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April 1999

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Summary

The Norwegian Institute for Air Research (NILU) was asked by the Norwegian State Pollution Control Authority (SFT) for support in defining the ambient air pollution component of the Industrial Pollution Prevention Programme (IPPP) operated by the Environmental Council of Zambia (ECZ).

As part of a second screening study to develop a plan for ambient air pollution monitoring in Zambia (Guerreiro, 1999), 34 SO_2 and 17 NO_2 passive samplers were placed inside the cities of Lusaka and Ndola, in Maamba and Mazabuka and around industries in the Copperbelt area. Of these passive samplers, 32 SO_2 and 15 NO_2 have been found and analysed. The passive samplers were installed in field to measure ground level concentrations as a result of emissions from traffic and industrial activities. SO_2 is particularly a problem in the Copperbelt area, due to the high industrial activity that characterises this area. The World Health Organisation's (WHO) air quality guidelines for SO_2, for both the averaging times of 24 hours and one year, are exceeded in Mufulira and Nkana, downwind of the smelters. While in Mufulira these concentrations can have a very serious impact on both vegetation and population living downwind of the smelter, in Nkana the population is less often exposed to extremely high SO_2 concentrations, since the townships are not located on the prevalent downwind direction from the industry. The SO_2 ambient air concentrations measured in Maamba, Ndola and Chingola were below the WHO air quality guidelines for both 24 hours and one year. Nevertheless, under episodes with high local emissions of SO_2 and / or poor meteorological dispersion conditions in these areas, high concentrations of SO_2 are likely to occur in neighbouring areas, exceeding the WHO air quality guidelines. The measured NO_2 concentrations are well below the WHO air quality guidelines and do not represent presently a motive of concern.

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1 Introduction

The Norwegian Institute for Air Research (NILU) was asked by the Norwegian State Pollution Control Authority (SFT) for support in defining the ambient air pollution component of the Industrial Pollution Prevention Programme (IPPP) operated by the Environmental Council of Zambia (ECZ).

As part of a second screening study to develop a plan for ambient air pollution monitoring in Zambia, 34 SO_2 and 17 NO_2 passive samplers were placed inside Lusaka, Maamba, Mazabuka, Ndola and around industries in the Copperbelt area. Of these passive samplers, 32 SO_2 and 15 NO_2 have been found and analysed. The passive samplers were installed in field to measure ground level concentrations as a result of emissions from traffic and industry.

2 The passive samplers

A sensitive diffusion sampler for sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) in ambient air has been used in several investigations to undertake a screening of the spatial concentration distribution.

The sampler was developed by the Swedish Environmental Research Institute (IVL) and has been used in several cases by NILU. The sampler includes an impregnated filter inside a small plastic tube. To avoid turbulent diffusion inside the sampler, a thin porous membrane filter covers the inlet. Gases are transported and collected by molecular diffusion.

The samplers are very easy to manufacture. For example, the samplers used by NILU are produced from commercially available 50 mm long polypropylene tubes. The tubes are cut to the desired length and then fitted with a solid cap containing the impregnated filter at one end, and an open cap containing the anticonvection mesh/membrane at the inlet end (as shown in Figure 1).

All components, except the impregnated filter can be reused. They have many other advantages as well for use in the field. For example they are small, light (~2 g), and require no electricity.

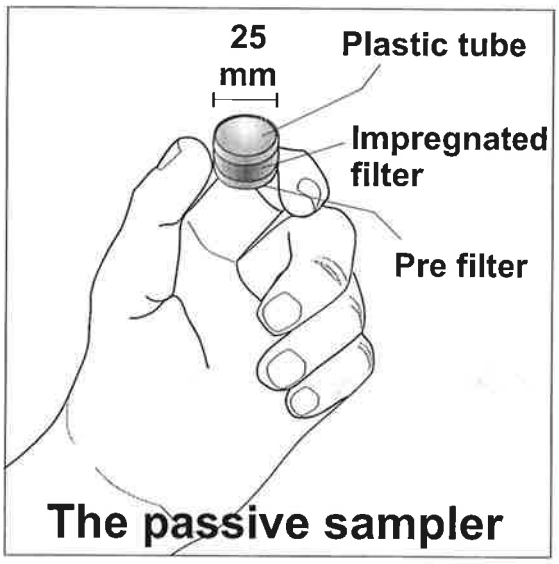

Figure 1: The passive sampler.

It should be emphasised that the samplers provide time integrated concentrations with continuous time coverage, with the averaging time determined by the period they are exposed to ambient air (which can be daily, weekly, monthly, etc.). They are obviously not well suited for monitoring temporal variations over short time intervals, or for detection of individual peak values, or when real time measurements are needed.

2.1 The basic principle

The sampling technique is based on the property of molecular diffusion of gases, hence the term passive (also referred to as diffusive) sampling. The gas molecules diffuse into the sampler where they are quantitatively collected on an impregnated filter or an absorbent material. Thus they achieve a time-integrated (or average) concentration. No electricity, pumps or other supporting equipment are needed.

If the sampling efficiency is sufficiently high, then the sampling rate can be calculated from the cross sectional area perpendicular to the transport direction and the distance the gas has to diffuse using Fick's first law of diffusion.

To work properly (and quantitatively) it is essential that the transport occurs solely by molecular diffusion and that no gas is lost to the walls of the sampler. Under these conditions then the sampling rate, and thus the concentration range of the sampler, is directly proportional to its cross sectional area and inversely proportional to its length.

Inorganic gases are absorbed by chemical reaction on a filter impregnated with a solution specific to each pollutant measured. The reaction product, which is washed out of the filter prior to analysis, is specific to the particular gas in question. When species do not react sufficiently fast with other chemicals (e.g., organics) they are instead trapped on an absorbent material. Such gases are then desorbed from the adsorbent during analysis.

2.2 Uptake rates and analyses

The uptake rate is only dependent upon the diffusion rate of the gas. The collection rate is 31 *l*/24h for SO_2 and 36 *l*/24h for NO_2. Also NH_3 can be collected at a rate of 59 *l*/24h.

For SO_2, the measuring ranges are approximately 0,1-80 ppb for a sampling period of one month. The corresponding range for NO_2 is 0,02-40 ppb. The passive samplers are assembled and made ready for use at NILU. After exposure the samplers are usually returned to NILU where concentrations of SO_2 are determined as sulphate by ion chromatography. NO_2 and NH_3 is determined by spectrophotometry.

The average concentration at the measurement site over the time period that the sampler is exposed to ambient conditions is determined by chemical analysis of the filter. Analysis consists of removing the impregnated filter and leaching the reaction product, typically using de-ionised water. The leachate is then analysed using an appropriate analytical technique. The highest concentration that can be measured depends on the amount of sorbent on the impregnated filter. This is typically estimated by the stoichiometric amount of the impregnate reduced by a safety factor (typically a factor of 2).

The lower detection limit of the samplers is determined by the use of blanks. As soon as a filter is impregnated it will begin to measure ambient levels. A filter kept in the laboratory will measure laboratory levels, while field blanks will measure the integrated exposure during the transport and storage periods.

The samplers are impregnated shortly before sent to the field, samplers labelled for batch number, a few filters checked immediately, and then filters identified for lab and field blanks. The laboratory blanks are stored in the lab and periodically tested. The field blanks are kept in their containers and accompany the samplers to the field and are returned after the filters are exposed. The field blanks are analysed along with the exposed samples. The concentrations determined from the exposed filters are then corrected using the blanks. The lower detection limit is commonly defined as 2 to 3 times the standard deviation of the blanks. The repeatability of the results is quantified and checked by use of duplicate samples.

3 Sampling sites in Zambia

Passive samplers were used to measure NO_2 and SO_2 concentrations at selected sites in Lusaka, Mazabuka, Maamba, Ndola, Luanshya, Nkana (Kitwe), Mufulira and Chingola. 34 SO_2 and 17 NO_2 passive samplers were placed in field, of which 32 SO_2 and 15 NO_2 passive samplers were found and analysed. The location and results from the passive samplers that were found are reported below.

In Lusaka three sites were selected to measure NO_2 and one to measure SO_2; one in the city background area, inside ECZ; a second one in the city centre, near a road with heavy traffic (Lumumba rd.), and a third one, measuring both SO_2 and NO_2, in the city business centre, near the main street (Cairo rd.).

In Mazabuka three sites were selected to measure NO_2 and SO_2 around the Nakambala sugar factory and plantations. Two sites were located in townships, surrounded by sugarcane plantation, and about 500 m north and 1.5 km northeast of the sugar factory. The other site was placed about 1.3 km southwest of the sugar factory, near the office area.

In Maamba 3 sites were chosen to measure SO_2 ambient air concentrations around Maamba Collieries. One site is located inside the industrial area stretching along the valley, between two open pit mines under spontaneous combustion. Another site was located south of the old cool pit field of Kanzinze that has been burning for several years, and about 4 km southwest of the present open pit mine in operation. The third site was placed in a residential area, about 1.6 km southeast, not affected by the main winds which blow along the valley (northeast / southwest).

In Ndola six sites measured NO_2 and SO_2. Two sites were placed in the city centre, one in one of the streets with most traffic and the other at the Savoy hotel. Another site was in the Mukuba hotel, downwind of the INDENI Petroleum Refinery and Bwana Mkubwa Mining. The other three sites were placed around Bwana Mkubwa Mining, two in the industrial area, downwind of the acid plant and one in the agricultural area southwest of the plant.

In Luanshya the smelter was closed. One site was chosen to measure SO_2 and NO_2 in a township near the smelter and to compare the present measurement of SO_2 with the previous one, taken when the smelter was in operation. Another site was chosen to measure NO_2 in the crossing of two main streets in the town centre.

In Nkana seven sites were chosen to measure SO_2 ambient air concentrations around the ZCCM Nkana smelter and the Scaw Zambia Ltd. foundry. The Central Shaft site was located inside the smelter area, about 1 km downwind from the smelter. The Fire brigade site was located about 500 m south of the smelter, on the border between the industrial area and Wusakili township. The Wusakili hospital site is located about 750 m upwind of the smelter, and the Nkana hospital site is located inside the city 1.5 km north of the smelter. The Mumana Clinic site was placed 2 km southeast of the smelter. No residential area is located in the main downwind direction from the industrial area, instead there is a golf court 2-3 km west of the industries. One site was placed in the golf court area. The last site was placed in the Mines Safety Dept. in Kitwe.

In Mufulira five sites measured the SO_2 ambient air concentrations around the ZCCM Mufulira smelter. Four of the sites were located inside townships, downwind (SW and NW) and at different distances from the smelter. The fifth site was located 4 km upwind of the smelter in a residential area.

In Chingola five sites were selected to measure SO_2 and one to measure NO_2 ambient air concentrations around ZCCM Chingola. The Faith Rise pre-school site was located very close to the leach plant, on the border between Chingola town and the industrial area. Two other sites were located at different distances east of the leach plant, in residential areas. The site of Malemba primary school was placed downwind, about 1.2 km southwest of the plant, and measured both

SO_2 and NO_2. This site is also affected by emissions from scrap dealers and copper melting in the close neighbourhood.

Table 1 describes the sampling sites in terms of location, main emission sources, position in relation to the emission sources, measured compounds and sampling periods. The maps in Appendix A give a picture of the spatial distribution of the sampling sites and residential areas in relation to the main sources, for each city.

Table 1: Sampling sites for the SO_2 and NO_2 passive samplers.

City/ Town	Site name (position)	Area	Emission source	Position to emission source	UTM co-ordinates		Passive samplers		Sampling period
					X	Y	SO_2	NO_2	(days)
Mazabuka	Ngamona, house 2	Township / industrial	Nakambala Sugar St.	≈ 1 km NW	583.8	250.6	1	1	20
Mazabuka	Kaleya Clinic	Township / rural	Nakambala Sugar St.	≈ 2 km NE	584.5	251.6	1	1	20
Mazabuka	Kabika	Industrial	Nakambala Sugar St.	≈ 2 km SW	581.7	248.7	1	1	20
Maamba	house of El. Ngwata	Residential	Maamba Collieries	≈ 1.6 km SE	522.3	080.7	1	-	21
Maamba	Substation Kanzinze	Rural/ Industrial	Maamba Collieries	≈ 4 km SW	519.0	078.8	1	-	20
Maamba	Power st.	Industrial	Maamba Collieries	≈ 1km W	519.9	081.7	1	-	20
Lusaka	Cairo rd. (Phonix)	City centre	Traffic	Main road	637.5	295.4	1	1	24
Lusaka	Lumumba rd.	City centre	Traffic	Main road	637.2	295.1	-	1	24
Lusaka	ECZ. church rd.	City backg.			639.4	295.5	-	1	24
Ndola	Bwana Mkubwa train st.	Industrial	Bwana Mkubwa	≈ 1.6 km WNW	683.5	558.4	2	1	11,23,23
Ndola	BDM Na'Andwe Farm pl. 28	Rural	Bwana Mkubwa	≈ 1.2 km SW	684.8	556.9	1	1	21
Ndola	Bwana Mkubwa A6	Industrial	Bwana Mkubwa	≈ 2.4 km NW	684.0	559.8	1	1	21
Ndola	Savoy Hotel	City centre	Traffic	Main road	681.3	551.9	1	1	23
Ndola	Ndola Chemists	City centre	Traffic	Main road	681.0	552.5	1	1	22
Ndola	Mukuba Hotel	City/ Ind.	INDENI/ Bwana Mkubwa	≈1.5 km WNW	682.5	558.0	1	1	22

City/ Town	Site name (position)	Area	Emission source	Position to emission source	UTM co-ordinates		Passive samplers		Sampling period
					X	Y	SO_2	NO_2	(days)
Luanshya	Section 5 clinic	Township/ Industrial	RAMCZ (closed)	≈1 km W	650.0	548.3	1	1	23
Luanshya	Zaone-Chachacha cross	City centre	Traffic				-	1	24
Mufulira	Clinic 5	Township/ Industrial	ZCCM	≈ 1 km NW	633.2	614.8	1	-	4
Mufulira	Clinic 7	Township/ Industrial	ZCCM	≈ 4 km NW	630.5	616.2	1	-	22
Mufulira	Clinic 3	Township/ Industrial	ZCCM	≈ 1 km SW	633.0	613.8	1	-	4
Mufulira	Clinic 2	Township/ Industrial	ZCCM	≈ 2 km SW	632.5	612.7	1	-	22
Mufulira	Clinic 8	Township	ZCCM	≈ 4 km ESE	638.0	612.7	1	-	22
Nkana	Central shaft	Industrial	ZCCM/ Scaw	≈ 1 km NW	630.0	580.9	1	-	3
Nkana	Fire brigade	Industrial/ Township	ZCCM/ Scaw	≈ 0.5 km S	630.9	579.9	1	-	3
Nkana	Mumana Clinic C-7	Township	ZCCM/ Scaw	≈ 2 km SSE	632.6	578.9	1	-	23
Nkana	Wusakili hospital	Township	ZCCM/ Scaw	≈ 0.75 km E	631.6	580.2	1	-	23
Nkana	Nkana hospital	Town	ZCCM/ Scaw	≈ 1.5 km N	630.7	581.8	1	-	23
Nkana	Golf - club 900m east	Leisure	ZCCM/ Scaw	≈ 2.1 km W	628.6	581.5	1	-	23
Kitwe/ Nkana	MSD	Town	ZCCM/ Scaw	≈ 3.5 km N	631.4	583.6	1	-	23
Chingola	Faith Rise pre-sch.	Town/ Industrial	ZCCM	≈ 0.2 km E	593.0	612.8	1	-	20
Chingola	9th st. Clinic	Town	ZCCM	≈ 2 km SE	593.7	612.4	1	-	20
Chingola	Malemba prim. sch.	Township/ Industrial	ZCCM	≈ 1.2 km SW	591.8	612.0	1	1	22
Chingola	Chawama health c.	Township	ZCCM	≈ 3 km SW	591.5	610.3	1	-	22
Chingola	Ms. Chitah house	Residen-tial	ZCCM	≈ 4.5 km ESE	596.8	612.1	1	-	20

4 Measured concentrations

The passive SO_2 and NO_2 samplers were brought to NILU for analysis. The results from the analysis are presented in Table 2.

Table 2: Measured ground level daily concentrations averaged over the sampling period.

Sampling period				Site name (position)	UTM co-ordinates		Concentration (µg/m³)	
From:		To:			X	Y	SO_2	NO_2
date:	hr:	date:	hr:					
8.4.99	12:25	28.4.99	12:20	Mazabuka. Ngamona. house 2	583.8	250.6	10	5
8.4.99	12:42	28.4.99	12:35	Mazabuka. Kaleya Clinic	584.5	251.6	3	3
8.4.99	12:58	28.4.99	12:55	Mazabuka. Kabika	581.7	248.7	1	2
8.4.99	17:45	29.4.99	08:55	Maamba. house of Elpher Ngwata	522.3	080.7	2	-
9.4.99	10:50	29.4.99	16:07	Maamba. Substation Kanzinze	519.0	078.8	8	-
9.4.99	11:05	29.4.99	12:10	Maamba. Power station	519.9	081.7	20	-
10.4.99	10:00	3.5.99	09:40	Ndola. Bwana Mkubwa train st.	683.5	558.4	NR*	-
10.4.99	11:45	3.5.99	09:37	Ndola. Bwana Mkubwa train st.	683.5	558.4	-	2
22.4.99	14:10	3.5.99	09:38	Ndola. Bwana Mkubwa train st.	683.5	558.4	36	-
10.4.99	12:12	1.5.99	12:02	Ndola. BDM Na'Andwe Farm. 28	684.8	556.9	NR*	1
10.4.99	13:00	1.5.99	12:35	Ndola. Bwana Mkubwa A6	684.0	559.8	8	2
10.4.99	15:10	3.5.99	11:08	Ndola. Savoy Hotel	681.3	551.9	8	8
11.4.99	08:40	3.5.99	10:20	Ndola Chemists. Mr. Kosavi	681.0	552.5	8	10
11.4.99	09:10	3.5.99	09:55	Ndola. Mukuba Hotel	682.5	558.0	18	2
11.4.99	11:50	4.5.99	19:14	Luanshya. Section 5 clinic	650.0	548.3	<1	3
11.4.99	12:25	5.5.99	13:50	Luanshya. Zaone-Chachacha cr.			-	5
12.4.99	10:47	5.5.99	15:06	Nkana hospital	630.7	581.8	48	-
12.4.99	11:35	5.5.99	15:14	Nkana. golf club 900m east	628.6	581.5	188	-
12.4.99	11:50	15.4.99	09:15	Nkana. Central shaft	630.0	580.9	2330	--
12.4.99	12:00	15.4.99	09:30	Nkana. Fire brigade	630.9	579.9	6	-
12.4.99	12:10	5.5.99	14:58	Nkana. C-7 Mumana Clinic	632.6	578.9	<1	-
12.4.99	12:20	5.5.99	14:49	Nkana. Wusakili hospital	631.6	580.2	5	-
12.4.99	13:05	5.5.99	15:35	Kitwe. Mines Safety Dep.	631.4	583.6	4	-
13.4.99	11:14	17.4.99	14:30	Mufulira. Clinic 5	633.2	614.8	524	-
13.4.99	11:28	5.5.99	17:20	Mufulira. Clinic 7	630.5	616.2	94	-
13.4.99	11:42	17.4.99	14:21	Mufulira. Clinic 3	633.0	613.8	105	-
13.4.99	11:49	5.5.99	17:40	Mufulira. Clinic 2. Kariba st.	632.5	612.7	14	-
13.4.99	12:41	5.5.99	17:05	Mufulira. Clinic 8	638.0	612.7	1	-

Sampling period				Site name (position)	UTM co-ordinates		Concentration (µg/m3)	
From:		To:			X	Y	SO_2	NO_2
date:	hr:	date:	hr:					
14.4.99	10:12	4.5.99	16:23	Chingola. Faith Rise pre-sch.	593.0	612.8	37	-
14.4.99	10:25	4.5.99	16:30	Chingola. 9th st. Clinic	593.7	612.4	28	-
14.4.99	10:55	6.5.99	12:20	Chingola. Malemba prim. sch.	591.8	612.0	40	5
14.4.99	11:25	6.5.99	12:35	Chingola. Chawama health c.	591.5	610.3	NR*	-
14.4.99	11:50	4.5.99	16:39	Chingola. Ms. Chitah house	596.8	612.1	30	-
16.4.99	13:42	10.5.99	10:04	Lusaka. Cairo rd. (Phoenix)	637.5	295.4	21	20
16.4.99	15:12	10.5.99	10:12	Lusaka. Lumumba rd.	637.2	295.1	-	19
16.4.99	15:40	10.5.99	08:55	Lusaka. ECZ. church rd.	639.4	295.5	-	9

*NR: Non-reliable result in analysis.

5 Air quality guidelines

The air quality guidelines for SO_2 and NO_2 from the Norwegian Pollution Control Authority (SFT, 1992) and World Health Organisation (WHO, 1987) are given in Table 3.

Table 3: Air quality guidelines for SO_2 and NO_2. Unit: µg/m³.

Component	Control Authority	Period		
		24 h	6 months	Year
SO_2 health	WHO	125		50
SO_2 vegetation	WHO	100		30
NO_2 health	WHO	150		
NO_2 vegetation	WHO			30
SO_2 health	SFT	90	40	
SO_2 vegetation	SFT	50		20
NO_2 health	SFT	75	50	
NO_2 vegetation	SFT			30

6 Discussions and conclusions

The averaging time of the measured concentrations corresponds to the sampling time, which was for the majority of the sites between 20 and 24 days. Exceptions were made for 4 sites, where the sampling time was 3 to 4 days, due to the high ambient air concentrations expected. The measured concentrations are compared both with the 24 hours averaging time guideline, which represents a non-conservative comparison, and with the 1 year guideline, which represents a conservative comparison.

In Mazabuka SO_2 and NO_2 concentrations were measured at 3 sites. The measured concentrations for both compounds are low, but higher than background concentrations, indicating some emissions in the area. The highest SO_2 and NO_2 concentrations, 10 and 5 $\mu g/m^3$, respectively, were measured at Ngomona site, about 1 km northwest of the sugar factory.

In Maamba, 3 sites measured SO_2 concentrations. In this area the wind blows along the valley (SW-NE), predominantly from NE. The site located in a residential area, outside the main wind directions, about 1.6 km southeast of an open pit mine under spontaneous combustion, measured a typically SO_2 background concentration of 2 $\mu g/m^3$. The other two sites were located along the valley, downwind of the open pit mine under spontaneous combustion. The closest site, about 1 km west of the mine, measured 20 $\mu g/m^3$ of SO_2, clearly indicating the existence of SO_2 emissions in the area. The third site, located further downwind of the mine, about 4 km southwest, measured as expected a lower concentration of SO_2 (8 $\mu g/m^3$). All measured concentrations were well under the air quality guidelines, both for daily and one year average. Nevertheless, under light stable and stable conditions, occurring most frequently during the winter and night time, high concentrations of SO_2 may occur several kilometres downwind of the open pit mines under spontaneous combustion.

At the two sites in Ndola city centre the measured SO_2 concentrations indicate that there are emissions of SO_2 in the area. The background concentration in the Copperbelt area is expected to be higher than in Lusaka, due to the industrial activity that characterises this area, but not as high as 10 $\mu g/m^3$. The concentration measured at the Mukuba hotel, located 1.5 km west-northwest of the INDENI Petroleum Refinery and about 2.5 km west of Bwana Mkubwa, indicate emissions of SO_2 in the area and the possible occurrence of episodes with high SO_2 concentrations, depending on the emissions from INDENI and Bwana Mkubwa and the wind direction. The concentration measured from 22/4/99 to 3/5/99 at Bwana Mkubwa train station, about 1.6 km downwind from Bwana Mkubwa acid plant, indicates emissions of SO_2 in the area. This sampling period occurred immediately after the testing of the new cooler, during which large amounts of SO_x were emitted from the cooler, as a low fugitive source. The analysis of the sampler that should have sampled SO_2 during the last days of the testing period (from 10/4/99) gave non-reliable results. The same happened with the sampler placed in a farm, about 1.2 km southwest of Bwana Mkubwa acid plant. The sampler placed at Bwana Mkubwa A6, about 2.4 km northwest of the acid plant, gave the same level of SO_2 concentration as the background concentration measured in the centre of Ndola, probably due to the seldom occurrence of winds from south and southeast during the sampling period.

The highest NO_2 concentrations in Ndola were measured in the city centre, due to the traffic, but they are still well below the WHO air quality guideline for health. The Concentrations measured at the other 4 sites in Ndola were very low; typically background concentrations, indicating no exposure to traffic or to other NO_2 sources in the area. The NO_2 measurement at Mukuba hotel, about 1.5 km downwind of INDENI Petroleum Refinery would be expected to be higher if the refinery re-opened during the sampling period, after the shutdown period during ECZ visit the 10 April 1999.

In Luanshya the SO_2 concentration measured was very low, as expected, due to the temporary shutdown of the smelter. The 2 NO_2 concentrations measured in Luanshya were very low. The NO_2 concentration at Zaone - Chachacha crossroad was higher due to the traffic.

In Nkana, as opposed to Mufulira, there are no townships in the main downwind direction from the industrial area. The measured SO_2 concentration in the Central shaft site, inside the smelter's area, is extremely high (2330 µg/m³), due both to the proximity of the smelter and to the fact that the wind blew much more often to its direction, than to the Fire Brigade site or to the Wusakili hospital site. These measurements indicate that in the periods the wind blows from south or from northwest, Nkana West and Wusakili, respectively, will be exposed to very high concentrations of SO_2. This was not the case during the 3 days of measurements at the Central shaft and at the Fire brigade, neither during the 23 days sampling period for the other sites. The SO_2 concentration measured over 23 days at the Nkana hospital site was close to the WHO air quality guideline for one year average. The measuring site located in the Golf camp, in the main downwind direction, 2.1 km from the smelter, registered a high SO_2 concentration of 188 µg/m³, above WHO air quality guidelines for daily and one year average.

In Mufulira the measured SO_2 concentrations indicate that there are very large emissions of SO_2 in the area. The sites located 1 km from the source in the northwest and southwest directions, both inside townships, measured 524 and 105 µg/m³ SO_2, respectively. The first concentration is 4 times higher than the WHO air quality guideline for health of 125 µg/m³ for 24 hours and 10 times higher than the guideline for one year, while the second is close to the guideline for 24 hours and 2 times higher than the guideline for one year. The SO_2 concentration dropped as expected between 1 and 4 km from the source along the northwest direction, probably due to the importance of the fugitive emissions for the measured concentrations close to the source. Nevertheless, the concentration measured 4 km northwest of the smelter is still considerably high. It is close to the WHO air quality guideline for 24 hours and above the guideline for one year. The site located 2 km southwest of the smelter measured a much lower concentration than the one at 1 km distance from the source. This difference is probably due both to the higher distance from the source and to the location about 10 degrees further east (see location of sampling sites in appendix A). The Clinic 8 site is located about 4 km upwind of the smelter, giving an extremely low background concentration of SO_2 for Mufulira, most probably not representative for the year.

In Chingola the measured SO_2 concentrations indicate that there are emissions of SO_2 in the area. The SO_2 concentration measured at Faire Rise pre-school site, located about 200 m east of the tank of the tailings leach plant, was expected to be higher, due to the proximity of the tank. Nevertheless, in days with stationary winds from west, it is likely to register SO_2 concentrations above the WHO air quality guidelines at this site. The SO_2 concentrations measured 2 km southeast and 4.5 km east-southeast of the plant were 28 and 30 µg/m³, respectively. The similarity in concentration level between the two sites, despite the distance to the source, may be explained by the fact that the closest site is still influenced by the low emissions from the tank of the tailings leach plant, while the other site is more exposed to the concentrator stack emissions. The Malemba primary school site

registered the highest concentration of SO_2, 40 µg/m3, and a NO_2 concentration of 5 µg/m3. This site is very close to an open-air scrap depot, where copper is melted. The emissions from such local activities contribute to higher SO_2 and NO_2 concentrations than would be expected if only the plant emissions and the low local traffic activity would be considered.

The SO_2 concentration measured at Cairo rd. in Lusaka indicates some SO_2 emission source in the neighbourhoods. SO_2 background concentrations in Lusaka are expected to be lower, probably under 5 µg/m^3, as measured in October 1998 (Guerreiro and Sivertsen, 1998). The measured NO_2 concentrations indicate traffic emissions, specially at Cairo rd., in the city business centre, and at Lumumba rd., with heavy traffic.

7 References

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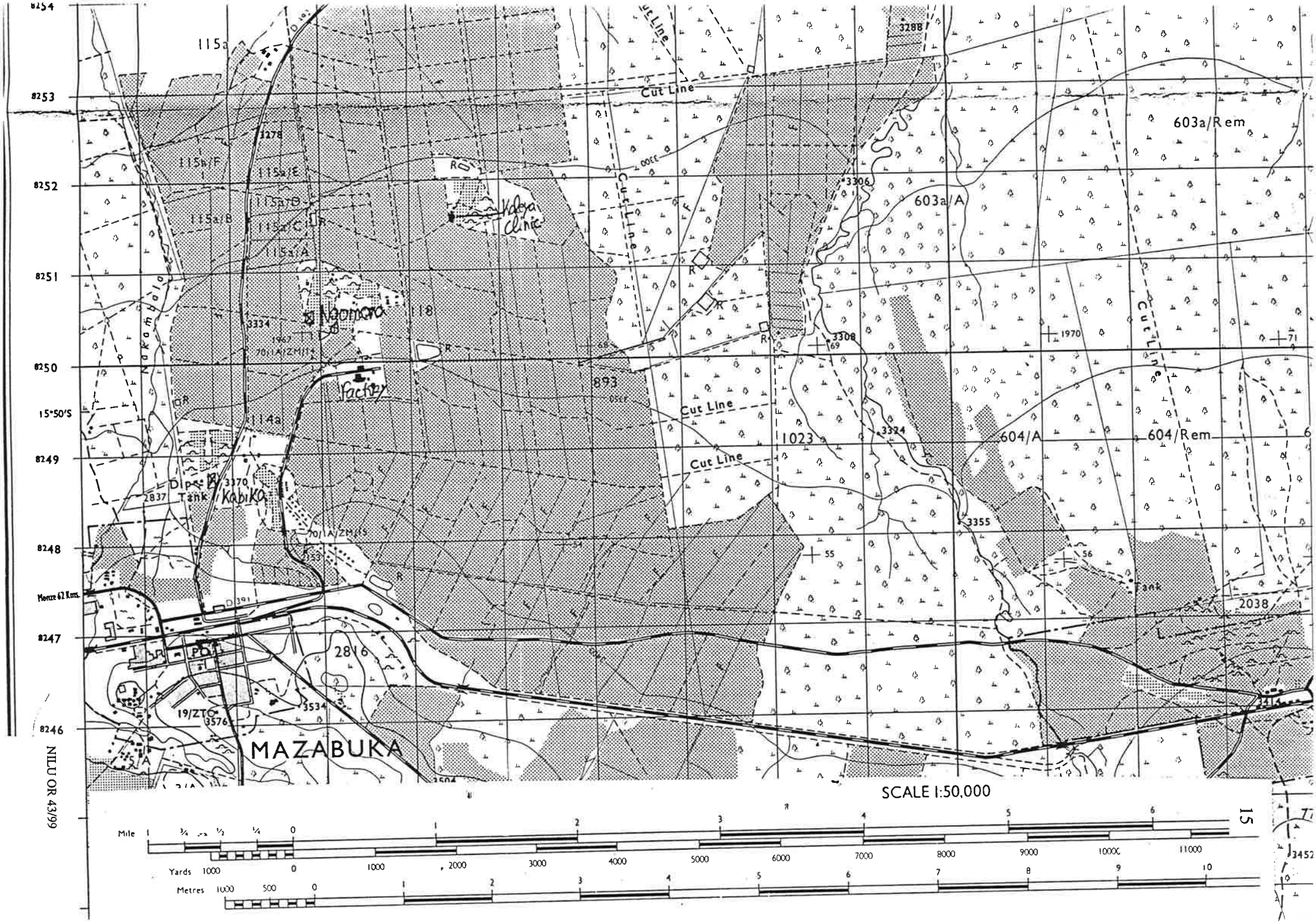
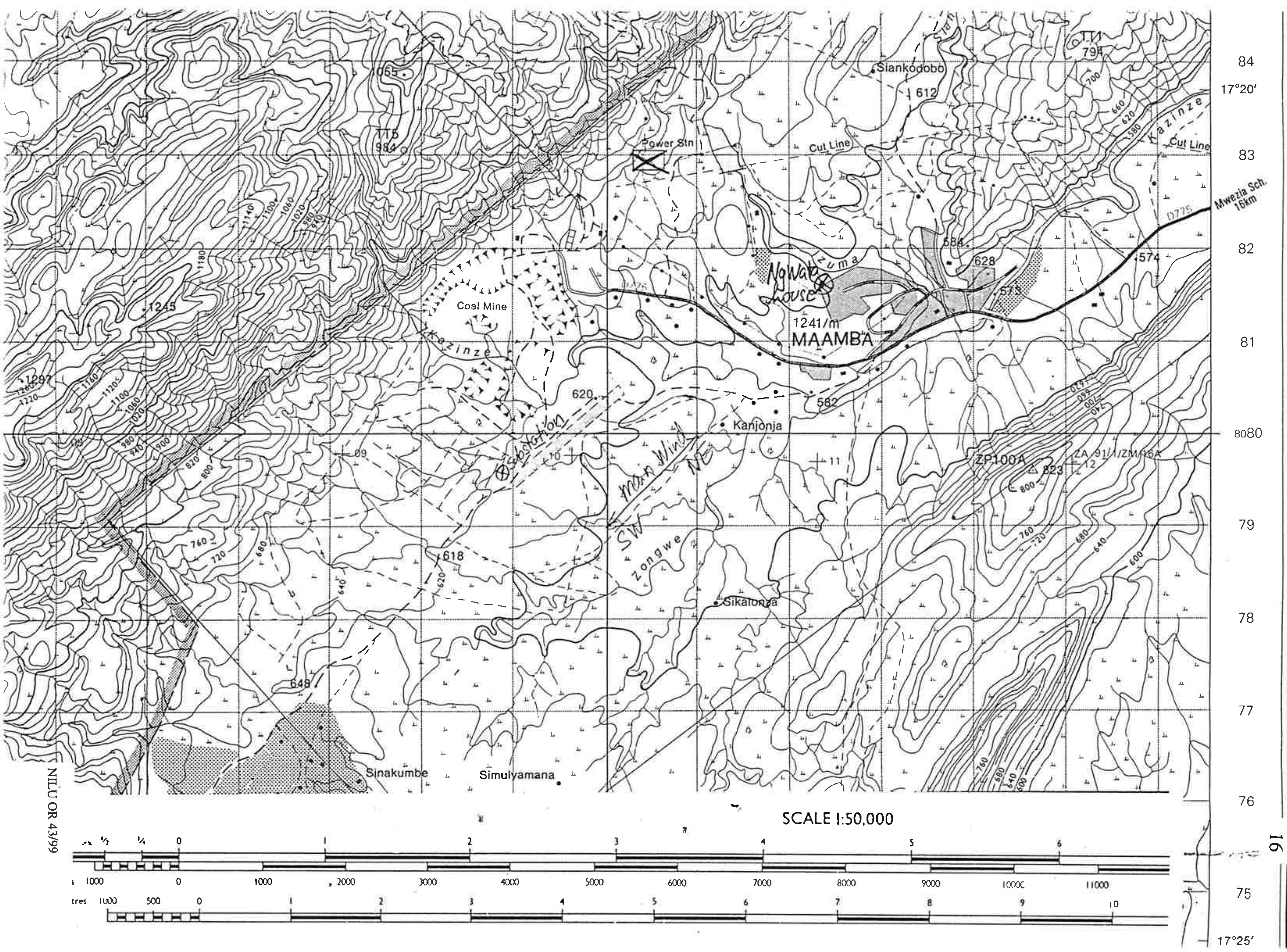
Appendix A

Location of sampling sites


8254
8253
8252
8251
8250
15°50'S
8249
8248
8247
8246
115a
115a/F
115a/E
115a/D
115a/B
115a/C
115a/A
Cut Line
603a/Rem
603a/A
Kabya clinic
Nakambala
Namora
Factory
893
114a
1023
604/A
604/Rem
Dip
Tank
Kabika
Mazabuka 62 Kms.
PO
2816
MAZABUKA
19/ZTO
3288
3306
3308
3324
3355
1970
2038
SCALE 1:50,000
Mile
Yards
Metres
15

NILU OR 43/99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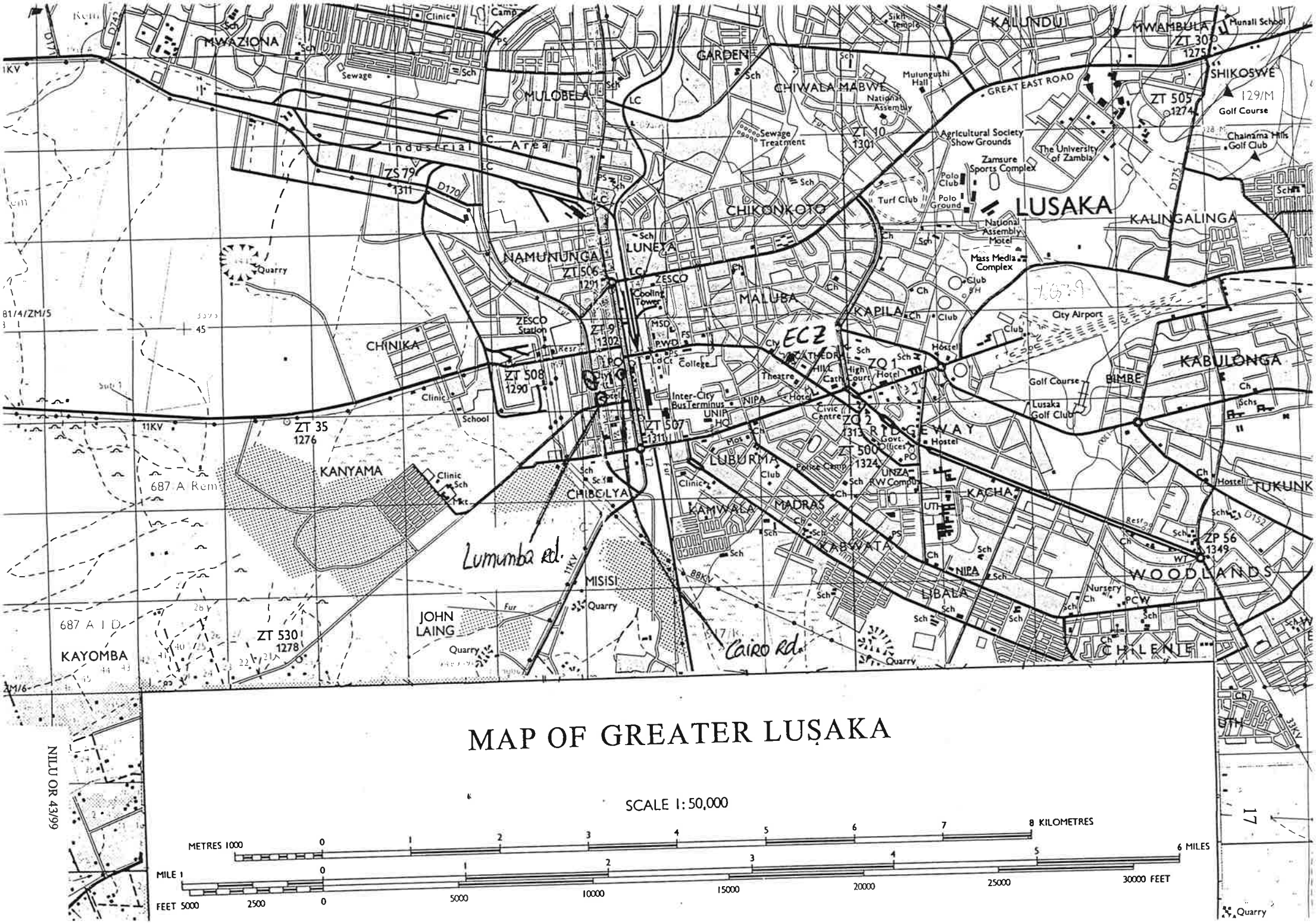
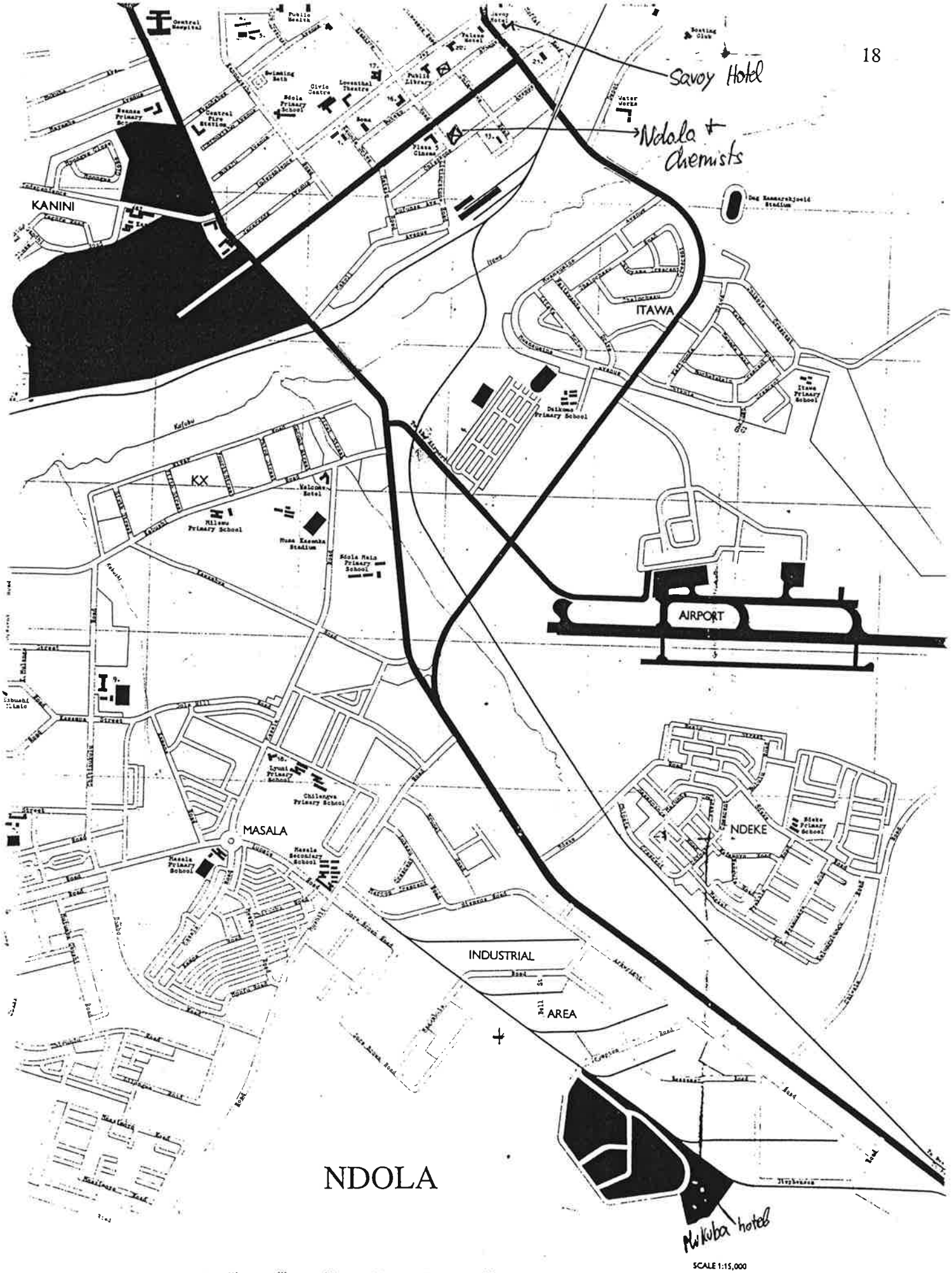
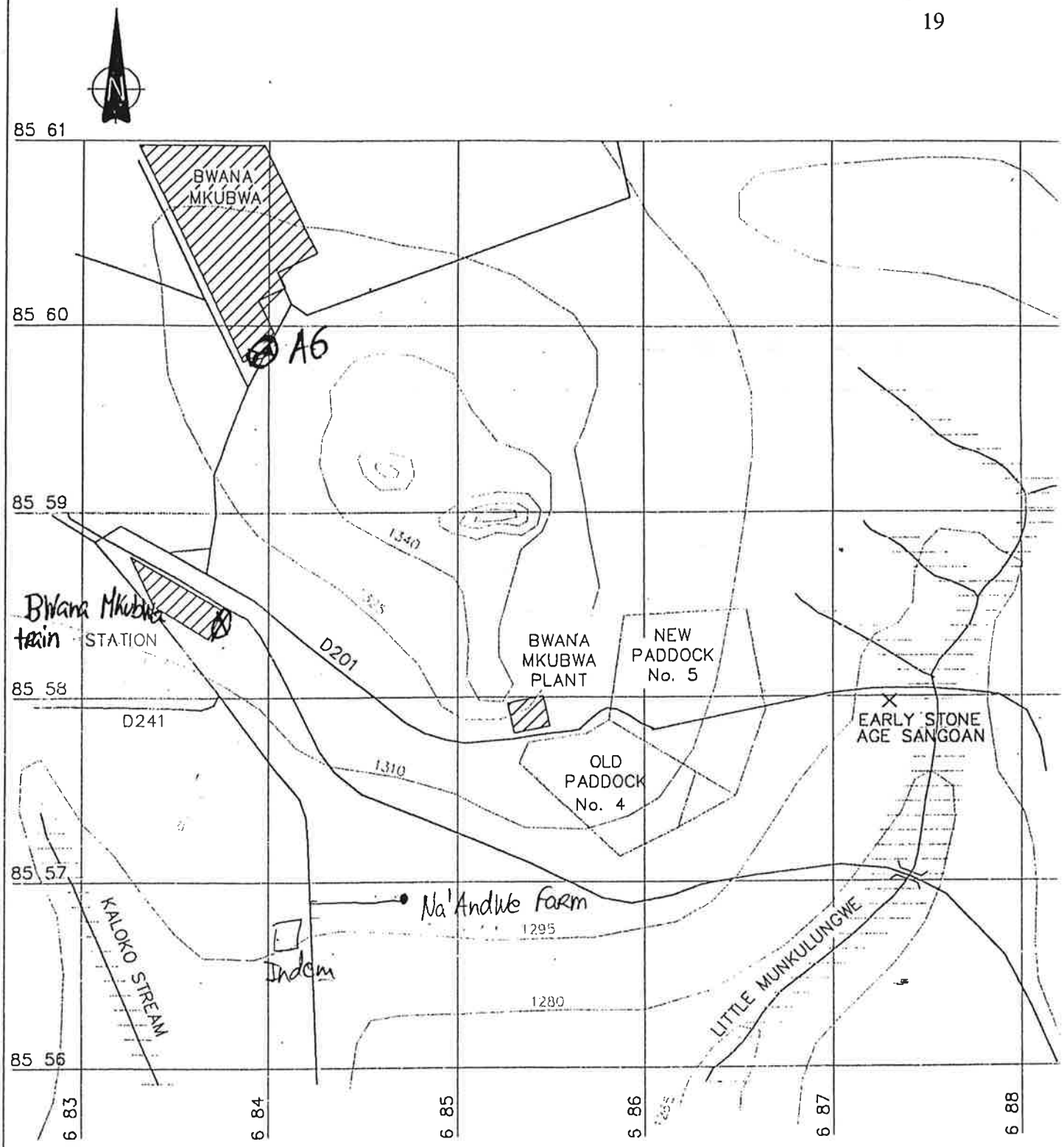
Power Stn
Cut Line
Siankodobo
Kazinze
Mweezia Sch. 16km
Kanjonja
Sikalonza
Sinakumbe
Simulyamana
Zongwe
Ngwata house
1241/m
Substation
main Wind
SW
NE
ZP100A
ZA 91/1/ZM/16A
TT1
TT5
1055
984
1245
1297
794
612
584
628
573
574
582
620
618
648
823
84
83
82
81
8080
79
78
77
76
75
17°20′
17°25′



MAP OF GREATER LUSAKA


Savoy Hotel
Ndola + Chemists
KANINI
ITAWA
KX
AIRPORT
MASALA
NDEKE
INDUSTRIAL
AREA
NDOLA
Mukuba hotel
SCALE 1:15,000



BWANA MKUBWA MINING LTD.

ENVIRONMENTAL PROJECT BRIEF

FIGURE 2

LOCATION PLAN

NDOI A

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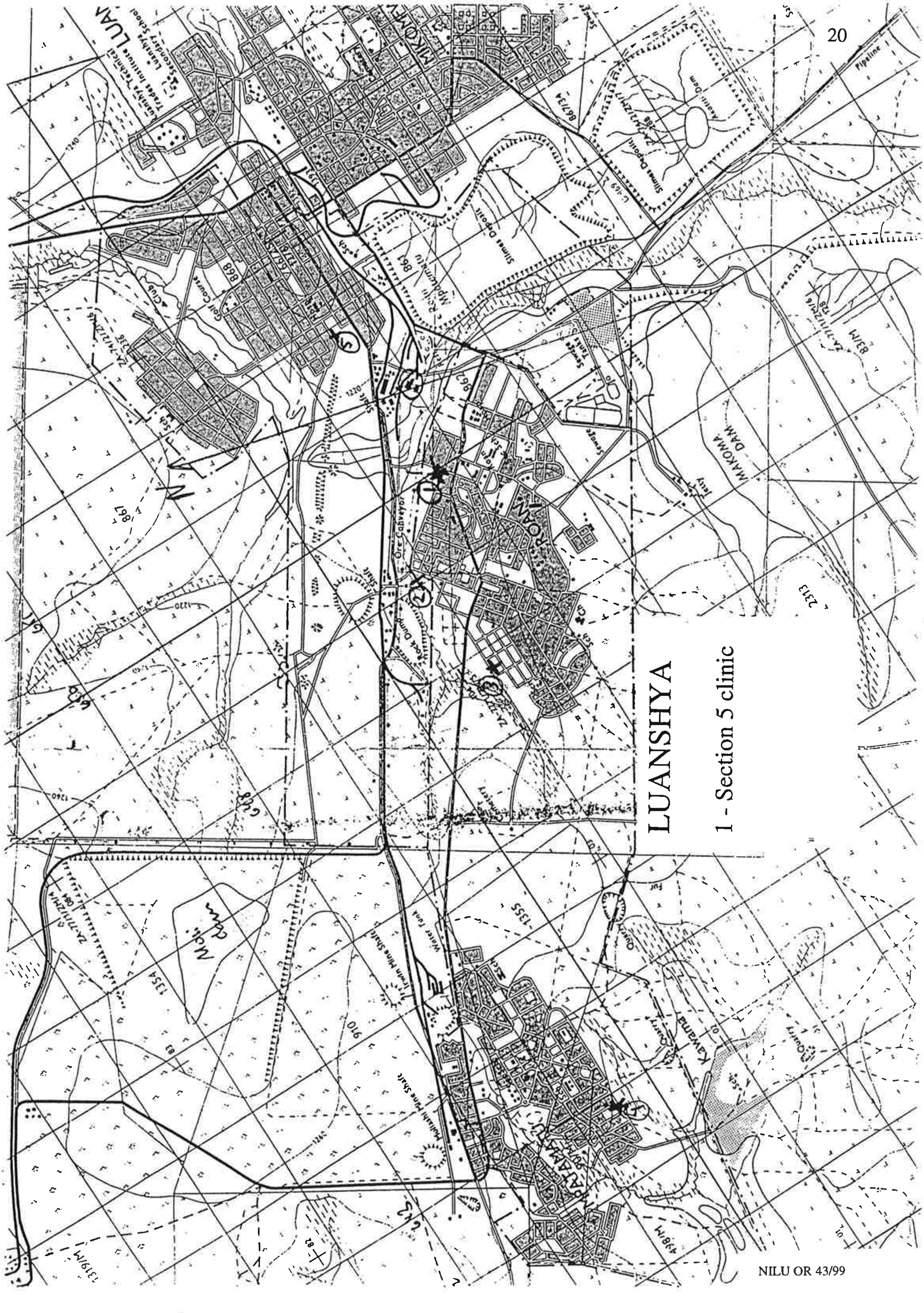
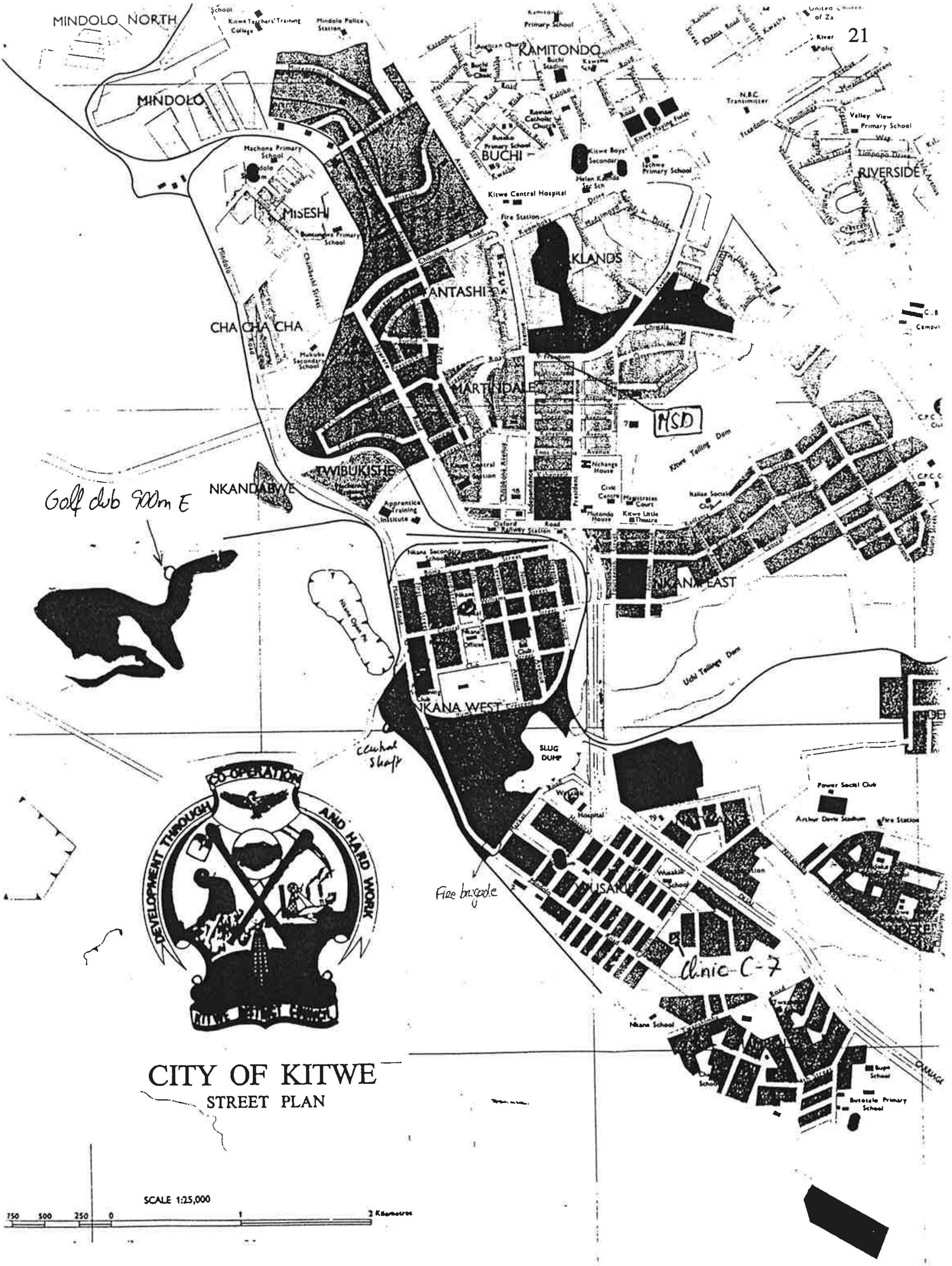
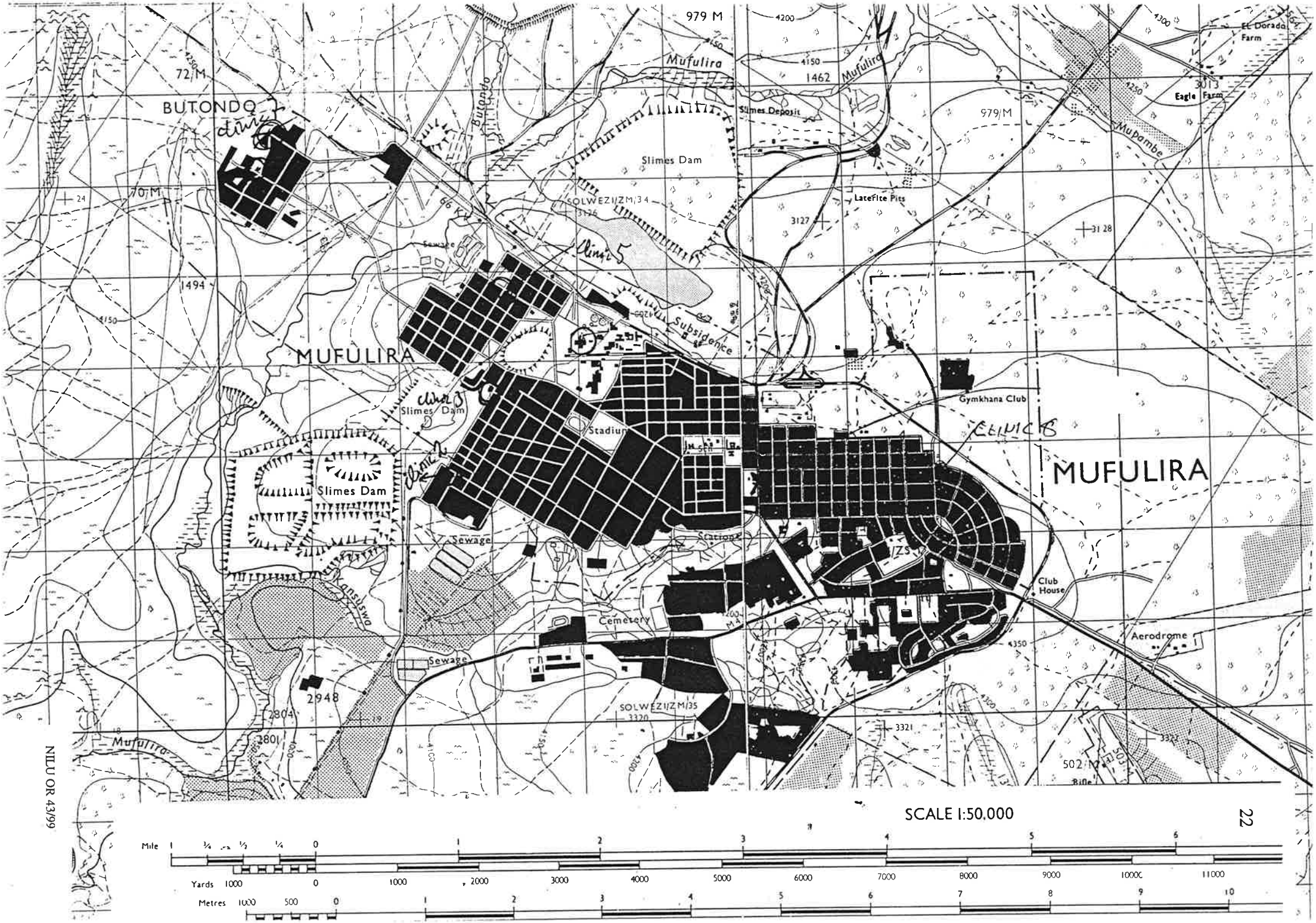

LUANSHYA
1 - Section 5 clinic
MAKOMA DAM
ROAN
MPATAMATU
Kawama
Quarry
Sewage
Sewage Tanks
Slimes Deposit
Golf Course
Club
Ore Conveyor
Rock Dump
Shaft
Water Tank
Irwin Mine Shaft
Mulbashi Mine Shaft
Jetty
Pipeline
Luanshya Technical Trades Institute
Luanshya Secondary School
MIKOMFWA


MINDOLO NORTH
MINDOLO
MISESHI
CHA CHA CHA
CHAMBISHI
KAMITONDO
BUCHI
KITWE CENTRAL HOSPITAL
RIVERSIDE
PARKLANDS
FANTASHI
MARTINDALE
TWIBUKISHE
NKANDABWE
NKANA EAST
NKANA WEST
SLUG DUMP
CHIMWEMWE
Kitwe Tailing Dam
Uchi Tailings Dam
Power Social Club
Nkana School
Golf club 900m E
Central shaft
Fire brigade
MSD
Clinic C-7
CO-OPERATION
DEVELOPMENT THROUGH
AND HARD WORK
CITY OF KITWE
STREET PLAN
SCALE 1:25,000
750
500
250
0
1
2 Kilometres



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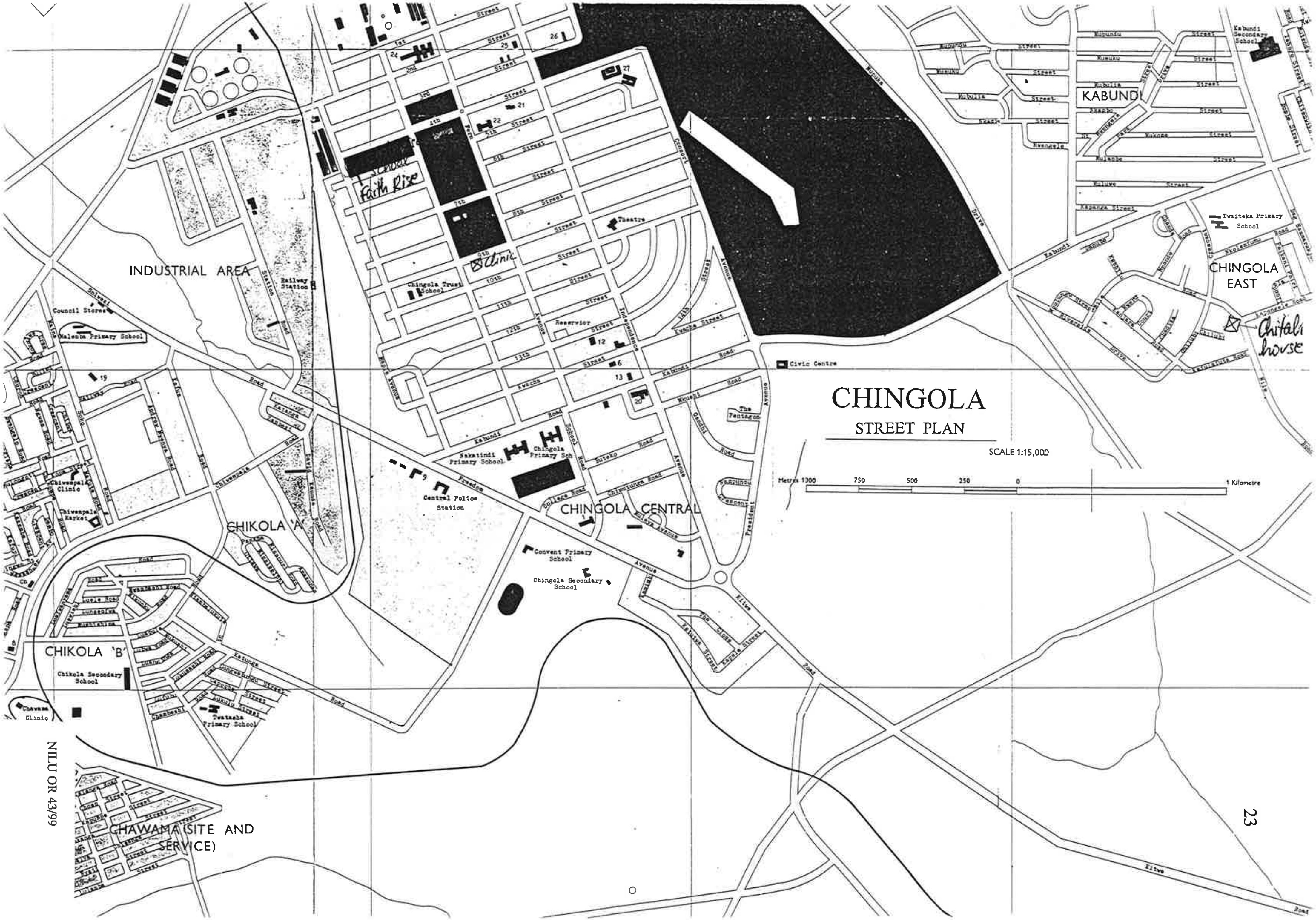
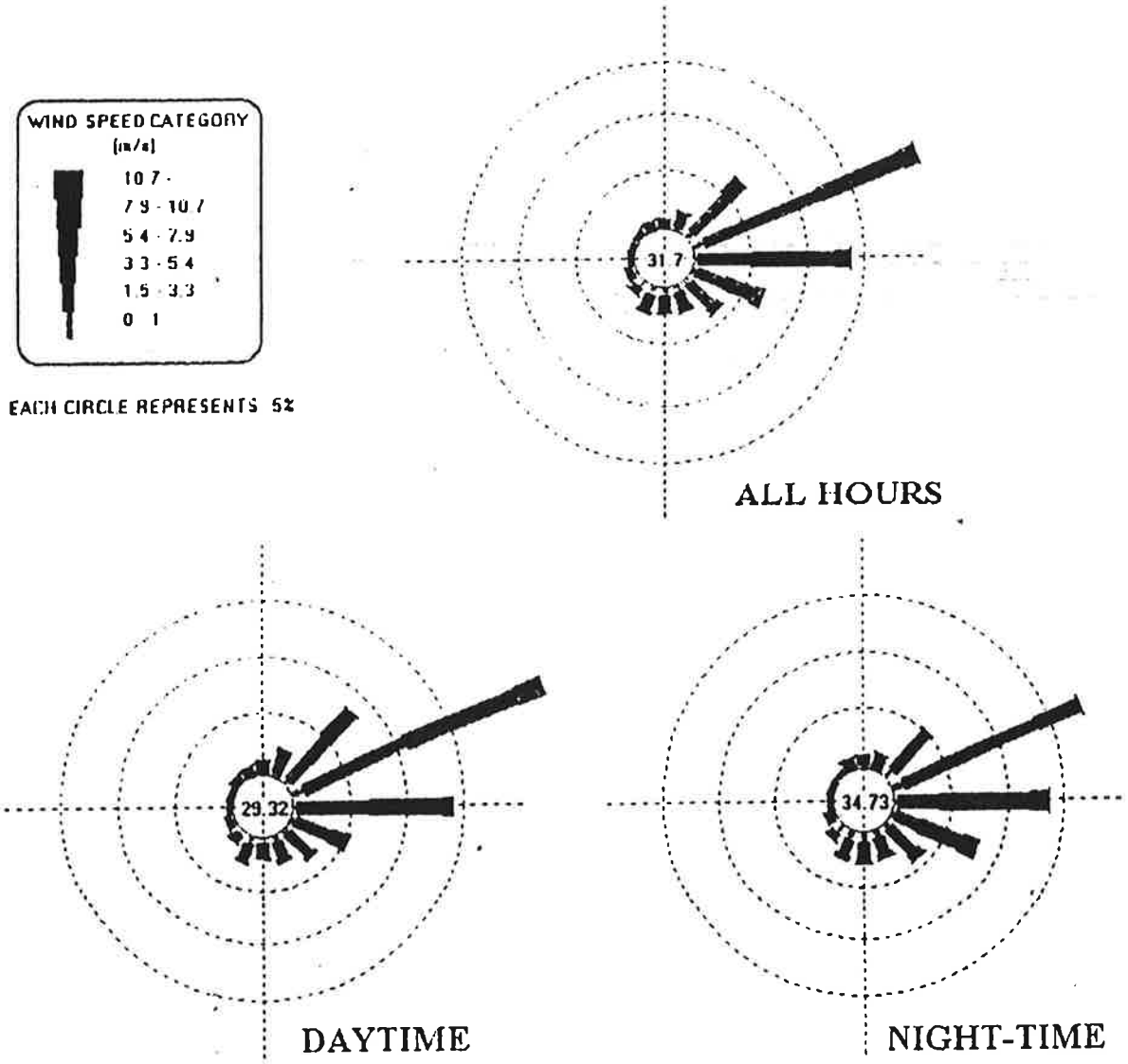
NILU OR 43/99


CHINGOLA
STREET PLAN
SCALE 1:15,000
Metres 1000
750
500
250
0
1 Kilometre
INDUSTRIAL AREA
KABUNDI
CHINGOLA EAST
CHINGOLA CENTRAL
CHIKOLA 'A'
CHIKOLA 'B'
CHAWAMA (SITE AND SERVICE)
Civic Centre
Theatre
Reservior
Railway Station
Council Stores
Chingola Trust School
Nakatindi Primary School
Chingola Primary Sch
Central Police Station
Convent Primary School
Chingola Secondary School
Chikola Secondary School
Chawama Clinic
Twatasha Primary School
Chiwempala Clinic
Chiwempala Market
Kabundi Secondary School
Twaiteka Primary School
The Pentagon
Faith Rise
Clinic
Chitali house

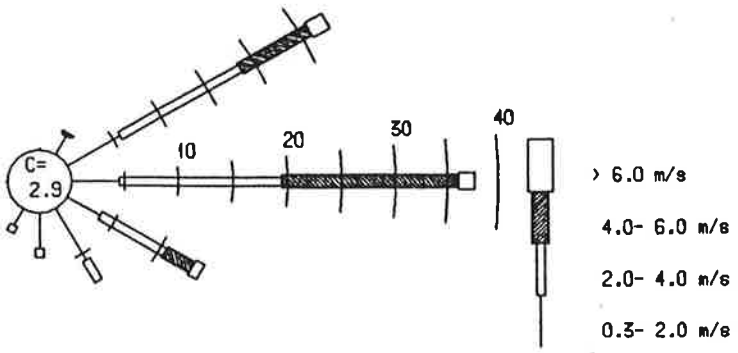
Appendix B

Wind roses

Wind roses for 1995 at Mufulira Smelter



Wind rose for 01.09.98 - 24.09.98 at Mufulira Smelter



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Scientific Report		ISSN 0807-7207	
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TITLE	PROJECT LEADER
Passive sampling of SO2 and NO2 ambient air concentrations in Zambia April 1999	Cristina Guerreiro NILU PROJECT NO. O-99008
AUTHOR(S) Cristina Guerreiro	CLASSIFICATION * A CONTRACT REF. Christel Benestad (SFT)

REPORT PREPARED FOR
Norwegian State Pollution Central Authority (SFT) and
the Environmental Council of Zambia (ECZ)

ABSTRACT
As part of a second screening study to develop a plan for ambient air pollution monitoring in Zambia (Guerreiro, 1999), 34 SO_2 and 17 NO_2 passive samplers were placed inside the cities of Lusaka and Ndola, in Maamba and Mazabuka and around industries in the Copperbelt area. The passive samplers were installed in field to measure ground level concentrations as a result of emissions from traffic and industrial activities. SO_2 is particularly a problem in the Copperbelt area, due to the high industrial activity that characterises this area. The World Health Organisation's (WHO) air quality guideline for SO_2 is exceeded in Mufulira and Nkana, downwind of the smelters. While in Mufulira these concentrations can have a very serious impact on both vegetation and population living downwind of the smelter, in Nkana the population is less often exposed to extremely high SO_2 concentrations, since the townships are not located on the prevalent downwind direction from the industry. The SO_2 ambient air concentrations measured in Maamba, Ndola and Chingola were below the WHO air quality guideline. Nevertheless under episodes with high local emissions of SO_2 and / or poor meteorological dispersion conditions in these areas, high concentrations of SO_2 are likely to occur in neighbouring areas, exceeding the WHO air quality guideline. The measured NO_2 concentrations are well below the WHO air quality guideline and do not represent presently a motive of concern

NORWEGIAN TITLE
Passiv prøvetaking av SO_2 og NO_2 luftkonsentrasjoner i Zambia. September 1998

KEYWORDS		
Passive sampling	Zambia	Screening study

ABSTRACT (in Norwegian)

* *Classification*
- *A Unclassified (can be ordered from NILU)*
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- *C Classified (not to be distributed)*