Suitability of Water within the Tswaing Crater Nature Reserve for Domestic Use

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1. Introduction and Background

A request was received from Mr I. Swart, the Technical Officer of the Tswaing Crater Nature Reserve (28 km North of Onderstepoort, Pretoria), by Dr P. Kempster of RQS to conduct an assessment of the suitability of water within the Tswaing Crater Nature Reserve for domestic (untreated) use. On 26th October 2004 Ms A. Gerber and Mr B. Hohls of RQS, DWAF, went to conduct the field investigation and take the necessary water quality samples and field measurements.

Samples and measurements were taken at four sites within the Nature Reserve:

1. **Zoutpan Tswaing Crater Lake in Tswaing Nature Reserve** (WMS number: 188186)**,** at Latitude: 25° 24' 28.7" South; and Longitude: 28° 04' 56.1" East,
2. **Zoutpan Tswaing Crater Lake Borehole** (WMS number: 1000010188)**,** at Latitude: 25° 24' 28.7" South; and Longitude: 28° 04' 56.1" East (at artesian borehole less than 5 metres from Site 1),
3. **Zoutpan Tswaing Crater Nature Reserve Borehole with Diesel Pump** (WMS number: 1000010190)**,** at Latitude: 25° 26' 05.2" South; and Longitude: 28° 04' 32.3" East, and
4. **Zoutpan Tswaing Crater Nature Reserve Borehole with Electric Pump** (WMS number: 1000010192)**,** at Latitude: 25° 25' 21.8" South; and Longitude: 28° 04' 46.5" East.

Samples were taken according to normally accepted methods for surface and ground water as applicable.

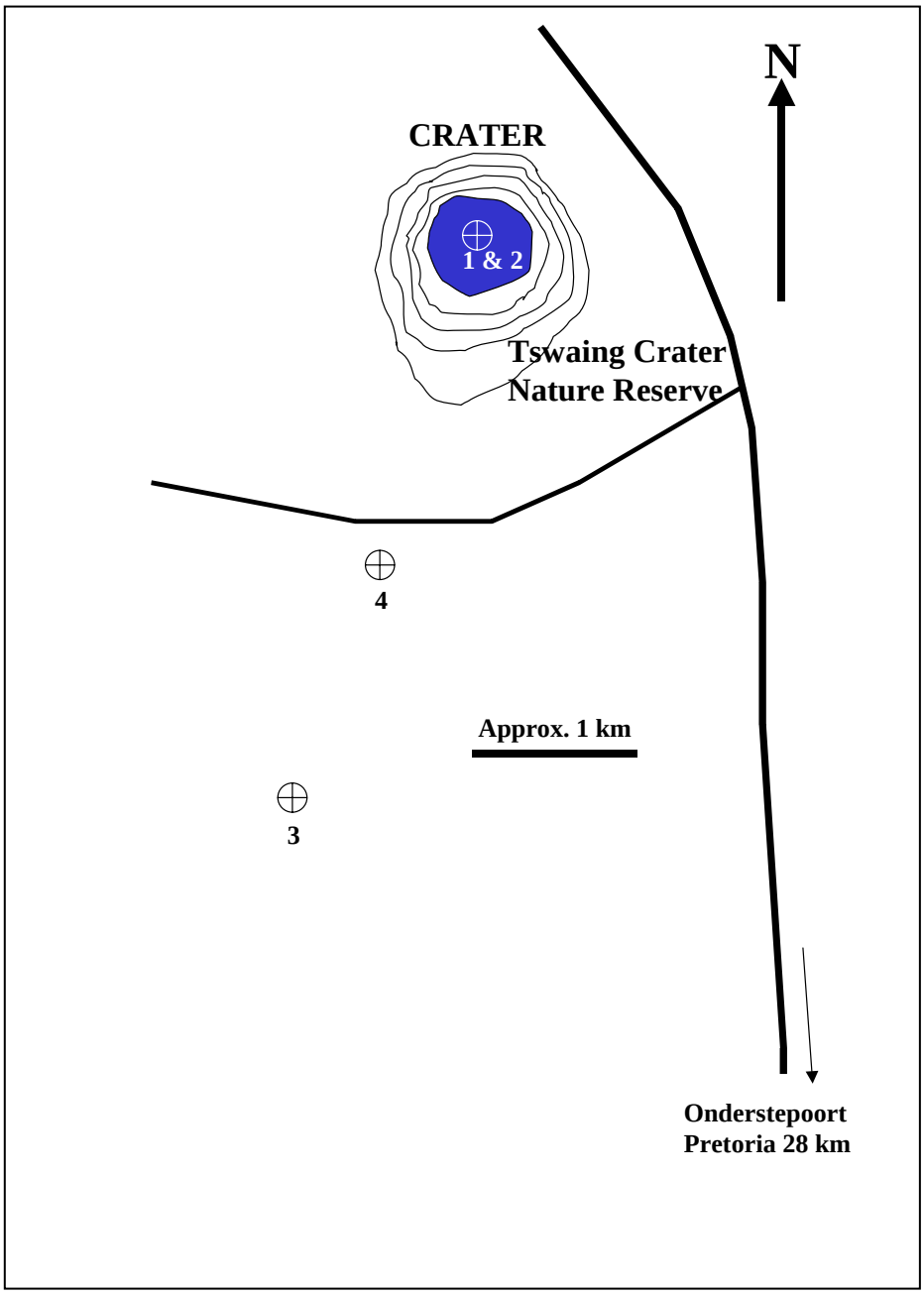

Figure 1. Diagrammatical representation of the sampling sites (numbers 1 to 4) within the Tswaing Crater Nature Reserve

The following sections outline the sampling and various analyses that were conducted at the four sites. This is followed by conclusions and recommendations made by the authors.

2. Sampling and Analysis Conducted

Various water quality samples were taken at the four sites indicated in Figure 1 according to accepted methods. These samples were used to determine the concentration of major inorganic constituents, micro inorganic constituents including trace metals, and the bacteriology of water samples. Temperature, pH, electrical conductivity (EC), and dissolved oxygen readings were taken on site since these attributes should be assessed *in situ* to be sure of accuracy.

3. Analytical Results and Discussion

Detailed results of the various water quality samples and measurements taken at the three sites are listed in the following sections.

3.1 Physical Measurements

Physical measurements were taken of as many attributes as possible with the available field instrumentation, specifically of those attributes such as temperature, dissolved oxygen, EC and pH that are prone to change prior to analysis in the laboratory. The values for these attributes are listed in Table 1.

Table 1. Measurements taken at the four sites on 26th October 2004

Attribute	Site 1 Crater Lake	Site 2 Crater Borehole	Site 3 Borehole with Diesel Pump	Site 4 Borehole with Electric Pump
Temperature (°C)	23.9	25.5	25.7	28.8
Dissolved Oxygen (%)	16.5	14.6	43.5	47.6
Dissolved Oxygen ($mg.\ell^{-1}$)	1.19	1.08	25.8	3.22
pH	9.58	9.34	6.33	7.08
EC ($mS.m^{-1}$)	7210	551	23.7	33.1
Latitude of sampling site	25° 24' 28.7" S	25° 24' 28.7" S	25° 26' 05.2" S	25° 25' 21.8" S
Longitude of sampling site	28° 04' 56.1" E	28° 04' 56.1" E	28° 04' 32.3" E	28° 04' 46.5" E

- The dissolved oxygen level at each of the sampling locations was very low.
- The pH at Site 1 was in the range where it would most likely be mildly irritating to mucous membranes and would have a soapy taste. At the other sites the pH would have resulted in no negative health effects.
- The Electrical Conductivity (EC) was extremely high at Site 1, but within normal ranges at Sites 3 and 4.

3.2 Major inorganic constituents

The major inorganic constituents analysed by the RQS laboratories are listed in Table 2, together with domestic use guidelines (DWAF, 1998) where they are available.

Table 2. Major inorganic constituent results of samples taken on 26th October 2004

Constituent	Site 1 Crater Lake	Site 2 Crater Borehole	Site 3 Borehole with Diesel Pump	Site 4 Borehole with Electric Pump	Domestic Use Guideline/ Category DWAF (1998)
pH	9.96	8.91	6.88	7.39	>5 and <9.5
Kjeldahl nitrogen as N	0.709	1.43	<0.3	<0.3	
Ammonium (NH_4^+) as N	0.378	1.15	0.056	0.046	TWQR 0–1.0
Nitrate + nitrite as N	<0.11	<0.11	7.86	0.148	<6 (<10 insig)
Fluoride as F	470	8.52	1.26	2.32	<0.7
Alkalinity as $CaCO_3$	2 012	340	77.3	146	
Sodium as Na	36 640	1008	18.6	17.08	<100
Magnesium as Mg	45	8.34	4.00	4.38	<70
Silicon as Si	9.25	10.9	28.1	19.6	
Total phosphate as P	13.3	-	0.043	<0.03	
Orthophosphate as P	11.7	0.054	0.028	<0.023	
Sulphate as SO_4	419	18.8	<6	<6	<200
Chloride as Cl	40 300	1 323	6.07	6.47	<100
Potassium as K	203	9.24	2.99	2.92	<25
Calcium as Ca	84	14.9	20.2	39.5	<80
EC ($mS.m^{-1}$ at 25 °C)	7 980	489	24.4	32.1	<70
Hardness	-	71.7	67.0	116	<200
Dissolved Major Salts	63 940	2 807	185	255	

Concentrations are in $mg.\ell^{-1}$ except for pH, and EC.

NB: Since the water from the first site especially was strongly coloured, the results for the bulk of the attributes cannot be accredited or guaranteed. The samples from the borehole sites, especially those equipped with pumps, were clear and the results are likely to be more dependable.

- The pH at Site 1 was in the range where it would most likely be mildly irritating to mucous membranes and would have a soapy taste. At the other sites the pH would have resulted in no negative health effects.
- The highest nitrate-nitrate concentration was recorded at Site 3, however, even at this level there would be insignificant risks to health and food preparation.
- Fluoride levels were elevated at all of the sites, but were especially high at Site 1 and to a lesser extent at Site 2. There would be high risk of health effects and tooth staining if the water from Sites 1 or 2 were used for domestic purposes. The lowest levels were seen at Site 3 and even here there would be increasing health effects and tooth staining among sensitive groups. At

Site 4 there would be possible health effects and tooth staining in all individuals.

- Sodium levels at Sites 1 and 2 in the crater were extremely high as could be expected. At both sites there is a definite health risk if the water was to be used for domestic purposes. The levels at Site 3 and 4 would have negligible effects.
- Magnesium levels were not significantly elevated.
- Only at Site 1 were the sulphate levels elevated to the point where there would be a slight chance of initial diarrhoea, and the water would have a bitter taste. The water would also be increasingly corrosive at this site.
- Chloride levels at Site 1 and 2 would be so high that they would result in dehydration in infants, nausea and vomiting, and the water would have a repulsively salty taste. The water would also be very corrosive.
- There would be possible health effects at Site 1 due to the elevated Potassium level.
- The highest Calcium level was at Site 1 and the effects there would be insignificant.
- The Electrical Conductivity (EC) was extremely high at Site 1 with the increasing risk of dehydration and salty and bitter taste. At Site 2 the EC has high enough to result in possible health risks to all individuals, with the water also tasting extremely salty. The EC was within normal ranges at Sites 3 and 4.
- Hardness values are available for Sites 2, 3 and 4. The water was moderately soft at Sites 2 and 3, and slightly hard at Site 4.
- The same can be said for DMS (assessed as TDS) as EC.

The water quality at Sites 1 and 2 can, therefore, be considered as poor to dangerous when considering a number of attributes (F, Na, Cl, EC and DMS).

3.3 Trace Metal Analyses

Samples for trace metal analysis were taken at all four sites to determine the trace metal concentrations at the time of sampling. The results of the analyses appear in Table 4.

Table 4. Trace metal concentrations recorded at the four sites

Constituent ($mg.\ell^{-1}$)	Limit of quantitation	Site 1 Crater Lake	Site 2 Crater Borehole	Site 3 Borehole with Diesel Pump	Site 4 Borehole with Electric Pump
B – dissolved	0.026	14.23	0.096	< 0.026	< 0.026
Al – dissolved	0.182	< 0.182	< 0.182	< 0.182	< 0.182
V – dissolved	0.022	< 0.022	< 0.022	< 0.022	< 0.022
Cr – dissolved	0.016	< 0.016	< 0.016	< 0.016	< 0.016
Mn – dissolved	0.012	< 0.012	< 0.012	< 0.012	0.069
Fe – dissolved	0.027	< 0.027	< 0.027	< 0.027	< 0.027
Ni – dissolved	0.032	< 0.032	< 0.032	< 0.032	< 0.032
Cu – dissolved	0.044	< 0.044	< 0.044	< 0.044	< 0.044
Zn – dissolved	0.014	< 0.014	< 0.014	< 0.014	0.310
Sr – dissolved	0.004	0.163	0.127	0.075	0.113
Mo – dissolved	0.037	< 0.037	< 0.037	< 0.037	< 0.037
Cd – dissolved	0.009	< 0.009	< 0.009	< 0.009	< 0.009
Ba – dissolved	0.014	0.097	< 0.014	< 0.014	< 0.014
Pb – dissolved	0.126	< 0.126	< 0.126	< 0.126	< 0.126
As - dissolved	0.127	< 0.127	< 0.127	< 0.127	< 0.127

The trace metal results were not really remarkable, with the following exceptions:

- Boron (B) at Site 1 was very elevated. This would render the water very unsuitable for uses such as irrigated agriculture. It is, however, not believed that there is the intention to make use of this water for agricultural purposes.
- Manganese levels were above the limit of quantitation at Site 4, but can still be considered to be good quality with negligible health effects. There may be a slight taste or colour to the water at this site.
- The Zinc levels at Site 4 would have had no effect on the domestic use of the water.
- Strontium levels were above the limit of quantitation, but Mr P. Botes (Botes, 2005) ensured me that elevated Sr levels are widespread in South African water and at this level are not a cause for concern.

3.4 Bacteriological Analyses

Table 5. Bacterial counts recorded at the four sites

Constituent (cfu.100 $m\ell^{-1}$)	Limit of quantitation	Site 1 Crater Lake	Site 2 Crater Borehole	Site 3 Borehole with Diesel Pump	Site 4 Borehole with Electric Pump
Faecal coliform	1	<1	<1	<1	<1
Faecal streptococci	1	300	<1	1	6
Escherichia coli	1	<1	<1	<1	<1

The South African water quality guidelines (DWAF, 1996 and DWAF, 1998) as they relate to bacteriology list only values for faecal coliforms and total coliforms. From a faecal coliform perspective, the water at all four of the sites should hold no risk for the domestic use of the water.

Faecal streptococci are not an absolute indicator of bacteria of human origin (DWAF, 1996) and the high levels evident at Site 1 could be as a result of the birds that visit the Tswaing Crater Lake and wade in the shallow water. It is also possible that the low counts recorded at Sites 3 and 4 are indicative of the boreholes having human intervention to start up the pumps and take the samples.

4. Conclusions and Recommendations

The inclusion of the Crater Lake (Site 1) and the Crater borehole (Site 2) in the field and analytical results is as a result of scientific curiosity mainly. It is assumed that it is not the intention to try and use the water from either of these sources for domestic purposes. Indeed it would be foolish and misguided to attempt to do so since the levels of many of the attributes are extremely high, making the water at best unpalatable, and at worst highly toxic.

The question that must be asked is as follows: Of the two out of crater borehole sites (Sites 3 and 4), would either be suitable for domestic use, and if both, which one would be the best one to use?

The differences in water quality between Sites 3 and 4 are not extreme. They are not spatially far removed from one another. It is, therefore, likely that they both withdraw water from the same aquifer. However, there are some differences evident between their water quality as it has been assessed.

While both boreholes would probably not be considered completely hazardous, the following does apply:
Site 3 had a slightly elevated nitrate-nitrite level, but with an insignificant associated risk. The fluoride level was also elevated (albeit to a lesser extent than at Site 4), representing an increasing health effects and tooth staining in sensitive groups.
Site 4 had a higher fluoride level which represented possible health effects in all groups and also tooth staining. The manganese level was slightly elevated to the extent that there would be a slight taste and colour to the water. The zinc level was

elevated, but not to the extent where an effect could be expected. The faecal streptococci count was higher at Site 4, but the levels are probably still low. It might be advisable to dose this water with chlorine if it is to be used for drinking purposes.

If the assumption is made that the various camp sites and administrative offices do not have another water source, such as municipally treated water, then one or both of the boreholes are already being used for domestic purposes.

It is, therefore, recommended that Site 3 be used preferentially for drinking purposes if no cleaner water source is available, and that the water from Site 4 be used as a backup or for other non-drinking purposes. Expect there to be some tooth staining taking place.

5. Acknowledgements

The authors would like to acknowledge the various RQS laboratory staff for the dedicated way in which they conducted the required analyses needed for this report.

6. References

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