TECHNICAL PAPER

JOURNAL OF THE SOUTH AFRICAN INSTITUTION OF CIVIL ENGINEERING

Vol 55 No 1, April 2013, Pages 22–35, Paper 797

Improving water quality in stormwater & river systems: an approach for determining resources

N Nel, A Parker, P Silbernagl

This paper is a showcase of the approach used to determine the additional resources required to improve inland water quality in the City of Cape Town to an acceptable level. As the improvement of water quality falls in the more complex realm of modern municipal engineering – where many of the issues are so-called "soft" in nature and the problems and solutions are not straightforward – the methods discussed in this paper were instrumental in creating an holistic overview of the state of the rivers and wetlands in the City of Cape Town, highlighting the complexity of the problem and assisting to plot a way forward to provide proactive, sustainable measures for the management of water pollution. The paper discusses: the evaluation of water quality data, catchment analysis and determination of pollution sources, a risk assessment, and a prioritisation exercise, and concludes with the novel points and obstacles encountered. In all, the methods discussed provide a significant contribution towards the quest to improve water quality in the City of Cape Town.

NICOLE NEL received her BSc (Eng) in civil engineering from the University of Cape Town in 2003 and went on to complete a Masters in Development Studies in 2008. She is currently employed by PD Naidoo & Associates Consulting Engineers in their Water and Waste Water Division.

Contact details:
Candidate Engineer
PD Naidoo & Associates Consulting Engineers (Pty) Ltd
PO Box 7786
Roggebaai
8012
South Africa
T: +27 21 440 5060
F: +27 21 418 6440
E: nicoler@pdna.co.za

ABDULLA PARKER obtained a BSc (Eng) and an MBA from the University of Cape Town. He is currently head of Catchment Planning for the City of Cape Town: Catchment Stormwater and River Management Branch. He previously worked for the Department of Water Affairs and Forestry where he was involved in water use management, institutional development and cooperative governance, social and environmental strategies and waterworks management and development.

Contact details:
Head of Catchment Planning
City of Cape Town: Catchment Stormwater and River Management Branch
PO Box 1694
Cape Town
8000
South Africa
T: +27 21 400 1385
F: +27 21 400 4554
E: abdullah.parker@capetown.gov.za

PETER SILBERNAGL (Pr Eng, CEng, Pr CPM), a past president of Consulting Engineers South Africa) graduated from UCT with a BSc Eng, GDEng and an MBA. His fields of expertise include project management, management of multi-disciplinary teams and subconsultants in general project management, but particularly in the areas of water and waste management. He has developed expertise in human resource and organisational development. He is currently a director at PD Naidoo & Associates Consulting Engineers.

Contact details:
Director
PD Naidoo & Associates Consulting Engineers (Pty) Ltd
PO Box 7786
Roggebaai
8012
South Africa
T: +27 21 440 5060
F: +27 21 418 6440
E: peters@pdna.co.za

Keywords: City of Cape Town, stormwater, pollution, methodology, resources

> In the end, all water is stormwater.
> – A Parker, 2010

> Whatever its origin or use, all water, whether from roofs, roads, wastewater treatment works, boreholes or bottles, becomes stormwater.

INTRODUCTION

The City of Cape Town (the City) has an extensive network of rivers and wetlands which fulfil diverse ecological, aesthetic, recreational and infrastructure network functions. They form an important part of the natural landscape, provide beauty and a sense of place and belonging to the people, encourage tourism, and provide recreational opportunities, health benefits, natural hazard regulation and other ecosystem services.

Over the past few decades, however, many of these watercourses have been adversely impacted by pollution. In terms of the Department of Water Affairs (DWA) water quality guidelines for recreation and aquatic ecosystems, 69% of vleis and 42% of rivers in Cape Town have poor to bad water quality (City of Cape Town 2008). This poses a significant risk to human health and aquatic biodiversity.

The impacts of poor water quality may be far-reaching, as the forgoing of recreational opportunities, for instance, may result in socially less desirable behaviour, negatively affecting the wellbeing of society and placing strain on social services in the City. Also, poor quality water used for urban farming activities may severely compromise food production, which is a source of income for many. Ultimately poor water quality poses a significant threat to human health, aquatic biodiversity and the added value that good quality water brings to the economy.

The challenge, therefore, is to protect the inland waters from the impact of pollution, and to improve inland water quality to an acceptable level. Current human and financial resources to manage pollution in inland waters are inadequate.

The Catchment, Stormwater and River Management (CSRM) Branch of the Transport, Roads, Stormwater and Major Projects Directorate of the City decided to launch a project to determine the additional resources required to manage pollution in stormwater and river systems to improve inland water quality compliance to an "acceptable level".

This paper is a showcase of the methodology used in this multifaceted and interdisciplinary project where the causes and solutions to water pollution are extremely complex, and large amounts of data, literature, opinions and information were at hand. The methods used to achieve the following project outputs are discussed:

- Identification of criteria for "acceptable water quality"

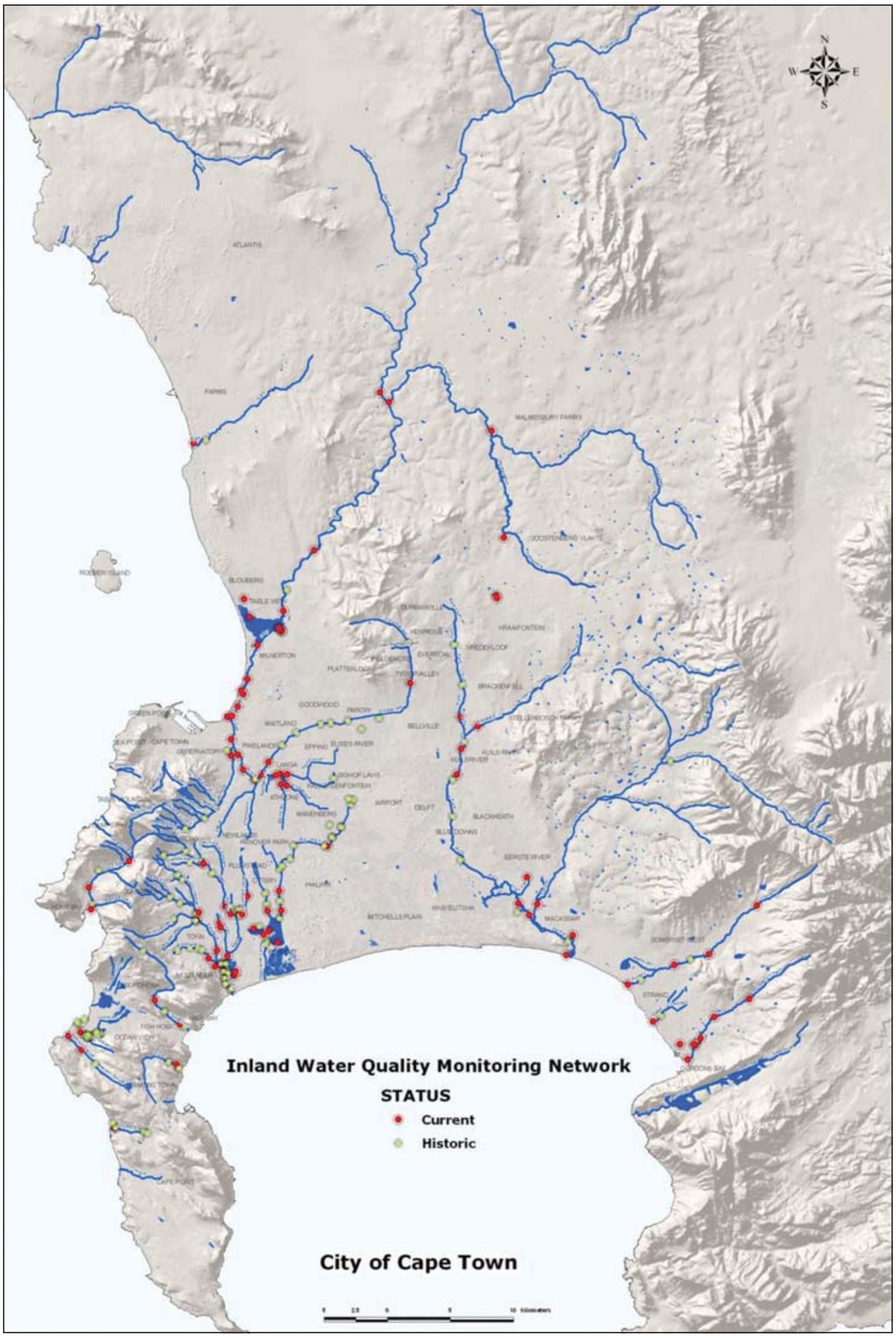

Figure 1: City of Cape Town: Inland monitoring network

Table 1 Trophic tendencies for phosphorus concentrations in inland water

Trophic tendency	Phosphorus range (mg/l P)	"Condition"
Oligotrophic	<0.005	**Excellent:** Low levels of nutrients and no water quality problems
Mesotrophic	0.005 – 0.025	**Good:** Intermediate levels of nutrients with emerging water quality problems
Eutrophic	0.025 – 0.125	**Fair to poor:** High levels of nutrients and increasing frequency of water quality problems
	0.125 – 0.25	
Hypertrophic	>0.25	**Bad:** Excessive nutrient levels and water quality problems are almost continuous

- Identification of catchment pollution sources
- Risk assessment of catchments to determine their vulnerability
- Prioritisation of catchments, rivers and wetlands for intervention
- Provision of prioritised cost estimates per district/region/subcouncil for the management of the various pollution sources, and identification of implementation mechanisms/partnerships.

ACCEPTABLE WATER QUALITY

One of the main challenges in the project was to determine what is meant by "acceptable water quality" in order to verify practical and achievable objectives in terms of water quality and to package vast amounts of water quality data in a meaningful manner to achieve the project objectives. Water quality standards and criteria ultimately drive the interventions necessary to bring water quality to a desired level.

City of Cape Town sampling, monitoring and evaluation of water quality

An inland surface water monitoring network with monitoring sites within each of the major catchment areas is maintained by the City. There are approximately 100 active sampling points which are located at strategic locations as indicated in Figure 1. Both rivers and wetlands are monitored and this occurs on a monthly basis, with both historical and current data being available.

Eighteen microbiological and chemical constituents are measured in inland water samples. There are therefore, for a 10 year period, **216 000** data points (18 constituents for around 100 sampling points taken on a monthly basis over 10 years). The key is to present this data in a meaningful way.

Reporting on water quality

For broad reporting purposes, the City currently assesses these monthly water quality results for inland waters from two perspectives: "ecosystem health" and "public health". The relevant Department of Water Affairs and Forestry (DWAF)[1] Water Quality Guideline series provides the basis for this evaluation.

Aquatic ecosystem health

For ease of reporting, total phosphorus is used by the City as an "indicator" of general chemical water quality in inland waters and provides a proxy measurement of the state of an aquatic system.

The median[2] "total phosphorus" concentration is calculated for river and vlei monitoring points in various systems, and compared to concentration ranges which indicate the trophic tendencies and conditions described in Table 1:

Public Health

"Faecal coliforms" is the constituent used by the City as an indication of the suitability

Table 2 SASS5 categories for the river health programme

Category	Description
Natural	No or negligible modification (relatively little human impact)
Good	Biodiversity and integrity largely intact (some human-related disturbance but ecosystems essentially in good state)
Fair	Sensitive species may be lost, with tolerant or opportunistic species dominating (multiple disturbances associated with socio-economic development)
Poor	Mostly only tolerant species present; alien species invasion; disrupted population dynamics; species are often diseased (high human densities of extensive resource exploitation)
Unacceptable	River has undergone critical modification; almost complete loss of natural habitat and indigenous species with severe alien invasion

of inland water for *intermediate contact* recreational use (activities involving an intermediate degree of water contact, e.g. sailing, canoeing and fishing).

The DWAF Water Quality Guideline for Recreation (DWAF 1996a) sets safe standards for the limits of pollutants that may be used for intermediate contact recreational use and states that samples should not exceed 1 000 faecal coliform organisms per 100 ml. The percentage of samples with ≤1 000 faecal coliform counts for the twelve-month period is thus used as an indication of the level of compliance.

Table 3 Public health criteria: ranges for full contact and intermediate contact recreation

Unit	DWAF Recreational Use Guidelines (Vol 2)											
	Full						Intermediate					
	Target	Acceptable	Risk	Unacceptable			Target	Acceptable	Risk	Unacceptable		
Faecal Coliform count / 100 ml	0–130	131–600	601–2 000	>2000			0–1 000	1 001–2 000	2 001–4 000	>4 000		
				Management 1	Management 2	Management 3				Management 1	Management 2	Management 3
				2 001–10 000	10 001–100 000	>100 000				4 000–10 000	10 001–100 000	>100 000
E.coli count / 100 ml	0–130	131–200	201–400	>400			No guideline	No guideline	No guideline	No guideline	No guideline	No guideline
				Management 1	Management 2	Management 3						
				401–2 400	2 401–20 000	>20 000						

Table 4 Ecosystem health criteria: categories

Variable	Units	Natural	Good	Fair	Poor	Unacceptable	Comments
Temperature*#	°C	Depends on background (Upper boundary = 90th percentile; Lower boundary = 10th percentile); Good ±2°C; Fair ±4°C; Poor ±>4°C					Need to determine typical background water quality – not essential for prioritisation exercise
Total suspended solids*#	mg/l	Depends on background (Not more than 10% higher than background)					Need to determine typical background water quality – not essential for prioritisation exercise
Conductivity (EC)*#	mS/m	Depends on background (not more than 15% different from normal cycles)					Need to determine typical background water quality – not essential for prioritisation exercise
pH*	units	8–6.5	9–8 or 6.5–5.75	10–9 or 5.75–5	>10; <5		Need to determine typical background water quality – not essential for prioritisation exercise
Dissolved oxygen*	mg/l	>8	8–6	6–4	4–2	<2	Also dependent on background DO levels to some extent. No unacceptable range given but if one selects equal bands then 2 mg/l is the next logical band and is applicable to assessing the actual data
Soluble reactive phorphorus*	mg/l	<0.005	0.005 – 0.025	0.025 – 0.125	0.125–0.250	>0.250	Ranges as recommended in the latest water quality benchmarks for the ecological reserve (DWAF 2005)
Total inorganic nitrogen*	mg/l	<0.25	0.25–1	1–4	4–10	>10	
Ammonia (NH3-N)*	mg/l	<0.015	0.015–0.058	0.058–0.1	0.1–0.2	>0.2	No unacceptable range given but if one selects equal bands then 0.2 mg/l is the next logical band and is applicable to assessing the actual data
Blue-green algae toxins (microcystins)@	µg/l	<10		10–50	>50		Ranges as recommended in the World Health Organisation (WHO) guidelines
Algae (Chl-a)*	µg/l	<10	10–20	20–30	30–40	>40	No unacceptable range given but if one selects equal bands then 40 µg/l is the next logical band and is applicable to assessing the actual data

\# South African Water Quality Guidelines (DWAF 1996b)
* Ecological reserve water quality benchmarks (Jooste & Rossouw 2002)
@ World Health Organisation Recreational Guidelines (2003)

River health programme

The City is a participant in the River Health Programme (RHP) which is a national bio-monitoring programme that uses a range of biological indices for determining the ecological health of rivers. The SASS5 index (South African Scoring System Version 5) is the most widely utilised bio-monitoring index in the RHP and consists of an assessment of aquatic macro-invertebrate communities present to determine ecological river health.

The local bio-monitoring programme of the City has been undertaken annually (where human resources allow) at approximately 40 river locations. Ideally it should be undertaken in spring, summer and autumn, which is now being done (Haskins, personal communication 2010).

The RHP utilises four descriptive categories of river condition as shown in Table 2. The fifth category ("unacceptable") was introduced for the purposes of this analysis, due to the need to address the severely modified rivers within the municipal boundaries (Belcher, personal communication 2010).

Methodological approach for the determination of acceptable water quality

A Water Quality Sub-Committee was established in order to determine "acceptable water quality" criteria and standards. Participants included the consultant team, water quality specialists and scientists and other relevant parties from the City.

The section below discusses the criteria decided upon, which were used to evaluate and colour-code the water quality data obtained from the City in order to provide a visual depiction of the water quality status of the rivers and wetlands of Cape Town.

Public health criteria

While it is acknowledged that public health risks associated with recreational water may be due to the presence and interaction of a range of constituents, faecal coliforms and *Escherichia coli* (*E. coli)* are considered to be reasonable "indicator" micro-organisms to assess health risks, as these are indicators of probable faecal pollution.

The "target", "acceptable", "risk" and "unacceptable" water quality categories for faecal coliforms and *E. coli* for both full contact recreation (swimming) and intermediate contact recreation (canoeing, waterskiing, sailing, angling, etc.)[3] were based on the South African Water Quality Guidelines (DWAF 1996a) (see Table 3).

As many of the *E. coli* and faecal coliform counts in the rivers within the municipal boundaries were found to fall within the "unacceptable" category (red); subdivisions of this category named Management 1, Management 2 and Management 3 were created. This is intended as a management tool to help establish the responses and actions needed, to prioritise rivers and wetlands, and to help determine the sources of pollution.

For instance, an *E. coli* count of 1 000 000 is likely to indicate a different source of pollution (probably a sewer overflow) than a count of 10 000, even though both are "unacceptable".

An analysis of all the *E. coli* counts for ten years of water quality data for all of the monitoring points in the Cape Town municipal area was undertaken to provide guidance on what the Management 1 to 3 sub-categories should be. It was found that a third of the data above the unacceptable (400 *E. coli* organisms/100ml) limit fell between 400 and 2 400 *E. coli* organisms/100ml, a third between 2 400 and 20 000 *E. coli* organisms/100ml, and the last third above

Table 5 Kuils River colour-coded public health and aquatic ecosystem health water quality results: monitoring point E19 – northern reaches, upstream of the Bottelary confluence

Results from Bacteriological Tests (EK19)			
Date	Faecal Coliforms		E. coli
	Full	Intermediate	Full
12/6/2003	1 300	1 300	700
16/10/2003	17 000	17 000	16 000
18/12/2003	5 400	5 400	3 700
15/1/2004	2 900	2 900	2 100
11/3/2004	48 000	48 000	20 000
10/6/2004	4 000	4 000	4 000
2/9/2004	2 300	2 300	1 800
9/12/2004	20 000	20 000	12 000
13/1/2005	100 000	100 000	100 000
10/3/2005	150 000	150 000	90 000
9/6/2005	15 000	15 000	18 000
8/9/2005	2 000	2 000	1 200
17/10/2005	1 600	1 600	1 700
8/12/2005	1 000	1 000	1 000
12/1/2006	900	900	400
14/3/2006	3 100	3 100	1 700
29/6/2006	15 000	15 000	15 000
21/9/2006	1 400	1 400	1 400
14/12/2006	100	100	100
18/1/2007	400	400	200
8/3/2007	380	380	280
14/6/2007	46 000	46 000	16 000
13/9/2007	330 000	330 000	90 000
6/3/2008	1 000 000	1 000 000	1 000 000
12/6/2008	5 000	5 000	5 000
4/9/2008	32 000	32 000	29 000
4/12/2008	26 000	26 000	17 000
15/1/2009	46 000	46 000	18 000
12/3/2009	1 000 000	1 000 000	1 000 000
18/6/2009	7 900	7 900	1 400

Target; Acceptable; Risk; Unacceptable (red 1); Unacceptable (red 2); Unacceptable (red 3)

Results from Aquatic Ecosystem Tests (EK19)				
Date	DO	tpon	nh_3	srp
12/6/2003	7.1	3.426	0.081	0.125
18/12/2003	5.7	1.35	0.073	0.162
15/1/2004	7.5	0.937	0.083	0.209
11/3/2004	3.3	1.123	0.135	0.263
10/6/2004	7.4	1.229	0.075	0.107
14/10/2004	7.2	1.31	0.056	0.075
9/12/2004	8	2.268	0.107	0.076
13/1/2005	3.5	1.556	0.011	0.186
10/3/2005	5.8	2.244	0.345	0.21
9/6/2005	7.2	2.281	0.065	0.076
8/9/2005	9.7	2.746	0.186	0.105
8/12/2005	8.9	4.889	0.099	0.285
12/1/2006	7.3	1.672	0.302	0.101
14/3/2006	1.1	7.92	6.13	0.044
29/6/2006	5.7	2.79	0.289	0.01
21/9/2006	6.6	2.53	0.13	0.01
14/12/2006	3.1	1.59	0.66	0.041
18/1/2007	3.2	1.747	0.346	<0.001
8/3/2007	4.1	1.366	0.161	0.034
14/6/2007	5.9	3.56	0.761	0.025
13/9/2007	6.2	3.275	0.221	0.051
13/12/2007	1.4	2.809	0.628	0.133
6/3/2008	1.1	1.095	0.016	0.184
12/6/2008	7.7	1.745	0.157	0.066
4/9/2008	7.4	4.25	0.228	0.048
4/12/2008	7	2.805	0.424	0.01
15/1/2009	5.4	1.906	0.12	0.145
12/3/2009	4.7	0.852	0.021	0.066
18/6/2009	6.5	2.591	0.1	0.067

Natural; Good; Fair; Poor; Unacceptable

Table 6 Kuils River colour-coded public health and aquatic ecosystem health water quality results: monitoring point EK09 – middle reaches at Bellville WWTW discharge at Rietvlei Road

Results from Bacteriological Tests (EK09)			
Date	Faecal Coliforms		E. coli
	Full	Intermediate	Full
18/1/2000	30 000	30 000	3 000
23/3/2000	4 000 000	4 000 000	3 500 000
6/6/2000	3 100 000	3 100 000	2 200 000
19/10/2000	1 100 000	1 100 000	600 000
18/1/2001	66 000	66 000	58 000
15/3/2001	4 000	4 000	3 000
7/6/2001	6 000	6 000	5 200
6/9/2001			140 000
6/12/2001	100 000	100 000	100 000
24/1/2002	100 000	100 000	100 000
14/3/2002	100 000	100 000	100 000
20/6/2002	82 000	82 000	60 000
19/9/2002	45 000	45 000	26 000
12/12/2002	41 000	41 000	21 000
23/1/2003	66 000	66 000	30 000
18/3/2003	200 000	200 000	160 000
12/6/2003	420 000	420 000	230 000
16/10/2003	34 000	34 000	27 000
18/12/2003	79 000	79 000	39 000
15/1/2004	580 000	580 000	390 000
11/3/2004	170 000	170 000	60 000
10/6/2004	430 000	430 000	190 000
2/9/2004	310 000	310 000	200 000
9/12/2004	25 000	25 000	11 000
13/1/2005	240 000	240 000	130 000
10/3/2005	150 000	150 000	30 000
9/6/2005	5 000	5 000	1 000
8/9/2005	600 000	600 000	270 000
8/12/2005	57 000	57 000	38 000
12/1/2006	150 000	150 000	60 000
14/3/2006	55 000	55 000	10 000
29/6/2006	9 000	9 000	2000
21/9/2006	46 000	46 000	39 000
14/12/2006	65 000	65 000	45 000
18/1/2007	260 000	260 000	80 000
8/3/2007	270 000	270 000	190 000
14/6/2007	13 000	13 000	9 000
13/9/2007	160 000	160 000	60 000
13/12/2007	680 000	680 000	580 000
6/3/2008	180 000	180 000	100 000
12/6/2008	29 000	29 000	11 000
4/9/2008	330 000	330 000	270 000
4/12/2008	960 000	960 000	770 000
15/1/2009	2 300 000	2 300 000	1 600 000
12/3/2009	8 300 000	8 300 000	4 600 000
18/6/2009	46 000	46 000	25 000

Target · Acceptable · Risk · Unacceptable (red 1) · Unacceptable (red 2) · Unacceptable (red 3)

Results from Aquatic Ecosystem Tests (EK09)				
Date	DO	tpon	nh_3	srp
18/1/2000	6.2		2.998	1.929
23/3/2000	5.1	29.18	6.909	2.749
6/6/2000	2.9	21.36	7.846	2.436
21/9/2000	4.1	21.76	12.32	0.23
16/11/2000	9.7	20.54	19.12	2.702
18/1/2001	6.2	22.31	12.59	2.093
15/3/2001	4.5	11.64	1.018	0.348
5/7/2001	8	9.06	1.26	0.681
6/9/2001	9.3	12.29	2.019	0.329
6/12/2001	3.9	23.63	20.84	3.098
24/1/2002	11.8	12.39	9.713	0.977
14/3/2002	8.4	22.68	19.91	15.19
20/6/2002	5	10.26	1.696	1.443
19/9/2002	6.2	20.14	14.87	1.911
12/12/2002	4.6		4.3	1.347
23/1/2003	7.4		8.92	3.475
18/3/2003	5.3	6.157	1.977	1.078
12/6/2003	6.4	16.51	11.48	3.618
18/9/2003	15.8	4.296	0.01	0.192
18/12/2003	5.3	11.69	9.121	4.652
15/1/2004	6.8	11.52	9.117	0.945
11/3/2004	4.5	12.42	8.812	3.997
10/6/2004	6.6	8.598	6.734	1.23
2/9/2004	5.5	16.88	11.15	6.4
9/12/2004		12.8	7.177	2.637
13/1/2005	5.1	16.18	11.72	4.104
10/3/2005	7.3	3.239	0.32	2.272
9/6/2005	8.9	9.924	2.583	1.361
8/9/2005	7.7	18.21	10.12	4.159
8/12/2005	6.3	13	9.728	2.293
12/1/2006	3	7.004	4.977	2.277
14/3/2006	5.5	9.44	2.86	5.77
29/6/2006	6.8	8.51	0.61	2.18
21/9/2006	5.8	10.41	5.65	2.27
14/12/2006	2.4	19.9	19.49	7.63
18/1/2007	4.7	9.421	6.814	1.881
8/3/2007	4.4	11.16	8.58	2.653
14/6/2007	6.1	8.04	2.22	1.06
13/9/2007	6.1	9.519	3.962	1.711
13/12/2007	4.6	26.28	25.25	5.901
6/3/2008	7.6	10.96	7.597	2.084
12/6/2008	4.8	5.794	0.212	1.025
4/9/2008	7.5	7.481	3.537	1.779
4/12/2008	5.3	19.87	18.55	5.421
15/1/2009	2.3	20.94	19.18	3.537
12/3/2009	1.6	22.39	20.68	6.323

Natural · Good · Fair · Poor · Unacceptable

20 000 *E. coli* organisms/100ml. These divisions are purely to guide management and to assist with the allocation of resources. These limits were then used for Management 1, 2 and 3 (i.e. the sub-categories of the "unacceptable" range).

The same method was used to determine the three sub-categories of the "unacceptable" range for the faecal coliform counts.

Ecosystem health criteria

The values for the various categories for the ecosystem health criteria were derived from both the South African Water Quality Guidelines (DWAF 1996b) and the ecological reserve water quality benchmarks (Jooste & Rossouw 2002). As many of the rivers in the Cape Town municipal area were found to fall within the "poor" category (red), an additional "unacceptable" category (dark red) was created as a management tool to be able to prioritise rivers, to establish the responses needed and to help determine the sources of pollution (see Table 4).

Temperature, total suspended solids (TSS), conductivity and pH are dependent on vegetation, geology etc, and the background levels of these would need to be determined for each of the water systems to establish applicable water quality ranges for each of these constituents within the various categories. Therefore, for the purposes of the project, the following constituents (highlighted in blue in Table 4) were decided upon under the auspices of the Water Quality Sub-Committee:

- Dissolved oxygen (DO)
- Ammonia (NH_3)
- Total inorganic nitrogen (TIN)
- Soluble reactive phosphorus (SRP)

All of these constituents relay different information in terms of water quality, and they would trigger different management responses. They are, however, all linked and a particular intervention can often result in an improvement in all constituent concentrations.

Algae (A), monitored in some wetlands ("vleis"), was a further constituent used to assess water quality specifically within the vleis. The occurrence of blue-green algae (Cyanophyceae) – a group known to produce toxins under certain conditions – is particularly important for assessing potential health risk.

All the public health and ecosystem health water quality data for all of the monitoring points were colour-coded according to the categories discussed above.

By way of illustration, Tables 5 – 7 are examples of colour-coded quarterly data for three monitoring points along the Kuils River (a river east of the Cape Town CBD). The first monitoring point (EK19) is in the northern, upper reaches of the river, upstream of its confluence with the Bottelary River; the second point (EK09) is in the middle reaches at the Bellville Wastewater Treatment Works (WWTW); and the third point (EK11) is in the lower reaches downstream of the Zandvliet WWTW discharge point.

The tables give a visual depiction of the quality of the water at these particular points over a 10-year period, thus creating insight into possible sources of pollution. At monitoring point EK19, shown in Table 5, the "unacceptable" levels of faecal coliforms and *E. coli* (reds and dark reds) in recent years in an area that is relatively affluent, and where there is no industry and wastewater treatment, is perhaps indicative of leaking sewers and/or stormwater ingress or infiltration. Further downstream, at monitoring point EK09 (Table 6), the water quality worsens (more reds and dark reds) from both a public health and ecosystem health perspective. This is perhaps a result of poor quality effluent from the Bellville WWTW. Even further downstream, at monitoring point EK11 (Table 7), the water quality from a public health perspective improves slightly (more blues, greens and yellows). It can be concluded that, in contrast to the concrete-lined sections higher up in the Kuils River, the natural wetlands in the vicinity of monitoring point EK11 are able to attenuate the bacteriological pollutants. The microbiological constituents, however, remain "unacceptable".

CATCHMENT ANALYSIS AND SOURCES OF POLLUTION

An analysis of each of the catchments, rivers (including canals) or river reaches, as the case may be, depending on the water quality information from the monitoring points, was undertaken to obtain an understanding of the situation in each of these discrete units.

A Project Steering Committee (including any interested parties and all City officials involved in water quality management) was established to provide assistance in this regard. Meetings were held every two months, or as necessary, and involved workshopping of ideas, sharing of knowledge and findings, and seeking consensus between the various City Departments.

Field visits to various informal settlements, industries, wastewater treatment works, pump stations, rivers and wetlands were held to gain further insight into water quality issues around Cape Town.

A literature review of previous reports made available by the City and the evaluation of historic water quality data created insight into the state of the rivers and wetlands in the municipal area of Cape Town.

Table 7 Kuils River colour-coded public health and aquatic ecosystem health water quality results: monitoring point EK11 – lower reaches, downstream of Zandvliet WWTW discharge

Results from Bacteriological Tests (EK11)			
Date	Faecal Coliforms		E. coli
	Full	Intermediate	Full
18/1/2000	1 900	1 900	1 600
23/3/2000	4 000	4 000	4 000
6/6/2000	610	610	580
19/10/2000	1 000	1 000	1 000
18/1/2001	680	680	500
15/3/2001	8 000	8 000	6 000
7/6/2001	4 100	4 100	3 600
6/9/2001			300
6/12/2001	1 200	1 200	1 000
24/1/2002	430	430	290
14/3/2002	410	410	240
20/6/2002	13 000	13 000	1 2000
19/9/2002	170	170	170
12/12/2002	850	850	790
23/1/2003	3 200	3 200	2 000
18/3/2003	1 000	1 000	600
12/6/2003	2 800	2 800	2 600
16/10/2003	2 800	2 800	2 600
18/12/2003	640	640	430
15/1/2004	3 800	3 800	3 000
11/3/2004	900	900	700
10/6/2004	350	350	270
8/7/2004	4 400	4 400	3 600
14/10/2004	13 000	13 000	12 000
9/12/2004	2 100	2 100	1 800
13/1/2005	2 100	2 100	900
10/3/2005	25 000	25 000	20 000
9/6/2005	1 500	1 500	1 400
8/9/2005	1 900	1 900	1 900
8/12/2005	520	520	450
12/1/2006	440	440	170
14/3/2006	10	10	10
29/6/2006	350	350	310
21/9/2006	620	620	590
14/12/2006	560	560	410
8/3/2007	500	500	200
12/7/2007	360	360	320
18/10/2007	220	220	160
13/12/2007	4 200	4 200	4 200
6/3/2008	7 200	7 200	1 100
12/6/2008	700	700	200
4/9/2008	80	80	70
4/12/2008	6 200	6 200	3 300
15/1/2009	2 200	2 200	1 300
12/3/2009	8 700	8 700	2 900
18/6/2009	89 000	89 000	41 000

Target · Acceptable · Risk · Unacceptable (red 1) · Unacceptable (red 2) · Unacceptable (red 3)

Results from Aquatic Ecosystem Tests (EK11)				
Date	DO	tpon	nh_3	srp
18/1/2000	2.6	3.106	0.744	1.403
23/3/2000		5.468	0.717	1.346
6/6/2000	6.5	7.061	2.924	1.589
21/9/2000	8.1	9.433	0.778	1.537
16/11/2000	4.1	4.724	1.878	1.694
18/1/2001	7.1	6.097	0.512	1.585
15/3/2001	6.4	8.016	4.021	0.037
7/6/2001	8.8	4.527	0.108	1.093
6/9/2001	7.7	3.525	0.03	0.107
6/12/2001	7.3	7.694	2.092	2.307
24/1/2002	5.2	3.868	0.158	1.5
14/3/2002	7.7	5.718	0.426	1.907
20/6/2002	5.6	4.732	0.223	1.25
19/9/2002	5.9	7.074	0.308	1.338
12/12/2002	4.3		0.6	2.17
23/1/2003	4.9		0.081	2.395
18/3/2003	5	6.584	0.072	2.224
12/6/2003	6.9	12.22	0.07	2.53
18/9/2003	5	4.72	0.143	1.629
18/12/2003	6.5	4.662	0.104	3.095
15/1/2004	8	4.964	0.31	3.256
11/3/2004	5.4	4.612	0.137	3.155
10/6/2004	6.8	3.952	0.864	1.544
2/9/2004	6.3	6.496	0.736	2.492
9/12/2004	8	5.489	0.173	1.616
13/1/2005	5.8	5.568	0.06	2.419
10/3/2005	8.8	5.109	0.2	1.944
9/6/2005	6.4	3.691	0.06	0.967
8/9/2005	7.7	4.485	0.064	1.484
8/12/2005		8.689	1.463	2.718
12/1/2006	9.2	5.496	0.778	2.586
14/3/2006	5.4	6.21	1.1	1.82
29/6/2006	5.5	4.85	0.076	1.65
21/9/2006	5.4	5.28	0.09	1.82
14/12/2006	2.6	4.74	2.76	4.66
18/1/2007	3.3	5.561	3.6	4.188
8/3/2007	3.8	6.683	5.979	2.99
14/6/2007	6.3	2.86	0.274	0.749
13/9/2007	4.4	5.106	2.234	1.342
13/12/2007	2.9	23.73	23.2	6.274
6/3/2008	1.6	14.87	12.99	3.429
12/6/2008	4.8	6.665	4.326	1.884
4/9/2008	5.1	4.048	0.601	1.31
4/12/2008	2.2	10.45	9.699	4.935
15/1/2009	2.2	15.55	14.14	4.594
12/3/2009	1.5	21.88	19.09	5.805
18/6/2009	3.5	3.422	1.888	1.028

Natural · Good · Fair · Poor · Unacceptable

Catchment Workshop November 2009

Name	
Surname	

Catchment	Silvermine
River/Wetland	Silvermine River
Monitoring Points	sil02, sil04
Water Quality (Bacto)	
Water Quality (Eco)	
Water Quality over time	
Land Use:	SANParks, Silvermine Dam, Clovelly residential, public open space, Fishhoek township, Clovelly CC and golf course
Water Use	
Possible sources of pollution	Sewer pumps
	Golf course runoff
	Informal areas
	Urban runoff

Department	Type of Intervention	Timing					Budget					Importance Scale of 1 (Important) to 5 (Not important)			Comments
		0–1 year	1–5 years	5–10 years	10–20 years	>20 years	R0–R100 000	R100 000–R1 mill	R1 mill–R10 mill	R10 mill–R100 mill	>R100 mill	Public Health	Environmental	Economic Growth (e.g. tourism)	
e.g Water and Sanitation															
	e.g. upgrade WWTW		x						x			5	5	1	

Figure 2 Template used in water quality workshops

Consultations were also held with the following organisations and entities in the interest of information-sharing and future collaboration:

- DWA
- South African National Parks (SANParks) / Table Mountain National Parks (TMNP)
- Swartland Municipality
- Stellenbosch Municipality and Cape Winelands District Municipality
- Department of Agriculture

Stakeholder engagement was sought through a two-day workshop (16 and 17 November 2009). The workshop was held with various area managers from the City in order to determine pollution sources, to suggest possible solutions and to gain management consensus. Water quality at the various monitoring points was discussed and attendees filled out templates as per Figure 2.

Through the process the sources of pollution with respect to water quality in river systems and stormwater, which stand out from the many, many types of point or diffuse sources of pollution, were found to be the following:

- **Perceived major pollutors:**
  - Blockages and overflows of sewers (whether due to extraneous waste disposed into sewers, illegal rainwater disposal or previous bad practice in construction)
  - Greywater and sewage from informal settlements
  - Sewage pump stations
  - Solid waste in water courses and such open areas
  - Wastewater treatment works
- **Perceived minor pollutors:**
  - Agriculture
  - General urban runoff
  - Golf courses
  - Industry and construction
  - Canalisation of rivers[4]

RISK ASSESSMENT

The purpose of the risk assessment was to determine the vulnerability of a catchment to human and ecological health impacts, should there be a pollution incident or water quality-related set of circumstances. It is not a reflection of what is happening on the ground, but rather an illustration of the inherent risk (without a management system in place) as opposed to the residual risk.

The risk assessment is one of the criteria that was fed into the catchment prioritisation exercise, as described later in this paper.

Risk events and their associated consequences were identified by the Project Steering Committee and Water Quality Sub-Committee as per Table 8:

Table 8 Risk events and risk consequences

Risk event	Consequence
WWTW breakdown	Partially or untreated sewage effluent (ecosystem and public health risk)
Pipe blockage or overflow	Sewage spill (ecosystem and public health risk)
Pump station breakdown & overflow	Sewage spill (ecosystem and public health risk)
Agricultural pollution incident	Ecosystem and public health risk
Inappropriate disposal of solid waste	Aesthetic, ecosystem and public health risk
Long-term degradation of land	Increased runoff-flooding, contamination
Densification/hardening of surfaces	Increased runoff-flooding, contamination
Increased informal settlements	Less water and sanitation capacity (ecosystem and public health risk), inappropriate greywater disposal, and less solid waste capacity and illegal dumping
Industrial pollution incident	Ecosystem and public health risk
Insufficient maintenance of municipal infrastructure	Sewage/stormwater leakage/intrusion (ecosystem and public health risk)
Leaking (i.e. due to ageing) and deteriorating infrastructure (new and old)	Sewage/stormwater leakage/intrusion (ecosystem and public health risk)

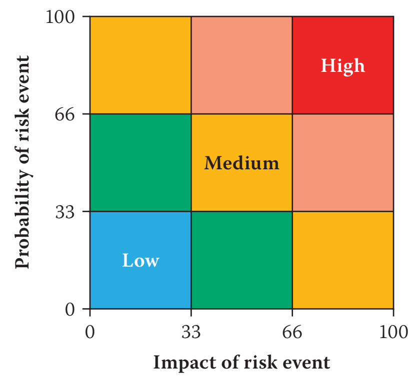

Figure 3 Methodology for obtaining the vulnerability score

Each inland environmental monitoring point or group of monitoring points (i.e. river reach) was assessed against the above risk events. The probability of the event happening and the potential impact of that risk were determined. A resultant risk or vulnerability score was obtained per river reach, as shown in Figure 3, where a high probability and high impact equate to a high vulnerability (red); and a low probability and low impact equate to a low vulnerability (blue).

Table 9 shows how the risk assessment works, with results for the Hout Bay River, Hout Bay catchment, as an example of what was carried out for all of the City's rivers and wetlands

Overall, the risk events which resulted in the highest vulnerability scores included:

- **Ongoing and chronic risk events:**
  - Deteriorating municipal infrastructure
  - Increased informal settlement
  - Insufficient maintenance of municipal infrastructure
- **Sporadic risk events:**
  - WWTW breakdown
  - Pipe blockage or overflow

PRIORITISATION OF CATCHMENTS, RIVERS AND WETLANDS

The catchment prioritisation exercise was intended to assist the City's management structures with the allocation of resources. The exercise provides guidance on a starting point for the allocation of resources. Ad hoc and emergency events that affect water quality will, however, still need to be attended to as the need arises.

The methodology, scores, weighting and input criteria for the prioritisation exercise were workshopped by the Project Steering Committee, Water Quality Sub-Committee and the Consultant Team.

Input criteria

The following criteria were used to prioritise catchments:

- Water usage (WU)
- Public health (PH)
- Ecosystem health (EH)
- Risk (R)
- Downstream impact (DI)[5] [rivers] or algae (A) [wetlands][6]
- Pollution load (PL)[7]

Initially "cost of intervention" and "time for implementation" were included as possible criteria, but after intensive debate at the various forums, these two criteria were withdrawn. These could, however, still be considered at a later stage to further prioritise catchments for management interventions.

Table 9 Risk assessment results for Hout Bay River, Hout Bay catchment

Catchment	Rivers and Wetlands	Reach/ Description	Monitoring point	Risk Event	Risk Consequence	Probablity	Impact (0/Low/ Med/High)	Priority/ Riskiness (0/Low/ Med/High)
Hout Bay	Hout Bay	Upper (Longkloof Rd)	dr04	WWTW breakdown	Raw sewage effluent – ecosystem and public health risk			0
				Pipe blockage or overflow	Sewage spill – public health risk			1 411
				P/S breakdown and overflow	Sewage spill – public health risk			0
				Agricultural pollution incident	Ecosystem health risk			850
				Inappropriate disposal of solid waste	Aesthetic, public health and/or ecosystem health risk			850
				Long-term degradation of the urban environment	Increased runoff-flooding, contamination			289
				Increased densification/ hardening of surfaces	Increased runoff-flooding, contamination			289
				Increased informal settlements	Less water and sanitation capacity – public health risk			1 411
				Industrial pollution incident	Ecosystem and public health risk			0
				Insufficient maintenance of infrastructure	Sewage/stormwater leakage – ecosystem and public health risk			1 411
				Leaking deteriorating infrastructure (new and old)	Sewage/stormwater leakage – ecosystem and public health risk			1 411
		Middle Victoria Rd	dr02	WWTW breakdown	Raw sewage effluent – ecosystem and public health risk			0
				Pipe blockage or overflow	Sewage spill – public health risk			4 150
				P/S breakdown and overflow	Sewage spill – public health risk			0
				Agricultural pollution incident	Ecosystem and public health risk			850
				Inappropriate disposal of solid waste	Aesthetic, public health and ecosystem health risk			4 150
				Long-term degradation of the urban environment	Increased runoff-flooding, contamination			1 411
				Increased densification/ hardening of surfaces	Increased runoff-flooding, contamination			1 411
				Increased informal settlements	Less water and sanitation capacity – public health risk			6 889
				Industrial pollution incident	Ecosystem and public health risk			0
				Insufficient maintenance of infrastructure	Sewage/stormwater leakage/intrusion – ecosystem and public health risk			4 150
				Leaking deteriorating infrastructure (new and old)	Sewage/stormwater leakag/intrusion – ecosystem and public health risk			4 150
		Lower Princess St & estuary	dr05 (bacto) dr01	WWTW breakdown	Raw sewage effluent – ecosystem and public health risk			0
				Pipe blockage or overflow	Sewage spill – public health risk			4 150
				P/S breakdown and overflow	Sewage spill – public health risk			6 889
				Agricultural pollution incident	Ecosystem and public health risk			0
				Inappropriate disposal of solid waste	Aesthetic, public health and ecosystem health risk			4 150
				Long-term degradation of the urban environment	Increased runoff-flooding, contamination			1 411
				Increased densification/ hardening of surfaces	Increased runoff-flooding, contamination			1 411
				Increased informal settlements	Less water and sanitation capacity – public health risk			6 889
				Industrial pollution incident	Ecosystem and public health risk			0
				Insufficient maintenance of infrastructure	Sewage/stormwater leakage/intrusion – ecosystem and public health risk			6 889
				Leaking deteriorating infrastructure (new and old)	Sewage/stormwater leakage/intrusion – ecosystem and public health risk			6 889

Point scoring system

A point scoring system was then developed for each of the criteria given above. The approach for the point allocation was as shown in Table 10.

Catchments (or river reaches) with good water quality, low levels of use, low risk of negative events, low pollution loads and low downstream impacts would have a lower priority for intervention than catchments (or river reaches) where all these attributes would score badly and thus achieve a higher score.

Each monitoring point or grouping of monitoring points (i.e. river reach) was assessed according to the above criteria and given a score between 1 and 5 as per Table 10.

The points allocated for Water Usage and Downstream Impact in each of the rivers and wetlands were derived from literature, and in consultation with the Project Steering Committee, Water Quality Sub-Committee and through the Consultant Team.

The points for Ecosystem Health, Public Health and Algae were derived from the Water Quality Results, whereas the points for Pollution Load were derived as follows:

- **Pollution Load = {Q (m^3/s)*(Ecosystem Health) (points allocated to the concentration (1–5))} + {Q (m^3/s)*(Public Health) (points allocated to the concentration (1–5))} + {Q (m^3/s)* (Sandiness of the area and/or propensity for solid waste)}**
  - **Q:** Flows for the various rivers and wetlands within the Cape Town municipal area were obtained from reports (Ninham Shand *et al* 1999), through personal communication with City officials (Wood, personal communication 2010) and from low-flow monitoring undertaken by the City in May 2002. Outstanding flows were further derived through inference of the available flows, the size of the relevant catchment and the land use in the catchment.
  - **Ecosystem Health and Public Health:** The points allocated for the Public Health and Ecosystem Health Water Quality concentration results (1–5), as described earlier in this paper, were utilised.
  - **Sandiness of the area/propensity for solid waste:** An allocation of 1 to 5 was given according to an area's sandiness and propensity for litter. A sandy area with high litter such as Guguletu obtained a score of 5 and an urban area with low litter such as Cape Town CBD obtained a score of 1.[8]

The final values obtained for the Pollution Load equation for each of the

Table 10 Points allocation for prioritisation exercise

	Water usage		Score
Water Usage (WU)	Full contact (formal and informal)	Intensive all yr	5
		Intensive part of yr	4
		Often used	3
		Seldom used	1
	Intermediate contact (formal and informal)	Intensive all yr	4
		Intensive part of yr	3
		Often used	2
		Seldom used	1
	Irrigation		3
	Industry		3
	Non-contact		1
Public & Ecosystem Health (PH & EH)	**Category**		**Score**
	Very Bad (mostly red)		5
	Bad (yellow/red)		4
	Intermediate (all colours)		3
	Good (blue/green)		2
	Very Good (mostly blue)		1
Risk (R) (Vulnerability Score)	**Category**		**Score**
	Very Bad (reds & oranges)		5
	Bad (orange & yellow)		4
	Intermediate (yellow/all colours)		3
	Good (green)		2
	Very Good (blue)		1
Downstream Impact (DI) (rivers only)	**Category**		**Score**
	Large impact	Large population, Blue Flag/intensively used beach, conservation area, tourism, recreational vlei, food source agriculture	5
	Medium to large impact	Fairly large population, beach, sea, vlei, some agriculture	4
	Medium impact	Medium population size, sea	3
	Low to medium impact	Small population	2
	Low impact	No downstream impact	1
Algae (A) (Microcystin Toxins)* (wetlands only)	**Category**		**Score**
	High toxin levels (>50 µg/l)		5
	Medium to high toxin levels (25–50 µg/l)		4
	Medium toxin levels (10–25 µg/l)		3
	Medium to low toxin levels (10–20 µg/l)		2
	Low toxin levels (<10 µg/l)		1
Pollution Load (PL)	**Category**		**Score**
	High pollution load		5
	Medium to high pollution load		4
	Medium pollution load		3
	Low to medium pollution load		2
	Low pollution load		1

* Microcystin toxin levels measured as a means to monitor the propensity of a wetland to develop harmful algal blooms (HABs)

Table 11 Pollution Load: Eerste/Kuils catchment

Catchment	Rivers/ Wetlands	Reach/ Description	Monitoring Pt	Low Flow (Q)	Concentration PH	Concentration EH	Sandiness/ Litter	Pollution Load	Pollution Load (1–5)
Eerste/ Kuils	Kuils	Upper u/s of Bottelary confluence	ek19	0.05	5	4	3	0.60	1
		Bellville WWTW discharge	ek09	0.7	5	4	3	8.40	2
		(Rietvlei Rd) u/s of Stellenbosch Arterial Rd	ek05						
		d/s of Baden Powell Bridge	ek08	1.2	4	4	5	15.60	4
		d/s of Zandtvliet discharge	ek11						
	Eerste	At N2 freeway-u/s of Kuils confluence	ek13	0.5	3	4	4	5.50	2
		Eerste River estuary	ek17	1.5	4	4	4	18.00	4
	Kleinvlei Canal		ek 15	0.01	5	4	4	0.13	1
	Moddergat-spruit		ek18	0.01	3	4	5	0.12	1
	Bottelary	At Amandel Road	ek03	0.043	3	3		0.26	1

Table 12 Weighting for prioritisation criteria

Criteria	Weighting
Public health (PH)	32%
Ecosystem health (EH)	32%
Water usage (WU)	8%
Downstream impact/algae (DI/A)	8%
Risk (R)	8%
Pollution load (PL)	12%

river reaches and wetlands ranged from 0 to 25. Values from 0 to 5 were then given a score of 1, values from 6 to 10 a score of 2, values from 11 to 15 a score of 3, values from 16 to 20 a score of 4, and values from 21 to 25 a score of 5 as the final input in the prioritisation exercise. As an example, Table 11 indicates the Pollution Load results for the rivers in the Eerste/ Kuils catchment.

- Points for risk were derived as described earlier in this paper.

Weighting of criteria

The final scores allocated for each of the criteria were then weighted as per Table 12 and added to obtain an overall prioritisation score for each of the river reaches and wetlands.

The prioritisation scores for each river reach and wetland within the various catchment areas were added and averaged to prioritise entire catchments.

Table 13 Full results for the prioritisation exercise, Hout Bay River

Catchment	Rivers/ Wetlands	Reach/ Description	Monitoring point	Prioritisation criteria			
				Criteria	Points	Weighting	Score
Hout Bay	Hout Bay	Upper (Longkloof Rd)	dr04	PH	1	32.0%	3
				EH	2	32.0%	6
				WU	1	8.0%	1
				DI	5	8.0%	4
				R	1	8.0%	1
				PL	1	12.0%	1
				Total			16
		Middle Victoria Rd	dr02	PH	5	32.0%	16
				EH	4	32.0%	13
				WU	3	8.0%	2
				DI	5	8.0%	4
				R	4	8.0%	3
				PL	1	12.0%	1
				Total			40
		Lower Princess St & estuary	dr05 (bacto only) dr01	PH	5	32.0%	16
				EH	4	32.0%	13
				WU	4	8.0%	3
				DI	5	8.0%	4
				R	5	8.0%	4
				PL	1	12.0%	1
				Total			41

Priority range – colour-coding

All the final prioritisation results were colour-coded in terms of four priority ranges:

- **Red:** High priority
- **Yellow:** Medium to high priority
- **Green:** Low to medium priority
- **Blue:** Low priority

These ranges were obtained by determining the difference between the highest and lowest priority scores in the prioritisation exercise and then dividing the number range into four equal 'bands'.

Prioritisation results

Table 13 is an example of the working and final scores for the prioritisation exercise for the Hout Bay River.

Overall prioritisation results for rivers were then obtained by averaging the scores for the various river reaches where applicable. In such cases it is important to view the river prioritisation exercise holistically. In the instance of the Hout Bay River, for example, it gets a low to medium priority in the overall river prioritisation exercise; while the middle to lower reaches are a high priority and the upper reaches are a very low priority.

By way of example, the prioritisation results for the vleis/wetlands in the Cape Town municipal area are shown in Table 14.

Prioritisation: way forward

The prioritisation results are based on a multi-criteria model using several inputs to determine those rivers, wetlands and catchments that should receive priority attention for the proposed interventions.

Table 14 Prioritisation results for vleis/wetlands

Catchment	Vlei/Wetland	Score	Priority
Zeekoe	Zeekoevlei	49	High
Diep	Milnerton Lagoon	47	
Diep	Rietvlei	40	Medium to High
Zeekoe	Rondevlei	40	
Noordhoek	Wildevoëlvlei	36	
Diep	Zoarvlei	34	Low to Medium
Sand River	Die Oog	31	
Sand River	Little Princessvlei	30	
Sand River	Langevlei	29	
Zeekoe	Princessvlei	26	Low
Sand River	Zandvlei	25	
Sand River	Westlake Wetland	24	
South Peninsula	Glencairnvlei	19	

The prioritisation model, although rigorous in its composition, can easily be expanded to include new criteria, or should a sensitivity analysis be required (to answer "what if?" questions).

DETERMINATION OF ADDITIONAL RESOURCES TO MANAGE POLLUTION IN STORMWATER AND RIVER SYSTEMS

The methods discussed above culminated in the determination of interventions, implementation mechanisms, resources and costs required by the City to reduce the burden of pollution in the inland water systems of the Cape Town municipal area. Proactive, sustainable measures were recommended as far as possible and were listed generally and per catchment.

It was concluded that R675.3 million in capital or once-off expenditure and R277.15 million in operational expenditure are required as additional resources to manage pollution in stormwater and river systems.

General resources applicable throughout most catchments were discussed under the following headings:

- Institutional issues
- Technical issues

Table 15 Summary of general recommendations (extract)

Recommendation	Duration	Benefit	Budget implication (R mill)		Priority: T, H, M, L
Description			Capex	Opex	
Approach to determining resources for stormwater and river systems					
Allocate more budget to and prioritise proactive measures	Permanent	More efficient allocation of resources for sustainable water quality improvement; reduces risk in longer term	–	–	T
Adopt "prevention is better than cure" as guiding principle	Permanent	Reduction in costly, after-the-event solutions ensuring sustainable water quality improvement	–	–	T
Institutional issues					
Establish inter-departmental water quality forum at senior level	Short-term to permanent	Consolidation of efforts, roles and responsibilities and improved knowledge sharing	–	–	H
Establish consolidated pollution task team	Short-term to permanent	Optimisation of resources to address pollution and avoidance of unintended consequences	–	–	H
Technical issues					
Use proactive asset management approach, including audits and inspections for timeous replacement and upgrading of infrastructure	Permanent	Greater budget, effort and energy efficiency	–	–	T
Establish programme for eradication of cross-connections, including documentation on GIS	Short- to medium-term	Improved knowledge and records of cross-connections, and therefore improved management response and water quality	R10.0	R5.0	H

Table 16 Summary of catchment-specific recommendations (extract)

Recommendation		Duration	Budget implication (R mill)		Priority 1 – 10 (H – L)
Number	Description		Capex	Opex	
4.6.1	**Diep River catchment: catchment priority: 1**				
•	The recommendations for the Diep River catchment should be read in conjunction with the report for project 233C/2008/09 (*Improving the quality of the stormwater discharging into the Diep River – Milnerton*), being compiled by iCE Group consulting engineers.				
•	Appoint additional pollution control inspector for each of five high-priority river reaches where intensive intervention programmes are to be launched	Medium-term	–	R0.5	1A
•	Appoint project manager for each of five identified priority areas to drive integrated improvement programme	Long-term (to move to next priority)	–	R0.75	1A
4.6.1.1	**Mosselbank River: priority level: high**				
•	Further improvements to Kraaifontein WWTW, including sludge management, phosphate removal, duplicate disinfection unit	Permanent	R15.0	R2.0	2
•	Implement in Scottsville area in particular findings from a report *Advice on the elimination of ingress of stormwater and infiltration of groundwater into the sewer system*	Medium-term	R1.0	–	3
•	Active campaign to reduce agricultural pollution	Medium-term	–	–	6
•	Removal of alien vegetation (including aquatic) and restore river banks	Long-term	R1.0	R0.5	10
•	Monitor 15 sewage pump stations for spillage and pollution	Permanent	–	–	5
•	Expand solid waste services to areas not currently serviced (e.g. water courses) and increase street sweeping	Permanent	–	–	4
4.6.1.2	**Diep River: priority level: high**				
•	Further upgrade to Potsdam WWTW, including duplicate disinfection unit	Permanent	R5.0	R1.0	2
•	Collaboration with Swartland Municipality and DWA	Medium-term	–	–	–
•	Provide ablution and car-washing facilities at Bayside Mall taxi rank	Medium-term	R1.0	R0.1	1B
•	Track pollution from Montague Gardens industrial area	Short-term	–	–	7
•	Monitor and resolve water quality from Theo Marais Park	Short-term	R0.5	–	3
•	Active campaign to reduce agricultural pollution, including runoff from Milnerton stables	Short-term	–	–	6
•	Monitor nine sewage pump stations for spillage and pollution	Permanent	–	–	5

- Planning and policy
- Communication and liaison

Table 15 is an extract of the summary table used to list general recommendations, indicating the duration, benefit and budget implications for each recommendation (an action and comments column have been omitted for the sake of clarity).

In addition to the general recommendations, the resources required to manage water pollution per catchment were discussed where catchment-specific details were necessary.

Table 16 is an extract of the summary table as used to list the catchment-specific recommendations. The table is in order of priority, as per the prioritisation exercise.

CONCLUSIONS

This paper discussed the inputs towards determining resources to manage inland water pollution in the City of Cape Town.

In the more complex realm of modern municipal engineering (where many of the issues are so-called "soft" in nature, and the problems and solutions are not straightforward) the methods discussed were instrumental in creating a holistic overview of the state of the rivers and wetlands in the City of Cape Town, highlighting the complexity of the problem and assisting to plot a way forward to provide proactive, sustainable measures for the management of water pollution.

The main obstacle was the time-consuming nature of some of the methods. The colour-coding of data and the compilation of inputs from the stakeholder workshops were particularly lengthy.

Another minor obstacle was agreeing on the points allocated for each of the prioritisation criteria. There was the later realisation, however, that the system was fairly robust and slight deviations in these points made little or no difference to the ultimate level of prioritisation of the particular river or wetland.

Some novel points included: the colour-coding exercise which helped to convert vast quantities of hard, scientific data into something meaningful and tangible to all involved; the risk assessment and prioritisation exercise to assist with the allocation of resources; getting inputs from a vast number and array of stakeholders; and the ultimate allotment of actions to City Managers for each recommendation.

In all, the methods discussed provided a significant contribution towards the quest to improve water quality in the City of Cape Town.

ACKNOWLEDGEMENTS

We wish to thank the following persons for their valuable contributions throughout this project:

- Mr Abdulla Parker for his leadership, patience, unwavering commitment to the cause and passion to make a difference.
- Mr Barry Wood for his invaluable expertise, guidance and support.
- Ms Candice Haskins for her commitment and insights into water quality in the City of Cape Town.
- Ms Jeanette Kane for her unfailing willingness to help with GIS expertise.
- Mr Johan Massyn for his willingness to share his local knowledge and unique personal experiences.
- Mr Richard Kotze for his reliability and for sharing his passion and knowledge.

Many thanks to the project team for their time, commitment to improving water quality, enthusiasm, expertise and inspiring insights:

- Dr Jo Barnes
- Ms Lyn Viviers
- Mr Simon Nicks
- Ms Toni Belcher

Sincere thanks also go to members of the Steering Committee and the Water Quality Sub-Committee, and workshop participants.

NOTES

1 The Department of Water Affairs and Forestry (DWAF) has since become known as the Department of Water Affairs (DWA)

2 Taken over time

3 It is important to note that while some of the City's rivers and water bodies are utilised for formal full and intermediate contact recreation activities (e.g. Zandvlei, Milnerton Lagoon, Zeekoevlei and Rietvlei), the majority of systems are used on a more informal basis.

4 This is an indirect pollution source, as pollution is not attenuated in canals as well as it is in natural rivers, therefore resulting in higher pollution levels. Furthermore, canals are not as aesthetically pleasing as natural river systems, and may therefore induce less considerate behaviour towards their preservation.

5 E.g. Blue Flag beaches, nature reserves, human habitation, sensitive environment, tourism hotspot etc, downstream of the water quality monitoring point.

6 While most wetlands do not have a downstream impact per se, their algal content (not measured in the rivers) had to be taken into account as it is an indication of the propensity for a vlei/wetland to develop harmful algal blooms (HAB) and therefore is significant in terms of public health. A distinction was therefore made between rivers and wetlands with these criteria.

7 It should be noted that the determination of the pollution load did not form part of the original scope of works and was later included as an ad hoc investigation, for which provision existed in the project budget.

8 Relevant data was obtained from Mr Barry Wood (CSRM, City of Cape Town).

REFERENCES

Belcher, A (Aquatic water scientist) 2010. Personal communication.

City of Cape Town (2008) *City of Cape Town State of the Environment Report 2007/8*. Cape Town: City of Cape Town, Environmental Resource Management Department.

DWAF (Department of Water Affairs and Forestry) (1996a). *South African Water Quality Guidelines,* 2nd edition. Vol. 2. Recreational uses. Pretoria: CSIR Environmental Services.

DWAF (Department of Water Affairs and Forestry) (1996b). *South African Water Quality Guidelines,* 2nd edition. Vol. 7. Aquatic ecosystems. Pretoria: CSIR Environmental Services.

Haskins, C (City of Cape Town) 2010. Personal communication.

Jooste, S & Rossouw, J N 2002. *Hazard-based water quality ecospecs for the ecological reserve in fresh surface water resources.* Report No N/0000/REQ0000, Pretoria: Department of Water Affairs and Forestry, Institute for Water Quality Studies.

Ninham Shand, Southern Waters, Cape Metropolitan Council 1999. *Kuils/Eerste River System evaluation of nutrient flux downstream of Bellville Wastewater Treatment Works.* Report No 3028/8851, Cape Town.

Wood, B (City of Cape Town) 2010. Personal communication.

World Health Organisation (WHO) 2003. *Guidelines for Safe Recreational Water Environments*, Volume 1, Coastal and Fresh Waters. Geneva.