WATER QUALITY EVALUATION

SWAZILAND RURAL WATER SUPPLIES

O.D.M. Baseline Study

BY

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DECEMBER 1978

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PREFACE

Each year the Overseas Development Administration (ODA) commissions a number of ex-post evaluation studies with two aims in mind; firstly, to assess the effectiveness of its aid activities and secondly, to learn lessons for improving the effectiveness of future aid activities.

This evaluation is one such study.

Evaluation studies are undertaken by individuals or by teams especially recruited for their particular knowledge with regard to the subject under study. Sometimes these teams will include personnel from ODA (increasingly teams are a mix of ODA and external personnel).

In all cases the reports and conclusions are attributable to the authors, who are finally responsible for their contents, and not to ODA.

Evaluation Unit
Manpower and Evaluation Department

EV67

ITINERARY

Sunday	3rd December	Drove to Johannesburg from Lobatse, overnight stop.
Monday	4th December	Collected bacteria culture media and other supplies from Millipore agents. Drove to Mbabane.
Tuesday	5th December	Meeting with Mr. P. Morris and Mr. D. Gordon-Mcloud at B.H.C. Visited Motshane and Dwalile.
Wednesday	6th December	Visited Gege
Thursday	7th December	Visited Mpolonjeni, Mafutseni and Luve.
Friday	8th December	Laboratory analysis and visited water board offices to obtain maps and information. Sent driver back to Gege to sample spring source.
Saturday	9th December	Final laboratory work and packing of equipment and samples for transportation back to Botswana.
Sunday	10th December	Drove to Johannesburg, overnight stop.
Monday	11th December	Returned to Lobatse.

ABSTRACT

Quality of water supplies in the six test areas designated for the base-line study were re-examined during the wet season (December 1978). Coliform counts were found to be significantly higher than when previously tested (March 1978). Fecal contamination of village water supplies by livestock and humans is a major problem and health hazard, strong recommendations are made to disinfect these supplies. Some of the new ground water supplies were also found to have been polluted with nitrate.

C O N T E N T S

DESCRIPTION OF LOCATIONS OF WATER SAMPLES COLLECTED FOR CHEMICAL ANALYSIS

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<u>MAPS</u> (not bound in report)

1. INTRODUCTION

This present study arose from the findings of a previous study (Lewis, 1978) which took place during the dry season, (March 1978). It was suggested that the water quality determined, both chemical and bacteriological could be different from that observed during the wet season. Hence the six areas tested were re-visited and water samples collected for chemical and bacteriological analysis during the period of heavy rains in December. Where some of the schemes were complete or in an advanced state of completion it was decided not to be re-test the former sources of supply e.g. surface streams etc. since these sources had been abandoned. Discussion of sources of pollution have not been included in this report if described in the earlier report.

2. METHOD OF SAMPLING AND ANALYSIS

The sampling and techniques of analysis were identical to those employed in the investigation which took place in March. A description of these test procedures can be found the subsequent report.

Due to the high incidence of fecal contamination of water sources found in the previous study it was decided to place greater emphasis on the bacteriological testing of water supplies. More samples were collected for examination during this study. Where a community was served by a piped reticulation scheme samples were collected at stand pipes in close, intermediate and distant proximity from the water source.

3. TEST SITES

3.1 Dwalile: Scheme No. 6

The major source of water supply to this community is still the nearby untreated stream. However the inhabitants of this community

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now have to walk to the stream to collect their water because the small ram pump feeding the two storage tanks at the school has been broken down since September. The proposed scheme of a ram pump with greater capacity and increased storage reservoirs has been abandoned. The new plan is to supply water from a borehole or boreholes. One borehole has been sited and partly drilled but through the inexperience of the drilling contractor, collapsed and had to be abandoned. Another borehole has been drilled but not yet completed and equipped. This borehole is in close proximity to the new secondary school which is being constructed. The original plan was changed from a surface to a groundwater source because it was felt that as opposed to the stream, the groundwater would not be polluted and would not need chlorination. However unless thorough well construction techniques are employed then this source too could also become polluted. This would of course depend on the depth of the water table, thickness of overburden and underlying geological formation. A possible source of pollution would be the pit latrines of the nearby school which could be in daily use by over two hundred people. It has been demonstrated (Lewis, Farr and Foster, 1978) that pit latrines are a major source of pollution to groundwater in the villages of Eastern Botswana.

The chemical and bacteriological analysis of the stream (see table 7A and 2) show results almost identical to the findings in March i.e. gross fecal contamination, the most important difference being a four fold increase in fecal coliform organisms detected. The water samples were collected during a heavy downpour of rain.

3.2 ERIC ROSENBURG AND GEGE: SCHEME NO. 15/16

This reticulation scheme supplying the communities of Eric Rosenburg and Gege was complete. A protected spring source feeds a concrete storage reservoir and the water is distributed by gravity feed through a ring main with thirty five stand pipes where water can be drawn off by the inhabitants. The stand pipes have been equipped with a tap which cannot be left running continuously. A drainage channel for spilled water has been provided but at a number of the stand pipes visited these showed evidence of blockage. The water was not chlorinated at any point. Seven water samples were collected for bacteriological examination and one sample for chemical analysis (see photo map 1). The chemical analysis (see table 7A) again demonstrates the purity of the water (total dissolved salt content 25 mg/l). Field p.H. measurements were taken at the various sample points and showed an increase with distance from the storage reservoir (3.9 - 5.2). The water samples when collected showed vigorous evolution of dissolved gases. When tested in the laboratory the p.H. had increased to 7.0 This p.H. unstability is probably due to the low solute concentrations and short supply of calcium carbonate in the geologic source (Feldspar - Quartz). This water would almost certainly cause corrosion of any metal fittings it came into contact with. The results of the bacteriological examination (see table 3) show total coliform counts ranging from 10 - 159 per 100 ml. No fecal coliforms were detected in any of the samples. The eye of the spring was tested and this had a coliform count of 22 organisms/100 ml. The levels encountered are not alarming but it would certainly be advisable to dose the reservoir with chlorine as a safety measure.

3.3 MPOLONJENI: SCHEME NO. 60

The original idea of using a groundwater supply has been changed to the use of surface water from the dam. This reticulation scheme was almost complote hovever the treatment plant has yet to be constructed. A new pump houso has been constructed adjacent to the odgo of the dam. This pumps water into two concrete storage reservoirs which in turn feed the reticulation scheme with the help of a booster pump which is located next to the reservoirs. Four water samples were collected for bacteriological testing and one sample for chemical analysis (see map 2). The results of the chemical analysis (see table 7A) is satisfactory but the hardness (175 mg/l as $CaCO_3$) puts it into the hard classification (Durfor and Becker, 1964). The water was also very dirty in appearance and had organic matter in suspension, but no doubt this problem should be cured or very much reduced when the proposed treatment plant is constructed.

The bacteriological examination results (see table 4) show gross fecal contamination. The samplo collected at the stand pipe at the secondary school had a count of 650 fecal coliforms and 54,000 total coliform organisms per 100 ml. These are alarming figures for coliform counts and there is a very definite health hazard to anybody drinking such severly polluted water. The sample collected at Siphoso primary school also had a count of 650 fecal coliform organisms per 100 ml. The headmaster of this school complained that the two small metal storage tanks were inadequate to cover the schools needs, and that some days they were without water.

The source water i.e. the dam had coliform counts half that of the schools and this is taken as strong evidence that bacteria are multiplying under storage conditions in the reservoirs. The conditions are probably ideal for growth with the high ambient temperatures in Summer and plentiful organic matter suspended in the water. The metal storage tanks are li'ely to be playing the role of giant incubators. The source water ha a temperature f 28°C whilst the sample collected at the secondary school was 32°C. The total coliform concentration shows a ten fold increase compared to the results of the study conducted in March 1978.

In view of the severity of fecal contamination of this water supply and the consequences to the health of the community drinking this water untreated, the construction of the treatment and chlorination plant should be treated as a matter of extreme urgency.

3.4 Mafutseni: Scheme 124

This scheme was complete and two communities on opposite sides of a stream are served by two boreholes. (see map 3) Mafutseni I is located near to the secondary school. A borehole has been drilled and equipped and this supplies water to the school and nearby community. Water is stored in twin concrete reservoirs adjacent to the school. Mafutseni II on the opposite side of the small valley is also served by a borehole equipped with a pump powered by a Windmill. This borehole supplies water to a concrete storage reservoir from which the water is distributed by gravity feed. At the time this study took place this borehole was not pumping because of a malfunction in the pump mechanism.

The results of the chemical analyses of samples taken from Mafutseni I (see table 7B) show it to contain almost twice the permitted W.H.O. nitrate concentration of 45 mg/l NO_3^- (W.H.O. 1973). The analysis of the sample from Mafutseni II (see table 7B) which is not far away from the other borehole has only 5 mg/l NO_3^-. These boreholes are not significantly far away from each other for these to be two distinct aquifers. Further the chemical pollution has increased the total dissolved salt content of other chemical species e.g. Ca^{++}, Mg^{++} and CL^- so that the overall hardness as $CaCO_3$ is

246 mg/l which is a very hard water. In fact the women complained to me about the hardness. The sample from Mafutseni II had a hardness of 152 mg/l which is in the hard classification. The saturation of these two waters with respect to calcite has been calculatod using the ion activity method described in a U.S.G.S. water supply paper. (Hem, 1961) and results indicate that the polluted groundwater is supersaturated and the unpolluted groundwater slighly unsaturated. This means that there is a likelihood of calcite depositing in the polluted well which in time may cause encrustation in the borehole with a resultant loss of production (Barns and Clarke, 1969). The overall charge in chemical character caused by pollution is best described with the aid of Stiff diagrams which are a method of displaying water chemistry as patterns (Stiff, 1951). Fig 1 and 2 are the Stiff diagrams drawn from the water analysis of Mafutseni I and II respectively. Fig. 3 shows a combined stiff diagram with the unpolluted water pattern superimposed on the polluted water pattern. The shaded area of Figure 3 represents the change in the chemical character of the groundwater due to pollution. This phenomenon of increased hardness with nitrate pollution has been observed in a provious mentioned study (Lewis, Farr and Foster 1978). Pollution is most probably caused by infiltration to the water table of water seeping from the nearby dam used for stock watering.

The Bacteriological examination of the water samples collected from Mafutseni I show (see table 5) collosal total coliform counts (> 30,000 per 100 ml) but no fecal coliform organism to be present. No provision was made to obtain a water sample directly from the borohole but one was obtained by disconnecting a water pressure guage. This sample was also grossly pc luted and is strong evidence for the case of pollution by infiltrat)n of contami ated surface water. No sample could be taken directly from the borehole of Hafutsoni II and so a sample was taken from the first stand pipe after the reservoir. This also proved to be polluted (500 coliform organisms/100 ml). This together with a 5 mg/l NO_3 concentration suggests that the pollution from the dam is also travelling through the aquifer and affecting the other supply well. Obviously in doing so it is becoming diluted. The stream which runs between the two boreholes could also be a source of recharge and this is known to be polluted from the findings of the previous study.

3.5 Luve: Scheme No. 29

This scheme was complete and the community of Luve draw their water from the reticulation scheme fed by the recently drilled borehole. Water is pumped from the borehole into twin storage reservoirs where it is gravity fed to the reticulation scheme. The system is not treated at any point. No provision was made to obtain a sample at the borehole neither was it possible to collect a sample of the discharge into the reservoir. Three samples were collected for bacteriological testing and are for chemical analysis from the first, intermediate and last stand pipe in the line (see map 4). The results of the bacteriological examination see table 6 show fecal contamination. The sample taken from the last stand pipe in the line (St. Andrews Anglican Mission) has four times the concentration of coliform organisms than that found in the other samples. This would suggest that contamination could be entering through a joint in the pipework. The chemical analysis (see table 7B) shows nitrate pollution (27 mg/l). The water table is quite shallow (16.8 m) and the most likely cause of contamination is direct infiltration of contaminated surface water to the water table.

3.6 Motshane: Scheme No. 27

This scheme was also complete. Samples were taken at various standpoints along the system (see map 5). The results of the bacteriological examination (see table 1) were very pleasing with extremely low counts for coliform organisms. However the coliform counts in the sample taken from the last stand pipe were much higher and this must be due to the fact that the last section of piping had only recently been connected to the system and prior to that had lain open for about 2 weeks. Contamination could have taken place during this period.

The chemical analysis (see table 7A) show it to be a very fresh water with low concentrations of dissolved salts.

4. CONCLUSIONS

4.1 There is a seasonal change in water quality, the total dissolved solids content of the waters examined are generally slightly higher in the wet season. The coliform organisms present are significantly higher than those found in the same sources tested in the dry season.

4.2 Fecal contamination of village water supplies is a major problem and health hazard. All the completed water reticulation schemes tested showed evidence of bacteriological contamination to some extent.

4.3 Contrary to previous information about the treatment of water supplies at the six test areas visited, it is planned to treat only the water supply in Mpolonjeni (verbal communication with rural water engineer).

4.4 Two out of three of the boreholes tested had groundwater pollution with nitrate and bacteria from fecal origins. It is therefore not safe to assume that a groundwater source will be clean and safe to drink without prior disinfection.

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4.5 Except for Motshane and possibly Eric Rosenburg/Gege as far as health aspects are concerned there has been no benefit to the communities, since they now have a supply of contaminated water on tap. In fact this could be a disadvantage because where the water supply sources was previously rivers and streams, some members of the community using this were probably aware of the likelihood of contamination from livestock and treated the water with due caution. Now that these dubious water sources are being replaced, the public served might falsely assume that the piped water supplied by the authorities was totally safe to drink without any prior treatment.

5. RECOMMENDATIONS

5.1 All vilage water supply schemes should be chlorinated as a matter of course. The World Health Organisation in their "Guide to simple sanitary measures for the control of enteric diseases" (Rajagoplan and Shiffman, 1974) recommend two distinct stages of disinfection. (i) An initial disinfection of the structures following their construction or repair to destroy any bacterial pollution incidental to such works. (ii) Routine chlorination of water supplies to destroy bacteria from any other sources. The initial chlorination should be conducted with a strong chlorine solution (approx 30 mg of applied chlorine per litre of water) to sterilize boreholes, reservoirs, tanks, mains etc prior to bringing them into service. The strongly chlorinated water should be left for at least 12 hours in the well or tank to achieve the necessary contact time to completely destroy all bacteria present. This water should not be used for drinking purposes. Wells should be pumped and the water rejected until residual chlorine is below 0.7 mg per litre of water. Tanks should be emptied completely and the water run to waste. For routine disinfection purposes chlorine should be added to the supply to maintain a residual chlorine level of 0.2 - 0.8 mg per litre of water. The chlorine demand will vary with different waters and this should be ascertained to determine the amount of chlorine that is necessary to produce given levels of residual chlorine in a particular water after a definite period of contact. These recommendations will of course need personnel to test the residual chlorine levels on a regular basis. This should not be too much of a problem as the test kits and testing procedures are not very complicated.

It is very evident from the findings of the epidemiologist's investigations made during the base-line study (Bell, 1978) that diarrhoeal disease accounts for a large proportion of clinic attendances in Dwalile and Luve where reliable records are available. Since there are some areas with worse water quality then it is probable that the health of those comminities are also affected by drinking polluted water to an equal or greater extent. It must therefore be emphasised that unless the above recommendations regarding disinfection of water supplies are implemented then the anticipated health benefits to the rural communities served by these new water reticulation schemes will not be achieved.

5.2 The nitrate pollution found in the groundwater supply at Mafutseni is a difficult problem to cure. There are methods available to remove nitrate, however such methods are at present very costly and therefore not viable. Unless an alternative water supply can be provided, the medical authorities in that area should be warned to be on the look out for possible cases of cyanosis in infants. Bottle fed babies would be at greatest risk to this disease and also to gastro intestinal disorders from the bacteria if the water was not sterilized by boiling.

5.3 Provision should be made to obtain a pumped water sample directly from the borehole in order that causes of pollution can be properly investigated. On a more trivial note stand pipes could be numbered for ease of identification when conducting such a sanitary survey as this.

5.4 For future base-line studies it may be useful to get the Water Quality Evaluation completed at an earlier stage so that the findings can be of assistance to the Engineer in making his plans e.g. location of boreholes away from possible polluting sources, degree of pollution of proposed supplies etc.

6. REFERENCES

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Table 1: COLIFORM MEASUREMENTS OF WATER SAMPLES FROM MOTSHANE SCHEME NO. 27 (5/12/78)

Sample point No. & Location	Fecal Coli (organisms/100 ml)	Total Coli (organisms/100 ml)
1. Stand Pipe 1 below 90 M^3 concrete reservoir	0	0
2. Stand Pipe 5, where main pipe branches	0	3
3. Stand pipe 10 immediately behind small shop adjacent to main road.	0	77

(See map 1 for exact location)

Table 2: COLIFORM MEASUREMENTS OF WATER SAMPLES FROM DWALILE SCHEME NO. 6 (5/12/78

1. Stream/River below dam	496 (120)*	3900 (3000)*

* Figures in brackets from study study made in March 1978.

Table 3: COLIFORM MEASUREMENTS OF WATER SAMPLES FROM GEGE SCHEME NO. 16 (6/12/78)

Sample No. and Location	Fecal Coli (organisms/100 ml)	Total Coli (organisms/100 ml)
1. feed pipe into 90 M^3 concrete reservoir	0* (0)	36* (800)
2. Eric Rosenbury School stand pipe	0	88
3. Stand pipe. Left side of road to Gege before road crosses river	0	159
4. Gege Methodist Primary School Stand pipe	0	24
5. Stand pipe where pipeline crosses road to Piet Retief	0	10
6. Stand pipe closest to the reservoir on the opposite side of valley	0	145
7. Spring Source	0	22

(see map 2 for exact location)

* figures in brackets from study made in March 1978.

Table 4: COLIFORM MEASUREMENTS OF WATER SAMPLES FROM MPOLONJENI SCHEME NO. 60 (7/12/78)

Sample point No. & Location	Fecal Coli (organisms/100 ml)	Total Coli (organisms/100 ml
1. Stand pipo beside pump house drawing water from the dam (Pumped sample)	380 (400)*	25'400 (2400)*
2. Stand pipe at Siphoso Primary School(reservoir sample)	650	'000
3. Stand pipe behind clinic	350	'700
4. Stand pipe at Secondary School (reservoir sample)	650	'000

(See map 3 for exact location)

* figures in brackets from March 1978 study.

Table 5: COLIFORM MEASUREMENTS OF WATER SAMPLES FROM MAFUTSENI

SCHEME NO. 124 (7/12/78)

Sample Point No. & Location	Fecal Coli (organisms/100 ml)	Total Coli (organisms/100 ml)
1. Stand pipe at the secondary school	0	> 30'000
2. Stand pipe some 200 m from school	0	> 30'000
3. Borehole (pumped sample)	0	>20'000
4. Mafutseni II, stand pipe near reservoir	2	500

(see map 4 for exact locations)

Table 6: COLIFORM MEASUREMENTS OF WATER SAMPLES FROM LUVE SCHEME NO. 29 (7/12/78)

Sample Point No. & Location	Fecal Coli (organisms/100 ml)	Total Coli (organisms/100 ml)
1. Nearest stand pipe to borehole on left side of road to Luve	2	750
2. Two stand pipes down the line from sample point 1	1	750
3. Stand pipe at St. Andrews Anglican Mission	1	3050

(see map 5 for exact location)

DESCRIPTION OF LOCATIONS OF WATER SAMPLES COLLECTED FOR CHEMICAL ANALYSIS

Sample No.	Location
78/549	Motshane, stand pipe immediately below $90m^3$ concrete reservoir.
78/550	Dwalile river, below dam.
78/551	Gege, stand pipe at Methodist Primary School.
78/552	Mpolonjeni, stand pipe behind clinic.
78/553	Mafutseni I, Borehole below school.
78/554	Mafutseni II, stand pipe nearest to reservoir fed by Borehole equipped with Windmill.
78/555	Luve, stand pipe beside road to Luve and nearest to borehole.

TABLE 7A: CHEMICAL ANALYSES OF WATER SAMPLES FROM THE SIX TEST AREAS

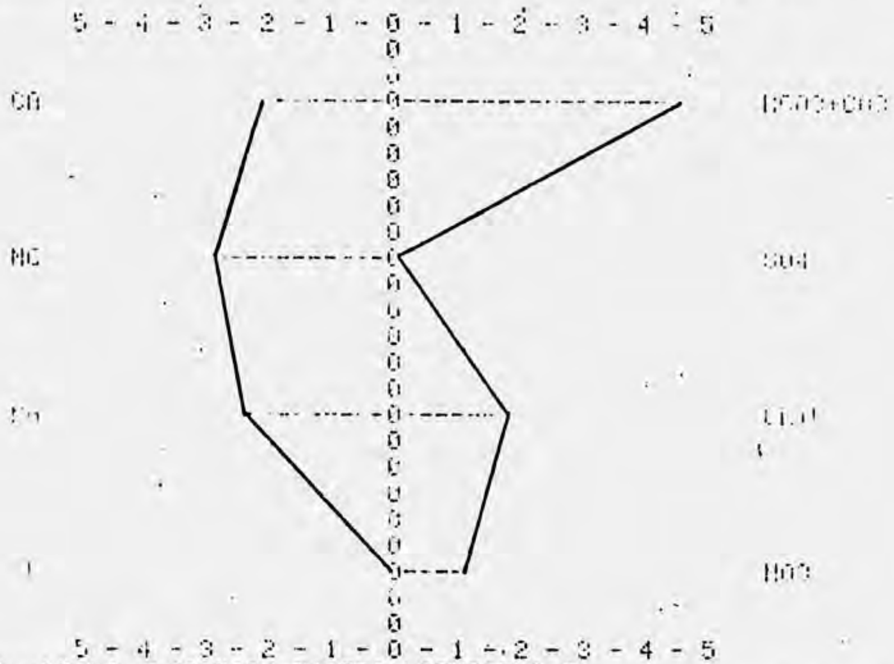
Sample No.	78/549		78/550		78/551		78/552	
Location	Motshane Sample Point 1		Dwalile Stream		Gege Sample Pt. 4		Mpolonjeni Sample Pt. 3	
Type	Stand pipe		Surface water		Stand pipe		Stand Pipe	
Sampled	5.12.78		5.12.78		6.12.78		7.12.78	
Analysed	12.12.78		21.12.78		21.12.78		21.12.78	
Conductivity	56 MICROMHOS		51 MICROMHOS		28.5 MICROMHOS		650 MICROMHOS	
PH (Field)	5.45		—		3.9		7.6	
PH (Lab)	6.82		7.32		7.0		7.85	
	mg/L	meq/L	mg/L	meq/L	mg/L	meq/L	mg/L	meq/L
CO_3	0.0	0.000	0.0	0.000	0.0	0.000		0.000
HCO_3	26.2	0.430	26.2	0.430	10.0	0.164	252.2	4.136
CL	2.1	0.059	2.1	0.059	4.1	0.116	82.2	2.319
SO_4	0.8	0.017	1.4	0.029	0.0	0.000	1.8	0.037
F	0.1	0.005	0.1	0.005	0.0	0.000	0.4	0.021
NO_3	0.0	0.000	0.0	0.000	0.0	0.000	0.4	0.007
SiO_2	N.D.		N.D.		N.D.		N.D.	
SUM OF ANIONS	29.2	0.511	29.8	0.523	14.1	0.280	337.0	6.520
K	0.8	0.020	0.9	0.023	0.6	0.015	1.6	0.041
NA	3.9	0.170	3.5	0.152	2.6	0.113	62.9	2.736
CA	3.9	0.195	3.7	0.185	1.7	0.085	30.6	1.527
MG	1.5	0.123	1.6	0.132	0.5	0.041	24.0	1.974
SUM OF CATIONS	10.1	0.508	9.7	0.492	5.4	0.254	119.1	6.278
TDS	31		34		25		334	
BALANCE	0.3%		3.1%		4.7%		1.9%	

TABLE 7b: CHEMICAL ANALYSES OF WATER SAMPLES FROM THE SIX TEST AREAS

Sample No.	78/553		78/554		78/555	
Location	Nafutseni 1 Borehole		Nafutseni II		Luvo, Sample Point 1	
Type	Pumped sample		Stand pipe		Stand Pipe	
Sampled	7.12.78		7.12.78		7.12.78	
Analysed	21.12.78		21.12.78		21.12.78	
Conductivity	770 MICROMHOS		540 MICROMHOS		380 MICROMHOS	
PH (Field)	7.9		7.1		6.8	
PH (Lab)	7.99		8.32		7.51	
	mg/L	meq/L	mg/L	meq/L	mg/L	meq/L
CO_3	0	0.000	0.0	0.000	0	0.000
HCO_3	276.2	4.530	269.8	4.425	111.5	1.829
CL	65.2	1.839	38.1	1.075	46.8	1.320
SO_4	7.8	0.162	4.6	0.096	1.1	0.023
F	0.5	0.026	0.8	0.042	0.0	0.000
NO_3	71.4	1.164	4.7	0.077	26.8	0.437
SiO_2	N.D.		N.D.		N.D.	
SUM OF ANIONS	421.1	7.709	318.0	5.713	186.2	3.604
K	4.3	0.110	2.7	0.069	0.6	0.015
NA	57.3	2.493	50.0	2.175	12.9	0.561
CA	40.6	2.026	24.3	1.213	33.3	1.662
MG	35.1	2.887	22.1	1.818	16.4	1.349
SUM OF CATIONS	137.3	7.516	99.1	5.275	63.2	3.587
TDS	444		306		216	
BALANCE	1.3%		4.0%		0.2%	

(MULTIPLY SCALE BY 1 & JOIN END'S OF DOTTED LINES)

Figure 1.

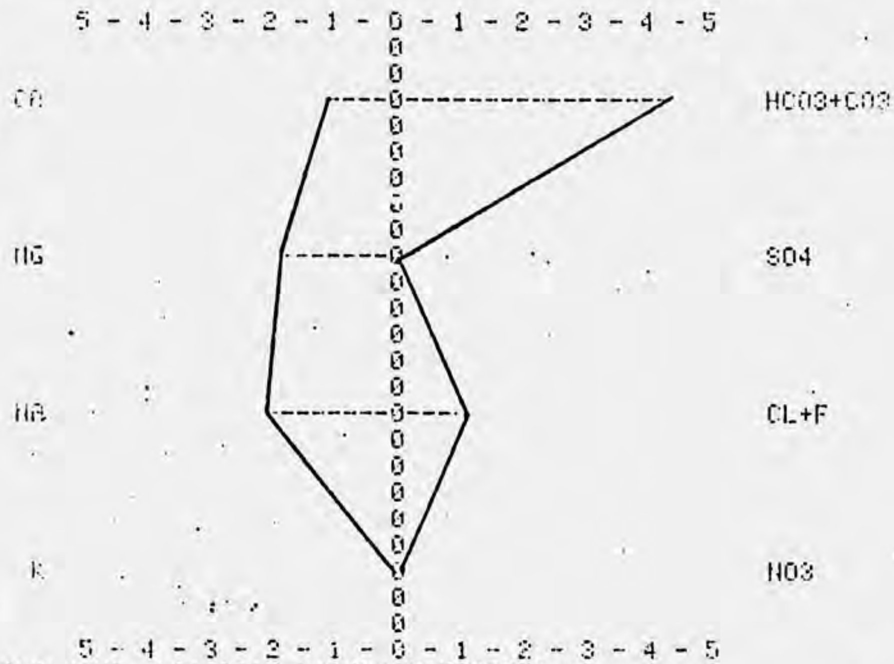


SAMPLE NO./LOCATION=78/553 MAFUTSENI I
TOTAL SCALE= 5 MULTIPLIED BY 1 EQUIVALENTS PER MILLION
EACH DASH= 0.25
CONSTITUENTS IN EQUIVALENTS PER MILLION

CA= 2.026	MG= 2.887	NA= 2.493	K= 0.11
HCO3+CO3= 4.53	SO4= 0.162	CL+F= 1.865	NO3= 1.1[illegible]

(MULTIPLY SCALE BY 1 & JOIN END'S OF DOTTED LINES)

Figure 2.

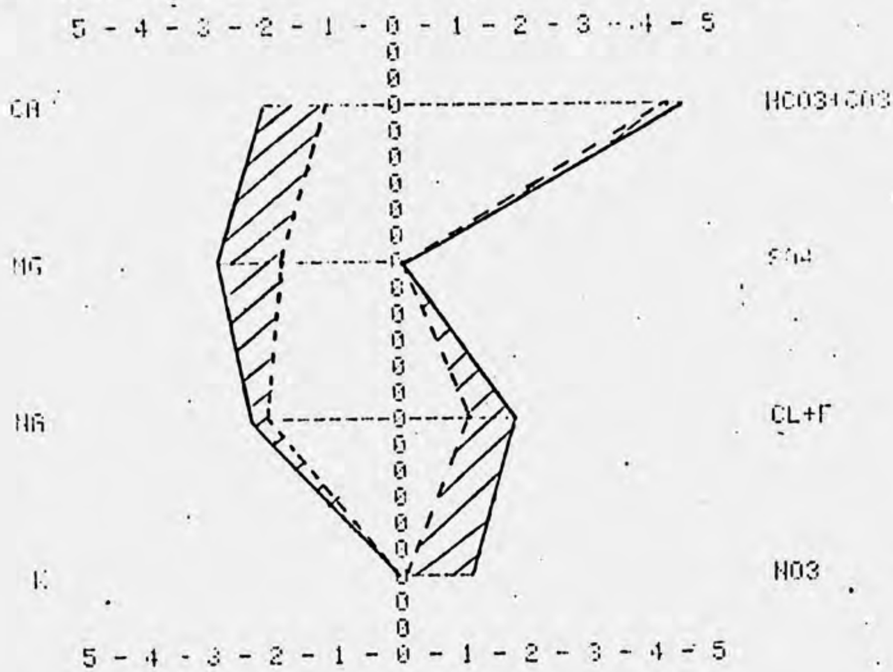


SAMPLE NO./LOCATION=78/554 MAFUTSENI II
TOTAL SCALE= 5 MULTIPLIED BY 1 EQUIVALENTS PER MILLION
EACH DASH= 0.25
CONSTITUENTS IN EQUIVALENTS PER MILLION

CA= 1.713	MG= 1.818	NA= 2.175	K= 0.065
HCO3+CO3= 4.425	SO4= 0.096	CL+F= 1.117	NO3= 0.677

Figure 3 COMBINED STIFF DIAGRAM SHOWING SAMPLE #78/554 (BROKEN LINE) SUPERIMPOSED ON SAMPLE #78/553 (SOLID LINE)

(MULTIPLY SCALE BY 1 & JOIN END'S OF DOTTED LINES)



(HATCHES) REPRESENT INCREASED SALTS CONTENT DUE TO POLLUTION