CHAPTER 6 – SURFACE WATER ANALYSIS

6.1 Introduction

Five dams – North West boundary dam, North boundary dam, the Holding dam, West boundary dam, and the Aquatic dam - and two sewage plants were sampled between 2000 and 2003. Water was also sampled both upstream and downstream of Savuka rock dump to determine the impact of the dump on the water quality. Water from both the aquatic dam and North Sewage Works is discharged into the environment. The aquatic dam is an earth fill dam; it discharges constantly via a pipe for downstream users, mostly farmers. Water from the South Sewage works is pumped into the aquatic dam. North West boundary dam is a return water anti-pollution dam. North boundary dam contains purified sewage effluent, process water from the Three Gold plant, seepage from the slimes dams and stormwater runoff from its surroundings. Any overflow from this dam would discharge to a small stream that eventually flows into the Wonderfontein Spruit. The holding dam receives processed water from main fans bulk air coolers at Mponeng mine and also acts as a receiving dam for treated sewage from the South sewage plant.

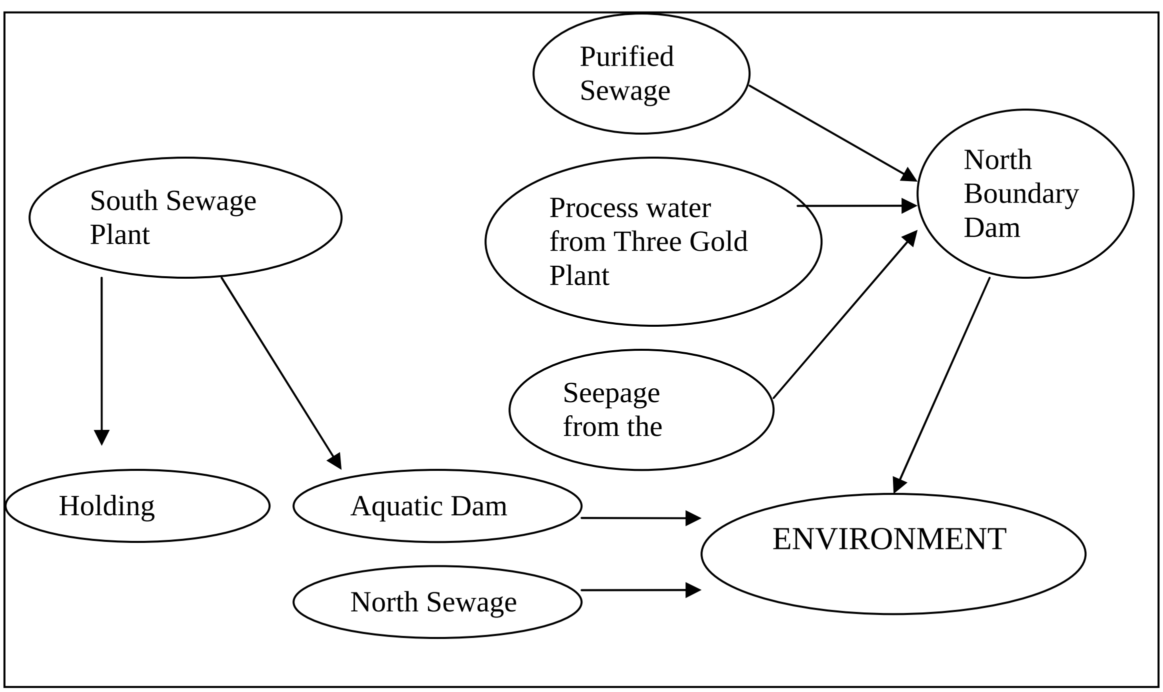

Figure 6.1 Schematic Diagram of the Surface Water Bodies

6.2 Ionic Balance

The cation anion balance was analysed by comparing the sum of cation milliequivalents/million to the sum of anion milliequivalents per million as follows:

Table 6.1 Ionic Balance in Surface Water

Cation	**Concentration (mg/l)**	**Equivalent weight**	**Meq/million**
Ca	600	20	30
Mg	196	32	6.13
Na	217	23	9.43
Total cation			**45.6**
Anion	**Concentration (mg/l)**	**Equivalent weight**	**Meq/million**
SO4	809	20	40.45
Cl	230	35.5	6.48
F	0.2	19	0.01
Total anion			**46.94**

The ratio of total cation to total anion was found to be less than 5%, this show the laboratory's accuracy in the analysis of electrically neutral water.

6.3 Statistical Analysis

The data was analysed statistically using EcoSSe (Eco Spatial Statistical Evaluation) program, a software for statistical and geostatistical analysis of spatial data created by Dr. Isobel Clark and Dr. Bill Harper.

The data were first analysed to determine whether they fell under normal or lognormal distribution. A probability plot of the data was constructed. The following equation was used to determine whether the distribution is normal or lognormal.

$V = n - 2$

Where n = number of samples

V = degrees of freedom

From the New Cambridge Elementary Statistical Tables, table 13 was used. Using table 13, a 5% confidence level was used, if

v> correlation X/Y then the distribution is normal

v< correlation X/Y then the distribution is lognormal

Correlation can be positive or negative. It is positive when one variable increases and the other also increases, it is negative when one variable increases and the other decreases.

Table 6.2 Correlation between surface water variables (0= no correlation, 1= correlation).

	Na	Cl	Fe	NO_3	EC	TDS	TH	Ca	Mg	SO_4	Mn
pH	0	0	0	0	0	0	0	0	0	0	0
Na		1		0	1	1	1	1	0	0	0
Cl			0	0	0	0	0	0	0	0	0
Fe				0	0	0	0	0	0	0	0
NO_3					0	0	0	0	0	0	0
EC						1	1	1	0	1	0
TDS							1	1	0	1	0
TH								1	1	1	0
Ca									0	1	0
Mg										1	0
SO_4											1

There is no correlation between SO_4 and the following variables- Fe, TDS, Na, NO_3, total hardness (TH), and Mg. SO_4 is correlated with Ca and Mn. Previous studies show that Ca exists as carbonate or sulphate (Liptrot, 1983). In this area Ca exists as both carbonates (in the form of dolomite) and sulphates, hence the positive correlation between Ca and SO_4 (see figure 6.1). There is no correlation between NO_3 and other variables because their sources are different; NO_3 is found either naturally in water/soils or it comes from fertilizers. The other variables come from either mining activities or from weathering of rocks.

SO_4 is not correlated to alkalinity because an increase in SO_4 content increases acidity which decreases alkalinity, resulting in low pH. There is no correlation between pH and Mn and Ca because as pH increases the concentration of hydroxyl ions (OH) also increases. The hydroxyl ions react with Mn and Ca to form $Mn(OH)_2$ and $Ca(OH)_2$ respectively. This means that Ca and Mn are removed from solution.

There is a strong correlation between Na and TDS, TH and Mg. There is a strong correlation between Na and TDS because Na is one of the ions that make up TDS. Mg is one of the primary ions that cause hardness. The correlation between Na and Cl and the correlation between Na and Mn are very weak.

There is a strong correlation between TH and Ca, Mg, TDS and Mn. Ca and Mg are the main causes of hardness and Mn may also contribute. The ions that contribute to total hardness also make up TDS, so it is only natural that when TH increases TDS also increases. There is correlation between TDS and Mg because Mg is one of the constituents of TDS.

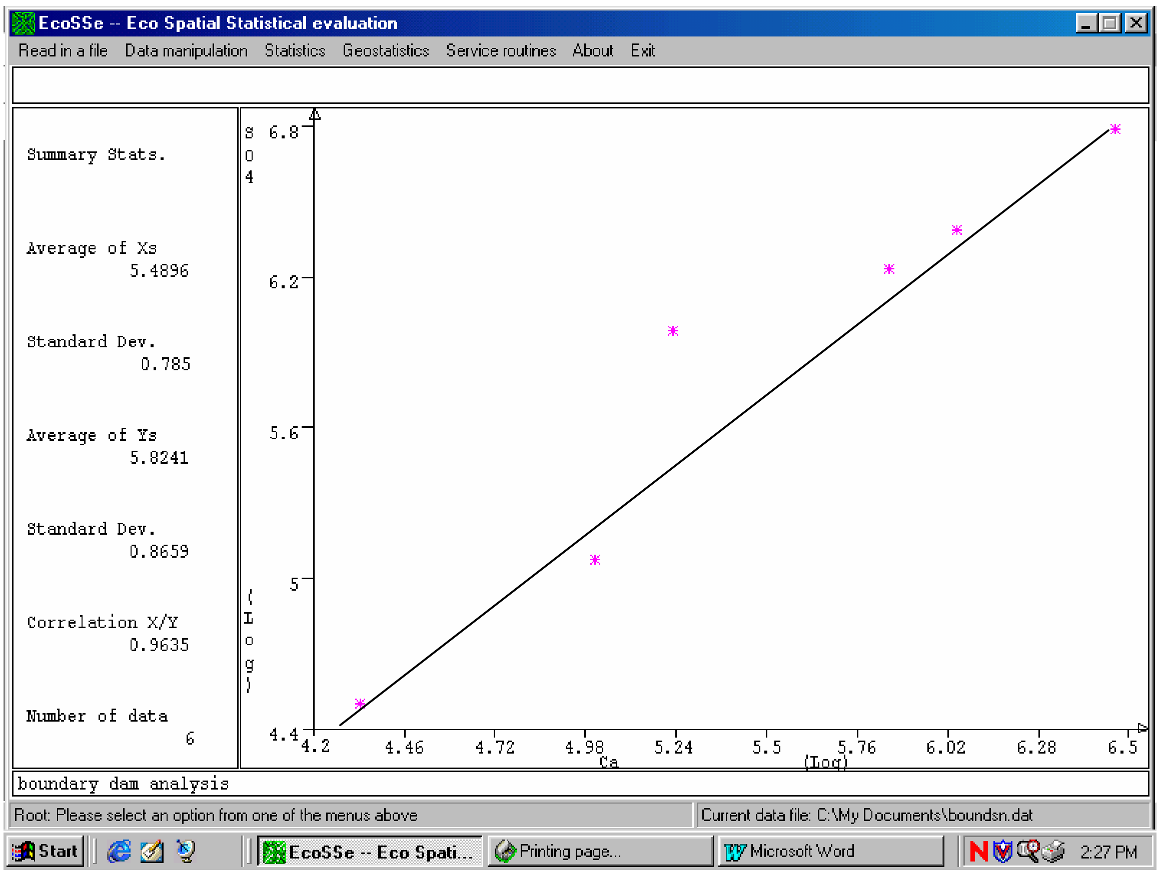

Figure 6.2 Correlation between surface water Ca and SO_4

6.4 Chemical Analysis of Surface Water

Old data was used in this study as the latest data was not accessible. This data is still useful in showing the changes over time.

6.4.1 North West Boundary Dam

The pH of the North West boundary dam ranged between 7 and 9 in 1998. The pH was higher than 9 for most months during the period November 2000-August 2003 (data for the period November 1998-October 2000 is not available). The pH dropped to a low of 7.04 (October 2003). The pH shows an increasing trend with the last sample (December 2003) showing a value of 7.54. The TDS concentration was within 1000-1500 mg/l range in 1998. The TDS concentration has been increasing and decreasing between October 2000 and December 2003 with the highest concentration of 2528 mg/l in September 2002 and a minimum concentration of 403 mg/l in October 2003. The high TDS concentration can cause the disruption of the organisms' physiological processes. Water osmotically leaves the organism and the organism may die (Anglo American Corporation, 1995). The water is hard with the highest concentration measured in September 2002 (951 mg/l) and the lowest concentration of 183 mg/l in October 2003. The $CaCO_3$ concentration (hardness) has been increasing and decreasing erratically during the 1998-2003 period. The water is hard due to high Ca, Mg and Na concentrations. Ca reached a maximum concentration of 814 mg/l in September 2002 and a lowest concentration of 126 mg/l in October 2003. Mg was at its highest concentration in October 1998 (271 mg/l) and the lowest concentration of 45 mg/l was measured in January 2002. Na concentration ranged between 39.3 mg/l (October 2003) and 383.1 mg/l (September 2002). The Na concentration remained below 200 mg/l in 1998.

The SO_4 concentration reached a maximum of 1127 mg/l in September 2002 and a minimum of 182 mg/l in March 1998. The latest (December 2003) concentration was 485 mg/l. The SO_4 concentration increases/decreases proportionally to TDS concentration, showing significant contribution of SO_4 to TDS concentration. The concentration of heavy metals (Pb and Fe) was high. The Fe concentration was highest in September 2001 at 3.455 mg/l while Pb reached its highest concentration of 0.115 mg/l in January 2003. During 1998 the highest Fe concentration was at 0.411 mg/l (April 1998) and Pb concentration was at 0.051 mg/l (July 1998). The highest Mn concentration was measured in September 2001 (1.656 mg/l). During 1998 Mn reached 0.732 mg/l (April 1998). The Cu concentration in May 2003 was 27.142 mg/l. The Cd concentration reached a maximum of 0.024 mg/l in March 2001. A maximum NO_3 concentration of 18 mg/l was measured in December 2000 and December 2001. A significant number of samples exceeded the NO_3 domestic limit of 6 mg/l.

6.4.2 North Boundary Dam

The pH ranged from 7.16 (December 2000) to 9.54 (September 2002) during 1998-2003 period. The EC was at its lowest concentration in February 1998 (172 mS/m) and its highest concentration was 338 mS/m in March-May 2003. The TDS reached a maximum concentration of 22,266 mg/l in June 1998. The TDS concentration ranged between 1327 mg/l (February 1998) and 2427 mg/l (December 2002). The water is hard with $CaCO_3$ concentration of between 220 mg/l (September 2001) and 1378 mg/l (December 2001). The lowest Mg concentration was 107 mg/l in February 1998 with the highest concentration at 332 mg/l in October 2002. The Ca concentration changed proportionally to Mg concentration and ranged between 425 mg/l (February 1998) and 880 mg/l (November 2002). The Na concentration exceeded 100 mg/l with the lowest concentration of 132.3 mg/l (November 2001) and a maximum concentration of 344.9 mg/l (December 2002 and January 2003). With the exception of March 1998 when the Cl concentration reached a high concentration of 3088 mg/l, Cl concentration remained below 500 mg/l during the 1998/2003 period. The Cl concentration ranged between 18 and 445 mg/l with an average concentration of 301.8 mg/l. The NO_3 concentration was high with the highest concentration of 34 mg/l (November 2000) and a minimum concentration of 0.2 mg/l (July 1998). The average concentration was 12.7 mg/l.

The minimum and maximum SO_4 concentration were 10.34 mg/l (June 2002) and 1119 mg/l (September 2001) respectively. The average SO_4 concentration was 887 mg/l. The Fe concentration ranged between 0 (April 1998) and 0.947 mg/l (September 2001). The average Fe concentration was 0.24 mg/l. The minimum and maximum Mn concentrations were 0.028 mg/l and 2.574 mg/l respectively with an average concentration of 0.46 mg/l. The Pb concentration reached a high of 0.172 mg/l (January 1998). No Pb was detected during the period March-April 1998, October 1998 and February 2002; the average Pb concentration of 0.027 mg/l was measured. Pb causes the inhibition of an enzyme that is responsible for the formation of haemoglobin in blood. It accumulates in the skeleton of man, replacing calcium. High concentrations become fatal (Anglo American Corporation, 1995). In November 2000 the ammonia concentration was 3.6 mg/l. A number of months recorded no ammonia (May 1998, October 1998, October 2001, June 2002, September-October 2002, February 2003 and May 2003). The average ammonium concentration was 0.8 mg/l.

The North boundary dam has overflowed a number of times during the sampling period with the highest overflow of 80,975 m^3 in February 2002. The overflows were due to heavy rains (this dam had insufficient storm water retention capacity – October-December 2001, January-March 2002 and October –November 2003), system failure (in January 2003 the level controller was incorrectly set, as a result the pump failed to start on time). In December 2003 the overflow was a result of no process water being returned to the shafts due to shut down for the Christmas period. The October 2001 overflow of 23,219 m^3 had Mn concentration of 2.6 mg/l. The overflow of 62,471 m^3 that occurred in December 2001 was hard with CaCO3 concentration of 1378 mg/l. The December 2002 overflow had Na concentration of 344.9 mg/l.

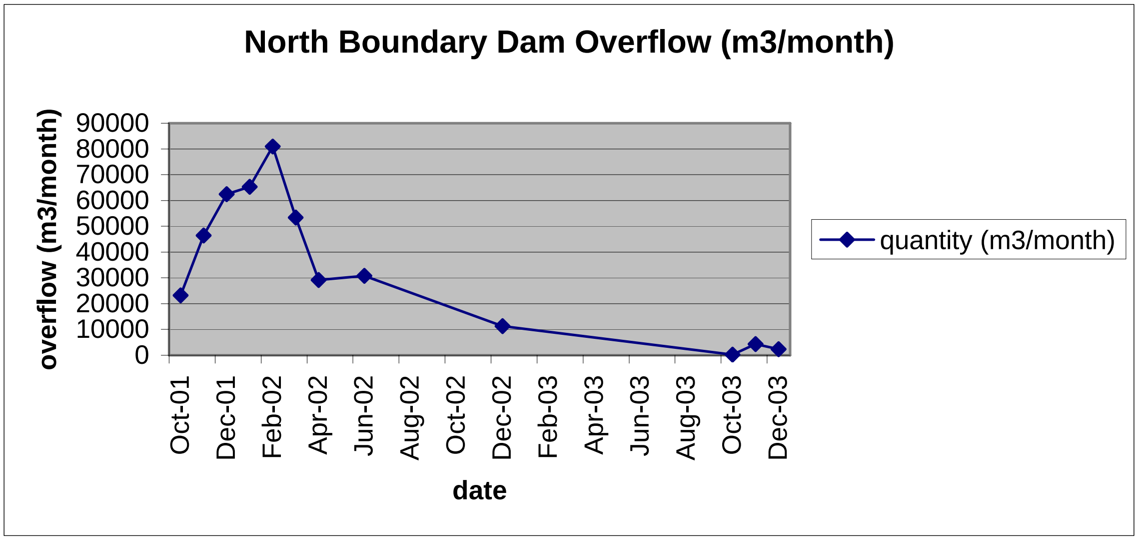

Figure 6.3 North Boundary dam overflows

The analysis of North boundary dam was compared to the 1995 study carried out by the Water Research Commission (EMPR -Western Deep Levels & Elandsrand Gold Mine Related to Surface Water). Generally, the North boundary water has deteriorated since 1993. There has been an increase in the concentration of EC, TDS, Ca (from 209.9 mg/l to 665.4 mg/l), Mg (from 37.5 mg/l to 231.8 mg/l), Na, Cl, SO_4 and the alkalinity has decreased. Improvement in the water quality was seen only with respect to NO_3, ammonia and F. The improvement in quality with respect to NO_3 and ammonia could be due to effective sewage treatment (some of the water in this dam comes from sewage works).

6.4.3 The Aquatic dam

The water in the aquatic dam is neutral to slightly alkaline with maximum pH of 10.5 recorded in November 2000. The average TDS of 425 mg/l is within DWAF's standard for domestic use. The Mn concentration in the aquatic dam exceeded the domestic limit, the irrigation limit and the aquatic ecosystem guideline during most months in the 2000-2003 period.

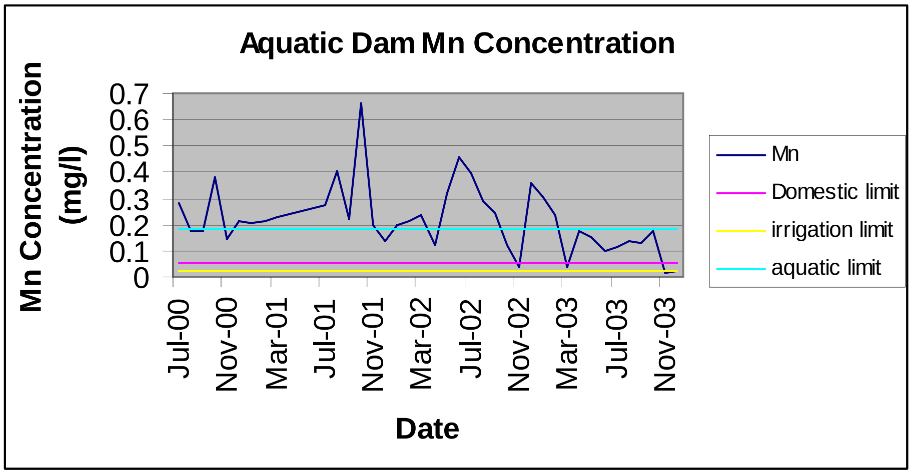

Figure 6.4 Aquatic Dam Mn Concentrations compared to standards for different water uses

With the exception of January 2001, the Fe concentration exceeded the domestic use guideline of 0.1 mg/l between July 2000 and March 2003. The Fe concentration has been below 0.1 mg/l between April and December 2003 showing improvement in water quality with respect to Fe concentration.

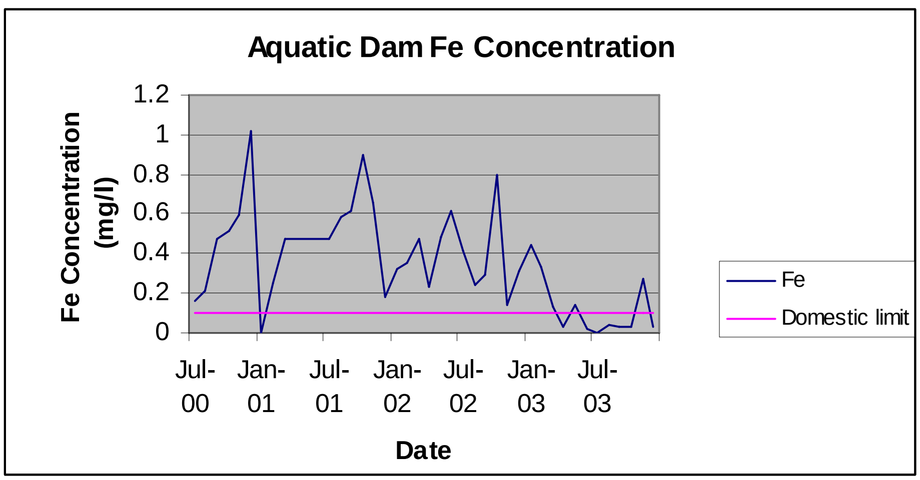

Figure 6.5 Aquatic Dam's Fe Concentration Compared to the Standard for Domestic Use

A study carried out in 1993 by Water Research Commission showed high TDS characteristic of mining-induced pollution with high phosphate (PO_4) that was tracked back to the discharge from the sewage works. The high pH resulted from algal growth causing more alkaline conditions to prevail. Compared to the 1995 Water Research Commission study there has been a decrease in EC, SS, TDS, alkalinity, hardness, NO_3, SO_4, Zn, PO_4, Ni, Pb, and Cd concentrations. There was increase in Ca, Mg, Mn, Cl and

F concentrations. Mn is a concern at an average concentration of 0.2 mg/l for the period 2000-2003, compared to an average concentration of 0.04 mg/l in 1993 and the DWAF standards for different water uses (domestic use limit of 0.05 mg/l, irrigation use limit of 0.02 mg/l and aquatic use limit of 180 microg/l).

The aquatic dam water meets all the standards for livestock watering.

Table 6.3 Livestock Watering Standards & Aquatic dam water quality (Water Research Commission, 1995)

Parameter	Criteria	Aquatic dam analysis
Ca	0-1000	132.9
Mg	0-500	60.5
Na	0-2000	76.6
Cl	0-3000	106.3
NO3	0-100	5.5
SO4	0-1000	155.3
Fe	0-10	0.34
Zn	0-20	0.02
Mn	0-10	0.22
Cu	0-5 (cattle)	0.05
Ni	0-1	0.06
Cd	0-.01	0.002
F	0-6	0.27

The discharges from the aquatic dam between October-December 2000, July-August 2002 and Jan-March 2001 were within the discharge guideline of 645 240 m^3 per month.

6.4.4 The Holding dam

The quality of the water is fairly good; the water quality meets the drinking standards for pH, TDS, EC, SO4, Cu, F and Zn with slightly elevated Ca, Mg, NO_3, and Cl concentrations. The Fe, Pb and Mn concentrations exceeded the domestic use limits of 0.1, 0.01 and 0.05 mg/l respectively during most months. The Fe and Pb concentrations were below their respective guideline for irrigation purposes while Mn exceeded the standard for irrigation purposes.

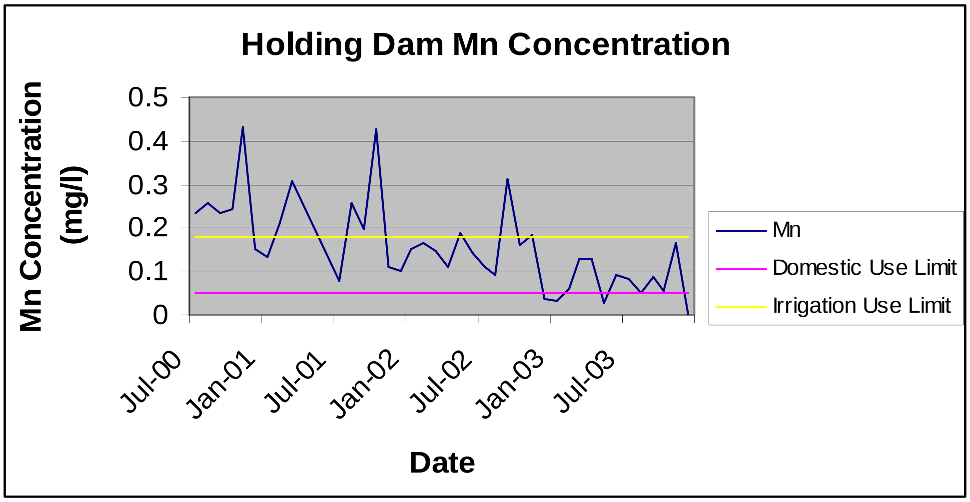

Figure 6.6 Holding Dam's Mn Concentration Compared to DWAF's Standards for Different Water Uses

The holding dam is unlined and the contaminants (such as Fe, Pb and Mn) seeping out have the potential to pollute groundwater.

6.4.5 West Boundary dam

The water is neutral to slightly alkaline with salt concentration in excess of 100 mS/m and average TDS concentration of 1,531 mg/l. The high TDS concentration is a result of high Ca, Mg, NO_3, SO_4 and Na concentrations. The water is permanently hard with an average $CaCO_3$ concentration of 711 mg/l. Zn, Ni and Cu concentrations meet the standards for drinking, aquatic and irrigation purposes. The Fe concentration does not meet the drinking water standard during most of the months but meets the irrigation standard throughout the 2000-2003 period. Pb concentrations are below both the aquatic ecosystem and irrigation standards but exceed the drinking water standard (on average). The Mn concentration exceeds the domestic, irrigation and aquatic standards tenfold.

6.4.6 Upstream of Savuka Rock Dump

The pH reached a high of 10.7 in July 2001. The EC concentration exceeds 250 mS/m between 2000 and 2003 and the TDS, except in October 2003 when it reached a minimum of 332 mg/l, exceeded 2200 throughout the sampling period. The high TDS concentration can cause habitat degradation (SRK, 1990). The range of TDS concentrations is wide, and most biota is more susceptible to sudden changes in TDS rather than the absolute value (Water Research Commission, 1995). Zn reached a maximum concentration of 25.7 mg/l in October 2002 (the same month that the 60.2 mg/l Mn concentration was recorded). The SO_4 concentration during the same month was 3,798 mg/l. The water is permanently hard with mean $CaCO_3$ concentration of 1,064 mg/l. Except for one month, SO_4 exceeded 1000 mg/l. Mean concentrations of Zn and Mn of 0.9 and 12 mg/l were recorded, respectively.

6.4.7 Below Savuka Rock Dump

Except in January 2001 the pH was within the 6 to 9 range. The high concentrations of the cations (Ca, Mg, Na, Fe, Pb and Zn) as well as SO_4 and NO_3 are responsible for the TDS concentration in excess of 1000 mg/l. The water is hard with $CaCO_3$ concentration of 515 mg/l. Mn concentrations ranged from 0.002mg/l to 60.2 mg/l, with an average concentration of 12.2 mg/l. The average SO_4 concentration was 530 mg/l. Compared to upstream of the dump, the downstream Mn concentration has decreased from 12.3 mg/l to 2.7 mg/l while Fe concentration has decreased from 6.05 mg/l to 0.77 mg/l. Only Zn concentration has increased from 0.91 mg/l to 3.77 mg/l.

The water quality downstream of the dump is much better than upstream of the dump. The reasons for the improvement in water quality downstream of the dump are not clear. Further investigation needs to be undertaken. The pH and the alkalinity increase, the hardness decreases and all the major cations, anions and heavy metal concentrations, except Zn decrease. This is due to the dolomitic nature of the rock. The calcium and magnesium carbonates within the dolomite buffers any acid generation.

6.4.8 North Sewage Works

The maximum TDS limit for North Sewage Works is 840 mg/l. During the period July 2000-December 2003 the limit was exceeded twice – in August 2001 (955 mg/l) and in November 2001 (990 mg/l). The Suspended Solids (SS) limit of 15 mg/l was exceeded a number of times during the same period – October 2001 (34 mg/l), November 2002 (19 mg/l), December 2002 (17 mg/l), Jan 2003 (37 mg/l), March and April 2003 (29 mg/l) and November and December 2003 (17 mg/l). Suspended inorganic substances have an electric charge and this results in dissolved substances, including nutrients and heavy metals adsorbing to these charged materials. This is desirable only if the adsorbed substances are toxic but disadvantageous if the nutrients are adsorbed and therefore not available to aquatic organisms (DWAF, 1996). Nitrate in the form of N exceeded the limit of 10 mg/l in July 2000 (18 mg/l), August 2000 (13.6 mg/l), February 2001 (16 mg/l) and March 2001 (10.4 mg/l). The majority of the samples exceeded the 0.2 mg/l limit for nitrite (as N). Most of the samples collected between October 2002 and December 2003 exceeded the limit for absorbed oxygen (3.6) while 13% of the samples exceeded the Chemical Oxygen Demand (COD) limit of 50 mg/l. COD is a measure of the overall level of organic contamination in wastewater. The contamination level is determined by measuring the equivalent amount of oxygen required to oxidize organic matter in the sample. A quarter of the samples exceeded the dissolved oxygen limit of 69.16. In environments with high dissolved oxygen concentration, photosynthesis of green algae is inhibited in favour of blue green algae (DWAF, 1996). This may become a nuisance for other water users. These samples were distributed unevenly with most having been collected between September 2001 and March 2002. Only 18% of the samples did not contain cyanide (the allowed cyanide concentration is 0 mg/l). The rest of the samples had cyanide concentrations that ranged from 0.052 and 0.676 mg/l. Respiration of aquatic organisms exposed to the cyanide-containing water is likely to be inhibited. The risk is low due to the low cyanide concentrations in most samples and also because cyanide does not persist in surface water, therefore there will be no cumulative effect.

Only pH, Cl, and S concentrations were below their respective allowed limits. There were no *faecal coli* during the July 2000- December 2003 period. Except for the January-March 2003 period and the last quarter of 2003, the sewage was analysed for *faecal coli* between January 2000 and December 2003.

Depending on where the sewage goes to, there are two permits – the general authorization permits 61,000 m^3 to be discharged into the environment and the other permit allows 270,000 m^3 to be discharged both into the environment and to be re-used. The discharge from North Sewage works into the environment exceeded the discharge permit limit of 61,000 m^3 in June 2003 and the 270,000 m^3 in November 2001 and June 2002. During the three months when the permit limits were exceeded, the concentration of nitrite exceeded the permitted limit of 0.2 mg/l. In addition, the concentration of dissolved oxygen and cyanide exceeded their respective limits in June 2002 and June 2003. The October 2001 discharge had TDS concentration that exceeded the limit of 840 mg/l. The environment into which the water is discharged will have high loads of pollutants which cannot be assimilated (the limits have been set to allow the particular water reserve to assimilate the pollutants load, beyond this limit the water reserve struggles to assimilate the pollution. This compromises the functioning of the water body as well as other water users).

6.4.9 South Sewage Works

The TDS concentration exceeded the limit of 625 mg/l between the period January 2001 and December 2001. The maximum TDS concentration was recorded in August 2001 at 764 mg/l. A significant number of samples (most of them collected between July 2000 and August 2001) exceeded the free and saline ammonia limit of 2 mg/l. During the period July-December 2003 the free and saline ammonia concentration remained below 2 mg/l. The SS limit of 5 mg/l was exceeded in the majority of the months between July

2000 and December 2003. Only four of the months exceeded the nitrate concentration limit of 10 mg/l – July 2000 (22.2 mg/l), February 2001 (16 mg/l), January 2002 (11 mg/l) and November 2002 (10.8 mg/l). Approximately 35% of the samples exceeded the nitrite limit of 0.2 mg/l with the maximum concentration of 3.9 mg/l recorded in May 2003. The absorbed oxygen limit of 3.6 was exceeded by 36% of the samples. The maximum concentration was reached in June 2003 (9.184). The COD was below the limit (of 115 mg/l) throughout the period July 2000-December 2003. A significant number of samples had dissolved oxygen in excess of 69.16, the limit allowed for South Sewage Works. There is likely to be an increase in the blue green algae in the aquatic dam due to increased dissolved oxygen. This upsets the balance of organisms in the aquatic dam. The pH was within the range 5.5-9.5 throughout the July 2000-December 2003 period. The Cl concentration was also below the allowed limit (of 155 mg/l). Only a quarter of the samples did not contain cyanide. No sulphides were detected between 2000 and 2003. No *faecal coli* was recorded except in April and May 2002 when it reached 7 and 25 respectively. Between July 2002 and March 2003 as well as July-December 2003 *faecal coli* was not analysed for.

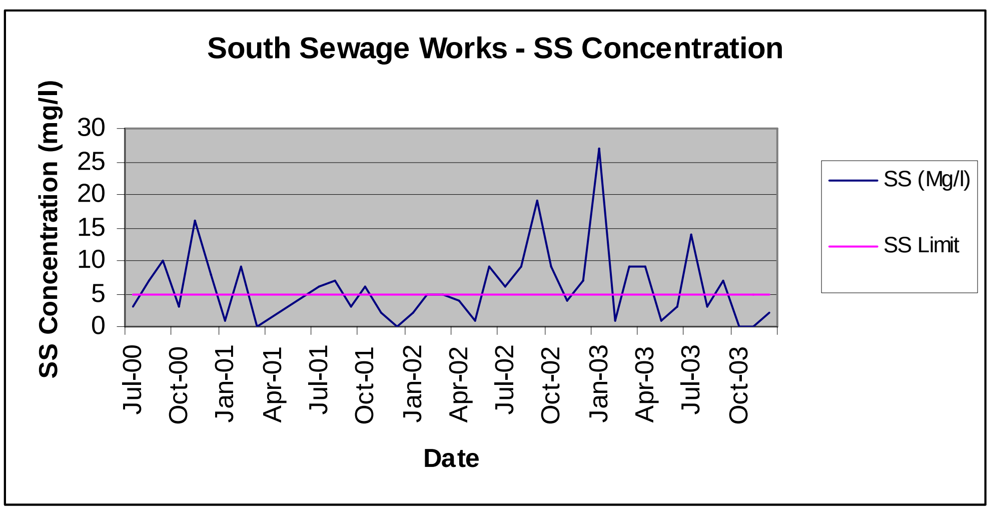

Figure 6.7 SS Concentration in South Sewage Works

The discharge permit limit of 62,281 m^3 was exceeded between October 2000 and March 2001 and between July and September 2001. The discharges were associated with high concentrations of TDS (January 2001, March 2001, July-August 2001), SS (November-December 2000, February 2001 and July-August 2001), free and saline ammonia

(October 2000, December 2000, February-March 2001, August 2001), nitrate (October 2000, February 2001, March 2001) and nitrite (July-August 2001). Except for March and September 2001, the water discharged during the periods of excessive discharges had cyanide.

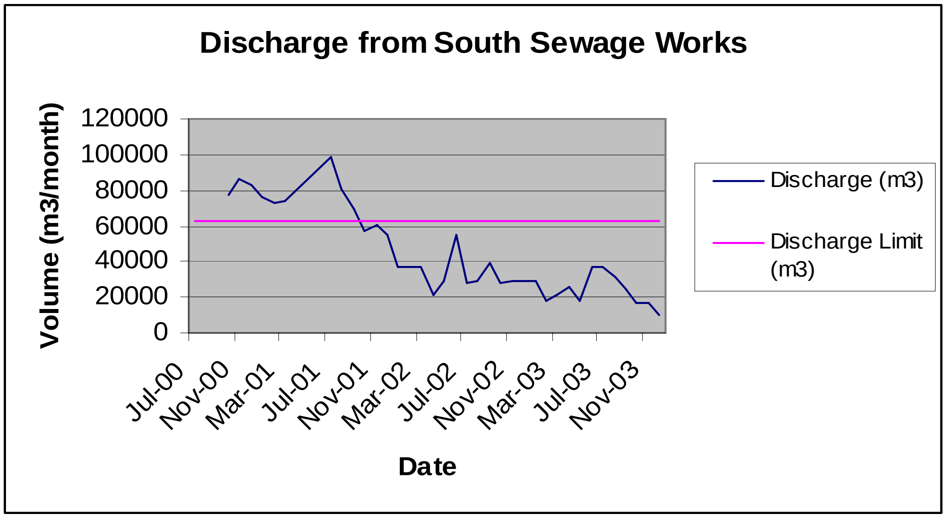

Figure 6.8 Quantities Discharged from South Sewage Works

6.5 Conclusion

The quality of water in the North West boundary dam is dependent on the amount of rainfall received (among other factors such as quality of water draining into the dam); the concentrations of most parameters (SO_4, Fe, Mn, TDS, Ca and Na) were at their highest just before the beginning of the wet season (in September) with the lowest concentrations of most parameters (SO_4, Pb, Mn, Cd, TDS, Ca, Mg, Na, and hardness) recorded during the wet season (between October and March). The water quality in the North West boundary dam is poor; the water is hard with high TDS and high concentration of heavy metals. There were no discharges/overflows from this dam during the sampling period. There is therefore little or no impact on the environment as long as the water does not leave the dam.

The quality of water contained in the North boundary dam is very poor, as expected since it is a pollution control dam. Water is not supposed to leave this dam and the overflows that occurred during a number of months between October 2001 and December 2003 probably had significant impact on the receiving environment. The loads discharged were high; aquatic organisms would have felt the impact as the water bodies would not immediately assimilate the load. The quality has been deteriorating since 1993. The Aquatic dam water is suitable for use in livestock watering.

The holding dam is likely to pollute the groundwater with heavy metals (Fe, Pb and Mn) as the concentrations of these parameters are high and the dam is unlined. Groundwater sampling is required to verify this. The West boundary dam has poor quality water that should be contained within the dam at all times. There were no discharges from this dam throughout the sampling period; there is therefore no impact on the environment from this dam. Savuka rock dump is the source of Zn that adds heavy metal toxicity to the environment. The availability of Zn is suppressed at high pH. The impact of Zn arising from the dump on the environment is therefore minimal at the high pH values (between 7 and 8) of the water draining from the dump. The dump seems to neutralize the upstream acidity and as a result the downstream quality improves.

The high load, in terms of volumes discharged and TDS, which was discharged from North Sewage works had a negative impact on the environment. The discharge also had high dissolved oxygen and chemical oxygen demand. Both the discharges that occurred in June 2002 and June 2003 exceeded the permit limits and had some cyanide. Cyanide is toxic to aquatic organisms and human beings even at small dosages. The South Sewage works did not meet the permit conditions throughout the 2000-2003 period. Some discharge complied with the permit's discharges quantities but not the concentration of some of the parameters while a quarter of the samples, in addition to excessive concentrations of some parameters, also exceeded the quantities specified in the permit. The impact on the receiving environment would be significant if the water is discharged directly into the environment. The poor quality of the water improves through dilution as the sewage water is pumped into the aquatic dam before being released into the environment. North sewage works outflow did not have any *faecal coli*. There is therefore no microbial pollution from the North sewage works into the environment.

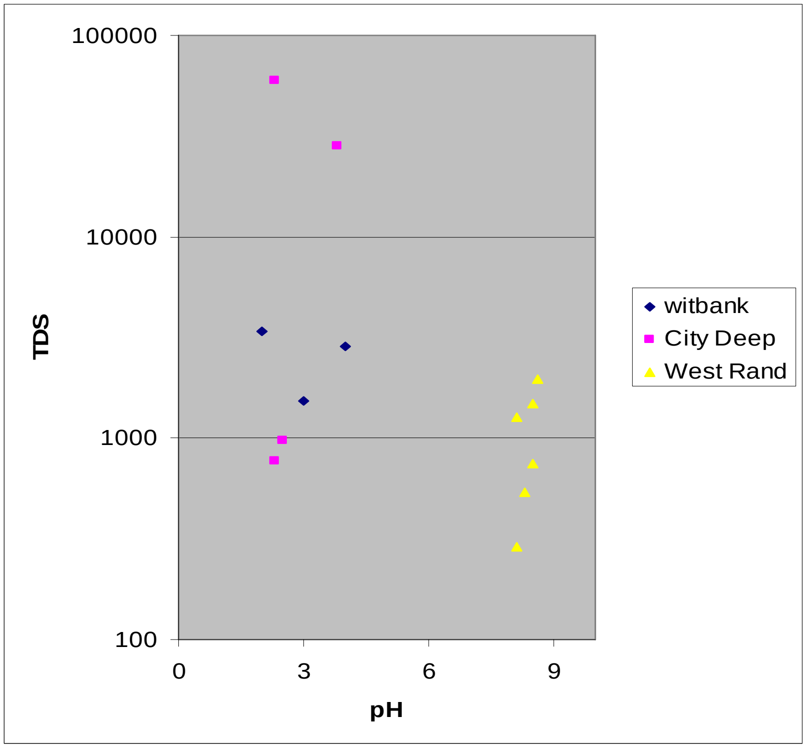

Figure 6.9 Water quality at West Rand Region, Witbank Coalfields (Kyeyune, 2001) and City Deep Gold Mines (Audouin, 1997)

The surface water quality of the West Rand Region is good compared to the water quality at the Witbank Coalfields of South Africa and City Deep Gold Mines with respect to pH and TDS.