The Management of Urban Impoundments in South Africa

VOLUME I • STATUS QUO REPORT

HNS Wiechers, MJ Freeman and MR Howard

THE MANAGEMENT OF URBAN IMPOUNDMENTS IN SOUTH AFRICA

VOLUME 1

STATUS QUO REPORT

by

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In association with:

Water & Waste Directorate
Greater Johannesburg
Transitional Metropolitan Council

WRC Report No TT 77/96
November 1996

Obtainable from:

WATER RESEARCH COMMISSION
PO BOX 824
PRETORIA
0001

The publication of this report emanates from a project entitled :

Research on the Management of Urban Impoundments (WRC Project No. K5/633)

ISBN 1 86845 248 4
Printed in the Republic of South Africa
Beria Printers

EXECUTIVE SUMMARY

This status quo report provides an overview of current practice with regard to the management of the water quality of urban impoundments in South Africa. The document is an interim research report. It has been published by the Water Research Commission in the belief that the information collected to date by the project team will be of immediate value to urban impoundment managers.

In the document, a register of South African urban impoundments and the results of a detailed analysis of environmental problems experienced in ten selected urban impoundments are presented. The document is structured as a guide which allows users to identify other impoundments with similar characteristics to their own and which also allows users to evaluate specific management strategies which have been implemented in ten South African urban impoundments in order to address water quality related problems.

The on-going research is investigating and evaluating various management strategies for urban impoundments, derived both locally and from overseas. These strategies can be placed into one of the following three categories:

- catchment management;
- pre-impoundment management; and
- in-lake control.

Urban impoundment management requires an **integrated approach** encompassing facets of all three of the above categories. The research project will ultimately provide guidelines for urban impoundment managers to develop unique integrated management plans for their own urban impoundments. These guidelines will be published during 1997, as a companion Volume 2 document to this report. For further information, please contact the authors.

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1. INTRODUCTION

This status quo report provides an overview of current practice with regard to the management of the water quality of urban impoundments in South Africa. It serves as an introductory document for a Water Research Commission sponsored research project aimed at producing guidelines for the management of urban impoundments. The management guidelines themselves will be available in 1997 after completion of the project, but the information collected and evaluated as part of the first phases of the project, and contained in this document, is of value to those people in the field who may already be grappling with pollution problems in their impoundments.

The document is directed particularly at those persons in local authorities whose responsibility it is to manage the water bodies in their areas. It is the experience of the authors that this responsibility is frequently located in different departments (e.g. Engineering, Parks, Health) depending on the local authority concerned, or the responsibility may even straddle various departments. The document will also prove valuable to recreational users of these water bodies and concerned individuals who may reside close to or within the catchment of an urban impoundment.

The major aims of this report are threefold:

- to present a register of urban impoundments found in the main cities and towns of South Africa, which contains basic information about each impoundment and can be used as a quick reference;

- to identify the most significant and prevalent environmental problems experienced in South African urban impoundments and how these affect the users thereof; and

- to present a range of solutions which have been implemented in South Africa by local authorities to combat water quality problems.

The document is intended to be used as a manual which allows responsible persons in local authorities, or concerned individuals, to access and exchange information about other impoundments which may be useful in addressing problems experienced in their own water bodies.

The report is divided into a number of sections:

- Background to the research project and definition of an urban impoundment (Sections 2 & 3).
- Guide to using the register of urban impoundments (Sections 4 & 5).
- Common problems associated with urban impoundments in South Africa (Section 6).
- Guiding principles for managing urban impoundments (Section 7).
- Guide to using a summarised analysis of information on ten selected impoundments (Sections 8 & 9).
- Appendix A : A register of urban impoundments.
- Appendix B : A review of existing information on the management of ten selected urban impoundments.

2. BACKGROUND

Local authorities provide urban impoundments primarily for recreation and storm-water control, as well as for a psychological escape for city dwellers from the pressures of modern urban life. In addition, urban water bodies are increasingly being developed because they enhance the value of real estate, houses, office blocks and commercial developments in their immediate vicinity.

Unfortunately, urban impoundments are fed predominantly by storm-water runoff from the urban catchments in which they are situated and urban runoff is usually polluted. Impoundments thus serve as reservoirs which intercept this pollution and the net effect can be:

- a silted-up impoundment;
- highly polluted water;
- eutrophication and the associated growth of undesirable algae and water weeds;
- health risks due to faecal pollution; and
- aesthetic problems such as unsightly algal scums, floating debris and malodours.

These problems can result in a public asset becoming a liability and, more seriously, a health risk.

Although urban impoundments have existed in South African cities and towns for a long time, and their numbers are increasing, proper and effective management has received little attention. Reasons for this include the lack of understanding within local authorities of the origin of and potential solutions to environmental problems, restricted local authority budgets, the non-optimal siting of impoundments with respect to water pollution and the insidious increase in pollution loads with increasing population density.

3. THE DEFINITION OF AN URBAN IMPOUNDMENT

For practical purposes, it was necessary to define an urban impoundment so as to limit the number of water bodies included in the research project. However, it should be stressed that much of the information contained in this report can be equally collected and applied to impoundments or water bodies which do not fulfil the criteria set in this study for the definition of an urban impoundment. These criteria were:

- a surface area greater than 4 hectares;
- a volume greater than 50 000 m^3;
- a catchment in a predominantly urban area; and
- accessibility by the general public.

No maximum size was set for an impoundment, but large bulk storage and water supply dams located near to or within urban areas were excluded from the research. Although many water bodies fulfilling the criteria set out above are man-made impoundments, natural water bodies which are now surrounded by urban areas but which meet the criteria are included. These comprise pans (located mainly in Gauteng) and vleis (located in the Western Cape). The importance of accessibility by the public is that environmental problems with urban impoundments usually manifest themselves as a result of human contact with the water body and its surrounds - i.e. from recreational use.

4. REGISTER OF URBAN IMPOUNDMENTS

The register of urban impoundments compiled as part of the first phase of the research project is shown in Appendix A. All the metropolitan areas and the usually recognised major cities in South Africa are covered in the register. The larger country towns, however, such as Pietersburg, I elspruit and Welkom are not included.

The register contains basic information about each impoundment including:

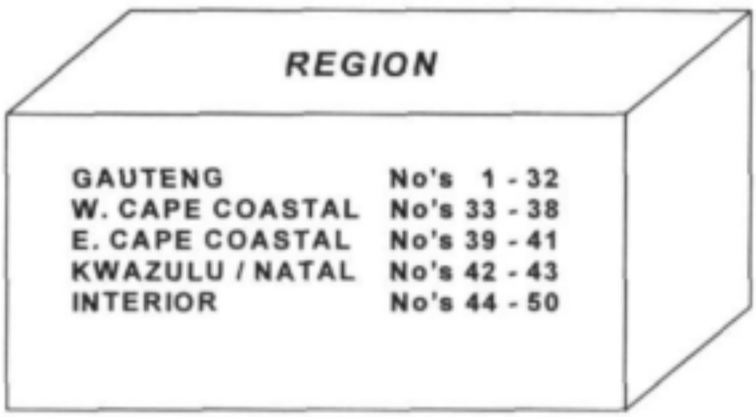
- the impoundment name and its location;
- the local authority area and its controlling authority;
- whether the water body is a man-made impoundment or a natural pan or vlei;
- its water surface area and the volume of water contained;
- the land use in the immediate catchment area;
- the main uses of the impoundment; and
- the amount of data (especially as regards water quality) available about the impoundment.

For the register to be of value to those concerned with the management of urban impoundments, a guide to using the register is presented in the following section. The guide enables users to identify water bodies or impoundments with similar characteristics to their own. A list of contact telephone numbers for information about each impoundment contained in the register is given in Appendix A.

5. GUIDE TO USING THE REGISTER OF URBAN IMPOUNDMENTS

The register of urban impoundments contains information on 50 water bodies (their locations are shown in Figures 1 to 3 on pages 11-13). These water bodies have been numbered in the register to facilitate identification.

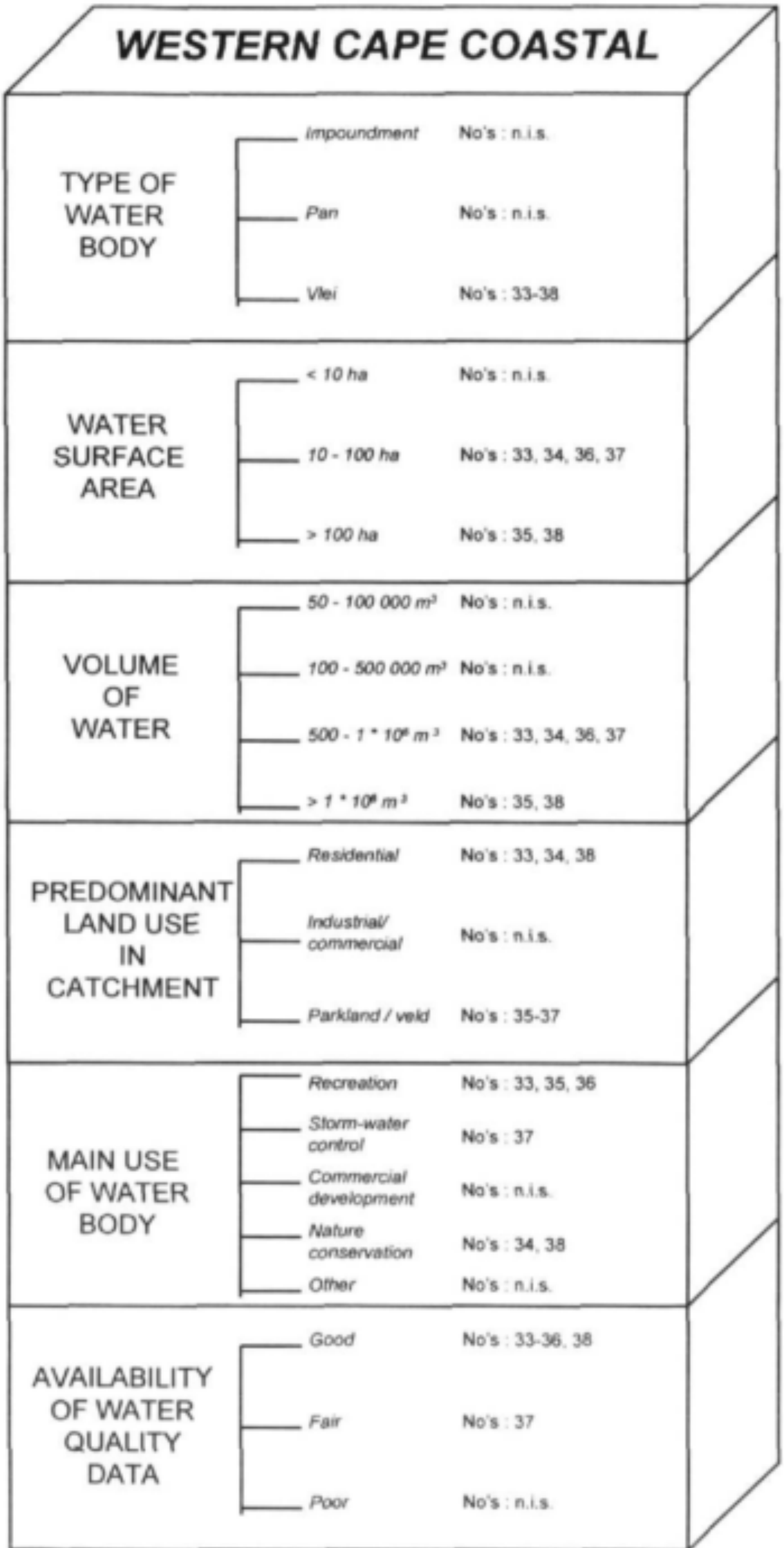
A reader of this document can use the block diagrams on the following pages to identify impoundment numbers in the register which have similar characteristics to ones in which the reader has an interest. The first block diagram below lists the impoundment numbers by region of which there are five - Gauteng, Western Cape Coastal, Eastern Cape Coastal, KwaZulu/Natal and Interior. The reader may then move to the block diagram for the region in which she/he has an interest and identify impoundment numbers which have further characteristics of similarity. In this way, the reader may quickly move to the impoundment numbers in the register which are of most value.



GAUTENG

TYPE OF WATER BODY	*Impoundment*	No's : 1 - 6, 8, 9, 12, 13, 15 - 19, 25 - 30
	Pan	No's : 7, 10, 11, 14, 20 - 24, 31, 32
	Vlei	No's : n.i.s.
WATER SURFACE AREA	*< 10 ha*	No's : 2 - 6, 8, 29
	10 - 100 ha	No's : 7, 9 - 28, 30, 31
	> 100 ha	No's : 1, 32
VOLUME OF WATER	*50 - 100 000 m^3*	No's : 3, 20, 21, 23
	100 - 500 000 m^3	No's : 2, 4-6, 8, 10, 12, 16, 17, 22, 25, 29
	*500 - 1 * 10^6 m^3*	No's : 9, 14, 15, 18, 19, 24, 28
	*> 1 * 10^6 m^3*	No's : 1, 7, 11, 13, 26, 27, 30-32
PREDOMINANT LAND USE IN CATCHMENT	*Residential*	No's : 1-3, 5, 13, 15-21, 23-25, 32
	Industrial/ commercial	No's : 6, 7, 10-12, 14
	Parkland / veld	No's : 4, 9, 22, 26-31
MAIN USE OF WATER BODY	*Recreation*	No's : 3-7, 9-13, 15, 16, 19, 22-24, 26, 28, 32
	Storm-water control	No's : 14, 17, 18, 25, 29-31
	Commercial development	No's : 2, 8, 21
	Nature conservation	No's : 20
	Other	No's : 1, 27
AVAILABILITY OF WATER QUALITY DATA	*Good*	No's : 1-8, 11, 15-24, 26-27, 29-31
	Fair	No's : 9, 12-14, 32
	Poor	No's : 10, 25, 28

n.i.s. = none included in study



n.i.s. = none included in study

EASTERN CAPE COASTAL

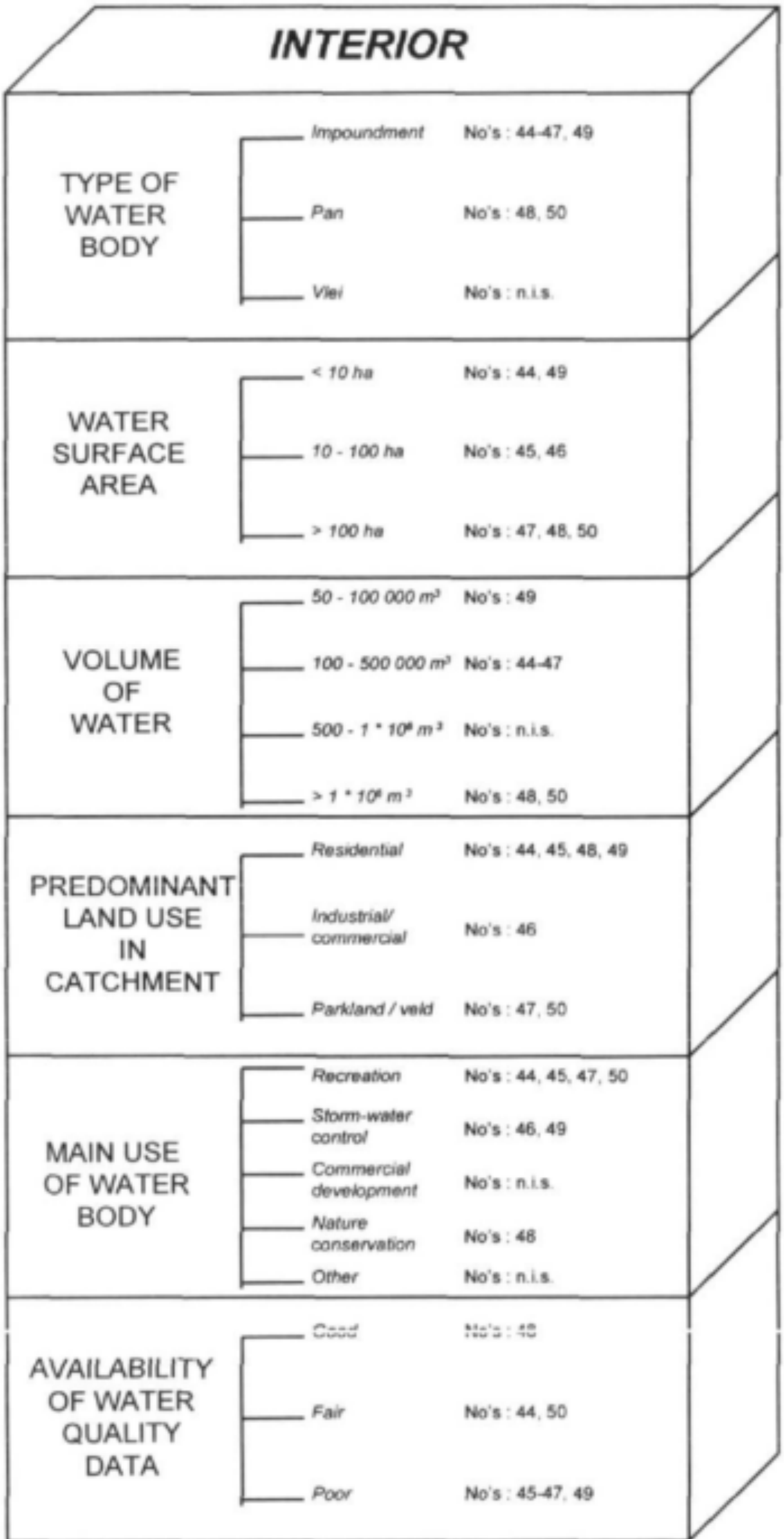
TYPE OF WATER BODY	*Impoundment*	No's : 41
	Pan	No's : 39, 40
	Vlei	No's : n.i.s.
WATER SURFACE AREA	*< 10 ha*	No's : 41
	10 - 100 ha	No's : 39
	> 100 ha	No's : 40
VOLUME OF WATER	*50 - 100 000 m³*	No's : n.i.s.
	100 - 500 000 m³	No's : 39, 41
	*500 - 1 * 10⁶ m³*	No's : n.i.s.
	*> 1 * 10⁶ m³*	No's : 40
PREDOMINANT LAND USE IN CATCHMENT	*Residential*	No's : 39, 40
	Industrial/ commercial	No's : n.i.s.
	Parkland / veld	No's : 41
MAIN USE OF WATER BODY	*Recreation*	No's : 39
	Storm-water control	No's : 41
	Commercial development	No's : n.i.s.
	Nature conservation	No's : n.i.s.
	Other	No's : 40
AVAILABILITY OF WATER QUALITY DATA	*Good*	No's : 39
	Fair	No's : n.i.s
	Poor	No's : 40, 41

n.i.s. = none included in study

KWAZULU / NATAL

TYPE OF WATER BODY	*Impoundment*	No's : 42, 43
	Pan	No's : n.i.s.
	Vlei	No's : n.i.s.
WATER SURFACE AREA	*< 10 ha*	No's : 42
	10 - 100 ha	No's : 43
	> 100 ha	No's : n.i.s.
VOLUME OF WATER	*50 - 100 000 m^3*	No's : n.i.s.
	100 - 500 000 m^3	No's : 42, 43
	*500 - 1 * 10^6 m^3*	No's : n.i.s.
	*> 1 * 10^6 m^3*	No's : n.i.s.
PREDOMINANT LAND USE IN CATCHMENT	*Residential*	No's : 42, 43
	Industrial/ commercial	No's : n.i.s.
	Parkland / veld	No's : n.i.s.
MAIN USE OF WATER BODY	*Recreation*	No's : 42, 43
	Storm-water control	No's : n.i.s.
	Commercial development	No's : n.i.s.
	Nature conservation	No's : n.i.s.
	Other	No's : n.i.s.
AVAILABILITY OF WATER QUALITY DATA	*Good*	No's : 43
	Fair	No's : n.i.s.
	Poor	No's : 42

n.i.s. = none included in study



n.i.s. = none included in study

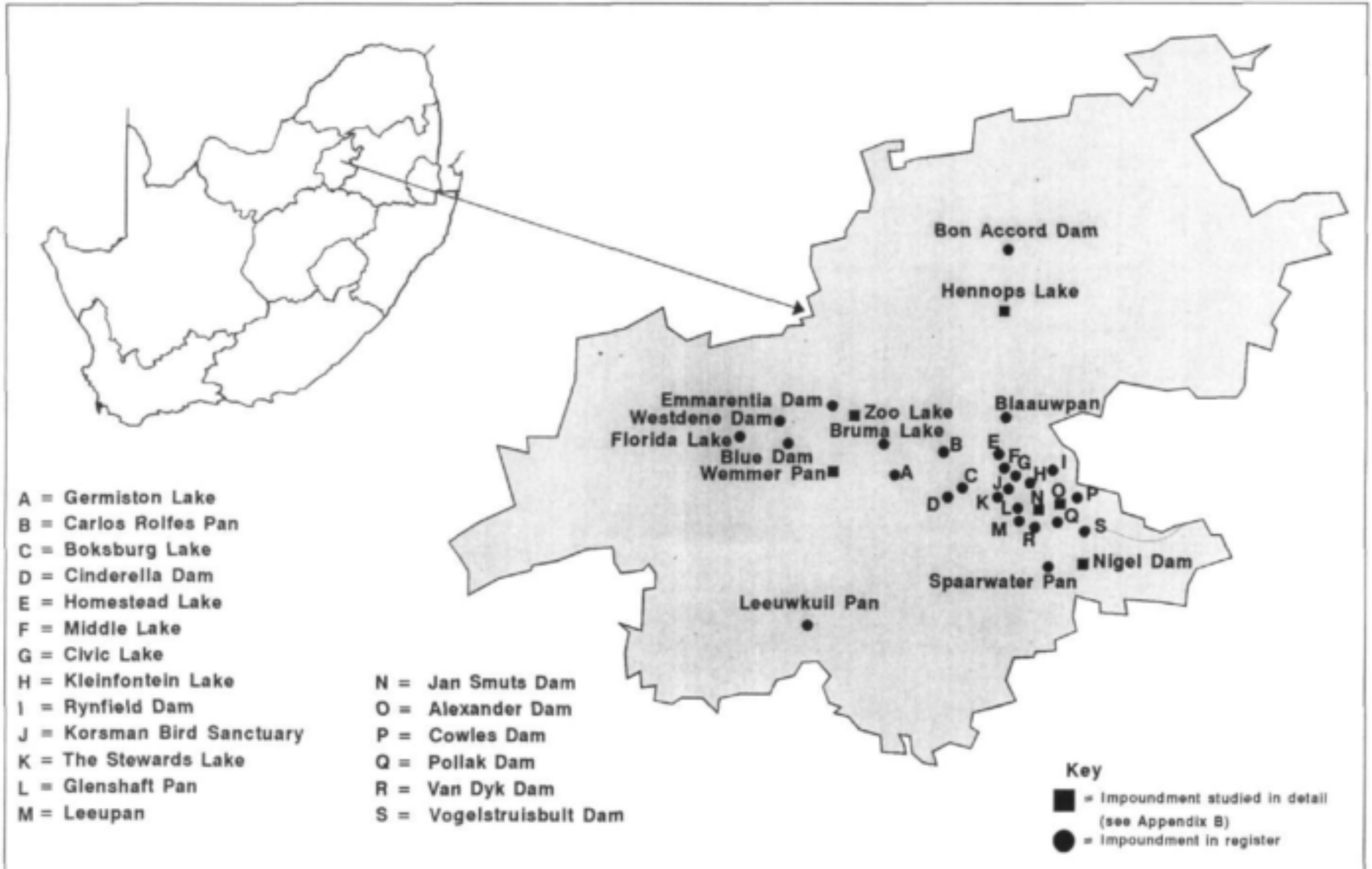


Figure 1 : Location of urban impoundments in Gauteng

Figure 2: Location of urban impoundments in the Western Cape Coastal Area

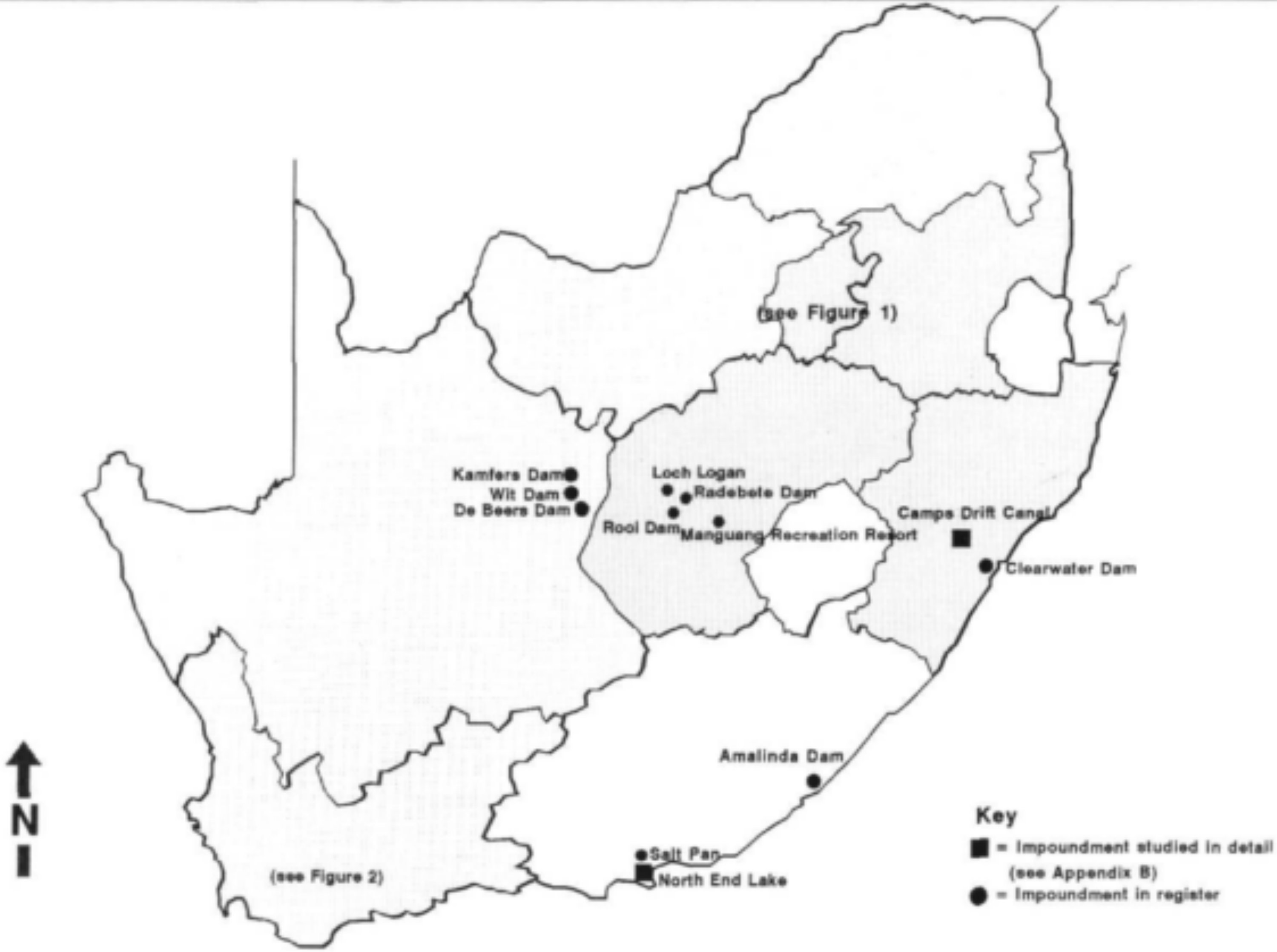


Figure 3 : Location of urban impoundments in the Eastern Cape Coastal Area, KwaZulu/Natal and Interior

6. COMMON PROBLEMS ASSOCIATED WITH URBAN IMPOUNDMENTS IN SOUTH AFRICA

In broad terms, a number of problem areas can be readily identified as occurring in urban impoundments in South Africa:

- eutrophication / nutrient enrichment resulting in excessive plant populations;
- sedimentation / siltation;
- bacteriological / faecal contamination;
- aesthetics; and
- once-off catastrophic pollution events.

The complex nature of water sources for urban impoundments typically results in the occurrence of a combination of the above problems.

Eutrophication / nutrient enrichment

Eutrophication has been defined as the excessive supply of nutrients to water supplies, principally as a result of man's activities. In most lakes and dams, plant production is regulated by the availability of nutrients. Should the level of nutrients within lakes and dams become excessive, as they frequently do in urban areas, large growths of plants (including algae) can be expected. These result in problems for users of lake waters.

Sedimentation / siltation

Sediments in rivers and dams are derived from a number of sources, such as:

- erosion (both natural weathering and man-induced);
- poor agricultural practices;
- construction; and
- urban activities.

Within the context of an urban impoundment, it can be expected that the land use within its catchment will determine the volume of sediment originating from each of these sources.

The results of an increase in sediment include:

- a reduction in the depth of water as layers of sediment build up and suspended sediment drops out;
- the smothering of submerged plants, thereby affecting the ecological productivity of the lake;
- a reduction in flood attenuation leading to increased inundation during high rainfall events; and
- the trapping of nutrients and organisms in the sediment, thereby acting as a sink from which resolubilisation and resuspension of organics can occur given the appropriate conditions.

Bacteriological / faecal contamination

Bacteriological / faecal contamination of urban impoundments can occur as a result of a number of causes, for example:

- waste-water treatment works effluent;
- direct faecal contamination from humans and animals;
- blocked and overflowing sewers and drains; and
- naturally occurring bacterial populations proliferating as a result of the impact of man's activities.

The prime influence of increasing numbers of bacteria in urban impoundments is on human health, usually detected and quantified by the presence of indicator species, such as *E. coli*. Use of the water for drinking, recreation and fishing can be negatively affected if bacterial populations increase to above a desirable or safe level.

Aesthetics

Aesthetic problems in urban impoundments are usually secondary manifestations of other underlying problems. Such aesthetic problems include:

- smells as a result of decaying algae and the release of hydrogen sulphide from bottom sediments, blocked and overflowing sewers and dead fish; and
- visual changes as a result of litter, dense mats of algal scums and suspended sediment.

Once-off catastrophic pollution events

Once-off catastrophic pollution events are placed in a separate category because they are usually single events which require treatment on an individual basis. The types of contaminants involved can be highly variable.

7. GUIDING PRINCIPLES FOR MANAGING TYPICAL URBAN IMPOUNDMENT PROBLEMS IN SOUTH AFRICA

What ultimately results in an urban impoundment in terms of water quality related issues is chiefly the result of processes and activities taking place upstream. The cycle of contamination of water systems starts with pollution generation. This could, for example, include effluent from a factory, fertiliser washoff, or diffuse pollution loads from an unserviced township area. After generation, a contaminant is transported into the receiving stream. This could be via a pipe, or by diffuse seepage from a large area. Once in the receiving stream, the contaminant flows within the stream until it enters the impoundment. There are therefore, three main areas in which water quality related problems can be addressed. These are :

- catchment management (watershed control);
- pre-impoundment treatment; and
- in-lake treatment.

Catchment Management (Watershed Control)

Problems which manifest themselves in urban impoundments are ideally tackled at this first level through the approach of integrated catchment management. This philosophy is current practice internationally, and is presently being implemented in South Africa by the Department of Water Affairs & Forestry. In essence the focus of catchment management is on addressing point and non-point sources of pollution. The integrated approach to catchment management is depicted in Figure 4.

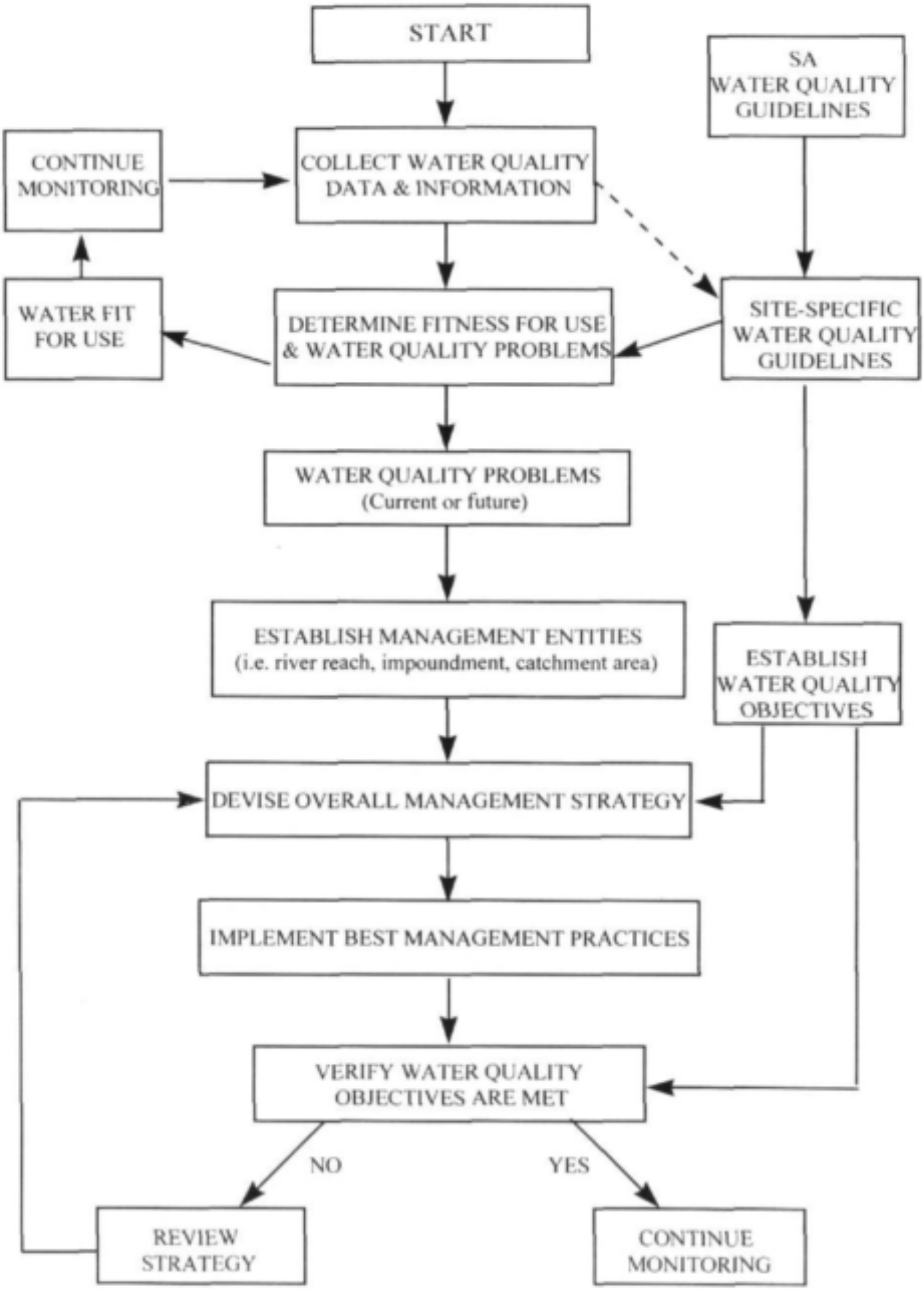


Figure 4: Integrated approach to catchment management

Pre-impoundment Management

The principle of pre-impoundment management is that poor quality water is treated in some way before being allowed into an impoundment.

In-lake Control

In-lake management strategies must be viewed as the treatment of the symptoms in most instances, rather than the causes of urban impoundment problems, which are best addressed at catchment level.

A diagram depicting the philosophy behind the in-lake management of urban impoundments is shown in Figure 5.

The research currently being undertaken by the authors is investigating and evaluating various management strategies (derived both locally and from overseas), which can be placed within one of the three approaches described above and which can be utilised to address common problems experienced in South African urban impoundments.

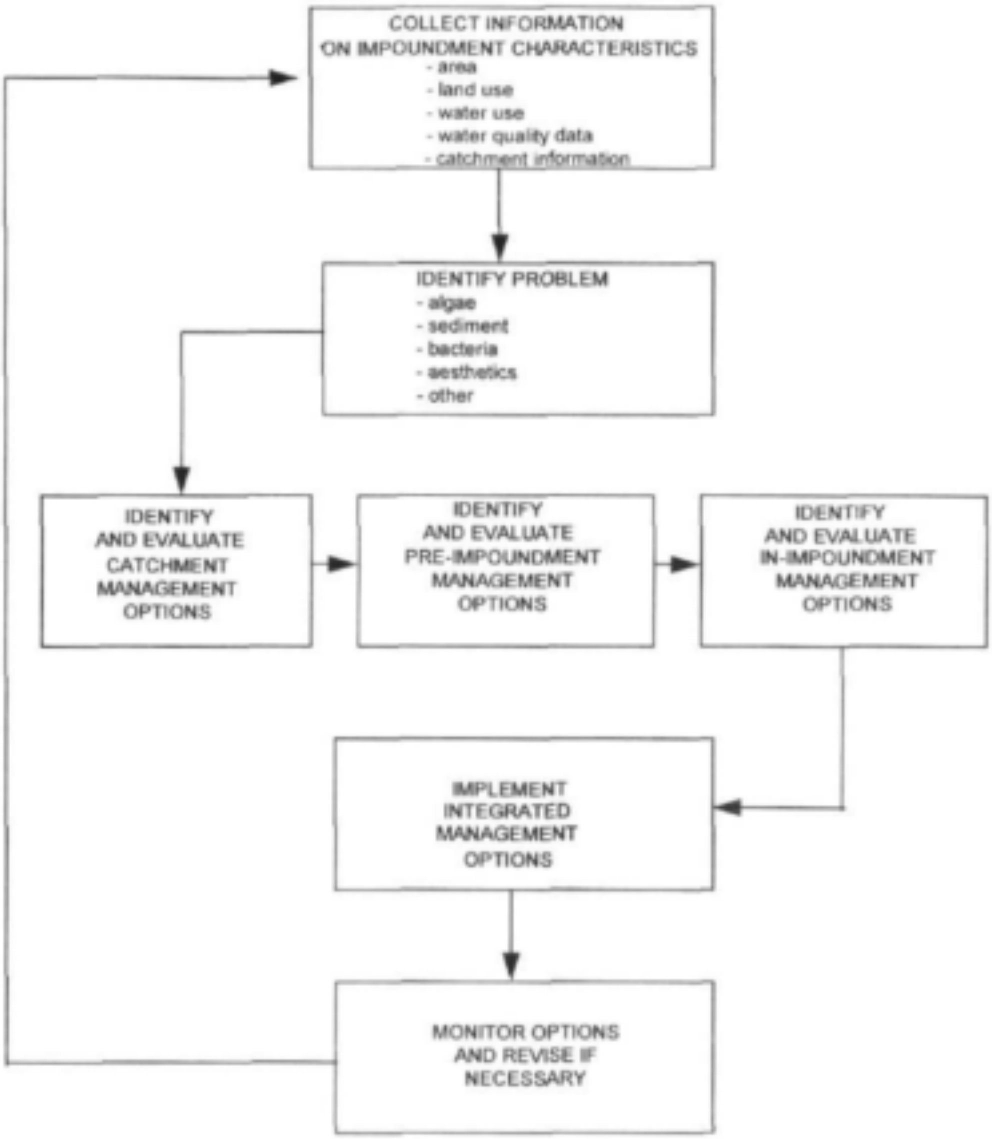


Figure 5 : The management of urban impoundments

8. DETAILED ANALYSIS OF TEN SELECTED URBAN IMPOUNDMENTS IN SOUTH AFRICA

As part of the investigation carried out by the authors, ten impoundments from different parts of South Africa were investigated in detail, in order to acquire a more in-depth knowledge of the common problems being experienced in our urban impoundments, and to identify what solutions have been implemented by local authorities to combat these problems. A comprehensive report on this part of the investigation is given in Appendix B. The ten impoundments studied in detail were:

- **A** Jan Smuts Dam, Brakpan
- **B** Princess Vlei, Cape Town
- **C** Zeekoevlei, Cape Town
- **D** Zoo Lake, Johannesburg
- **E** Wemmer Pan, Johannesburg
- **F** Nigel Dam, Nigel
- **G** Camps Drift Canal, Pietermaritzburg
- **H** North End Lake, Port Elizabeth
- **I** Alexander Dam, Springs
- **J** Hennops Lake, Centurion

A user guide is presented in Figure 6. The guide identifies which of the ten impoundments investigated in detail experiences commonly occurring urban impoundment problems. The reader may use the guide in conjunction with Section 9 which contains a summary of readily available information collected on each of the ten impoundments (including location, impoundment characteristics, summarised water quality data, a description of the common water quality problems experienced and a description of management strategies in place). Appendix B contains more detailed information on each of the ten impoundments. Ideally, more detailed information concerning catchment characteristics should be collected in order to assist with the effective management of urban impoundments.

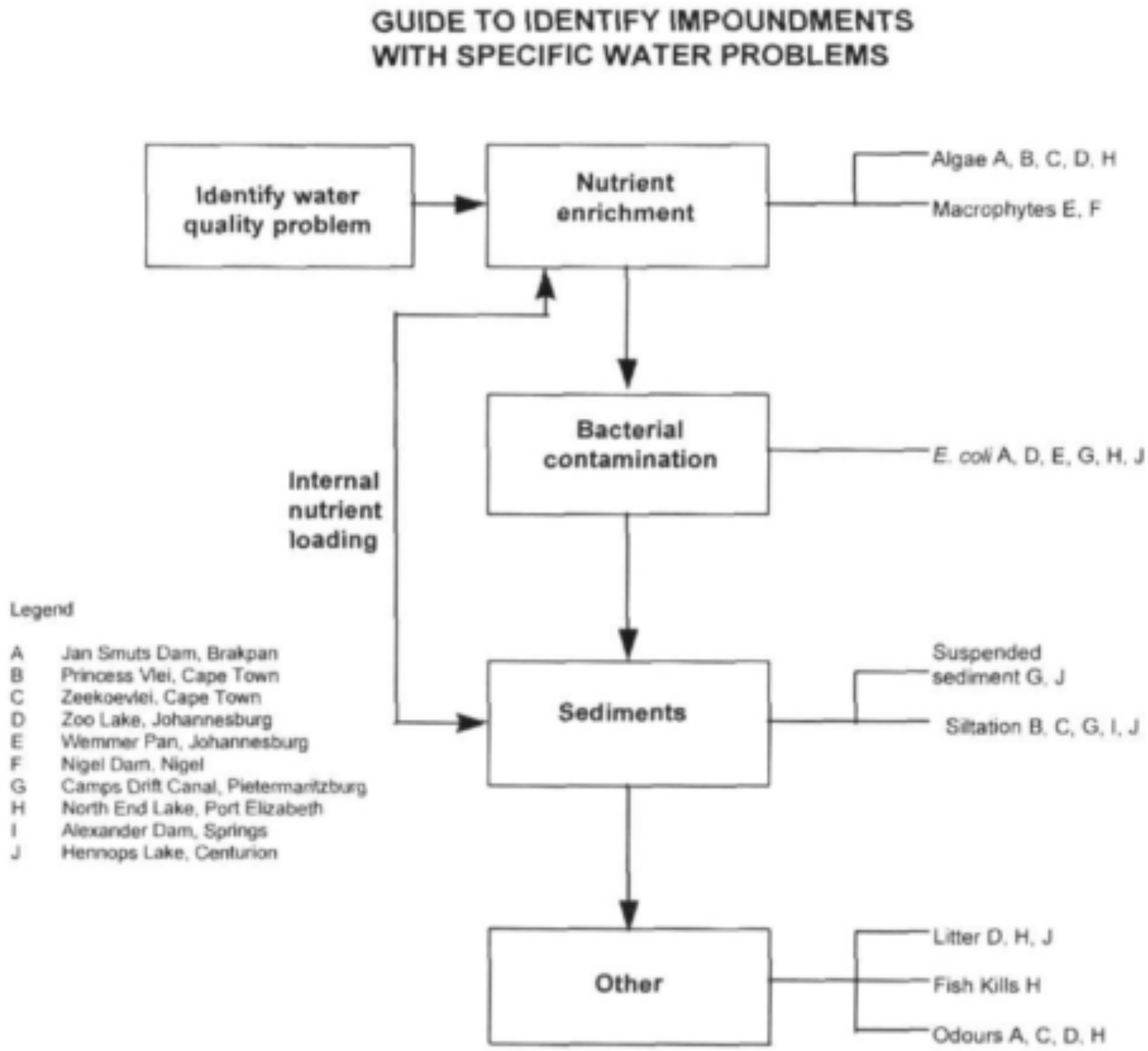


Figure 6 : Flow chart indicating impoundments with specific water problems

9. SUMMARY OF RELEVANT INFORMATION FOR THE TEN IMPOUNDMENTS

A. JAN SMUTS DAM, BRAKPAN

1. Location

2. Impoundment characteristics

Description	Value
Area	70 ha
Volume	810 000 m^3
Mean Depth	1.2 m
Source Water	Storm-water runoff and treated sewage effluent
Catchment Use	35 % high income residential 20 % commercial 20 % park land 15 % low income residential 10 % industrial
Impoundment Use	Recreation (intermediate contact) Storm-water control Receiving body for treated sewage effluent
Geographic Region	Highveld
Rainfall Range	MAP 500-900 mm

JAN SMUTS DAM, BRAKPAN - continued

3. Summarised water quality at the outflow (1992-1993)

Description	Minimum	Maximum	Average
pH (pH units)	6.9	8.6	7.8
Electrical conductivity (mS/m)	55	90	64
Nitrates (mg/ℓ as N)	0.4	4.6	2.61
Orthophosphate (mg/ℓ as P)	0.3	2.4	0.66
Suspended solids (mg/ℓ or NTU)	24 mg/ℓ	114 mg/ℓ	58 mg/ℓ
Chlorophyll *a* (μg/ℓ)	no data	no data	no data
E. coli (counts / 100 mℓ)	60	500 000	80 000

4. Description of water quality problems

- Highly nutrient enriched
- High algal numbers:

  Accumulation of thick scums

  On die-off, obnoxious odours are released

  Possible conditions for toxic algae

  Recreational potential reduced

  Debris gets trapped and accumulates in scums
- Bacterial contamination.

5. Description of management strategies in place

- Aerators have been installed
- Shoreline modifications to reduce areas for algal die-off
- Options considered but rejected:

  Sewage treatment works to comply to 0.05 mg/ℓ phosphate

  Divert water from sewage works away from pan

  Sediment phosphorus immobilisation
- Options which could be considered:

  Final polishing of effluent with a wetland system

  Rooted macrophytes could be established

  Sediment could be removed.

For detail please refer to Appendix B, Chapter 1.

B. PRINCESS VLEI, CAPE TOWN

1. Location

2. Impoundment characteristics

Description	Value
Area	29 ha
Volume	715 000 m³
Mean Depth	2.4 m
Source Water	Southfield Canal - urban catchment of 800 ha
Catchment Use	60 % high income residential 35 % park land 5 % light industrial
Impoundment Use	Recreation (non-contact) Storm-water retention Source of water for municipal irrigation
Geographic Region	Cape Peninsula
Rainfall Range	MAP 600 - 800 mm

PRINCESS VLEI, CAPE TOWN - continued

3. Summarised water quality at outflow (1992-1993)

Description	Minimum	Maximum	Average
pH (pH units)	8.1	9.0	8.6
Electrical conductivity (mS/m)	44	64	54
Nitrates (mg/ℓ as N)	0.01	1.61	0.12
Orthophosphate (mg/ℓ as P)	<0.01	0.02	0.01
Suspended solids (mg/ℓ or NTU)	11 mg/ℓ	47 mg/ℓ	32 mg/ℓ
Chlorophyll *a* (μg/ℓ)	65	99	84
Faecal coliforms (counts / 100 ml)	?	120 *	3

* Value represents 90th percentile

4. Description of water quality problems

- Nutrient enriched
- Algal scums.

5. Description of management strategies in place

- Dredging of the vlei was done in 1983 resulting in:

  Renewal of natural flushing regime

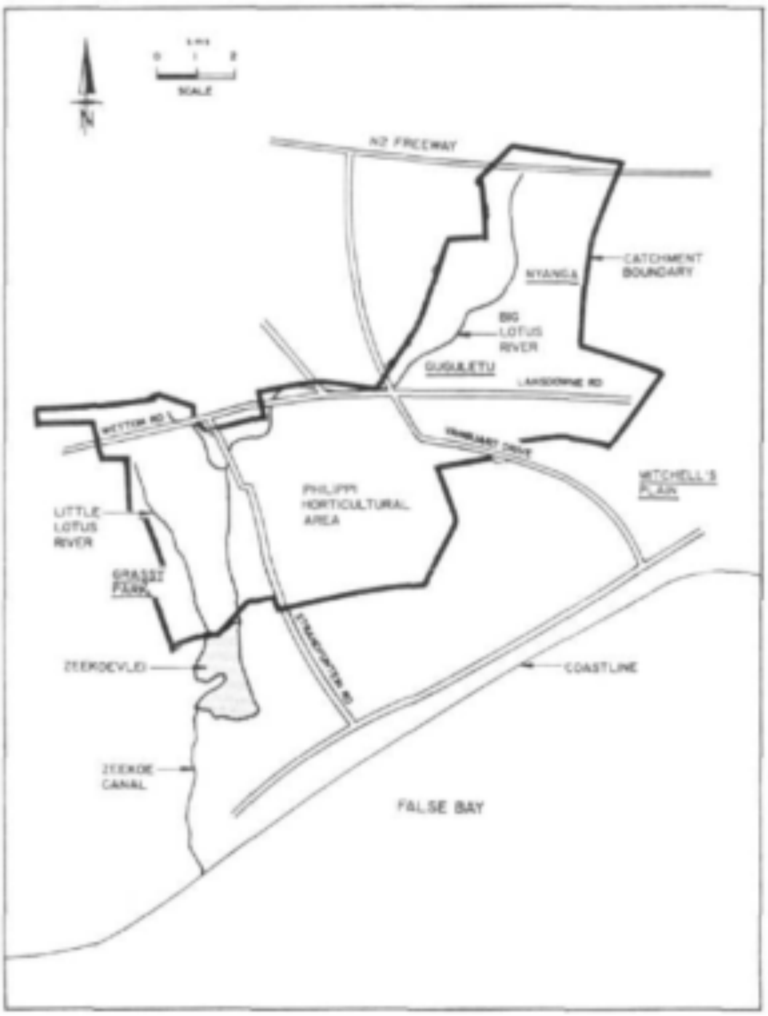
  Algal populations washed out

  Increased clarity of water.

For detail please refer to Appendix B, Chapter 2.

C. ZEEKOEVLEI, CAPE TOWN

1. Location



2. Impoundment characteristics

Description	Value
Area	256 ha
Volume	5 000 000 m^3
Mean Depth	1.9 m
Source Water	Little Lotus River - urban catchment Big Lotus River - horticultural and urban catchment Total area - 8 000 ha
Catchment Use	55 % horticultural 20 % high income residential 15 % low income residential 5 % light industrial 5 % commercial
Impoundment Use	Recreation (full contact)
Geographic Region	Cape Peninsula
Rainfall Range	MAP 600 - 800 mm

ZEEKOEVLEI, CAPE TOWN - continued

3. Summarised water quality at outflow (1992-1993)

Description	Minimum	Maximum	Average
pH (pH units)	8.4	10.1	9.3
Electrical conductivity (mS/m)	56	150	107
Nitrates (mg/ℓ as N)	<0.01	4.26	0.12
Orthophosphate (mg/ℓ as P)	<0.01	0.67	0.09
Suspended solids (mg/ℓ or NTU)	21 mg/ℓ	120 mg/ℓ	59 mg/ℓ
Chlorophyll *a* (μg/ℓ)	140	420	260
Faecal coliforms (counts / 100 ml)	?	390 *	10

* Value represents 90th percentile

4. Description of water quality problems

- Dense algal blooms causing:
    - "Pea-green soup" scums affect recreational use
    - Die-off results in obnoxious odours
- Encroachment of reeds
- Thick layer of algal rich sediment:
    - Internal source of nutrients
    - Interferes with yachtsmen and water-skiers
    - Hydrogen sulphide released causes obnoxious odours.

5. Description of management strategies in place

- Dredging has been identified but funds not available
- Catchment management of inflows
- Options evaluated but rejected:
    - Wetlands in Zeekoevlei
    - Chemical treatment of inflows
    - Nutrient diversion
    - Dilution and flushing
    - Sediment treatment
    - Manipulation of N:P ratio
    - Biological control

- Options still to be considered:

  Improved management of catchment runoff

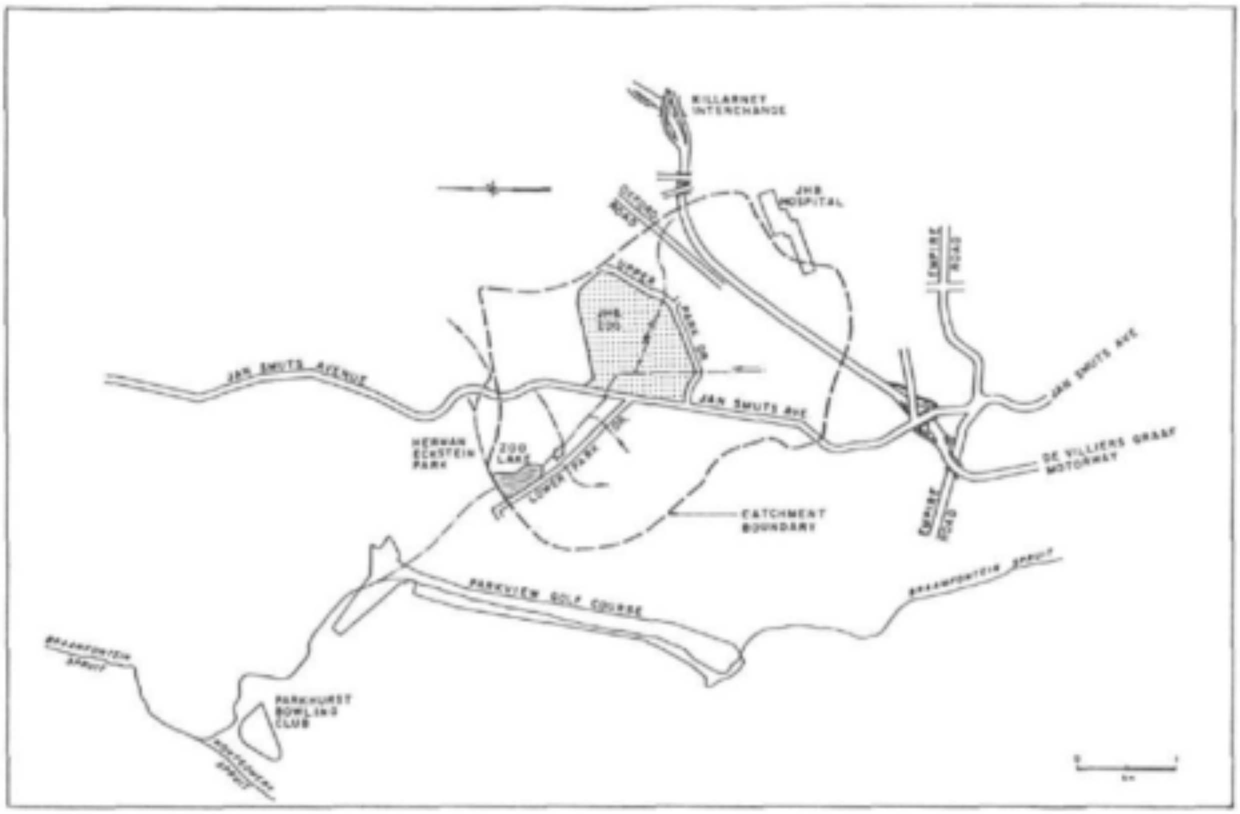
  Education of farmers

  Wetlands to treat agricultural runoff.

For detail please refer to Appendix B, Chapter 3.

D. ZOO LAKE, JOHANNESBURG

1. Location



2. Impoundment characteristics

Description	Value
Area	4.3 ha
Volume	64 000 m^3
Mean Depth	1.0 m
Source Water	Baseflow - washdown water from zoo Storm water - catchment runoff
Catchment Use	75 % high income residential 25 % park land (including the zoo)
Impoundment Use	Recreation (non-contact) Shoreline used extensively by walkers, joggers etc.
Geographic Region	Highveld
Rainfall Range	MAP 500-900 mm

ZOO LAKE, JOHANNESBURG - continued

3. Summarised water quality (1991-1994)

Description	Minimum	Maximum	Average
pH (pH units)	7.1	9.3	8.3
Electrical conductivity (mS/m)	22	45	30
Nitrates (mg/ℓ as N)	no data	no data	no data
Orthophosphate (mg/ℓ as P)	<0.01	0.52	0.06
Suspended solids (mg/ℓ or NTU)	1 mg/ℓ	1 705 mg/ℓ	62 mg/ℓ
Chlorophyll *a* (µg/ℓ)	-	-	60*
E. coli (counts / 100 mℓ)	0	6 500	800

*Sample set < 4 data points

4. Description of water quality problems

- Dense algal blooms:

    Dense algal scums affect aesthetic appeal

    Die-off results in obnoxious odours
- Litter
- Silting-up of pre-impoundment
- Bacterial contamination.

5. Description of management strategies in place

- Effluent treatment system, which includes settlers and a wetland, are being constructed
- Shorelines of island designed to retain guano for routine removal
- More litter bins have been provided
- Options still to be evaluated:

    Flushing dynamics of the lake

    Aspirators to mix the lake water

    Introduction of algal eating fish

    Chemical control
- Pre-impoundment is periodically dredged to remove accumulated silt.

For detail please refer to Appendix B, Chapter 4.

E. WEMMER PAN, JOHANNESBURG

1. Location

2. Impoundment characteristics

Description	**Value**
Area	33 ha
Volume	1 000 000 m³
Mean Depth	3.0 m
Source Water	Storm water from south-central Johannesburg and residential area south of pan; some seepages from old mine dumps
Catchment Use	45 % light industrial 30 % high income residential 15 % parkland 5 % mine dumps 5 % commercial
Impoundment Use	Recreation (full contact) Storm water retention
Geographic Region	Highveld
Rainfall Region	MAP 500-900 mm

WEMMER PAN, JOHANNESBURG - continued

3. Summarised water quality at outflow (1991-1994)

Description	Minimum	Maximum	Average
pH (pH units)	?	8.8	7.7
Electrical conductivity (mS/m)	20	55	34
Nitrates (mg/ℓ as N)	0.4	2.0	1.2
Orthophosphate (mg/ℓas P)	<0.01	0.8	0.03
Suspended solids (mg/ℓ or NTU)	<1 mg/ℓ	125 mg/ℓ	17 mg/ℓ
Chlorophyll *a* (µg/ℓ)	-	-	3.4*
E. coli (counts / 100 mℓ)	0	48 000	1 305

*Sample set < 4 data points

4. Description of water quality problems

- Nuisance growth of fennel-leaved pondweed, *Potomageton pectinatus*:

  Interferes with rowers, canoers and anglers.

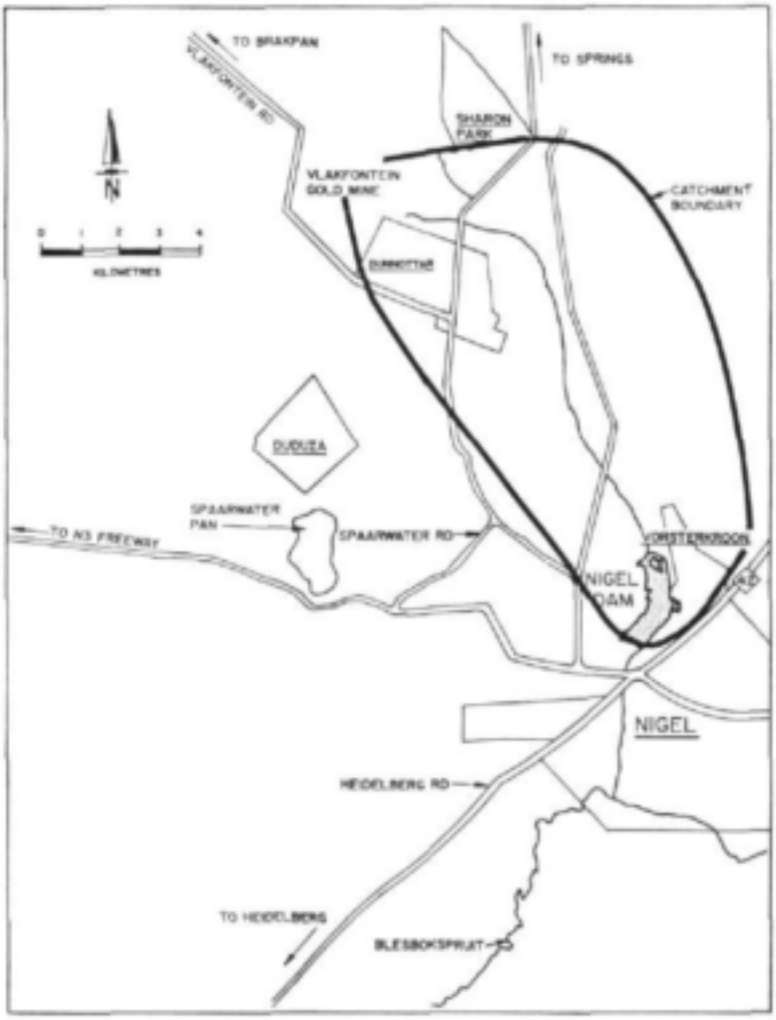
5. Description of management strategies in place

- Mechanical control of the plant using a harvester
- Future biological control through introduction of the Chinese carp (*Ctenopharyngodon idella* (Val)).

For detail please refer to Appendix B, Chapter 5.

F. NIGEL DAM, NIGEL

1. Location



2. Impoundment characteristics

Description	Value
Area	72 ha
Volume	1 800 000 m^3
Mean Depth	2.5 m
Source Water	Natural runoff; effluent from CF Grundling Sewage Works; seepage from reclamation of slimes dam
Catchment Use	35% parkland / veld 30% high income residential 20% mine tailings dams 15% heavy industrial
Impoundment Use	Storm-water control; source water for reclamation of slimes dam; recreation (full contact)
Geographic Region	Highveld
Rainfall Range	MAP 500-900 mm

NIGEL DAM, NIGEL - continued

3. Summarised water quality at outflow (1991)

Description	Minimum	Maximum	Average
pH (pH units)	3.8	8.5	5.5
Electrical conductivity (mS/m)	130	270	185
Nitrates (mg/ℓ as N)	<0.1	3.0	0.85
Orthophosphate (mg/ℓ as P)	<0.03	0.07	0.03
Suspended solids (mg/ℓ or NTU)	1 NTU	98 NTU	9 NTU
Chlorophyll *a* (μg/ℓ)	no data	no data	no data
Faecal coliforms (counts / 100 mℓ)	0	9	1

4. Description of water quality problems

- High total dissolved salts concentration, particularly sodium, chloride and sulphate
- High ammonia concentration
- High concentration of metals
- Infestation by fennel-leaved pondweed, *Potomageton pectinatus*.

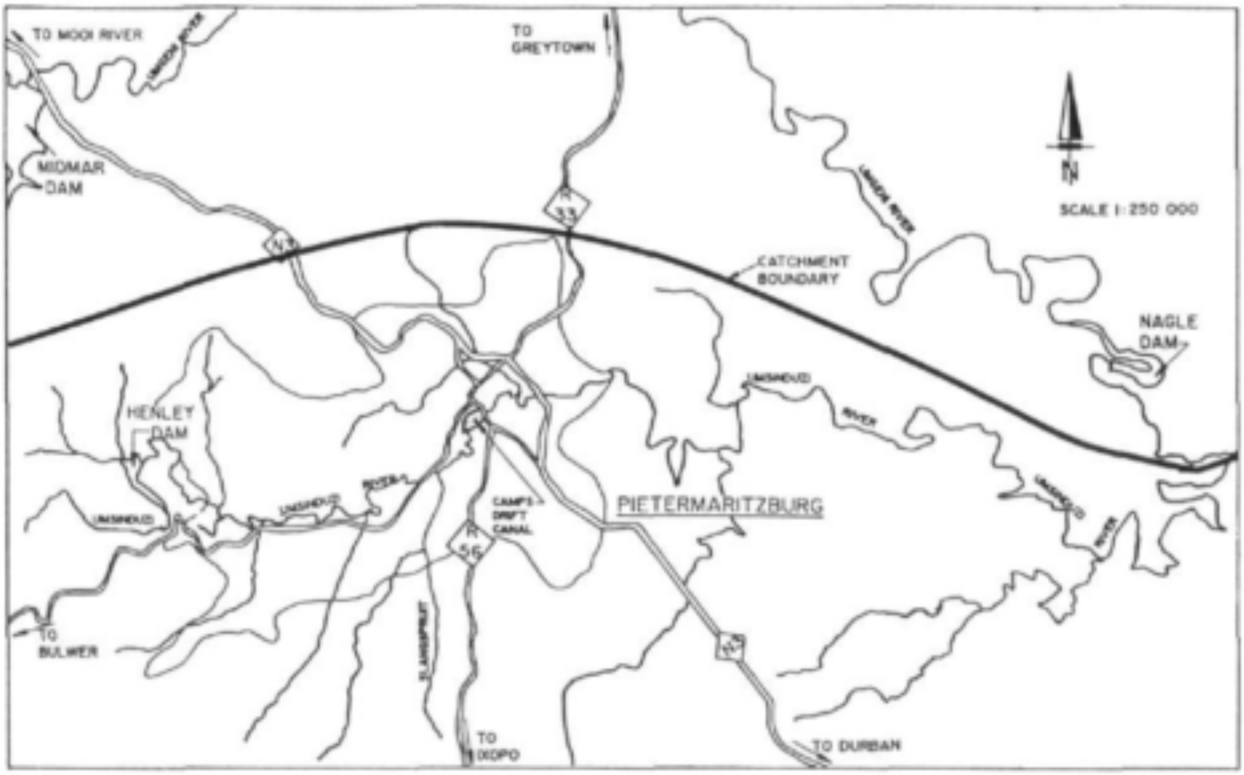
5. Description of management strategies in place

- Source reduction for high salt, ammonia and metal concentrations by:
  Improved treatment of tannery effluent on site
  Reclamation of slimes dam soon to be completed (this will remove a potential source of poor quality seepages)
- Chinese carp (*Ctenopharyngodon idella* (Val)) have been introduced to control fennel-leaved pondweed, *Potomageton pectinatus*..

For detail please refer to Appendix B, Chapter 6.

G. CAMPS DRIFT CANAL, PIETERMARITZBURG

1. Location



2. Impoundment characteristics

Description	Value
Area	28 ha
Volume	500 000 m^3
Mean Depth	2.0 m
Source Water	Natural runoff; diffuse water from high density residential areas
Catchment Use	Below Henley Dam: 75% low income residential 15% high income residential 5% industrial 5% parkland / veld
Impoundment Use	Construction of canal originally to reclaim land for commercial development; silt control; bacterial control; recreation (full contact - starting point for the Duzi canoe marathon)
Geographic Region	Natal Midlands
Rainfall Range	MAP 900-1000 mm

CAMPS DRIFT CANAL, PIETERMARITZBURG - continued

3. Summarised water quality at outflow (1990-1994)

Description	Minimum	Maximum	Average
pH (pH units)	6.8	9.5	7.0
Electrical conductivity (mS/m)	7	31	18
Nitrates (mg/ℓ as N)	0.15	2.63	0.95
Orthophosphate (mg/ℓ as P)	<0.01	0.03	0.01
Suspended solids (mg/ℓ or NTU)	9 mg/ℓ	750 mg/ℓ	69 mg/ℓ
Chlorophyll *a* (μg/ℓ)	no data	no data	no data
E. coli (counts / 100 mℓ)	0	50 000	1 790

4. Description of water quality problems

- High sediment loads in inflow
- High bacteria loads in inflow
- Increasing concentrations of phosphorus, nitrogen and bacteria
- Flooding of land occurred sporadically.

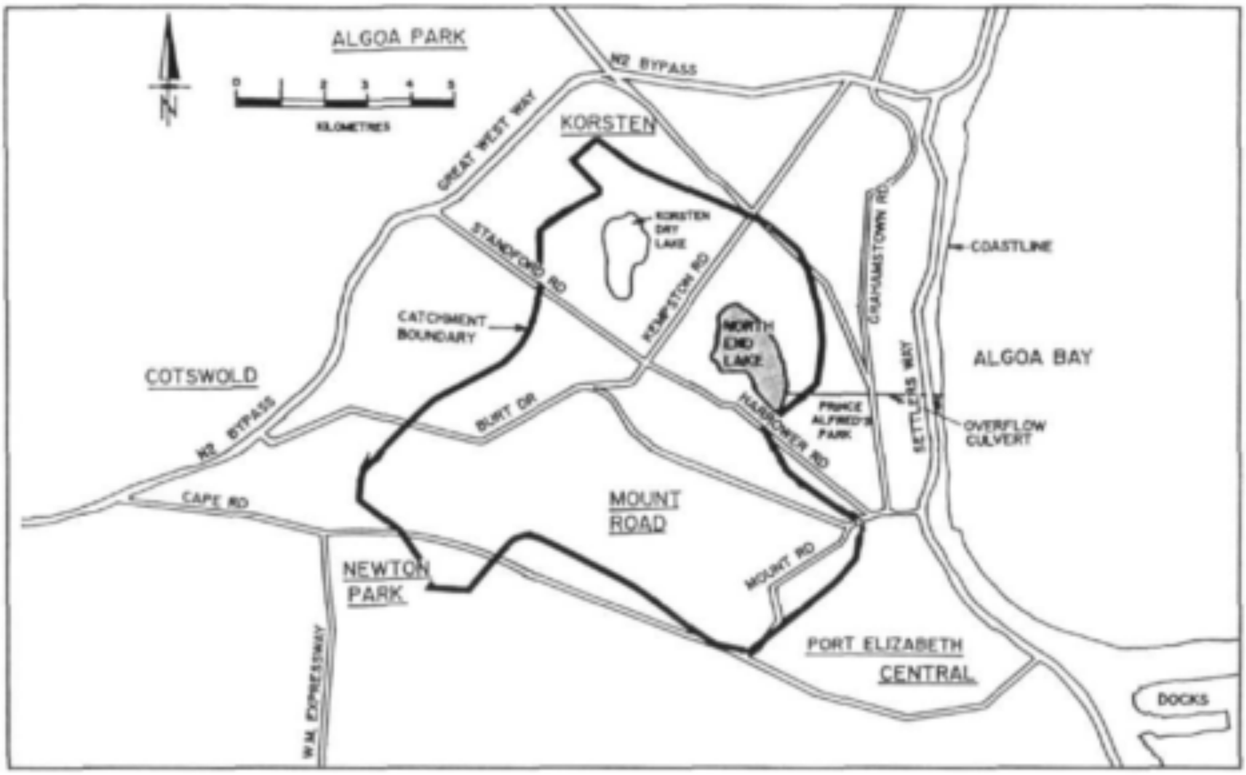
5. Description of management strategies in place

- Canal was constructed as a management strategy
- Pre-impoundment acts as a sediment trap.

For detail please refer to Appendix B, Chapter 7.

H. NORTH END LAKE, PORT ELIZABETH

1. Location



2. Impoundment characteristics

Description	Value
Area	30 ha
Volume	477 000 m^3
Mean Depth	1.6 m
Source Water	Storm water; industrial discharges
Catchment Use	75% high income residential 25% industrial
Impoundment Use	Recreation (full contact); storm water control
Geographic Region	Eastern Cape
Rainfall Range	MAP 600-1000 mm

3. Summarised water quality at outflow (1991-1994)

Description	Minimum	Maximum	Average
pH (pH units)	7.8	9.0	8.3
Electrical conductivity (mS/m)	150	275	208
Nitrates (mg/ℓ as N)	0.01	2.20	0.21
Orthophosphate (mg/ℓ as P)	0.02	1.00	0.17
Suspended solids (mg/ℓ or NTU)	13 mg/ℓ	51 mg/ℓ	32 mg/ℓ
Chlorophyll *a* (µg/ℓ)	no data	no data	no data
Faecal coliforms (counts / 100 mℓ)	100	167 000	1 400

4. Description of water quality problems

- Eutrophic conditions resulting in algal blooms
- Bacterial contamination
- Problems with swarms of midges
- Fish kills
- Hydrogen sulphide generation
- Litter
- High salinities.

5. Description of management strategies in place

- Rubbish collection traps have been installed
- An education programme has been started
- Strategies which are currently under investigation are:

    Installation of floating aerators

    Installation of fountains

    Construction of reedbeds

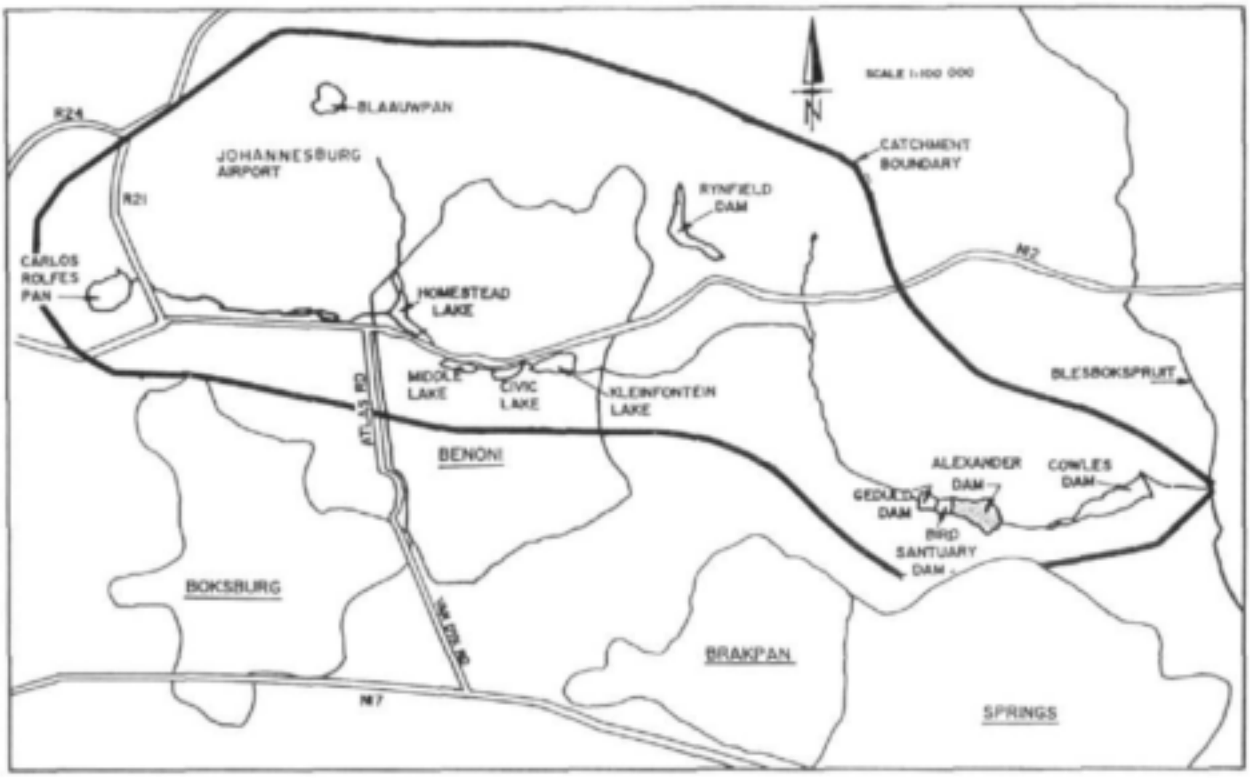
    Diversion of the first storm events of the rain season

    Alternative sources of water for flushing could be found.

For detail please refer to Appendix B, Chapter 8.

I. ALEXANDER DAM, SPRINGS

1. Location



2. Impoundment characteristics

Description	Value
Area	80 ha
Volume	3 000 000 m³
Mean Depth	3.75 m
Source Water	Natural runoff; storm water; effluent discharge; seepages from mine dumps
Catchment Use	Immediate catchment: 70 % park land 25 % high income residential Upper catchment is heavily urbanised, industrialised areas of Brakpan and Benoni
Impoundment Use	Recreation (full contact)
Geographic Region	Highveld
Rainfall Range	MAP 500-900 mm

ALEXANDER DAM, SPRINGS - continued

3. Summarised water quality at outflow (1991-1994)

Description	Minimum	Maximum	Average
pH (pH units)	4.7	7.4	6.5
Electrical conductivity (mS/m)	47	128	64
Nitrates (mg/ℓ as N)	<0.01	2.00	0.44
Orthophosphate (mg/ℓ as P)	<0.01	2.75	0.21
Suspended solids (mg/ℓ or NTU)	<1 mg/ℓ	18 mg/ℓ	4 mg/ℓ
Chlorophyll *a* (μg/ℓ)	no data	no data	no data
E. coli (counts / 100 mℓ)	0	10 000	850

4. Description of water quality problems

- Low pH
- Sediment of dam contains gold and there are plans to reclaim the sediment.

5. Description of management strategies in place

- Dredging of the impoundment to reclaim the gold
- Dredging could lead to other situations:

  Removal of the wetlands (which are typically *Phragmites* sp.) could result in a more diverse ecology

  There is a small potential of a resuspension of sediments, an increase in salts and possible increases in metals in the water

  There is a possibility that algal blooms could occur once the ecology of the lake is disturbed by the dredging.

For detail please refer to Appendix B, Chapter 9.

J. HENNOPS LAKE, CENTURION

1. Location

2. Impoundment characteristics

Description	Value
Area	7 ha
Volume	145 000 m³
Mean Depth	1.7 m
Source water	Natural runoff; treated sewage effluent; localised storm water; raw sewage from Tembisa
Catchment use	40% parkland / veld 30% low income residential 25% high income residential 5% commercial
Impoundment Use	Recreation (full contact); enhancement of commercial developments such as shops and offices
Geographic Region	Highveld
Rainfall Range	MAP 500-900 mm

HENNOPS LAKE, CENTURION - continued

3. Summarised water quality at outflow (1993-1994)

Description	Minimum	Maximum	Average
pH (pH units)	7.4	8.4	7.8
Electrical conductivity (mS/m)	25	63	52
Nitrates (mg/ℓ as N)	2.1	5.0	3.17
Orthophosphate (mg/ℓ as P)	-	-	0.71*
Suspended solids (mg/ℓ or NTU)	29 mg/ℓ	1 045 mg/ℓ	157 mg/ℓ
Chlorophyll *a* (μg/ℓ)	no data	no data	no data
E. coli (counts / 100 mℓ)	1 200	189 000	52 000

*Sample set < 4 data points

4. Description of water quality problems

- Eutrophic conditions
- Bacterial contamination
- Suspended sediment
- Siltation
- Litter.

5. Description of management strategies in place

- In-stream chlorination to address bacterial contamination
- Dredging is due to commence to deepen the lake
- Improvements to the Olifantsfontein Sewage Treatment Works to improve the quality of the effluent
- Plans to upgrade the infrastructure in Tembisa.
- Plans to investigate the viability of a wetland system to polish the inflow to the lake.

For detail please refer to Appendix B, Chapter 10.

APPENDIX A

A REGISTER OF URBAN IMPOUNDMENTS

CONTENTS

ANNEXURE

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS AND CONTACT TELEPHONE NUMBERS FOR FURTHER INFORMATION

The assistance of the following departments in the former local authority areas in completing the register of urban impoundments is gratefully acknowledged. Contact telephone numbers have been provided for readers requiring further information on specific impoundments.

		Telephone No
Benoni	City Engineers Department	(011)845-1650
Bloemfontein	Parks and Recreation Department	(051)405-8127
Boksburg	City Engineers Department	(011)899-4205
Brakpan	Town Engineers Department	(011)741-2100
Cape Town	Scientific Services, City Engineers Department	(021)637-9090
Centurion	City Engineers Department	(012)671-7433
Durban	Water and Waste Directorate	(031)300-2001
East London	Directorate of Planning and Engineering Services	(0431)349-111
Germiston	City Health Department	(011)871-7450
Johannesburg	Scientific Services, Water and Waste Directorate	(011)728-7373
Kempton Park	City Engineers Department	(011)921-2223
Kimberley	City Engineers Department	(0531)806-911
Milnerton	Town Engineers Department	(021)550-1111
Nigel	Town Engineers Department	(011)739-5942
Pietermaritzburg	City Engineers Department	(0331)951-111
Port Elizabeth	Scientific Services, City Engineers Department	(041)506-2911
Pretoria	City Engineers Department	(012)313-7660
Roodepoort	Parks and Recreation Division	(011)472-1439
Springs	Town Engineers Department	(011)360-2000
Vereeniging	City Engineers Department	(016) 503-080

URBAN IMPOUNDMENTS RESEARCH PROJECT :
A REGISTER OF URBAN IMPOUNDMENTS

1. INTRODUCTION

Stewart Scott Incorporated (SSI), Pulles, Howard and de Lange Incorporated (PHD) and the former City Council of Johannesburg (now the Greater Johannesburg Transitional Metropolitan Council), were appointed by the Water Research Commission in January 1994 to carry out research into urban impoundments (i.e. water bodies in urban areas) with the aim of developing guidelines which could be used by authorities to manage these water bodies. The research project was divided into three phases:

- the compilation of a register of urban impoundments;
- an investigation of existing problems and data on ten selected urban impoundments; and
- a detailed survey and analysis of three chosen urban impoundments.

Together with a literature survey and an investigation of management strategies, processes and costs, the above three study phases will culminate in the development of management guidelines for urban impoundments. This document, however, presents the findings of the first phase of the study - the compilation of a register of urban impoundments.

2. RESEARCH APPROACH FOR COMPILING THE REGISTER OF URBAN IMPOUNDMENTS

In devising an approach for compiling a register of urban impoundments three main issues were given attention:

- the definition of an urban impoundment;
- urban areas to be included in the study; and
- basic details to be obtained about each urban impoundment included in the register.

2.1 The definition of an urban impoundment

No precise definition of an urban impoundment was arrived at for the research project, but rather a set of criteria or conditions, all of which the urban impoundment needed to meet or fall within.

For inclusion in the register, certain minimum criteria were set. These were:

- a surface area greater than 4 hectares (in order to exclude minor dams and ponds);
- a volume greater than 50 000 m^3; and
- a catchment which was predominantly in a built-up, urban area.

No maximum size was set, but it was decided to exclude large bulk storage and water supply dams which might be near or within urban areas.

Although most eligible water bodies were likely to be man-made urban impoundments, it was agreed to include natural water bodies which fell within urban areas and the set criteria. These comprised mainly pans [1] (located chiefly on the Witwatersrand) and vleis [2] (located in the Western Cape).

A final factor which was influential was that the urban impoundments should be reasonably accessible to the public, since water quality problems experienced with urban impoundments often manifest themselves as a result of human contact with the water body or its surrounds. Thus, recreational use of an urban impoundment was considered very important for inclusion in the register.

2.2 Urban areas included in the study

As a result of budget and logistical constraints, it was not possible to include in the research project every town in South Africa of significant size. It was decided, however,

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1 A pan is a term used in Southern Africa to describe a water body contained in a depression in the ground which has no outlet.

2 The term vlei is applied in South Africa to wetland areas within river drainage systems.

that all the metropolitan areas and the usually recognised major cities would be included. Based largely on water bodies identified from maps which might be eligible for inclusion in the study, 20 former local authority areas were selected to be approached (see Figure A1).

The former local authority areas selected were Pretoria and Centurion in the north of Gauteng Province, Johannesburg, Roodepoort, Kempton Park, Germiston, Boksburg, Benoni, Brakpan, Springs and Nigel on the Witwatersrand, Vereeniging in the south of Gauteng Province, Cape Town and Milnerton in the Western Cape, Port Elizabeth and East London in the Eastern Cape, Durban and Pietermaritzburg in KwaZulu/Natal, and Bloemfontein and Kimberley in the interior.

This coverage meant the larger platteland towns (e.g. Pietersburg, Nelspruit, Welkom etc.) were not included in the study, resulting in a selective rather than an all-encompassing survey.

2.3 Basic details regarding urban impoundments in the register

For those urban impoundments included in the register, certain basic details regarding each one were obtained. The main aim of the register is to act as a quick reference document. A balance needed to be struck, therefore, between ease of use of the register and the inclusion of pertinent information such that the data contained therein was neither superfluous nor unwieldy and too detailed for the user.

It was decided to include the following details regarding each impoundment:

- the local authority area;
- the impoundment name;
- the location of the impoundment;
- its controlling authority;
- whether the water body was a man-made impoundment or a natural pan or vlei;

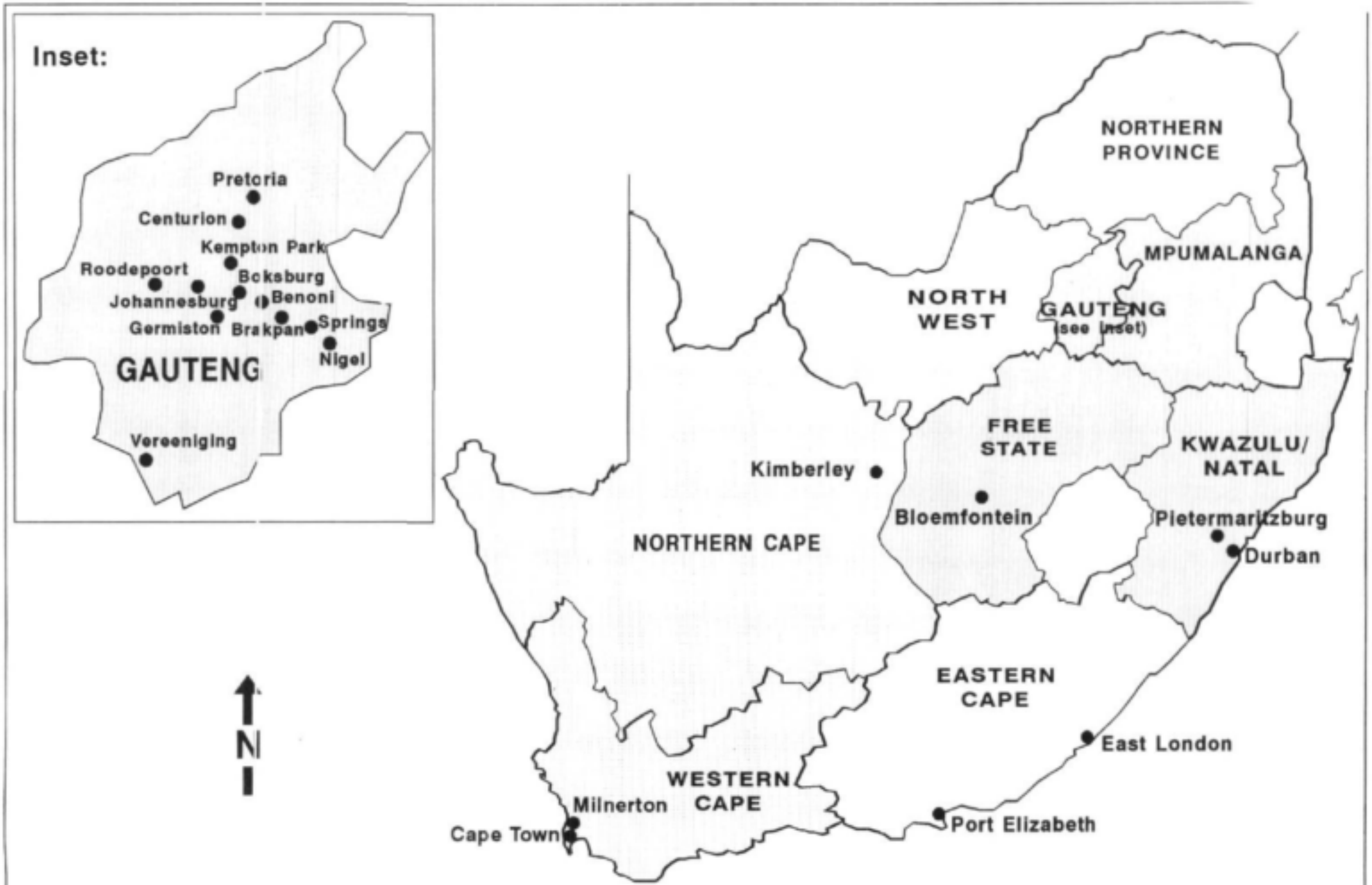

Figure A1 : Former local authority areas included in the register of urban impoundments

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- its water surface area and the volume of water contained;
- the land use in the immediate catchment area;
- the main uses of the impoundment; and
- the amount of data (particularly as regards water quality) available about the impoundment.

The last mentioned detail, especially, was to be an important factor together with impoundment type, size and geographical location in assisting the research team to decide which ten impoundments to include in the second phase of the project for more detailed analysis (see Appendix B to this report).

In some respects, the information supplied about each impoundment had to be assessed subjectively (e.g. land use in the catchment and availability of data) or had to be estimated (e.g. water surface area and volume). This was particularly applicable where accurate information was either not available or not readily accessible.

The register should thus be seen as a starting point and a quick reference, which could be refined and updated by the Water Research Commission, as local authorities obtain new information about impoundments and become familiar with the existence of the register. A list of contact telephone numbers for the former local authority departments which assisted in supplying the information contained in the register is given on page (Aiii) of this document. These contact numbers can be used as a starting point for readers interested in either contacting the local authority regarding available/further information or updating the information found in the register.

3. RESEARCH METHODOLOGY

In compiling the register of urban impoundments, three main tasks were carried out:

(i) An initial scan of local authorities and urban impoundments identified from maps.

(ii) A first approach to identified local authorities informing them of the research project and attempting to obtain a contact person, an indication of the preparedness of the local authority to get involved in the three phases of the research project and the identification of urban impoundments in the local authority area which met the specified criteria for inclusion in the register.

(iii) A follow-up exercise which compared urban impoundments identified by each local authority with those identified by the initial scan. Impoundments were then to be either included or excluded from the register after appropriate discussion. Once agreement was obtained on which water bodies to include in the register, the contact person in each local authority was to be requested to complete a table supplying relevant details about each impoundment. A more detailed assessment of the availability of information about each impoundment would also be obtained through further discussion.

All of the above tasks were carried out by fax and telephone. Each contact person was asked to complete two forms - one for task (ii) and one for task (iii) - and these are shown in Annexure A to this document.

4. THE INITIAL SCAN

Given the need, for project manageability's sake, to restrict the number of local authorities included in the study, an initial scan of maps of the major urban areas in South Africa was carried out. This had the dual purpose of identifying both appropriate local authorities to be approached and urban impoundments which might be eligible for inclusion in the project. It was decided to limit the number of local authorities to be approached to 20. These covered all the metropolitan areas in the country and the major towns and cities. The former local authorities approached together with the possible water bodies identified from maps which might be eligible for inclusion in the register are shown in Table A1 overleaf.

Table A1: Urban Impoundments - The Initial Scan	
Former Local Authority	**Water Bodies Identified from Maps**
Pretoria	Dam adjacent to Quagga Road; Austin Roberts Bird Sanctuary; Struben Dam; dam adjacent to N1/R21 interchange; Bon Accord Dam
Centurion	Hennops Lake (formerly Verwoerdburg Lake); dam adjacent to Botha Road, Doringkloof
Johannesburg	Delta Park Dam; Melrose Bird Sanctuary; Zoo Lake; Bruma Lake; Emmarentia Dam; Westdene Dam; Russel Dam; Blue Dam; Wemmer Pan; Rosherville Dam; Orlando Dam; water bodies in Klipriver Basin near Eldorado Park and Lenasia
Roodepoort	Skinners Dam; Wilgespruit Dams; Princess Dam; Bennie Heinecke Dam; Florida Lake; Hennie Hugo Dam; New Canada Dam; Fleurhof Dam; mines dams and pans
Kempton Park	Isekelo Pan (Tembisa); Bredell Dam; Dries Niemandt Dam; Blaauwpan
Germiston	Germiston (Victoria) Lake; Rondebult Bird Sanctuary
Boksburg	Witfield Dam; dams adjacent to R22; Elsburg Dam; Angelo Pan; Boksburg Lake; Cinderella Dam; Carlos Rolfes Pan
Benoni	Bullfrog Dam; Sandpan; Homestead Lake; Middle Lake; Civic Lake; Kleinfontein Lake; Rynfield Dam; Korsman Bird Sanctuary; The Stewards Lake; Leeupan; Glenshaft Pan; Amata Pan; mines dams and pans
Brakpan	Apex Pan; Jan Smuts Dam; Van Dyk Dam; Brakpan Bird Sanctuary; mines dams and pans
Springs	Pans adjacent to Eastvale; Alexander Dam; Cowles Dam; Pollak Park Dam; Selcourt Dam; Vogelstruisbult Dam; mines dams and pans
Nigel	Nigel Dam; Spaarwater Pan; Marievale Bird Sanctuary; mines dams and pans
Vereeniging	Leeuwkuil Pan (Sharpeville)
Cape Town	Little Princess Vlei; Princess Vlei; Langvlei; Rondevlei; Zeekoevlei; Zandvlei; Wildevoëlvlei
Milnerton	Rietvlei
Port Elizabeth	North End Lake; Salt Pan; Varsvlei; Salt Pan (Ibhayi)
East London	Amalinda Dam; Umzoniana Reservoir
Durban	Sea Cow Lake
Pietermaritzburg	Henley Dam
Bloemfontein	Loch Logan; Radebete Dam (Kafferfontein/Blou Dam); dam in Flora suburb (Rooi Dam)
Kimberley	Kamfers Dam; Kenilworth Dam; De Beers Yacht Club Dam

5. THE FIRST APPROACH TO LOCAL AUTHORITIES

Once the preliminary selection was complete, each of the 20 local authorities chosen for inclusion in the study were contacted by telephone and fax. They were informed about the project and were requested to supply a contact person who would then identify water bodies in the local authority area deemed suitable for inclusion in the register and who would indicate whether the local authority was in a position to participate further in phases two and three of the project.

The summarised responses obtained from the former local authorities are shown in Table A2 overleaf. A few water bodies were identified by the local authorities for inclusion in the register which were not picked up in the initial scan whilst, for a number of reasons, many of the water bodies identified in the initial scan and some suggested by the local authorities were rejected for inclusion in the register. These latter water bodies together with the reason for their rejection are shown in Table A3 on page A10.

Table A2: Results of the First Approach to Local Authorities

Former Local Authority	Identified Water Bodies Included in the Register	Participation in			
		Phase 2		Phase 3	
		Yes	No	Yes	No
Pretoria	Bon Accord Dam	✓			✓
Centurion	Hennops Lake (formerly Verwoerdburg Lake)	✓		✓	
Johannesburg	Zoo Lake; Bruma Lake; Emmarentia Dam; Westdene Dam; Blue Dam; Wemmer Pan	✓		✓	
Roodepoort	Florida Lake	✓		✓	
Kempton Park	Blaauwpan	✓			✓
Germiston	Germiston (Victoria) Lake	✓		✓	
Boksburg	Boksburg Lake; Cinderella Dam; Carlos Rolfes Pan	✓		✓	
Benoni	Homestead Lake; Middle Lake; Civic Lake; Kleinfontein Lake; Rynfield Dam; Korsman Bird Sanctuary; The Stewards Lake; Leeupan; Glenshaft Pan	✓			✓
Brakpan	Jan Smuts Dam; Van Dyk Dam	✓		✓	
Springs	Alexander Dam; Cowles Dam; Pollak Park Dam; Vogelstruisbult Dam	✓		✓	
Nigel	Nigel Dam; Spaarwater Pan	✓			✓
Vereeniging	Leeuwkuil Pan	✓			✓
Cape Town	Princess Vlei; Rondevlei; Zeekoevlei; Zandvlei; Wildevoëlvlei	✓		✓	
Milnerton	Rietvlei	✓		✓	
Port Elizabeth	North End Lake; Salt Pan	✓		✓	
East London	Amalinda Dam		✓		✓
Durban	Clearwater Dam	✓		✓	
Pietermaritzburg	Camps Drift Canal	✓		✓	
Bloemfontein	Loch Logan; Radebete Dam; Rooi Dam; Manguang Recreation Resort		✓		✓
Kimberley	Kamfers Dam; Wit Dam; De Beers Yacht Club Dam	✓			✓

Table A3: Urban Impoundments Excluded from the Register	
Former Local Authority	**Identified Water Bodies Considered but Rejected for Inclusion in the Register (reasons stated in brackets)**
Pretoria	Dam adjacent to Quagga Road (for use of power station only); Austin Roberts Bird Sanctuary (too small); Struben Dam (too small); dam adjacent to R21/N1 interchange (quarry dam/too small); Zeekoegat and Rooiwal dams (water care works/not used by public); Rietvlei and Roodeplaat Dams (bulk storage/rural catchment)
Centurion	Dam adjacent to Botha Road, Doringkloof (quarry dam/not used by public)
Johannesburg	Delta Park Dam (silted up); Melrose Bird Sanctuary (too small); Russel Dam (mine dam not used by public); Rosherville Dam (silted up); Orlando Dam (for use of power station only); Klipriver Basin - Eldorado Park/Lenasia area (too small)
Roodepoort	Skinners Dam (too small); Wilgespruit Dams (too small/private dams used by plotholders); Princess Dam (too small); Bennie Heinecke Dam (too small); Hennie Hugo Dam (too small); New Canada Dam (mine dam/not used by public); Fleurhof Dam (mine dam/not used by public); mines dams/pans (not used by public)
Kempton Park	Isekelo Pan - Tembisa (too small); Bredell Dam (too small); Dries Niemandt Dam (too small); pan adjacent to R25 (too small)
Germiston	*Rondebult Bird Sanctuary (too small)*
Boksburg	Witfield Dam (too small); dams adjacent to R22 (not perennial/some are private dams used by plotholders); Elsburg Dam (mine dam/not used by public); Angelo Pan (mine dam/not used by public)
Benoni	Bullfrog Dam (not perennial); Sandpan (not perennial); Amata Pan (too small)
Brakpan	Apex Pan (not perennial/not used by public); Brakpan Bird Sanctuary (too small); mine dams/pans (not used by public)
Springs	Pans adjacent to Eastvale (too small); Selcourt Dam (too small); mine dams/pans (not used by public)
Nigel	Marievale Bird Sanctuary (too small); mine dams/pans (not used by public)
Vereeniging	Bedworth Park Dam (too small)
Cape Town	Little Princess Vlei (too small); Langvlei (too small)
Port Elizabeth	Varsvlei (too small); Saltpan - Ibhayi (too small/being filled in)
East London	Umzoniana Reservoir (for water supply system/not used by public/undeveloped catchment)
Durban	Sea Cow Lake (too small); Pani Dam (irrigation dam/rural catchment/not used by public); Marshall Dam (irrigation dam/rural catchment/not used by public)
Pietermaritzburg	Henley Dam (bulk storage/rural catchment)
Kimberley	Kenilworth Dam (mine dam/not used by public)

6. THE REGISTER OF URBAN IMPOUNDMENTS

When consensus was reached on those urban impoundments to include in the register, the contact person for each local authority was requested to submit basic information regarding each impoundment as described in Section 2.3 of the document (p. A3). This information is shown on the following pages and serves as the initial version of the register of urban impoundments. Maps showing the location of the impoundments are also included at the end of the register (p. A19 - p. A35).

CONTENTS OF THE REGISTER

Former local authority	No of impoundments	Figure No showing location of impoundments	Page No for basic details about impoundments
Pretoria	1	A2	A12 + A19
Centurion	1	A3	A12 + A20
Johannesburg	6	A4 + A5	A12 + A21/A23
Roodepoort	1	A4	A12 + A21
Kempton Park	1	A6	A13 + A25
Germiston	1	A5	A13 + A23
Boksburg	3	A7	A13 + A27
Benoni	9	A7	A14 + A27
Brakpan	2	A8	A14 + A28
Springs	4	A8 +A9	A15 + A28/A29
Nigel	2	A9	A15 + A29
Vereeniging	1	A10	A15 + A30
Cape Town	5	A11	A16 + A31
Milnerton	1	A12	A17 + A33
Port Elizabeth	2	A13	A17 + A34
East London	1	A14	A17 + A35
Durban	1	A15	A17 + A36
Pietermaritzburg	1	A16	A17 + A37
Bloemfontein	4	A17	A18 + A39
Kimberley	3	A18	A18 + A41
TOTAL	50		

The results of the survey carried out in compiling the register show that there are 50 water bodies in South Africa's main urban areas which meet the criteria set for inclusion in the register. Of this total, two-thirds are found in Gauteng Province. Forty per cent of the total are natural water bodies (pans or vleis), although these have all been modified by man to some extent as they have become absorbed into the urban fabric. The remaining sixty per cent are man-made impoundments. Barely twenty per cent of the water bodies in the register are located in proximity to disadvantaged communities.

LOCAL AUTHORITY AREA	IMPOUNDMENT NAME AND NUMBER	LOCATION	CONTROLLING AUTHORITY	IMPOUNDMENT, PAN OR VLEI	WATER SURFACE AREA (ha)	VOLUME OF WATER (m^3)	LOCAL CATCHMENT TYPE (%) *	MAIN USES OF IMPOUNDMENT ** (in order of importance)	AVAILABILITY OF DATA (especially water quality data)
Pretoria	1. Bon Accord Dam	Near Onderstepoort, Pretoria	Bon Accord Irrigation Board/Dept. of Water Affairs & Forestry/ Pretoria City Council	Impoundment	170	4 293 000	F = 50% H = 20% C = 15% A = 5% B = 5% D = 5%	F (Irrigation) + A + B	Good
Centurion	2. Hennops Lake	Centurionstad Centurion	Centurion City Council	Impoundment	7,1	145 000	H = 40% F = 30% E = 25% C = 5%	D + B + A	Good
Johannesburg	3. Zoo Lake	Near Parkview, Johannesburg	Johannesburg City Council	Impoundment	4,3	64 000	F = 75% I (Zoo) = 20% H = 5%	B + A	Good
	4. Emmarentia Dam	Emmarentia, Johannesburg	Johannesburg City Council	Impoundment	9,7	250 000	H = 70% F = 30%	B + A	Good
	5. Westdene Dam	Westdene, Johannesburg	Johannesburg City Council	Impoundment	7	152 000	F = 80% H = 20%	B	Good
	6. Blue Dam	Near Homestead Park, Johannesburg	Johannesburg City Council	Impoundment	6	180 000	B = 65% D = 30% I (Mine tailings) = 5%	B	Good
	7. Wemmer Pan	Near La Rochelle, Johannesburg	Johannesburg City Council	Pan	33,2	1 000 000	B = 45% F = 30% H = 15% C = 5% I (Mine tailings) = 5%	B + A	Good
	8. Bruma Lake	Bruma, Johannesburg	Johannesburg City Council	Impoundment	8,4	200 000	F = 65% B = 20% D = 5% H = 5% C = 5%	D + B + A	Good
Roodepoort	9. Florida Lake	Florida, Roodepoort	Roodepoort City Council	Impoundment	26	520 000	H = 45% F = 40% C = 10% D = 5%	B + A	Fair

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E = High Density and Low Socio-economic Residential
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G = Low Density and Low Socio-economic Residential
H = Parkland/Veld
I = Other (specify)

**** Impoundment uses:**
A = Recreation (water based)
B = Recreation (waterside based)
C = Storm-water Control
D = Enhancement of Commercial Development
E = Nature Conservation
F = Other (specify)

LOCAL AUTHORITY AREA	IMPOUNDMENT NAME AND NUMBER	LOCATION	CONTROLLING AUTHORITY	IMPOUNDMENT, PAN OR VLEI	WATER SURFACE AREA (ha)	VOLUME OF WATER (m^3)	LOCAL CATCHMENT TYPE (%) *	MAIN USES OF IMPOUNDMENT ** (in order of importance)	AVAILABILITY OF DATA (especially water quality data)
Kempton Park	10. Blaauwpan	Bonaero Park, Kempton Park	Kempton Park City Council	Pan	30	360 000	I (Airport) = 50% B = 25% F = 20% H = 5%	B+A+C	Poor
Germiston	11. Germiston (Victoria) Lake	Near Delville, Germiston	Germiston City Council	Pan	59	1 525 000	B = 30% F = 20% A = 15% H = 15% I (Airport) = 10% C = 10%	A+B+C	Good
Boksburg	12. Boksburg Lake	Near Boksburg CBD, Boksburg	Boksburg City Council	Impoundment	16	400 000	F = 25% D = 20% A = 20% B = 15% C = 15% H = 5%	B+C+A	Fair
	13. Cinderella Dam	Near Farrar Park, Boksburg	Boksburg City Council (but privately owned)	Impoundment	45	1 125 000	D = 25% F = 20% A = 10% B = 10% C = 10% E = 10% I (Mine tailings) = 10% H = 5%	A+B+C	Fair
	14. Carlos Rolfes Pan	Jet Park, Boksburg	Boksburg City Council (but privately owned)	Pan	80	800 000	A = 50% C = 25% B = 20% F = 5%	C+B	Fair

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LOCAL AUTHORITY AREA	IMPOUNDMENT NAME AND NUMBER	LOCATION	CONTROLLING AUTHORITY	IMPOUNDMENT, PAN OR VLEI	WATER SURFACE AREA (ha)	VOLUME OF WATER (m^3)	LOCAL CATCHMENT TYPE (%) *	MAIN USES OF IMPOUNDMENT ** (in order of importance)	AVAILABILITY OF DATA (especially water quality data)
Benoni	15. Homestead Lake	Near Farrarmere, Benoni	Benoni City Council	Impoundment	30	900 000	F = 95% H = 5%	A+C+B	Good
	16. Middle Lake	Near Lakefield, Benoni	Benoni City Council	Impoundment	16	350 000	F = 80% H = 20%	A+B+C	Good
	17. Civic Lake	Near Benoni CBD, Benoni	Benoni City Council	Impoundment	10	116 000	F = 50% C = 45% H = 5%	C+A+D+B	Good
	18. Kleinfontein Lake	Near Benoni CBD, Benoni	Benoni City Council	Impoundment	42	700 000	F = 50% C = 25% B = 15% H = 10%	C+A+B+D	Good
	19. Rynfield Dam	Near Rynfield, Benoni	Benoni City Council	Impoundment	40,5	540 000	F = 70% H = 30%	A+B+C+E	Good
	20. Korsman Bird Sanctuary	Westdene, Benoni	Benoni City Council	Pan	12,5	50 000	F = 90% H = 10%	E+B+C	Good
	21. The Stewards Lake	The Stewards, Benoni	Benoni City Council	Pan	12	82 000	F = 60% A = 25% C = 15%	D+C	Good
	22. Leeupan	Near Wattville, Benoni	Benoni City Council	Pan	55	360 000	H = 60% E = 40%	A+B	Good
	23. Glenshaft Pan	Near Actonville, Benoni	Benoni City Council	Pan	5,2	50 000	E = 70% H = 30%	B+C+F (Effluent)	Good
Brakpan	24. Jan Smuts Dam	Near Brakpan North, Brakpan	Brakpan Town Council	Pan	70	810 000	F = 30% G = 20% H = 20% C = 20% A = 5% B = 5%	B+A+C+F (Effluent)	Good
	25. Van Dyk Dam	Dalpark Ext. 1, Brakpan	Brakpan Town Council	Impoundment	12,1	242 000	H = 50% F = 50%	C+E	Poor

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LOCAL AUTHORITY AREA	IMPOUNDMENT NAME AND NUMBER	LOCATION	CONTROLLING AUTHORITY	IMPOUNDMENT, PAN OR VLEI	WATER SURFACE AREA (ha)	VOLUME OF WATER (m^3)	LOCAL CATCHMENT TYPE (%) *	MAIN USES OF IMPOUNDMENT ** (in order of importance)	AVAILABILITY OF DATA (especially water quality data)
Springs	26. Alexander Dam	Near Dersley, Springs	Springs Town Council	Impoundment	80	3 000 000	H = 70% F = 25% I (Mine tailings) = 5%	B+A	Good
	27. Cowles Dam	Near East Geduld, Springs	SAPPI/Dept of Water Affairs & Forestry	Impoundment	65	2 600 000	H = 35% F = 30% I (Mine tailings) = 20% A = 15%	F (Discharge for SAPPI mill)+B	Good
	28. Vogelstruisbult Dam	Near Struisbult, Springs	Springs Town Council	Impoundment	22	900 000	H = 75% F = 25%	B+A	Poor
	29. Pollak Park Dam	Near Pollak Park, Springs	Springs Town Council	Impoundment	8	150 000	H = 50% E = 25% I (Mine tailings) = 10% B = 10% A = 5%	C+E	Good
Nigel	30. Nigel Dam	Near Vorsterkroon, Nigel	Nigel Town Council	Impoundment	72	1 800 000	H = 35% F = 30% I (Mine tailings) = 20% A = 15%	C+B+A+F (Effluent and discharge for tannery)	Good
	31. Spaarwater Pan	Near Duduza, Nigel	Duduza Town Council	Pan	60	1 500 000	H = 55% E = 40% I (Mine tailings) = 5%	C+B+F (Effluent)	Good
Vereeniging	32. Leeuwkuil Pan	Near Sharpeville, Vereeniging	Administrator of Sharpeville	Pan	122	6 100 000	E = 80% H = 15% B = 5%	B+F (Effluent)	Fair

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F = Other (specify)

LOCAL AUTHORITY AREA	IMPOUNDMENT NAME	LOCATION	CONTROLLING AUTHORITY	IMPOUNDMENT, PAN OR VLEI	WATER SURFACE AREA (ha)	VOLUME OF WATER (m^3)	LOCAL CATCHMENT TYPE (%) *	MAIN USES OF IMPOUNDMENT ** (In order of importance)	AVAILABILITY OF DATA (especially water quality data)
Cape Town	33. Princess Vlei	Near Diepriver, Cape Town	Cape Town City Council	Vlei	29	715 000	F = 60% H = 35% B = 5%	B+C	Good
	34. Rondevlei	Near Grassy Park, Cape Town	Western Cape RSC	Vlei	47,5	760 000	F = 70% H = 20% B = 5% C = 5%	E+C	Good
	35. Zeekoevlei	Zeekoevlei, Cape Town	Cape Town City Council	Vlei	256	5 000 000	H = 55% F = 20% E = 15% B = 5% C = 5%	A+B+C	Good
	36. Zandvlei	Near Lakeside, Cape Town	Cape Town City Council	Vlei	56	793 000	H = 60% F = 30% C = 5% B = 5%	A+B+C	Good
Western Cape RSC	37. Wildevoëlvlei	Near Kommetjie, Cape Peninsula	Western Cape RSC (but privately owned)	Vlei	25	125 000	H = 70% F = 20% G = 5% C = 5%	C+B+F (Effluent)	Fair

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LOCAL AUTHORITY AREA	IMPOUNDMENT NAME	LOCATION	CONTROLLING AUTHORITY	IMPOUNDMENT, PAN OR VLEI	WATER SURFACE AREA (ha)	VOLUME OF WATER (m^3)	LOCAL CATCHMENT TYPE (%) *	MAIN USES OF IMPOUNDMENT ** (in order of importance)	AVAILABILITY OF DATA (especially water quality data)
Milnerton	38. Rietvlei	Near Table View, Milnerton	38. Milnerton Town Council	Vlei	325	6 500 000	F = 45% A = 20% H = 20% D = 5% B = 5% E = 5%	E+A+B+F (Effluent)	Good
Port Elizabeth	39. North End Lake	Near North End, Port Elizabeth	39. Port Elizabeth City Council	Pan	30,1	477 000	F = 60% D = 15% B = 15% A = 10%	B+A+C+F (Effluent)	Good
	40. Salt Pan	Near Bethelsdorp, Port Elizabeth	40. Port Elizabeth City Council	Pan	385,5	4 818 750	E = 50% H = 30% G = 20%	F (Salt works)	Poor
East London	41. Amalinda Dam	Near Amalinda, East London	41. East London City Council	Impoundment	9,5	450 000	H = 85% B = 10% A = 5%	C+F (Fisheries station) +B	Poor
Durban	42. Clearwater Dam	Near Chatsworth, Durban	42. Durban City Council	Impoundment	7,9	400 000	E = 50%	B+A	Poor
Pietermaritzburg	43. Camps Drift Canal	Near Camps Drift, Pietermaritzburg	43. Pietermaritzburg City Council	Impoundment	28	500 000	E = 50%	B+A+D+C	Good

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****Impoundment uses:**
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B = Recreation (waterside based)
C = Storm-water Control
D = Enhancement of Commercial Development
E = Nature Conservation
F = Other (specify)

LOCAL AUTHORITY AREA	IMPOUNDMENT NAME	LOCATION	CONTROLLING AUTHORITY	IMPOUNDMENT, PAN OR VLEI	WATER SURFACE AREA (hectares)	VOLUME OF WATER (m^3)	LOCAL CATCHMENT TYPE (%) *	MAIN USES OF IMPOUNDMENT ** (in order of importance)	AVAILABILITY OF DATA (especially water quality data)
Bloemfontein	44. Loch Logan	Near Bloemfontein CBD, Bloemfontein	Bloemfontein City Council	Impoundment	5,2	110 475	F = 80% C = 10% H = 10%	B+A+C	Fair
	45. Rooi Dam	Lourier Park, Bloemfontein	Bloemfontein City Council	Impoundment	16,7	230 000	F = 90% H = 10%	B+A+C	Poor
	46. Radebete Dam	Near Manguang, Bloemfontein	Manguang City Council	Impoundment	15	150 000	B = 50% H = 50%	C+B	Poor
	47. Manguang Recreation Resort	Near Manguang, Bloemfontein	Bloemfontein City Council	Impoundment	120	250 000	H = 60% F = 40%	B+A+C	Poor
Kimberley	48. Kamfers Dam	Near Kimdustria, Kimberley	Kimberley City Council (but privately owned)	Pan	560	3 360 000	F = 50% E = 25% B = 25%	E+B+F (Effluent)	Good
	49. Wit Dam	Near Galashewe, Kimberley	Kimberley City Council	Impoundment	6	50 000	E = 90% H = 10%	C+B	Poor
	50. De Beers Yacht Club Dam	Near Greenpoint, Kimberley	De Beers	Pan	103	1 545 000	H = 50% F = 25% E = 25%	A+C+F (Water for De Beers Mine)	Fair

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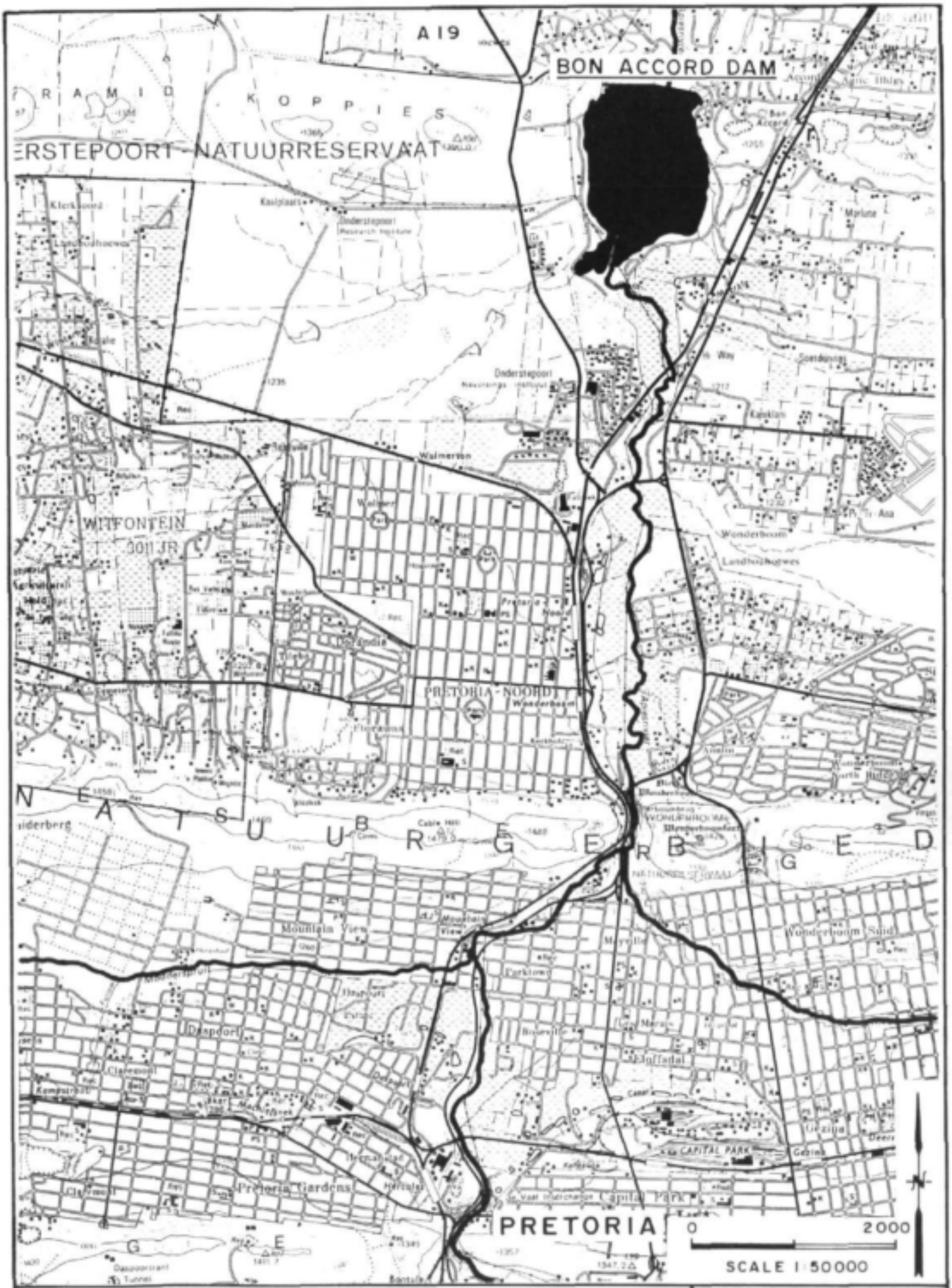
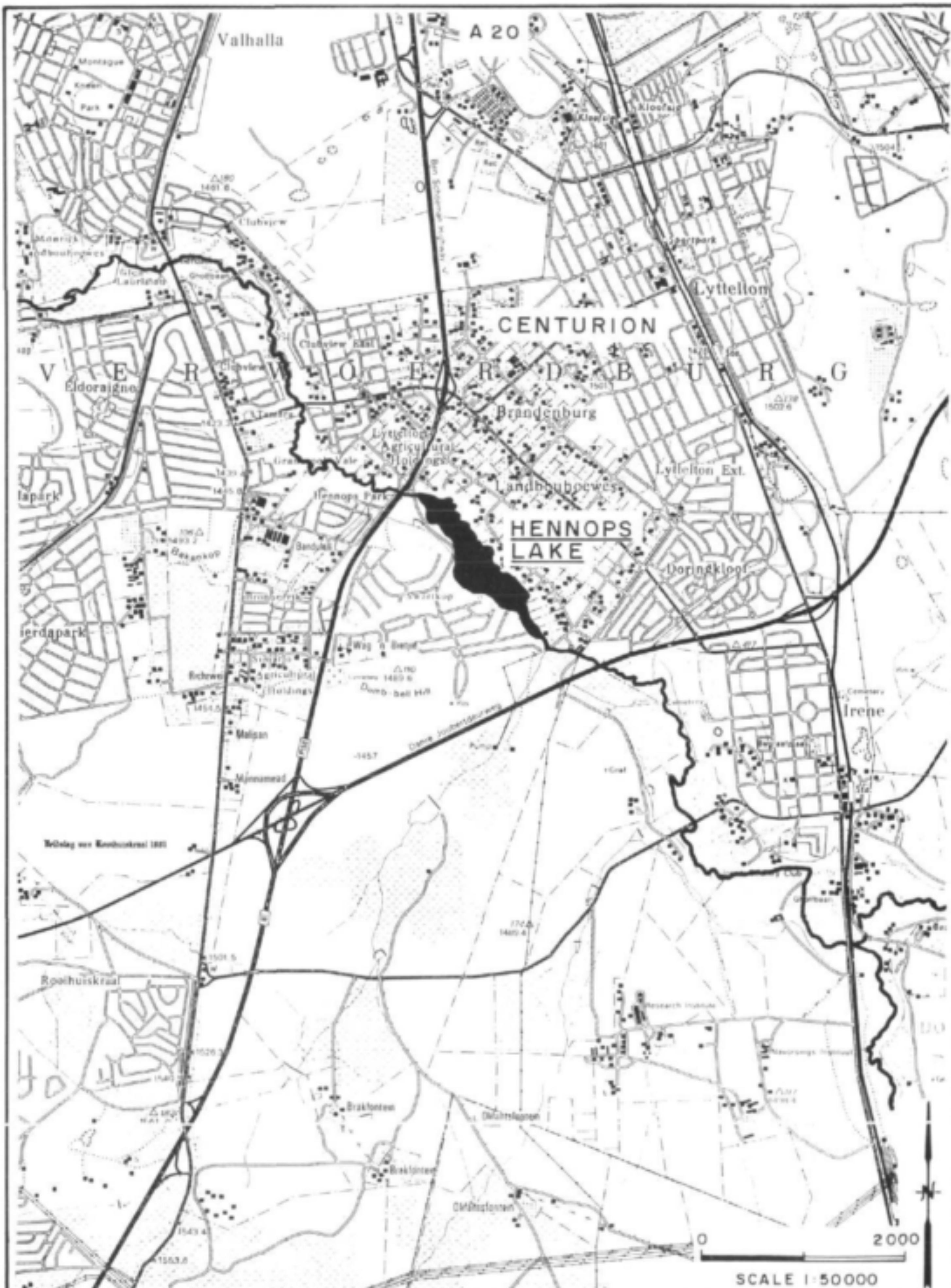
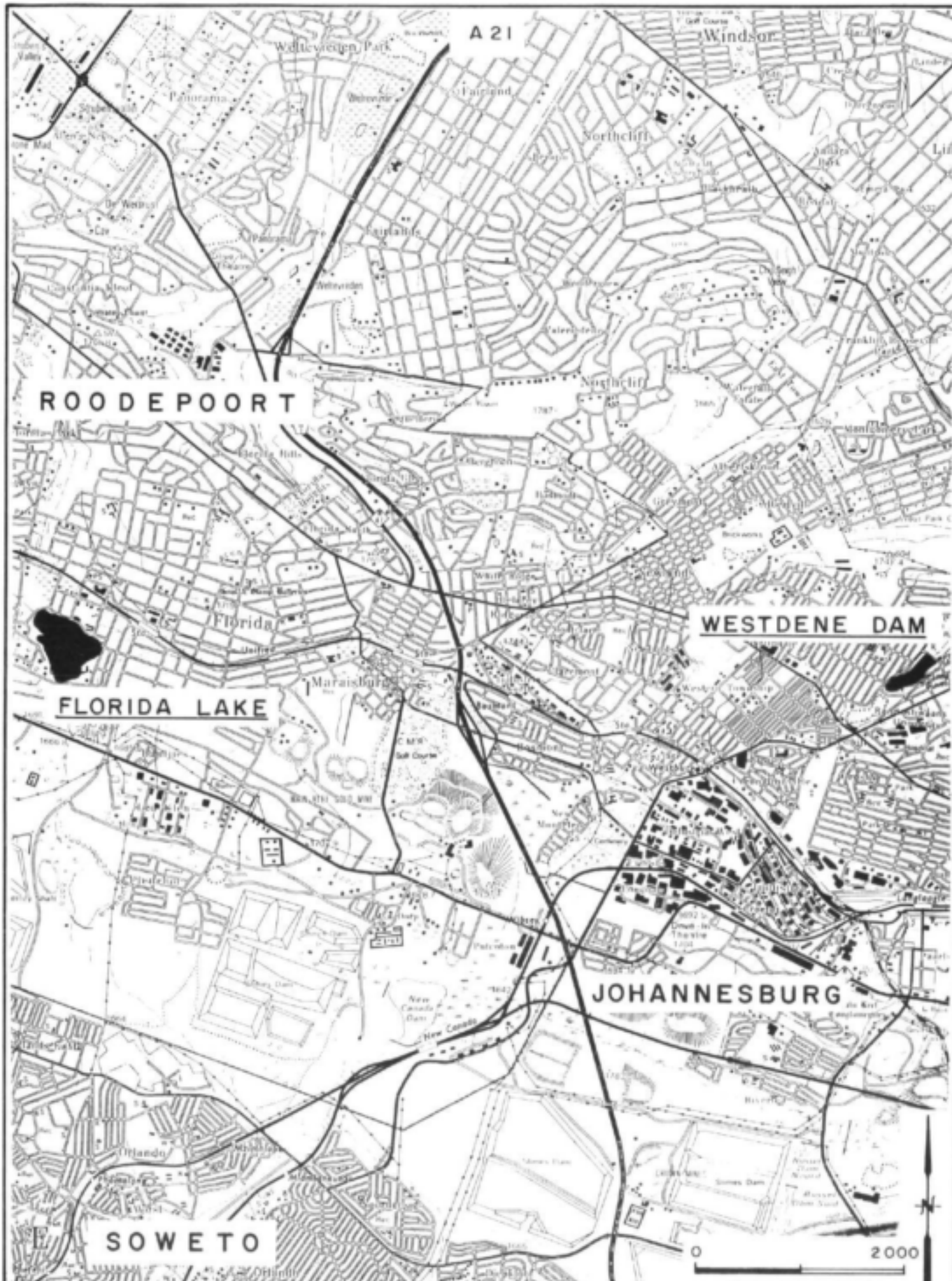


REGISTER OF URBAN IMPOUNDMENTS:
PRETORIA (Bon Accord Dam)

FIGURE No.
A2

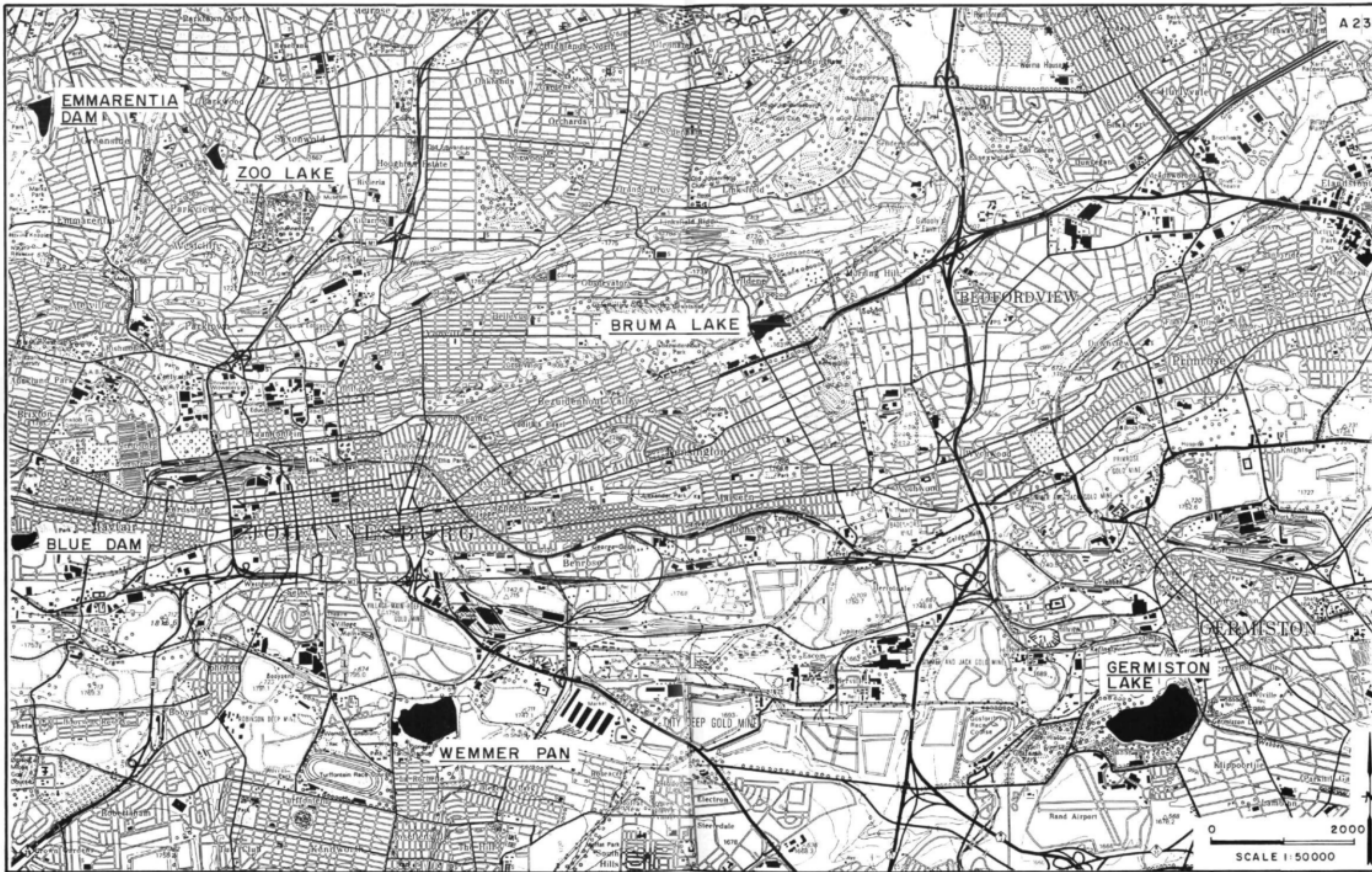


REGISTER OF URBAN IMPOUNDMENTS: CENTURION (Hennops Lake)	FIGURE No. A3



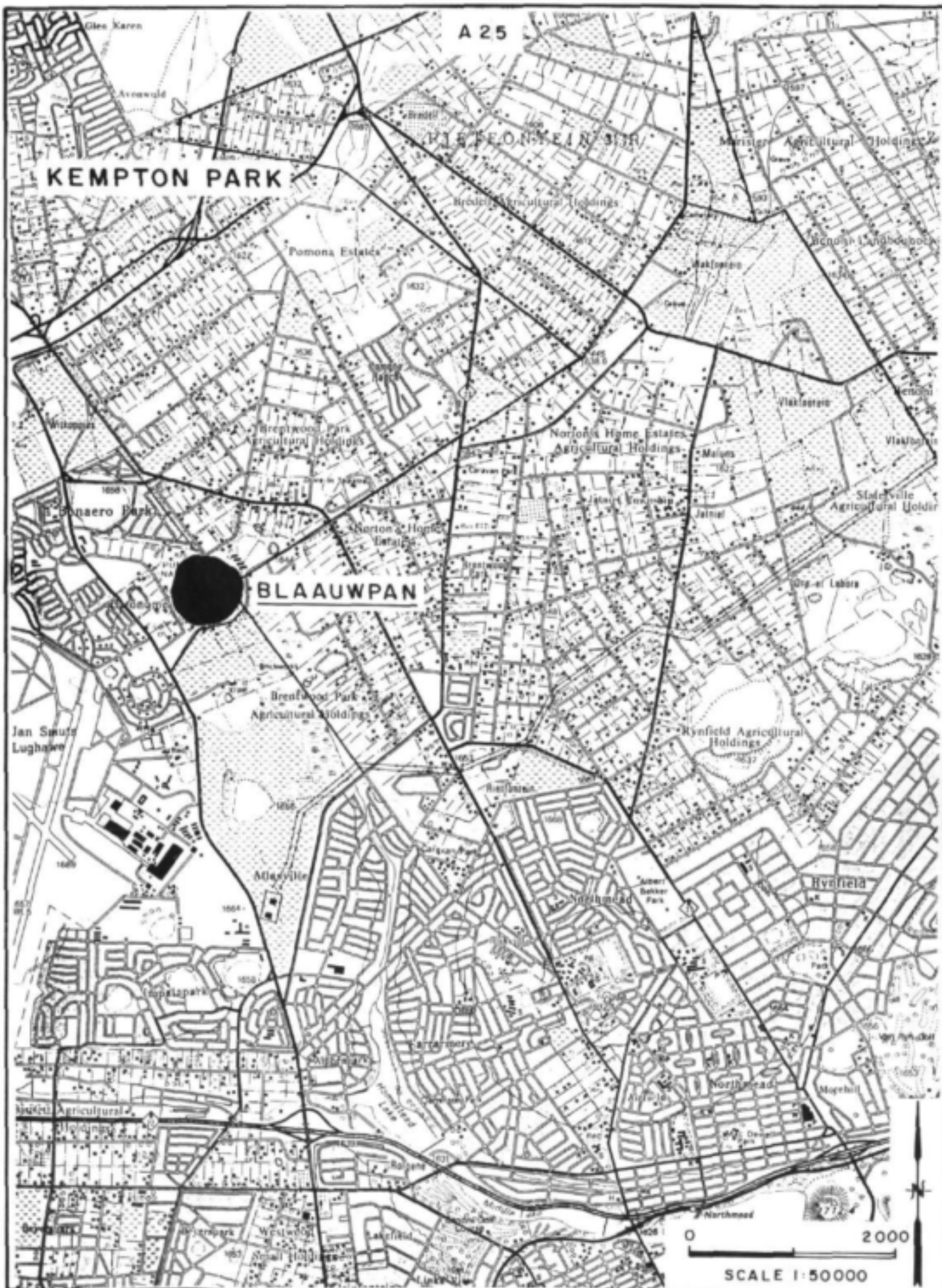
REGISTER OF URBAN IMPOUNDMENTS: ROODEPOORT (Florida Lake); JOHANNESBURG (Westdene Dam)

FIGURE No. A4



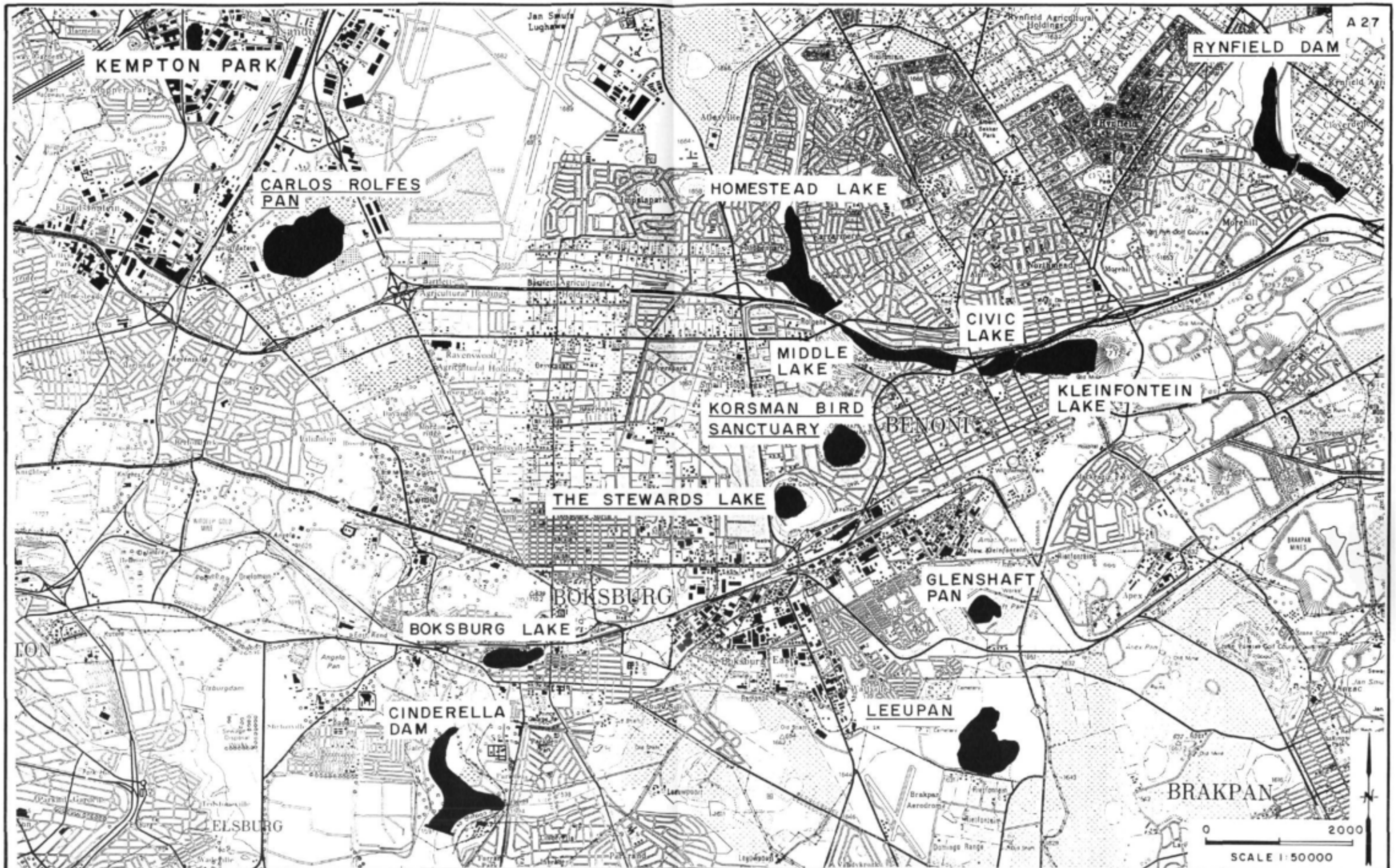
REGISTER OF URBAN IMPOUNDMENTS:
JOHANNESBURG (Blue Dam; Emmarentia Dam; Zoo Lake; Bruma Lake; Wemmer Pan); GERMISTON (Germiston Lake)

FIGURE No. A5



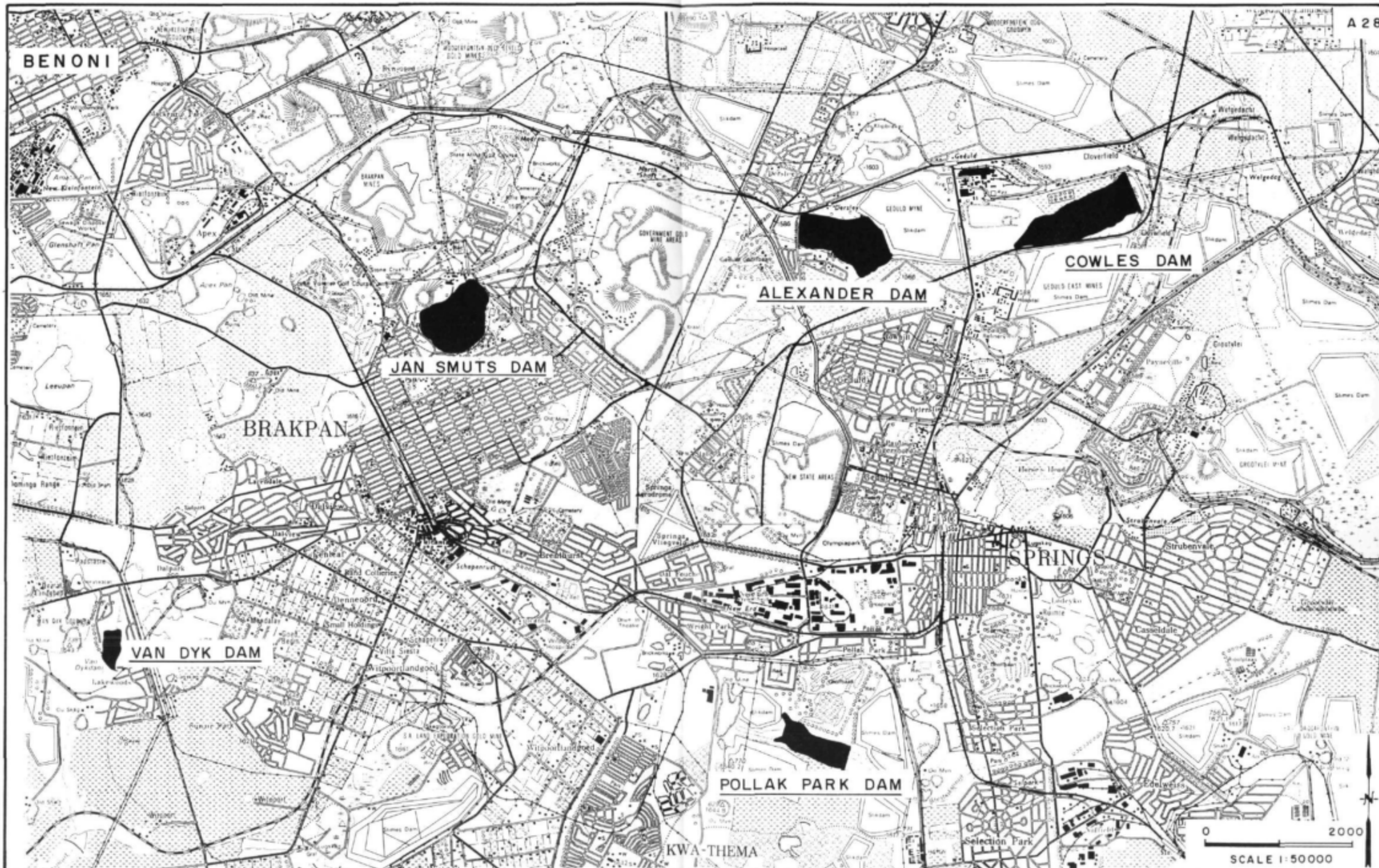
REGISTER OF URBAN IMPOUNDMENTS:
KEMPTON PARK (Blaauwpan)

FIGURE No.
A6



REGISTER OF URBAN IMPOUNDMENTS:
BOKSBURG (Boksburg Lake; Cinderella Dam; Carlos Rolfes Pan); BENONI (Homestead Lake; Middle Lake; Civic Lake; Kleinfontein Lake; Rynfield Dam; Korsman Bird Sanctuary; The Stewards Lake; Leeupan; Glenshaft Pan)

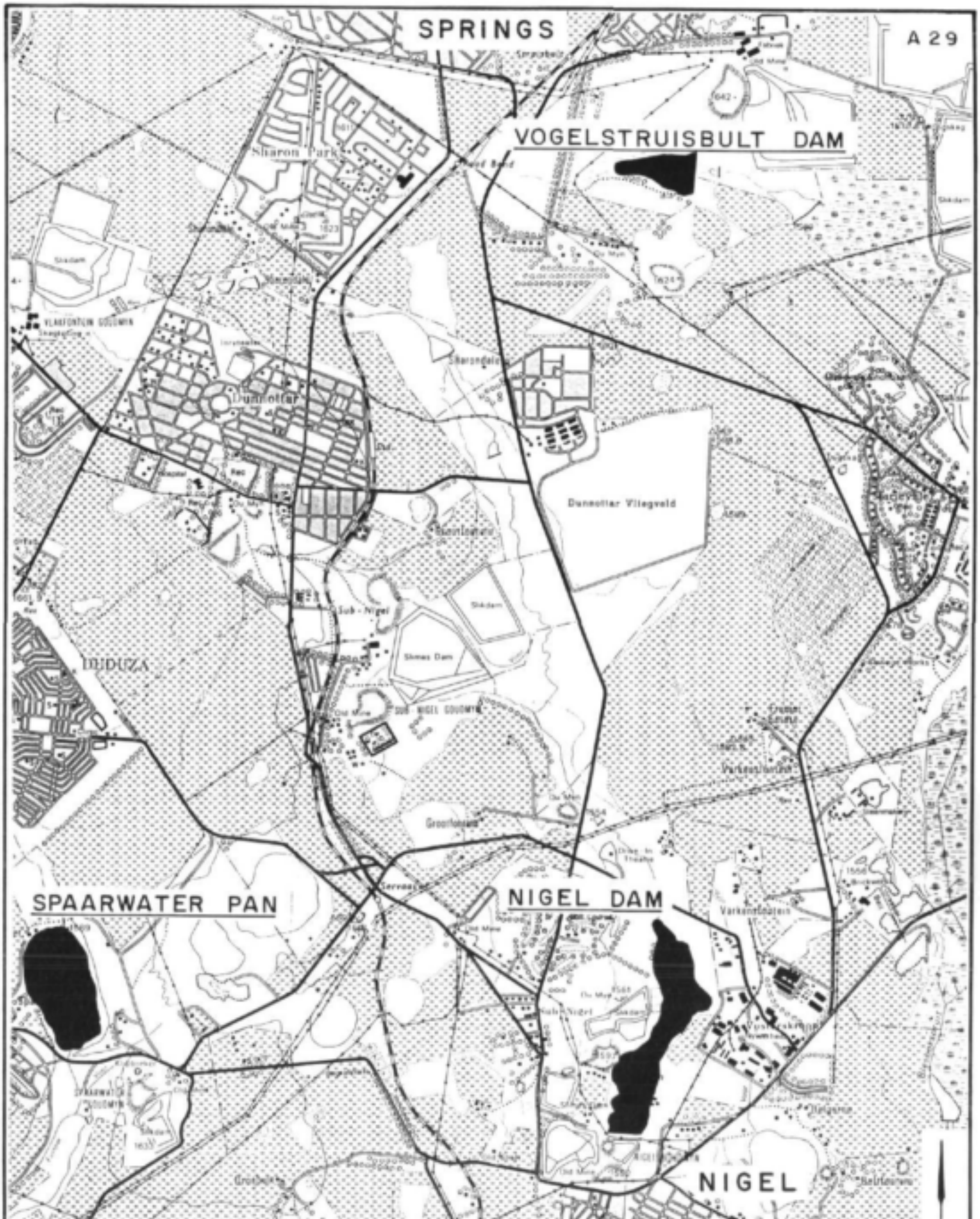
FIGURE No. A7



REGISTER OF URBAN IMPOUNDMENTS:

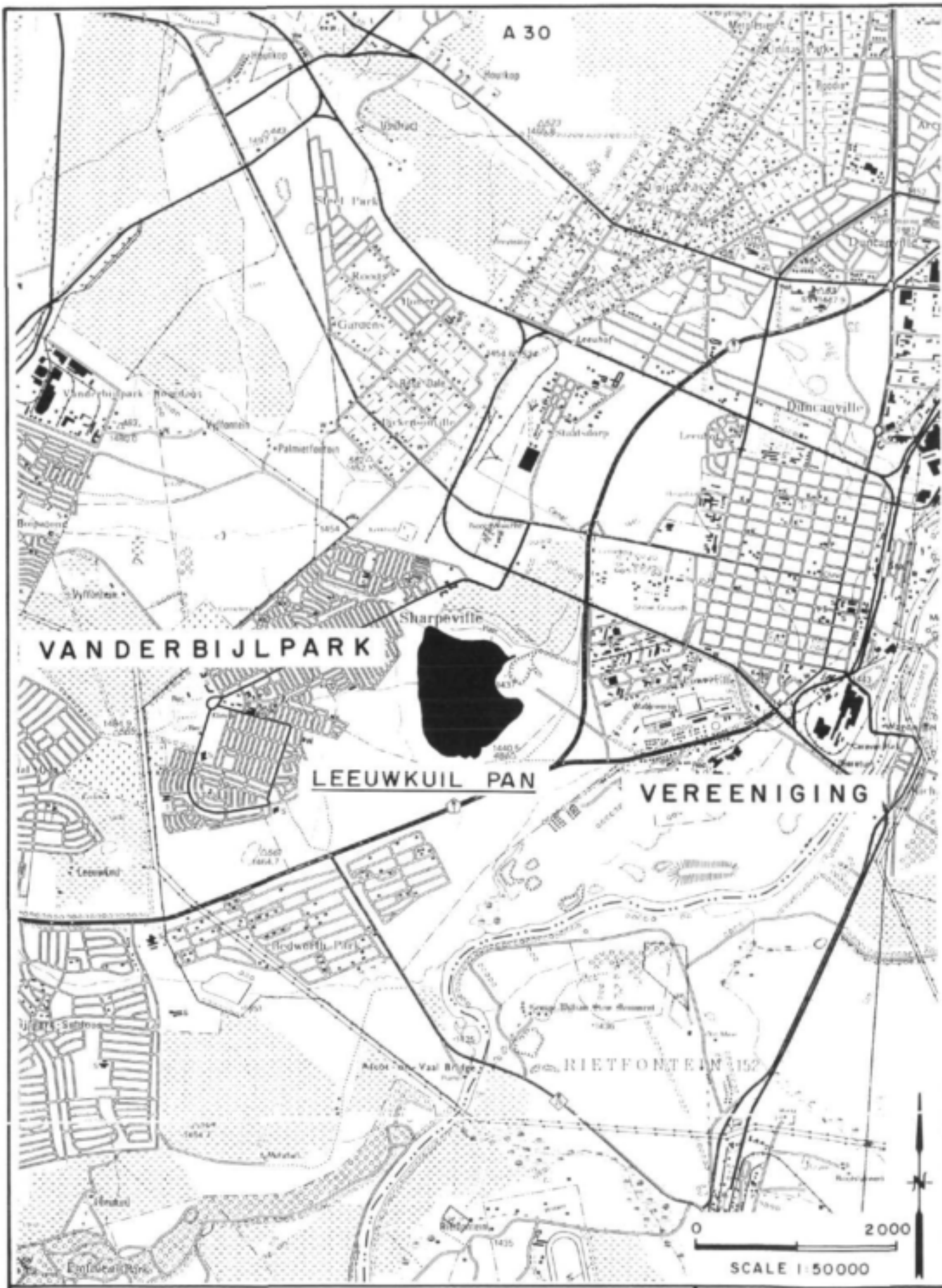
BRAKPAN (Jan Smuts Dam; Van Dyk Dam); SPRINGS (Alexander Dam; Cowles Dam; Pollak Park Dam)

FIGURE No. A 8

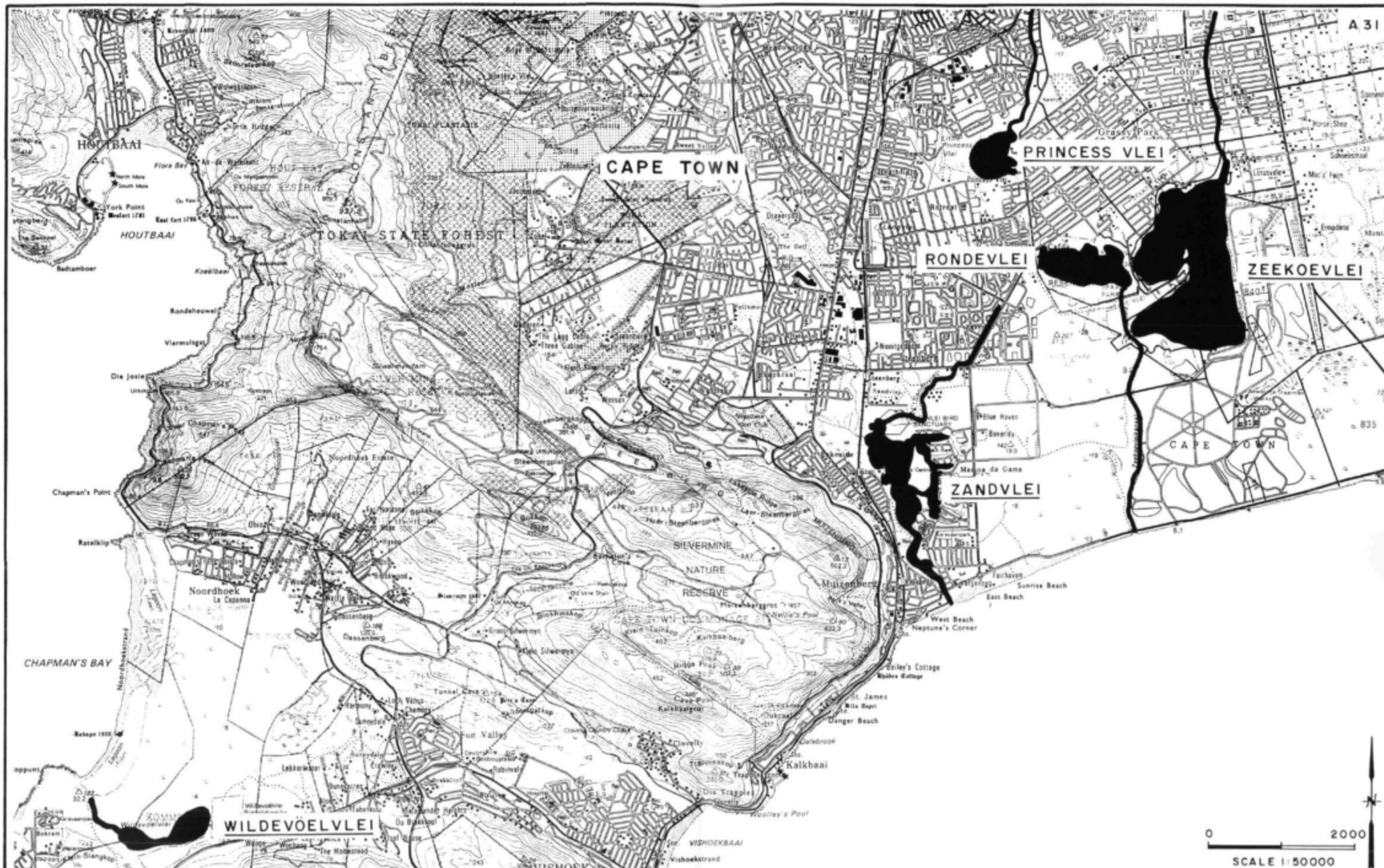


REGISTER OF URBAN IMPOUNDMENTS:
SPRINGS (Vogelstruisbult Dam); NIGEL (Nigel Dam; Spaarwater Pan)

FIGURE No. A9

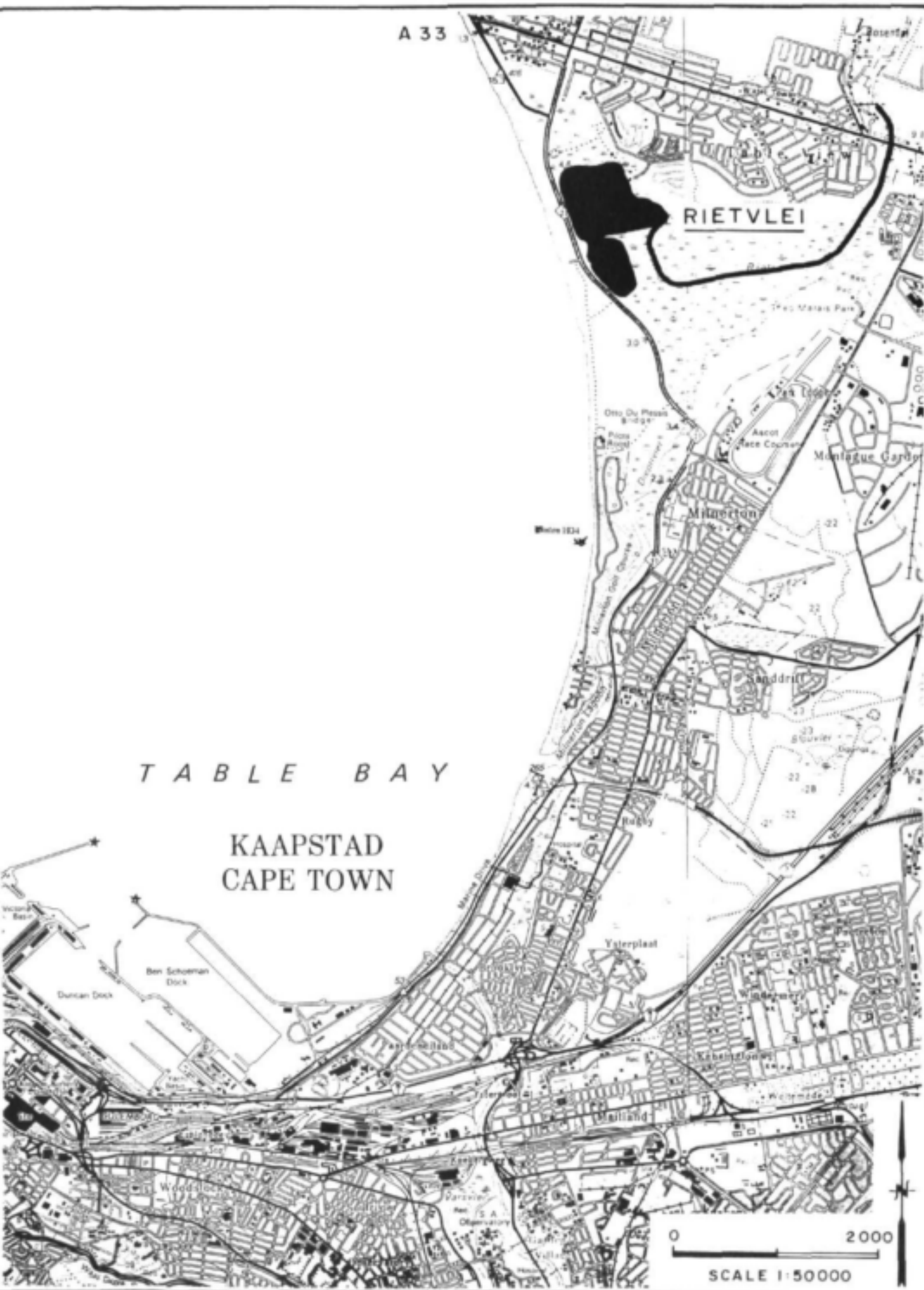


REGISTER OF URBAN IMPOUNDMENTS: VEREENIGING (Leeuwkuil Pan)	FIGURE No. A10

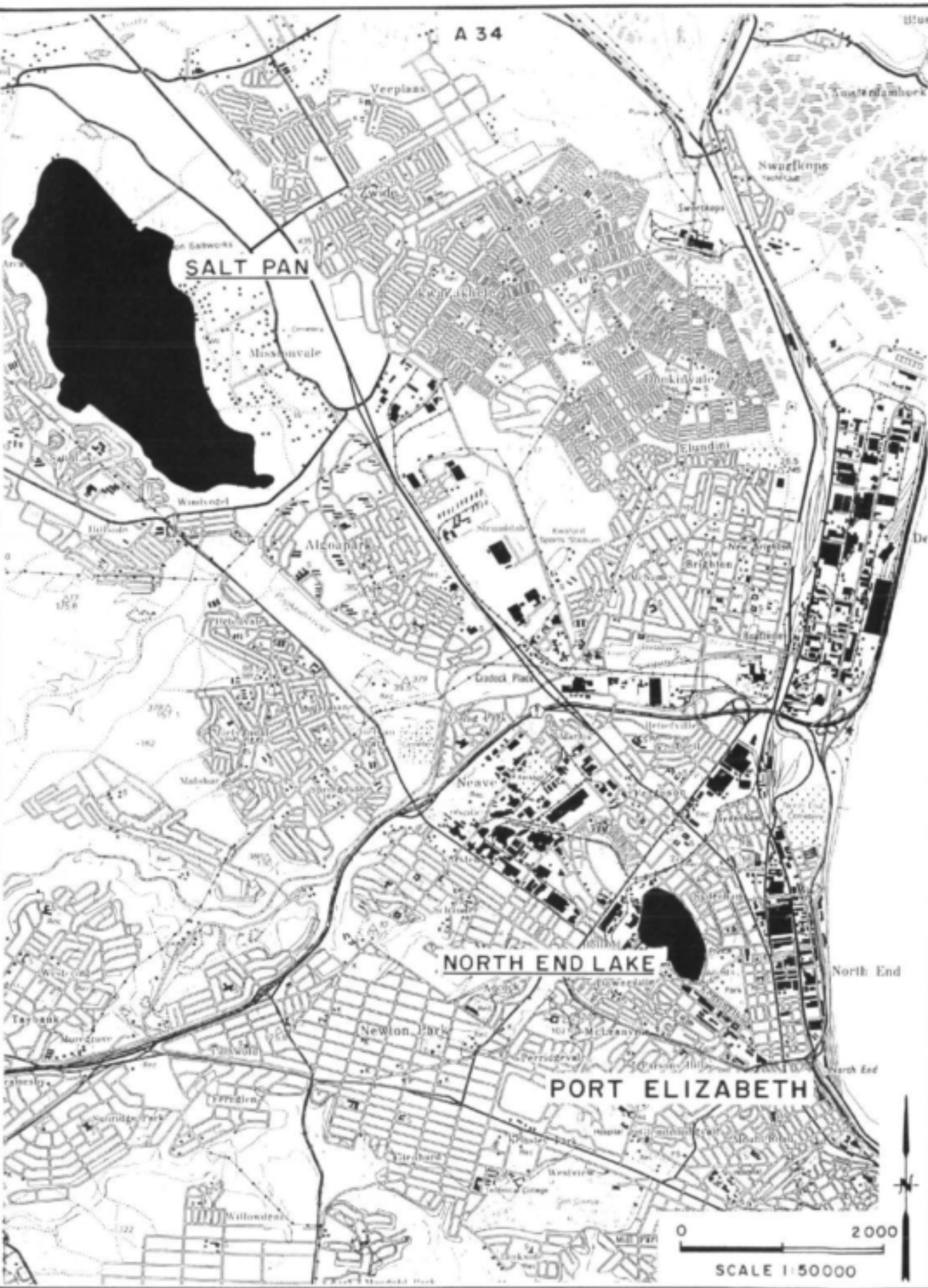


REGISTER OF URBAN IMPOUNDMENTS:
CAPE TOWN (Princess Vlei; Rondevlei; Zeekoevlei; Zondvlei; Wildevöelvlei)

FIGURE No.
A II



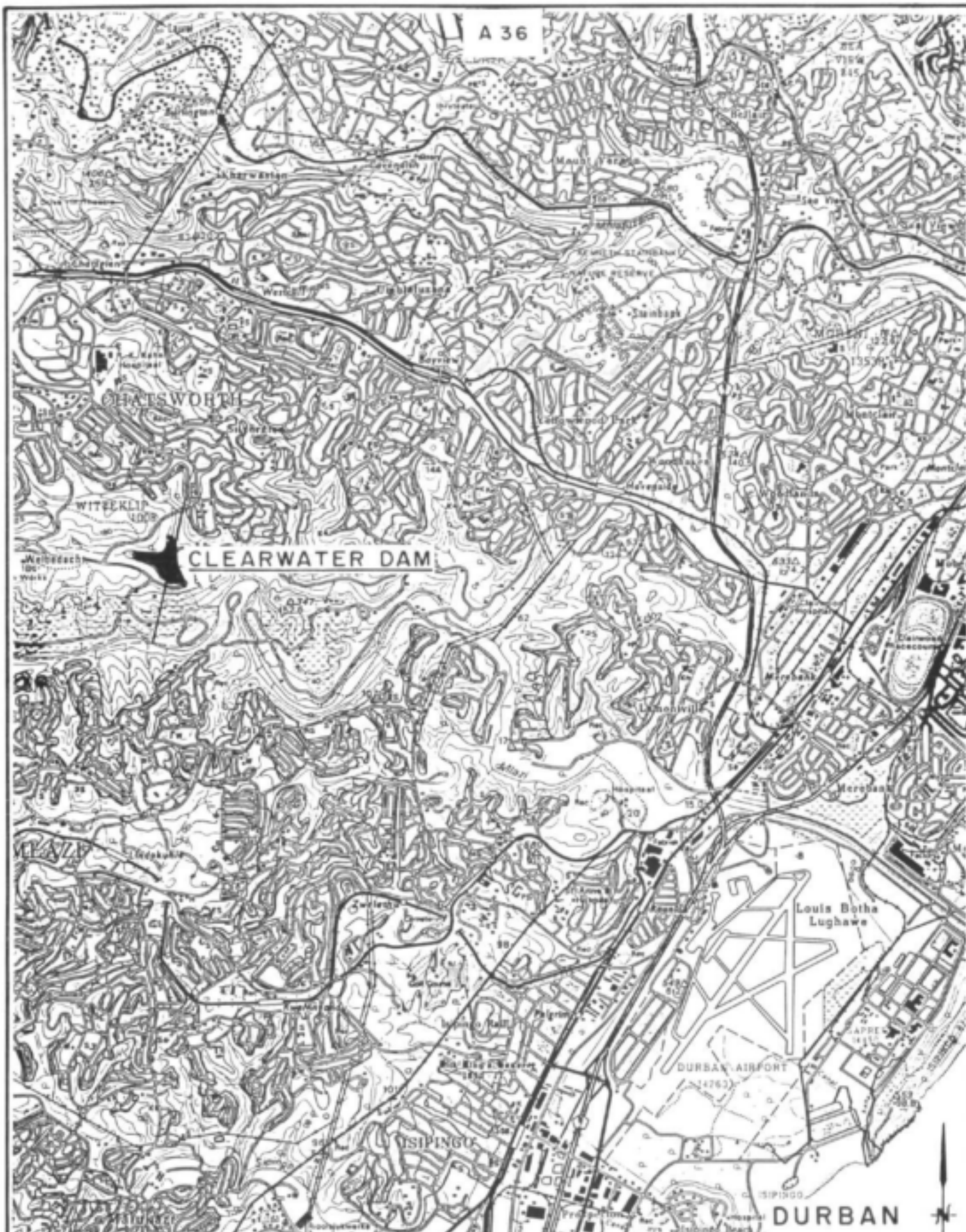
REGISTER OF URBAN IMPOUNDMENTS: MILNERTON (Rietvlei)	FIGURE No. A12



REGISTER OF URBAN IMPOUNDMENTS:
PORT ELIZABETH (North End Lake; Salt Pan)

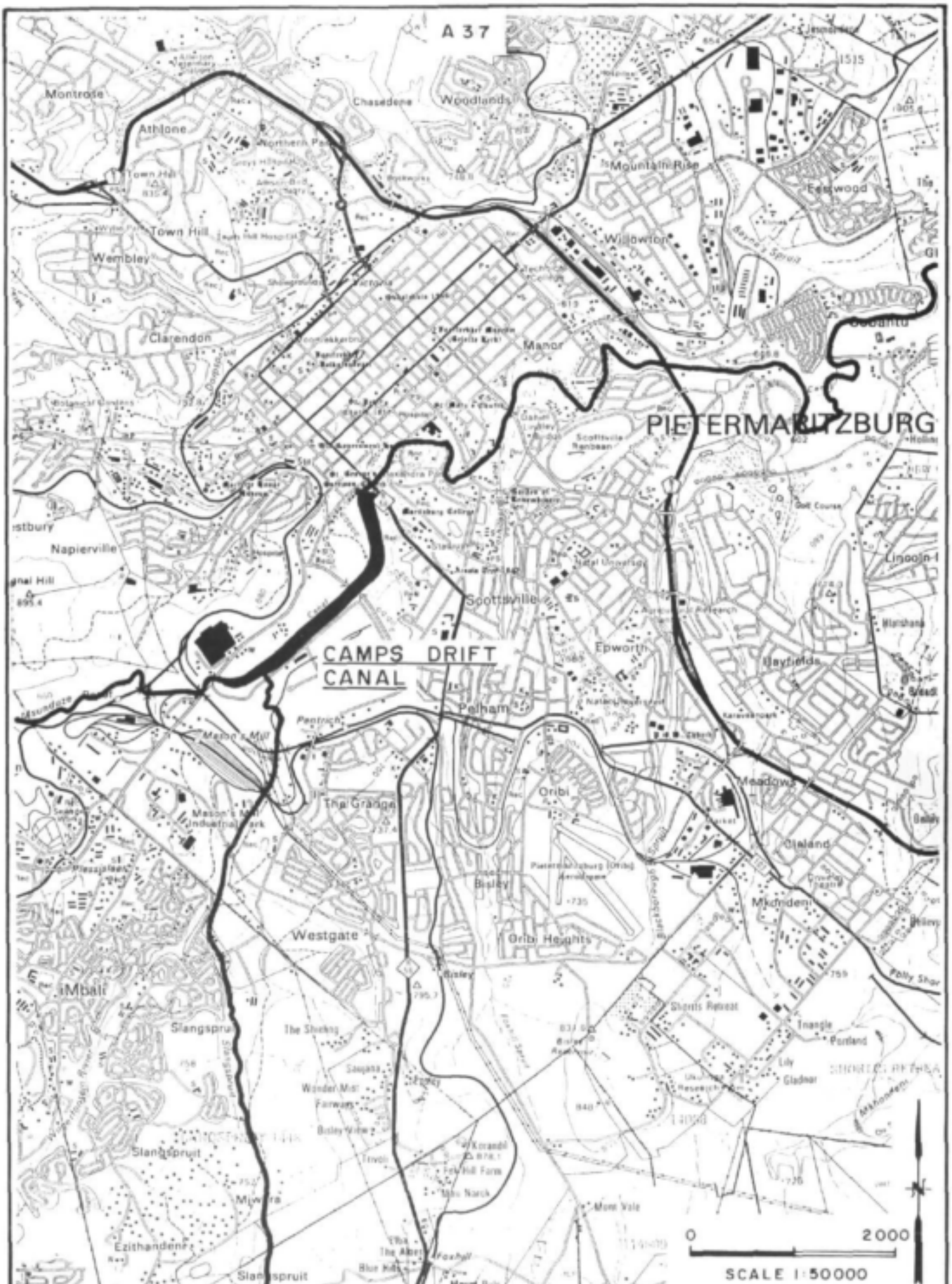
FIGURE No.
A13

REGISTER OF URBAN IMPOUNDMENTS: EAST LONDON (Amalinda Dam)	FIGURE No. A 14

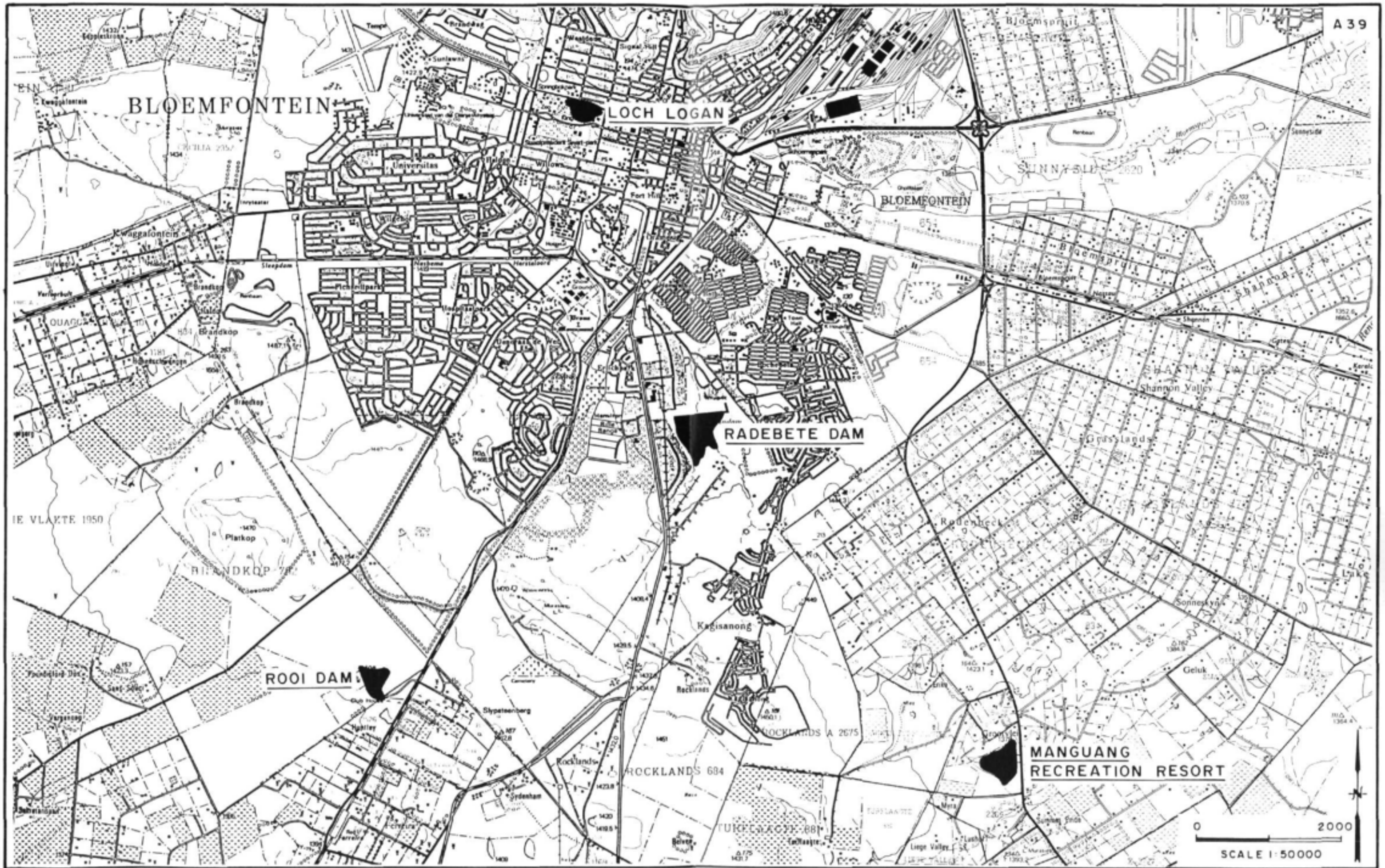


REGISTER OF URBAN IMPOUNDMENTS:
DURBAN (Clearwater Dam)

FIGURE No.
A15

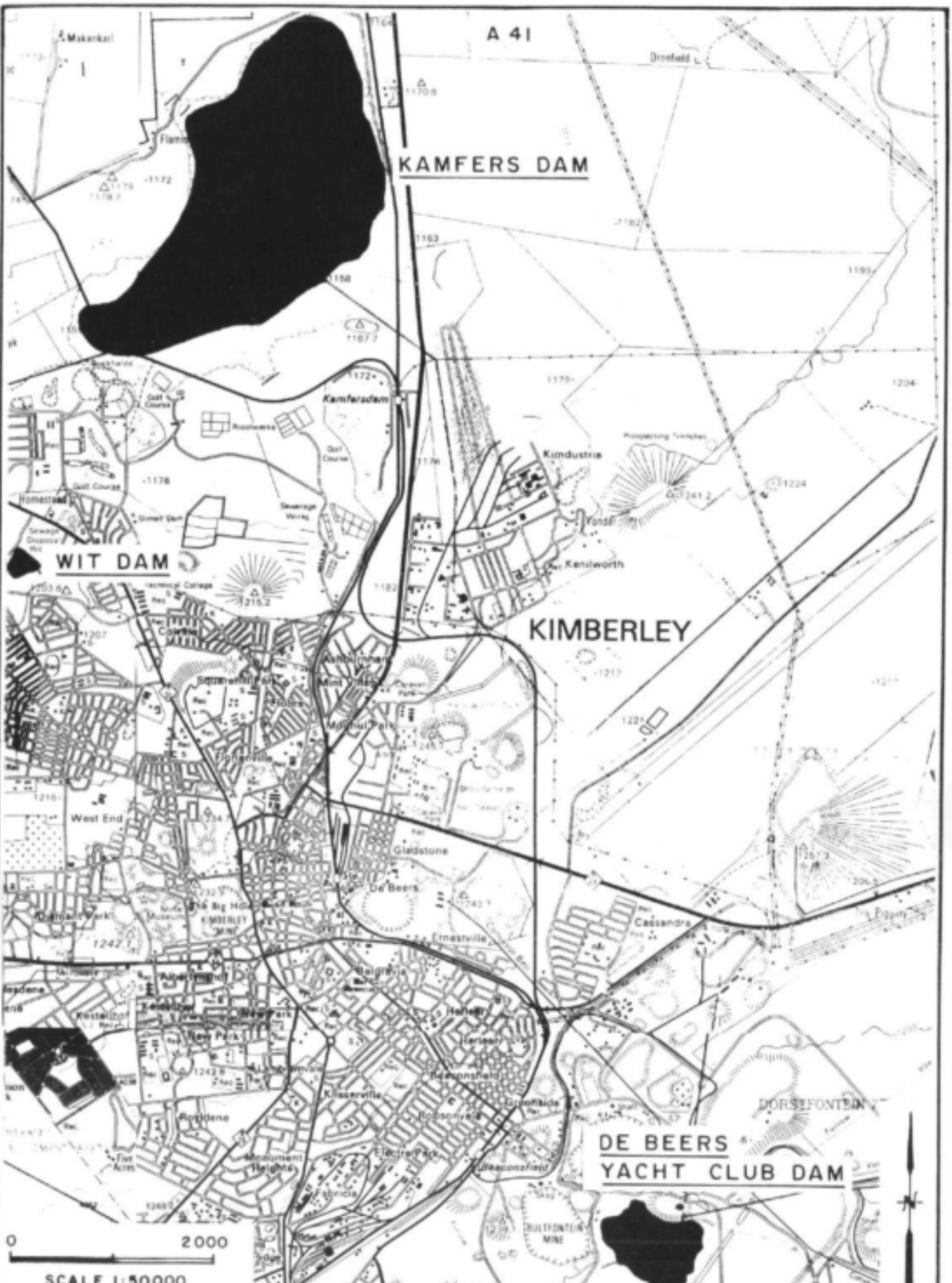


REGISTER OF URBAN IMPOUNDMENTS: PIETERMARITZBURG (Camps Drift Canal)	FIGURE No. A16



REGISTER OF URBAN IMPOUNDMENTS:
BLOEMFONTEIN (Loch Logan; Rooi Dam; Radebete Dam; Manguang Recreation Resort)

FIGURE No.
A 17



REGISTER OF URBAN IMPOUNDMENTS:
KIMBERLEY (Kamfers Dam; Wit Dam; De Beers Yacht Club Dam)

FIGURE No.
A 18

ANNEXURE A

SURVEY FORMS

A. Initial Survey Form to Local Authorities
B. Follow-up Survey Form to Local Authorities

(A)

URBAN IMPOUNDMENTS PROJECT FOR THE WATER RESEARCH COMMISSION
INITIAL SURVEY FORM

1. NAME OF LOCAL AUTHORITY . . . .

   CONTACT PERSON . . . .

   POSITION AND DEPARTMENT . . . .

   TELEPHONE NO . . . . FAX NO . . . .

   POSTAL ADDRESS . . . .

   . . . .

2. LISTED BELOW ARE THE NAMES OF URBAN IMPOUNDMENTS IN MY LOCAL AUTHORITY AREA WHICH ARE GREATER THAN 4 HECTARES IN AREA, HAVE A VOLUME IN EXCESS OF 50 000M^3 AND HAVE A CATCHMENT IN AN URBAN AREA AND ARE THUS ELIGIBLE FOR INCLUSION IN THE REGISTER OF URBAN IMPOUNDMENTS:

NAME OF URBAN IMPOUNDMENT	BRIEF COMMENT ON TYPE OF INFORMATION, IF ANY, AVAILABLE FOR EACH URBAN IMPOUNDMENT

3. MY LOCAL AUTHORITY IS INTERESTED IN PARTICIPATING IN THE URBAN IMPOUNDMENTS PROJECT AND IS WILLING TO PROVIDE INFORMATION:

	Please tick appropriate box	
(a) FOR THE REGISTER OF URBAN IMPOUNDMENTS (minimal, basic information)	YES	NO
(b) FOR THE INVESTIGATION OF 10 SELECTED IMPOUNDMENTS (based on readily available information)	YES	NO
(a) FOR THE DETAILED SURVEY OF 3 CHOSEN IMPOUNDMENTS (requiring the collection of new information by the local authority)	YES	NO

Please return to Mark Freeman of Stewart Scott, Fax No (011) 880-6429

(B)

FOLLOW UP SURVEY FORM TO LOCAL AUTHORITIES

LOCAL AUTHORITY AREA	IMPOUNDMENT NAME	LOCATION	CONTROLLING AUTHORITY	IMPOUNDMENT, PAN OR VLEI	WATER SURFACE AREA (ha)	VOLUME OF WATER (m^3)	LOCAL CATCHMENT TYPE (%) *	MAIN USES OF IMPOUNDMENT ** (in order of importance)	AVAILABILITY OF DATA (especially water quality data)

*Catchment Land Uses:

A = Heavy Industrial
B = Light Industrial
C = Commercial
D = High Density and High Socio-economic Residential
E = High Density and Low Socio-economic Residential
F = Low Density and High Socio-economic Residential
G = Low Density and Low Socio-economic Residential
H = Parkland\Veld
I = Other (specify)

**Impoundment Uses:

A = Recreation (water based)
B = Recreation (waterside based)
C = Storm-water Control
D = Enhancement of Commercial Development
E = Nature Conservation
F = Other (specify)

APPENDIX B

A REVIEW OF EXISTING INFORMATION ON THE MANAGEMENT OF TEN SELECTED URBAN IMPOUNDMENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS AND NOTES

The assistance of the following local authority staff in supplying information and data about the ten impoundments selected for detailed study is gratefully acknowledged:

Mr R Reyneke (Jan Smuts Dam)

Mr W Harding (Princess Vlei and Zeekoevlei)

Dr L Lötter; Mr D Ketley and Mr C Kruger (Zoo Lake and Wemmer Pan)

Mrs L Roode (Nigel Dam)

Mr D Baker and Mrs M Higgs (Camps Drift Canal)

Mr G Devy and Mr G Flanagan (North End Lake)

Mr G Lumgair (Alexander Dam)

Mr L Lötter (Hennops Lake)

The water quality data supplied by each local authority have been used in the report in the format it was received. No verification of the data was undertaken nor was any allowance made for differing sampling procedures and laboratory analyses between the local authorities.

Local authority structures and certain place and lake names were undergoing name changes at the time of going to press. Account has been taken of this where appropriate, but further changes are likely to occur after publication.

URBAN IMPOUNDMENTS RESEARCH PROJECT: A REVIEW OF EXISTING INFORMATION ON THE MANAGEMENT OF TEN SELECTED URBAN IMPOUNDMENTS

A) INTRODUCTION

Stewart Scott Incorporated (SSI), Pulles, Howard & de Lange Incorporated (PHD) and the former City Council of Johannesburg (now the Greater Johannesburg Transitional Metropolitan Council) were appointed by the Water Research Commission in January 1994 to carry out research into urban impoundments (i.e. water bodies in urban areas) with the aim of developing guidelines which could be used to manage these water bodies. The research project was divided into three phases:

- the compilation of a register of urban impoundments;
- a review of existing information on the management of ten selected urban impoundments; and
- a detailed survey and analysis of three chosen urban impoundments.

Together with a literature survey and an investigation of management strategies, processes and costs, the above three study phases will culminate in the development of management guidelines for urban impoundments. This document presents the findings of the second phase of the study - a review of existing information on the management of ten selected urban impoundments.

B) THE SELECTION OF TEN URBAN IMPOUNDMENTS FOR DETAILED STUDY

Once the register of urban impoundments had been compiled, phase two of the project, i.e. to select ten impoundments which would be studied in more detail, was initiated. The aim of the second phase of the project was to identify typical problems encountered with urban impoundments as well as to review local experience with management strategies which have been introduced to combat such problems.

In selecting the ten impoundments, an attempt was made to obtain a sample of different impoundments, representative of those found in South Africa in terms of size, geographical location, climate, catchment characteristics and whether the impoundment was a man-made impoundment or a natural pan or vlei. Another critical criterion in the selection process was whether much information was readily available. In particular, the availability of chemical and bacteriological water quality data for the impoundment was seen as important, whilst reports on investigations into specific problems encountered at an impoundment were an additional positive factor. The willingness to provide information by the local authority to be involved in the project was also a vital pre-requisite in terms of selection.

Deliberations amongst the research team based on feedback obtained in compiling the register of urban impoundments for the first phase of the project culminated in the selection of the following ten impoundments for more detailed study (listed in alphabetical order by local authority area):

Local Authority Area	**Urban Impoundment**
Brakpan	Jan Smuts Dam
Cape Town	Princess Vlei
Cape Town	Zeekoevlei
Johannesburg	Zoo Lake
Johannesburg	Wemmer Pan
Nigel	Nigel Dam
Pietermaritzburg	Camps Drift Canal
Port Elizabeth	North End Lake
Springs	Alexander Dam
Centurion	Hennops Lake

The results of the more detailed analysis of the ten impoundments follow in the subsequent sections of this document.

1. JAN SMUTS DAM, BRAKPAN

1.1 Location and Catchment Characteristics

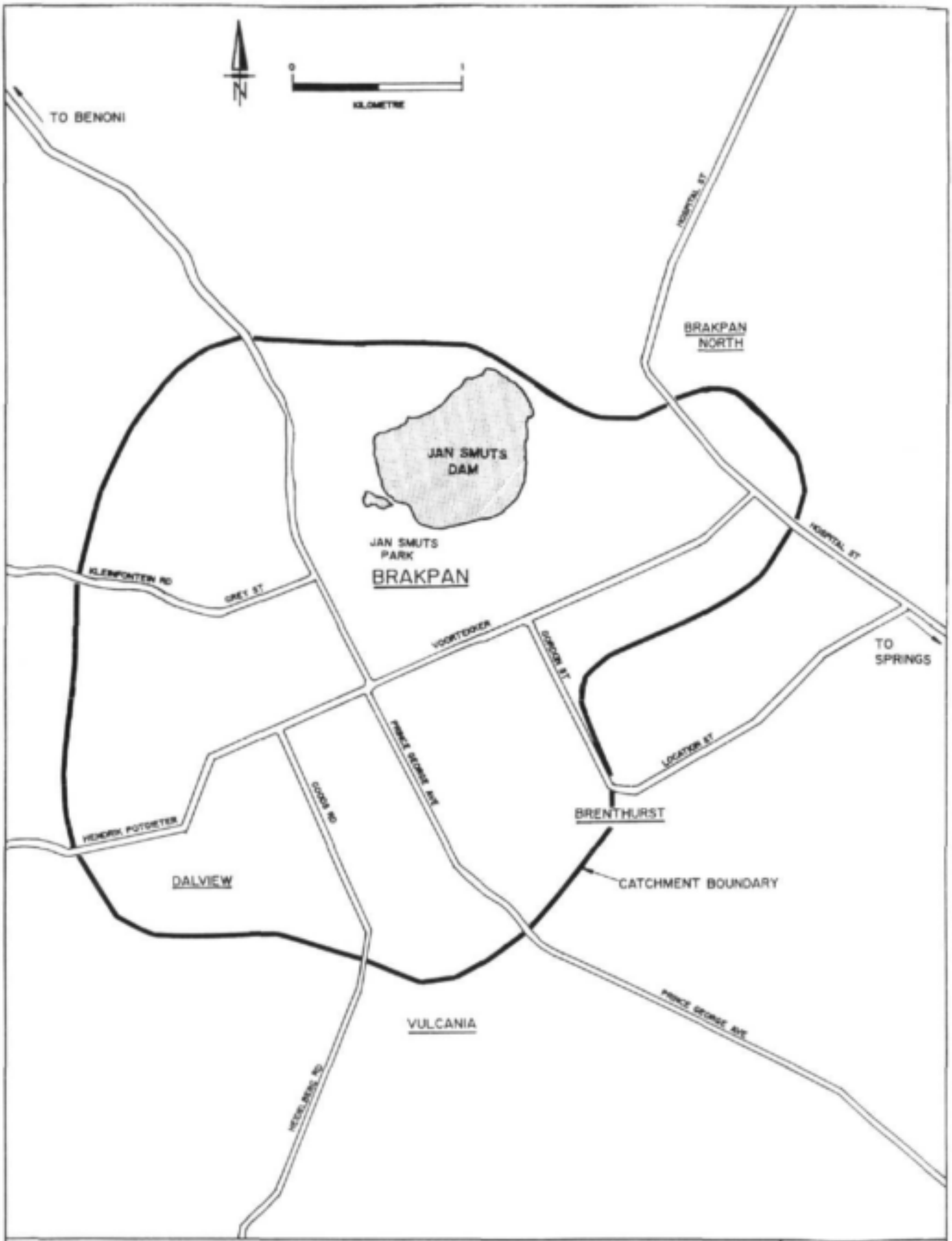
Jan Smuts Dam is a shallow, natural pan situated just north of the Brakpan CBD (Figure B1.1). It is at a height of 1 600 m above mean sea level (AMSL), has a surface area of 70 ha and has a small island in the centre. Some of its basic characteristics are summarised in Table B1.1.

Table B1.1 : Characteristics of Jan Smuts Dam

Geographic Location	26° 13' S ; 28° 22' E
Elevation	1 600 m AMSL
Surface Area	70 ha
Volume	810 000 m^3
Mean Depth	1,2 m
Maximum Depth	1,4 m
Length	1 805 m
Width	875 m

The land use in the catchment is mixed. 50% of the catchment is occupied by residential areas, of which approximately two-thirds serve the medium to high socio-economic groups of the population and one third the lower socio-economic segment. Commercial land and parkland each occupy approximately 20% of the catchment, whilst light and heavy industrial areas make up 5% each. An ash heap and refuse dump is situated on the northern shore.

Jan Smuts Dam is fed by storm-water runoff and receives treated effluent from the sewage treatment works on its eastern shore. A storm-water drain flows into a small flooded quarry (approximately 100 m in diameter and over 30 m in depth), which is connected to the south-western part of the pan by a short canal. The pan has no natural outlet. During periods of high rainfall, water is actively pumped out of the pan into a tributary of the Blesbokspruit. During the dry season, there is no outflow from the pan.



LOCATION AND CATCHMENT AREA OF JAN SMUTS DAM

FIGURE No.
B 1.1

1.2 Pan History

In the early part of this century, Jan Smuts Dam filled during the rainy season and dried out in winter. Since 1938, the Brakpan sewage disposal works has released its treated effluent into the pan which now remains full throughout the year. Storm water from central Brakpan also drains into the pan and maintains water levels.

In the past, water was abstracted from the pan for cooling purposes at a power station situated on the northern bank, but the power station has now been closed down. During the 1950s, the area around the southern shore was developed as a park and recreation resort. Jan Smuts Dam has experienced pollution problems since the 1940s and has an extensive history of investigation (see Section 1.4).

1.3 Pan Use

Although, as described earlier, Jan Smuts Dam serves as a storm-water retention pond and as an outlet for discharge from the Brakpan sewage treatment plant, its most visible use is as a recreation node for the inhabitants of Brakpan and neighbouring towns.

Active recreational uses include water sports such as sailing, motorboating and fishing. On the southern bank, an extensive recreational resort has been developed including a caravan park, children's playground, restaurant and picnicking facilities.

1.4 Pan Limnology

Jan Smuts Dam is located within the Highveld climatic zone and thus experiences a mean annual precipitation range of 500-900 mm with rainfall concentrated during the summer season. No accurate hydrological information is available on inflows into the pan, nor is much documented information available regarding flora and fauna in and around the pan. Most of the southern and western shores alongside the recreational resort have been landscaped as parkland. Carp and catfish are caught from the pan by anglers.

Extensive and detailed information is available, however, with regard to problems caused by populations of blue-green algae (cyanobacteria) which infest Jan Smuts Dam. Problems associated with these algae were first identified in South Africa earlier this century when domestic stock animals died after drinking water from dams and pans in the Vaal River catchment which were contaminated with the algae. It was established that favourable conditions for the growth of the algae were warm, dry and calm weather, long hours of sunlight and broad, stagnant stretches of water with elevated nutrient concentrations such as pans and vleis. After a few dry days of calm, sunny weather, large masses of algae accumulated on the water and the slightest breeze was sufficient to drive the floating algae to the edge of the dam or pan, where the water became very poisonous. Ingestion of these algae when animals drank from these floating scums led to toxic poisoning and death within a few hours. This explained the mortality of animals which so often coincided with certain winds. Since the algae require fairly warm weather for luxuriant growth, there was normally a considerable reduction in the quantity present during the winter months. The decomposition of the algae was accompanied by the emission of an obnoxious smell which could be detected at a considerable distance from the affected water body. In the 1940s, the algae were treated with copper sulphate in order to destroy them.

When the recreational resort on the southern bank of the Jan Smuts Dam was created in the 1950s, the condition of the pan was investigated by the Brakpan Town Council in order to evaluate any possible risks to public health resulting from use of the pan for recreational activity. The presence of algal growths were noted along with contamination from storm water collected from urban surfaces and effluent from the sewage works. However, at the time, the pan's self-purification capacity was stressed and the public was prevented only from accessing small areas of the pan around the storm-water and sewage effluent discharge outlets. A programme of surveillance of pollution reaching the pan was also recommended, by monitoring the chemical and bacteriological quality of the water in the pan.

An examination of Jan Smuts Dam was carried out again by the Brakpan Town Council in 1960 in order to investigate the algal nuisance problem which had then reached serious proportions. The study identified three main causes for the algal blooms. Firstly, although a sewage works effluent with a satisfactory quality was being discharged into the pan, it was highly nitrified and as a result supplied considerable quantities of nitrogen to the pan water which stimulated the growth of algae. Secondly, an extremely dry summer had meant a drop in the level of the water, causing an increase in the concentration of dissolved solids in the water. Lastly, uncontrolled storm water discharged into the pan was adding materially to the pollution load. This situation confirmed that where water systems receive the normal municipal effluent in the form of controlled sewage disposal or uncontrolled runoff via the storm-water system, the receiving body of water will, provided it has sufficient buffering capacity (alkalinity), become so enriched that algal blooms eventually occur. In the case of Jan Smuts Dam, which is a natural pan, this situation was being aggravated due to the absence of any natural outlet resulting in no flushing through of water during rainy periods.

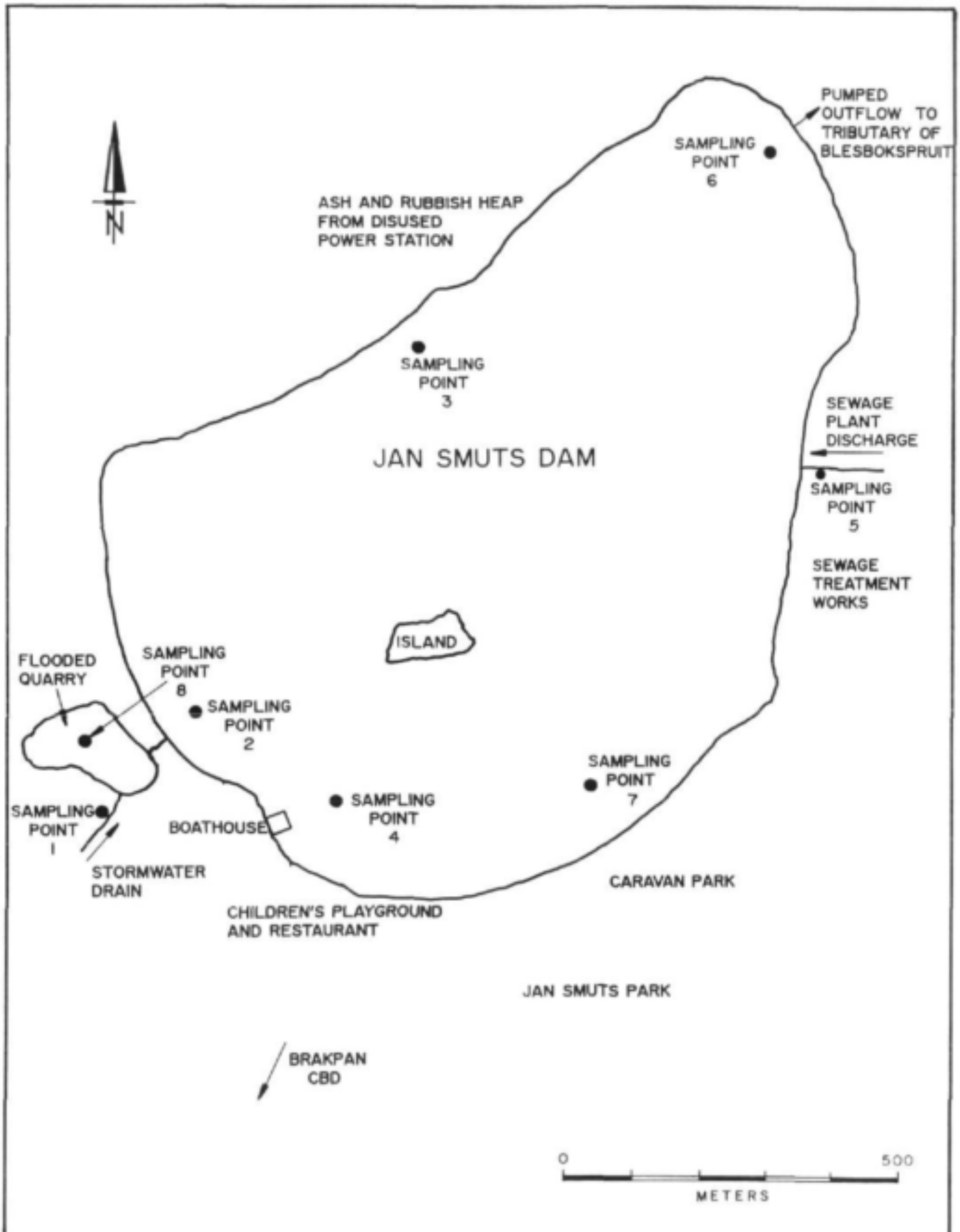
Recommendations from the 1960 study included maintaining the level of the pan, using the quarry adjacent to the south-western corner of the pan as a maturation pond for incoming storm water to try and increase aeration and that the possibility of providing the pan with an outlet be investigated.

In 1961, algal contamination was affecting the small dam used by the power station and the adjacent quarry and it was recommended that attempts be made to eradicate the algae by means of copper sulphate and by clearing the marginal vegetation around the quarry and the pan so that stagnant water areas would not develop.

Water samples collected in 1975 showed that algal growths remained a problem in Jan Smuts Dam. The most abundant alga was identified as *Microcystis aeruginosa*. A 1981 study (Thornton and Chutter, 1981) confirmed that the water quality of the pan was extremely poor, with very high phosphorus and nitrogen concentrations. The shallow nature of the pan and heavy sediment nutrient concentrations compounded the problem as did stormwater seepage through the ash and refuse dump of the disused power station on the northern shore.

A 1988 study (Scott and De Waal and the Division of Water Technology, CSIR, 1988) reported that the only feasible means of reducing the phosphorus load in the pan was by keeping out the sewage effluent. The problem with this solution, however, was that the pan would likely dry out in winter without the sewage effluent flow to keep it full and that the dam sediments contained such high concentrations of phosphorus that these would leach out into the water body over a long period of time resulting in the continuation of the algal problem. Pumping Brakpan's sewage elsewhere would clearly have cost implications, but it was proposed that if this was done, an alternative low phosphorus source of water from nearby rivers would be required to maintain water levels. In addition, the existing phosphorus-rich sediments in the pan could be isolated from the water body by covering the floor of the pan with a layer of fly ash. The cationic elements in the fly ash such as calcium, iron and aluminium would chemically bind the phosphorus and thus prevent it reaching the water body.

The Brakpan Town Council has monitored the water quality of the pan over a considerable period of time. Samples are presently undertaken at eight sampling points (Figure B1.2). Table B1.2 presents summarised water quality data for 1992-93 for Jan Smuts Dam. It can be seen that the prime source of water for the pan is from the sewage treatment works, since all water quality



DETAIL OF JAN SMUTS DAM AND WATER QUALITY SAMPLING POINTS

FIGURE No. B I.2

variables monitored yielded similar results to those for the inflow from the works. Nutrient concentrations are similar to those found in the earlier studies, orthophosphate concentrations are 0,6 mg/ℓ for both the sewage works inflow and pump station sites, and nitrates are 2,0 mg/ℓ to 2,6 mg/ℓ. This clearly indicates sufficient nutrient availability for algal blooms to occur.

Table B1.2 : Water quality data for Jan Smuts Dam (January 1992 - August 1993)

Sampling Points (see Figure B1.2)	No of Samples
1. Stormwater Inflow	19
2. Pan Inflow	19
3. Fishing Point	19
4. Boat Landing Point	19
5. Sewage Plant Discharge	19
6. Pumped Outflow	19
7. Caravan Park	19
8. Quarry	19

Chemical*/Physical Variables	Reading	Sampling Points							
		1	2	3	4	5	6	7	8
pH	Min	6,7	6,7	7,1	7,4	6,8	6,9	7,3	6,6
	Max	8,3	9,1	8,9	8,8	8,5	8,6	9,3	8,2
	Ave	7,6	7,8	8,2	8,2	7,4	7,8	8,1	7,2
Electrical Conductivity (mS/m)	Min	30	30	45	55	55	55	55	30
	Max	206	140	85	90	90	90	90	125
	Ave	106	65	63	63	64	64	64	61
Total Dissolved Solids	Min	230	255	323	390	427	414	400	197
	Max	1 526	644	648	947	641	636	644	1 124
	Ave	791	464	489	535	508	504	504	482
Total Alkalinity (as $CaCO_3$)	Min	78	40	40	34	42	42	38	58
	Max	312	163	162	162	153	155	162	250
	Ave	194	100	99	99	103	96	104	132
Total Hardness (as $CaCO_3$)	Min	74	26	44	8	20	36	32	56
	Max	996	238	184	370	370	180	742	742
	Ave	362	149	134	139	144	130	163	224
Chloride (as Cl)	Min	40	40	88	84	80	80	84	36
	Max	110	140	160	160	154	148	156	140
	Ave	70	98	120	122	122	121	122	63
Ammonia (as N)	Min	1,00	1,00	1,40	1,00	1,60	1,30	1,30	1,90
	Max	20,80	8,40	9,10	8,40	8,40	9,70	9,20	7,00
	Ave	3,95	3,57	3,78	3,45	4,69	4,48	3,96	3,55
Nitrate Nitrogen (as N)	Min	0	0	0,40	0,20	0,10	0,40	0	0
	Max	6,50	4,00	7,70	4,00	4,30	4,60	4,80	4,00
	Ave	2,83	1,91	2,05	1,78	2,09	2,61	2,21	0,93
Orthophosphate (as P)	Min	0,09	0,12	0,20	0,20	0,40	0,30	0,10	0,06
	Max	3,30	1,00	0,70	1,90	1,70	2,40	1,10	0,80
	Ave	0,47	0,37	0,35	0,44	0,67	0,66	0,43	0,34
Suspended Solids	Min	1	3	30	27	9	24	10	6
	Max	204	397	230	238	279	114	129	64
	Ave	25	82	83	75	87	58	56	22
Settling Solids	Min	0	0	0	0	0	0	0	0
	Max	20	1	0	0	3	0	0	2
	Ave	1	0	0	0	0	0	0	1
Dissolved Oxygen (as O)	Min	0	0	2,5	0,6	0	0,4	2,8	0,5
	Max	15,7	12,1	10,8	10,1	9,2	10,8	10,2	14,9
	Ave	8,0	6,3	7,0	6,8	4,3	6,0	6,5	4,1
Oxygen Absorbed (as O)	Min	1,6	0	6,3	6,0	5,7	5,5	5,2	3,0
	Max	14,5	23,2	15,7	17,9	18,0	11,5	12,5	12,2
	Ave	4,6	8,9	9,7	9,5	10,4	8,3	7,8	6,9

* Units are mg/ℓ unless otherwise indicated.

The significance of sediment phosphorus requires closer investigation. The suspended solids data indicates that resuspension of the sediments is occurring. The average value recorded for the site where the sewage effluent enters the pan is 87 mg/ℓ, and 58 mg/ℓ for the pump station. Without a breakdown of the components of the suspended solids fraction, it is not possible to say what processes are taking place within the pan. Two probable hypotheses are proposed. Firstly, that the effluent from the sewage treatment works contains suspended solids or secondly, that the action of the effluent entering the pan causes resuspension of sediments at the inflow and that wind causes resuspension at all sites. Unfortunately, no wind data were readily available to assess this, but the role of resuspension certainly warrants investigation. The release of phosphates from the sediments appears to be a significant source of nutrients; figures of 5 mg P/g of sediment have been reported. This represents a net sink. The reported values of chlorophyll *a* indicate that some algal blooms of over 300 μg/ℓ have been recorded.

Bacteriological data for Jan Smuts Dam for 1992-93 are shown in Table B1.3. The figures indicate that there is significant bacterial contamination of the pan, and that average values considerably exceed the guidelines for recreational use (Department of Water Affairs & Forestry, 1993).

Table B1.3 : Bacterial quality of Jan Smuts Dam (November 1992 - November 1993)

Bacteriological Variable	Reading	Sampling Points (see Figure B1.2)			
		3	4	5	6
E. coli per 100 mℓ	Min Max Ave	10 500 000 83 155	30 500 000 78 185	800 430 000 61 085	60 500 000 79 878

1.5 Pollution Problems and Management Strategies

As the previous section describes, Jan Smuts Dam has a long history of algal growth and eutrophication problems. It can be described as hypertrophic or excessively enriched with algal growth nutrients. The dominant alga, *Microcystis aeruginosa*, accumulates at the surface in calm conditions in wind-protected sites and forms thick, green scums. Within days the upper layers begin to rot, releasing foul-smelling odours that result in public complaints. The scums reduce aesthetic value and severely impair the recreational potential of the pan. Wind blown debris also becomes trapped in the scums, increasing their unacceptable appearance.

Strong winds disperse the scums, but at the same time, they enhance the release of obnoxious odours and the dispersal of scums may lead to oxygen depletion of the water and subsequent fish kills. Another problem associated with the over-abundance of *Microcystis* is a health problem. Although it is known that the algae produce toxins which cause disease and death of livestock and other animals that drink algae infested water, no human deaths from *Microcystis* have been proved. Accidental ingestion of the water, however, while swimming or boating has caused gastro-enteritis and skin contact with the blooms is known to cause skin irritations.

The main source of the algal problems are the high concentrations of nutrients within the pan as well as in the major inflow. Two major categories of management can therefore be discussed - catchment and in-lake strategies.

In terms of catchment strategies, it must be remembered that the prime source of the nutrients in Jan Smuts Dam is the Brakpan waste-water treatment plant. Earlier investigations conducted by Scott and De Waal and the CSIR (1988) have identified that even if the works could comply with a stricter standard (e.g. 0.05 mg/ℓ), algal problems could still be expected, primarily as a result of the phosphates bound to the sediments.

The diversion of water from the pan would reduce the source of nutrients, but the pan would dry out and this would negatively affect the use of the pan as a recreational resource unless diversion was restricted to the summer rainfall period only. Additionally, the sediments would still contain significant amounts of phosphorus.

A number of further options could be pursued within the catchment:

- Alternate sources of water could be found, to either dilute the effluent or to replace it. It is unlikely that such sources exist, but the option should still be explored, specifically in view of the number of mines in the area either closing down or nearing the end of their working lives, which means the cessation of regular pumping of water from underground. The net result of this termination of dewatering may well be to flood certain mines and this water may eventually decant from mines in sensitive areas. A research project has been recently completed which identifies the potential for flooding and the likely decant zones (Scott, 1994). Co-operative schemes may be necessary if such zones are undesirable and therefore a source of water may become available.

- The effluent from the treatment works could be polished by a wetland or marsh system to reduce the nutrient loading to the pan. A fully integrated system would have to be developed in order that its hydraulic loading design criteria are sufficient to cater for large storm events and to ensure that adequate removal occurs. This could be viewed as an extension to the recreational resources within the area by developing new habitats around the pan.

- The phosphorus could be stripped from the effluent to lower levels within the treatment works, using conventional stripping techniques, but this would be a costly exercise.

With respect to the in-lake strategies, the Brakpan Town Council has spent approximately R2 million over the past three years on studies (e.g. Van Wyk and Louw, 1992) and implementation projects to eliminate the algae and smell problems during the summer months at Jan Smuts Dam.

The capital projects involved the construction of a concrete wall around the pan to eliminate algae accumulations on the embankment. Ten aerators were also installed in the pan in order to keep the algae in suspension and prevent the formation of scum, and possibly cause a species shift to a more desirable green algal species. The hydrology, shallow depth and lack of an outflow make Jan Smuts Dam particularly sensitive to nutrient loading and although the aerators can reduce the occurrence of algal scums, there is unlikely to be a reduction in the nutrient content of the pan, although it may enhance phosphate sediment entrapment by keeping the pan aerobic at all times. The possibility also exists that localised resuspension of sediments could occur in the vicinity of the aerators.

Further options which could be considered are:

- The sediment within the pan could be bound so that phosphate cannot readily be released to the system. This could be achieved by the use of flyash.

- An outflow weir could be constructed in order to facilitate flushing and regulation of the water level. There is no information at present concerning the hydrology of the catchment, but it can be expected that flash floods do occur. The energy from these storms may well be utilised to resuspend sediment and to flush it from the system. Additionally, the periodic replacement of highly enriched water with storm water would influence the dynamics of the algal populations in the pan.

- If the pan were allowed to dry out, the sediment could be removed, at great cost, and disposed of on a landfill site. This would depend on the make up of the soil, and a detailed assessment would have to be conducted before such an option is implemented.

- The relationship between rooted macrophytes and algae in the local area should be investigated. In certain dams and lakes within the region, dense growths of macrophytes are not associated with algal scums. Competition for resources may favour a complex species, such as a rooted macrophyte. This would have to be carefully investigated, as the deliberate introduction of certain plant species could have a negative impact on the pan.

- The use of barley straw bales could also be investigated to control the algal population. The Brakpan Town Council have already expressed an interest in this option and it has shown great promise internationally. Trials commenced on Loch Vaal during 1994, but it is still too early to assess their success. This strategy, however, would only address the symptom and not the cause of the problems. The fundamental philosophy in the management of urban impoundments should remain source reduction, effluent reuse and effluent treatment.

1.6 References

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2. PRINCESS VLEI, CAPE TOWN

2.1 Location and Catchment Characteristics

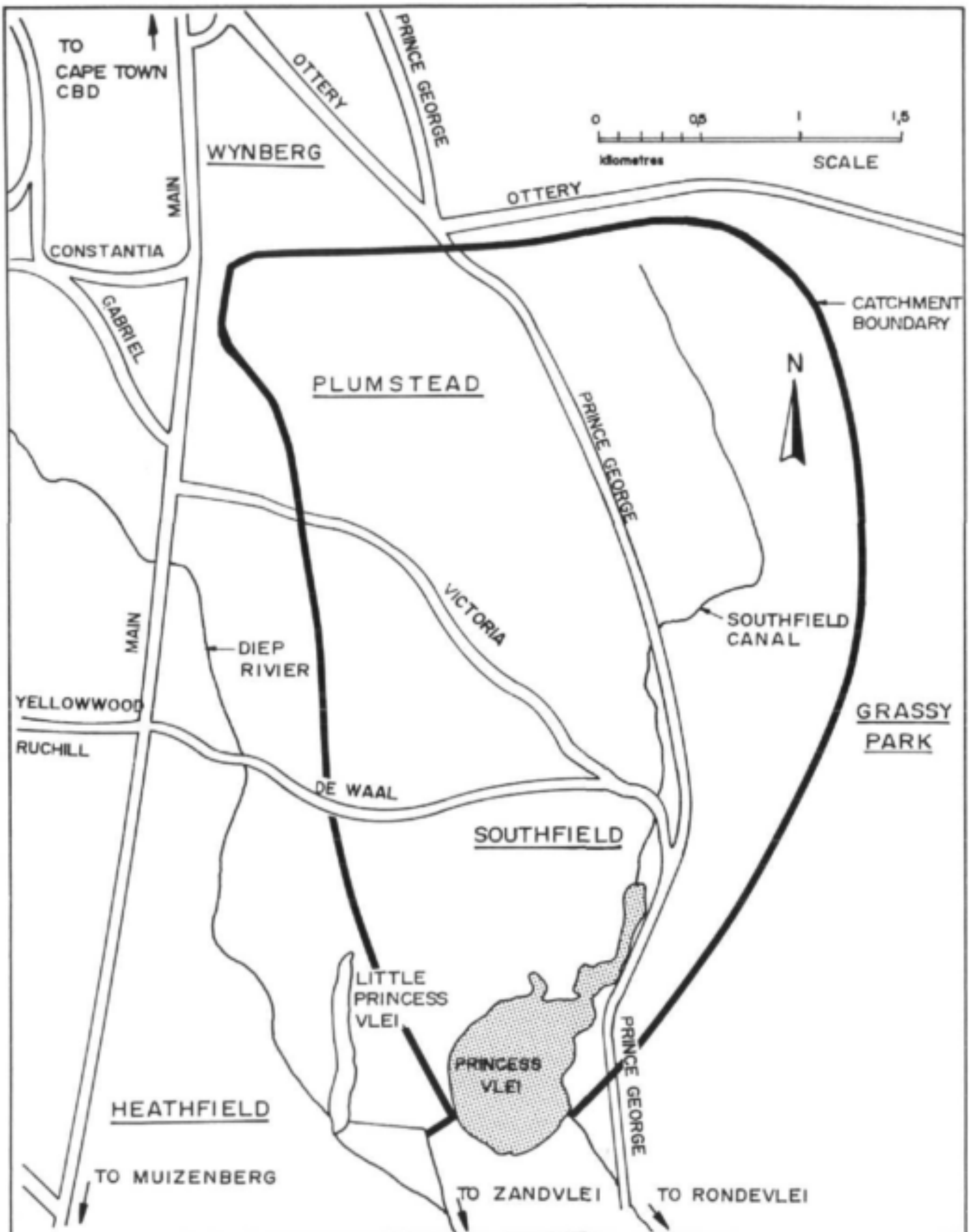
Princess Vlei is a small (29 ha), shallow (mean depth 2,4 m), permanent, freshwater coastal lake situated in the Diepriver area of Cape Town, about 15 km south of the Cape Town CBD. It has a perimeter of 2,4 km and lies on sandflats which were originally submerged beneath the sea. Of the four largest vleis on the Cape Peninsula, viz. Zeekoevlei, Zandvlei, Rondevlei and Princess Vlei, the latter is the smallest and probably the oldest. Basic characteristics of Princess Vlei are shown in Table B2.1.

Table B2.1 : Characteristics of Princess Vlei

Geographic Location	34° 3' S; 18° 28' E
Elevation	6,6 m AMSL
Surface Area	29 ha
Volume	715 000 m^3
Mean Depth	2,4 m
Maximum Depth	5,0 m
Length	600 m
Width	500 m

Princess Vlei's inflow emanates from the Southfield Canal which drains an urban catchment of approximately 800 ha (Figure B2.1). The vlei is bordered to the north and south by formal residential areas serving the medium to high socio-economic segment of the population. This land use contributes approximately 60% of the catchment. To the east and west of the vlei is public open space comprising 35% of the catchment. Light industrial areas to the north of the vlei make up the remaining 5% of the catchment. In addition to the inflow from the Southfield Canal, several storm-water pipes enter the vlei at various points around its perimeter.

An outlet weir lies to the south-east of the vlei and drains into a canal linking Princess Vlei to Rondevlei. A flood protection overflow weir is located to the south-west of the vlei which drains into the Sand River and ultimately into the Zandvlei. The volume of the vlei has been calculated as 715 000 m^3, with sediments accounting for approximately 150 000 m^3 or 21% thereof.



LOCATION AND CATCHMENT AREA OF PRINCESS VLEI

FIGURE No. B2.1

Outflow from Princess Vlei usually occurs between April and October during the winter rains. The Cape Town City Council has three sewage pumping stations in the Princess Vlei catchment which, during time of malfunction or overloading, are designed to overflow into the Southfield Canal. Prior to 1985, such overflows were relatively frequent during the winter months, but subsequent modifications have greatly reduced the incidence of overflow events so that only two overflows were recorded between January 1986 and December 1990.

2.2 Vlei History

Princess Vlei is a natural freshwater lake. The only man-made modifications to the vlei have been a temporary outlet weir located on the south-east shore (crest height 6,45 m AMSL) that was replaced in 1990 with a permanent structure (crest height 6,6 m AMSL). In addition, a flood-protection overflow weir (crest height 7,4 m AMSL) is situated on the south-western shore.

2.3 Vlei Use

Together with Zeekoevlei, Zandvlei and Rondevlei, Princess Vlei is one of only four substantial, naturally-occurring areas of inland water suitable for recreation within the Cape Town municipal area, serving a population of over 1 million people. In a metropolitan context (i.e. inclusive of neighbouring municipalities forming part of the Greater Cape Town area), this figure would exceed 2 million people.

Princess Vlei presently attracts only passive recreational activities and is mainly utilised on a regular basis by casual and club anglers, especially during the winter months. It also acts as a storm-water retention pond and water is abstracted from the vlei by the City Council for irrigation of the surrounding public open space. Plans have been developed to enhance the vlei as a venue for boating by constructing jetties and boardwalks, but funds are not currently available to implement these plans.

2.4 Vlei Limnology

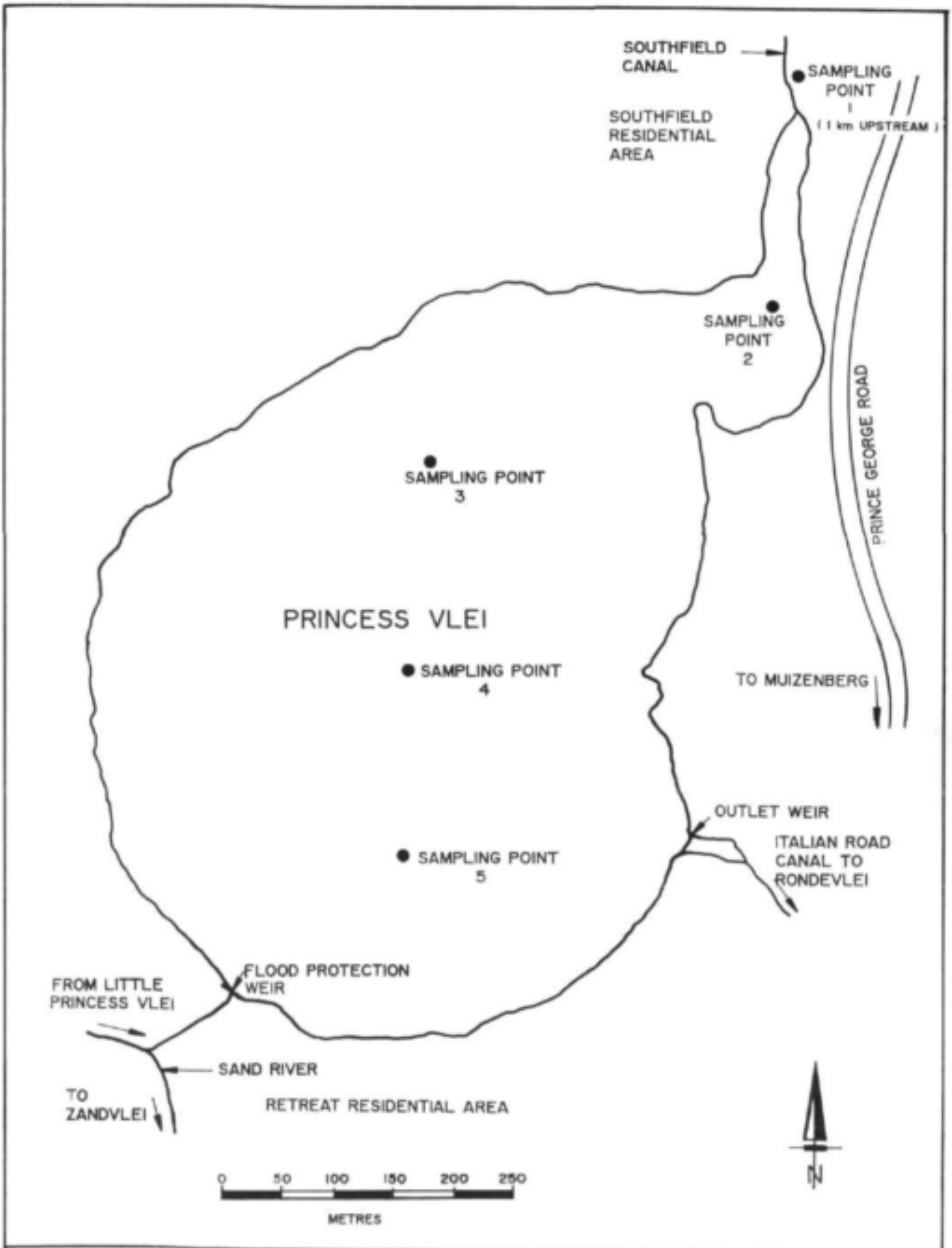
Two historical studies which investigated Princess Vlei classified the lake as alkaline during the 1920s and as being alkaline and eutrophic during the 1940s. Proposals for an ecological investigation of surface waters in the Cape Peninsula in 1976 afforded Princess Vlei a low priority with respect to research needs. At that time, attention regarding the vlei was directed largely towards the removal of water hyacinth. Monitoring of Princess Vlei by the Cape Town City Council began in earnest in 1982.

The vlei was dredged between March and July 1983 in order to remove a shallow sand-bar, running from north-west to south-east across the middle of the vlei. This sill effectively divided the vlei into two basins and precluded hydraulic flushing, thereby allowing dense phytoplankton populations and algal blooms to develop. The bathometry of Princess Vlei was recently surveyed and the results showed that the sill has been replaced by a central deepening of the vlei and some redistribution of sediments.

The first detailed, long-term and published analysis of ecological aspects of Princess Vlei resulted from an intensive study of the vlei conducted between April 1989 and March 1991 (Harding, 1992). This study comprised fortnightly limnological monitoring and phytoplankton collections with monthly water chemistry monitoring coinciding with one of the fortnightly visits. Monthly heavy metal analyses of the water sediments were also carried out between December 1989 and December 1990. The water samples were taken from a boat at four stations in the vlei (the inlet, north, centre and south of the vlei) and at a point 1 km north of the vlei in the Southfield Canal. These points continue to serve as regular sampling stations (Figure B2.2).

Evaluation of a range of chemical, physical and bacteriological variables was carried out on the 1989 - 1991 data, using US, European and South African parameters for trophic state definition. Princess Vlei was classified eutrophic with respect to mean water transparency, chlorophyll, phosphorus and nitrogen. Phytoplankton concentrations present in the water were also characteristic of a eutrophic water body.

The presence of a timber treatment plant in the industrial area north of Princess Vlei had been implicated in high levels of chromium measured in the ground water drawn from nearby boreholes. This prompted the investigation of trace metal concentrations in the vlei, but concentrations of metals complied with European standards. Elevated iron levels recorded were generally regarded as non-critical with respect to toxicity.



DETAIL OF PRINCESS VLEI AND WATER QUALITY SAMPLING POINTS

FIGURE No. B 2.2

Data giving meteorological conditions experienced at Princess Vlei were also collected for the 1989-1991 study. Rainfall data were obtained from a rainfall gauging station situated on the northern shore of the vlei. On-site wind recordings were limited to surface speed and direction measurements made at the time of water sampling. Supplementary wind, rainfall, sunshine and incident solar radiation data were obtained from the meteorological office at Cape Town Airport.

From April 1989 to March 1991, the monthly average sunshine period measured at Cape Town Airport ranged between 6,0 and 11,1 h/d with minima during June and July and maxima during January. Wind speed measurements made at the time of sampling gave a mean surface wind speed of 7,3 m/s over a range of 0 to 25 m/s. Calm conditions, representing speeds < 1 m/s, were recorded on 9 out of 45 occasions. The Cape Peninsula experiences highest wind speeds (southerly) during the summer, and lowest speed and greatest incidents of calm during the winter.

Annual rainfall totals for the individual years of this study were 636 and 715 mm, respectively. The bulk of the rainfall was measured between April and August of each year with peak falls during April, July and August. The water level of the vlei fluctuated between 6,17 and 6,95 m AMSL, with a mean level of 6,43 m AMSL during the study.

Recent (1992-1993) water quality data for Princess Vlei are shown in Table B2.2. Whilst the recorded orthophosphate values are low, the average inflow concentration of 0,05 mg/ℓ is sufficient to sustain algal populations. The average concentration at the south end of the vlei is 0,01 mg/ℓ. At these levels it may well be that phosphates are in limiting concentrations, although it must be remembered that significant quantities of phosphate may be bound within the algae. The average chlorophyll *a* concentration of 84 μg/ℓ in the south area is high, and perhaps the average for the central area of the vlei, 16 μg/ℓ, is more representative.

The EC of the inflow, 55 mS/m, is similar to the southern area of the vlei, where the EC was recorded at 54 mS/m. There appears to be little variation within the vlei itself. No time series data were available for this report, therefore no assessment can be made regarding monthly variations and trends in salinity.

Table B2.2 : Water quality data for Princess Vlei (1992-93)

Sampling Points (see Figure B2.2)	No of Samples
1. Southfield Canal	16
2. Princess Vlei Inlet	16
3. Princess Vlei North	16
4. Princess Vlei Central	16
5. Princes Vlei South	16

Chemical*/Physical Variables	Reading	Sampling Points				
		1	2	3	4	5
pH	Min	7,3	7,4	7,3	7,0	8,1
	Max	8,7	9,1	9,0	9,0	9,0
	Ave	7,8	8,3	8,3	8,3	8,6
Electrical Conductivity (mS/m)	Min	42	29	28	28	44
	Max	65	64	64	64	64
	Ave	55	47	46	46	54
Total Alkalinity (as $CaCO_3$)	Min	63	55	55	53	55
	Max	140	110	110	110	110
	Ave	90	86	83	84	78
Ammonia (as N)	Min	0,01	0,01	0,01	0,01	0,03
	Max	0,32	0,33	0,40	0,74	0,15
	Ave	0,08	0,05	0,04	0,06	0,06
Orthophosphate (as P)	Min	0,03	< 0,01	< 0,01	< 0,01	<0,01
	Max	0,08	0,03	0,03	0,03	0,02
	Ave	0,05	0,01	0,01	0,01	0,01
Total Phosphate (as P)	Min	0,08	0,01	0,03	0,04	0,11
	Max	0,33	0,21	0,22	0,23	0,37
	Ave	0,14	0,10	0,12	0,13	0,17
Suspended Solids	Min	4	1	4	7	11
	Max	14	44	35	45	47
	Ave	6	18	20	26	32
Dissolved Oxygen (as O)	Min	6,5	5,5	6,8	5,3	6,6
	Max	12,1	19,4	19,4	18,6	19,5
	Ave	8,2	9,4	9,5	9,1	9,3
Oxygen Saturation (%)	Min	72	65	69	61	77
	Max	136	220	220	216	224
	Ave	89	97	100	95	103
Secchi Transparency (cm)	Min	-	35	37	37	38
	Max	-	84	114	125	68
	Ave	-	52	54	53	45
Total Kjeldahl Nitrogen (as N)	Min	0,3	1,2	0,6	0,8	1,1
	Max	1,2	2,6	2,6	1,6	2,4
	Ave	0,7	1,6	1,3	1,3	1,5
Reactive Silicon dissolved (as Si)	Min	0,85	0,01	0,01	0,01	0,20
	Max	4,59	1,08	1,06	0,96	0,91
	Ave	2,36	0,24	0,18	0,18	0,42
Chlorophyll *a* corr. for Phaeoph. ($\mu g/\ell$)	Min	-	10	14	16	65
	Max	-	96	89	120	99
	Ave	-	53	56	16	84
Phaeophytin ($\mu g/\ell$)	Min	-	4	7	5	8
	Max	-	19	26	26	23
	Ave	-	12	14	13	15
Temperature °C	Min	14,9	12,5	12,5	12,7	16,3
	Max	24,3	24,2	24,4	24,2	24,4
	Ave	19,1	17,4	17,5	17,5	20,6

* Units are all mg/ℓ unless otherwise indicated

Microbiological data (1992-1993) for Princess Vlei are shown in Table B2.3. The data indicate sporadic inputs of water with high bacterial numbers. However, the 50 percentile values would indicate no significant impact on identified users. As far as the 90 percentile values are concerned, possible impacts on users could be expected in the upper reaches of the vlei.

Table B2.3 : Bacterial quality of Princess Vlei (1992-93)

Bacteriological Variable	Percentiles	Sampling Points (see Figure B2.2)				
		1	2	3	4	5
Faecal Coliforms per 100 mℓ	90	27 000	330	30	79	120
	80	12 000	190	19	70	93
	50	1 000	6	3	6	3

In terms of biological information, vegetation bordering Princess Vlei is sparse, with grass and stands of semi-aquatic reeds (*Typha capensis*). The inlet bay has dense fringes of *Typha*, and is subject to infestation by water hyacinth (*Eichhornia crassipes* (Mart) Solms). Control of these plants is carried out at intervals using glyphosate herbicides and physical removal. The vlei currently exhibits seriously perturbed benthic macroinvertebrate and fish populations. Details of the zooplankton diversity and periodicity, nutrient loading processes and other biophysical interactions are not well understood at present. This is currently being investigated and may provide some insight pertinent to the future management of the vlei.

2.5 Pollution Problems and Management Strategies

Princess Vlei is a small, well-mixed and eutrophic freshwater lake which is subject to annual hydraulic flushing during the winter. This flushing effect has been evident since the dredging of the vlei in 1983. Although hydrological data are not available, the rainfall induced flushing increases water clarity and decreases phytoplankton numbers and contributions. Cape Town City Council officials have reported that Princess Vlei used to be green in colour all year round prior to its dredging. Severe algal blooms and the green coloration have not been recorded since 1983, although the chlorophyll *a* values indicate that large populations of algae are present. The washout of phytoplankton from the vlei acts as a natural control mechanism preventing dense populations of nuisance algae such as *Microcystis* from becoming permanently established.

Ecological conditions, however, are such that phytoplankton blooms of cyanophyte species may occur during the summer months. The recent bloom of *Anabaena* in the summer of 1991 may have been fuelled by ineffective control measures applied in the eradication of water hyacinth, which experienced a prolific growth in the spring and summer of 1990-91 and covered the surface of the small inlet bay to the north-east of the vlei. Growth of this macrophyte has in the past been limited to a thin fringe of plants along the shoreline. The 1990-91 overgrowth of this floating weed may have been fuelled by the uncharacteristically high orthophosphate concentrations prevailing into spring and summer after the annual winter rains introduced nutrients into the vlei. Control of water hyacinth in Princess Vlei is usually effected by spraying with herbicide and/or manual removal. In this instance, the sheer volume of material precluded timeous removal and the bulk of the plant tissue was left to decay in the water, possibly providing the nutrients necessary to sustain increased phytoplankton growth during the otherwise nutrient-poor summer season.

The possibility of inundation of the previously exposed shoreline, brought about by the 0,15 m increase in weir height carried out in 1990 and/or any changes in the hydraulics and water retention in Princess Vlei, is not considered to be implicated in the observed increased development of cyanophyte algae. Water levels in the vlei only attained the new operating level of 6,6 m AMSL for the first time during the winter of 1991.

In essence, phytoplankton diversity in Princess Vlei is poor, typical of an urban-impacted, nutrient-enriched water body. However, the dredging of the vlei during the early 1980s can be said to have been successful in renewing the natural hydraulic flushing effect during the winter rains. Coupled with the *ad hoc* measures of chemical spraying or physical clearing of aquatic vegetation, these management strategies are stabilising the condition of the vlei although in the long term, attention will have to be given to managing the catchment. This is likely to be the only effective way to substantially improve water quality in the vlei.

2.6 Reference

Harding, WR (1992). A contribution to the knowledge of South African coastal vleis : The limnology and phytoplankton periodicity of Princess Vlei, Cape Peninsula. *Water SA*, Vol **18** (2).

3. ZEEKOEVLEI, CAPE TOWN

3.1 Location and Catchment Characteristics

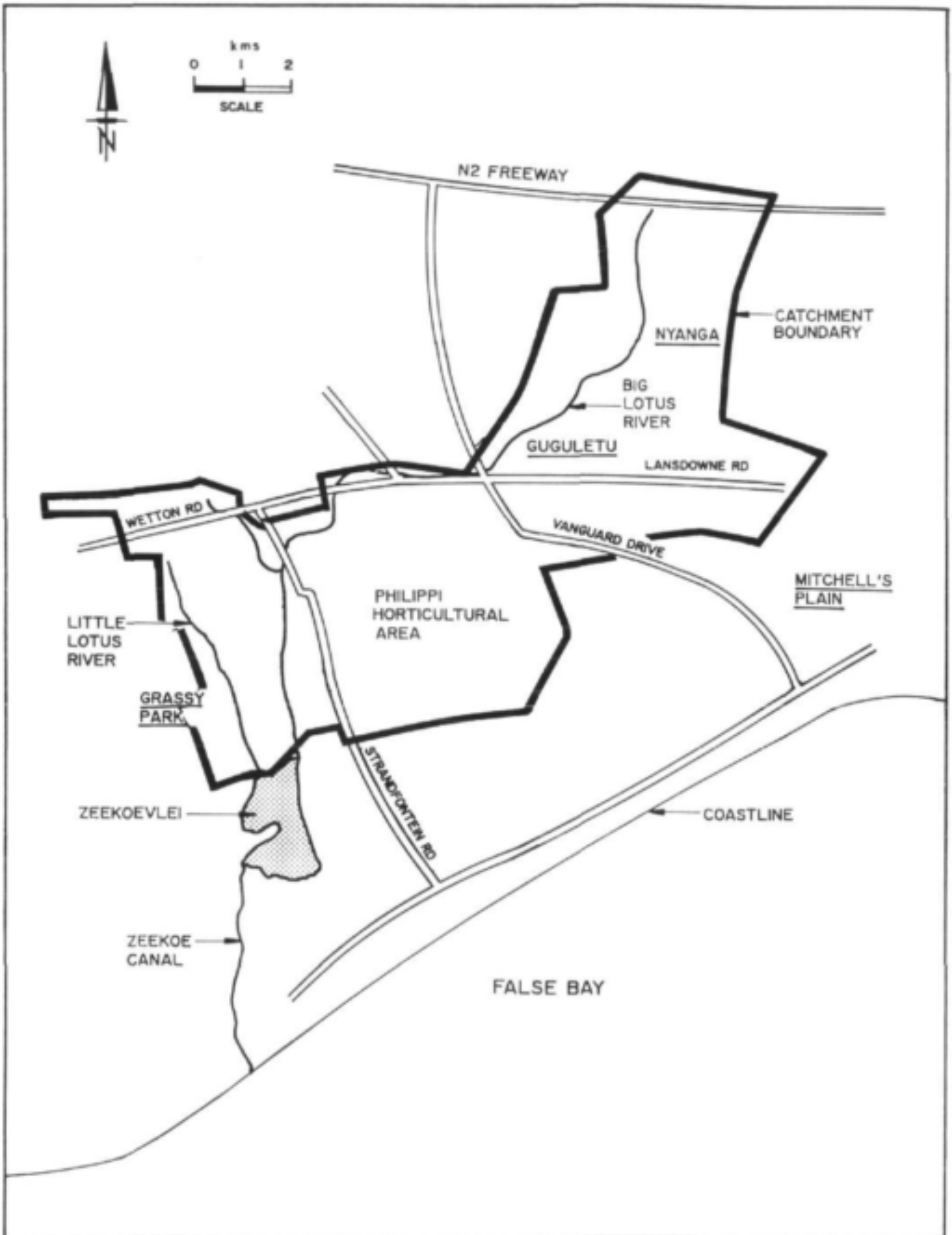
Zeekoevlei, a fresh water coastal lake, is situated on the sandy Cape Flats of metropolitan Cape Town near the suburbs of Zeekoevlei and Lotus River, approximately 17 km from the Cape Town CBD. The vlei is a shallow lake with a surface area of 256 ha and a mean depth of 1,9 m. It has a perimeter of 12,6 km. Basic characteristics regarding Zeekoevlei are shown in Table B3.1.

Table B3.1 : Characteristics of Zeekoevlei

Geographic Location	34° 4' S; 18° 31' E
Elevation	18 m AMSL
Surface Area	256 ha
Volume	5 000 000 m^3
Mean Depth	1,9 m
Maximum Depth	5,0 m
Length	2 500 m
Width	1 200 m

The lake is fed by two rivers - the Big Lotus and Little Lotus Rivers, which drain a combined catchment of approximately 8 000 ha (Figure B3.1). Typical mean inflows from the Big Lotus and Little Lotus Rivers for 1986 - 1990 were 14 600 Mℓ/year and 2 600 Mℓ/year respectively. Water residence time in the lake has been estimated at 0,25 years. The Little Lotus River flows through urbanised areas whilst the Big Lotus River drains an area consisting of horticultural land, urban residential areas and under-developed or open space. Land use in the catchment is made up of 55% horticultural land and open space, 20% formal residential serving the medium to higher socio-economic groups, 15% residential serving the lower socio-economic group, 5% light industrial land and 5% commercial land.

The water from the lake is discharged at the southern end of the lake into the Zeekoe Canal, which in turn drains into the sea (False Bay). A waste-water treatment works is situated immediately south of Zeekoevlei but does not discharge into the lake. The volume of the vlei has been estimated as 5 000 000 m^3 with sediments occupying approximately 20% of this.



LOCATION AND CATCHMENT AREA OF ZEEKOEVLEI

FIGURE B 3.1

3.2 Vlei History

Zeekoevlei is a natural freshwater coastal lake. The only man-made modification to it has been a weir which was constructed in 1948 on the south-western shore to control the water level of the impoundment.

3.3 Vlei Use

Zeekoevlei is an important regional recreational area, forming part of a proposed recreation park for metropolitan Cape Town. The main recreational uses include full contact recreational activities such as power-boating, water-skiing, yachting, windsurfing, canoeing, as well as fishing and picnicking.

3.4 Vlei Limnology

During the past half-century, increased use of fertilisers to support intensive horticultural activities and large-scale catchment urbanisation have contributed to nutrient loading of Zeekoevlei. The implementation of water level control, through the construction of a weir in 1948, combined with large-scale herbicide control of submerged macrophytes, have reduced the effects of flushing, increased water retention time and effectively eliminated the natural periodic cycling of phytoplankton and macrophyte flora in Zeekoevlei.

Earlier studies of the lake in 1962 and 1982 show that cyanobacterial algal blooms did occur in Zeekoevlei from time to time in the past. However, hydraulic flushing and occasional drying out phases of the lake served as natural mechanisms to reduce the phytoplankton biomass and to allow sufficient light for the rooted hydrophyte *Potamogeton pectinatus* to become established. Thus, the lake cycled between periods of algal and macrophyte dominance.

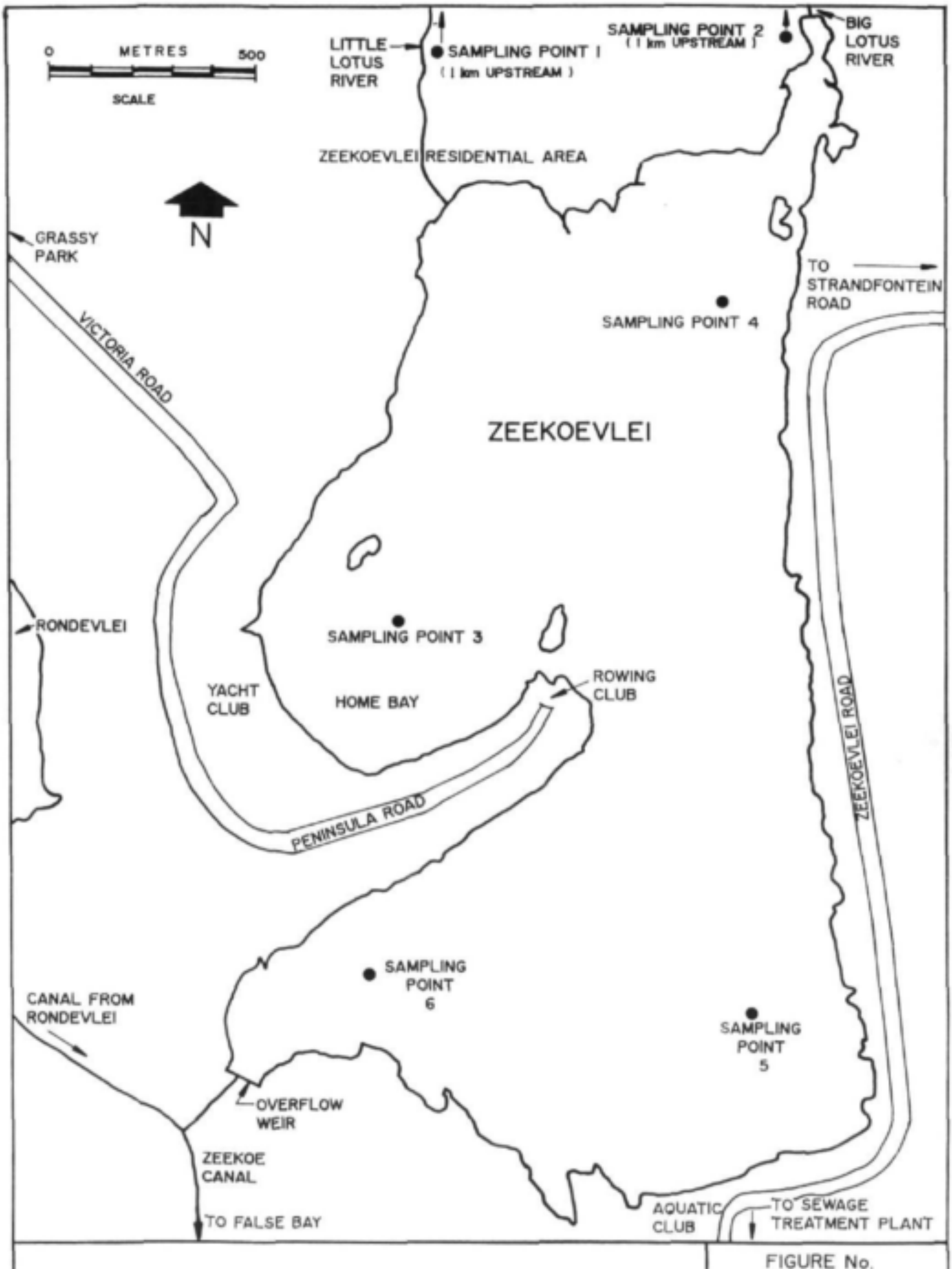
A combination of high nutrient loading rates, high incident solar radiation and diurnal mixing of the water column has today resulted in dense populations of cyanobacteria occurring in Zeekoevlei. The hypertrophic conditions, coupled with the consistently low N:P ratios are characteristic of systems where the phytoplankton is dominated by cyanobacteria. In addition, encroaching stands of bulrushes and reeds occur along the entire shoreline and substantial quantities of organic sediments have accumulated within the basin. Field studies by the Cape Town City Council in 1989 showed that sediments reach up to depths of 3 m in certain places and sediment is estimated to be accumulating at a rate of 35 000 m^3 per year.

A small dredging operation was conducted in Home Bay, Zeekoevlei during 1983. An estimated 200 000 m^3 of material was removed, leaving a hole 4 m deep in which future sediments could accumulate. This appears to have dramatically altered the density of phytoplankton, water transparency increased whilst the level of chlorophyll decreased. The dredging had no visible effect on chemical water quality, however, and by 1989 the hole was full again.

Apart from nutrient inputs in the rivers, internal loading from the accumulated sediments in Zeekoevlei probably play a significant role in the supply of phosphorus and such a sediment-rich system has probably become self-sustaining. Zeekoevlei also has large populations of carp and Mozambique bream which were estimated in 1977 to be 683 and 91 kg per hectare, respectively. These bottom feeding fish continually stir up the sediments. Investigations into the nutrient dynamics of Zeekoevlei are still in their early stages. Initial estimates from Cape Town City Council data give an internal loading rate of orthophosphate in Zeekoevlei of 8 500 kg per year. This is similar to conditions experienced in the past in the hypertrophic reservoir of Hartebeespoort Dam near Pretoria.

The Zeekoevlei phytoplankton is now dominated year round by *Microcystis* species with genera of Chlorophyta and diatoms showing muted sub-dominant population maxima during the summer and winter respectively, and Cyanophyte blooms occurring during the early spring. Zeekoevlei experienced *Microcystis* maxima during the spring seasons of a two-year (1989 - 1991) study period. These maxima occurred at a time when incident solar radiation, water temperatures and concentrations of nitrogen and phosphorus in the lake were increasing and wind speeds were low. A large population of *Microcystis* cells was present in the vlei year round. These formed thin surface layers and wind rows, as well as dense scums in sheltered areas around the perimeter of the lake. The morphometry of Zeekoevlei provides natural, sheltered accumulation sites for *Microcystis* during windy conditions. These populations may seed the main body of the lake when conditions are more favourable (i.e. reduced turbulence). This occurs from mid-winter to mid-spring when relatively low wind speeds prevail and when by September mean hours of sunlight per day increase from a mid-winter minimum of 6 h/d. The spring maximum of *Microcystis* populations coincide with seasonal peaks of soluble reactive phosphorus in the lake.

Regular monitoring of Zeekoevlei is carried out by the Cape Town City Council at six sampling points (Figure B3.2) and results for the chemical water quality of the lake for 1992/93 are shown in Table B3.2.



DETAIL OF ZEEKOEVLEI AND WATER QUALITY SAMPLING POINTS

FIGURE No. B 3.2

Table B3.2 : Water quality data for Zeekoevlei (1992-93)

Sampling Points (see Figure B3.2):	No of Samples
1. Little Lotus River	25
2. Big Lotus River	25
3. Horse Bay	24
4. Opposite Inlet of Big Lotus River	25
5. Opposite Cape Peninsula Aquatic Club	25
6. Adjacent to Weir	22

Chemical*/Physical Variables	Reading	Sampling Points 1	2	3	4	5	6
pH	Min	6,8	7,2	8,2	8,2	8,2	8,4
	Max	9,0	8,5	10,1	10,1	10,1	10,1
	Ave	7,8	7,9	9,3	9,2	9,2	9,3
Electrical Conductivity (mS/m)	Min	39	76	55	56	57	56
	Max	94	163	150	150	150	150
	Ave	69	131	104	104	105	107
Total Alkalinity (as $CaCO_3$)	Min	92	130	78	68	70	86
	Max	270	270	190	200	200	220
	Ave	130	210	130	130	130	130
Ammonia (as N)	Min	0,01	0,01	0,01	0,01	0,01	<0,01
	Max	0,14	1,60	0,17	0,08	0,12	0,30
	Ave	0,05	0,06	0,03	0,03	0,04	0,03
Orthophosphate (as P)	Min	0,04	0,12	<0,01	0,01	0,01	0,01
	Max	0,15	0,70	0,51	0,69	0,61	0,67
	Ave	0,09	0,31	0,07	0,08	0,09	0,09
Total Phosphate (as P)	Min	0,10	0,29	0,22	0,33	0,34	0,31
	Max	0,21	0,93	0,86	0,83	0,87	0,85
	Ave	0,15	0,50	0,45	0,51	0,54	0,57
Suspended Solids	Min	1	2	37	36	26	21
	Max	78	150	91	150	150	120
	Ave	6	11	57	61	57	59
Dissolved Oxygen (as O)	Min	6,6	7,1	7,1	6,3	6,2	6,9
	Max	11,8	14,3	15,8	16,4	16,4	16,0
	Ave	8,6	9,1	11,1	10,9	10,3	10,9
Oxygen Saturation (%)	Min	70	72	77	72	71	76
	Max	125	164	168	185	164	170
	Ave	91	96	116	116	110	115
Secchi Transparency (cm)	Min	8	5	14	13	14	14
	Max	8	8	38	42	37	39
	Ave	8	8	26	27	26	26
Total Kjeldahl Nitrogen (as N)	Min	0,2	1,2	0,5	1,0	0,6	1,4
	Max	1,8	4,3	4,3	4,4	4,5	5,2
	Ave	1,0	1,8	2,0	2,3	2,1	2,8
Reactive Silicon dissolved (as Si)	Min	1,03	0,49	0,06	0,06	0,06	0,02
	Max	5,46	6,78	3,20	2,84	3,01	2,78
	Ave	2,64	1,90	1,06	0,95	1,01	0,87
Chlorophyll *a* corr. for Phaeoph. (µg/ℓ)	Min	-	-	140	100	120	140
	Max	-	-	430	450	470	420
	Ave	-	-	260	240	270	260
Phaeophytin (µg/ℓ)	Min	-	-	20	18	24	30
	Max	-	-	87	180	110	100
	Ave	-	-	47	43	48	51
Temperature °C	Min	11,5	10,5	11,4	11,2	11,5	11,5
	Max	27,5	27,5	23,8	23,6	23,9	23,8
	Ave	18,2	17,9	17,2	17,8	17,7	17,5

* Units are mg/ℓ unless otherwise indicated

The net result of the increased loading for the inflowing rivers is seen in the orthophosphate concentrations recorded for the Little Lotus and Big Lotus Rivers. The average for 1992/1993 for these two rivers was 0,09 mg/ℓ and 0,31 mg/ℓ, respectively. These concentrations can be expected to give rise to large standing crops of algae. In-lake concentrations are in the order of 0,09 mg/ℓ, a concentration which will support large algal populations, as seen in the chlorophyll *a* values of 260 µg/ℓ.

Additionally, the high levels of salts in the water in the Big Lotus River (EC of 131 mS/m) is reflected in the Zeekoevlei itself at 107 mS/m. These concentrations are expected, as a consequence of the horticultural activities in the Big Lotus catchment, and the concomitant increase in salts from irrigation return flow. The Little Lotus River has an average EC of 69 mS/m, which would best represent runoff from urban areas.

Microbiologically, both inflows contribute large amounts of faecal coliforms. In-lake concentrations are reduced, however, and should not pose any significant health risk for typical users of the system, although they exceed accepted criteria for full contact recreation. The bacterial results are presented in Table B3.3.

Table B3.3 : Bacterial quality of Zeekoevlei (1992-93)

Bacteriological Variable	Percentiles	Sampling points (see Figure B3.2)					
		1	2	3	4	5	6
Faecal Coliforms per 100 mℓ	50	1 000	840	9	20	4	10
	80	7 300	20 000	190	380	120	73
	90	27 000	76 000	330	4 000	780	390

3.5 Pollution Problems and Management Strategies

To the detriment of its recreational function, Zeekoevlei experiences dense algal blooms, the encroachment of bulrushes and reeds along the shore and in shallow lake areas and it has a thick benthic layer of sediments of algal origin. Recent studies have shown that the influence of water quality on user-avoidance is inversely correlated to the visual appearance of the water body. The presence of "pea-soup green" water, accumulations of malodorous decaying algal cells together with litter and the build up of sediments rich in organic matter, lead to user avoidance with the associated problems and implications for water quality managers. Apart from its role as an internal nutrient source, the presence of sediments in Zeekoevlei presents a physical hindrance to yachtsmen and water skiers. In addition, odours (hydrogen sulphide) emanating from the sediments, especially on calm days, are objectionable and low oxygen concentrations in sheltered areas result in occasional fish kills.

The Cape Town City Council has investigated management options for hypertrophic lakes as well as their applicability for Zeekoevlei (Harding and Quick, 1992). At the same time, it has also been recognised that the scale and adaptation, or combination of methods, necessary for a particular water body are usually site-specific and dependent on the severity of the conditions. Having identified desired uses of the lake through a user assessment study, the Council has evaluated appropriate restoration techniques which can be divided into three groups:

(i) reduction of nutrient inflow;
(ii) disruption of internal nutrient cycles; and
(iii) acceleration of nutrient outflow.

These approaches and their applicability to Zeekoevlei have been evaluated with "catchment" and "in-lake" categories. It is considered that available loading and flushing data for Zeekoevlei are not accurate enough for models to be used with confidence.

Catchment options evaluated included management of urban and agricultural runoff, biological or chemical treatment, nutrient diversion, dilution and flushing, education of the catchment population and legislation. In-lake options covered dredging, sediment treatment and biological treatment.

Studies of these options suggest both catchment and lake based management strategies are needed for Zeekoevlei. The options rejected as being not applicable to Zeekoevlei are presented in Table B3.4.

Table B3.4 : Management strategies rejected

Strategy	Reason for Rejection
Wetlands in Zeekoevlei	Insufficient land available
Chemical Treatment of Inflows	High costs
Nutrient Diversion	High costs; potential impact if discharged to ocean; detrimental effect on hydraulics
Dilution and Flushing	No water available
Sediment Treatment	May have limited effect in short term; would not satisfy all users
Manipulation of N:P Ratio	Too costly; limited success reported worldwide
Biological Control	Fish harvesting - introduction of other species; species manipulation - could shift to diatoms, but relative success unknown

It was therefore decided that the focus should be on removal of the accumulated sediments in the lake and a reduction in inflowing nutrient levels. The cost of removing the sediment from Zeekoevlei was estimated during 1990 at R10 m. and would necessitate a large-scale programme. With any dredging effort, the problems of transporting, storing, drying and disposal of the sludge have to be answered. Complete removal of sludge should drastically reduce the internal nutrient loading and lead to a subsequent decrease in overall phytoplankton numbers and an increase in water clarity. Improved water clarity would then promote the re-establishment of rooted macrophytes.

This would only be a relatively short-term measure, however, if the influent rivers, in their present nutrient-enriched state, continue to load the lake with nutrients. Therefore, the long-term success of any dredging option will be dependent on the parallel control of the external nutrient sources.

Funds are not currently available for a dredging programme. In the interim, however, a storage site or use for the dredged sediment needs to be identified. Because of the large volume of nutrient-rich sediment in the lake, and heavy nutrient loading from influent rivers, Zeekoevlei is endowed with a resilience to any minor attempts to alter the phosphorus balance in the vlei such as phosphorus inactivation, bottom sealing of the sediments and biological harvesting. Such measures would only be practicable in conjunction with a dredging operation to remove the bulk of the accumulated sediments and management of the catchment to reduce nutrient loading from influent rivers. Hence lake-based options on their own are not considered feasible at the present time.

Catchment-based water quality management can and should be implemented. This would include improved management of runoff together with the identification of point sources of input into the catchment, the education of farmers in the horticultural area and residents of the urban areas in the catchment and the use of a wetland area through which agricultural runoff could discharge.

3.6 Reference

Harding WR and Quick AJR (1992). Management options for shallow hypertrophic lakes with particular reference to Zeekoevlei, Cape Town. *South African Journal of Aquatic Science*, **18** (1/2) 3-19.

4. ZOO LAKE, JOHANNESBURG

4.1 Location and Catchment Characteristics

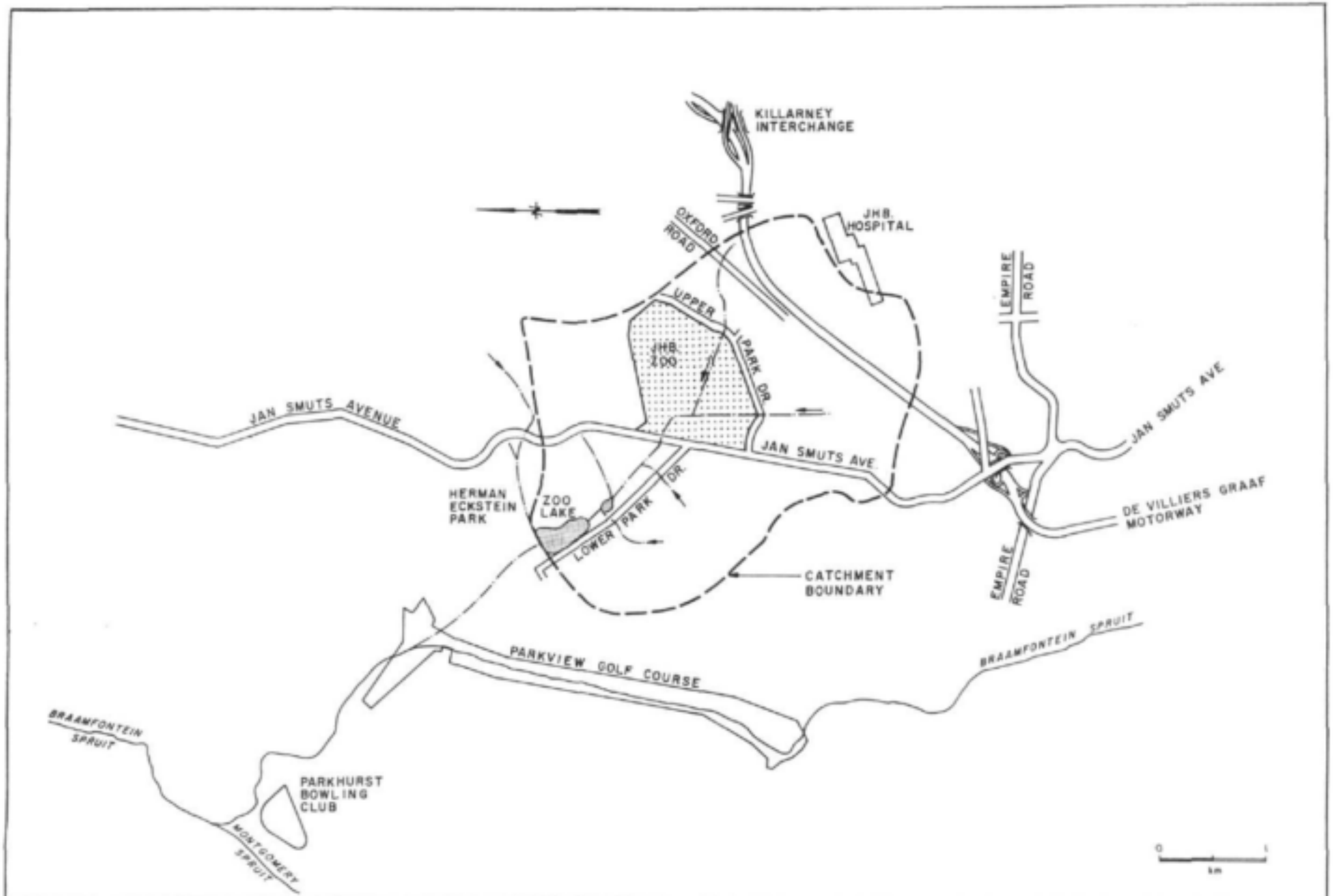
Zoo Lake is situated approximately 5 km to the north of the Johannesburg CBD in the suburb of Parkview. It is adjacent to the Johannesburg Zoo. The lake is a man-made impoundment with a surface area of 4,3 ha. The basic characteristics of Zoo Lake are shown in Table B4.1.

Table B4.1: Characteristics of Zoo Lake

Geographic Location	26° 9' S ; 28° 2' E
Elevation	1 610 m AMSL
Surface Area	4,3 ha
Volume	64 000 m^3
Mean Depth	1,0 m
Maximum Depth	2,0 m
Length	300 m
Width	100 m

The total catchment area of Zoo Lake comprises 432 ha, of which approximately 75% is made up of residential areas serving the high socio-economic segment of the population. The remaining 25% of the catchment comprises park land (including the zoo). The catchment area extends from the Johannesburg and Kenridge hospitals in the south to Englewood Drive in the north and from Kildare and Pallinghurst Road in the west to Saxonwold Drive and the Parktown Convent School in the east (Figure B4.1). The lake is fed by storm water from its catchment and washdown water from the zoo. Several small islands exist in the lake including the large central island.

There are two inlets to the lake, both situated on the south-eastern side of the lake. One of the inlets has been bricked up and only minor seepage of water occurs through this inlet. The other inlet is fed by a small lakelet upstream of the main lake. The small lakelet effectively acts as a silt trap and is equipped with a surface aerator to keep the water aerobic. Water exits Zoo Lake over a weir sited at the northern end of the lake, as well as via a valve tower, situated under a concrete jetty, which is also at the northern end of the lake. During heavy runoff from the catchment, excess water is diverted past the lake by means of a storm-water by-pass drain located on the south-western side of the lake.



LOCATION AND CATCHMENT AREA OF ZOO LAKE

FIGURE No
B 4.1

Water from Zoo Lake discharges into a culvert, which in turn discharges into the Braamfontein Spruit. The Braamfontein Spruit feeds the Jukskei River which joins the Crocodile River north of Johannesburg. The Crocodile River flows into the Hartebeespoort Dam.

4.2 Impoundment History

Zoo Lake was built in the first decade of this century. Modifications and extensions to the storm-water drains and retaining walls at the inlet of the lake were carried out in 1937. An additional inlet from the lakelet upstream of Zoo Lake was built in 1938. This inlet is still in use today, but the original inlet to the lake has been sealed. The fountain in the lake was designed and installed in 1939. The storm-water by-pass channel round the lake as well as the valve tower under the concrete jetty were built in 1946. The valve tower can be used to control the level of the lake. In 1983, the storm-water bypass channel was covered for most of the way with reinforced concrete slabs. In 1991, a small offtake to the local sewer was built to the west of the small lakelet, allowing part of the storm-water flows from the zoo to be diverted from the lake.

4.3 Impoundment Use

Zoo Lake is used mainly for passive recreational purposes. Major activities that take place on and around the lake include rowing and cycling boats which are hired out by the Lions Club, picnicking/braaiing and strolling along the pathways and lawns surrounding the impoundment. Angling takes place, but this is more restricted to locals frequenting the lake. There are also two sports clubs next to Zoo Lake, the Zoo Lake Sports Club and the Zoo Lake Bowling Club, and a restaurant.

4.4 Impoundment Limnology

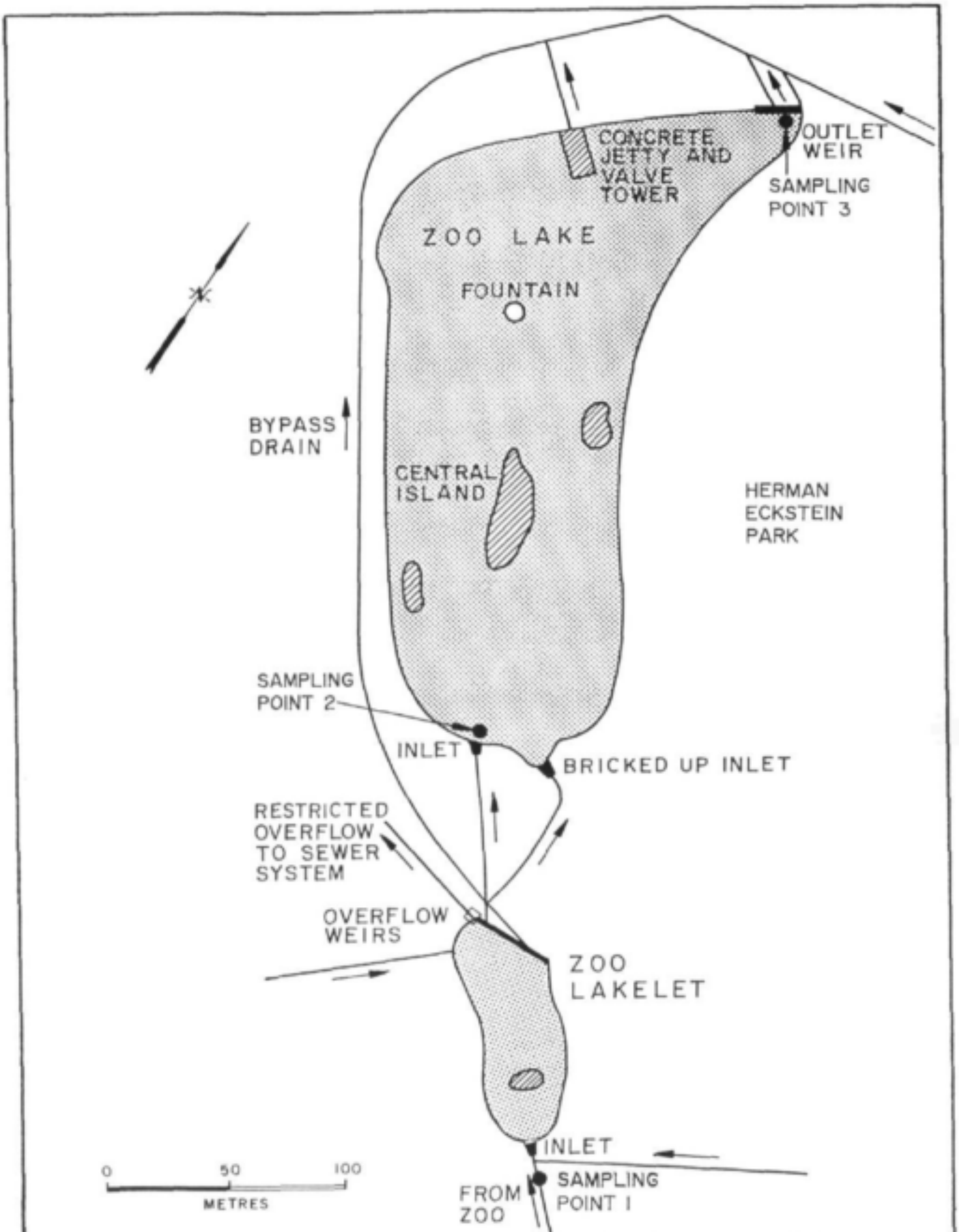
Situated in the Highveld climatic zone, Zoo Lake receives most of its rainfall in summer between November and March. The long-term annual average rainfall for the area is 800 mm. The capacity of the outlet weir from the lakelet is reported to be 65 m^3/s and that of the storm-water by-pass drain between 50 and 60 m^3/s. Incoming flows in excess of the 20 year flood will overtop the lakelet and travel overland to Zoo Lake.

In order to establish the water quality in the Zoo Lake system, the Johannesburg City Council initiated an extensive programme of water sampling during October 1989 which is still on-going. Eight sampling points in the catchment are monitored for bacteriological as well as chemical parameters. Five sampling points are in the catchment storm-water system. Three sampling points are at the lake itself -

at the inflow and outflow points of the main lake and at the inflow of the lakelet (Figure B4.2). Up until August 1992, the sampling frequency was monthly, and from September 1992 onwards, sampling has been on a weekly basis.

A summary of the chemical water quality data taken at the two sampling points in the lake is given in Table B4.2. The results show the lake is experiencing heavy nutrient loads in terms of nitrogen and phosphorus, but that these loads are lower in the water leaving the lake as a result of sedimentation of suspended solids and the uptake of nutrients by aquatic plants such as reeds and algae. Although the lakelet acts as a very effective silt trap in low flows, during storm flows, accumulated silt is washed from the lakelet into the main lake. The silt that has accumulated in the lakelet has a high organic matter content, which decomposes resulting in anaerobic conditions and associated malodorous smells.

In order to quantify the bacterial contamination of the waste water and storm water from the zoo (suspected as a pollution source), a monthly sampling and bacterial analysis programme was begun in 1991. Samples are collected at the storm-water culvert entering the lakelet and the overflow from Zoo Lake. The results of the tests show that the bacteriological quality of the water in Zoo Lake is poor (Table B4.3). The water is heavily contaminated with bacterial counts ranging from 100 to 10 200 coliforms per 100 mℓ, 0 to 6 500 *E. coli* per 100 mℓ and 0 to 26 000 counts of *Streptococci* per 100 mℓ. When compared to water quality criteria for recreational purposes, it is clear that the use of the water should be limited to non-direct contact recreation.



DETAIL OF ZOO LAKE AND WATER QUALITY SAMPLING POINTS	FIGURE No. B 4.2

Table B4.2: Water quality data for Zoo Lake (July 1991 - June 1994)

Sampling Points (see Figure B4.2)

1. Inflow to Lakelet
2. Inflow to Zoo Lake
3. Outflow from Zoo Lake

Chemical*/Physical Variables	Reading	Sampling Points		
		1	2	3
pH	Min	6,7	6,7	7,1
	Max	8,2	9,4	9,3
	Ave	7,7	7,8	8,3
	No of samples	75	75	74
Electrical Conductivity (mS/m)	Min	13	14	22
	Max	55	50	45
	Ave	33	31	30
	No of samples	75	75	74
Turbidity (NTU)	Min	0	1	3
	Max	85	184	75
	Ave	16	21	18
	No of samples	23	23	23
Total Alkalinity (as $CaCO_3$)	Min	75	35	46
	Max	146	144	143
	Ave	102	95	94
	No of samples	24	25	25
Chloride (as Cl)	Min	8	7	10
	Max	108	47	35
	Ave	23	21	21
	No of samples	75	75	74
Sulphate (as SO_4)	Min	0	0	0
	Max	78	330	63
	Ave	28	33	22
	No of samples	73	74	74
Ammonia (as N)	Min	0	0	0
	Max	10,00	15,00	3,50
	Ave	1,20	1,38	0,90
	No of samples	73	73	72
Orthophosphate (as P)	Min	0	0	0
	Max	1,80	1,90	0,52
	Ave	0,23	0,10	0,06
	No of samples	74	74	73
Total Phosphate (as P)	Min	0	0	0
	Max	3,90	19,40	2,10
	Ave	0,77	1,07	0,42
	No of samples	66	67	67
Chemical Oxygen Demand (as O)	Min	5	0	10
	Max	790	2 970	1 333
	Ave	74	146	82
	No of samples	74	73	73
Dissolved Oxygen (as O)	Min	0,6	0,7	1,9
	Max	9,2	16,2	15,4
	Ave	6,2	6,3	6,9
	No of samples	61	60	59
Suspended Solids	Min	1	1	1
	Max	2 487	4 120	1 705
	Ave	98	154	62
	No of samples	75	75	74
Total Kjeldahl Nitrogen (as N)	Min	0	0	0
	Max	159,0	234,0	26,0
	Ave	7,0	9,0	4,1
	No of samples	68	68	67

* Units are all mg/ℓ unless otherwise indicated

Table B4.3: Bacterial quality of Zoo Lake (October 1989 - March 1994)

Bacteriological Variable	Reading	Sampling Points (see Figure B4.2)	
		1	3
Faecal Coliforms per 100 mℓ	Min Max Ave No of Samples	0 2 600 212 53	100 10 200 2 171 55
E. coli per 100 mℓ	Min Max Ave No of Samples	0 25 600 228 51	0 6 500 802 56
Faecal Streptococci per 100 mℓ	Min Max Ave No of Samples	0 39 000 3 891 53	0 26 000 2 421 56

Two major sources of bacteriological pollution to the lake have been identified and these are the wash water from the zoo and contamination by waterfowl and dogs. The wash water from the zoo is expected to be bacteriologically contaminated, since this water is used to wash down the animal cages to remove animal faeces and urine. The waterfowl frequenting the lake, as well as dogs brought into the Zoo Lake area by visitors, defecate in the catchment of the lake. Rainfall runoff probably transports part of this contaminated material into the lake.

The bacterial contamination appears worse in the summer months, with bacterial counts coming down during the winter, although they are still unacceptably high from a health perspective. The bacterial counts in Zoo Lake are of the same order of magnitude as those in the storm water/wash water exiting the zoo. It appears that retention in the lake (1-6 months) has little or no effect on the bacterial contamination. Probably the most important contributing factor is the recontamination of the lake water by waterfowl and dog excreta.

4.5 Pollution Problems and Management Strategies

A number of aesthetic and health-risk related problems are being experienced in the Zoo Lake system. These include malodorous smells from the Zoo Lake and lakelet, unsightly and decomposing algal scums on the lake surface and shore, littering on the lake shore and floating litter on the lake surface, silting up of the lakelet, dog and waterfowl faeces on the lake shore and walking paths, and water recreation restricted to non-contact sports due to the poor bacterial quality of the lake water.

Consultants investigated a severe odour problem experienced at Zoo Lake during 1988-89 (WLPU, 1989). Based on their recommendations, housekeeping and disposal of effluent in the zoo was improved, the lakelet upstream of the Zoo Lake was desilted, guano was removed more frequently from the central island in the lake and the water quality of the lake was monitored more extensively. Further steps were also taken in 1991 to reduce the nutrient load on the lake by diverting a small portion of the storm water at the lakelet weir to a nearby sewer.

More recently, a study (Stewart Scott Inc., 1993 and 1994) has been carried out to evaluate a range of management options in order to identify practical means to eliminate, ameliorate or reduce the problems described earlier. Areas that require improved management were identified and proposals on how to deal with the problems were made. These include the following:

- Control of pollution discharged from the zoo - it has been suggested that the master plan currently being developed for the zoo incorporate a formal waste and water management plan. Furthermore, it is proposed that the sewer reticulation system of the zoo be extended to capture all polluted water currently discharged to the storm-water drains. Alternatively, the polluted water could be intercepted in the storm-water culvert leaving the zoo, pumped to a settler for solids removal and further treatment through a wetland.

- Removal of waterfowl guano and control of waterfowl population - the guano should be removed from the central island in Zoo Lake on a regular basis. In the longer term, consideration needs to be given to reducing the waterfowl population and to replacing them with smaller numbers of indigenous species.

- Control of littering - more litter bins should be provided at strategic points in the park adjoining the lake, litter collectors should be appointed to do duty during weekends and public holidays, and the public should be encouraged not to litter through an anti-litter campaign.

- Control of the phosphorus load on the lake - projections indicate that potentially, the mean annual chlorophyll *a* concentrations in the lake can be reduced from 60 to 6 $\mu g/\ell$. A programme of incremental reduction in the P load from the major sources is proposed to a level where the problems associated with algae are tolerable.

- Management of the lake - due to a lack of a detailed understanding of the algal growth dynamics and the factors which control them, an experimental approach to ameliorate algal problems in the lake is proposed. This approach could include the use of aspirators to mix the lake water body and possibly cause a shift from the troublesome blue-green algae to a more desirable green algae; introduction of fish species which eat algae; flushing of the lake with storm water to wash out algae and reduce the nutrient load; and chemical control of algae.

- Public participation - it is proposed that before major changes are made to the management of the Zoo Lake system, the public's involvement should be canvassed and a public participation programme should be launched.

- Monitoring - the monitoring programme on Zoo Lake should be expanded and refined in order to quantify the effectiveness of the proposed new management procedures.

A zoo effluent treatment system has been designed and is currently under construction. It comprises the interception and collection of effluent in the storm-water culvert exiting the zoo and removal of suspended solids by settling and treatment of the settled effluent through a constructed wetland. The treated effluent will be discharged back to the storm-water culvert.

The lakelet was de-silted during May-June 1993 at a cost of R100 000. This should help reduce the nutrient loading of the main lake. It is also planned to install aspirators in the main lake at a cost of approximately R50 000 in an effort to mix the lake water and possibly cause a shift in the algal population to the more desirable green algae. Gunniting of the embankments, to prevent erosion, was subsequently carried out at a cost of R150 000.

4.6 References

Stewart Scott Inc. (1993). *Improving the Trophic and Aesthetic Status of Zoo Lake. Phase 1 Report : Preliminary Investigations and Short Term Solutions.*

Stewart Scott Inc. (1994). *Improving the Trophic and Aesthetic Status of Zoo Lake. Phase 2 Report : Evaluation of Management Options for Zoo Lake.*

Watermeyer, Legge, Piésold and Uhlmann (WLPU) (1989). *Report for Johannesburg City Council on an Odour Problem at Zoo Lake.* Report No 1305/1.

5. WEMMER PAN, JOHANNESBURG

5.1 Location and Catchment Characteristics

Wemmer Pan lies less than 5 km south-east of the Johannesburg CBD (Figure B5.1) at an altitude of approximately 1 700 m AMSL, making it one of the highest lying lakes in South Africa. The pan covers an area of 33,2 ha and holds a volume of 1 000 000 m^3 of water. The basic characteristics describing Wemmer Pan are shown in Table B5.1.

Table B5.1 : Characteristics of Wemmer Pan

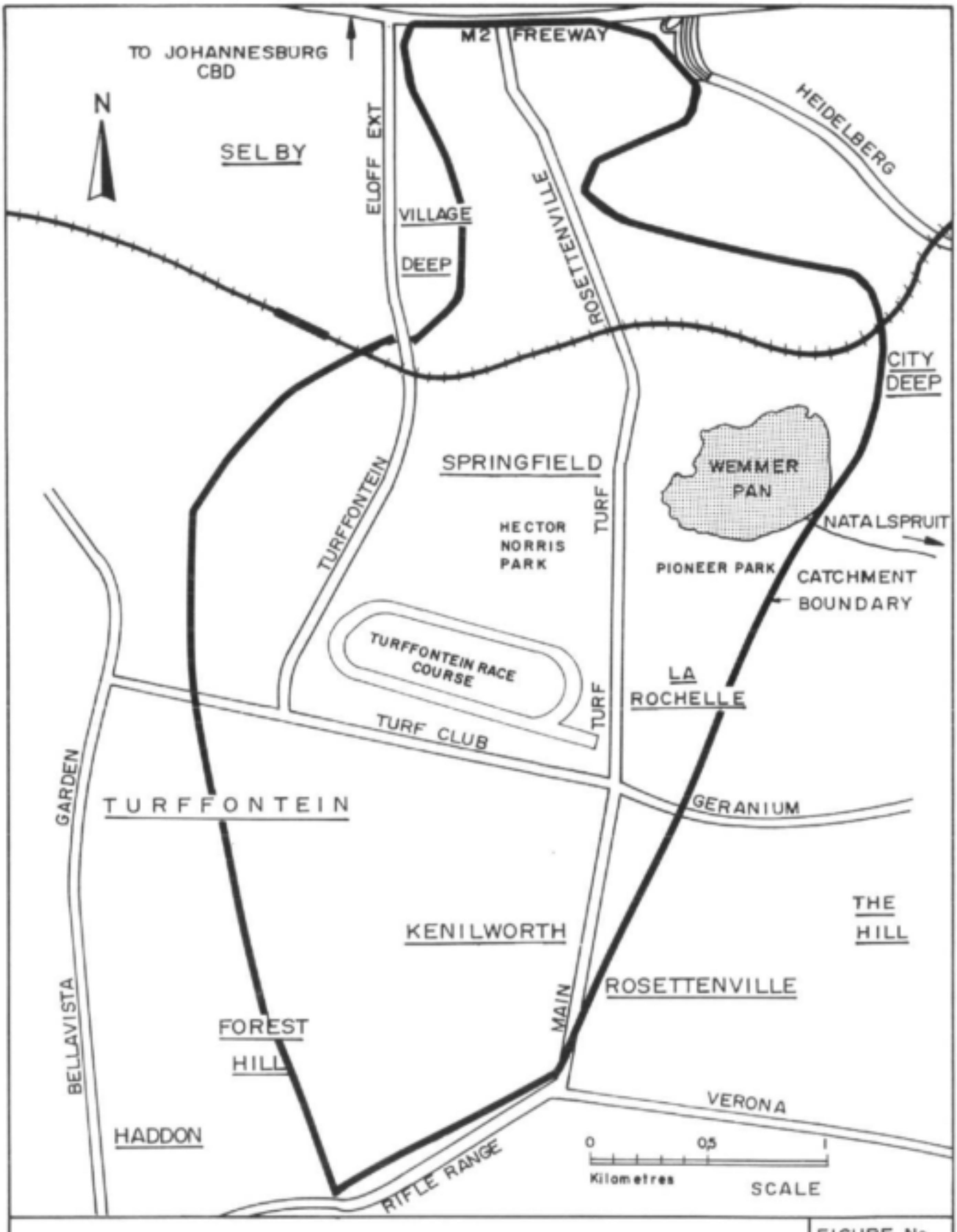
Geographic Location	26° 14' S; 28° 3' E
Elevation	1 700 m AMSL
Surface Area	33 ha
Volume	1 000 000 m^3
Mean Depth	3,0 m
Maximum Depth	5,0 m
Length	800 m
Width	500 m

The pan has a small natural catchment area, but is also fed by the storm-water system from the industrial and commercial area of south-central Johannesburg and the residential suburbs south of the pan. Seepage from adjacent gold mine dumps and slimes dams may also enter the pan. Land use in the catchment area is predominantly light industrial (45%) and residential (30%), the residential area serving the higher socio-economic segment of the population. The remainder of the catchment is made up of parkland (15%) immediately around the south and west of the pan, mining land and tailings dams (5%) and commercial land (5%).

Wemmer Pan lies in the headwaters to the Natalspruit, which drains the south-eastern suburbs of Johannesburg and then flows southwards to join the Klip River, which in turn enters the Vaal River near Vereeniging.

5.2 Pan History

Wemmer Pan is a natural pan but has been subject to minor man-made modifications. A weir in the south-eastern corner of the pan controls overflow into the Natalspruit whilst the eastern shore has been embanked in an attempt to prevent seepage from the adjacent tailings dam.



LOCATION AND CATCHMENT AREA OF WEMMER PAN	FIGURE No. B 5.1

5.3 Pan Use

As well as functioning as a storm-water retention pond, Wemmer Pan serves as a major recreational focus for the southern suburbs of Johannesburg.

Sailing, motor-boating, rowing and underwater diving activities take place on the pan and angling along the shores. Several other recreational attractions are located on the banks of the pan, including a model village known as Santarama on the north-western shore, a transport museum on the south-western shore, musical fountains adjacent to the south bank, the Wemmer Pan Commando Training Centre and numerous sporting facilities associated with the adjoining Pioneer and Hector Norris Parks. The musical fountains have recently fallen into disrepair.

In the past, water from the pan was used for irrigating nearby slimes dams.

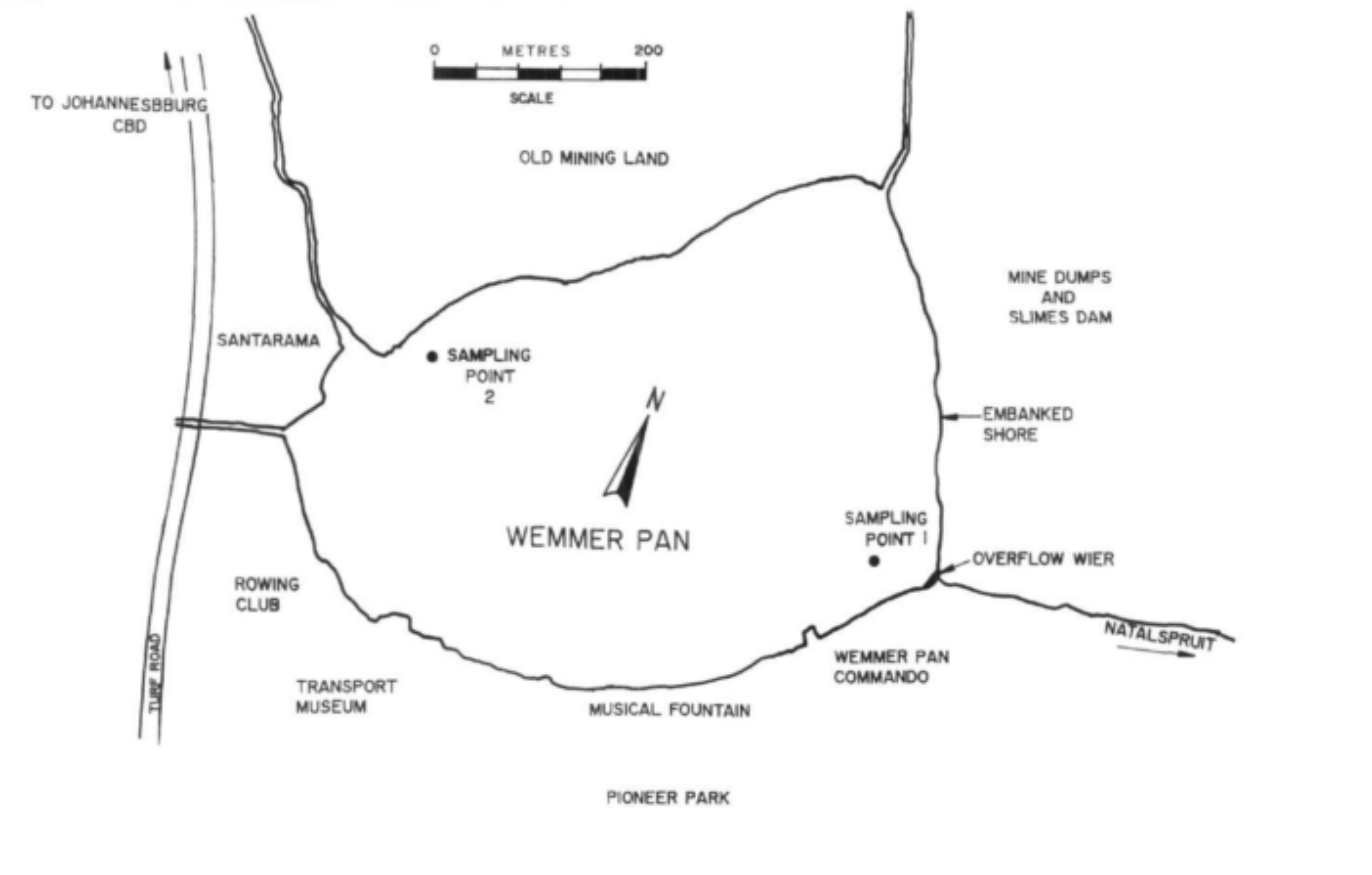
5.4 Pan Limnology

Wemmer Pan experiences a typical Highveld climate with a summer wet season and a mean average rainfall of 600-800 mm per annum. No data are available on runoff and hydrological flows into the pan.

A thesis carried out by a student at RAU (Kilger, 1974) serves as the only in-depth historical record of the chemical and bacteriological condition of Wemmer Pan. Water samples were taken from ten points around the shores of the pan for this study, which in essence showed that seepage and runoff from nearby mining land was mainly responsible for the low pH values, high sulphates and high dissolved solids concentrations (especially of iron and manganese) found in the pan. The western side of the pan also showed bacterial contamination, especially coliforms. It was recommended that a diversion canal be constructed north of the pan to divert runoff from the mining land past the pan.

The dominant vegetation types noted growing around the edges of the pan at the time of the aforementioned study were *Phragmites* species and *Typha latifolia*. Water quality tests at Wemmer Pan are currently carried out monthly by the Johannesburg City Council at two sampling points (Figure B5.2).

Recent water quality results from Wemmer Pan indicate that there has been an overall improvement in water quality between 1974 and 1992-93 (Table B5.2). This is seen in the reduction of salts in



DETAIL OF WEMMER PAN AND WATER QUALITY SAMPLING POINTS

FIGURE No. B5.2

the water (EC dropping from 64 mS/m to 37 mS/m). Additionally, the concentration of sulphates has dropped from 290 to 68 mg/ℓ indicating a reduced contribution from mining related activities. A slimes dam on the northern bank of the pan has been removed. The slight increase in chlorides, from 18 to 28 mg/ℓ would indicate that the relative contribution from urban storm water is increasing. Hydrological differences between the two years of data could not be quantified.

Table B5.2 : Comparative water quality data for Wemmer Pan (1974 and 1992-1993)

Chemical*/Physical Variables	1974	1992/3
pH	6,5	8,1
Electrical conductivity (mS/m)	64	37
Nitrates (as N)	1,45	0,4
Orthophosphates (as P)	0,08	no data
Total Phosphates (as P)	no data	0,85
Chlorides (as Cl)	17,6	27,8
Sulphates (as SO_4)	290	68

* Units are all mg/ℓ unless otherwise indicated.

The concentration of nutrients, specifically nitrates, has decreased since 1974. As far as phosphorus is concerned, no assessment can be made because comparable data are unavailable. The total phosphorus recorded for 1992-93 would indicate that there are sufficient nutrients in the water to sustain good plant growth. Furthermore, it can be expected that the sediments in the pan would have a high concentration of phosphate build-up over time and that this is also contributing to favourable conditions for rooted macrophyte growth. Wemmer Pan has in recent years suffered from a macrophyte infestation which has resulted in a dense mat of vegetation which is affecting boaters, rowers and anglers using the lake.

An assessment of the water quality data over time, indicates that sudden deteriorations in quality do occur, principally as a result of storm-water runoff. Figure B5.3 shows the variations in quality for electrical conductivity for the period 1991 to 1994.

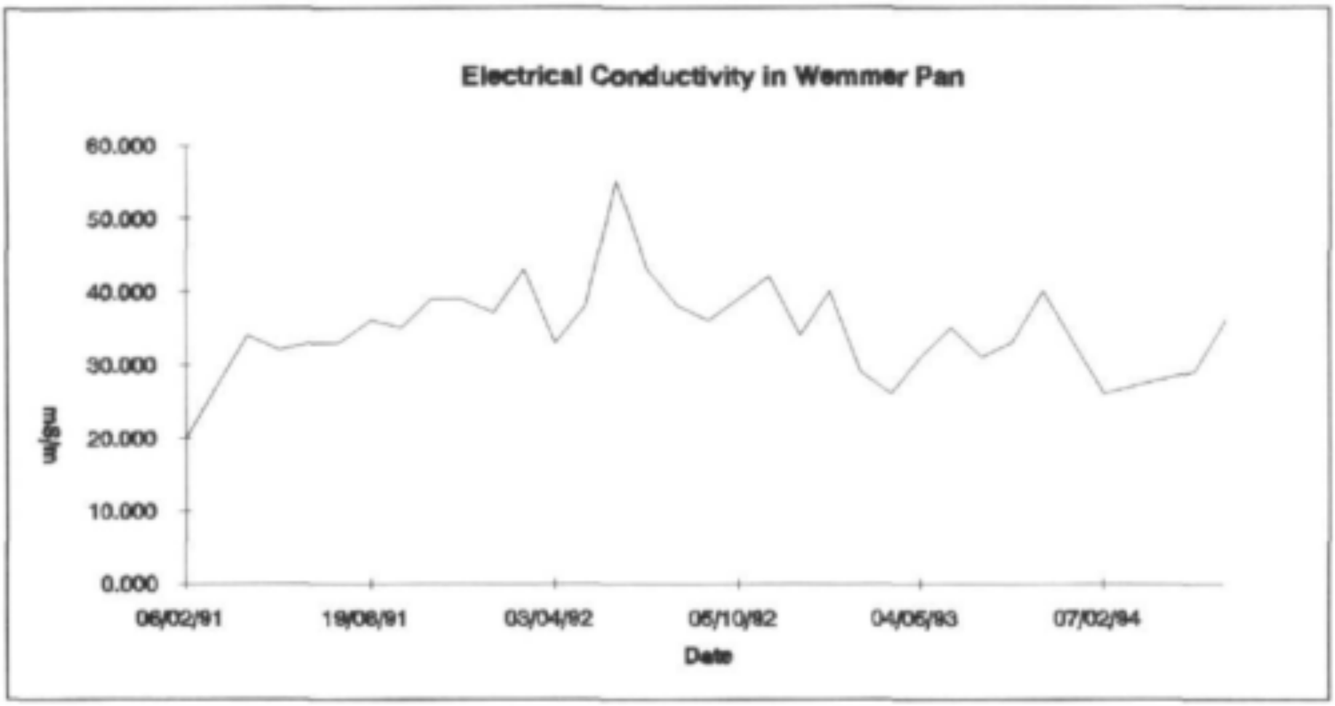


Figure B5.3 : Electrical conductivity in Wemmer Pan

Full details of the water quality at Wemmer Pan are detailed in Table B5.3.

As far as bacterial populations are concerned, it appears as though there are periodic incidents of bacterially contaminated water entering the lake (Table B5.4). This could be as a result of one or more of the following factors :

- direct effluent discharges;
- storm-water drainage;
- on-site contamination by users of the impoundment; and
- leaks from septic tanks, sewers.

These periodic fluctuations are presented in Figure B5.4.

Table B5.3: Water quality data for Wemmer Pan (January 1991-July 1994)

Sampling Points (see Figure B5.2)

1. Wemmer Pan - South East

Chemical*/Physical Variables	Reading	Sampling Point
		1
pH	Min	0
	Max	8,8
	Ave	7,7
	Median	8,0
	No of Samples	36
Electrical Conductivity (mS/m)	Min	20
	Max	55
	Ave	34
	Median	34
	No of Samples	36
Turbidity (NTU)	Min	<1
	Max	111
	Ave	22
	Median	5
	No of Samples	6
Total Alkalinity (as $CaCO_3$)	Min	36
	Max	71
	Ave	58
	Median	57
	No of samples	9
Chloride (as Cl)	Min	8
	Max	86
	Ave	23
	Median	20
	No of samples	35
Sulphate (as SO_4)	Min	0
	Max	235
	Ave	72
	Median	67
	No of samples	34
Ammonia (as N)	Min	0
	Max	5,10
	Ave	0,34
	Median	0
	No of samples	36
Nitrate Nitrogen (as N)	Min	0,40
	Max	2,00
	Ave	1,20
	Median	1,20
	No of samples	2
Nitrite Nitrogen (as N)	Min	0
	Max	0
	Ave	0
	Median	0
	No of samples	2
Orthophosphate (as P)	Min	0
	Max	0,80
	Ave	0,03
	Median	0
	No of samples	35

* Units are all mg/ℓ unless otherwise indicated

(continued overleaf)

Chemical*/Physical Variables	Reading	Sampling Points
		1
Total Phosphate (as P)	Min	0
	Max	8,40
	Ave	0,70
	Median	0
	No of samples	33
Chemical Oxygen Demand (as O)	Min	0
	Max	169
	Ave	41
	Median	25
	No of samples	36
Oxygen Absorbed (as O)	Min	4,0
	Max	4,0
	Ave	4,0
	Median	4,0
	No of samples	1
Suspended Solids	Min	0
	Max	125
	Ave	17
	Median	8
	No of samples	33
Dissolved Oxygen (as O)	Min	5,0
	Max	9,0
	Ave	7,2
	Median	7,1
	No of samples	28
Total Kjeldahl Nitrogen (as N)	Min	0
	Max	17,0
	Ave	3,5
	Median	2,4
	No of samples	30
Chlorophyll (μg/ℓ)	Min	3,4
	Max	3,4
	Ave	3,4
	Median	3,4
	No of samples	1

* Units are all mg/ℓ unless otherwise indicated

Table B5.4: Bacterial quality of Wemmer Pan (January 1990 - July 1994)

Bacteriological Variable	Reading	Sampling Points (see Figure B5.2)	
		1	2
Faecal Coliforms per 100 mℓ	Min	0	0
	Max	777 777	26 000
	Ave	16 115	3 005
	Median	650	1 000
	No of samples	60	59
E. coli per 100 mℓ	Min	0	0
	Max	330 000	48 000
	Ave	6 175	1 305
	Median	100	100
	No of samples	60	59
Faecal Streptococci per 100 mℓ	Min	0	0
	Max	91 000	38 000
	Ave	3 451	1 039
	Median	200	100
	No of samples	59	59

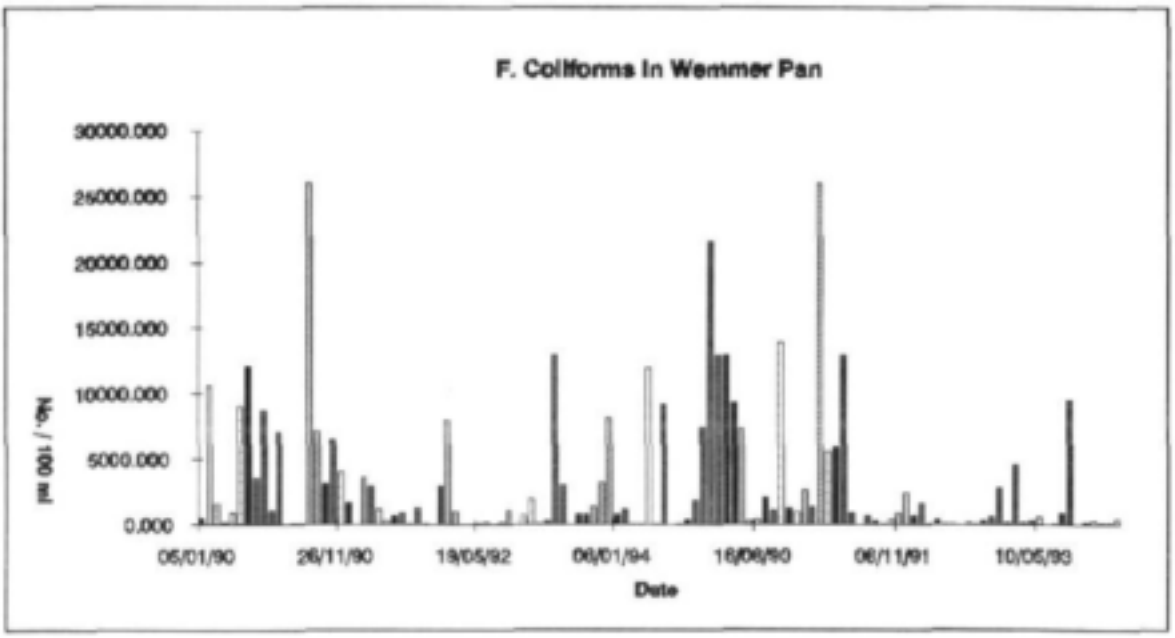


Figure B5.4 : Faecal coliforms in Wemmer Pan

5.5 Pollution Problems and Management Strategies

The fact that Wemmer Pan is a storm-water collection pond does not appear to have negatively affected the water quality of the pan. The TDS values found were low and the water quality can be described as good. There are occasions when the quality is poor, principally as a result of inflows of polluted water probably during storm events.

The most serious problem experienced in Wemmer Pan in recent years has, however, been the prolific growth of the submerged macrophyte *Potomageton pectinatus*, a species common in South Africa. It is a very vigorous plant which thrives in nutrient-rich water, can tolerate high salinities, and is able to grow in turbid waters. It can survive drying-out periods and is a useful plant in terms of its supply of nesting material and food for waterfowl as well as dampening wave action and reducing bank erosion.

The macrophyte problem appears to have started in 1988 and is now so prolific that it causes the rudders of boats, rowers' oars and anglers' fishing lines to become entangled. There are three basic categories of macrophyte management and control - mechanical, chemical and biological.

The control of aquatic plants by mechanical means tends to utilise dredging or harvesting of the plants. The Johannesburg City Council purchased a mechanical harvester in 1989 and this is currently used on a routine basis for the removal of the plant. The harvester is used daily in the summer growing season, but lower winter water temperatures control the growth of the plant. Although the operating costs of the harvester are low, it has to be viewed as an on-going strategy with long-term continuous costs.

At present, there is no satisfactory chemical method to control submerged macrophytes.

Chinese carp, *Ctenopharyngodon idella* (Val), have been used successfully to control *P. pectinatus* biologically in nearby Germiston Lake and in Florida Lake. The introduction of triploid Chinese grass carp is ecologically and economically attractive as a management option. The triploid form is rendered sterile by shock treatment, and thus its spread to other systems can be controlled. It is very temperature resistant and consumes more than its own body mass of plant material each day (Van Senus, 1993). Typical stocking rates to effect 80 % efficiencies would be in the region of 50 to 60 fish per hectare. This would mean that for effective control of *Potomageton* in Wemmer Pan, some 1 650 fish would be needed.

This option appears to hold a definite potential for solving the macrophyte problem at Wemmer Pan (Stewart Scott Inc., 1994).

5.6 References

Kilger B (1974). *Investigations into the Ecology of the Lake Wemmer Pan, Johannesburg.* Thesis ; Rand Afrikaans University.

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Van Senus P (1993). Management Strategies to Combat the Growth of Aquatic Weeds in Fresh Water Impoundments. *IMIESA*.

6. NIGEL DAM, NIGEL

6.1 Location and Catchment Characteristics

Nigel Dam is situated in the catchment of a tributary of the Blesbokspruit and is located adjacent to the industrial area of Vorsterkroon on the northern side of central Nigel (Figure B6.1). The stream which feeds the dam at its northern end has its origin at the Vlakfontein Gold Mine, near the suburbs of Dunnottar and Sharon Park, approximately 5 km north-west of Nigel. The stream is seasonal in nature, particularly in the upper parts of the catchment with runoff normally occurring only in the rainy season. Before reaching Nigel Dam, the stream passes several mine tailings dams.

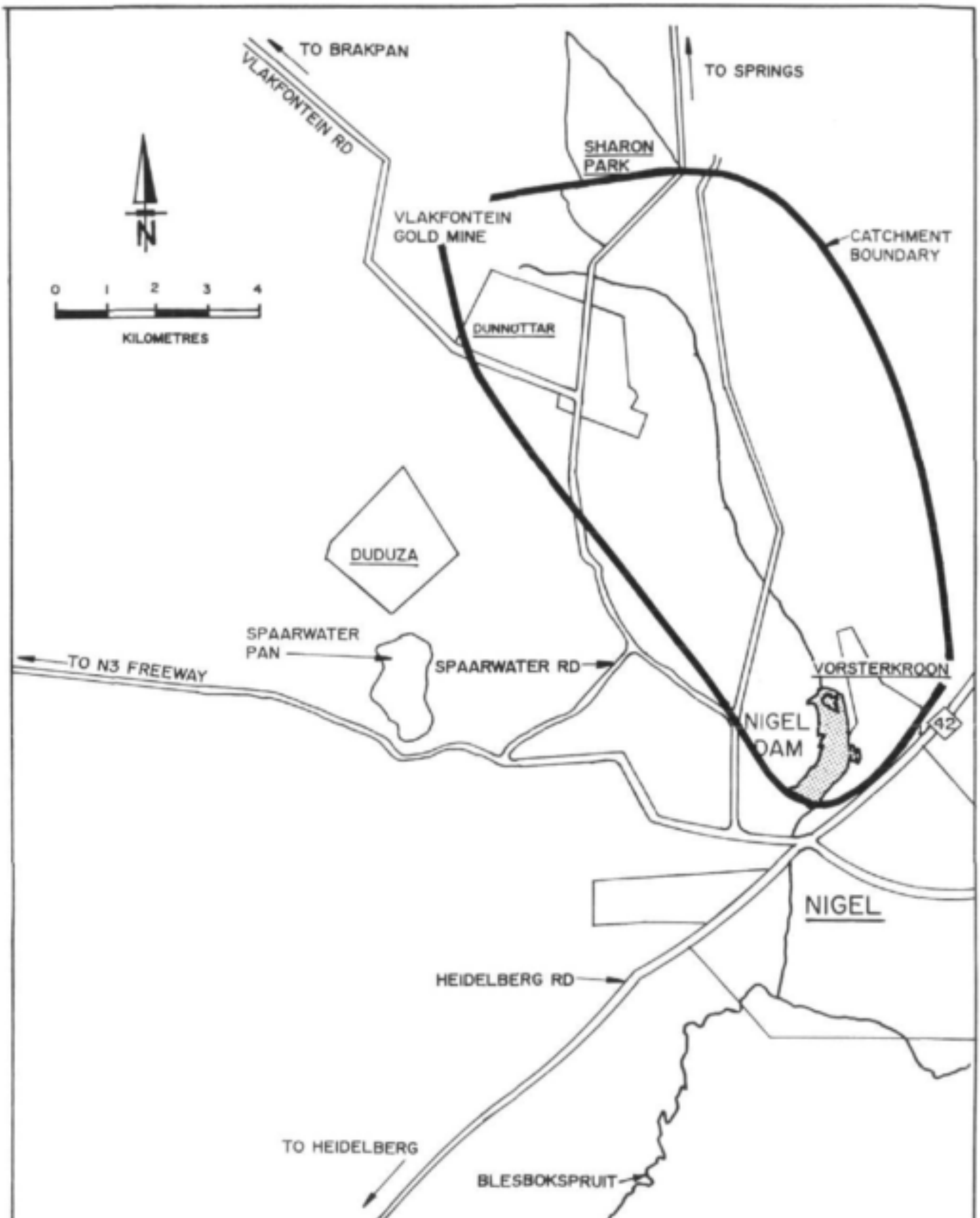
The surface area of Nigel Dam is 72 ha and it contains a volume of 1 800 000 m^3 when full. Basic characteristics of the dam are shown in Table B6.1. A small island is situated in the northern reaches of the dam.

Table B6.1 : Characteristics of Nigel Dam

Geographic Location	26° 25' S; 28° 28' E
Elevation	1 550 m AMSL
Surface Area	72 ha
Volume	1 800 000 m^3
Mean Depth	2,5 m
Maximum Depth	5,0 m
Length	1 250 m
Width	425 m

Land use in the catchment area of the dam is made up of parkland or veld (35%), low density residential areas serving the high socio-economic segment of the population (30%), mining land and tailings dams (20%) and the Vorsterkroon heavy industry area (15%).

A mine tailings dam is located on the lower western shore of Nigel Dam from which gold is presently being reclaimed by Ergo Ltd. using high pressure water jets fed by water from Nigel Dam. As a consequence of this activity, seepage from the tailings dam into Nigel Dam has increased. Nigel Dam also receives effluent from the CF Grundling Sewage Works which discharges chlorinated effluent into the river upstream of the dam. During the winter dry season, the effluent from the sewage works contributes virtually the only source of water for the dam.



LOCATION AND CATCHMENT AREA OF NIGEL DAM

FIGURE No. B6.1

Below the dam wall, the outlet stream flows into a canal through the town of Nigel and joins the Blesbokspruit in the southern suburbs of Nigel.

6.2 Impoundment History

Nigel Dam was commissioned in September 1985. It serves as an upgrade to the previous storm-water control system which consisted of two linked earthwall dams.

6.3 Impoundment Use

The primary function of Nigel Dam is storm-water control, although it also serves as a source of water for nearby mining activities, as a point of discharge for effluent from the CF Grundling Sewage Works, as well as a recreational focus for the inhabitants of Nigel and its surrounds.

Recreational use of Nigel Dam is considerable, both on the water itself and around the shores. Activities include angling, picnicking, sailing and water-skiing. The Stan Madden Bird Sanctuary, located on the eastern shore, is an attraction for bird-watchers and has recently been upgraded by the Nigel Parks Department and the Wildlife Society. A golf course is situated adjacent to the north-western shore.

Extensive upgrading of recreational facilities around Nigel Dam is being planned. The eastern side of the dam is to be developed into a recreational area for day visitors whilst the western shoreline will be turned into a holiday resort consisting of chalets, a caravan park and camping area and a recreational area with swimming pools, tennis courts and other facilities. A start on these improvements is under way and picnicking facilities have already been provided.

6.4 Impoundment Limnology

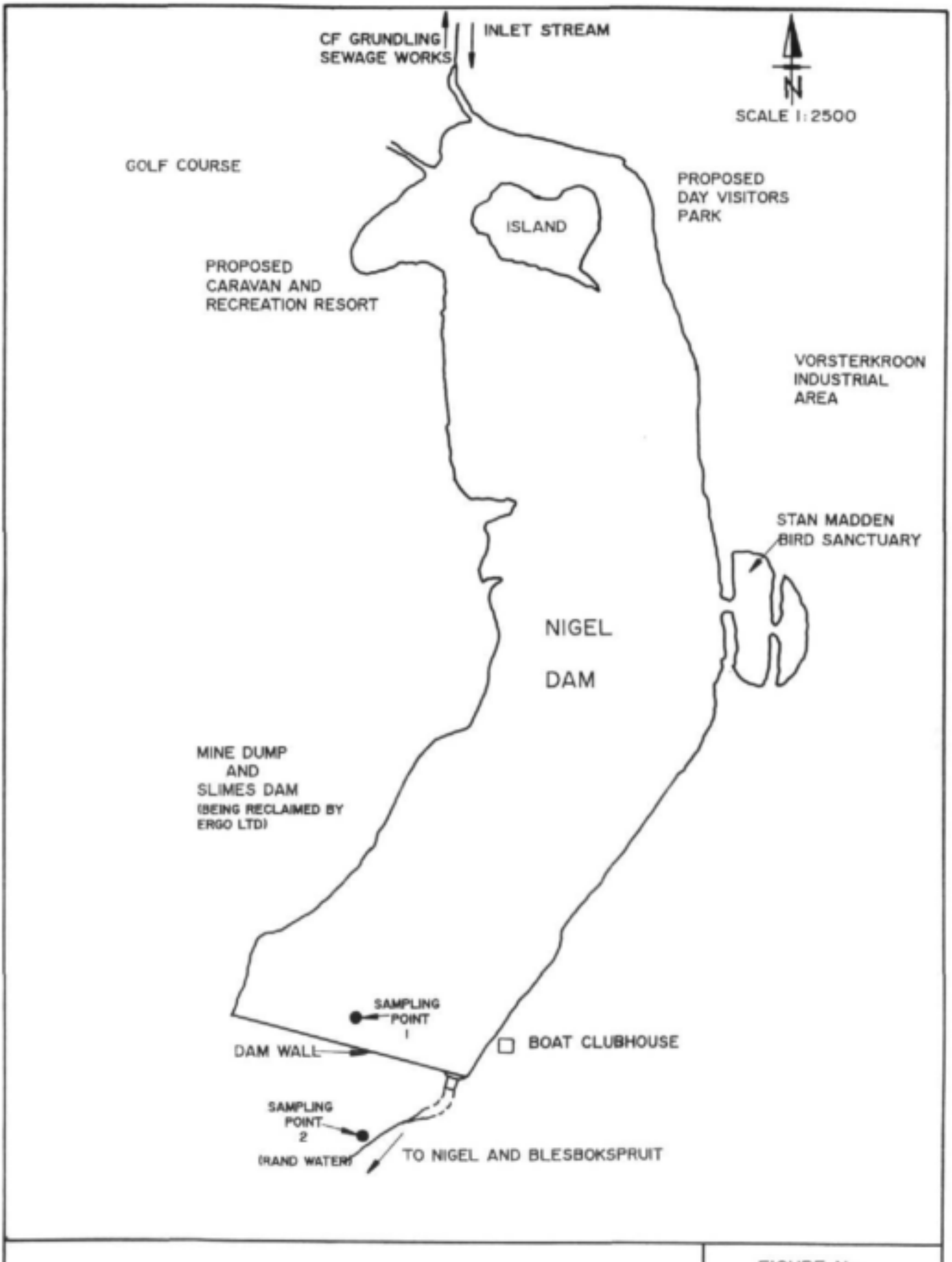
Nigel Dam, being located on the eastern edge of the Witwatersrand urban complex, experiences a typical Highveld climate with the bulk of its rainfall falling in the summer months. Between 1988 and 1992, annual rainfall ranged between 500 and 900 mm with an average of 620 mm. Historical rainfall records suggest a mean annual runoff for the catchment of $2,48 \times 10^6$ m^3.

A study of the ecological conditions in Nigel Dam was conducted in 1988-89 by a RAU student (De Wet and Schoonbee, 1990), which in terms of macro-invertebrates indicated that Nigel Dam was in a fairly unpolluted state. Since 1990, effluent from the CF Grundling Sewage Works has been discharged into the dam and there has subsequently been a deterioration in the quality of the water.

The Nigel municipality monitors the water quality of the dam on a monthly basis at the dam wall (Figure B6.2). Parameters tested for have increased since the beginning of 1994 and now include a range of chemical and bacteriological parameters. Some historical water quality information is also available from Rand Water below the dam wall. A comparison of the available data is shown in Table B6.2.

Prior to 1990, all sewage effluent was used by the Sub Nigel Gold Mine, Nigel Gold Mine and a small gold recovery works. Rand Water data for the overflow from Nigel Dam indicate that even at this time, certain aspects of the chemical water quality were relatively poor. High concentrations of salts (EC 165 mS/m) were dominated by sulphate concentrations of 780 mg/ℓ. This would indicate that seepage from the gold mines in the region was occurring. Additionally, the manganese (5,7 mg/ℓ) and iron (7,6 mg/ℓ) concentrations were high. These values would therefore represent background levels which could be expected within the dam itself.

In 1990, direct discharges from the sewage treatment works into Nigel Dam commenced. The influence on certain aspects of the water quality was significant. The concentration of sodium increased by 40 mg/ℓ in 1991, and for chlorides the increase was 45 mg/ℓ. Sulphates decreased from 780 mg/ℓ to 560 mg/ℓ in 1991. Manganese and iron values also decreased to 2,3 mg/ℓ and 1,1 mg/ℓ respectively. By 1993, however, the quality of water in the dam had deteriorated. Sodium and chloride concentrations peaked in August 1993 at 857 mg/ℓ and 1 500 mg/ℓ respectively (results supplied by Nigel municipality). Sulphate concentrations also increased significantly to an average of 1 491 mg/ℓ for the 1993-94 period. In September 1993, the first rains fell in what was to be a very wet year following an unusually dry period. The result was a flushing of the impoundment and a reduction in sodium and chloride concentrations to 270 mg/ℓ and 260 mg/ℓ respectively by April 1994.



DETAIL OF NIGEL DAM AND WATER QUALITY SAMPLING POINTS.

FIGURE No.
B6.2

Table B6.2: Water quality data for Nigel Dam (1988-89, 1991 and January 1993-May 1994)

Sampling Points (see Figure B6.2)

1. Nigel Dam Wall (Nigel Municipality)
2. Below Nigel Dam (Rand Water)

Chemical*/Physical Variables	Reading	Sampling Points		
		1 (1993-94)	2 (1988-89)	2 (1991)
pH	Min	7,2	3,7	3,8
	Max	8,2	8,2	8,5
	Ave	7,6	5,0	5,5
	Median	7,3	-	4,8
	No of Samples	17	21	9
Electrical Conductivity (mS/m)	Min	219	120	130
	Max	501	280	270
	Ave	383	165	185
	Median	401	-	190
	No of Samples	17	21	9
Turbidity (NTU)	Min	-	1	1
	Max	-	14	98
	Ave	-	4	9
	Median	-	-	7
	No of Samples	-	21	9
Total Alkalinity (as $CaCO_3$)	Min	-	0	0
	Max	-	240	215
	Ave	-	160	56
	Median	-	-	2
	No of samples	-	21	9
Total Hardness (as $CaCO_3$)	Min	-	440	315
	Max	-	1 080	840
	Ave	-	750	540
	Median	-	-	510
	No of samples	-	21	9
Calcium (as $CaCO_3$)	Min	-	98	75
	Max	-	305	245
	Ave	-	190	140
	Median	-	-	140
	No of samples	-	21	9
Magnesium (as $CaCO_3$)	Min	-	41	31
	Max	-	105	74
	Ave	-	64	44
	Median	-	-	43
	No of samples	-	21	9
Chloride (as Cl)	Min	260	21	31
	Max	1 650	330	450
	Ave	1 028	140	185
	Median	990	-	195
	No of samples	15	21	9
Sulphate (as SO_4)	Min	560	430	135
	Max	2 560	1 390	930
	Ave	1 491	780	560
	Median	1 548	-	540
	No of samples	7	21	9

* Units are all mg/ℓ unless otherwise indicated

(continued overleaf)

Chemical*/Physical Variables	Reading	Sampling Points		
		1 (1993-94)	2 (1988-89)	2 (1991)
Sodium (as Na)	Min	156	32	34
	Max	1 195	260	310
	Ave	656	120	160
	Median	695	-	190
	No of samples	12	21	9
Potassium (as K)	Min	-	9,7	14,0
	Max	-	22,0	21,0
	Ave	-	15,0	16,0
	Median	-	-	16,0
	No of samples	-	21	9
Ammonia (as N)	Min	8,90	<0,05	0,12
	Max	18,70	9,90	12,00
	Ave	14,38	2,80	0,76
	Median	14,85	-	0,58
	No of samples	16	21	9
Nitrate Nitrogen (as N)	Min	-	<0,10	<0,10
	Max	-	3,70	3,00
	Ave	-	1,10	0,85
	Median	-	-	<0,10
	No of samples	-	21	9
Nitrite Nitrogen (as N)	Min	-	<0,10	<0,10
	Max	-	0,21	0,13
	Ave	-	<0,10	<0,10
	Median	-	-	<0,10
	No of samples	-	21	9
Orthophosphate (as P)	Min	-	<0,03	<0,03
	Max	-	0,29	0,07
	Ave	-	<0,03	0,03
	Median	-	-	<0,03
	No of samples	-	21	9
Total Phosphate (as P)	Min	-	<0,30	<0,30
	Max	-	1,00	<0,30
	Ave	-	0,40	<0,30
	Median	-	-	<0,30
	No of samples	-	20	3
Chemical Oxygen Demand	Min	-	<10	24
	Max	-	36	53
	Ave	-	16	33
	Median	-	-	31
	No of samples	-	19	9
Zinc (as Zn)	Min	0	<0,10	<0,10
	Max	0,30	1,90	1,20
	Ave	0,09	0,89	0,31
	Median	0,10	-	<0,10
	No of samples	15	21	9
Chromium (as Cr)	Min	0	<0,05	<0,05
	Max	0,10	0,05	<0,05
	Ave	0,01	<0,05	<0,05
	Median	0	-	<0,05
	No of samples	15	21	9

* Units are all mg/ℓ unless otherwise indicated

(continued overleaf)

Chemical*/Physical Variables	Reading	Sampling Points		
		1 (1993-94)	2 (1988-89)	2 (1991)
Lead (as Pb)	Min	0,10	<0,30	<0,30
	Max	0,30	<0,30	<0,30
	Ave	0,23	<0,30	<0,30
	Median	0,20	<0,30	<0,30
	No of samples	8	21	9
Copper (as Cu)	Min	0	<0,10	<0,10
	Max	0,20	0,48	0,14
	Ave	0,06	0,12	<0,10
	Median	0	-	<0,10
	No of samples	7	21	9
Nickel (as Ni)	Min	0,20	<0,10	<0,10
	Max	0,50	8,70	3,30
	Ave	0,36	2,50	0,71
	Median	0,35	-	<0,10
	No of samples	8	21	9
Iron (as Fe)	Min	0,10	0,34	<0,05
	Max	1,20	51,00	3,60
	Ave	0,46	7,60	1,10
	Median	0,45	-	1,10
	No of samples	16	21	9
Manganese (as Mn)	Min	4,00	<0,30	0,36
	Max	6,10	14,00	6,70
	Ave	4,76	5,70	2,30
	Median	4,10	-	1,00
	No of samples			
Cadmium (as Cd)	Min	0	<0,05	<0,05
	Max	0,10	<0,05	<0,05
	Ave	0,02	<0,05	<0,05
	Median	0	-	<0,05
	No of samples	14	21	9
Aluminium (as Al)	Min	0	0,94	<0,10
	Max	0,50	19,00	11,00
	Ave	0,29	9,20	2,60
	Median	0,30	-	1,50
	No of samples	7	21	8
Boron (as B)	Min	-	-	0,37
	Max	-	-	0,37
	Ave	-	-	0,37
	Median	-	-	0,37
	No of samples	-	-	1
Cobalt (as Co)	Min	-	<0,10	<0,10
	Max	-	3,40	0,88
	Ave	-	0,93	0,24
	Median	-	-	<0,10
	No of samples	-	21	9
Molybdenum (as Mo)	Min	0	-	-
	Max	0,10	-	-
	Ave	0,02	-	-
	Median	0	-	-
	No of samples	5	-	-

* Units are all mg/ℓ unless otherwise indicated

(continued overleaf)

Chemical*/Physical Variables	Reading	Sampling Points		
		1 (1993-94)	2 (1988-89)	2 (1991)
Total Kjeldahl Nitrogen (as N)	Min	-	< 1,10	< 1,0
	Max	-	12,00	< 1,0
	Ave	-	3,70	< 1,0
	Median	-	-	< 1,0
	No of samples	-	20	2
Reactive Silicon Dissolved (as Si)	Min	-	2,30	< 1,0
	Max	-	18,00	18,00
	Ave	-	10,00	8,10
	Median	-	-	8,50
	No of samples	-	21	9
Total Silica (as Si)	Min	-	7,00	3,90
	Max	-	25,00	21,00
	Ave	-	13,00	13,00
	Median	-	-	14,00
	No of samples	-	21	9
Dissolved Organic Carbon	Min	-	< 2,00	< 2,00
	Max	-	9,30	11,00
	Ave	-	5,10	4,30
	Median	-	-	3,40
	No of samples	-	21	9

* Units are all mg/ℓ unless otherwise indicated

Bacteriological data are shown in Table B6.3. Although there have been periodic high bacterial counts in Nigel Dam, the quality of the water generally meets guidelines for recreational use.

Table B6.3: Bacterial quality of Nigel Dam (January 1993 - May 1994)

Bacteriological Variable	Reading	Sampling Point (see Figure B6.2)
		1
Faecal Coliforms per 100 mℓ	Min	0
	Max	9
	Ave	1
	Median	0
	No of samples	12
Total Coliforms per 100 mℓ	Min	0
	Max	67
	Ave	24
	Median	19
	No of samples	12

6.5 Pollution Problems and Management Strategies

Due to problems experienced with the quality of water in Nigel Dam and the performance of the sewage works upstream from the dam, consultants were appointed in 1993 to investigate the contribution of a nearby tannery's effluent to the problems (Jones and Wagener and Waterlab Research, 1994).

The CF Grundling Sewage Works is an orbal activated sludge plant with anaerobic, anoxic and aerobic zones designed for nutrient removal. The plant has a hydraulic capacity of 3,2 Mℓ/d and is currently loaded to full capacity. The sewage works receives its waste water from three major sources - household waste from nearby townships, waste water from a soft drink bottling company and waste water from the tannery. The waste water from the tannery enters the sewage works in a separate pipeline, where the flowrate is first measured before it is mixed with the raw sewage from the other sources. The average volume from the tannery of 520 kℓ/d constitutes approximately 16% of the average hydraulic load on the plant.

Of the 3 237 kℓ/d entering the plant as raw waste water, 105 kℓ/d (3%) of aerobically digested sludge is irrigated on land. The treatment plant produces 3 132 kℓ of secondary effluent per day of which 2 180 kℓ/d (70%) is discharged into the vlei alongside the sewage works from where it flows directly into the Nigel Dam. The remaining 952 kℓ/d (30%) is pumped to an active gold mine.

The effluent from the tannery is made up of two major waste streams. One, which originates from the limeyard, contains high concentrations of sulphate, sodium chloride (from salt cured hides) and organic material and has a high pH. The sulphides are oxidised in an aeration basin after which the waste is blended with a more acidic stream in a buffer dam. This acidic stream originates mainly from the chromeyard and contains ammonia, sulphates and reduced chromium. The combined effluent is then pumped to a dissolved air flotation tank for the removal of suspended material. Ferric chloride is used as a flocculant whilst lime is added simultaneously for pH correction. The floating sludge is then scraped off and pumped onto drying beds, while the relatively clear effluent is discharged into the municipal sewer.

Tests carried out on the waste leaving the tannery suggest the following constituents in the tannery's effluent have an adverse effect on the final quality of effluent discharged from the sewage plant: iron, sodium, chloride, ammonia and nitrogenous material and sulphate.

In terms of the General Effluent Standard (South African Water Act), effluent from the CF Grundling Sewage Works does not comply with the following parameters:

- electrical conductivity (which is an indication of the total dissolved solids in the water);
- sodium (which together with chloride, sulphate, calcium, magnesium and potassium contributes to the high dissolved solids content of the effluent);
- manganese;
- boron;
- free and saline ammonia;
- chemical oxygen demand and oxygen absorbed; and
- faecal coliforms.

The tannery contributes the major fraction of the constituents in the raw water and the activated sewage plant is unable to reduce total dissolved solids, calcium, magnesium, sodium, potassium, manganese, chloride, sulphate and boron. These constituents need to be removed from the waste stream by the tannery.

The situation in Nigel Dam, however, cannot be explained solely by the effluent of the sewage works. Recent water quality data obtained by the Nigel municipality near to the dam wall show a better standard for the lake water than might be expected given the quality of the waste water effluent. Other factors appear to be at work in the dam and/or the catchment, therefore, which may be diluting the poor quality of effluent being discharged from the sewage treatment plant.

Tests carried out in ponds formed by seepage water from the slimes dams next to the western shore of Nigel Dam show high concentrations of ammonia, sodium and chloride. These constituents originate from the water already in the dam since dam water is used in the gold reclamation process and seeps back through the slimes dams. No other sources for ammonia-nitrogen could be found in the slimes dams, apart from the contributions from Nigel Dam itself.

This slimes dam reclamation project will be completed shortly. It can therefore be expected that the pollution contribution will be reduced at completion. As mentioned earlier, the contribution from the other mines in the region would appear to be significant, but is masked by the effluent discharged from the sewage treatment works.

Nevertheless, Nigel Dam is presently being polluted to such an extent that it has become a risk for a number of downstream users in the Blesbokspruit. Not all of the pollutants come from the tannery, but it is responsible for the high levels of sodium, chloride and ammonia-nitrogen in the Nigel Dam as well as the loads of potassium and boron, the latter two constituents being at acceptable levels for most users. The tannery also contributes a major fraction of the sulphate in the water.

The dam has a high total dissolved solids content indicating that the pollution load from both the tannery and the slimes dams is significant and will have an adverse effect on the ecology of the dam. Sediment samples from the bottom of the dam confirm this. Benthic organisms belonging to the phylum *Annelida* and *Diphtheria* are present giving a strong indication of organic pollution (Jones and Wagener and Waterlab Research, 1994). The dam also suffers from aquatic waterweeds such as *Potamogeton pectinatus* and Chinese carp have recently been introduced into the dam to control this problem.

Potential management strategies and their repercussions for this impoundment include the following:

- The water management system in the tannery needs to be investigated. The principles of source reduction, effluent reuse and finally effluent treatment, could reduce the impact of the waste water from the tannery on the sewage treatment works. There may be little that can be done in terms of source reduction, apart from improving the efficiency of the existing treatment strategies. The tannery could investigate the reuse of the effluent, in conjunction with their existing supply, to reduce the load on the treatment works. Finally, should none of these approaches be satisfactory, then additional effluent treatment will be required.

- The reduced load on the sewage treatment works can be expected to improve the quality of the effluent discharged to Nigel Dam, particularly for salts and certain metals. However, the reduction in volume would need to be assessed in terms of the operation of the dam.

  The reduction of seepages by improved pollution control measures in the other parts of the catchment will also help in reducing the load of salts to the dam. The removal of the slimes dam on the banks of the dam may have a significant effect on the quality, but there is no information to critically assess this aspect.

- The internal loadings within the dam would tend to be reduced over time, as the impoundment is flushed and scoured by storm events. There is little information on plant nutrients within the system, but the data which are available indicates that the high concentration of ammonia would influence the biotic diversity of the dam. This is seen in the shift in species recently observed in the dam sediments from those recorded before 1990 and after 1990. The reduction in ammonia loading from the tannery will also lead to a reduction in ammonia in the sewage effluent. The levels of phosphate found were also low, indicating that this system may not suffer from severe algal blooms, but there are no chlorophyll *a* data to support this.

- The potential does exist for the pollution status for the dam to change if the above strategies are implemented. However, the relative contribution of plant nutrients may become more important if the other sources of pollution are removed, and therefore the impoundment may experience increasing algal and other plant problems in the future. Appropriate management strategies to address these issues should be pursued.

The importance of Nigel Dam to the communities in and around Nigel is reflected in the development and upgrading scheme currently under way by the Nigel municipality where grassing of large areas on the banks of the dam is taking place, especially on the eastern side. The dam plays host to a wide variety of birdlife, particularly waders and several rare species have been spotted. Its use as a recreational area would tend to support the implementation of pollution management measures within the catchment.

6.6 References

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7. CAMPS DRIFT CANAL, PIETERMARITZBURG

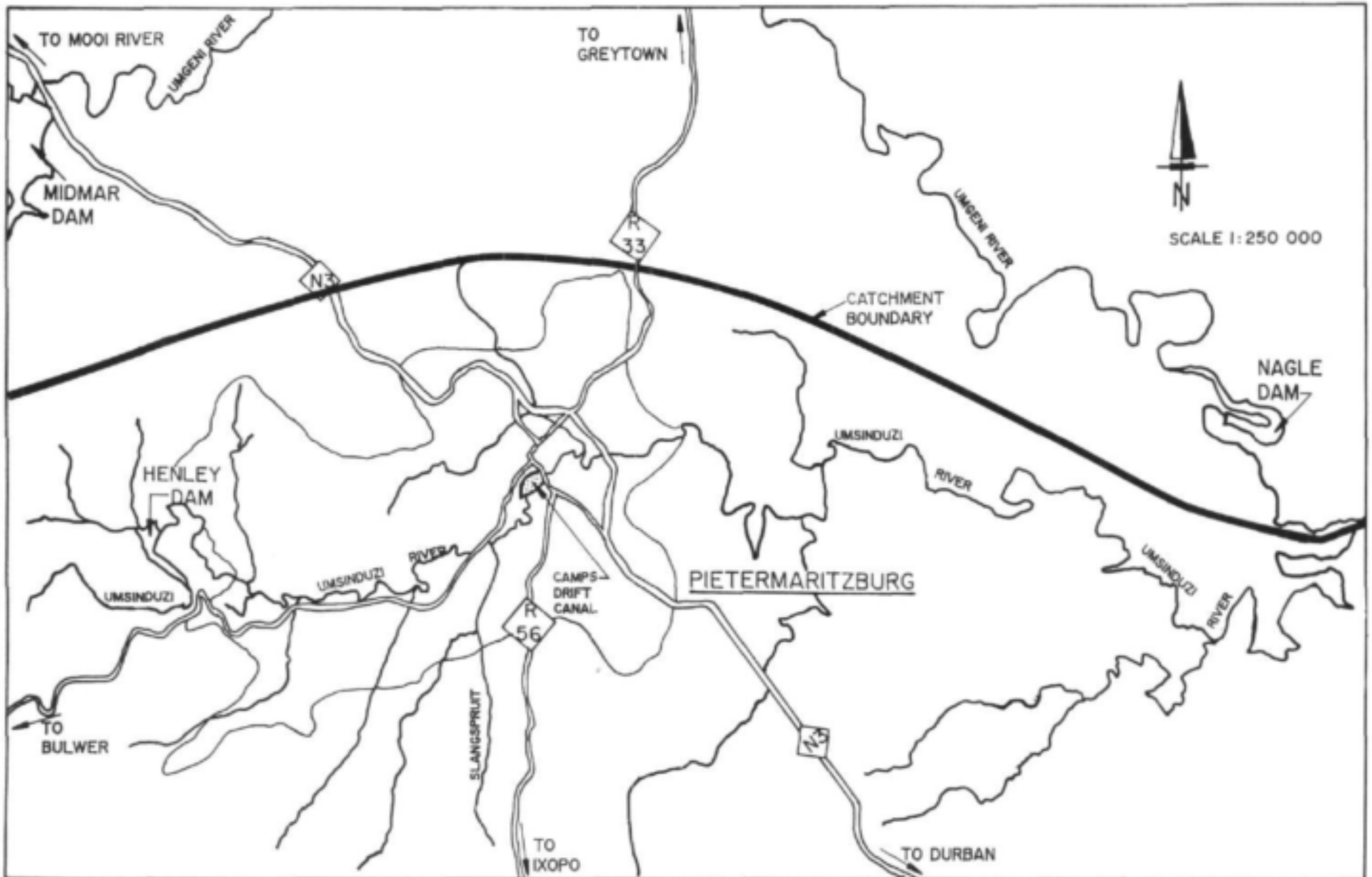
7.1 Location and Catchment Characteristics

Camps Drift Canal is a flooded earth canal situated south of the central business district of Pietermaritzburg. The canal is used to control the flow of the Umsimduzi River through an area of the city which was previously prone to flooding. The flooded canal provides a water surface area of 110 m wide by 2 500 m long (28 ha) and the total storage area of the canal is 500 000 m^3. The canal occupies the former river valley from the Edendale Road bridge downstream to the College Road bridge. A small tributary, the Slangspruit, flows into the upper reaches of the canal. The top water level in the main part of the canal is 624,2 m AMSL and the water level of the sedimentation trap just upstream of the canal is 627,2 m AMSL. Basic characteristics regarding Camps Drift Canal are shown in Table B7.1.

Table B7.1 : Characteristics of Camps Drift Canal

Geographic Location	29° 37'S ; 30° 22' E
Elevation	624 m AMSL
Surface Area	28 ha
Volume	500 000 m^3
Mean Depth	2,0 m
Maximum Depth	4,0 m
Length	2 500 m
Width	110 m

The catchment upstream of Camps Drift Canal has an area of 380 km^2 (Figure B7.1). The length of the Umsimduzi River up to this point is 50 km over which the average slope is about 1,3%. Henley Dam commands the upper 240 km^2 of the catchment which is used mainly for agriculture and forestry. The catchment below Henley Dam is, however, heavily urbanised. This section of the catchment is comprised predominantly of residential areas serving the lower socio-economic segment of the population (70% - approximately two-thirds of which is formal and high density in nature and one third informal and low density), a smaller residential area serving the higher socio-economic segment of the population (15%), light and heavy industrial areas (5% each) and parkland or veld (5%).



LOCATION AND CATCHMENT AREA OF CAMPS DRIFT CANAL

FIGURE No.
B 7.1

Immediately below the barrage weir at the head of the canal, the Umsimduzi River meanders through Alexandra Park and beneath the N3 freeway before leaving the built-up area of Pietermaritzburg. The Umsimduzi eventually joins the Umgeni River below the Nagle Dam.

7.2 Impoundment History

Camps Drift Canal was designed and constructed in 1983-84 with the main purpose being to reclaim nearby land which was prone to inundation upstream of the College Road bridge, thereby satisfying the demand for industrial land in the vicinity.

Prior to this time, a flood plain existed in the area of the present canal caused by a narrowing of the river where the College Road bridge now stands due to the presence of a dolerite sill intrusion across the river bed. In the past, this feature induced the river to deposit a layer of silt about 4 m thick through which the river meandered haphazardly. As a result of this propensity to inundation, the flood plain was left fallow and undeveloped.

Originally, there was no intention to flood the canal, but because of concern about expected prolific weed growth which would aggravate the deposition of silt during high flows, it was decided to keep the canal flooded in order to control erosion and the growth of aquatic weeds whilst simultaneously creating a body of water which could be utilised as a recreation facility.

The final design of the control structures for the canalisation scheme took account of investigations into hydrology and floodlines, sediment, eutrophication potential, geotechnical aspects and environmental problems.

The adopted design consisted of four main elements which are briefly summarised below beginning at the upper end of the canal:

(i) A semi-circular, submerged concrete weir (70 m long x 1,5 m high), located immediately downstream of the Edendale Road bridge crossing, but upstream of the sedimentation basin outlet weir for the express purpose of dissipating the high energy of the incoming flow.

(ii) A concrete weir (90 m long x 3 m high) flanked on either side by control chambers each containing a 1 m diameter penstock. This weir is located at the upper end of the canal for the purpose of creating a sedimentation basin to trap silt in a position that will facilitate easy removal. A concrete ramp into the basin provides for easy access by mechanical equipment.

(iii) A semi-circular, concrete barrage weir (90 m long x 4,5 m high), located just before the College Road bridge. The primary purpose of this weir is to create the necessary area behind it to reduce the velocity of water flow in the canal during floods. The crest of the weir is stepped to train and contain low flows and a hydraulically operated adjustable crest weir 3 m wide is positioned in the centre of the structure to allow the flushing out of collected scum and debris and to provide a concentrated flow of water for the stepped canoe chute-cum-fish ladder. Two 1 m diameter penstocks in the control chamber on the right bank allow for the draining of the canal. The weir also forms an artificial lake with a minimum depth of 2 m to comply with international requirements for a rowing course. To eliminate a sewer siphon located under the river below the College Road bridge, a 1 350 mm diameter sewer was incorporated in the main barrage permitting the existing sewers on the right bank serving the Edendale area to be diverted.

(iv) The provision of an additional span to the College Road bridge, in order to overcome the constriction of the river at this point which was compounded by the existing bridge - the waterway through the bridge being only 23 m wide as compared with the 80 m of the canal. The doubling of the College Road waterway thus allowed the canal system to be capable of containing floods and protecting the low lying area between the two bridges.

7.3 Impoundment Use

When it was built, the primary function of the Camps Drift Canal was to reclaim land for industrial development whilst at the same time helping to control the silt and suspended solids loads in the river and, through the limited retention of water brought about by the canal, to assist in reducing the effect of harmful organisms and other pollutants arriving in the canal.

The excavated material from the canal was spread and compacted on the right bank to raise the ground level and thus increase protection of the proposed industrial development against floods. Services were provided to develop 38 ha of rail served and 18 ha of non-rail served industrial land on the reclaimed area.

The canal is perhaps best known, however, for the recreational opportunities it affords. In particular, the public knows it as the starting point for the Duzi canoe marathon. The canal, together with the nearby Alexandra Park, is enjoyed by canoeists and rowers, model boaters, nature lovers and picnickers and many local people believe it was built specifically for recreation.

7.4 Impoundment Limnology

Prior to investigations carried out for the Camps Drift Canalisation scheme, some limited published information is available on the nature and water quality of the Umsimduzi River flowing into Pietermaritzburg.

A study carried out in the late 1970s (Archibald et al., 1980) of Henley Dam in the upper catchment of the Umsimduzi showed that the river carried large silt loads during periods of high rainfall which were reducing the storage capacity of the dam. Data also showed a high concentration of nitrate (over 0,7 mg /ℓ for 75% of observations) in the water of the reservoir, but low levels of phosphate (<0,01 mg/ℓ for at least 50% of observations). Although the nitrate concentrations were high for a reservoir in a rural catchment, when linked to the phosphorus levels, the dam was classified as at the oligo-mesotrophic boundary.

Assuming this assessment of Henley Dam could be applied to the catchment below it as background conditions, it is reasonable to expect that the river below the dam at that time would have had a similar chemical quality. The data were collected during the relatively wet years of the late 1970s. However, samples collected during 1982-83 from the river and its tributaries immediately below the dam and prior to the construction of Camps Drift Canal showed a marked increase in phosphorus (two orders of magnitude higher), thus indicating the influence of catchment activities below Henley Dam. Comparable data for nitrogen are unavailable, but it would be reasonable to have expected an equivalent increase.

This, coupled with high bacterial numbers in the river near the proposed canalisation, gave cause for concern to the scheme's proposers, because to fill the envisaged canal with poor quality water would materially influence its use as a recreation focus. The Slangspruit was identified as a principal source of the deterioration in water quality. The high bacteriological values were also associated with a greatly reduced overflow due to the drought experienced at that time. In effect, the catchment was not being washed down by the convective rainfall typical of the Natal Midlands. The mean annual precipitation over the catchment upstream of Camps Drift Canal is between 900 and 1 000 mm per annum and mean annual run-off is approximately 150 mm or 60 x 10^6 m^3.

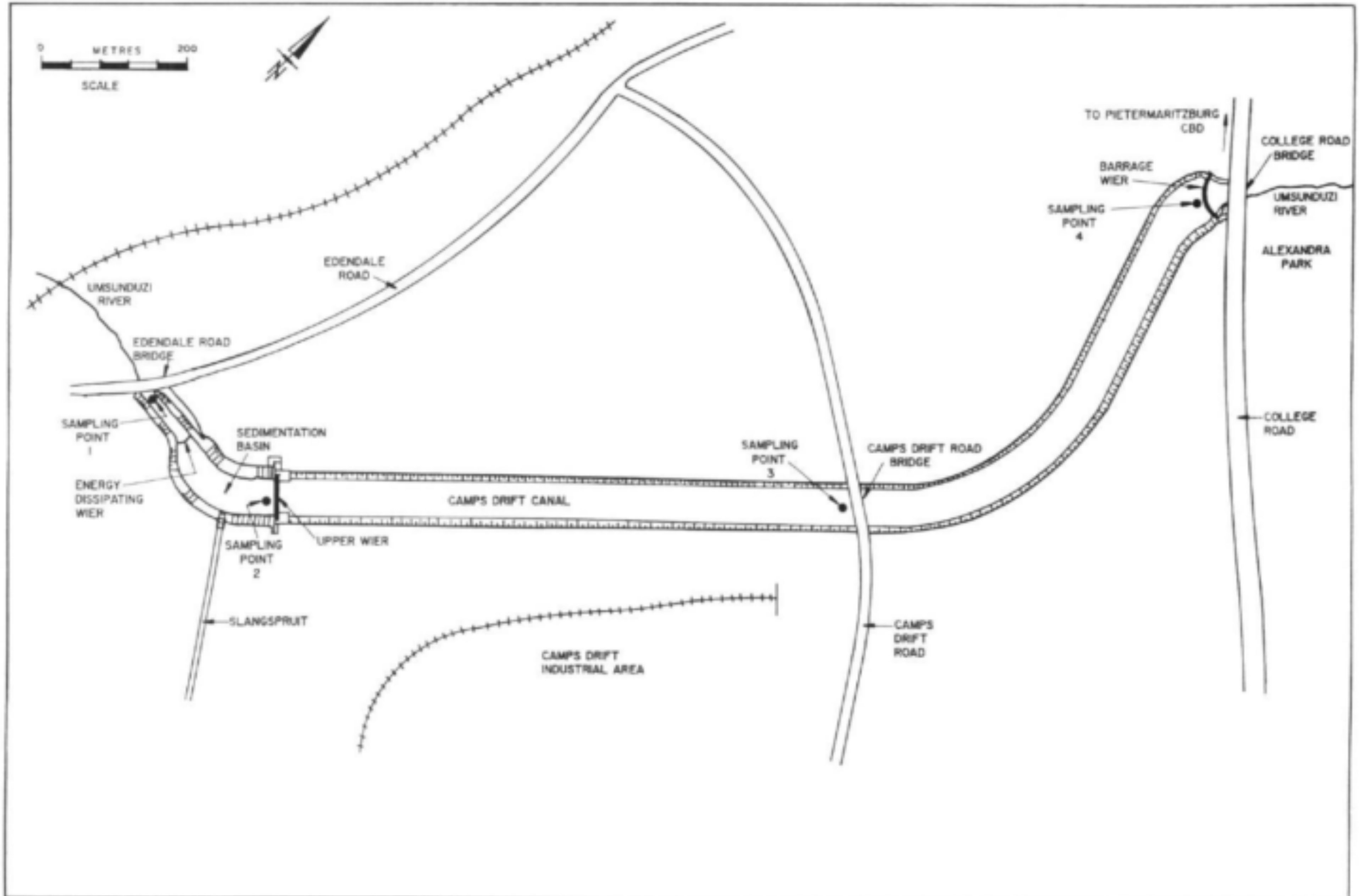
Investigations carried out for the canalization scheme (Stewart, Sviridov and Oliver, 1983) resulted in a recommendation, amongst others, that a regular monitoring programme of the waters in the proposed lake be established in addition to the normal health tests routinely undertaken at that time. This recommendation was adopted and the monitoring programme is now undertaken by Umgeni Water, who took over the role from Pietermaritzburg City Council Laboratories. Umgeni Water is now responsible for testing water quality in the entire Umsimduzi catchment as well as in other river systems affecting bulk water supply in the region.

Water quality tests are currently carried out at four points in the Camps Drift Canal (Figure B7.2) as well as in the Slangspruit tributary above its confluence with the Umsimduzi and at points below the Camps Drift barrage weir. A summary of the water quality data is presented in Table B7.2.

All values reported are median values for the period 1990 to 1994, except where otherwise stated. The quality of water in Camps Drift Canal can be described as generally good. Electrical conductivity values drop slightly from 19 mS/m at the inflow to 18 mS/m at the outflow. Similarly, nutrient concentrations are low. Nitrates vary from 1,01 mg/ℓ at the inflow to 0,99 mg/ℓ at the outflow. Orthophosphate concentrations drop from 0,02 mg/ℓ at the inflow to 0,01 mg/ℓ at the outflow. These concentrations are low, the changes are not significant, and combined with the low residence time forecast for water in the canal, would tend to confirm earlier investigations which predicted little chance for nuisance algal conditions. However, no chlorophyll data are available, and therefore the reality of this prediction can not be assessed.

There are, however, two aspects which were predicted in the 1983 studies, and which have a direct bearing on the operation of the system. These are the suspended solids in the water and the microbial populations.

The levels of suspended sediments found in the water are high. The median inflow values of 27 mg/ℓ rise slightly at the outflow to 35 mg/ℓ. An assessment of the water quality data for 1990 to 1994, indicates that there is a gradual increase in suspended solids within the canal. The expected reaction within the canal was the settling of suspended material. The time series data indicate that for the inflows, there is an increase in suspended sediments during summer, and a drop in winter. This is expected as a result of the prime driving force behind the suspended sediment being the summer rains. There also appears to be a gradual increase in suspended sediment concentrations on an annual basis from 1990 to 1994. Within the canal, there were insufficient data to compare year to year variations.



DETAIL OF CAMPS DRIFT CANAL AND WATER QUALITY SAMPLING POINTS	FIGURE No. B 7.2

Table B7.2 : **Water quality data for Camps Drift Canal (January 1990 - May 1994)**

Sampling Points (See Figure B7.2):

1. Duzi at Edendale Road
2. Camps Drift Upper Weir
3. Camps Drift Bridge
4. Camps Drift Lower Weir

Chemical*/Physical Variables	Reading	Sampling Points			
		1	2	3	4
pH	Min	6,8	6,8	6,9	6,8
	Max	9,5	9,5	9,5	9,5
	Ave	7,9	7,9	7,9	7,0
	Median	7,9	7,8	7,9	7,8
	No of Samples	218	218	213	218
Electrical Conductivity (mS/m)	Min	7	7	7	7
	Max	34	32	31	31
	Ave	19	19	19	18
	Median	19	18	19	18
	No of Samples	226	48	55	48
Turbidity (NTU)	Min	2	7	6	3
	Max	*72 000*	*1 749*	728	*1 033*
	Ave	421	116	91	96
	Median	27	40	46	48
	No of Samples	224	55	48	48
Total Dissolved Solids	Min	76	-	-	-
	Max	328	-	-	-
	Ave	129	-	-	-
	Median	103	-	-	-
	No of Samples	17	-	-	-
Total Alkalinity (as $CaCO_3$)	Min	18	-	-	-
	Max	130	-	-	-
	Ave	56	-	-	-
	Median	55	-	-	-
	No of Samples	225	-	-	-
Total Hardness (as $CaCO_3$)	Min	24	--	-	-
	Max	84	-	-	-
	Ave	53	-	-	-
	Median	50	-	-	-
	No of Samples	54		-	-
Calcium (as $CaCO_3$)	Min	4	-	-	-
	Max	17	-	-	-
	Ave	11	-	-	-
	Median	10	-	-	-
	No of Samples	54	-	-	-
Magnesium (as $CaCO_3$)	Min	3	-	-	-
	Max	10	-	-	-
	Ave	6	-	-	-
	Median	7	-	-	-
	No of Samples	54	-	-	-
Chloride (as Cl)	Min	8	-	-	-
	Max	40	-	-	-
	Ave	19	-	-	-
	Median	19	-	-	-
	No of Samples	225	-	-	-

* Units are mg/*l* unless otherwise indicated

(continued overleaf)

Chemical*/Physical Variables	Reading	Sampling Points			
		1	2	3	4
Sulphate (as SO_4)	Min	2	-	-	-
	Max	25	-	-	-
	Ave	9	-	-	-
	Median	8	-	-	-
	No of Samples	225	-	-	-
Sodium (as Na)	Min	6	-	-	-
	Max	33	-	-	-
	Ave	17	-	-	-
	Median	16	-	-	-
	No of Samples	54	-	-	-
Potassium (as K)	Min	0,6	-	-	-
	Max	2,7	-	-	-
	Ave	1,5	-	-	-
	Median	1,5	-	-	-
	No of Samples	54	-	-	-
Ammonia (as N)	Min	0,01	0,02	0,02	0,02
	Max	1,54	0,73	0,43	0,41
	Ave	0,10	0,16	0,17	0,16
	Median	0,07	0,14	0,14	0,11
	No of Samples	223	47	47	47
Nitrate Nitrogen (as N)	Min	0,03	0,03	0,03	0,15
	Max	2,93	2,28	2,51	2,63
	Ave	1,00	0,95	0,90	0,95
	Median	1,01	0,93	0,91	0,99
	No of Samples	225	47	47	47
Nitrite Nitrogen (as N)	Min	0,03	-	-	-
	Max	0,74	-	-	-
	Ave	0,03	-	-	-
	Median	0,03	-	-	-
	No of Samples	225	-	-	-
Orthophosphate (as P)	Min	<0,01	<0,01	<0,01	<0,01
	Max	1,44	0,48	0,94	0,03
	Ave	0,05	0,04	0,01	0,01
	Median	0,02	0,01	<0,01	0,01
	No of Samples	225	46	54	47
Total Phosphate (as P)	Min	0,01	0,01	0,01	0,01
	Max	2,12	0,52	0,13	0,26
	Ave	0,13	0,11	0,06	0,05
	Median	0,09	0,09	0,05	0,03
	No of Samples	223	46	47	54
Chemical Oxygen Demand (as O)	Min	10	-	-	10
	Max	241	-	-	38
	Ave	29	-	-	19
	Median	23	-	-	10
	No of Samples	32	-	-	12
Biological Oxygen Demand (as O)	Min	0,23	-	-	0,50
	Max	9,72	-	-	2,90
	Ave	2,92	-	-	1,34
	Median	2,10	-	-	1,18
	No of Samples	43	-	-	12
Suspended Solids	Min	2	8	2	9
	Max	1 733	1 040	359	750
	Ave	76	78	66	69
	Median	27	37	42	35
	No of Samples	223	54	47	46

* Units are mg/l unless otherwise indicated

(continued overleaf)

Chemical*/Physical Variables	Reading	Sampling Points			
		1	2	3	4
Total Plate Count	Min	1,0	2,3	2,5	1,0
	Max	19,5	17,1	8,5	11,2
	Ave	3,7	4,5	4,2	4,2
	Median	3,1	4,1	3,8	3,9
	No of Samples	212	40	47	40
Coliphages (PFU/10 mℓ)	Min	60	20	220	300
	Max	190	4320	380	350
	Ave	117	651	300	325
	Median	100	300	300	325
	No. of Samples	3	11	2	2
Geosmin	Min	0,19	-	-	-
	Max	0,19	-	-	-
	Ave	0,19	-	-	-
	Median	0,19	-	-	-
	No of Samples	1	-	-	-
Fluoride (as F)	Min	38	-	-	-
	Max	259	-	-	-
	Ave	64	-	-	-
	Median	38	-	-	-
	No of Samples	17	-	-	-
Zinc (as Zn)	Min	0,01	-	-	-
	Max	0,07	-	-	-
	Ave	0,02	-	-	-
	Median	0,01	-	-	-
	No of Samples	53	-	-	-
Chromium (as Cr)	Min	<0,01	-	-	-
	Max	0,11	-	-	-
	Ave	0,02	-	-	-
	Median	0,01	-	-	-
	No of samples	52	-	-	-
Lead (as Pb)	Min	<0,01	-	-	-
	Max	0,02	-	-	-
	Ave	<0,01	-	-	-
	Median	<0,01	-	-	-
	No of samples	52	-	-	-
Copper (as Cu)	Min	0,01	-	-	-
	Max	0,05	-	-	-
	Ave	0,01	-	-	-
	Median	0,01	-	-	-
	No of samples	53	-	-	-
Nickel (as Ni)	Min	<0,01	-	-	-
	Max	0,04	-	-	-
	Ave	0,01	-	-	-
	Median	<0,01	-	-	-
	No of samples	53	-	-	-
Iron (as Fe)	Min	0,23	-	-	-
	Max	16,20	-	-	-
	Ave	1,05	-	-	-
	Median	0,74	-	-	-
	No of samples	225	-	-	-
Manganese (as Mn)	Min	0,01	-	-	-
	Max	0,58	-	-	-
	Ave	0,13	-	-	-
	Median	0,10	-	-	-
	No of samples	225	-	-	-
Cadmium (as Cd)	Min	<0,01	-	-	-
	Max	<0,01	-	-	-
	Ave	<0,01	-	-	-
	Median	<0,01	-	-	-
	No of samples	52	-	-	-

* Units are mg/ℓ unless otherwise indicated

(continued overleaf)

Chemical*/Physical Variables	Reading	Sampling Points			
		1	2	3	4
Aluminium (as Al)	Min	0,01	-	-	-
	Max	9,38	-	-	-
	Ave	0,39	-	-	-
	Median	0,18	-	-	-
	No of samples	219	-	-	-
Silica (as Si)	Min	2,20	-	-	-
	Max	12,90	-	-	-
	Ave	7,16	-	-	-
	Median	7,20	-	-	-
	No of samples	224	-	-	-
Mercury (as Hg)	Min	<0,01	-	-	-
	Max	<0,01	-	-	-
	Ave	<0,01	-	-	-
	Median	<0,01	-	-	-
	No of samples	53	-	-	-
Selenium (as Se)	Min	<0,01	-	-	-
	Max	<0,01	-	-	-
	Ave	<0,01	-	-	-
	Median	<0,01	-	-	-
	No of samples	53	-	-	-
Boron (as B)	Min	0,01	-	-	-
	Max	0,06	-	-	-
	Ave	0,03	-	-	-
	Median	0,03	-	-	-
	No of samples	14	-	-	-
Temperature (° C)	Min	9,4	10,6	10,7	11,4
	Max	30,0	30,8	31,5	31,2
	Ave	19,9	20,4	21,0	20,8
	Median	20,6	20,8	21,5	21,0
	No of samples	218	218	213	218

* Units are mg/ℓ unless otherwise indicated

In terms of the average values, there appears to be a decrease in suspended sediment concentrations through the canal (76 mg/ℓ dropping to 69 mg/ℓ). This would seem to be the result of the maximum values significantly affecting the average values. It thus makes it difficult to assess the settling efficiency of the canal.

The microbial populations directly affect the use of the water for recreational purposes. As has been detailed earlier, the catchment has a significant amount of informal settlements and these have periodically experienced problems with their sewage systems. It can be expected, therefore, that high bacterial populations would be recorded. This is seen in the water samples collected for the inflow to the system, where the faecal coliforms measured 5 300/100 mℓ (Table B7.3). The outflows recorded a value of 995/100 mℓ. This indicates that the system itself is reducing the bacterial populations. The prime mechanism can be expected to be settling of the bacteria attached to sediments. A study undertaken by Umgeni Water showed that the microbiological populations associated with the sediment were able to survive for a period of two months *in situ* (Howard, 1994.) This would result in re-inoculation with bacteria whenever sediment was resuspended, either as a result of wind action, or as a result of large volumes of inflowing water.

Table B7.3 : Bacterial quality of Camps Drift Canal (January 1990 - May 1994)

Bacteriological Variable	Reading	Sampling Points (see Figure B6.2)			
		1	2	3	4
Faecal Coliforms per 100 mℓ	Min	66	8	4	2
	Max	400 000	500 000	440 000	420 000
	Ave	19 024	20 002	11 676	7 039
	Median	5 300	5 300	1 900	995
	No of Samples	224	265	261	266
E. coli per 100 mℓ	Min	6	2	0	0
	Max	72 000	123 000	170 000	50 000
	Ave	4 793	6 069	3 623	1 789
	Median	1 560	1 600	450	260
	No of Samples	224	265	261	266
Faecal Streptococci per 100 mℓ	Min	0	0	0	0
	Max	16 000	26 300	25 000	30 000
	Ave	732	859	404	347
	Median	120	105	50	38
	No of Samples	223	264	260	264

It can therefore be expected that the removal from the system of the settled sediments will not only reduce the internal loading of nutrients, but also the potential for re-inoculation by bacteria.

7.5 Pollution Problems and Management Strategies

Camps Drift Canal has attempted to act as a solution to various problems experienced in the Umsimduzi River where it passes through central Pietermaritzburg. Although the major motivation for the project was reclamation of land for industrial development by protecting that land against regular flooding, some of the biggest difficulties threatening the scheme were the sediment transported by the river as well as the polluted water and the possibility of eutrophication and algal blooms resulting from the high levels of nutrients in the water.

With respect to the sediment problem, the construction of a dam upstream of the canal was considered the most effective solution, but the costs of this were excessive and the most suitable dam site would have flooded the nearby Edendale township. The alternative of a small dam immediately upstream of the canal would also have had a high cost as well as a short life. Another alternative was the construction of a by-pass diversion canal. Although this alternative had advantages, a lack of space and a very high cost mitigated against it.

The solution adopted, a sedimentation basin at the upper end of the canal, enabled the trapping of the bulk of the incoming silt being transported by the Umsimduzi as well as that of the Slangspruit tributary. It was calculated that the sediment load at the canal would be 150 000 t/a. Assuming the lake created by the barrage weir would have a trap efficiency of 66%, the expected silt levels which would be trapped would be approximately 100 000 t/a, occupying a volume of 100 000 m^3. This approximates to 20% of the storage capacity (the total storage volume of the canal being 500 000 m^3), but does not necessarily imply the canal would be full of sediment within 5 years because of the wide temporal variations experienced in sediment loads in the river.

A second advantage of the sedimentation basin is that it acts, to some extent, as a nutrient sink trapping the deposited silt and some of the aquatic vegetation and pollutants carried by the river. In order to create a quiescent environment for the silt to settle out in the sedimentation basin, it was found to be essential to construct the weir upstream of the basin to destroy the high energy of the incoming flow. The sedimentation basin has been cleared at least four times since 1986 and the system has remained effective and worked in line with original expectations. The costs of the dredging are high, however, and the problem of removing accumulated silt in the main canal section below the sedimentation basin remains. Nevertheless, the dredged silt does provide material for use in reclaiming land and for fill in roadway embankments.

The clearing of the sedimentation basin, usually before the onset of the rainy season, is also an important consideration in terms of potential pollution trends in the canal. If the basin is allowed to fill with reeds and plants, it creates an ideal breeding ground for snails and becomes a focus for bilharzia infection. For this reason, the canal edges were bank-edged to prevent heavy plant growth in these areas and help reduce the trapping of debris as well as curbing erosion of the banks.

A further problem with the draining of the whole canal system, is the resultant loss of fish stocks within the system. As the water is drained off, local inhabitants descend on the river bed and collect all the fish floundering without water. This can be expected to have an impact on the short-term use of the impoundment for angling.

The scouring of the canal itself, using the two scour valves, can be expected to transport highly turbid water downstream. This may have an impact on downstream users, since it can be expected that the resultant levels of suspended sediment would be extremely high.

The large volume of water in the canal also helps limit the possibility of contracting bilharzia and the long, relatively shallow shape of the canal minimises the potential for eutrophication. The retention time of the water is generally too short for nuisance blooms or algal scums to develop. The option of keeping turbidity high to ensure low light penetration and using slow sand filters for purifying the water in the canal was rejected in favour of relying on the self-purifying ability of the canal water together with the use of a crest gate at the barrage weir to skim off algal scums.

Despite these measures, the waters of the Umsimduzi and the Slangspruit still suffer from pollution. Phosphorus and nitrogen content and the bacterial counts have been steadily rising over the years. This would have remained a concern whether or not the canal had been built. Besides wash-off from urban township surfaces, high pollution levels have been caused by blockages in the main outfall sewers from nearby townships such as Edendale and Imbali as well as from informal settlements further upstream. Pollution indicator boards have been erected in the area next to the canal to warn users of potential health hazards and the public is not encouraged to frequent the highly polluted Slangspruit. The indicators are updated three times per week.

Camps Drift Canal was not an inexpensive undertaking. On completion in 1988, the costs of investigation, design and construction of the canal's control features totalled R5 500 000 and this sum does not include the costs of excavating the canal which was completed four years earlier. The construction of the control features also suffered a setback from the severe September 1987 floods when the sedimentation basin was completely filled, the barrage weir was overtopped by 4 m (with an estimated flow of 800 m^3/s) and some of the earthworks were damaged.

Nevertheless, the project demanded input from a wide spectrum of scientific and engineering disciplines to produce a scheme which has encouraged development of dormant land and provided, together with the adjacent Alexandra Park, a readily accessible recreational facility almost in the centre of Pietermaritzburg.

7.6 References

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8. NORTH END LAKE, PORT ELIZABETH

8.1 Location and Catchment Characteristics

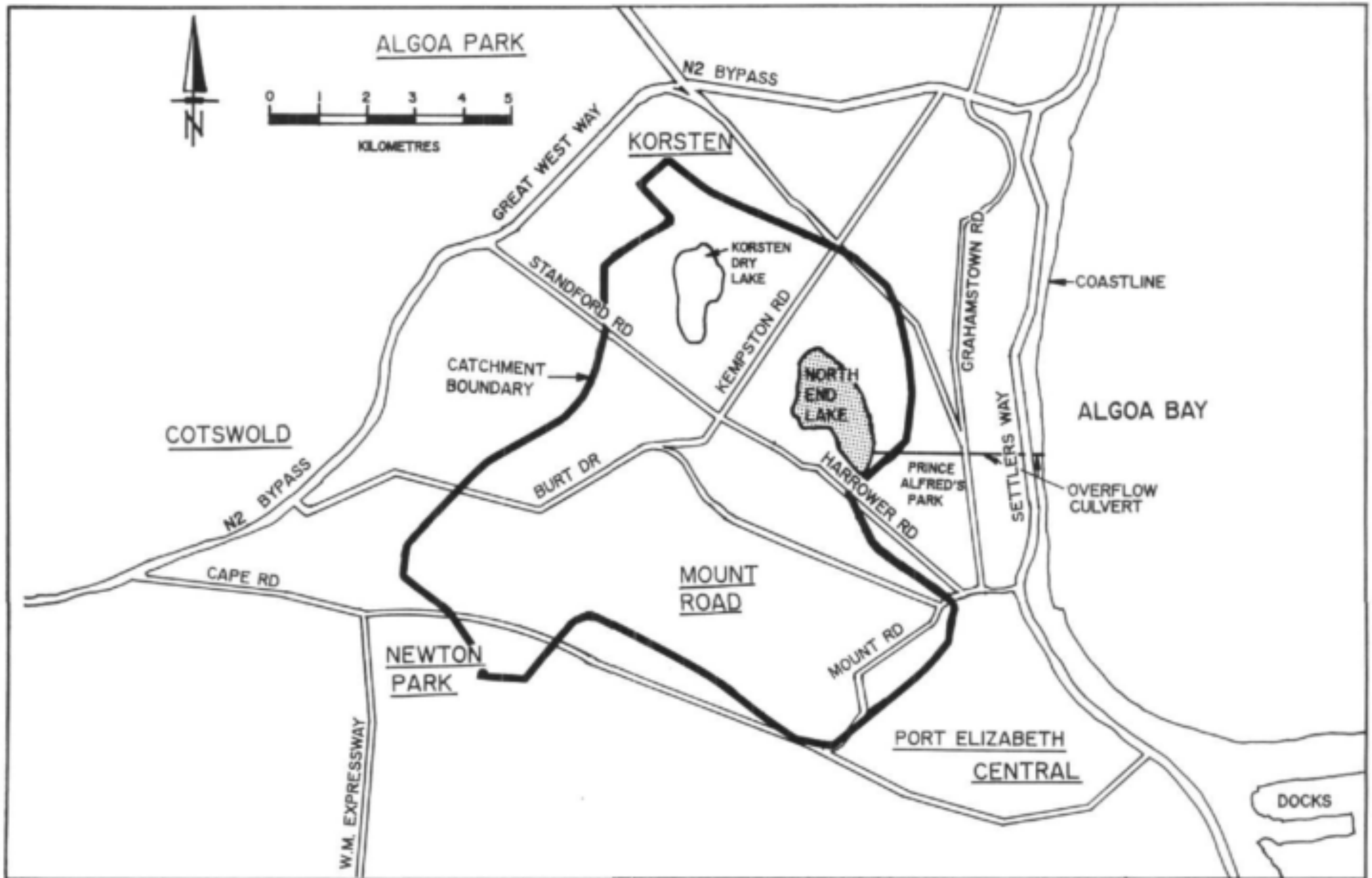
North End Lake is situated in the suburb of Sidwell, approximately 4 km north of the Port Elizabeth CBD and less than 2 km west of the sea (Algoa Bay). It is easily accessible from all parts of the city. Basic details regarding the characteristics of the lake are shown in Table B8.1.

Table B8.1 : Characteristics of North End Lake

Geographic Location	33° 56' S; 25° 35' N
Elevation	16 m AMSL
Surface Area	30 ha
Volume	477 000 m^3
Mean Depth	1,6 m
Maximum Depth	5,0 m
Length	900 m
Width	400 m

North End Lake is a natural pan which has been absorbed over time into the urban fabric of Port Elizabeth as the city expanded and it is now completely surrounded by urban development. The pan is not part of any river system and has no natural watercourses feeding or leaving it. It does, however, serve as a storm-water retention pond for an urban catchment of 911 ha, which extends from Cape Road in the south to Uitenhage Road in the north and from Newbolt Street in the west to Mount Road in the east (Figure B8.1). 75% of this storm-water catchment is residential whilst 25% is industrial land. The residential area generally serves the higher socio-economic segment of the population and the 75% of the catchment it constitutes can be said to be 60% low density and 15% high density residential. Of the industrial area in the storm-water catchment, 15% could be considered light industry and 10% heavy industry. A small area of parkland (Prince Alfred's Park) abuts the south-eastern border of the pan.

North End Lake has a surface area of 30,1 ha and its water level is controlled at a height of 16,3 m AMSL by a concrete spillway located near its southern end. The spillway discharges into a pressure culvert which is routed across Prince Alfred's Park and then beneath Innes and Darling Streets, discharging into the sea east of the Darling Street interchange. A 900 mm diameter section of this



LOCATION AND CATCHMENT AREA OF NORTH END LAKE	FIGURE No. B 8.1

culvert from Main Street to the outfall controls the maximum discharge to between 4,4 and 4,6 cumecs dependent on the water level of the pan. The maximum storage capacity of 477 000 m^3 is reached when at a water level of 17,7 m AMSL, the pan overflows its southern bank into Prince Alfred's Park.

8.2 Pan History

North End Lake is a natural pan, but it has been modified by the introduction of storm-water runoff via the storm-water drainage system and a concrete weir to take away excess storm water has been constructed on the south-eastern shore. In the past, water was abstracted from the pan and chlorinated for use in a power station on Mount Road. Two jetties have been built on the southern shore to facilitate the launching of boats.

8.3 Pan Use

North End Lake serves as a significant recreation node for the surrounding urban area. Major recreational activities that take place on or around the pan include angling, water-skiing, boating/canoeing, bathing and picnicking/braaiing.

According to the Eastern Province Angling Association, competitive freshwater anglers consider the North End Lake to be one of the best freshwater angling venues in the country. It is used for inter-provincial and national freshwater angling competitions and would likely be used for any future international competitions. Visiting holiday makers who enjoy angling also make use of the lake. Additionally, a small amount of subsistence fishing occurs (Batchelor, 1994).

The Eastern Province Power Boat Club is located on the southern shore of the pan where they lease a portion of land from the City Council. Boating and water-skiing competitions are held regularly on the pan. The Blue Water Canoe Club also leases a municipal building (the old chlorinator building) situated in the same area.

It has been recognised for some time by both Council officials and lake users that North End Lake has the potential for being developed into one of Port Elizabeth's main recreation areas. It is felt that the pan is an asset which should be upgraded. Although competing with attractions along the sea front, the pan serves as a focal point for a broad range of activities and could, in conjunction with the adjacent Prince Alfred's Park, have the carrying capacity for large numbers of people. The various municipal departments which have an interest in the lake are thus considering its upgrading.

Early in 1994, the Architectural Division of the City Engineers Department, in collaboration with the Parks Department, drafted development proposals and guidelines for improving the surrounds of the pan. The focus was to be on improving the visual quality of the area through intensive tree planting and providing amenities such as parking, lighting, fencing, litter bins, clubhouses and ablution blocks, pathways and board-walks, fishing jetties, braai places, tables and benches. Upgrading of the area commenced in 1994.

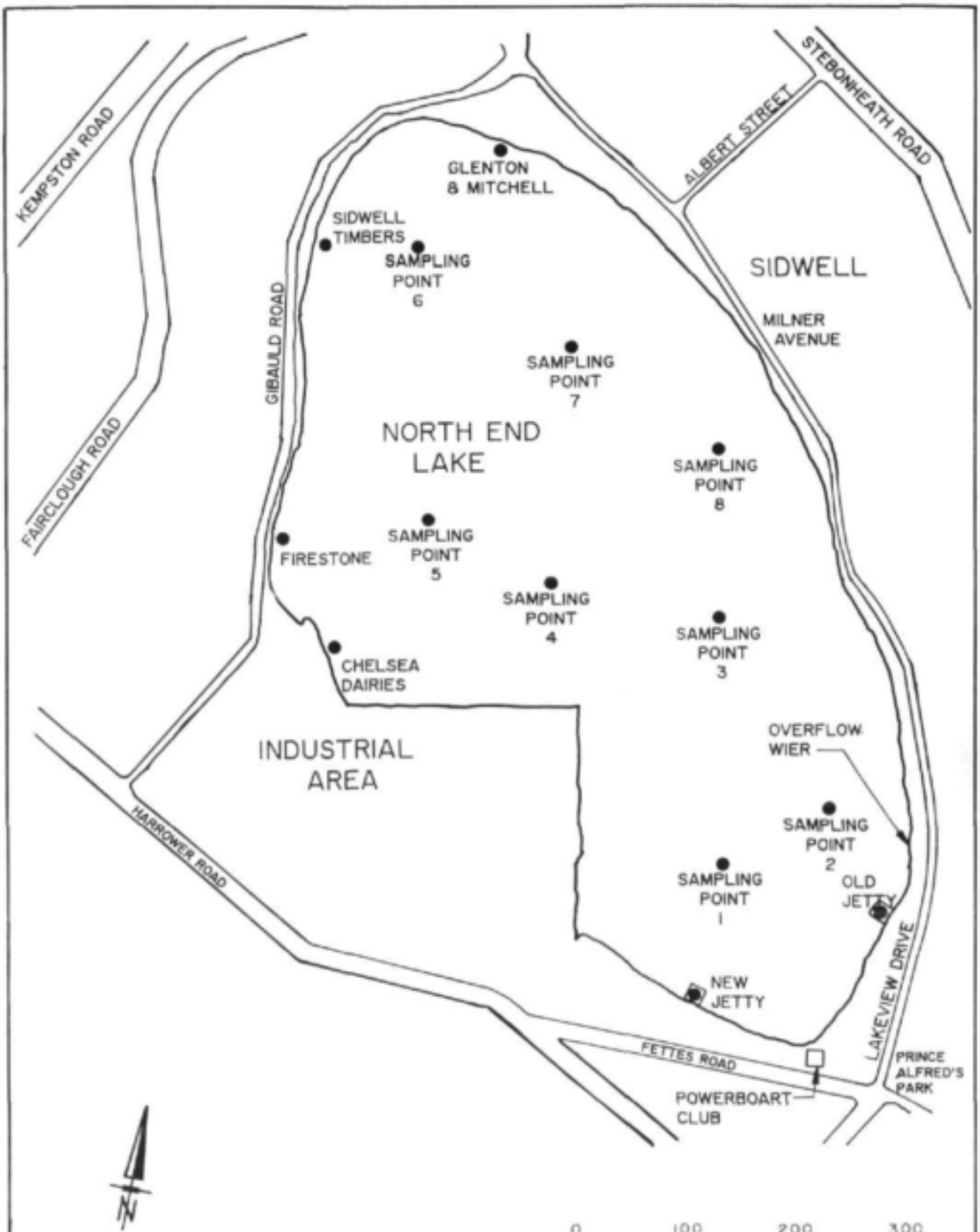
In addition to its recreational use, it should be noted that the pan is also used as a retention pond for storm-water runoff via the municipal storm-water drainage system. In addition, several factories from the neighbouring Korsten industrial area, adjacent to the western shore, discharge effluent into the pan. Some of the effluent includes hot sterilised water.

8.4 Pan Limnology

North End Lake has been the subject of regular bacteriological testing for many years, but since 1986 an extended sampling programme including analysis of the chemical quality of the water has been undertaken. This was the result of the establishment of the Stormwater and Miscellaneous Water Pollution (SWAMP) Action Committee which is attended by representatives of the Water Reclamation, Scientific Services, Health, Sewerage, Roads and Stormwater Divisions of the Port Elizabeth municipality as well as a representative of the Department of Water Affairs and Forestry. The committee meets regularly to investigate water pollution problems experienced in the city and North End Lake forms a major component of the committee's discussions.

Bacteriological tests (i.e. for faecal coliforms) are conducted monthly at eight sampling points in the body of the lake as well as at five inshore stations which are close to storm-water outlets (Figure B8.2). Tests for a comprehensive range of 31 chemical and physical variables are also carried out. These latter tests are made on composite water samples from the different sampling points.

Water quality data on the pan water composite samples taken over the last three years, are presented in Table B8.2.



DETAIL OF NORTH END LAKE AND WATER QUALITY SAMPLING POINTS

FIGURE No. B 8.2

Table B8.2 : Water quality data for North End Lake (January 1991 - April 1994)

Chemical*/Physical Variables	Composite Data for 8 Sampling Points (see Figure B8.2)		
	Maximum	Minimum	Average
pH	9,0	7,8	8,3
Electrical Conductivity (mS/m)	275	150	208
Colour (Pt/Co units)	77	2	13
Turbidity (NTU)	32	6	14
Total Dissolved Solids	1 580	908	1 255
Total Alkalinity (as $CaCO_3$)	234	137	167
Carbonate Alkalinity (as $CaCO_3$)	46	0	9
Bicarbonate Alkalinity (as $CaCO_3$)	234	121	159
Carbonate Hardness (as $CaCO_3$)	234	106	167
Non-carbonate Hardness (as $CaCO_3$)	178	0	90
Total Hardness (as $CaCO_3$)	381	106	256
Calcium (as $CaCO_3$)	178	27	116
Magnesium (as $CaCO_3$)	274	50	141
Chloride (as Cl)	670	346	508
Sulphate (as SO_4)	135	60	91
Sodium (as Na)	410	110	313
Potassium (as K)	29,0	0,6	15,9
Ammonia (as N)	1,00	0,01	0,29
Nitrate Nitrogen (as N)	2,20	0,01	0,21
Orthophosphate (as P)	1,00	0,02	0,17
Total Phosphate (as P)	1,08	0,04	0,22
Chemical Oxygen Demand	125	38	79
Permanganate Value - 4 h	8,0	5,0	5,8
Suspended Solids	51	13	32
Zinc (total as Zn)	0,09	0,01	0,03
Chromium (total as Cr)	0,10	< 0,01	0,01
Lead (total as Pb)	0,10	< 0,01	0,03
Copper (total as Cu)	0,03	0,01	0,01
Nickel (total as Ni)	0,03	< 0,01	0,01
Iron (total as Fe)	1,24	0,03	0,43
Manganese (total as Mn)	0,40	0,01	0,05
Cadmium (total as Cd)	0,02	< 0,01	< 0,01

* Units are mg/ℓ unless otherwise indicated

The average pH of the water is 8,3. Without inflow water qualities it is not possible to identify the reason for this slightly elevated level in pH, but since algal blooms are observed in the pan, it can be stated that these blooms will be contributing to the level of the pH found. The total dissolved solids (TDS) concentrations are high. The average value for TDS is calculated at 1 255 mg/ℓ. The primary components of this are sodium (313 mg/ℓ) and chlorides (508 mg/ℓ). These concentrations are indicative of a system receiving only storm-water runoff and effluent discharges, with little good quality water entering the system to dilute other inputs.

The phosphate levels found in the pan, although not extremely high at 0,17 mg/ℓ (as orthophosphate), are still sufficient to maintain large standing crops of algae. No data exist for algal populations.

For the remainder of the water quality variables analysed, there appears to be no elements which have noticeably high concentrations. As can be expected, in view of the catchment of this pan, periodic inflows from industries and storm-water runoff will temporarily increase the concentration of certain elements. This is seen in the maximum recorded value for iron of 1,24 mg/ℓ.

Internal reports produced in the late 1980s by the municipal Scientific Services Division and a study by a student of the Oceanography Department of the University of Port Elizabeth (MacKay, 1989) examined the bacteriological quality of the pan. Judgement of the quality of the pan water at that time was not easy since there were no accepted South African standards for a body of water such as North End Lake. Instead other standards were used which were not strictly applicable. These were Lusher's water quality criteria for the South African coastal zone (1984) and the European Economic Community's microbiological standards for sea bathing waters (1976). The results of samples of water taken from the pan showed that they did not comply with the aforementioned standards indicating high levels of faecal pollution. Samples from stations in the western and north-western end of the pan showed a significantly greater level of pollution than samples from the southern end.

The current monitoring programme indicates that these trends in bacterial quality are still continuing. It appears from the data presented in Table B8.3 that the degree of bacterial pollution found is indeed a cause for concern.

These numbers indicate a severe contamination. It has already been identified that the primary use of this pan is recreation. The Department of Water Affairs & Forestry have recently produced a series of water quality guidelines for various users, including recreation (Department of Water

Affairs & Forestry, 1993). Their limit for full contact recreation is 0 - 150 counts/100 mℓ, at which levels no significant health effects are expected. The lowest median value in the pan was found to be 800 counts/100 mℓ at the sampling point closest to the pan's outflow weir. This would indicate that there is an elevated risk of health problems occurring in full contact users of the lake.

Table B8.3 : Bacterial quality of North End Lake (January 1991 - April 1994)

Sampling Location (see Figure B8.2)	Faecal Coliforms (No per 100 mℓ)		
	Maximum	Minimum	Median
Old jetty	20 000	50	800
New jetty	20 000	80	900
Glenton & Mitchell	20 000	600	1900
Sidwell Timbers	20 000	0	4000
Firestone	2 000 000	800	7000
Chelsea Dairies	2 000 000	200	11000
Sampling Point 1	77 000	50	1300
Sampling Point 2	132 000	50	1100
Sampling Point 3	200 000	100	1200
Sampling Point 4	135 000	200	3300
Sampling Point 5	200 000	100	1800
Sampling Point 6	200 000	50	1700
Sampling Point 7	200 000	50	1200
Sampling Point 8	167 000	100	1400

8.5 Pollution Problems and Management Strategies

Despite a history of problems at the North End Lake resulting from factors such as algal blooms, faecal pollution, midges, dead fish and hydrogen sulphide generation, the lake is still regularly used for recreation. In effect, the pan functions as a storm-water attenuation pond and so potentially will always be subjected to intermittent pollution, mainly from non-point sources such as industrial and urban runoff during periods of rainfall. The first runoff after a dry period is normally particularly concentrated. However, no clear link has been established between bacteriological test results (faecal pollution) and daily rainfall totals. This implies faecal pollution is more likely to arise from sporadic sewage contamination of the storm-water system, from entry into the storm-water system of water used in the industrial premises around the pan or from people using the pan and who do not have access to adequate ablution facilities. Litter around the shores of the pan and in the shallows may contribute to the problem.

Since North End Lake was never intended to be primarily a recreational area, it is doubtful whether anything short of a major redesign of the pan and its surrounds will ever make it entirely suitable for such purposes. There is no river feeding the pan and although the pan has an inherent self-treatment capacity, regular heavy rainfall is necessary to flush out the pan and remove incoming polluted storm water. Given this situation, it is unlikely that the quality of the water will satisfy the criteria for full recreational use. It is equally unlikely, however, that the recreational use of the pan will stop and despite occasional mention of the pollution problems in the local press, this has not deterred those who continue to use the pan for recreation.

While monitoring of the pan has indicated that the sources of pollution are intermittent, and that there are no permanent discharges of effluent from industry, reports of pollution incidents are immediately investigated by the municipality. Nevertheless, accidental industrial spillages do appear to be occurring. The bulk of the pollution that enters the pan is organic pollution of faecal origin resulting in high bacteria levels. As a consequence, relatively high nutrient levels can also lead to undesirable algal blooms. Water quality deteriorates during dry periods when there is insufficient rainfall to cause the pan to overflow and wash out some of the longstanding water. The southern area of the pan suffers less from faecal pollution than the northern end. This may be attributable to the lawns up to the shore, less litter and little industry on the south bank. It could be viewed that the southern section of the pan represents background levels of bacteria within the system, and therefore that any elevated level in the remainder of the pan must be coming from external sources. The background values (900 to 1 300 counts/100 mℓ) may be attributable to recreational users, anglers and subsistence fishermen as well as the residual pool of organisms within the system. This would indicate that the inflow of water through the storm-water systems would need to be monitored to identify the potential sources of such bacterial pollutants. Although regular samples are collected, it would be of benefit to regularly review the objectives of the monitoring programme in order to identify key areas which need to be targeted.

Regular cleaning of the pan shores and shallows can help contain the level of pollution, but the only way to prevent contamination of the storm-water system would be to keep the streets and hard surfaces in the area as clean as possible and to prevent the overflow of sewage into the storm-water system. This requires on-going checks of factory premises and yards and early detection and prompt action when sewer blockages occur.

The Port Elizabeth municipality has responded in several ways to combat pollution of the pan. In the late 1980s, notice boards were erected at different points around the pan warning the public that the water was not suitable for recreational purposes and that they used the pan at their own risk. The warning about the potential danger was aimed at those in direct contact with the water (bathers) rather than those in boats on the pan or fishermen. In any case, there does not seem to have been any reports of ill health amongst users of the pan.

Rubbish collection fences have recently been placed fairly deep into the pan to collect debris which is discharged from the storm-water drainage outfalls. The fences work well in preventing such material from spreading over the pan. However, after they have been put in place, they last only a few weeks before they are demolished by vagrants and the materials stolen. The cost of constructing the fences is considerable and so is the amount of manpower required to continually replace them to the extent that it is now not economically or practically feasible to continue with the exercise unless some means of preserving the fences can be found. This could involve investigating different engineering options, different placement of the structures and different approaches to the problem.

Some of the potential options would be:

- different design and construction of the fences so that removal is restricted;
- alternative or upgrading of the culvert design; and
- employment of vagrants to collect litter.

It is accepted that these are not the only strategies available, and that a more detailed assessment is needed to quantify their relative benefits.

In tandem with the upgrading of the surrounds of North End Lake, investigations are also being carried out to see if something can be done to improve the water quality of the pan. These investigations include the installation of floating aerators or fountains in the pan to assist with its self-purification capacity. This would enable the lowering of the organic content of the water and improve the bacteriological quality. Another option being considered is the placing of reedbeds around the worst offending storm-water outlets which would help filter incoming pollution. The installation of reedbeds would in all probability entail a certain amount of redesign of the pan area. This would be required in order to have a sufficient area available for the reedbed systems to work. However, the development of reedbed systems could be viewed as adding to the aesthetic appeal of the pan and providing additional uses for the water body.

Due consideration would also have to be given to preventing the wash away of reedbeds during major storm events. Integration of conflicting uses such as powerboating and the development of a bird sanctuary requires investigation.

It has been reported by various groups involved in North End Lake, that the first flush of rains tends to bring large amounts of pollution to the system. The possibility of diverting this first flush of water away from the pan could be investigated. A system of pipes and canals could divert the water either directly to the sea, or to sewage treatment works, or to another dam. Additionally, alternate sources of water for flushing during low rainfall years could be sought.

The success of any improvement in the water quality of the pan, however, is seen as dependent on close co-operation between various municipal departments and the lakeside industries as well as addressing certain social problems associated with the surrounds of the pan. The principles of source reduction, effluent reuse and water treatment should be the guideline on which the future management of the system is based. It has already been noted that this pan will continue to be a key recreational area and therefore the efficient management of the whole system is required. Without this co-operation and commitment, the prime function of the water quality monitoring programme operated by the municipality will remain one of providing a punitive surveillance facility.

8.6 References

Batchelor A, (1994). Personal communication. CSIR.

Department of Water Affairs & Forestry (1993). *South African Water Quality Guidelines Volume 2 : Recreational Use*, (First Edition).

MacKay HM, (1989). *Statistical Analysis of Microbiological Data from North End Lake, Port Elizabeth*. Department of Oceanography, University of Port Elizabeth.

9. ALEXANDER DAM, SPRINGS

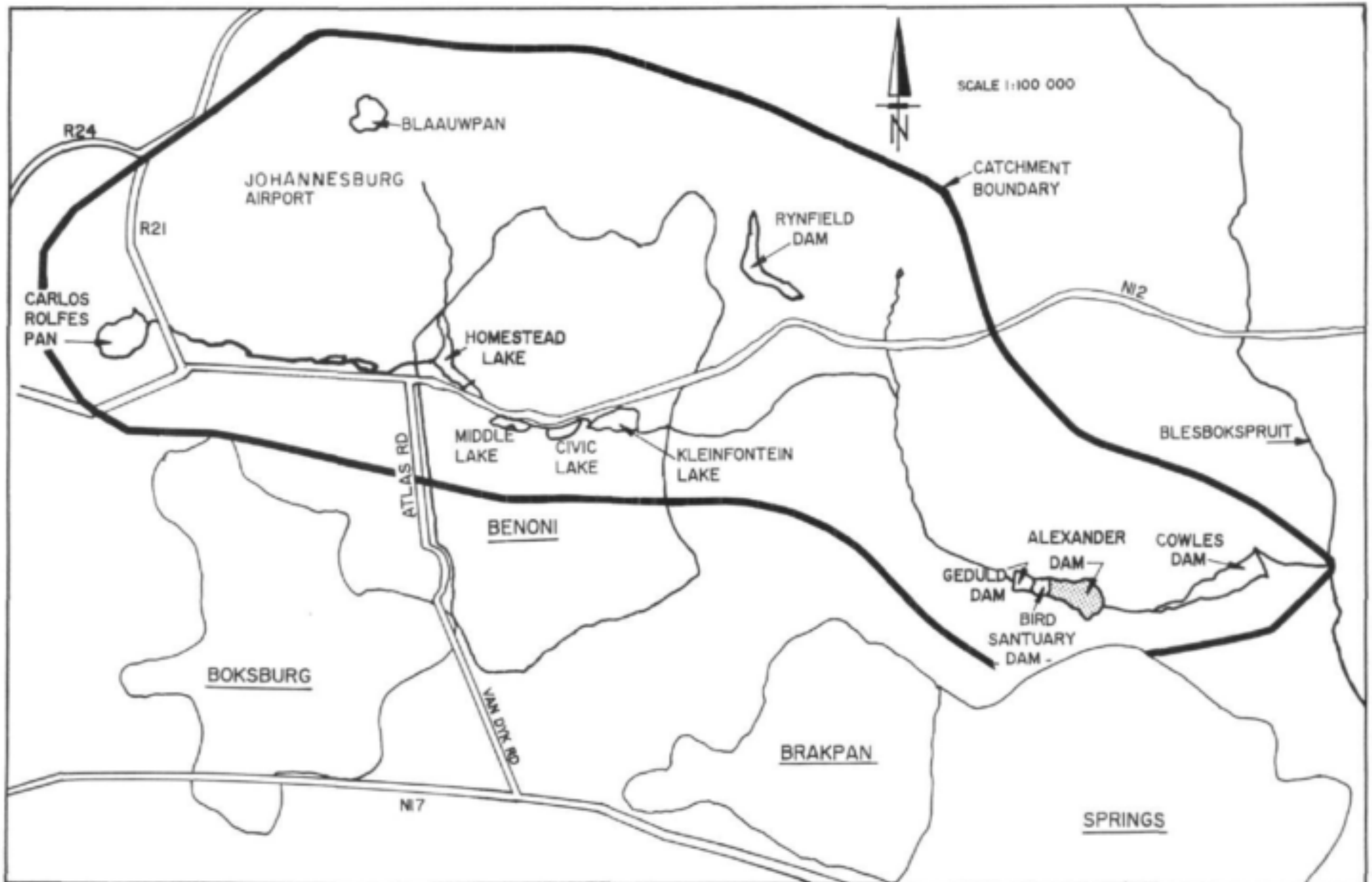
9.1 Location and Catchment Characteristics

Alexander Dam is the lowermost dam in a series of three adjacent dams on a tributary of the Blesbokspruit, which is in the catchment of the Vaal River. The other dams in the series are Geduld Dam and Bird Sanctuary Dam. Alexander Dam is situated approximately 5 km north-west of the Springs CBD, 15 km south-east of the Benoni CBD and 5 km north-east of the Brakpan CBD (Figure B9.1). Alexander Dam is itself dammed by the tailings dam of the Geduld Mine, which is currently being reclaimed by Ergo Ltd.

The Paul Kruger Highway crosses over Geduld Dam whilst Orpiment Road crosses over the dam wall between Geduld and Bird Sanctuary Dams. Access to Alexander Dam is through Murray Park, a recreational park situated on the southern bank of Alexander Dam, and across the Bird Sanctuary Dam wall embankment.

The catchment of Alexander Dam originates approximately 20 km to the west of the dam in the Boksburg and Benoni districts. The area of the catchment extends for 190 km^2. The tributary on which Alexander Dam is situated flows through the Springs district in an easterly direction and joins the Blesbokspruit approximately 10 km east of the dam. From this point, the Blesbokspruit flows in a south-westerly direction through Nigel and Heidelberg to the Vaal River, which it joins in the Vereeniging district. A large stretch of wetland along the Blesbokspruit, approximately 20 km downstream of the Alexander Dam, is being managed as a nature reserve and incorporates the Marievale Bird Sanctuary. This wetland was recently declared a Ramsar wetland in terms of the Ramsar Convention, which aims to conserve important wetlands.

The tributary on which Alexander Dam is located has been dammed extensively, especially in the Benoni and Springs districts. Impoundments in the catchment include the Carlos Rolfes Pan in Boksburg, the Benoni "Lakes" and downstream of Alexander Dam in the Springs district, Cowles Dam. Alexander Dam has a surface area of 80 ha and a volume of 3 000 000 m^3. Basic characteristics of the dam are described in Table B9.1.



LOCATION AND CATCHMENT AREA OF ALEXANDER DAM

FIGURE No. B 9.1

Table B9.1 : Characteristics of Alexander Dam

Geographic Location	26° 13' S; 28° 25' E
Elevation	1 580 m AMSL
Surface Area	80 ha
Volume	3 000 000 m^3
Mean Depth	est 3,75 m
Maximum Depth	N/A
Length	1 250 m
Width	500 m

The catchment in which Alexander Dam is situated is an industrial and gold mining area that is also highly urbanised. It has therefore been subjected to pollution and human interference such as the canalisation of stream beds. The immediate catchment of Alexander Dam, however, contains predominantly recreation and residential areas. 70% of the land adjacent to the dam has been zoned as public open space. This zoning has been extended southwards to form two recreational parks, President's Park and Murray Park, each with an area of approximately 500 ha. The residential suburbs of Dersley and Presidents Dam are situated less than half a kilometre to the north and south-west of Alexander Dam respectively. These suburbs serve the higher socio-economic segment of the population and constitute 25% of the immediate catchment. The remaining 5% of land is made up of mining land and tailings dams.

9.2 Impoundment History

Alexander Dam and the neighbouring Bird Sanctuary and Geduld Dams resulted largely from the commencement of gold mining operations in the Springs area in the late 1890s and early 1900s. Originally a farm dam, Geduld Dam was the first to be used by the gold mining industry following the establishment of the Geduld Mine. Tailings from the Geduld Mine were deposited downstream, approximately 1 km east of Geduld Dam, resulting in the further damming of the stream and the formation of Alexander Dam.

During the operational life of the Geduld Mine, Alexander Dam filled up to such an extent that it reached the wall of Geduld Dam. This necessitated the construction of a cocopan railway track across the dam in order to transport ore from the mining shafts on one side of Alexander Dam to the reduction works on the other side. This resulted in the formation of Bird Sanctuary Dam, the cocopan railway track wall becoming the wall of Bird Sanctuary Dam. This wall was lowered in 1983 when a nearby section of the Paul Kruger Highway was constructed. This was to prevent flooding of that section of road.

9.3 Impoundment Use

Water in Alexander Dam is no longer abstracted for mining activities but is used solely for recreational purposes. Land on the eastern bank of Alexander Dam and the adjoining dams upstream has been declared public open space for aesthetic, conservation and recreational purposes and reserved in terms of the structure plan for the town of Springs for recreational uses.

Presidents Park, situated approximately 500 m to the south-west of Alexander Dam, has been developed from the Geduld Mine golf course and comprises a children's farm, a youth camp, a pony trekking and picnicking area. Immediately to the south of Alexander Dam is Murray Park which has been developed as a caravan park and recreation resort. The caravan park is owned by the Springs Town Council, but is operated privately. Facilities include a shop, padding pools, a children's playground, a pony camp and ablution facilities. There is also a nature trail around the dam.

Alexander Dam is popular with the sailing, canoeing and angling fraternities. A boathouse and launch pad have been developed on the northern bank of the dam to the east of the caravan park. Although bird-watchers frequent Alexander Dam, the Springs Town Council regards the adjacent Bird Sanctuary Dam, and not Alexander Dam, as a nature conservation area. The bird life at Bird Sanctuary Dam makes it a popular bird-watching site.

Of major significance with regard to possible future use of Alexander Dam is the fact that the Benoni Gold Mining Company is applying for mining authorisation to reclaim gold-enriched sediments, which have accumulated in the dam from various gold processing operations in the catchment upstream of the dam. An environmental management programme report (EMPR) has been prepared for the proposed tailings sediment-reclaim operation (Steffen, Robertson and Kirsten, 1994) and will accompany the mining application. The estimated reclaimable reserves of gold-enriched sediments in the dam is 220 000 tons. At a planned production rate of 15 000 - 20 000 tons per month (based on a 24 hour day and a 26 day working month) the life of the operation is expected to be between one and two years. The gold-enriched sediments will be reclaimed using a dredger. They will be vacuumed up by the dredger and transported in a floating pipeline to a group of settling ponds. After a period of settling, free water will be decanted to an adjacent return water dam and discharged into the river upstream of Geduld Dam. The sediments in the settling dams will be adjusted to a slurry density suitable for transport in a 12 km pipeline to the Benoni Gold Mining Company's gold plant in Benoni. The EMPR was submitted in February 1994 and a decision on the mining application is awaited.

9.4 Impoundment Limnology

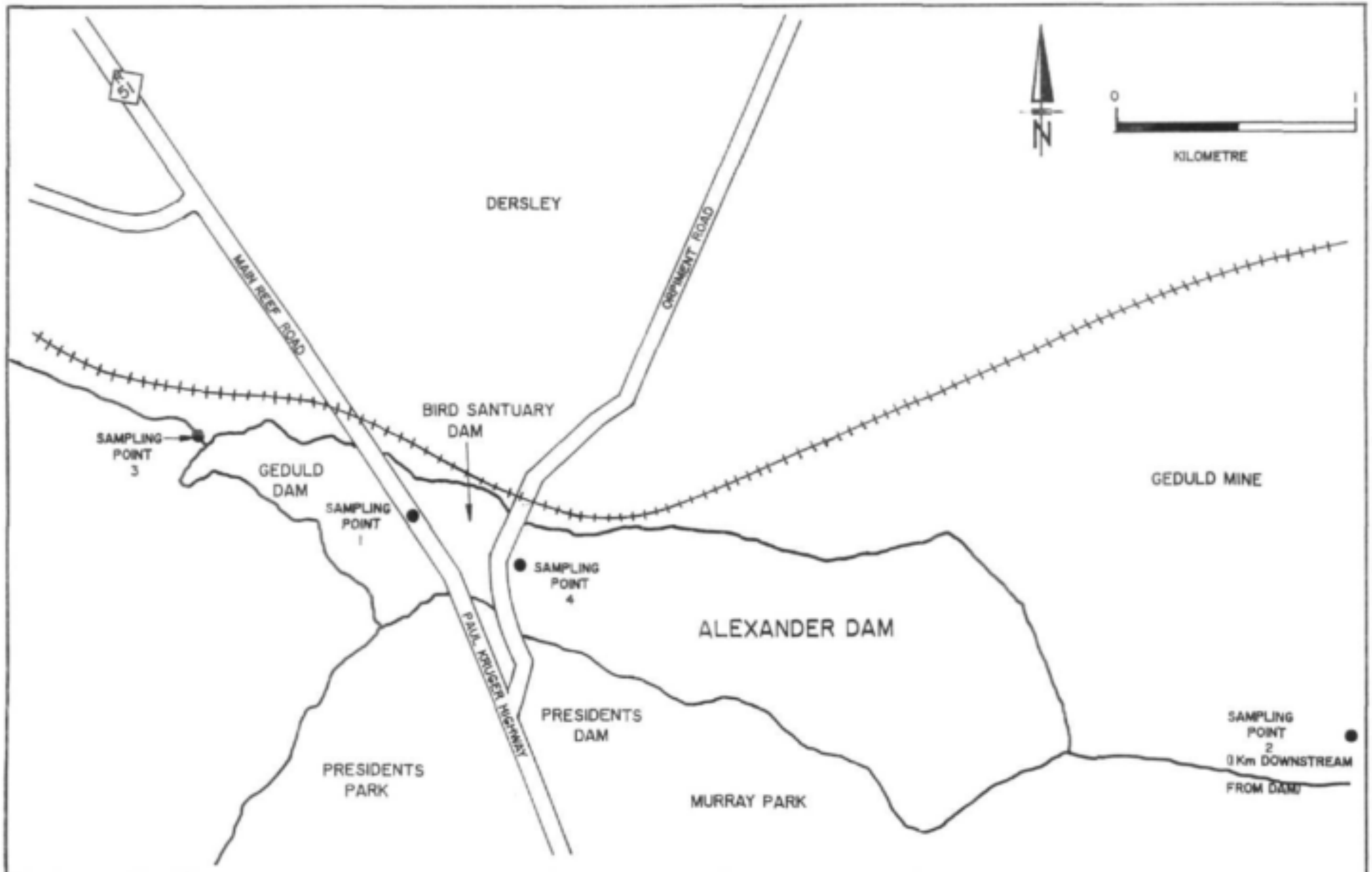
Alexander Dam is situated in the Highveld climatic zone and experiences a mean annual precipitation of 718 mm. The mean annual runoff from the catchment upstream of Alexander Dam has been estimated to be approximately 16 x 10^6 m^3. Normal dry weather flow has also been estimated from simulated monthly flow data based on historical rainfall records and the flow at Alexander Dam is calculated to be approximately 0,5 m^3/s in summer and 0,15 m^3/s in winter.

About two-thirds of the surface of Alexander Dam is open water, the remaining third comprises vegetation of a reed-wetland nature which is typical of the riverine vegetation in the Blesbokspruit catchment. This wetland is not the "natural" vegetation of the region, but is believed to have formed as a result of man's activities in the area. *Phragmites australis* is the dominant species in the Alexander Dam wetland interspersed with patches of *Typha latifolia* and *Cypens* species. Black wattle trees have colonised the banks of the dam near the dam wall and appear to be spreading at the expense of other species. In the dam, the submerged aquatic plant *Potamogeton pectinatus* has been observed. No endangered, rare or vulnerable plant species are known to occur in or around the dam.

Wetlands in the Blesbokspruit catchment are best known as an important habitat for water bird communities and are also believed to support numerous amphibian and fish species. The current status of Alexander Dam as a breeding colony for birds is unknown, but no endangered, rare or vulnerable species are known to occur in the dam or its surrounds. Fish species caught in the dam include catfish, kurper, bass and carp.

The tributary entering Alexander Dam is fed by runoff, ground water recharge and treated effluent from industry and sewage treatment works. In general, the water quality is acceptable with only minor levels of trace elements. Ground water quality in the area, however, has deteriorated as a result of mining activities in the region. If this water is in hydraulic connection with the dam, it is possible that this could lead to a flushing of contaminants into the dam.

The Springs municipality monitors the water quality in the vicinity of the Alexander Dam at two points (Figure B9.2). One of the monitoring points is upstream of the Alexander Dam at the causeway near the Paul Kruger Highway in Geduld Dam. The other monitoring point is at a bridge downstream of Alexander Dam. Bacteriological water samples are taken at two further points - one at the inflow to Geduld Dam and one at the inflow to Alexander Dam. In the period 1982-87,



DETAIL OF ALEXANDER DAM AND WATER QUALITY SAMPLING POINTS	FIGURE No. B 9.2

sulphate values upstream of Alexander Dam were often worse than downstream. Since that time, however, downstream values have tended to be slightly high, but there has generally been a consistent improvement in quality with sulphate values now being in the region of 200 mg/ℓ. The changes are probably the result of generally improved pollution control measures and changes in the discharge volumes from sewage treatment plants.

In general, the historic water quality data have been acceptable with only minor levels of gold and related trace elements such as zinc and nickel. These latter concentrations, however, are higher than values considered safe for aquatic life. In a sampling exercise during May 1993, water samples were collected from the surface and near the bottom of a number of dams in the area. Results showed very little change in quality with depth, with some indication of slightly higher levels and chemical oxygen demand and zinc in bottom samples. There was no indication of acid development near the base of the dams.

Table B9.2 presents recent selected water quality data for Alexander Dam for the two sampling sites. An analysis of the data indicates that there was little difference in quality between the inflow and the outflow for the period 1991 - 1994. Total dissolved solids concentrations of approximately 400 mg/ℓ are good for an urban impoundment. It can be expected that the dam receives runoff from a number of different sources and therefore a worse quality water could be expected.

The concentrations of nutrients would indicate the potential for abundant plant growth. This is seen in the encroachment of reedbed areas within the dam, although no information is available on the algal populations in the dam. It can be expected, however, that without competition for nutrients from the macrophytes in the dam, that subsequent to their removal during reclamation, the potential for algal problems would increase. Although this may be a short-term problem, it could affect the recreational use of the dam.

In the EMPR prepared for the Benoni Gold Mining Company, it is postulated that any sediment re-suspended would settle out within hours. This assessment was, however, based on the effects of the suspended sediment itself. During the reclamation process, it could be expected that there would be an increase in certain nutrients within the lake. It is well known that even slight stirring or sediments by bottom feeding fish can cause a resolubilisation of phosphates. No information is available on the concentrations of phosphate within the sediment, but it can be expected that phosphate would have accumulated in the sediments. This resuspension could generate conditions favourable for algal blooms to occur.

Table B9.2 : Water quality data for Alexander Dam (January 1991-April 1994)

Sampling Points (see Figure B9.2)

1. Geduld Dam
2. Downstream of Alexander Dam

Chemical*/Physical Variables	Reading	Sampling Points	
		1	2
pH	Min	4,3	4,7
	Max	7,7	7,4
	Ave	6,2	6,5
	Median	6,5	6,8
	No of Samples	15	15
Electrical Conductivity (mS/m)	Min	39	47
	Max	72	128
	Ave	58	64
	Median	57	59
	No of Samples	15	15
Total Dissolved Solids	Min	286	299
	Max	506	1250
	Ave	402	511
	Median	392	444
	No of Samples	15	15
Total Alkalinity (as $CaCO_3$)	Min	20	<0,01
	Max	120	180
	Ave	68	61
	Median	60	60
	No of samples	15	15
Total Hardness (as $CaCO_3$)	Min	180	200
	Max	340	620
	Ave	255	296
	Median	240	220
	No of samples	15	15
Chloride (as Cl)	Min	80	60
	Max	160	140
	Ave	119	111
	Median	120	120
	No of samples	15	15
Sulphate (as SO_4)	Min	78	146
	Max	234	342
	Ave	148	201
	Median	153	185
	No of samples	15	15

* Units are all mg/ℓ unless otherwise indicated

(continued overleaf)

Chemical*/Physical Variables	Reading	Sampling Points	
		1	2
Sodium (as Na)	Min	35	31
	Max	75	98
	Ave	56	59
	Median	56	62
	No. of samples	15	15
Ammonia (as N)	Min	<0,01	<0,01
	Max	4,20	4,00
	Ave	0,47	0,37
	Median	0,22	0,10
	No. of samples	15	15
Nitrate Nitrogen (as N)	Min	0,02	<0,01
	Max	3,04	2,00
	Ave	0,94	0,44
	Median	0,71	0,23
	No. of samples	15	15
Ortho-Phosphate (as P)	Min	<0,01	<0,01
	Max	0,72	2,75
	Ave	0,15	0,21
	Median	0,07	<0,01
	No. of samples	15	15
Suspended Solids	Min	<0,01	<0,01
	Max	21	18
	Ave	3	4
	Median	1	2
	No. of samples	15	15
Zinc (as Zn)	Min	<0,01	<0,01
	Max	1,00	1,00
	Ave	0,13	0,17
	Median	<0,01	<0,01
	No. of samples	15	15
Chromium Trioxide (as CrO_3)	Min	<0,01	<0,01
	Max	0,06	0,07
	Ave	<0,01	<0,01
	Median	<0,01	<0,01
	No. of samples	15	15
Lead (as Pb)	Min	<0,01	<0,01
	Max	0,10	0,10
	Ave	0,01	0,01
	Median	<0,01	<0,01
	No. of samples	15	15

* Units are all mg/ℓ unless otherwise stated

(continued overleaf)

Chemical*/Physical Variables	Reading	Sampling points	
		1	2
Copper (as Cu)	Min	<0,01	<0,01
	Max	1,00	0,04
	Ave	0,07	<0,01
	Median	<0,01	<0,01
	No of samples	15	15
Nickel (as Ni)	Min	<0,01	<0,01
	Max	1,00	1,00
	Ave	0,37	0,28
	Median	<0,01	<0,01
	No of samples	15	15
Iron (as Fe)	Min	<0,01	<0,01
	Max	2,00	1,00
	Ave	0,70	0,17
	Median	1,00	<0,01
	No of samples	15	15
Manganese (as Mn)	Min	<0,01	<0,01
	Max	2,00	2,00
	Ave	0,60	0,49
	Median	0,12	<0,01
	No of samples	12	12
Cadmium (as Cd)	Min	<0,01	<0,01
	Max	0,12	0,14
	Ave	0,01	0,01
	Median	<0,01	<0,01
	No of samples	15	15
Cobalt (as Co)	Min	<0,01	<0,01
	Max	0,13	0,20
	Ave	0,02	0,03
	Median	<0,01	<0,01
	No of samples	15	15
Permanganate Value	Min	0,30	0,68
	Max	3,00	8,00
	Ave	1,42	1,52
	Median	1,00	1,00
	No of samples	15	15

* Units are all mg/ℓ unless otherwise indicated

Table B9.3 shows the bacterial quality of Alexander Dam, which indicates no severe contamination.

Table B9.3: Bacterial quality of Alexander Dam (January 1991-April 1994)

Bacteriological Variables	Reading	Sampling Points (see Figure B9.2)	
		3	4
Total Coliforms per 100 mℓ	Min Max Ave Median No. of Samples	0 10 000 967 16 53	0 10 000 2 329 29 48
E.coli per 100 mℓ	Min Max Ave Median No. of Samples	0 10 000 389 3 53	0 10 000 853 8 48
Total Visible Organisms per 1 mℓ	Min Max Ave Median No. of Samples	1 10 000 2 561 110 53	2 10 000 3 861 286 48

9.5 Pollution Problems and Management Strategies

The water of Alexander Dam has low pH values which reflect the results of mining activity in the area. This impacts upon the productivity and ecology of the dam, but water quality parameters are not exceeded in terms of recreational use. No severe pollution problem can thus be said to occur at Alexander Dam given its location within an active mining area.

The immediate short-term implications of the Benoni Gold Mining Company's application to dredge the dam will, however, if successful, provide the opportunity to study in detail the impacts of such an operation on the water quality of Alexander Dam. The EMPR produced to accompany the mining application outlines the environmental impacts, controls and rehabilitation activities which will be undertaken to leave the dam in a condition that will satisfy the requirements of the regulatory authorities.

No river diversions are required for the sediment reclamation operations and the dredging activities are restricted to the surface of the dam and will not be expected to disturb normal water flow in the system. As a result of the hydraulic transportation of slurry off the site of the operation, requiring the abstraction of water from the dam, approximately 1 400 m^3/d will be lost from the river system. During normal winter flows, this will amount to a loss of 12% and less than 3% for normal summer flows.

Most of the expected impacts of the operations pertain to the removal of the reed-wetland vegetation and water from the dam. These activities will impact on land use, vegetation, animal life, recreational use and the visual appeal of the dam during the short life of the operations. It is expected that all of these impacts will be reversed by the rehabilitation programme to be undertaken during the decommissioning phase. This will involve the replanting of *Typha latifolia* and *Cyperus* species within the dam at those sites where reeds occur now, and karee and bush willow trees on the banks. It is expected that *Phragmites* will recolonise of its own accord, rapidly. The Springs Town Council expressed strong views that Alexander Dam should not be drained during mining operations due to the recreational facilities offered by the dam.

The removal of the wetlands in the dam will affect bird, reptile, amphibian and fish habitats as well as disturbing recreational uses such as bird-watching. However, it is expected that the subsequent re-establishment of wetland could have positive impacts such as an increase in plant species and consequently animal species diversity due to the removal of dense stands of *Phragmitis australis*. In addition, it is expected that the establishment of a more natural ecosystem will be likely as a result of the removal of tailings sediment from the floor of the dam and there will be an increase in the depth of the dam resulting in a reduction in the proportion of water occupied by vegetation.

Concerns about the water quality in Alexander Dam due to the sediment reclamation operations pertain to increased turbidity of the water due to dredging; the dissolution of salts from the disturbed sediments and the quality of decanted water returned from the settling pond to the river system. Effects are predicted to be limited. As far as nutrients are concerned, there may be an increase in concentration of phosphates as a result of resolubilisation. This could give rise to two possible problems:

- Algal blooms developing which would affect the aesthetic quality of the dam.

- The establishment of dense stands of submerged macrophytes in the expanded open water areas. This would affect the use of the impoundment for angling. Additionally, should a plant such as *Potamogeton pectinatus* become established, then the introduction of Chinese carp to control it would have to be investigated if the dam is to be restocked with fish as part of the rehabilitation plan.

Should there be a shift in plant dominance, then specific strategies will need to be put in place to manage the system until the wetlands have become re-established. Such strategies could include the following:

- If algal blooms occur, then the use of barley straw could be investigated.
- If submerged plants occur, the introduction of fish to control their growth should be investigated before they become a problem.

In this impoundment, in-lake management strategies would have to be employed, since the changes to the system will be through reclamation of the sediments, and not by changes in the catchment. The end result of the reclamation would be similar to dredging of the lake, and this has typically given rise to an improved quality of water within impoundments. Specifically this has been seen in Princess Vlei in the Western Cape, and to a certain extent in Zoo Lake in Johannesburg.

The impacts on surface water quality in the environment of Alexander Dam will be monitored throughout the construction, operational and decommissioning phases of the proposed sediment reclamation scheme. Water samples will be taken at monthly intervals from three monitoring points - at the inflow to the dam, from the settling ponds of the reclamation operation and at the outflow of the dam. Each sample will be monitored for pH, electrical conductivity, suspended solids, sulphate, sodium, chloride, zinc, manganese, nickel, chemical oxygen demand and the sodium absorption ratio. Ground water will also be monitored. Monthly reports on the water quality analyses will then be submitted to the Department of Water Affairs & Forestry.

9.6 Reference

Steffen, Robertson and Kirsten (1994). *Benoni Gold Mining Company : Environmental Management Programme Report for Alexander Dam, Springs*. Report No 202657/1.

10. HENNOPS LAKE, CENTURION

10.1 Location and Catchment Characteristics

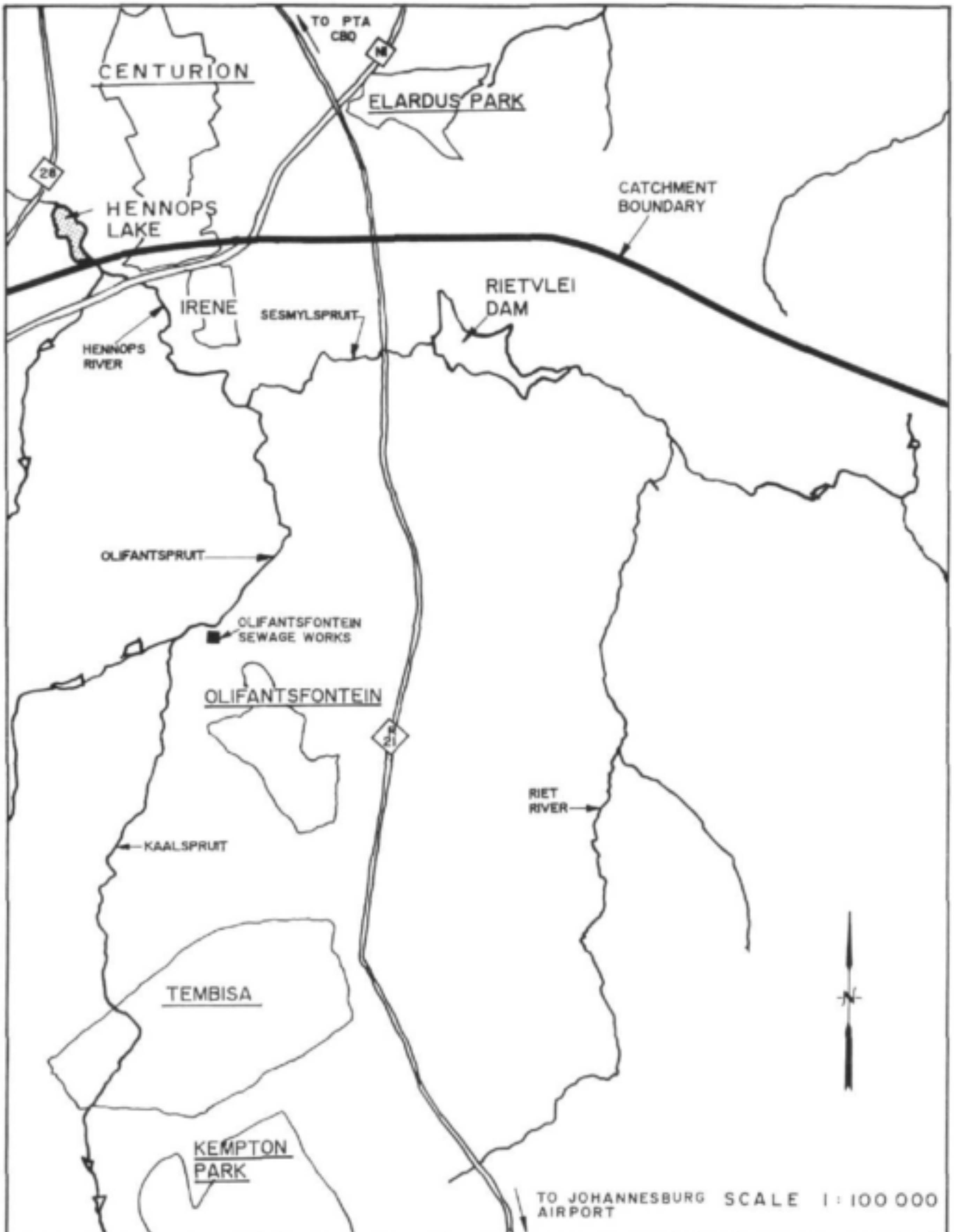
Hennops Lake is located within the main commercial node of Centurion. It has served as the focal point around which shops, offices and recreational facilities have been developed over the past decade. The lake covers 7,1 ha and has a volume of 145 000 m^3. Basic characteristics of the lake are shown in Table B10.1.

Table B10.1 : Characteristics of Hennops Lake

Geographic Location	25° 51' S; 28° 11' E
Elevation	1 410 m AMSL
Surface Area	7 ha
Volume	145 000 m^3
Mean Depth	1,7 m
Maximum Depth	2,5 m
Length	600 m
Width	120 m

The catchment of Hennops Lake extends over a wide area (Figure B10.1). To the east and south-east, the catchment is drained by the Riet River, which has its origins in the Kempton Park area and is dammed by Rietvlei Dam as a bulk water supply source for the city of Pretoria. The outflow from this dam is known as the Sesmylspruit, which is more commonly referred to as the Hennops River, before it flows into Hennops Lake. However, because of the demands for water supply from Rietvlei Dam, Hennops Lake receives very little runoff from this part of the catchment. Instead, the bulk of the water feeding the lake originates from the Kaalspruit and Olifantspruit, which drain the area immediately south of the lake in the vicinity of Midrand and Tembisa. The Kaalspruit joins the Olifantspruit near Olifantsfontein where a sewage treatment plant is located. The Olifantspruit and Sesmylspruit join to form the Hennops River near Irene, before flowing into Hennops Lake.

The land use in the main catchment feeding the lake (the Kaalspruit and Olifantspruit) is mixed, but is made up of parkland or veld (40%), low density residential areas serving the medium to high socio-economic groups (30 %), high density areas serving the low socio-economic group (25%) and commercial land (5%).



LOCATION AND CATCHMENT AREA OF HENNOPS LAKE

FIGURE No. B 10.1

Downstream of Hennops Lake, the Hennops River flows into the Crocodile River, which in turn drains into the Hartebeespoort Dam.

10.2 Impoundment History

Hennops Lake is a man-made impoundment which was constructed comparatively recently in 1983, and around which Centurion's central business district has subsequently been developed.

10.3 Impoundment Use

Hennops Lake is a classic example of the construction of a man-made impoundment in order to enhance and add value to surrounding commercial developments, as well as serving as a focus for recreational activities.

The lakeside offices and shopping centre enjoy a pleasant atmosphere within which to conduct business activity whilst extensive recreational facilities have been provided to attract visitors. These include the musical fountain in the lake itself, the Atlantis Water Park just upstream of the lake and the Hennops River Hiking Trail which runs between the Centurion Park Cricket Stadium (half a kilometre upstream of the lake) and the Zwartkop Nature Reserve, about 12 km downstream of the lake. Open spaces have been developed along the banks of the Hennops River downstream of the lake and wetlands unsuitable for building purposes form the habitat for many bird species.

Recreational activities associated with the lake itself include boating, canoeing, windsurfing, angling and occasional swimming.

10.4 Impoundment Limnology

Hennops Lake is located in the Highveld climatic region and experiences summer rainfall. However, there is little readily available published information on the mean annual rainfall and runoff figures for the catchment or the general ecology of the lake and its surrounds.

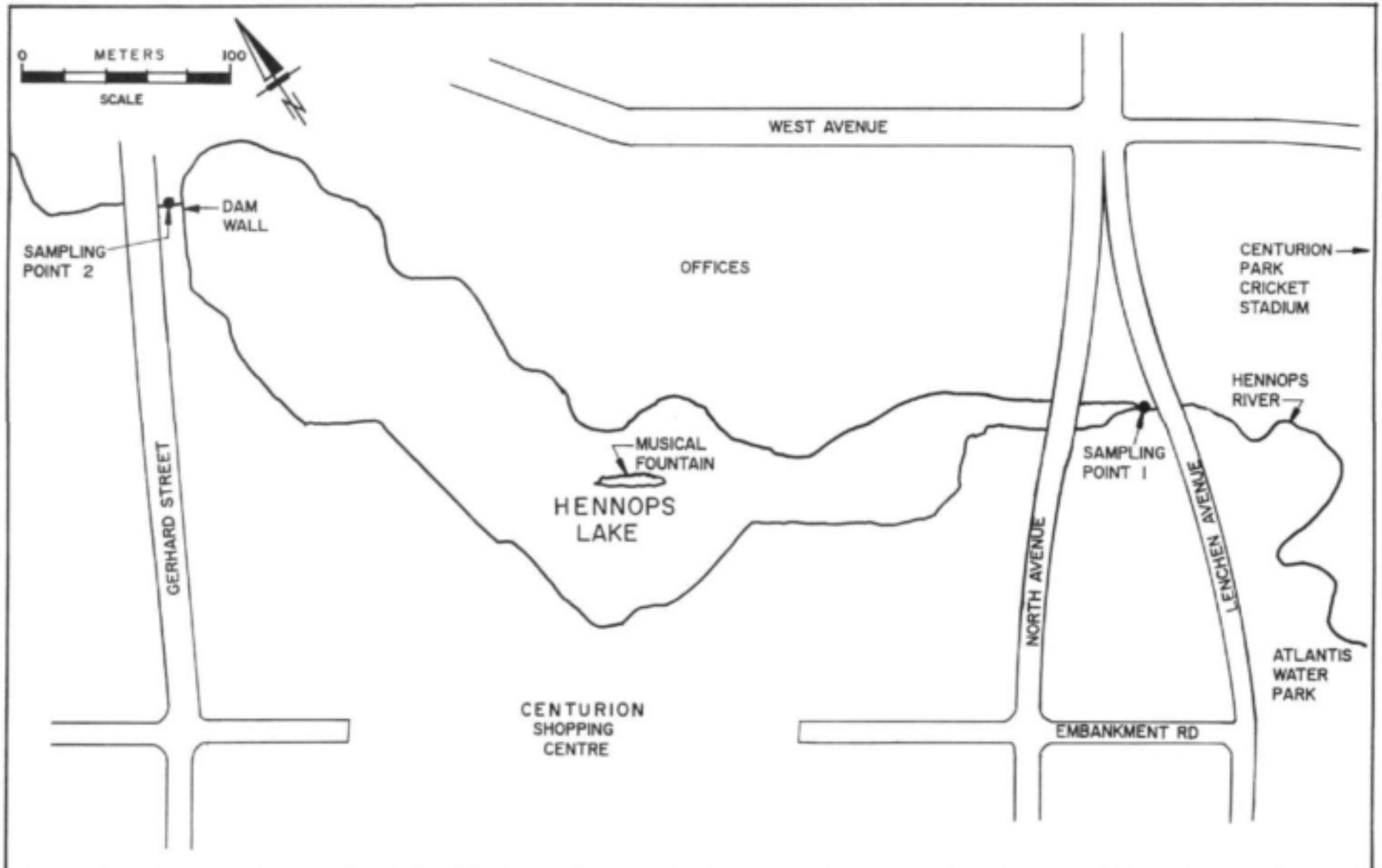
The only historical study conducted within the catchment area (Toerien and Walmsley, 1979) was carried out between 1973 and 1975 on the river system above Rietvlei Dam. The investigation showed that the Kempton Park sewage works, situated in the headwaters of the river feeding Rietvlei Dam, was a major contributor to water flow (over 70%) and mineral loading of the river. Despite the high concentration of treated sewage effluents, the chemical quality of the river conformed to prescribed potable water standards. However, Rietvlei Dam was described as eutrophic and showed a high potential for the growth of nitrogen-fixing blue green algae, although phosphorus and nitrogen loads in the river system feeding the dam were reduced after passing through vlei areas.

Hennops Lake was commissioned in 1983. Since 1990, attention has mainly focused on bacteriological contamination of this lake. The source of the pollution has been identified as coming from the Kaalspruit and Olifantspruit catchments, which now supply most of the water flowing into the lake.

Bacteriological samples have been collected during 1991 - 1993 at several points in the catchment as well as in the lake itself. More recently, an intensive study of the chemical quality of water from the catchment was initiated by the Water Research Commission. Table B10.2 presents water quality data from this study for the inflow and outflow to Hennops Lake. The monitoring points are shown in Figure B10.2. The data were supplied by Wates Meiring and Barnard, the consultants for the study.

Chemically, Hennops Lake shows clear signs of eutrophication. High levels of phosphates and nitrates are present in the inflow to the lake as well as the outflow. Phosphates entering the lake have average summer and winter concentrations of 2,3 mg/ℓ and 4,9 mg/ℓ respectively. Outflow from the lake is 2,6 mg/ℓ and 4,9 mg/ℓ for summer and winter respectively. These values would indicate that algal blooms could occur, but no records are available, and algal blooms are not considered to be problematic by managers of the lake in winter.

One factor contributing to limiting algal growth is the high concentrations of suspended solids in the lake. The lake, visually, appears turbid for much of the time, and this is borne out by the suspended sediment concentration of 235 mg/ℓ and 51 mg/ℓ in summer and winter, for the inflow. For the outflow, the corresponding values are 157 mg/ℓ and 85 mg/ℓ. It can be seen that the inflow in summer, during the rainy season, is bringing in a large of amount of sediment from the catchment. Some 35% of this sediment remains in the lake. During winter, the levels are lower than for summer, but still remain high. Interestingly, there is an increase in suspended solids through the lake.



DETAIL OF HENNOPS LAKE AND WATER QUALITY SAMPLING POINTS

FIGURE No.
B 10.2

Table B10.2: Water quality data for Hennops Lake (1993-1994)

Sampling Points (see Figure B10.2)

1. Inflow to Hennops Lake
2. Outflow from Hennops Lake

Chemical*/Physical Variables	Reading	Sampling Points			
		1 (summer)	1 (winter)	2 (summer)	2 (winter)
pH	Min	7,1	7,6	7,4	7,6
	Max	8,2	8,2	8,4	8,3
	Ave	7,7	7,8	7,8	7,8
	No of Samples	23	11	23	11
Electrical Conductivity (mS/m)	Min	19	37	25	41
	Max	65	71	63	75
	Ave	52	58	52	58
	No of Samples	23	11	22	11
Total Alkalinity (as $CaCO_3$)	Min	-	-	-	-
	Max	-	-	-	-
	Ave	60	148	57	154
	No of samples	-	-	-	-
Calcium (as $CaCO_3$)	Min	-	-	-	-
	Max	-	-	-	-
	Ave	35	36	30	36
	No of samples	-	-	-	-
Magnesium (as $CaCO_3$)	Min	-	-	-	-
	Max	-	-	-	-
	Ave	15	14	14	14
	No of samples	-	-	-	-
Chloride (as Cl)	Min	-	-	-	-
	Max	-	-	-	-
	Ave	40	48	40	45
	No of samples	-	-	-	-
Sulphate (as SO_4)	Min	-	-	-	-
	Max	-	-	-	-
	Ave	40	43	40	43
	No of samples	-	-	-	-
Sodium (as Na)	Min	-	-	-	-
	Max	-	-	-	-
	Ave	32	63	32	63
	No of samples	-	-	-	-
Ammonia (as N)	Min	0,40	0,60	0,40	0,60
	Max	5,80	8,00	5,20	7,60
	Ave	2,36	4,51	2,56	4,46
	No of samples	23	11	23	11
Nitrate Nitrogen (as N)	Min	1,60	2,40	2,10	2,80
	Max	7,00	8,30	5,00	7,80
	Ave	3,94	5,91	3,17	5,45
	No of samples	23	11	23	11
Orthophosphate (as P)	Min	-	-	-	-
	Max	-	-	-	-
	Ave	0,80	2,68	0,71	2,47
	No of samples	-	-	-	-

* Units are mg/ℓ unless otherwise stated

(continued overleaf)

Chemical*/Physical Variables	Reading	Sampling Points			
		1 (summer)	1 (winter)	2 (summer)	2 (winter)
Total Phosphate (as P)	Min	0,60	1,10	0,70	2,90
	Max	7,00	13,20	9,50	9,60
	Ave	2,30	4,90	2,60	4,90
	No of samples	23	10	23	10
Chemical Oxygen Demand	Min	16	12	12	24
	Max	136	88	90	68
	Ave	53	42	42	43
	No of samples	23	11	23	11
Suspended Solids	Min	25	9	29	15
	Max	2290	221	1045	272
	Ave	235	51	157	85
	No of samples	23	8	22	8
Dissolved Oxygen (as O_2)	Min	3,70	2,90	3,70	3,50
	Max	10,20	8,50	10,20	8,50
	Ave	5,80	5,34	5,77	5,36
	No of samples	21	11	20	11
Zinc (as Zn)	Min	-	-	-	-
	Max	-	-	-	-
	Ave	0,08	0,08	0,04	0,09
	No of samples	-	-	-	-
Chromium Trioxide (as CrO_3)	Min	-	-	-	-
	Max	-	-	-	-
	Ave	0,05	0,04	0,05	0,04
	No of samples	-	-	-	-
Lead (as Pb)	Min	-	-	-	-
	Max	-	-	-	-
	Ave	0,05	0,05	0,05	0,05
	No of samples	-	-	-	-
Copper (as Cu)	Min	-	-	-	-
	Max	-	-	-	-
	Ave	0,05	0,04	0,05	0,04
	No of samples	-	-	-	-
Nickel (as Ni)	Min	-	-	-	-
	Max	-	-	-	-
	Ave	0,03	0,03	0,03	0,03
	No of samples	-	-	-	-
Iron (as Fe)	Min	-	-	-	-
	Max	-	-	-	-
	Ave	1,30	0,31	0,63	0,23
	No of samples	-	-	-	-
Manganese (as Mn)	Min	-	-	-	-
	Max	-	-	-	-
	Ave	0,54	0,16	0,46	0,13
	No of samples	-	-	-	-
Cadmium (as Cd)	Min	-	-	-	-
	Max	-	-	-	-
	Ave	0,03	0,03	0,03	0,03
	No of samples	-	-	-	-

* Units are mg/ℓ unless otherwise stated

(continued overleaf)

Chemical*/Physical Variables	Reading	Sampling Point (See Figure B10.2)			
		1 (summer)	1 (winter)	2 (summer)	2 (winter)
Mercury	Min	-	-	-	-
	Max	-	-	-	-
	Ave	0,03	0,01	0,03	0,01
	No of samples	-	-	-	-
Cobalt (as Co)	Min	-	-	-	-
	Max	-	-	-	-
	Ave	0,03	0,03	0,03	0,03
	No of samples	-	-	-	-
Total Kjeldahl Nitrogen (as N)	Min	-	-	-	-
	Max	-	-	-	-
	Ave	9,77	12,70	11,20	12,73
	No of samples	-	-	-	-
Temperature (°C)	Min	10,2	5,3	10,9	5,3
	Max	24,5	20,9	25,7	21,4
	Ave	20,6	15,8	20,8	16,2
	No of samples	21	11	20	11

* Units are mg/ℓ unless otherwise indicated

There are a number of possible reasons for this:

- wind resuspension;
- resuspension as a result of stirring caused by the pumps for the musical fountains; and
- recreational uses including the use of the paddle steamer.

No data exist concerning the settlability of the suspended solids, and therefore no clear indication can be given concerning the dominant process. The suspended sediment could also be contributing to the phosphate concentrations within the lake, as well as the bacterial populations. Bacterial cells resuspended in the water column could be re-inoculating the lake.

As mentioned earlier, Hennops Lake has a bacteriological contamination problem. *E. coli* data are presented in Table B10.3. Average *E. coli* values for summer and winter for the inflow to the lake were 166 000 and 12 150 cells/100 mℓ, respectively. The outflow had reduced numbers, but still high at 52 036 and 18 022 cells/100 mℓ for summer and winter. It can be expected that these values would impact on the use of the lake for recreation, and in fact, during 1991 the public were warned to not use any of the river reaches in the Hennops River catchment.

Table B10.3 : Bacterial quality of Hennops Lake (January 1993-April 1994)

		Sampling Points (see Figure B10.2)			
Bacteriological Variables	**Reading**	**1 (summer)**	**1 (winter)**	**2 (summer)**	**2 (winter)**
E. coli per 100 mℓ	Min	1 400	220	1 200	390
	Max	680 000	81 000	189 000	135 000
	Ave	166 814	12 150	52 036	18 022
	No. of Samples	22	10	22	9

10.5 Pollution Problems and Management strategies

The poor bacteriological quality of the water flowing into Hennops Lake has caused concern to the Centurion local authority, because this has undermined the recreational use potential of the lake. The pollution of the lake has in particular represented a potential health risk to water sport users of the lake.

An attempt to combat this problem has been the installation of a chlorination system at the inflow to the lake. This has been a relatively low cost measure. The equipment cost just over R30 000 to install whilst running costs amount to approximately R60 000 per annum. Chlorine is purchased in 890 kg containers at R2 600 a container and chlorine dosages amount to 1,5 kg/h in winter and 3 kg/h during low flows in summer, which is deemed sufficient to reduce bacterial levels without killing fish.

This strategy has been partially successful as *E. coli* levels in the upper reaches of the lake have been reduced. However, lower down the lake the bacterial counts rise again. As mentioned earlier, the resuspension of the sediments could be re-inoculating the lake. The sediment loads accumulating in the lake reduced the average depth by up to 0,5 m between 1988 and 1993.

Centurion City Council have also recently commissioned a firm of consultants to investigate the use of a wetland system in the upper reaches of the catchment to reduce bacterial populations. The bacteria appear to be coming predominately from the Olifantsfontein and Tembisa areas.

The mechanism for the resuspension of sediments in the impoundment should be investigated to identify the net contributions to the nutrient and bacterial systems. Whilst the suspended sediment levels cause the lake to look turbid, it may be reducing light penetration into the lake and thus limiting algal growth.

Other management strategies which could be employed are :

- development of a meadow or reedbed system upstream of the inflow to the lake;
- source reduction within any treatment works;
- identification of the exact sources of the bacteria and the adoption of the principle of source reduction;
- installation of a sediment trap upstream of the lake; and
- identification of upstream activities which contribute to the sediment load.

Each of these strategies would need to be investigated in some detail in order to prevent the solution to any one problem causing a greater problem within the lake.

10.6 References

Toerien DF and Walmsley RD (1979). The Chemical Composition of the Upper Hennops River and its implications on the Water Quality of Rietvlei Dam. *Water SA*, *Vol 5* (2).

Wates, Meiring and Barnard (1994). *Non-point Source Pollution in the Hennops River Valley.* Report No 518/1/95 to the Water Research Commission.