impacted by encroachment of informal settlements. Progress reported to date comprises. - Professional Service Provider's proposal to be reviewed - Phase 1B to commence in FY23/24 – subject to budget availability - Determine next steps through consultation with stakeholders and role-players. 3. Development of Standard Operating Procedures (SOPs) for the opening and closing of recreational vleis – this SOP was approved in 2023. 4. Development of the River Warden Programme Some 204 job opportunities have been created since 2022, allowing for the housing of river wardens at Rietvlei, Zandvlei and False Bay Nature Reserves. The primary objective of the River Warden Programme is to enhance ecosystem health in the City's catchment areas, championing the eradication of invasive plant species, rehabilitation activities along our waterways, and litter collection and removal	
WS5: Communication and partnership		
Inland Water Quality Data & Reporting	Water quality data for inland watercourses is published regularly on the City's data portal and is publicly accessible.	In addition, annual to two-yearly water quality reports are produced (e.g. this project). Water quality data that are important for decision-making and gauging watercourse trajectory are however frequently unreliable, missing or have too high a detection level to be useful. Such issues must be addressed with urgency (see **Section 9**)
Partnerships.	A Section 80 Advisory Committee for Water Quality in Wetlands and waterways has been established. Existing forums such as Protected Area Advisory Committees (PAACs) for the Table Bay, Zandvlei and False Bay nature	These initiatives are fully supported – provided that input from these forums and committees is both sought when necessary and considered when provided.

Work stream focal area and sub-programmes	Progress	Additional comments and recommendations, drawn from project team experience and, mainly, from discussions with CCT officials including Stormwater Planning Region managers
	reserves and site liaison committees for sensitive wetland/vleis/lagoons are liaised with on an ongoing basis The Sand River Catchment Management Forum was established in 2023 The Hout Bay Rivers Catchment Forum was established in 2016 and has been growing since then. C40 CFF funding has been sourced to drive development of recommendations for terms of reference and mandates for the planned Zeekoe Catchment Management Forum, and this project outcomes will be used to drive the formation of other Catchment Management Forums. Project in progress.	
Learning and innovation.	The presentation of Gerrans (2022) stated that "a 'Cape Town Water Exchange' with 'Leading Utilities of the World' network has been established, and regular knowledge exchanges with leading utilities internationally are happening." and "Design-led thinking processes/ workshops will be utilised to identify possible innovative solutions to deal with diffuse pollution sources" Funding for Green Infrastructure planning has been provided by the C40 Cities Finance Facility (CFF) through the Liveable Urban Waterways Programme (see Section 7.4) (project commenced in 2023)	These initiatives are fully supported and if engaged with thoughtfully, will add to the knowledge-base and capacity for informed decision-making by the CCT

7.4 The Liveable Urban Waterways Programme

7.4.1 Background

The Liveable Urban Waterways (LUW) Programme is a strategic and transversal programme developed by the CCT in response to the Water Strategy, Resilience Strategy and Environment Strategy. The programme aims to demonstrate how water sensitive design, waterway rehabilitation and a new approach to waterway management can achieve multiple benefits for society, the environment, and the economy (McDonald 2024).

Implicit in the LUW approach is the concept of roll-out of projects at scale, to achieve measurable impacts at a catchment scale.

Seven core principles are intended to guide the LUW Programme and its individual projects:

- Collaboration and partnering
- Identification of waterways as connectors and catalysts
- Designing with nature
- Designing for many users
- Building in resilience
- Designing for attractive and usable public places
- Allowing for post project care and maintenance.

What is a liveable waterway ?

In the LUW Programme, it

1. Has acceptable water quality
2. Makes space for the water
3. Has a functioning ecology
4. Connects the waterway to the water table and the floodplain
5. Connects communities; and used and enjoyed by communities
6. Provides a range of ecosystem services, economic and social benefits.

The pilot phase of the LUW Programme focused on the Sand River catchment, where several project sites, divided into five work packages, were identified. These projects are intended to be used to test different rehabilitation typologies and water sensitive design approaches, to develop and foster cross-departmental collaboration and planning within the CCT, and to co-design appropriate solutions with communities who live near the waterways or who use the space. Additional projects are included in the Lower Salt Sub-catchment (Vygekraal River) and the Soet Sub-catchment (Asanda Wetland).

Following multidisciplinary specialist input into concept designs and a series of stakeholder engagements including a number of well-attended stakeholder co-design workshops (reported on in Day et al 2023), detailed project design and planning followed, in the current 2022-2023 reporting period.

The project designs all include some degree of river channel and bank reshaping, management of bed and bank erosion, creation of new wetlands and riparian habitats, enhancing public open space, and installing new amenity facilities. Some improvement in water quality might be envisaged as a result- the degree to which this would be measurable would depend on the magnitude of intervention and the level of water quality impairment.

7.4.2 Planned LUW projects

7.4.2.1 Sand River Catchment projects

Planned projects in this catchment comprise

- **Sand and Langevlei Canals**: At the confluence of the Sand and Langevlei Canals, sections of concrete canal will be broken out and a wetland created for the treatment of stormwater before it enters Zandvlei. New litter- and sediment-traps will be installed upstream of the wetland, and laterite pathways and seating areas established alongside the waterway to encourage recreational use;
- **Keysers River**: One project focuses on a narrow corridor where the river flows through the Steenberg industrial area, and a second on a drainage channel behind the Blue Route Mall. In both projects, steep embankments will be reshaped and planted with low-growing wetland species, and recreational nodes with pathways, bridges and seating areas created to provide lunch-break areas for factory workers and shop assistants.

- **Westlake River**: The Westlake River Upper project seeks to upgrade the walkway and pedestrian bridge that provide access around an extensive reedbed between Westlake Village and the nearby shopping centre, and to establish a variety of recreational and 'outdoor classroom' facilities. The Westlake Lower project focuses on the Kirstenhof greenbelt, where the existing pathways will be upgraded, and the wetland areas rehabilitated to provide an increased range of wetland habitat types and improved stormwater treatment;
- **Spaanschemat and Prinskasteel River**: This work package comprises three project sites within the Constantia–Tokai greenbelt along the Spaanschemat River, including the Silverhurst Trail and Sillery in the upper reaches, the confluence with the Grootboschkloof River, and the confluence with the Prinkasteel River further downstream. The interventions at all three sites will primarily focus on river and wetland rehabilitation, with upgrading of pathways and bridges where appropriate;
- **Grootboschkloof River**: One project focuses on the river reach on both sides of Nova Constantia Road, where the river flows through dense reedbeds within a grassed corridor. The rehabilitation work will include the installation of a sediment trap, weirs, and swales, while recreational use will be encouraged by providing pedestrian movement routes along both banks. The second project further downstream, within the well-used Grootboschkloof River Walk greenbelt below Spaanschemat Road, will include installation of gabion weirs to reduce erosion and re-wet the surrounding wetland, among other interventions. A new multi-use pathway will be constructed in the uppermost 'paddocks' area, and other pathways upgraded where needed.

7.4.2.2 Nantes Park: Lower Salt River Sub-catchment projects

This sub-catchment includes a planned LUW project on the Vygekraal River, where it flows through Nantes Park (see Figure 7.3). The project will include

Rehabilitation of the river corridor between Jakes Gerwel Drive and the Athlone WWTW: creation of new wetland and instream habitat, naturalisation of channel embankments, repairing erosion, removing sediments and invasive plants, planting indigenous vegetation and trees, installing new footpaths, seating, lighting and informational signage, replacing footbridges, integrating the river corridor into the surrounding urban form, particularly at nodal points by roads and crossings and through Nantes Park (Mc Donald 2024).



Photo 7.1
Nantes Park – site for planned LUW project on the Vygekraal River.
Photo from McDonald (2024)

7.4.2.3 Zeekoe Sub-catchment and Diep (Sand Sub-catchment projects

These projects, which focus on the identification of opportunities for future projects were carried out with funding of approximately R10 million by the C40 Cities Finance Facility (CFF) for the CCT's 'Green Infrastructure Options for Improved Waterway and Catchment Management Project'. The projects focus on the Zeekoe Catchment (upstream of Zeekoevlei) as well as the Diep (South Peninsula)[13] section of the Sand catchment.

What is Green Infrastructure?

Green infrastructure can be defined as a strategically planned, designed and managed network of multifunctional natural open spaces and 'engineered' ecological systems, with other environmental features, that provide ecological, community and infrastructure services.

The projects will develop masterplans for implementing waterway rehabilitation, green infrastructure (GI) and

[13] Note that this river is not the main stem Diep River entering Milnerton Lagoon – this Diep River forms part of the Sand River catchment and rises on the Constantiaberg mountain range.

nature-based solutions (NbS) through the LUW Programme and the CCT's Green Infrastructure Programme. They include a number of technical studies (completed in early 2024), which were conducted to inform a climate change vulnerability and ecosystem goods and services assessment (due in mid-2024).

The GI and NbS interventions will then be designed to provide adaptation to the anticipated climate change impacts (such as flooding and deteriorated water quality), while improving the ecological status and functioning of waterways, where possible, and providing additional socio-economic benefits.

The Diep (South) study area focuses on the Diep (South) River and its minor tributaries, Wynberg Stream, Mocke River, Little Princessvlei, Sand River Canal, Langevlei and Langevlei Canal, while the Zeekoe study area includes the Big Lotus River, Little Lotus River, and Woodland Canal. The wetlands and open spaces of all these waterway corridors are also an integral part of the study.

7.4.3 Progress in LUW Project implementation

7.4.3.1 Asanda Wetland Park: Soet / Sir Lowry's Pass River Sub-catchment

This LUW project in fact commenced prior to the start of the LUW Programme but has since been incorporated into the programme. It comprises the rehabilitation of the Asanda Wetland and development of the Asanda Village Wetland Park. This is a 5 ha public open space and wetland that forms part of a pedestrian route between the N2 freeway, three adjacent schools and the surrounding residential areas of Asanda Village, Nomzamo and Lwandle. In 2015 the site was identified as a space with rehabilitation potential. A co-design workshop was hosted with various stakeholders to assist the City with the conceptual design for the wetland park. In 2019, and a multi-disciplinary team was appointed to do the detailed designs and implementation. Construction was completed in June 2023 (**Photos 7.2 and 7.3**). The space has been transformed with a rehabilitated and ecologically functioning wetland area, a stormwater system that can handle the upstream catchment flows, a formal non-motorised route through the public open space, hard and soft landscaping upgrades and a multi-use recreational and play areas (after McDonald 2024).



Photo 7.2

Construction of a gabion weir across the Asanda wetland to spread stormwater inflows from upstream stormwater inflows. Earth and rubble fill as well as alien vegetation were removed at the same time



Photo 7.3
Pedestrian walkway over wetland at Asanda Wetland Park

Further establishment of wetland vegetation in disturbed areas and solid waste removal are challenges affecting the success of this LUW project going forwards (Day 2023)

7.4.3.2 Other LUW project progress

Implementation of the Sand and Lower Salt Sub-catchment projects was expected to start in 2024, once internal approval processes and detailed design had been finalised and the required water use, environmental and heritage authorisations from National and Provincial government obtained. This implementation phase lies outside of the current water quality reporting period. However, it is material to this report to note that, in early 2024, budget cuts effected through National Treasury resulted in implementation

of four of the six planned LUW projects being pushed out to the CCT's 2033/2034 financial cycles (Mc Donald 2024). Only the Sand/Langvlei Canal and Vygekraal River projects have been allocated funding for implementation.

The resultant ten year delay means that:

- Effectively, funding used for stakeholder engagement, planning and detailed project design has been wasted, as a ten year project hold will require all aspects to be updated, and stakeholders re-engaged with – a total of R 9,818,816 has been spent on project planning for the four delayed projects in total (data from McDonald 2024);
- The high levels of stakeholder engagement and enthusiasm that have characterized the project planning to date are likely to give rise to similarly high levels of stakeholder disappointment, despondency and cynicism, leading to reduced engagement in future or other LUW projects going forwards;
- Key Performance Indicators for project implementation cannot be met (see **Table 7.3**);
- The key aims of the LUW projects to achieve measurable impacts by rolling out projects at a catchment scale are de-railed, as the two supported projects lie in different catchments and neither is likely, on its own, to achieve measurable improvement in downstream watercourses;
- Low confidence in actual project implementation going forwards is likely to impact on aspects such as plant propagation and nursery development, which are usually required upfront before the commencement of earthworks in rehabilitation projects, and need to adhere to strict timelines to avoid wastage of plants;
- Much-needed employment benefits (e.g. through the River Wardens Programme and in the construction, plant propagation, landscaping and alien clearing industries) will not be realised.

It is strongly recommended that the cut in LUW programme budget should be re-evaluated by the CCT and funds to re-commence with the four halted projects at least should be prioritized, if this programme is to gain the traction that it requires to bring about the change in Cape Town's waterways that is a pre-requisite for the CCT's aims of becoming a water-sensitive city by 2040, in line with its current status as a Ramsar wetland city.

Table 7.3
Rated Key Performance Indicators (KPIs) used to track overall programme progress over the medium to long term (5 to 10 years) - as evaluated in McDonald (2024).

KPI	Baseline	Target	2021/22	2022/23	2023/24	2024/25	2025/26	Status	Notes
Waterways or reaches of waterways made liveable (according to the monitoring framework definitions)	-	3 every 5 years	0	0	1	-	-	Behind target	Capital budget cuts have put a hold on the delivery of implementation ready projects, and until such time as budget is prioritised for projects under the LUW programme then this KPI will not be met.
Percentage of residents surveyed that have used a waterway in the last year	6% (2018 customer perception survey)	2% improvement between surveys (30% by 2030)	6%	6%	-	-	-	Behind target	This indicator reflects progress of more than the LUW programme.
Percentage of residents surveyed that are either very satisfied (excellent) or satisfied (very good) with the state of their nearest waterway	30% (2018 customer perception survey)	2% improvement between surveys (50% by 2030)	30%	19%	-	-	-	Behind target	This indicator reflects progress of more than the LUW programme.
Catchments with project pipeline developed and budget needs identified	Zero (2021)	4 by Dec 2024	0	1	1	-	-	On target	Western sub-catchments of the Sand catchment have a developed project pipeline. Sector planning and study underway (C40 CFF) to develop city wide pipeline.

8 WATER QUALITY IN PRIORITY CATCHMENTS ADDRESSED BY THE CCT'S WATER QUALITY IMPROVEMENT PROGRAMMES

8.1 Context

8.1.1 Overview

The various CCT programmes that have been developed in order to improve water quality and general watercourse condition (see **Section 7**) focus in particular on the six priority sub-catchments already mentioned in **Section 2.6**, as well as the Sand Sub-catchment.

These sub-catchments are considered more holistically in this section, which presents key water quality data for individual monitoring points in each priority sub-catchment, and highlights areas where particular interventions are planned or have been implemented. This allows interested readers to home in on water quality issues in particular parts of each priority sub-catchment. Note however that only key interventions relevant to improving inland water quality are highlighted here.

The priority sub-catchments considered in this section are indicated in **Figure 8.1.1** and comprise the following:

- The Lower Diep River (upstream of Milnerton Lagoon) (Central and Northern Stormwater Management Regions)
- The Sir Lowry's Pass and Soet River (Eastern Stormwater Management Region)
- The Lower Salt River (Northern and Central Stormwater Management Regions)
- The Kuils / Eerste Rivers (Eastern Stormwater Management Region)
- The Hout Bay River (Southern Stormwater Management Region)
- The Big and Little Lotus Rivers (within the Zeekoe catchment) (Southern Stormwater Management Region)
- The Sand catchment (upstream of Zandvlei) (Southern Stormwater Management Region).

8.1.2 Summary of key issues highlighted in discussion with Stormwater Planning Region teams

Input into this section was informed by data and information presented and discussed in previous sections, but more specifically by information gained during on-line discussions with the CSRM's Stormwater Planning Region managers and their teams, from the CCT's four stormwater management regions (see **Section 2.7**).

Although officials from each region were engaged with separately, common threads emerged across all four regions, regarding critical issues impacting on water quality (and the CCT's ability to improve ambient water quality as a result). The most pervasive of these issues comprised the following:

- The most serious issues affecting the water quality of the CCT's rivers and wetlands comprise **solid waste and sewage**, and the passage of the latter into watercourses by way of dry-weather flows from settlements; stormwater flows; sewage pump station overflows; sewer manholes and failed sewer lines. These issues are controlled by other line departments, but catchment managers and their teams are at the receiving end of failed systems, and accountable for polluted watercourses and the ecological and other impacts of this pollution, but are powerless to effect change at source.
- Issues such as repeatedly failing pump stations; pump stations with inadequate capacity for low-flow sewage diversions to sewer; and the years required for upgrades to WWTWs to be carried out, mean that important watercourses (e.g. the lower Diep River and Milnerton Lagoon) are likely to remain direly polluted until at least the upgraded Potsdam WWTW comes on line, and even then will remain severely impacted by pollution from unmanaged informal settlements.
- The Big Lotus River, Zeekoevlei, the Mosselbank River (downstream of Bloekombos settlements) and the lower Kuils / Eerste Rivers and their wetlands are also examples of watercourses at the mercy of expanding, largely unserviced urban informal settlements beyond the mandate or resources of CSRM to manage.
- Issues such as crime, vandalism, extortion and highly polluted, unsafe watercourses also hinder the effective implementation of PASAPs and their TAPs, which is further hampered by a culture of unaccountability in some CCT departments, with critical interventions required for essential sewer and

stormwater maintenance and service delivery simply not taking place in some areas;

- Budget issues (e.g. a recent moratorium on over-time and out-of-hours work) affect response rates to sewage overflows and basic repair and maintenance issues, as well as pollution mitigation measures, such as over-pumping to sewers, which has also been stopped as a result of budgetary constraints;
- The focus of CCT's attention has been on areas for which it has received Directives or Pre-Directives from DEADP for pollution. These tend to be areas with high levels of public or political interest (e.g. Zeekovlei, Milnerton Lagoon), while large areas with extremely high levels of pollution are unmanaged (e.g. Bloekombos, Wallacedene areas of the Mosselbank and Kuils River Sub-catchments respectively).

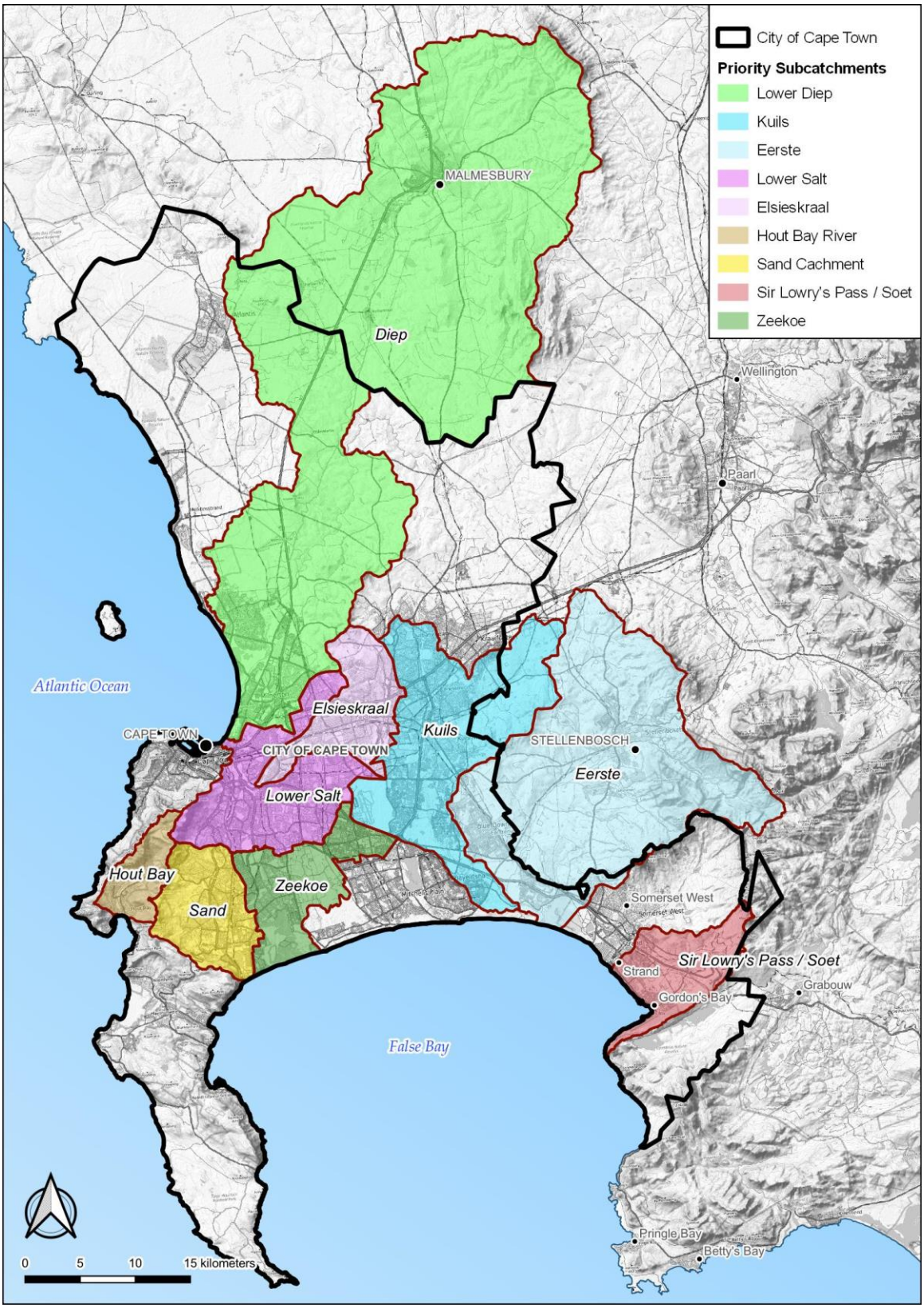


Figure 8.1.1
The CCT's priority sub-catchments

8.2 Diep River sub-catchment

8.2.1 Catchment overview

This priority catchment comprises the Diep River Sub-catchment, from upstream of Milnerton Lagoon. Rehabilitation and remediation of the Lagoon itself is currently being dealt with separately, through other MPP projects (e.g. Rose et al 2023 and a lagoon water aeration project, currently being trialed by CCT to assess its efficacy in short-term odour control). The sub-catchment falls within both the Central and Northern Stormwater Management Regions.

The Diep River catchment extends far north and east of the boundary of the City of Cape Town and includes parts of the Swartland Local Municipality (West Coast District) as well as portions of the Drakenstein and Stellenbosch Municipalities (Cape Winelands District). The Diep River itself rises in the Riebeek Kasteel mountains north of the town of Malmesbury and flows through agricultural areas (mainly vineyards and wheat) before passing through Malmesbury, where it receives treated effluent from the Malmesbury WWTW. Downstream of the town, the river flows through primarily agricultural areas, where its condition is impacted by abstraction from numerous on- and off-channel dams, poor water quality from crops and feed-lots and extensive invasion of its banks by alien vegetation (both eucalyptus and various invasive acacia species) (Rose et al 2023).

The river is joined in the Philadelphia area by its largest tributary, the Mosselbank River, which flows in from the east, rising in the Kraaifontein area of Cape Town and passing through mainly residential and urban / peri-urban areas in its upper reaches and then mainly farms and smallholdings including agricultural feedlots in its lower reaches (ICE 2009). The Mosselbank River is a naturally seasonal, low-nutrient river system that does however now receive perennial effluent inflows from the Kraaifontein and Fisantekraal WWTWs.

Downstream of the Malibongwe Drive / M12 road bridge, the river passes into a burgeoning urban environment. Although formal settlement lies largely outside of the wide 1:100 year floodplain, invasion of the floodplain by informal settlements in the Dunoon area has expanded significantly in the past decade (Rose et al 2023). Most of the informal settlements within the floodplain occur in the area between Malibongwe Drive and the railway bridge and extend well into the floodplains of both the Diep River and its minor tributary, the Kleine Stink River, which enters the Diep River within this zone, passing under Malibongwe Drive some 780 m south east of the Diep River crossing.

Downstream of the Blaauwberg Road bridge, the remnant water bodies and surrounding undeveloped areas form a broad triangle, included as part of the CCT-managed Table Bay Nature Reserve, and comprising reedbeds and extensive saltpans, as well as Rietvlei, which is made up of a (northern) recreational standing water portion and a (southern) bird sanctuary portion. Rietvlei itself is the product of excavation of natural estuarine saltmarsh and sand dune mosaic habitat in the 1970s to provide infill for development of Cape Town Harbour's Duncan Dock area (Brown and Magoba 2009).

Under pre-development conditions, the Diep River is believed to have flowed through these wetlands, out-letting at times into the sea via an estuary mouth in the north, close to today's Dolphin Beach area, as well as from its current position in the south (Scott and Millard 1954). Today however, outside of flood conditions, the Diep River bypasses these wetlands in a diversion channel along the eastern edge of the wetland. This channel receives treated effluent from the Potsdam WWTW as well as stormwater inflows from the Theo Marais channel, just downstream of the WWTW inflows. The channel passes under Theo Marais Drive and enters Milnerton Lagoon. Flows from the diversion canal make up the main source of water from the upstream catchment into the lagoon, outside of flood conditions (Rose et al 2023). Downstream of Otto Du Plessis Drive, various stormwater channels from the eastern catchment also discharge into the lagoon. Of these, the Erica Road outlet is most problematic, as it discharges grey- and black-water, mainly generated in the Jo Slovo settlement, with its high levels of backyard dwellings, the occupants of which often have no alternatives but to discharge sewage and domestic waste into the stormwater system.

While inflows from the Potsdam WWTW result in perennial flows in the lower Diep River today, early literature suggests (e.g. Scott and Millard 1954) that the Diep River and its tributaries were naturally seasonal, with the Diep River and Rietvlei wetlands drying up completely in summer, when the river stopped flowing, around December.

Since then, the hydrological functioning within the catchment has been subject to significant human-induced change. Flows entering the estuary from the upstream catchment are estimated to have been reduced by up to 38% as a result of agricultural abstraction of water (Clark 2018). However, the estuary receives supplementary flows in the form of treated wastewater from the Potsdam WWTW, which currently offset upstream abstraction (Rose et al 2023), although if effluent quality could be managed, the volume of treated effluent that could be sold for industrial, agricultural or other uses is likely to increase significantly.

During the present (2022 and 2023) reporting periods, the catchment was impacted by several major floods, in particular in June and September 2023, resulting in flooding of informal settlements in the floodplain (Dunoon / Doornbach areas) and wash-out of pollutants from flooded areas into the river and downstream estuarine areas.



Photo 8.2.1
Informal settlement in Dunoon on the Diep River floodplain – following June 2023 floods
(Photo: Courtesy Ms C. Marx: "Rethink the Stink")



Photo 8.2.2
Diep River at the railway crossing downstream of Dunoon – standing water only in summer 2022



Photo 8.2.3
Theo Marais channel downstream of inflows from the Koeberg pump station (March 2024)



Photo 8.2.4
Aerial view of Potsdam WWTW, effluent outlet (arrowed) and bypass channel.
(Photo courtesy J. Rose).

8.2.2 Major sources of pollution in the catchment

Major sources of pollution in this priority sub-catchment have been identified (from data presented in Section 5, Rose et al (2023) and Day (2024) as:

- Inflows from the Mosselbank sub-catchment:
    - Treated effluent from three relatively small WWTWs in the upper reaches, including the poorly

performing Klipheuwel WWTW (see Section 5.6);

- Inflows from informal settlements – Bloekombos is located in the upper part of the sub-catchment and there are smaller areas of informality further downstream (e.g. Fisantekraal area);
- Inflows from agricultural feedlots and effluent from various chicken farms in Fisantekraal area

- Inflows from the Diep River upstream of the CCT boundary, receiving runoff from agricultural areas, feedlots and from the Malmesbury WWTW;
- Point-source inflows from within the sub-catchment within the CCT boundary, including:
  - Rapidly growing informal settlements without adequate access to sewage services:
    - Dunoon and Doornbach, from where raw sewage and grey water from domestic use pass into the Kleine Stink River, its floodplain and the Diep River (Day 2024 and Rose et al 2023);
    - Numerous informal settlements and informal backyard dwellings throughout the broader Milnerton urban area, including Phoenix, Jo Slovo, Freedom Park – sewage and greywater is discharged or flows into stormwater systems leading to the Diep River (e.g. the Erica Road discharge);
  - Overflows from pump stations that discharge at times large volumes of raw sewage into the Diep River via stormwater pipes and channels (e.g. the Koeberg pump station that discharges into the Theo Marais channel);
  - Discharges of variously treated effluent from the Potsdam WWTW – data presented in **Section 5.6.2** show that this WWTW accounted for 9% of the CCT's average daily effluent volume in the 2023 reporting year, with effluent that did not comply with general limits for several key variables (e.g. COD and total ammoniacal nitrogen). Poor effluent quality coupled with high volumes mean that the Potsdam WWTW was (and remains) a major, permanent contributor to downstream nutrient loading and chemical oxygen demand, with severe effects on the river and downstream estuary.

    Rose et al (2023) showed that the loading of TSS, total ammonia and COD from the Potsdam WWTW into Milnerton Lagoon by far exceeds polluted inflows from the upstream catchment throughout most of the year. In fact, the Diep River upstream of Blaauwberg Bridge flows as trickle flow to no flow through most of summer. This means that while inflows from Dunoon via direct channels and the Kleine Stink River, which runs through Dunoon, have high concentrations of PO4-P, NH_3, total ammonia and *E. coli*, these tend to dissipate in summer into pools within the floodplain. During winter, they are flushed downstream. Flows from the WWTW, however, pass continually into the diversion channel and thence into the lagoon, or overflow and pass into the Theo Marais channel and thence into the Milnerton Lagoon. They result in permanent loading of the lagoon with high levels of organic sediment and nutrients with high CODs;
  - Solid waste, particularly from areas with high levels of informal and backyard settlement, and often high levels of crime, which affect CCT's service delivery capacity;
  - Illegal discharges from industry and other users into the stormwater system;
  - Stormwater runoff from urban areas, carrying residues from petrol and oil on roads (e.g. various heavy metals and hydrocarbons); solid waste; runoff from fertilized sportsfields and gardens and other contributors to conventional urban stormwater quality (e.g. Kadlec 2020).

It is noted that, of the above sources of pollution in the Diep River Sub-catchment, it is only the last that comprises actual stormwater runoff. The other, major contributors to river and wetland water quality in the sub-catchment are all derived from sewage and solid waste streams, highlighting the complexity and challenges of dealing with water quality by the CSRM.

8.2.3 Water quality through the catchment – condition and trajectory

At the time of writing this report, Milnerton Lagoon (i.e., the Diep River estuary from downstream of the Otto Du Plessis Road bridge) was rated as an estuary in a state of severe ecosystem collapse, attributed primarily to prolonged inflows of water with high Chemical Oxygen Demand, high levels of (mainly organic) suspended sediments and high total ammonia concentrations from the Potsdam WWTW (Rose et al 2023 and see **Section 6**). The impacts of these inflows are compounded by smaller volumes of polluted inflows as described above.

Figures 8.2.1-8.2.4 present summary annual water quality data for phosphate (as PO4-P), dissolved oxygen (DO), free ammonia (NH_3) and *E. coli* data, with actual analyses as outlined in **Section 3.8.10** of this report.

These figures, viewed in conjunction with data already presented in **Sections 5** and **6**, suggest that:

- Water quality entering Milnerton Lagoon was compromised by activities throughout its catchment.
- High levels of summer time abstraction as well as the impacts of alien vegetation along the riparian area reduce natural summer flows in particular, preventing dilution of polluted inflows.
- Total phosphorus (vlei) and orthophosphate phosphorus (rivers and the estuary) concentrations shown in **Figure 8.2.1** show that:
    - River water was phosphate-enriched to Unacceptable (hypertrophic) concentrations even upstream of the CCT boundary, where it is affected by the upstream activities described in Section 8.2.2;
    - Despite median phosphate concentrations lying in the Unacceptable range, some improvement noted, both in the upstream Diep and Mosselbank Rivers, and in sites in the Milnerton Lagoon – large flood flows in the 2023 reporting period (June and September 2023) may have contributed to this impact, by flushing and dilution;
    - Poor quality effluent (with regard to orthophosphates) entered Rietvlei from the Bayside Canal, and contributed to the ongoing hypertrophic condition of this system;
    - Zoarvlei, located south of the estuary outlet (sites PEV1 and PEV2), and discharging into the sea via a pipeline (, also showed high median total phosphorus concentrations, again indicative of hypertrophic conditions with runoff from a highly urbanized industrial area.
- Dissolved oxygen concentrations (DO) (summarized in **Figure 8.2.2**) showed:
    - DO concentrations were generally very low in the upstream Mosselbank Sub-catchment in the upstream Mosselbank River (within the CCT boundary, in the Fisantekraal area) (Unacceptable and Poor), and Poor in the Diep River in the agricultural areas upstream of the Mosselbank confluence;
    - These concentrations improved to the Target range from the Mosselbank confluence, suggesting that, despite elevated orthophosphate phosphorus in the latter, some water quality amelioration takes place with distance downstream of the major urban nutrient sources;
    - DO remained within Target concentrations as far as the start of urban settlements, dropping to Poor with distance through the burgeoning informal settlements of Dunoon and Doornbach (site RTV22);
    - From Blaauwberg Road downstream, DO concentrations fell to Unacceptable at all sampling sites within the diversion channel and in the estuary / Milnerton Lagoon areas downstream of the Otto Du Plessis Drive bridge. These reflect the high COD of this watercourse, with high COD loading from Potsdam creating an untenable demand for oxygen (see **Figure 5.6.5** in **Section 5.6**);
    - Some improvement in median DO concentrations was however apparent in the lower estuary, where median concentrations increased to Poor, and improved to Target at the estuary mouth. These improvements are assumed to reflect observed flushing of the lower estuary during the September 2023 floods, which visibly removed some of the built-up organic sediments in these areas and created an extended period of mouth opening (Mr G. Oelofse, CCT, pers. comm. to Liz

Day, March 2024);

- DO concentrations were Unacceptable in the polluted Zoarvlei, and likely to have impacted on chemical and biological functioning in this aquatic ecosystem, creating conditions that would tend to support only very hardy aquatic organisms;

- Spatial patterns in median annual **free ammonia (NH_3)** concentrations shown in **Figure 8.2.3** suggest that:
  - Ammonia toxicity was unlikely to have been a concern in the upper reaches of the Diep and Mosselbank Rivers outside of urban areas;
  - Significant downstream deterioration is however evident in the data, which indicate both a temporal (deterioration between 2022 and 2023 reporting periods) and a spatial deterioration (Unacceptable in all reaches downstream of the Potsdam WWTW);
  - The above results are not surprising – **Figure 5.6.5** shows high total ammoniacal nitrogen concentrations well above general limits for this variable in Potsdam effluent, resulting in very high downstream loading, which would persist under low dissolved oxygen conditions in the estuary, relative to the chemical and biological oxygen demand of the system. Data in Figure 5.6.5 do indicate some improvement towards the latter part of the 2023 reporting period, as a result of diversion of treated effluent from contaminated maturation ponds;
  - Ammonia toxicity was thus likely in the estuary over extended periods of time – very low oxygen concentrations in the estuary would in any case have exerted severe pressures on any aquatic species reliant on access to dissolved oxygen in estuarine waters over this time;
  - Zoarvlei data suggest that, despite low oxygen and elevated phosphorus concentrations, ammonia toxicity was probably not a factor affecting this waterbody over the current reporting periods – this reflects much lower nitrogen pollutant loads into this system; a longer retention time than in the flowing lagoon; and more effective relative nitrification processes as a result;

- ***Escherichia coli*** data within the CCT's boundary in the Diep Sub-catchment showed that:
  - *E. coli* concentrations in the Diep River at the N7 roadbridge were generally within Target range for this indicator of faecal pollution, but deteriorated to Poor within the reaches upstream of Blaauwberg Road and then deteriorated further to Unacceptable, which levels were sustained downstream and through the Milnerton Lagoon;
  - The data indicate high levels of raw sewage that enter the river from informal and backyard settlements, via the Kleine Stink River past Dunoon and Doornbach settlements, and from Jo Slovo and other similar settlements in this area, which discharge sewage and grey water into the stormwater system.
  - Significant raw sewage also overflows at least at times were from pump stations, including the Koeberg pump station that discharges into the Theo Marai channel;
  - The Bayside channel also receives overflows of sewage from both blocked pump stations and low-lying manholes in the Bayside area, and from the Table View West pump station in particular, contributing to its Unacceptable rating in Figure 8.2.4. Note however that the Rietvlei recreational water body (also referred to as Flamingo Vlei) showed mean *E. coli* concentrations in the Acceptable range throughout the waterbody;
  - Data for the Potsdam WWTW showed that, despite other serious causes of downstream pollution, *E. coli* concentrations in final effluent were generally well within general limits, reflecting efficient disinfection with chlorine (albeit also contributing to downstream ecological issues as a result of assumed high and persistent chloramine levels (Rose et al 2023))
  - *E. coli* concentrations from WWTWs in the Mosselbank Sub-catchment upstream showed however that at least some of these facilities produced final effluent in the range of Unacceptable risk, and potentially impacting on downstream agricultural and other users;
  - Zoarvlei data showed high *E. coli* at the upstream (southern) end of the vlei, reducing to

Acceptable in the northern end of the vlei, reflecting both reduced sources of contaminated stormwater inflows in the north, and die-off of *E. coli* as a result of exposure to sunlight with distance through the vlei.

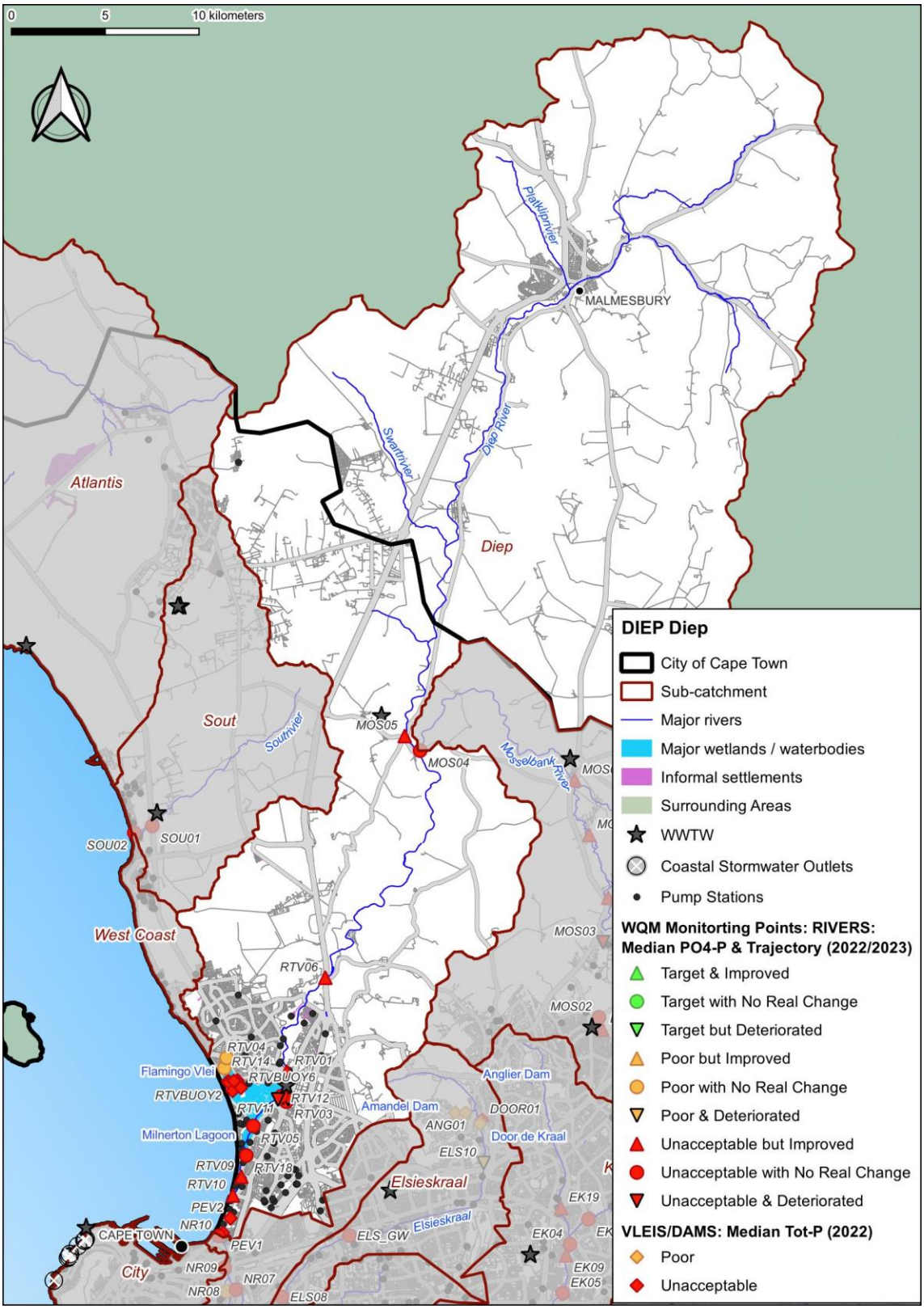


Figure 8.2.1
Median annual orthophosphate phosphorus (PO4-P) data (rivers) and median annual total phosphorus (Tot-P) (vleis), focusing on the DIEP Sub-catchment. Tot-P data provided only for 2022, due to missing data from January 2023 onwards. No Tot-P trajectories thus calculated. PO4-P trajectories calculated as explained in Section 3.8.14.

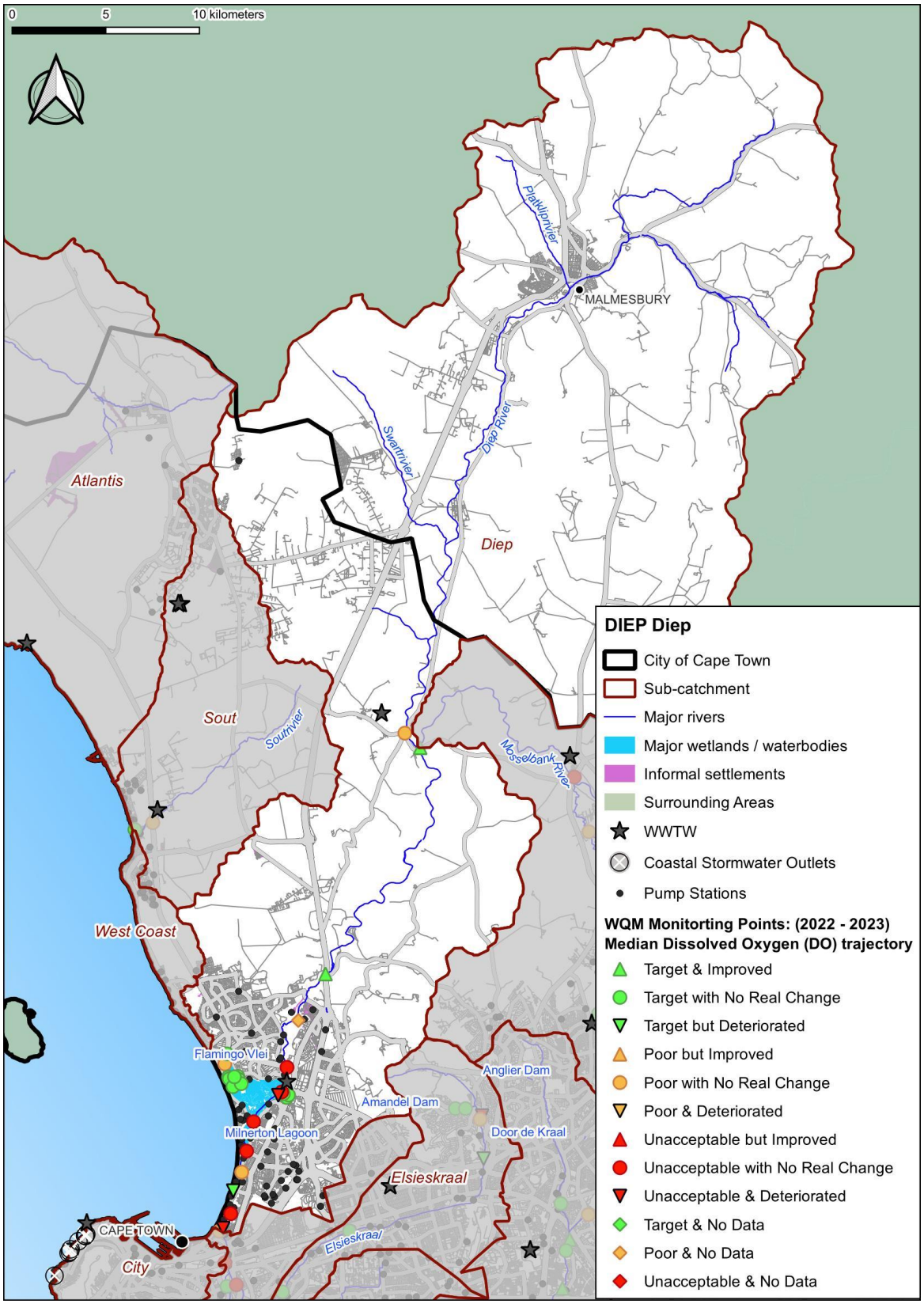


Figure 8.2.2
Median annual Dissolved Oxygen (DO) concentrations, focusing on the DIEP Sub-catchment. Data coded as to level of change in the 2023 reporting period, compared with the 2022 reporting period. Trajectory calculations explained in Section 3.8.14.

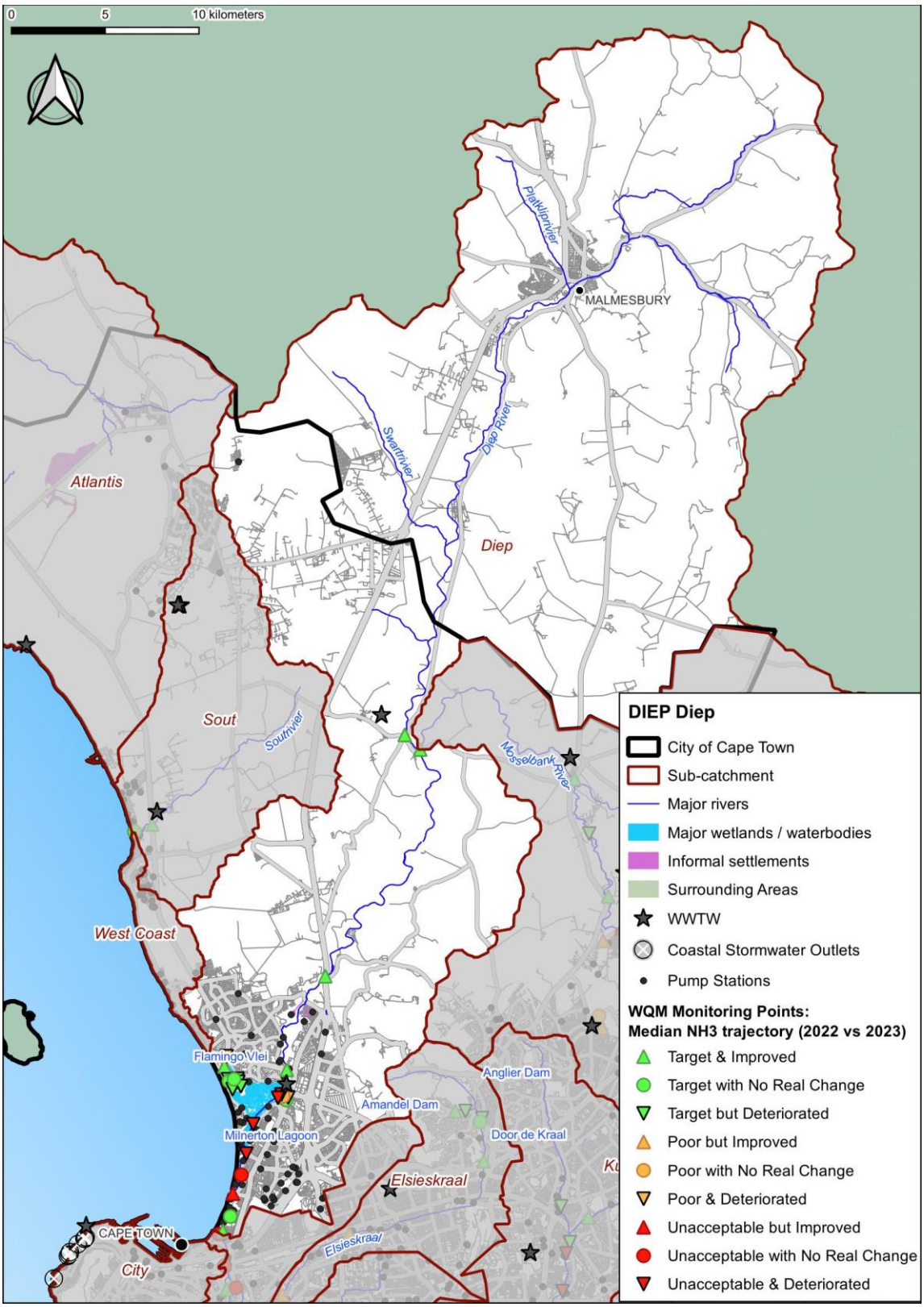


Figure 8.2.3
Median annual free ammonia (NH_3) concentrations, focusing on the DIEP Sub-catchment. Data coded as to level of change in the 2023 reporting period, compared with the 2022 reporting period. Trajectory calculations explained in Section 3.8.14.

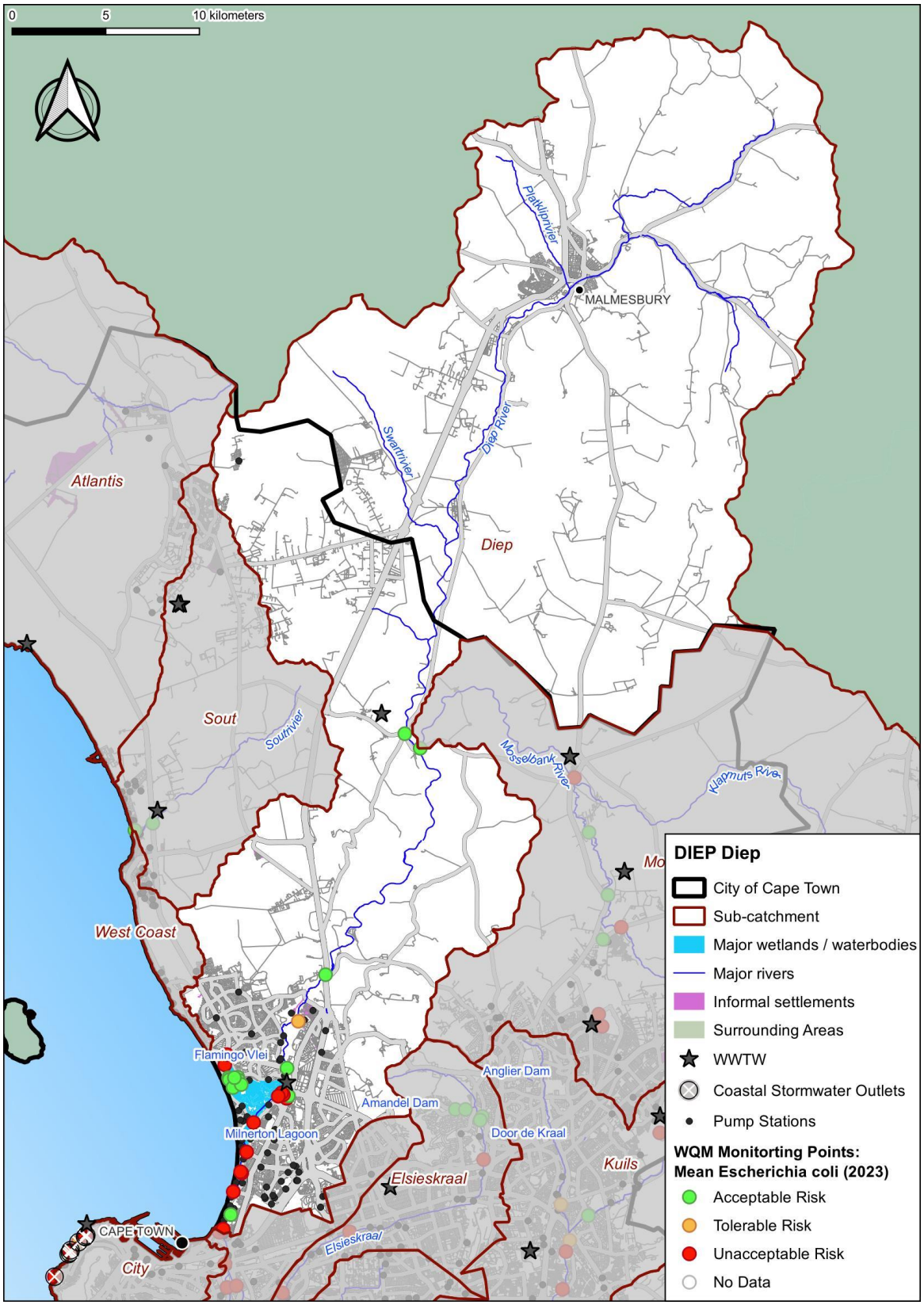


Figure 8.2.4
Mean *E. coli* data (geometric means), focusing on the DIEP Sub-catchment. Data coded as to human health risk (see Table 3.5). No reliable data available for the 2021 and 2022 reporting periods, so 2023 data shown only.

8.2.4 Major challenges

Water quality in the Diep Sub-catchment has been on a deteriorating trajectory over the past decade and a half at least (see ICE 2009). Based on discussions with the CCT's Stormwater Planning Region managers responsible for different parts of this sub-catchment, which straddles parts of both the Northern and the Regions, the **main** issues confronting the CSRM's catchment managers working in this area comprise:

- The seemingly insurmountable issues of burgeoning informal settlement that is expanding across large areas of the Diep and Kleine Stink River floodplains, and resulting in both direct loss / degradation to infilled wetlands and river channels; and permanent streams of sewage and greywater waste into the Diep River, well beyond any natural ameliorative or assimilative capacity of this system and its downstream estuary;
- Uncontrolled accumulations of solid waste including organic waste in many areas;
- Extensive backyard dwellings across large parts of the urban environment east of Potsdam Road, in some cases comprising two or three story stacked structures with little access to formal sewerage networks, designed for vastly smaller populations in these areas (see **Photo 8.2.5**);
- Pump stations that fail with high frequency and discharge large volumes of raw sewage, ultimately into the Diep River and its estuary (see **Section 5.6.3**);
- Large volumes of poor quality effluent from Potsdam WWTW, and the realistic extended period before the expanded and upgrade works will come on line (estimated 2027), meaning that downstream systems will continue to be exposed to effluent with high COD loading, with the resultant impact on downstream DO concentrations; ammonia toxicity; production of noxious hydrogen sulphide gases and methane from anaerobic systems; resulting in an ecologically dysfunctional estuary, potentially for at least the next few years;
- Discrepancies in the volumes of sewage effluent being pumped by pump stations, compared with expected / modelled flows – actual flows are in the region of at least four times the expected volume for the number of feeder households and landuse. This impacts significantly on pump station capacity, and the efficiency and capacity of the Potsdam WWTW.



Photo 8.2.5
Aerial view of Jo Slovo Park showing erf coverage by multiple informal dwelling units

8.2.5 Focus areas of the CCT's water quality interventions within the sub-catchment

Although budget constraints reported on in early 2024 are clearly not conducive to addressing the pressing water quality issues in the sub-catchment, the following activities have been undertaken by CCT in an effort to at least moderate the impacts of the above on water quality in the Sub-Catchment (see also **Table 7.2** in **Section 7)**:

- The following main **investigative reports** have been contracted to external consultants over the 2021 to 2023 reporting periods, to provide recommendations on management and other pollution abatement interventions by CCT:

- A remediation plan for Rietvlei[14] (Infinity 2022), which recommended focused management of pondweed habitat in the vlei, mitigation of upstream pollution sources (mainly in the Bayside canal) and future (but not immediate) dredging of vlei sediments;
- A water quality remediation plan for Milnerton Lagoon (Rose et al 2023), which recommended a number of interventions to address water quality in the Lagoon, including measures to address pollution from the WWTW and Erica Road outlets; dredging of Milnerton Lagoon as a short-term emergency remediation measure; and short-term aeration of the lagoon, to try to address odour issues;
- A stormwater management plan for the Dunoon / Doornbach areas of the Diep River, including consideration of the merits of diversion of the Klein Stink River from the informal settlement area, to reduce river pollution, along with other measures to improve water quality and reduce aquatic ecosystem risk (Lukhozi Consulting report due early 2024);

- **Commencement** of a number of interventions based on previously approved designs:
  - Trialing of an aeration system in the Milnerton Lagoon, in an effort to reduce the magnitude and frequency of emissions of malodorous gases from the lagoon sediments – the aeration system was installed in late 2023 and the trial will run until *ca* June 2024 (**Photo 8.2.6**);
  - Diversion of treated effluent past contaminated maturation ponds at the Potsdam WWTW. Re-contamination of effluent by these ponds had previously been shown to have significantly impacted on effluent quality (see Rose et al 2023);
  - Upgrading of the Potsdam WWTW to include ultrafiltration of treated effluent for the new works, and improved filtration systems for the existing (upgraded) works – this project commenced in April 2023;



Photo 8.2.6
Aeration units in the Milnerton Lagoon(March 2024)

  - Remediation of contaminated reedbeds downstream of the WWTW maturation and outlet ponds, to remove contaminated sediments and allow these to be redesigned in part as short-term holding ponds for contaminated effluent, pending repumping back into the WWTW, and (separately) for possible stormwater filtration (as per Rose et al 2023);
  - Upgrading of the Koeberg sewage pumpstation, to include screening and a bypass pond for effluent storage during breakdown or load-shedding periods;
  - Installation of a new major sewer line through the Montague Gardens area, which will allow maintenance / repairs to the existing major line to the Koeberg pump station;
  - Construction of a flood attenuation pond with allowance for water quality filtration through a reedbed wetland between Rietvlei and the Bayside Canal, to address polluted inflows from this point source;
  - Diversion of polluted low flows from the Erica Road stormwater pipeline via a gravity-fed low flow diversion to the sewer on the upstream side of Otto Du Plessis Drive – this system is however vulnerable to any blockages in the pipeline, which can cause polluted flows to continue down

[14] Note that "Rietvlei" in the cited report refers to the greater reedbed and saltmarsh area and the area referred to in the current report as Rietvlei is referred to in the cited report as Flamingo Vlei

the stormwater pipeline to the discharge point into Milnerton Lagoon (Mr B. De Wet, CCT, pers. comm to Liz Day);

- Purchase and deployment of a weed harvester for Rietvlei, to allow improved management of pondweed in the wetland, from the perspective of both water quality improvement and recreational use (as per Infinity 2022).

- **Completion of detailed design** of:
  - Interventions in the stormwater system in the vicinity of Milky Way, just downstream of the Jo Slovo settlement, to:
    - Include pumped offtakes of contaminated low flows to the adjacent Phoenix pump station;
    - Include screens to capture rags, and other solid waste upstream of the pump station and so reduce the frequency of blockages;
    - Potential construction /re-design of ponds as holding areas for sewage overflows to allow back-pumping;
    - Potential implementation of stormwater biofiltration systems in this area (as per Rose et al 2023).

    Implementation of the above project has had to be delayed, as the affected pump stations do not have sufficient capacity for the additional sewage load that would result from the planned diversion. Pump station upgrades are thus urgently required (Mr B. De Wet, CCT, pers. comm to Liz Day).
- **Exploration** of possible reasons for the higher-than-expected volumes of sewage discharging from informal settlements in the sub-catchment.

8.2.6 Recommendations

Most of the interventions required in this priority sub-catchment are related to the need to provide adequate sewerage and water services to a growing informal community, rather than to management of rain-driven stormwater impacts and its quality on rivers and wetlands. This means, as the CCT's Stormwater Planning Region managers are well aware, that interventions that need to impact measurably on the quality of the City's watercourses need to be championed and executed across a wide range of CCT's branches and departments, and cannot be driven by CSRM alone. Engagement and buy-in from the CCT's Human Settlements, Waste Water Treatment Works, Sewage Reticulation; Waste Services; Engineering and Asset Management and Law Enforcement branches / departments is essential to effect real long-term water quality change in this catchment going forwards.

From a water quality perspective, it is recommended that the following interventions should be prioritised:

- Upgrades to Potsdam WWTW are essential and should be fast-tracked as far as possible;
- Interventions that reduce delays in repairs of sewerage infrastructure should be implemented – for example, addressing contaminated effluent at Potsdam WWTW was delayed over many months as a result of only one suitable pump being available to effect effluent diversion – the ecological, economic and reputational damage caused by this tipping-point damage to the Milnerton Lagoon are likely to have far outweighed the costs of equipment procurement;
- A water budget that identifies how much water is being used and discharged where in the catchment is urgently needed and should inform where particular management , law enforcement or other interventions are appropriate;
- Diversion of the Kleine Stink River from the Dunoon and Doornbach informal settlements on the Diep River floodplain should be pursued with urgency – and the high economic costs associated with such extreme interventions should be noted as the cost of a failure to provide sewage services to a growing

portion of the City's population;

- The remaining areas of the Diep River floodplain that have not been settled on should be defended by the CCT, not only for ecological reasons, but also because *inter alia* they represent a rapidly shrinking resource, urgently needed for improving urban flood resilience. The Kleine Stink situation moreover highlights the long-term crippling financial costs of trying to manage unserviceable settlements in these low-lying flood-prone areas;

- Finally, it is noted that areas of the catchment appear to be increasingly abandoned by local authorities, presumably largely as a result of concerns over crime and safety. The result in many affected areas is the accumulation of large volumes of solid waste; uncontrolled polluted runoff through streets; and an ongoing assault on downstream receiving environments. Innovative measures to address these issues must be sought in this and other sub-catchments of the City.

8.3 Soet River Sub-catchment

8.3.1 Catchment overview

The Soet River (also referred to as the 'Soete River' in some maps and documents) is a small stream that rises in the Schapenberg Hills above the suburb of Dennegeur in Somerset West, forming a small catchment wedged between the Lourens and Sir Lowry's Pass River catchments, within the CCT's Eastern Stormwater Planning Region. A number of minor tributaries feed it from the hillslopes, and it passes through a number of large housing developments, including Heritage Park, where flow from these streams as well as stormwater generated in Heritage Park and other near-by developments are managed in a series of large detention ponds. Upstream erosion results in significant sedimentation at times in catchpits both upstream of the estate and in the detention ponds immediately upstream of the N2. Prior to urban development in this area, the gently sloping foothills of the Schapenberg included extensive hillslope seep wetlands, most of which were destroyed by agriculture.

The other main Soet tributaries lie some 500 m further southeast, and are conveyed downslope east of Chris Nissen Village and under the N2, where they pass through Asanda and Nomsamo –high-density suburbs with large numbers of informal settlements and backyard dwellings. Accumulation of solid waste in open space areas is high.

A small remnant wetland (Asanda Wetland) remains between the N2 and Asanda Village. The wetlandwas previously subject to infilling, dumping of solid waste including abattoir waste, and encroachment by informal settlement, urban agriculture and livestock. In early 2021, following extensive community engagement, the CCT initiated a community-driven rehabilitation project in the wetland. The rehabilitation project, completed in 2023, has been included among the LUW programme projects, and is the first such project to be completed (see **Section 7.4**).

The Asanda wetland is fed mainly by one of the Soet tributaries, channeled along the edge of Heritage Park. Downstream of the wetland, these flows are piped through Asanda and Nomsamo, as are the other stream flows. They emerge downstream of these settlements and converge to flow within a single wide, mainly earth, canal between more formal developments. In these reaches, the open channel is visibly polluted with high levels of organic waste, raw sewage from the informal settlement upstream as well as from overflowing manholes, and high levels of solid waste. It is piped from Naomi Street, daylighting again as a polluted stream downstream of the R44. From here, it flows through Greenways Golf Estate – a private golfcourse and housing development, before it passes into False Bay.



Photo 8.3.1
Fast flows from a steep erosion-prone catchment bring sediment via the upper Soet, depositing it in stormwater ponds and channels (inset)



Photo 8.3.2
The rehabilitated Asanda Wetland (2023), showing spread of stormwater flows by a gabion structure



Photo 8.3.3
Solid waste in the Soet catchment



Photo 8.3.4
Soet River downstream of Asanda and Nomsamo

8.3.2 Major sources of pollution in the catchment

Major sources of pollution in this priority sub-catchment have been identified (from data presented in Section 5; site drive-overs by the present study team; and from the CCT's PASAP for the Soet River Sub-catchment (CCT 2023b) as the following:

- Overflows from sewage pump stations – in the event of pump station failure, three of the four pump stations located in this catchment discharge directly into the Soet River, while the fourth discharges into the ocean. None of the pump stations have emergency ponds or bund walls (CCT 2023b);
- Unmonitored inflows from private sewage package plants located in the catchment;
- Runoff of raw sewage and grey water from informal settlements in the N2 and other road reserves as well as from backyard developments in Nomzamo/Lwandle and Asanda;
- Runoff from activities such as a car washing, open air cooking, informal butcheries into the adjacent canals
- Seepage from piled solid waste including offal, dead dogs and other waste along pavements and in the roads in these areas (pers. obs) – CCT (2023b) notes that there is no door-to-door solid waste removal;
- Sewer overflows – these are often not reported and may persist for long periods of time;
- Illegal dumping into wetlands and canals and wind blown pollution;
- Pollution from oil and toxic substances, disposed into grid inlets, catchpits or road surfaces.

8.3.3 River water quality through the catchment – condition and trajectory

The CCT includes only one routine water quality monitoring point in this catchment (SOE02), located within the Greenways Golf Estate. Data presented spatially in **Figures 8.3.1-8.3.4** show that:

- Phosphate. dissolved oxygen and free ammonia (NH_3) concentrations were all in the Unacceptable range in both the 2022 and the 2023 reporting periods, reflecting similar patterns to those of previous reporting years (see Section 5 and Day et al 2023);
- Of the above, it is interesting to note that some improvement in ammonia concentrations is however indicated in the 2023 period compared with 2022, and this is also reflected in compliance reporting in **Figure 5.5.4** (**Section 5**), with a slightly lower percentage of samples in the Unacceptable range compared with the 2022 reporting period.
- Similarly, DO compliance data showed a slight increase in the proportion of samples that were better

than Unacceptable, helping to account for the improved free ammonia results, and reflecting increased nitrification processes. This may reflect increased clean-up activity by CCT in the catchment over this period, reducing the loading of organic waste. It may also reflect impacts such as major floods, particularly in the City's Eastern Region catchments, in June and September 2023, which may have resulted in short-term dilution of polluted flows from these areas;

- *E. coli* data were in the Unacceptable range for the assessed 2023 reporting period, reflecting a system constituting a high risk to human health for intermediate recreational use. Since many people in the upstream settlements are forced to walk through stormwater flows on a daily basis in the wet season, such human health risks extend well beyond recreational users. Facilities such as the new pedestrian bridge in the Asanda Park wetland (see Section 7.4.3) are important measures to reduce human risk in this regard.
- Overall, water quality data shown here and presented in Section 5 in relation to other sub-catchments in the City, indicate highly polluted watercourses, indicative of extremely dirty catchment areas. The data in **Section 5** repeatedly highlight the Soet Sub-catchment as one of the most poorly performing sub-catchments within the City, across most variables.
- **Figure 5.6.11** (**Section 5**) also shows the Soet Sub-catchment to be a hot-spot for sewage spills from sewer manholes. Although it does not rate as one of the worst sub-catchments in terms of pump station overflows (**Figure 5.6.9**), these data are deceptive, as the Soet is a relatively small sub-catchment compared to the others and the data are not weighted for area.

8.3.4 Major challenges

Major challenges in addressing severe long-term water quality issues in this sub-catchment were highlighted in discussions with the CCT's Stormwater Planning Region management team for the Eastern Region. Key issues comprise:

- High levels of informal settlement, often in land not owned by the CCT (e.g. SANRAL owned), which [15]complicate management interventions
- Block ablution facilities provided to informal settlement residents are often not used (because of security concerns, distance and hygiene considerations) and sewage and grey water are often disposed of into stormwater catchpits or the roads instead;
- Increasingly blocked access to channels for machine maintenance (e.g. dredging of solid waste and sludge), as a result of expanding informal settlements along channel edges – this means that maintenance needs to be carried out with manual labour, exposing staff to highly polluted waters. The need ofor protective gear and vaccinations against disease makes manual labour increasingly problematic to use in these areas;
- Low levels of solid waste collection from informal settlements;
- Although provision has been made for refuse bags to be handed out to communities and then collected from centralized areas, the length of time between bag drop-off and collection is slow, and allows waste pickers time to open bags and disperse their contents – much of this waste ends up in the stormwater channels
- Inadequate collection of solid waste and management of informal settlement encroachment in public open space areas such as Asanda Wetland Park;
- Passage of raw sewage and grey water waste into the river channel, with COD concentrations and assumed loading beyond the capacity of the system to ameliorate it (see CCT 2023b), resulting in a toxic riverine system that also poses high risks to human health;
- High levels of criminality in and near informal settlements, affecting service delivery;

[15] Discussions with the Eastern Region manager, Mr Gerhardt Muller, it emerged that the CCT has a Memorandum of Understanding with SANRAL, allowing for removal of solid waste by CCT staff

- Vandalism and dumping in public open spaces (e.g. the newly created Asanda Park) affecting their sustainability.

8.3.5 Focus areas of the CCT's current remediation programmes

The following activities have been implemented by the CCT to improve water quality in this catchment:

- Rehabilitation of the Asanda wetland to incorporate it into a community wetland park: This is a LUW project - management of illegal dumping, removal of solid waste, alien plant invasion and management of goats are ongoing challenges (Day 2023);
- Removal of solid waste from the Soet River channel downstream of Asanda / Nomsamo – accumulation of solid waste is however an ongoing issue in this sub-catchment;
- Development of a PASAP for the sub-catchment (CCT 2023b), which identifies problem issues in the sub-catchment and recommends implementation of the following:
    - Management of pollution at source through pollution prevention measures such as law enforcement, education, public engagement, enforcement of "polluter pays principles" and increased service delivery with regard to waste removal;
    - Regulation of sewage treatment package plants, including ad hoc inspections and assessment of testing results (it is assumed however that these would in any case need to comply with the CCT's Standard Operating Procedure for package plants (see **Table 7.2** in **Section 7.3)**;
    - Upgrading of pump stations to include bunding and stand-by generatos – it is noted in the PASAP that none of the Soet River pump stations have been prioritized for upgrades;
    - Increased frequency of inspections and pro-active cleaning of sewer manholes;
    - Appointment of river wardens to clean rivers of solid waste and to report sewer overflows that would otherwise remain undetected;
    - Improving conditions in temporary informal settlements by:
        - Covering over open drains to reduce human exposure to polluted waste streams;
        - Upgrading ablution facilities to include provision of washing facilities and formalized access to clean structures linked to the sewer network;
    - Improving solid waste removal through:
        - The provision of wheelie bins to informal settlement residents;
        - Implementation of a "swap shop" system – cleaned, recyclable items that can be traded for items in the "swap shop" (e.g. clothes, air time etc);
    - Removal of people from the SANRAL road reserve in the medium to long term and provision of basic services to these people in the interim;
- Compilation of a TAP for the sub-catchment (CCT 2023c), which outlines specific actions aimed at addressing the issues outlined in the PASAP. These include:
    - Attention to litter removal – although the TAP does not define clearing frequency, which is

Box 8.3.1

Greenways Golf Estate bioremediation and nano-bubbling project

In response to the visibly polluted and malodorous Soet River channel through this estate, at the downstream end of the catchment, the Estate appointed Blue Planet to apply a combined bioremediation and nan-bubbler intervention in the channel in its reaches through the Estate. This intervention commenced in December 2023, Early results presented by Blue Planet (McDonald 2024) indicated seemingly positive results in reducing visible sludges; increasing water clarity; and reducing odour issues. The CCT is now considering replication of this intervention in upstream areas, although the use of bioremediation enzymes used by Blue Planet are not currently approved by the CCT (see CCT 2023c)

clearly a major issue affecting current solid waste accumulation

- Consideration of a low flow diversion to sewer along the southern river channel;
- Inspection and pro-active repairs to problem sewers and manholes;
- Consideration of the installation of nano-bubbler generators along the river;
- Improved water quality monitoring in the catchment;
- Law enforcement to intervene on illegal discharges to the stormwater system (e.g. from car washes and informal garages);
- Re-location of public toilets in informal settlements away from open stormwater systems, away from the open SW system.

8.3.6 Recommendations

Large areas of unserviced dwellings, with associated disposal into the stormwater system of black and grey water as well as dumped solid waste that causes frequent overflows from sewage pump stations and manholes, mean that management of the Soet catchment is challenging for the CCT.

Implementation of the management recommendations outlined in the PASAP would go a long way towards addressing pollution in this relatively small, and therefore theoretically more manageable sub-catchment than in other such as the Diep and Lower Salt. However, the TAP intended to give impetus to the PASAP lacks detail and structure, and moreover most of the interventions are allowed for only in the long-term, making them, irrelevant from a pollution abatement perspective. It is recommended that the TAP be amended to include:

- Specifications for the frequency of solid waste collection from informal settlements that are in line with the rate of solid waste accumulation;
- Reduced time frames for symptomatic interventions such as:
  - Low flow diversions to sewer;
  - The introduction of nano bubbler (or similar) techniques, even without enzyme inoculation;
  - Canal enclosure studies, design and implementation (if supported by study outcomes);
- Additional water quality monitoring points in the Soet River upstream of Greenways Golf Estate, so that (private) downstream interventions do not cloud interpretation of the degree of upstream pollution and its human health impacts;
- Specific attention to implementation of the Asanda Wetland Park MMP, in order to ensure that this project remains a CCT and community asset.

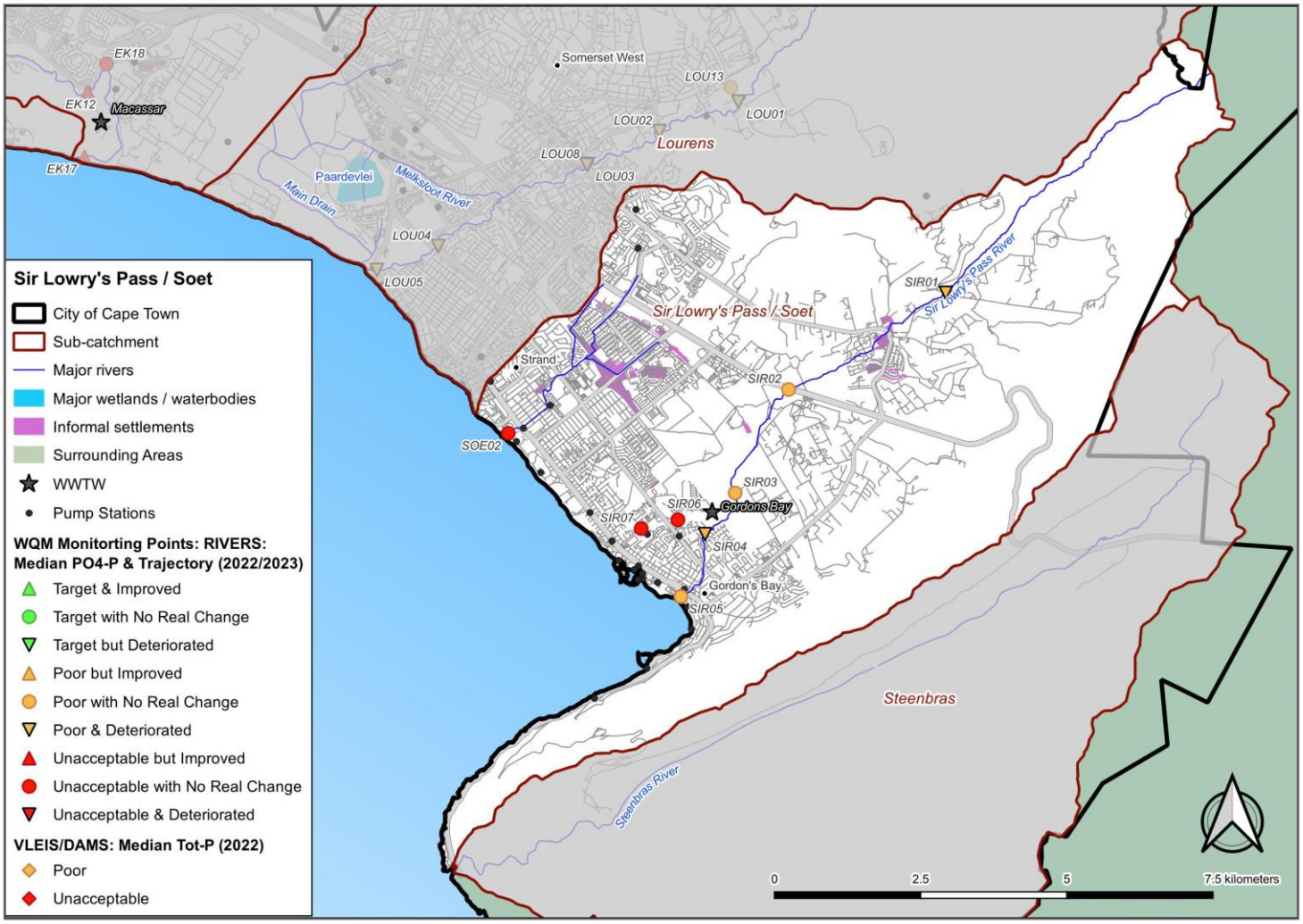


Figure 8.3.1
Median annual orthophosphate phosphorus (PO4-P) data (rivers) and median annual total phosphorus (Tot-P) (vleis), focusing on the SOET RIVER in the Sir Lowry's Pass / Soet Sub-catchment. PO4-P trajectories calculated as explained in Section 3.8.14

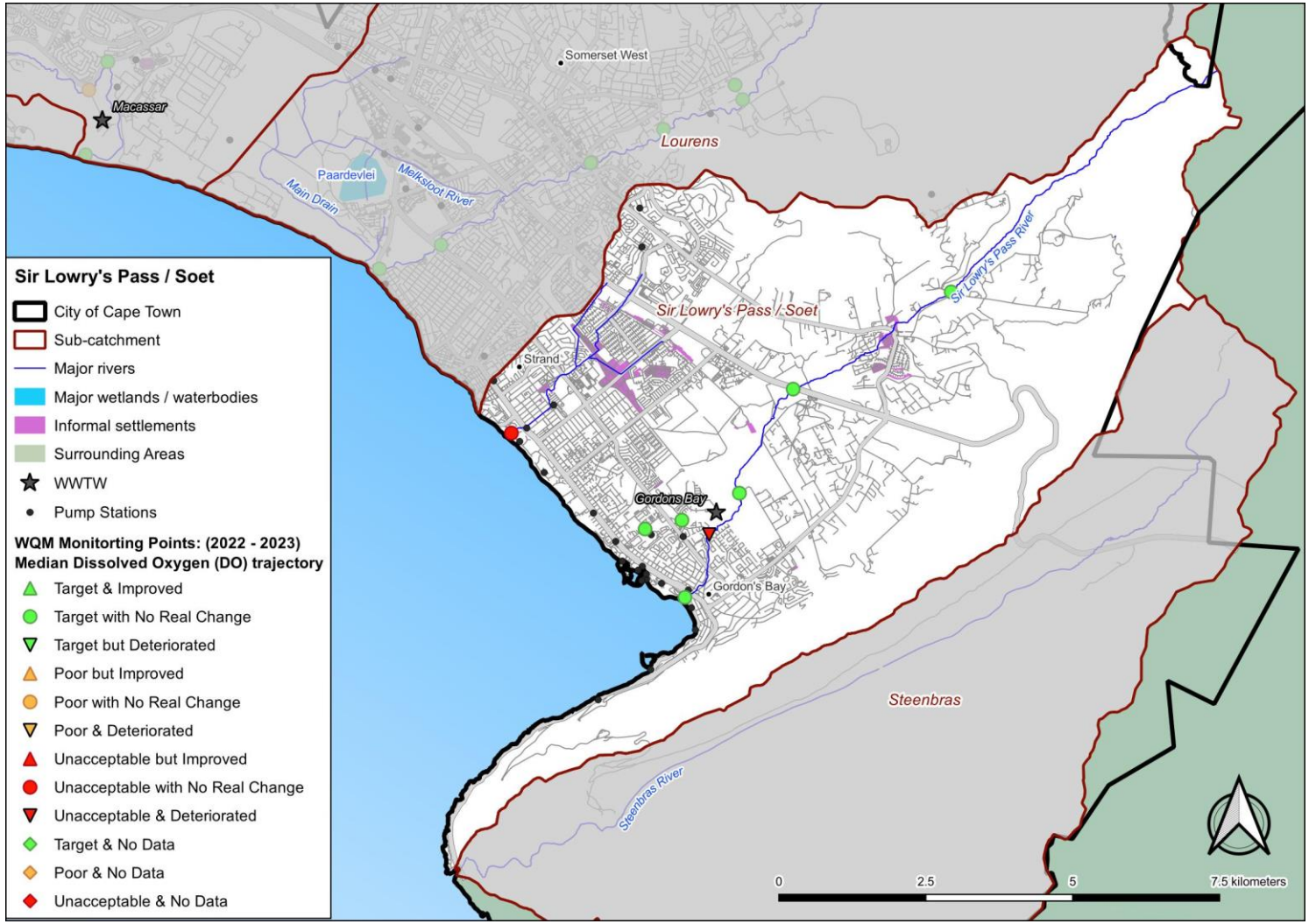


Figure 8.3.2
Median annual Dissolved Oxygen (DO) concentrations, focusing on the SOET RIVER in the Sir Lowry's Pass / Soet Sub-catchment. Data coded as to level of change in the 2023 reporting period, compared with the 2022 reporting period. Trajectory calculations explained in Section 3.8.14.

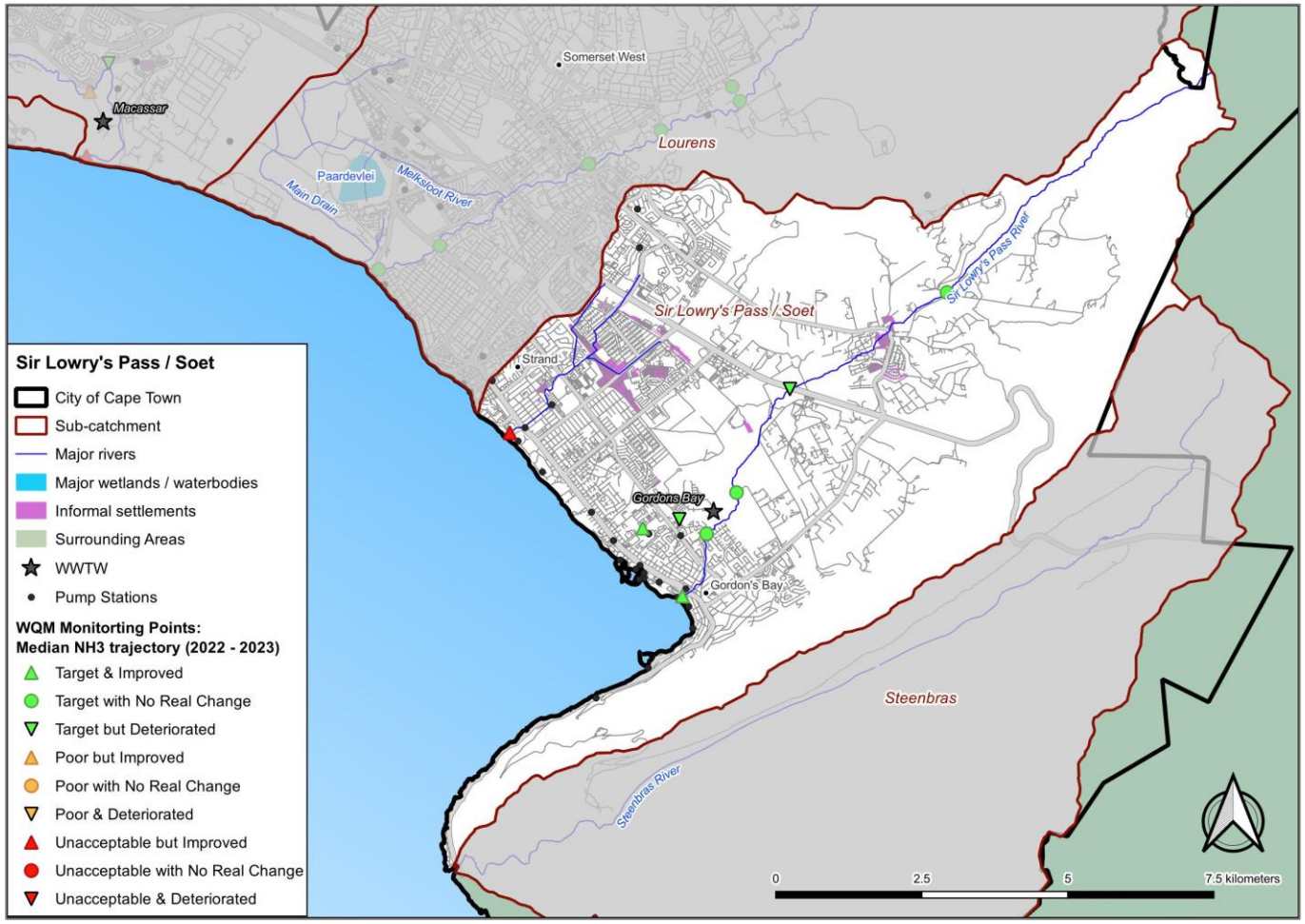


Figure 8.3.3
Median annual free ammonia (NH_3) concentrations, focusing on the SOET RIVER in the Sir Lowry's Pass / Soet Sub-catchment. Data coded as to level of change in the 2023 reporting period, compared with the 2022 reporting period. Trajectory calculations explained in Section 3.8.14.

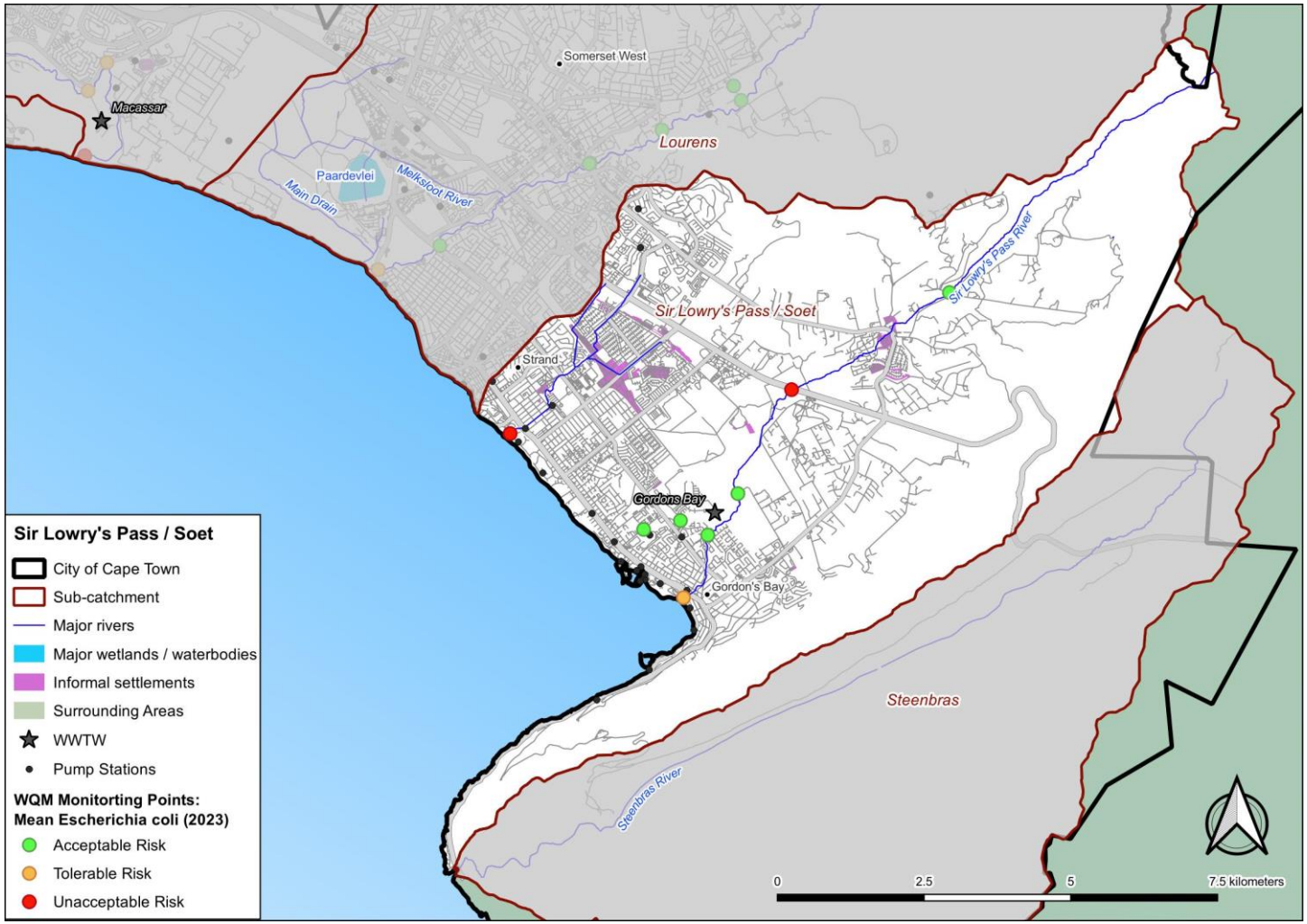


Figure 8.3.4
Mean E. coli data (geometric means), focusing on the SOET RIVER in the Sir Lowry's Pass / Soet Sub-catchment. Data coded as to human health risk (see Table 3.5). No reliable data available for the 2021 and 2022 reporting periods, so 2023 data shown only.

8.4 Lower Salt River

8.4.1 Catchment overview

The Lower Salt River sub-catchment is relatively large, ranked 6th by area of the 17 major sub-catchments within the CCT boundary. It overlaps three of the four CCT Stormwater Planning Regions (Central, Northern and Southern regions), meaning that three different CCT Catchment Managers are responsible for different sections (see **Figure 2.2**).

The sub-catchment is highly developed to the north, east and south, and most of the 'rivers' in these portions of the sub-catchment are in fact concrete canals (e.g., **Photo 8.4.1**), many of which were originally constructed in an attempt to drain historically extensive wetland areas on the low-lying land that are fed by the high water-table associated with the underlying Cape Flats Aquifer (Brown and Magoba 2009). An exception to this is the Vygekraal River, which flows within an earth channel through at least some of its reaches, including through the Nantes Park area (the site for one of the CCT's LUW projects).

Many of the low-lying rivers in the sub-catchment pass through socio-economically challenged suburbs characterised by high levels of informal settlement and/or backyard settlements (e.g., in the suburb of Langa and surrounds, and the north-western edge of KTC), which are often plagued by high levels of crime and gang activity, affecting both local communities and the ability of the CCT to conduct routine monitoring and implement effective interventions. These rivers all join the Black River in the vicinity of the N2, and flow from there until just downstream of the confluence with the Liesbeek River in Observatory. Permanent flows of nutrient-enriched water support the growth of water hyacinth, which requires ongoing management by the CCT. Downstream of the railway bridge, the river channel is canalised to its outlet into Table Bay, and is referred to as the Salt River canal.

Rivers draining into the sub-catchment from the west form part of the catchment area of the Liesbeek River, which flows into the Black River in the downstream reaches of the Lower Salt sub-catchment. These rivers drain the eastern slopes of Table Mountain. Their upper reaches lie within the Table Mountain National Park, where they flow as mountain streams first through relatively unimpacted fynbos in the areas above former forestry plantations, Kirstenbosch Botanical Gardens and high-lying affluent suburbs on the lower mountain slopes. With distance downstream into densely urbanised areas such as Newlands, Claremont and Rondebosch, most of the rivers are canalised or in some cases piped. An active Friends Group (Friends of the Liesbeek River) partners with the CCT in alien plant and litter clearing along the Liesbeek River.

The Borcherd's Quarry WWTW and Athlone WWTW (see **Photo 8.4.2**) are both located in the Lower Salt sub-catchment. The former discharges treated effluent into the Jakkalsvlei Canal flowing immediately north of and along the N2, through the southern edge of Langa, before joining with the Vygekraal River opposite the Athlone WWTW, and passing under the N2. Treated effluent from the Athlone WWTW is discharged into the Vygekraal River, which is then known as the Black River. Apart from treated effluent, the Black River is subject to high levels of solid waste as well as inflows of raw sewage from adjacent settlements.



Photo 8.4.1
The canalized Black River upstream of the N2, through Keurboom Park



Photo 8.4.2
Aerial view of the Athlone WWTW [image from Moodley (2024)]

8.4.2 Major sources of pollution

The main sources of water pollution within the Lower Salt sub-catchment include:

- Sub-standard effluent from the under-performing Athlone WWTW (discharging into the Vygekraal River), which is one of the largest WWTWs in Cape Town in terms of discharge volumes (current hydraulic capacity of 105 ML/day), and Borcherds Quarry WWTW (discharging into the Jakkalsvlei Canal), as discussed in **Section 5.6.2**). Current compliance challenges include sludge wasting and disposal problems at the Athlone WWTW, and inlet works capacity problems and a lack of screening at the Borcherds Quarry WWTW, as well as no backup generators being present at this plant currently (Moodley 2024);
- Periodic spillages of raw sewage and sludge from the Athlone WWTW into the Vygekraal River, due to problems with feeding the sludge from this WWTW to the interconnected Cape Flats WWTW in the Zeekoe sub-catchment via the dedicated sludge pipeline;
- Inflows of raw sewage into mostly canalised river channels from informal settlement and areas with high numbers of backyard dwellers (e.g., **Photo 8.4.3**);
- Sewer spills into watercourses, resulting from blockages (typically caused by high levels of uncollected solid waste entering stormwater and sewerage infrastructure, as in **Photo 8.4.4**) and/or sewer pump station failures (often related to load-shedding), as well as leakages from an ageing sewerage network in many parts of the sub-catchment [As indicated in **Sections 5.6.3 & 5.6.4**, some of the areas with the highest frequency and severity of sewage overflows in the City are located in the Lower Salt sub-catchment];
- Runoff of contaminants from the limited industrial areas in the sub-catchment, mainly around Epping, Ndabeni and Maitland, and from numerous roads through the highly urbanised sub-catchment; and
- Runoff of nutrient-enriched water from fertilised lawns and extensive gardens (including Kirstenbosch Botanical Garden) in the more affluent suburbs into the Liesbeek River portion of the sub-catchment.



Photo 8.4.3
Informal housing built right over the edge of the Jakkalsvlei Canal, along the N2 past Langa



Photo 8.4.4
Accumulation of solid waste in the Bokmakierie Canal just upstream of the Black River confluence, despite CCT's attempts to reduce access for dumping with fences

8.4.3 Water quality through the catchment – condition and trajectory

Figures 8.4.1 to **8.4.3** illustrate spatial patterns and trends in phosphate, dissolved oxygen and un-ionised ammonia concentrations the Lower Salt sub-catchment for Reporting Years 2022 and 2023, while **Figure 8.4.4** shows spatial patterns in *E. coli* concentrations in Reporting Year 2023 only.

These figures show that, for the Lower Salt sub-catchment:

- The Liesbeek River catchment was in relatively good condition, with both monitoring sites on this river lying within the Target range for median ammonia and dissolved oxygen concentrations during Reporting Year 2023. The mean *E. coli* level at the upper site (NR22) was also in the Target range during Reporting Year 2023, but the site located further downstream just before the confluence with the Black River (NR08) was in the Unacceptable category;
- Despite these results, median orthophosphate concentrations at both monitoring points on the Liesbeek River were in the Poor category for Reporting Year 2023, possibly partly due to nutrient inputs from extensive residential gardens in the Bishopscourt area and from Kirstenbosch Botanical Garden;
- Throughout the rest of the Lower Salt subcatchment, water quality was severely compromised and in the Unacceptable range during Reporting Year 2023 for most of the mapped variables (orthophosphates, un-ionised ammonia and *E. coli*) at all but one of the sample points (NR24 on the Black River channel in Rondebosch, where median PO4-P and NH_3 concentrations were in the Poor category). The median NH_3concentration for Reporting Year 2023 at monitoring point NR01 on the polluted Blomvlei Canal was also in the Poor (instead of Unacceptable) category but this was probably due to the relatively low pH values (6.8 to 7.6) recorded here during 2023 as opposed to low ammonia levels;
- Median DO concentrations were slightly more variable through the lower-lying portions of the sub-catchment during Reporting Year 2023, compared to PO4-P, NH_3 and *E. coli*, with Target levels recorded at monitoring site NR24 on the Black River channel in Rondebosch (as was the case for the Liesbeek River sites) and concentrations in the Poor category recorded in the Vygekraal River downstream of the Athlone WWTW (at monitoring site NR25) and upstream of the Blomvlei Canal (at NR02), in the Kalksteenfontein Canal (at NR17) and in the Salt River Canal at Marine Drive Bridge (monitoring point NR10, near the outlet of the sub-catchment into the sea). At the rest of the sampling points in the sub-catchment, median DO concentrations were in the Unacceptable category, similar to the situation for

the other variables considered here;

- In terms of trajectories of change in water quality over time, the mapped data show that:
    - On the Liesbeek River, an improvement in median un-ionised ammonia concentrations was recorded at both monitoring sites in Reporting Year 2023 compared to 2022, while there was a deterioration in terms of median orthophosphate concentration at the upper site (NR22) but no real change at the lower site (NR08). There was no real change in median dissolved oxygen concentration from 2022 to 2023 at either of the monitoring points;
    - No improvements were recorded in Reporting Year 2023, compared to 2022, for median DO concentrations at any of the monitoring sites in the sub-catchment, but a deterioration (together with Unacceptable median concentrations) was recorded for this parameter in the Jakkalsvlei Canal at sites downstream of the Borcherds Quarry WWTW (NR26 and NR15), in the Langa Canal (at NR16), in the Vygekraal River at sites both upstream and downstream of the Athlone WWTW (NR03 and NR04), and in the Black River at Raapenberg Road bridge (NR06);
    - Median NH_3concentrations at most monitoring points not on the Liesbeek River deteriorated in Reporting Year 2023 or remained similar to 2022, staying in the Unacceptable category (except for a site on the Blomvlei Canal (NR1) and another site on the upper Black River at the Rondebosch Golf Course (NR11) where median NH_3 concentrations remained in the Poor category). An improvement in median NH_3 concentrations for Reporting Year 2023, compared to 2022, was only recorded at the two sites on the Liesbeek River (as indicated above) and at two other monitoring sites in the remainder of the sub-catchment, namely NR06 (on the Black River at Raapenberg Road bridge) and NR17 (on the Kalksteenfontein Canal);
    - Between the 2022 and 2023 reporting periods, there was only one monitoring point in the low-lying portion of the sub-catchment outside of the Liesbeek River portion where the median orthophosphate concentration declined further (i.e., at NR16 on the Langa Canal). An improvement in median PO4-P concentrations, although generally still well within the Unacceptable range, was recorded at a number of sites in the subcatchment, namely NR06 (on the Black River at Raapenberg Road bridge), NR04 (on the Vygekraal River downstream of the Athlone WTWW), NR15 (on the Jakkalsvlei Canal at the N2 freeway) and NR26 (on the Jakkalsvlei Canal downstream of the Borcherd's Quarry WWTW), as well as at NR11 on the upper Black River at the Rondebosch Golf Course where the median PO4-P concentration was in the Poor category.

8.4.4 Focus areas of the CCT's water quality interventions within the sub-catchment

A draft PASAP has been compiled for the Lower Salt sub-catchment, but it has not yet been finalised for implementation. The Nantes Park project along the Vygekraal River, which forms part of the LUW Programme, has, however, been initiated in the Lower Salt sub-catchment. The main aims of this project are not to improve water quality *per se* but, rather, to improve/create wetland and instream aquatic habitat, and to increase amenity value. This is to be done though rehabilitation of the river corridor between Jakes Gerwel Drive and the Athlone WWTW (see aerial view in **Photo 8.4.5**) involving, amongst other interventions, naturalisation of channel embankments, repairing erosion, removing sediments and invasive plants, planting indigenous vegetation and trees, installing new footpaths, seating, lighting and informational signage, replacing footbridges, and integrating the river corridor into the surrounding urban landscape (e.g., see **Photo 8.4.6**) as far as possible (Mc Donald 2024).

Some of the interventions undertaken by the CCT in the Lower Salt River during Reporting Year 2023, which have a direct impact on water quality, include:

- Continuation with the Athlone WWTW Phase 1 upgrade project, due for completion in 2026, which involves refurbishment and process upgrade of the existing treatment infrastructure;
- Completion of the upgrading of the Langa sewage pump station;
- Ongoing removal of solid waste from the river / stormwater channels – the visible build-up of solid waste in the channels suggests, however, that solid waste removal at a catchment level is inadequate compared to the scale of the problem (e.g., see **Photo 8.4.4**);

- Continuation with the Manenberg canal rehabilitation project, which aims to facilitate improved solid waste management in the Manenberg area, particularly in the vicinity of open canals, including the Vygekraal and Blomvlei canals;
- Increasing provision of back-up generators and UPS systems for pump stations to reduce sewage overflow frequency as a result of load-shedding.



Photo 8.4.5
Aerial view of Nantes Park, showing the river corridor that is to be rehabilitated as part of the LUW Programme [image from Mc Donald (2024)]



Photo 8.4.6
Vygekraal River near Nantes Park at site of proposed pedestrian bridge and near park to be upgraded as part of the LUW Programme

8.4.5 Major intervention challenges

The main challenges to implementing water pollution abatement measures in the Lower Salt sub-catchment include:

- The absence of a finalised and approved PASAP for the sub-catchment, with associated TAPs, which could have been used to secure priority funding for implementation of the recommended measures;
- A lack of funding to implement even basic pollution abatement measures, due to severe cuts to both capital expense and operating budgets for the relevant departments within the CCT;
- Theft, vandalism and destruction of stormwater, sewage and sanitation infrastructure, which is a major problem in many parts of the Lower Salt sub-catchment;
- Hampering of more frequent collection of solid waste in certain areas within the sub-catchment that are hotspots for criminal activities, often linked to gangs, including the violent intimidation and extortion of CCT workers and contracted service providers;
- The failure of WWTW equipment and sewage pumps at pump stations throughout the sub-catchment, typically related to load-shedding and electrical faults; and
- Fragmented management, with three CCT Stormwater Planning Regions having jurisdiction over the sub-catchment, which severely hampers the implementation of strategic interventions and possibly results in economically inefficient duplication of efforts in relation to certain water pollution control activities. This is further complicated by the involvement of multiple departments from the CCT in the implementation of pollution control measures, including the Environmental Management Department, Recreation and Parks Department, Waste Services Department, and the Water and Sanitation Department, amongst others, with the Water and Sanitation Department itself including separate Branches for CSRM, Reticulation, Wastewater Treatment Works, and Scientific Services.

8.4.6 Recommendations going forward

The main recommendation for the Lower Salt sub-catchment is that the draft PASAP should be finalised as a matter of urgency, and the associated TAPS should be rationalised as far as possible in the light of the recent major budget cuts. The finalised PASAP should then be put forward as a MPP so that budget allocations towards the proposed pollution abatement measures can be prioritised going forward. Without securing the funding that will be necessary to implement pollution control measures in the Lower Salt sub-catchment, it is highly unlikely that much success will be achieved.

Like many of the CCT's sub-catchments, the Lower Salt is managed by multiple Catchment Planners. As stated elsewhere in this report, it is recommended that consideration should be given to the rationalisation of the management system into one that is catchment-based, to facilitate more holistic management and responsibility within CCT structures. In the interim, it is recommended that procedures and communication channels should be formulated to ensure more effective coordination between the various management structures that have jurisdiction over matters that affect the water quality of watercourses in the Lower Salt sub-catchment.

On a more proactive level, opportunities should be actively sought to implement SUDS treatment interventions in the catchment area for the Liesbeek River (including its tributaries), designed for water quality polishing and removal of low pollution loads. This river system should respond well to such interventions because the main present-day water quality issues in this system are related primarily to real stormwater-driven urban runoff only, and not to the mix of sewage and stormwater that affects watercourses in many other parts of the City. The pursuit of such interventions would at least facilitate the maintenance relatively good water quality in this portion of the sub-catchment. Focus areas for such measures should be reaches showing signs of water quality degradation.

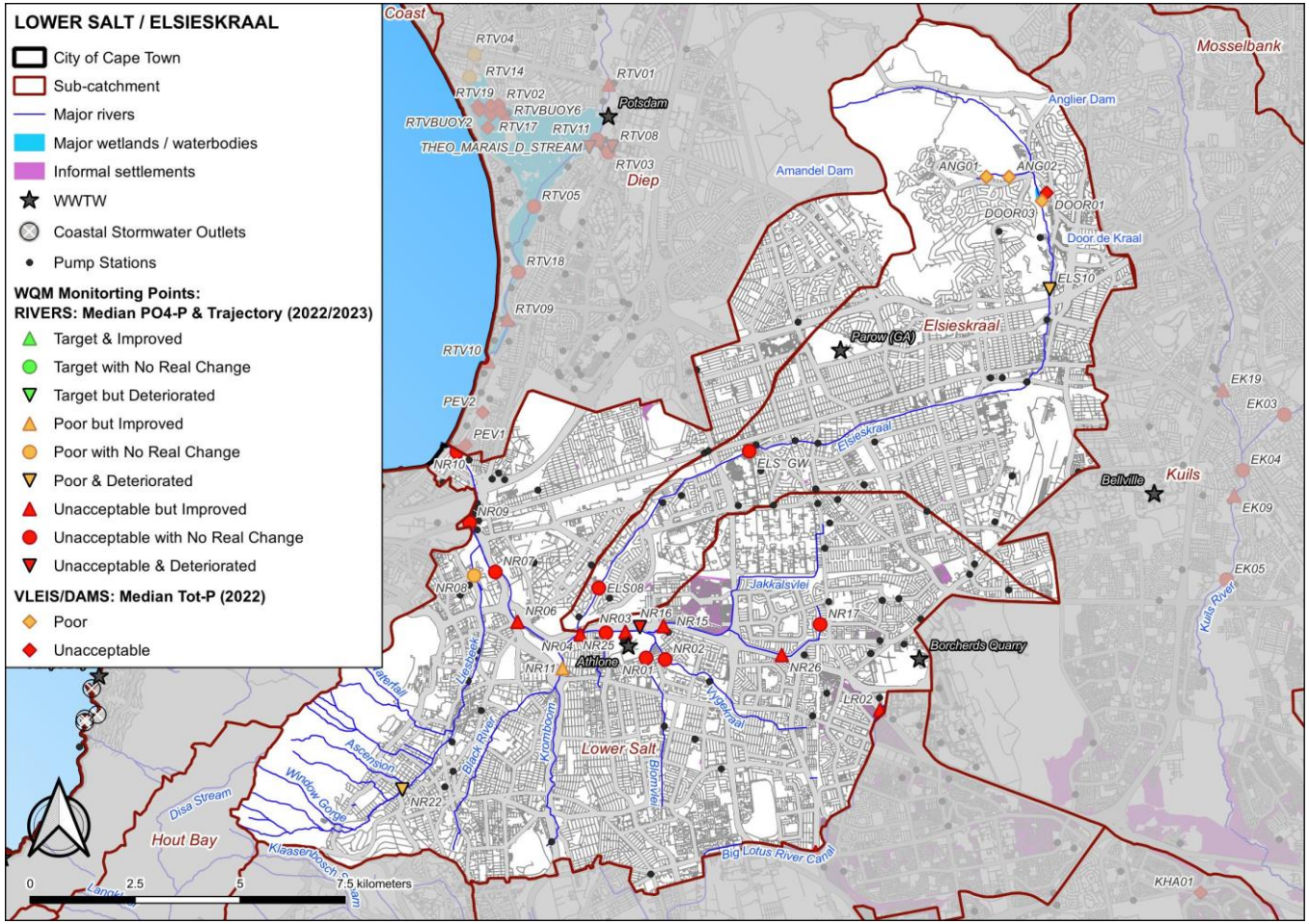


Figure 8.4.1
Median annual orthophosphate phosphorus (PO4-P) data (rivers) and median annual total phosphorus (Tot-P) (vleis), focusing on the LOWER SALT sub-catchment. Tot-P data provided only for 2022, due to missing total phosphorous data from January 2023 onwards. No Tot-P trajectories thus calculated. PO4-P trajectories calculated as explained in Section 3.8.14.

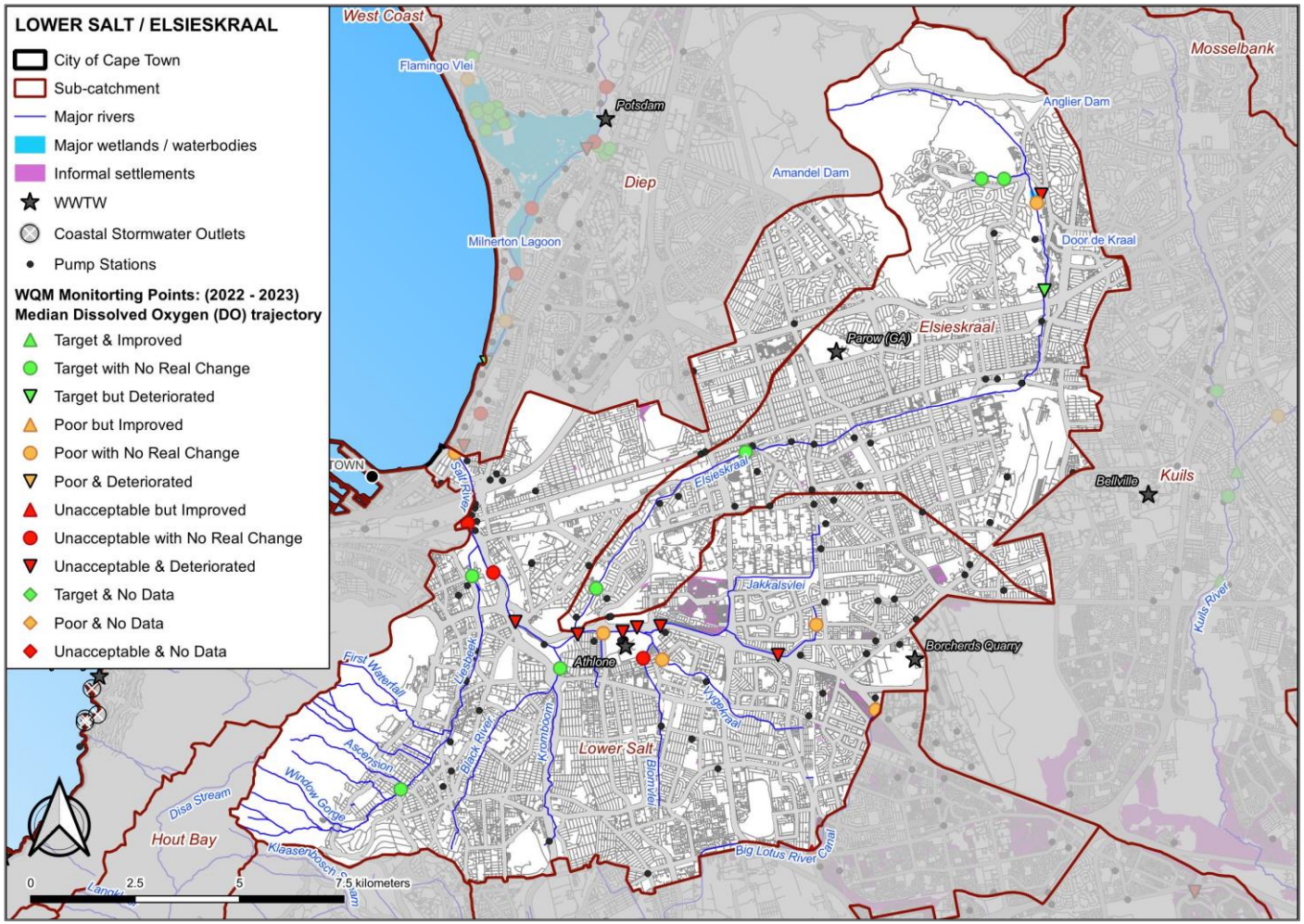


Figure 8.4.2

Median annual Dissolved Oxygen (DO) concentrations, focusing on the LOWER SALT Sub-catchment. Data coded as to level of change in the 2023 reporting period, compared with the 2022 reporting period. Trajectory calculations explained in Section 3.8.14.

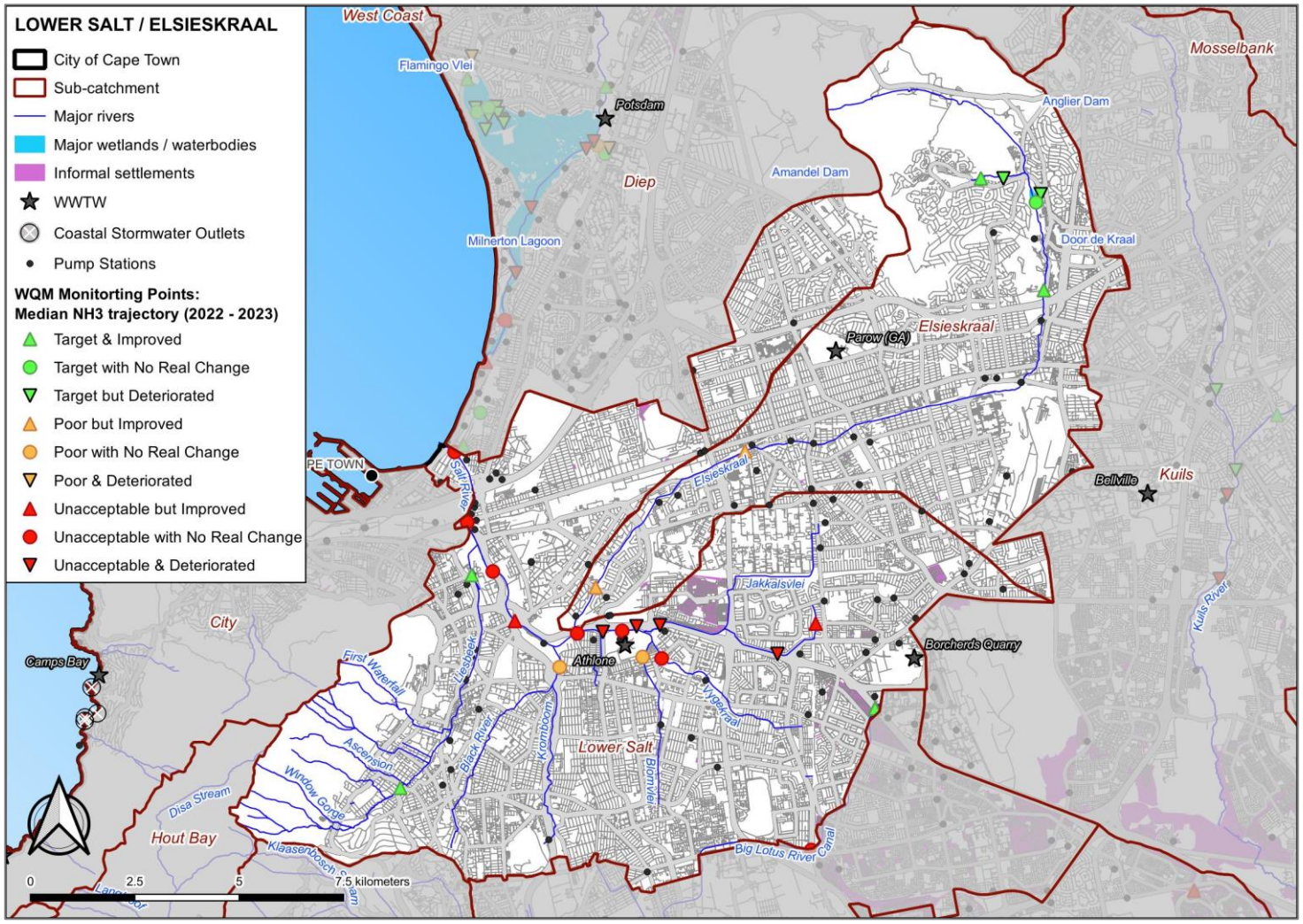


Figure 8.4.3

Median annual free ammonia (NH_3) concentrations, focusing on the LOWER SALT Sub-catchment. Data coded as to level of change in the 2023 reporting period, compared with the 2022 reporting period. Trajectory calculations explained in Section 3.8.14.

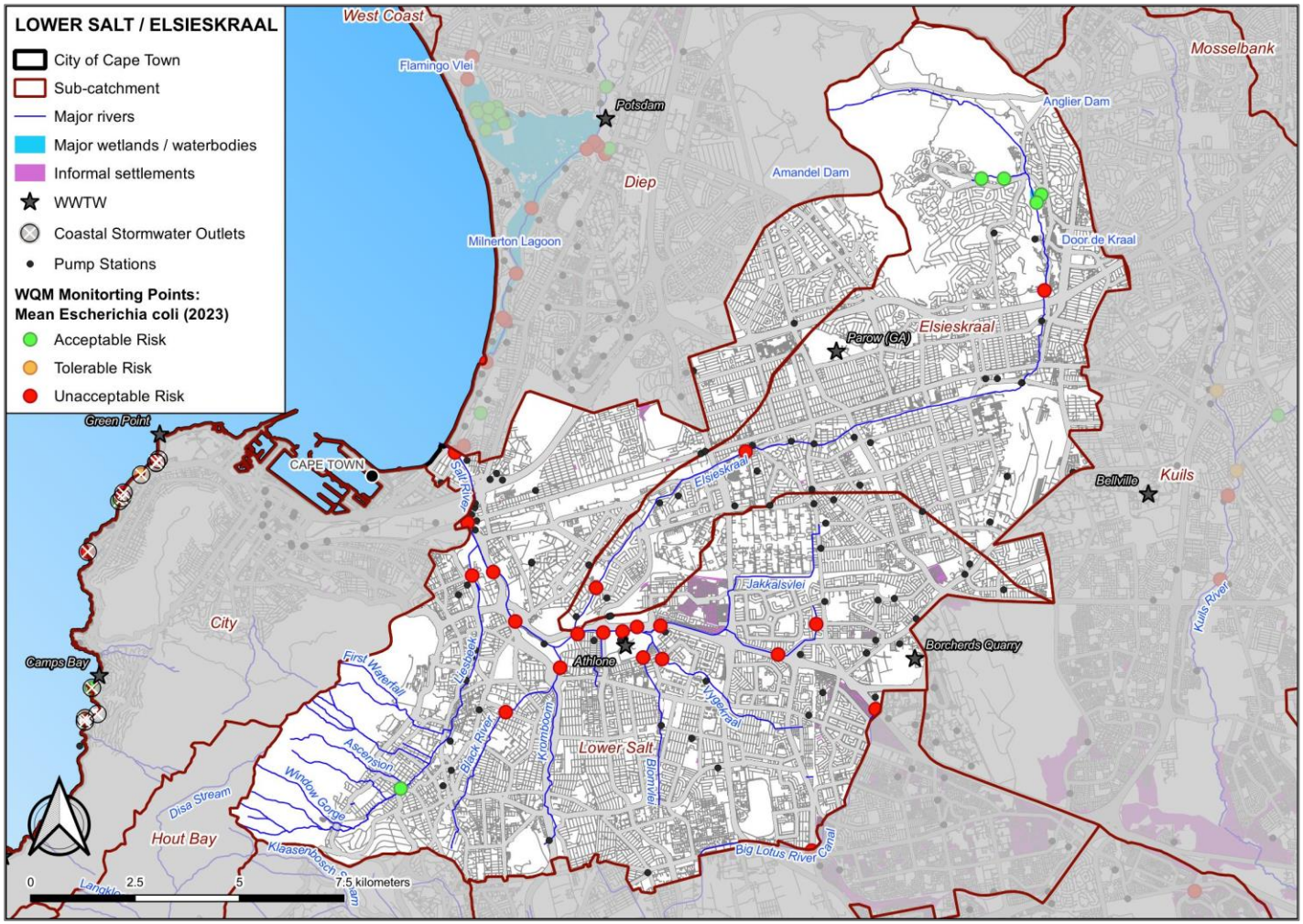


Figure 8.4.4
Mean *E. coli* data (geometric means) for Reporting Year 2023, focusing on the LOWER SALT Sub-catchment. Data coded as to human health risk (see Table 3.3). No reliable data available for the 2022 reporting period, so no trajectories shown.

8.5 Kuils / Eerste River

8.5.1 Catchment overview

This large priority catchment includes the Kuils River sub-catchment and the downstream portion of the Eerste River subcatchment. Most of the Kuils River and its tributaries lie within the CCT boundary, while most of the Eerste sub-catchment lies in the Stellenbosch Municipal area, only entering the CCT boundary in its lower reaches just upstream of the N2 road crossing. Three municipal WWTWs are in operation in the Kuils River sub-catchment, and one (the Macassar WWTW) in the Eerste River sub-catchment. Of these, the Zandvliet works has recently undergone a major upgrade, which was completed in Reporting Year 2023, to increase treatment capacity and improve effluent quality.

Land use in the Kuils sub-catchment is primarily urban, and includes major industrial and commercial areas such as Bellville CBD, Brackenfell, Stikland and Kuilsrivier, likely to reflect in stormwater quality typical of these land uses. An exception is the north-eastern corner of the sub-catchment in the vicinity of the Scottsdene WWTW, which includes some agricultural land use (mainly wine estates) and more open spaces including golf courses. With distance south through the sub-catchment, land use moves to primarily residential, with high density, low-cost housing predominating downstream of the Stellenbosch Arterial Road (M12). The Driftsands Nature Reserve is located in the largely built-up southern portion of the sub-catchment, but this now-deproclaimed Nature Reserve has been subject to significant land invasion and encroachment of informal settlement into the area (e.g., see **Photo 8.5.1**). These invasions have resulted in the loss of important, previously protected wetlands. In nearby CCT-owned land in the Mfuleni area, similar land invasions have resulted in marked expansion of informal and unserviced areas into wetlands (e.g., see **Photo 8.5.2**).



Photo 8.5.1
Land invasion and encroachment of informal settlement into the Driftsands Nature Reserve



Photo 8.5.2
Encroachment of informal settlement into wetlands in the Mfuleni area

In the relatively small portion of the Eerste River sub-catchment that falls within the CCT boundary, the dominant land uses in the northern half of the sub-catchment (to the north of Old Faure Rd) are high-density housing (to the east of the R102, Voortrekker Rd) and agriculture (to the west of the R102). To the south, the land-use is predominantly rural to semi-rural, with the exception of the urbanised areas of Macassar and Croydon, while there is open space along the section of the Lower Eerste River below the confluence with the Kuils River. The Macassar WWTW is located at the lower end of the sub-catchment, just upstream of the Eerste River estuary.

8.5.2 Major sources of pollution

The main sources of water pollution within the Eerste/Kuils catchment include:

- Input of inadequately treated sewage effluent from under-performing WWTWs, especially into the Kuils River, although this has improved significantly for the Lower Kuils River since the Zandvliet WWTW was

upgraded;

- Numerous and often prolonged sewage spills (e.g., **Photo 8.5.3**), caused by pump station overflows and/or the blockage of sewage pipes as a result of high levels of dumping and littering that enter the drainage networks (e.g., **Photo 8.5.4**), which typically affects nearby and downstream watercourses such as the Kleinvlei Canal in the Eerste sub-catchment (which then flows into the Lower Kuils River downstream);
- Runoff and direct input of untreated sewage and highly polluted grey water from informal settlements and areas with high levels of backyard dwelling into stormwater systems, and from there either directly or indirectly into rivers and wetlands;
- Stormwater runoff from commercial and industrial areas within the catchment, and from roads and built-up urban areas; and
- Pollution inputs into river and wetland systems from the agricultural areas within the catchment, mainly in the form of nutrients (phosphates and nitrates).



Photo 8.5.3
An overflowing sewer manhole near Mfuleni in the Kuils sub-catchment



Photo 8.5.4
Accumulation of litter in a major stormwater drain within the Kuils sub-catchment

8.5.3 Water quality through the catchment – condition and trajectory

Figures 8.5.1-8.5.4 present summary water quality data for phosphate (as PO4-P), dissolved oxygen, free ammonia (NH_3) and *E. coli* for Reporting Years 2022 and 2023, with present condition and trajectory of change analyses undertaken as outlined in **Sections 3.8.12 to 3.8.14** of this report.

These figures show that, for the Kuils and Eerste sub-catchments:

- Although there was an improvement in terms of median phosphate concentrations at some sites compared to the 2022 reporting period, all sampling sites throughout both the Kuils and Eerste sub-catchments were in the Unacceptable category (representative of hypertrophic conditions) in Reporting Year 2023, with WWTW effluent undoubtedly being a major contributor (as discussed in **Section 5.6.2.4**);
- These high levels of phosphate enrichment occurred even at the Kuils River main-stem monitoring point EK19, located upstream of both the Bellville WWTW and inflows from the Bottelary River, which receives treated effluent from the Scottsdene WWTW, suggesting that there are significant sources of phosphorus-enriched runoff in the Bellville CBD and upstream (which would include runoff from inner city areas with high levels of homeless communities as well as inflows from suburban gardens in the

more affluent areas, amongst other sources);

- Median DO concentrations for Reporting Year 2023 were in the Target range at a high proportion of the sampling sites in both the Kuils and Eerste sub-catchments, including sites a short distance downstream of WWTW discharge points but this is not too surprising because all of the WWTW facilities in these catchments were associated with relatively low COD concentrations (largely compliant with the General Limit) and loading rates (as shown in **Section 5.6.2**);
- The median DO concentration for Reporting Year 2023 (and 2022) was, however, in the Unacceptable category at the sampling point on the Kuils River immediately downstream of Baden Powell Drive (EK08), where a lot of untreated sewage and contaminated grey water enters the river from the rapidly expanding informal settlement along this portion of the Kuils River;
- Median DO concentrations at the next two sampling sites downstream (at EK11 on the Kuils River by the outlet of the Zandvliet WWTW and at EK12 on the Eerste/Kuils River below the confluence) were slightly better but still in the Poor category in Reporting Year 2023 (and 2022), presumably due to some oxygenation from the input of treated effluent from the Zandvliet WWTW;
- The median DO concentration was also in the Poor category during Reporting Year 2023 (and 2022) at the sampling point (EK03) on the Bottelary River just before it enters the Kuils River, presumably due to the runoff of irrigation return flows with a relatively high oxygen demand from the nearby Kuilsrivier Golf Course and upstream farming areas situated along the Bottelary River;
- Median un-ionised ammonia concentrations suggest that the upstream catchment of the Kuils River was unlikely to have been significantly impacted by ammonia toxicity during Reporting Year 2023 (and 2022, when the situation was better), with monitoring points upstream of the Bellville WWTW within the Target range for NH_3;
- A similar situation, with median NH_3 concentrations in the Target range for Reporting Year 2023 (suggesting a low risk of ammonia toxicity), were recorded in the Eerste River (at sampling point EK13) and the Moddergatspruit (at EK18) just before these rivers join the Kuils River;
- Threats to aquatic ecosystems posed by ammonia toxicity increased markedly in the Kuils River downstream of the Bellville WWTW inflow, with the two closest sites downstream of this point (EK09 and EK05) being rated as Unacceptable and Deteriorated for Reporting Year 2023;
- Median NH_3 concentrations in the Unacceptable range were also recorded downstream of the Zandvliet and Macassar WWTWs (at sampling points EK11 and EK17) in Reporting Year 2023;
- Median concentrations of un-ionised ammonia in the Poor range (indicative of chronic toxicity risk) were recorded for Reporting Year 2023 in the Kuils River at the monitoring point immediately downstream of Baden Powell Drive (EK08) where the river receives sewage-contaminated runoff from rapidly expanding informal settlement, at the point further downstream below the confluence with the Eerste River (EK12), and at the monitoring point on the Kleinvlei Canal (EK15) where periodic sewage spills into the Canal are a problem;
- Mean *E. coli* densities recorded in the Kuils and Eerste sub-catchments during Reporting Year 2023 were in the Unacceptable Risk category at all sites immediately below WWTW outlets, and at the monitoring points on the Kuils River below Baden Powell Drive and on the Kleinvlei Canal, which are subject to sewage inputs;
- Compliance with the Target range in terms of mean *E. coli* densities for Reporting Year 2023 (representative of an Acceptable Risk) was recorded at only two monitoring points in the Kuils/Eerste catchment, situated on the Bottelary River (at EK03) and the Eerste River (at EK13) just before these rivers join the Kuils River;
- Mean *E. coli* densities recorded for Reporting Year 2023 were reflective of a Tolerable Risk at the two monitoring points on the Kuils River upstream of the Bellville WWTW, at the point immediately upstream of the Macassar WWTW, and at the monitoring point on the Moddergatspruit tributary.

8.5.4 Focus areas of the CCT's water quality interventions within the sub-catchments

No PASAPs have, to date, been compiled for the Kuils or Eerste sub-catchments. Furthermore, over the reporting period under consideration here (Reporting Years 2022 and 2023), there have been very few direct interventions by the CCT to specifically address water quality in these socially and economically complex, rather large sub-catchments (the Kuils sub-catchment is the 4th largest by area in the City). A service delivery turn-around programme (Van Geer 2021a) and interim solutions for sewer overflows (Van Geer 2021b) have, however, been drafted and are in the process of being implemented for the under-serviced Wallacedene / Bloekombos areas, a small portion of which falls into the northern part of the Kuils sub-catchment (the greater proportion of Wallacedene / Bloekombos falls within the Mosselbank sub-catchment).

8.5.5 Major intervention challenges

The biggest challenge to the development and implementation of focussed interventions targeted towards the improvement of environmental water quality in the Eerste and Kuils sub-catchments is, arguably, a lack of budget and recent budget cuts within the CCT. Other challenges, which apply across most of the City, include the theft and vandalism of sewage and stormwater infrastructure, and the failure of sewage pumps related to load-shedding and electrical faults. These problems are of particular importance in the Kuils River sub-catchment, which has three significant WWTW facilities.

Another major challenge in both the Eerste and, especially, Kuils sub-catchments is the high rate of land invasion and non-serviced informal settlement in many areas. The CCT does not have the resources or budget to timeously provide sanitation and waste collection services to these areas, which are also often plagued by rampant criminal activity and intimidation or extortion of service providers.

The implementation of strategic interventions in both the Kuils and Eerste sub-catchments is also hampered by fragmented jurisdiction over these sub-catchments. In the case of the Kuils sub-catchment, part of it falls within the Eastern Region of the CCT and another part within the Northern Region (see map in **Figure 2.2**), while the most northern portion of the sub-catchment falls outside of the CCT boundary, extending into the Stellenbosch Municipal Area. Although the Eerste sub-catchment is only under the jurisdiction of one CCT Stormwater Planning Region (the Eastern Region), a majority of this sub-catchment falls within the Stellenbosch Municipal Area, yet many of the impacts from upstream are experienced within the portion of the sub-catchment forming part of the CCT.

8.5.6 Recommendations going forward

The main recommendation for the Kuils and Eerste sub-catchments is that PASAPs should be compiled and implemented for these sub-catchments. These PASAPs should contain realistic targets, taking into account the budgetary constraints of the relevant departments in the CCT who would be responsible for implementation of the various measures. The following measures, amongst others, should be considered for inclusion in the PASAPs:

- A sustained and measurable increase in solid waste collection, in terms of both the frequency and volume of solid waste removal at source, to prevent the build-up of organic, plastic and other waste in the sub-catchments;
- Pollution tracking within new and existing high-density housing areas to identify pollution streams and sources (e.g., to discern between pollution stemming from non-serviced backyard or informal housing elements, versus that caused by blocked or vandalised infrastructure);
- Implementation of appropriate measures to address the sources of pollution identified, such as the construction and maintenance of low-flow diversions of stormwater to sewer where sewage-contaminated stormwater is a major issue;
- Urgent implementation of interventions to provide sewage and stormwater servicing to the rapidly expanding informal and backyard settlements in the area;
- Implementation of measures to minimise sewage pump station failures related to load-shedding and electrical faults;

- Upgrading of the Scottsdene, Bellville and Macassar WWTW to ensure more compliant final effluent quality; and
- Development of procedures and communication channels to ensure more effective coordination between the various management structures that have jurisdiction over matters that affect the water quality of watercourses in the Kuils and Eerste sub-catchments.

In addition to the development and implementation of PASAPs for the Kuils and Eerste sub-catchments, it is strongly recommended that consideration be given to the inclusion of an additional water quality monitoring point at the Kuils River crossing on Old Faure Road, as a potentially useful means of providing water quality information about the contribution of this part of the catchment to downstream nutrient loading. It has also already been recommended that monitoring of the Kuils River in the reaches used bythe Khayelitsha Canoe Club should be included in the CCT's monitoring programme.

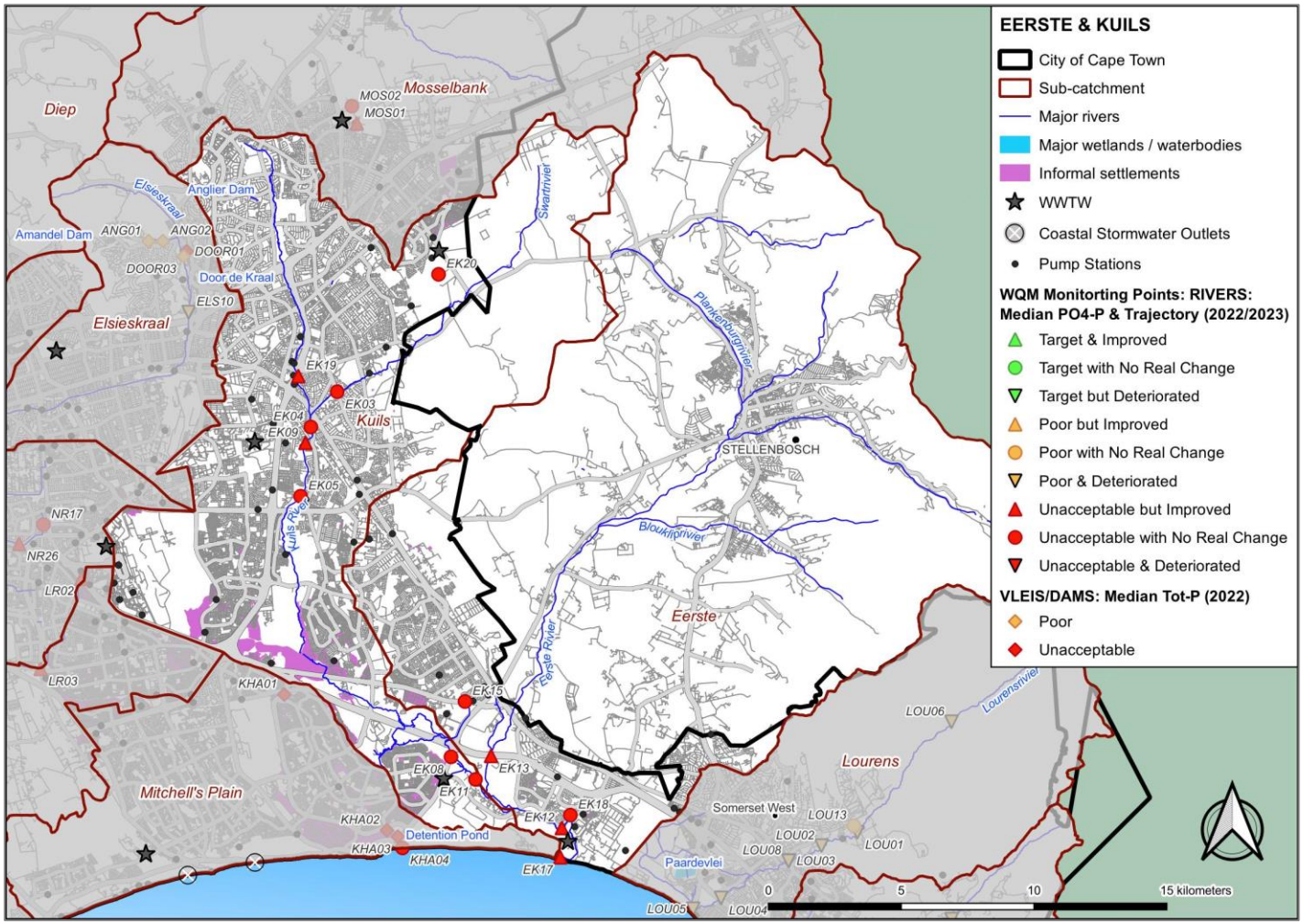


Figure 8.5.1

Median annual orthophosphate phosphorus (PO4-P) data (rivers) and median annual total phosphorus (Tot-P) (vleis), focusing on the KUILS & EERSTE sub-catchments. Tot-P data provided only for 2022, due to missing total phosphorus data from January 2023 onwards. No trajectories thus calculated. PO4-P trajectories calculated as explained in Section 3.8.14.

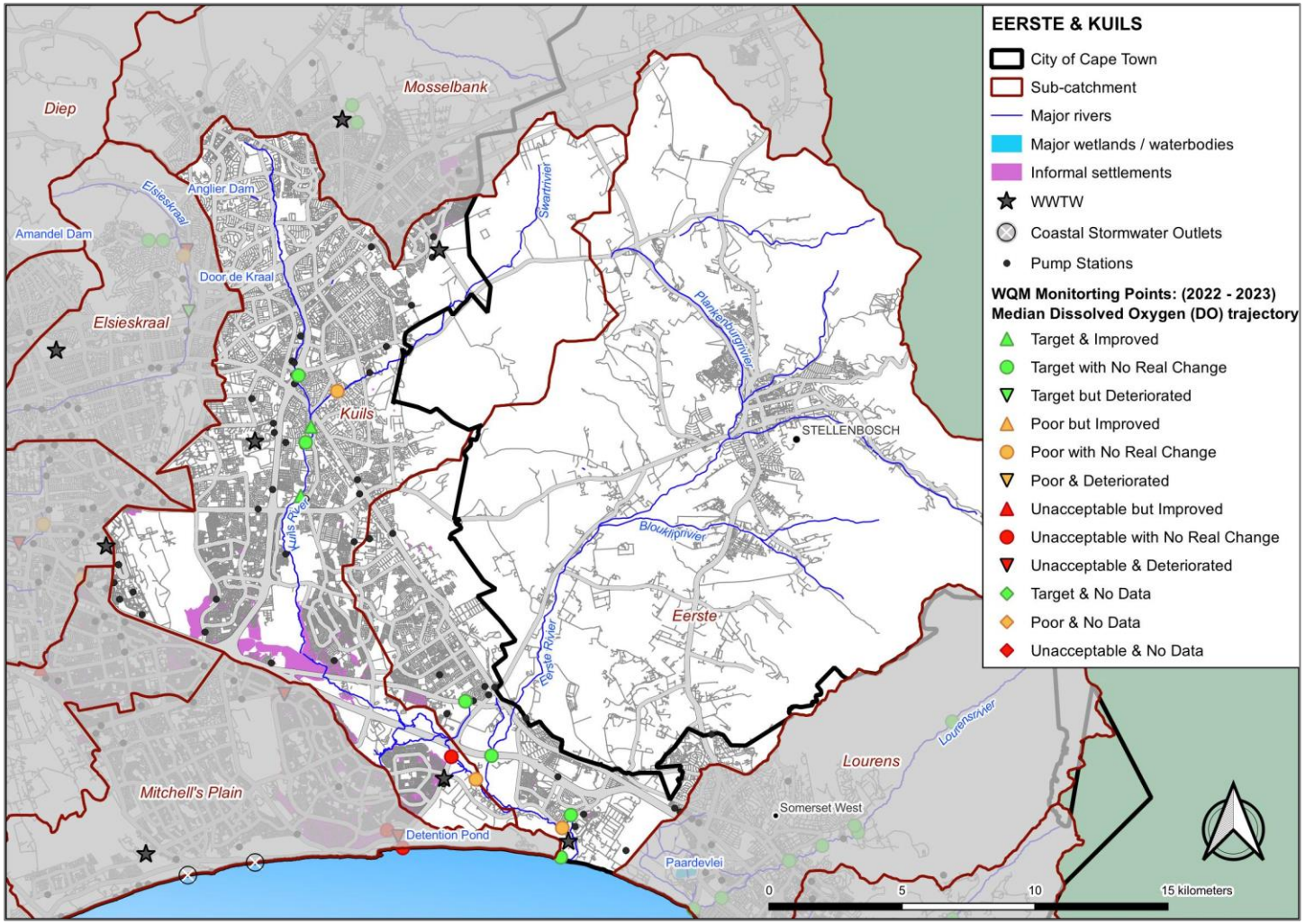


Figure 8.5.2
Median annual Dissolved Oxygen (DO) concentrations, focusing on the KUILS & EERSTE sub-catchments. Data coded as to level of change in the 2023 reporting period, compared with the 2022 reporting period. Trajectory calculations explained in Section 3.8.14.

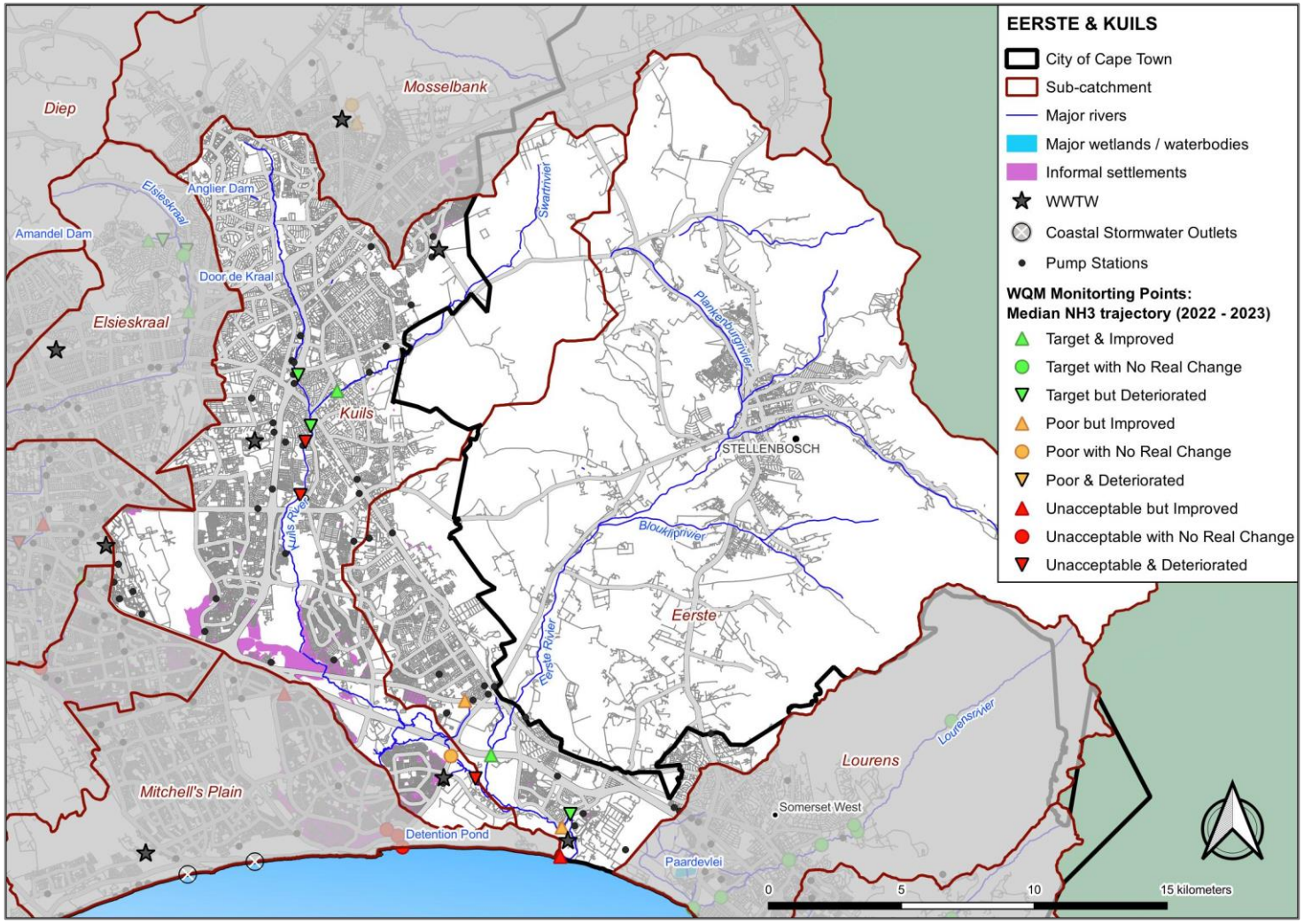


Figure 8.5.3

Median annual free ammonia (NH_3) concentrations, focusing on the KUILS & EERSTE sub-catchments. Data coded as to level of change in the 2023 reporting period, compared with the 2022 reporting period. Trajectory calculations explained in Section 3.8.14.

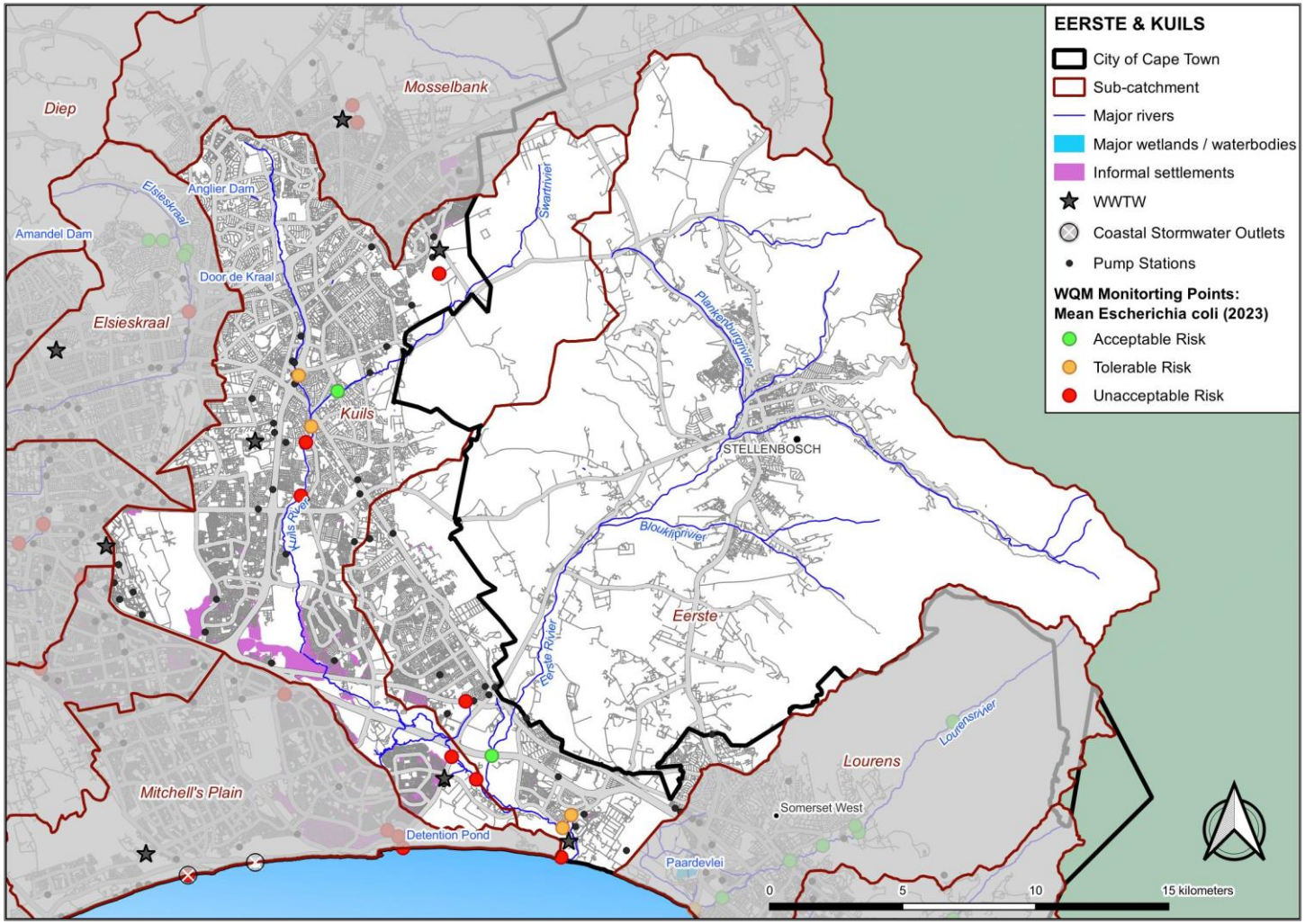


Figure 8.5.4
Mean E. coli data (geometric means) for Reporting Year 2023, focusing on the KUILS & EERSTE sub-catchments. Data coded as to human health risk (see Table 3.3). No reliable data available for the 2022 reporting period, so no trajectories shown.

8.6 Hout Bay River

8.6.1 Catchment overview

Most of this contextual information is taken from the State-of-Rivers Report prepared by the River Health Programme (RHP, 2003). The Hout Bay River catchment is a relatively small catchment (approximately 40 km^2 in areal extent), with the entire upper catchment located within the Table Mountain National Park consisting mostly of natural areas. The middle to lower portion of the catchment is, however, dominated by urban, peri-urban, and commercial land-uses, occupying approximately 20% of the catchment area. There is a relatively large (especially in relation to the catchment size) informal settlement (Imizamo Yetho) in the lower reaches of the catchment. A number of domestic water supply dams in the upper catchment (see **Box 8.6.1**) have significantly affected the flows of the Hout Bay River.

Box 8.6.1
Dams in the upper Hout Bay catchment

The Hout Bay River was an important water resource for Cape Town over 100 years ago, with some of the earliest domestic water supply dams for the City having been constructed in the upper reaches of the catchment (on top of Table Mountain). There are five in-stream dams, namely:

- **Woodhead Dam** (built in 1897) and **Hely-Hutchinson Dam** (built in 1904) on the Disa tributary; and
- **Alexandra** and **Victoria Dams** (built in 1903), and **De Villiers Dam** (built in 1907) on the Original Disa tributary.

The total storage volume of the five dams is approximately 2.5 Mm^3, representing 24% of naturalised MAR of the catchment (RHP, 2003). These dams now supply less than 15% of Cape Town's water requirements.

The Disa and the Original Disa tributaries originate on Table Mountain at an altitude of 720 m AMSL. These streams join to form the Hout Bay River in the access-controlled Orange Kloof section of the Table Mountain National Park, which contains a relatively large, intact area of Afromontane forest. The Hout Bay River is approximately 12 km long, with steep and fast-flowing, naturally acidic waters in the more natural upper to middle reaches. The river meanders through farmlands and residential areas in the lower reaches, where extensive reed beds flank the river channel, before it widens into a small lagoon which discharges into the sea on Hout Bay beach.

The name Hout Bay refers to the abundance of indigenous trees that once occurred in the middle to upper reaches of the catchment ("hout" is the Afrikaans word for wood). The lower reaches of the Hout Bay River originally consisted of a naturally braided channel flowing through an extensive palmiet (*Prionium serratum*) and reed wetland area. Large-scale harvesting of the indigenous forest in the upper catchment and removal of palmiet and reed beds in the naturally wide floodplain resulted in severe erosion along the middle and lower reaches of the Hout Bay River, which was addressed by the construction of the rather extensive concrete Longkloof weir that had its own negative impacts on the ecological functioning of the downstream reaches of the river.

Other impacts in the middle to lower reaches of the Hout Bay River include the encroachment of invasive alien vegetation along the riverbanks (e.g., see **Photo 8.6.1**), channel straightening, dredging of sediments from the channel and construction of levees to prevent flooding of riverside properties. There are no WWTWs that discharge wastewater into rivers in the Hout Bay catchment because primary treated wastewater from the area is released into Hout Bay via a deep-sea outfall. There are, however, sewage pipelines in the catchment, as well as septic tanks and the informal settlement of Imizamo Yethu, which cause sewage-related pollution problems and the proliferation of algae, reeds and other alien instream vegetation in the middle to lower reaches of the Hout Bay River (e.g., see **Photo 8.6.2**).



Photo 8.6.1
The middle reaches of the Hout Bay River are only moderately impact by water quality (runoff from paddocks and gardens) and instream habitat is relatively good. Extensive alien invasion impacts on riparian quality



Photo 8.6.2
Close-up photo showing the visibly polluted lower reaches of the Hout Bay River, where there is a proliferation of algal growth and instream alien vegetation

8.6.2 Major sources of pollution

The main sources of water pollution within the Hout Bay catchment, as confirmed in the Hout Bay Catchment Pollution Abatement Strategy and Action Plan (PASAP) (Martin 2024), are:

- Smallholdings and horses in the middle reaches of the Hout Bay River;
- Sewage overflows from blocked pipes and pump station failures, mainly in the middle to lower reaches of the catchment (e.g., see **Photo 8.6.3**); and
- Input and runoff of sewage-contaminated water into the stormwater system from the largely informal Imizamo Yethu settlement, which flows into the lower reaches of the Hout Bay River, as well as from the Hangberg area where a large portion of the formal housing is associated with backyard dwellings.

Although it is not a direct source of water pollution, the accumulation of litter in the Hangberg and especially Imizamo Yethu settlements is a major problem that often leads to the blockage of sewerage and stormwater infrastructure, which in turn results in sewage overflows into watercourses. This problem is exacerbated by solid waste collection challenges, particularly in Imizamo Yethu (see **Photo 8.6.4**), such as those reported on in a recent article in the *People's Post* local newspaper (Boshoff 2024).



Photo 8.6.3
An overflowing sewer manhole in the Hout Bay catchment, caused by a blockage [photo copied from Hout Bay Catchment PASAP]



Photo 8.6.4
Litter accumulating in Imizamo Yethu [photo copied from Hout Bay Catchment PASAP]

8.6.3 Water quality through the catchment – condition and trajectory

Figures 8.6.1-8.6.4 present summary water quality data for phosphate (as PO4-P), dissolved oxygen, free ammonia (NH_3) and *E. coli* for Reporting Years 2022 and 2023, with present condition and trajectory of change analyses undertaken as outlined in **Sections 3.8.12 to 3.8.14** of this report.

These figures show that, for the Hout Bay River and associated catchment:

- Water quality was generally better upstream of the more urbanised portion of the catchment (above site DR06 at Bethel Road), with DO, NH_3 and *E. coli* all in the Target range and not deteriorating, but median PO4-P concentrations at the upstream sites were in the Poor category for Reporting Year 2023 (indicating eutrophication), having deteriorated by more than 25% from Reporting Year 2022;
- At all three sampling sites downstream of Imizamo Yethu (i.e., at and below DR02 at Victoria Road), median PO4-P and mean *E. coli* concentrations were in the Poor and Unacceptable categories in Reporting Year 2023, indicating phosphate enrichment and sewage contamination in these lower reaches of the river;
- Median DO concentrations for Reporting Year 2023 were also in the Unacceptable and Poor categories at the two most downstream sampling sites (DR01 and DR05) but, rather unexpectedly, the median DO concentration at the sampling site immediately downstream of Imizamo Yethu (DR02) was within the Target range in Reporting Year 2023, having improved significantly from Reporting Year 2022;
- While median NH_3 concentrations were within the Target range at all sampling sites along the Hout Bay river in both Reporting Years 2022 and 2023 (with no significant change from one year to the next), this is largely attributable to the generally low pH values currently prevalent in the river (all measurements <7.5 with median <7.25 in both reporting years), which reduces the proportion of total ammonia that exists as free ammonia and thus reduces the risk of ammonia toxicity, rather than low concentrations of total ammonia in the river.

8.6.4 Focus areas of the CCT's water quality interventions within the sub-catchment

The eutrophication and bacterial contamination of the middle to lower reaches of the Hout Bay River are largely attributable to inflows of untreated sewage from the Imizamo Yethu informal settlement into the

stormwater network and sewer overflows as a result of blocked pipes and/or pump station failures, exacerbated by significantly reduced river flows during summer from dams and other abstraction in the catchment. Taking cognizance of this, the main focus areas for the interventions by the CCT to address water quality issues in the Hout Bay catchment revolve around minimising the incidence of and dealing more effectively with sewer overflows throughout the catchment, and putting measures in place to prevent or at least reduce the input of bacteriologically contaminated water from Imizamo Yethu into stormwater systems.

In March 2023, a Pollution Abatement Strategy and Action Plan (PASAP) was drafted by the CCT for the Hout Bay Catchment, which is now in its 8th revision (Martin 2024). A comprehensive study for the catchment was also completed by Lukhozi Engineering for the CCT in June 2023. The overall aim of the Hout Bay Comprehensive Study was to create a comprehensive integrated report, to guide a professional plan of action to address the chronic sewage pollution affecting Hout Bay.

The strategic approach and recommendations put forward in the Hout Bay Catchment PASAP, to address pollution issues in the catchment, include:

- Ongoing engagement with the Hout Bay River Catchment Forum as an important strategic partner in informing the City of pollution incidents, and assisting with addressing pollution issues in the catchment and with education and awareness-raising amongst communities within the catchment;
- Increasing the frequency of repair and maintenance schedules for sewage and stormwater infrastructure in the catchment, to keep the systems functional and clean in the face of excessive vegetation growth, siltation and degradation of infrastructure resulting from elevated nutrient levels and from dumping, theft and vandalism;
- Installation of sufficient pumps and effectively functioning telemetry systems at sewage pumpstations, and UPS systems at high-risk greywater pumpstations to aid with the problems arising as a direct result of load-shedding;
- Elimination of all existing grey water connections incorrectly connected to the stormwater infrastructure and correctly connecting these wastewater streams to the sewerage system;
- Elimination of solid waste dumping through provision of sufficient formal solid waste collection centres, swop-shops and recycling centres.

The proposed approach, as set out in the PASAP, will require input and coordination from each affected department within the CCT. The stipulated focus of the proposed interventions is to address pollution sources, at source within the affected catchment.

The following high-level actions have been taken by the CCT to move towards implementing some of the recommended interventions of the Hout Bay Catchment PASAP:

- A consultant has been appointed to undertake the design and installation of a bulk stormwater line that has been proposed along the Hout Bay Main Road, among other infrastructure to be constructed;
- A meeting was held by various CCT departments in conjunction with members of the Hout Bay River Catchment Forum to discuss the possible use of an existing detention pond as a temporary holding facility for highly polluted stormwater from Imizamo Yethu, as a possible interim solution while the recommended long-term solutions are constructed or installed;
- Ongoing discussions have been held between CSRM, Hout Bay River Catchment Forum and Solid Waste Area Cleaning and Solid Waste Collections to improve Solid Waste Services in especially the informal areas, and the formal areas with backyarders in and around the informal areas of Hout Bay (Imizamo Yethu and Hangberg);
- A detailed Strategic Action Plan was compiled (and included as an annexure to the PASAP). This Action Plan itemises each pollution source, identifies the affected / responsible CCT department, and the actions

and interventions required. The plan also indicates the recommended timeframes for implementing the stipulated interventions for each specified pollution issue.

On the ground, the following interventions *inter alia* were undertaken in the Hout Bay catchment during the 2022 and 2023 reporting periods by the CCT (or by contractors for the CCT:

- Rollout of a few education and awareness sessions among communities within the catchment, with one of the sessions undertaken in Reporting Year 2023 focusing specifically on the improper use and disposal of sanitary material and ablution material into the sewer system;
- Engagement with landowners of smallholdings and the World of Birds to manage manure from animals better;
- Increased frequency of cleaning of stormwater infrastructure compared to previous periods, in an attempt to address ongoing theft, vandalism and dumping in the stormwater infrastructure;
- Periodic cleaning and maintenance of communal sanitation facilities (toilets, wash water bays, decanting facilities, etc.) in all the informal areas of Hout Bay;
- Periodic cleaning of key bulk sewer lines, using a combination of bucket and jet cleaning, to prevent the blocking and surcharging of sewer pipes (e.g., see **Photo 8.6.5**);
- Installation of litter socks (e.g., see **Photo 8.6.6**) onto some of the more problematic stormwater bulk pipes (before they discharge into the main river course), and the damaged litter sock at Victoria Bridge emergency outlet was removed and reinstated;
- Construction of a number of low-flow stormwater to sewer diversions and of a new sediment forebay just before the Victoria Rd stormwater to sewer low-flow diversions works;
- Installation of a steel cage around the telemetry box at the greywater pumpstation associated with the Victoria Rd stormwater to sewer low-flow diversion works and procurement of UPS system for the pumpstation;
- Construction of additional stormwater catch pits as part of a road upgrade project in Imizamo Yethu;
- Identification of a number of illegal stormwater-to-sewer connections, with notices issued to the relevant property owners for them to remove the illegal connections, and corrective action underway by CCT where necessary;
- Implementation of a number of *ad-hoc* interventions to improve sanitation services in informal areas, including porta-loos and septic toilets, with varying degree of success.



Photo 8.6.5
Debris cleared from sewer pipes in the Hout Bay catchment (April 2022) [photo credit: Andrew Taylor, City of Cape Town]



Photo 8.6.6
A litter sock attached to a stormwater outlet in the Hout Bay catchment [photo copied from Hout Bay Catchment PASAP]

8.6.5 Major intervention challenges

The main challenges to implementing water pollution abatement measures in the Hout Bay catchment have been identified as follows:

- A lack of funding for many of the proposed initiatives, due to severe cuts to both capital expense and operating budgets for the relevant departments within the CCT;
- Theft, vandalism and destruction of stormwater, sewage and sanitation infrastructure;
- Hampering of more frequent collection of solid waste in the informal areas, especially Imizamo Yethu, through protests about service providers, and extortion and intimidation of service providers;
- A lack of awareness amongst some community members within the catchment about the consequences of certain actions with respect to pollution, water quality and human health risk (e.g., unawareness that the illegal connection of stormwater lines to sewer lines typically results in blockages and the subsequent spillage of sewage-contaminated water, which flows into downstream watercourses and pollutes them, and represents a major human health risk both at the spill site and in the downstream watercourses).

8.6.6 Recommendations going forward

The main water quality issues in the Hout Bay catchment are associated with a lack of adequate sanitation in the Imizamo Yethu informal settlement and the subsequent inflows of untreated sewage into the stormwater network that discharges into the lower reaches of the Hout Bay River.

The following recommendations are made, to facilitate improvement in the water quality of the middle to lower reaches of the Hout Bay River catchment:

- An urgent focus on interventions to provide proper sanitation facilities to the Imizamo Yethu informal settlement, in conjunction with the provision of formalised housing;
- Facilitating access to funding for the recommended interventions already proposed in the Hout Bay Catchment PASAP and associated Strategic Action Plan, which could be through the formation of private-public partnerships and/or motivating for additional budget to be allocated to the Hout Bay catchment as one of the priority catchments within the CCT;
- Urgent implementation of measures to address the current issues hampering the more frequent collection of solid waste from Imizamo Yethu; and
- Increased attention on education and awareness-raising amongst community members about water quality issues in the catchment, and the use of more innovative approaches to this through the involvement of environmental education specialists.

Although the Hout Bay catchment is split into two CCT stormwater management regions (see **Section 2.7** and **Figure 2.2**), the portion of the catchment that falls within the Central region is almost all within the mostly unpolluted Table Mountain National Park, while the portion that falls within the Southern region includes the middle to lower portions of the catchment where there are serious water quality issues that need to be addressed. As such, the problem of fragmented management of water quality due to the stormwater management regions not aligning with topographical catchments is less of an issue in the case of the Hout Bay catchment than it is for other "split" catchments in the City.

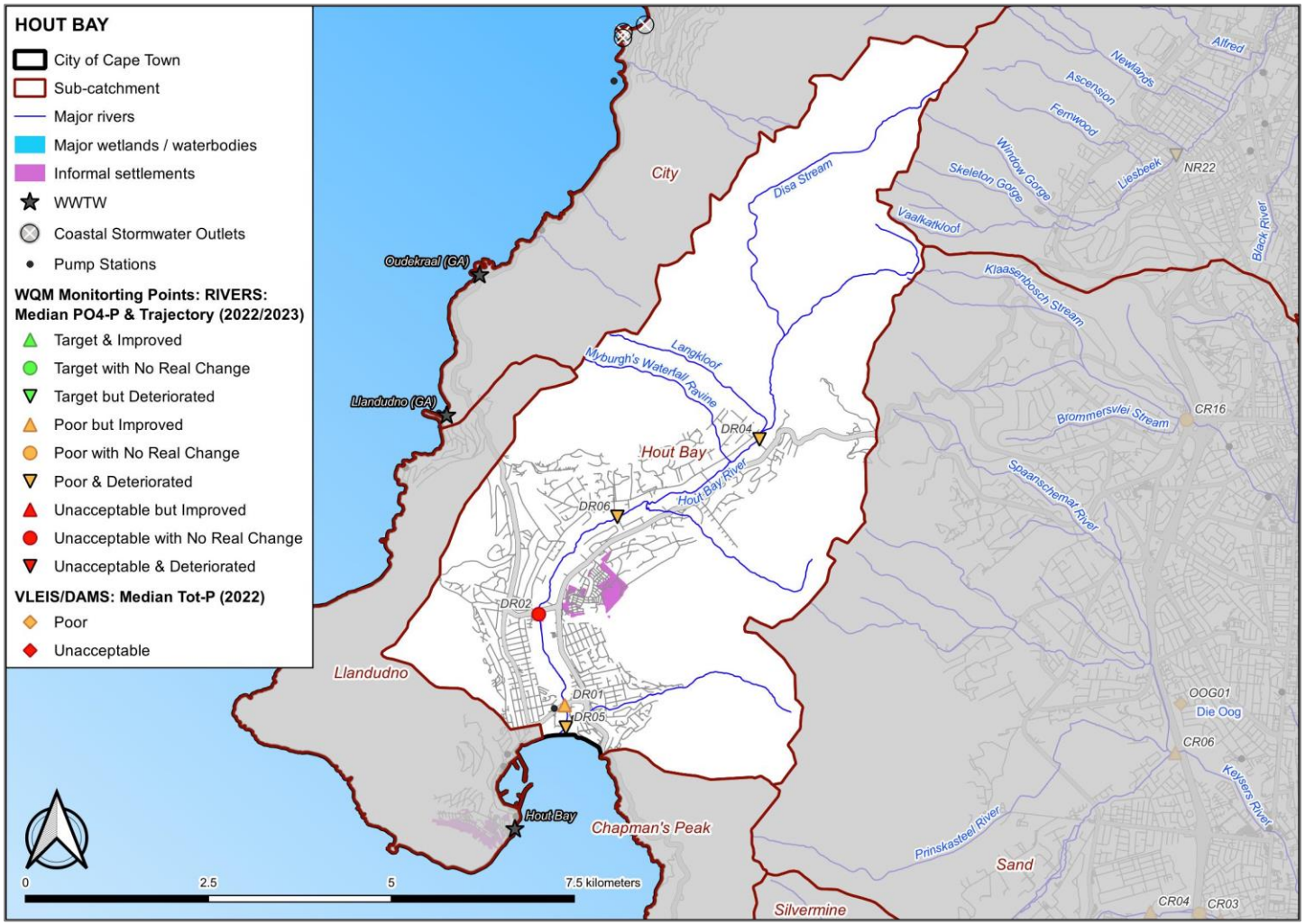


Figure 8.6.1
Median annual orthophosphate phosphorus (PO4-P) data (rivers) and median annual total phosphorus (Tot-P) (vleis), focusing on the HOUT BAY Sub-catchment. Tot-P data provided only for 2022, due to missing total phosphorus data from January 2023 onwards. No trajectories thus calculated. PO4-P trajectories calculated as explained in Section 3.8.14.

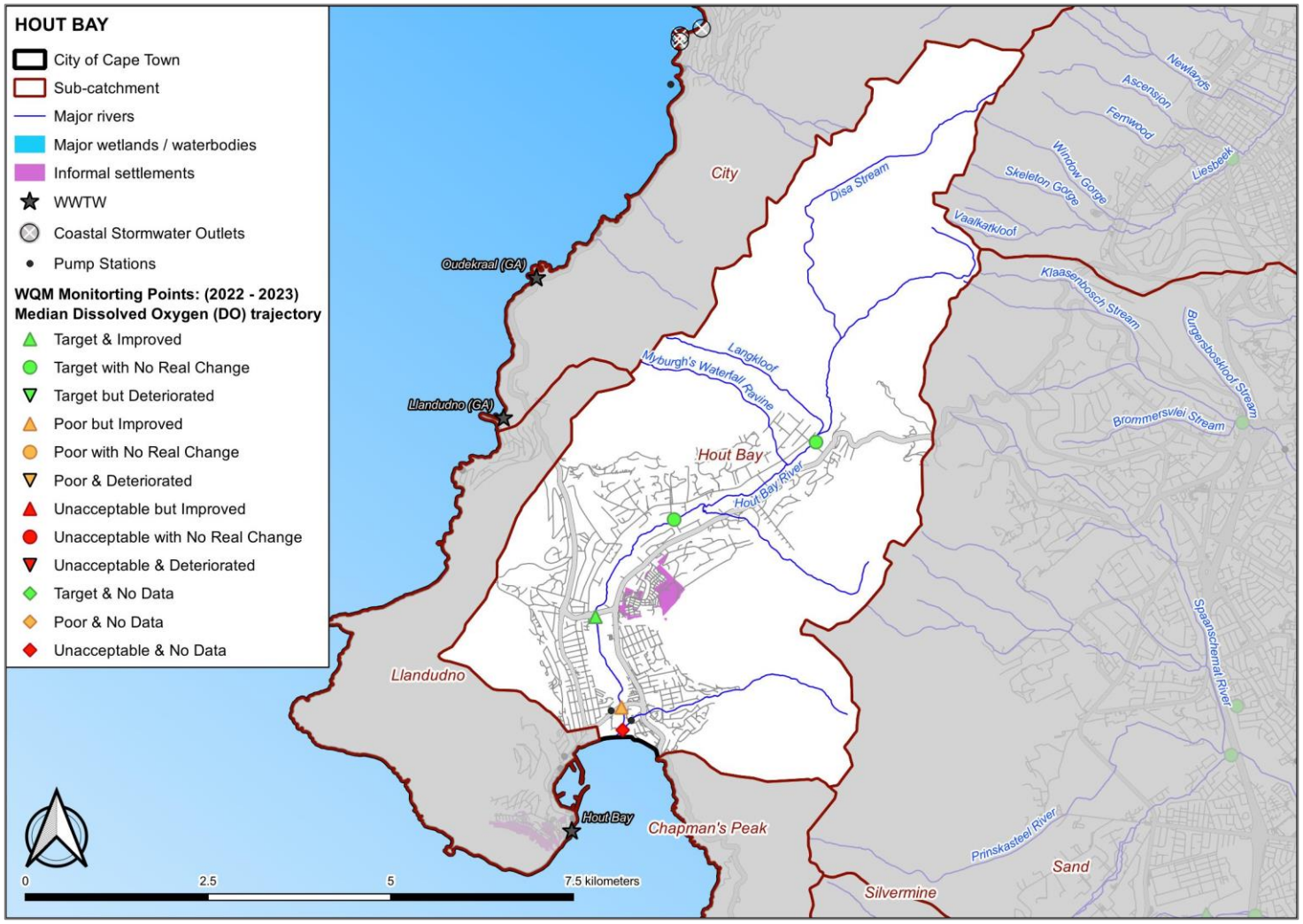


Figure 8.6.2

Median annual Dissolved Oxygen (DO) concentrations, focusing on the HOUT BAY Sub-catchment. Data coded as to level of change in the 2023 reporting period, compared with the 2022 reporting period. Trajectory calculations explained in Section 3.8.14.

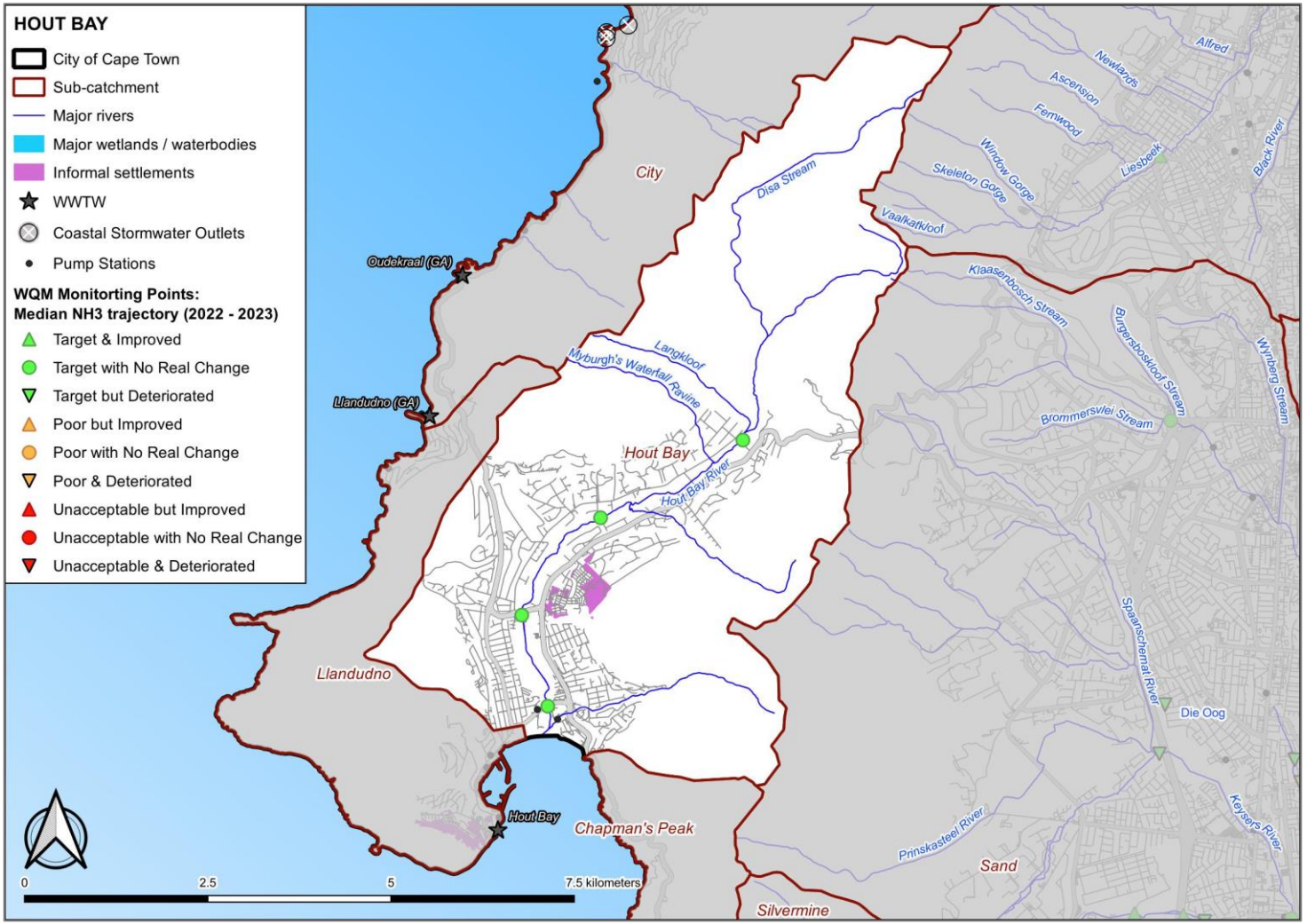


Figure 8.6.3
Median annual free ammonia (NH_3) concentrations, focusing on the HOUT BAY Sub-catchment. Data coded as to level of change in the 2023 reporting period, compared with the 2022 reporting period. Trajectory calculations explained in Section 3.8.14.

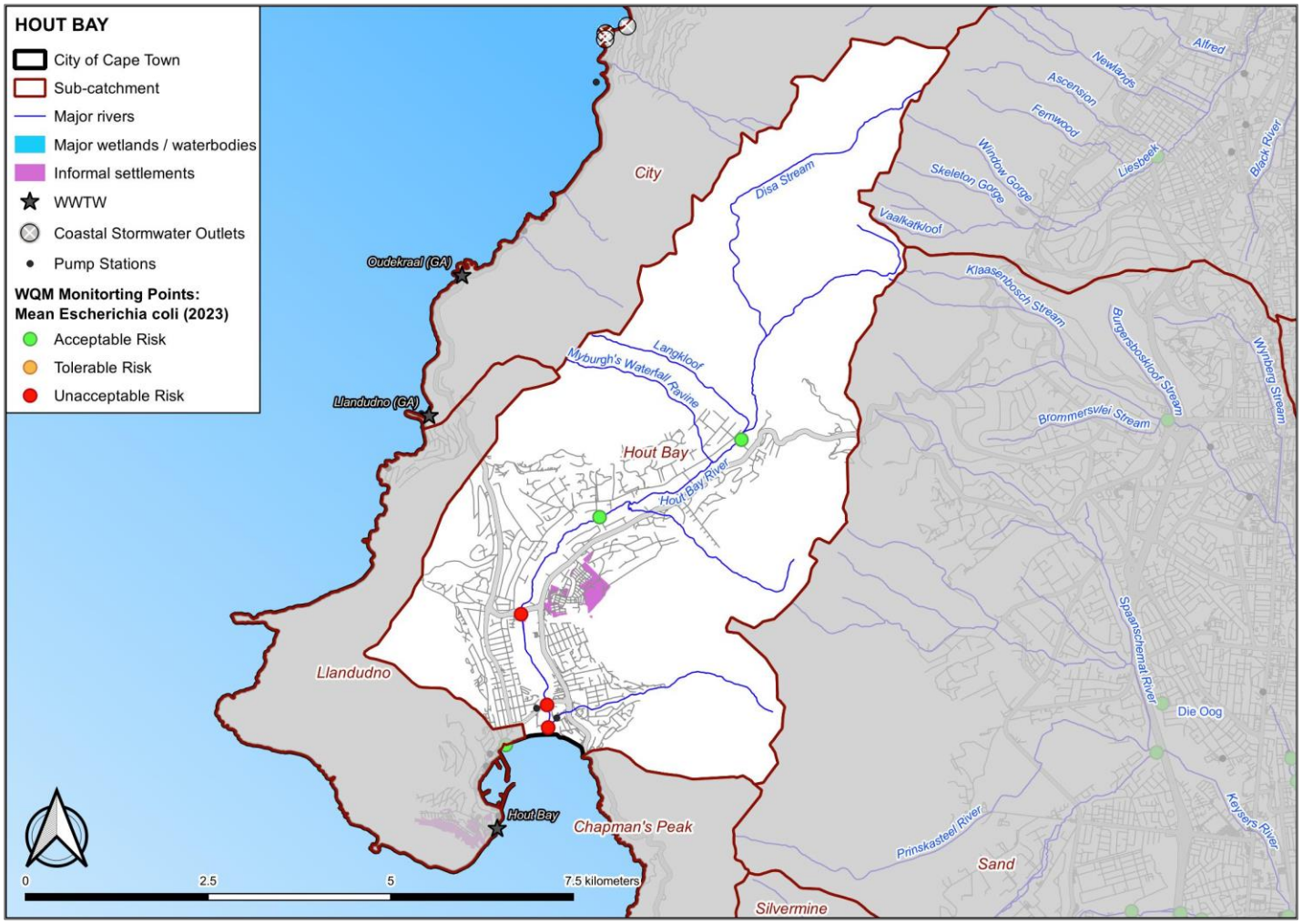


Figure 8.6.4
Mean E. coli data (geometric means) for Reporting Year 2023, focusing on the HOUT BAY Sub-catchment. Data coded as to human health risk (see Table 3.5). No reliable data available for the 2022 reporting period, so no trajectories shown.

8.7 Sand Sub-catchment

The Sand Sub-catchment was added to the priority catchments areas during compilation of the 2023 Water Quality Inland Report at the recommendation of CSRM, supported by the consultant team, mainly because it is the focal catchment for the pilot phase of the LUW Programme (see **Section 7.4**).

8.7.1 Catchment overview

The Sand catchment is distinguished from many of the City's other catchments by the absence of any WWTWs or major informal settlements. This means that it'

Zandvlei, which is one of two estuarine vleis in Cape Town that are major recreational water bodies, is located in this catchment. Zandvlei drains into False Bay at Muizenberg beach and receives the bulk of its fresh water from three river systems originating on the east-facing slopes of the Table Mountain - Constantiaberg mountain chain. These are the Sand/Diep, Keysers and Westlake Rivers.

Box 8.7.1:
Standing water bodies in the Sand catchment

There are a number of standing water bodies in the Sand catchment. The main vleis, besides Zandvlei, are Little Princessvlei, Langevlei and Die Oog. There are also extensive wetland areas, including the Westlake Wetland, the Kirstenhof Wetlands Park and the Keysers River wetlands. In addition, there are a number of dams (artificial open water bodies), including Pollsmoor Dam.

The Diep / Sand River Sub-catchment is the most northerly of the sub-catchments feeding into Zandvlei, and drains off the eastern slopes of Table Mountain just south of Kirstenbosch National Botanical Gardens. In addition to the Diep River itself, the sub-catchment includes a number of tributaries, of which the most significant comprise the Wynberg, Klaasenbosch, Brommersvlei, Burgersboskloof and Cecilia Forest Streams, all of which enter the Diep River upstream of Main Road. The Diep River is canalised downstream of Main Road, and flows into the lower reaches of Little Princessvlei. A small informal settlements has developed along the river margins, just upstream of Roscommon Road.

Little Princessvlei is also fed by the Mocke. Its outlet is the Sand River, which is a canal that flows southwards and then in a south-westerly direction from the outlet of Little Princessvlei to Zandvlei. The canal is prone to high levels of accumulation of solid waste, particularly downstream of Retreat Road.

The Langevlei system, which enters the Sand River just upstream of its confluence with Zandvlei estuary is also canalised throughout its reaches to the confluence with the Sand River Canal.

Two significant open water bodies (or vleis) occur within the Diep/Sand sub-catchment, namely Little Princessvlei, on the lower Diep River near Elfindale, and Langevlei, on the Langevlei Canal in Retreat. In addition, the sub-catchment includes several on- and off channel stormwater detention and retention basins, used in the City's stormwater management system.

The Keysers River rises on the east-facing slopes of the Constantiaberg mountain as a series of small streams, the most significant of these being the Spaanschemat, Grootboschkloof, and Prinkasteel Rivers. The upper reaches of the Grootboschkloof and Prinskasteel Rivers are located within the undeveloped Table Mountain National Park. Upstream of the M3 freeway, the tributaries of the Keysers River flow through forestry, agricultural (vineyards) and residential land-uses in Constantia and Tokai. From the confluence of all the tributaries just to the west of the freeway, the Keysers River flows south-eastwards under the freeway and through urban open space (old farmland) in Dreyersdal until it reaches Main Road where commercial land-use dominates. After going under Main Road, the river turns southwards and flows through an industrial area and a portion of the high-density residenial suburb of Steenberg before reaching the wetland area on the north-western fringes of Zandvlei.

The Westlake River has its source on the lower slopes of the Constantiaberg mountain, within an agricultural estate below Silvermine Nature Reserve. Steenberg. It flows through the gardens of the Norval Foundation, under Steenberg Road and past a commercial node (Steenberg Village shopping centre), before turning eastward and flowing alongside the Westlake low-income settlement and then through the agricultural fields of Polsmoor Prison into the Polsmoor Dam. Downstream of the dam, the Westlake River flows under the M3

freeway and then south-eastwards through the residential suburb of Kirstenhof via the Kirstenhof Wetlands Park before turning (unaturally) sharply southwards to flow via a canal under Steenberg Road. Downstream of Steenberg Road, the river turns south-eastward again and flows under Main Road, straight into the wetland area on the north-western fringes of Zandvlei.

The entire Sand catchment ultimately drains into Zandvlei, which means that the vlei is particularly susceptable to water quality problems emanating from the catchment. Catchment landuse includes extensive agricultural areas (vineyards on the Constantiaberg mountains); suburban areas; small areas of informal and backyarding settlements; commercial reas (shopping centres and parking lots) and light industrial areas.

Water level in the estuary is artificially controlled by a rubble weir and a sand bar, which is periodically opened. The estuary has benefited from the artificial opening of its mouth because this allows saline water from the sea to flow into the estuary, ensuring that the system is able to function more naturally and remain in a more healthy ecological state.

See **Photos 8.7.1-8.7.6** for ilustrations.



Photo 8.7.1
Sewage spilling into Zandvlei [photo credit: Kyran Wright, City of Cape Town]



Photo 8.7.2
Artificially managed outlet of Zandvlei at Muizenberg Beach allows flushing of the vlei and increases salinity



Photo 8.7.3
Sand River canal at Joe Marks Boulevarde



Photo 8.7.4
Lower reaches of Sand Canal with off-channel litter trap – in area targeted for new LUW intervention



Photo 8.7.5
Langevlei Canal



Photo 8.7.6
The Langevlei wetland

8.7.2 Major sources of pollution in the catchment

Although this catchment is relatively unpolluted compared with the other priority catchments presented in this section, it nevertheless does include a number of problem landuses, associated with persistent or episodic pollution that affect water quality in its watercourses. The most significant sources of pollution in this priority sub-catchment have been identified as follows, drawing on data presented in Section 5; site drive-overs by the present study team; and from specialist input into the CFF funded masterplan for the Diep/Sand River Sub-catchment of the Sand Catchment (Day 2023):

- Vineyards in the high-lying western parts of the catchment (Constantiaberg mountain range) are a source of nutrients, pesticides, herbicides, possible other contaminants of emerging concern and sediment, all of which passes eventually into Zandvlei (Wright 2023);
- Nutrients and sediments from suburban gardens also pass into the catchment's watercourses, particularly from generally more affluent areas to the west and north west;
- Inputs of oil, heavy metals and other toxicants also enter from the increasingly urbanised catchment, with its large shoping complexes, parking areas and extensivve roads;
- Sewage spills, however, remain the most significant contributor to poor water quality in Zandvlei, and have resulted in a number of extebnded significant closures to recreational use since 2018 (pers. comm., Kyron Wright, CCT; Kotze, 2020; Human, 2021). The longest closure to date was May 2021-February 2022, and there have been no vlei closures since then. Sewage spills contribute to nutrient enrichment of the vlei, exacerbating the incidence of algal blooms and the prolific growth of problem plants in the vlei.
- Sedimentation from extensive erosion in existing and previous forestry areas, mainly in the upper reaches of the catchment is also a problem, having resulted in a decrease in the depth of the vlei by approximately 0.5 m by early 2022 (pers. comm., Kyron Wright, CCT) and probably being a significant source of particle-bound phosphorus into the system, thus also contributing to nutrient enrichment;
- Solid waste is also a major concern in the catchment, with hotspot areas for waste accumulation and dumping in watercourses being the Sand River, between Retreat Road and Military Road.

8.7.3 River water quality through the catchment – condition and trajectory

The CCT includes 29 routine water quality monitoring points in this catchment, with most monitoring points lying in thew lower reaches of the catchment and in Zandvlei itself.

Figures 8.7.1-8.7.4 present summary annual water quality data for phosphate (as PO4-P), dissolved oxygen

(DO), free ammonia (NH_3) and *E. coli* data, respectively, with analyses undertaken as outlined in **Section 3.8.10** of this report.

- In terms of **phosphorus enrichment** (**Figure 8.7.1**), the main findings for the Sand catchment were as follows:
    - Median concentrations were never better than Poor for any sample sites – compliance data presented in **Figure 5.1.1** showed that < 5% of samples collected in the 2023 reporting period were within the Target range for this variable;
    - All sites within the **Keysers** and **Westlake River** systems showed median annual orthophosphate concentrations (2023 reporting period) in the range of Poor – but generally improving or no real change;
    - Phosphate enrichment in the **Langevlei** system were by contrast in the Unacceptable range, and deteriorating in the 2023 period, while water quality in the **Diep/ Sand** system showed deterioration at some sites, but all sites nevertheless fell within the Poor rather than Unacceptable range;
    - Within Zandvlei and Marina Da Gama, at the downstream receiving end of the catchment, phosphorus enrichment was high and in the Unacceptable range for most sites in Marina Da Gama, as well as in Zandvlei at ZA10S (Rutter Road) near to the outlet from the Westlake Wetland, and at the Zandvlei outlet to the sea, represented by samples from ZA05S, which are impacted at times by overflows from sewage manholes just upstream of the monitoring site. Elevated phosphorus in Zandvlei supports a highly productive ecosystem, and as increasing salinities cause a die-back of *Stuckenia pectinata* (pondweed), so there has been an increasing frequency in algal blooms (see Section 6.6.2);
- Data for **dissolved oxygen** concentrations showed that:
    - The catchment was generally well-performing in terms of measured DO concentrations, with most sites within the Target range for this variable, reflecting relatively low levels of eutrophication and low chemical and biological demand. These data suggest that river ecosystems health was likely to have been good, from a water quality perspective over the assessment period;
    - Wetlands and river reaches where DO was in the Unacceptable range were in the lower reaches of the Keysers River (CR20) at Military Road, abutting a sewage pump station but a site not characterised by high E. coli counts in this area, and thus probably reflecting upstream inputs from the industrial area as well as a river reach characterised by dense surface (mainly alien) vegetation that creates low DO concentrations beneath the floating surface vegetation;
    - River and wetland reaches affected by median DO in the Poor range comprised the upper reaches of the Westlake River into Zandvlei (CR01) and Zandvlei at the confluence of the Keysers River (CR22);
- Median **free ammonia** (NH_3) concentrations in the Sand catchment were all within the Target range during the 2023 reporting period (**Figure 8.7.3**), other than in Langevlei and the upper reaches of Little Princessvlei, where NH_3 was rated as Poor. This suggests that there was a low risk of ongoing ammonia toxicity within the Zandvlei catchment. It is however important to bear in mind that occasional spikes in NH_3 concentrations (into the Poor and Unacceptable categories) have been recorded at certain sites within the catchment, so ammonia toxicity could at times have been a problem in certain river and wetland areas;
- In terms of ***E. coli***, mean values in reporting year 2023 (**Figure 8.7.4**), the main findings were as follows:
    - Mean *E. coli* data were within the Acceptable Risk range for this variable, at all sites save for Litle Princessvlei (which is assumed to be impacted on by inflows from a small informal settlement upstream of Roscommon Road (Day 2023); downstream of the Langevlei and Sand canal casnal confluence; and Zandvlei at the confluence of the Keysers River (CR22);

- These downstream sites tally with sites prone to discharges from problem sewage pumpstations and manholes.

8.7.4 Focus areas of the CCT's current remediation programmes

Some of the active interventions undertaken by the CCT in the Sand catchment during the present 2022 – 2023 reporting periods included, *inter alia*:

- Relaunching of the Sand River Catchment Forum by the CCT (November 2022) with the aim of driving collaborative water governance to address the issues in the catchment;
- Ongoing repairs and upgrades to the sewerage reticulation network and more rapid responses to blockages and overflows by CCT officials;
- Detailed planning and design of five pilot projects within the Sand catchment through the Living Urban Waterways (LUW) Programme, including engagement between and within diverse communities across the catchment, in developing design interventions for the following:
    - Grootboschkloof River Corridor Rehabilitation and Public Space Enhancements
    - Spaanschemat, and Prinskasteel River Corridor Rehabilitation and Public Space Enhancements
    - Sand and Langevlei Canal Rehabilitation
    - Westlake River Corridor Rehabilitation and Public Space Enhancements
    - Keyser River Corridor Rehabilitation and Public Space Enhancements.

Budget cuts in the CCT in early 2024 meant however that at the time of this report, implementation of only the Sand and Langevlei Canal Rehabilitation project was planned in the Sand Sub-catchment. This means that the overall intention of thee LUW of achieving measurable change at scale will not be met.

- Upgrading of the Raapkraal sewage pump station;
- Compilation (and approval of) the Raapkraal Sewage Failure Response Protocol, as a measure to deal swiftly with sewage blockages and overflows at this pump station – emergency protocols such as this will be rolled out elsewhere by CCT for other problem pump stations;
- Ongoing Cured-in-Place Pipe (CIPP) lining of leaking and/or old sewer pipes at a number of locations in the catchment;
- Repair of damaged sewage infrastructure as soon as possible when incidents occurred;
- Engagement with the Zandvlei Protected Advisory Action Committee through the City's Stormwater and Biodiversity Management branches (CCT, 2021);
- Collection and clearing of litter from the waterways that flow into Zandvlei;
- Erection of barriers along Jo Marks Boulevarde to deter dumping into the Sand Canal from the roadside – however, the barrier also makes cleaning of the canal more difficult in this area;
- Active engagement and interest by local ward councilors as well as residents has resulted in building strong partnerships with the CCT and contributed to improved catchment management in the Sand Sub-catchment (Mr A. Parker, CSRM, pers comm to Liz Day);
- Continued implementation of the Mouth Management Plan, which has seen a (desirable) increase in in-lake salinity and a die-back of *Stuckenia pectinata* weeds, accompanied however by increased filamentous algae and phytoplankton blooms (Wright 2023 and Section 6.6);
- Purchase (2023) and application of a new aquatic weed harvester by CCT, for weed management;
- Long-term planning for vlei dredging – this is not however on CCT's immediate budget.



Photo 8.7.7
New weed harvester [photo credit: Kyran Wright, CCT]



Photo 8.7.8
Westlake Wetland (LUW project site)
Photo courtesy Andrew Mc Donald (CCT)

8.7.5 Recommendations

A number of actions have already been initiated to improve water quality and the general ecological state of Zandvlei and the aquatic ecosystems in the Sand catchment, as described above. Some of these have already resulted in improvements in the ecological health of the estuary, such as more effective saline intrusion and tidal interchange through better management of the estuary mouth, and a subsequent increase in the diversity of indigenous fish species as well as expansion in the area of occurrence of sand prawns (Wright 2023). The relatively good water quality of Zandvlei compared to many other aquatic ecosystems in Cape Town, outside of sewage spill incidents, is largely attributable to a relatively unpolluted catchment area, with no WWTW inflows and limited areas of informal settlement. Management of the entire Sand catchment within one stormwater Planning Region Southern Region), as shown in **Section 2.7**, also makes for co-ordinated management by CSRM within this catchment, although it is also noted that the Southern Region is a large area, including several important catchments, all requiring concerted efforts.

Notwithstanding the above, Sections 8.7.2 and 8.7.3 highlight a number of pressing water quality problems. The following recommendations are made with a view to facilitating improvement in water quality in Zandvlei and its catchment:

- Rapid response protocols for all problem sewage pump stations in the catchment should be rolled out, using the Raapkraal protocol as a proto-type, and thus facilitating the ongoing attention to the repairs to and upgrades of sewer infrastructure in this catchment;

- Pro-active lining and clearing of sewer pipes in the catchment is supported and should continue as required;

- The Sand catchment should be formally listed amongst the MMP's Priority Sub-catchments, so that it can benefit from assignment of budget to ongoing sewer upgrades and repairs even during the current CCT budget cuts. This is important, as Zandvlei is the only one of the City's recreational waterbodies that has seen some improvement in ecological condition over the past five years, but is vulnerable to rapid deterioration if pollution is not addressed on an ongoing and accelerating basis;

- Improvement in the frequency and volume of solid waste collection in open spaces in some parts of the

catchment is urgently required, to prevent the passage of solid waste into watercourses. The Sand and Langevlei Canals are particularly vulnerable to dumping of solid waste, which accumulates along the canal banks and bed;

- Dredging of the main portion of Zandvlei, which is currently being planned, should be implemented as a priority action in this catchment as this should help to lower nutrient levels (especially phosphate concentrations), raise DO levels and improve the hydrological functioning of the estuary;
- Land management in the upstream areas of the catchment should be improved to reduce erosion as a source of sediment, and ultimately reduce the frequency of future dredging requirements in the estuary going forwards. This means that the CCT should engage with landowners, particularly in agriculture and with SANParks, regarding addressing erosion in these areas;
- Implementation of SUDS approaches should be encouraged throughout the catchment, as these interventions might achieve measurable impacts at least in moderately impacted systems such as the Westlake and Keysers River systems and their upstream reaches in particular;
- The CCT should continue to actively engage with the recently re-established Sand River Sub-catchment Forum, to understand where the most urgent problem areas are and to formulate solutions together;
- Finally, and as stated in Section 7.4.3, it is strongly recommended that the CCT should re-evaluate the cut in LUW budget, to allow implementation of the five pilot projects planned in the Sand Sub- catchment, if this programme is to gain the traction that it requires by acting at scale, at a catchment level.

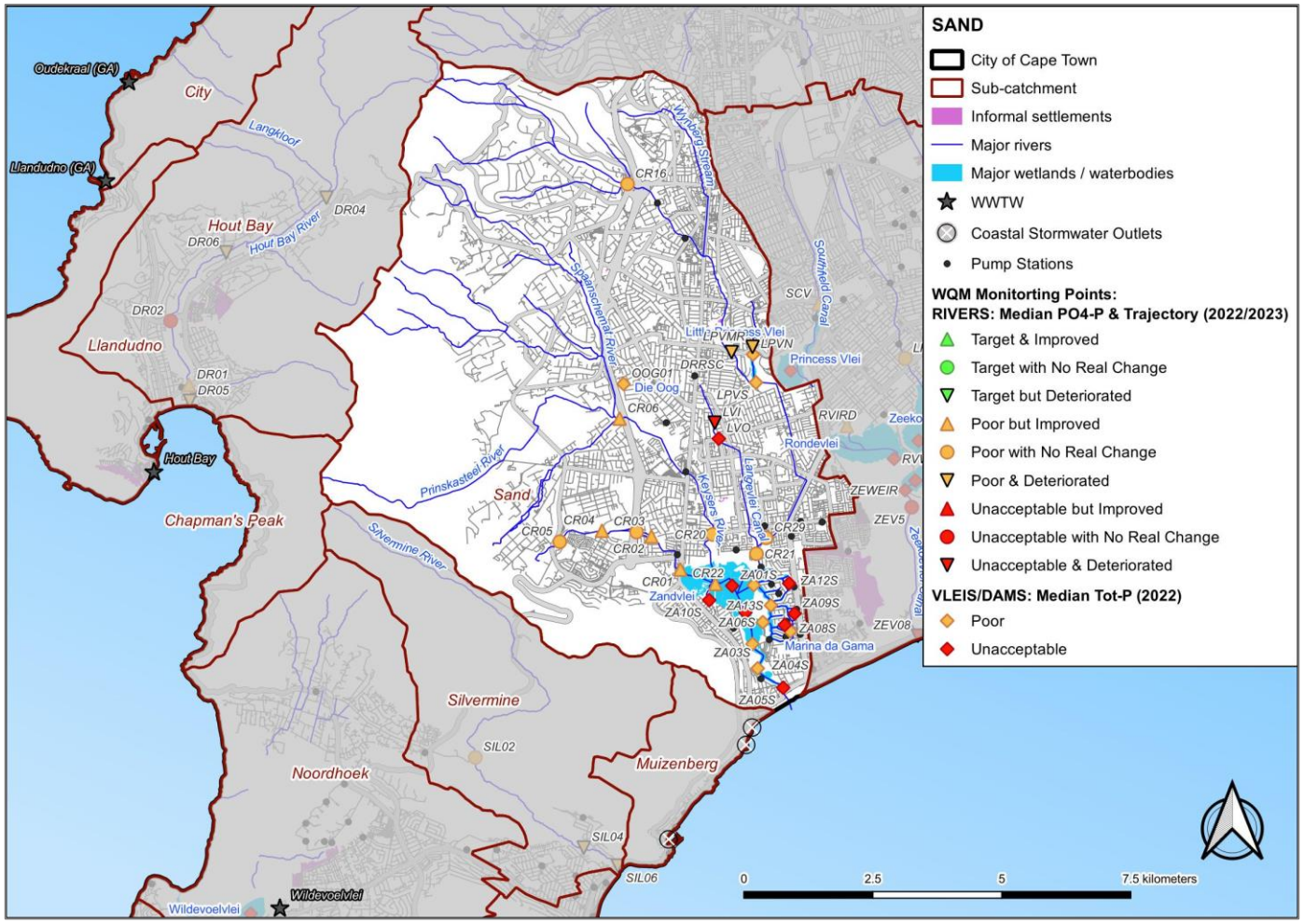


Figure 8.7.1
Median annual orthophosphate phosphorus (PO4-P) data (rivers) and median annual total phosphorus (Tot-P) (vleis), focusing on the SAND RIVER Sub-catchment. PO4-P trajectories calculated as explained in Section 3.8.14

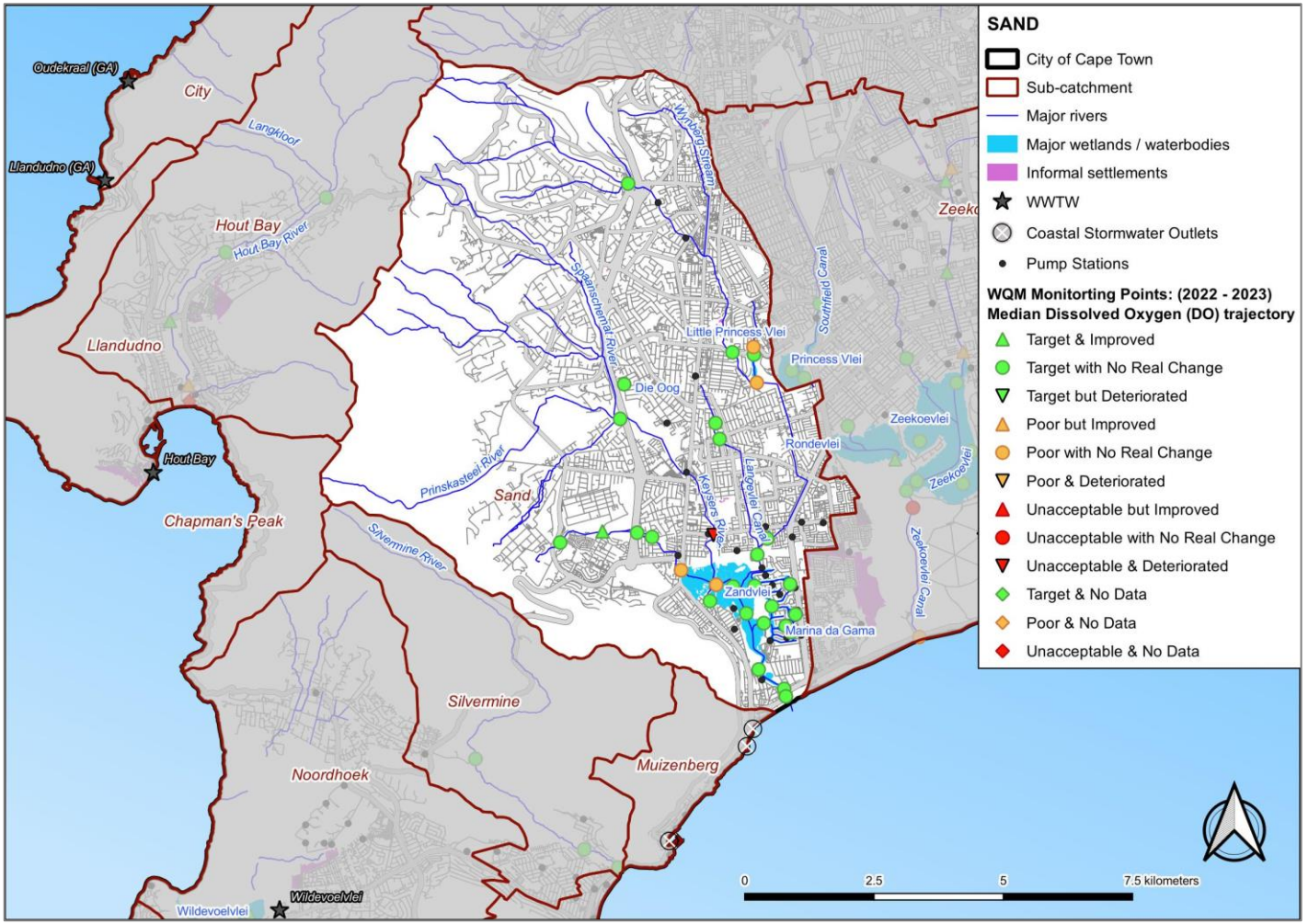


Figure 8.7.2
Median annual Dissolved Oxygen (DO) concentrations, focusing on the SAND RIVER Sub-catchment. Data coded as to level of change in the 2023 reporting period, compared with the 2022 reporting period. Trajectory calculations explained in Section 3.8.14

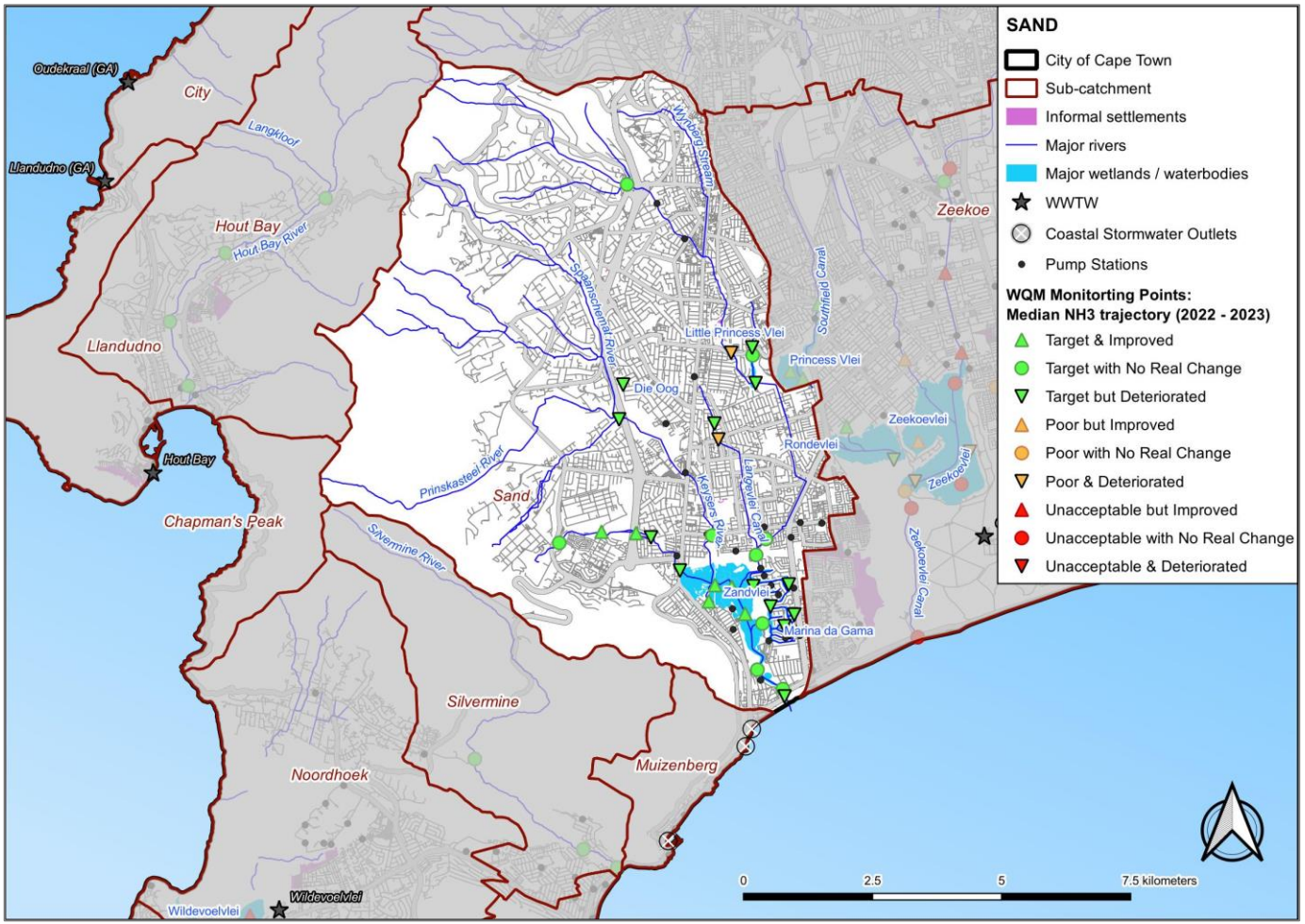


Figure 8.7.3
Median annual free ammonia (NH_3) concentrations, focusing on the SAND RIVER Sub-catchment. Data coded as to level of change in the 2023 reporting period, compared with the 2022 reporting period. Trajectory calculations explained in Section 3.8.14

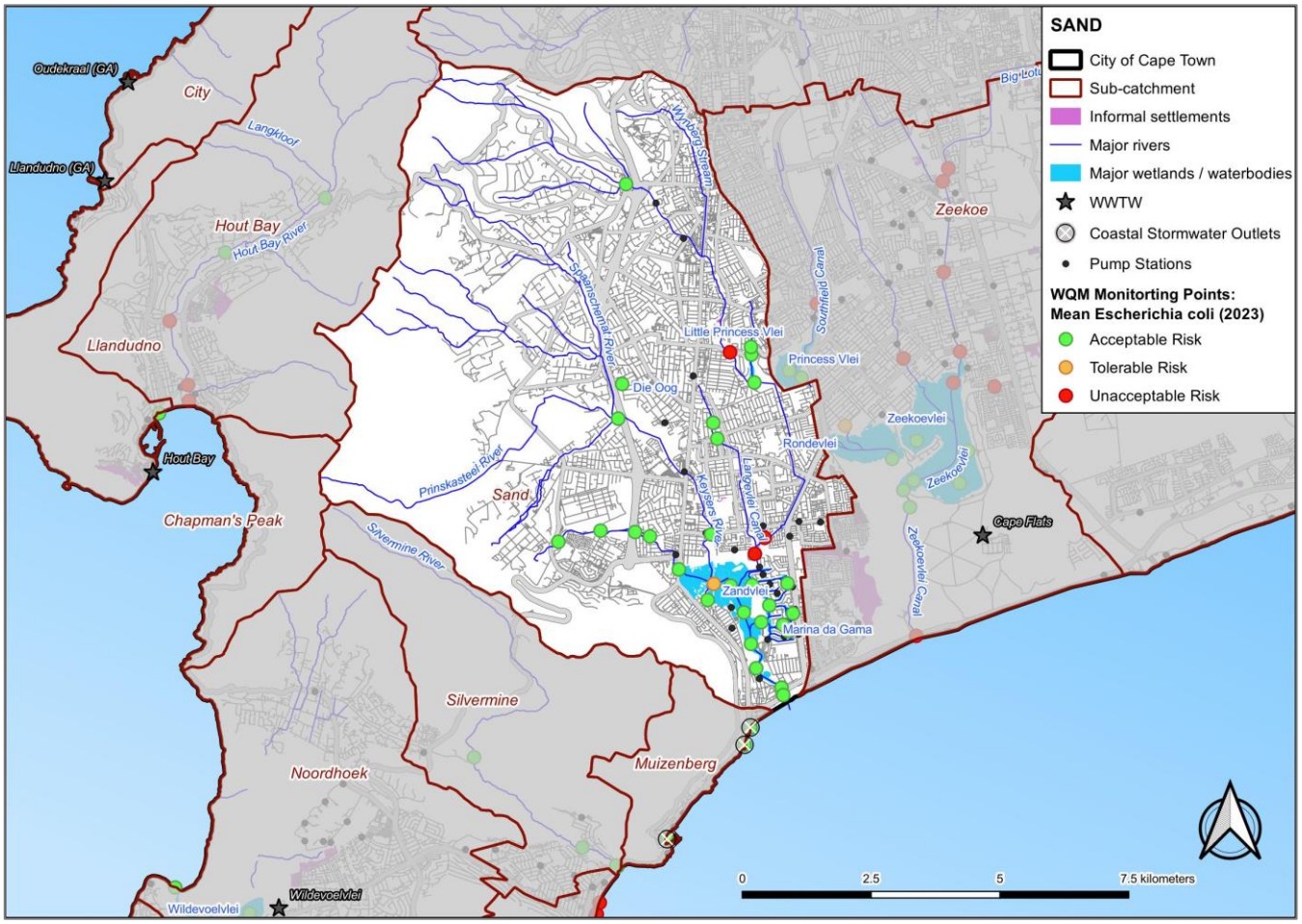


Figure 8.7.4
Mean E. coli data (geometric means), focusing on the SAND RIVER Sub-catchment. Data coded as to human health risk (see Table 3.5). No reliable data available for the 2021 and 2022 reporting periods, so 2023 data shown only.

8.8 Big and Little Lotus River catchments

8.8.1 Catchment overview

The Big and Little Lotus Rivers are the main sources of surface flow into Zeekoevlei, and the False Bay Nature Reserve (FBNR) (see **Figures 8.8.1-8.8.4** for context). Of these, the Big Lotus River has a far larger catchment, starting as a small stormwater channel just north of the N2, through the airport industrial area. Immediately downstream of the N2, it flows through parts of Nyanga, Gugulethu and New Crossroads, mainly as a lined canal. These areas are all densely populated, with high levels of backyard and other informal settlement. Downstream, the river flows along the southern edges of Manenberg and Hanover Park. Many of these areas have significant socio-economic problems and high levels of crime and gang violence, which challenge effective catchment management activities, including the CCT's capacity to effect basic service delivery in the form of solid waste removal in some areas.

Box 8.1:
Natural watercourses in the Zeekoe catchment

Typical of many areas of the Cape Flats, the Zeekoe catchment is characteristically sandy, with a high wet season water table in many areas. This feature gave rise, under natural circumstances, to an abundance of seasonal, groundwater-fed wetlands across low-lying areas of the catchment. In some areas, localised lenses of calcrete have also given rise to perched, seasonally inundated wetlands, many of which have high biodiversity importance.

The Big and Little Lotus Rivers are not natural rivers, but were both constructed to drain water from areas with a high water table and so allow expansion of urban development.

The Big Lotus swings south just east of Wetton, being crossed by Govan Mbeki Road and passing through parts of the Philippi Horticultural Area, where agriculture as well as associated manure and composting forms the main land use. In these river reaches, a low-flow diversion (the Springfield Diversion) diverts a portion of flow from the river to the nearby Cape Flats WWTW, in an effort to reduce downstream water quality impacts on Zeekoevlei. From the Springfield Diversion, the river flows, still as an open channel, through residential and commercial land uses in Ottery and is joined by the Woodlands Canal, just east of the remnant and ecologically highly important Bamboesvlei seasonal wetland (see Day 2024 and Emms 2022). The canal flows from here through parts of the residential areas of Lotus River and Grassy Park, before entering Zeekoevlei, just south of Fisherman's Walk.

The Big Lotus River has been subjected to numerous inflows of raw sewage from blocked manholes and failed pump stations over the past few years, contributing to the documented progressive decline in water quality and wetland ecosystem quality in Zeekoevlei (Day et al. 2022).

The Little Lotus River, by contrast, drains a smaller and less impacted catchment than the Big Lotus River. It rises just south of Ottery Road (east of the Royal Golf Course) and flows through the mainly residential areas of Parklands and Grassy Park, mainly as a lined canal, before entering Zeekoevlei, south of the Big Lotus River confluence. The river is generally less vulnerable to raw sewage inflows and solid waste accumulation than the Big Lotus River, but nevertheless experiences periodic pollution episodes (Day et al. 2022). High levels of criminality in parts of the Little Lotus River Sub-catchment also impact on services such as solid waste removal.

As a result of ongoing receipt of unacceptably high loads of solid waste (including health hazards such as loads of used disposable nappies) into Zeekoevlei, and the high costs and effort required for its removal once in the vlei, local community / CCT partnerships have facilitated and funded litter fences at the outlet of both the Big and the Little Lotus Rivers into Zeekoevlei.

See photo illustrations (**Photos 8.8.1-8.8.6**).



Photo 8.8.1
Litter in the Big Lotus River near Hanover Park



Photo 8.8.2
Public toilets located along the edge of the Big Lotus River in Gugulethu



Photo 8.8.3
Polluted (phosphorus enriched) flows in the Big Lotus River past the Springfield Diversion



Photo 8.8.4
Big Lotus River channelised through Ottery



Photo 8.8.5
Inflows of raw sewage and waste into the Big Lotus River from the informal settlement east of Buck Rd



Photo 8.8.6
Little Lotus into Zeekoevlei, showing maintained litter fence

8.8.2 Major sources of pollution in the catchment

Major sources of pollution in the catchment are those plaguing many of the priority sub-catchments considered in this section and center on large areas of informality in the upper reaches of the Big Lotus River, from downstream of the N2, and high levels of backyard settlements, coupled with an accumulation of solid waste throughout much of the catchment, including along the channel margins and within the channels. Solid waste includes offal, dead animals, used nappies and other sources of pollution to aquatic resources that they enter.

Sewage blockages, sewage pump station failure, sewer manhole overflows and occasional failure at the Cape Flats WWTW inlet are also major contributors to river and vlei pollution, occurring at a rate throughout the catchment that cumulatively is probably permanent rather than episodic, and exacerbated by load-shedding and vandalism (see Section 5.6).

In addition, the following serious issues have also been identified (e.g. Abbot Grobbicki 1998; Day et al 2022):

- Runoff from agricultural areas (mainly in the Philippi Horticultural Area), including from fertilisers, manure, insecticides and herbicides);
- Illegal discharges of oil and other waste into watercourses – Day et al (2022) present findings of a 2022 fish study in Zeekoevlei, which found extremely high levels of lead and mercury in fish tissue in this vlei, well above safe levels for human consumption. This is assumed to derive from light industrial and agricultural land uses in the sub-catchment;
- Runoff from roads and parking areas, in places with high levels of solid waste.

Rapid growth of reedbeds, aquatic alien invasive water hyacinth and algal blooms are all management issues in the rivers and particularly in Zeekoevlei itself, as a result of the high nutrient concentrations passing into this sub-catchment.

Box 8.8.1
Solid waste management realities and conundrums

Solid waste accumulation in the Big and Little Lotus catchments is an issue of serious concern.to effect removal of dumped and other solid waste. It reflects two different aspects – dumping of waste by city residents and the failure of the CCT.

Dumping of solid waste along and within the Big Lotus River in particular is largely confined to areas that are accessible for wheelie bins, vehicles and trollies - that is, river channels and other areas adjacent to road crossings. Day (2024) suggested on the basis of discussions with some community leaders that dumping of solid waste by residents is influenced *inter alia* by the following factors:

- Many residents have no access to transport to take large waste items (mattresses, couches) to waste disposal sites;
- The City does not take away builder's rubble or waste that does not fit into wheelie bins;
- It is difficult for women and children to put waste into high-standing skips;
- Many homes have large numbers of people residing in them and the weekly waste collection service that is offered by the City is inadequate for the volume of waste generated;
- The confined spaces in which many residents live mean that storage of waste over a week between waste collection cycles creates untenable conditions in the home – and results in waste needing to be disposed of more frequently, especially if it is malodorous (e.g. used nappies).

Discussions with CCT officials in the present project highlighted issues affecting effective collection of solid waste as including:

- The CCTs existing by-laws that do not allow for collection of items such as rubble and large items;
- Theft and vandalism of infrastructure;
- High levels of gangsterism in many areas, resulting in unsafe working conditions for municipal workers, and hence avoidance of areas where workers might be robbed or shot.

These seemingly intractable issues need to be addressed.

8.8.3 River water quality through the catchment – condition and trajectory

Figures 8.8.1-8.8.4 present summary annual water quality data for phosphate (as PO4-P), free ammonia (NH3) and *E. coli* data, with actual analyses as outlined in **Section 3.8.14** of this report. The data are presented spatially, on a per-site basis.

Read in conjunction with catchment-level data presented in **Section 5**, these figures show that, for the Big and Little Lotus Rivers (i.e., priority catchment areas) that drain into Zeekoevlei:

- **Phosphate enrichment** was pervasive in the Zeekoevlei Sub-catchment over the assessed reporting periods, with inflows from the Big Lotus River being always well within the Unacceptable levels for orthophosphate phosphorus;
- The data do however suggest some reduction in concentration over the 2022/2023 reporting period in some the upper catchment – median concentrations were "Unacceptable but Improved" at LR05, LR03 and LR02;
- Increased enrichment was however noted for LR06 – this site represents water quality in the Woodlands Channel. This channel flows only after rainfall and in the wet season and receives runoff from a growing informal settlement upstream, north east of Bamboesvlei;
- The only monitored stormwater channel entering Zeekoevlei is represented by POC01, located in an artificial vegetated channel that receives stormwater from parts of the Schaapkraal agricultural and peri-urban areas as well as from parts of Pelican Park. The orthophosphate data show Unacceptable enrichment in this channel as well, correlating with high *E. coli* concentrations (see **Figure 8.8.4**) and suggesting sources
- Orthophosphate enrichment of the Little Lotus Canal Orthophosphate was, on the basis of median annual data, less enriched than in the Big Lotus River, albeit still in a Poor condition;
- The above spatial data underscore the continued hypertrophic condition of Zeekoevlei itself, with these nutrients promoting in-lake algal growth and occasional blooms, which contribute to a build-up of organic material on the (shallowing) vlei bottom and ongoing in-lake nutrient cycling;
- Dissolved oxygen concentrations, used here to indicate COD and BOD that exceeds the treatment capacity of the waterbody, highlight:
    - Poor conditions in the upper catchment upstream of the N2, where mainly light industrial activities and road runoff contribute runoff that flows slowly through a shallow, often stagnant channel, liable to low oxygen concentrations as a result of heating and decomposition;
    - Critically low DO in the river reaches downstream of Gugulethu (LR03), reflecting high loads of black- and grey water runoff with high CODs – these low DO concentrations are unlikely to sustain any but the most pollution tolerant aquatic biota, and even in the absence of canalisation, would not support functioning riverine ecosystems of any viable quality. This has relevance for river rehabilitation efforts in these reaches – without serious attention to water quality issues, meaningful river rehabilitation would fail;
    - Median DO concentrations were in Target range for the rets of the Big and Little Lotus Rivers downstream of the above monitoring points, with the exception of LR08, where a Poor rating probably derives from inflows from the informal settlement immediately upstream (east of Buck Road) as well as from pump station overflows in the area and backing up of flows from Zeekoevlei in this part of the channel during high water periods;
- It is noted however that surface DO concentrations in the Target range should however be interpreted with caution in highly polluted watercourses, as particularly under slow flow conditions, they can be elevated by high algal photosynthesis rates near the surface, by day;
- The above point is highlighted by free ammonia (NH3) concentrations in the Big Lotus River downstream of the N2 that were always in the Unacceptable range for this toxin, again suggesting riverine conditions untenable for aquatic ecosystem biota that could sustain riverine ecosystems of any desirable quality;
- Median free ammonia concentrations in the little Lotus River (represented by LR10 only) fell within the Poor range, suggesting lower risks of ammonia toxicity and a system that might lend itself more to aquatic rehabilitation efforts;
- Mean ***Escherichia coli*** data for the 2023 reporting period showed, like the 2020 dataset (the last reliable previous dataset reported on by Day et al (2023), that:
    - All sites downstream of the N2 were always in an Unacceptable condition in both the Big and the Little Lotus Rivers;

- Data for the Woodlands Canal also showed *E. coli* concentrations at Unacceptable levels, suggesting a degradation in this part of the catchment over the past few years;
- These data reflect a catchment subject to high levels of inflow from backyard and informal settlements, as well as a high frequency of sewage and pump station overflows – **Figure 5.6.9** in **Section 5.6** shows that the Zeekoevlei Sub-catchment had the fourth highest frequencies of pump station overflows in the city in the 2022 reporting period, including at least one rated as "Catastrophic" and several Major failures. Mechanical and electrical failure, pump tripping and load shedding (in descending order) were listed in the CCT's datasets as the main reasons for these failures (**Figure 5.6.10** in **Section 5.6**).

- As noted in **Section 8.8.3**, Solid waste was also serious issue throughout the catchment, contributing to frequent blockages of both stormwater and sewer systems, including the Springfield diversion system, and resulting in both unsightly and unhygienic conditions within the upstream catchment, and the need for ongoing expensive clean-ups of Zeekoevlei in the FBNR, by CSRM, local communities, Friends groups and the CCT's BMB.

8.8.4 Focus areas of the CCT's current remediation programmes

This section has been informed mainly by discussions with CCT's Stormwater Planning Region manager for the Southern Region (Mr A. Parker) and his team during the course of this project, but also by observed interventions in the catchment, discussions at the FBNR PAAC meetings and the findings of other CCT projects including the CFF NbS and GI project for the Zeekoe Sub-catchment (reported on inter alia in Anchor 2024 and Day 2024).

The most serious issues affecting water quality in the Big and (to a lesser extent) the Little Lotus Rivers, comprise **solid waste and sewage.** Sewage in particular passes into watercourses by way of **dry-weather flows** from formal and informal settlements; stormwater flows; sewage pump station overflows; sewer manholes and failed sewer lines. As noted in Section 8.1 however, these issues are controlled by other line departments, with catchment managers and their teams, as well as the CCT's BMB, being at the receiving end of failed systems, and accountable for polluted watercourses and the ecological and other impacts of this pollution, while often being powerless to effect change at source.

While issues such as solid waste accumulation, vandalism, theft, load-shedding and the knock-on effects of these issues on water quality are difficult to address effectively at present, CCT has however undertaken the [16]following specific measures with a view to bringing about some improvement in catchment condition, particularly from a water quality perspective:

- Planning activities:
  - Passing of a 'Motion of exigency' by the CCT sub-council at its meeting of 17/11/2022, for the establishment of the Zeekoevlei Catchment Forum – the forum itself has not yet been set up (see below);
  - C40 CFF FUNDING has been sourced by CCT to drive development of recommendations for terms of reference and mandates for the planned Zeekoe Catchment Management Forum;
  - Securing CFF funding (March 2022) for investigations to identify opportunities within the Big and Little Lotus River catchments for non-structural interventions and green infrastructure (GI), including sustainable drainage systems (SuDS) and nature-based solutions (NbS) (see **Section 7.4**) – this project was due for completion by mid 2024.
  - Pollution tracking up the Big Lotus River by teams from CSRM and Water Pollution Control between March and April 2022, intended to identify point source pollution inflows into the river: no interventions to address the identified pollution sources have however been initiated to date;
  - Compilation of Standard Operating Procedures (SOPs) to standardize decision-making about the

[16] Note that some of these activities were included in the previous inland water quality report (Day et al 2023) – there is some overlap between current and previous reporting periods in 2022

opening and closing of recreational vleis – this SOP was approved in 2023;

- Meeting the requirements of DEADP Directives:
    - Following significant sewage overflows into the sub-catchment in 2021, recommendations were made for a number of remedial interventions both within the Zeekoe Catchment and in Zeekoevlei itself, to address the impacts of significant ongoing long term pollution of these watercourses. These measures were outlined in a five part plan presented to the CCT in 2022 (see Day et al 2023). The CCT was subsequently Directed by DEADP to implement these measures.
    - Remediation of water quality in Zeekoevlei through implementation of some of the required measures is included in Work Stream 4.2 of the MPP on Sanitation and Inland Water Quality (**Section 7.3** and **Table 7.2**). To date:
        - Funding has been set aside by CCT for:
            - Dredging and (medium term) disposal of organic sediments from Zeekoevlei;
            - Upgrading of the Zeekoevlei and Rondevlei weirs to allow for deeper draw-down of the former and the passage of estuarine fish up the Zeekoe Canal into both of these;
        - The EIA and Water Use License Applications for the dredging project have been submitted to DEAFF and DWS respectively, and approved by the latter;
        - The proposed weir upgrades are in their detailed design phase, and specialist teams have been appointed to undertake the required reporting for the EIA and WULA for this project, due for commencement (if authorized) in late 2025;
- Communications and liaison:
    - Improved liaison between CSRM, the CCT's BMB, and community activists including the Friends of Zeekoevlei and Rondevlei (FOZR) in working together for solutions to problems of litter and pollution in the downstream environment. These include litter clean-ups and monitoring and management of litter fences;
    - Development of the River Warden Programme:
        - CCT reports that some 204 job opportunities have been created since 2022, allowing for the housing of river wardens at (*inter alia*) False Bay Nature Reserve (see **Table 7.2** in **Section 7.2**). The primary objective of the River Warden Programme is to enhance ecosystem health in the City's catchment areas, championing the eradication of invasive plant species, rehabilitation activities along our waterways, and litter collection and removal – this programme could also open up opportunities for improved river pollution surveillance and reporting; alien weed clearing;
- Focused interventions:
    - Ongoing focused strategic cleaning of sewers in the southern part of the catchment (downstream of Strandfontein Road) by Waste Water Conveyance (Region 1) – this is a pro-active response to reduce sewer blockages and overflows into the stormwater system, previously reported on in Day et al (2023);
    - Ongoing repairs to sewer bulk infrastructure – these should start to yield results in reduced spill frequency and risk;
    - Ongoing attention to timeous removal of solid waste from the Little Lotus and Big Lotus River litter fences;
    - Implementation of required burning of reedbed wetland in FBNR to reduce long-term impacts of the 2021 sewage spill into the reedbed.



Photo 8.8.3
Clearing solid waste from Zeekoevlei at the mouth of the Big Lotus River in 2023. CCT and FOZR-funded teams at work in photo. Photo courtesy Mr S. Jacobs, FOZR



Photo 8.8.4
CCT work teams clearing invasive water hyacinth from the mouth of the Big Lotus River in late 2023 – CCT / FOZR partnerships worked together in this venture. Photo courtesy Mr S. Jacobs, FOZR

8.8.5 Recommendations

The main water quality issues in the Big and Little Lotus River derive primarily from poor provision of solid waste management and provision of adequate sanitation to manage sewage and grey water produced in inadequately serviced areas. Faecal pollution is a threat to the health and dignity of local communities in the Big Lotus catchment, as well as to users of Zeekoevlei and the beaches along the False Bay coastline adjacent to the Zeekoe canal outlet. Nutrients and other chemical pollutants associated with this water impact important downstream inland aquatic ecosystems (Zeekoevlei).

In this context, the following measures, which require co-operative buy-in across multiple CCT departments and branches, should be focused on by the CCT, if there is to be any measurable improvement in water quality in the Big and Little Lotus River catchments, and by implication in Zeekoevlei downstream:

- Significantly increased focus on the frequency and volume of removal of solid waste at source – this requires innovative thinking around how to address the broader issues of safety and security of CCT workers, within a context of gangsterism and general criminality in many areas;
- Attention to addressing existing known effluent discharges into the Big Lotus Canal, by diversion into sewers, or alternative [17]re-routing of currently piped sections of the river away from significant sewage inflow areas, to allow for diversion of concentrated black and grey water flows into sewers without dilution from river flows. Known significant point source inflows are visible in the Big Lotus River at:
    - Klipfontein Road culvert – this includes runoff from Barcelona;
    - The culvert at NY5 Street, downstream of the cemetery in Gugulethu;
    - A culvert entering the river at NY3 Road, also in Gugulethu;
    - Inflows from the informal settlement east of Buck Road (Lotus River area);
- A focus on interventions to provide sewage and stormwater servicing to the rapidly expanding informal and backyard settlements in the area;
- A focus on provision of improved bunding and short-term storage of effluent at all sewage pump stations, but particularly those abutting the FBNR and the Big and Little Lotus River canals – progress in this regard should be reported on to the FBNR PAAC on an ongoing basis, against the total number of pump stations to be addressed in the sub-catchment;

[17] This intervention was suggested by Prof N. Armitage as having particular application to re-routing the piped big lotus river flows away from the Barcelona informal settlement just downstream of the N2, thus allowing black water and domestic waste to be sent to new or existing sewers

- Since mechanical and electrical failure appear to be the main reasons for pump station failure / sewage overflows in the Zeekoe Sub-catchment (see **Section 5.6.3**), it seems reasonable that pro-active maintenance attention should be paid to addressing the most persistently poorly performing pump stations;
- Implementation of the CCT's existing plans for upgrading of the Cape Flats WWTW and ongoing rehabilitation and upgrading of the sewers in the catchment;
- A change in the CCT's regional structure, so as to align with hydrological (major river) catchments, rather than with the current stormwater management regions (see **Section 2.8**) and sewage reticulation management regions, which do not relate to surface runoff and do not facilitate strategic pollution abatement at a catchment level, since different managers have responsibility for different parts of the catchment. For example, at present, two Senior Professional Officers oversee different sections of the Zeekoe Catchment – one upstream of Strandfontein Road and one downstream, with the result that the downstream officer has no control on inputs or efforts from the upstream area.

As recommended in the previous Inland Water Quality Report, it is also noted that there are no routine monitoring points between the N2 and Govan Mbeki Road downstream of Jakes Gerwel Drive. This means that point-source pollutants between these points cannot be identified without focused pollution tracking. Additional routine monitoring sites within this pollution hotspot should be included to assist in pollution tracking, and pollution tracking itself should be followed up by active interventions to address identified pollution sources.

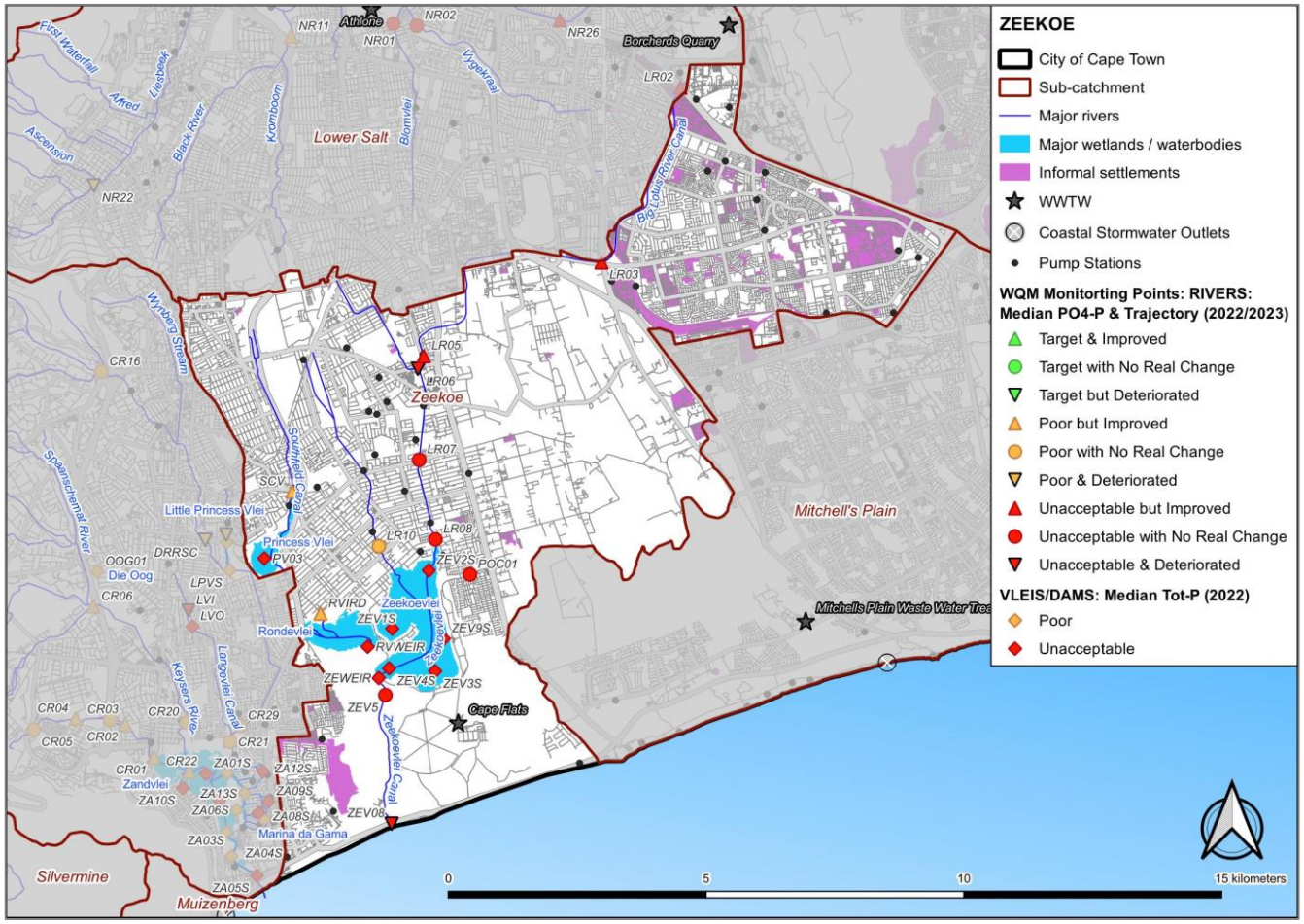


Figure 8.8.1

Median annual orthophosphate phosphorus (PO4-P) data (rivers) and median annual total phosphorus (Tot-P) (vleis), focusing on the BIG and LOTUS RIVERS in the ZEEKOE Sub-catchment. Tot-P data provided only for 2022, due to missing total phosphorus data from January 2023 onwards. No trajectories thus calculated.No Tot-P PO4-P trajectories calculated as explained in Section 3.8.14

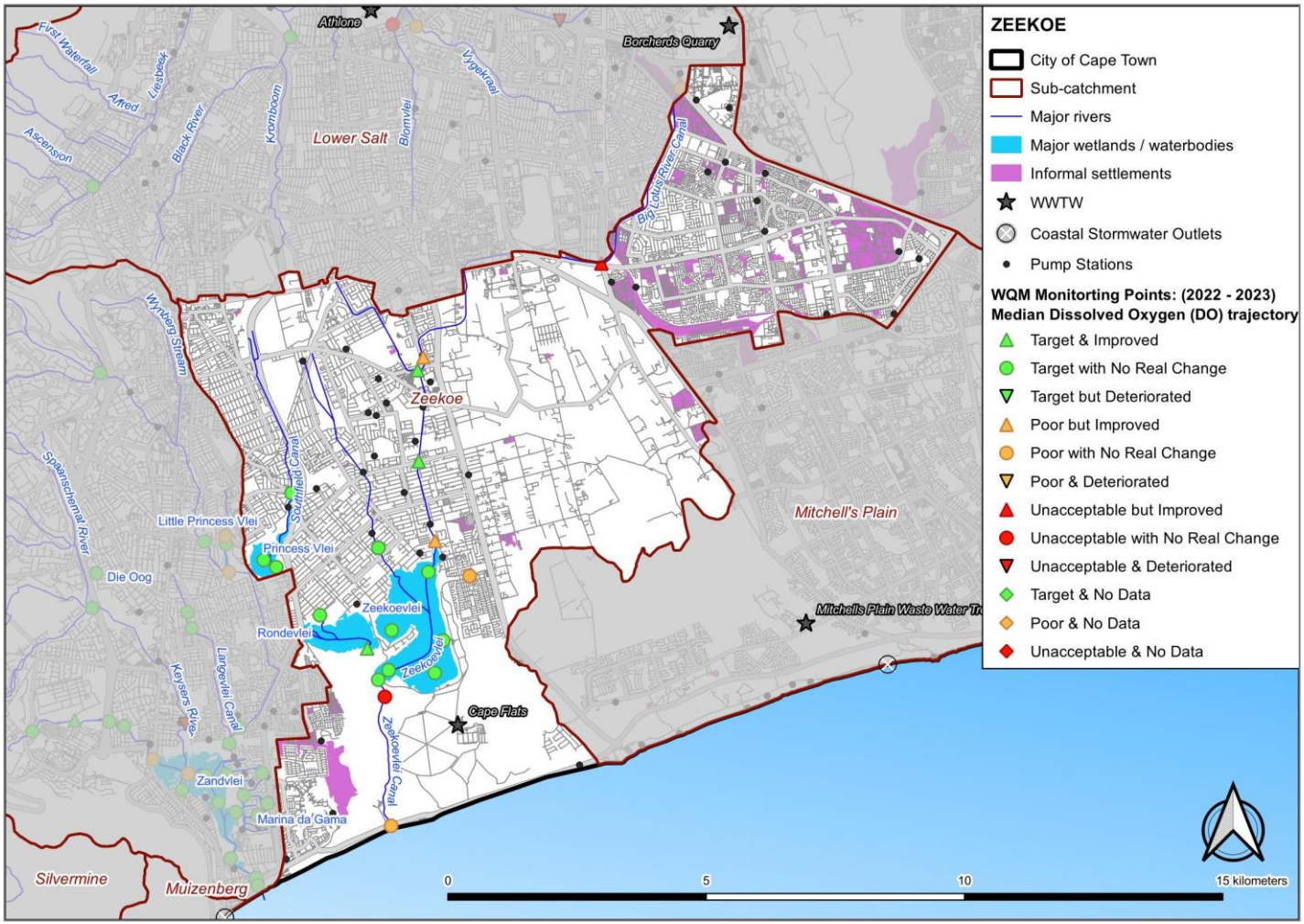


Figure 8.8.2
Median annual Dissolved Oxygen (DO) concentrations, focusing on the BIG AND LITTLE LOTUS RIVERS in the ZEEKOE Sub-catchment.
Data coded as to level of change in the 2023 reporting period, compared with the 2022 reporting period. Trajectory calculations explained in Section 3.8.14

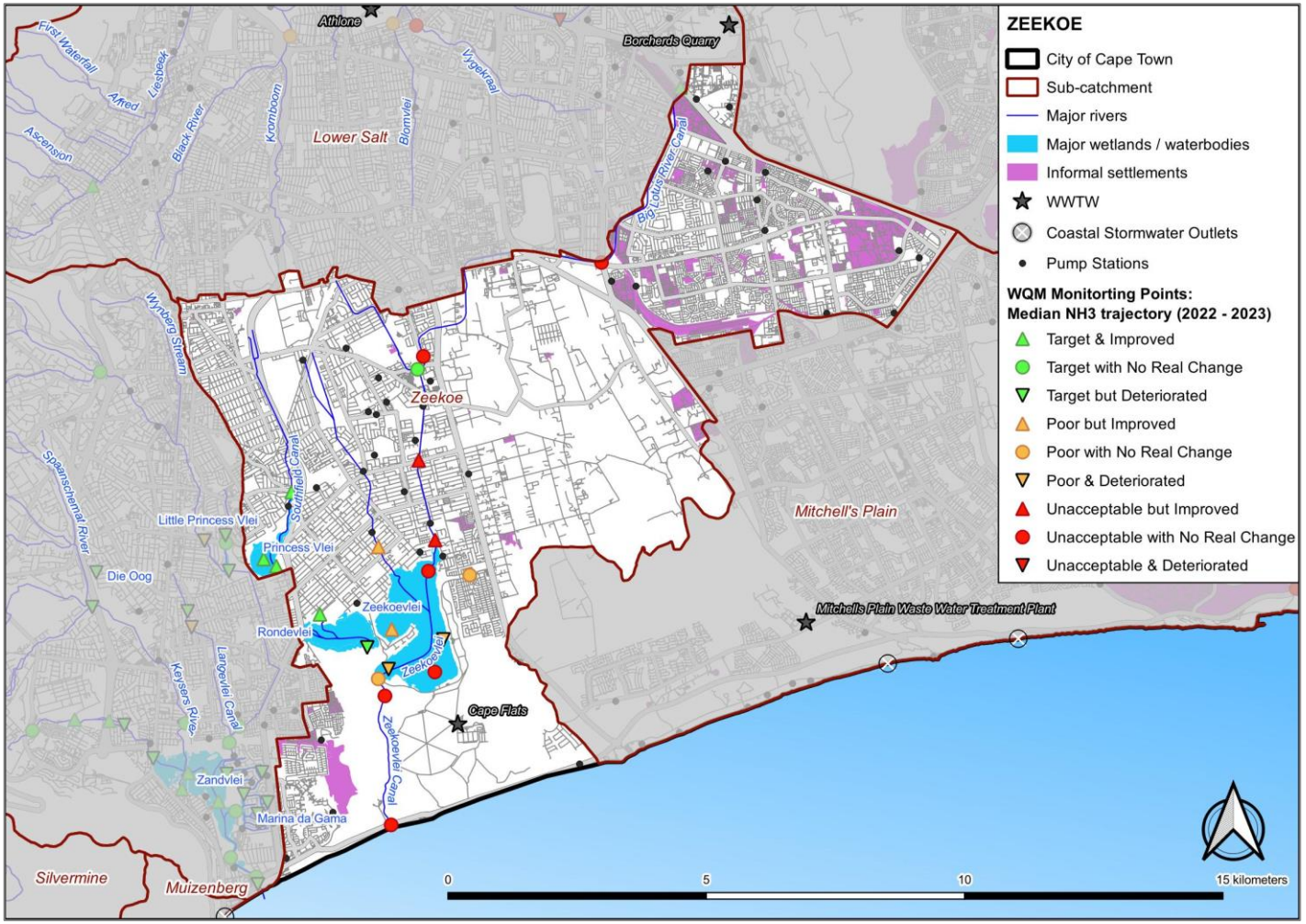


Figure 8.8.3
Median annual free ammonia (NH3) concentrations, focusing on the BIG AND LITTLE LOTUS RIVERS in the ZEEKOE Sub-catchment.
Data coded as to level of change in the 2023 reporting period, compared with the 2022 reporting period. Trajectory calculations explained in Section 3.8.14

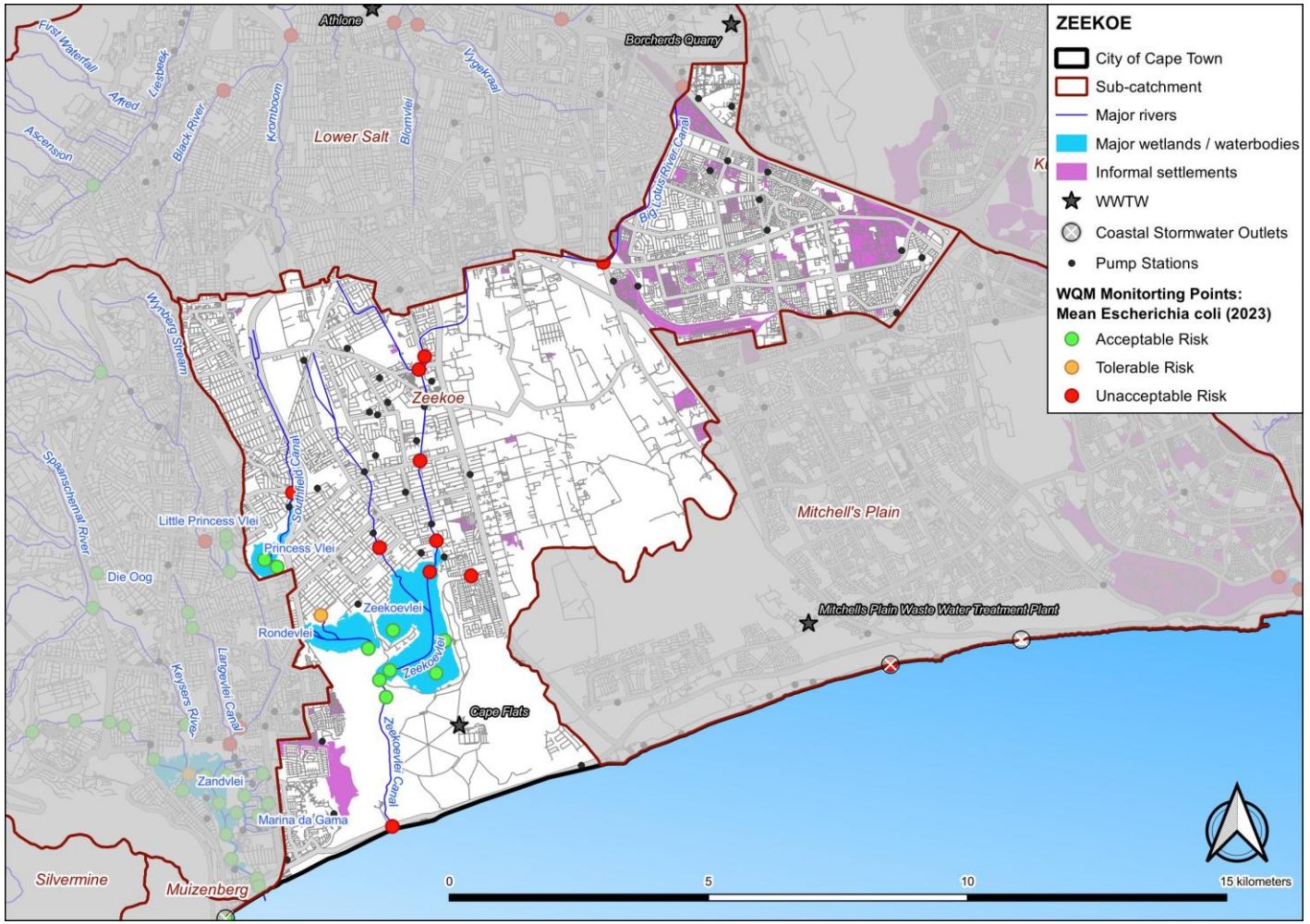


Figure 8.8.4
Mean *E. coli* data (geometric means), focusing on the BIG AND LITTLE LOTUS RIVERS in the ZEEKOE Sub-catchment.
Data coded as to human health risk (see Table 3.5). No reliable data available for the 2021 and 2022 reporting periods, so 2023 data shown only.

8.9 What of non-priority catchment areas?

Effective catchment management measures that prevent pollution of CCT's waterways and downstream receiving environments is as important in non-priority catchments as in priority catchments. The priority catchments addressed in this report include, with the exception of the Sand Sub-catchment (see Section 8.7.5), most of the worst-performing, most problematic catchments in the CCT boundary. Missing from these is however arguably the Sir Lowry's Pass River catchment, which ought also to be included as an additional priority catchment. This system has severe upstream pollution issues, stemming at least in part from poor servicing of expanding backyard and informal settlements. In its reaches downstream of the N2, the CCT has commenced with a major river works project (Sir Lowry's Pass River re-alignment), that will result in channelisation of the river to provide space for floodplain development. If water quality problems from upstream persist, the required ecological mitigation measures that made this project ecologically acceptable will not be realised.

The remaining sub-catchments were, at least over the reporting periods considered here, in generally better condition from a water quality perspective. It is, however, very important that water quality in these systems does not deteriorate, and should ideally improve further. For this reason, it is strongly recommended that ongoing attention be paid to data for key indicative water quality parameters from sites in these systems, and any persistent (i.e., more than two consecutive months, or a once-off but large-scale) deterioration in any of the monitored variables should be followed up by pollution tracking to identify likely pollution sources, followed up with interventions to address identified issues.

Input from local residents, Friends Groups, and other organisations relating to water quality concerns and known pollution 'hotspots' should be facilitated by the CCT.

8.10 Key take-away points

The following key points emerge from the above discussions:

- All of the CCT's priority catchments include runoff from informal settlements with poor access to sewerage systems. This means that water quality in stormwater systems is in many areas compromised, to levels where standard application of SUDS and other stormwater quality polishing / improvement approaches are unlikely to be effective – the Sand Sub-catchment is the exception to this, but even this includes small areas of informality and some suburbs with extensive backyard dwellers.
- In areas not subject to high levels of sewage-impacted stormwater, the CCT is encouraged to implement or require implementation of SUDS-type interventions and implement pollution tracking when water quality deterioration is detected. These measures will help to maintain the current relatively good status of water quality in these sub-catchments. These sub-catchments comprise:
    - The Silvermine Sub-catchment
    - The Lourens Sub-catchment
    - The South Peninsula Sub-catchment and
    - The Liesbeek River and its tributaries within the Lower Salt Sub-catchment.
- The accumulation of solid waste is also rife in many areas of the City, particularly in low-income areas. This waste passes readily into stormwater systems, from where it is costly to remove. It also blocks or is used to block sewers and pump stations, resulting in added watercourse pollution. Addressing this issue through significantly ramped-up solid waste collection is strongly recommended;
- Halting of the planned implementation of four of six of LUW projects, all within the Sand catchment, has been questioned in this report. In the less-polluted Sand catchment in particular, their implementation might well have given rise to measurable water quality impacts as a result of

catchment-scale interventions, carried out in combination with pollution abatement strategies such as sewer and pump station upgrades and repairs;

- The CCT's current stormwater management system results in some catchments extending across two or more Stormwater Planning Regions. This means that in some cases, river catchments are managed by two or more catchment planners, making integration of projects and responsibilities difficult, and accountability for catchment condition unwieldly;
- Similarly, sewage reticulation activities are also not carried out on a (river) catchment basis – this again means that efforts in one part of a reticulation zone may be negated by a lack of co-ordination with upstream managers, or different strategies and level of effort in different areas.

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Overview of water quality in rivers and other monitored water bodies

This report focused on the CCT's water quality data for the 2022 and 2023 reporting periods[18], against a baseline of data from the previous three years (2019 to 2021 reporting periods). Other data such as rainfall data, sewage pump station overflow data, WWTW effluent quality data and sources of information gathered from CCT officials and others regarding planned interventions to address water quality going forwards, and those highlighted for the seven priority catchments in particular, were also considered, and drawn into various discussions in the report. This has made for a long, and in places technical, report. Its key findings and recommendations have however been pulled out relatively simply in this section, and will be summarized for broader public consumption in the planned Summary Water Quality Document for the 2022 and 2023 reporting periods.

Overall, the analyses highlighted the fact that, from an ecological perspective, the most problematic and pervasive water quality issue almost throughout the CCT's monitored rivers and other watercourses was (and remains) **phosphate enrichment.**

Phosphate data indicate that phosphorus enrichment negatively affects most of Cape Town's monitored rivers and other stormwater systems, which over the 2022 and 2023 reporting periods lay generally well within the hypertrophic (Unacceptable) range for this variable. Although median phosphorus concentrations reduced in many catchments over the 2023 reporting period, the proportion of samples within an Acceptable range reduced by almost half, with just under 80% of samples lying within the Unacceptable range. Since many of these nutrient enriched rivers feed into the City's vleis and dams, the impacts of river phosphorus enrichment is passed on to, and magnified within these standing water bodies.

The Silvermine, Lourens and Hout Bay Sub-catchments continued to be the best-performing catchments among monitored riverine systems in the City, but nevertheless all showed a decrease in the proportion of samples in an Acceptable condition over the 2023 reporting period. In the Silvermine Sub-catchment, this was attributed at least in part to the impacts of periodic pump station failure, the effects of which are exacerbated by upstream abstraction.

The worst-performing sub-catchments, characterized by permanent non-compliance in analysed samples, comprised the Mosselbank, Sout and Soet systems.

The City's monitored standing water systems (vleis and dams) were all highly nutrient-enriched, with water quality lying within either the range for Poor (eutrophic) or for Unacceptable (hypertrophic) conditions throughout the three reporting periods considered. These data reflect inflows from significantly more polluted rivers and stormwater systems, which load standing water bodies with nutrients that accumulate over time, in the water bodies themselves, as well as in bottom sediments and living plant material. In inland aquatic ecosystems, high phosphate availability results in excessive plant growth, promoting the growth of reeds, aquatic weeds (many of them invasive alien species) and algae. These come at high management costs, requiring ongoing removal or other management interventions, and affecting the fitness for use of at least some recreational water bodies. The monitored vleis and dams were also characterised by low N:P ratios, in the range most likely for these systems to be dominated by blue-green algae rather than rooted plants or other less problematic algal groups.

These findings highlight how catchment condition reflects in river water quality, with the least developed catchments having the least impacted water quality while catchments subject to the accumulation of solid waste, treated and untreated sewage inflows and other sources of contaminated stormwater including fertilisers, are characterized by impacted river waters.

Analysis of chlorophyll-*a* data (a measure of algal productivity) in this report, showed that the most problematic systems, where the risk of algal blooms would have been high during the reporting periods being considered, were Zeekoevlei, Princessvlei, Wildevoelvlei and Langevlei (although there was a noticeable

[18] Note that the reporting periods used in this report are different from those of previous years' reporting, and run from October to September of any year, with the naming year for each reporting period being the year ending September.

improvement in the situation at Wildevoelvlei in Reporting Year 2023). High levels of non-compliance were recorded for Rietvlei in Reporting Years 2022 and 2023 (with <25% of the samples within the Target range for Chl-*a*).

Analysis of microcystin toxin data showed however that, although blue-green algal blooms were clearly present on numerous occasions over the 2022 and 2023 reporting periods covered in this report, the only vlei in which microcystin toxins were recorded at concentrations of concern was Zeekoevlei.

This means that, excluding Zeekoevlei's waters, and despite periodic blue-green algal blooms, Cape Town's recreational watercourses were assumed to be relatively safe for human use over the 2022 and 2023 reporting periods, from the perspective of exposure during intermediate contact use to microcystin toxins in water from these systems.

Analysis of other ecologically important variables highlighted concerns that often go hand-in-hand with eutrophication. For example, concentrations of **dissolved oxygen** (DO) (a variable essential for most aquatic life) showed that in the City's rivers, 40% or more of the measurements collected over the five-year period from Reporting Year 2019 to 2023 consistently reflected Poor to Unacceptable conditions, although there was some overall improvement from the 2022 to the 2023 reporting period. Summer DO conditions were characteristically (and expectedly) worse than cold winter conditions. It must however be stressed that sample point selection has historically selected problematic sites for monitoring, and a more important measures is thus change in condition over time.

Grouped results for standing water systems (vleis and dams) show a trajectory of some improvement in terms of DO compliance over the three reporting periods considered here, with the most significant improvements in terms of recorded DO concentrations observed at Rondevlei and Glencairnvlei in Reporting Year 2023, at Zeekoevlei, Westlake and Langevlei in Reporting Year 2022 and at Zandvlei in both Reporting Years 2022 and 2023, the latter reflecting a general trend in improved ecosystem condition in this waterbody.

DO concentrations often reduce when bottom decomposition rates are high (e.g. when hypertrophic conditions promote rapid algal growth with high turnover rates, resulting in a 'rain' of dead algal cells onto the lake or wetland floor). Inflows of water with high chemical oxygen demand (COD) can also reduce DO concentrations in water bodies. Data for most of Milnerton Lagoon for example showed very low DO concentrations over the 2022 and 2023 reporting periods, attributed mainly to high COD loading from the Potsdam WWTW.

Linked with low DO concentrations in many systems were high levels of total ammonia, which included potentially toxic 'free' ammonia. **Ammonia** concentrations in samples from hypertrophic vleis such as Wildevoelvlei and Zeekoevlei (the latter characterised by deep layers of anoxic sediments in some areas) were almost always in the range of acute aquatic ecosystem toxicity (i.e. rated Unacceptable).

A major contributor to the degradation of many of the City's watercourses is contamination with raw sewage. This study assessed *Escherichia coli* data for the 2023 reporting period, and compared these with data from the 2019 and 202 reporting periods, due to issues over data reliability in the intervening periods. It found that the proportion of river samples rated as Unacceptable from a human risk perspective increased over the assessed reporting periods (2019, 2020 and 2023), with data showing increases from 49% Unacceptable (2019 dataset) to 59% in the 2023 dataset, attributed to an increased frequency of load-shedding, with its effects on sewage pump stations and WWTWs, as well as burgeoning poorly serviced informal settlements in many sub-catchments.

The data showed that the most poorly-performing sub-catchment was the Soet (90 – 100 % Unacceptable samples) reflecting a stormwater system fed almost entirely by grey- and black-water inflows from informal settlements. By contrast, the Silvermine and the Lourens River catchments were least impacted by *E. coli* (and by assumption, raw sewage), with > 80% of samples lying within the Acceptable range, and explaining in part their generally low levels of nutrient enrichment and elevated ecosystem condition. Nevertheless, even these generally cleaner sub-catchments were impacted at least at times by raw sewage inflows.

Standing water systems (vleis, dams, detention ponds) typically showed lower *E. coli* concentrations and performed better in terms of compliance data than did the rivers feeding into them. This is attributed mainly to extended retention time within standing water bodies (especially the large vleis), allowing exposure of *E.*

coli to ultra-violet (UV) light in sunlight (which kills these bacteria) and dilution of point-source inflows in large water bodies. Summary *Escherichia coli* for standing water bodies suggest that although all of the CCT's recreational water bodies periodically posed risks to human health during the 2023 reporting period, they were largely in an Acceptable condition, conducive to their recreational use. The exception to this was Milnerton Lagoon, which was mostly in an Unacceptable condition, and its use for recreation would probably have posed risks to human health most of the time. Sample points in Milnerton Lagoon were all rated as Unacceptable, with the main sources of raw sewage assumed to stem from the catchment between Blaauwberg Bridge and Otto DU Plessis Drive, including overflows from the Koeberg and other sewage pump stations, overflows from the Potsdam WWTW, and inflows of polluted stormwater from poorly serviced informal settlements, unmanaged urban areas (e.g. Phoenix and Jo Slovo Park) and backyard dwellings.

9.2 Identification of key pollution sources

The main drivers of the aquatic ecosystem degradation, and phosphate enrichment in particular, that persisted and in some cases worsened in the City's sub-catchments over the current reporting periods, revolved primarily around a number of issues, most of which do not relate to stormwater flows and their effects on rivers and wetlands, but relate rather to inflows of sewage and solid waste from various sources. These issues comprise the following

1. **Inflows of treated effluent from WWTWs** across the City result at best (if licensing requirements are met) in permanent flows of nutrient-enriched[19] effluent into sometimes seasonal or small river systems, and downstream vleis or estuaries. However, not all (or even most) of the CCT's 17 inland discharging WWTWs meet General Effluent Limits and some of the CCTs major WWTWs produce effluent that has high CODs, high levels of suspended (organic sediments); high total ammoniacal nitrogen concentrations; and faecal bacteria (represented by *E. coli* counts). Many other contaminants (pathogens, heavy metals, contaminants of emerging concern (CECs) (e.g. food additives, pharmaceuticals, and natural and synthetic hormones) are largely unquantified in the CCT's waste streams. Downstream water quality impacts may also be exacerbated by unanticipated impacts of disinfection. Where chlorination is used to disinfect effluent with high total ammonia concentrations, persistent potentially toxic chloramines may be formed and passed into downstream receiving water bodies.

   High concentrations of phosphorus in effluent from all WWTWs were apparent in final effluent data, despite high compliance with regulated general limits over the 2022 and 2023 reporting periods. However, the general limit for this variable is very high from an ecological perspective – 10mg P/L. This is nearly an order of magnitude greater than the hypertrophic ("Unacceptable") thresholds for this variable of 0.125 and 0.130 mg P/L in rivers and standing water systems respectively;

   Escherichia coli data showed that in the 2023 reporting period, only five of the CCT's WWTWs consistently produced effluent within general limits for *E. coli*, with most of the other WWTWs producing effluent with *E. coli* counts several orders of magnitude higher, and highlighting the risks posed by such effluent to downstream water users in contact with the water.

   COD data are probably the most useful for highlighting the magnitude of downstream chemical risk to aquatic ecosystems. These data indicate that the most poorly performing WWTWs in this regard feed into the following river aquatic ecosystems:

   - Diep River estuary and Milnerton Lagoon (Potsdam WWTW)
   - Black River and Salt River canal (Athlone and Borcherd's Quarry WWTW)
   - Wildevoelvlei (Wildevoelvlei WWTW)
   - Zeekoe canal (Cape Flats WWTW)
   - Mosselbank River (and lower Diep River) (Klipheuwel WWTW) – note however that the effluent volume from this system was relatively low, so downstream loading was not marked)
   - Eerste River estuary (Macassar WWTW).

[19] The DWS' General Effluent Limits for phosphate (as PO4-P) in effluent discharge are 10 mg P/l. That is, two orders of magnitude above the threshold for hypertrophic conditions.

Of the above, the impacts of the Potsdam WWTW on the downstream systems are considered most significant, having contributed largely to the collapse of this estuary and its once-important nursery for juvenile fish (Rose et al 2023). Similarly, the Macassar WWTW, the effects of which are multiplied by inflows from the Bellville, Scottsdene and Zandvliet WWTWs upstream in the catchment) has contributed to the severe degradation of the Eerste River estuary.

Although the Cape Flats, Athlone and Borcherd's Quarry WWTWs essentially now feed into canalised artefacts of urban drainage, these systems nevertheless play important roles in Cape Town's urban society and poor effluent quality both actively detract from the value of the areas through which they pass, and has significant ecological costs – for example, the potential for estuarine fish to migrate up the Zeekoe Canal is compromised by large volumes of effluent outflows, often of very poor quality. Similarly, the Black River accumulates organic sludges from upstream inflows of *inter alia* treated effluent, with CODs well above the capacity of this system to effect aerobic decomposition.

Improved performance in some WWTWs (e.g. Potsdam and Zandvliet) was however apparent in both loading and effluent quality data, in the latter part of the 2023 reporting period. The downstream impacts of these systems nevertheless remain significant.

2. **Episodic overflows from sewage pump stations and surcharging manholes** result in overflows that pass either directly into watercourses or enter them via the stormwater system. These result in plugs of effluent with high COD, elevated total ammoniacal nitrogen concentrations, high phosphate concentrations, high organic loading and often high levels of solid waste passing into downstream watercourses.

Data from the CCT's records of pump station overflows (see **Section 5.6.3**) show that (for the 2022 reporting period for which data were available):

- By far the most prevalent causes of damage were reported as pump tripping and electrical failures (both 23%) and mechanical failure (17%);
- Load shedding was the factor that accounted for the fourth highest number of pump station overflows (9 %);
- Mains supply faults, blockages / breakdowns as a result of rags and foreign objects including sand in the pump station wet wells, and generator failure accounted for 7%, 6% and 5% of break-downs respectively;
- Theft accounted for 1% of pump station failures.

3. **Runoff from informal settlements** and housing areas with high levels of backyard dwelling and/or where there is poor attention paid to maintenance of existing infrastructure result in permanent, generally low level but highly contaminated waste streams passing out of informal settlements and into the City's watercourses. Not only do these outflows constitute a severe health risk for children and other residents of local communities who live, play and have to cross though these areas, but they also can significantly impact on water quality in downstream rivers and other receiving water bodies, and can negate river rehabilitation activities in these reaches.

4. **Accumulations of large volumes of solid waste and illegal dumping of waste** that characterise many areas of the City's open spaces, roadways and pavements. Much of this waste enters watercourses, where it may contribute harmful pollutants to aquatic ecosystems (e.g. cans containing oil and other waste; old nappies and other organic waste) or block stormwater drains and channels. When solid waste is disposed of into the sewer system, it can block sewers and clog pumps at sewage pump stations.

   This issue stems largely from inadequate solid waste collection, compared with the volume of waste generated. The problem is concentrated in less affluent areas, and exacerbated by issues such as:

   - Often confined spaces in shacks for hygienic refuse storage between collection periods;
   - Lack of alternative options for the disposal of solid waste that is not accommodated by existing CCT waste disposal services (e.g. large objects such as couches and mattresses and rubble, that

is not collected by the CCT);

- Poor compliance with and enforcement of bylaws around dumping and littering.

There are many other activities and landuses that contribute to cumulative water quality degradation in the City. The above are considered by far the most significant, and unless they can be addressed or their impacts mitigated, there is little likelihood that the CCT will be able to effect meaningful and measurable improvement in water quality in most of its managed sub-catchments.

9.3 Responses by the CCT to water quality issues

The above findings are not new – similar findings were presented in both the 2020 and 2023 Inland Water Quality Reports, and the MPP for Sanitation and Inland Water Quality as well as the WQIP (see **Section 7**) all recognise and reference the urgent need to address the above complex issues.

However, budget cuts (from early 2024) will clearly constrain the ability of the CCT *inter alia* to increase sewer servicing to expanding informal communities, often in low-lying (essentially unserviceable) areas; to increase solid waste collection frequency and efficiency; to enforce existing by-laws around dumping and pollution; and to ensure within-city compliance with meeting the water quality licensing requirements of its WWTWs and preventing pollution of watercourses through sewage pump station failure and sewer overflows.

Although in the current (2024) climate of severe budget cuts, budgets for key MPP projects will be maintained, including allowance for sewer pipe replacement and expansion and upgrades of priority pump stations, areas such as the priority Soet sub-catchment (for example) have not been prioritised for pump station upgrades, and most planned interventions in this sub-catchment are listed in the TAP as "long term" interventions. These are examples of direct, budget-related impacts on the likely ability of the CCT to be able to make meaningful inroads into improving water quality at a measurable level in its catchments.

In such circumstances, a consideration for the CCT would be to focus efforts on achieving measurable outcomes on one priority catchment at a time, while meeting minimal standards elsewhere.

9.4 Key recommendations from this report

Recommendations to address water quality at a municipal level in a city where water quality is severely compromised could constitute a study on its own, and incorporate measures from major interventions to best practices that should result in water quality improvement if rolled out at scale. This section rather highlights the key interventions and/ or activities that stem from this assessment.

Upfront it must be stated that until the pervasive issues of pollution from WWTWs and informal settlements can be addressed, it is unlikely that there will be a significant turn-around in water quality in many areas.

9.4.1 Addressing pollution from major WWTWs

This report strongly supports major capital investment by the CCT in upgrading of its WWTWs, informed by various consultative studies (see **Table 7.2** in **Section 7**).

It is also understood that the CCT is investigating the upgrade and other requirements of existing WWTWs across the City (see **Section 7**). From a receiving water quality perspective (i.e. wetlands, rivers and estuaries), it is recommended that prioritisation of such interventions take cognizance of the importance, sensitivity and restorability of receiving watercourses, when determining which WWTWs to focus on for upgrades. WWTWs discharging into the Kuils, Eerste, Mosselbank and Diep Rivers in particular should be prioritized, as these river systems retain elements of natural aquatic ecosystem function and include important downstream estuaries and floodplain wetlands. This recommendation is not intended to imply that polluted discharges into other systems do not also result in major ecological and human health consequences. The recommendation is rather about prioritisation of effort.

This study found that although CCT's WWTWs were compliant with regard to meeting limits on orthophosphate phosphorus concentrations at least, the General Limit for this variable is very high from an ecological perspective (nearly an order of magnitude greater than the hypertrophic ("Unacceptable") thresholds for

this variable in rivers and standing water systems. It is recommended that measures to further reduce final effluent concentrations should be prioritised by the CCT for WWTWs that discharge into rivers that feed into important vleis, coastal lakes or estuaries, and contribute to algal and other plant blooms; and an increase in organic sludges from algal growth. Reduced loading from WWTWs should reduce both the ecological (and knock-on recreational and economic) costs of degraded aquatic ecosystems in urban areas, but also result in reduced management costs, in terms of clearing of invasive aquatic vegetation such as water hyacinth as well as reeds and the need for river and vlei dredging.

Rapid access to basic equipment for management of WWTWs under emergency / breakdown conditions also appears to be a serious limitation in the CCT's current management structures. A system for fast-tracking procurement of, or keeping in stock, equipment that is likely to be required on an emergency basis for all WWTWs should be investigated, noting the opportunities for graft that such systems could also enable.

It is further recommended that CSRM should include final effluent water quality and discharge volumes from all WWTWs in its data base, to allow for more integrated interpretation of water quality data in receiving water bodies. **It is acknowledged that in the current reporting period, such data were however readily available through the CSRM.**

9.4.2 Addressing pollution from informal settlements and suburbs with high levels of backyard settlement

It is clear that there is an urgent need to address access to adequate sewerage and stormwater services within all CCT managed settlements. From a water quality perspective, there is however no time to wait for such an eventuality and in the interim it is recommended that the CCT pursue less-ideal measures such as diversions of polluted dry-weather flows to WWTWs via existing or new sewers. In the case of the Kleine Stink River that passes through the Doornbach and Dunoon informal settlements, diversion of the river outside of these essentially permanent settlements is recommended – but should be informed by current reporting to the CCT (see Lukhozi 2024).

The rapid and uncontrolled expansion of informal settlements in many areas of the City also needs to be addressed. Addressing this issue falls outside of the scope of this report but remains highly relevant to water quality concerns.

9.4.3 Addressing sewage overflows from pump station failure

Section 5.1.3 highlights the fact that the main reasons for pump station overflows, at least over the 2022 reporting period, appeared to be rooted in mechanical and equipment failure, rather than from load-shedding, although load-shedding impacts have probably increased over the past three years, with increased frequency of power outages. Ensuring the availability of crucial spare parts; pro-active maintenance; and strategic upgrading of pump stations should all be prioritised.

Pump station upgrades should include allowance for upstream sediment and solid waste traps, additional bunding as well as inclusion of grids / grates to reduce ingress by foreign objects, which clearly play a role in periodic pump station failure. The present inclusion of single grids that leave wet wells and pumps vulnerable to clogging during routine grid clearing should be re-visited and a dual grid system implemented instead.

9.4.4 Reducing the passage of solid waste into stormwater systems and watercourses

Collection of solid waste must be upscaled in the City to reduce the high levels of waste that accumulate in many areas and blow, wash or are dumped into the stormwater system. Sub-catchments that are particularly prone to the build-up of solid waste include the Soet, upper Sir Lowry's Pass, lower Kuils, Lower Salt, Diep, lower Hout Bay, north-eastern Sand and upper Zeekoe sub-catchments.

The frequency of solid waste collection at source should be increased in the above areas so that collection outstrips the rate of solid waste accumulation. Innovative approaches such as the "Swap shop" recommended for roll-out in the Soet Sub-catchment and already piloted in some parts of Cape Town should be considered for broader implementation, as such approaches add value to waste.

Engagement with and co-operation from CCT's Waste Services Department is essential for progress to be

made in this regard.

9.4.5 Making changes in stormwater and sewerage reticulation management structures

An important recommendation from both this and previous Inland Water Quality reports is for a change in the CCT's regional management structures, across both sewerage reticulation areas and stormwater planning regions, so as to align management areas and responsibilities with hydrological (major river) catchments, rather than with the current stormwater (see **Section 2.8**) and sewage reticulation regions, which do not relate to surface runoff and do not facilitate strategic pollution abatement at a catchment level, since different regional managers and their teams have responsibility for different parts of the catchment.

9.4.6 Fast-tracking implementation of PASAPs and TAPs

PASAPs and associated TAPs have been developed for several areas of the City to date. However, their actual implementation in most cases appears slow, with long periods between draft PASAP and TAP preparation and finalization, suggesting a lack of urgency which is further illustrated by the long time scales allowed for in the assessed TAPs to undertake any significant interventions. It is strongly recommended that implementation of the PASAPs be fast-tracked and their TAPs align with the sub-catchment condition and priorities.

It is also recommended that additional PASAPs should be compiled and implemented for other key pollution hotspots, including the lower Kuils River, the upper Sir Lowry's Pass River, the upper Sand River through Retreat and the Diep River sub-catchments, outside of the areas managed by the Diep River Estuary Management Plan.

9.4.7 Changing targets for interpreting sewage contamination in water quality data

The CCT has a 60% target for meeting Acceptable *E. coli* Risk levels in any sub-catchment. This low target seems counter-productive and it is strongly recommended that a target of 100% Acceptable samples would be more appropriate. This is particularly so because many of the CCT's citizens are regularly exposed to contact with water in watercourses that are not managed for recreational use. This recommendation is carried through from the previous Inland Water Quality Report.

9.4.8 Conservation of existing sub-catchments in relatively good condition

Water quality data reported on in this document highlighted the fact that some sub-catchments and portions of sub-catchments were in a generally good condition (i.e. target thresholds for key ecological and human health variables were usually met). These sub-catchments should be safeguarded, with attention paid to addressing any sources of periodic pollutant inflows. Such an approach would at least ensure that these systems remain in relatively good condition. The best-performing sub-catchments include (in descending order) the Silvermine, Lourens, (upper) Hout Bay and parts of the Sand sub-catchments, as well as the Liesbeek River sub-catchment of the Salt River catchment. None of these sub-catchments receive WWTW effluent, and only the Hout Bay sub-catchment receives significant runoff from poorly serviced informal settlements.

Problem manholes and pump stations in these areas should be attended to as a matter of urgency.

9.4.9 Conservation of remnant floodplains and their wetlands

Few of the City's rivers today retain floodplain wetlands in good condition. The most important remnants today comprise those along the Diep River, downstream of the railway line crossing; the Kuils River (Nooiensfontein wetland and surrounding floodplain; uninvaded wetlands downstream of the N2) and the lower Eerste River (downstream of the N2). These areas in particular should be safe-guarded by the CCT as critically important systems from both a biodiversity / habitat protection perspective, but as importantly from the perspective of increasing the City's resilience to floods and flooding, particularly in the light of climate change projections. From a water quality perspective, such an approach would also avoid the devastating permanent and largely unmitigable impacts of sewage and grey water pollution that would be associated with the alternative likely establishment of unserviceable settlements in these low-lying flood-prone areas.

9.4.10 Prioritisation of LUW programme implementation

The LUW programme is a forward-thinking potentially far-reaching programme that offers the CCT opportunities to effect measurable change in river condition and function at scale. Once implemented, projections and experience of similar approaches in eThekwini Municipality suggest (Mc Donald 2024) that the economic gains per catchment, including avoided costs such as flood damage, and benefits such as increased property value and provision of public amenity, readily outweigh implementation costs. The catchment approach also offers other strengths, in allowing more holistic management of watercourses. For example, attention to the systematic removal of water hyacinth at a catchment scale offers a much more efficient approach to effecting long term plant control than the narrow approach of focusing operations on repeat clearance of single vleis or river sections, which at best achieve short-term maintenance.

At the time of writing this report, funding for implementation of four out of six LUW projects had been lost, with these projects being rolled onto the CCT's ten year budget cycles.

It is strongly recommended that the cut in LUW programme budget should be re-evaluated by the CCT and funds to re-commence with the four halted projects at least should be prioritized, if this programme is to gain the traction that it requires to bring about the change in Cape Town's waterways that is a pre-requisite for the CCT's aims of becoming a water-sensitive city by 2040, in line with its current status as a Ramsar wetland city.

9.4.11 Changes to the CCT's water quality monitoring programme

The recommendations made in this section relate specifically to changes that would improve the efficacy of the current CCT water quality monitoring programme in being able to inform water quality data interpretation, water quality management and water quality improvement policy and implementation.

9.4.11.1 Sample sites

CSRM are currently engaging with SSB around the inclusion of additional samples in its routine monitoring programme.

Through discussions with various Stormwater Planning Region management teams, a number of additional monitoring sites were recommended for inclusion, as follows:

- A sample site in the upper reaches of the Silvermine sub-catchment, upstream of Clovelly Golf Course;
- A second sample site in the Soet Sub-catchment, upstream of the Greenways Golf Estate aeration interventions;
- In the Sout River upstream of the Melkbosstrand WWTW, to allow tracking of water quality changes as a result of burgeoning upstream development;
- In the Khayelitsha Wetland Park, at a representative site for the water bodies utilised by the Khayelitsha Canoe Club;
- Downstream monitoring sites for all WWTW effluent outfalls into rivers or channels (that is, all non-marine discharge points).

9.4.11.2 Water quality variables

Monitoring of the following additional variables is recommended:

- At existing or new sampling points downstream of all WWTWs that discharge effluent into rivers, vleis or estuaries:
    - Chloramine and COD testing in receiving waters downstream of WWTWs;
    - Heavy metal analyses, with heavy metals to be determined based on subcatchment landuse characteristics – given the costs of such analyses, heavy metal analysis could be carried out infrequently (e.g. annually), with a view to identifying systems where some metals may be accumulating in concentrations of concern;

- At all existing inland recreational water bodies, where *E. coli* counts are currently analysed:
    - Enterococci testing should be allowed for as well, with a view to moving from *E. coli* to enterococci testing over time and providing alternative data against which to check E. coli data, which have not always been reliable
- Orthophosphate phosphorus and total phosphorus analyses must be carried out to lower detection limits than the current 0.1 mg P/L. A return to previous analytical methods that allowed for detection limits of <0.01 mg P/L is strongly recommended if changes in phosphorus pollution trajectory is to be adequately tracked;
- Analyses for total phosphorus must be re-commenced as a matter of urgency;
- Assessment of the City's water bodies for a suite of Contaminants of Emerging Concern (CECs) should also be carried out by CSRM, even if only on an occasional basis, to provide context to CEC data to be produced during planned monitoring of coastal waters in the vicinity of the City's coastal waste water outfalls.

9.4.12 Reporting water quality data

The system for reporting of *E. coli* and other bacteriological data must be standardised to allow for better statistical analyses of these data. It is important that data reflecting samples that have not been analysed to an actual count are at least taken as close to that number as possible, through multiple laboratory dilutions, facilitated by the Colilert system currently being used bySSB. In particular, ">" annotation should not be used to reflect counts that are less than the threshold for Unacceptable. Moreover, in highly polluted watercourses, data simply reflecting ">x", where x is above the Unacceptable limit but still relatively low relative to the actual degree of pollution, such data do not allow pollution tracking or the identification of likely zones of increasing contamination. As in the previous Inland Water Quality Report, it is again recommended that samples should be diluted to levels where at least reporting up to 10 000 000 cfu/100ml is possible. SSB should be engaged with in this regard, to set consistent rules for data dilution and reporting.

9.4.13 Water quality data availability

The CCT's allowance in early 2022 for open public access to water quality data from its routine monitoring programme through the CCT data portal is fully supported.

9.4.14 The need to link water quality data to pollution control interventions

The CCT's routine water quality monitoring produces an extensive ongoing dataset. However, without using these data to trigger further investigations or to design and carry out specific interventions to address sources of pollution or police identified polluters, the CCT is simply producing a record of water quality deterioration. It is recommended that targeted short-term pollution tracking projects should also be set up in all of the priority sub-catchments, and the findings of these programmes used to design appropriate interventions, with a view to using water quality data to make sound management decisions and interventions.

9.4.15 Improvements in data quality or data availability from other CCT datasets

9.4.15.1 Flow data

Water quality data on their own do not allow calculations of loading on downstream ecosystems. This means that the impact of high concentrations from small discharge sources may be over-estimated, while significant impacts resulting from large discharges of less polluted effluent may be missed.

The CCT currently collects flow data from some routine monitoring points. These data are not however collected at the same time as water quality samples, making calculations of loading impossible. Furthermore, the datasets themselves are problematic, with many missing datapoints.

It is recommended that regular flow measurements should be taken from selected points in all of the CCT's major rivers, at the same time as water samples are collected. Flow measurement approaches could be technology-driven with recording devices, or (more practically) carried out using depth measurements at

controlled areas (e.g. culverts), where the cross-section can be surveyed and discharge curves calculated.

9.4.15.2 Tracking interventions

The CCT is currently undertaking numerous interventions across the City, carried out by various departments, branches and sections within the Water and Waste Directorate. It is recommended that a coordinated log of these interventions should be kept, showing intervention, date, subcatchment and location, to allow these interventions / efforts to be correlated with changes, if any, in water quality data.

9.4.16 Capturing spill data per catchment

The CCT has commenced logging data for sewage pump station overflows. These data now include locations tagged to sub-catchments and are a valuable source of information for water quality data interpretation and to guide repair and maintenance effort. These datasets should be maintained and should form part of water quality assessments going forward.

9.5 Inland Water Quality Reporting

9.5.1 Separation of sub-catchments within the South Peninsula Sub-catchment grouping

To date, the Inland Water Quality Reports have considered the CCT's South Peninsula grouping of rivers as a unit, water quality data for which are analysed collectively. However, the area includes rivers in very different condition, from the Bokramspruit River through Ocean View to the Schusters River, through largely undeveloped mountain slopes and wetlands, but with growing informal settlements in its upper reaches. Grouping of rivers in this area for analysis potentially masks important shifts in water quality that need rather to be highlighted and addressed.

9.5.2 Use of the CCT's Water Quality indices in inland water quality

The present Terms of Reference for and format of the Inland Water Quality Report make for extensive reporting that details watercourse change and condition with regard to a range of key water quality variables. In order to simplify water quality reporting, and make its outputs more accessible to wider non-technical audiences, it is recommended that the CCT updates its (2013) Ecological and Recreational Use Water Quality Indices, and use these in annual reporting instead of the current format. The Indices output a single rating per water sample (A-F), which is based on consideration of the concentrations and condition thresholds of the full range of variables considered individually here.

The Technical Manual for these indices, outlined in Day et al (2013) would provide a starting point for this approach.

9.6 Role of residents in improving water quality in Cape Town's watercourses

Finally -it must be stressed that water quality in Cape Town's watercourses is not determined solely by the CCT's interventions. Residents also need to play a role in reducing sources of pollution into watercourses.

The following are the CCT's top ten changes that could lead to a measurable improvement in water quality in many systems, if they are consistently applied by enough residents:

1. Household waste should be binned, recycled or composted, depending on the type. Do not throw it down the stormwater drain or into the sewer network, as it either blocks the system and causes localised flooding or sewer overflows, or ends up in and pollutes our waterways. If household waste is not collected often enough, then contact the CCT or your Ward Councillor.
2. Don't flush nappies, sanitary products, wipes, earbuds, condoms, hair, rags or newspapers into toilets or sewers. These can block the sewer network, which result in overflows of raw sewage into the environment.
3. Dirty household wastewater, swimming pool backwash, bin washing water and other polluted water should be disposed of in the sink or toilet so that it enters the sewer network and travels to WWTWs for treatment, rather than the stormwater system. If such wastewater reaches the stormwater

system instead, it is destined for our waterways and, ultimately, the ocean, where it will pollute and harm these ecosystems.

4. Report sewage spills or sewage pump overflows in any areas to the CCT's "Report a fault" (C3 notification) system by phoning 0860 103 089 or going online to: www.capetown.gov.za/servicerequests.
5. Get involved - join local river clean-up groups and help prevent waste from getting into waterways in the first place.
6. Restaurants should clean out grease traps regularly, as a build-up of fats in the sewer system is a major cause of blockages and sewer overflows.
7. Don't wash vehicles on hard surfaces near a drain, as the chemicals in the greywater will run directly into the stormwater system. Rather wash your vehicle on a soft surface, where the greywater gets absorbed into the soil. Also make sure that your local car wash facility takes steps to prevent runoff of dirty detergent-laden wastewater.
8. Dispose of used oil, paint and other products that contain harmful chemicals at a City-approved drop-off facility, and not into the stormwater system or sewer network.
9. Use eco-friendly products in gardens and for cleaning vehicles. When it rains, chemicals in fertilisers, pest control and cleaning products end up in the stormwater system, harming our rivers, streams, wetlands and the ocean.
10. Make a concerted effort to use low-phosphate detergents and other products, wherever possible, to help reduce the phosphate load on rivers, vleis and wetlands, and to help transition Cape Town towards a phosphorus-free city.

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APPENDIX A: WATER QUALITY SAMPLING SITES AND MONITORING RECORD

Table A1
Frequency of samples COLLECTED per site in each sub-catchment for the 2019-2021; 2022; and 2023 reporting periods

Sub-catchment	Type	Site	Description of sample point location	Reporting period		
				2019 to 2021	2022	2023
City	River dataset	CN06B	Rocklands stormwater pipe discharge		1	7
		CN16B	Saunders Rocks stormwater discharge		13	19
		CN17A	Three Anchor Bay pipe discharge SW rocks (left from top) - A		13	18
		CN17B	Three Anchor Bay pipe discharge SW (center) rocks - B			6
		CN17C	Three Anchor Bay pipe discharge SW rocks (right from top) - C		13	18
		CN17E	Three Anchor Bay pipe discharge SW rocks (west of subway) - E			6
		CN24	Graafs Pool stormwater 1 discharge			2
		CN25	Graafs Pool stormwater 2 discharge			4
		CN26	Graafs Pool stormwater 3 discharge		12	14
		CN27	Bakoven stormwater discharge		12	18
		CN28	Camps Bay stormwater discharge			5
Diep	River dataset	MCC	Milnerton Canoe Club (Diep River)	70	27	20
		MOS05	Diep River u/s Mosselbank River confluence	52	19	18
		RTV01	Diep River at Blauwberg Road bridge	203	94	107
		RTV03	Stormwater canal from Theo Marais Park (Montagu Gardens)	115	46	53
		RTV04	Stormwater channel from Bayside Mall (into Rietvlei)	102	50	50
		RTV05	Outlet from Rietvlei at Otto du Plessis Drive bridge	195	106	112
		RTV06	Diep River downstream of N7 road bridge	75	37	48
		RTV08	Duikersvlei Stream u/s of confluence with Theo Marais canal	101	46	53
		RTV09	Diep River estuary at Woodbridge Island (Loxton Rd)	150	73	69
		RTV10	Diep River estuary at mouth	160	73	68

Sub-catchment	Type	Site	Description of sample point location	Reporting period		
				2019 to 2021	2022	2023
		RTV11	Diep River d/s of Potsdam WWTW	200	96	106
		RTV12	Canal d/s confluence TM & Duikersvlei	118	43	56
		RTV14	Stormwater channel next to Bayside Mall d/s of Blaauberg Rd	40	42	46
		RTV18	Rietvlei north of island opp Broad Rd	69	67	64
		RTV22	Railway bridge near container yard			4
		THEO_MARAIS_D_STREAM	100m d/s of TM Park STW system	67	58	60
	Standing water	MAC	Rietvlei in front of Milnerton Aquatic Club	83	90	72
		PEV1	Zoarvlei (south end) at corner of Vrystraat and Grey St	104	45	50
		PEV2	Zoarvlei (centre) at Wemmys road footbridge	94	49	59
		RTV02	Rietvlei at jetty	178	72	62
		RTV17	Water Sport Area middle; Rietvlei	3	51	61
		RTV19	Rietvlei north west near Bayside Canal inlet	10	57	59
		RTVBUOY1	Rietvlei Water Body@Bouy1	13	65	60
		RTVBUOY2	Rietvlei Water Body@Bouy2	27	68	61
		RTVBUOY4	Rietvlei Water Body@Bouy4	26	68	60
		RTVBUOY6	Rietvlei Water Body@Bouy6	26	68	61
		RV_SCOT	Northern shore- Scotto Hide - right side of boardwalk			1
Eerste	River dataset	EK08	Kuils River d/s of Baden Powell Drive bridge	289	77	75
		EK11	Kuils River d/s of Zandvliet discharge (dirt road bridge)	288	77	75
		EK12	Eerste River u/s of Macassar WTW (d/s of Kuils confluence)	198	74	73
		EK13	Eerste River on N2 Freeway (u/s of Kuils confluence)	61	23	23
		EK15	Kleinvlei canal	64	23	23
		EK17	Eerste River estuary	207	74	73
		EK18	Moddergatspruit River at Macassar Rd	60	21	22
Elsieskraal		ELS_GW	Elsieskraal River near Grandwest and Goodwood Station	64	22	22

Sub-catchment	Type	Site	Description of sample point location	Reporting period		
				2019 to 2021	2022	2023
	River dataset	ELS08	Elsieskraal River at Nightingale Way	62	22	22
		ELS10	Elsieskraal at Carl Cronje Rd	49	20	22
	Standing water	ANG01	Angelier Park upper dam near Van Riebeekshof Rd	108	33	33
		ANG02	Angelier Park lower dam near Van Riebeekshof Rd	96	24	33
		DOOR01	Doordekraal Dam at large stormwater outlet on Angelier Stre*	68	19	24
		DOOR03	Doordekraal Dam at south end next to dam wall	108	33	33
Hout Bay	River dataset	DR01	Hout Bay River at Princess St	72	24	23
		DR02	0	73	22	23
		DR04	Hout Bay River at Longkloof Rd	67	23	23
		DR05	0	36	12	12
		DR06	Disa River at Bethal Rd	66	22	23
		HB11	Yacht Club Stormwater		1	3
Kuils	River dataset	EK03	Bottelary River at Amandel Rd	64	23	19
		EK04	Kuils River at Carinus street bridge	217	73	73
		EK05	Kuils River in canal u/s of Stellenbosch Arterial Rd	62	23	23
		EK09	Kuils River d/s Belville WWTW discharge at Rietvlei Rd	219	74	74
		EK19	Kuils River d/s R300 off old bridge	64	23	23
		EK20	River d/s of Scottsdene WWTW	140	46	59
	Standing water	KHA01	Pond in Site C on Mew Way	65	19	21
Lourens	River dataset	LOU01	Lourens River at Vergelegen Estate	72	22	22
		LOU02	Lourens River in P.O.S., Hillcrest Rd	65	22	22
		LOU03	Lourens River at Main Rd - Somerset West	65	22	22
		LOU04	Lourens River at Broadway Rd	63	22	21
		LOU05	Lourens River on Beach Road	72	22	21
		LOU06	Lourens River in Lourensford Estate at "Red Bridge"	64	20	22

Sub-catchment	Type	Site	Description of sample point location	Reporting period		
				2019 to 2021	2022	2023
		LOU08	Lourens River between Old Bridge and Main Rd Bridge	64	22	21
		LOU13	Stormwater outlet from wetland on Vergelegen Rd	31	9	13
Lower Salt	River dataset	NR01	Blomvlei Canal at Koodoo Street u/s of Vygekraal River conf*	64	20	22
		NR02	Vygekraal River at Cornflower Street u/s of Blomvlei Canal *	64	20	22
		NR03	Vygekraal River u/s of Athlone WTW	128	20	20
		NR04	Vygekraal River d/s Athlone WTW	72	20	20
		NR06	Black River at Raapenberg Road bridge	63	22	23
		NR07	Black River on Footbridge to Alexandra Institute	65	22	22
		NR08	Liesbeek River downstream of Lake weir opp. Hartleyvale	64	22	22
		NR09	Salt River Canal at Voortrekker Road bridge	64	22	20
		NR10	Salt River Canal at Marine Drive Bridge - Paarden Eiland	72	22	22
		NR11	Black River in Rdbosch Golf Course	62	20	22
		NR15	Jakkalsvlei Canal at N2	212	74	73
		NR16	Langa Canal on N2	64	22	22
		NR17	Kalksteenfontein Canal nr Netreg Stn	63	20	22
		NR22	Liesbeek River on Paradise Road	41	12	13
		NR24	Black River at Sandown Road	35	12	5
		NR25	Vygekraal d/s of Athlone WWTW at Jan Smuts Drive	127	22	22
		NR26	Kalksteen Canal at corner Robert Subukwe and N2	220	72	73
Mosselbank	River dataset	MOS01	Maastricht Canal u/s WWTW	236	90	74
		MOS02	Maastricht Canal d/s WWTW	230	90	70
		MOS03	Mosselbank trib d/s Fisantkraal	70	37	23
		MOS04	Mosselbank River u/s Diep River confluence	64	20	21
		MOS06	Mosselbank River nr Klipheuwel	36	16	16
		MOS07	Mosselbank River u/s Fisantekraal WWTW	159	53	66
		MOS08	Mosselbank River d/s Fisantekraal WWTW	172	57	65

Sub-catchment	Type	Site	Description of sample point location	Reporting period		
				2019 to 2021	2022	2023
		MOS09	Mosselbank tributary d/s Fisantkraal settlement	66	31	15
MPlain	River dataset	KHA04	Outlet from Khayelitsha stormwater system to sea	72	19	21
	Standing water	CS23	Mitchell's Plain West STW Drain	76	32	26
		CS24	Mitchell's Plain East STW Drain	5	2	
		KHA02	Canal inlet to detention pond near litter device	68	19	21
		KHA03	Detention pond near outlet on Baden Powell Drive	68	19	21
Noordhoek	Standing water	WV02	Centre of EAST vlei	112	33	33
		WV05	Centre of WEST vlei	110	33	33
		WV08	Wildevoelvlei mouth to sea	35	9	12
Sand	River dataset	CR01	Westlake River cnr Main and Chenel Roads	60	24	26
		CR02	Westlake River at Orange St - Kirstenhof	18	24	26
		CR03	Westlake River Altenburg Rd - Kirstenhof	19	20	24
		CR04	Westlake River in Pollsmoor Prison grounds	18	13	14
		CR05	Westlake River at Steenberg Rd	5	17	22
		CR06	Prinskasteel River in greenbelt off Lismore Rd (close to M3)	60	21	20
		CR16	Diep River at Alphen Rd in canal d/s of CR15	52	21	24
		CR20	Keysers River at Military Rd	72	20	24
		CR21	Sand River at Oudevlei Road (d/s conf Langvlei & Sand)	74	21	24
		CR22	Downstream of Westlake and Keysers River near railway line	68	15	18
		CR29	Sand River at Coniston Rd (u/s of litter trap)	4	20	24
		CS01B	Kalk Bay Harbour Beach Stormwater		6	10
		CS22	Muizenberg Station stormwater		12	13
		CS26	Baileys Cottage stormwater		12	13
		DRRSC		64	22	25
		LPVMR	Mocke River inflow to Little Princessvlei	66	22	27
		LVI	Langevlei - canal at vlei inlet	66	22	116

Sub-catchment	Type	Site	Description of sample point location	Reporting period		
				2019 to 2021	2022	2023
		SCV	Southfield Canal at Victoria Road	67	21	28
	Standing water	LPVN	Little Princessvlei - north	98	34	121
		LPVS	Little Princessvlei - south	104	34	128
		LVO	Langevlei - vlei oulet	108	34	115
		OOG01	Die Oog at Midwood Avenue, Bergvliet	81	34	43
		PV03	Princessvlei - centre	106	32	127
		PVWEIR	Princessvlei near outlet weir	68	20	122
		ZA01S	Zandvlei - north, surface	142	73	59
		ZA02S	Zandvlei - centre (opp Imperial Yacht Club), surface	150	73	60
		ZA03S	Zandvlei- south (opposite Playwaters), surface	28	4	1
		ZA04S	Outlet channel - midway to mouth, surface	16	65	56
		ZA05S	Outlet channel near Royal Road bridge, surface	100	70	57
		ZA06S	South entrance to Marina da Gama canals, surface	3	45	41
		ZA07S	North entrance to Marina da Gama canals, surface	13	46	44
		ZA08S	Marina da Gama canal near "The Anchorage", surface	113	68	56
		ZA09S	Marina da Gama canal, surface	98	65	56
		ZA10S	Westlake Wetland opposite Rutter Rd (old WLW)	107	66	53
		ZA11S	Marina da Gama canal East Lake (old BM20), surface	101	66	56
		ZA12S	Marina da Gama canal Baalen Way (old BM22), surface	99	67	57
		ZA13S	Marina da Gama canal Park Island Bridge (old BM23), surface	116	69	57
		ZAWEIR	Zandvlei outlet channel at Rubble Weir, surface	105	73	57
Silvermine	River dataset	SIL02	Silvermine River near Sunbird Environmental Centre	60	23	24
		SIL04	Silvermine River a wooden bridge near Winkle Rd - Clovelly	38	14	16
		SIL06	Silvermine River at Bridge on Main Rd, Clovelly	73	23	22
		SRE	Silvermine River East Stormwater		9	23
		SRW	Silvermine River West Stormwater		9	23

Sub-catchment	Type	Site	Description of sample point location	Reporting period		
				2019 to 2021	2022	2023
SLPass	River dataset	SIR01	Sir Lowrys Pass River at Wedderwill Farm	64	23	26
		SIR02	Sir Lowrys Pass River d/s N2	64	23	26
		SIR03	Sir Lowrys Pass River at Gustrouw Rd	57	21	42
		SIR04	Sir Lowrys Pass River (original river channel) at Dolphin Rd	26	5	16
		SIR05	Sir Lowrys Pass River (original river channel) Hendon Park	68	21	24
		SIR06	Sir Lowrys Pass River d/s of WWTW (diversion canal)	217	74	73
		SIR07	Sir Lowrys Pass River at Hibiscus Rd (diversion canal)	72	21	24
Soet	River dataset	SOE02	Soet River u/s of Greenways Rd	71	21	24
Sout	River dataset	SOU01	Sout River at R27	213	65	74
		SOU02	Sout River at Otto du Plessis Drive	72	22	23
SPen	River dataset	BOK02	Bokramspruit River upstream of Slangkop Road	66	23	24
		BOK03	Bokramspruit River a short distance d/s of Flamingo Rd	64	23	21
		FHC	Fish Hoek culvert stormwater		8	13
		FHLH	Fish Hoek Lighthouse Stormwater		7	4
		SCH02	Schusters River at Schusterskraal Reserve entrance	50	23	20
		SCH04	Pound canal (stormwater)	34	12	16
	Standing water	GC02	Glencairn vlei centre - at concrete berm	107	34	33
Zeekoe	River dataset	LR02	Lotus River on (N2) 500m from Airport Approach Rd	64	25	24
		LR03	Lotus River at corner Duinefontein and Lansdowne Roads	64	26	24
		LR05	Lotus River at entrance to Council Depot on Old Strandfonte*	64	26	24
		LR06	Woodlands Canal at New Ottery Road (near Ottery Hypermarket)	58	22	24
		LR07	Lotus River at Klip Road	63	25	24
		LR08	Lotus River at Fisherman's Walk bridge (just u/s of vlei bo*	79	26	25
		LR10	Little Lotus River at Eighth Avenue	72	24	24

Sub-catchment	Type	Site	Description of sample point location	Reporting period		
				2019 to 2021	2022	2023
		LR19A	Lotus River Channel at Buck Road		1	
		LR19B	Lotus River DS of PS and DS of Buck Rd Channel		1	
		LR20A	Lotus River LHS pipe below bridge		1	
		LR20B	Lotus River RHS pipe below bridge		1	
		POC01	Phillipi stormwater outlet upstream site	70	21	22
		RVIRD	Italian Rd canal leading to Rondevlei	62	24	19
		ZEV08	Zeekeovlei canal mouth at Baden Powell drive		9	42
	Standing water	RVWEIR	Rondevlei at weir	69	28	33
		ZEV1S	Zeekoevlei Home Bay in front of Zeekoevlei Yacht Club	117	69	55
		ZEV2S	Opposite inlet of Big Lotus River	49	62	43
		ZEV3S	Zeekoevlei in front of Cape Peninsula Aquatic Club	127	73	60
		ZEV4S	SW corner pprox. 200m from weir	36	45	15
		ZEV9S	Zeekoevlei Eastern shore near stormwater outlet from picnic area at traffic circle		60	62
		ZEWEIR	Zeekoevlei near weir	23	65	68

APPENDIX B: THRESHOLD VALUES USED IN DATA INTERPRETATION

B1 Thresholds for the interpretation of ecosystem condition

The City of Cape Town is included in the Berg Catchment and many of its watercourses have been assigned specific Resource Quality Objectives (RQOs) through the Berg Classification (see **Section 3.5**). It is thus important that the rating ranges and rating terminology used in assessments of the CCT water quality data should align with those of the Berg RQOs, and be readily referenceable to these gazetted requirements. This approach also ensures that any ecological categorisation of water quality for the CCT aligns to the categories of water quality condition employed at a 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 estuaries and 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[20]Ideal 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 B1.** In the previous CCT inland water quality report (Day et al. 2020), a simpler approach, with fewer but still comparable categories was utilised, for ease of interpretation by a wide range of users. The rating scale included in **Table B1** was thus adopted, with its ratings of Good, Fair, Poor and Unacceptable, with the desired threshold (break point) being "Fair".

Table B1
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 and their simplified interpretation, compared with the Ideal to Unacceptable categories used in DWAF (2021) 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 – this report			
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	POOR	**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%	

[20] **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 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)

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 B2** and **B3**.

In the previous (2020 and the 2023) CCT Water Quality Reports, orthophosphate concentrations were used as a measure of both flowing and standing water phosphorus enrichment. In the present report, total phosphorus concentrations are, instead, used to evaluate standing water phosphorus enrichment (**Table B3**), based on the threshold values provided by DWAF (2002) and reiterated in the DWAF (2011) guidelines for lakes and dams. The 2020 RQOs for dams in the Berg catchment erroneously use the same orthophosphate phosphorus thresholds for dams and rivers, whereas the use of total phosphorus concentrations is a more useful measure for standing water systems such as vleis, lakes and dams (Cooke et al 2005).

Table B2
Rating ranges for variables considered in this assessment of water quality in City Rivers

City Water Quality Categories (CWQC)	Interpretation of CWQC	[21]PO4-P mg P/l	[16]TIN mg N/l	[16]DO mg/l	[22]N:P	[17]NH_3 mg/l
GOOD	TARGET	≤ 0.015 (oligotrophic)	≤ 0.70 (oligotrophic - mesotrophic)	>7	>25	≤ 0.007
FAIR		> 0.015 - 0.025 (mesotrophic)	>0.70-1.00 (mesotrophic)	>6-7		> 0.007 -0.015
POOR	POOR	> 0.025- 0.125 (eutrophic)	>1.00 -4.00 (mesotrophic -eutrophic)	>4 -6	10-25	> 0.015-0.1 (chronic toxicity)
UNACCEPTABLE	UNACCEPTABLE	> 0.125 (hypertrophic)	> 4.00 (eutrophic - concentrations > 10mg/L classified as hypertrophic)	≤ 4	< 10	> 0.1 (acute toxicity)

Table B3
Rating ranges for variables considered in this assessment of water quality in City Vleis and Dams

City Water Quality Categories (CWQC)	Interpretation of CWQC	[23]TOTAL PHOSPHORUS mg P/l	[24]TIN mg N/l	[19]DO mg/l	[25]N:P	[20]NH_3 mg/l	RUNNING MEAN ANNUAL CHL-A µg/l
GOOD	TARGET	≤ 0.015 (oligotrophic)	≤ 0.7	> 7	>25	≤ 0.007	≤ 5
							>5 - 10
FAIR		> 0.015 – 0.047 (mesotrophic)	>0.7 -1	>6-7		> 0.007 -0.015	>10 -20
POOR	POOR	>0.047 - 0.130 (eutrophic)	>1.0-4.0	>4 -6	10-25	> 0.015-0.1 (chronic toxicity)	> 20 - 30
UNACCEPTABLE	UNACCEPTABLE	>0.130 (hypertrophic)	> 4	≤ 4	<10	> 0.1 (acute toxicity)	> 30

[21] Based on DWAF (2008)
[22] Based on DWAF (1996a) guideline
[23] Based on DWAF (2002)
[24] Based on DWAF (2008)
[25] Based on DWAF (1996a) guideline

B2 Thresholds for the interpretation of water quality risks to recreational users

B2.1 General

Human health risk ratings for *Escherichia coli* data were also based on those used in the Berg RQOs study. Day et al. 2020 used an expanded version of these thresholds, to identify examples of extreme exceedance of these thresholds (as developed by the CCT in routine reporting), as shown in **Table B4**, while Microcystin toxin thresholds were based on those included in the CCT's Recreational Use Water Quality Index. These are slightly more conservative than those used in WHO (2021).

The ratings include both full contact (i.e., swimming) and intermediate contact (e.g. canoeing, sailing) for *E. coli.*

Note however that, given issues around reporting of ">" data over the 2020 reporting period, in the present report, the expanded range of values was not utilised. It has been included in this appendix for future possible application.

B2.2 Microbial indicators

The most frequent adverse health outcome associated with exposure to water contaminated with faecal material is enteric illness (WHO 2021).

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; 2021; Australian Government National Health and Medical Research Council 2008).

While there are guidelines for the interpretation of *E. coli* in waters used for full contact recreation (e.g. EU guidelines), 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 CCT's historical inland water quality database includes both faecal coliform and *E. coli* data.

However, all current water microbial assessments include only *E. coli* data[26]. 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 CCT 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 B4**. 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.

Table B4
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	>2 500-4000 CFU/100 ML
UNACCEPTABLE	>4000 CFU/100 ML

Table B5
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 CCT's E. coli specific target for full contact recreation, as per DWAF (1996b). The 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 [27]CFU/100 ML \
ACCEPTABLE RISK INTERMEDIATE CONTACT	≤ 2 500 CFU/100 ML
TOLERABLE RISK - INTERMEDIATE CONTACT	> 2 500-4000 CFU/100 ML
UNACCEPTABLE RISK - INTERMEDIATE CONTACT	>4000 CFU/100 ML

"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 • Address using stormwater / catchment management measures. • Ensure sewer spill responses are adequate and timely. • 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. • 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

[26] This was due to a change in 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 (see Day et al. 2020).
[27] 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
		factors. • Transversal approach to pollution abatement is necessary. • 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.* • Urgent management intervention to address the source/s of contamination. • Transversal approach to pollution abatement is necessary. • Significant funding likely to be required

Enterococci data were interpreted using the same thresholds used by the CCT for its coastal enterococci evaluations, which are drawn from the national guidelines of DEA (2012) WHO (2021) confirm that the same thresholds can be applied to both marine and inland (fresh) waters.

Guidelines for the interpretation of single sample data have been used in this report for compliance type reporting. These guidelines are provided in DEA (2012) as well. The latter report does note however that single sample interpretation is not ideal, as it does not allow reasonable determination of Risk for water users. However, in the present reporting context, it does allow evaluation of suitability of water for intermediate contact use over a number of sampling periods.

One of the issues also highlighted in this report was that of repeated sampling of sites where sewage spills have taken place or are suspected. This results in multiple potentially highly contaminated water samples, the data from which can skew Hazen assessments of long-term data, by increasing the 90th and 95th percentiles considerably. Such issues need to be considered carefully in the interpretation of long-term data with high potential event-driven variability.

Table B6
Approach to assessment of microbial data (intestinal enterococci counts)
Percentile data calculated using the Hazen Method
Water quality categories as used in the CCT's Coastal Water Quality Reporting[28]
Single sample ratings from DEA (2012)
See **Appendix B** for derivation of threshold values.

Interpretation	**Descriptor in Coastal Water Quality Reporting**	**Estimated risk of illness per exposure[2]**	**Enterococci (cfu/100 ml)**	**Enterococci (cfu/100 ml) - for single samples**
TARGET	EXCELLENT	< .9% Gastrointestinal Illness (GI) risk	< 100 (95th percentile)	
ACCEPTABLE RISK INTERMEDIATE CONTACT	GOOD	<5% Gastrointestinal Illness (GI) risk	< 200 (95th percentile)	≤240
TOLERABLE RISK - INTERMEDIATE CONTACT	SUFFICIENT	<8.5% Gastrointestinal Illness (GI) risk	< 185 (90th percentile)	240 – 380
UNACCEPTABLE RISK - INTERMEDIATE CONTACT– LEVEL 1	POOR	>8.5% Gastrointestinal Illness (GI) risk	≥ 185 (90th percentile)	>380

[2] 'Exposure' defined as 10 minutes of swimming with three head immersions

[28] (https://www.capetown.gov.za/explore%20and%20enjoy/nature-and-outdoors/our-precious-biodiversity/coastal-water-quality)

B2.3 Microcystin toxins

Cyanobacteria (or blue-green algae) are a common and naturally occurring component of most recreational water environments (WHO 2021). 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 thresholds for interpretation shownin Table B6 are used by the CCT, and were developed for use in its Recreational Water Quality Index (Day and Clark 2012). These thresholds are based on the WHO (2003) guidelines for full and intermediate contact recreation. Note that WHO (2021) provides an updated GV Recreation ($GV_{RECREATION}$) Threshold of 24 ug/L for microcystins, below which recreational water use should be within acceptable risk limits. This suggests that the Medium Risk values in **Table B7** are slightly conservative

Table B7
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

APPENDIX C: SUMMARY VALUES FOR KEY VARIABLES

Table C.1
Summary data for key variables per sub-catchment for reporting periods 2022 and 2023 – for flowing water systems (rivers and stormwater channels).
Data presented as median values for all variables except *E. coli*, for which data are presented as geometric means.

SUB-CATCHMENT	VLEI NAME	2022 Reporting Year				2023 Reporting Year			
		PO4-P (mg P/L)	*E coli* (cfu/100 ml)	NH_3 (mg/.L)	TIN (mg N/.L)	PO4-P (mg P/L)	*E coli* ((cfu/100 ml)	NH_3 (mg/.L)	TIN (mg N /.L)
City			19,951.02				15,317.29		
Diep		2.282	22,664.34	0.029	8.089	1.450	15,225.78	0.020	4.864
	Milnerton Lagoon	3.989	19,638.63	0.240	13.777	2.834	27,338.64	0.269	21.765
Eerste		2.300	20,696.31	0.061	9.800	1.726	9,556.68	0.042	9.434
Elsieskraal		0.208	27,347.07	0.082	1.932	0.178	43,071.95	0.025	2.095
Hout Bay		0.032	9,855.75	0.001	0.223	0.050	5,104.37	0.001	0.472
Kuils		1.900	35,792.71	0.028	7.300	1.600	21,462.92	0.031	9.200
Lourens		0.019	376.53	0.001	0.400	0.041	435.79	0.001	0.374
Lower Salt		3.318	120,599.84	0.188	12.922	2.123	121,991.98	0.172	13.988
Mosselbank		1.305	28,252.23	0.040	5.472	1.200	5,704.37	0.017	3.500
MPlain		1.472	664,470.45	0.219	16.205	1.191	918,775.31	0.223	12.015
Sand		0.068	4,831.60	0.001	0.725	0.061	2,362.20	0.002	0.904
Silvermine		0.018	497.61	0.001	0.132	0.033	326.97	0.001	0.088
SLPass		0.120	974.53	0.001	1.062	0.100	1,384.68	0.001	0.800

SUB-CATCHMENT	VLEI NAME	2022 Reporting Year				2023 Reporting Year			
		PO4-P (mg P/L)	*E coli* (cfu/100 ml)	NH_3 (mg/.L)	TIN (mg N/.L)	PO4-P (mg P/L)	*E coli* ((cfu/100 ml)	NH_3 (mg/.L)	TIN (mg N /.L)
Soet		2.670	160,142.47	0.725	25.519	2.445	419,003.46	0.252	20.719
Sout		6.728	1,369.94	0.001	0.079	6.750	669.52	0.001	0.097
SPen		0.246	6,519.54	0.009	2.070	0.167	3,046.28	0.004	2.268
Zeekoe		0.558	69,230.98	0.107	6.479	0.591	39,732.71	0.072	5.217

Table C.2
Summary data for key variables per subcatchment for reporting period 2020 and 2021 – for standing water systems (vleis and lakes/ dams). Data presented as median values for all variables except *E. coli*, for which data are presented as geometric means

SUB-CATCHMENT	VLEI NAME	2022 Reporting Year				2023 Reporting Year			
		PO4-P (mg P/L)	*E coli* (cfu/100 ml)	NH_3 (mg/.L)	TIN (mg N/.L)	PO4-P (mg P/L)	*E coli* ((cfu/100 ml)	NH_3 (mg/.L)	TIN (mg N /.L)
Diep	Rietvlei	0.140	104.33	0.005	0.073	0.057	18.56	0.008	0.160
	Zoarvlei	0.185	729.07	0.002	0.467	0.234	1,330.75	0.002	0.437
Elsieskraal	Elsieskraal dams	0.017	412.79	0.002	0.154	0.050	180.16	0.001	0.159
Kuils	Mew Way DP	1.898	803,252.35	0.170	16.517	1.151	1,071,087.98	0.124	12.064
MPlain	Mplain DP	1.446	701,003.45	0.187	15.020	0.998	968,489.58	0.177	11.529
Noordhoek	Wildevoelvle	5.031	1,441.15	0.822	40.036	4.327	233.00	0.615	26.595

SUB-CATCHMENT	VLEI NAME	2022 Reporting Year				2023 Reporting Year			
		PO4-P (mg P/L)	*E coli* (cfu/100 ml)	NH_3 (mg/.L)	TIN (mg N/.L)	PO4-P (mg P/L)	*E coli* ((cfu/100 ml)	NH_3 (mg/.L)	TIN (mg N /.L)
Sand	Die Oog	0.017	443.69	0.002	0.101	0.050	166.16	0.008	0.548
	Langevlei	0.046	437.76	0.005	0.444	0.134	213.66	0.028	1.110
	Little Princessvlei	0.012	669.12	0.001	0.207	0.050	424.45	0.002	0.446
	Princessvlei	0.011	4,633.14	0.003	0.111	0.017	483.17	0.002	0.113
	Westlake	0.097	2,093.07	0.011	0.371	0.055	263.43	0.005	0.392
	Zandvlei	0.044	436.30	0.003	0.111	0.050	241.60	0.005	0.147
SPen	Glencairn vlei	0.010	254.32	0.001	0.072	0.014	275.82	0.001	0.167
Zeekoe	Rondevlei	0.076	90.77	0.002	0.199	0.101	537.94	0.013	0.742
	Zeekoevlei	0.590	961.69	0.068	1.026	0.483	287.64	0.091	0.860

Table C.3
Median values for key variables per subcatchment for flowing water systems (river and stormwater channels) and standing water systems (vleis and lakes / dams) for each site. Data presented as median values for all variables except E. coli, for which data are presented as geometric means.

SUB-CATCHMENT	SITE	Type	Vlei name	2022-					2023-				
				Tot P (mg P/l)	PO4-P (mg P/l)	*E coli* (cfu/100 ml)	NH_3 (mg/l)	TIN (mg N/l)	Tot P (mg P/l)	PO4-P (mg P/l)	*E coli* (cfu/100 ml)	NH_3 (mg/l)	TIN (mg N/l)
CITY	CN06B	River dataset				10.00					3,827.43		
	CN16B	River dataset				11,830.98					28,378.40		
	CN17A	River dataset				22,062.13					26,813.86		
	CN17B	River dataset									21,399.60		
	CN17C	River dataset				89,390.44					60,264.97		
	CN17E	River dataset									36,634.70		
	CN24	River dataset									155.55		
	CN25	River dataset									5,802.77		
	CN26	River dataset				118,462.97					58,453.13		
	CN27	River dataset				1,969.14					2,780.80		
	CN28	River dataset									345.63		
DIEP	MAC	Standing water	Rietvlei	0.217	0.128	307.13	0.003	0.065	0.195	0.055	43.13	0.013	0.204
	MCC	River dataset	Milnerton lagoon			7,346.74			4.236	3.760	11,294.86		30.825

SUB-CATCHMENT	SITE	Type	Vlei name	2022-					2023-				
				Tot P (mg P/l)	PO4-P (mg P/l)	*E coli* (cfu/100 ml)	NH_3 (mg/l)	TIN (mg N/l)	Tot P (mg P/l)	PO4-P (mg P/l)	*E coli* (cfu/100 ml)	NH_3 (mg/l)	TIN (mg N/l)
	MOS05	River dataset			2.583	1,306.57	0.032	2.506	3.045	1.343	2,470.69	0.008	1.823
	PEV1	Standing water	Zoarvlei	0.448	0.121	2,629.38	0.009	0.794	0.580	0.220	4,021.11	0.006	0.935
	PEV2	Standing water	Zoarvlei	0.459	0.294	127.86	0.001	0.175	0.292	0.244	440.40	0.001	0.134
	RTV01	River dataset			3.452	2,897.46	0.007	11.100	3.834	2.201	1,153.74	0.006	7.100
	RTV02	Standing water	Rietvlei	0.224	0.167	169.18	0.005	0.073	0.181	0.061	22.82	0.015	0.216
	RTV03	River dataset			0.138	15,348.96	0.009	2.372	0.295	0.145	16,963.28	0.009	1.313
	RTV04	River dataset			0.059	59,656.22	0.017	1.386	0.126	0.074	35,717.46	0.039	1.840
	RTV05	River dataset			3.600	143,010.45	0.217	14.350	5.548	3.545	181,080.18	0.429	31.683
	RTV06	River dataset			2.430	2,093.31	0.007	0.791	2.547	1.386	632.56	0.005	1.217
	RTV08	River dataset			0.227	10,433.55	0.029	4.601	0.537	0.397	1,886.33	0.046	6.124
	RTV09	River dataset	Milnerton lagoon		4.209	28,255.01	0.289	13.777	5.029	3.184	33,772.25	0.260	23.285
	RTV10	River dataset	Milnerton lagoon		2.616	12,383.24	0.306	11.029	4.996	1.958	14,508.68	0.144	12.800
	RTV11	River dataset			4.300	93,724.50	0.200	15.150	6.153	3.600	114,599.65	0.492	32.400
	RTV12	River dataset			0.290	54,127.67	0.039	3.601	0.559	0.389	44,858.90	0.033	3.397
	RTV14	River dataset			0.066	28,631.56	0.020	1.419	0.347	0.082	11,961.98	0.011	1.393
	RTV17	Standing water	Rietvlei	0.204	0.147	52.90	0.006	0.073	0.184	0.061	12.52	0.008	0.196

SUB-CATCHMENT	SITE	Type	Vlei name	2022-					2023-				
				Tot P (mg P/l)	PO4-P (mg P/l)	*E coli* (cfu/100 ml)	NH_3 (mg/l)	TIN (mg N/l)	Tot P (mg P/l)	PO4-P (mg P/l)	*E coli* (cfu/100 ml)	NH_3 (mg/l)	TIN (mg N/l)
	RTV18	River dataset	Milnerton lagoon		3.911	67,212.69	0.217	14.495	4.786	3.342	77,707.59	0.413	30.432
	RTV19	Standing water	Rietvlei	0.219	0.141	55.54	0.005	0.111	0.178	0.064	39.65	0.011	0.160
	RTV22	River dataset								1.225	2,611.85	0.001	1.505
	RTVBUOY1	Standing water	Rietvlei	0.216	0.136	75.10	0.007	0.100	0.183	0.066	11.86	0.006	0.138
	RTVBUOY2	Standing water	Rietvlei	0.205	0.140	70.03	0.007	0.154	0.178	0.054	15.60	0.007	0.109
	RTVBUOY4	Standing water	Rietvlei	0.208	0.138	66.41	0.005	0.067	0.169	0.062	15.19	0.007	0.137
	RTVBUOY6	Standing water	Rietvlei	0.212	0.137	76.08	0.004	0.053	0.176	0.050	6.84	0.006	0.105
	THEO_ MARAIS_DS	River dataset			1.325	49,149.45	0.140	11.346	5.241	2.824	124,689.65	0.315	26.130
EERSTE	EK08	River dataset			2.300	28,311.81	0.076	7.675	3.350	2.181	6,416.43	0.066	8.900
	EK11	River dataset			2.293	35,633.37	0.121	11.150	3.685	2.000	10,037.74	0.176	12.900
	EK12	River dataset			2.300	20,621.26	0.130	9.750	3.015	1.400	3,846.65	0.088	9.700
	EK13	River dataset			1.540	2,531.41	0.005	2.220	1.692	0.220	2,082.82	0.004	2.593
	EK15	River dataset			0.174	191,625.05	0.096	2.926	0.185	0.150	162,812.29	0.046	2.764
	EK17	River dataset			3.100	23,486.10	0.613	21.650	2.560	2.100	27,513.96	0.431	17.601
	EK18	River dataset			0.138	5,640.78	0.004	0.807	0.159	0.143	2,818.63	0.006	0.794
ELSIESKRAAL	ANG01	Standing water	Elsieskraal dams	0.051	0.005	100.21	0.002	0.085	0.051	0.047	82.39	0.001	0.108

SUB-CATCHMENT	SITE	Type	Vlei name	2022-					2023-				
				Tot P (mg P/l)	PO4-P (mg P/l)	*E coli* (cfu/100 ml)	NH_3 (mg/l)	TIN (mg N/l)	Tot P (mg P/l)	PO4-P (mg P/l)	*E coli* (cfu/100 ml)	NH_3 (mg/l)	TIN (mg N/l)
	ANG02	Standing water	Elsieskraal dams	0.051	0.005	333.57	0.001	0.073	0.051	0.015	126.11	0.002	0.113
	DOOR01	Standing water	Elsieskraal dams	0.149	0.102	6,711.98	0.005	1.363	0.160	0.133	951.36	0.010	2.125
	DOOR03	Standing water	Elsieskraal dams	0.051	0.017	164.32	0.001	0.128	0.051	0.008	106.59	0.001	0.121
	ELS_GW	River dataset			0.283	164,525.69	0.214	3.082	0.647	0.323	158,795.10	0.064	3.971
	ELS08	River dataset			0.251	87,616.88	0.155	2.503	0.122	0.221	81,130.61	0.029	2.184
	ELS10	River dataset			0.049	980.13	0.003	0.255	0.196	0.070	6,202.43	0.002	0.847
HOUT BAY	DR01	River dataset			0.179	32,634.19	0.004	0.938	0.224	0.124	73,580.11	0.003	1.261
	DR02	River dataset			0.127	109,345.71	0.004	1.206	0.294	0.156	64,133.11	0.003	1.416
	DR04	River dataset			0.019	370.90	0.001	0.072	0.051	0.034	124.71	0.001	0.083
	DR05	River dataset				45,565.32				0.094	31,432.72	0.002	0.641
	DR06	River dataset			0.018	1,241.03	0.001	0.134	0.051	0.028	318.41	0.001	0.087
	HB11	River dataset				9,800.00					729.73		
KUILS	EK03	River dataset			2.665	5,418.23	0.021	8.579	2.956	2.800	583.46	0.009	10.477
	EK04	River dataset			1.200	16,583.46	0.004	5.100	1.160	1.150	3,685.69	0.009	4.500
	EK05	River dataset			2.146	355,943.54	0.070	7.972	3.499	2.142	578,266.28	0.184	9.432
	EK09	River dataset			2.500	201,573.07	0.096	11.100	2.876	1.700	319,304.35	0.215	13.750

SUB-CATCHMENT	SITE	Type	Vlei name	2022-					2023-				
				Tot P (mg P/l)	PO4-P (mg P/l)	*E coli* (cfu/100 ml)	NH_3 (mg/l)	TIN (mg N/l)	Tot P (mg P/l)	PO4-P (mg P/l)	*E coli* (cfu/100 ml)	NH_3 (mg/l)	TIN (mg N/l)
	EK19	River dataset			0.216	10,662.68	0.001	1.132	0.276	0.171	3,780.83	0.008	2.117
	EK20	River dataset			2.500			12.600		2.200	28,804.13		23.700
	KHA01	Standing water	Mew way dp	2.225	1.898	803,252.35	0.170	16.517	2.055	1.151	1,071,087.98	0.124	12.064
LOURENS	LOU01	River dataset			0.018	335.32	0.001	0.582	0.051	0.030	193.72	0.001	0.524
	LOU02	River dataset			0.020	146.29	0.001	0.482	0.051	0.032	211.41	0.001	0.454
	LOU03	River dataset			0.017	764.01	0.001	0.432	0.051	0.025	609.32	0.001	0.424
	LOU04	River dataset			0.017	1,494.32	0.001	0.338	0.051	0.034	1,678.13	0.001	0.356
	LOU05	River dataset			0.035	1,702.71	0.001	0.477	0.199	0.058	2,663.54	0.001	0.381
	LOU06	River dataset			0.022	33.36	0.001	0.064	0.051	0.043	60.71	0.001	0.061
	LOU08	River dataset			0.018	857.88	0.001	0.423	0.051	0.028	792.65	0.001	0.449
	LOU13	River dataset			0.053	25.15	0.001	0.126	0.197	0.069	252.00	0.001	0.204
LOWER SALT	NR01	River dataset			0.315	212,153.61	0.019	2.324	0.830	0.265	293,614.40	0.020	4.462
	NR02	River dataset			0.812	89,667.97	0.129	8.970	1.502	1.026	82,564.16	0.126	9.243
	NR03	River dataset			3.930	340,113.75	0.196	11.440	3.995	1.888	225,395.91	0.241	10.546
	NR04	River dataset			3.665	314,637.45	0.329	26.240	5.442	2.131	482,762.61	0.335	24.115
	NR06	River dataset			3.749	208,714.23	0.353	24.562	3.696	1.694	381,442.71	0.266	19.454

SUB-CATCHMENT	SITE	Type	Vlei name	2022-					2023-				
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	NR07	River dataset			3.894	327,483.78	0.365	25.694	4.407	4.296	353,857.70	0.337	26.045
	NR08	River dataset			0.042	10,943.72	0.005	0.627	0.121	0.046	6,557.41	0.003	0.783
	NR09	River dataset			3.552	306,913.13	0.310	22.630	4.360	3.466	248,673.55	0.289	23.125
	NR10	River dataset			3.465	225,274.17	0.375	21.898	3.763	3.621	135,622.54	0.340	24.375
	NR11	River dataset			0.322	30,943.01	0.059	3.185	0.581	0.119	11,575.39	0.064	1.486
	NR15	River dataset			5.000	237,663.29	0.149	12.900	6.852	3.150	507,771.17	0.246	16.200
	NR16	River dataset			0.714	284,030.75	0.120	5.485	2.957	1.395	331,100.53	0.210	10.758
	NR17	River dataset			1.100	200,383.97	0.336	11.334	1.475	0.895	379,432.38	0.249	9.499
	NR22	River dataset			0.030	1,494.69	0.004	0.483		0.050	2,248.52	0.001	0.120
	NR24	River dataset			0.110	18,161.10	0.002	1.559			9,206.04		
	NR25	River dataset			3.655	278,257.86	0.205	17.043	4.465	3.020	545,021.94	0.435	28.257
	NR26	River dataset			5.910	389,754.22	0.080	13.050	9.340	3.450	159,326.73	0.148	15.350
MOSSELBANK	MOS01	River dataset			0.600	65,920.19	0.092	6.000	0.633	0.400	18,926.96	0.029	3.750
	MOS02	River dataset			0.747	119,674.01	0.025	5.100	1.347	0.800	28,920.12	0.024	3.575
	MOS03	River dataset			0.559	21,308.07	0.042	5.444	2.780	1.084	1,635.11	0.022	3.351
	MOS04	River dataset			1.734	7,824.48	0.019	1.469	5.717	2.160	2,345.82	0.007	2.521

SUB-CATCHMENT	SITE	Type	Vlei name	2022-					2023-				
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	MOS06	River dataset			2.979	22,889.31	0.024	3.405	5.825	2.274	13,808.35	0.012	3.424
	MOS07	River dataset			3.700	3,619.91	0.013	6.200	6.874	2.000	1,767.08	0.010	3.500
	MOS08	River dataset			3.100	6,810.93	0.004	4.600	5.248	2.300	1,404.81	0.007	3.200
	MOS09	River dataset			20.229	43,945.25	0.389	25.621	39.614	8.863	51,311.51	0.185	23.999
MPLAIN	CS23	Standing water				72,167.13					79,727.90		
	CS24	Standing water				100,000.00							
	KHA02	Standing water	Mplain dp	1.440	1.070	749,898.91	0.176	11.509	1.480	0.958	1,062,515.33	0.157	11.419
	KHA03	Standing water	Mplain dp	2.003	1.487	655,296.11	0.187	15.713	2.188	1.175	882,784.51	0.217	12.021
	KHA04	River dataset			1.472	664,470.45	0.219	16.205	2.241	1.191	918,775.31	0.223	12.015
NOORDHOEK	WV02	Standing water	Wildevoelvlei	7.296	5.031	1,215.15	0.930	39.913	8.051	4.197	206.80	0.701	26.290
	WV05	Standing water	Wildevoelvlei	7.255	5.802	1,398.54	0.821	40.036	7.750	4.554	175.91	0.567	26.982
	WV08	Standing water	Wildevoelvlei			1,761.25					347.70		
SAND	CR01	River dataset			0.084	11,557.56	0.001	0.662	0.274	0.057	2,341.11	0.002	1.402
	CR02	River dataset			0.057	2,463.23	0.001	0.662	0.051	0.044	1,076.95	0.001	1.191
	CR03	River dataset			0.060	1,821.97	0.002	3.254	0.051	0.050	1,192.60	0.001	2.263
	CR04	River dataset			0.068	18,982.72	0.004	1.128		0.050	2,125.06	0.002	0.820

SUB-CATCHMENT	SITE	Type	Vlei name	2022-					2023-				
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	CR05	River dataset			0.047	1,039.39	0.001	0.226	0.201	0.050	175.37	0.001	0.193
	CR06	River dataset			0.267	2,033.77	0.001	0.406	0.313	0.117	1,942.58	0.001	0.506
	CR16	River dataset			0.044	2,211.86	0.001	0.427	0.168	0.050	2,105.04	0.001	0.542
	CR20	River dataset			0.130	16,290.43	0.001	0.686	0.214	0.117	1,130.15	0.001	0.540
	CR21	River dataset			0.061	53,761.64	0.007	1.931	0.270	0.050	31,052.32	0.007	1.253
	CR22	River dataset			0.109	7,317.16	0.010	0.545	0.368	0.065	3,620.56	0.002	0.672
	CR29	River dataset	0		0.043	32,122.99	0.005	1.650	0.223	0.050	20,682.97	0.006	1.351
	CS01B	River dataset	0			25,577.57					1,597.84		
	CS22	River dataset	0			773.60					1,065.06		
	CS26	River dataset	0			378.75					654.75		
	DRRSC	River dataset	0		0.054	87,553.79	0.010	1.165	0.352	0.101	59,064.56	0.056	1.965
	LPVMR	River dataset	0		0.015	259.47	0.001	0.106	0.235	0.050	576.26	0.001	0.155
	LPVN	Standing water	Little princessvlei	0.051	0.005	305.46	0.001	0.106	0.051	0.050	138.09	0.001	0.156
	LPVS	Standing water	Little princessvlei	0.102	0.016	1,465.71	0.001	0.633	0.170	0.050	1,185.73	0.003	0.812
	LVI	River dataset	0		0.075	1,247.65	0.004	0.496	0.356	0.182	1,474.53	0.006	0.884
	LVO	Standing water	Langevlei	0.184	0.046	437.76	0.005	0.444	0.345	0.134	213.66	0.028	1.110

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	OOG01	Standing water	Die oog	0.051	0.017	443.69	0.002	0.101	0.051	0.050	166.16	0.008	0.548
	PV03	Standing water	Princessvlei	0.196	0.015	4,555.52	0.003	0.109	0.149	0.016	495.24	0.002	0.184
	PVWEIR	Standing water	Princessvlei	0.194	0.005	4,722.05	0.004	0.112	0.163	0.019	471.39	0.001	0.098
	SCV	River dataset	0		0.115	85,579.13	0.008	4.538	0.177	0.083	18,982.62	0.003	4.649
	ZA01S	Standing water	Zandvlei	0.159	0.046	699.46	0.006	0.170	0.134	0.046	341.73	0.004	0.248
	ZA02S	Standing water	Zandvlei	0.157	0.052	656.51	0.008	0.214	0.111	0.050	189.89	0.005	0.118
	ZA03S	Standing water	Zandvlei	0.051	0.032	20,976.28	0.025	0.225			579.00		
	ZA04S	Standing water	Zandvlei	0.130	0.082	802.30	0.003	0.125	0.114	0.052	500.17	0.003	0.095
	ZA05S	Standing water	Zandvlei	0.149	0.102	512.45	0.003	0.117	0.125	0.070	383.09	0.003	0.172
	ZA06S	Standing water	Zandvlei	0.119	0.021	302.27	0.013	0.096	0.084	0.038	199.12	0.014	0.186
	ZA07S	Standing water	Zandvlei	0.130	0.022	653.64	0.007	0.093	0.133	0.037	224.63	0.014	0.271
	ZA08S	Standing water	Zandvlei	0.122	0.025	266.84	0.004	0.103	0.111	0.038	145.11	0.006	0.110
	ZA09S	Standing water	Zandvlei	0.138	0.019	257.12	0.003	0.052	0.051	0.029	152.44	0.006	0.105
	ZA10S	Standing water	Westlake	0.197	0.097	2,093.07	0.011	0.371	0.190	0.055	263.43	0.005	0.392
	ZA11S	Standing water	Zandvlei	0.133	0.028	208.87	0.003	0.105	0.120	0.033	114.78	0.006	0.113
	ZA12S	Standing water	Zandvlei	0.132	0.028	379.95	0.002	0.052	0.113	0.045	279.56	0.010	0.147

SUB-CATCHMENT	SITE	Type	Vlei name	2022-					2023-				
				Tot P (mg P/l)	PO4-P (mg P/l)	*E coli* (cfu/100 ml)	NH_3 (mg/l)	TIN (mg N/l)	Tot P (mg P/l)	PO4-P (mg P/l)	*E coli* (cfu/100 ml)	NH_3 (mg/l)	TIN (mg N/l)
	ZA13S	Standing water	Zandvlei	0.128	0.020	196.98	0.006	0.103	0.051	0.027	152.74	0.010	0.160
	ZAWEIR	Standing water	Zandvlei	0.160	0.111	587.63	0.003	0.122	0.143	0.074	590.88	0.004	0.164
SILVERMINE	SIL02	River dataset	0		0.027	109.81	0.001	0.145	0.051	0.028	28.49	0.001	0.091
	SIL04	River dataset	0		0.018	1,151.89	0.001	0.101	0.205	0.046	54.50	0.001	0.095
	SIL06	River dataset	0		0.012	473.96	0.001	0.079	0.051	0.029	108.79	0.001	0.084
	SRE	River dataset	0			714.90					642.68		
	SRW	River dataset	0			1,213.27					1,787.99		
SLPASS	SIR01	River dataset	0		0.033	185.58	0.001	0.254	0.051	0.047	182.20	0.001	0.194
	SIR02	River dataset	0		0.097	8,782.13	0.001	0.676	0.138	0.087	12,669.50	0.002	0.822
	SIR03	River dataset	0		0.079	6,490.01	0.001	0.983	0.141	0.100	2,122.91	0.001	0.942
	SIR04	River dataset	0		0.044	0.50	0.001	0.269	0.273	0.059	194.92	0.001	0.173
	SIR05	River dataset	0		0.080	1,193.44	0.001	0.289	0.184	0.073	3,969.97	0.001	0.342
	SIR06	River dataset	0		0.200	234.26	0.001	1.762	0.426	0.200	818.70	0.001	1.000
	SIR07	River dataset	0		0.155	1,469.32	0.008	1.250	0.369	0.171	1,668.56	0.004	0.910
SOET	SOE02	River dataset	0		2.670	160,142.47	0.725	25.519	3.437	2.445	419,003.46	0.252	20.719
SOUT	SOU02	River dataset	0		6.728	1,369.94	0.001	0.079	7.958	6.750	669.52	0.001	0.097

SUB-CATCHMENT	SITE	Type	Vlei name	2022-					2023-				
				Tot P (mg P/l)	PO4-P (mg P/l)	*E coli* (cfu/100 ml)	NH_3 (mg/l)	TIN (mg N/l)	Tot P (mg P/l)	PO4-P (mg P/l)	*E coli* (cfu/100 ml)	NH_3 (mg/l)	TIN (mg N/l)
SPEN	BOK02	River dataset	0		0.995	125,017.22	0.100	11.134	0.373	0.296	23,675.53	0.014	3.384
	BOK03	River dataset	0		0.139	25,177.92	0.021	5.988	0.152	0.167	7,031.51	0.020	3.228
	FHC	River dataset	0			8,166.17					5,242.28		
	FHLH	River dataset	0			2,770.24					9,486.36		
	GC02	Standing water	Glencairn vlei	0.051	0.010	254.32	0.001	0.072	0.051	0.014	275.82	0.001	0.167
	SCH02	River dataset	0		0.025	340.86	0.001	0.751	0.118	0.035	197.45	0.001	0.162
	SCH04	River dataset	0		0.265	1,095.54	0.002	1.788	0.396	0.263	354.41	0.001	2.064
ZEEKOE	LR02	River dataset	0		0.291	45,749.89	0.016	1.290	0.986	0.283	4,270.00	0.002	0.740
	LR03	River dataset	0		0.921	231,014.69	0.237	18.085	1.881	0.812	839,810.80	0.253	18.848
	LR05	River dataset	0		1.121	187,383.16	0.146	12.765	1.727	0.951	83,480.55	0.119	7.765
	LR06	River dataset	0		0.109	32,478.40	0.007	2.159	0.317	0.163	11,942.17	0.007	2.157
	LR07	River dataset	0		1.133	221,422.41	0.190	12.675	1.636	1.101	212,856.17	0.103	6.786
	LR08	River dataset	0		1.218	197,793.52	0.184	13.355	2.358	1.040	237,508.18	0.139	7.178
	LR10	River dataset	0		0.102	29,148.30	0.115	2.134	0.112	0.100	13,004.58	0.017	1.910
	LR19A	River dataset	0						10.052	8.439			83.615
	LR19B	River dataset	0						2.476	1.839			21.675
	LR20A	River dataset	0						6.963	5.558			66.365
	LR20B	River dataset	0						0.555	0.562			42.827

SUB-CATCHMENT	SITE	Type	Vlei name	2022-					2023-				
				Tot P (mg P/l)	PO4-P (mg P/l)	*E coli* (cfu/100 ml)	NH_3 (mg/l)	TIN (mg N/l)	Tot P (mg P/l)	PO4-P (mg P/l)	*E coli* (cfu/100 ml)	NH_3 (mg/l)	TIN (mg N/l)
	POC01	River dataset	0		0.231	9,870.37	0.024	5.607	0.375	0.260	7,712.76	0.023	5.180
	RVIRD	River dataset	0		0.067	18,137.08	0.009	1.973	0.225	0.050	2,957.66	0.003	1.840
	RVWEIR	Standing water	Rondevlei	0.249	0.076	90.77	0.002	0.199	0.134	0.101	537.94	0.013	0.742
	ZEV08	River dataset	0		3.302	134,239.87	0.258	27.453	7.504	4.543	85,421.82	0.338	25.570
	ZEV1S	Standing water	Zeekoevlei	1.090	0.546	654.37	0.093	1.640	1.035	0.441	169.59	0.050	0.562
	ZEV2S	Standing water	Zeekoevlei	1.157	0.634	6,132.08	0.096	3.204	1.597	0.772	12,920.30	0.112	5.834
	ZEV3S	Standing water	Zeekoevlei	1.139	0.634	683.83	0.112	1.742	1.104	0.591	129.11	0.115	2.356
	ZEV4S	Standing water	Zeekoevlei	0.974	0.462	389.76	0.015	0.115	1.025	0.340	33.72	0.094	0.552
	ZEV9S	Standing water	Zeekoevlei	0.996	0.597	1,127.86	0.063	0.705	0.974	0.478	186.31	0.098	1.521
	ZEWEIR	Standing water	Zeekoevlei	1.124	0.479	613.34	0.022	0.580	1.032	0.437	171.12	0.021	0.600

APPENDIX D: BOXPLOTS OF ANNUAL DATA FOR KEY VARIABLES

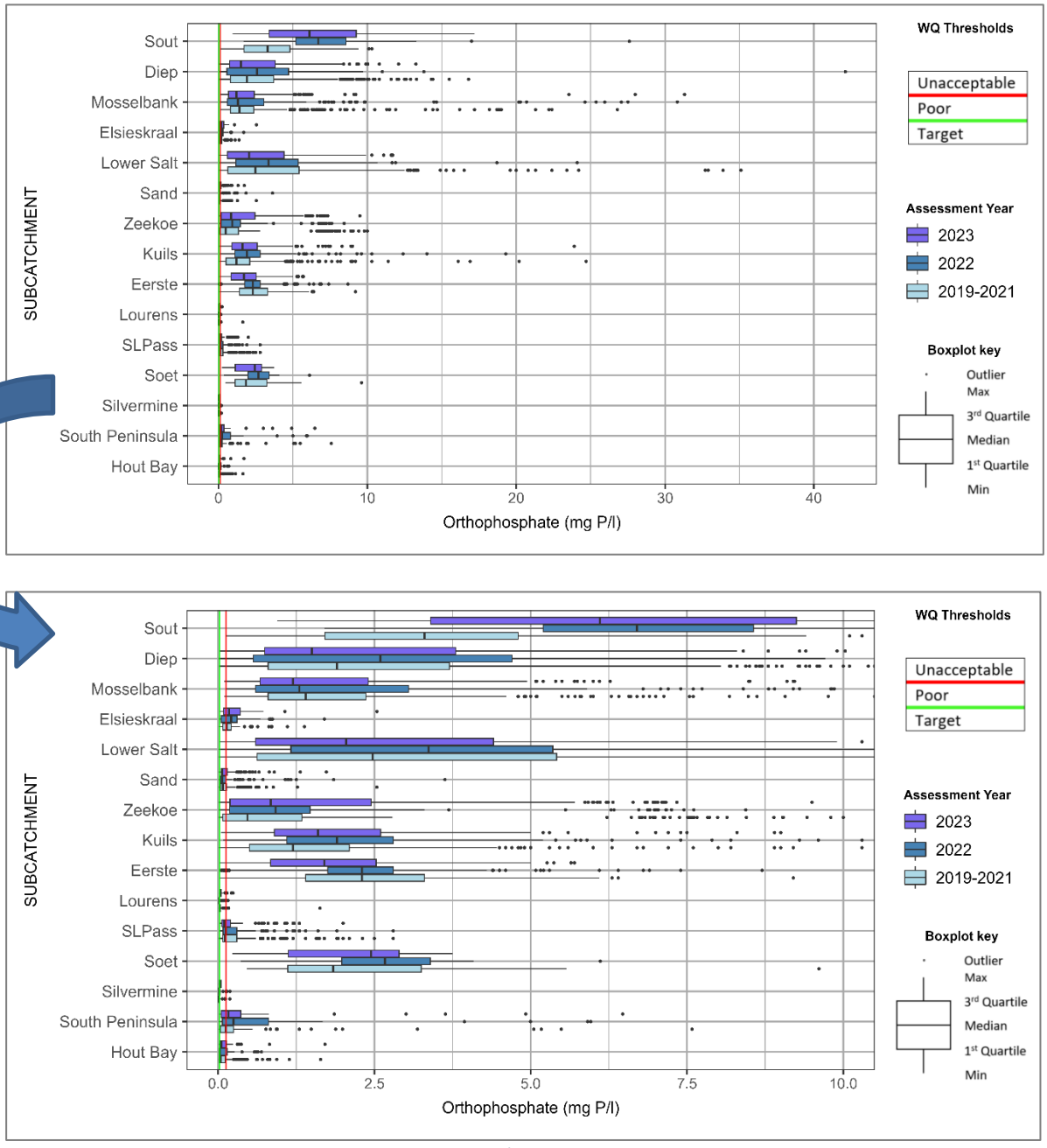


Figure D1.1
Comparison of phosphate (PO4-P) data for flowing water systems (rivers and stormwater channels) from the 2023 reporting period with those from 2022 and the previous three years (2019 to 2021) combined. Sub-catchments as shown in Figure 2.1. Marked thresholds as per Table 3.2. Closer view (reduced y-axis) shown in bottom figure (arrowed).

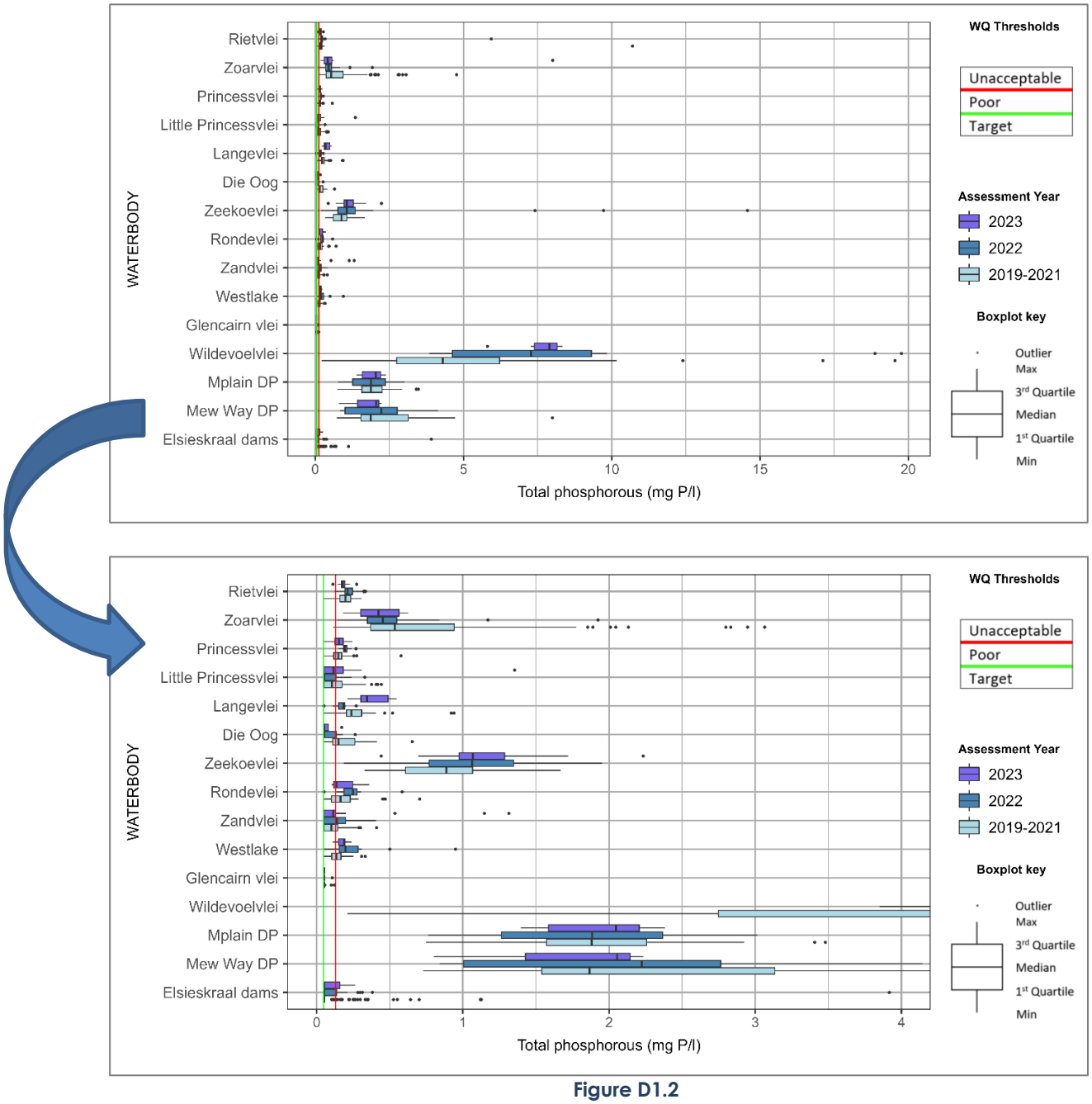


Figure D1.2
Comparison of total phosphorus (Tot-P) data for standing water systems (vleis, dams and detention ponds) from the 2023 reporting period with those from 2022 and the previous three years (2019 to 2021) combined. Marked thresholds as per Table 3.3. Closer view (reduced y-axis) shown in bottom figure (arrowed).

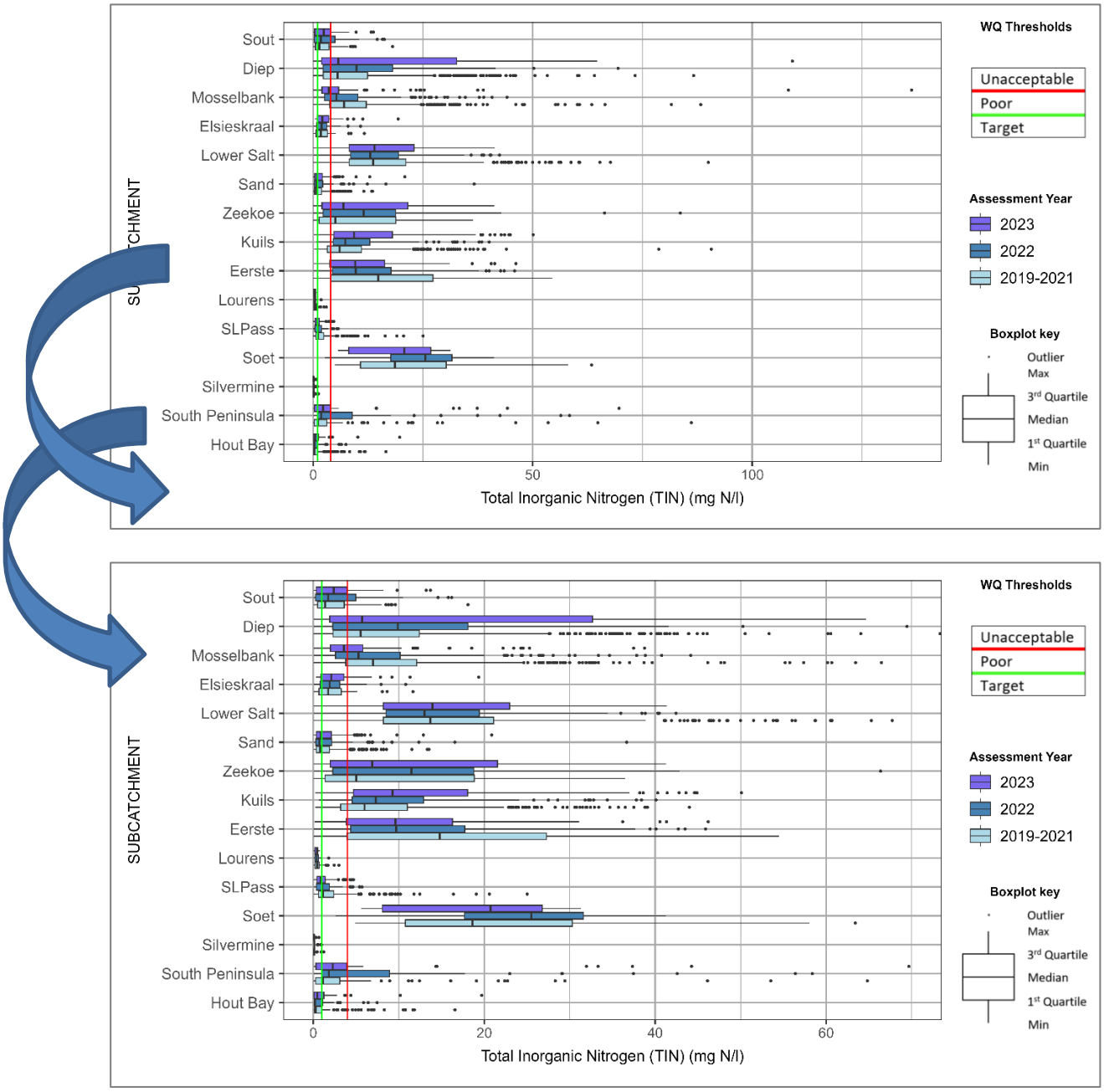


Figure D1.3
Comparison of Total Inorganic Nitrogen (TIN) data for flowing water systems (rivers and stormwater channels) from the 2023 reporting period with those from 2022 and the previous three years (2019 to 2021) combined. Sub-catchments as shown in Figure 2.1 Marked thresholds as per Table 3.2. Closer view (reduced y-axis) shown in bottom figure (arrowed)

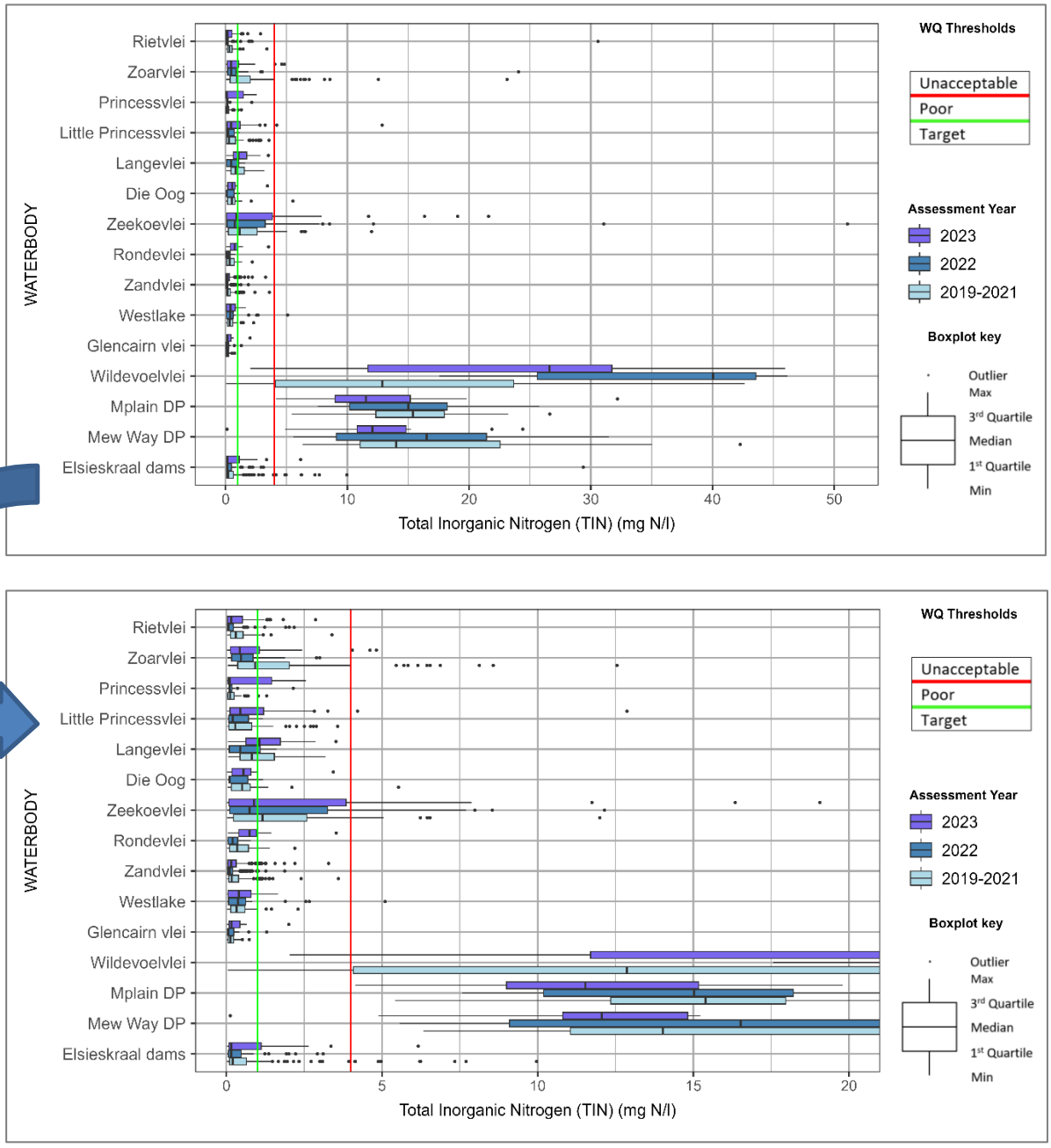


Figure D1.4
Comparison of Total Inorganic Nitrogen (TIN) data for standing water systems (vleis, dams and detention ponds) from the 2023 reporting period with those from 2022 and the previous three years (2019 to 2021) combined. Marked thresholds as per Table 3.3. Closer view (reduced y-axis) shown in bottom figure (arrowed)

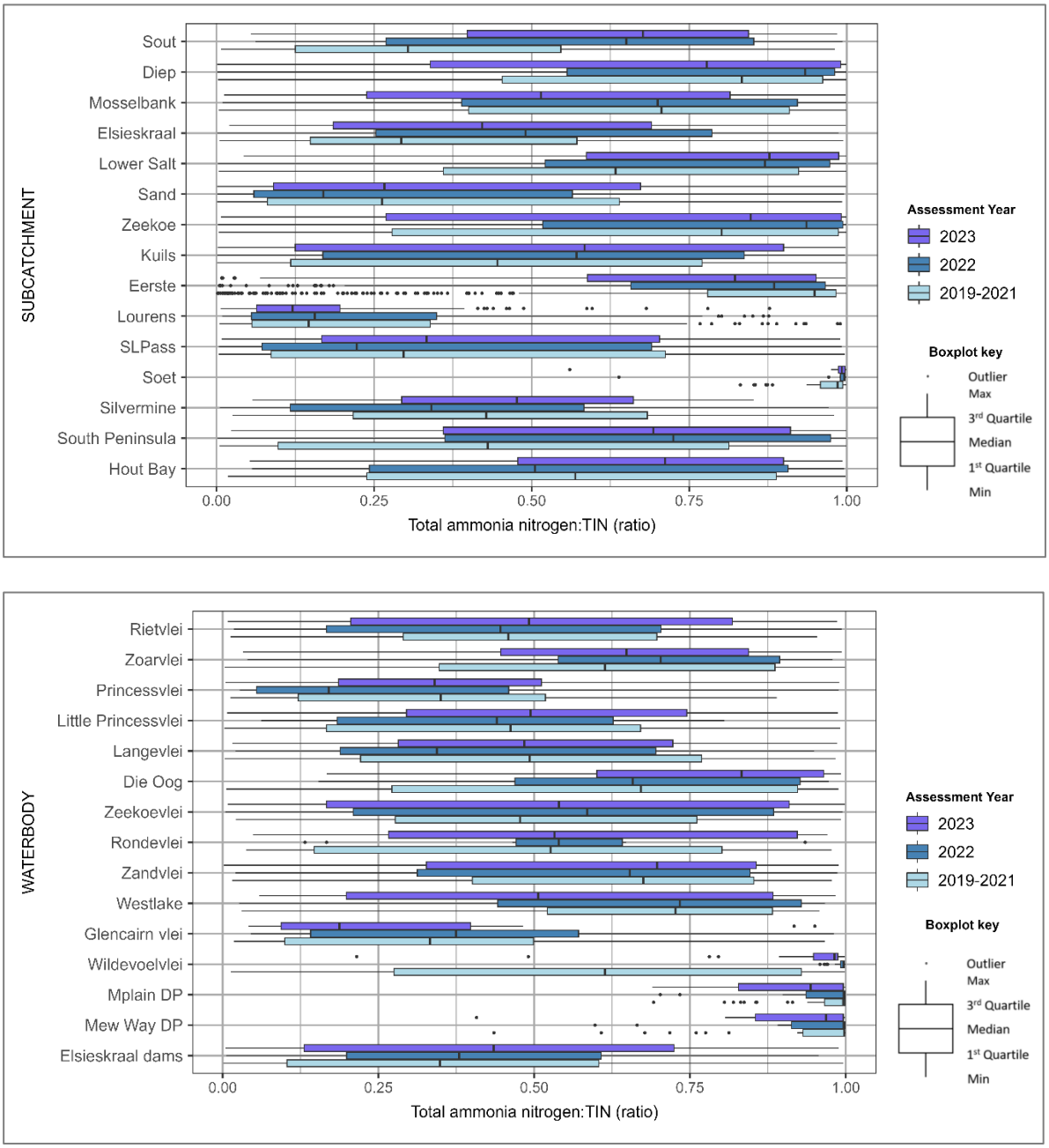


Figure D1.5
Comparison of ratios of total ammonia nitrogen (NH4-N) to Total Inorganic Nitrogen (TIN) for flowing systems (rivers and stormwater channels) (top) and standing water systems (vleis, dams and detention ponds) (bottom) from the 2023 reporting period with those from 2022 and the previous three years (2019 to 2021) combined. Sub-catchments as shown in Figure 2.1. Marked thresholds as per Table 3.2 and 3.3.

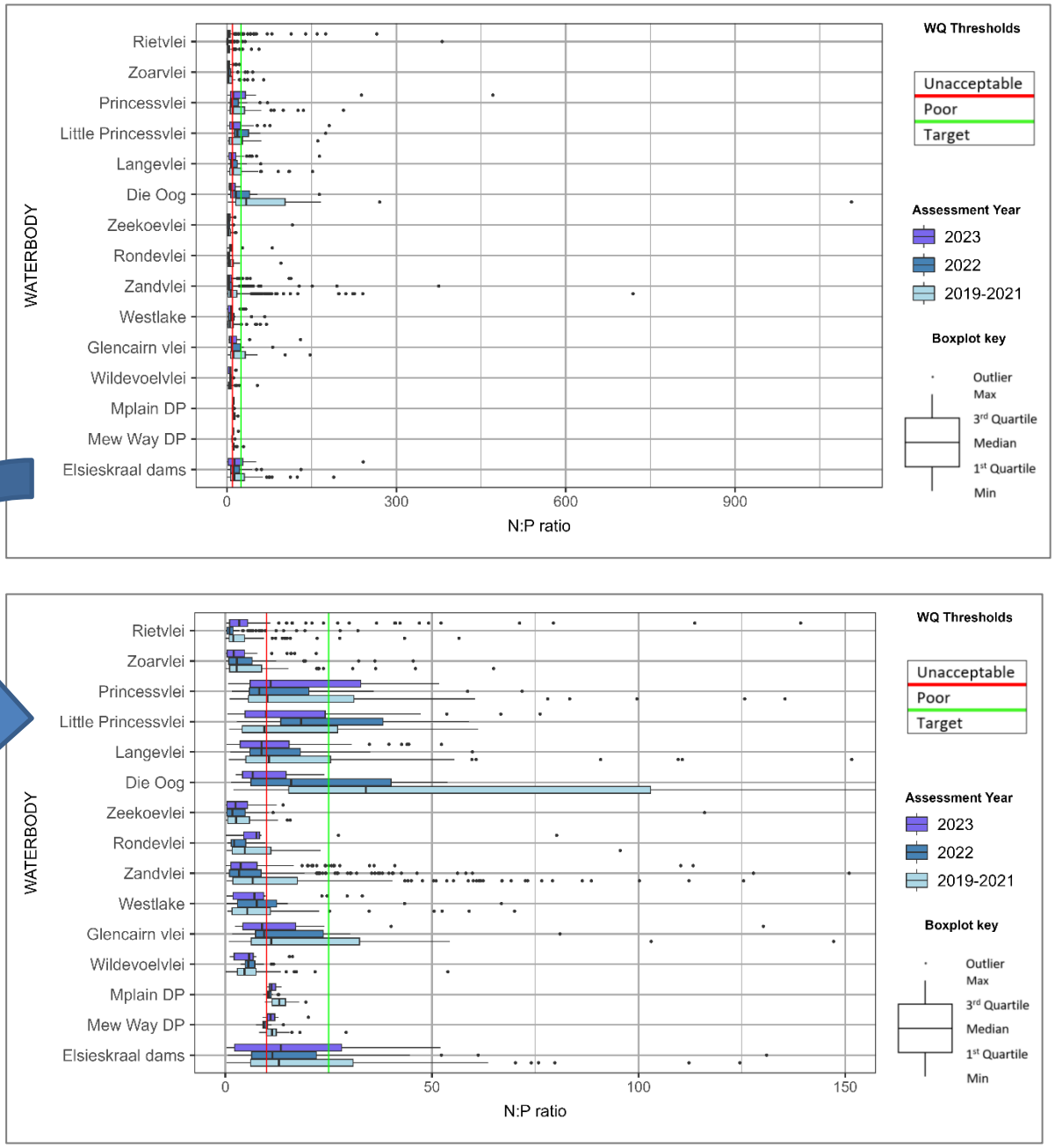


Figure D1.6
Comparison of ratios of Total Inorganic Nitrogen (TIN) to phosphate (PO4-P) for standing water systems (vleis, dams and detention ponds) from the 2023 reporting period with those from 2022 and the previous three years (2019 to 2021) combined. Marked thresholds as per Table 3.2. Closer view (reduced y-axis) shown in bottom figure (arrowed).

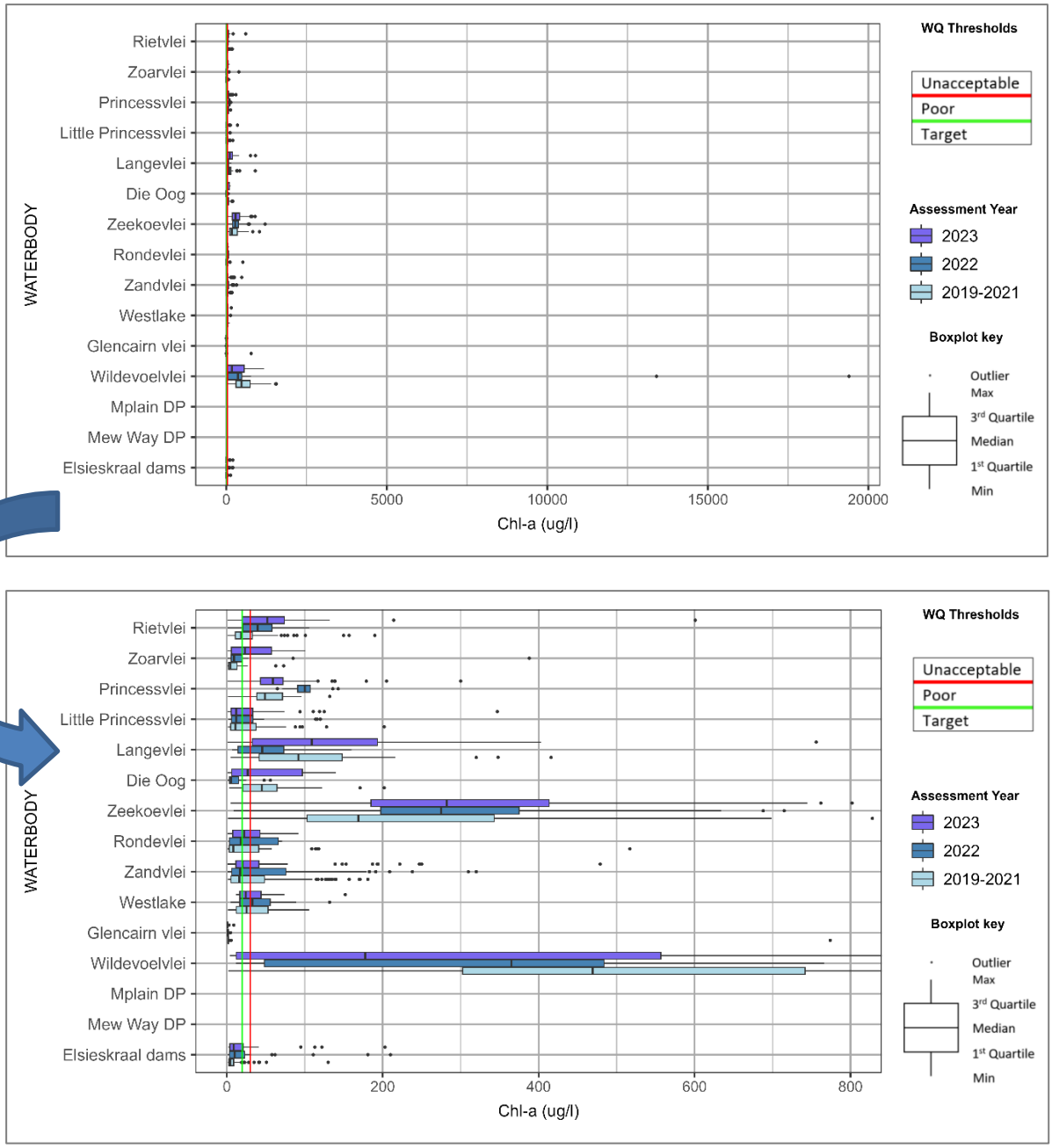


Figure D2.1
Comparison of chlorophyll-*a* data for standing water systems (vleis, dams and detention ponds) from the 2023 reporting period with those from 2022 and the previous three years (2019 to 2021) combined. Marked thresholds as per Table 3.2. Closer view (reduced y-axis) shown in bottom figure (arrowed).

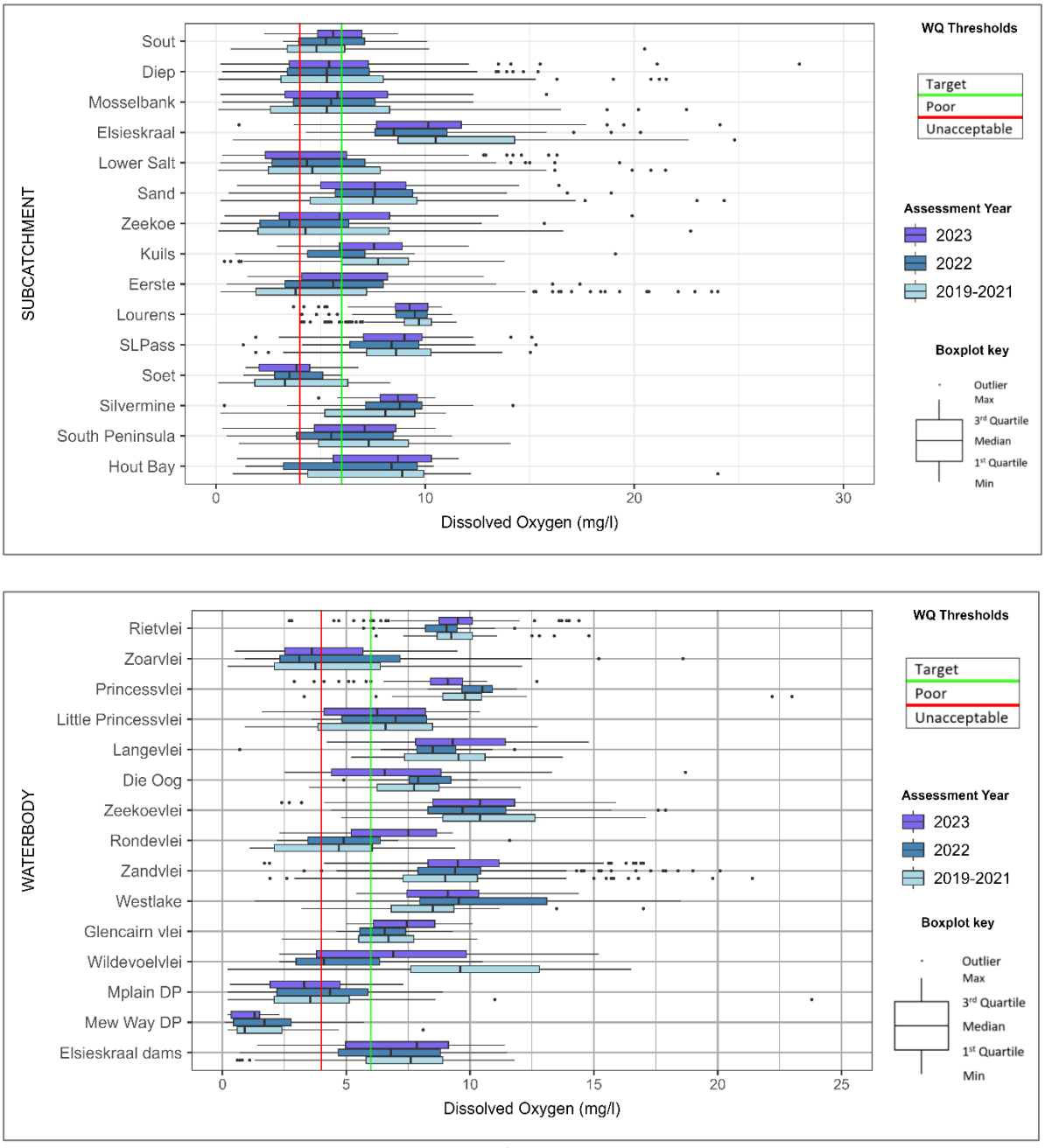


Figure D3.1
Comparison of Dissolved Oxygen for flowing systems (rivers and stormwater channels) (top) and standing water systems (vleis, dams and detention ponds) (bottom) from the 2023 reporting period with those from 2022 and the previous three years (2019 to 2021) combined. Sub-catchments as shown in Figure 2.1. Marked thresholds as per Table 3.2 and 3.3.

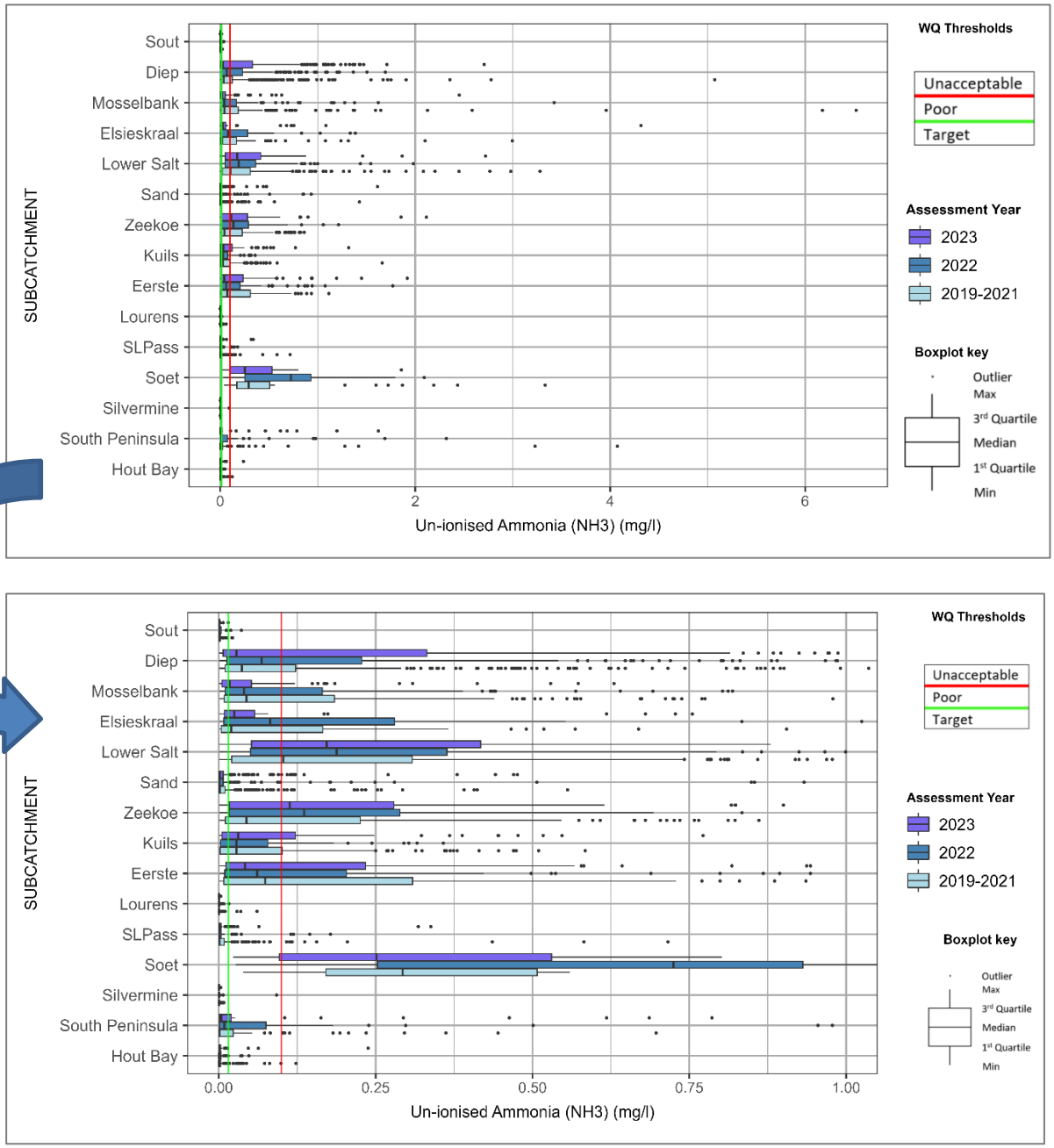


Figure D4.1
Comparison of un-ionised ammonia for flowing systems (rivers and stormwater channels) from the 2023 reporting period with those from 2022 and the previous three years (2019 to 2021) combined. Sub-catchments as shown in Figure 2.1. Marked thresholds as per Table 3.2. Closer view (reduced y-axis) shown in bottom figure (arrowed).

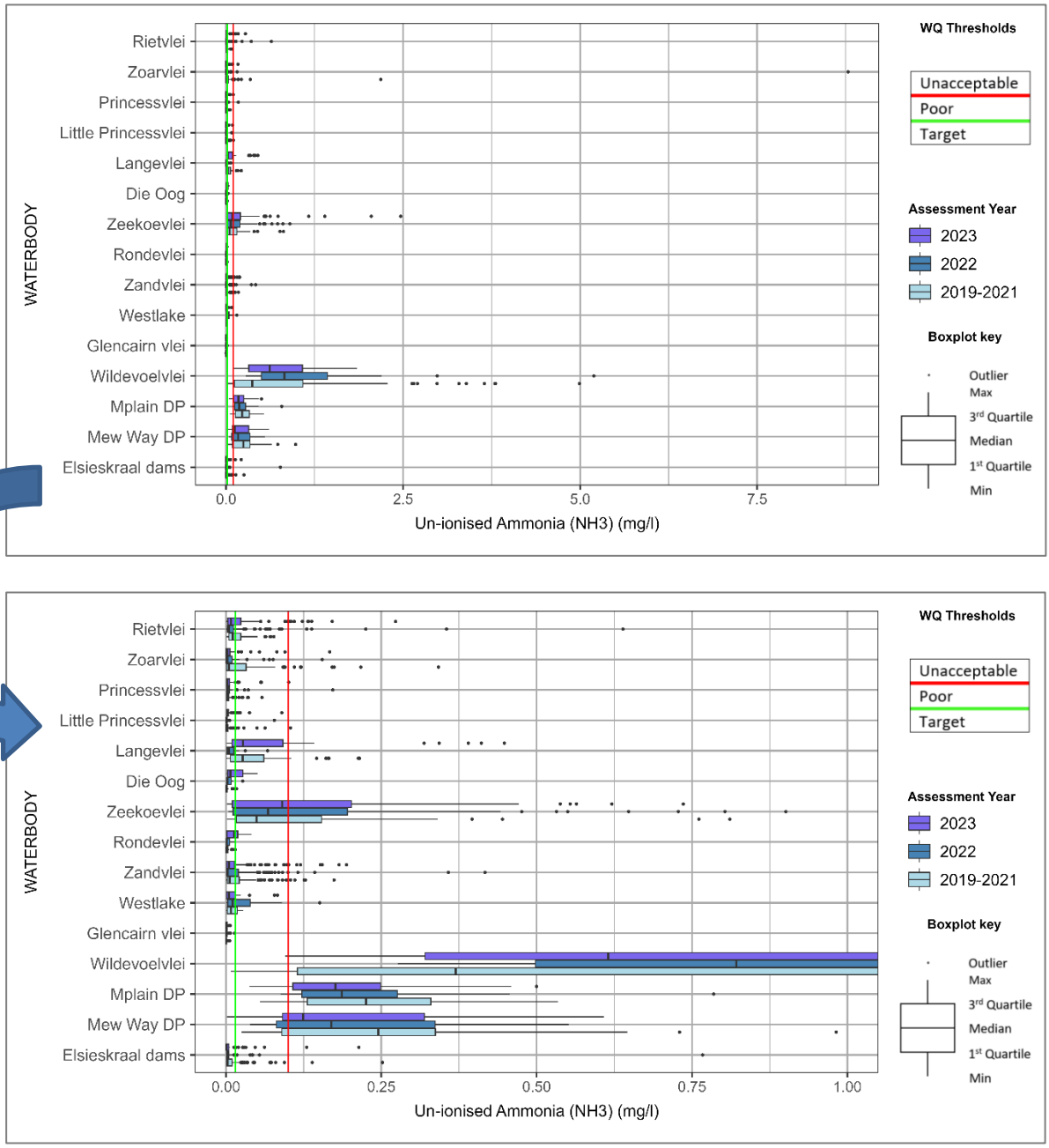
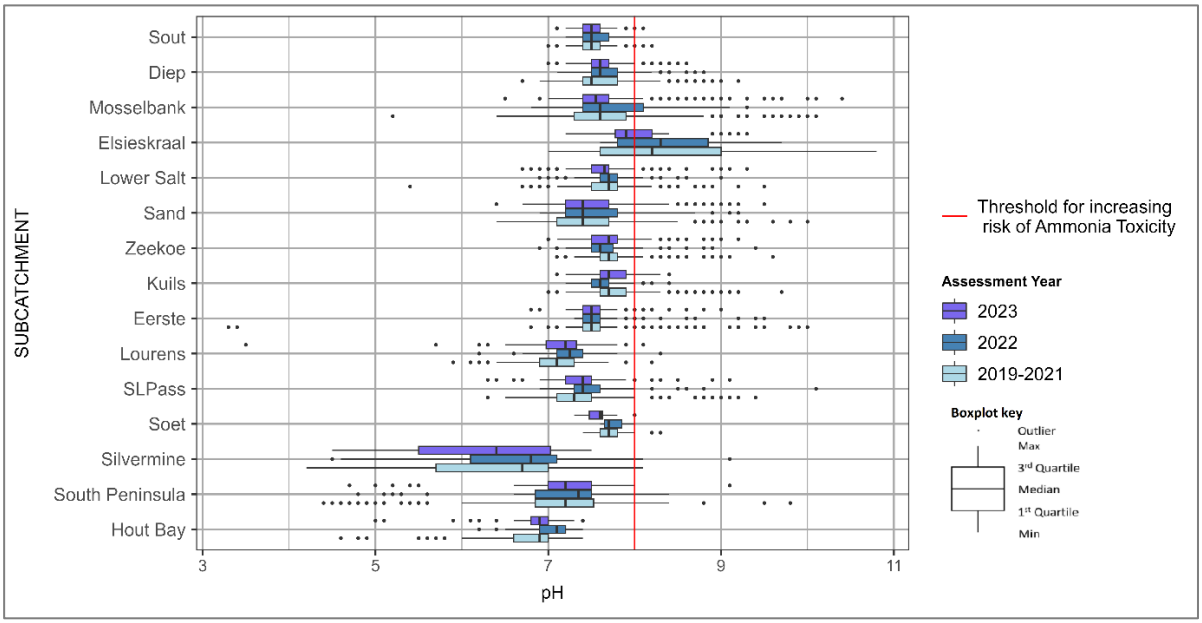


Figure D4.2
Comparison of un-ionised ammonia for standing water systems (vleis, dams and detention ponds) from the 2023 reporting period with those from 2022 and the previous three years (2019 to 2021) combined. Marked thresholds as per Table 3.3. Closer view (reduced y-axis) shown in bottom figure (arrowed)



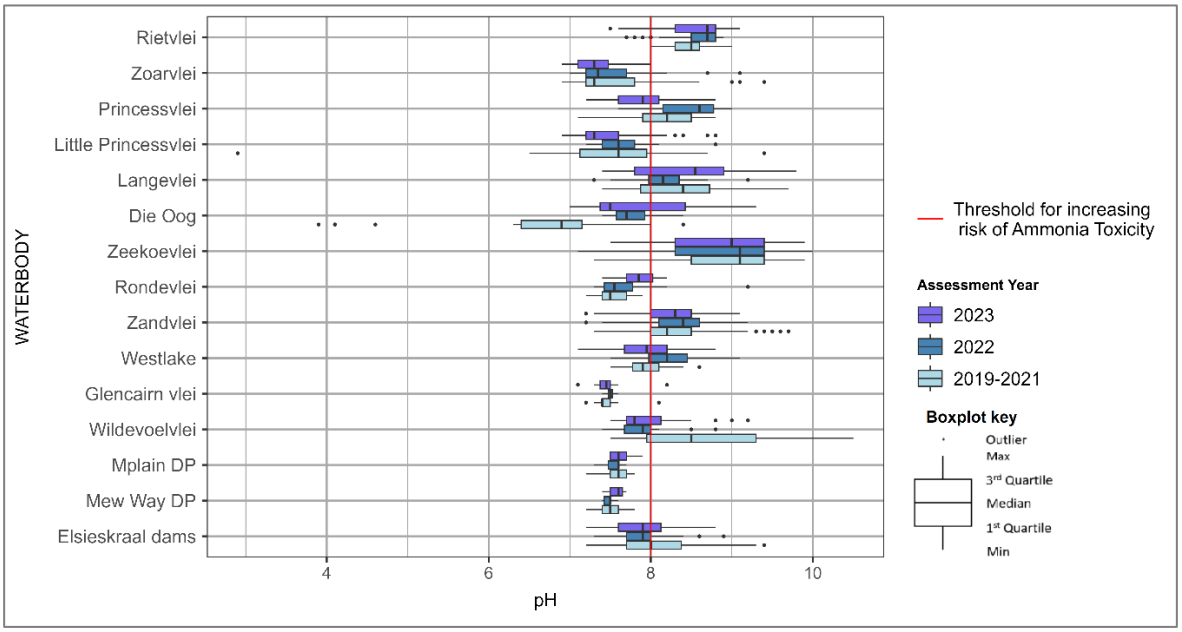


Figure D5.1
Comparison of pH for flowing systems (rivers and stormwater channels) from the 2023 reporting period with those from 2022 and the previous three years (2019 to 2021) combined. Marked thresholds show pH > 8, used in this report to indicate increased risk of ammonia toxicity in samples with elevated total ammonia

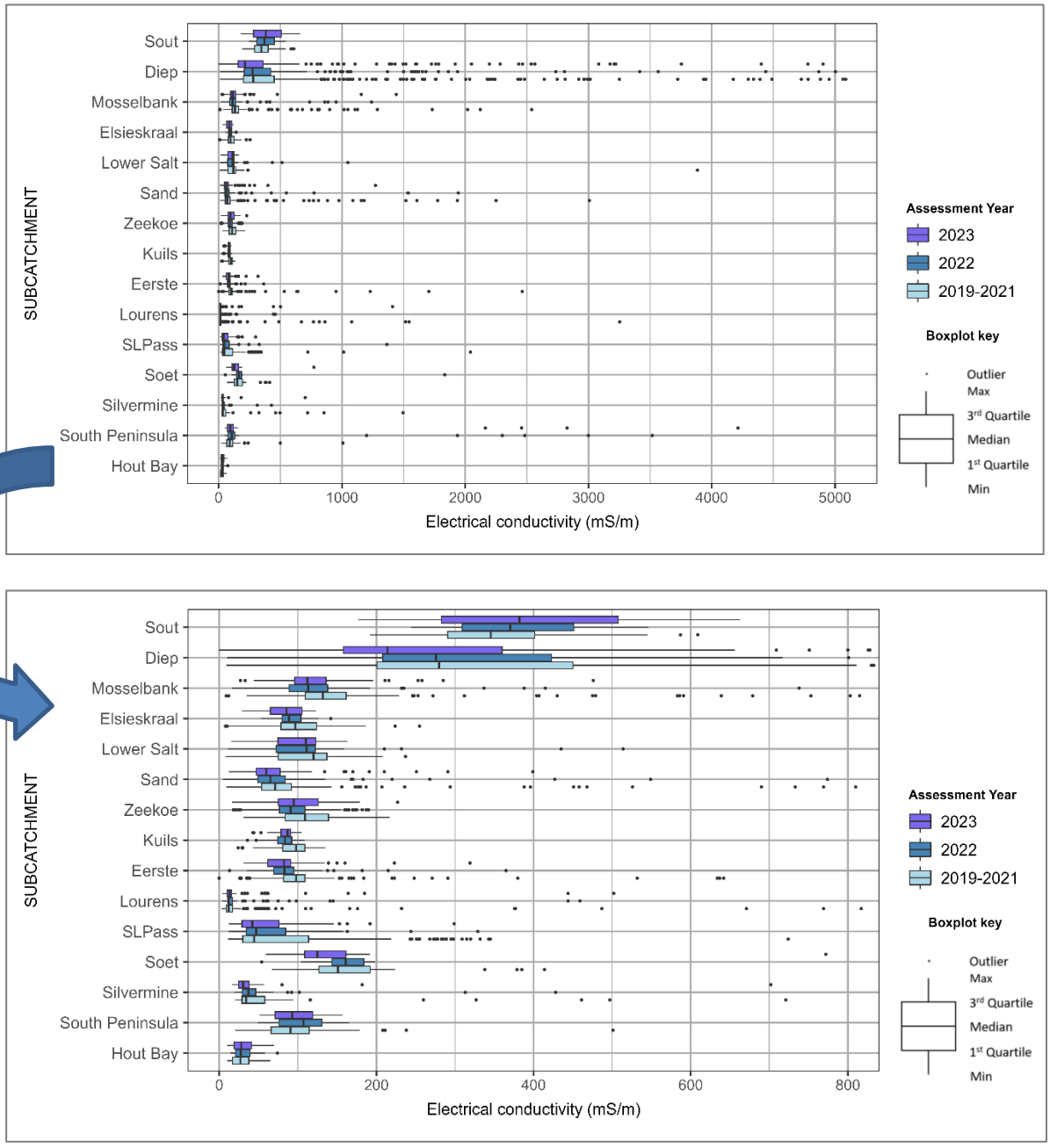


Figure D5.2
Comparison of Electrical Conductivity (EC) for flowing water systems (rivers, channel, canals and stormwater channels) from the 2023 reporting period with those from 2022 and the previous three years (2019 to 2021) combined.

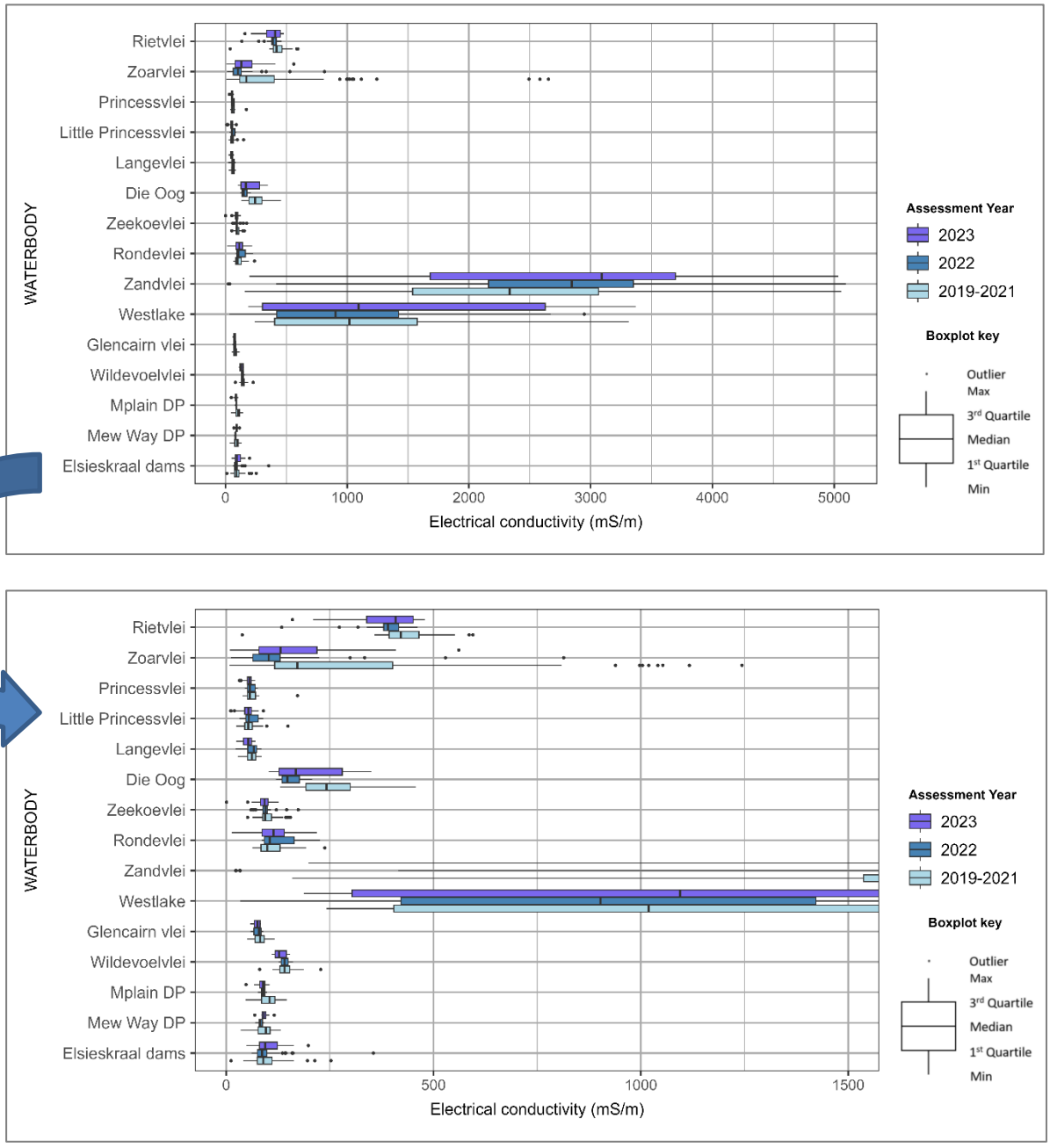
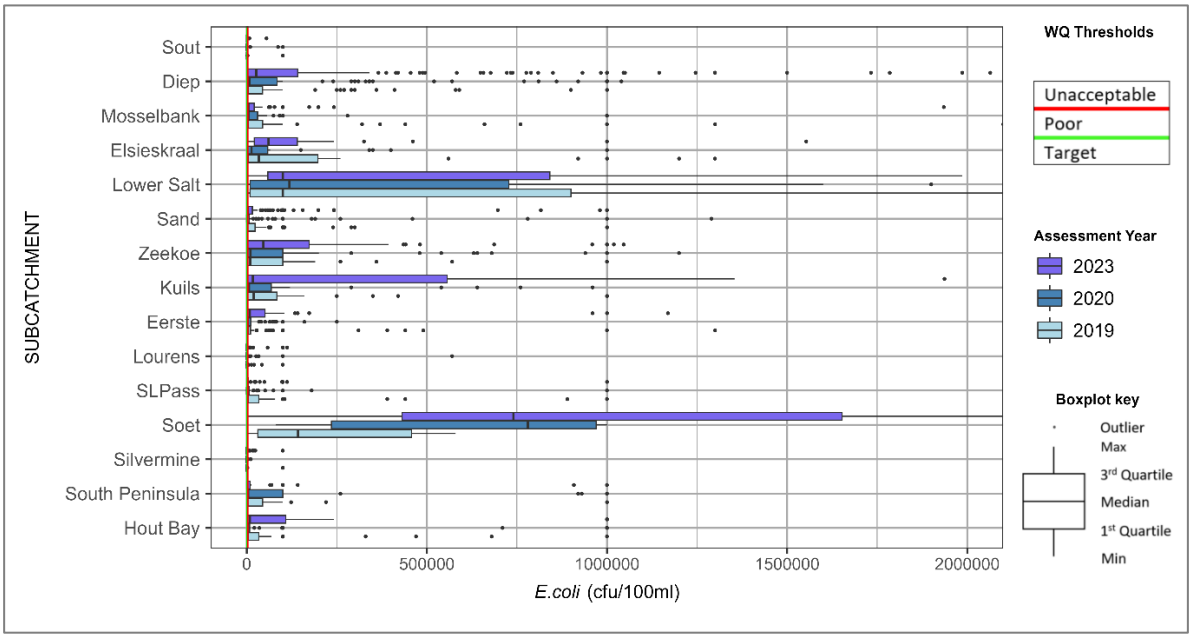


Figure D5.2
Comparison of Electrical Conductivity (EC) for standing water systems (dams, vleis) from the 2023 reporting period with those from 2022 and the previous three years (2019 to 2021) combined



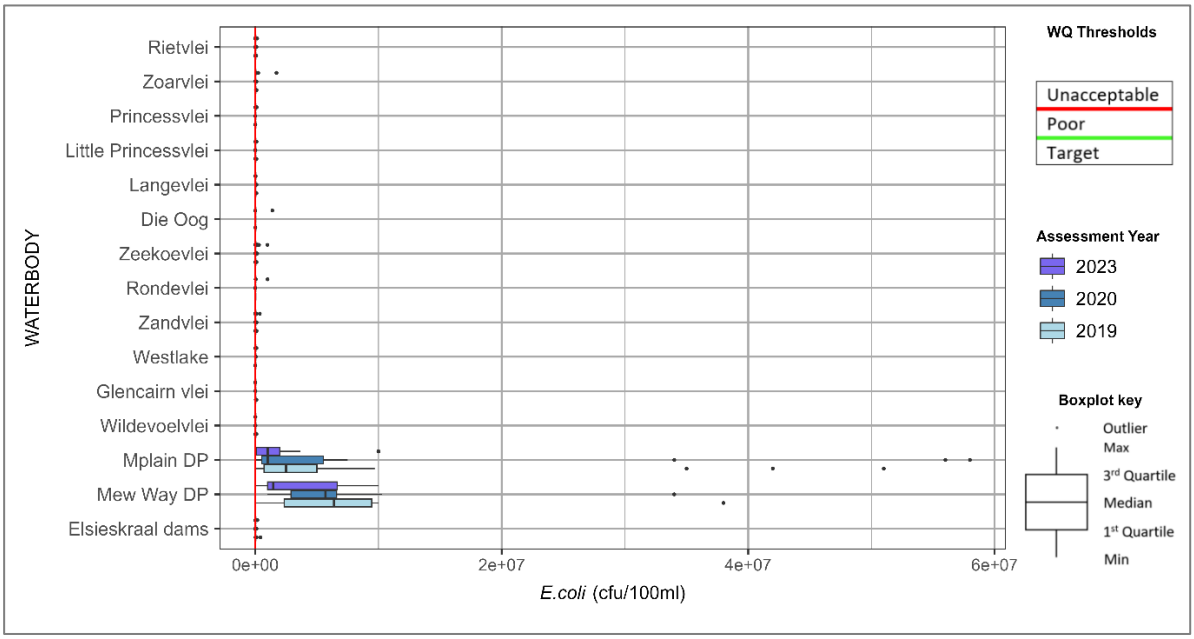


Figure D5.2
Comparison of *Escherichia coli* data for flowing (rivers, channels, canals and stormwater channels) and standing (dams, vleis) water systems from the 2023 reporting period with those from 2020 and 2019. Data shown as median data. All other *E. coli* summary data presented as geometric means.

APPENDIX E: SALINITY OF ESTUARINE VLEIS IN RELATION TO GAZETTED RESOURCE QUALITY OBJECTIVES

In November 2020, a Notice was published by the national Department of Water and Sanitation relating to 'Determination of Classes of Water Resource and associated Resource Quality Objectives for the Berg Catchment' (Government Notice No. 1179 in *Government Gazette* No. 43872 of 6 November 2020). This Notice contains RQOs for prioritised (water) Resource Units within the study area, including rivers, estuaries, dams, and groundwater, but excluding inland wetlands and standing waterbodies. The following vleis within Cape Town were delineated as estuaries, as they fall within the legislated Estuarine Functional Zone (EFZ) defined to include the '*area below the 5 m topographical contour (referenced from the indicative mean sea level)*':

- Milnerton Lagoon and Rietvlei (both delineated to form part of the 'Rietvlei/Diep Estuary')
- Wildevoelvlei
- Zandvlei
- Zeekoevlei and Rondevlei (both delineated to form part of the 'Zeekoevlei Estuary').

Through the water resource classification study for the Berg Catchment, Estuarine RQOs were set for the above four estuaries, which comprise six of the vlei systems distinguished in the current report. Of these, Rietvlei, Rondevlei and Zeekoevlei do not however have any present estuarine function, although they lie within the EFZ. Van Niekerk *et al*. (2020) define an estuary as an area that is subject to tidal action, salinity penetration or back-flooding under closed mouth conditions. This aligns with the legal definition of an estuary in terms of the National Environmental Management: Integrated Coastal Management Act (Act No. 24 of 2008), whereby an estuary is '*a body of surface water— a) that is permanently or periodically open to the sea; b) in which a rise and fall of the water level as a result of the tides is measurable at spring tides when the body of surface water is open to the sea; or in respect of which the salinity is higher than fresh water as a result of the influence of the sea, and where there is a salinity gradient between the tidal reach and the mouth of the body of surface water*.'

Salinity was one of the parameters for which Estuarine RQOs were set for the above systems (see **Table E1**). In the analysis undertaken for the current report, the salinity values (in dimensionless Practical Salinity Units) were converted to EC values (in mS/m) to allow for a comparison with the data collected from these systems by the CCT. The conversion was done by making use of an online 'salinity unit calculator' (https://reefapp.net/en/salinity-calculator), which applies algorithms based on UNESCO (1983).

Table E1
Salinity RQOs for estuaries in the City from the Berg Catchment water resource classification study

Estuary name	Vlei name/s	Salinity RQOs		Derived EC RQOs	
		Average	Max	Average	Max
Rietvlei/Diep	Milnerton Lagoon	>20	<35	>3210 mS/m	<5310 mS/m
	Rietvlei				
Wildevoelvlei	Wildevoelvlei	>2	n/a	>380 mS/m	n/a
Zandvlei	Zandvlei	>15	<35	>2470 mS/m	<5310 mS/m
Zeekoevlei	Zeekoevlei	>10	<35	>1700 mS/m	<5310 mS/m
	Rondevlei				

In the Inland Water Quality Report for the 2020 and 2021 reporting periods (Day *et al*. 2023), it was shown that the Estuarine RQO thresholds for salinity far exceed the range of EC values typically

measured in Rietvlei, Wildevoelvlei, Zeekoevlei and Rondevlei, indicating that none of these inland water systems are influenced by saline intrusion from a connection to the sea. As none of these systems are influenced by tidal fluctuations either, they are not true estuaries, rendering evaluation against the Gazetted Estuarine RQOs for salinity a meaningless exercise because the specified objectives are not relevant. On this basis it was recommended that the only vlei systems in the City that should be evaluated against the Gazetted Estuarine RQOs for salinity and other estuarine variables, as part of the ongoing monitoring of water quality, are Milnerton Lagoon (excluding Rietvlei) and Zandvlei because these are the only currently functional estuarine systems. Following on from this recommendation, only the results for these two systems have been reported on in terms of compliance with the Estuarine RQOs for salinity in the current report.

The boxplots in **Figure E1** provide a statistical summary of the EC data for **Milnerton Lagoon** and **Zandvlei** by reporting period in relation to the average and maximum salinity/EC thresholds that have been Gazetted as Estuarine RQOs through the water resource classification study for the Berg Catchment. In the case of Milnerton Lagoon, this system is taken to be the waterbody downstream of Otto Du Plessis Drive, which is where estuary water quality RQOs should be applicable according to the 2020 Estuary Management Plan for the Diep River Estuary (CCT and Infinity 2021).

These plots show that:

- EC never exceeded the maximum RQO threshold of 5310 mS/m (equivalent to a salinity of 35) in either Milnerton Lagoon or Zandvlei during any of the 2019-2023 reporting periods, indicating that hypersalinity is not a problem either of these estuarine systems;
- In the case of the Milnerton Lagoon, for all three reporting periods the median EC (ranging between approximately 250 and 750 mS/m) was well below the minimum required threshold for average salinity that this system should remain above according to the relevant RQO (i.e., 3210 mS/m), and the third quartile for all three reporting periods (at <2 000 mS/m) was also below the target EC of the RQO;
- The upper limit of the range of recorded EC values in Milnerton Lagoon did, however, extend above the RQO target for average salinity in Reporting Year 2023 and the 2019-2021 reporting period, implying limited compliance with the RQO at times during these periods (but not during Reporting Year 2022, when the upper limit of recorded values remained below 2 000 mS/m).
- The above results all suggest that there has been a significant 'freshening' of the Milnerton Lagoon estuary, relative to the expected reference range of salinities according to the RQOs, which is undoubtedly, at least in part, due to significant non-saline inflows from the Potsdam WWTW and stormwater runoff;
- Zandvlei, on the other hand, shows relatively good compliance with the Estuarine RQOs for salinity/EC in all three reporting periods, with the median EC for each reporting period (ranging between approximately 2200 and just over 3000 mS/m) being close to the average salinity threshold that was set for this system (2470 mS/m);
- The median EC for Zandvlei did increase from one reporting period to the next, for the reporting periods considered in the current report, being noticeably higher in Reporting Year 2023 (when it exceeded 3 000 mS/m) than it was in the 2022 or 2019-2021 reporting periods;
- The third quartile (upper bound of the boxes in the boxplots) for EC values recorded in Zandvlei also increased from one reporting period to the next, being significantly higher (representing more saline conditions) in Reporting Year 2023 than it was in the previous reporting periods, while at the same time having a bigger interquartile range;
- The above results suggest that, while there was general compliance with the RQOs for salinity in Zandvlei during Reporting Year 2023, there was an increase in the frequency of elevated salinity levels in this reporting period indicating that there may have been a slight deficit of freshwater input into the system.

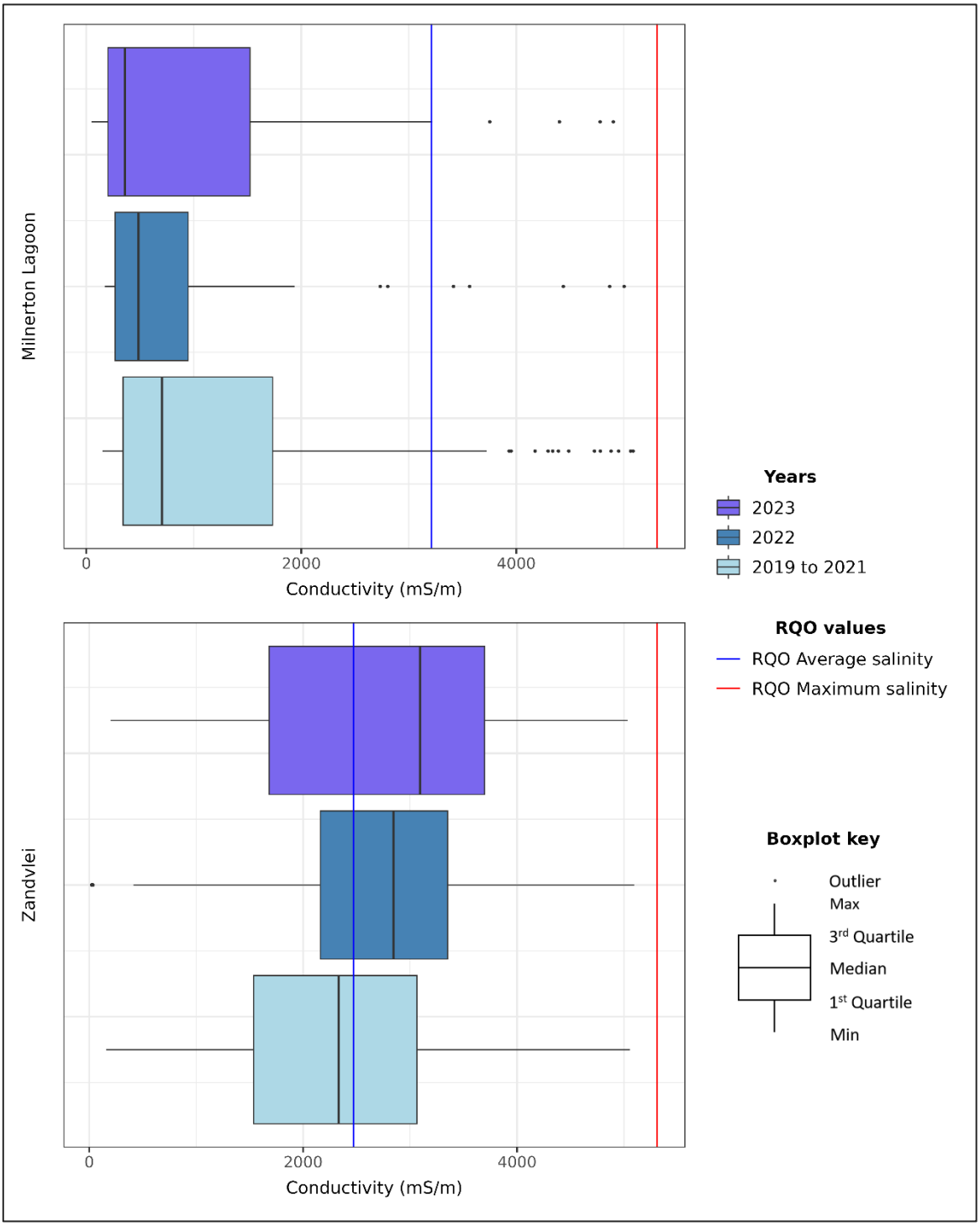


Figure E1
Comparison of electrical conductivity in Milnerton Lagoon and Zandvlei from the 2023 reporting period, with those from 2022 and the previous three years (2019 to 2021) combined. Marked salinity thresholds from the Gazetted Estuarine RQOs.