SPATIO-TEMPORAL VARIATIONS OF FLUORIDE IN SURFACE AND GROUND WATER:

A CASE STUDY OF THE UMGENI WATER OPERATIONAL AREA, KWAZULU-NATAL.

By

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ABSTRACT

In September 2000 water fluoridation became mandatory in South Africa. Since then water service providers like Umgeni Water (UW), a bulk water supply authority in the KwaZulu-Natal (KZN) province of South Africa began the process of implementing the legislation. This study was undertaken to establish the spatio-temporal variations of fluoride concentrations in surface and ground waters within the Umgeni Operational Area, to establish whether these waters would require fluoridation or defluoridation to meet a fluoride concentration of 0.70 mg/ℓ, and to assess the potential impacts of water fluoridation.

Baseline fluoride concentrations of surface and ground water: It was concluded that the fluoride concentration of all sample types (rivers, dams, water works raw and final waters, wastewater influent and effluents, and boreholes), except pollution point sources, is less than 0.5 mg/ℓ, 50 percent of the time. Some rivers (Mshazi, KwaNyuswa, KwaNgcolosi, Mshwati and the MgoShongweni) exhibited high fluoride concentrations, while some boreholes also exhibited high fluoride concentrations.

Temporal Variations and Seasonality: There are seasonal variations in the fluoride concentrations for surface waters, with higher fluoride concentrations in winter than in summer (64 out of 125 occasions). This low fluoride concentration in summer can be attributed to the dilution effects caused by rainfall runoff.

Identification of "Hot Spots": "Hot Spots", sites where the fluoride concentration exceeds 1 mg/ℓ are present within the study area, for surface and borehole water. For surface water, the MgoShongweni exhibited fluoride concentrations in excess of 1mg/ℓ at least 75% of the time. The KwaNgcolosi and Mshwati exhibited fluoride concentrations in excess of 1mg/ℓ at least 25% of the time, while the Mshazi and the KwaNyuswa exhibited fluoride concentrations in excess of 1mg/ℓ only 5% of the time.

The storm water discharge below AECI had high fluoride concentrations in excess of 1mg/ℓ at least 20% of the time and the concentrations exceeded the fluoride concentration for seawater (1.4 mg/ℓ) at least 5% of the time.

Of the 286 boreholes sampled, 17 boreholes (6% of all boreholes sampled) had fluoride levels in excess of 1 mg/ℓ. The impacts of long term consumption of water from these boreholes could range from slight mottling of the dental enamel in sensitive individuals (boreholes JD26, C29, H19, CB7, 112/1, 69/5, Thembeni 108 and E&C Charcoal) to severe tooth damage and crippling skeletal fluorosis (Thembeni 105, Keats Drift boreholes 1 and 2).

Spatial patterns and possible sources of high fluoride concentrations: With respect to spatial patterns, relatively high concentrations of fluoride (300 µg/ℓ to 1000 µg/ℓ) can be found in surface water in the Msunduzi river, the Mgeni river downstream of the Msunduzi confluence and along the coastal belt. No spatial patterns are evident with respect to borehole water.

For surface water, high fluoride concentrations in the Mshazi, KwaNyuswa and the KwaNgcolosi streams (inflows to the Inanda dam) appear to be associated with the catchment geology. The high fluoride concentrations in Mshwati and the MgoShongweni are most likely as a result of industrial activities in the respective catchments. For borehole water, high fluoride concentrations may be attributed to catchment geology.

Additional fluoride dosage at water treatment works: Since the fluoride concentrations at the water works were low (mean ranging between 0.5 mg/ℓ to 0.38 mg/ℓ), fluoride would need to be added to meet the fluoride standard of 0.7 mg/ℓ. For most of the water works, the additional fluoride (sodium fluoride) requirement to meet the fluoride standard of 0.7 mg/ℓ, ranged from 1.201 kg/Mℓ to 1.555 kg/Mℓ. For the water works, Imfume and Umzinto, the additional fluoride requirement is 0.768 kg/Mℓ and 0.109 kg/Mℓ respectively. In final water, the fluctuations in fluoride concentrations observed would translate to continuous testing being required to maintain optimal dosing of fluoride.

Comparison of influent and effluent fluoride concentrations at wastewater works: There was no evidence of fluoride removal at the Mpophomeni Wastewater Works. There was evidence of 22.4% fluoride removal at the Darvill Wastewater Works possibly due to the activated sludge treatment process at the wastewater works.

Future fluoride levels in surface water that will receive return flows: Once water fluoridation is implemented, the Darvill Wastewater Works would receive fluoridated return flows, and discharge its fluoride rich effluent into the Msunduzi river. The average monthly fluoride load discharged from Darvill Wastewater Works would increase from 0.23 tons to 1.46 tons, an additional 1.23 tons per month on the aquatic environment of the Msunduzi river. The sludge fluoride load, disposed to land, could increase from 4 056 tons/month to 27 863 tons/month, which implies an increase in the fluoride runoff potential from the sludge-lands to the Msunduzi river.

Number of people in sensitive groups that could be affected by water fluoridation: A significant number of people in KZN could be sensitive to water fluoridation. This has been estimated to be at least one third of KZN's population that are HIV infected.

Recommendations were made and the most important ones are as follows: In the light of the large number of people, one-third the population of KZN, that is HIV positive and therefore could be sensitive to fluoridated water, it is recommended that the South African legislation mandating water fluoridation be withdrawn.

Examination of the most recent literature indicated a significant lack of confidence in the best available studies that researched the safety and efficacy of water fluoridation. In the light of this it is recommended that the South African Department of Health re-examine and withdraw its legislation that mandates water fluoridation.

PREFACE

This document was produced by the author in the capacity of a part-time student at the Centre of Environment and Development, University of Natal (Pietermaritzburg). The work outlined in this document was undertaken at Umgeni Water, the author's employer, during July 1999 to January 2000 (revised during November 2000 to July 2001) under the supervision of Dr F Ahmed (School of Applied Environmental Sciences) and Dr N Quinn (Centre for Environment and Development). The final update was completed in October 2002 under the supervision of Dr F Ahmed.

This documentation represents original work and where use has been made of the work of others, it has been duly acknowledged. The author also declares that this work has not been submitted to any other University for a degree or diploma.

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Dedication

I dedicate this effort to my daughters

Nikita and Olenka.

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LIST OF ACRONYMS

AECI	:	African Explosives and Chemical Industries
DMFT	:	Decayed, missing or filled teeth
Duzi	:	Msunduzi river
DWAF	:	Department of Water Affairs and Forestry
ESRI		Environmental Systems Research Institute
GIS	:	Geographical Information Systems
HIV	:	Human Immunodeficiency Virus
KZN	:	KwaZulu-Natal
N	:	Sample Size
NHMRC	:	National Health and Medical Research Council (Australia)
USA	:	United States of America
UW	:	Umgeni Water
WHO	:	World Health Organisation
WRC	:	Water Research Commission
WW	:	Water Works
WWW	:	Wastewater Works

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

In the interest of conserving human health, many water authorities in USA, Australia, UK, Canada and other countries fluoridate water. While certain concentrations of fluoride have been shown to reduce the incidence of dental caries these concentrations of fluoride have also caused dental fluorosis. According to Dick *et al* (1999), a concentration of 1 mg/ℓ of fluoride in drinking was suitable for reducing dental caries with no scientifically proven ill effect other than dental fluorosis (at concentrations between 1 to 2 mg/ℓ). At much higher concentrations mottling of teeth enamel and skeletal fluorosis are possible. To prevent fluorosis, water with high fluoride concentrations is often defluoridated to more acceptable concentrations. Hence, the issue of fluoridating potable water to control the incidence of dental caries is highly controversial and there is much debate about whether or not the consumption of fluoridated water does in fact reduce the incidence of dental caries. According to Muller *et al* (1998), "Since the South African Department of Health tabled legislation to make fluoridation of public water supplies mandatory, the issue of whether fluoride is beneficial or harmful has, once again, become controversial in South Africa".

Umgeni Water (UW) is one of the larger catchment-based water service providers in South Africa, providing drinking water to an area of 24 000 km^2 in the province of KwaZulu-Natal (KZN). Umgeni Water is primarily a bulk water supplier that provides approximately 331 million cubic metres of water per year for domestic and industrial use to its major consumers in the Pietermaritzburg, Durban and surrounding areas. Wastewater is also treated to safeguard the receiving water resources against pollution. Since treatment costs increase with deteriorating water quality, Umgeni Water is committed to working with its customers and the public at large to manage water resources on a catchment basis.

In June 1998, the Minister of Health published draft regulations for the fluoridation of public water supplies (DOH, 1998) proposing an optimal fluoride concentration of

0.7 mg/ℓ (not more than 0.7 mg/ℓ). In September 2000, this legislation was mandated in regulations under the Health Act of 1977 (Act No. 63 of 1977, see Appendix 14). Water service providers including Umgeni Water are required to implement this legislation or apply for an exemption.

Compared with the legislated fluoride standard of 0.7 mg/ℓ for potable water, the natural concentration of fluoride in surface water is much lower, ranging between 0.1 and 0.3 mg/ℓ (Water Research Commission, 1998), implying that water service providers will need to fluoridate the water. The fluoride concentrations of borehole water are usually less than 3 mg/ℓ but can range between 3 mg/ℓ and 12 mg/ℓ as a result of leaching from fluoride containing minerals to the ground water (Water Research Commission, 1998). Depending on the fluoride concentration of the water source (surface or borehole water) water service providers may be required to fluoridate or defluoridate the water to adjust the fluoride concentrations to the legislated 0.7 mg/ℓ.

In Australia, it has been reported that water fluoridation at optimal levels, varying from 0.6 mg/ℓ in subtropical regions to 1.1 mg/ℓ in temperate climates, continues to provide significant benefits for both deciduous and permanent teeth (NHMRC, 1999). This report also indicates that while evidence for a protective effect on dental health is strongest in childhood it can also be demonstrated in adults. The South African Water Quality Guideline for Domestic Use (DWAF, 1996a) reports that fluoride concentrations of 1 mg/ℓ to 1.5 mg/ℓ can cause slight mottling of dental enamel in sensitive individuals. The threshold for marked dental mottling with associated tooth damage due to softening of dental enamel was reported as 1.5 mg/ℓ. Given the South African optimal fluoride concentration of 0.7 mg/ℓ and the impacts (between 1 to 1.5 mg/ℓ), there remains a relatively narrow range of fluoride concentrations (0.7 to 1.0 mg/ℓ) that appears to be beneficial to human health.

Reasons for not fluoridating the water supply are based on the fact that ingestion of an excess of fluoride is poisonous (Muller *et al.*, 1998). Hence, optimal control of the fluoride concentration by water service providers becomes critical. In addition, fluoride has no taste, colour, or smell and therefore cannot be detected using these methods, even at high concentrations. Consequently, the detection of fluoride concentrations by water service providers would be critical and strongly reliant on adequate monitoring and analytical techniques.

While some monitoring of surface and borehole water has been undertaken in the Umgeni Water Operational Area, the existing fluoride data have not been closely studied. This includes, the spatio-temporal variations, the location of high concentrations of fluoride, potential impacts and cumulative effects of water fluoridation.

1.2 Aim and Objectives

This study aims to establish the spatio-temporal variations of fluoride concentrations in surface and ground waters within the Umgeni Water Operational Area and hence assess the potential impacts of fluoridation of potable water. The main objectives are to:

- Establish the baseline fluoride concentrations in surface and ground water;
- identify temporal variations (or seasonality) of surface water fluoride concentrations over the period January 1996 to September 1999;
- identify "hot spots", sites where the concentration of fluoride is greater than or equal to 1 mg/ℓ;
- identify spatial patterns of surface water and borehole fluoride concentrations and possible sources of high fluoride concentrations;
- calculate the additional fluoride dosage at water treatment works that will be required to meet the legislated optimal fluoride concentration (or fluoride standard) of 0.7 mg/ℓ;
- establish whether there is any loss of fluoride during a wastewater treatment process;
- predict future fluoride levels (i.e. after fluoridation is implemented) in surface water that will receive return flows (e.g. from effluent). Then evaluate the predicted fluoride concentrations in surface water against environmental and potable water criteria; and
- estimate the number of people in 'sensitive groups' that could be affected by water fluoridation.

Chapter 2: Literature Review

2.1 Introduction

In an attempt to solve the mystery of the Colorado Brown Stain in the 1930s, Dr Fredrick S. Mackay discovered fluoride in the drinking water and subsequently its effect on dental enamel and prevention of dental caries. This discovery is the foundation of water fluoridation (Peterson, 1997). Since then many investigations have shown a decrease in the levels of dental caries through water fluoridation. Bolin (1997) states that more than sixty percent of the European countries have achieved the goal of no more than 3 diseased, missing or filled deciduous teeth (DMFT) at 12 years. Large relative benefits in caries reduction have been demonstrated in fluoridated communities compared with non-fluoridated communities. This is further supported by a study done by Povart and Carmicheal (1995) in the English county of Durham on five-year-old children. The study showed a decrease in caries with water fluoridation and higher dental caries were associated with lower social economic groups in non-fluoridated areas. Studies done in the North of England, in Newcastle (fluoridated) and Liverpool (non-fluoridated) showed that "social deprivation and tooth decay were significantly correlated in areas with and without water fluoridation" (Jones & Worthington, 2000). This study concluded that implementation of water fluoridation markedly reduced tooth decay in 12-year-old children and that socio-economic dental health inequalities are reduced. Another study (Riley *et al.,* 1999) also claimed that, "water fluoridation reduces dental caries experienced more in materially deprived wards, than in affluent wards and the introduction of water fluoridation would substantially reduce inequalities in dental health".

On the 8 September 2000 the South African Minister of Health, after consultation with the Minister of Water Affairs and Forestry published regulations under the Health Act, 1977 (Act No.63 of 1977) for the fluoridation of water supplies. These regulations state that, "every water provider must practice fluoridation, unless exempted in writing by the Director-General". This review examines the status of water fluoridation internationally and nationally and draws attention to implications of the above regulations for water service providers in South Africa.

2.2 What is Water Fluoridation?

Some definitions of water fluoridation are listed below:
A definition used internationally states that fluoridation is the scientific control of the amount of fluoride in a water supply (Ritchie, 1981). According to Easley (1990), fluoridation is a process of adding a carefully measured amount of a fluoride compound to community drinking water at a level that is optimum for the prevention of dental caries. Easley (1990) also stated that, in the United States of America the optimal fluoride level has been determined to be between 0.7 and 1.2 mg/ℓ, depending on the community's annual mean daily temperature. (Diesendorf, 1995) described the process of fluoridation as "this involves artificially raising the natural fluoride concentration in drinking water to 1 mg/ℓ of fluoride in places with a temperate climate". A definition used nationally by the South African Health Act (1977) states that, "fluoridation means, to adjust the fluoride concentration of a water supply by the addition of a fluoride compound to obtain an optimal fluoride concentration", where fluoride compound refers to sodium fluoride, sodium fluorosilicate or fluorosilicic acid and optimal fluoride concentration refers to a fluoride concentration of not more than 0.7 mg/ℓ.

From these definitions it can be deduced that the term fluoridation is generally associated with the addition of artificial fluoride compounds to a water supply. The South African case even lists the fluoridating compounds that should be used and only the artificial fluoride compounds were listed. Easley (1990) even provides the reason why water is fluoridated.

2.3 Why are public drinking water supplies often fluoridated?

In Australia, studies demonstrated DMFT below the WHO guideline in both fluoridated and non-fluoridated areas, with lower caries in fluoridated areas (Riordan, 1991). Riordan (1991) used multivariate analysis to demonstrate that water fluoridation was associated with lower DMFT scores. The study also showed that a combination of brushing with toothpaste and consumption of fluoridated water was required for no caries. Higher dental caries were associated with lower social economic groups especially in non-fluoridated areas (Patterson, 1993). Studies in New Zealand also showed a decrease in DMFT levels for five-year-old children living in fluoridated areas compared with non-fluoridated areas (Treasure & Denver, 1991).

The province of KwaZulu-Natal, South Africa, had a population of 8.7 million people in 1995 with a growth rate of 2.8% per annum (Allan *et al.,* 1998). Of concern is the fact that at least 57% of the households live in poverty with poor sanitation and hygiene. Health care facilities are inadequate and poorly distributed in relation to need, with 318 trained environmental health professionals in KZN compared with an estimated need of 579 (Allan *et al.,* 1998). Tooth decay is one of the most common health problems in South Africa and leads to loss of working and schooling days as a result of pain and suffering. Dental caries affect 90 to 93% of the South African population. Oral health in the disadvantaged community is "in a sad state of affairs" (Muller *et al.,* 1998). Studies undertaken by du Pleissis and van der Merve (1995) in South Africa showed that black children benefited from drinking water with higher fluoride concentrations. A larger benefit was observed amongst 12 year olds (85% decrease in DMFT) and a lower benefit among 6 year olds (52% decrease in the DMFT).

Having been provided with evidence that water fluoridation reduces dental caries and reduces socio-economic dental health inequalities, many countries fluoridate their water supplies. Some countries, including South African have taken this more seriously by mandating water fluoridation.

2.4 WHAT ARE THE LEVELS OF FLUORIDE IN SURFACE AND GROUND WATER?

According to the Water Research Commission (1998), the baseline concentration of fluoride in surface water is typically 0.1 to 0.3 mg/ℓ. The fluoride concentrations of borehole water is usually less than 3 mg/ℓ but can range between 3 mg/ℓ and

12 mg/ℓ as a result of leaching from fluoride containing minerals to the ground water. The literature review showed no specific references to baseline fluoride concentrations of surface and borehole waters within the Umgeni Water Operational Area. It therefore indicated an area for closer examination and research.

2.5 How is Water Fluoridated?

Knowledge of the baseline fluoride concentration of the raw water and the final concentration of drinking water, as laid out by the legislation, are required. Once the baseline fluoride concentration is established, it is also important to establish whether seasonal fluctuations or trends exist as this would affect the amount of additional fluoride required. Thereafter, the concentration of the fluoridating agent required to increase the fluoride concentration of the water to the optimal level can be calculated. According to Haarhoff (1998), the amount of fluoridating agent required to obtain 1 mg fluoride/ℓ is:

- sodium fluoride: approximately 2.329 to 2.458 kg/Mℓ
- sodium silicofluoride: approximately 1.684 kg/Mℓ
- hydrofluosilicic acid: approximately 4.21 to 5.497 ℓ/Mℓ

Selection of fluoride injection points is important in terms of locating the common flow point of all water being treated so that optimal dosing can take place. Prevention of fluoride losses in filters needs to be considered as " there can be a 30 percent loss if the alum dosage rate is 100 mg/ℓ of alum" (Haarhoff, 1998). Further consideration is given to chemical compatibility, since chemicals containing calcium can cause fluoride losses through precipitation. Australia's National Health and Medical Research Council (NHMRC, 1999) state that, "in areas where artificial fluoridation of the reticulated water supply has been implemented it is undertaken after clarification and chlorination of the water. It is achieved primarily through the use of compounds such as sodium hexafluorosilicate (Na_2SiF_6) in a slurry, fluorosilicic acid (H_2SiF_6) in solution, or occasionally sodium fluoride (NaF) in a saturated solution".

The South African regulations for water fluoridation state that only three fluoride compounds may be used in fluoridating water supplies, these are sodium fluoride, fluorosilicic acid and sodium fluorosilcate. These fluoride compounds are artificially manufactured and according to Benefield *et al.*, (1982) large quantities of fluorides are released when fertilizer is manufactured from phosphate rock containing fluorapatite. Fluoride is found in the earth's crust, often as a constituent of fluorite (CaF_2) also known as fluospar or calcium fluoride (DWAF, 1996b). Naturally fluoridated waters contain the fluoride ion derived from sparingly soluble minerals such as fluoroapatites or fluorite. The usual range of concentrations varies from 0.05 to 5 mg/ℓ, with most values falling between 0.1 to 2 mg/ℓ (Cantor, 1997). Peng *et al.* (1996) provided methods for fluoridation with natural fluorspar, a mineral form of CaF_2, which would be a more publicly acceptable approach with many advantages over other widely used fluoridation chemicals. It would therefore be reasonable to explore this option, particularly since South Africa has been an important producer of fluospar since 1917 (Crocker, 1988). Furthermore, given the controversy regarding fluoridation, use of a natural source of fluoride may be more acceptable to the general public.

2.5 Optimal levels of fluoride in potable water

The optimal levels of fluoride in Australia's artificially fluoridated water range from 0.6 mg/ℓ in the subtropical climate of Darwin to 1.1 mg/ℓ in temperate Hobart (NHMRC, 1999). The optimal fluoride level in the United States has been determined to be between 0.7 and 1.2 mg/ℓ, depending on the community's annual mean daily temperature. However, the most stringent fluoride standard set by the Environmental Protection Agency (EPA) is the Secondary Maximum Contaminant Level (SMCL) of 2.0 mg/ℓ which is much higher than the optimal levels. The SMCL limits those contaminants that may adversely affect the aesthetic quality of drinking water such as taste, odor, color and appearance. The Recommended Maximum Contaminant Level (RMCL) and the Maximum Contaminant Level (MCL) are the same concentration at 4.0 mg/ℓ (Balog, 1997) but much higher than the SMCL of 2.0 mg/ℓ. RMCL is based only on health and safety considerations while MCL takes feasibility and cost into consideration. These standards are much higher than the guideline value of 1.5 mg/ℓ set by the World Health Organisation (WHO, 1996) that states "concentrations above this value carry an increasing risk of dental fluorosis, and much higher concentrations lead to skeletal fluorosis". According to the South African Water Quality Guidelines (DWAF, 1996a), discolouration of dental enamel and mottling occur at concentrations in the range of 1.5 - 2.0 mg/ℓ in persons whose teeth are undergoing mineralisation while skeletal fluorosis may occur when concentrations of fluoride in water exceed 3 – 6 mg/ℓ.

Epidemiological work done in the Free State Goldfields during 1991 and 1992 revealed that for the High Veld of South Africa, taking into account the average daily maximum air temperature, the altitude above sea level, the nutritional status of the children, and availability of other forms of fluoridating the mouth, 0.55 mg/ℓ is the optimum concentration of fluoride (Plessis, 1998). The safe maximum concentration was considered to be 0.7 mg/ℓ and at 0.9 mg/ℓ objectionable dental fluorosis will definitely occur. Plessis (1998), also indicated that the optimal value calculated in the investigation would be valid for the Johannesburg, Soweto and Vereeniging areas and that the Natal coastal areas, especially Durban and the North coast, will have to start with lower fluoride concentrations due to higher annual average maximum temperature than Johannesburg and slowly build up as evidence of safety is gathered. Muller *et al.* (1998) suggested that the fluoridation level in South Africa be determined by the use of a sliding scale guideline of 0.4 to 0.7 mg/ℓ, and indicated that Cape Town may decide on a higher fluoride level than Durban because Cape Town has a lower annual average maximum temperature than Durban.

According to DWAF (1996a) there is a relationship between air-temperature and recommended fluoride concentrations for drinking water, based on the premise that water consumption increases with high air temperatures (Table 1). Fluorides and Oral Health (WHO, 1994) also recommend a maximum fluoride level of 0.5 mg/ℓ for tropical and subtropical areas. The South African Health Act mandated an optimal fluoride concentration of not more than 0.7 mg/ℓ (Appendix 14), which is above that recommended by WHO (1994), Plessis (1998) and DWAF (1996a). This should be addressed as a matter of urgency.

TABLE 1.1: RELATIONSHIP BETWEEN AIR TEMPERATURE AND RECOMMENDED FLUORIDE CONCENTRATIONS FOR DRINKING WATER

Maximum Daily Air Temperature (°C)	Optimum Fluoride Concentration (mg/ℓ)
16	1.0
20	0.9
24	0.8
29	0.7
34	0.6*
40	0.5*

* Extrapolated values, and table extracted from (DWAF, 1996a)

2.5 WHY DO MANY PEOPLE REJECT WATER FLUORIDATION?

Many studies have shown no positive relationship between water fluoridation and dental caries. Colquhoun (1997) a former advocate of fluoridation and dentist provided reasons for his changing opinion on the subject in a paper entitled, "why I changed my mind about water fluoridation". According to Colquhoun's studies, fewer dental fillings were required by people in the non-fluoridated part of Auckland (New Zealand), than the fluoridated parts. The dental statistics for greater Auckland (which contains a quarter of New Zealand's population) also showed similar results, in fact teeth were slightly better in the non-fluoridated areas. Colquhoun (1997) also regrets having believed that, "there was no scientific case against fluoridation, and that only misinformed lay people and a few crackpot professionals were foolish enough to oppose it". He also regrets using his strong ability to 'articulate' in supporting and promoting water fluoridation in New Zealand.

2.5.1 Calcium, not fluoride reduces dental caries

A 30-year study done in India demonstrated the inter-relationship between calcium and fluoride. An increase in caries was demonstrated in children with adequate calcium nutrition in areas where water fluoride concentrations ranged between 0.7 mg/ℓ and 2.85 mg/ℓ. Dental caries was significantly higher in the 2.85 mg/ℓ fluoride area (Teotia and Teotia, 1994). With high calcium concentration the caries (decay) rate was 2%, but if fluoride was present it was 9.8%. With low calcium concentrations the caries rate was 31.4%, but if fluoride was present it was 74%. It was also demonstrated that calcium and not fluoride reduced the diseased missing and filled (DMF) rate. In fact fluoride inhibited the action of calcium in reducing dental caries. It should be noted that the Australian NMHRC (1999) described this study as being pivotal with a large sample size.

2.5.2 Water fluoridation and dental fluorosis

Studies have shown associations between water fluoridation and dental fluorosis, for example, Riordan and Banks (1991) demonstrated that the prevalence of fluorosis was 40% in fluoridated Perth (0.8 mg/ℓ F and a sample size of 338) and only 33% in unfluoridated Bunbury (0.2 mg/ℓ F with a sample size of 321), for $p=0.055$. It was also found that fluorosis was more prevalent with long exposure to water fluoridation than to short exposure (45% prevalence for 2.5 to 4 years exposure; 20% prevalence for less than 1 year exposure).

Teotia and Teotia (1994) demonstrated an increase in dental fluorosis for high fluoride and low dietary calcium exposure. These studies were based on two groups. The first group had a sample size of 400 300 children who were lifetime residents of a non-endemic area with fluoride concentrations < 1mg/ℓ (mean = 0.5 mg/ℓ). The second group had a sample size of 200 000 children from an endemic area with fluoride concentrations > 1mg/ℓ (mean = 4.2 mg/ℓ). For the first group (non-endemic area), children with adequate calcium nutrition showed 7% dental fluorosis and 2% dental caries, while children with inadequate calcium nutrition children exhibited 14.2% dental fluorosis and 31.4% dental caries. In the second group (endemic area), children with adequate calcium nutrition showed 59% dental fluorosis and 9.8% dental caries while children with inadequate calcium nutrition showed almost 100% dental fluorosis and 74% dental caries.

2.5.3 Water fluoridation and hip fracture

Studies done in the UK (Hillier *et al.*, 2000), showed a low risk of hip fracture for lifetime exposure of fluoridated water. It should however be noted that while the authors suggest that this low risk should not be a reason to withhold water fluoridation, no estimate of the risk to future generations (cumulative effects) was made. Another study by Danielson *et al.*, (1992) found a small but significant increase in the risk of hip fracture in both men and women exposed to artificial fluoridation at 1 mg/ℓ, suggesting that low levels of fluoride may increase the risk of hip fracture in the elderly.

2.5.4 People sensitive to fluoride

People with certain health problems could experience deterioration in their condition due to sensitivity to fluoride. According to the Water Research Commission (1998), the groups of people sensitive to fluoride are:

- children up to the age of three years
- individuals with HIV infection
- individuals with suboptimal dietary calcium
- individuals with liver or kidney disease
- individuals with malnutrition, particularly those with zinc deficiency
- individuals with a high daily water intake
- individuals on renal dialysis

According to the Preliminary State of the Environment Report for KwaZulu-Natal (Allan *et al.*, 1998), 57% of the households in KZN live in poverty. If it is assumed that these individuals are malnourished it would imply that at least 57% of the population in KZN could be sensitive to fluoride. It would therefore be necessary to undertake health impact assessments to establish the impacts of water fluoridation on people that belong to these sensitive groups.

The prevalence of AIDS in KZN is 32.5% (Department of Health, 2001). This implies that 32.5% of the KZN population could be sensitive to fluoridated water.

2.5.5 Quality Of Scientific Methodology In Fluoride Studies

The quality of the scientific methodology applied in studies that have examined the safety and efficacy of water fluoridation, have been questioned. An example of this is the NHS Centre For Reviews and Dissemination (2000) who conducted a review to:

- examine the effect of water fluoridation on the reduction of dental caries;
- determine whether water fluoridation resulted in a reduction of caries across social groups and between geographical groups, bringing equity, and;
- establish whether water fluoridation had negative effects.

Examination of the effect of water fluoridation on the reduction of dental caries (NHS Centre For Reviews and Dissemination, 2000): Since there were no Level A studies available (highest quality of evidence, minimal risk of bias), twenty six Level B studies (evidence of moderate quality, moderate risk of bias) were examined. The best available evidence suggested that fluoridation of drinking water does reduce caries. The results of the review, however, showed that the estimates of effect could be biased due to poor adjustment for the effects of potential confounding factors.

To determine whether water fluoridation resulted in a reduction of caries across social groups and between geographical groups, bringing equity (NHS Centre For Reviews and Dissemination, 2000): nine studies were included in the review, however, there were no Level A (highest quality of evidence, minimal risk of bias) or Level B studies (evidence of moderate quality, moderate risk of bias) available. Hence, only Level C studies (lowest quality of evidence, high risk of bias) were reviewed. The results showed that there was some evidence that water fluoridation reduces the inequalities in dental health across social classes in 5 and 12 year-olds, using the DMFT measure. It should be noted that this effect was not seen in the proportion of caries-free children among 5 year-olds, and that the data for children of other ages did not show any effects. Furthermore, the small quantity of studies, differences between these studies, and their low quality rating suggest caution in interpreting these results.

To establish whether water fluoridation had negative effects: The first negative effect considered was fluorosis. The studies showed that the prevalence of fluorosis at a water fluoride level of 1.0 mg/ℓ was estimated to be 48% (95% CI 40 to 57) and for fluorosis of aesthetic concern it was predicted to be 12.5% (95% CI 7.0 to 21.5). A very rough estimate of the number of people who would have to be exposed to water fluoride levels of 1.0 mg/ℓ before one additional person could develop fluorosis at any level was estimated to be 6, when compared with a theoretical low fluoride level of 0.4 mg/ℓ. It was also estimated that only one quarter of these would have fluorosis of aesthetic concern. However, the review indicated that the precision of these estimates is low. Studies examining impacts such as bone fracture (and bone development problems), cancer studies and other possible effects showed no association with water fluoridation. However, the review indicated a major weakness of these studies to be the failure to control for confounding effects.

A summary of the best available and most reliable evidence on the safety and efficacy of water fluoridation was presented. The review (NHS Centre For Reviews and Dissemination, 2000) concluded that:

> "Given the level of interest surrounding the issue of public water fluoridation, it is surprising to find that little high quality research has been undertaken. As such this review should provide both researchers and commissioners of research with an overview of the methodological limitations of previous research conducted in this area.
>
> The evidence of a benefit of a reduction in caries should be considered together with the increased prevalence of the dental fluorosis. The research evidence is of insufficient quality to allow confident statements about other potential harms or whether there is an impact on social inequalities. This evidence on benefits and harms needs to be considered along with the ethical, environmental, ecological, costs and legal issues that surround any decisions about water fluoridation.

> Any future research into the safety and efficacy of water fluoridation should be carried out with appropriate methodology to improve the quality of the existing evidence of bias".

From the above it appears that scientists have yet again faltered in the way the scientific method has been applied. Moreover, it appears that many studies have been conducted without considering the possible impacts to the environment and future generations, leaving unanswered questions regarding the sustainability of water fluoridation. Worse still is the fact that many people have accepted these studies as fact, totally rejecting the questions of anti-fluoridationists, and like South Africa, have legislated water fluoridation.

2.5.6 Problems with defluoridation

Many countries have problems with fluorosis due to high natural fluoride concentrations in their water sources. Kloos and Haimanot (1999) reported high fluoride concentrations (> 5mg/ℓ) in water sources in the Rift Valley of Ethiopia (hot springs, lakes, shallow wells and boreholes). The paper described the need to defluoridate not only their drinking water sources but also the water used for irrigation purpose, at the Wonji irrigation scheme.

Removal of fluoride from water is difficult since fluoride is a relatively stable anion (DWAF, 1996a). Calcium is unsuitable for fluoride removal since its solubility is of an order of magnitude higher than the levels required. Methods for fluoride removal include:

- removal with aluminium sulphate treatment;
- removal with polyaluminium chloride;
- adsorption on a bed of activated alumina;
- removal in ion exchange columns along with other anions;
- removal in membrane processes such as reverse osmosis and electrodialysis together with virtually all other ions.

It should however be noted that the latter two defluoridation techniques, while being effective, are sophisticated and relatively expensive in capital and operating costs (DWAF, 1996a). In addition a high level of skill is required in the design, operation and maintenance of the equipment. The health implications of high fluoride concentrations and the problems associated with defluoridation lead to many people adopting an anti-fluoridation attitude.

2.5.7 Mitigation measures associated with fluoridation

With regard to human health, fluorosis is less severe when drinking water is hard, rather than soft, since the occurrence of calcium together with fluoride limits fluoride toxicity (DWAF, 1996a). However, there is no way of mitigating against the effects of long-term ingestion of higher than recommended concentrations of fluoride.

With regard to agricultural use such as irrigation, DWAF (1996a) outlined common on-farm management practices to mitigate against fluoride uptake by plants on irrigated land:

- apply agricultural lime in order to raise or maintain soil pH to neutral to slightly alkaline;
- switch to crops that are more tolerant of fluoride; and
- apply agricultural gypsum to raise the soil calcium content and promote the formation of fluoride which has a relatively low solubility. Addition of gypsum to irrigation water will have a similar effect.

2.6 When would it be appropriate to fluoridate water supplies?

To answer the above question, another question has often been asked. This is whether or not it is cost-effective to use water fluoridation in the prevention of dental caries. A study undertaken by O'Mullane (1990) in Ireland concluded that water fluoridation continues to be an effective and cost-effective strategy for caries prevention. The new thinking regarding cost-benefit analyses are presented in Resource Environmental Economics that also take environmental costs and benefits into account.

While it is appropriate to use Resource Environmental Economics to estimate environmental costs and benefits of a project, it is necessary to identify and quantify the short-term and cumulative effects of water fluoridation. For one to make an informed decision whether or not to fluoridate water, there is a definite need for more reliable epidemiological studies that would identify and quantifying short and long-term effects of water fluoridation on humans and the environment.

Techniques such as Environmental Impact Assessments can be used to identify the possible impacts of a project and offer appropriate mitigation measures. Section 5(2) of the South African Health Act of 1997, requires that the water provider conduct "an assessment of the impact of fluoridation on all catchments receiving effluent return flows originating from fluoridated water supplies". A study undertaken by Hunt (1998) identified the impacts associated with the operation of a water fluoridation programme, for Umgeni Water. The study used the life cycle assessment technique to identify mitigation options that could be used to reduce the impacts of water fluoridation. This assessment identified inputs and outputs, the associated risks and suggestions for mitigation. However, an assessment of the Impact of fluoridation on all catchments receiving effluent return flows originating from fluoridated water supplies has yet to be undertaken.

Before deciding to fluoridate water it is essential to explore the use of alternative methods to prevent dental caries. According to the Merck Manual of medical information (Berkow *et al.*, 1997), dental caries are commonly caused by the bacterium *Streptococcus mutans*. According to the Preventative Dental Health Association this bacterium is easily killed with salt. This article on oral health also indicated that in order to control tooth decay use of a paste of equal parts of salt and baking soda worked into the collar of the gum and teeth is recommended. The article also indicated that American Indians made use of "prickly ash bark" for tooth care. In the South African context it may be necessary to identify possible alternatives through a participatory rural appraisal. This would allow people to share their traditional knowledge of oral care and hygiene.

Public participation is necessary in deciding whether or not a region should fluoridate their water or not. This however, does not apply when water fluoridation is mandatory. According to the South African Health Act, the public can appeal against fluoridation provided there is sufficient evidence to show that there are limited dental caries in a particular region.

In South Africa, the water service provider may be exempted from fluoridating its supplies if the raw water already contains the optimal fluoride concentration. It would therefore be necessary to calculate the fluoride concentration of raw water sources. Exemption may also be granted if it can be shown that the water resources are negatively impacted by effluent or diffuse discharges originating from the fluoridated supplies. It is therefore necessary to predict the fluoride concentration of water bodies receiving fluoride rich effluent and its possible impacts on the environment.

2.7 Are all public drinking water supplies fluoridated – global trends?

All Australian capital cities, except Brisbane have implemented water fluoridation (NHMRC, 1999). In 1992, Welsh Water withdrew the successful water fluoridation scheme on Anglesey. Despite evidence of the benefits of water fluoridation and the rise in number of children with tooth decay since the scheme's withdrawal, Welsh Water is still not prepared to re-establish the scheme (Hulse *et al.,* 1995). The piped water of Kuopio, Finland, was fluoridated in 1959. Owing to strong opposition by civic groups, water fluoridation was stopped at the end of 1992 (Seppya *et al.,* 1998). In Norway, there is no water fluoridation and little naturally occurring fluoride in water (Wang, 1997). The graph below (Figure 2.1) shows tooth decay trends for 12 year olds in fluoridated and unfluoridated countries (Fluoride action Network, 2001). It is evident that unfluoridated countries such as Belgium, Denmark, France, Germany, Italy, Netherlands, Norway and Sweden have experienced similar or greater declines in dental cavities compared with the United States of America (fluoridated). This decline in dental cavities in the unfluoridated countries is associated with improved oral awareness and hygiene.

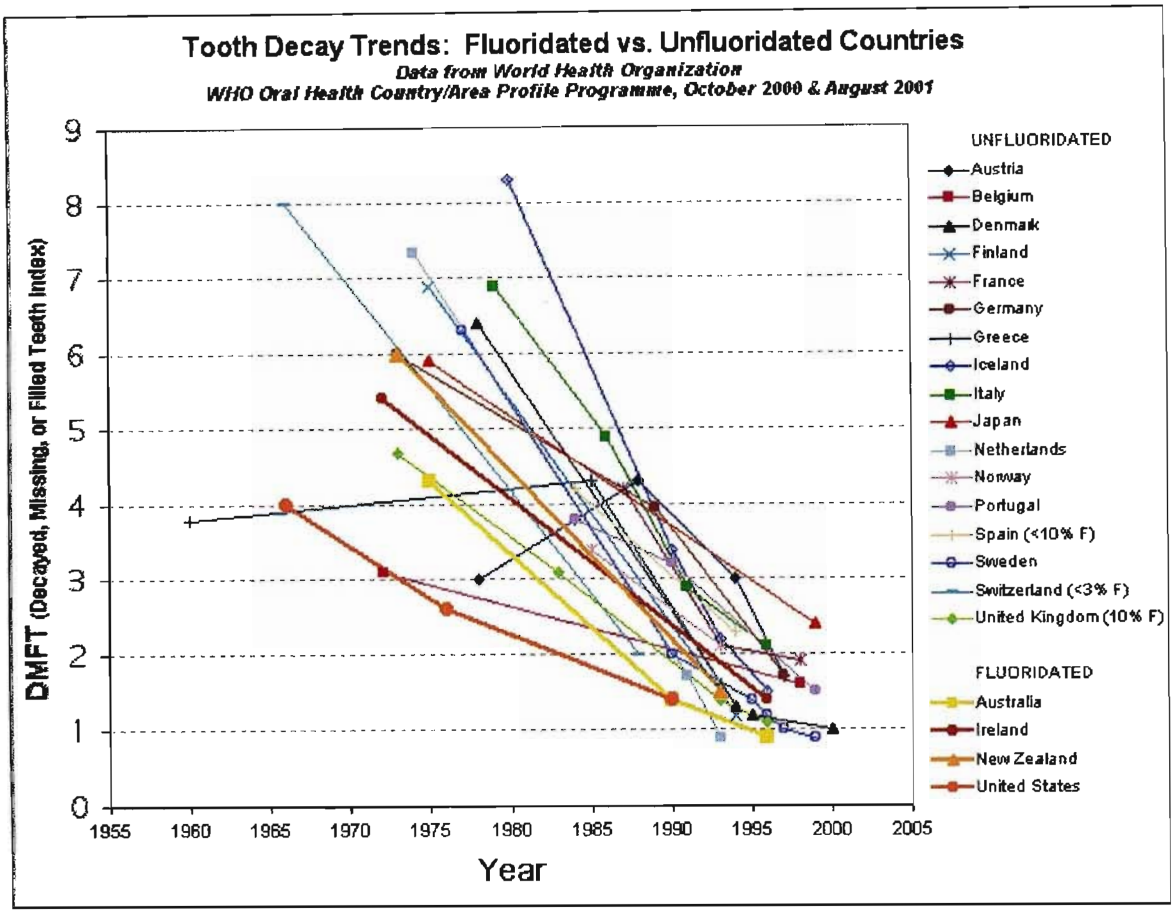


FIGURE 2.1: TOOTH DECAY TRENDS IN 12-YEAR OLDS IN FLUORIDATED AND UNFLUORIDATED COUNTRIES (FLUORIDE ACTION NETWORK, 2001)

2.8 SUMMARY

While the pros and cons of fluoridation of drinking water have been discussed at great length by many scientists all over the world, we in South Africa, specifically the Umgeni Water Operational Area in KwaZulu-Natal, have not established the baseline concentration of fluoride in the surface waters. In addition, the location of high concentrations of fluoride sources of these high concentrations (if any), and the potential impacts and cumulative effects that may develop with fluoridation of potable water have not been examined in much detail.

This study aims to identify spatial and temporal variations in the fluoride concentrations of surface and ground water within the Umgeni Operational Area and hence assess the potential impact of fluoridation of potable water.

CHAPTER 3: METHODOLOGY

3.1 Data Sources

Fluoride concentration data for surface water were obtained from Umgeni Water for rivers, dams, water works raw and final waters, and wastewater influents and effluents for the period January 1996 to September 1999. The sampling frequency was quarterly for rivers, monthly for water works raw and final waters, and weekly for wastewater effluents. In terms of analysis, during the period 1996 to 1997, the ion selective electrode method on the Skalar segmented flow analyser was used to measure fluoride concentrations (the detection limit was 50 µg/ℓ). Subsequent to 1997, the ion selective electrode method using a Metrohm ion meter was used to measure the fluoride concentration (the detection limit was 100 µg/ℓ).

Fluoride data for borehole data were obtained from Umgeni Water. These results were based on one-off sampling undertaken by Umgeni Water and the Natal Hydrogeological Mapping Project as a joint investigation. The boreholes were sampled during the period 1994 to 1996 and were not season specific.

The geology data were captured by DWAF in 1996 at a capture scale of 1 : 50 000. Landuse data were mapped by the CSIR in 1996 from 1 : 250 000 precision-corrected satellite images referred to Spacemaps. These Spacemaps were captured primarily during 1994 to 1995. The topographic data used in this study were the South African 1 : 50 000 maps (third edition, 1981) published by the chief director of Surveys and Mapping.

3.2 Study Area

3.2.1 Locality Of The Study Area

The study area, Umgeni Water Operational Area (Figure 3.1), lies within the province of KwaZulu-Natal (KZN). The province of KZN lies along the eastern shores of the Republic of South Africa with the Drakensberg demarcating the western border and the Indian Ocean in the east. KZN occupies an area of approximately 92 180 square kilometres and covers 7.6% of South Africa's geographic area.

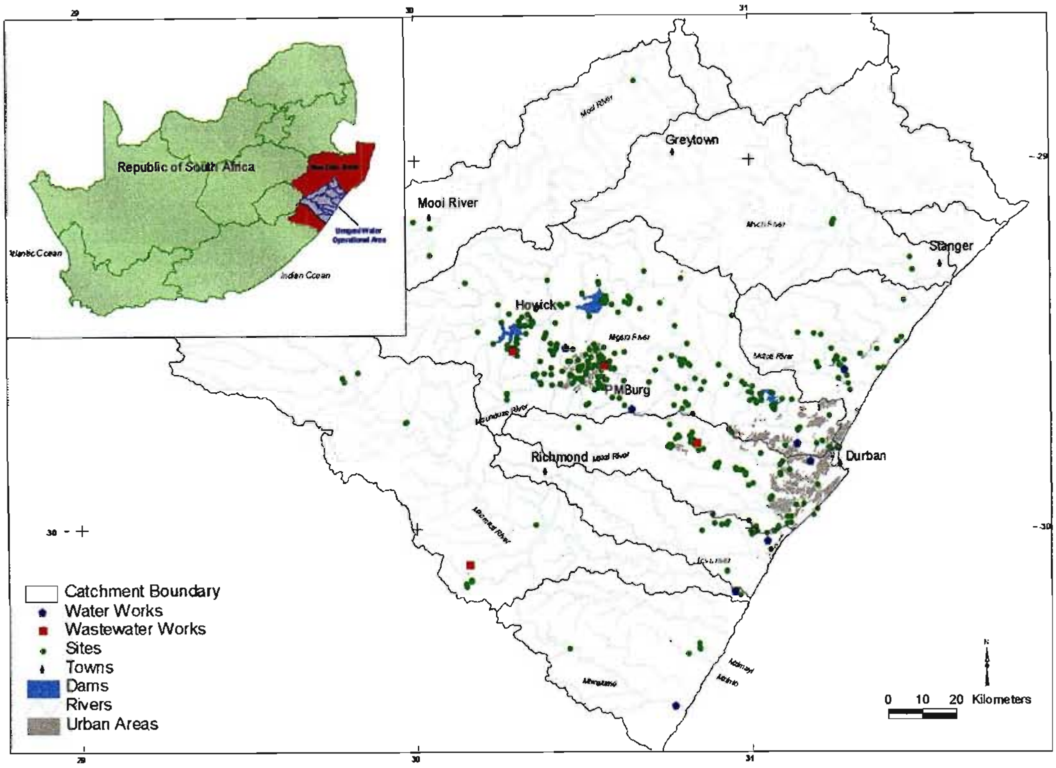
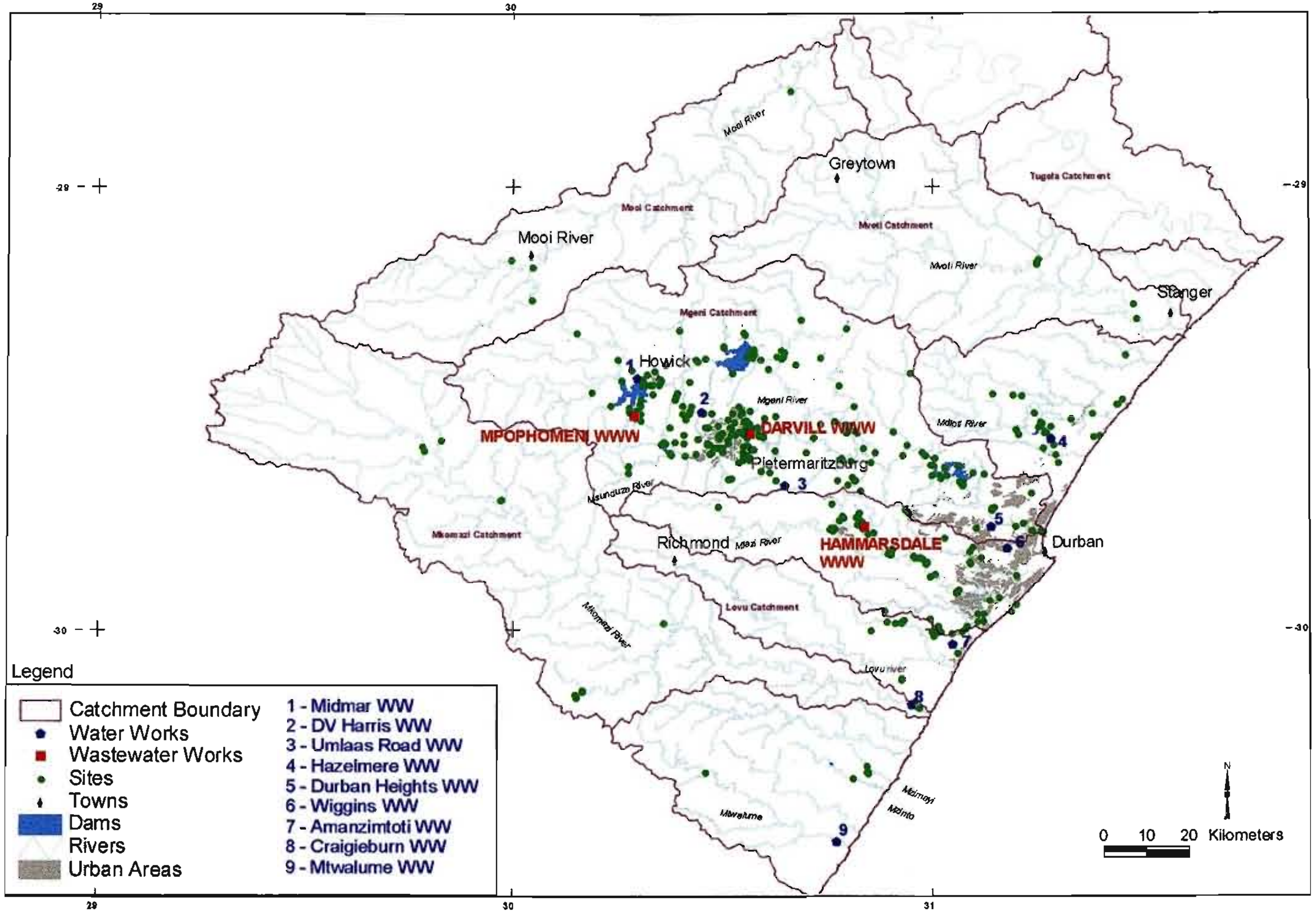


FIGURE 3.1 : LOCATION OF THE STUDY AREA WITHIN RSA

3.2.2 The Umgeni Water Operational Area

The Umgeni Water Operational area (Figure 3.2) extends from the Tugela river in the north of the province to the Mtwalume river in the south, the Mooi river in the west to the Indian Ocean in the east. The Umgeni Water Operational Area covers approximately 24 000 square kilometres of KZN. Umgeni Water operates 13 water treatment works of which Durban Heights, Wiggins and Midmar are the largest. As part of the catchment management approach, ten impoundments and 13 rivers are monitored regularly for various bacteriological, algal and chemical water quality variables, including fluoride concentrations. Figure 3.2 shows all surface water sites that are monitored for fluoride within the Umgeni Water Operational area.

FIGURE 3.2 : THE UMGENI WATER OPERATIONAL AREA



3.2.3 Climate And Landuse In The Umgeni Water Operational Area

The mean annual precipitation for the period 1996 to 1998 varied within the Umgeni Water Operational Area, with approximately 1330 mm/a recorded at Umzinto in the south coast, 900 mm/a at Hazelmere in the north coast, 840 mm/a inland at Darvill, Pietermaritzburg and 860 mm/a further inland at the Mearns Pumpstation. Average daily maximum temperatures for Durban and Pietermaritzburg are 24.7°C and 24.0°C respectively.

Surface water quality is determined by the impacts of landuse activities. These impacts depend on the nature of the specific landuse activity. The most likely source of artificially introduced fluoride in surface water is areas with industrial activity. Detailed landuses (CSIR, 1996) were calculated and tabulated in TABLE 3.1 and represented in Figure 3.3. This landuse data was used in the study to locate sources of high fluoride concentrations in surface water.

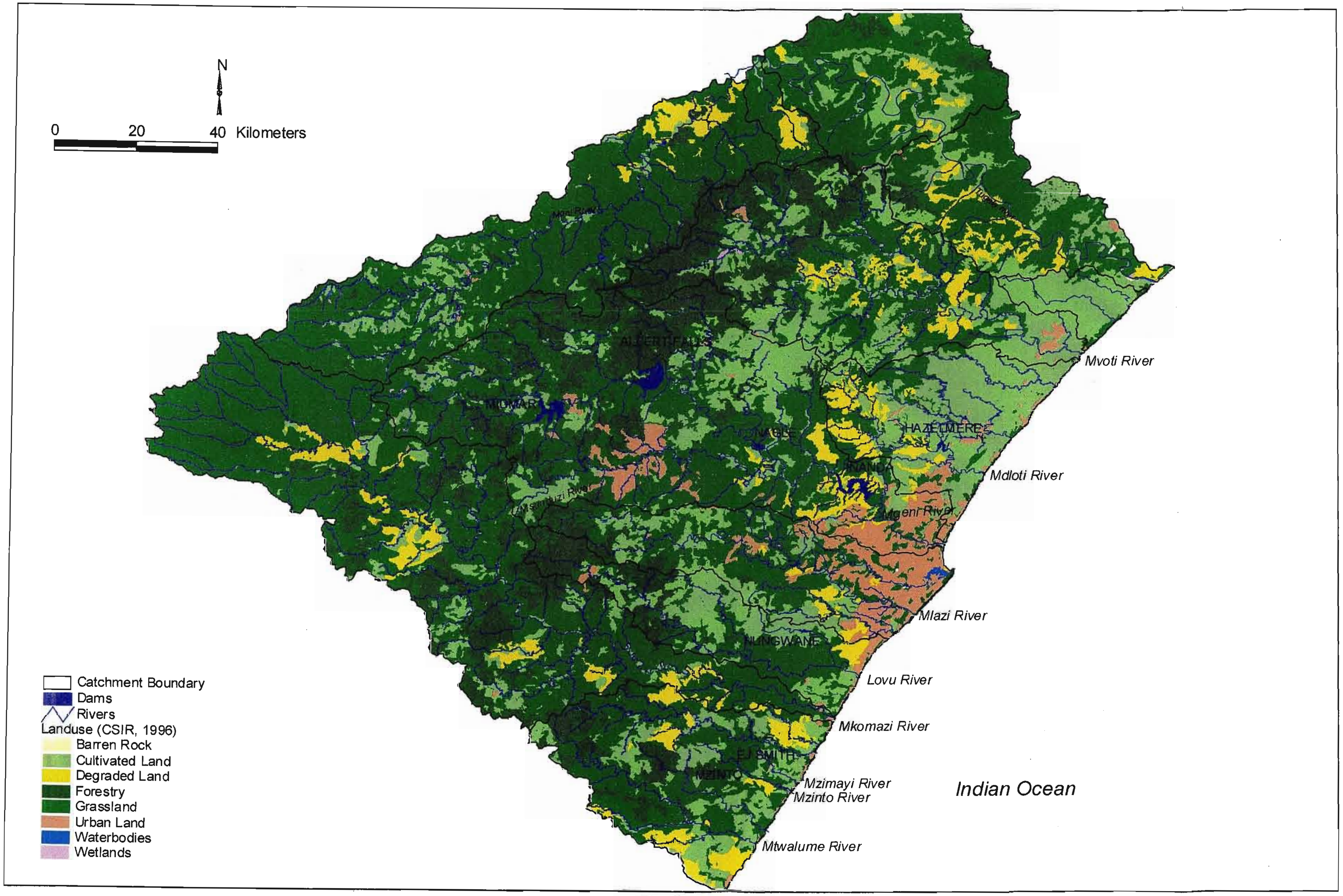
TABLE 3.1. SUMMARY OF LANDCOVER DETAILS IN THE UMGENI WATER OPERATIONAL AREA

LAND COVER DESCRIPTION	AREA (km^2)	% AREA
Unimproved grassland	7562.2	31.8
Thicket & bushland (etc.)	5020.8	21.1
Forest plantations	2729.3	11.5
Cultivated: permanent - commercial sugarcane	2632.7	11.1
Cultivated: temporary - semi-commercial/subsistence dryland	1865.7	7.8
Degraded: thicket & bushland (etc.)	1051.4	4.4
Urban / built-up land: residential	677.2	2.8
Degraded: unimproved grassland	499.4	2.1
Cultivated: temporary - commercial dryland	467.4	2.0
Cultivated: temporary - commercial irrigated	377.6	1.6
Forest	267.9	1.1
Improved grassland	166.1	0.7
Waterbodies	130.3	0.5
Urban / built-up land: residential (small holdings: bushland)	87.8	0.4
Degraded: forest and woodland	73.3	0.3
Urban / built-up land: industrial / transport	59.3	0.2
Urban / built-up land: commercial	28.5	0.1
Urban / built-up land: residential (small holdings: grassland)	27.5	0.1
Forest and Woodland	24.3	0.1
Wetlands	17.8	0.1
Shrubland and low Fynbos	16.0	0.1
Dongas & sheet erosion scars	6.2	0.0

TABLE 3.1. SUMMARY OF LANDCOVER DETAILS IN THE UMGENI WATER OPERATIONAL AREA, CONTINUED...

LAND COVER DESCRIPTION	AREA (km^2)	% AREA
Barren Rock	6.0	0.0
Mines & quarries	3.9	0.0
Cultivated: permanent - commercial irrigated	3.3	0.0
Cultivated: permanent - commercial dryland	0.2	0.0
Urban / built-up land: residential (small holdings: shrubland)	0.2	0.0
TOTAL	**23802.1**	**100**

FIGURE 3.3 : LANDUSE IN THE UMGENI WATER OPERATIONAL AREA



3.3 METHOD

3.3.1 Baseline Fluoride Concentrations Of Surface And Ground Water.

To establish baseline fluoride concentrations of surface and ground water, the data were tabulated, summary statistics calculated and time series graphs prepared in the software package Excel, version 7 (Microsoft, 1995).

3.3.2 Temporal Variations And Seasonality.

To identify the presence of temporal variations or seasonality, the summary statistics for summer and winter were compared and time series graphs were prepared. The Wilcoxon Matched Pairs test was used to compare summer and winter fluoride concentrations and to establish in which season the fluoride concentrations were higher.

3.3.3 Identification Of "Hot Spots"

The summary statistics were used to identify "hot spots", sites where the concentration of fluoride was greater than 1 mg/ℓ. The maximum fluoride concentration was noted and sites with a maximum fluoride concentration in excess of 1 mg/ℓ were identified. Sites with a maximum fluoride concentration in excess of the 0.7 mg/ℓ standard (but were less than 1 mg/ℓ) were identified. The percentage time that the standard was exceeded was calculated. Sites with a maximum fluoride concentration between 0.5 mg/ℓ and 0.7 mg/ℓ were also identified.

3.3.4 Spatial Patterns And Possible Sources Of High Fluoride Concentrations.

To identify spatial patterns, maps were prepared using quarterly fluoride data. This was achieved by preparing a database file (comprising the sample sites and the fluoride concentration) in Excel, saving the file in a DBase file format, then preparing maps in a proprietary GIS package, Arcview by the Environmental Systems Research Institute (ESRI, 1996). The fluoride data were then represented spatially on a colour-coded map using the DWAF guidelines to classify the data showing the various risk levels for domestic use.

Possible sources of high fluoride concentrations were identified (e.g. geological, anthropogenic activities such as industries, and other urban activities). This was done by relating the problem site "hot spots" with landuse, geology and soils data and from discussions with Umgeni Water personnel dealing with integrated catchment management.

3.3.5 Calculation Of The Additional Fluoride Dosage At Water Treatment Works.

The additional fluoride dosage at the Umgeni Water water treatment works that will be required to meet the fluoride standard of 0.7 mg/ℓ was calculated. This was done through several steps. The difference between the fluoride standard and average baseline fluoride concentration was calculated for the various water treatment works. The difference was then multiplied by the average dosage requirement of the fluoridating agent for one mega-litre of potable water (based on the calculations of Haarhoff, 1998). The mass of the fluoridating agent (Sodium fluoride, Sodiumfluorosilicate and Fluorosilicic acid) required to treat the average daily/annual production volume at the water treatment works was calculated by, multiplying the dosage requirement for one mega-litre by the average daily/annual production volume at each of the water treatment works.

3.3.6 Comparison Of Influent And Effluent Fluoride Concentrations At Wastewater Works.

To establish whether there was any loss of fluoride during a wastewater treatment process, influent and effluent fluoride concentrations were compared. The data sets were checked for normality by comparing the skewness of the data sets with skewness limits. Since the data sets were found to be non-parametric, the Wilcoxon Matched Pairs test was used to compare the influent and effluent data sets. For the data sets that were significantly different, the percentage fluoride loss was calculated by subtracting the average effluent fluoride concentration from the influent, to get the loss, and expressing this loss as a percentage of the influent fluoride concentration.

3.3.7 Calculation Of Future Fluoride Levels In Surface Water That Will Receive Return Flows.

Future fluoride levels in surface water that will receive return flows, after potable water is fluoridated, were calculated and evaluated against environmental and potable criteria. As a case study, the impact of the Darvill WWW return-flows on the Inanda impoundment was determined (using a mass balance approach), this was subsequently used to predict the fluoride concentration in the Inanda impoundment (the raw water source for Wiggins Water Works), Figure 4.10. This process involved several steps. Firstly, the baseline monthly average fluoride concentration of Darvill effluent and the average monthly discharge from the WWW were used to calculate the average monthly fluoride load from the WWW. The baseline fluoride concentration of the Darvill effluent reflects Pietermaritzburg's fluoride discharge (use of toothpaste, dental care products, industrial activities etc.) before water fluoridation. After fluoridation of potable water, the effluent fluoride concentration would increase by an additional 0.7 mg/ℓ (i.e. baseline fluoride concentrations of Darvill effluent arising from use of e.g. toothpaste in the city plus 0.7 mg/ℓ from potable water discharged to the sewer). Hence the average monthly fluoride concentration was added to the proposed fluoride standard of 0.7 mg/ℓ to obtain the average monthly fluoride concentration of the effluent after fluoridation. The predicted average monthly fluoride concentration and the average monthly flow of the effluent from Darvill WWW were used to obtain the potential monthly fluoride load from Darvill WWW to the Msunduzi river, after fluoridation of drinking water. The fluoride loads were calculated for various sites along the Msunduzi river and for the Inanda impoundment. The fluoride load at the main basin was then used to predict the increased fluoride concentration in Inanda main basin due to fluoridation.

3.3.8 Estimate Of The Number Of People In 'Sensitive Groups' That Could Be Affected By Water Fluoridation.

People in 'sensitive groups', that is people that could be affect by fluoridated water, such as children between the ages of zero to three years, malnourished people with a zinc deficiency and those infected with HIV were estimated using the 1996 census data and literature.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Baseline Fluoride Concentrations Of Surface And Ground Water

The baseline fluoride concentrations of surface and ground water sampling sites in the Umgeni Water Operational Area are summarised in Table 4.1. Detailed summary statistics and time series graphs are presented in Appendices 1 to 7.

- Fluoride concentrations for impoundments, water works raw and final water, wastewater works influent and effluent and boreholes, indicated that the fluoride concentration is less than 0.5 mg/ℓ fifty percent of the time.
- The fluoride concentrations in rivers vary, with some river sites exhibiting median fluoride concentrations as low as 0.05 mg/ℓ while other river sites have concentrations as high as 1.79 mg/ℓ. Since the baseline fluoride concentration of surface water is typically 0.1 - 0.3 mg/ℓ (WRC, 1998), the high fluoride concentrations in some rivers represent atypical behavior which may be due to pollution.
- Raw water entering water treatment works were found to have fluoride concentrations that are less than 0.6 mg/ℓ ninety five percent of the time. This implies that potable water will need to be fluoridated to meet the legislated optimal concentration of 0.7 mg/ℓ.
- High fluoride concentrations, in excess of 1 mg/ℓ, were recorded at some boreholes. This implies that water abstracted for domestic use from these sites would require defluoridation to reduce the fluoride concentrations to safer levels.

TABLE 4.1. SUMMARY STATISTICS OF BASELINE FLUORIDE DATA FOR THE VARIOUS SAMPLE TYPES, EXPRESSED AS A RANGE (MANY SITES AND ROUTINE MONITORING)

	Summary Statistics - Fluoride Concentrations (mg/ℓ)					
Sample Type	**No. of Sites**	**Average**	**Median**	**75th Percentile**	**95th Percentile**	**Maximum**
Rivers	121	0.04 - 1.99	0.05 - 1.80	0.05 - 2.09	0.05 - 4.20	0.06 - 5.00
Impoundments	11	0.05 - 0.23	0.05 - 0.25	0.05 - 0.28	0.06 - 0.34	0.06 - 0.37
WW Raws	11	0.04 - 0.45	0.05 - 0.45	0.05 - 0.51	0.05 - 0.58	0.05 - 0.72
WW Finals	11	0.05 - 0.38	0.05 - 0.41	0.05 - 0.48	0.09 - 0.57	0.11 - 0.65
WWW Influents	3	0.08 - 0.32	0.05 - 0.27	0.11 - 0.41	0.16 - 0.76	0.20 - 1.01
WWW Effluents	3	0.08 - 0.34	0.05 - 0.34	0.11 - 0.40	0.14 - 0.57	0.17 - 0.68
Point Source	3	0.14 - 0.84	0.15 - 0.84	0.17 - 0.98	0.19 - 1.43	0.20 - 1.65
Boreholes	286	3.0	0.38	1.42	12.13	98.78

Note : WW denotes Water Works; WWW denotes Wastewater Works; Boreholes were sampled as once-off.

4.2 TEMPORAL VARIATIONS OR SEASONALITY.

Summary statistics for rivers were calculated for the summer and winter seasons, and time series graphs plotted (Appendix 1 to 4). The summer data set comprises data monitored during October to March and the winter data set is represented by data monitored during April to September.

The distribution of the summer and winter data sets was determined by calculating the skewness coefficient. The skewness coefficient for the summer data set was 3.91 while that for the winter data set was 4.28. Both these values are greater than the critical value of 0.36 (for sample size of 125), indicating that the data sets are significantly skewed. Since the data sets were significantly skewed, a non-parametric test was used to compare the summer and winter data. Median fluoride concentrations of rivers for summer where compared with those for winter using the non-parametric Wilcoxon Matched pairs test. It was found that the fluoride concentrations for summer were significantly different from those for winter, at the 95% confidence limit (Table 4.2). Closer examination of the data indicated that the median fluoride concentrations for surface water were higher in winter (64 out of 125 occasions) and ranged from (0.04 mg/ℓ to 1.79 mg/ℓ). This low fluoride concentration in summer (0.04 mg/ℓ to 1.21 mg/ℓ) can be attributed to the dilution effects caused by rainfall runoff, as the Umgeni Water Operational Area experiences high rainfall during summer.

This seasonal fluctuation in fluoride concentrations will impact on the receiving impoundment and ultimately have implications for water treatment (and additional fluoride dosage).

TABLE 4.2 RESULTS OF THE WILCOXON MATCHED PAIRS TEST, COMPARING SUMMER AND WINTER FLUORIDE CONCENTRATIONS IN RIVERS

	Sample Size	No. of Tied pairs	No. of positive differences (summer – winter)	No. of negative differences (summer – winter)	Z statistic
Comparison of median fluoride concentrations	125	33	28	64	3.73

4.3 IDENTIFICATION OF "HOT SPOTS"

4.3.1 Surface Water "Hot Spots"

Surface water sites that exhibit fluoride concentrations in excess of 1 mg/ℓ were identified and listed in Table 4.3. These sites were identified because fluoride concentrations in excess of 1 mg/ℓ are considered to be unsafe for human consumption as long-term exposure to this concentration could lead to dental and skeletal fluorosis (DWAF, 1996a).

TABLE 4.3 "HOT SPOTS" FOR RIVERS, POLLUTION POINTS AND INFLUENTS

	Summary Statistics of fluoride concentrations (mg/ℓ)								
Sample Sites - Rivers	n	Minimum	25^{th} Percentile	Average	Median	75^{th} Percentile	80^{th} Percentile	95^{th} Percentile	Maximum
Mshazi above Mgeni Confluence	15	0.16	0.38	0.69	0.79	0.90	0.92	1.08	1.20
Kwanyuswa adjacent to Mshazi	14	0.14	0.57	0.65	0.72	0.80	0.81	0.93	1.10
KwaNgcolosi inflow (minor) to Inanda Dam	12	0.05	0.35	0.75	0.91	1.04	1.07	1.17	1.22
Mshwati	14	0.05	0.21	0.66	0.51	1.16	1.18	1.31	1.36
MgoShongweni Stream	7	0.26	1.11	1.92	1.79	2.09	2.24	4.20	5.00
Sample Sites - Pollution Point									
AECI storm water	31	0.11	0.72	0.84	0.84	0.98	1.03	1.43	1.65
Sample Sites - WWW Influent									
Hammarsdale Influent	68	0.05	0.18	0.32	0.27	0.41	0.45	0.76	1.01

n = sample size

The MgoShongweni stream exhibits fluoride concentrations in excess of 1 mg/ℓ at least 75 percent of the time (Figure 4.1). The sample size of the data would reduce the confidence that one would place on it. However, the unusually high fluoride concentrations could imply inputs from the upper catchment and could warrant closer investigation. In terms of domestic use, this water will need to be defluoridated to reduce the fluoride concentrations to safer levels and reduce cumulative effects. In terms of livestock watering, MgoShongweni stream displays fluoride concentrations between 2 to 4 mg/ℓ at least 25 percent of the time. Long-term exposure to these concentrations could have chronic adverse effects associated with dental fluorosis in monogastrics but no adverse effects to ruminants (DWAF, 1996a).

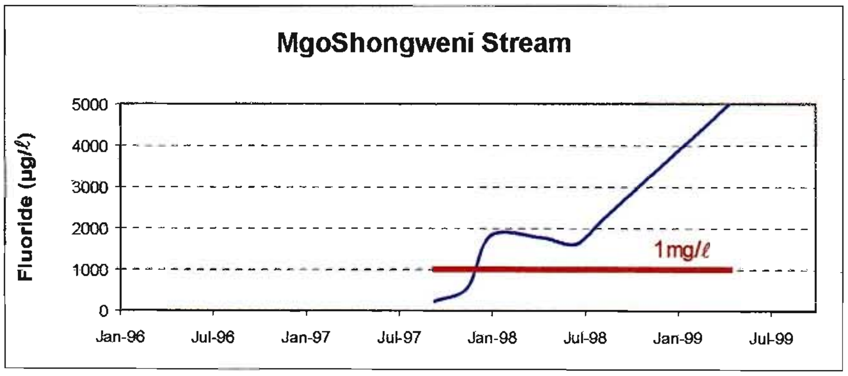


FIGURE 4.1: TIME SERIES GRAPH OF THE MGOSHONGWENI STREAM

The KwaNgcolosi and Mshwati streams have fluoride concentration in excess of 1 mg/ℓ at least 25 percent of the time, while the Mshazi and KwaNyuswa streams exceeded this concentration about 5 percent of the time (Figure 4.2).

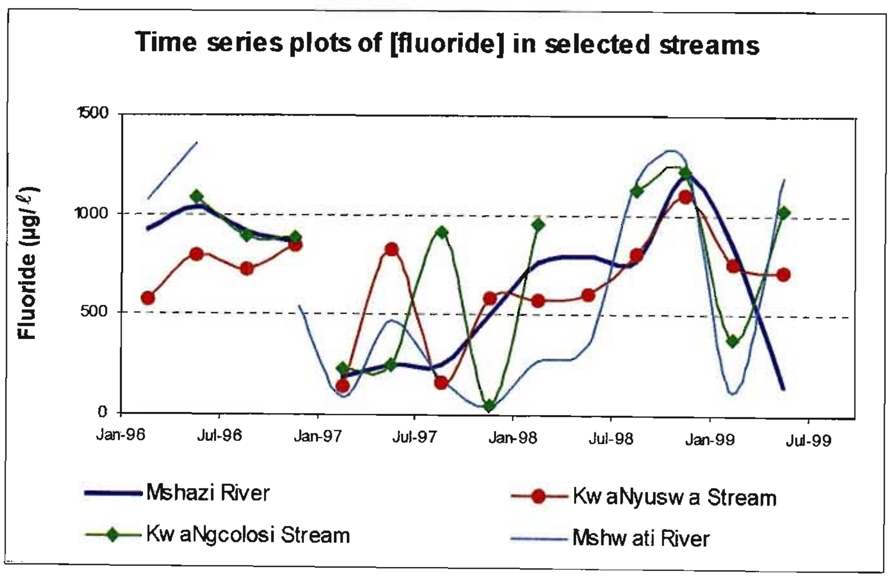


FIGURE 4.2: TIMES SERIES PLOT OF SELECTED STREAMS

The African Explosives and Chemical Industries (AECI) storm water discharge has high fluoride concentrations at least 20 percent of the time (Figure 4.3). The concentrations exceed 1.4 mg/ℓ at least 5 percent of the time i.e. the fluoride concentration of AECI storm water discharge exceeds the average fluoride concentration of sea water of 1.4 mg/ℓ (DWAF, 1996a) at least 5 percent of the time. This translates to a potential impact on the sea environment at least 5 percent of the time. It should however be noted that the fluoride concentrations have generally decreased.

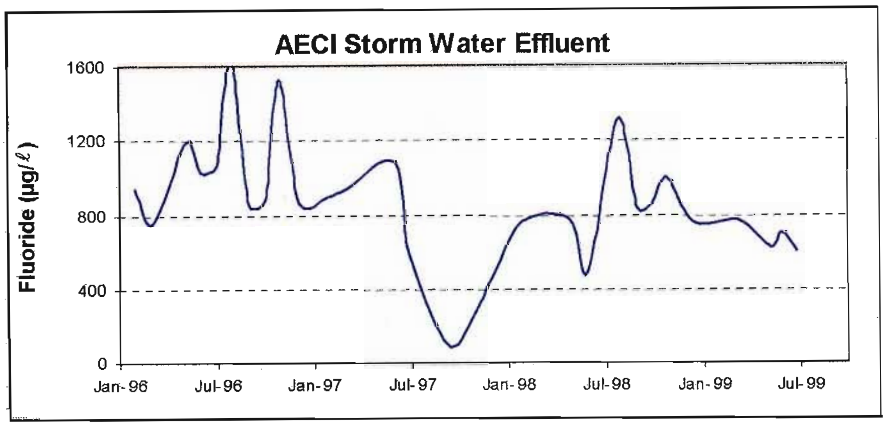


FIGURE 4.3: TIME SERIES PLOT OF THE AECI STORM WATER EFFLUENT

The Hammarsdale influent has high fluoride concentrations (>1 mg/ℓ) less than 5 percent of the time. However, the effluent concentrations were below the 1 mg/ℓ fluoride standard (DWAF standards) for effluent discharge. The high fluoride concentrations most likely arise from the effluent discharged from industries in the Hammarsdale area as the fluoride concentrations of the potable water in the area are low.

Since the natural concentration of fluoride in unpolluted surface water is typically 0.1 - 0.3 mg/ℓ, it is clear that the sites listed above indicate varying levels of pollution. Hence, users of this water, particularly for consumption may display symptoms of long-term exposure to high fluoride concentrations. In order to control further exposure, steps need to be taken to defluoridate the water and minimise health risks.

Surface water sites with fluoride concentrations greater than 0.7 mg/ℓ but less than 1 mg/ℓ are listed in Table 4.4.

TABLE 4.4 INTERMEDIATE FLUORIDE CONCENTRATIONS

	Summary Statistics - Fluoride (µg/ℓ)								
Sites	n	Minimum	25th Percentile	Average	Median	75th Percentile	80th Percentile	95th Percentile	Maximum
East Stream Inflow to Inanda Dam (site 44)	12	0.25	0.59	0.70	0.75	0.86	0.87	0.91	0.92
Slangspruit (site 61)	16	0.05	0.20	0.28	0.21	0.27	0.30	0.75	0.96
Isipingo above Umlazi WWW (site 108)	11	0.08	0.13	0.21	0.16	0.21	0.24	0.50	0.72

The east stream inflow to Inanda dam exceeded the fluoride standard of 0.7mg/ℓ and the target water quality range (of 0.75mg/ℓ) for aquatic ecosystems (DWAF, 1996b) at least 50 percent of the time. The Slangspruit exceeds these concentrations at least 5 percent of the time, while the Isipingo upstream of Umlazi WWW exceeded the fluoride standard less than 5 percent of the time.

Surface water sites where the concentration of fluoride is greater than 0.5 mg/ℓ but less than 0.7 mg/ℓ are listed in *TABLE 4.5*.

TABLE 4.5 RELATIVELY LOW RANGE FLUORIDE CONCENTRATIONS

	Summary Statistics - Fluoride (mg/ℓ)								
Sites	n	Minimum	25th Percentile	Average	Median	75th Percentile	80th Percentile	95th Percentile	Maximum
Mngeweni above Mgeni Confluence	14	0.15	0.39	0.40	0.42	0.47	0.49	0.51	0.52
Mgeweni Junction Cato Ridge Abattoir Effluent	13	0.03	0.05	0.15	0.07	0.21	0.21	0.47	0.54
Mgeni at Athlone Bridge surface	8	0.05	0.21	0.31	0.23	0.50	0.52	0.55	0.55
Mgeni at Ellis Brown surface	8	0.05	0.20	0.37	0.34	0.61	0.63	0.65	0.65
Blackboroughspruit	16	0.05	0.15	0.22	0.16	0.18	0.19	0.63	0.64
KwaWiliWili above Mlazi Confluence	14	0.16	0.27	0.38	0.34	0.51	0.53	0.58	0.62
Umzinto River at Wellpoint Abstraction	29	0.05	0.26	0.31	0.29	0.35	0.38	0.54	0.58
Umzinto Final	33	0.03	0.23	0.26	0.29	0.31	0.32	0.39	0.56
Imfume Final	109	0.05	0.33	0.38	0.40	0.47	0.48	0.58	0.65
Hammarsdale Effluent	81	0.05	0.28	0.35	0.34	0.41	0.44	0.57	0.68
AECI Grab Sea Outfall	18	0.17	0.21	0.30	0.30	0.36	0.41	0.46	0.48
AECI Grab Sea Outfall	19	0.03	0.21	0.31	0.26	0.44	0.46	0.51	0.68

An optimal level of 0.5 mg F/ℓ is likely to ensure the greatest protection against dental caries with the least risk of dental fluorosis or other health risks (Muller *et al.*, 1998). The median fluoride concentration in the Mngeweni upstream of the Mgeni river exceeds 0.40 mg/ℓ 50 percent of the time. Investigations could be done in this area to assess the level of dental caries on the consumers of this water (if any).

4.3.2 Borehole - "Hot Spots"

The fluoride concentrations of borehole waters are generally much higher than unpolluted surface water (DWAF, 1996a). Of the 286 boreholes sampled 17 boreholes (6% of all boreholes sampled) had fluoride levels in excess of 1 mg/ℓ. The fluoride concentrations of borehole water are presented in Figure 4.4.

- In terms of domestic use, long-term exposure to the fluoride concentrations 1 to 1.5 mg/ℓ, at boreholes JD26, C29, H19, CB7, 112/1, 69/5, Thembeni 108 and E&C Charcoal could lead to slight mottling of the dental enamel in sensitive individuals.
- Long-term consumption of water from borehole 77/1 could lead to marked dental mottling and tooth damage. According to DWAF (1996a) the threshold for marked dental mottling with associated tooth damage due to softening of enamel is 1.5 mg/ℓ.
- Continuous consumption of water from borehole JD27 (fluoride concentrations between 3.5 to 4 mg/ℓ - the threshold for chronic effects of fluoride exposure) could lead to severe tooth damage especially to infants' temporary and permanent teeth, softening of enamel and dentine could also occur.
- Long-term consumption of water from the Clansthal Caravan Park Borehole could lead to severe tooth damage with skeletal fluorosis. However, it is not likely that there would be "permanent" campers at this site and therefore the risk to health would be lessened. It is not likely that there would be long-term effects to the high fluoride concentration for occasional campers. However, campers should be warned of the high fluoride concentrations as it could impact on people that are sensitive to fluoride. These include, individuals with HIV infection, sub-optimal dietary calcium, liver or kidney disease, a high daily water intake and individuals on renal dialysis (Water Research Commission, 1998).
- Long-term consumption of water from Thembeni 105, Keats Drift borehole 1 and 2 could lead to severe tooth damage and crippling skeletal fluorosis.

Detailed health impact studies in the above areas should be undertaken to assess the effects of long-term exposure to high fluoride concentrations and advice should be given to consumers on defluoridation techniques.

4.4 Spatial Patterns and Sources of Fluoride

The fluoride concentration, based on domestic use, was plotted for borehole water (Figure 4.4). No obvious spatial patterns were observed. The 95th percentile values of fluoride concentrations of all surface water sites were plotted spatially (Figure 4.5). It was found that relatively high fluoride concentrations (0.7 to 1.5 mg/ℓ) were recorded in the Msunduzi river, the Mgeni river downstream of the Msunduzi confluence and along the coastal belt. Examination of the spatial patterns (Appendix 9) in conjunction with a landuse map indicates that the relatively high fluoride concentrations were recorded in surface water in urban areas. Urban activities such as domestic use of dental care products and industrial activities could give rise to higher fluoride concentration in surface water. It is evident that sites upstream of the urban area, along the Msunduzi river, have a lower fluoride concentration than sites in the urban area (Figure 4.6).

Fluoride compounds may arise from natural or man-made sources. According to Benefield *et al.* (1982), fluoride commonly occurs in the earth's crust as fluorspar (CaF_2), cryolite (Na_3AlF_6), and fluorapatite ($Ca_5(PO_4)_3F$). Benefield *et al.* (1982) also indicated that fluoride is present in seawater at concentrations of 1.4 mg/ℓ, and concentrations as high as 9 to 10 mg/ℓ are not uncommon in some ground waters. The source of most fluoride ions in surface water is weathering of the mineral fluorapatite, $Ca_5(PO_4)_3F$ (Baird, 1995). However, Gehr and Choueiri (1998), explain that the marked insolubility of most natural fluorides limit their diffusion in water. This implies a low level of contamination of surface water through natural sources.

Apart from the natural sources, fluoride has been relocated and concentrated in the environment as a result of industrial activities. Fluoride is present in large quantities in effluents from glass manufacture, electroplating operations, aluminium and steel production and manufacture of electronic parts. In addition to this, large quantities of fluorides are released when fertilizer is manufactured from phosphate rock containing fluorapatite (Benefield *et al.*, 1982).

Consequently, if the concentration of fluoride in surface water is substantially higher than 0.1 - 0.3 mg/ℓ, it can be deduced that the source of fluoride is most likely associated with pollution activities.

Possible sources of high fluoride concentration at the "hot spots" were investigated by using topographic data (Figures 4.7 to 4.9), by overlaying landuse (Figure 4.6), geology and soils data with fluoride data, and through consultation with Water Quality Scientists at Umgeni Water. For surface water, the fluoride sources were found to be mainly industrial activity and geology (Terry, 2000).

- The Mshazi, Kwanyuswa and KwaNgcolosi are all minor inflows to Inanda Dam, situated within the Valley of a Thousands Hills (Figure 4.7). This landuse in this area is primarily semi-rural to transitional settlements and the source of the high fluoride concentrations can probably be attributed to the impact of the weathering of igneous rocks such as granites that are intrusive in the area (Terry, 2000).
- Smelting and aluminium recovery plants normally use fluxing agents such as sodium fluoride in their production processes and according to (Gehr and Choueiri, 1998) for decades, the aluminium industry has been known to be at the origin of most of the fluoride emissions into the environment. In addition Benefield *et al.* (1982) states that large quantities of fluorides are released when fertilizer is manufactured from phosphate rock containing fluorapatite. The Mshwati is a tributary of the Msunduzi river and is a home to some industries such as Feralloys (a smelting plant), an aluminium recovery plant and a fertilizer production plant that are likely sources of fluoride (Terry, 2000), however, more detailed investigations are required to support this contention. Other industries in the area such as a hide and skin tannery south of the Lion Park, a water treatment plant, and the Umlaas Road Water Works do not use fluoride compounds in their treatment process and therefore are not fluoride sources.

- The MgoShongweni stream is a tributary of the Mlazi river, downstream of the Shongweni dam (Figure 4.9). This stream drains the Enviroserve Hazardous Waste Disposal Site (class H:h which include hazardous but not highly hazardous substances), which is the source of fluoride. The waste disposal site contains many types of industrial waste including fluoride sources such as electroplating wastes, metal processing and refining wastes. The waste disposal site is not leak proof, as the storm dams that contain the leachate have been washed out many times during floods and high rainfall, contaminating the surface and ground water that drains into the MgoShongweni (Terry, 2000).
- The high fluoride concentration in the storm water site at AECI most likely arises from the AECI effluent as a result of the chemical activities at this industrial plant. A detailed survey is required to prove this.
- The high fluoride concentration in the Hammarsdale effluent most likely arises from effluent discharged from some industries in the Hammarsdale area. A detailed survey is required to prove this.

To determine whether the borehole fluoride concentrations were dependent on the underlying geology (Figure 4.10), borehole fluoride concentrations were separated into three ranges (low = <0.5mg/ℓ; medium between 0.5mg/ℓ and 1mg/ℓ; high >1mg/ℓ) and the number per range for each geological type was tabulated. The Chi-Squared test was then performed on these data (Appendix 12). The calculated chi-squared (47.4) was found to be greater than the table value of 36.4 (24 degrees of freedom) at the alpha level of 0.05. Hence, the varying fluoride concentrations (low, medium and high range) can be said to be dependent on the underlying geology. However, closer examination of the data would be required to determine which geology types are associated with high fluoride concentrations.

The Chi-Squared test was also performed on the data (Appendix 13), to determine whether the borehole fluoride concentrations were associated with the distance from fault lines. The calculated chi-squared (11.0) was found to be less than the table value of 21.0 (12 degrees of freedom) at the alpha level of 0.05. Hence, the varying fluoride concentrations are not dependent on the distance from fault lines.

The depth of boreholes could also have been related to fluoride concentrations, however this information was not available.

FIGURE 4.4: SPATIAL REPRESENTATION OF BOREHOLE "HOT SPOTS" AND ITS FITNESS FOR DOMESTIC USE

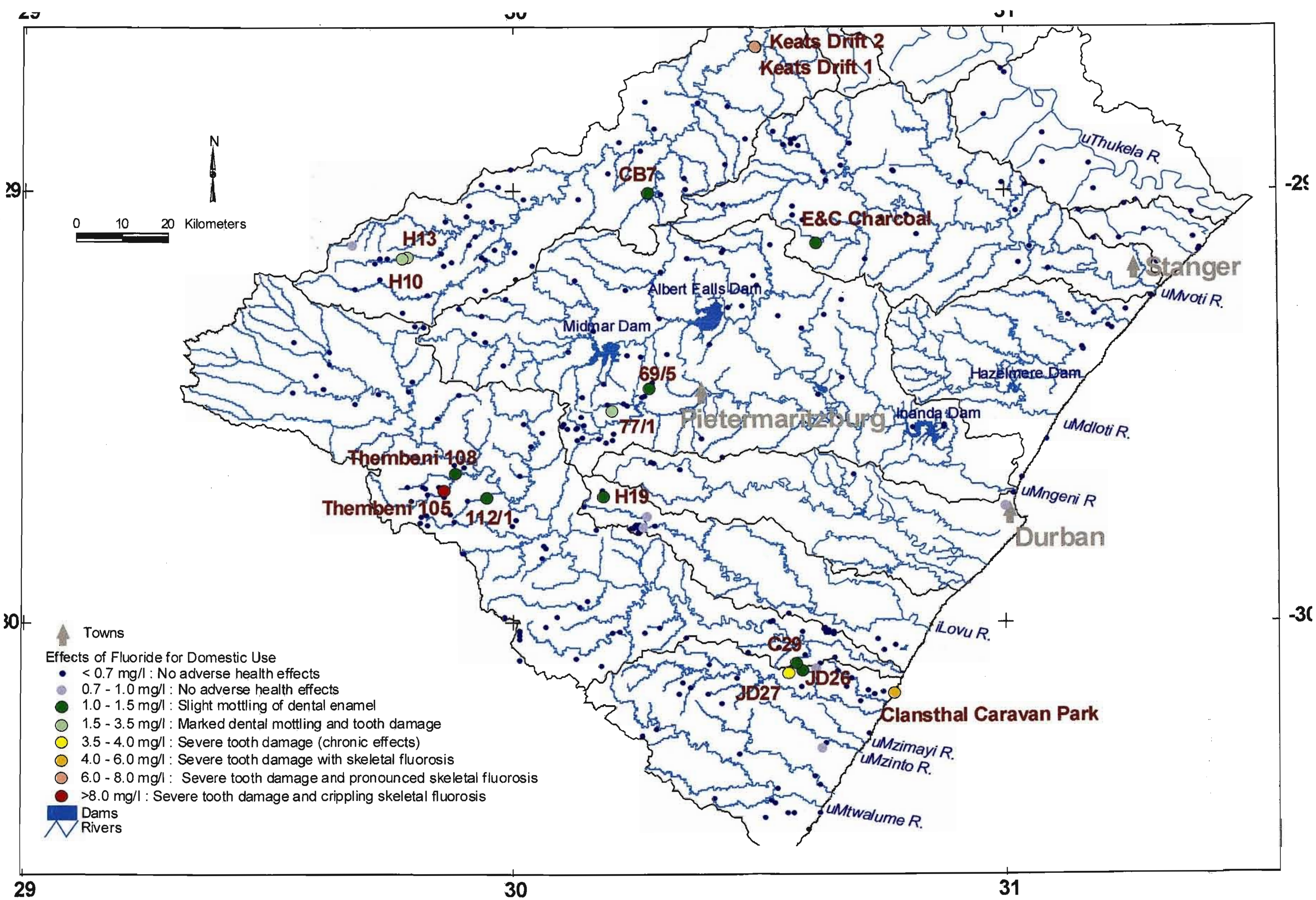


FIGURE 4.5: SPATIAL DISTRIBUTION OF FLUORIDE IN SURFACE WATER IN THE UW OPERATIONAL AREA

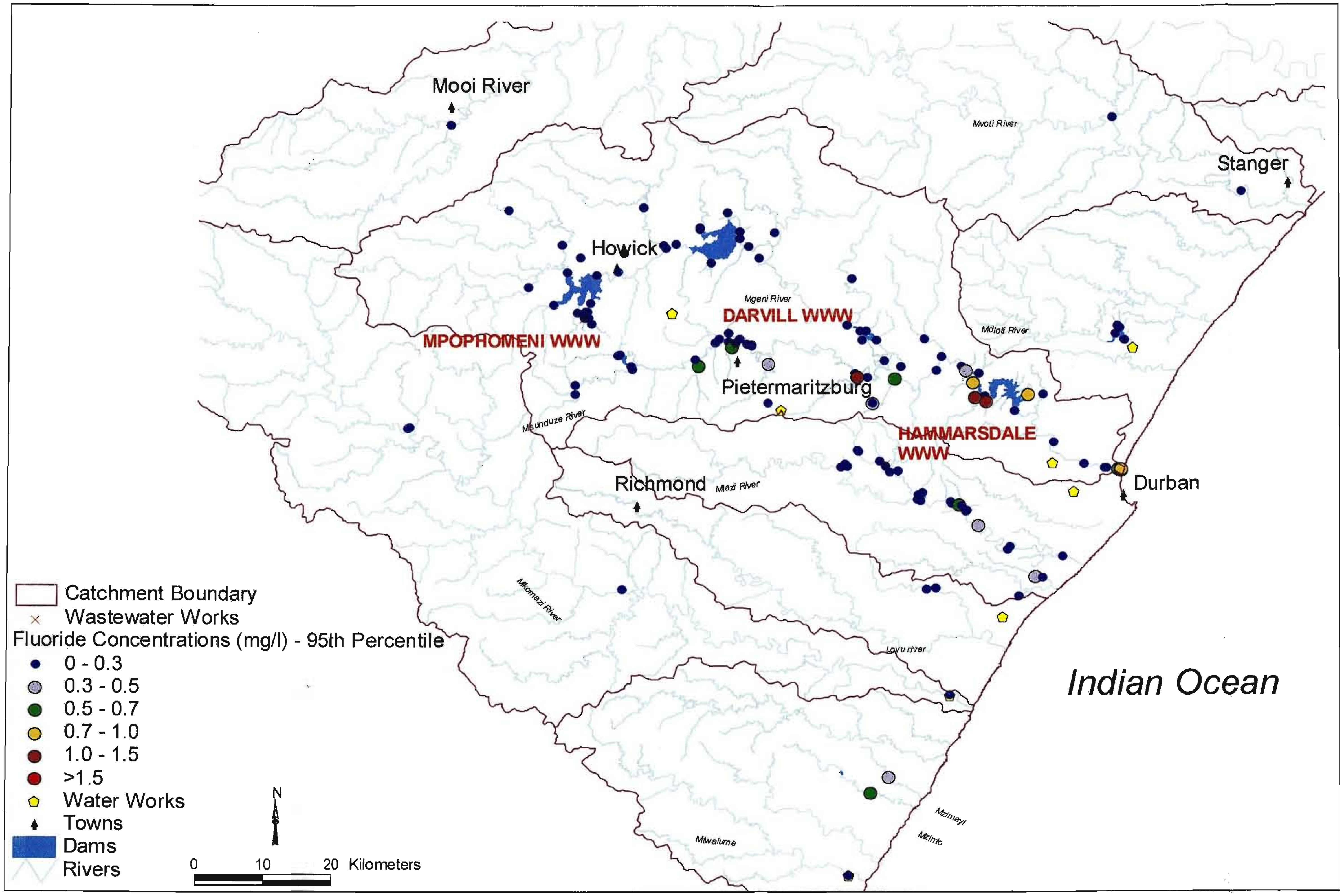


FIGURE 4.6 : LANDUSE AND SURFACE WATER FLUORIDE CONCENTRATIONS

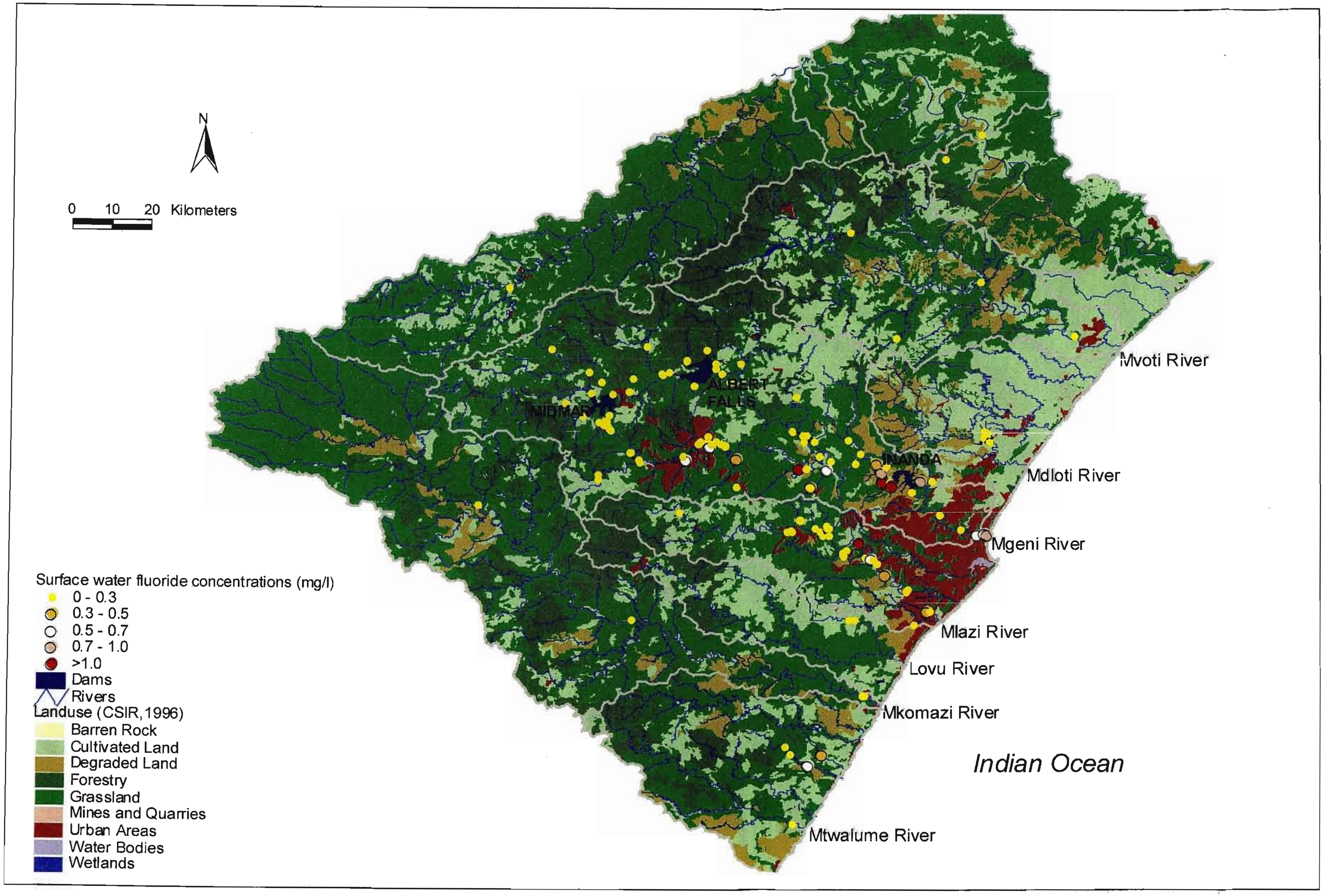


FIGURE 4.7: TOPOGRAPHICAL MAP SHOWING MSHAZI, KWANYUSWA AND KWANGCOLOSI INFLOWS TO INANDA DAM

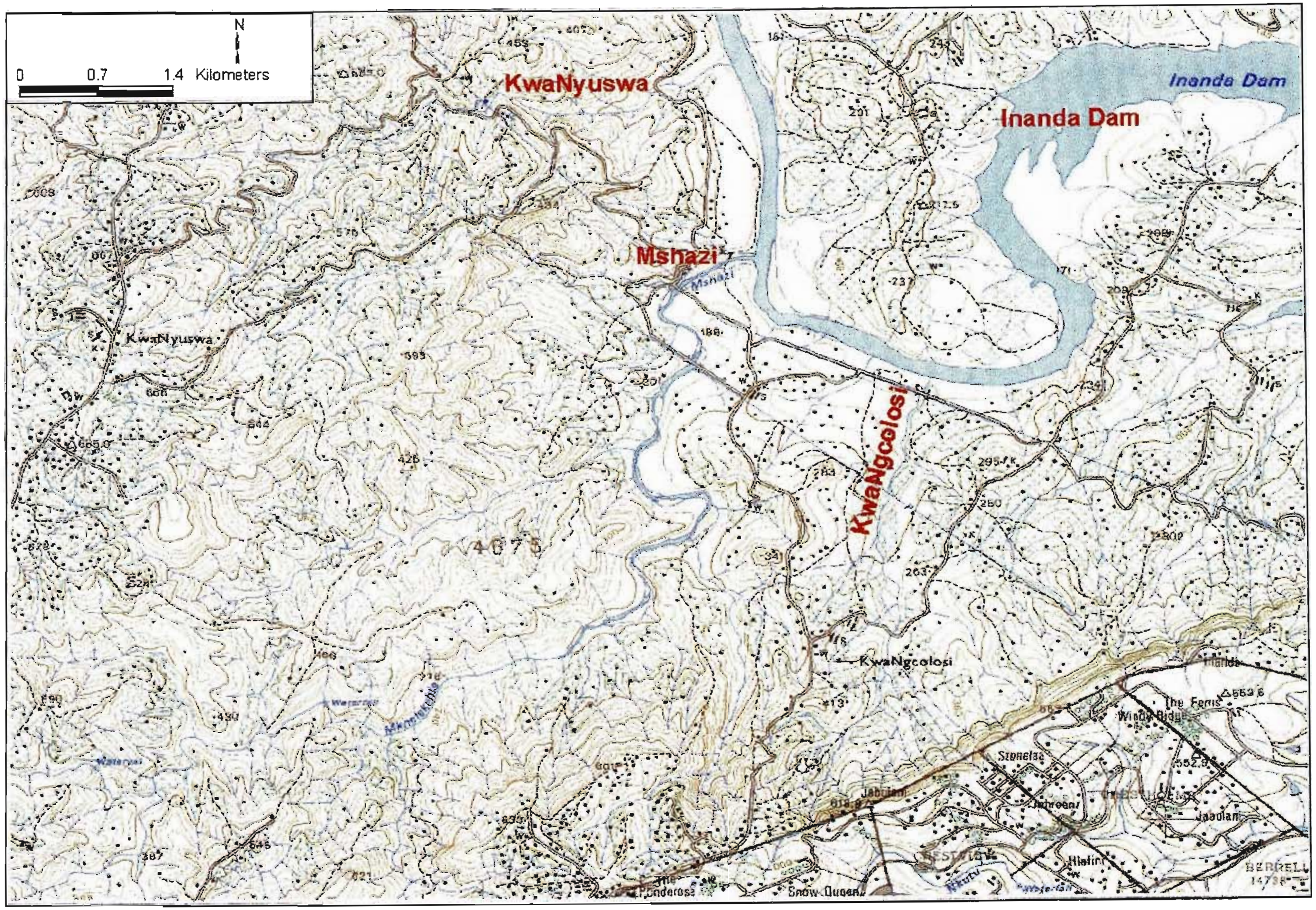


FIGURE 4.8: TOPOGRAPHICAL MAP SHOWING THE FLUORIDE SOURCES OF THE MSHWATI STREAM

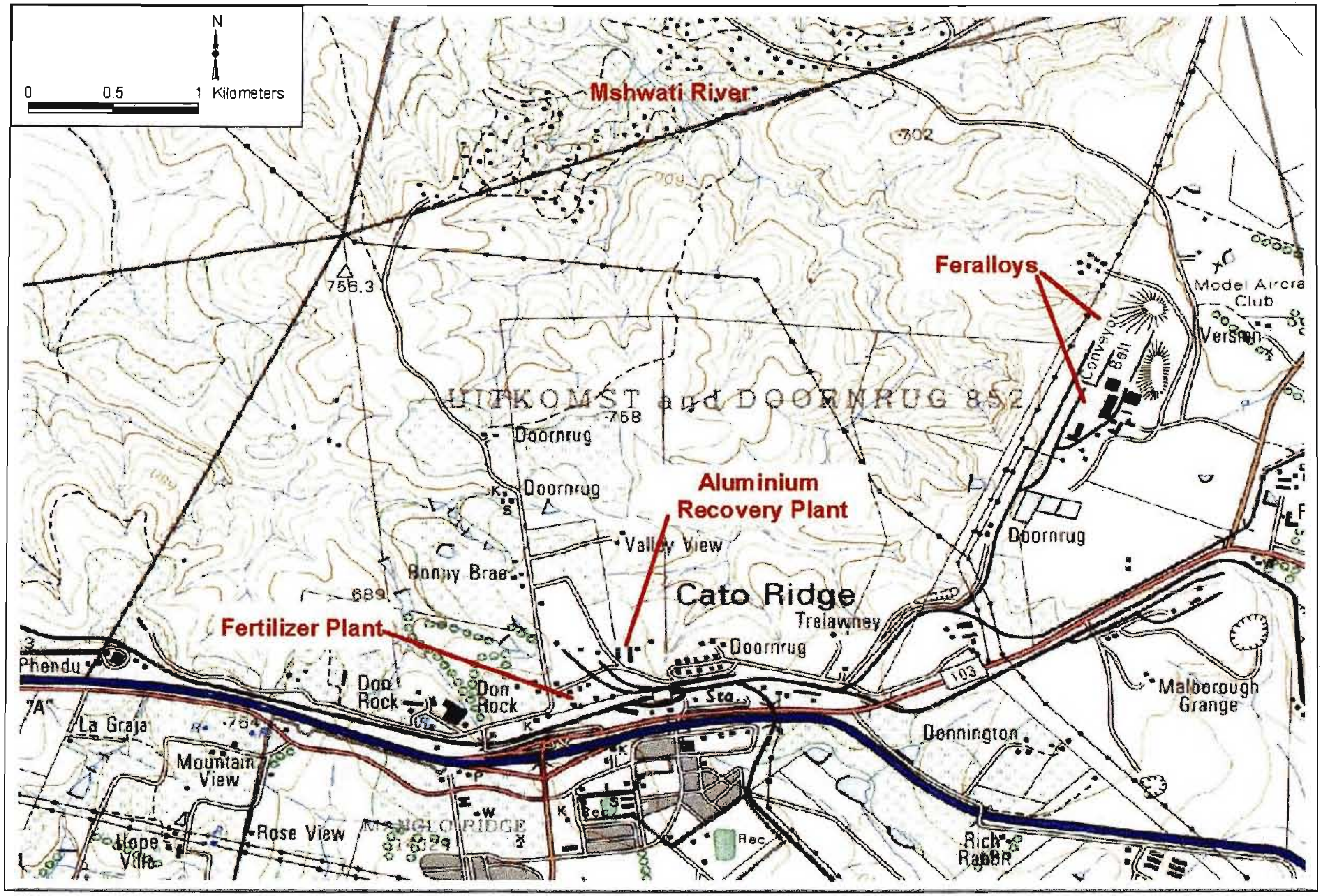


FIGURE 4.9: TOPOGRAPHICAL MAP SHOWING THE MGOSHONGWENI CATCHMENT

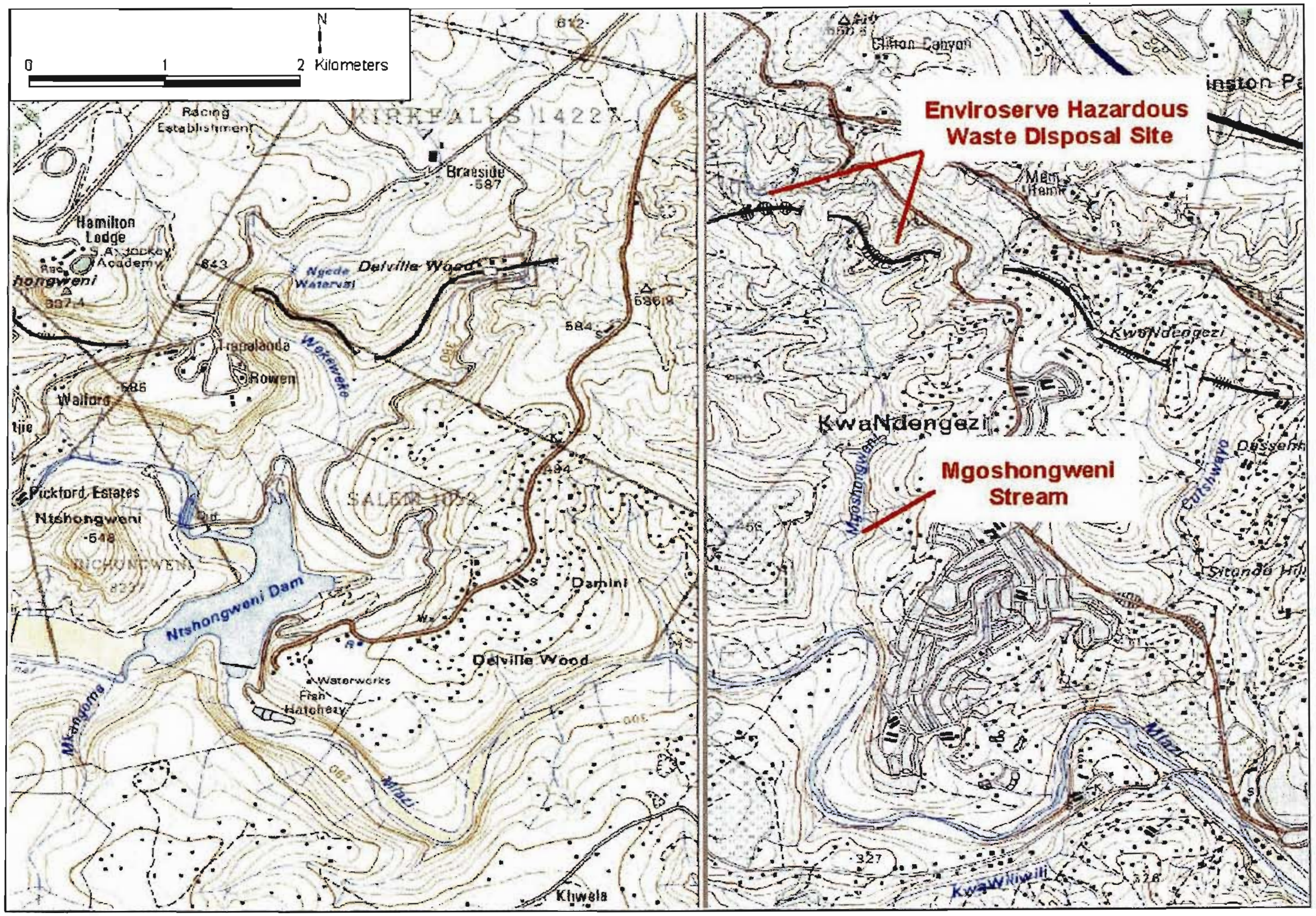
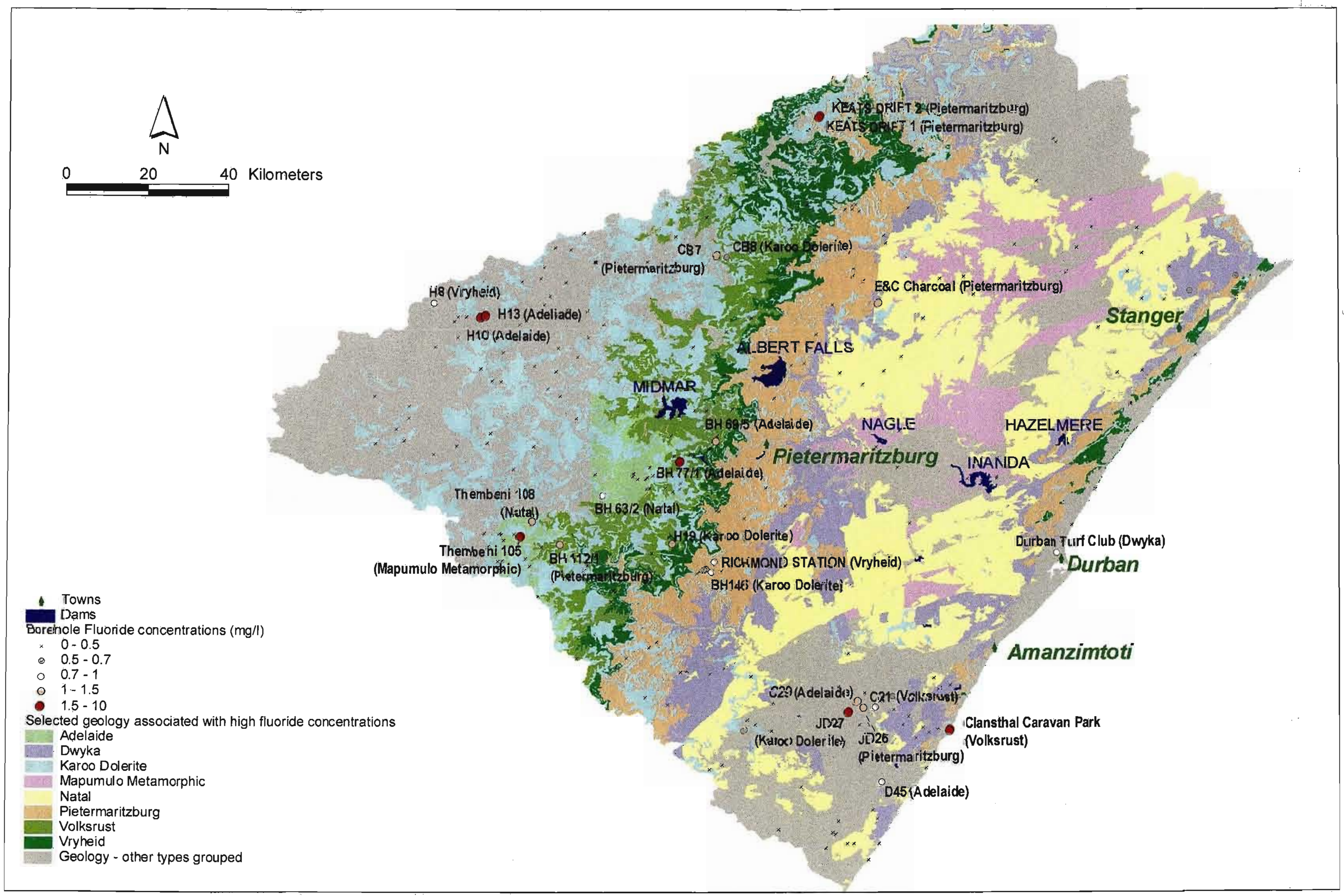


FIGURE 4.10 :BOREHOLE WATER FLUORIDE CONCENTRATIONS AND ASSOCIATED GEOLOGY



4.5 ADDITIONAL FLUORIDE DOSAGE AT UMGENI WATER'S WATER TREATMENT WORKS.

The amount of fluoridating agent (sodium fluoride, sodium fluorosilicate and fluosilicic acid) required to increase the fluoride concentrations to the fluoride standard of 0.7 mg/ℓ will depend on the baseline fluoride concentration of the water works raw or final water. The fluoride concentrations of the final water were used to estimate the additional fluoride dosage required to meet the proposed fluoride concentration (Table 4.6). The mass of fluoride required to be added at the waterworks per annum is also shown in Table 4.6.

TABLE 4.6. ADDITIONAL FLUORIDE DOSAGE REQUIREMENT

Water Works	Mean baseline F^- concentration (mg/ℓ)	Mean additional F^- required (mg/ℓ)	Mean Dosage Requirement per Mℓ		
			NaF (kg/Mℓ)	Sodiumfluorosilicate (kg/Mℓ)	Fluosilicic acid (ℓ/Mℓ)
Amanzimtoti	0.051	0.649	1.553	1.093	3.149
Midmar	0.053	0.647	1.548	1.089	3.139
DV Harris	0.055	0.645	1.545	1.087	3.132
Durban Heights	0.057	0.650	1.555	1.094	3.153
Hazelmere	0.136	0.564	1.349	0.949	2.735
Wiggins	0.137	0.563	1.347	0.948	2.731
Ixopo	0.160	0.540	1.293	0.910	2.622
Ogungini	0.164	0.536	1.283	0.902	2.601
Mtwalume	0.198	0.502	1.201	0.845	2.436
Umzinto	0.245	0.455	1.090	0.767	2.210
Imfume	0.379	0.321	0.768	0.540	1.557

With the exception of Imfume and Umzinto, the final water fluoride concentration at most of the works is below 0.2 mg/ℓ on average. This indicates that additional fluoride (1.201 to 1.555 kg/Mℓ of sodium fluoride) will be required to meet the proposed 0.7 mg/ℓ standard for potable water. Mean fluoride concentrations for Imfume and Umzinto were 0.379 mg/ℓ and 0.245 mg/ℓ, respectively. This indicates that a smaller amount of fluoride (0.768 and 0.109 kg/Mℓ of NaF) would be needed to increase the fluoride level to the proposed standard at these treatment works. It should be noted that the above calculations are based on mean results and that in reality the fluoride concentrations fluctuate (Appendix 6). Hence, adjustments will have to be made in calculating the actual fluoride requirement based on the fluoride concentrations of the final water (at the various water works) at the time.

The additional fluoride dosage required to meet the proposed standard would incur many costs to Umgeni Water, these include, purchase and installation of fluoridating equipment, training of operators, fluoridating agents, monitoring of fluoride concentrations, environmental impact assessments, etc. These estimates were not available for reference. However, the cost and benefits of water fluoridation using Resource Environmental Economics could be estimated to decide whether fluoridation is sustainable.

4.6 Comparison Of Influent And Effluent Fluoride Concentrations At Wastewater Works

During wastewater treatment processes, a large number of microbes and many chemical substances are removed from the influent, resulting in lower concentrations of microbes and chemical substances in the effluent. This is done so that the water quality variables meet effluent discharge standards (the standard for fluoride is 1 mg/ℓ) that are set by the Department of Water Affairs and Forestry. Wastewater works operated by Umgeni Water do not have defluoridation mechanisms in their processes. It was decided to compare the fluoride concentrations of the influents and effluents at Darvill, Hammarsdale and the Mpophomeni WWW's to establish statistically whether there is any loss or removal of fluoride during the current treatment process. The data sets were found to be not normally distributed (instead skewed to the right, see Appendix 10) the Wilcoxon Matched Pairs Test, was used to compare the fluoride data for influents and effluents (Table 4.7).

Table 4.7. Results of Wilcoxon Matched Pairs test - Comparison of fluoride data for influents and effluents

Wastewater Works	|Z|-Statistic (95% C L)	Sites Significantly Different (Z > 1.96)
Mpophomeni	0.73	Not significantly different
Hammarsdale	2.52	significantly different
Darvill	5.51	significantly different

C L : Confidence limit

The influent and effluent results for Mpophomeni were found to be not significantly different at the 95 percent confidence limit (Table 4.7), indicating no removal of fluoride during the treatment process. The results are illustrated using time series (Figure 4.11).

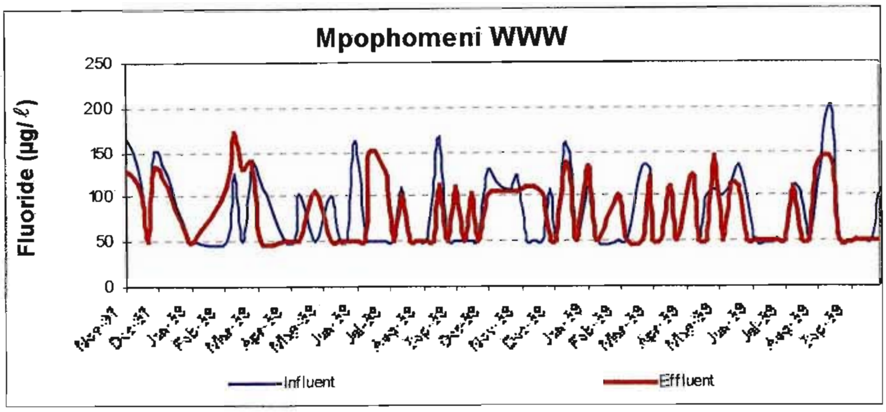


FIGURE 4.11: TIME SERIES GRAPH OF FLUORIDE DATA FOR MPOPHOMENI WWW

For Darvill WWW, the influent and effluent fluoride concentrations were found to be significantly different with the fluoride concentrations lower in the effluent (Table 4.7), indicating some removal of fluoride during the treatment process. The results are illustrated in Figure 4.12. This loss of fluoride was found to be 22.4 percent and was most likely removed by the activated sludge process at this wastewater works, resulting in a loss of fluoride from the influent and a gain in fluoride concentration in the sludge. This implies that the fluoride concentrations of the sludge would need to be monitored to assess the impact of sludge fluoride on the environment.

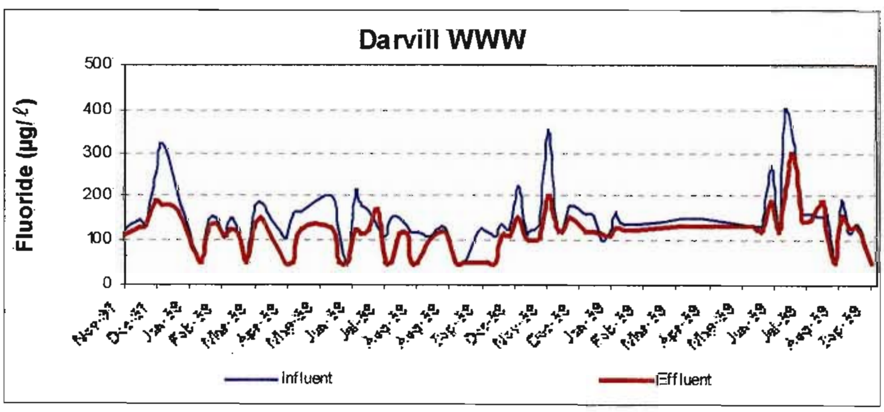


FIGURE 4.12: TIME SERIES GRAPH OF FLUORIDE DATA FOR DARVILL INFLUENT AND EFFLUENT

The influent and effluent results for Hammarsdale were found to be significantly different, with the fluoride concentrations of the effluent generally higher than those of the influent (Table 4.7). Consequently, it was not possible to estimate the percentage fluoride removal due to treatment. A possible reason for the discrepancy could be that the influent and effluent data were not actual pairs and it is necessary to consider a process time of approximately three days when carrying out the estimate. Closer examination of the graph (Figure 4.13) does appear to indicate a slight lag in the response time. Due to insufficient monitoring (weekly monitoring versus 3-day lag) the calculations could not be repeated to include the lag factor.

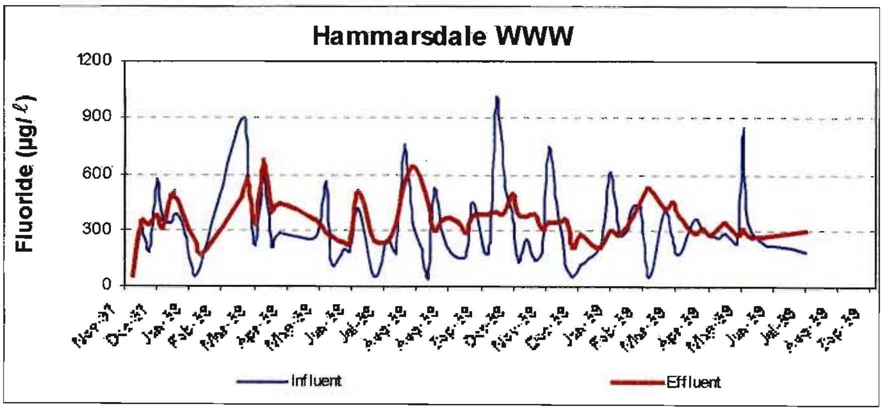


FIGURE 4.13: TIME SERIES GRAPH OF FLUORIDE DATA FOR HAMMARSDALE INFLUENT AND EFFLUENT

4.7 CALCULATION OF FUTURE FLUORIDE LEVELS IN SURFACE WATER THAT WILL RECEIVE RETURN FLOWS.

The impact of the Darvill Wastewater Works return-flows, to the Msunduzi river which drains into the Inanda impoundment, was calculated and the results displayed in Figure 4.14 and Table 4.8. This was used to predict the concentration of fluoride that will pertain in the raw water to the Wiggins water works abstracted from the Inanda impoundment. The flow and fluoride concentrations used for the load calculations are presented in Appendix 11.

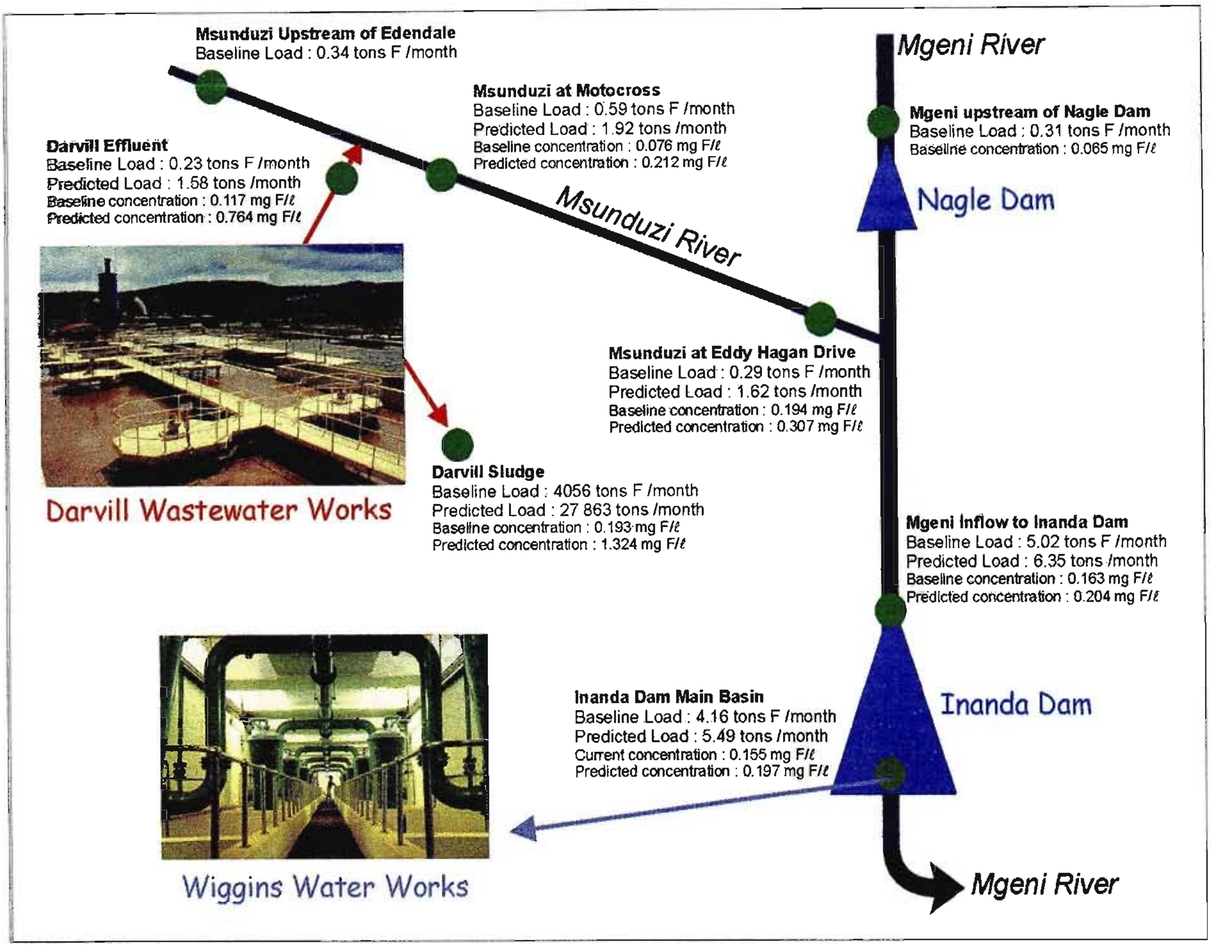


FIGURE 4.14: SCHEMATIC DIAGRAM OF THE POTENTIAL IMPACT OF DARVILL EFFLUENT AFTER FLUORIDATION OF POTABLE WATER

TABLE 4.8 FLUORIDE LOADS FROM DARVILL WWW TRACED TO INANDA DAM

	Average Fluoride Load (tons / month)								Fluoride conc. (mg/ℓ)
	Duzi Upstream of Edendale	Darvill Effluent	Darvill Sludge	Duzi at Motocross	Duzi at Eddy Hagan	Nagle Dam Inflow	Inanda Dam Inflow	Inanda Dam Main Basin	Inanda Dam Main Basin
Current	0.34	0.23	4 056	0.59	0.29	0.31	5.02	4.16	0.155
After Fluoridation	0.34	**1.58**	27 863	1.92	1.62	0.31	**6.35**	**5.49**	**0.197**

With reference to Figure 4.8, the average fluoride load per month in the Msunduzi river upstream of Edendale is 0.34 tons and the load downstream of Pietermaritzburg City is 0.59 tons (at the Motocross). The load from the cities wastewater works, Darvill (0.23 tons), contributes towards the difference. After fluoridation of potable water, the fluoride concentration of the Darvill effluent is expected to increase from 0.117 to 0.764 mg/ℓ, thus complying with the fluoride standard of 1 mg/ℓ for effluent discharge (National Water Act, 1956). The increase in the Darvill effluent concentration from 0.117 mg/ℓ to 0.764 mg/ℓ would cause an increase in the fluoride concentration of the Msunduzi river from 0.076 mg/ℓ to 0.212 mg/ℓ. This could significantly impact the *Daphnia* population, and cause fluoride induced reduction of food supply for fish and other aquatic life, according to Foulkes and Anderson (1994), who claim that artificial fluoride concentrations as low as 0.1 mg/ℓ have been shown to be lethal to the water flea, *Daphnia magna*. The effect of increased fluoride concentrations on *Daphnia* can be determined by analysing the samples for possible toxicity.

The reason for the Darvill effluent discharge being raised above 0.7 mg/ℓ is that the City's activity (industrial and use of fluoridated dental care products) raises the present influent concentration at Darvill WWW by 0.64 mg/ℓ. The average monthly fluoride load discharged from Darvill Wastewater Works would increase from 0.23 tons to 1.46 tons, an additional 1.23 tons per month on the aquatic environment of the Msunduzi river. With water fluoridation, the baseline fluoride load for Darvill sludge is likely to increase from 4 056 tons/month to 27 863 tons/month. This is a significant increase in fluoride loads that would be disposed off to the sludge-lands, and indicates an increased potential impact on the Msunduzi river.

The average monthly fluoride load to Inanda dam main basin is predicted to increase from 4.16 to 5.37 tons resulting in the fluoride concentration of the water abstracted from Inanda dam for treatment at the Wiggins Water Works increasing from 0.155 mg/ℓ to 0.197 mg/ℓ.

According to legislation, a water provider will be required to carry out an environmental impact assessment of the catchment receiving return flows resulting from fluoridated water so that full impact of this fluoride load on the environment can be estimated.

4.8 Estimate of the number of people in 'sensitive groups' that would be affected by water fluoridation.

Estimate of children up to the age of three years:

The South African census data for 1996, indicate for KZN there are 110 755 children between the ages of zero and four years old. If it is assumed that three quarters of this number of children are between the ages of zero to three years, then at least 83 066 babies in KwaZulu - Natal could be sensitive to fluoridated water.

KZN's population is 8, 4 million, according to the South African census data for 1996. This implies that the ratio between sensitive children to total population in KZN is 83 066 : 8 400 000 or 9.89%. Since Umgeni Water sells water to approximately 6 million people (Umgeni Water, 2001) it would imply that approximately 606 673 babies could be sensitive to fluoridated water, supplied by Umgeni Water.

Estimate of the number of people that are malnourished:

According to the Preliminary State of the Environment Report, 57% of the households in KwaZulu-Natal live in poverty. If these individuals are malnourished, there would be a potential for about 57% of the population in KZN being sensitive to water fluoridation. It would therefore be necessary to undertake health impact assessments to establish the effects of water fluoridation on people that belong to these sensitive groups.

Estimate of the number of people that are infected with HIV:

Of the 8.4 million people living in KwaZulu-Natal one out of every three people are infected with HIV. This implies that one third of the KZN population could be sensitive to fluoridated water.

Other groups of people that are sensitive to fluoride (WRC, 1998), showing significant sensitivity to fluoride concentrations between 0.7 and 1 mg/ℓ, are as follows :

- individuals with suboptimal dietary calcium;
- individuals with liver or kidney disease;

- individuals with a high daily water intake;
- individuals on renal dialysis.

Due to a lack of data, the number of individuals in these groups could not be estimated.

4.9 LIMITATIONS OF THE METHODOLOGY ADOPTED.

Baseline fluoride concentrations of surface and ground water: The baseline fluoride concentrations for boreholes were limited to once off grab samples. A better estimate of the baseline data could have been achieved with a larger sample set with adequate seasonal data.

Temporal variations and seasonality: The water quality software, WQ Stat, uses the Kendall Tau Test and Sen Slope estimate for trend analysis and is highly recommended by Ward *et al.*, (1990). However, this software was not available and the estimate of temporal variations in this study is therefore limited.

Identification of "Hot Spots": For boreholes, the data were limited to once off sampling. A better estimate of the borehole "hot spots" could have been achieved with larger data sets.

Spatial patterns and possible sources of high fluoride concentrations: The assessment of the relationship between borehole fluoride concentration and geology provided a response of fluoride concentration to a single variable, geology. However, the fluoride concentration of borehole water can be dependent on many factors such as, geology, depth of borehole, distance from fault lines, retention times etc. However, apart from geology and borehole distance from fault lines, the other data were not available. A better estimate of the response of fluoride concentration could be achieved if a multiple regression was used on all the explanatory variables.

Calculation of the additional fluoride dosage at water treatment works: The calculation of the additional fluoride dosage was restricted to using the legislated standard of 0.7 mg/ℓ. Epidemiological work done in the Free State Goldfields during 1991 and 1992 revealed that for the High Veld of South Africa, 0.55 mg/ℓ is the optimum concentration of fluoride (Plessis, 1998). Plessis (1998), also indicated that the optimal value calculated in the investigation would be valid for the Johannesburg, Soweto and Vereeniging areas and that the Natal coastal areas, especially Durban and the North coast, will have to start with lower fluoride concentrations due to higher annual average maximum temperature than Johannesburg and slowly build up as evidence of safety is gathered. Since the optimal fluoride concentration is expected to be lower than 0.55mg/ℓ, an estimate of the additional fluoride dosage required would be lower than that calculated against the legislated standard of 0.7mg/ℓ. If the additional dosage required is significantly low and does not justify the expense of fluoridating water, then this information could be used in decision-making. However, this estimate could not be made because regional optimal fluoride concentrations have not been calculated by the Department of Health.

Comparison of influent and effluent fluoride concentrations at wastewater works: It was not possible to estimate the percentage fluoride removal for the Hammarsdale Wastewater Works with the existing data, since the monitoring frequency of the wastewater works was greater than the process time of three days, from influent to effluent.

Calculation of future fluoride levels in surface water that will receive return flows: The fluoride loads into the Msunduzi and Mgeni rivers can be considered to be conservative estimates for the following reasons:

- It was assumed that there is only one wastewater works and one sludge land in the system but this is not necessarily the case;
- The model did not take into account the fluoride loads arising via storm water drains as a result of washing activities.

Estimate of the number of people in sensitive groups that could be affected by water fluoridation: The estimate of people that are HIV positive is conservative and did not take into account the increasing trend of HIV infections in KZN. Data for many of the “sensitive groups” were not available. These groups are individuals with sub-optimal dietary calcium, individuals with liver or kidney disease, individuals with high daily water intake, and individuals with renal dialysis.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Baseline fluoride concentrations of surface and ground water:

It was concluded that the fluoride concentration of all sample types (rivers, dams, water works raw and final waters, wastewater influent and effluents, and boreholes), except pollution point sources, is less than 0.5 mg/ℓ, 50 percent of the time. Some rivers (Mshazi, KwaNyuswa, KwaNgcolosi, Mshwati and the MgoShongweni) exhibited high fluoride concentrations, while some boreholes also exhibited high fluoride concentrations.

Temporal Variations and Seasonality:

There is a significant seasonal trend in fluoride concentrations for surface waters, with higher fluoride concentrations in winter than in summer (64 out of 125 occasions). This low fluoride concentration in summer can be attributed to the dilution effects caused by rainfall runoff during summer.

Identification of "Hot Spots":

"Hot Spots", sites where the fluoride concentration exceeds 1 mg/ℓ are present within the study area, for surface and borehole water. For surface water, the MgoShongweni exhibited fluoride concentrations in excess of 1mg/ℓ at least 75% of the time. The KwaNgcolosi and Mshwati exhibited fluoride concentrations in excess of 1mg/ℓ at least 25% of the time, while the Mshazi and the KwaNyuswa exhibited fluoride concentrations in excess of 1mg/ℓ only 5% of the time.

The storm water discharge below AECI had high fluoride concentrations in excess of 1mg/ℓ at least 20% of the time. These concentrations exceeded the fluoride concentration for seawater (1.4 mg/ℓ) at least 5% of the time.

Of the 286 boreholes sampled, 17 boreholes (6% of all boreholes sampled) had fluoride levels in excess of 1 mg/ℓ. The impacts of long term consumption of water from these boreholes ranged from slight mottling of the dental enamel in sensitive individuals (boreholes JD26, C29, H19, CB7, 112/1, 69/5, Thembeni 108 and E&C Charcoal) to severe tooth damage and crippling skeletal fluorosis (Thembeni 105, Keats Drift boreholes 1 and 2).

Spatial patterns and possible sources of high fluoride concentrations:
With respect to spatial patterns, relatively high concentrations of fluoride (300 to 1000 µg/ℓ) can be found in surface water in the Msunduzi river, the Mgeni river downstream of the Msunduzi confluence and along the coastal belt. No spatial patterns are evident with respect to borehole water.

For surface water, high fluoride concentrations in the Mshazi, KwaNyuswa and the KwaNgcolosi streams (inflows to the Inanda dam) appear to be associated with the catchment geology. The high fluoride concentrations in Mshwati and the MgoShongweni are most likely as a result of industrial activities in the respective catchments. For borehole water, high fluoride concentrations may be attributed to catchment geology. There was no association between fluoride concentrations and distance of boreholes from fault lines.

Additional fluoride dosage at water treatment works:
Since the fluoride concentrations at the water works were low (mean ranging between 0.5 mg/ℓ to 0.38 mg/ℓ), fluoride would need to be added to meet the fluoride standard of 0.7 mg/ℓ. For most of the water works, the additional fluoride (sodium fluoride) requirement to meet the fluoride standard of 0.7 mg/ℓ, were between 1.201 to 1.555 kg/Mℓ. For the water works, Imfume and Umzinto, the additional fluoride requirement is 0.768 and 0.109 kg/Mℓ respectively. In final water, the fluctuations in fluoride concentrations observed would translate to continuous testing being required to maintain optimal dosing of fluoride.

Comparison of influent and effluent fluoride concentrations at wastewater works:

There was no evidence of fluoride removal at the Mpophomeni Wastewater Works. There was evidence of 22.4% fluoride removal at the Darvill Wastewater Works possibly due to the activated sludge treatment process at the wastewater works. An estimate of the percentage fluoride removal for the Hammarsdale Wastewater Works was not done due to insufficient data.

Future fluoride levels in surface water that will receive return flows:

Once water fluoridation is implemented, the Darvill Wastewater Works would receive fluoridated return flows, and discharge its fluoride rich effluent into the Msunduzi river. The fluoride concentration of the Darvill effluent is expected to increase from 0.117 to 0.764 mg/ℓ, complying with the 1mg/ℓ fluoride standard for effluents. This could significantly impact the *Daphnia* population, and cause fluoride induced reduction of food supply for fish and other aquatic life, according to Foulkes and Anderson (1994), who claim that artificial fluoride concentrations as low as 0.1 mg/ℓ have been shown to be lethal to the water flea, *Daphnia magna*. In addition the average monthly fluoride load discharged from Darvill Wastewater Works would increase from 0.23 tons to 1.46 tons, an additional 1.23 tons per month on the aquatic environment of the Msunduzi river. The sludge fluoride load that is disposed to land could increase from 4 056 tons/month to 27 863 tons/month, which implies an increase in the fluoride runoff potential from the sludge-lands to the Msunduzi river.

Number of people in sensitive groups that could be affected by water fluoridation:

At least 83 066 children in KZN up to the age of three years could be sensitive to fluoridated water. More specifically, approximately 606 673 babies could be sensitive to water fluoridated by Umgeni Water. About 57% of KZN's malnourished population can be sensitive to fluoridated water. A significant number of people, least one third of KZN's population, could be sensitive to fluoridated water since they are HIV infected.

5.2 RECOMMENDATIONS

Baseline fluoride concentrations of surface and ground water:

To ensure that the fluoride levels in surface water remains within the target water quality range for aquatic ecosystems, it is recommended that the fluoride concentrations of surface water be monitored and that an increase in fluoride concentration in excess of 20% of the seasonal median be reported and investigated.

Temporal Variations and Seasonality:

It is recommended that where the daily fluoride concentrations are not available at a water treatment works, the seasonal fluctuations be considered when estimating the additional fluoride concentrations required for dosage to meet the legislated requirement.

Identification of "Hot Spots":

For surface water sites identified as hot spots, it should be established whether rural people use this as a drinking water source. If these sites are used as drinking water sources then, rural people should be advised of defluoridation techniques or they could be advised to increase their calcium consumption which will reduce the effects of fluoride (e.g. by consuming more milk).

For boreholes with high fluoride concentrations:

- people using this water should be advised of defluoridation techniques to reduce the fluoride concentrations consumed to safer levels;
- people could be advised to increase their calcium consumption to reduce the effects of fluoride (e.g. by consuming more milk);
- people should be given alternate drinking water supplies.

It is recommended that the "effluents" from the respective industries are monitored and the industries be advised to reduce the fluoride concentration in their effluent (and impact on the environment) to meet the standards set by the Department of Water Affairs and Forestry.

It is also recommended that detailed impact assessments be undertaken in areas where water, high in fluoride concentrations, is being consumed.

Spatial patterns and possible sources of high fluoride concentrations:

For surface water, it is recommended that detailed investigations be done in the:

- Mshwati catchment to establish whether the high fluoride concentrations are associated with industrial activities in this catchment;
- MgoShongweni catchment to establish whether the high fluoride concentrations are arising from the Enviroserve Hazardous Waste Disposal Site;
- area upstream of the AECI storm water site to establish whether the high fluoride concentrations are arising from the AECI effluent or other industries;

For borehole water, it is recommended that detailed studies be undertaken for a better understanding of the:

- geology/borehole fluoride concentration relationship;
- borehole distance from fault line/borehole fluoride concentration relationship;
- depth of borehole/borehole fluoride concentration relationship;
- multiple regression analysis should be undertaken for a better estimate of the response of fluoride concentration to all contributing factors or co-variables.

Additional fluoride dosage at water treatment works:

It is recommended that the additional fluoride dosage at water treatment works be based on whether or not the consumers want their drinking water fluoridated. Since the optimal fluoride concentration is expected to be lower than 0.55mg/ℓ (Plessis, 1998), an estimate of the additional fluoride dosage required would be lower than that calculated against the legislated standard of 0.7mg/ℓ. If the additional dosage required is significantly low and does not justify the expense of fluoridating water, it is then recommended that a decision be taken against fluoridating water.

If consumers want their water fluoridated then the optimal fluoride concentration for that region should be calculated. This is expected to be lower than 0.55 mg/ℓ due to various factors including the higher mean annual temperatures in KZN (Plessis, 1998). The additional fluoride dosage required should then be based on this calculated optimal fluoride concentration and not the fixed standard of 0.7 mg/ℓ legislated by the South African Government. If the optimal concentrations are not recalculated it is likely that non-government organizations, community based organizations etc. would contest this.

Comparison of influent and effluent fluoride concentrations at wastewater works:

It is recommended that fluoride concentrations of the Darvill sludge be monitored to assess the impact of sludge fluoride on the environment.

Since it was not possible to estimate the percentage fluoride removal for the Hammarsdale Wastewater Works with the existing data, it is recommended that the estimate of fluoride removal be repeated for the Hammarsdale Wastewater Works by taking in to account the process time of three days, from influent to effluent.

Future fluoride levels in surface water that will receive return flows:

It is recommended that an environmental impact assessment be done on the catchments receiving fluoridated return flows.

It is also recommended that toxicity testing of effluents on *Daphnia* be undertaken to detemine the effects of fluoride.

Number of people in sensitive groups that could be affected by water fluoridation:

In light of the large number of people, one-third the population of KZN, that are HIV positive and therefore could be sensitive to fluoridated water it is recommended that the South African legislation mandating water fluoridation be withdrawn.

With regard to water service providers such as Umgeni Water, it is recommended that exemptions from water fluoridation be obtained from the Department of Water Affairs and Forestry, until the uncertainties regarding water fluoridation are clarified and the regulations are reviewed.

The latest literature advises the need for caution with regard to water fluoridation. There is an urgent need to estimate the short and long-term effects of water fluoridation with proper scientific methodology that would account for confounding factors and environmental effects. It is therefore also recommended that the sustainability of water fluoridation in caries prevention be established using techniques such as Resource Environmental Economics.

Examination of the most recent literature indicated a significant lack of confidence in the best available studies that researched the safety and efficacy of water fluoridation. In light of this it is recommended that the South African Department of Health re-examine and withdraw its legislation that mandates water fluoridation.

REFERENCES

Allan, S. Archer, D. Thompson, G. & Plaistowe, M. 1998. *Preliminary State of the Environment Report for KwaZulu-Natal. Conditions and Trends. Facts and Figures. Problems and Possible Solutions.*

Baird, C. 1995. *Environmental Chemistry.* Published by W. H. Freeman and Company. USA.

Balog, DA. 1997. *Fluoridation of Public Water Systems: Valid Exercise of State Police Power or constitutional violation?* Pace Environmental Law Review. Vol 14, No.2, Summer 1997.

Benefield, L D. Judkins, J F (JR) & Weand, B L. 1982. Process Chemistry for Water and Wastewater Treatment. Published by Prentice-Hall, New Jersey.

Berkow, R. Beers, MH & Fletcher, AJ. 1997. *The Merck Manual of Medical Information. Home edition*. Merck Research Laboratories.

Bolin, AK. 1997. *Children's dental health in Europe, An Epidemiological investigation of 5 and 12 year old children from eight EU countries.* Swedish Dental Journal Supplement 122

Cantor, KP. 1997. *Drinking Water and Cancer.* Cancer-Causes-Control, 8, 292.

Colquhoun, J. 1997. *Why I Changed My Mind About Water Fluoridation.* Perspectives in Biology and Medicine, 41, 1. Published by the University of Chicago Press.

Crocker, IT. Martin, JEJ & Sohnge, APG. 1988. *Handbook of the Geological Survey. The Fluorspar deposits of the Republic of South Africa and Bophuthatswana.* Handbook 11. Department of Mineral and Energy Affairs. Republic of South Africa.

Danielson, C. Lyon JL, Egger, M & Goodenough, GK. 1992. *Hip fractures and fluoridation in Utah's elderly population*. Jama. August 1992. Vol. 268 (6), pp 746-748.

Department of Health (DOH). 1998. *Regulations on the Fluoridations of Public Water Supplies*. http://www.doh.gov.za/docs/pr/1998/pr0612a.html

Department of Health. 2001. *AIDS in South Africa*. Web Site: http://www.aids.org.za/aids_in_south_africa.htm

Department of Water Affairs and Forestry, 1996a. *South African Water Quality Guidelines* (second edition). Volume 1*: Domestic Use.*

Department of Water Affairs and Forestry, 1996b. *South African Water Quality Guidelines* (second edition). Volume 7*: Aquatic Ecosystems.*

Dick AE, Ford RPK, Schluter PJ & Mitchell EA. 1999. *Water fluoridation and the sudden infant death syndrome*. New Zealand Medical Journal. 13 August 1999. pp 286 to 289.

Diesendorf, M. 1995. *How Science can Illuminate ethical debates: A case study on water fluoridation*. Fluoride, Vol. 28, No. 2, pp 887-104. May 1995.

du Pleissis, JB & van der Merve, C A. 1995. *Water fluoridation in South Africa: will it be effective?* J Dent Assoc South Africa. Vol. 50, pp545-9

Easley MW. 1990. *The status of community water fluoridation in the United States*. Public Health Rep; 1990 Jul-Aug; Vol. 105 (4), pp. 348-53.

Environmental Systems Research Institute (ESRI), 1996. *Using ArcView GIS*.

Fluoride Action Network, 2001. *Tooth decay trends: Fluoridated vs unfluoridated*. Website:http://fluoridealert.org/WHO-DMFT.htm

Foulkes RG. & Anderson AC. 1994. *Impact of Artificial Fluoridation on Salmon species in the NorthWest USA and British Columbia, Canada*. Fluoride Vol. 27. No. 4 pp 220 - 226

Gehr, R & Choueiri, N. 1998. *Fluoride in Drinking Water. Fluoride Chemistry and Measurement*. Published by the Rand Afrikaans University, Water

Research Group as a short course.

Haarhoff, J. 1998. *Fluoride Addition to Water.* Published by the Rand Afrikaans University, Water Research Group as a short course.

HCS, Fluoridation: *Fluoride levels in water supplied to Victorian towns and cities.* Human Services – Water Technology Unit, Melbourne (1993).

Hillier, S. Cooper, C. Kellingray S. Russel, G. Hughes, H & Coggon, D. 2000. *Fluoride in drinking water and risk of hip fracture in the UK: a case-control study.* Lancet Jan 2000. Vol. 355 (9200), pp265-9.

Hulse, G. Kenrick, A. Thomas, CH. Thomas, A, Davies, DJ & Lennon, MA. 1995. *Welsh Water should reinstate fluoridation on Anglesey.* BR Dent J; 1995 Jan 21; Vol. 178 (2), pp. 46-7.

Hunt, RP. 1998. *The environmental impacts associated with the operation of a water fluoridation programme.* Presentation to Umgeni Water, their customers and stakeholders. September 1998.

Jones, CM. Worthington, H. 2000. *Water fluoridation, poverty and tooth decay in 12-year-old children.* J Dent. Aug 2000. Vol. 28 (6), pp389-93.

Kloos, H. Haimanot, RT. 1999. *Distribution of fluoride and fluorosis in Ethiopia and prospects for control.* Trop Med Int Health. May 1999. Vol. 4 (5), pp355-364.

Microsoft Office, 1995. *Excel Users Manual*. Version 7

Muller, WJ. Heath, RGM. & Villet, MH. 1998. *Finding the Optimum : Fluoridation of Potable Water in South Africa.* Water SA. Vol. 24. No 1. pp 21- 27.

National Health and Medical Research Council, 1999. *Review of Fluoridation and Fluoride Intake from Discretionary Fluoride Supplements.* Melbourne, Australia

National Water Act, 1956. *Requirements for the purification of wastewater or* *effluent*. Section 21 (1) (a) Act 54 of 1956. No. 991. South Africa.

NHS Centre For Reviews and Dissemination. 2000. *A Systematic Review of Public Water Fluoridation*. The University of York.

O'Mullane, DM. 1990. The Future of Water Fluoridation. J Dent Res. Feb 1990. Vol. 69. pp 756-9.

Patterson, AF. 1993. *A study of the dental health of primary school children in the local government areas of blue mountains and Hawkesbury, NSW*. NSW Health Department.

Peng, CG. Qi, J & Rubin, AJ. 1996. Evaluating fluospar for fluoridation. Journal AWWA. January 1996. pp. 97- 106.

Petersen, J. 1997. *Solving the Mystery of the Colorado Brown Stain*. J Hist Dent; 1997 Jul; Vol. 45 (2), pp.57-61.

Plessis, JB. 1998. *Medical perspectives on Fluoridation*. Published by the Rand Afrikaans University, Water Research Group as a short course

Povart, SJ & Carmicheal, CL. 1995. *The relationship between caries, fluoridation and material deprivation in five-year-old children in County Durham*. Comm Dental Health. Vol. 12, pp200-203.

Preventative Dental Health Association. *Oral Health Cayce and Keyes*. Website: http://emporium.turnpike.net/P/PDHA/health/keyes.htm

Republic of South Africa Government Gazette, No 6208, *Department of Health, Health profession's act, 1974 (Act No. 56 of 1974)*.

Riley, JC. Lennon, MA & Ellwood, RP. 1999. *The effect of water fluoridation and social inequalities on dental caries in 5-year-old children*. Int J Epidemiology. Apr 1999. Vol. 28 (2), pp 300-5.

Riordan , PJ & Banks, JA. 1991. *Dental fluorosis and fluoride exposure in Western Australia*. J Dent Res. Vol. 70, pp1022-8.

Riordan, PJ. 1991. *Dental caries and fluoride exposure in Western Australia*. J Dent Res 1991, Vol. 70, pp1029-34.

Ritchie, J. 1981. *"What Should we be doing?" Fluoridation.* The Zimbabwe Science News, Vol. 15, No. 8. August 1981.

Seppya, L. Kyarkkyainen & S. Hausen, H. 1998. *Caries frequency in permanent teeth before and after discontinuation of water fluoridation in Kuopio, Finland.* Community Den Oral Epidemiol; 1998 Aug; Vol. 26 (4), pp 256-62.

Statistics South Africa, 1998. *The People of South Africa Population Census,1996. Census in Brief.* Pretoria.

Teotia, SPS & Teotia, M. 1994. *Dental caries: a disorder of high fluoride and low dietary calcium interactions*. Fluoride. Vol. 27, pp59-66.

Terry S, 2000. Pollution Prevention Scientist at Umgeni Water. Personal communication.

Treasure, ET. Denver, JD. 1991. The prevalence of caries in five year old children living in fluoridated and non-fluoridated communities. NZ Dent J, Vol. 88, pp9-13.

Wang, NJ. Gropen, AM & Ogaard, B. 1997. Risk factors associated with fluorosis in a non-fluoridated population in Norway. Community Den Oral Epidemiol; 1997 Dec; Vol. 25 (6), pp 396-401.

Ward, RC. Loftis, JC & Mcbride, GB. 1987. *Design of Water Quality Monitoring Systems.* Van Nostrand Reinhold.

Water Research Commission. 1998. *Quality of Domestic Water Supplies* (second edition). Published by the Department of Water Affairs and Forestry, Department of Health and the Water Research Commission, South Africa.

World Health Organisation, 1996. *Guideline for drinking-water quality, second* *edition. Volume 2, health criteria and other supporting information.* Published by WHO, Geneva.

World Health Organisation. 1994. *Fluorides and Oral Health.*

APPENDIX 1

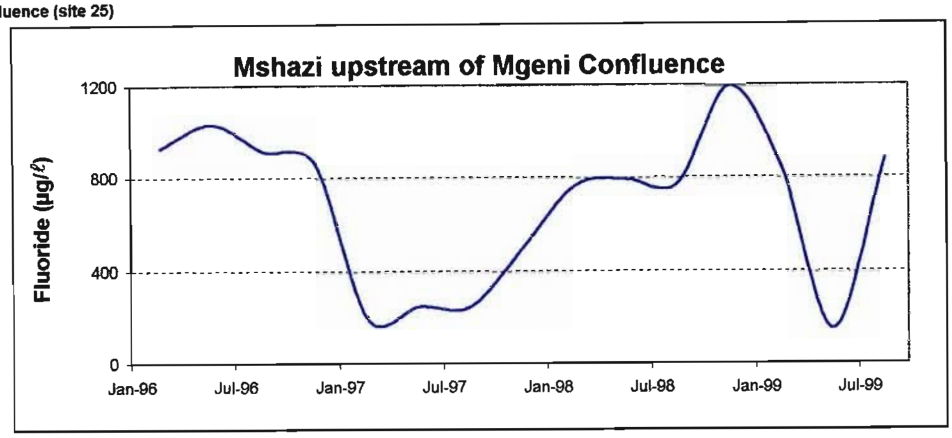
Time Series Graphs and Summary Statistics

" Hot Spots", sites with maximum fluoride concentration > 1 mg/ℓ

Appendix 1 : "Hot Spots", sites with maximum fluoride concentration > 1 mg/ℓ.

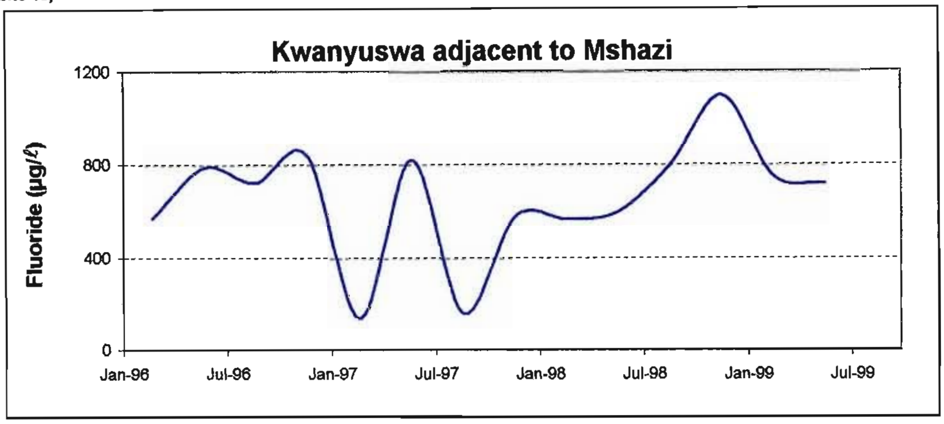
Mgeni River Catchment : Mshazi upstream of Mgeni Confluence (site 25)

Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	155.0	194.0	155.0
25th Percentile	375.1	824.0	781.1
Average	691.3	757.9	633.0
Median	794.0	849.0	786.5
75th Percentile	902.0	896.5	894.5
80th Percentile	919.6	916.6	905.0
95th Percentile	1084.5	1119.0	993.7
Maximum	1200.0	1200.0	1035.0



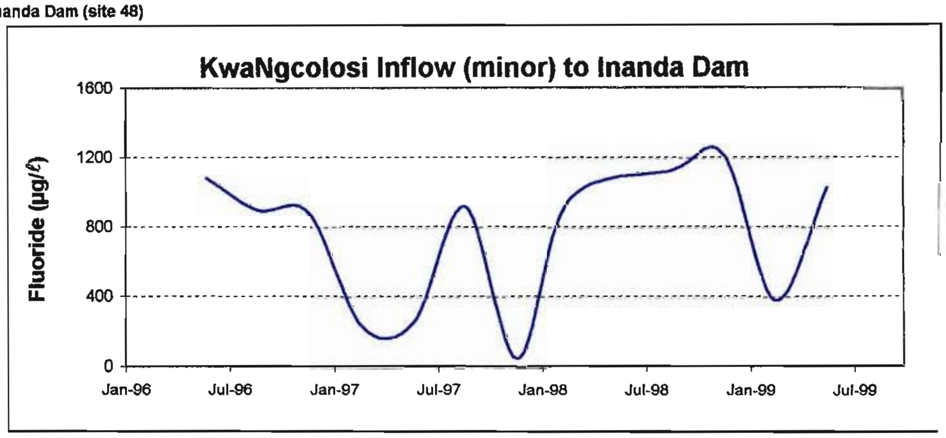
Mgeni River Catchment : Kwanyuswa adjacent to Mshazi (site 46)

Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	138.0	138.0	160.0
25th Percentile	573.3	570.0	660.0
Average	654.9	650.2	659.7
Median	721.5	580.2	724.0
75th Percentile	798.5	796.5	796.0
80th Percentile	809.4	823.2	799.0
95th Percentile	931.7	1022.3	815.7
Maximum	1100.0	1100.0	822.0



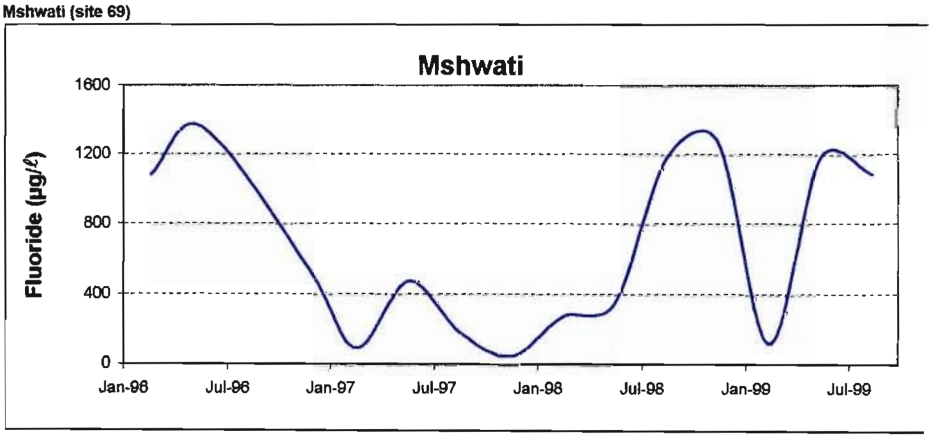
Mgeni River Catchment : KwaNgcolosi inflow (minor) to Inanda Dam (site 48)

Statistics	Entire Dataset	Summer	Winter
N	12	6	6
Minimum	50.0	50.0	253.0
25th Percentile	349.0	270.0	903.0
Average	752.7	620.0	885.3
Median	908.0	631.0	974.0
75th Percentile	1043.3	936.5	1069.8
80th Percentile	1072.4	955.0	1083.0
95th Percentile	1170.5	1153.8	1118.3
Maximum	1220.0	1220.0	1130.0



Mgeni River Catchment (Msunduzi River Sub-catchment) : Mshwati (site 69)

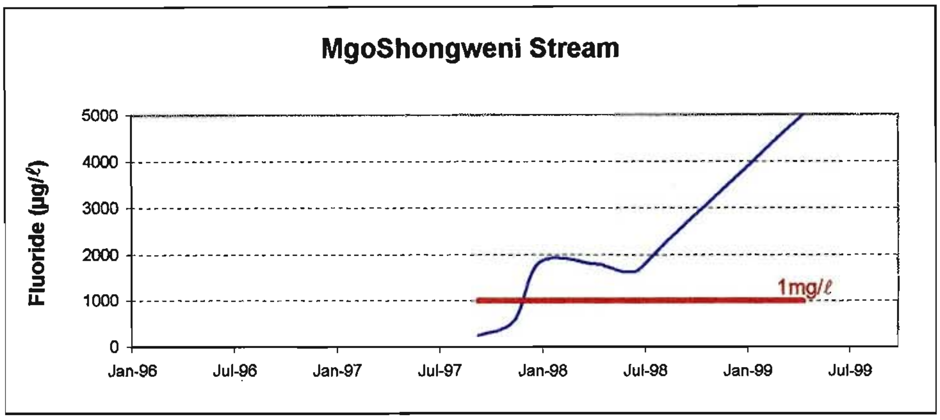
Statistics	Entire Dataset	Sumer	Winter
N	14	7	7
Minimum	50.0	50.0	186.0
25th Percentile	208.0	110.3	413.5
Average	662.8	492.2	833.3
Median	509.5	274.0	1090.0
75th Percentile	1157.5	810.5	1185.0
80th Percentile	1184.0	971.0	1188.0
95th Percentile	1308.0	1219.4	1309.0
Maximum	1360.0	1280.0	1360.0



Appendix 1 : "Hot Spots", sites with maximum fluoride concentration > 1 mg/ℓ.

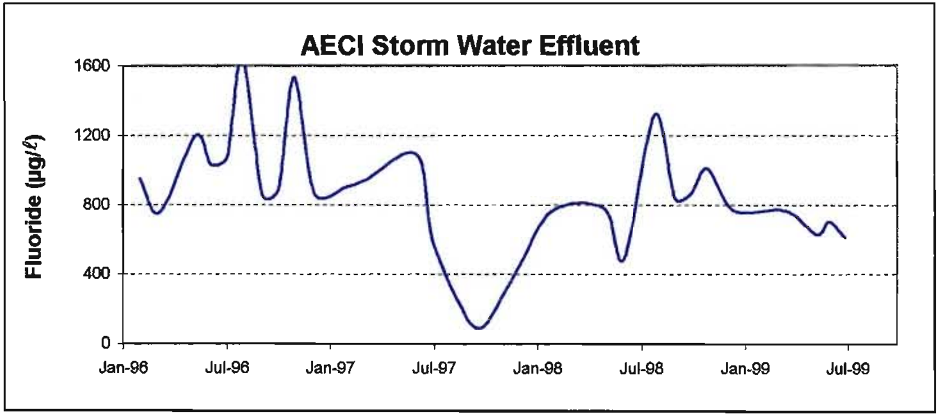
Mlazi River Catchment : Mgoshongweni Stream (site 82.1)

Statistics	Entire Dataset	Summer	Winter
N	7	2	5
Minimum	257.0	583.0	257.0
25th Percentile	1112.5	897.3	1642.0
Average	1922.6	1211.5	2207.0
Median	1792.0	1211.5	1792.0
75th Percentile	2092.0	1525.8	2344.0
80th Percentile	2243.2	1588.6	2875.2
95th Percentile	4203.2	1777.2	4468.8
Maximum	5000.0	1840.0	5000.0



AECI storm water effluent (site 858)

Statistics	Entire Dataset	Summer	Winter
N	31	14	17
Minimum	107.0	461.0	107.0
25th Percentile	724.0	758.3	613.0
Average	842.8	868.6	821.5
Median	842.0	841.0	842.0
75th Percentile	980.0	933.0	1074.0
80th Percentile	1031.0	945.8	1087.6
95th Percentile	1426.5	1193.1	1386.8
Maximum	1654.0	1533.0	1654.0



APPENDIX 2

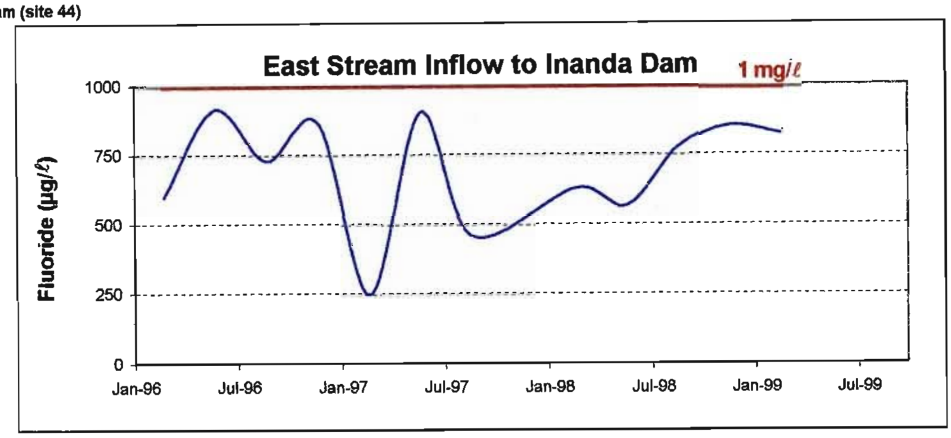
Time Series Graphs and Summary Statistics

Sites with maximum fluoride concentration > 0.7 mg/ℓ but < 1 mg/ℓ

Appendix 2 : Sites with maximum fluoride concentration > 0.7 mg/ℓ but < 1 mg/ℓ.

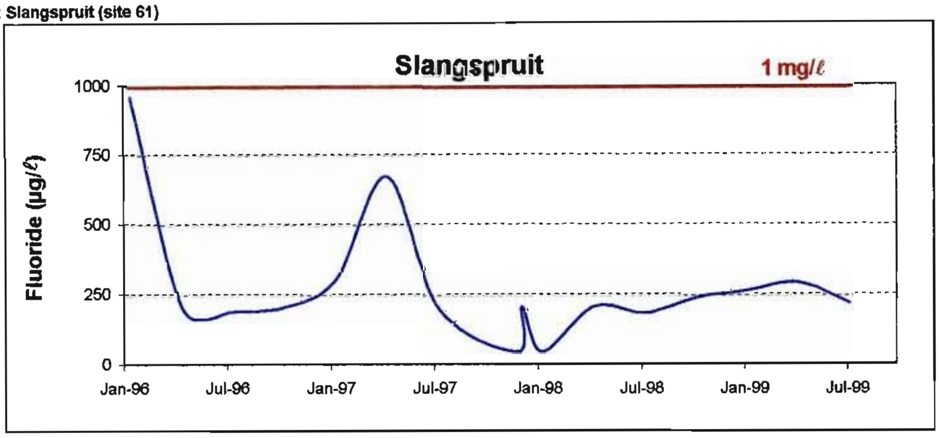
Mgeni River Catchment : East Stream Inflow to Inanda Dam (site 44)

Statistics	Entire Dataset	Summer	Winter
N	12	6	6
Minimum	251.0	251.0	461.0
25th Percentile	592.3	607.5	809.0
Average	700.8	674.7	727.0
Median	754.0	733.0	754.0
75th Percentile	864.3	856.3	874.3
80th Percentile	867.0	863.0	906.0
95th Percentile	911.4	866.8	915.0
Maximum	918.0	868.0	918.0



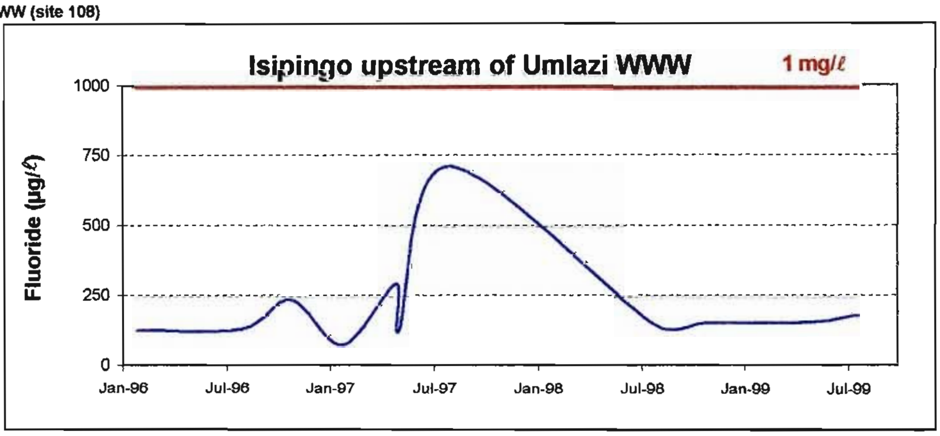
Mgeni River Catchment (Msunduzi River Sub-catchment) : Slangspruit (site 61)

Statistics	Entire Dataset	Summer	Winter
N	16	8	8
Minimum	50.0	50.0	187.0
25th Percentile	197.5	168.1	197.5
Average	279.7	286.7	272.8
Median	210.5	225.0	207.5
75th Percentile	274.0	277.0	239.5
80th Percentile	295.0	291.0	265.4
95th Percentile	746.0	732.8	541.4
Maximum	962.0	962.0	674.0



Isipingo River Catchment : Isipingo upstream of Umlazi WWW (site 108)

Statistics	Entire Dataset		
N	11	4	7
Minimum	75.0	75.0	131.0
25th Percentile	131.5	114.8	142.0
Average	214.7	149.0	252.3
Median	156.0	142.0	157.0
75th Percentile	211.0	176.3	239.5
80th Percentile	237.0	188.4	272.2
95th Percentile	504.5	224.9	588.7
Maximum	715.0	237.0	715.0



APPENDIX 3

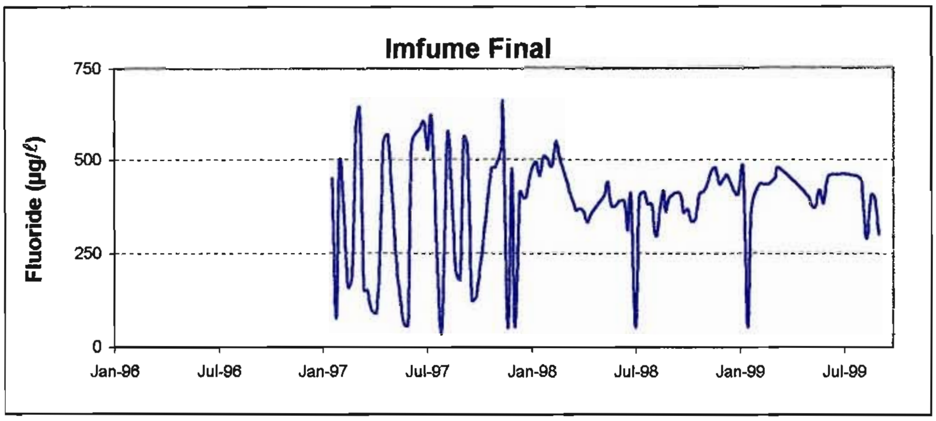
Time Series Graphs and Summary Statistics

Sites with maximum fluoride concentration > 0.5 mg/ℓ but < 0.7 mg/ℓ

Appendix 3 : Sites with maximum fluoride concentration > 0.5 mg/ℓ but < 0.7 mg/ℓ.

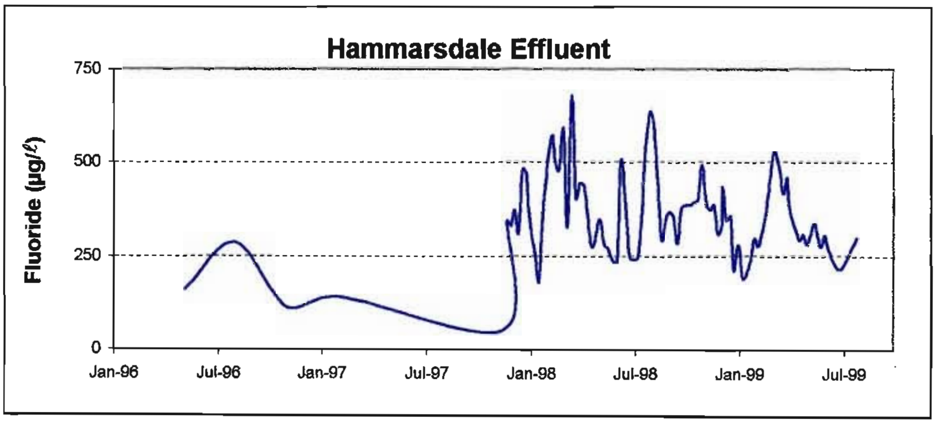
Imfume Final (site 455.2)

Statistics	Entire Dataset	Summer	Winter
N	109	51	58
Minimum	50.0	50.0	50.0
25th Percentile	332.0	367.0	295.3
Average	375.9	394.9	359.2
Median	403.0	433.0	382.0
75th Percentile	469.0	476.5	419.5
80th Percentile	477.0	481.0	448.6
95th Percentile	575.8	563.5	572.5
Maximum	649.0	649.0	614.0



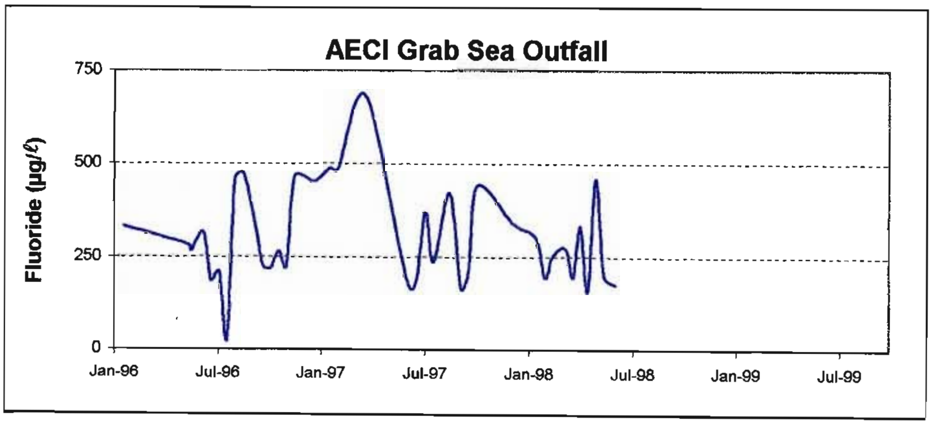
Mlazi River Catchment : Hammarsdale Effluent (site 599)

Statistics	Entire Dataset	Summer	Winter
N	81	48	33
Minimum	50.0	50.0	158.0
25th Percentile	278.0	304.8	273.0
Average	350.1	362.8	331.6
Median	343.0	372.0	297.0
75th Percentile	414.0	445.5	350.0
80th Percentile	442.0	464.6	372.6
95th Percentile	566.0	552.7	562.4
Maximum	676.8	676.8	635.0



AECI Grab Sea Outfall (site 857)

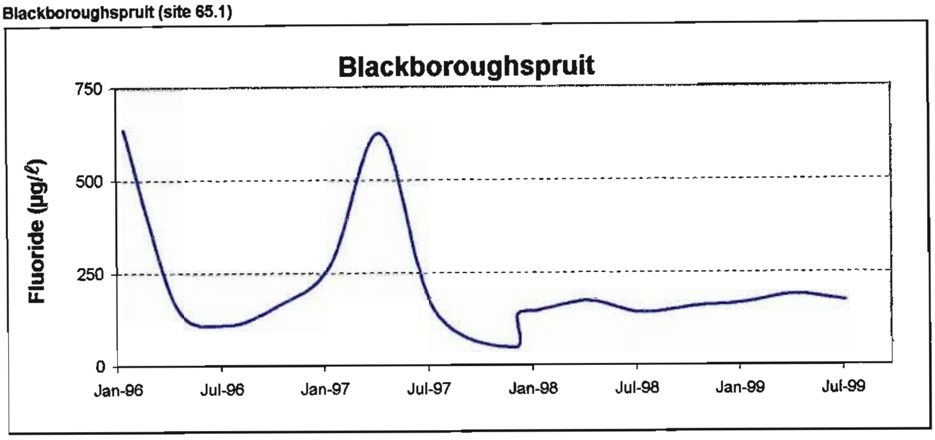
Statistics	Entire Dataset	Summer	Winter
N	37	16	21
Minimum	25.0	193.0	25.0
25th Percentile	207.0	244.5	184.0
Average	304.1	342.1	275.2
Median	272.0	315.5	235.0
75th Percentile	421.0	453.5	369.0
80th Percentile	448.8	461.0	421.0
95th Percentile	483.6	534.0	459.0
Maximum	678.0	678.0	476.0



Appendix 3 : Sites with maximum fluoride concentration > 0.5 mg/ℓ but < 0.7 mg/ℓ.

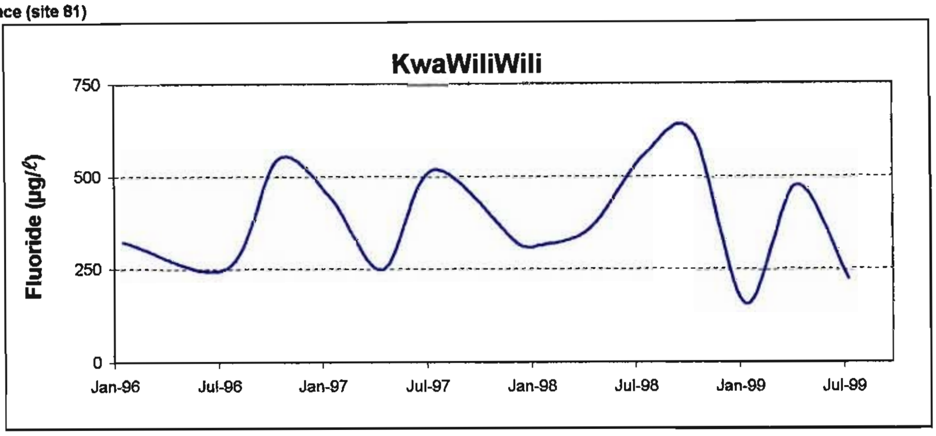
Mgeni River Catchment (Msunduzi River Sub-catchment) : Blackboroughspruit (site 65.1)

Statistics	Entire Dataset	Summer	Winter
N	16	8	8
Minimum	50.0	50.0	109.0
25th Percentile	147.0	145.5	150.0
Average	217.2	217.9	216.5
Median	162.5	162.5	166.0
75th Percentile	179.5	195.8	179.5
80th Percentile	193.0	231.8	185.8
95th Percentile	630.0	510.9	475.1
Maximum	639.0	639.0	627.0



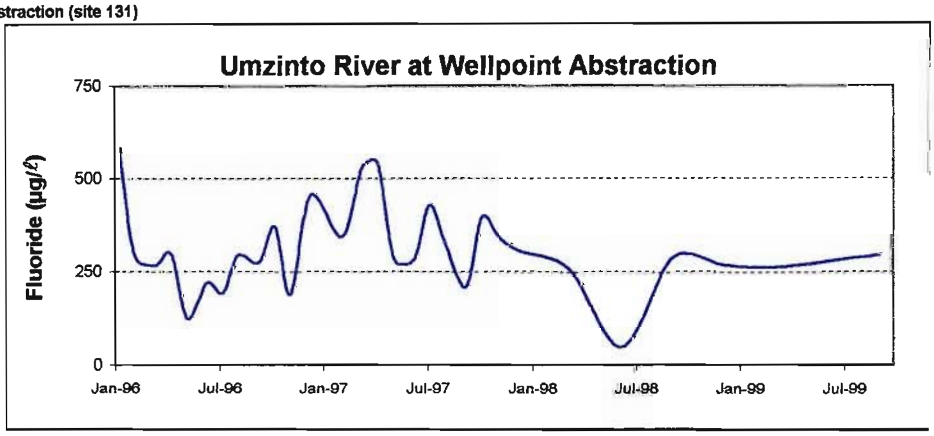
Mlazi River Catchment : KwaWiliWili above Mlazi Confluence (site 81)

Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	160.0	160.0	224.0
25th Percentile	267.3	315.5	250.0
Average	383.1	390.1	376.1
Median	341.0	323.0	359.0
75th Percentile	510.0	497.5	500.0
80th Percentile	531.6	528.4	512.0
95th Percentile	575.2	600.1	541.0
Maximum	622.0	622.0	550.0



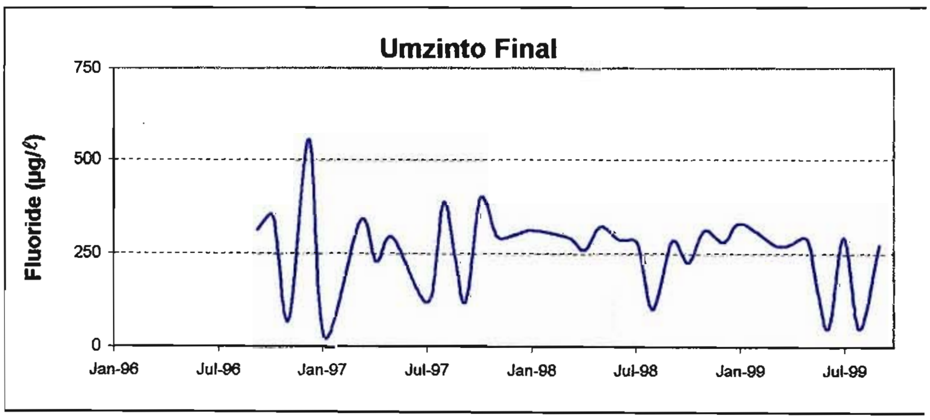
Umzinto River Catchment : Umzinto River at Wellpoint Abstraction (site 131)

Statistics	Entire Dataset	Summer	Winter
N	29	14	15
Minimum	50.0	187.0	50.0
25th Percentile	264.0	265.8	214.0
Average	309.3	347.5	273.5
Median	293.0	326.0	284.0
75th Percentile	345.0	390.6	298.0
80th Percentile	381.6	420.6	302.4
95th Percentile	535.8	546.9	462.6
Maximum	582.0	582.0	541.0



Umzinto River Catchment : Umzinto Final (site 431.1)

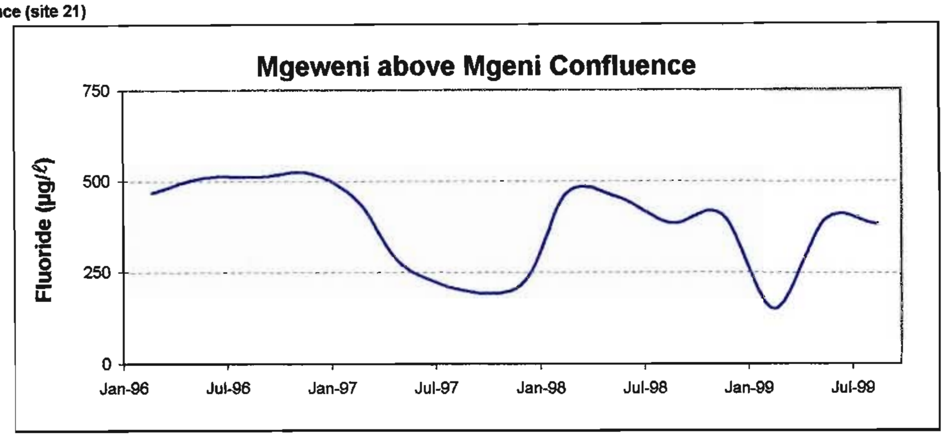
Statistics	Entire Dataset	Summer	Winter
N	33	15	18
Minimum	25.0	25.0	50.0
25th Percentile	228.0	277.0	147.0
Average	260.5	291.2	234.9
Median	286.0	302.0	278.5
75th Percentile	313.0	334.5	291.5
80th Percentile	319.6	339.4	293.6
95th Percentile	393.4	446.5	333.8
Maximum	555.0	555.0	389.0



Appendix 3 : Sites with maximum fluoride concentration > 0.5 mg/ℓ but < 0.7 mg/ℓ.

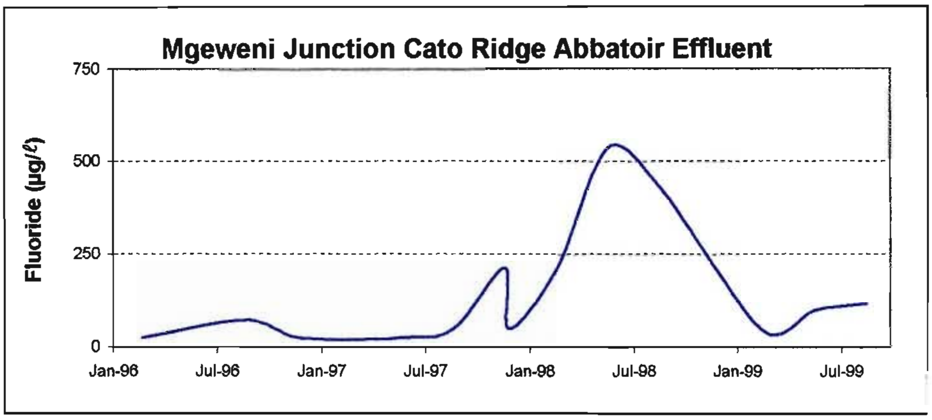
Mgeni River Catchment : Mgeweni above Mgeni Confluence (site 21)

Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	150.0	150.0	251.0
25th Percentile	394.4	414.4	386.8
Average	396.3	379.6	413.0
Median	424.0	441.0	397.0
75th Percentile	468.5	468.0	482.5
80th Percentile	485.0	468.6	498.4
95th Percentile	514.2	504.7	510.4
Maximum	520.0	520.0	511.0



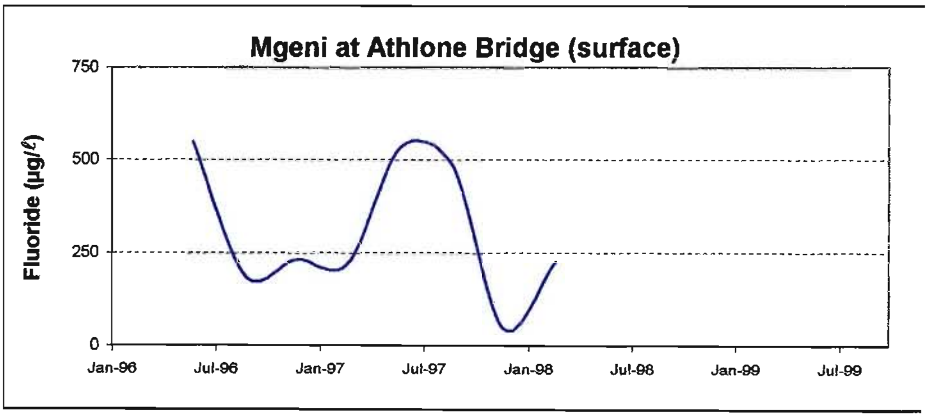
Mgeni River Catchment : Mgeweni Junction Cato Ridge Abbatoir Effluent (site 22)

Statistics	Entire Dataset	Summer	Winter
N	13	6	7
Minimum	25.0	25.0	25.0
25th Percentile	50.0	31.3	61.5
Average	146.5	95.2	190.4
Median	73.0	50.0	100.0
75th Percentile	209.0	169.3	273.5
80th Percentile	210.9	209.0	366.8
95th Percentile	472.6	211.4	505.3
Maximum	538.0	212.2	538.0



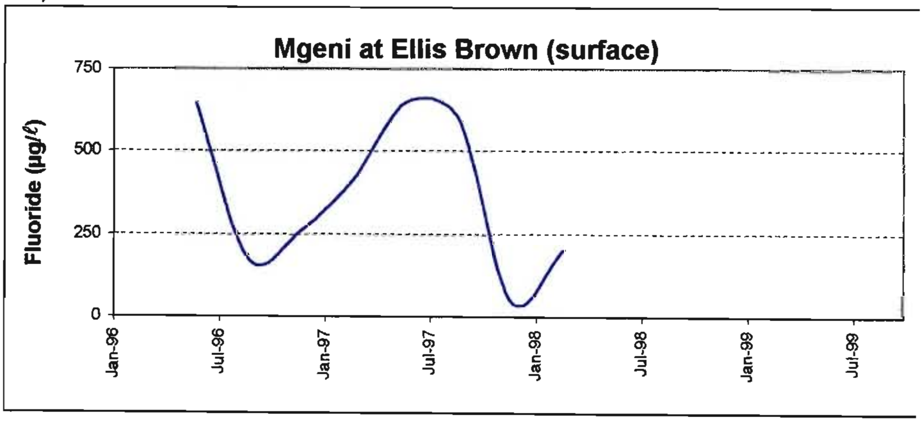
Mgeni River Catchment : Mgeni at Athlone Bridge (surface) (site 28.3)

Statistics	Entire Dataset	Summer	Winter
N	8	4	4
Minimum	50.0	50.0	189.0
25th Percentile	214.5	179.8	413.3
Average	311.8	182.8	440.8
Median	229.0	225.0	511.5
75th Percentile	499.8	228.0	539.0
80th Percentile	516.2	228.6	541.4
95th Percentile	545.4	230.4	548.6
Maximum	551.0	231.0	551.0



Mgeni River Catchment : Mgeni at Ellis Brown surface (site 28.4)

Statistics	Entire Dataset	Summer	Winter
N	8	4	4
Minimum	50.0	50.0	174.0
25th Percentile	195.0	164.0	492.0
Average	374.4	232.8	516.0
Median	339.5	232.0	621.5
75th Percentile	609.8	300.8	645.5
80th Percentile	626.2	324.0	645.8
95th Percentile	646.3	393.8	646.7
Maximum	647.0	417.0	647.0



APPENDIX 4

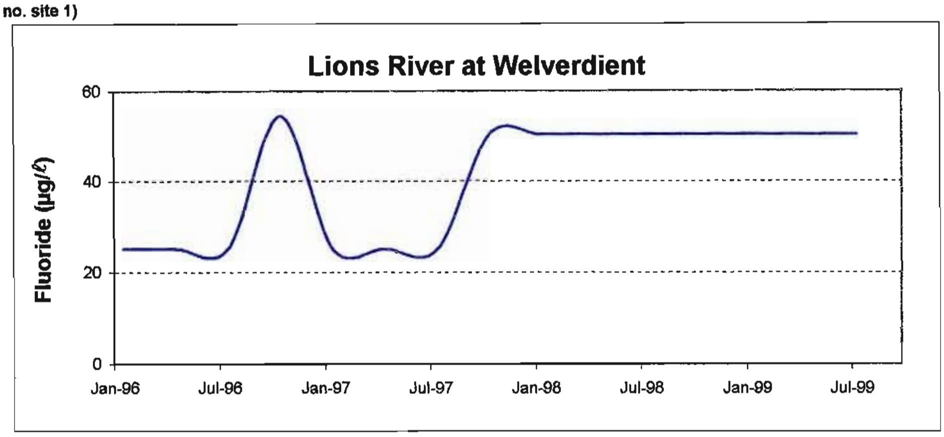
Time Series Graphs and Summary Statistics

Sites with maximum fluoride concentration < 0.5 mg/ℓ

Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

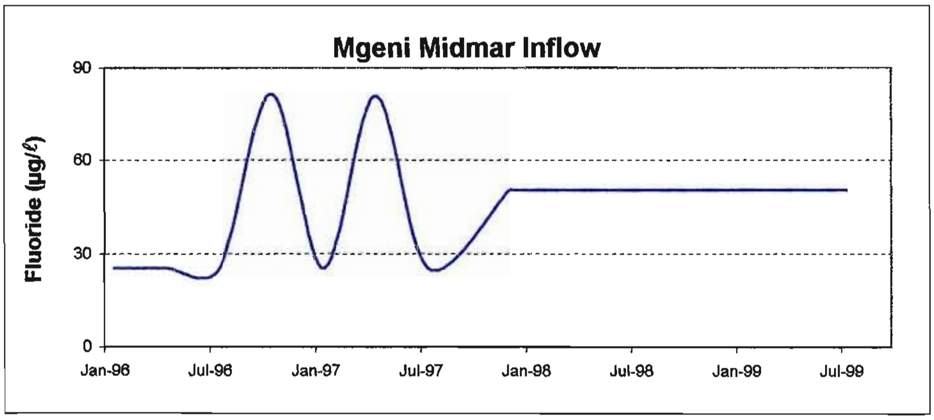
Mgeni River Catchment : Lions River at Welverdient (UW no. site 1)

Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	25.0	25.0	25.0
25th Percentile	25.0	37.5	25.0
Average	40.3	43.5	37.5
Median	50.0	50.0	37.5
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	50.0
95th Percentile	51.3	53.0	50.0
Maximum	54.3	54.3	50.0



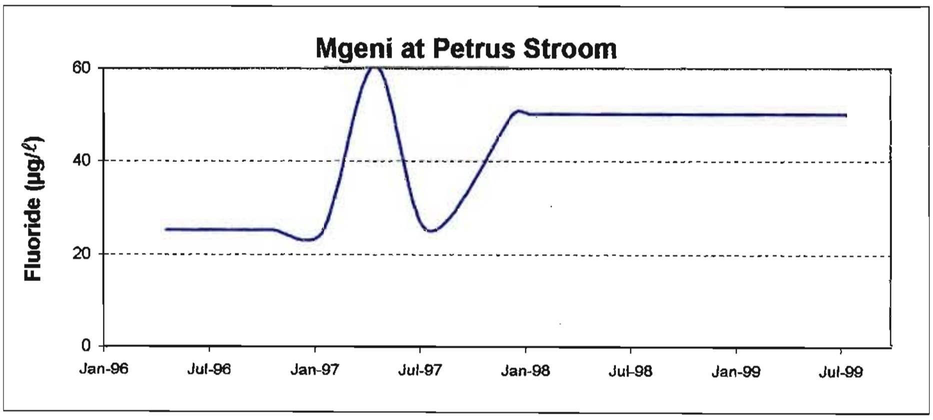
Mgeni River Catchment : Mgeni Midmar Inflow (site2)

Statistics	Entire Dataset	Summer	Winter
N	16	8	8
Minimum	25.0	25.0	25.0
25th Percentile	25.0	43.8	25.0
Average	46.1	47.7	44.5
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	50.0
95th Percentile	80.9	70.3	70.0
Maximum	81.3	81.3	80.7



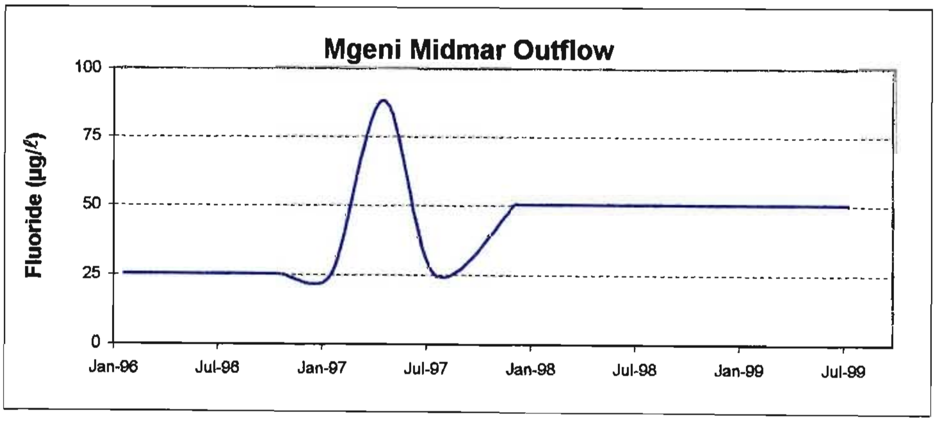
Mgeni River Catchment : Mgeni at Petrus Stroom (site 2.1)

Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	25.0	25.0	25.0
25th Percentile	25.0	25.0	25.0
Average	40.0	39.3	40.8
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	50.0
95th Percentile	53.6	50.0	57.3
Maximum	60.4	50.0	60.4



Mgeni River Catchment : Mgeni Midmar Outflow (site 3)

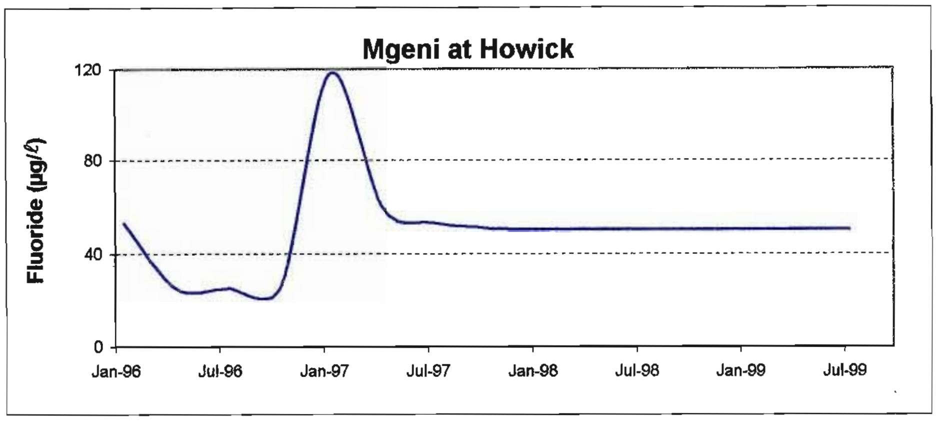
Statistics	Entire Dataset	Summer	Winter
N	15	8	7
Minimum	25.0	25.0	25.0
25th Percentile	25.0	25.0	37.5
Average	44.2	40.6	48.3
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	50.0
95th Percentile	61.4	50.0	76.7
Maximum	88.1	50.0	88.1



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

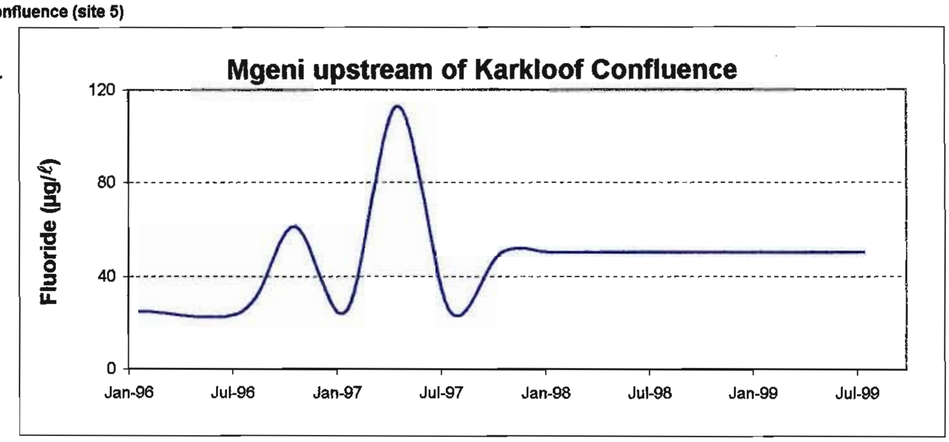
Mgeni River Catchment : Mgeni at Howick (site 3.1)

Statistics	Entire Dataset	Summer	Winter
N	16	8	8
Minimum	25.0	25.0	25.0
25th Percentile	50.0	50.0	43.8
Average	50.5	55.8	45.3
Median	50.0	50.0	50.0
75th Percentile	50.7	50.8	50.7
80th Percentile	52.9	51.8	51.7
95th Percentile	74.0	95.3	57.1
Maximum	118.0	118.0	59.3



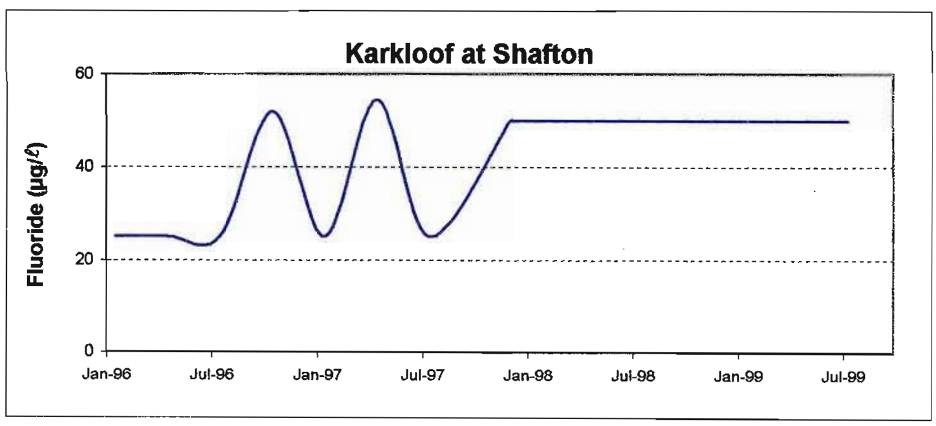
Mgeni River Catchment : Mgeni upstream of Karkloof Confluence (site 5)

Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	25.0	25.0	25.0
25th Percentile	31.3	37.5	37.5
Average	48.1	44.4	51.9
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	50.0
95th Percentile	79.2	57.7	94.1
Maximum	113.0	61.0	113.0



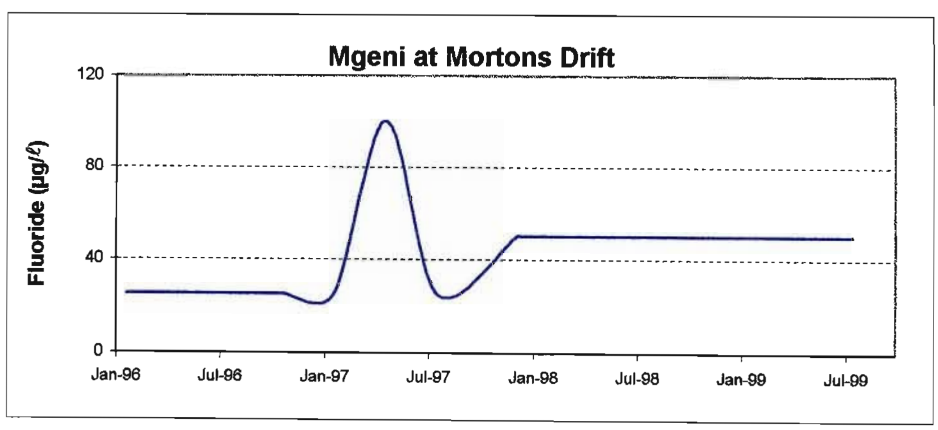
Mgeni River Catchment : Karkloof at Shafton (site 5.1)

Statistics	Entire Dataset	Summer	Winter
N	16	8	8
Minimum	25.0	25.0	25.0
25th Percentile	25.0	43.8	25.0
Average	42.6	44.0	41.2
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	50.0
95th Percentile	52.6	51.3	52.9
Maximum	54.5	52.0	54.5



Mgeni River Catchment : Mgeni at Mortons Drift (site 6)

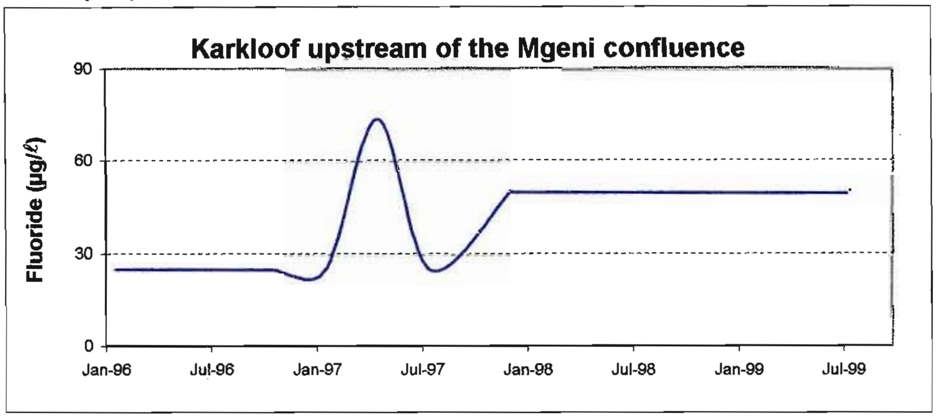
Statistics	Entire Dataset	Summer	Winter
N	13	7	6
Minimum	25.0	25.0	25.0
25th Percentile	25.0	25.0	31.3
Average	44.2	39.3	50.0
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	50.0
95th Percentile	70.0	50.0	87.5
Maximum	100.0	50.0	100.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

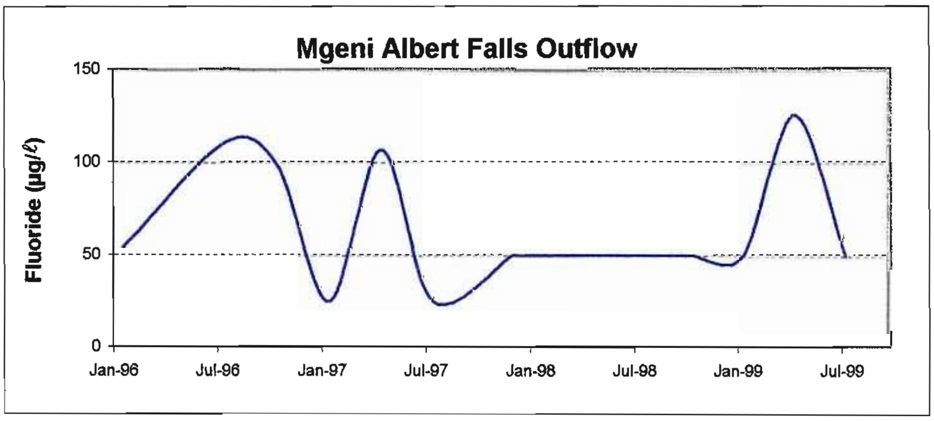
Mgeni River Catchment : Karkloof upstream of the Mgeni confluence (site 7)

Statistics	Entire Dataset	Summer	Winter
N	15	8	7
Minimum	25.0	25.0	25.0
25th Percentile	25.0	25.0	37.5
Average	43.2	40.6	46.2
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	50.0
95th Percentile	57.1	50.0	66.5
Maximum	73.6	50.0	73.6



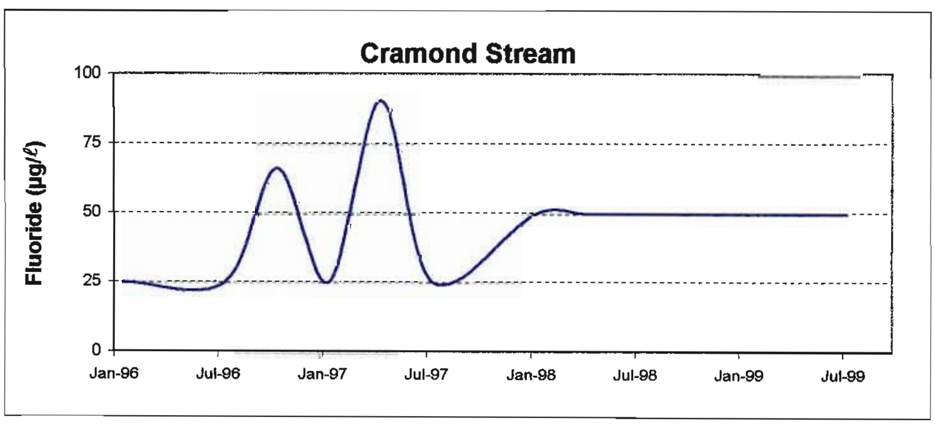
Mgeni River Catchment : Mgeni Albert Falls Outflow (site 8)

Statistics	Entire Dataset	Summer	Winter
N	15	8	7
Minimum	25.0	25.0	25.0
25th Percentile	50.0	50.0	50.0
Average	63.1	53.4	74.1
Median	50.0	50.0	50.0
75th Percentile	76.2	51.0	109.0
80th Percentile	100.1	52.4	110.2
95th Percentile	115.5	82.9	121.5
Maximum	126.0	98.4	126.0



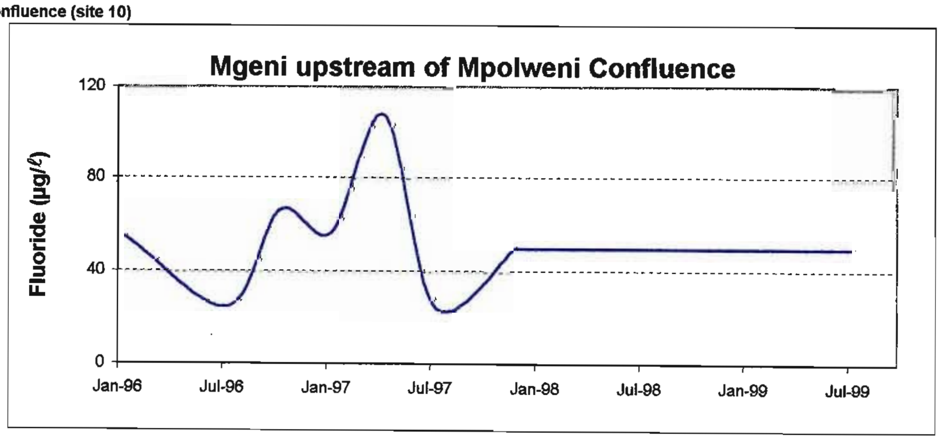
Mgeni River Catchment : Cramond Stream (site 9)

Statistics	Entire Dataset	Summer	Winter
N	13	6	7
Minimum	25.0	25.0	25.0
25th Percentile	25.0	31.3	37.5
Average	46.7	44.4	48.7
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	50.0
95th Percentile	76.0	62.2	78.4
Maximum	90.6	66.2	90.6



Mgeni River Catchment : Mgeni upstream of Mpolweni Confluence (site 10)

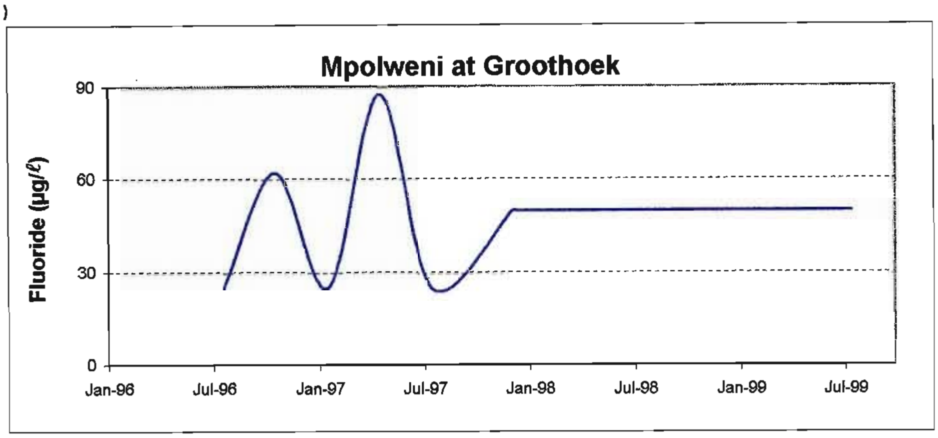
Statistics	Entire Dataset	Summer	Winter
N	15	8	7
Minimum	25.0	50.0	25.0
25th Percentile	50.0	50.0	37.5
Average	52.4	53.6	51.1
Median	50.0	50.0	50.0
75th Percentile	52.5	55.5	50.0
80th Percentile	55.4	56.2	50.0
95th Percentile	79.0	63.2	90.6
Maximum	108.0	66.5	108.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

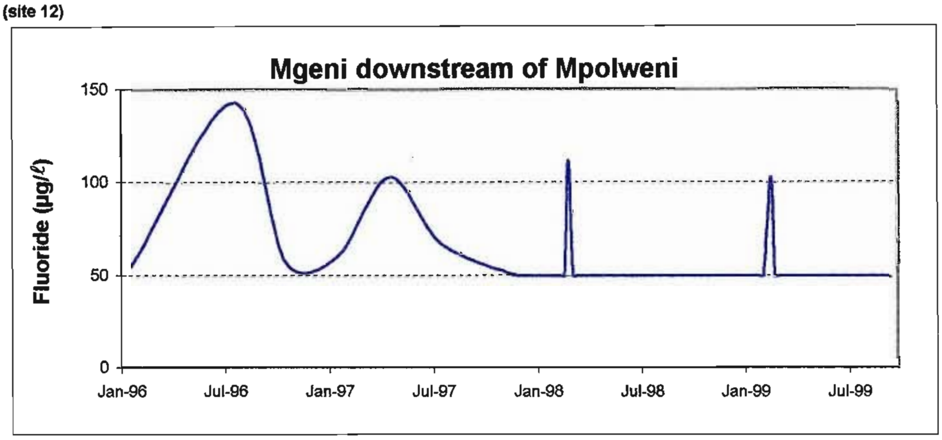
Mgeni River Catchment : Mpolweni at Groothoek (site 11.1)

Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	25.0	25.0	25.0
25th Percentile	50.0	50.0	37.5
Average	48.2	48.2	48.2
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	50.0
95th Percentile	71.0	58.5	76.3
Maximum	87.6	62.1	87.6



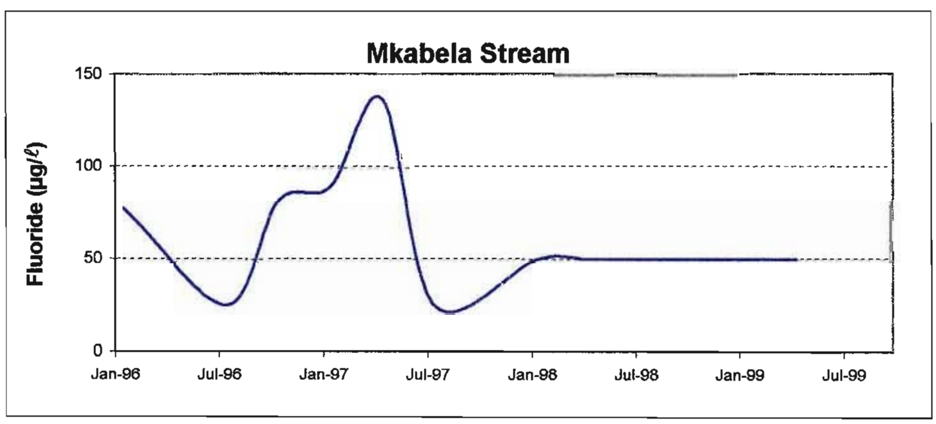
Mgeni River Catchment : Mgeni downstream of Mpolweni (site 12)

Statistics	Entire Dataset	Summer	Winter
N	60	45	15
Minimum	50.0	50.0	50.0
25th Percentile	50.0	50.0	50.0
Average	55.0	53.1	60.9
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	53.4
95th Percentile	103.0	59.9	115.0
Maximum	143.0	112.0	143.0



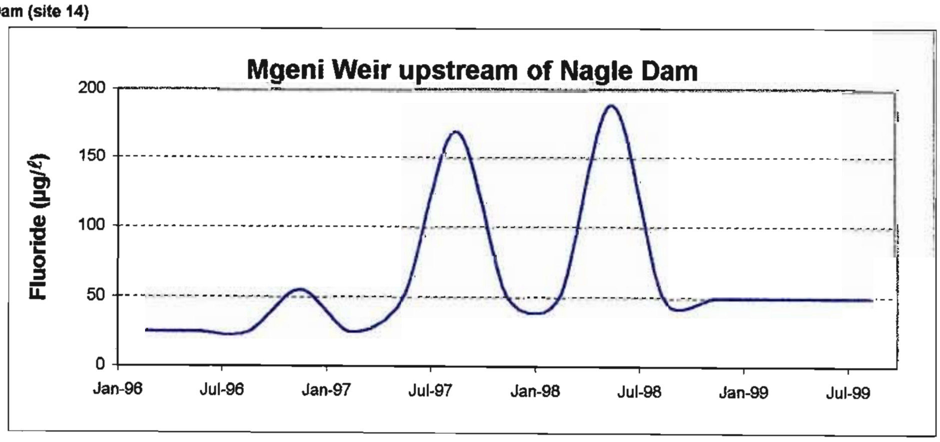
Mgeni River Catchment : Mkabela Stream (site 13)

Statistics	Entire Dataset	Summer	Winter
N	12	6	6
Minimum	25.0	50.0	25.0
25th Percentile	50.0	50.0	31.3
Average	61.4	66.6	56.2
Median	50.0	64.0	50.0
75th Percentile	79.0	80.9	50.0
80th Percentile	81.1	81.9	50.0
95th Percentile	111.1	87.9	115.3
Maximum	137.0	89.9	137.0



Mgeni River Catchment : Mgeni Weir upstream of Nagle Dam (site 14)

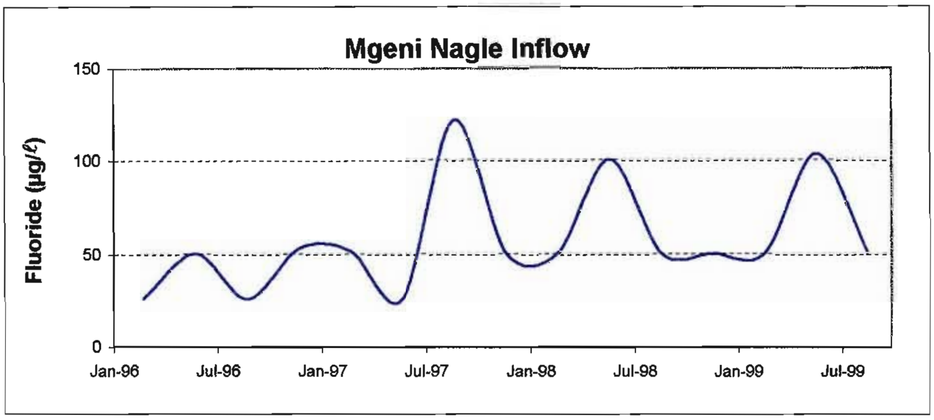
Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	25.0	25.0	25.0
25th Percentile	37.5	37.5	43.8
Average	60.9	43.6	76.0
Median	50.0	50.0	50.0
75th Percentile	50.1	50.0	79.8
80th Percentile	51.1	50.0	121.4
95th Percentile	175.0	53.6	182.0
Maximum	189.0	55.1	189.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

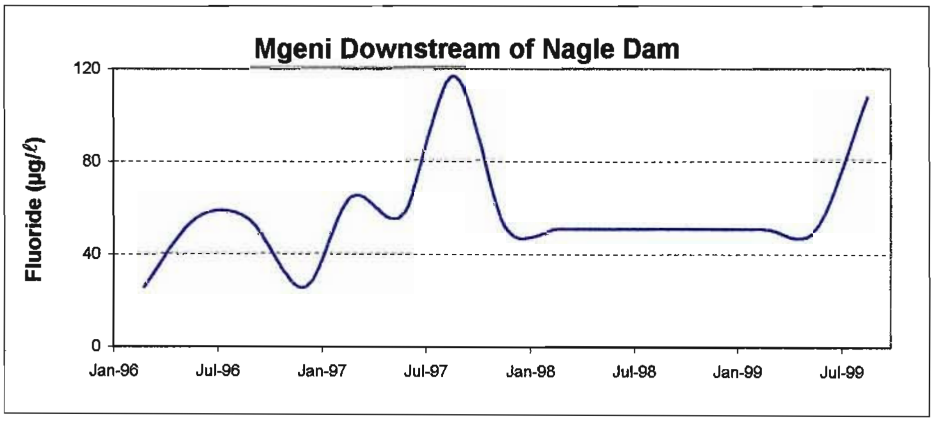
Mgeni River Catchment : Mgeni Nagle Inflow (site 15)

Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	25.0	25.0	25.0
25th Percentile	50.0	50.0	43.8
Average	56.9	47.0	65.5
Median	50.0	50.0	50.0
75th Percentile	52.1	50.7	100.8
80th Percentile	62.2	51.1	101.8
95th Percentile	108.4	52.3	114.7
Maximum	121.0	52.7	121.0



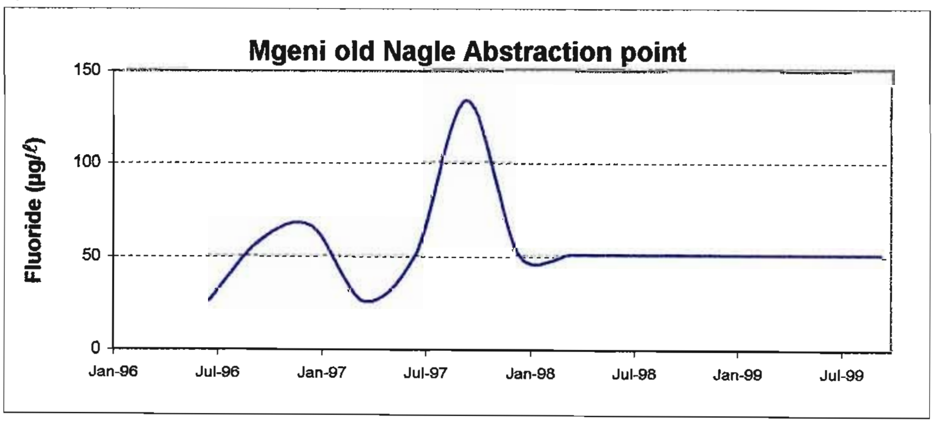
Mgeni River Catchment : Mgeni downstream of Nagle dam (site 16)

Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	25.0	25.0	50.0
25th Percentile	50.0	37.5	50.0
Average	56.9	44.9	67.5
Median	50.0	50.0	55.0
75th Percentile	56.0	50.0	69.5
80th Percentile	58.5	50.0	87.0
95th Percentile	109.7	60.0	112.9
Maximum	116.0	64.3	116.0



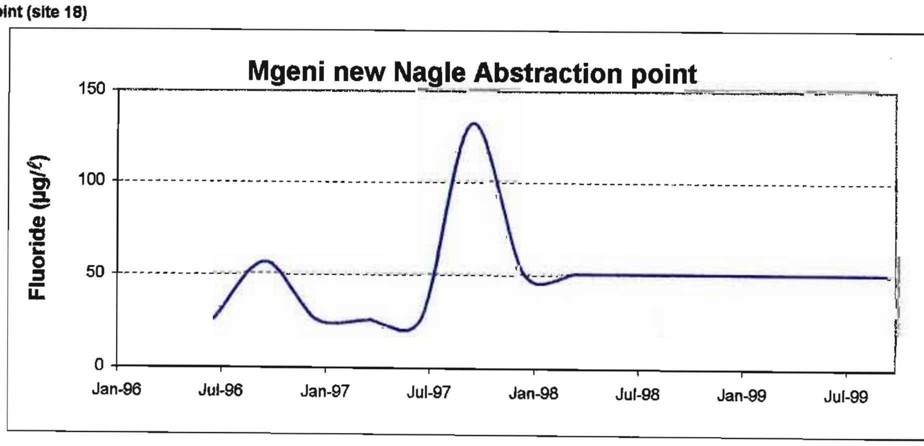
Mgeni River Catchment : Mgeni old Nagle Abstraction point (site 17)

Statistics	Entire Dataset	Summer	Winter
N	14	6	8
Minimum	25.0	25.0	25.0
25th Percentile	50.0	50.0	50.0
Average	54.0	48.4	58.2
Median	50.0	50.0	50.0
75th Percentile	50.2	50.0	52.1
80th Percentile	53.2	50.0	54.7
95th Percentile	89.1	61.6	106.6
Maximum	133.0	65.5	133.0



Mgeni River Catchment : Mgeni new Nagle Abstraction point (site 18)

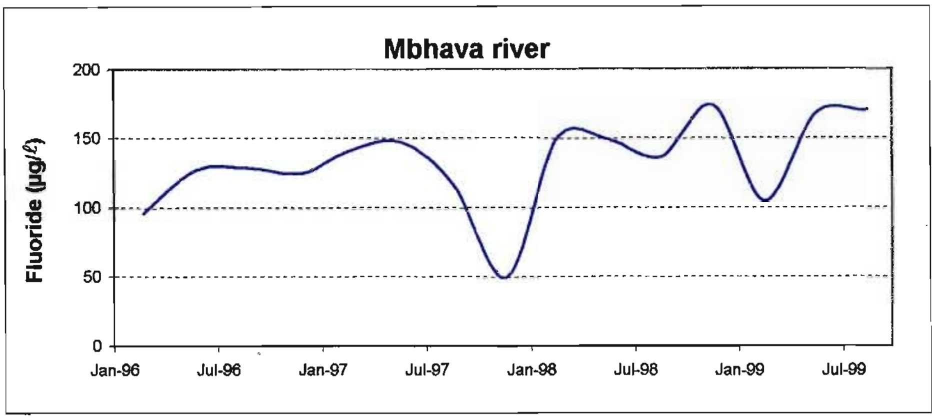
Statistics	Entire Dataset	Summer	Winter
N	14	6	8
Minimum	25.0	25.0	25.0
25th Percentile	31.3	31.3	43.8
Average	49.1	41.7	54.6
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	51.5
80th Percentile	50.0	50.0	53.6
95th Percentile	82.3	50.0	104.8
Maximum	131.0	50.0	131.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

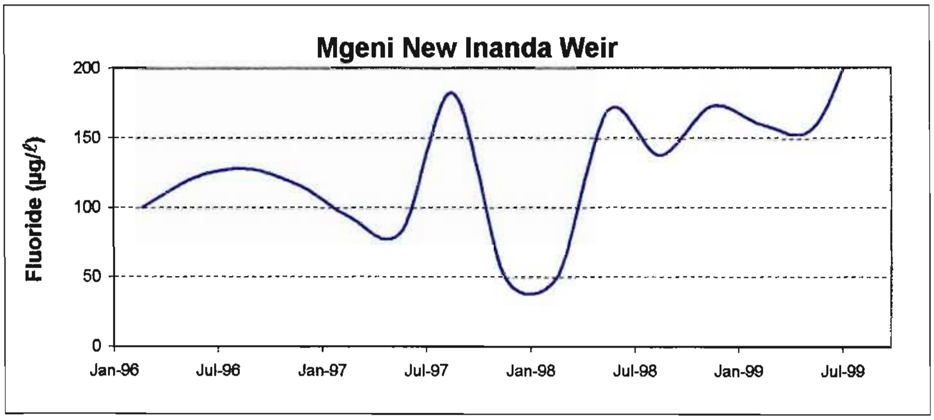
Mgeni River Catchment : Mbhava river (site 19)

Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	50.0	50.0	116.0
25th Percentile	120.5	100.5	128.5
Average	132.3	120.1	142.9
Median	137.0	125.0	142.0
75th Percentile	149.5	145.5	153.8
80th Percentile	153.6	148.2	160.4
95th Percentile	171.2	166.8	169.3
Maximum	174.0	174.0	170.0



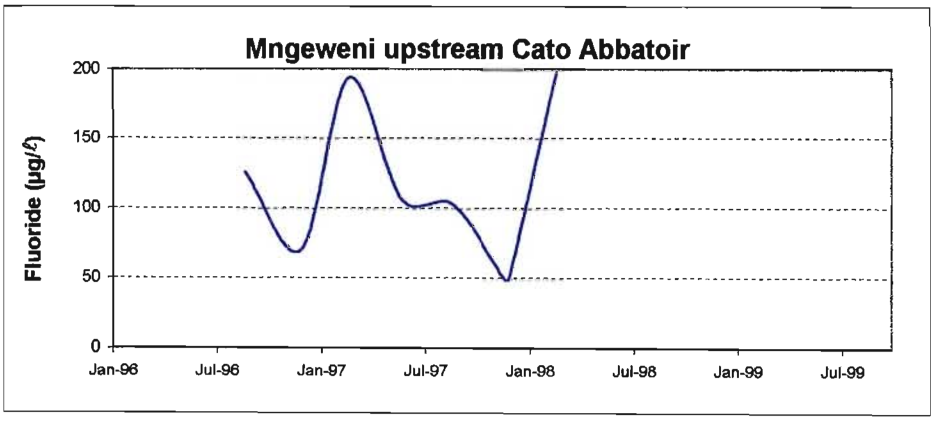
Mgeni River Catchment : Mgeni New Inanda Weir (site 20)

Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	50.0	50.0	82.5
25th Percentile	96.6	71.6	126.3
Average	130.9	105.9	152.8
Median	128.0	100.0	148.5
75th Percentile	165.0	137.5	173.0
80th Percentile	170.6	151.0	177.2
95th Percentile	200.0	169.1	221.0
Maximum	242.0	173.0	242.0



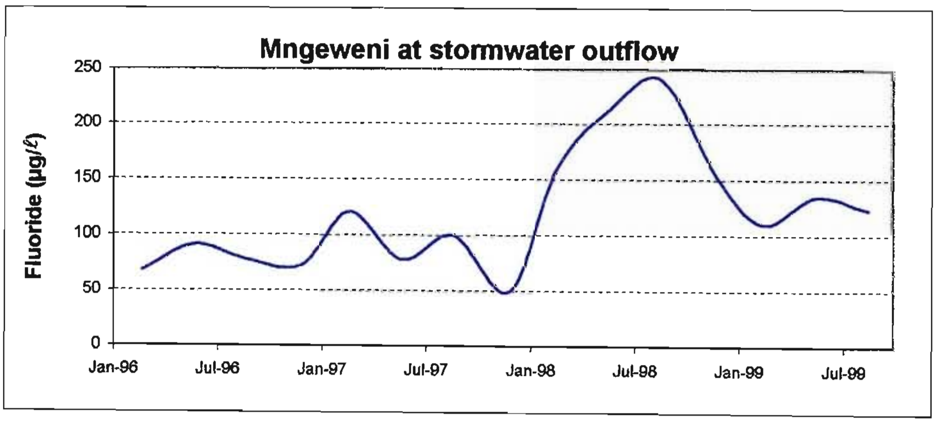
Mgeni River Catchment : Mngeweni upstream Cato Abbatoir (site 22.1)

Statistics	Entire Dataset	Summer	Winter
N	8	5	3
Minimum	50.0	50.0	103.0
25th Percentile	65.2	50.0	105.0
Average	112.3	112.4	112.0
Median	105.0	70.2	107.0
75th Percentile	143.0	194.0	116.5
80th Percentile	166.8	194.8	118.4
95th Percentile	196.6	197.2	124.1
Maximum	198.0	198.0	126.0



Mgeni River Catchment : Mngeweni at stormwater outflow (site 22.2)

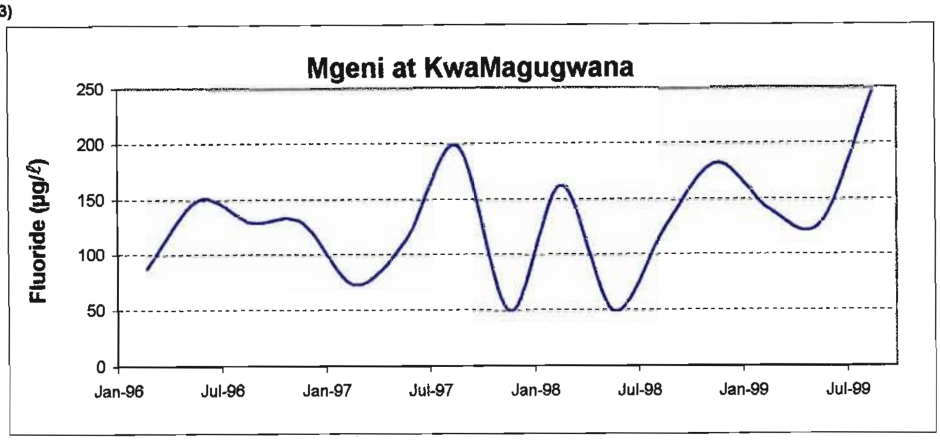
Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	50.0	50.0	78.0
25th Percentile	78.0	70.3	87.8
Average	119.5	104.8	132.4
Median	110.0	110.0	111.5
75th Percentile	143.5	136.5	154.5
80th Percentile	153.6	145.8	181.8
95th Percentile	221.4	157.6	231.2
Maximum	241.0	160.0	241.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

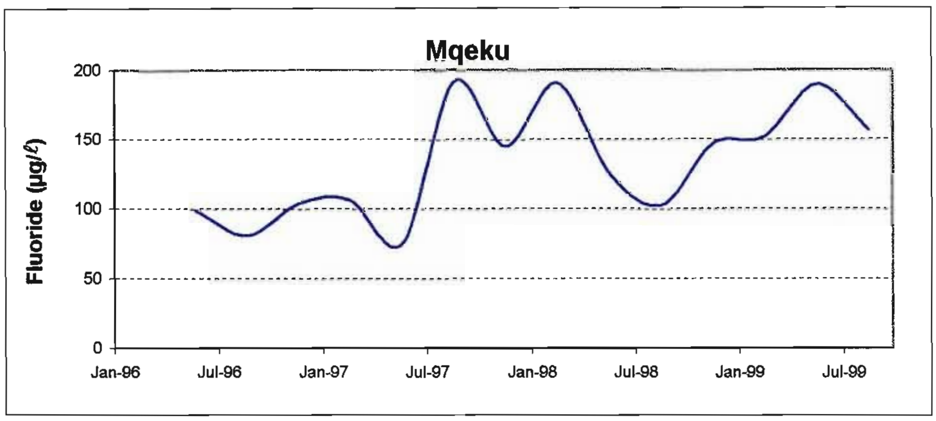
Mgeni River Catchment : Mgeni at KwaMagugwana (site 23)

Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	50.0	50.0	50.0
25th Percentile	101.0	80.6	123.0
Average	131.5	118.5	143.0
Median	130.0	130.0	129.5
75th Percentile	156.5	152.5	162.0
80th Percentile	167.0	158.8	178.8
95th Percentile	212.7	177.0	229.9
Maximum	247.0	183.0	247.0



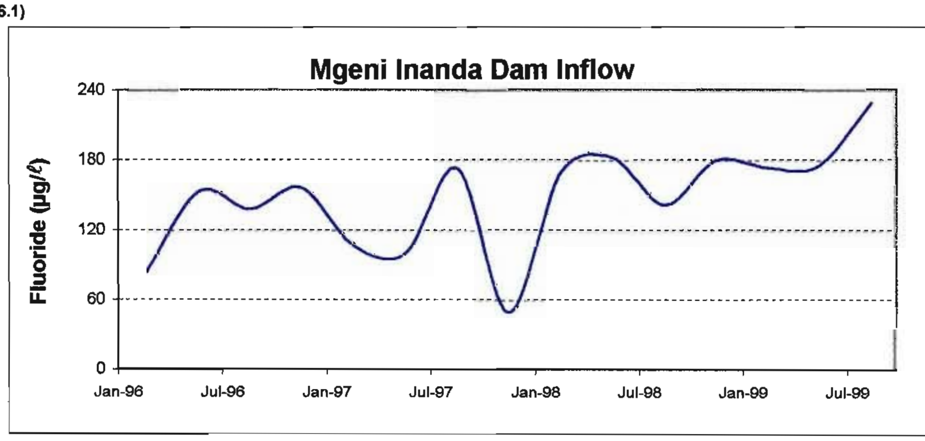
Mgeni River Catchment : Mqeku (site 24)

Statistics	Entire Dataset	Summer	Winter
N	14	6	8
Minimum	75.3	104.0	75.3
25th Percentile	103.3	115.7	94.5
Average	133.4	140.8	127.8
Median	134.9	145.9	114.0
75th Percentile	155.8	150.8	165.3
80th Percentile	170.2	152.0	176.8
95th Percentile	191.4	181.3	191.3
Maximum	192.0	191.0	192.0



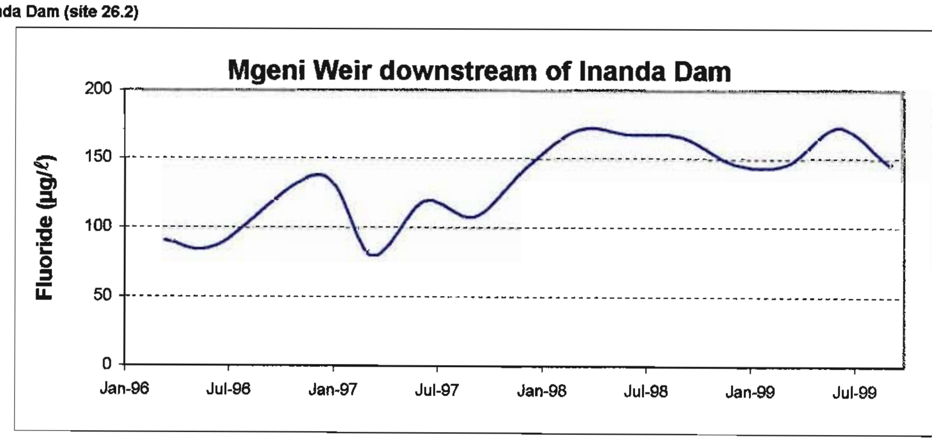
Mgeni River Catchment : Mgeni Inanda Dam Inflow (site 26.1)

Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	50.0	50.0	100.0
25th Percentile	122.5	95.5	141.0
Average	147.7	131.6	161.8
Median	156.0	156.0	163.0
75th Percentile	175.0	172.0	177.5
80th Percentile	176.8	173.2	179.6
95th Percentile	196.4	178.2	213.2
Maximum	230.0	180.0	230.0



Mgeni River Catchment : Mgeni Weir downstream of Inanda Dam (site 26.2)

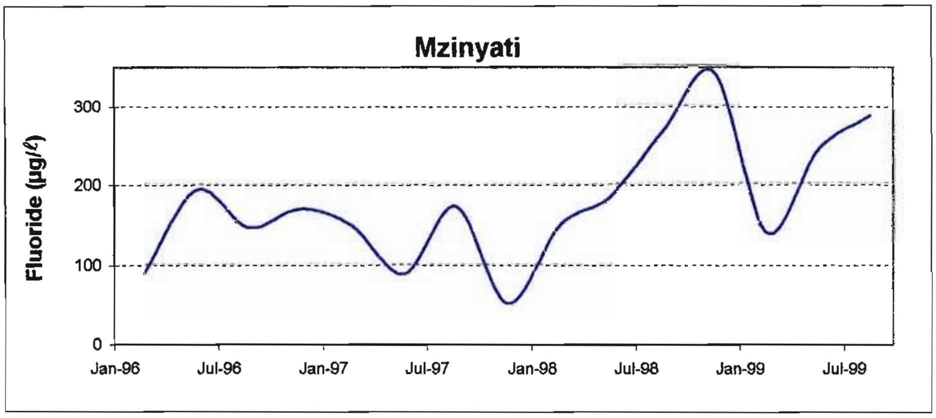
Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	79.9	79.9	87.0
25th Percentile	110.8	114.5	113.5
Average	134.5	131.0	138.0
Median	144.5	144.0	145.0
75th Percentile	161.0	146.0	167.0
80th Percentile	166.8	146.0	167.6
95th Percentile	172.2	164.1	171.5
Maximum	173.0	171.8	173.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

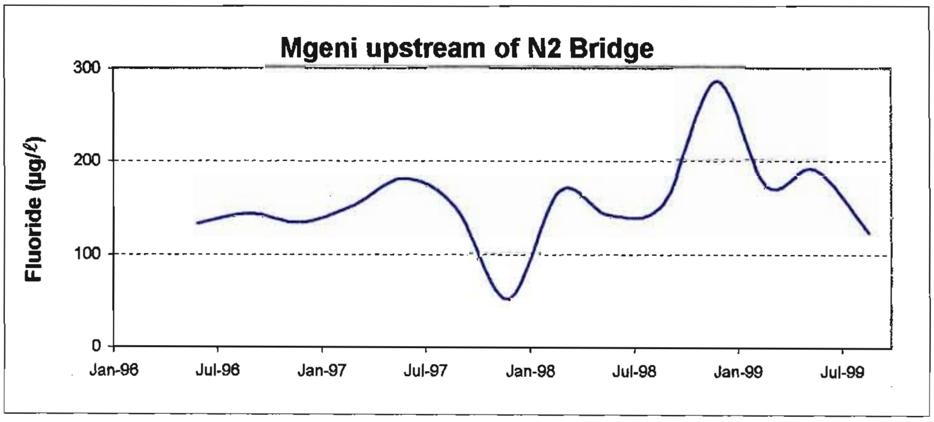
Mgeni River Catchment : Mzinyati (site 27)

Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	50.0	50.0	87.7
25th Percentile	141.5	113.5	165.3
Average	177.2	154.6	197.0
Median	168.0	148.0	188.5
75th Percentile	217.0	158.0	248.0
80th Percentile	246.8	164.0	256.4
95th Percentile	302.5	289.1	279.0
Maximum	341.0	341.0	286.0



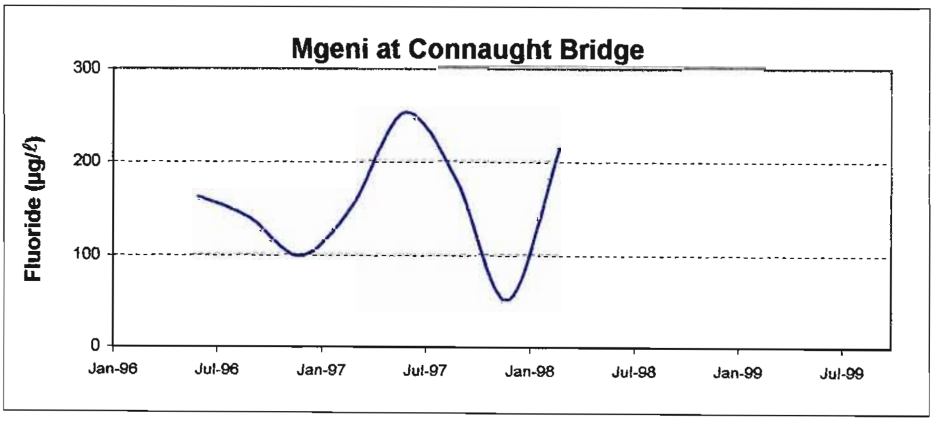
Mgeni River Catchment : Mgeni upstream of N2 Bridge (site 28.1)

Statistics	Entire Dataset	Summer	Winter
N	14	6	8
Minimum	50.0	50.0	122.0
25th Percentile	134.3	136.5	138.5
Average	154.3	159.0	150.8
Median	149.0	158.0	145.0
75th Percentile	170.5	170.5	159.8
80th Percentile	175.2	172.0	169.2
95th Percentile	222.3	256.0	185.9
Maximum	284.0	284.0	189.0



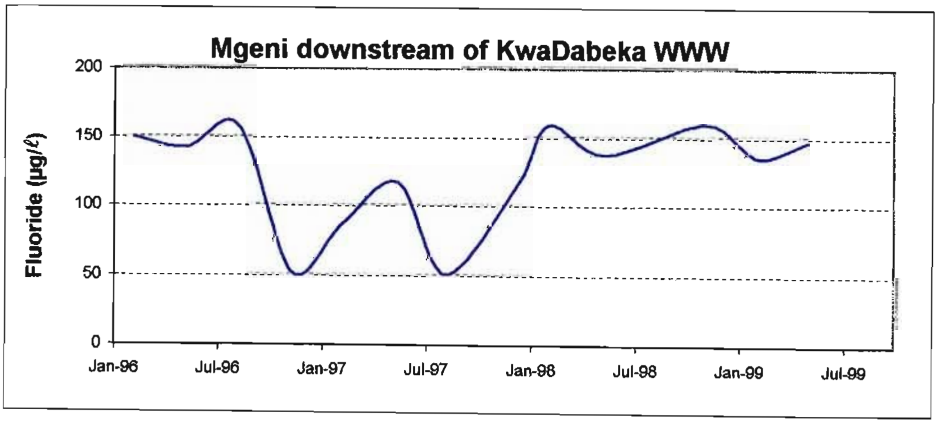
Mgeni River Catchment : Mgeni at Connaught Bridge (site 28.2)

Statistics	Entire Dataset	Summer	Winter
N	8	4	4
Minimum	50.0	50.0	139.0
25th Percentile	128.7	85.8	155.5
Average	155.7	128.7	182.8
Median	156.5	124.9	170.0
75th Percentile	188.0	167.8	197.3
80th Percentile	200.6	177.2	208.2
95th Percentile	239.1	205.6	241.1
Maximum	252.0	215.0	252.0



Mgeni River Catchment : Mgeni downstream of KwaDabeka WWW (site 28.5)

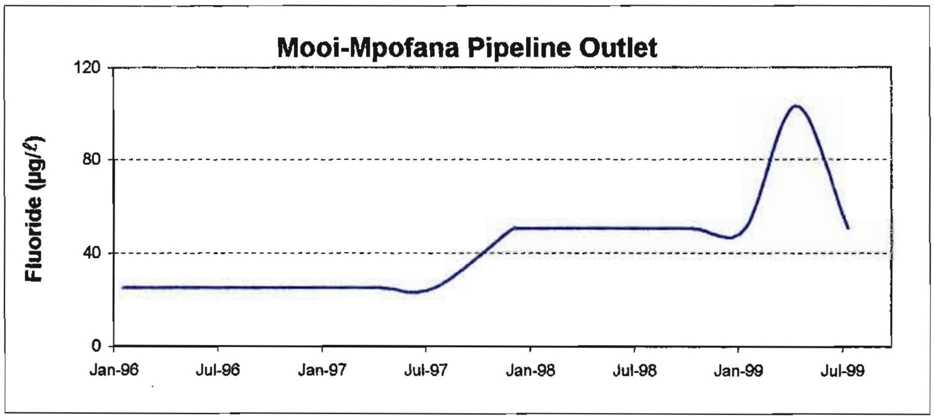
Statistics	Entire Dataset	Summer	Winter
N	13	7	6
Minimum	50.0	51.1	50.0
25th Percentile	115.6	100.0	121.0
Average	122.9	121.6	124.3
Median	136.0	134.0	138.5
75th Percentile	149.0	153.5	144.8
80th Percentile	153.8	156.2	146.0
95th Percentile	158.4	158.7	154.3
Maximum	159.0	159.0	157.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

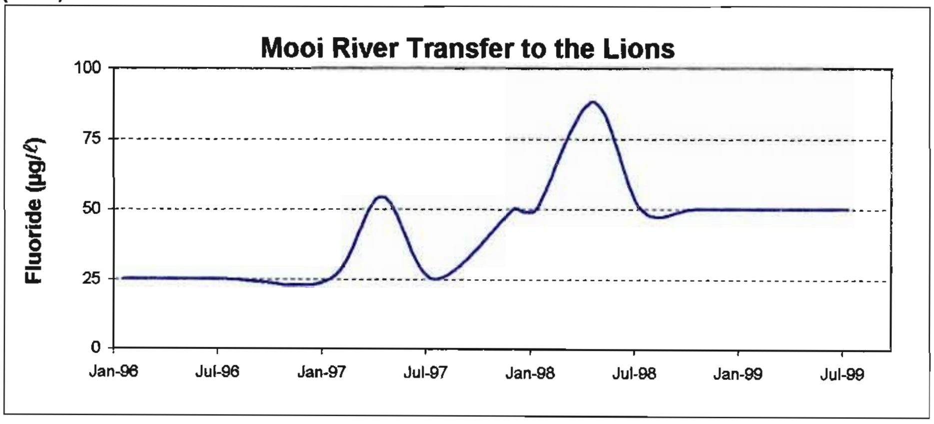
Mgeni River Catchment : Mooi-Mpofana Pipeline Outlet (site 29)

Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	25.0	25.0	25.0
25th Percentile	25.0	37.5	25.0
Average	44.9	42.9	46.9
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	50.0
95th Percentile	68.6	50.0	87.1
Maximum	103.0	50.0	103.0



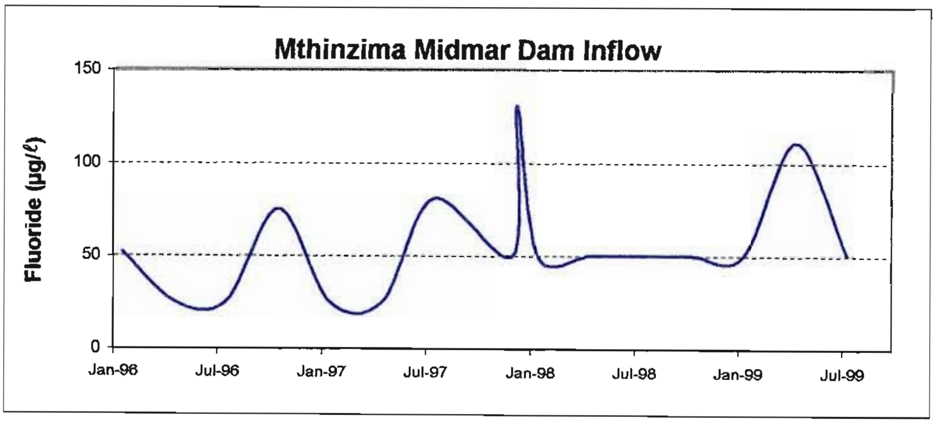
Mgeni River Catchment : Mooi River Transfer to the Lions (site 30)

Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	25.0	25.0	25.0
25th Percentile	31.3	37.5	37.5
Average	45.9	42.9	48.9
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	52.1
80th Percentile	50.0	50.0	53.4
95th Percentile	66.0	50.0	77.8
Maximum	87.9	50.0	87.9



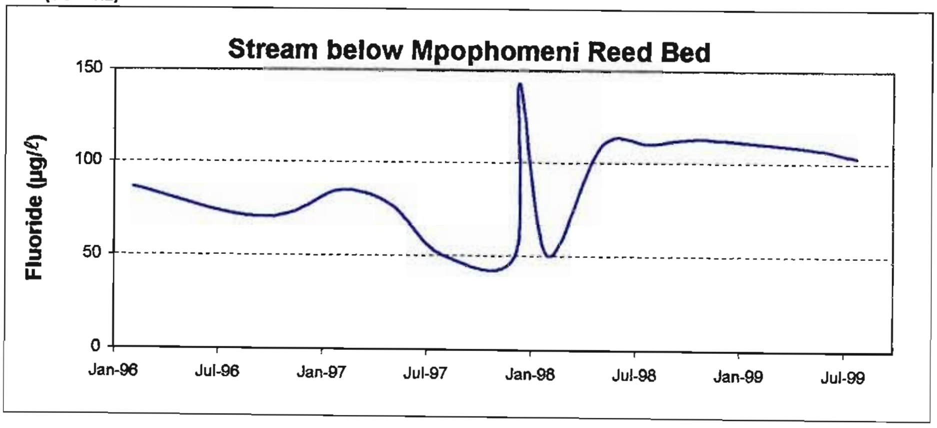
Mgeni River Catchment : Mthinzima Midmar Dam Inflow (site 30)

Statistics	Entire Dataset	Summer	Winter
N	16	8	8
Minimum	25.0	25.0	25.0
25th Percentile	43.8	50.0	25.0
Average	56.2	60.4	52.1
Median	50.0	50.0	50.0
75th Percentile	57.8	57.8	57.6
80th Percentile	75.0	65.8	68.3
95th Percentile	116.0	111.4	100.3
Maximum	131.0	131.0	111.0



Mgeni River Catchment : Stream below Mpophomeni Reed Bed (site 31.2)

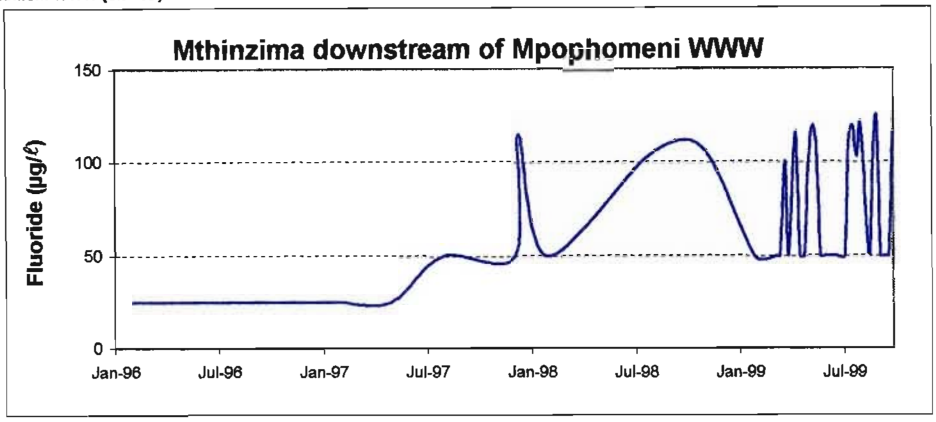
Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	50.0	50.0	50.0
25th Percentile	71.7	61.0	74.2
Average	87.6	85.5	89.8
Median	85.3	84.5	103.0
75th Percentile	108.8	99.5	108.5
80th Percentile	109.4	107.6	108.8
95th Percentile	123.5	134.0	109.7
Maximum	143.0	143.0	110.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

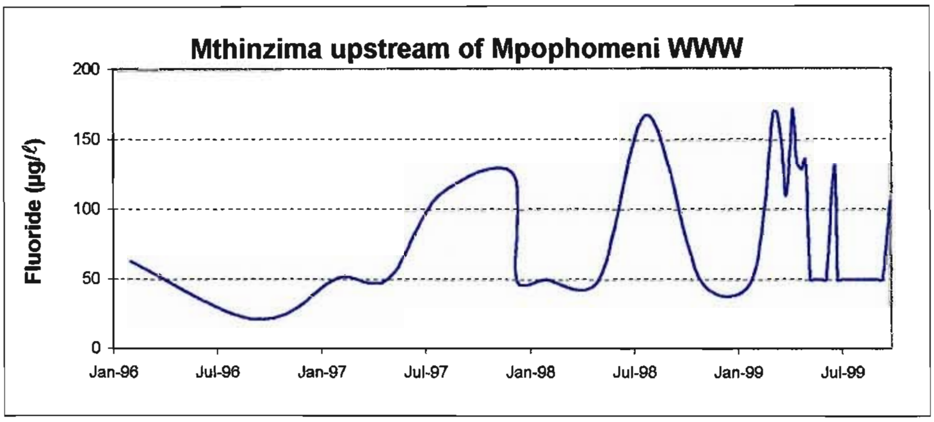
Mgeni River Catchment : Mthinzima downstream of Mpophomeni WWW (site 32)

Statistics	Entire Dataset	Summer	Winter
N	39	12	27
Minimum	25.0	25.0	25.0
25th Percentile	50.0	43.8	50.0
Average	71.6	58.3	77.6
Median	50.0	50.0	50.0
75th Percentile	105.0	62.8	109.0
80th Percentile	109.6	90.8	114.4
95th Percentile	120.0	111.2	120.0
Maximum	124.0	115.0	124.0



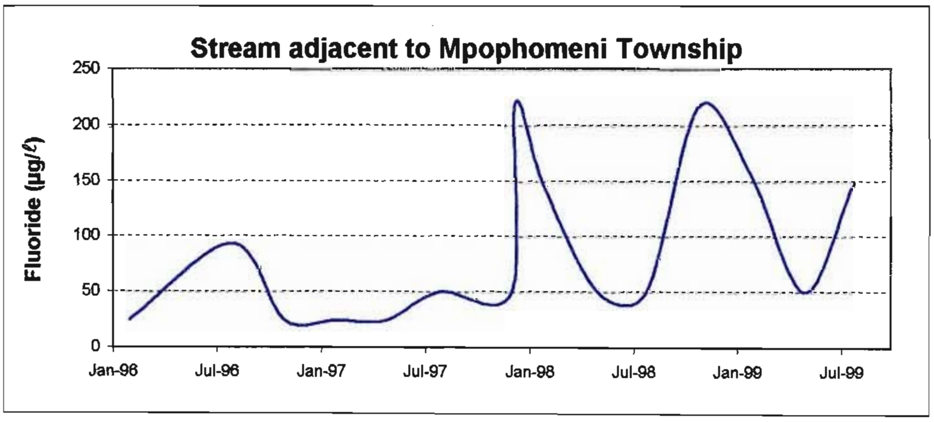
Mgeni River Catchment : Mthinzima upstream of Mpophomeni WWW (site 32.1)

Statistics	Entire Dataset	Summer	Winter
N	40	12	28
Minimum	25.0	25.0	25.0
25th Percentile	50.0	50.0	50.0
Average	80.5	88.3	77.2
Median	50.0	56.9	50.0
75th Percentile	127.2	131.0	115.5
80th Percentile	132.4	140.5	130.8
95th Percentile	170.0	170.0	160.7
Maximum	172.0	170.0	172.0



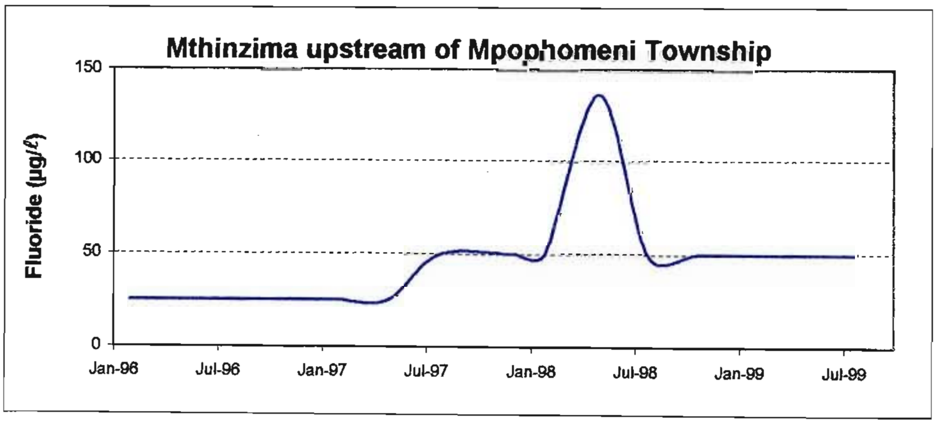
Mgeni River Catchment : Stream adjacent to Mpophomeni Township (site 33)

Statistics	Entire Dataset	Summer	Winter
N	15	8	7
Minimum	25.0	25.0	25.0
25th Percentile	37.5	25.0	50.0
Average	88.9	108.3	66.7
Median	50.0	98.5	50.0
75th Percentile	147.5	172.0	72.0
80th Percentile	149.8	193.0	85.1
95th Percentile	217.9	219.0	131.8
Maximum	220.0	220.0	148.0



Mgeni River Catchment : Mthinzima upstream of Mpophomeni Township (site 33.1)

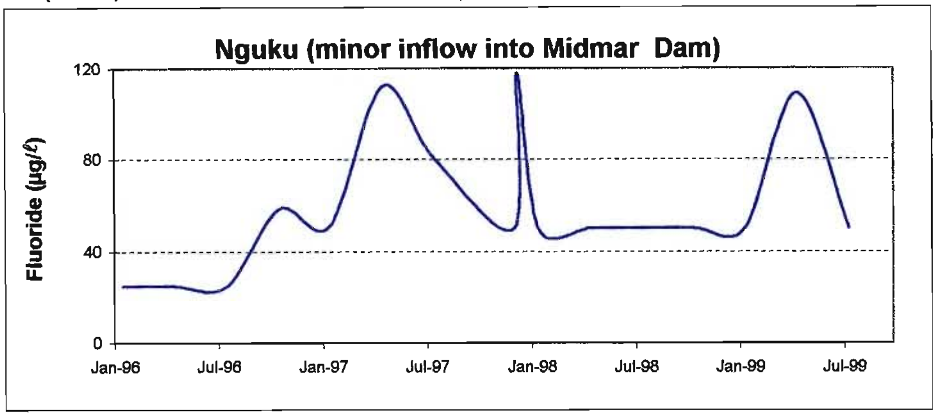
Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	25.0	25.0	25.0
25th Percentile	25.0	25.0	37.5
Average	47.3	39.3	55.3
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	50.0
95th Percentile	80.5	50.0	110.9
Maximum	137.0	50.0	137.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

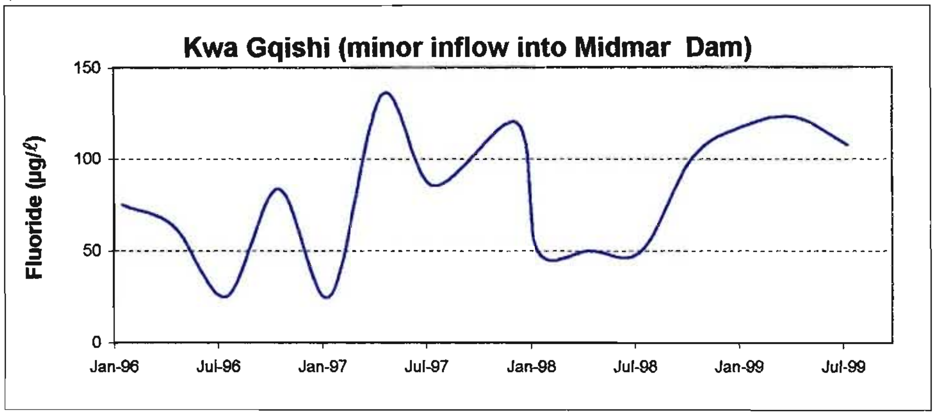
Mgeni River Catchment : Nguku, minor inflow into Midmar Dam (site 34.1)

Statistics	Entire Dataset	Summer	Winter
N	16	8	8
Minimum	25.0	25.0	25.0
25th Percentile	50.0	50.0	43.8
Average	59.6	56.6	62.7
Median	50.0	50.0	50.0
75th Percentile	63.9	52.9	87.9
80th Percentile	80.8	55.4	97.7
95th Percentile	113.5	97.1	111.0
Maximum	118.0	118.0	112.0



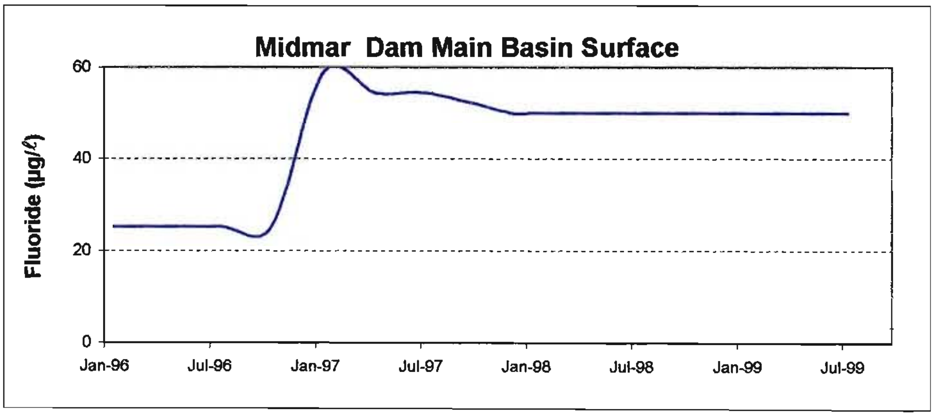
Mgeni River Catchment : Kwa Gqishi, minor inflow into Midmar Dam (site 35)

Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	25.0	25.0	25.0
25th Percentile	50.0	62.5	50.0
Average	80.8	81.8	79.9
Median	83.5	83.5	74.2
75th Percentile	113.0	109.5	111.8
80th Percentile	118.4	114.6	117.0
95th Percentile	126.6	119.4	130.8
Maximum	135.0	120.0	135.0



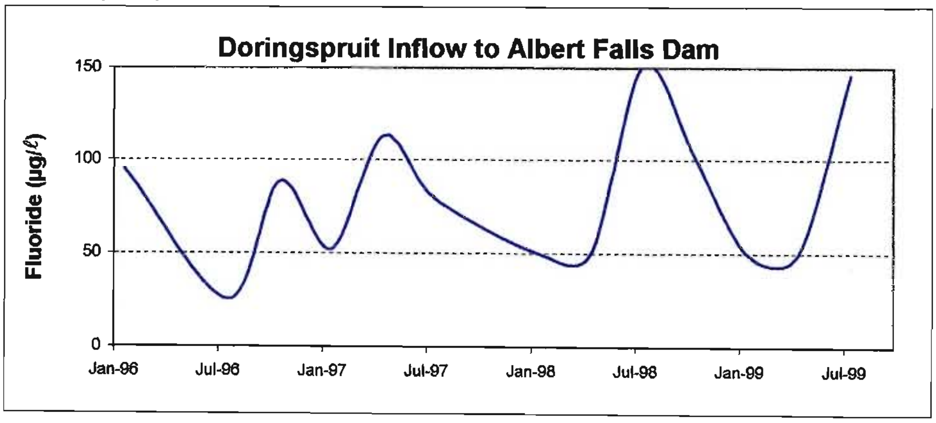
Mgeni River Catchment : Midmar Dam Main Basin Surface (site 36.1)

Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	25.0	25.0	25.0
25th Percentile	50.0	37.5	50.0
Average	45.9	44.1	47.7
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	52.2
80th Percentile	51.7	50.0	53.4
95th Percentile	55.9	56.2	54.3
Maximum	58.9	58.9	54.3



Mgeni River Catchment : Doringspruit minor inflow to Albert Falls Dam (site 37)

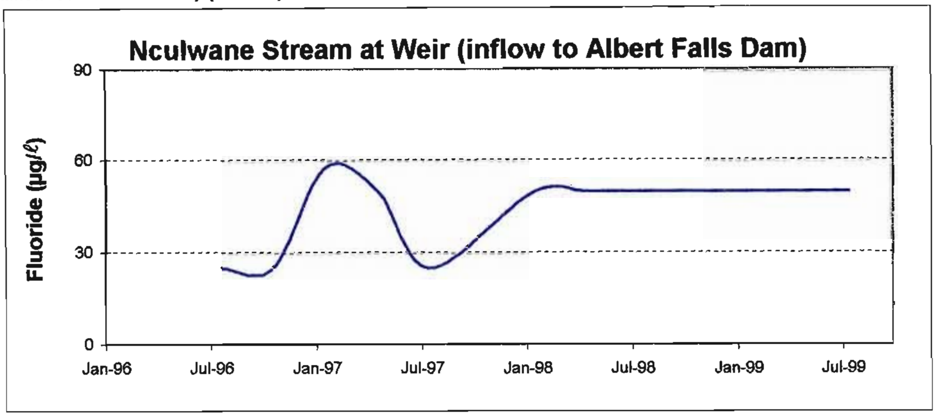
Statistics	Entire Dataset	Summer	Winter
N	13	6	7
Minimum	25.0	50.0	25.0
25th Percentile	50.0	50.5	50.0
Average	80.9	72.9	87.7
Median	78.9	70.1	78.9
75th Percentile	102.0	93.3	129.5
80th Percentile	108.6	95.0	139.4
95th Percentile	148.0	100.3	149.5
Maximum	151.0	102.0	151.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

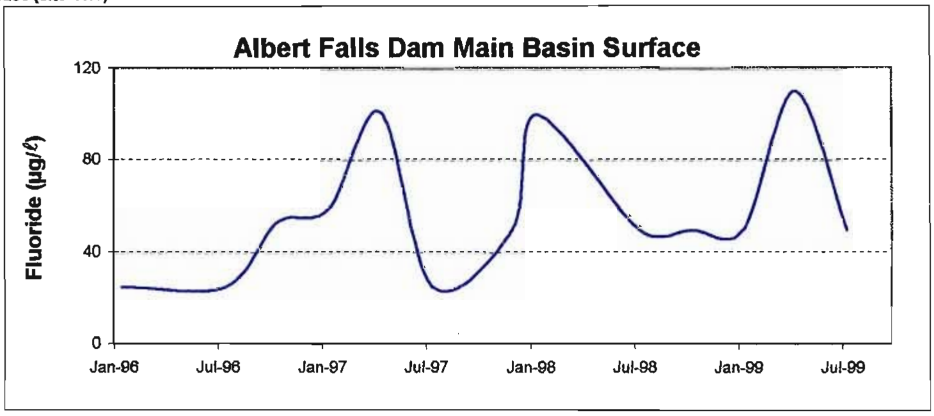
Mgeni River Catchment : Nculwane Stream at Weir (minor inflow to Albert Falls Dam) (site 38.1)

Statistics	Entire Dataset	Summer	Winter
N	12	5	7
Minimum	25.0	25.0	25.0
25th Percentile	43.8	50.0	37.5
Average	44.4	46.6	42.9
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	51.6	50.0
95th Percentile	53.5	56.2	50.0
Maximum	57.8	57.8	50.0



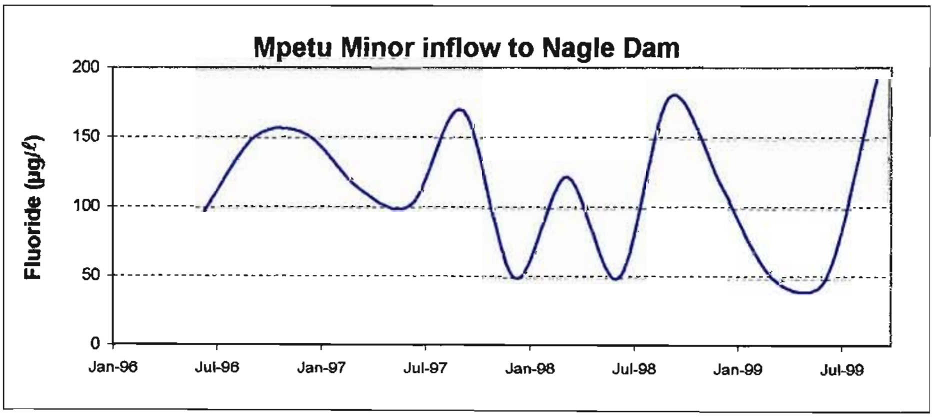
Mgeni River Catchment : Albert Falls Dam Main Basin Surface (site 41.1)

Statistics	Entire Dataset	Summer	Winter
N	13	7	6
Minimum	25.0	25.0	25.0
25th Percentile	50.0	50.0	31.3
Average	57.5	55.3	60.2
Median	50.0	50.0	50.0
75th Percentile	58.8	55.9	88.3
80th Percentile	83.5	57.6	101.0
95th Percentile	104.6	87.6	107.8
Maximum	110.0	100.0	110.0



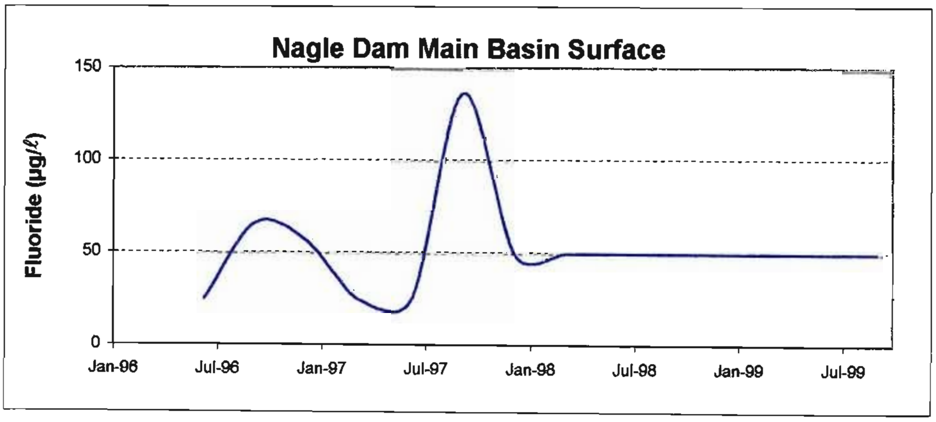
Mgeni River Catchment :Mpetu Minor inflow to Nagle Dam(site 42)

Statistics	Entire Dataset	Summer	Winter
N	14	6	8
Minimum	50.0	50.0	50.0
25th Percentile	61.8	65.8	85.3
Average	114.0	100.5	124.1
Median	114.5	114.5	126.5
75th Percentile	151.8	120.5	172.5
80th Percentile	159.2	122.0	176.0
95th Percentile	184.6	144.5	188.5
Maximum	193.0	152.0	193.0



Mgeni River Catchment : Nagle Dam Main Basin Surface (site 43.1)

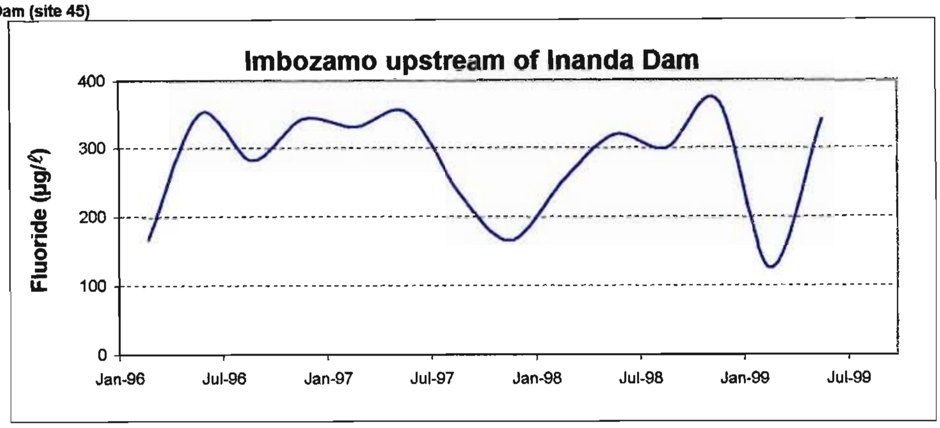
Statistics	Entire Dataset	Summer	Winter
N	14	6	8
Minimum	25.0	25.0	25.0
25th Percentile	50.0	50.0	43.8
Average	52.5	46.9	56.7
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	54.1
80th Percentile	52.6	50.0	59.7
95th Percentile	91.0	55.0	112.2
Maximum	137.0	56.6	137.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

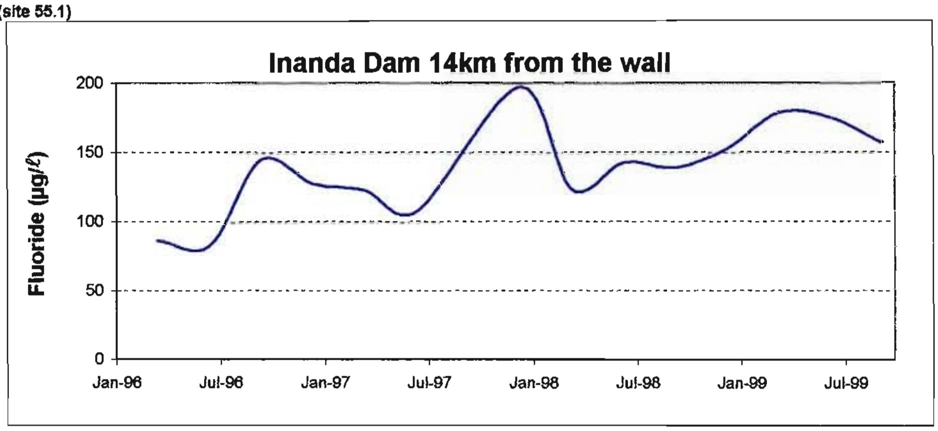
Mgeni River Catchment : Imbozamo upstream of Inanda Dam (site 45)

Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	127.0	127.0	235.0
25th Percentile	239.3	167.1	291.0
Average	281.6	251.2	312.0
Median	310.0	252.0	320.0
75th Percentile	343.0	337.0	347.0
80th Percentile	346.2	340.6	349.4
95th Percentile	359.3	362.6	352.4
Maximum	371.0	371.0	353.0



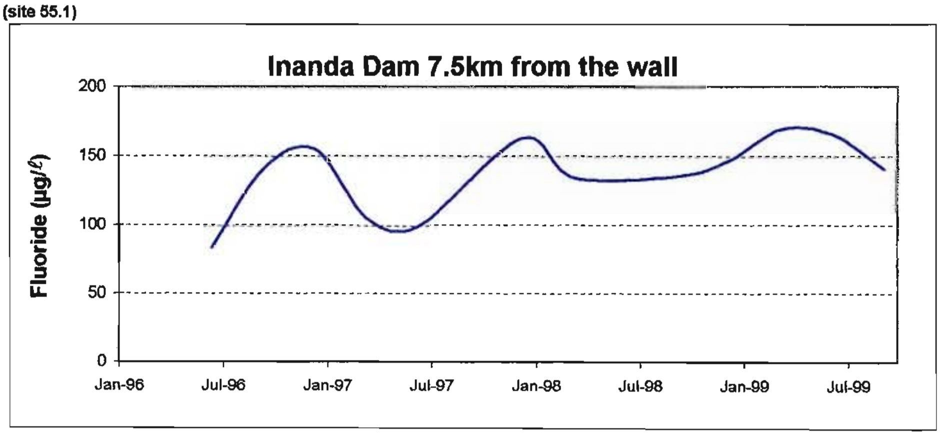
Mgeni River Catchment : Inanda Dam 14km from the wall (site 55.1)

Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	83.0	87.0	83.0
25th Percentile	123.2	123.4	123.5
Average	138.6	141.5	135.7
Median	141.0	128.0	143.0
75th Percentile	156.0	166.0	151.0
80th Percentile	164.2	173.8	154.6
95th Percentile	185.3	191.6	169.6
Maximum	197.0	197.0	175.0



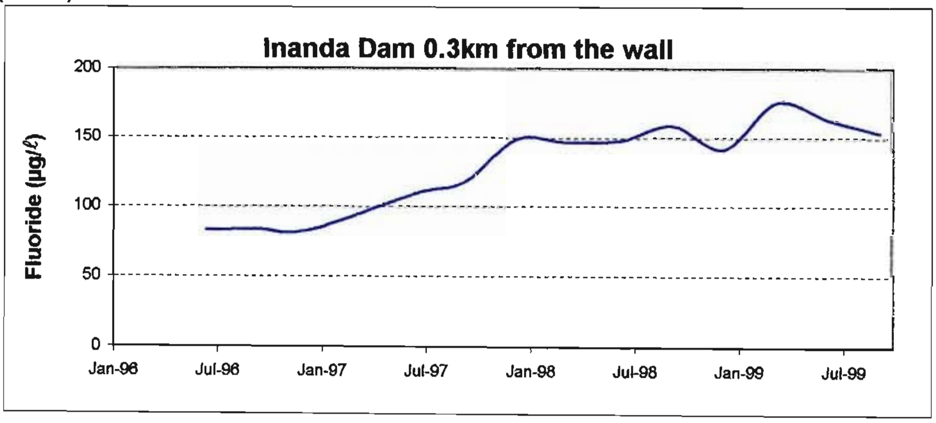
Mgeni River Catchment : Inanda Dam 7.5km from the wall (site 55.1)

Statistics	Entire Dataset	Summer	Winter
N	12	6	6
Minimum	84.0	105.0	84.0
25th Percentile	127.4	137.9	109.0
Average	136.9	145.8	128.0
Median	140.9	151.0	138.4
75th Percentile	157.0	161.0	141.0
80th Percentile	161.4	163.0	141.0
95th Percentile	167.8	168.3	159.8
Maximum	170.0	170.0	166.0



Mgeni River Catchment : Inanda Dam 0.3km from the wall (site 55.1)

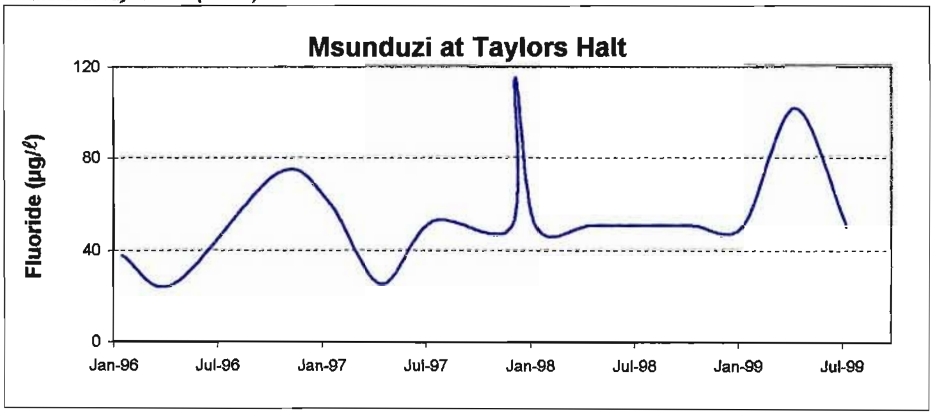
Statistics	Entire Dataset	Summer	Winter
N	13	5	8
Minimum	82.9	82.9	83.0
25th Percentile	109.0	142.0	102.6
Average	131.9	139.3	127.2
Median	146.8	146.8	133.0
75th Percentile	154.0	149.0	155.3
80th Percentile	157.0	154.4	157.0
95th Percentile	168.2	170.6	161.6
Maximum	176.0	176.0	163.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

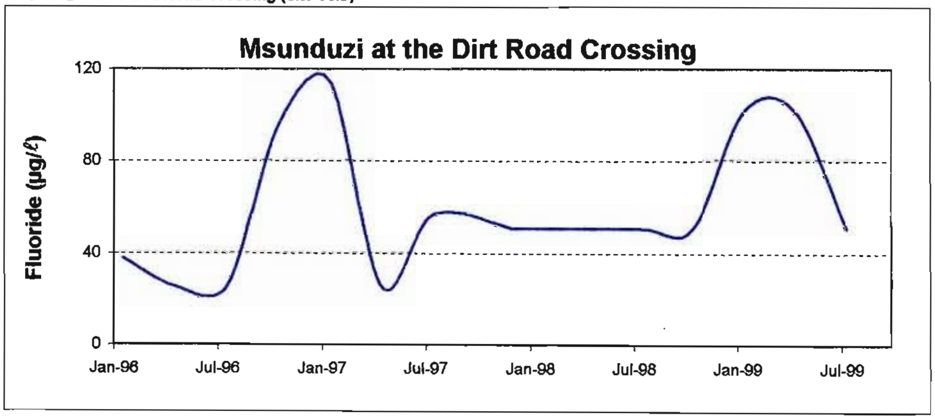
Mgeni River Catchment (Msunduzi River Sub-catchment) : Msunduzi at Taylors Halt (site 56)

Statistics	Entire Dataset	Summer	Winter
N	15	8	7
Minimum	25.0	37.5	25.0
25th Percentile	50.0	50.0	37.5
Average	56.0	60.8	50.4
Median	50.0	50.0	50.0
75th Percentile	56.4	63.8	51.1
80th Percentile	63.2	68.1	51.7
95th Percentile	105.2	100.3	86.3
Maximum	115.0	115.0	101.0



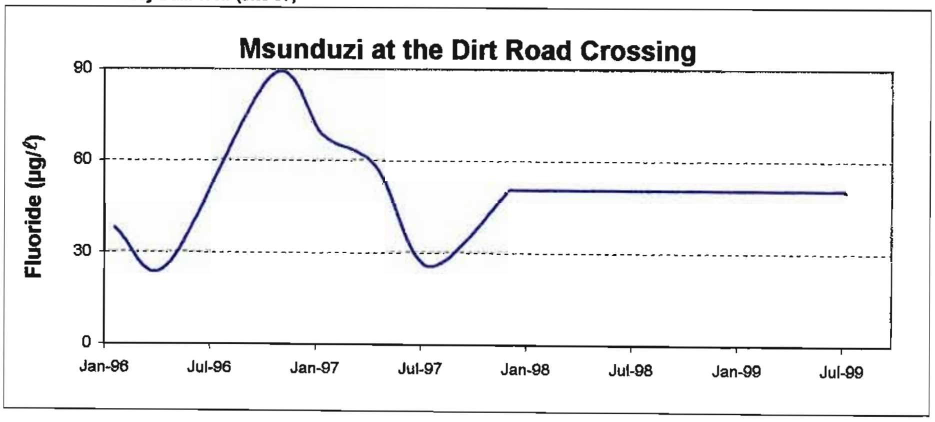
Mgeni River Catchment (Msunduzi River Sub-catchment) : Msunduzi at the Dirt Road Crossing (site 56.2)

Statistics	Entire Dataset	Summer	Winter
N	15	8	7
Minimum	25.0	37.5	25.0
25th Percentile	43.8	50.0	25.0
Average	58.7	68.5	47.5
Median	50.0	50.0	50.0
75th Percentile	75.8	96.7	53.1
80th Percentile	96.4	98.7	55.0
95th Percentile	104.9	109.5	87.6
Maximum	114.0	114.0	101.0



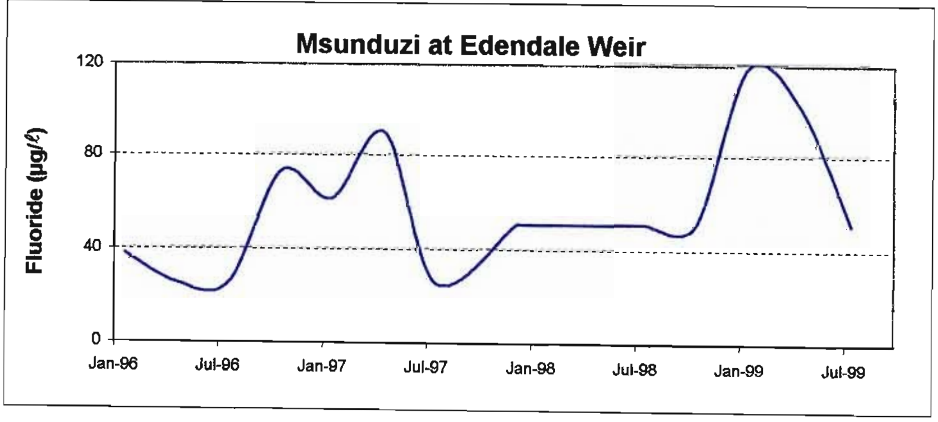
Mgeni River Catchment (Msunduzi River Sub-catchment) : Msunduzi at Henley Dam Weir (site 57)

Statistics	Entire Dataset	Summer	Winter
N	15	8	7
Minimum	25.0	37.5	25.0
25th Percentile	50.0	50.0	37.5
Average	50.0	55.4	44.0
Median	50.0	50.0	50.0
75th Percentile	50.0	54.5	50.0
80th Percentile	51.5	60.7	50.0
95th Percentile	73.8	80.6	55.4
Maximum	87.4	87.4	57.7



Mgeni River Catchment (Msunduzi River Sub-catchment) : Msunduzi at Edendale Weir (site 62)

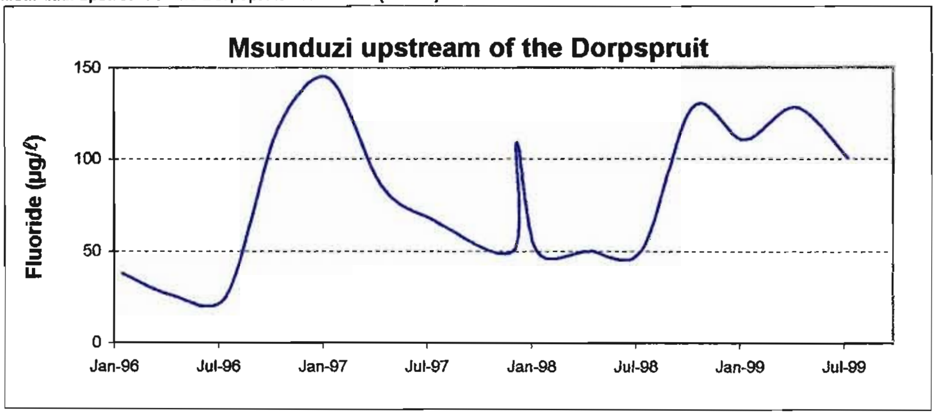
Statistics	Entire Dataset	Summer	Winter
N	16	8	8
Minimum	25.0	37.5	25.0
25th Percentile	46.9	50.0	25.0
Average	56.6	61.1	52.0
Median	50.0	50.0	50.0
75th Percentile	63.7	63.7	59.8
80th Percentile	72.4	67.8	73.6
95th Percentile	106.0	102.0	97.6
Maximum	118.0	118.0	102.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

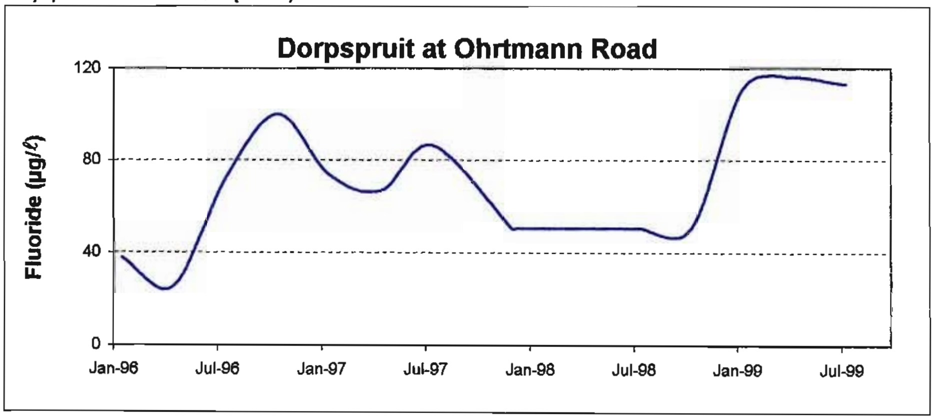
Mgeni River Catchment (Msunduzi River Sub-catchment) :Msunduzi upstream of the Dorpspruit Confluence (site 63)

Statistics	Entire Dataset	Summer	Winter
N	16	8	8
Minimum	25.0	37.5	25.0
25th Percentile	50.0	50.0	43.8
Average	79.7	93.1	66.3
Median	76.1	109.5	58.4
75th Percentile	111.5	119.0	89.1
80th Percentile	116.0	123.2	94.2
95th Percentile	132.0	138.4	118.2
Maximum	144.0	144.0	128.0



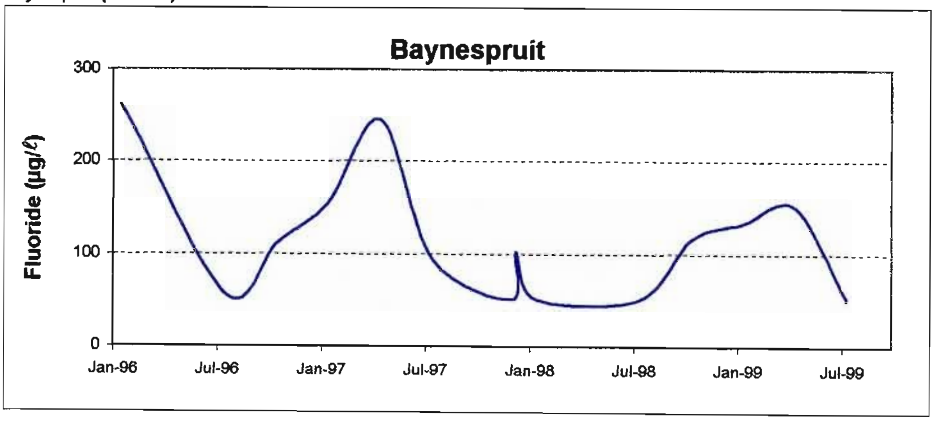
Mgeni River Catchment (Msunduzi River Sub-catchment) : Dorpspruit at Ohrtmann Road (site 64)

Statistics	Entire Dataset	Summer	Winter
N	16	8	8
Minimum	25.0	37.5	25.0
25th Percentile	50.0	50.0	50.0
Average	68.8	65.3	72.3
Median	58.3	50.0	69.3
75th Percentile	89.7	80.2	92.9
80th Percentile	100.0	89.4	102.3
95th Percentile	113.8	107.2	115.0
Maximum	116.0	111.0	116.0



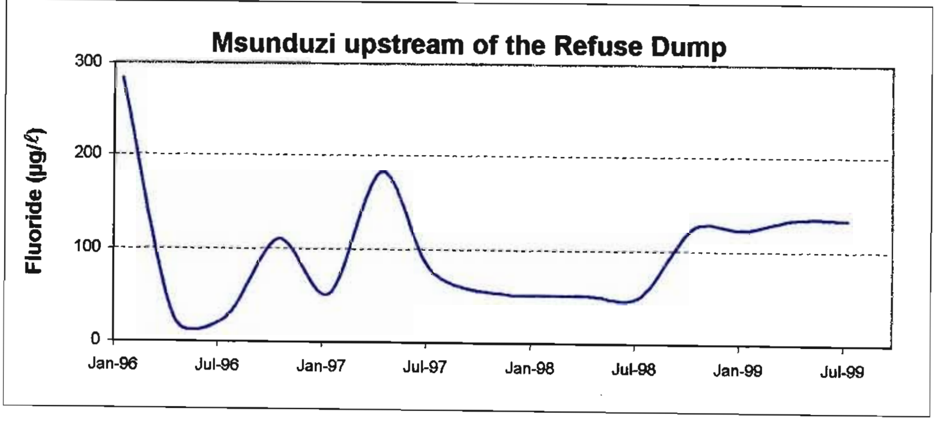
Mgeni River Catchment (Msunduzi River Sub-catchment) : Baynespruit (site 64.1)

Statistics	Entire Dataset	Summer	Winter
N	14	8	6
Minimum	50.0	50.0	50.0
25th Percentile	51.4	89.0	51.4
Average	115.8	122.3	107.3
Median	106.5	113.5	74.4
75th Percentile	146.5	138.5	136.6
80th Percentile	152.6	146.2	151.0
95th Percentile	250.0	223.9	220.8
Maximum	261.0	261.0	244.0



Mgeni River Catchment (Msunduzi River Sub-catchment) : Msunduzi upstream of the Refuse Dump (site 65)

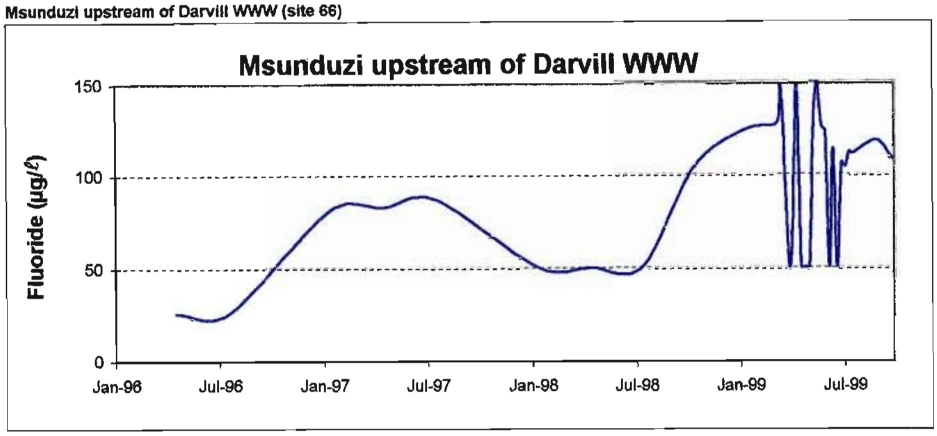
Statistics	Entire Dataset	Summer	Winter
N	16	8	8
Minimum	25.0	50.0	25.0
25th Percentile	50.0	50.0	43.8
Average	94.4	104.9	84.0
Median	62.9	80.6	62.3
75th Percentile	125.3	122.3	132.3
80th Percentile	132.0	122.6	132.6
95th Percentile	207.3	227.0	164.9
Maximum	283.0	283.0	182.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

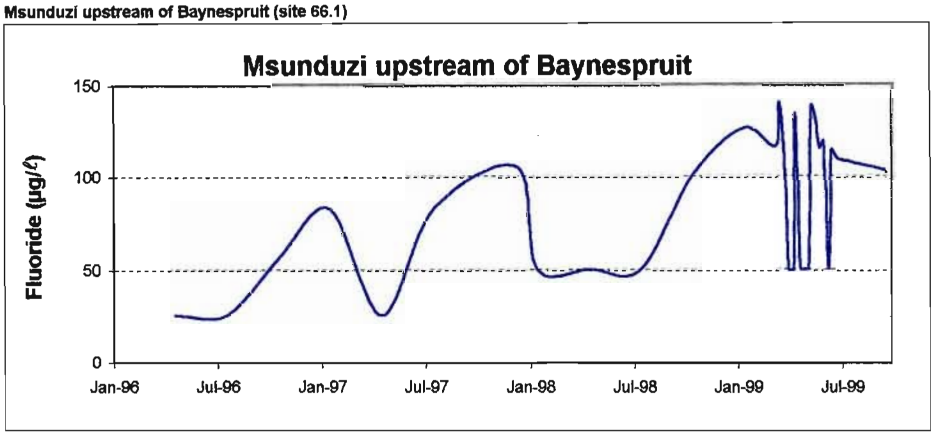
Mgeni River Catchment (Msunduzi River Sub-catchment) : Msunduzi upstream of Darvill WWW (site 66)

Statistics	Entire Dataset	Summer	Winter
N	31	7	24
Minimum	25.0	50.0	25.0
25th Percentile	50.0	65.5	50.0
Average	90.9	97.9	88.9
Median	104.0	104.0	105.0
75th Percentile	120.5	126.0	117.3
80th Percentile	124.0	127.2	120.0
95th Percentile	148.5	142.0	145.6
Maximum	151.0	148.0	151.0



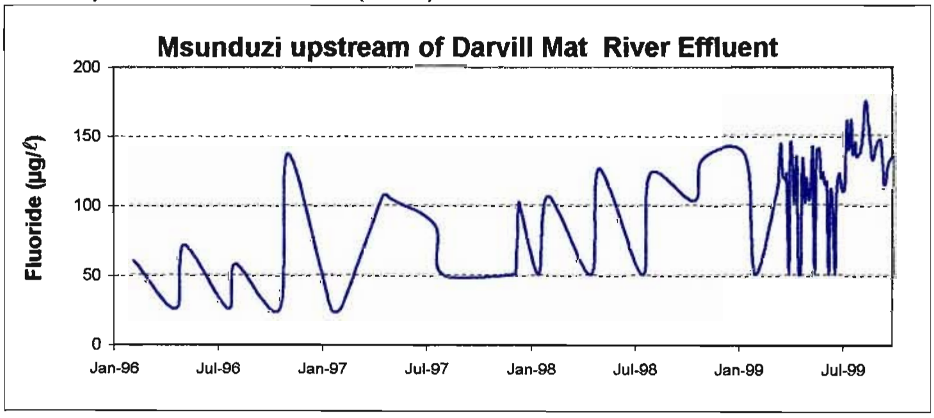
Mgeni River Catchment (Msunduzi River Sub-catchment) : Msunduzi upstream of Baynespruit (site 66.1)

Statistics	Entire Dataset	Summer	Winter
N	30	10	20
Minimum	25.0	50.0	25.0
25th Percentile	50.0	62.6	50.0
Average	83.9	93.4	79.1
Median	91.8	103.0	66.3
75th Percentile	114.8	113.8	114.3
80th Percentile	116.6	116.0	115.8
95th Percentile	136.2	133.7	134.2
Maximum	140.0	140.0	138.0



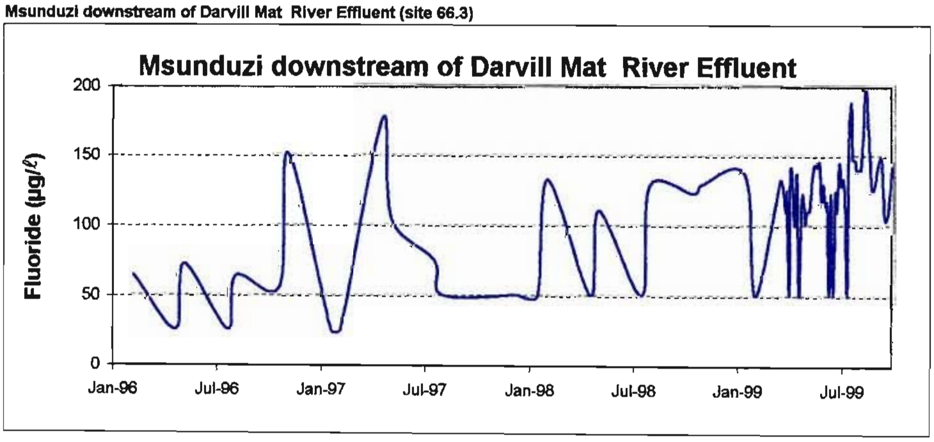
Mgeni River Catchment (Msunduzi River Sub-catchment) : Msunduzi upstream Darvill Mat River Effluent (site 66.2)

Statistics	Entire Dataset	Summer	Winter
N	77	22	55
Minimum	25.0	25.0	25.0
25th Percentile	60.0	50.0	101.5
Average	102.9	88.2	108.8
Median	113.0	102.5	115.0
75th Percentile	133.0	121.5	135.0
80th Percentile	135.8	124.4	139.0
95th Percentile	148.0	136.9	157.2
Maximum	174.0	144.0	174.0



Mgeni River Catchment (Msunduzi River Sub-catchment) : Msunduzi downstream of Darvill Mat River Effluent (site 66.3)

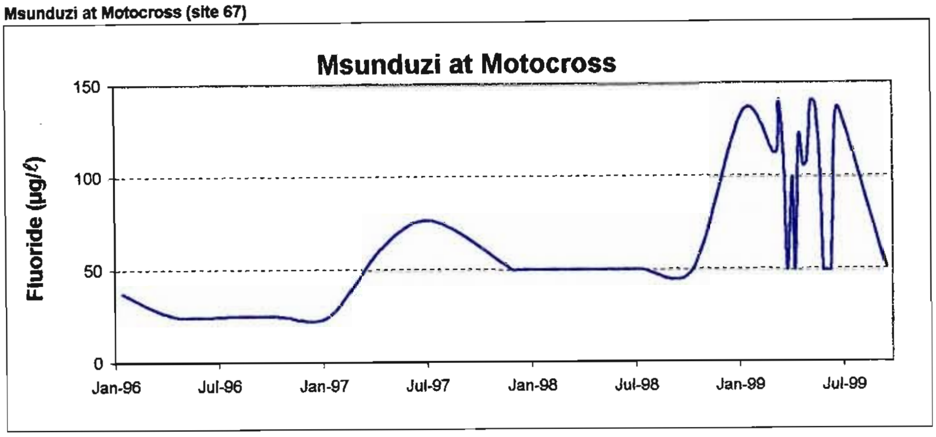
Statistics	Entire Dataset	Summer	Winter
N	75	21	54
Minimum	25.0	25.0	25.0
25th Percentile	63.9	50.0	100.3
Average	106.5	89.5	113.1
Median	120.0	109.0	121.0
75th Percentile	136.0	128.0	140.0
80th Percentile	140.0	129.0	142.4
95th Percentile	163.3	136.0	168.2
Maximum	198.0	151.0	198.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

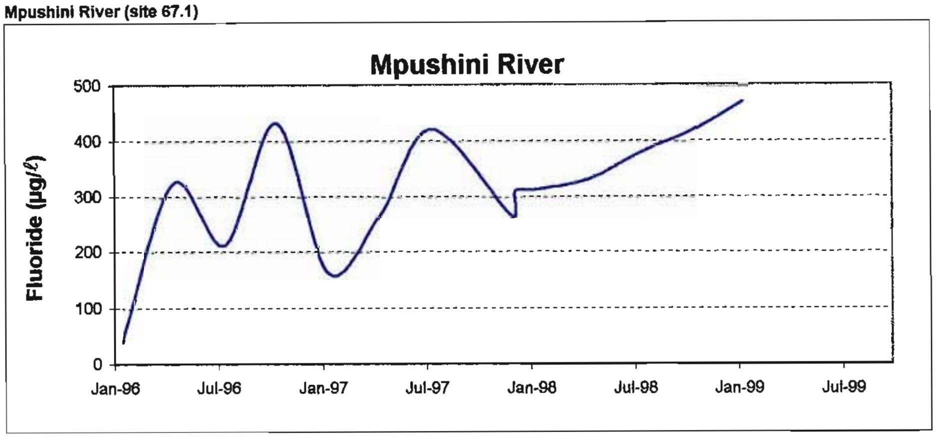
Mgeni River Catchment (Msunduzi River Sub-catchment) : Msunduzi at Motocross (site 67)

Statistics	Entire Dataset	Summer	Winter
N	32	12	20
Minimum	25.0	25.0	25.0
25th Percentile	50.0	46.9	50.0
Average	77.2	69.5	81.8
Median	50.0	50.0	69.0
75th Percentile	113.5	108.5	116.8
80th Percentile	120.6	111.8	123.0
95th Percentile	140.5	138.3	140.1
Maximum	141.0	141.0	141.0



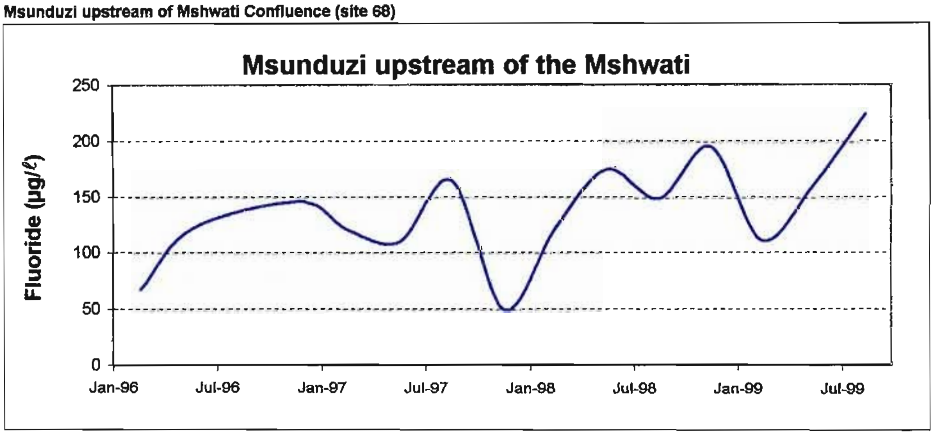
Mgeni River Catchment (Msunduzi River Sub-catchment) : Mpushini River (site 67.1)

Statistics	Entire Dataset	Summer	Winter
N	14	8	6
Minimum	37.5	37.5	214.0
25th Percentile	266.0	240.5	280.5
Average	310.9	302.1	322.7
Median	319.0	312.0	327.5
75th Percentile	409.0	422.5	367.0
80th Percentile	420.2	427.4	379.0
95th Percentile	447.0	459.0	411.3
Maximum	473.0	473.0	422.0



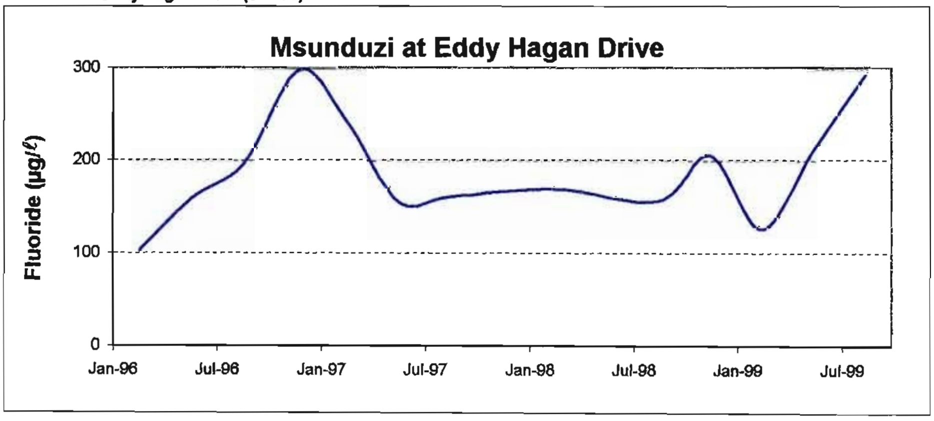
Mgeni River Catchment (Msunduzi River Sub-catchment) : Msunduzi upstream of Mshwati Confluence (site 68)

Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	50.0	50.0	110.0
25th Percentile	114.3	90.0	135.5
Average	137.4	116.4	158.4
Median	134.0	121.0	162.0
75th Percentile	164.3	134.0	170.5
80th Percentile	169.4	141.2	173.8
95th Percentile	206.2	181.0	210.3
Maximum	225.0	196.0	225.0



Mgeni River Catchment (Msunduzi River Sub-catchment) : Msunduzi at Eddy Hagan Drive (site 70)

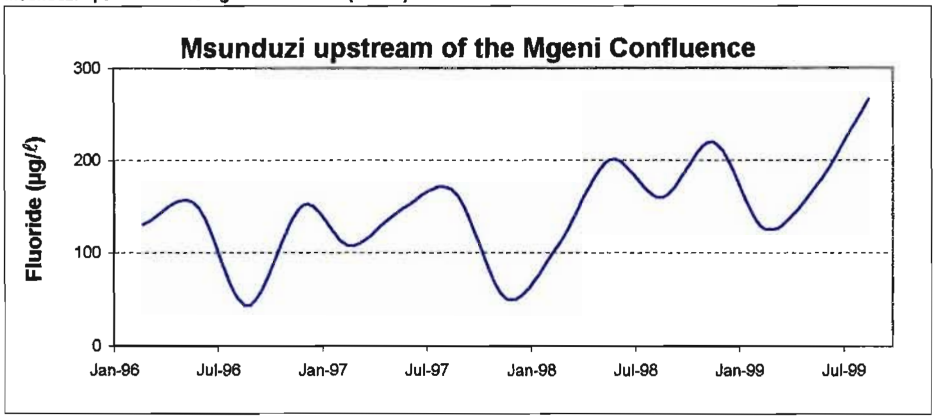
Statistics	Entire Dataset	Summer	Winter
N	13	6	7
Minimum	103.0	103.0	156.0
25th Percentile	157.0	137.8	158.0
Average	191.0	191.2	190.9
Median	170.0	188.0	161.0
75th Percentile	212.0	233.8	204.5
80th Percentile	230.6	243.0	209.0
95th Percentile	295.6	284.3	269.4
Maximum	298.0	298.0	294.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

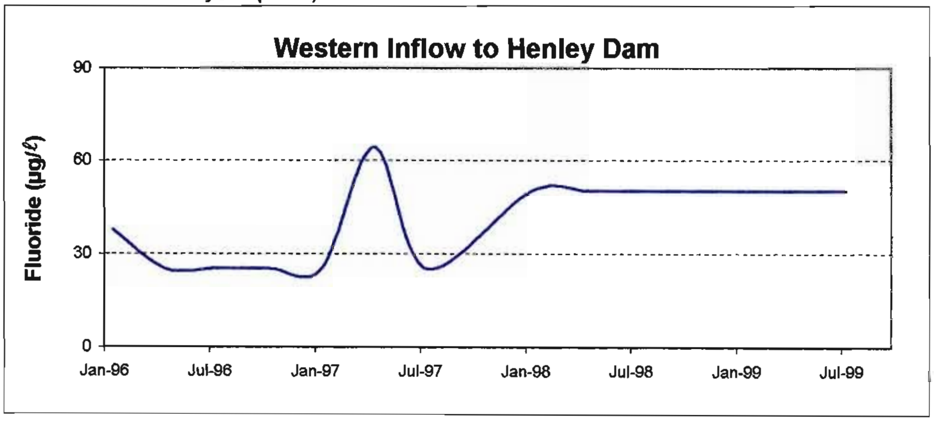
Mgeni River Catchment (Msunduzi River Sub-catchment) : Msunduzi upstream of the Mgeni Confluence (site 71)

Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	42.6	50.0	42.6
25th Percentile	116.5	107.0	151.5
Average	146.6	127.1	163.7
Median	151.0	126.0	163.0
75th Percentile	170.0	140.5	180.5
80th Percentile	179.2	146.8	189.6
95th Percentile	233.4	198.6	243.6
Maximum	267.0	219.0	267.0



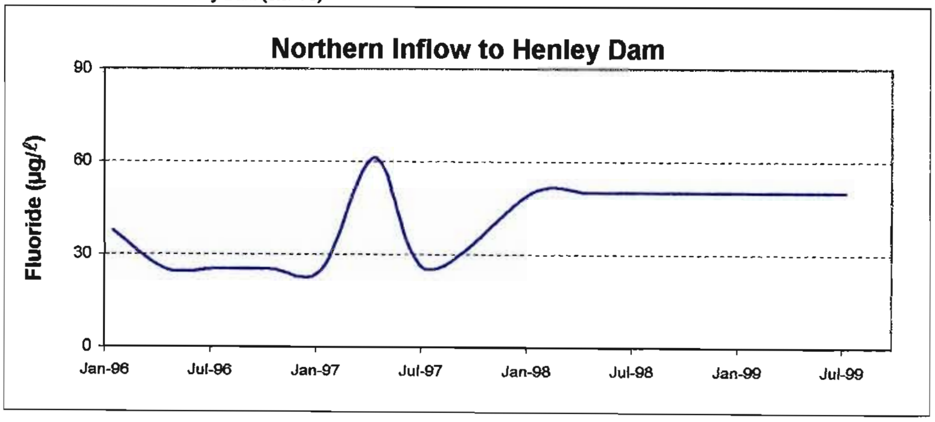
Mgeni River Catchment (Msunduzi River Sub-catchment) : West Drain Inflow to Henley Dam (site 72)

Statistics	Entire Dataset	Summer	Winter
N	14	6	8
Minimum	25.0	25.0	25.0
25th Percentile	25.0	28.1	25.0
Average	41.2	39.6	42.4
Median	50.0	43.8	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	50.0
95th Percentile	54.9	50.0	59.2
Maximum	64.1	50.0	64.1



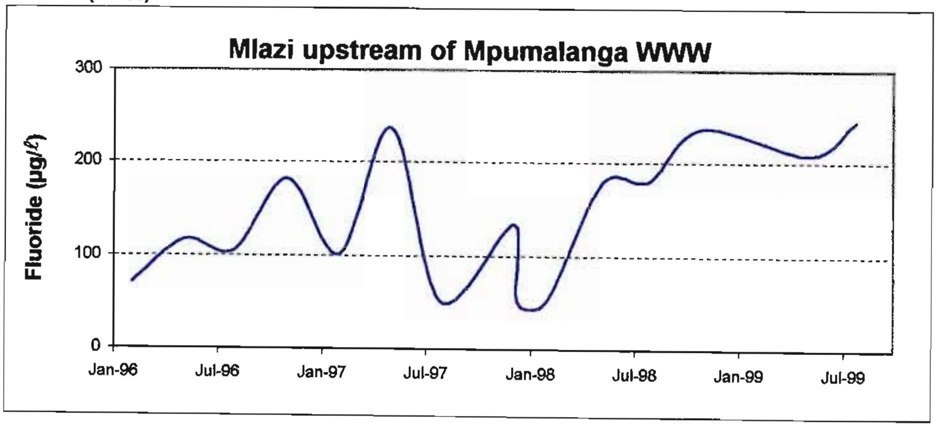
Mgeni River Catchment (Msunduzi River Sub-catchment) : North Drain Inflow to Henley Dam (site 73)

Statistics	Entire Dataset	Summer	Winter
N	14	6	8
Minimum	25.0	25.0	25.0
25th Percentile	25.0	28.1	25.0
Average	41.0	39.6	42.0
Median	50.0	43.8	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	50.0
95th Percentile	53.9	50.0	57.2
Maximum	61.1	50.0	61.1



Mlazi Catchment : Mlazi upstream of Mpumalanga Wastewater Works (site 75)

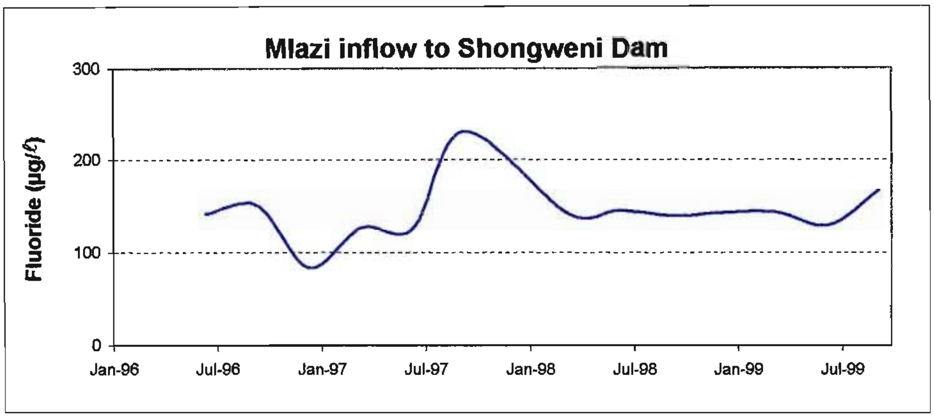
Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	50.0	50.0	50.0
25th Percentile	85.5	60.0	113.3
Average	142.7	117.5	164.8
Median	133.8	101.0	179.0
75th Percentile	195.0	157.9	215.0
80th Percentile	213.6	172.4	224.8
95th Percentile	238.7	219.8	241.9
Maximum	245.0	236.0	245.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

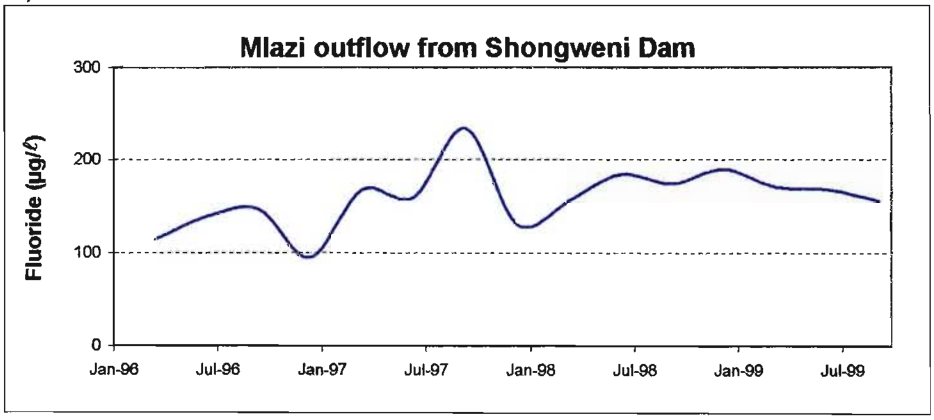
Mlazi Catchment : Mlazi inflow to Shongweni Dam (site 77)

Statistics	Entire Dataset	Summer	Winter
N	13	5	8
Minimum	82.5	82.5	125.0
25th Percentile	129.0	126.0	136.5
Average	143.0	126.9	153.1
Median	141.0	141.0	143.0
75th Percentile	145.0	142.0	154.0
80th Percentile	148.0	142.2	159.6
95th Percentile	191.6	142.8	207.6
Maximum	230.0	143.0	230.0



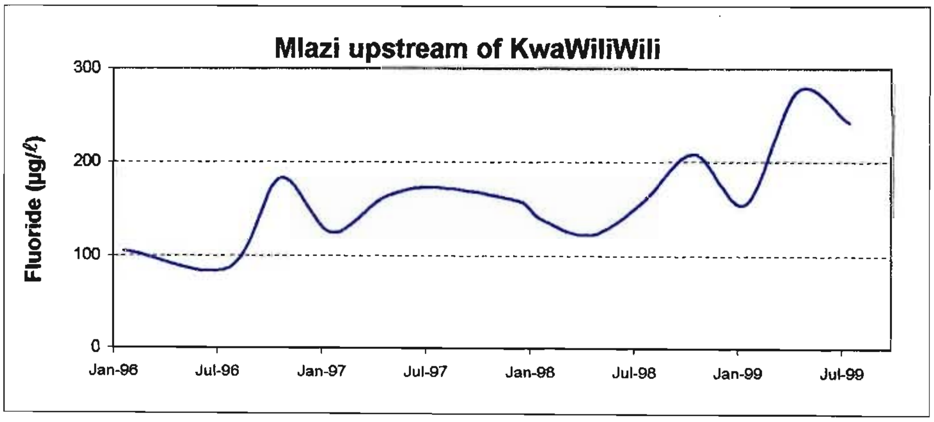
Mlazi Catchment : Mlazi outflow from Shongweni Dam (site 78)

Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	94.4	94.4	138.0
25th Percentile	142.0	122.0	152.8
Average	158.3	145.8	169.3
Median	159.0	156.0	163.0
75th Percentile	171.5	168.5	175.5
80th Percentile	175.0	169.4	179.0
95th Percentile	202.2	183.3	215.5
Maximum	233.0	189.0	233.0



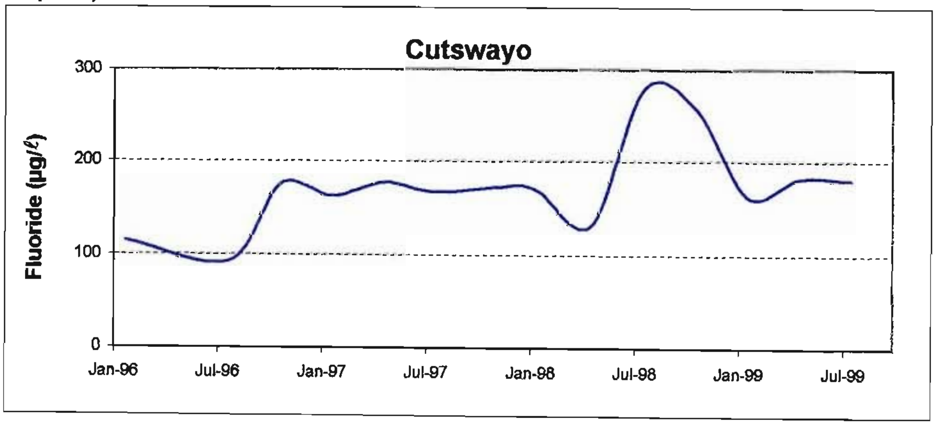
Mlazi Catchment : Mlazi upstream of KwaWiliWili (site 80)

Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	86.1	105.0	86.1
25th Percentile	128.0	132.0	139.5
Average	163.3	153.1	173.4
Median	157.5	155.0	161.0
75th Percentile	179.5	170.0	206.5
80th Percentile	192.4	177.2	227.2
95th Percentile	252.9	200.2	264.8
Maximum	275.0	208.0	275.0



Mlazi Catchment : Cutswayo upstream of the Mlazi confluence (site 82)

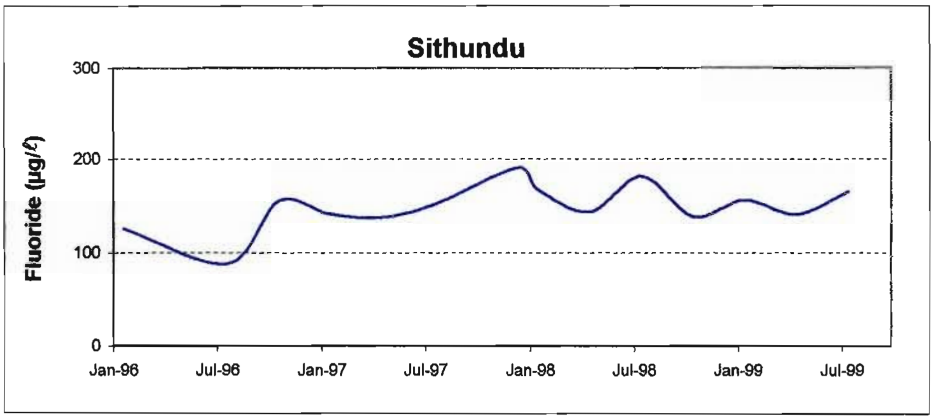
Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	92.2	114.0	92.2
25th Percentile	162.0	162.0	148.5
Average	172.5	172.9	172.2
Median	169.5	166.0	177.0
75th Percentile	179.3	174.0	180.5
80th Percentile	180.4	174.6	180.8
95th Percentile	265.0	233.1	248.9
Maximum	278.0	258.0	278.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

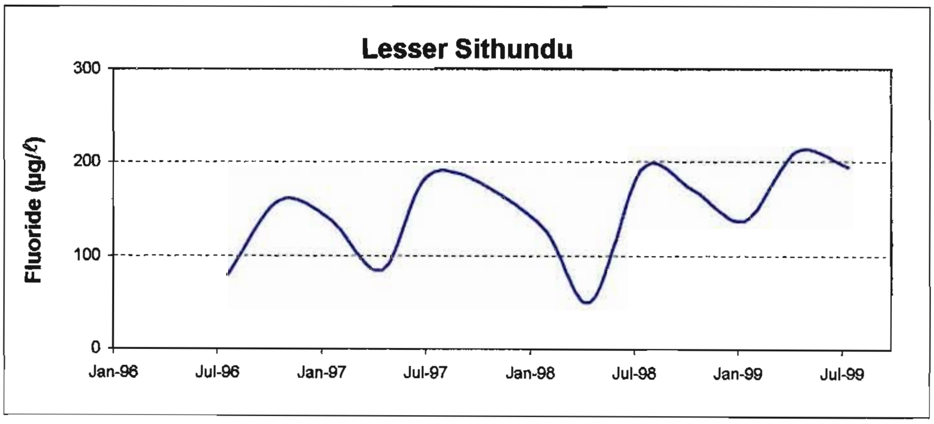
Mlazi Catchment : Sithundu (site 83)

Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	87.7	125.0	87.7
25th Percentile	138.5	139.5	138.5
Average	148.3	153.0	143.5
Median	147.0	154.0	143.0
75th Percentile	162.8	161.5	158.0
80th Percentile	165.8	164.8	162.2
95th Percentile	184.2	183.1	176.2
Maximum	190.0	190.0	181.0



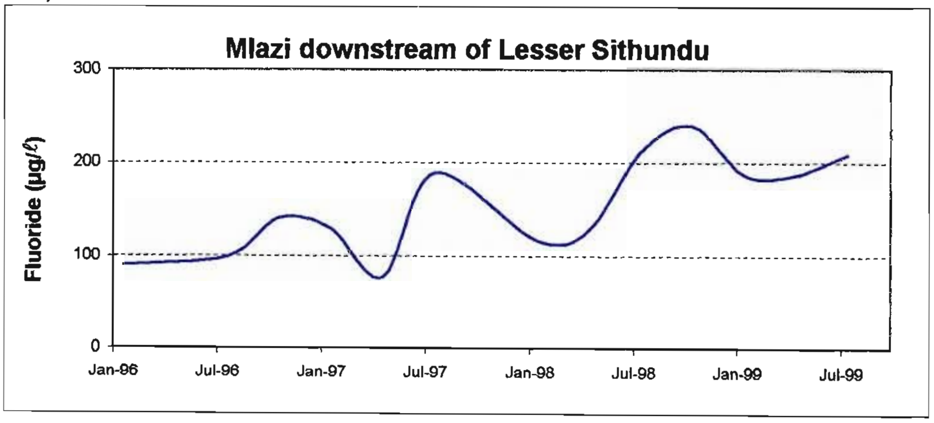
Mlazi Catchment : Lesser Sithundu (site 84)

Statistics	Entire Dataset	Summer	Winter
N	12	5	7
Minimum	50.0	136.0	50.0
25th Percentile	123.1	137.0	81.6
Average	144.8	147.8	142.7
Median	148.0	138.0	189.0
75th Percentile	189.8	158.0	193.0
80th Percentile	191.4	160.4	193.6
95th Percentile	201.7	167.6	205.9
Maximum	211.0	170.0	211.0



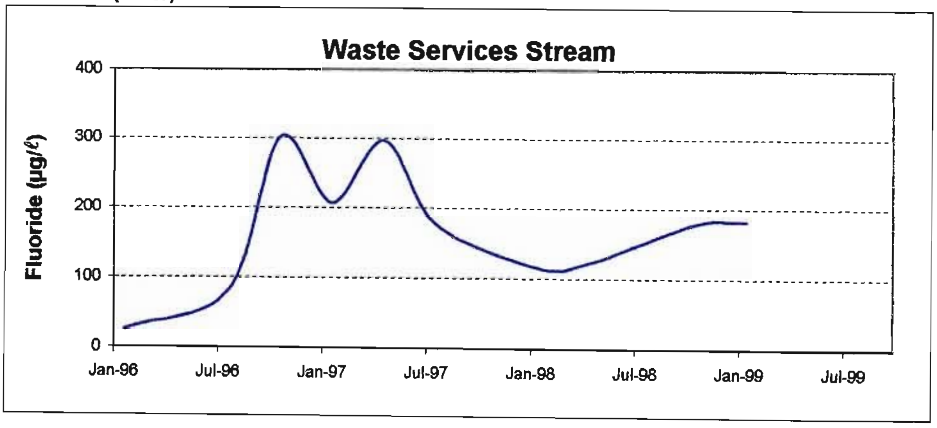
Mlazi Catchment : Mlazi downstream of Lesser Sithundu (site 85)

Statistics	Entire Dataset	Summer	Winter
N	13	6	7
Minimum	76.5	89.0	76.5
25th Percentile	116.0	119.3	113.0
Average	153.7	150.0	156.9
Median	140.0	134.5	187.0
75th Percentile	188.0	175.3	198.5
80th Percentile	200.6	187.0	204.8
95th Percentile	222.8	226.0	211.1
Maximum	239.0	239.0	212.0



Mlazi Catchment : Waste Services Stream upstream of Mlazi Confluence (site 87)

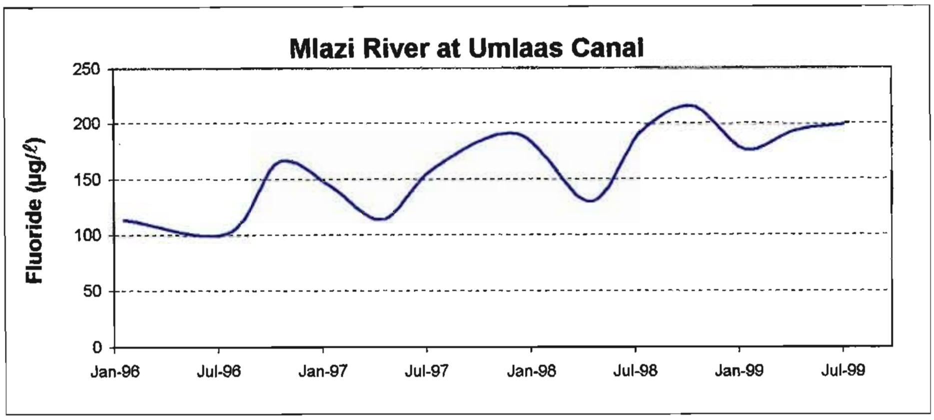
Statistics	Entire Dataset	Summer	Winter
N	10	6	4
Minimum	25.0	25.0	80.3
25th Percentile	116.3	129.8	112.3
Average	167.9	167.3	168.8
Median	176.5	179.0	149.5
75th Percentile	199.8	199.8	206.0
80th Percentile	224.0	206.0	224.0
95th Percentile	298.8	277.3	278.0
Maximum	301.0	301.0	296.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

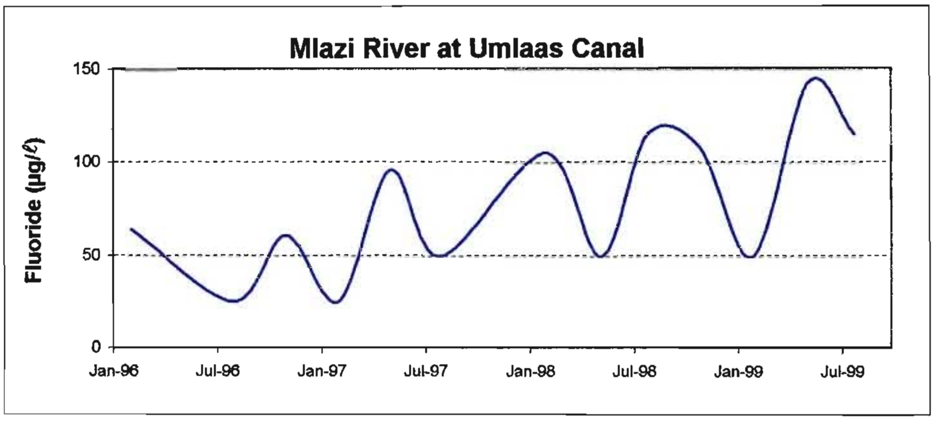
Mlazi Catchment : Mlazi River at Umlaas Canal (site 88.4)

Statistics	Entire Dataset	Summer	Winter
N	13	6	7
Minimum	102.0	114.0	102.0
25th Percentile	130.0	149.3	122.0
Average	161.5	167.7	156.1
Median	165.0	171.0	160.0
75th Percentile	193.0	186.8	193.5
80th Percentile	193.6	190.0	193.8
95th Percentile	208.4	209.5	198.2
Maximum	216.0	216.0	200.0



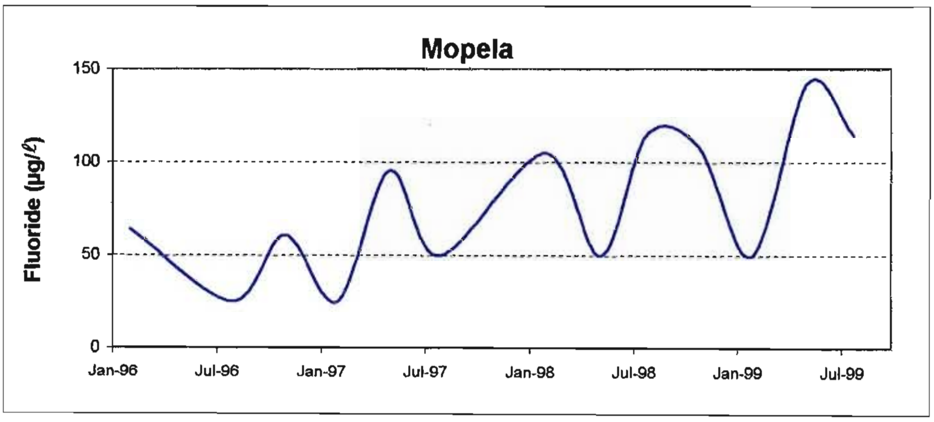
Mlazi Catchment : Mlazi River at Umlaas Canal (site 88.4)

Statistics	Entire Dataset	Summer	Winter
N	13	6	7
Minimum	25.0	25.0	25.0
25th Percentile	50.0	52.7	50.0
Average	77.4	68.8	84.8
Median	84.0	62.5	95.5
75th Percentile	108.0	94.8	115.0
80th Percentile	112.2	105.0	115.0
95th Percentile	126.2	107.3	134.6
Maximum	143.0	108.0	143.0



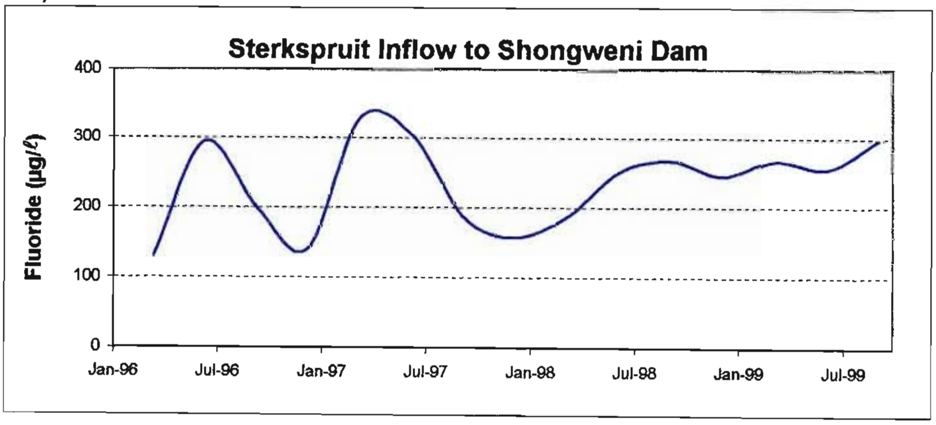
Mlazi Catchment : Mopela (site 85)

Statistics	Entire Dataset	Summer	Winter
N	13	6	7
Minimum	25.0	25.0	25.0
25th Percentile	50.0	52.7	50.0
Average	77.4	68.8	84.8
Median	84.0	62.5	95.5
75th Percentile	108.0	94.8	115.0
80th Percentile	112.2	105.0	115.0
95th Percentile	126.2	107.3	134.6
Maximum	143.0	108.0	143.0



Mlazi Catchment : Sterkspruit Inflow to Shongweni Dam (site 91)

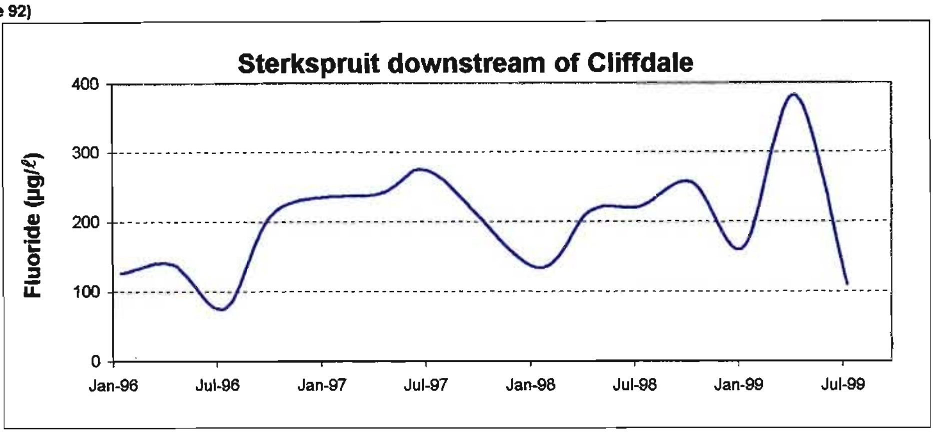
Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	131.0	131.0	187.0
25th Percentile	187.5	149.5	238.3
Average	234.7	208.6	257.6
Median	251.0	188.0	262.0
75th Percentile	281.0	256.5	295.3
80th Percentile	295.0	263.4	297.0
95th Percentile	312.9	310.7	303.6
Maximum	329.0	329.0	306.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

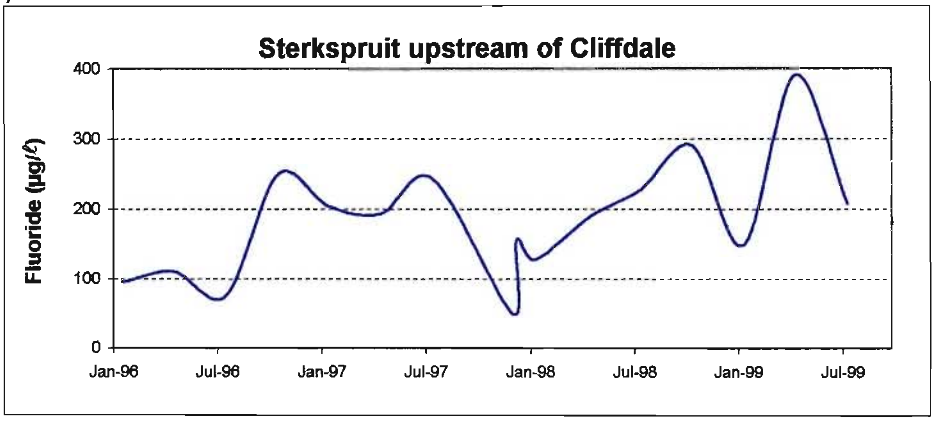
Mlazi Catchment : Sterkspruit downstream of Cliffdale (site 92)

Statistics	Entire Dataset	Summer	Winter
N	13	5	8
Minimum	76.1	126.0	76.1
25th Percentile	135.0	135.0	131.8
Average	196.5	179.6	207.0
Median	215.0	163.0	218.5
75th Percentile	241.0	217.0	248.5
80th Percentile	250.6	225.0	259.0
95th Percentile	315.4	249.0	343.2
Maximum	382.0	257.0	382.0



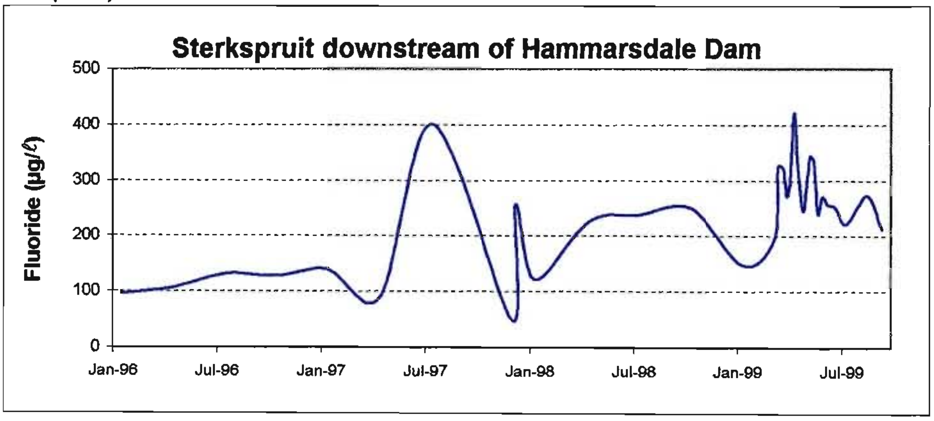
Mlazi Catchment : Sterkspruit upstream of Cliffdale (site 93)

Statistics	Entire Dataset	Summer	Winter
N	16	8	8
Minimum	50.0	50.0	75.8
25th Percentile	123.5	119.8	170.0
Average	184.9	165.3	204.6
Median	191.5	152.5	200.5
75th Percentile	230.8	215.3	230.8
80th Percentile	242.0	231.0	236.0
95th Percentile	316.0	276.3	338.9
Maximum	391.0	291.0	391.0



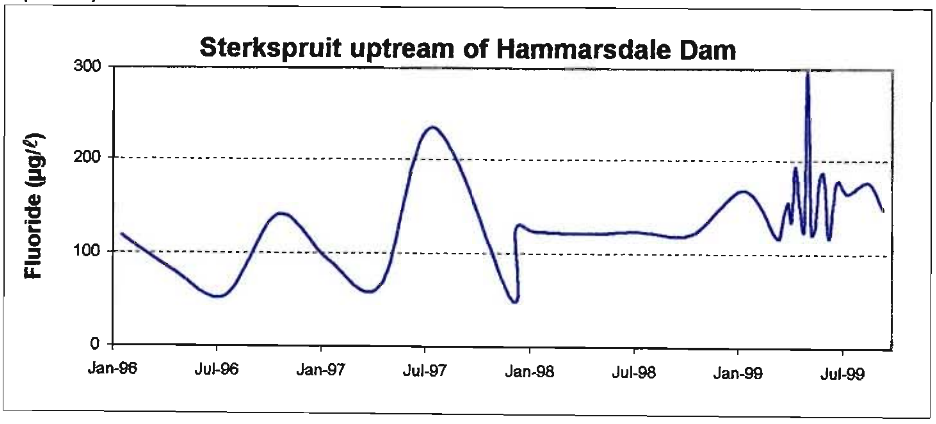
Mlazi Catchment : Sterkspruit downstream of Hammarsdale Dam (site 94)

Statistics	Entire Dataset	Summer	Winter
N	32	12	20
Minimum	50.0	50.0	90.7
25th Percentile	146.5	125.5	225.0
Average	233.5	191.8	258.5
Median	247.5	172.0	254.5
75th Percentile	290.3	259.8	306.8
80th Percentile	315.0	268.0	320.6
95th Percentile	369.7	323.4	402.1
Maximum	422.0	325.0	422.0



Mlazi Catchment : Sterkspruit uptream of Hammarsdale Dam (site 94.1)

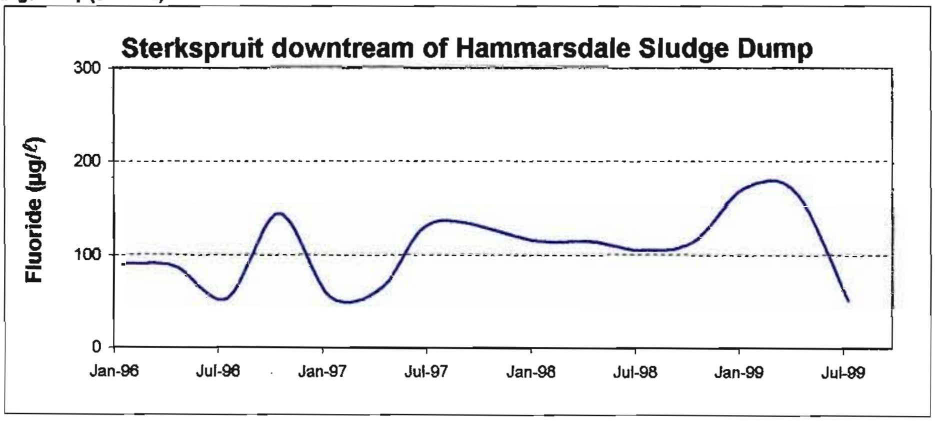
Statistics	Entire Dataset	Summer	Winter
N	32	12	20
Minimum	50.0	50.0	53.9
25th Percentile	118.8	117.8	121.0
Average	139.1	122.8	148.9
Median	128.0	122.0	141.0
75th Percentile	165.0	141.0	176.3
80th Percentile	174.4	143.2	178.8
95th Percentile	212.5	160.9	238.1
Maximum	297.0	168.0	297.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

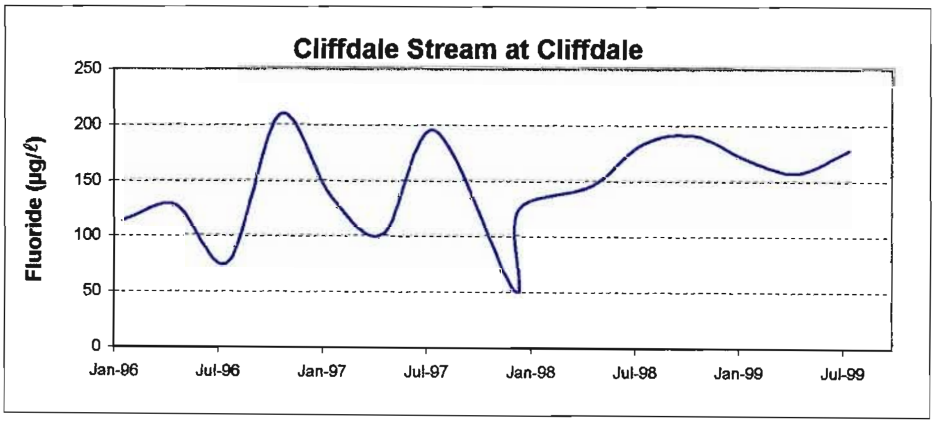
Mlazi Catchment : Sterkspruit uptream of Hammarsdale Sludge Dump (site 94.2)

Statistics	Entire Dataset	Summer	Winter
N	14	6	8
Minimum	50.0	53.8	50.0
25th Percentile	69.3	95.0	60.7
Average	103.5	113.6	95.8
Median	108.5	113.5	95.0
75th Percentile	129.0	135.8	118.3
80th Percentile	137.6	143.0	125.6
95th Percentile	165.8	162.5	153.5
Maximum	169.0	169.0	164.0



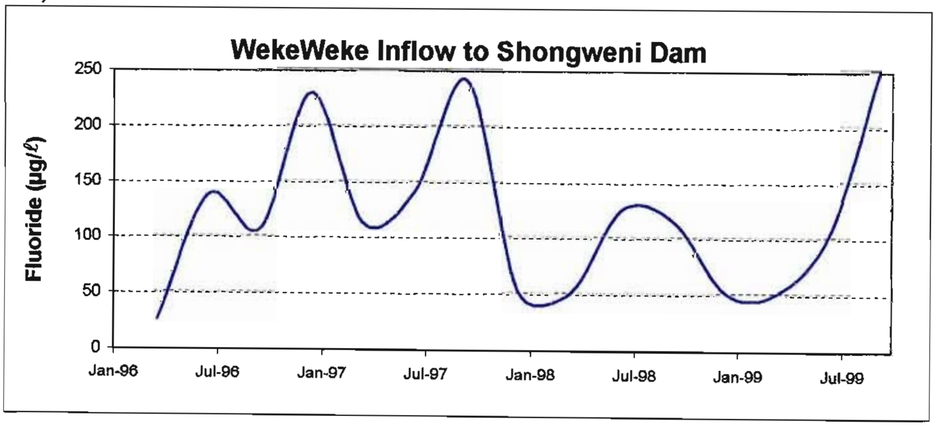
Mlazi Catchment : Cliffdale Stream at Cliffdale (site 95.2)

Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	50.0	50.0	75.0
25th Percentile	118.0	118.0	120.5
Average	143.0	141.1	144.6
Median	145.0	135.0	150.5
75th Percentile	179.5	179.5	178.3
80th Percentile	183.6	185.8	180.0
95th Percentile	198.2	202.6	189.8
Maximum	208.0	208.0	194.0



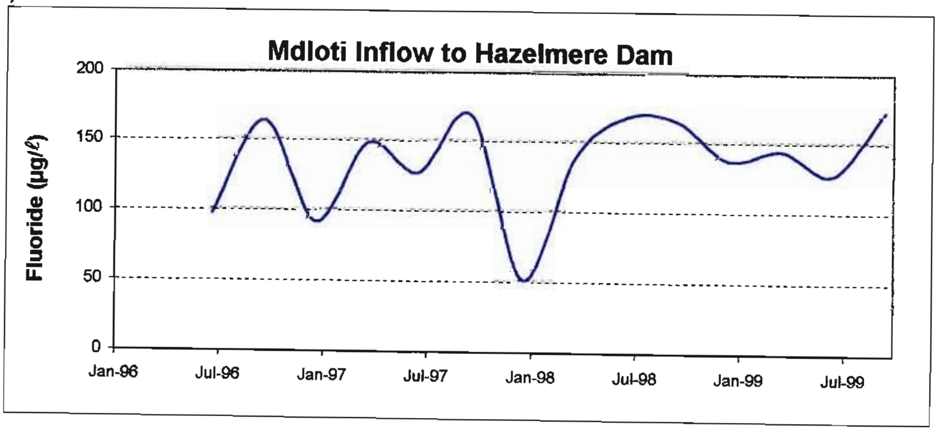
Mlazi Catchment : WekeWeke Inflow to Shongweni Dam (site 96)

Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	25.0	25.0	105.0
25th Percentile	50.0	50.0	111.3
Average	119.1	80.9	152.5
Median	112.0	50.0	131.0
75th Percentile	139.0	81.0	165.8
80th Percentile	158.6	99.6	200.4
95th Percentile	243.9	193.9	248.5
Maximum	253.0	229.0	253.0



Mdloti Catchment : Mdloti Inflow to Hazelmere Dam (site 98)

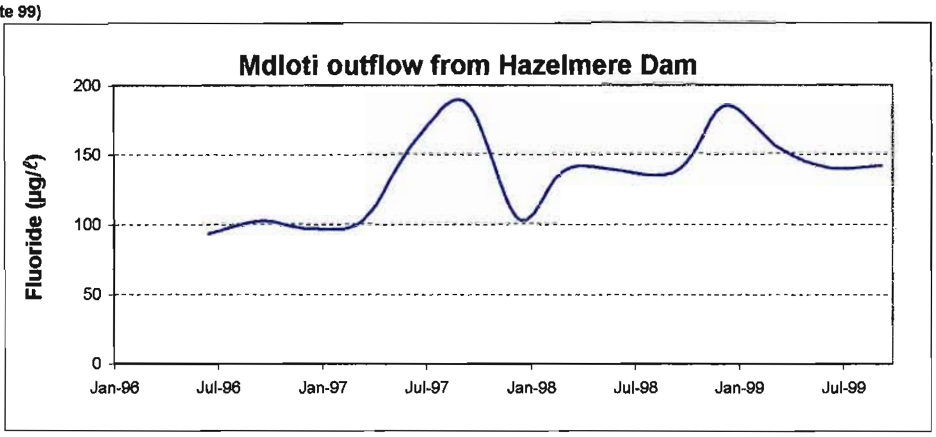
Statistics	Entire Dataset	Summer	Winter
N	14	6	8
Minimum	50.0	50.0	96.0
25th Percentile	126.0	102.0	126.0
Average	134.7	117.3	147.8
Median	140.1	136.6	163.5
75th Percentile	163.8	141.5	167.3
80th Percentile	165.2	143.0	167.6
95th Percentile	169.4	146.0	170.6
Maximum	172.0	147.0	172.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

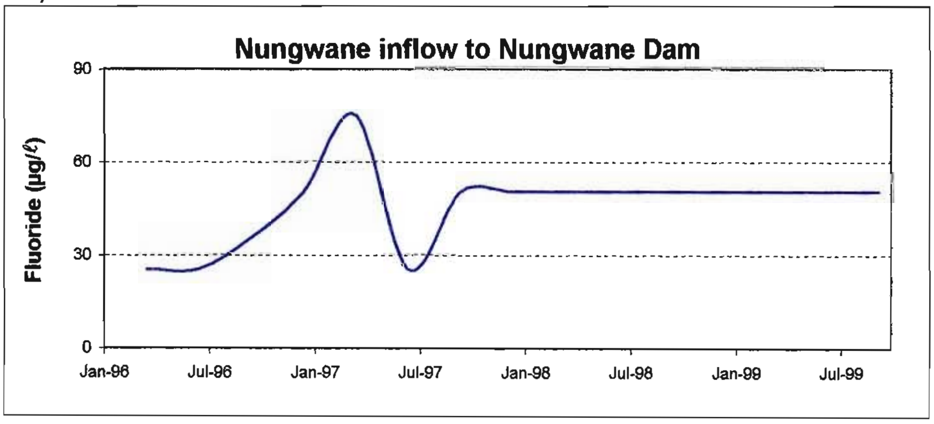
Mdloti Catchment : Mdloti outflow from Hazelmere Dam (site 99)

Statistics	Entire Dataset	Summer	Winter
N	14	6	8
Minimum	89.0	96.2	89.0
25th Percentile	102.3	103.0	99.8
Average	130.4	130.0	130.6
Median	137.5	121.4	137.5
75th Percentile	150.8	150.5	145.3
80th Percentile	155.6	154.0	151.2
95th Percentile	185.1	176.5	176.9
Maximum	187.0	184.0	187.0



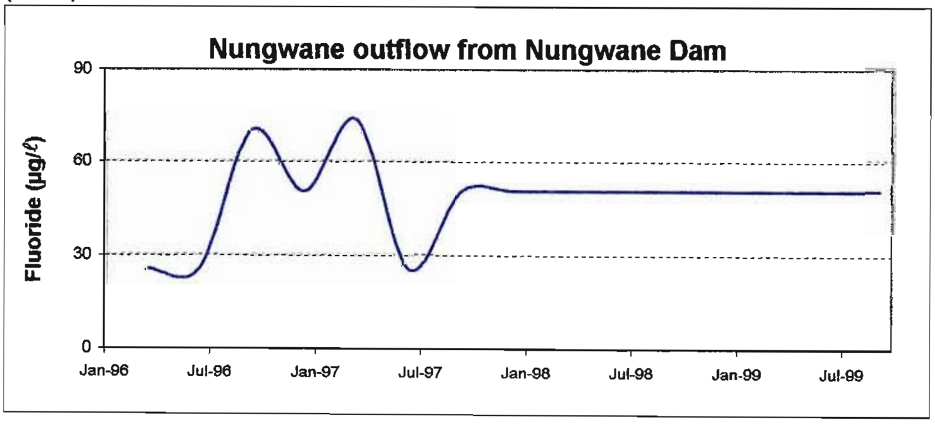
Lovu Catchment : Nungwane inflow to Nungwane Dam (site 104)

Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	25.0	25.0	25.0
25th Percentile	39.0	50.0	30.2
Average	45.4	50.0	40.8
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	50.0
95th Percentile	58.7	67.4	50.0
Maximum	74.9	74.9	50.0



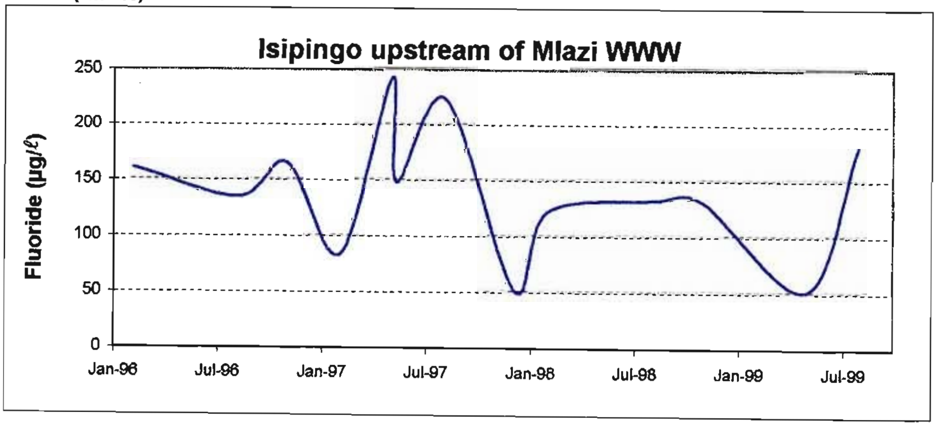
Lovu Catchment : Nungwane outflow from Nungwane Dam (site 105)

Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	25.0	25.0	25.0
25th Percentile	50.0	50.0	43.8
Average	47.9	49.8	46.3
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	50.0
95th Percentile	71.1	66.5	63.0
Maximum	73.5	73.5	70.0



Isipingo Catchment : Isipingo upstream of Mlazi Wastewater Works (site 109)

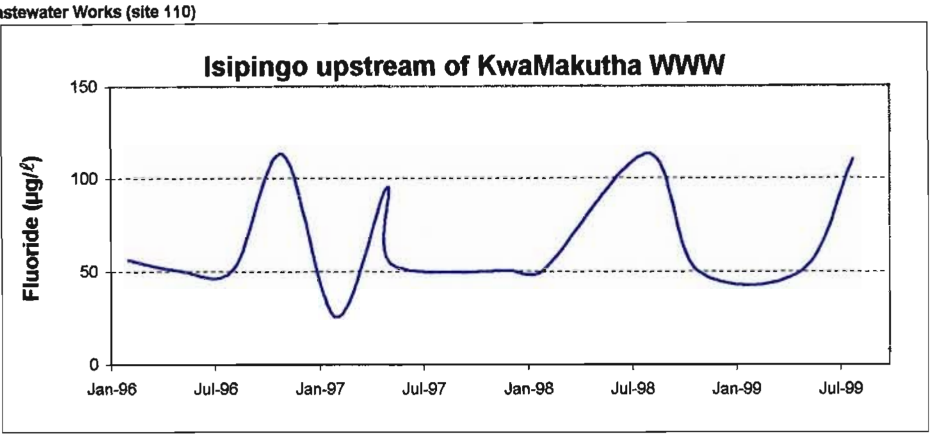
Statistics	Entire Dataset	Summer	Winter
N	13	6	7
Minimum	50.0	50.0	50.0
25th Percentile	121.0	92.6	132.5
Average	139.5	118.0	157.9
Median	134.0	125.5	147.0
75th Percentile	164.0	152.5	200.5
80th Percentile	173.0	160.0	213.4
95th Percentile	230.0	163.0	236.0
Maximum	242.0	164.0	242.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

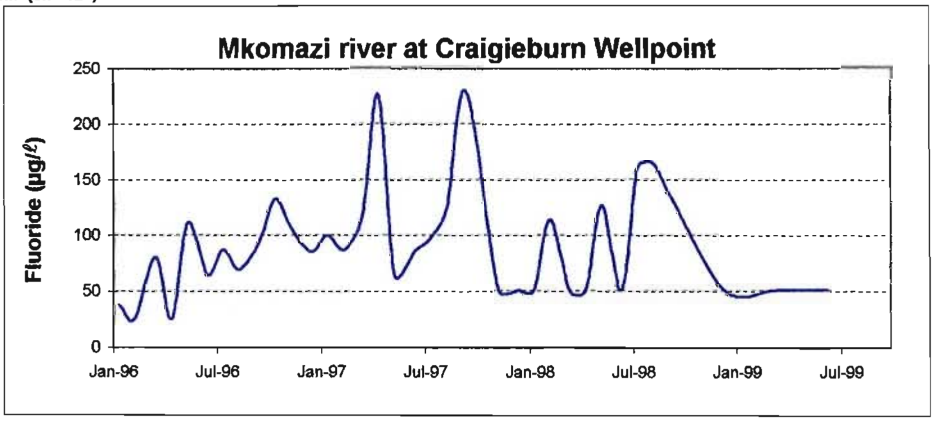
Isipingo Catchment : Isipingo upstream of KwaMakutha Wastewater Works (site 110)

Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	25.0	25.0	50.0
25th Percentile	50.0	50.0	50.5
Average	65.4	56.3	74.6
Median	50.5	50.0	53.4
75th Percentile	85.1	53.0	102.4
80th Percentile	100.9	54.8	107.0
95th Percentile	113.0	95.9	112.1
Maximum	113.0	113.0	113.0



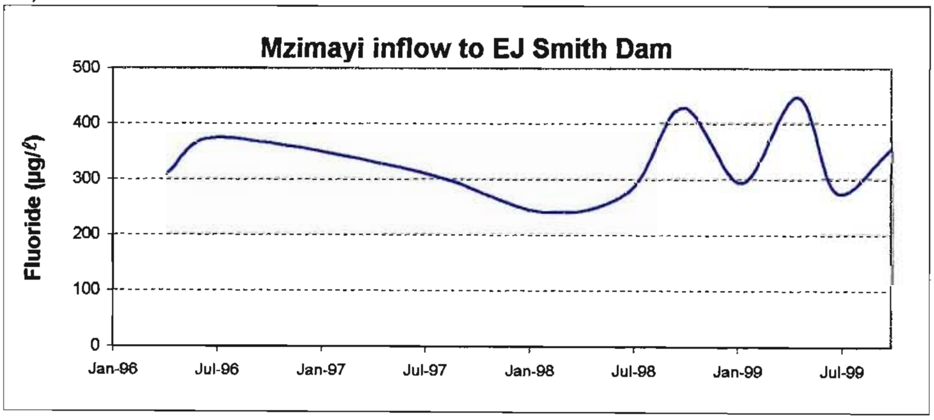
Mkomazi Catchment : Mkomazi river at Craigieburn Wellpoint (site 125)

Statistics	Entire Dataset	Summer	Winter
N	35	16	19
Minimum	25.0	25.0	25.0
25th Percentile	50.0	50.0	64.1
Average	91.1	73.9	105.6
Median	85.1	65.0	93.8
75th Percentile	115.5	101.1	128.5
80th Percentile	124.4	106.0	142.6
95th Percentile	182.6	120.8	226.3
Maximum	229.0	132.0	229.0



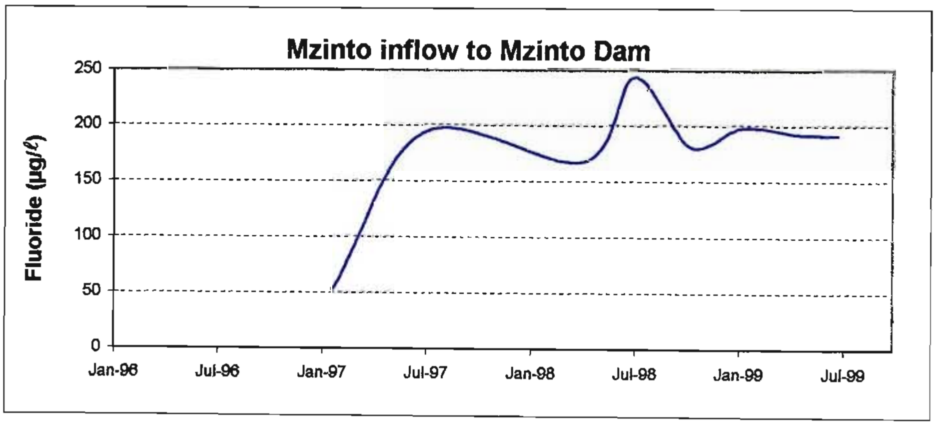
Mzimayi Catchment : Mzimayi inflow to EJ Smith Dam (site 126)

Statistics	Entire Dataset	Summer	Winter
N	10	2	8
Minimum	241.0	241.0	273.0
25th Percentile	280.3	254.0	300.0
Average	330.2	267.0	346.0
Median	309.0	267.0	332.5
75th Percentile	368.5	280.0	386.5
80th Percentile	383.8	282.6	405.4
95th Percentile	437.5	290.4	439.4
Maximum	446.0	293.0	446.0



Mzinto Catchment : Mzinto inflow to Mzinto Dam (site 128)

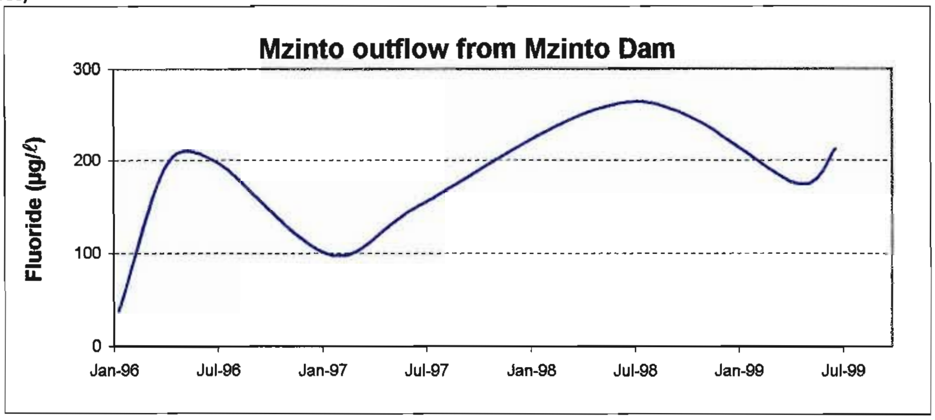
Statistics	Entire Dataset	Summer	Winter
N	8	3	5
Minimum	52.6	52.6	166.0
25th Percentile	176.5	116.3	190.0
Average	176.5	143.2	196.4
Median	190.5	180.0	191.0
75th Percentile	193.3	188.5	192.0
80th Percentile	195.0	190.2	202.2
95th Percentile	226.9	195.3	232.8
Maximum	243.0	197.0	243.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

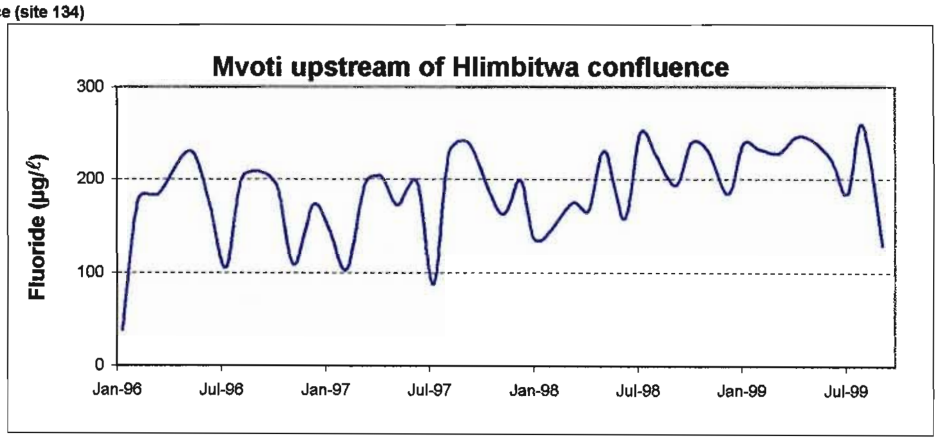
Mzinto Catchment : Mzinto outflow from Mzinto Dam (site 130)

Statistics	Entire Dataset	Summer	Winter
N	8	2	6
Minimum	37.5	37.5	153.0
25th Percentile	139.2	52.6	180.3
Average	166.8	67.6	199.8
Median	185.5	67.6	197.5
75th Percentile	202.3	82.7	208.8
80th Percentile	206.8	85.7	212.0
95th Percentile	245.8	94.7	251.0
Maximum	264.0	97.7	264.0



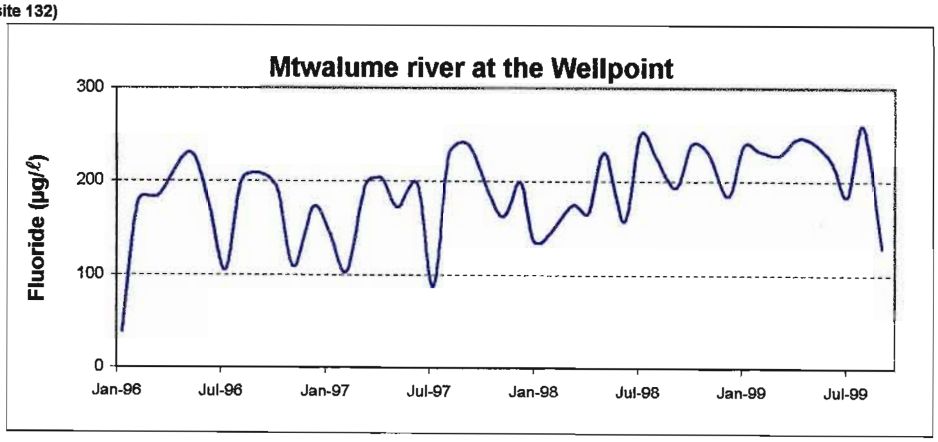
Mvoti Catchment : Mvoti upstream of Hlimbitwa confluence (site 134)

Statistics	Entire Dataset	Summer	Winter
N	42	19	23
Minimum	37.5	37.5	87.1
25th Percentile	167.0	154.0	171.0
Average	187.5	175.4	197.5
Median	194.0	183.0	203.0
75th Percentile	229.8	213.5	230.5
80th Percentile	231.0	229.2	235.8
95th Percentile	244.9	238.1	249.5
Maximum	259.0	239.0	259.0



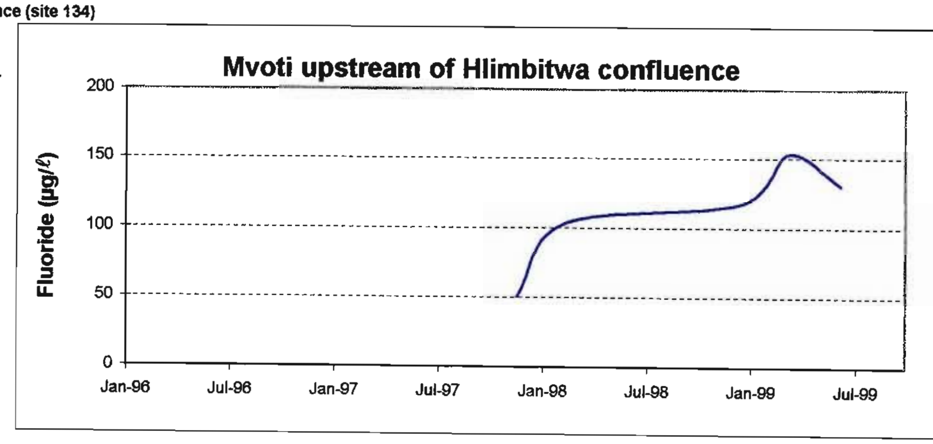
Mtwalumei Catchment : Mtwalume river at the Wellpoint (site 132)

Statistics	Entire Dataset	Summer	Winter
N	42	19	23
Minimum	37.5	37.5	87.1
25th Percentile	167.0	154.0	171.0
Average	187.5	175.4	197.5
Median	194.0	183.0	203.0
75th Percentile	229.8	213.5	230.5
80th Percentile	231.0	229.2	235.8
95th Percentile	244.9	238.1	249.5
Maximum	259.0	239.0	259.0



Mvoti Catchment : Mvoti upstream of Hlimbitwa confluence (site 134)

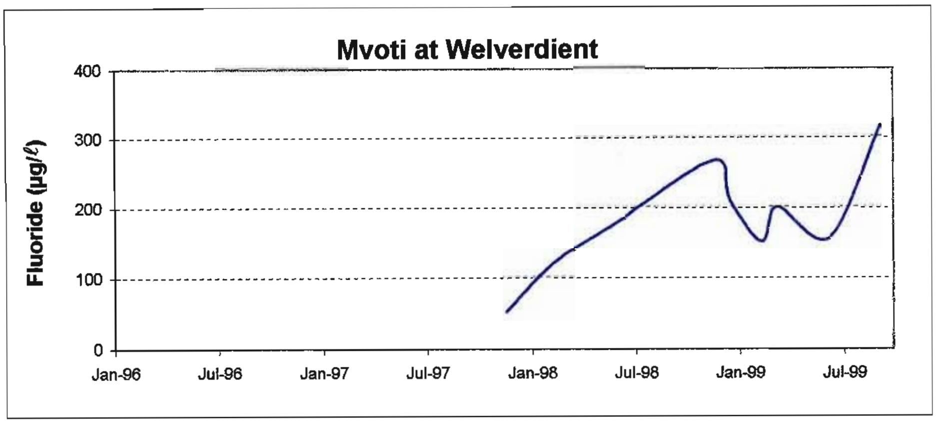
Statistics	Entire Dataset	Summer	Winter
N	5	4	1
Minimum	50.0	50.0	130.0
25th Percentile	103.0	89.8	130.0
Average	110.6	105.8	130.0
Median	117.0	110.0	130.0
75th Percentile	130.0	126.0	130.0
80th Percentile	134.6	131.4	130.0
95th Percentile	148.4	147.6	130.0
Maximum	153.0	153.0	130.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

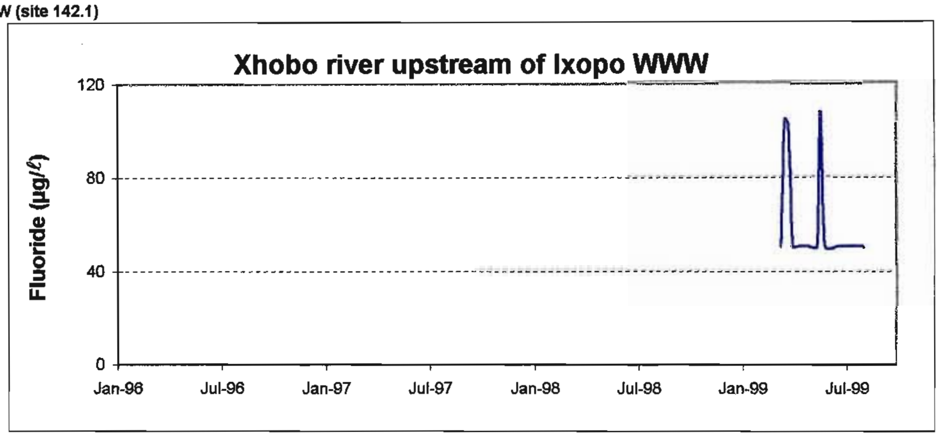
Mvoti Catchment : Mvoti at Welverdient (site 137)

Statistics	Entire Dataset	Summer	Winter
N	9	6	3
Minimum	50.0	50.0	155.0
25th Percentile	149.0	127.3	163.0
Average	181.6	165.2	214.3
Median	171.0	174.0	171.0
75th Percentile	208.0	205.8	244.0
80th Percentile	230.8	208.0	258.6
95th Percentile	296.2	250.8	302.4
Maximum	317.0	265.0	317.0



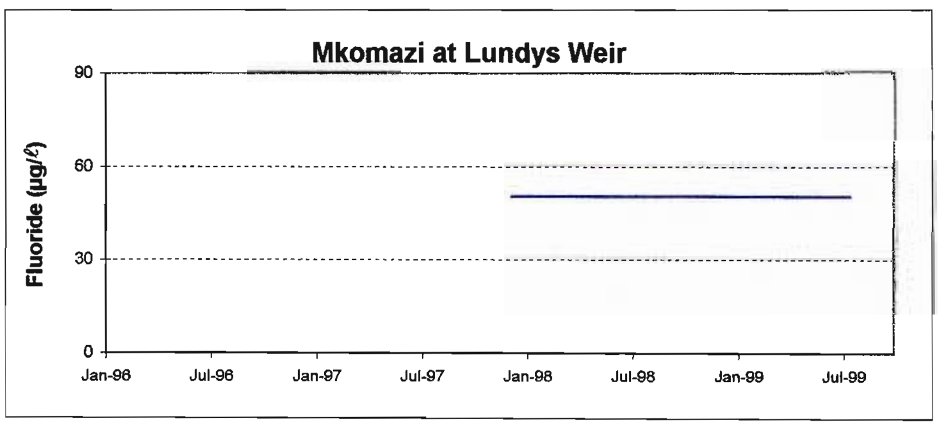
Mkomazi Catchment : Xhobo river upstream of Ixopo WWW (site 142.1)

Statistics	Entire Dataset	Summer	Winter
N	14	4	10
Minimum	50.0	50.0	50.0
25th Percentile	50.0	50.0	50.0
Average	61.6	76.3	55.8
Median	50.0	75.5	50.0
75th Percentile	50.0	101.8	50.0
80th Percentile	70.4	102.2	50.0
95th Percentile	105.4	103.6	81.9
Maximum	108.0	104.0	108.0



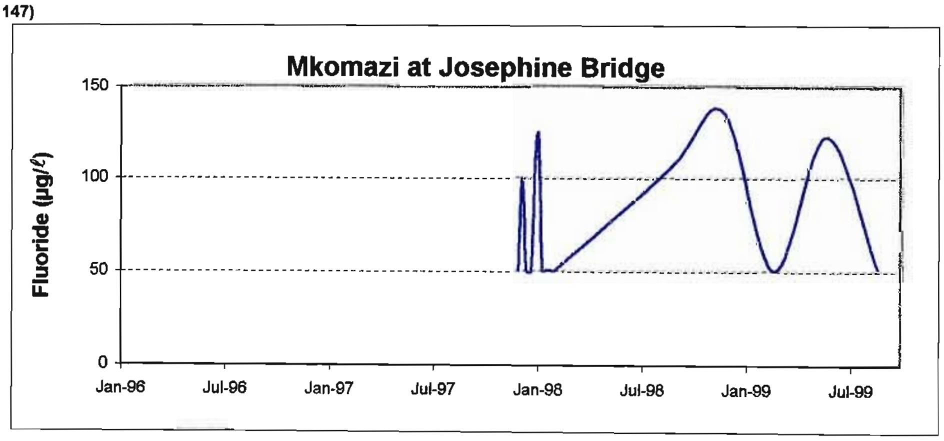
Mkomazi Catchment : Mkomazi at Lundys Weir (site 143)

Statistics	Entire Dataset	Summer	Winter
N	12	10	2
Minimum	50.0	50.0	50.0
25th Percentile	50.0	50.0	50.0
Average	50.0	50.0	50.0
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	50.0
95th Percentile	50.0	50.0	50.0
Maximum	50.0	50.0	50.0



Mkomazi Catchment : Mkomazi at Josephine Bridge (site 147)

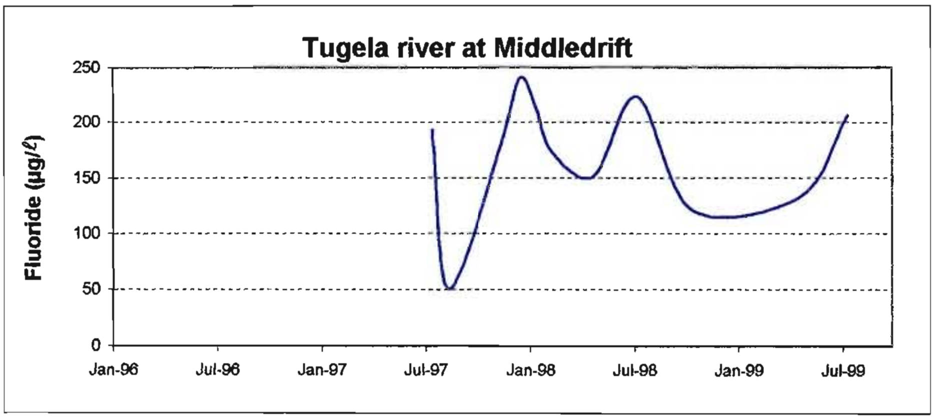
Statistics	Entire Dataset	Summer	Winter
N	15	12	3
Minimum	50.0	50.0	50.0
25th Percentile	50.0	50.0	77.5
Average	76.3	72.3	92.3
Median	50.0	50.0	105.0
75th Percentile	106.5	102.0	113.5
80th Percentile	110.8	106.4	115.2
95th Percentile	126.9	128.9	120.3
Maximum	136.0	136.0	122.0



Appendix 4 : Mgeni River Catchment - Sites with maximum fluoride concentration < 0.5mg/ℓ.

Tugela Catchment : Tugela river at Middledrift (site 150)

Statistics	Entire Dataset	Summer	Winter
N	11	5	6
Minimum	50.0	121.0	50.0
25th Percentile	142.0	173.0	137.5
Average	170.8	184.6	159.3
Median	177.0	177.0	171.5
75th Percentile	209.5	212.0	203.3
80th Percentile	212.0	217.6	207.0
95th Percentile	231.5	234.4	219.0
Maximum	240.0	240.0	223.0



APPENDIX 5

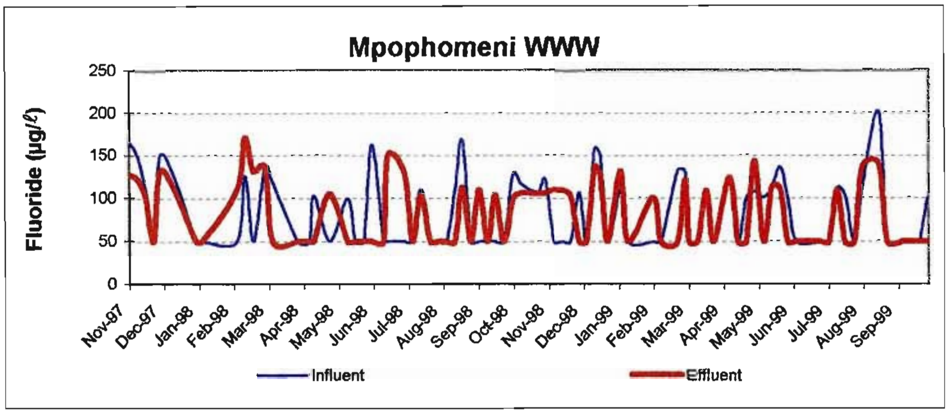
Time Series Graphs and Summary Statistics

Fluoride concentrations of Influents and Effluents at Wastewater Works

Appendix 5 : Fluoride concentrations of Influents and Effluents at Wastewater Works.

Mpophomeni WWW

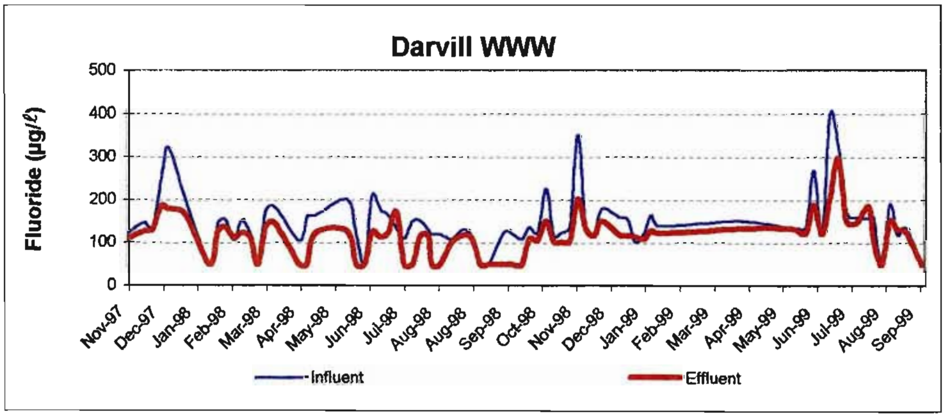
Statistics	Influent	Effluent
N	78	78
Minimum	50.0	50.0
25th Percentile	50.0	50.0
Average	84.4	81.3
Median	50.0	50.0
75th Percentile	111.8	110.0
80th Percentile	119.8	117.8
95th Percentile	158.8	137.5
Maximum	202.0	171.0



Wilcoxon Matched Pairs test indicate: Influent and Effluent are NOT significantly different at the 95% confidence limit (Z statistic = 0.73)

Darvill WWW

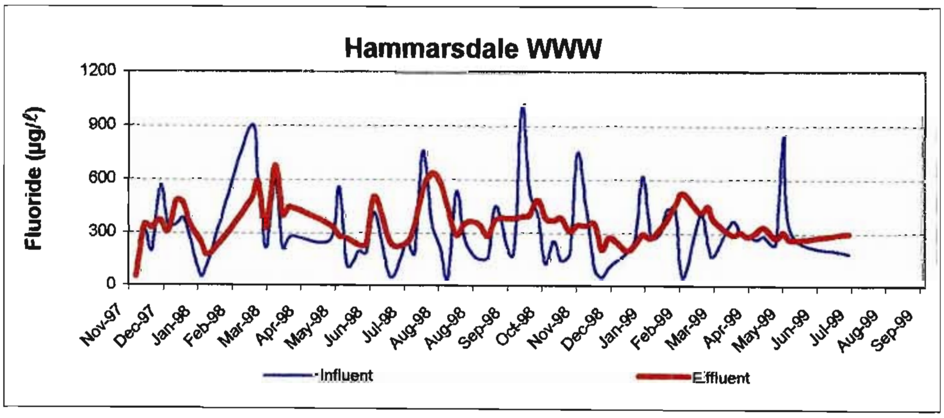
Statistics	Influent	New Effluent Effluent
N	73	73
Minimum	50.0	50.0
25th Percentile	120.0	102.0
Average	149.7	116.1
Median	137.0	120.0
75th Percentile	164.0	134.0
80th Percentile	177.6	144.6
95th Percentile	290.6	187.8
Maximum	399.0	298.0



Wilcoxon Matched Pairs test indicate: Influent and Effluent ARE significantly different at the 95% confidence limit (Z statistic = 6.27)

Hammarsdale WWW

Statistics	Influent	Effluent
N	68	68
Minimum	50.0	50.0
25th Percentile	184.8	282.8
Average	319.1	355.9
Median	272.0	344.0
75th Percentile	406.3	400.8
80th Percentile	445.0	440.8
95th Percentile	755.5	572.7
Maximum	1010.0	676.8



Wilcoxon Matched Pairs test indicate: Influent and Effluent ARE significantly different at the 95% confidence limit (Z statistic = 2.53)

APPENDIX 6

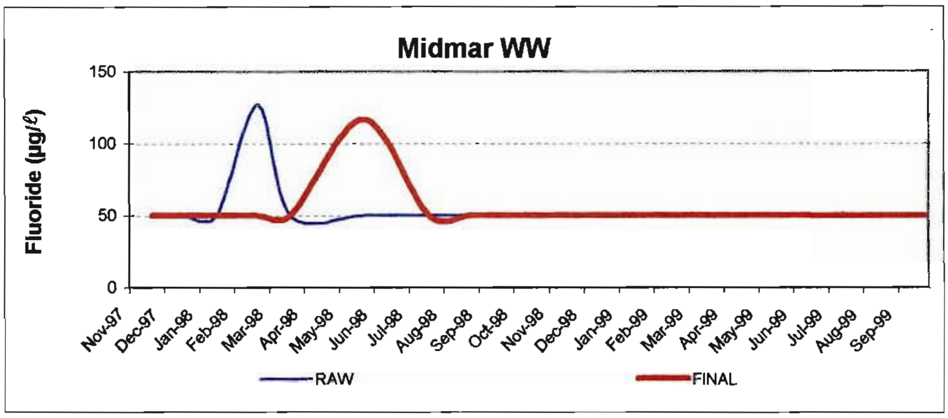
Time Series Graphs and Summary Statistics

Fluoride concentrations of Raw and Final at Water Treatment Works

Appendix 6 : Fluoride concentrations of Raw and Final water at Water Treatment Works.

Midmar WW

Statistics	Raw	Final
N	20	20
Minimum	50.0	50.0
25th Percentile	50.0	50.0
Average	53.9	53.4
Median	50.0	50.0
75th Percentile	50.0	50.0
80th Percentile	50.0	50.0
95th Percentile	53.9	53.4
Maximum	127.0	117.0



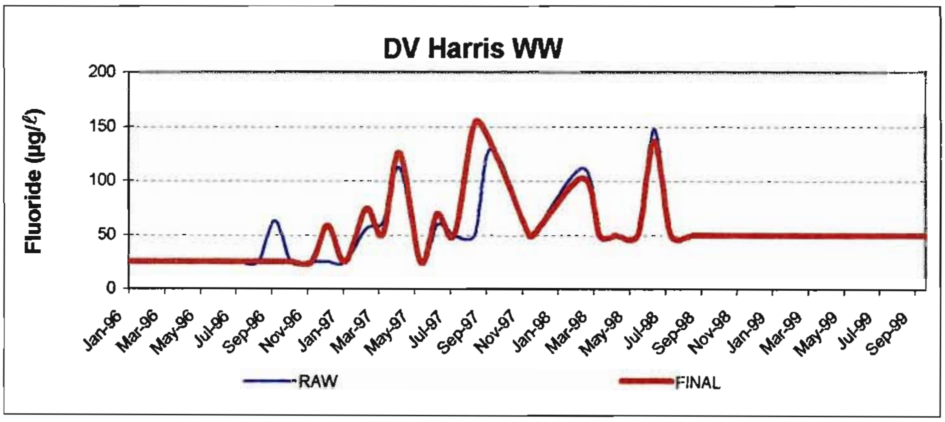
The Wilcoxon Matched Pairs Test indicated that the :

Raw and Final are NOT significantly different at the 95% confidence limit (Z statistic = 0.89)

Note, most results are below the detection limit (100µg/l)

DV Harris WW

Statistics	Raw	Final
N	39	39
Minimum	25.0	25.0
25th Percentile	25.0	25.0
Average	51.7	54.6
Median	50.0	50.0
75th Percentile	50.0	50.0
80th Percentile	52.3	53.6
95th Percentile	113.8	134.3
Maximum	147.0	153.0

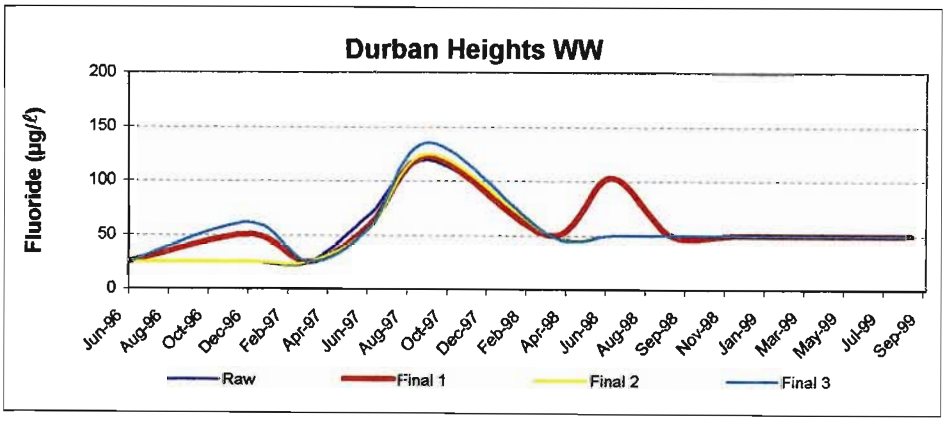


The Wilcoxon Matched Pairs Test indicated that the :

Raw and Final are NOT significantly different at the 95% confidence limit (Z statistic = 0.92)

Durban Heights WW

Statistics	Raw	Final 1
N	12	12
Minimum	86.0	63.5
25th Percentile	106.8	111.8
Average	124.0	131.0
Median	123.5	137.5
75th Percentile	143.8	159.0
80th Percentile	145.4	159.0
95th Percentile	155.6	164.7
Maximum	166.0	168.0

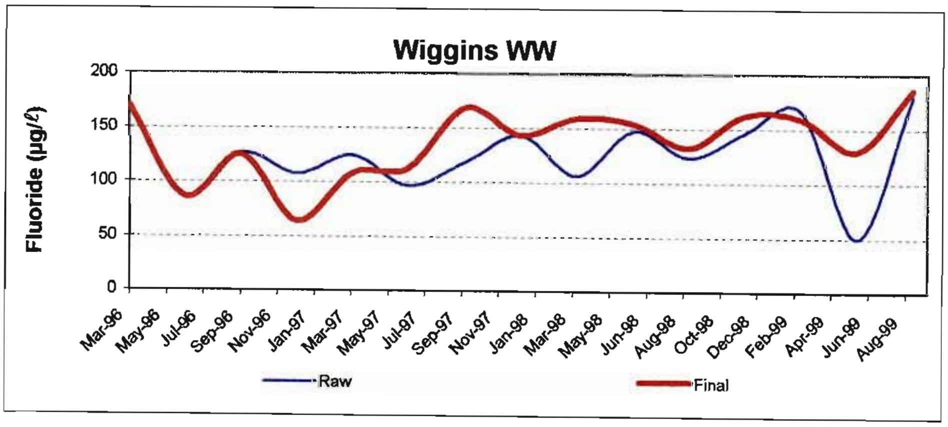


The Wilcoxon Matched Pairs Test indicated that the :

Raw and Final 1 are not significantly different at the 95% confidence limit (Z statistic = 1.27)

Wiggins WW

Statistics	Raw	Final
N	15	15
Minimum	50.0	63.5
25th Percentile	106.5	118.9
Average	125.9	137.2
Median	124.0	143.0
75th Percentile	146.5	160.5
80th Percentile	150.8	163.2
95th Percentile	173.7	174.8
Maximum	180.0	186.0



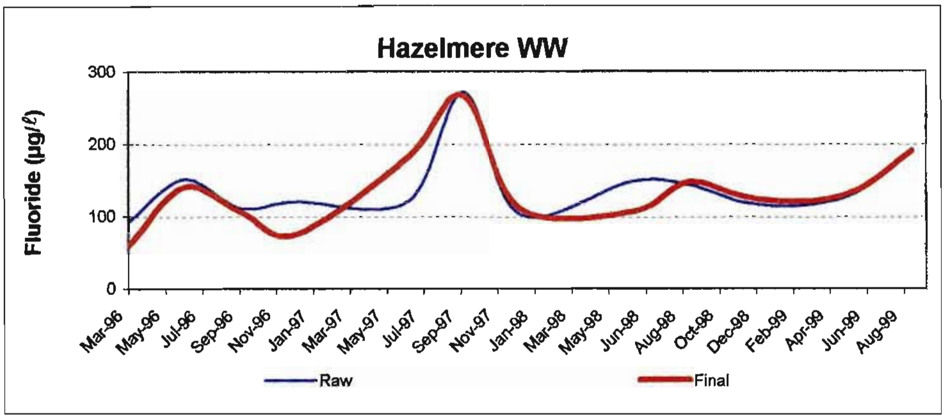
The Wilcoxon Matched Pairs Test indicated that the :

Raw and Final 1 are NOT significantly different at the 95% confidence limit (Z statistic = 1.47)

Appendix 6 : Fluoride concentrations of Raw and Final water at Water Treatment Works.

Hazelmere WW

Statistics	Raw	Final
N	13.0	13.0
Minimum	92.0	59.0
25th Percentile	115.0	107.0
Average	140.8	136.5
Median	121.0	128.0
75th Percentile	149.0	148.0
80th Percentile	150.8	168.4
95th Percentile	225.2	221.4
Maximum	272.0	267.0

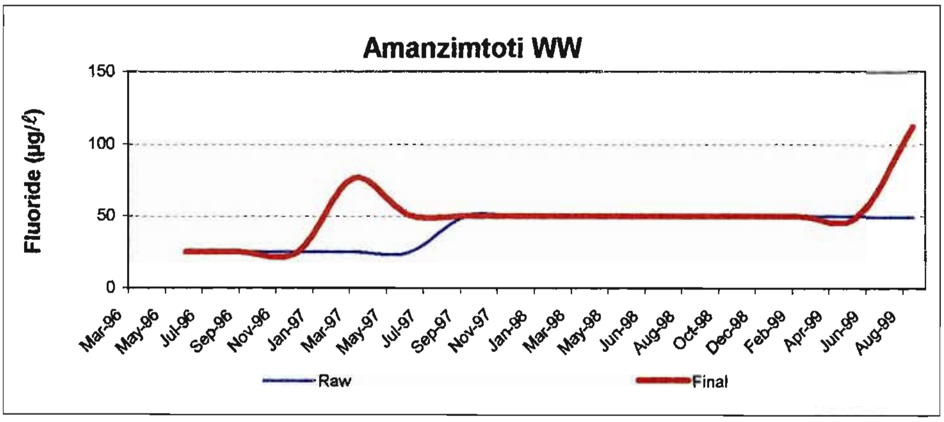


The Wilcoxon Matched Pairs Test indicated that the :

Raw and Final 1 are NOT significantly different at the 95% confidence limit (Z statistic = 0.59)

Amanzimtoti WW

Statistics	Raw	Final
N	13.0	13.0
Minimum	25.0	25.0
25th Percentile	25.0	50.0
Average	42.3	53.1
Median	50.0	50.0
75th Percentile	50.0	50.0
80th Percentile	50.0	50.7
95th Percentile	50.0	91.0
Maximum	50.0	113.0

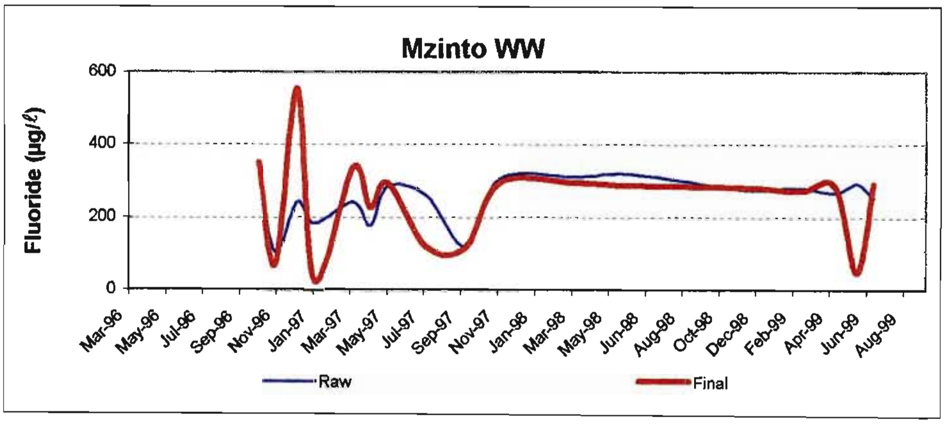


The Wilcoxon Matched Pairs Test indicated that the :

Raw and Final are NOT significantly different at the 95% confidence limit (Z statistic = 1.87)

Mzinto WW

Statistics	Raw	Final
N	16.0	16.0
Minimum	106.0	25.0
25th Percentile	226.5	119.8
Average	245.4	238.2
Median	264.0	284.0
75th Percentile	287.5	294.0
80th Percentile	292.0	294.0
95th Percentile	312.6	391.5
Maximum	318.0	555.0

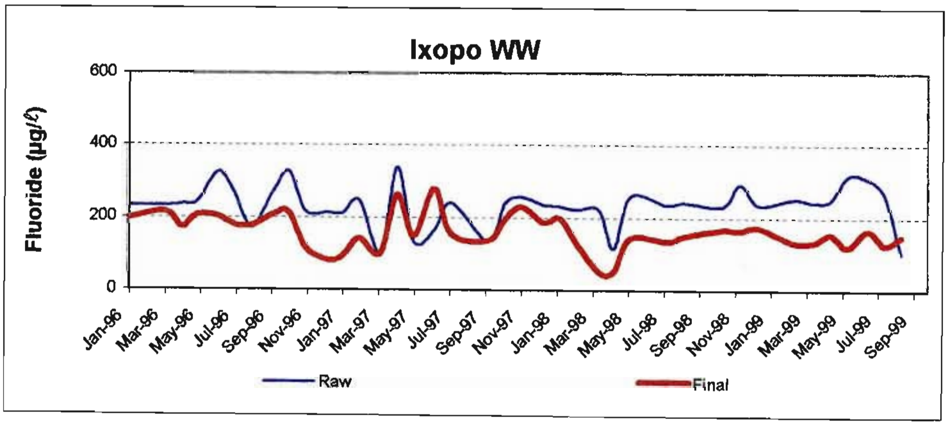


The Wilcoxon Matched Pairs Test indicated that the :

Raw and Final are NOT significantly different at the 95% confidence limit (Z statistic = 0.17)

Ixopo WW

Statistics	Raw	Final
N	38.0	38.0
Minimum	102.0	50.0
25th Percentile	217.3	133.0
Average	231.4	158.8
Median	237.5	154.5
75th Percentile	257.5	191.8
80th Percentile	261.6	200.8
95th Percentile	323.3	233.8
Maximum	338.0	279.0



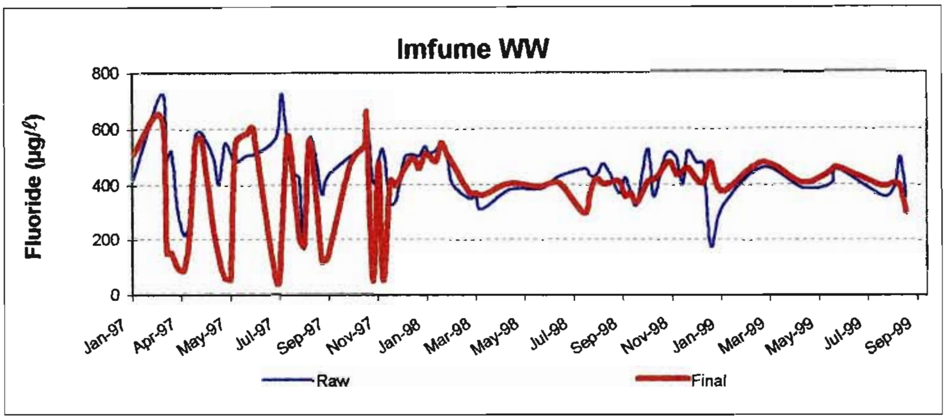
The Wilcoxon Matched Pairs Test indicated that the :

Raw and Final are significantly different at the 95% confidence limit (Z statistic = 4.75)

Appendix 6 : Fluoride concentrations of Raw and Final water at Water Treatment Works.

Imfume WW

Statistics	Raw	Final
N	77.0	77.0
Minimum	166.0	50.0
25th Percentile	380.0	332.0
Average	445.9	379.3
Median	453.0	406.0
75th Percentile	510.0	476.0
80th Percentile	518.6	491.4
95th Percentile	579.6	573.0
Maximum	721.0	649.0

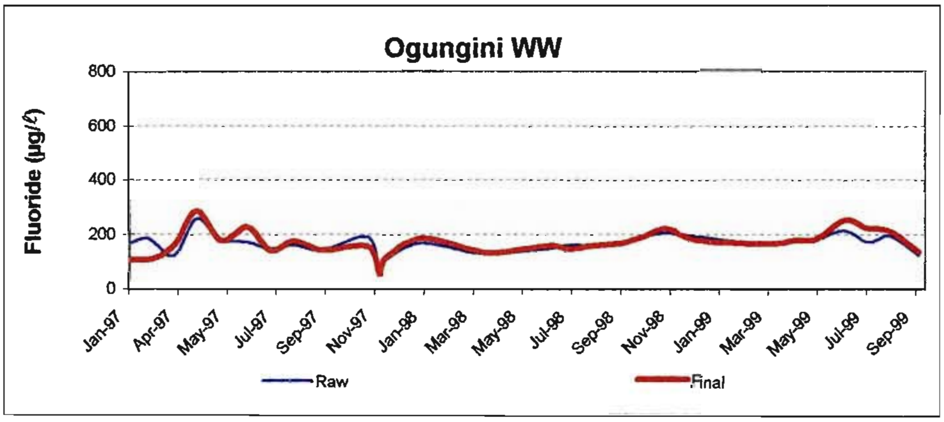


The Wilcoxon Matched Pairs Test indicated that the :

Raw and Final are significantly different at the 95% confidence limit (Z statistic = 2.95)

Ogungini WW

Statistics	Raw	Final
N	32.0	32.0
Minimum	50.0	50.0
25th Percentile	142.0	136.8
Average	161.7	164.1
Median	162.5	164.0
75th Percentile	187.5	180.3
80th Percentile	189.8	187.4
95th Percentile	221.0	234.7
Maximum	252.0	282.0

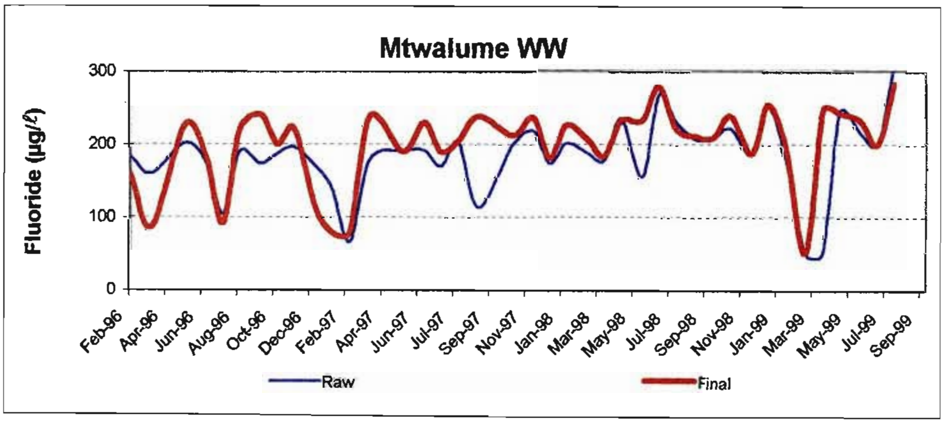


The Wilcoxon Matched Pairs Test indicated that the :

Raw and Final are not significantly different at the 95% confidence limit (Z statistic = 1.08)

Mtwalume WW

Statistics	Raw	Final
N	40.0	40.0
Minimum	50.0	50.0
25th Percentile	172.3	185.3
Average	183.6	198.2
Median	188.0	211.0
75th Percentile	206.0	233.0
80th Percentile	215.6	237.2
95th Percentile	252.7	255.2
Maximum	309.0	283.0



The Wilcoxon Matched Pairs Test indicated that the :

Raw and Final are significantly different at the 95% confidence limit (Z statistic = 2.58)

APPENDIX 7

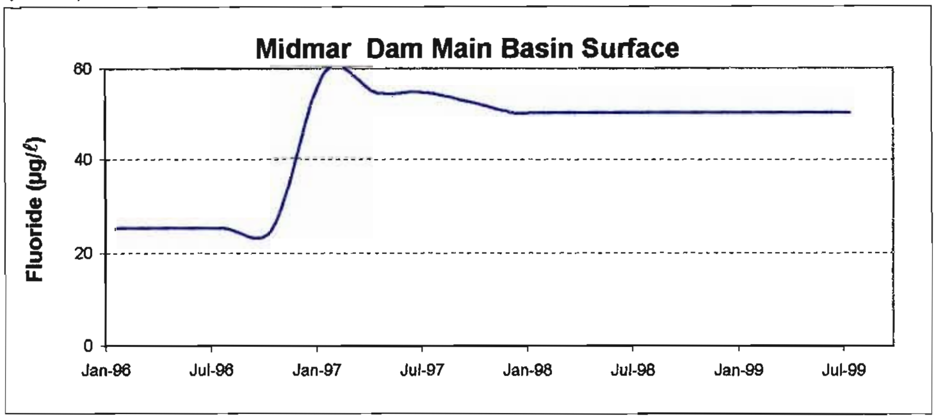
Time Series Graphs and Summary Statistics

Fluoride concentrations at impoundment Sites

Appendix 7 : Fluoride concentrations at impoundment sites.

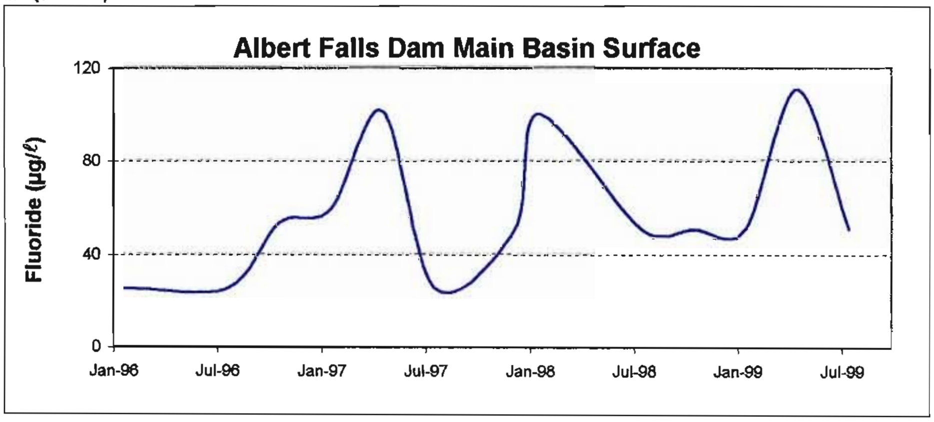
Mgeni River Catchment : Midmar Dam Main Basin Surface (site 36.1)

Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	25.0	25.0	25.0
25th Percentile	50.0	37.5	50.0
Average	45.9	44.1	47.7
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	52.2
80th Percentile	51.7	50.0	53.4
95th Percentile	55.9	56.2	54.3
Maximum	58.9	58.9	54.3



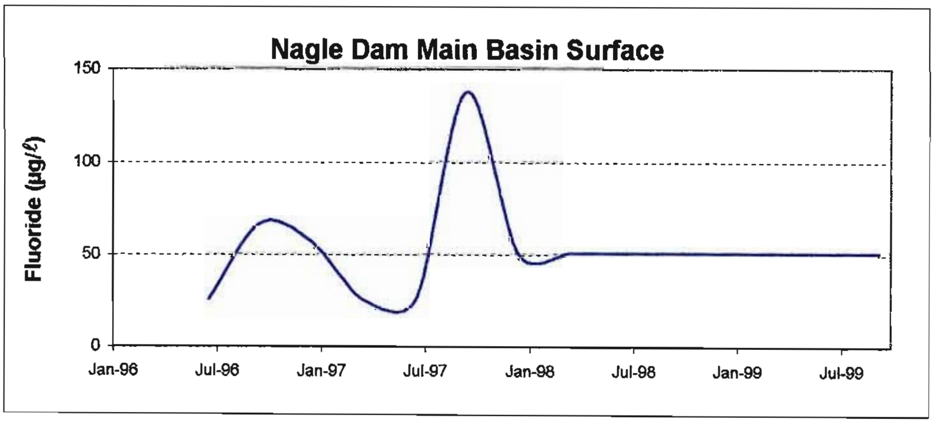
Mgeni River Catchment : Albert Falls Dam Main Basin Surface (site 41.1)

Statistics	Entire Dataset	Summer	Winter
N	13	7	6
Minimum	25.0	25.0	25.0
25th Percentile	50.0	50.0	31.3
Average	57.5	55.3	60.2
Median	50.0	50.0	50.0
75th Percentile	58.8	55.9	88.3
80th Percentile	83.5	57.6	101.0
95th Percentile	104.6	87.6	107.8
Maximum	110.0	100.0	110.0



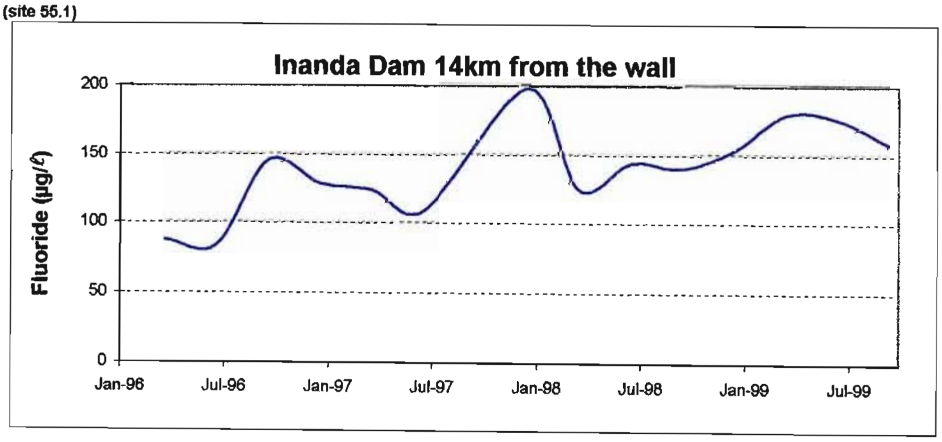
Mgeni River Catchment : Nagle Dam Main Basin Surface (site 43.1)

Statistics	Entire Dataset	Summer	Winter
N	14	6	8
Minimum	25.0	25.0	25.0
25th Percentile	50.0	50.0	43.8
Average	52.5	46.9	56.7
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	54.1
80th Percentile	52.6	50.0	59.7
95th Percentile	91.0	55.0	112.2
Maximum	137.0	56.6	137.0



Mgeni River Catchment : Inanda Dam 14km from the wall (site 55.1)

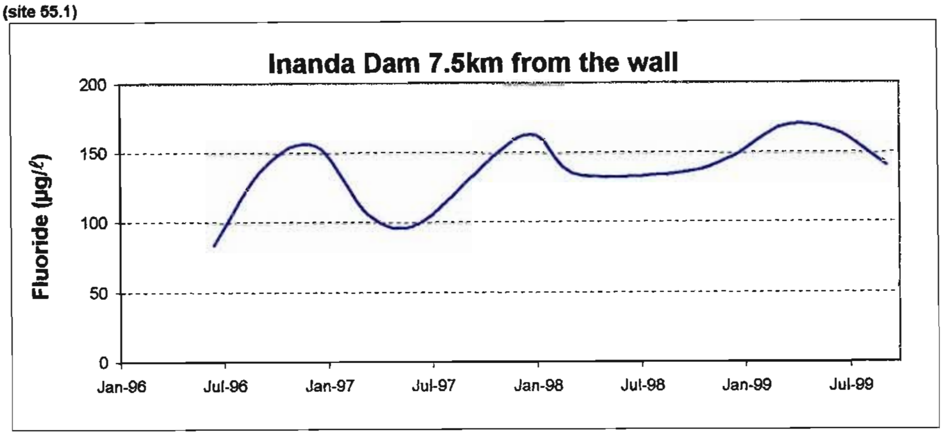
Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	83.0	87.0	83.0
25th Percentile	123.2	123.4	123.5
Average	138.6	141.5	135.7
Median	141.0	128.0	143.0
75th Percentile	156.0	166.0	151.0
80th Percentile	164.2	173.8	154.6
95th Percentile	185.3	191.6	169.6
Maximum	197.0	197.0	175.0



Appendix 7 : Fluoride concentrations at impoundment sites.

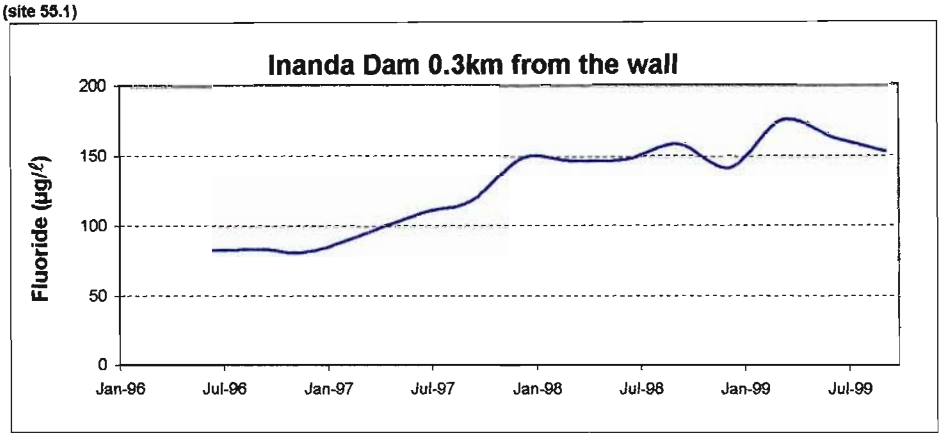
Mgeni River Catchment : Inanda Dam 7.5km from the wall (site 55.1)

Statistics	Entire Dataset	Summer	Winter
N	12	6	6
Minimum	84.0	105.0	84.0
25th Percentile	127.4	137.9	109.0
Average	136.9	145.8	128.0
Median	140.9	151.0	138.4
75th Percentile	157.0	161.0	141.0
80th Percentile	161.4	163.0	141.0
95th Percentile	167.8	168.3	159.8
Maximum	170.0	170.0	166.0



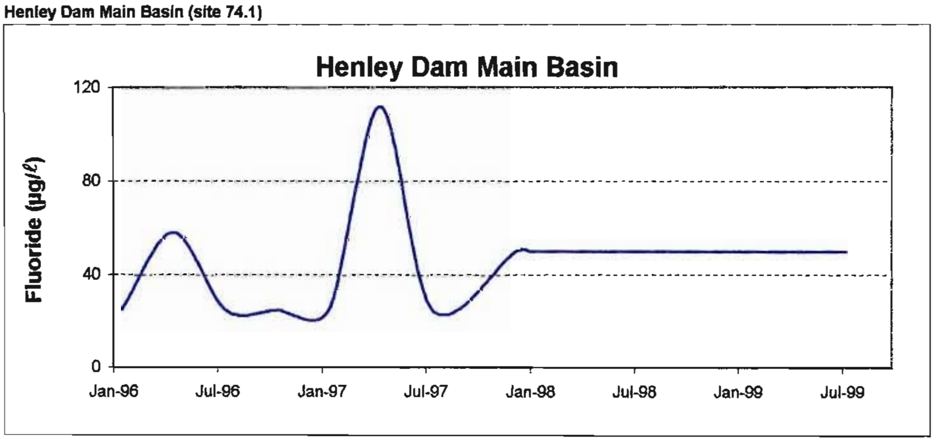
Mgeni River Catchment : Inanda Dam 0.3km from the wall (site 55.1)

Statistics	Entire Dataset	Summer	Winter
N	13	5	8
Minimum	82.9	82.9	83.0
25th Percentile	109.0	142.0	102.6
Average	131.9	139.3	127.2
Median	146.8	146.8	133.0
75th Percentile	154.0	149.0	155.3
80th Percentile	157.0	154.4	157.0
95th Percentile	168.2	170.6	161.6
Maximum	176.0	176.0	163.0



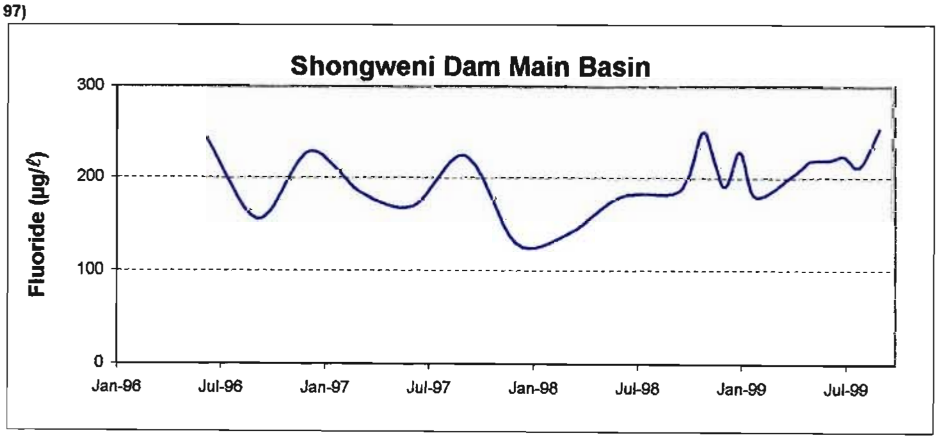
Mgeni River Catchment (Msunduzi River Sub-catchment) : Henley Dam Main Basin (site 74.1)

Statistics	Entire Dataset	Summer	Winter
N	15	7	8
Minimum	25.0	25.0	25.0
25th Percentile	25.0	25.0	43.8
Average	46.3	39.3	52.5
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	52.0
80th Percentile	50.0	50.0	54.8
95th Percentile	74.2	50.0	93.1
Maximum	112.0	50.0	112.0



Mlazi River Catchment : Shongweni Dam Main Basin (site 97)

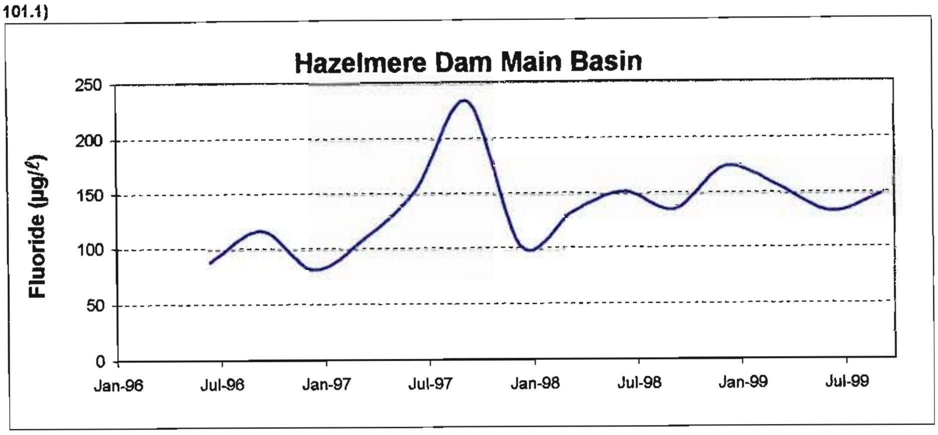
Statistics	Entire Dataset	Summer	Winter
N	21	9	12
Minimum	130.0	130.0	155.0
25th Percentile	180.0	180.0	182.3
Average	201.5	193.1	207.8
Median	206.0	191.0	216.0
75th Percentile	225.0	229.0	224.3
80th Percentile	229.0	229.0	224.8
95th Percentile	251.0	242.2	249.0
Maximum	255.0	251.0	255.0



Appendix 7 : Fluoride concentrations at impoundment sites.

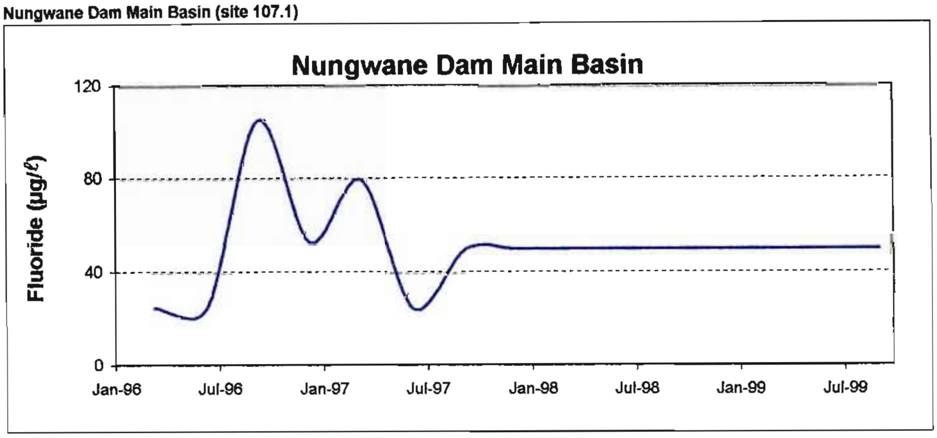
Mdloti River Catchment : Hazelmere Dam Main Basin (site 101.1)

Statistics	Entire Dataset	Summer	Winter
N	14	6	8
Minimum	81.8	81.8	89.0
25th Percentile	112.5	105.0	129.8
Average	137.6	126.8	145.8
Median	135.0	122.4	143.0
75th Percentile	153.5	150.5	152.5
80th Percentile	154.8	156.0	153.2
95th Percentile	195.7	170.3	206.0
Maximum	234.0	175.0	234.0



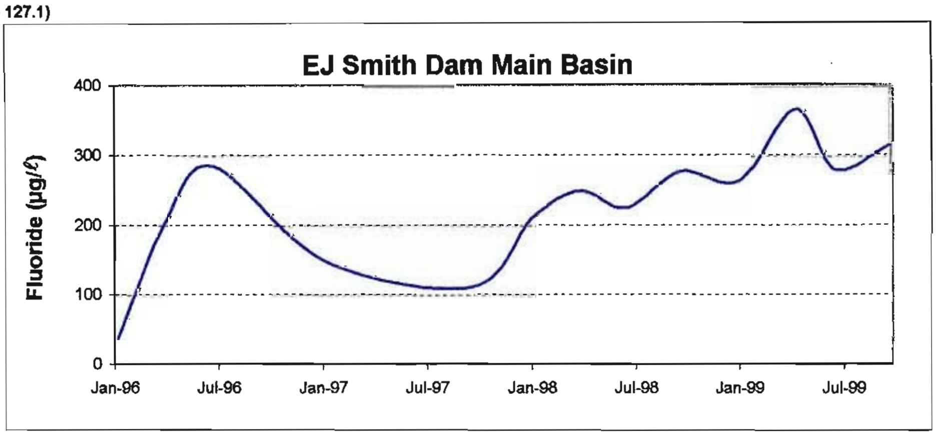
Lovu River Catchment (Nungwane River Sub-catchment) : Nungwane Dam Main Basin (site 107.1)

Statistics	Entire Dataset	Summer	Winter
N	14	7	7
Minimum	25.0	25.0	25.0
25th Percentile	50.0	50.0	37.5
Average	50.9	51.1	50.7
Median	50.0	50.0	50.0
75th Percentile	50.0	51.5	50.0
80th Percentile	51.2	52.3	50.0
95th Percentile	88.4	71.5	88.5
Maximum	105.0	79.5	105.0



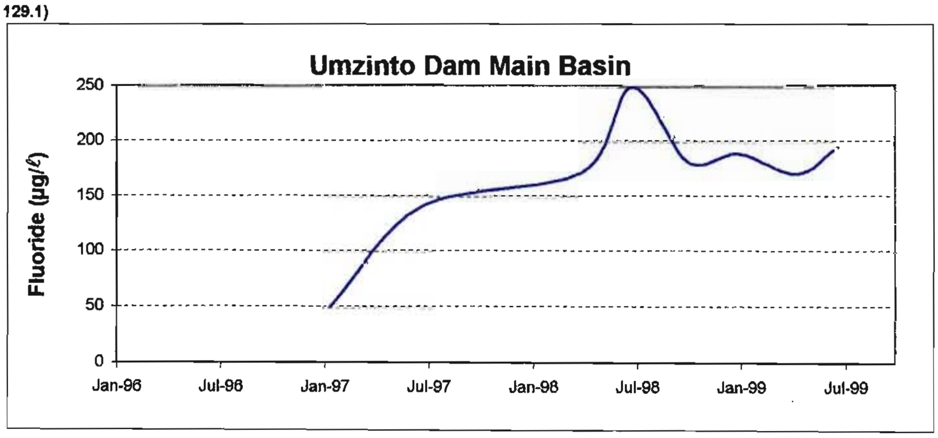
Mzimayi River Catchment : EJ Smith Dam Main Basin (site 127.1)

Statistics	Entire Dataset	Summer	Winter
N	13	4	9
Minimum	37.5	37.5	112.0
25th Percentile	208.0	121.1	226.0
Average	230.0	165.9	258.4
Median	251.0	180.5	278.0
75th Percentile	281.0	225.3	285.0
80th Percentile	283.4	233.2	298.2
95th Percentile	337.6	257.1	347.4
Maximum	367.0	265.0	367.0



Umzinto River Catchment : Umzinto Dam Main Basin (site 129.1)

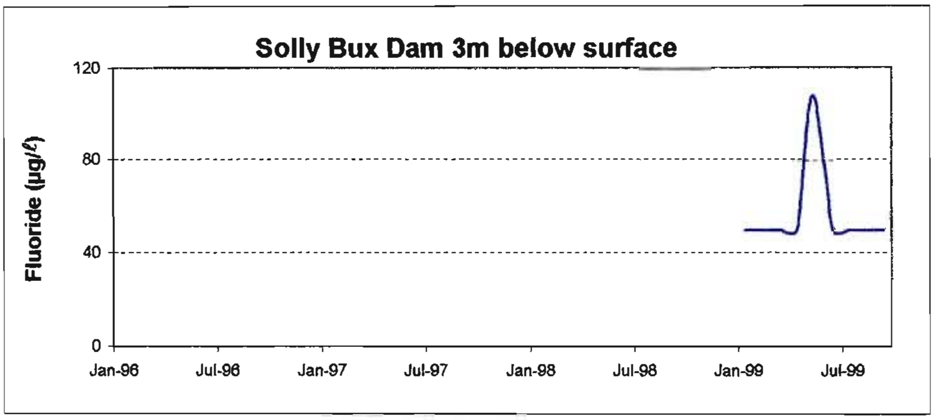
Statistics	Entire Dataset	Summer	Winter
N	8	3	5
Minimum	50.5	50.5	141.0
25th Percentile	163.5	116.3	171.0
Average	168.7	140.5	185.6
Median	177.0	182.0	172.0
75th Percentile	190.3	185.5	194.0
80th Percentile	192.0	186.2	205.2
95th Percentile	230.4	188.3	238.8
Maximum	250.0	189.0	250.0



Appendix 7 : Fluoride concentrations at impoundment sites.

Xobho River Catchment : Solly Bux Dam (site 153.2)

Statistics	Entire Dataset	Summer	Winter
N	9	3	6
Minimum	50.0	50.0	50.0
25th Percentile	50.0	50.0	50.0
Average	56.4	50.0	59.7
Median	50.0	50.0	50.0
75th Percentile	50.0	50.0	50.0
80th Percentile	50.0	50.0	50.0
95th Percentile	84.8	50.0	93.5
Maximum	108.0	50.0	108.0



APPENDIX 8

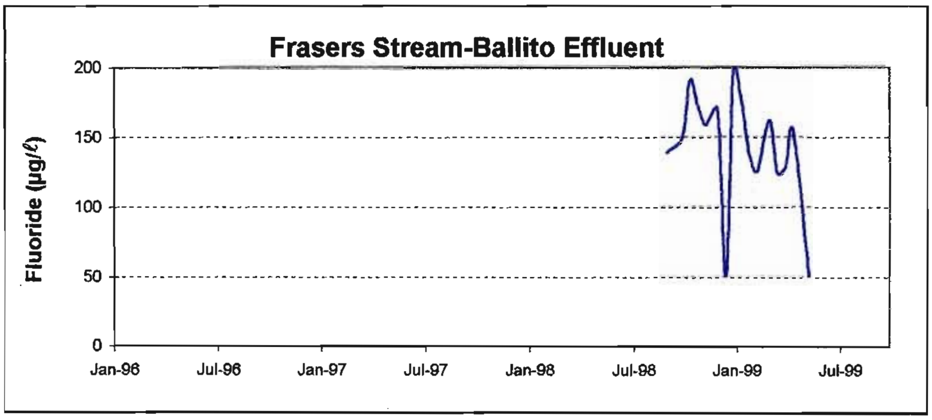
Time Series Graphs and Summary Statistics

Fluoride concentrations at Pollution Point Sources

Appendix 8 : Fluoride concentrations at Pollution Points.

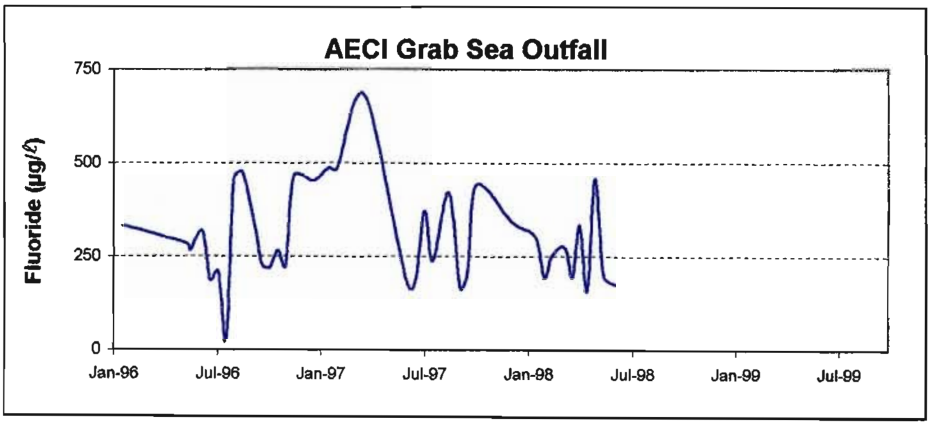
Frazers Stream-Ballito Effluent (site 849)

Statistics	Entire Dataset	Summer	Winter
N	16	12	4
Minimum	50.0	50.0	50.0
25th Percentile	127.3	127.3	116.0
Average	142.7	149.3	123.0
Median	152.0	160.0	144.0
75th Percentile	170.5	173.0	151.0
80th Percentile	172.0	175.2	151.6
95th Percentile	193.0	194.6	153.4
Maximum	199.0	199.0	154.0



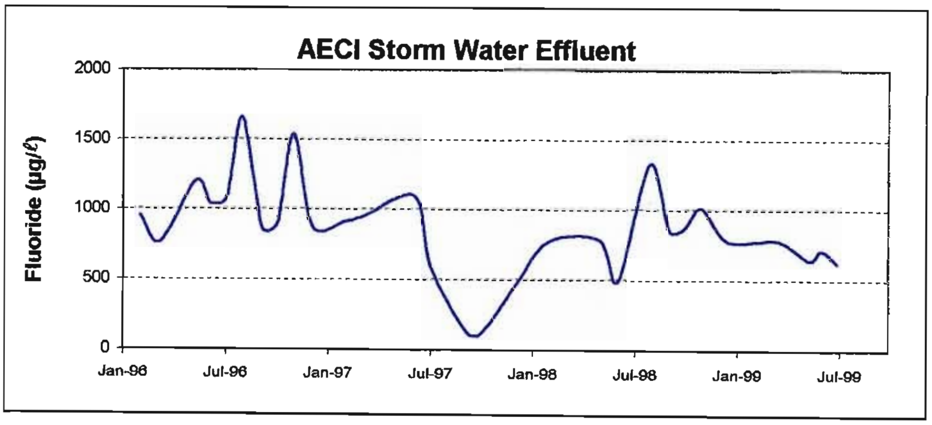
AECI Grab Sea Outfall (site 857)

Statistics	Entire Dataset	Summer	Winter
N	37	16	21
Minimum	25.0	193.0	25.0
25th Percentile	207.0	244.5	184.0
Average	304.1	342.1	275.2
Median	272.0	315.5	235.0
75th Percentile	421.0	453.5	369.0
80th Percentile	448.8	461.0	421.0
95th Percentile	483.6	534.0	459.0
Maximum	678.0	678.0	476.0



AECI Storm Water Effluent (site 858)

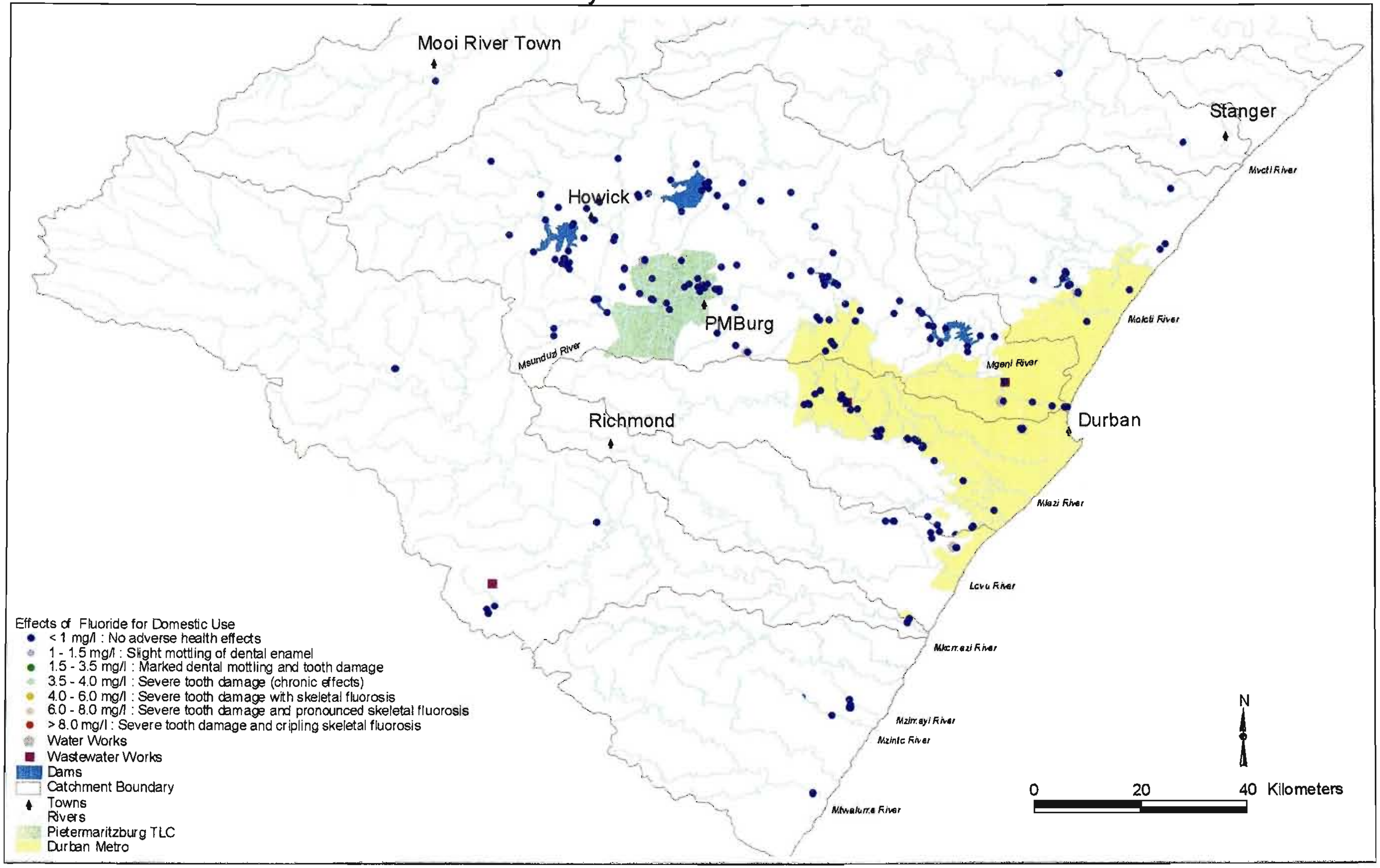
Statistics	Entire Dataset	Summer	Winter
N	31	14	17
Minimum	107.0	461.0	107.0
25th Percentile	724.0	758.3	613.0
Average	842.8	868.6	821.5
Median	842.0	841.0	842.0
75th Percentile	980.0	933.0	1074.0
80th Percentile	1031.0	945.8	1087.6
95th Percentile	1426.5	1193.1	1386.8
Maximum	1654.0	1533.0	1654.0



APPENDIX 9

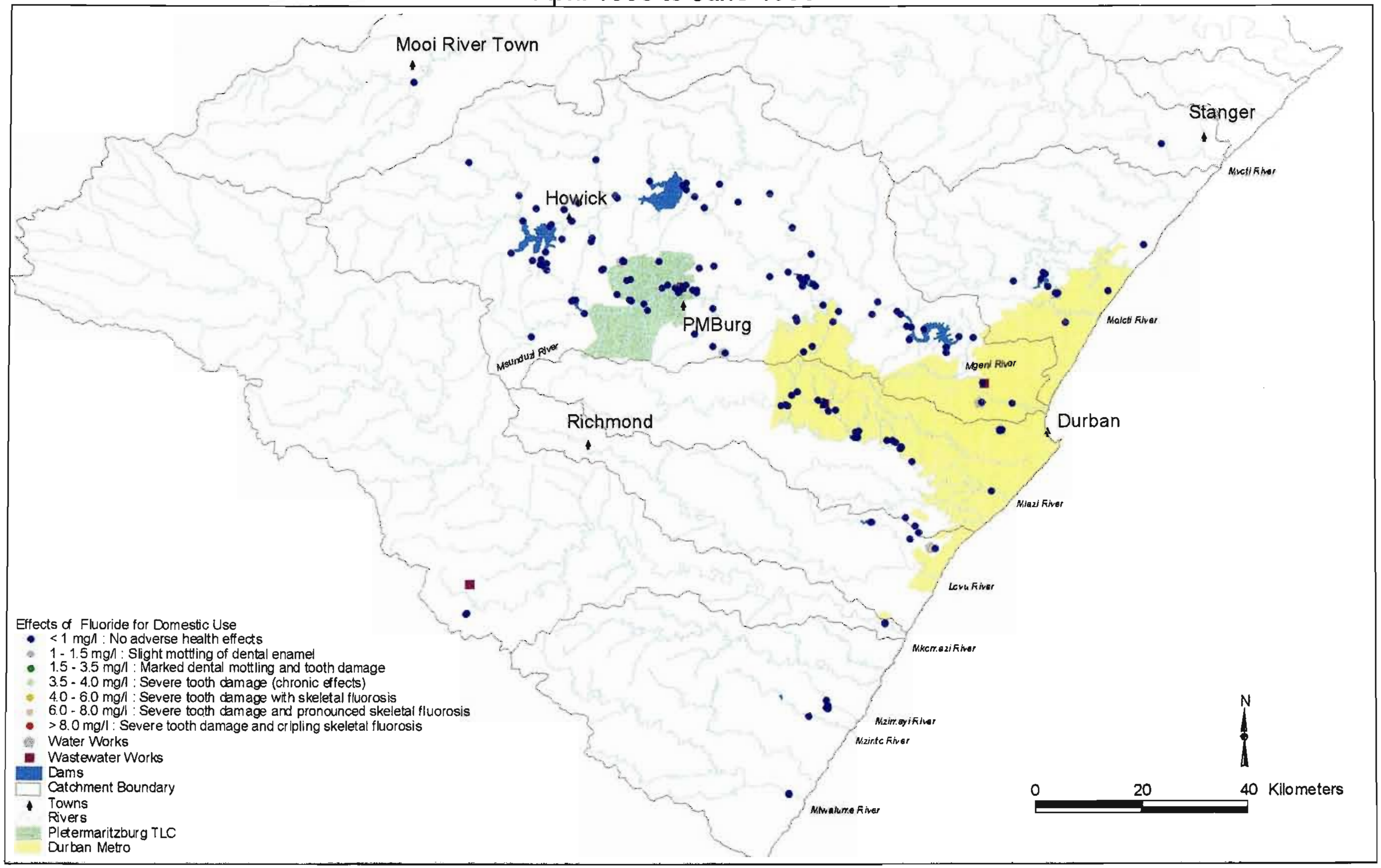
Spatial presentation of fluoride concentration for surface water based on its fitness for domestic use

Surface Water Fitness for Domestic Use - Based on Fluoride Concentrations
January 1998 to March 1998



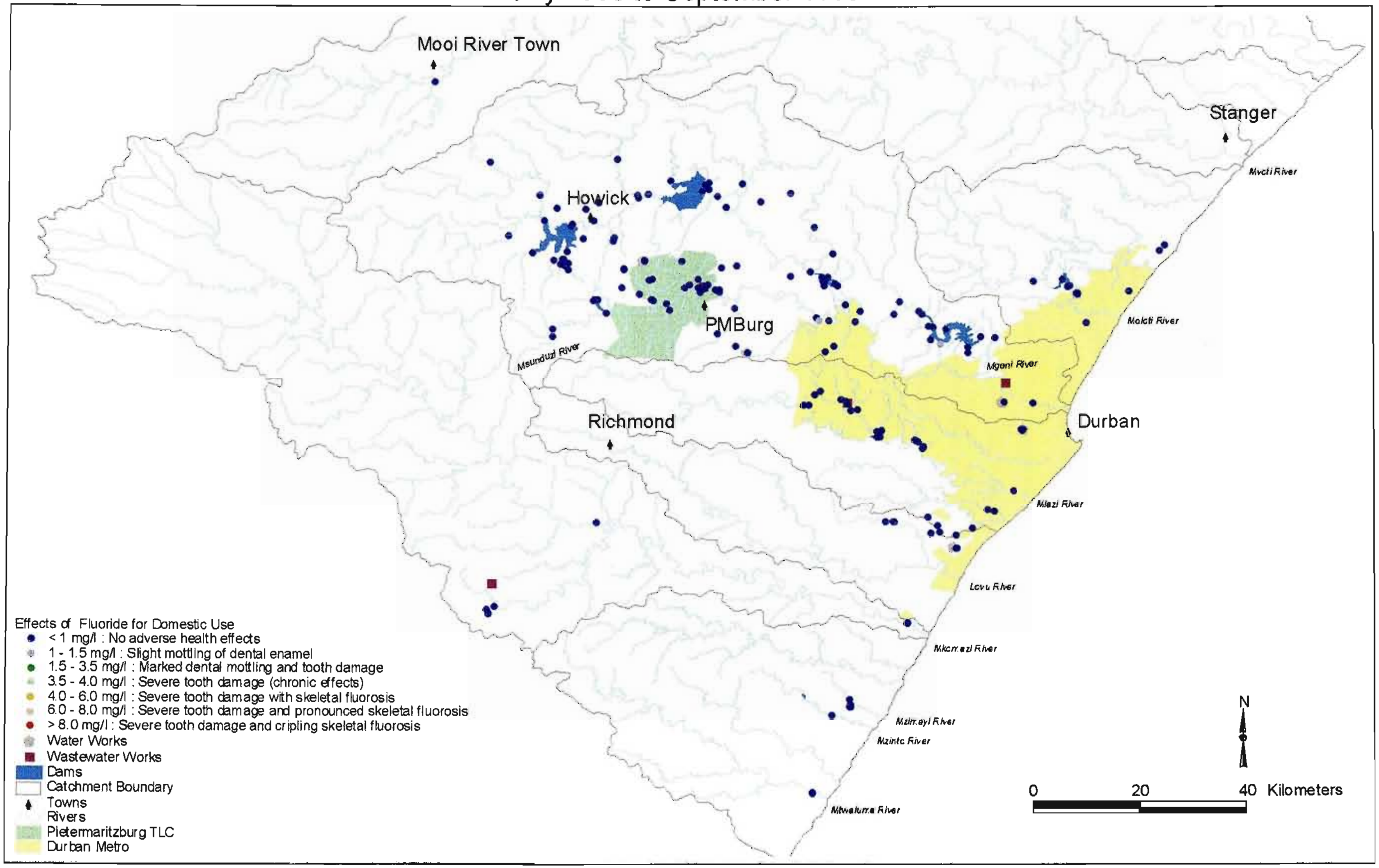
Surface Water Fitness for Domestic Use - Based on Fluoride Concentrations

April 1998 to June 1998



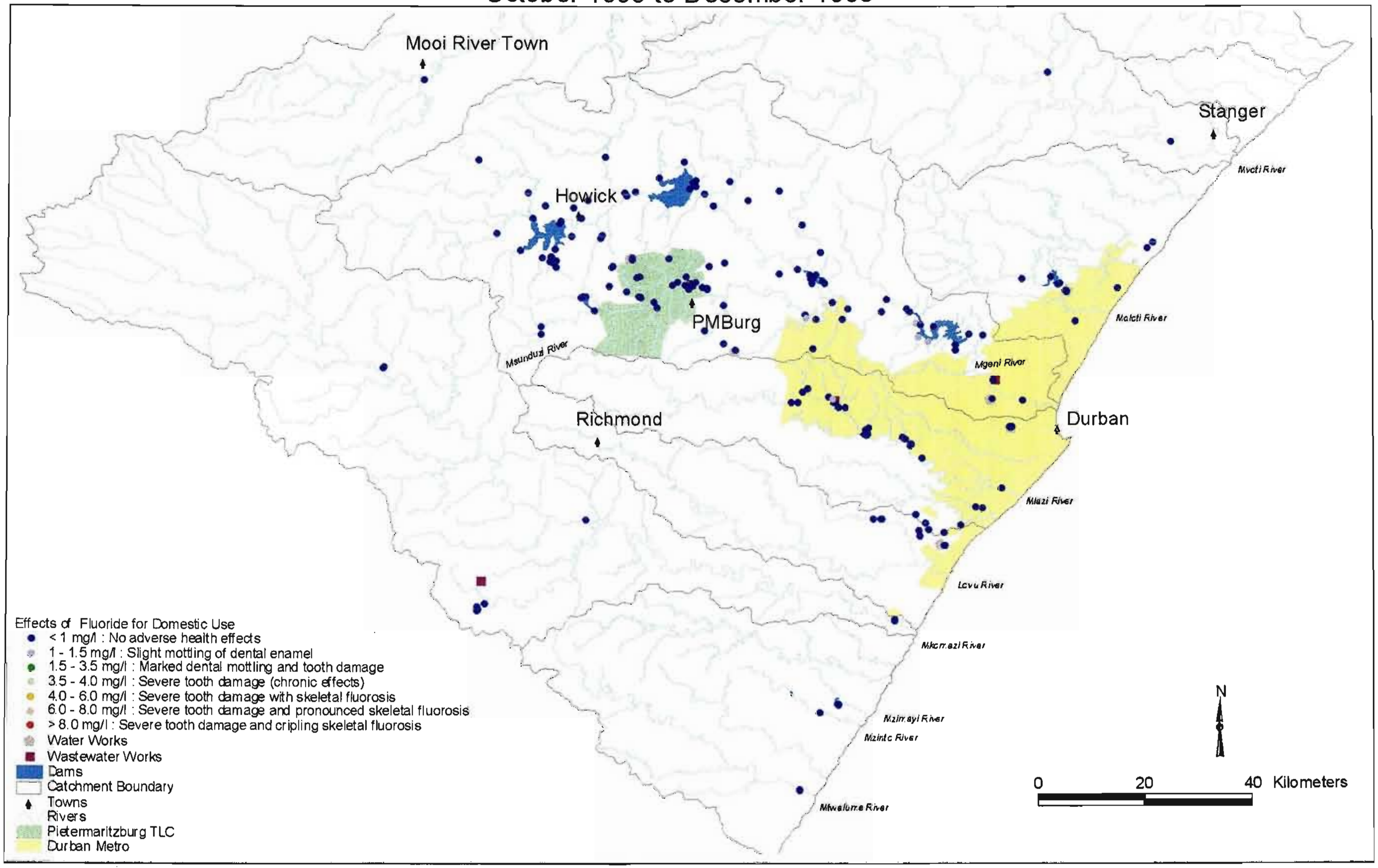
Surface Water Fitness for Domestic Use - Based on Fluoride Concentrations

July 1998 to September 1998



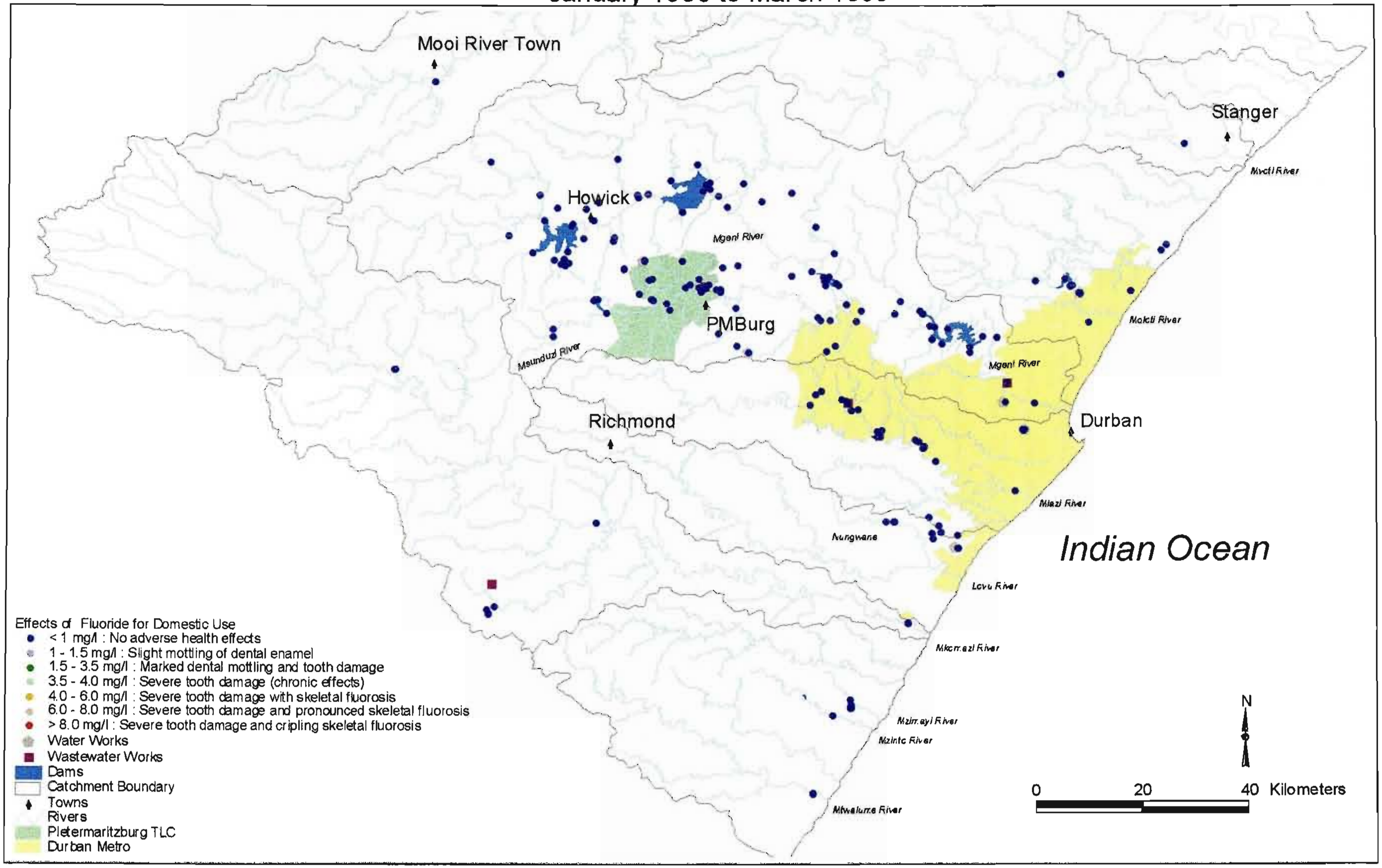
Surface Water Fitness for Domestic Use - Based on Fluoride Concentrations

October 1998 to December 1998



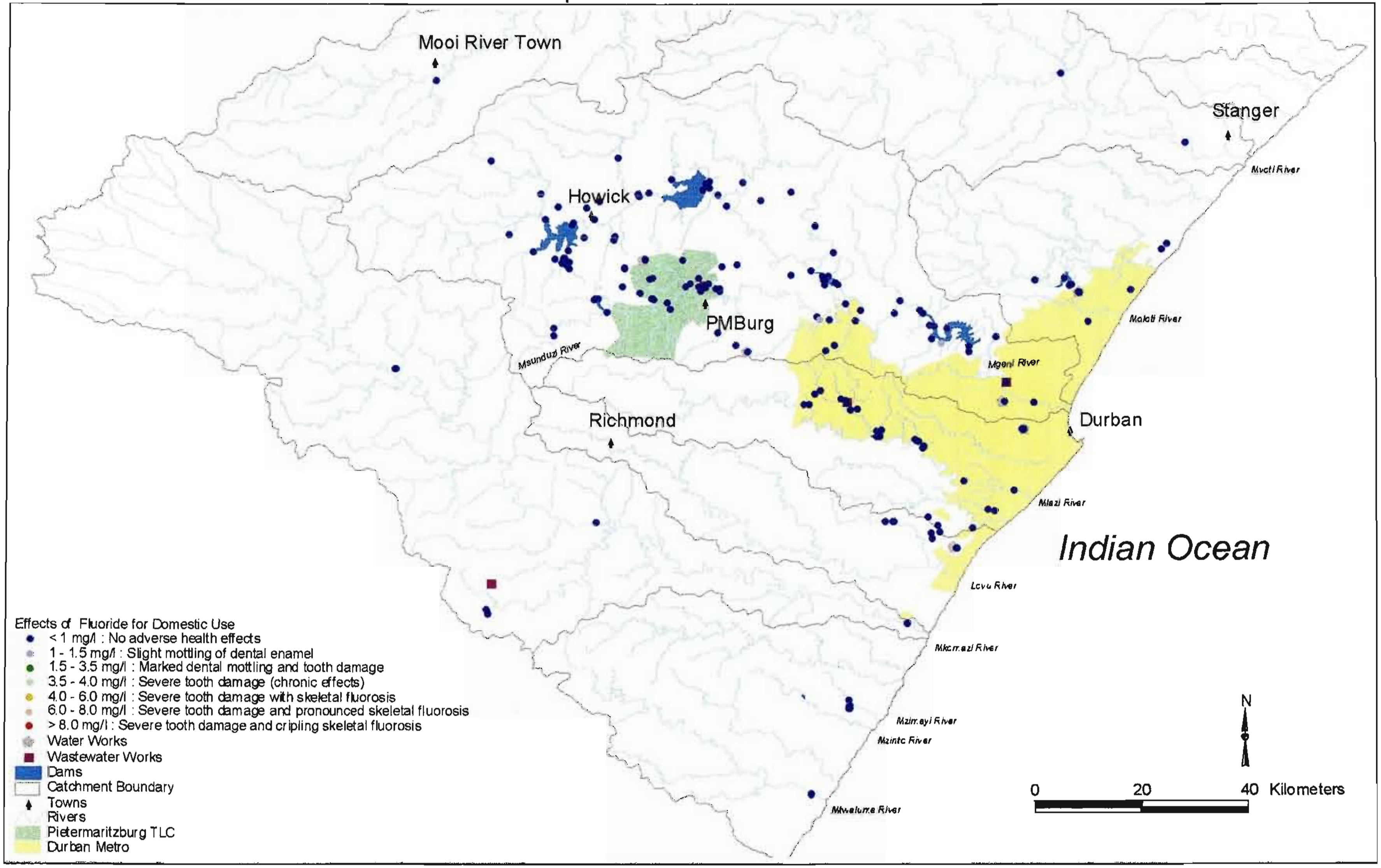
Surface Water Fitness for Domestic Use - Based on Fluoride Concentrations

January 1999 to March 1999



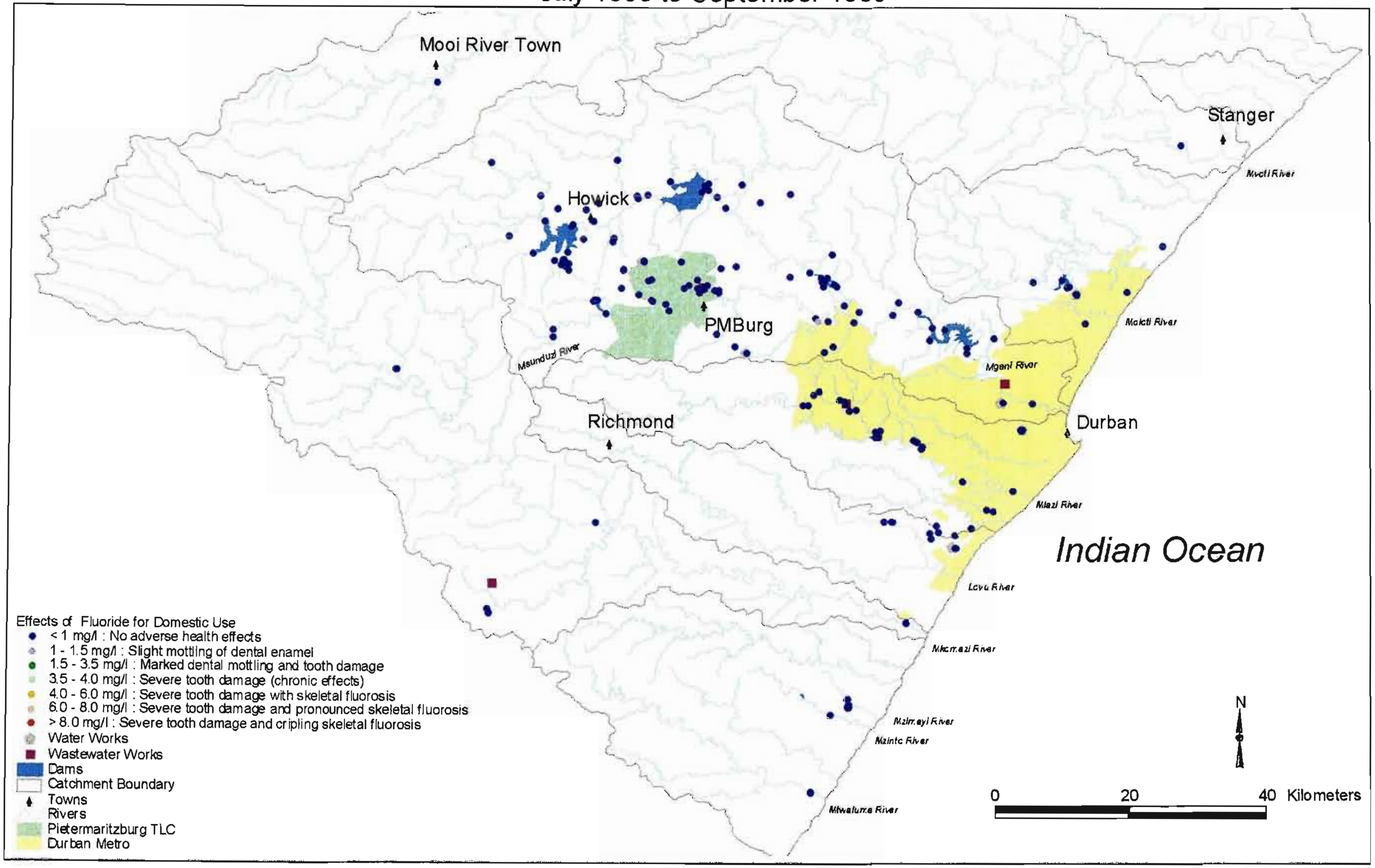
Surface Water Fitness for Domestic Use - Based on Fluoride Concentrations

April 1999 to June 1999



Surface Water Fitness for Domestic Use - Based on Fluoride Concentrations

July 1999 to September 1999



APPENDIX 10

Check for Normality using Skewness for WWW influents and Effluents

Data set	Sample Size (N)	Skewness	Limits for Skewness	Distribution
Mpophomeni Influent	78	0.74	-0.4639 to +0.4639	Not Normally Distributed
Mpophomeni Effluent	78	0.52	-0.4639 to +0.4639	Not Normally Distributed
Hammarsdale Influent	68	1.26	-0.4812 to +0.4812	Not Normally Distributed
Hammarsdale Effluent	68	0.57	-0.4812 to +0.4812	Not Normally Distributed
Darvill Influent	56	2.45	-0.5157 to +0.5157	Not Normally Distributed
Darvill Effluent	56	2.10	-0.5157 to +0.5157	Not Normally Distributed

APPENDIX 11

Flow and Fluoride Concentrations - Downstream of Darvill WWW

Month	Flow (million cubic metres) Darvill Effluent	Duzi at Hamstead Park	Duzi at Eddy Hagan	Inanda Dam Inflow	Fluoride concentration (ug/l) Darvill Effluent	Darvill Effluent after fluoridation	Duzi at Hamstead Park	Duzi at Hamstead Park (with additional F)	Duzi at Eddy Hagan	Inanda Dam Inflow
Nov-97	2.0	11.8	14.4	27.9	123.7	760.1				50.0
Dec-97	2.4	14.1	17.3	37.4	148.7	785.1	50.0	135.4		
Jan-98	2.1	24.5	32.1	105.7	165.7	802.1	50.0	70.3		
Feb-98	2.0	25.2	33.2	125.4	177.0	813.4			170.0	170.0
Mar-98	3.0	21.1	23.1	116.6	131.7	768.1				
Apr-98	2.3	11.2	10.5	68.2	114.3	750.7	50.0	155.4		
May-98	2.3	7.6	7.0	17.7	104.3	740.7				182.0
Jun-98	2.3	6.3	6.1	10.1	125.0	761.4				
Jul-98	1.8	4.5	6.4	10.6	123.3	759.7	50.0	304.6		
Aug-98	1.9	4.6	4.8	12.4	116.3	752.7			157.0	142.0
Sep-98	1.3	3.7	4.6	8.9	95.7	732.1				
Oct-98	1.8	4.3	5.3	9.7	101.3	737.7	50.0	307.4		
Nov-98	1.5	5.1	5.7	13.5	111.3	747.7			206.0	180.0
Dec-98	1.9	12.3	13.9	25.3	111.3	747.7				
Jan-99	1.9	11.6	15.3	24.2	81.7	718.1	136.0	117.4		
Feb-99	2.3	15.6	22.7	43.2	74.3	710.7			127.0	174.0
Mar-99		6.6	6.0	12.3			102.8			
Apr-99		4.4	5.2	8.5			94.5			
May-99		4.1	5.1	6.5			111.2		212.0	176.0
Jun-99	1.3	3.6	4.9	5.6	75.0	711.4	91.0	255.7		
Jul-99	1.5	3.4	4.9	5.2	96.0	732.4				
Aug-99	1.6	3.5	4.1	5.9	120.0	756.4			294.0	230.0
Sep-99	1.5	2.5	4.0	6.4	135.7	772.1	50.0	457.2		

APPENDIX 12

CHI Squared test – fluoride concentrations vs geology

Level	Adelaide/Estcourt	Berea	Dwyka	Karoo Dolerite	Mapumulo Metamorphic	Mzumbe Granotoid	Namibian	Natal	Pmb	Quaternary	Tarkastad	Volksrust	Vryheid	total
Low (<0.5mg/l)	43	5	19	30	7	9	10	33	26	7	20	19	10	238
medium (0.5 - 1mg/l)	1	0	1	3	0	0	0	1	0	0	0	6	2	14
high (>1mg/l)	5	0	0	2	1	0	0	1	7	0	0	1	0	17
total	49	5	20	35	8	9	10	35	33	7	20	26	12	269

Expected

Level	Adelaide/Estcourt	Berea	Dwyka	Karoo Dolerite	Mapumulo Metamorphic	Mzumbe Granotoid	Namibian	Natal	Pmb	Quaternary	Tarkastad	Volksrust	Vryheid	total
Low (<0.5mg/l)	43.35	4.42	17.70	30.97	7.08	7.96	8.85	30.97	29.20	6.19	17.70	23.00	10.62	
medium (0.5 - 1mg/l)	2.55	0.26	1.04	1.82	0.42	0.47	0.52	1.82	1.72	0.36	1.04	1.35	0.62	
high (>1mg/l)	3.10	0.32	1.26	2.21	0.51	0.57	0.63	2.21	2.09	0.44	1.26	1.64	0.76	
total														
	0.00	0.08	0.10	0.03	0.00	0.14	0.15	0.13	0.35	0.11	0.30	0.70	0.04	2.11
	0.94	0.26	0.00	0.76	0.42	0.47	0.52	0.37	1.72	0.36	1.04	15.96	3.03	25.85
	1.17	0.32	1.26	0.02	0.48	0.57	0.63	0.66	11.58	0.44	1.26	0.25	0.76	19.42
													chi squared	47.38

APPENDIX 13

CHI Squared test – fluoride concentrations vs distance from fault lines

Level	<=500m	500 to 1000m	1000 to 2500m	2500 to 5000m	5000 to 10000m	10000 to 15000m	15000 to 35000m	total
Low (<0.5mg/l)	26	14	35	43	54	38	39	249
medium (0.5 - 1mg/l)	0	2	4	2	4	1	1	14
high (>1mg/l)	1	0	3	3	4	1	5	17
total	27	16	42	48	62	40	45	280

Expected

Level	<=500m	500 to 1000m	1000 to 2500m	2500 to 5000m	5000 to 10000m	10000 to 15000m	15000 to 35000m	total
Low (<0.5mg/l)	24	14	37	43	55	36	40	
medium (0.5 - 1mg/l)	1	1	2	2	3	2	2	
high (>1mg/l)	2	1	3	3	4	2	3	
total								

0.2	0.0	0.1	0.0	0.0	0.2	0.0	0.5337455
1.4	1.8	1.7	0.1	0.3	0.5	0.7	6.3914491
0.2	1.0	0.1	0.0	0.0	0.8	1.9	4.0402347
					Chi squared		10.965429

APPENDIX 14

REGULATIONS UNDER THE HEALTH ACT, 1977 (ACT NO. 63 OF 1977)

GOVERNMENT NOTICE

8 September 2000

Regulation No. R 873 of 2000

DEPARTMENT OF HEALTH

REGULATIONS UNDER THE HEALTH ACT, 1977 (ACT NO. 63 OF 1977)

The Minister of Health has, under section 37, read with section 40(1), of the Health Act, 1977 (Act No. 63 of 1977), and after consultation with the Minister of Water Affairs and Forestry, made the regulations in the Schedule.

SCHEDULE

REGULATIONS ON FLUORIDATING WATER SUPPLIES

Definitions

c. In these regulations any expression to which a meaning has been assigned in the Act shall have such meaning and, unless the context indicates otherwise –

"authorised officer" means an officer of the national Department of Health or of a provincial government or any other person generally or specifically authorised in writing by the Director-General;

"Director-General" means the Director-General of the national Department of Health;

"fluoridation" means to adjust the fluoride concentration of a water supply by the addition of a fluoride compound to obtain an optimal fluoride concentration;

"fluoride compound" means sodium fluoride (NaF), sodium fluorosilicate (Na_2SiF_6) (also known as sodium silicofluoride) or fluorosilicic acid (H_2SiF_6);

"optimum fluoride concentration" means a fluoride concentration of not more than 0,7 milligrams fluoride per litre in a water supply;

"the Act" means the Health Act, 1977 (Act No. 63 of 1977);

"waste water discharges" means water discharges containing waste;

"waste" means any solid material or material that is suspended, dissolved or transported in water (including sediment) and which is spilled or deposited on land or into a water resource in such volume, composition or manner as to cause, or to be reasonably likely to cause, the water resource to be polluted;

"water distribution system" means the supply of water by a water provider through pipes to the end user;

"water fluoridation plant" means the equipment used and the procedures applied in the addition of a fluoride compound to a water supply;

"water fluoridation scheme" means the delivery to the end user of water containing an optimum concentration of fluoride, which is supplied by a water fluoridation plant through a water distribution system;

"water provider" means any drinking-water treatment authority, body or organisation supplying drinking water from its treatment facility;

"water resources" means a watercourse, surface water, estuary or aquifer;

"water supply" means the supply of water intended for human use or food processing.

Obligation

c. Every water provider must practise fluoridation, unless exempted in writing by the Director-General.

Registration

c. (1) Every water provider practising as such immediately prior to the promulgation of these regulations must, within 12 months after the promulgation of these regulations, submit –

   d. an application for registration, in duplicate, in the format set out in Annex A; and

   e. a form on technical information set out in Annex C,

to the Director-General.

(2) A water provider commencing operations as such after the promulgation of these regulations must, within 12 months of becoming a water provider, register with the Director-General as contemplated in subregulation (1).

(3) A water provider must enter into an agreement with the local authority whose population is supplied by such water provider if the water provider is not itself a local authority.

(4) Information regarding an agreement referred to in subregulation (3) must be indicated by the water provider in paragraph 6 of Annex A when the water provider submits its application for registration, referred to in subregulation (1).

Public information

c. (1) A water provider must, once these regulations have been promulgated or when commencing operations, inform every local authority to whom it supplies drinking water that the water supply will be fluoridated.

(2) The local authority referred to in subregulation (1) must, once these regulations have been promulgated or when a water provider in such local authority's area commences operations, inform the public concerned by means

of a notice in two or more regional newspapers generally read by the public in the area in question regarding the intended fluoridation of their water supply.

(3) The notice referred to in subregulation (2) must state that interested persons are invited to submit any substantiated comments on the intended fluoridation of their water supply or representations they wish to make in regard thereto to their local authority within 30 days of the date of publication of such notice.

(4) In addition to the publication of the notice referred to in subregulation (2), the local authority must also broadcast the content of such notice on an appropriate radio station.

(5) A water provider must attach the comments received by the local authority from the public to the application for registration referred to in regulation 3.

Consideration by Director-General regarding implementation of fluoridation by water provider

c. (1) The following information must be taken into account by the Director-General:

   d. Dental caries experience in the supply area of the water provider;

   e. the population size in the supply area of the water provider;

   f. the estimated per capita costs of fluoridation in the supply area of the water provider;

   g. the feasibility of using alternative fluoride supplements; and

   h. the information required in Annex A.

(2) The information referred to in subregulation (1) must, at the written request of the Director-General, be submitted by public oral health services, water providers and local authorities, as applicable.

(3) The Director-General must consult with the Director-General of Water Affairs and Forestry regarding any possible influence of the proposed fluoridation of the water resources in the affected areas and; should the Director-General of Water Affairs and Forestry be of the opinion that there may be an unacceptable impact on these water resources, the Director-General may require the water provider to carry out an assessment of this impact.

(4) The assessment referred to in subregulation (3) must be evaluated by the Director-General and the Director-General of Water Affairs and Forestry.

(5) After a water provider's application for registration has been registered, such water provider must implement fluoridation within a period of not more than two years, or within such extended period as determined by the Director-General upon a written request by the water provider.

(6) The Director-General may at any time before or after a water fluoridation plant comes into operation, request a water provider to submit any other additional information on the water fluoridation scheme to him or her.

(7) If a water provider makes any changes, except with regard to the optimum fluoride concentration, after the implementation of fluoridation, which differ with regard to any of the items specified as technical information in Annex C, such water provider must inform the Director-General in writing regarding such changes and the reasons therefor.

(8) The Director-General determines the optimum concentration of fluoride in the water supplied by a water provider.

(9) If a water provider wishes to amend the optimum fluoride concentration referred to in subregulation (8), as approved by the Director-General, such water provider must apply in writing to the Director-General for approval to amend the optimum fluoride concentration, stating the reasons for such amendment.

(10) The Director-General may authorise an officer from the national or a provincial Department of Health or any other person authorised by him or her to carry out any prescribed inspection of a water fluoridation plant at any reasonable time, and may request any specified report on the functioning of the water fluoridation scheme to be submitted to him or her.

Exemption of water provider from implementation of fluoridation, or termination of fluoridation

c. (1) If a water provider wishes to be exempted from the implementation of fluoridation or wishes to terminate the fluoridation of a water supply, such water provider must submit its application for such exemption or termination in duplicate to the Director-General in the format set out in Annex B.

(2) The Director-General must use the criteria and guidelines in Annex D to determine whether an application referred to in subregulation (1) should be approved or not.

(3) If the Director-General is of the opinion that such an exemption or termination is necessary, the Director-General must approve such an exemption or termination.

(4) The Director-General may withdraw his or her approval referred to in subregulation (3) for a specific period if he or she is of the opinion that such an exemption or termination is unnecessary.

(5) The Director-General must approve an application for exemption or termination in consultation with the Director-General of Water Affairs and Forestry, if the latter is of the opinion that the water provider concerned should be exempted from the implementation of fluoridation or permitted to terminate the fluoridation of a water supply owing to the unacceptable impact on the water resources receiving fluoridated water or waste water discharges.

(6) The Director-General must inform the water provider concerned in writing whether its application referred to in subregulation (1) has been approved or not, as well as provide the reasons in the case of disapproval.

Appeals

c. (1) Any local authority, water provider, other authority, public organisation or body may appeal in writing to the Minister against any decision made by the Director-General in terms of any provision of these regulations.

(2) An appeal in terms of subregulation (1) must be lodged within 60 days of the decision appealed against having come to the knowledge of the local authority, water provider, other authority, public organisation or body, as the case may be, and must clearly state –

c. against which decision such appeal is lodged; and

d. the grounds on which such appeal is lodged.

(3) An appeal in terms of these regulations must be lodged with the Director-General, who must submit it to the Minister, together with his or her reasons for the decision against which the appeal is being lodged.

(4) The Minister may confirm, amend or revoke a decision taken by the Director-General in terms of the provisions of these regulations and inform the local authority, water provider, other authority, public organisation or body, as the case may be, in writing of his or her decision.

Operational criteria for fluoridation

c. (1) The water fluoridation plant must –

d. be of such design as to be capable of ensuring the fluoride concentration indicated under point 3 of Annex C; and

e. incorporate alarm arrangements to prevent the overdosing of a water supply with fluoride resulting in more than 1,0 milligrams fluoride per litre above the optimum fluoride concentration indicated under point 3 of Annex C as a result of a breakdown or malfunction of any part of the water fluoridation plant equipment or a change in the flow rate of the fluoridated water.

(2) Only a fluoride compound approved by the Director-General in terms of regulation 14 of these regulations shall be used to fluoridate a water supply.

(3) The fluoride compounds referred to in subregulation (2) must be stored in a secure place by a water provider so that –

c. any unforeseen or accidental spillage of such fluoride compound does not contaminate the environment or cause injury; and

d. no unauthorised person can tamper with such fluoride compounds.

(4) A water provider must ensure that the fluoride concentration in the fluoridated water, measured at a point soon after the addition of the fluoride compound referred to in subregulation (2) and the mixing thereof with the water, is maintained within 0,2 milligrams fluoride per litre of the optimum fluoride concentration indicated under point 3 of Annex C.

(5) The fluoride concentration referred to in subregulation (4) must be maintained at least 90 percent of the time.

(6) The average monthly fluoride concentration of the fluoridated water, calculated for the periods when the water fluoridation plant is in operation, must not deviate by more than 0,1 milligrams fluoride per litre from the optimum fluoride concentration indicated under point 3 of Annex C.

(7) If a water fluoridation plant is shut off for a period of two months or longer, for whatever reasons, the water provider concerned must inform the relevant local authorities who must inform the public concerned by means of a notice in two or more local newspapers and broadcasting on an appropriate radio station.

Monitoring of the fluoride concentration

c. (1) The fluoride concentration of the fluoridated water leaving the water fluoridation plant must be monitored by –

   d. a continuous-recording fluoride monitor which is calibrated once every 24 hours; or

   e. the sampling of such fluoridated water in every shift, using the analytical procedures laid down by the Department of Health as specified in the Technical Manual for Water Plant Operators.

(2) The fluoride monitor referred to in subregulation (1)(a) must be linked to an alarm system which should be activated when the fluoride concentration exceeds 1,7 milligrams fluoride per litre for a period of more than five minutes.

(3) In the case of sampling referred to in subregulation (1)(b), the water fluoridation plant must be staffed 24 hours per day to ensure proper functioning.

(4) A minimum of one sample per week must be taken randomly from a number of places in the distribution system and the result recorded.

(5) The number of samplings referred to in subregulation (4) will depend on the layout of that distribution system.

Record keeping and reporting

c. (1) The water provider must record the following particulars daily for the first month after a water fluoridation plant has come into operation, and thereafter daily or at any other interval not exceeding seven days:

   d. The volume of water fluoridated after the last recording;

   e. the amount of fluoride used in the water referred to in paragraph (a);

   f. the average fluoride concentration of the fluoridated water leaving the plant after the last recording;

   g. the average fluoride concentration, based on historical information or on actual measurement, in the unfluoridated water which entered the water fluoridation plant after the last recording;

   h. the average monthly fluoride concentration in the fluoridated water leaving the water fluoridation plant, as recorded by the fluoride monitor referred to in regulation 9(1)(a), as well as the highest and lowest fluoride concentration in such fluoridated water during that month;

i. the average monthly fluoride concentration in the samples referred to in regulation 9(1)(b), as well as the highest and the lowest fluoride concentration in such samples during that month; and

j. remarks on any events such as breakdowns, equipment failure, repairs, maintenance or any other activity that may have an effect on the fluoride concentration referred to in paragraphs (c), (d), (e) and (f), and whether steps were taken to prevent the recurrence of such events or activities.

(2) The amount of fluoride referred to in subregulation (1)(b) is determined by the subtraction of the amount of fluoride in stock at the end of the present period from the sum of the amount of fluoride received on site after the last recording and the amount of fluoride in stock at the beginning of the present period.

(3) The average fluoride concentration referred to in subregulation (1)(c) and (d) is determined by the following factors:

c. The volume of the water referred to in subregulation (1)(a);

d. the amount of fluoride added to such water; and

e. the fluoride content of the unfluoridated water referred to in subregulation (1)(d).

(4) A monthly summary of the records referred to in subregulation (1) must be submitted by a water provider to the health department of the local authority concerned and to other relevant health authorities, together with a report on any non-compliance with subregulation (1), (5), (6) or (7) and the steps taken to prevent a recurrence of such non-compliance.

(5) The records referred to in subregulation (1) and the report referred to in subregulation (4) must be submitted by the water provider via the local and provincial health authority, to the national Department of Health for audit as deemed necessary by the local or provincial health authority or the national Department of Health.

(6) Any incident of an overdose of between 1,7 milligrams and 10 milligrams fluoride per litre in a 24-hour period must be recorded and reported immediately to the health department of the local authority concerned and to any other health authority concerned.

(7) Accidental over-fluoridation of more than 10 milligrams per litre or a major spill must be recorded, and the water provider must inform the local and provincial health authority, the Director-General, the Director-General of Water Affairs and Forestry, as well as the users of such water, immediately or as soon as is practicable.

(8) All records and reports of a water provider relating to fluoridation must be open for public inspection and must be kept for a period of ten years.

(9) A summary of the records and reports referred to in subregulations (4), (5) and (6) must be submitted by the water provider to the local authorities concerned, who will in turn submit it to –

c. the MEC for Health of the responsible provincial government, every three months;

d. the Director-General of the national Department of Health, annually; and

e. the Director-General of the Department of Water Affairs and Forestry, annually.

Inspections

c. (1) An authorised officer may at any time, and as often as he or she may deem necessary, inspect a water fluoridation plant.

(2) The owner or occupier or the person in charge or apparently in charge of, or any employee on or in a water fluoridation plant, must render to the authorised officer in terms of these regulations all information the authorised officer may require with regard to the organisation and management of a water fluoridation plant and the process of fluoridation.

(3) No person may in any way obstruct an authorised officer in carrying out his or her inspections or refuse to furnish to the best of his or her knowledge any information requested by such an authorised officer.

The operation, maintenance and employees of a water fluoridation plant

c. (1) A water provider must establish a comprehensive operational programme, safety measures and emergency procedures regarding -

d. the operation of the water fluoridation plant;

e. the inspection, servicing and maintenance of the equipment of the water fluoridation plant;

f. the monitoring of the fluoride concentration referred to in regulation 9; and

g. the storage and handling of fluoride compounds at the water fluoridation plant,

in order to achieve consistent, effective and safe performance of the water fluoridation plant.

(2) The operational programme, safety measures and emergency procedures referred to in subregulation (1) must be made available in written format to the managers, supervisors, operators, maintenance staff and other employees working at the water fluoridation plant in accordance with their duties, responsibilities and tasks.

(3) A water provider must ensure that the people referred to in subregulation (2) are adequately trained in all aspects of their duties, responsibilities and tasks.

(4) The operator of a water fluoridation plant must have a classification of at least Class III, in accordance with the classification system for water-care plant operators of the Department of Water Affairs and Forestry.

Health and safety

c. All activities related to a water fluoridation plant must be in compliance with the Occupational Health and Safety Act, 1993 (Act No. 85 of 1993).

Fluoride compounds

c. (1) The following fluoride compounds may be used in the fluoridation of a water supply:

d. Sodium fluoride;

e. fluorosilicic acid;

f. sodium fluorosilicate.

(2) Potential importers or manufacturers must apply to the Director-General for registration and approval of fluoride compounds other than those mentioned in subregulation (1) prior to the fluoridation of a public water supply.

(3) A water provider must ensure that the compounds used meet the quality standards of the Department of Health as described in the Technical Manual for Water Plant Operators, published by the Department of Health.

(4) Documentary evidence of the quality of the fluoride compound to be used must be submitted to the Department of Health by the water provider concerned.

ANNEX A

APPLICATION BY A WATER PROVIDER FOR REGISTRATION TO FLUORIDATE A WATER SUPPLY

c. Name and address of water provider:

Name of responsible person:

Position/rank:

Telephone no:
Cellular no:
Fax no:

Name of responsible person from the appropriate health authority:

Position/rank:

Telephone no:
Cellular no:
Fax no:

c. Volume of water supplied per month:

d. List separately the names of local authorities supplied with drinking water by the water provider and the number of people in the supply area(s).

e. The following information may also be provided separately if more space is required:

(a) Source(s) of raw water [i.e. point(s) of abstraction]

c. River catchment(s)

d. River(s)/Dam(s)/Other

e. Location(s) of drinking water treatment facility/facilities

(b) Point(s) of discharge of effluent(s) originating from the proposed fluoridated water supply/supplies in the supply area covered by the water provider

c. River catchment(s)

d. River(s)/Dam(s)/Other

e. Location(s) of effluent treatment facility/facilities

f. Attach comments received from the public [regulation 4(5)]

g. Provide information on the agreement reached between the water provider and the local authority with respect to :

h. The terms of the agreement between the water provider and the local authority;

i. the respective responsibilities for ongoing monitoring and reporting on fluoride levels in the water supply; and

j. action to be taken in the event of over-fluoridation [regulation 10(7)]

Signature:

Name:

Position/Rank:

On behalf of:

Date:

For office use only:

Registration number:

Registration date:

....

For Director-General
Department of Health

Date:

ANNEX B

APPLICATION BY A WATER PROVIDER TO BE EXEMPTED FROM THE IMPLEMENTATION OF FLUORIDATION OR TO TERMINATE THE FLUORIDATION OF A WATER SUPPLY

c. Name and address of water provider:

Name of responsible person:

Position/rank:

Telephone no:
Cellular no:
Fax no:

Name of responsible person from theappropriate health authority

Position/rank:

Telephone no:
Cellular no:
Fax no:

c. Place where water fluoridation plant is installed:
(in the case of termination only)

d. Reason(s) for requesting exemption from the implementation of fluoridation or for the termination of fluoridation of a water supply:

Signature:

Name:

Position/Rank:

On behalf of:

Date:

For office use only:

Approved/Not approved

....

Director-General
Department of Health

Date:

ANNEX C

TECHNICAL INFORMATION PROVIDED BY THE WATER PROVIDER

Technical information to be submitted by the water provider to the Director-General.

c. Name and address of water provider:

Name of responsible person:

Position/rank:

Telephone no:
Cellular no:
Fax no:

Name of responsible person from the appropriate health authority:

Position/rank:

Telephone no:
Cellular no:
Fax no:

c. Place where water fluoridation plant is installed:

d. (a) Amount of water to be fluoridated per month:

(b) Fluoride compound to be used:

(c) Mean annual fluoride concentration of present water supply: ...mg F/l

(d) Proposed optimum fluoride concentration (not more than 0,7 mg F/l): ...mg F/l

c. Name and description of areas to be supplied with fluoridated water:

d. Explanatory documentation attached:

e. Steps taken to inform the public.

f. Types and names of fluoridation monitoring equipment and description of fluoride monitoring and alarm systems.

g. Fluoridation plant inspection, servicing and maintenance programme, and emergency procedures.

h. Employee training programme and duty sheets.

i. Agreement between local authority and water provider, if applicable.

Signature:

Name:

Position/Rank:

On behalf of:

Date:

For office use only:

Registration number:

Registration date:

....

For Director-General
Department of Health

Date:

ANNEX D

Criteria and guidelines for the exemption of a water provider from the implementation of fluoridation or for the termination of fluoridation

Introduction

On a submission of an application and under specific circumstances the Director-General may allow the exemption of a water provider from the implementation of fluoridation or for the termination of fluoridation of a water supply. This document defines the nature of the circumstances under which such an exemption or termination should be granted. It focuses on the criteria that should be used in determining the outcome of an application for exemption or termination. Such an application by the water provider must be submitted in the format provided for in Annex B.

Criteria

The following three elements are necessary for successful fluoridation:

c. The water;

d. the community; and

e. specific resources.

Difficulties with any one of these elements can make the implementation of a fluoridation programme impossible for a period of time. Taking these three elements into consideration, the Director-General should specify the period for which exemption from the implementation of fluoridation is granted.

These elements are examined separately to determine the criteria that would make fluoridation either impossible or unnecessary, which would then mean that alternative methods of fluoride supplementation should be considered.

c. The water

- If the raw water available to a supplier already contains the optimum concentration of fluoride as defined in the regulations, or more, then fluoridation is unnecessary and should not be undertaken.
- If the raw water available to a supplier is available intermittently only, then reliable fluoridation can be problematic and should not be undertaken.
- If it is demonstrated that fluoridation of a water supply will have unacceptable impacts on those water resources which receive effluent or diffuse discharges originating from the fluoridated supplies, exemption or termination should be approved.

c. The community

- A community may have limited experience of dental decay and therefore, so long as this remains the case, there is no need for fluoridation.

c. Specific resources

- Staff - Properly trained staff are vital to the success of fluoridation. Until such staff are appointed, temporary exemption from the implementation of fluoridation should be granted.
- Equipment - Fluoridation requires accurate and well maintained equipment. Until such equipment is available, temporary exemption from the implementation of fluoridation should be granted.
- Chemicals - Specific chemicals in appropriate quantities are needed on a continuing basis for successful fluoridation. Until such chemicals are available, temporary exemption from the implementation of fluoridation should be granted.
- Finance - The water provider must finance the water fluoridation plant, and the users of drinking water must finance the bill for operating the water fluoridation plant. Until such finances are available, temporary exemption from the implementation of fluoridation should be granted.

MINISTER OF HEALTH
DATE: 25. 8. 2000