THE DETERMINATION OF A DATABASE WITH RESPECT TO THE TRANSPORTATION OF HAZARDOUS MATERIALS BY ROAD IN THE PWV AREA

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A project report submitted to the Faculty of Engineering, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering

Johannesburg, 1992

ABSTRACT

The formulation of effective safety measures to counteract the potential for disaster presented by the transportation of hazardous materials requires that reliable data is available as to the nature and extent of such traffic. Such data is currently unavailable and a roadside interview survey was conducted in the PWV area in order to ascertain the quantities and type of material being transported locally, the routes used, the types of vehicles and containers involved, and compliance with existing regulations. It was found that of the 1068 vehicles surveyed carrying hazardous material, only 22% fully complied with existing legislation.

A risk assessment model for use by both operators and authorities is then developed, in which the survey data is input to determine the least risk route between Johannesburg and Sasolburg.

DECLARATION

I declare that this project report is my own work. It is being submitted for the degree of Master of Science in Engineering in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

9TH day of December 1992

ACKNOWLEDGEMENTS

I am indebted to my Supervisor Dr. R F del Mistro for his help and comment during this study.

The financial support of the Department of Transport: Directors of Land Transport, in providing research funds to undertake data collection surveys is acknowledged.

The assistance given by J C Hillman during the first two stages of the study is gratefully appreciated.

The constant support and encouragement of the Directors of Stanway Edwards Associates Inc. is gratefully acknowledged.

My sincere thanks go to Mrs T V Scholtz for the typing of this manuscript.

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1. INTRODUCTION

The transportation of hazardous materials on the roads of South Africa presents special problems from the standpoint of safety, not because the probability of accidents is greater but because the results of such may be far more severe than those of the more usual type of accident.

Accurate statistics on the number of accidents in South Africa involving vehicles carrying hazardous materials are unavailable. However, studies undertaken by the United States Department of Transport (1) in 1977 found that less than 0,1 per cent of the total traffic death toll was attributable to the transportation of hazardous materials.

The possible consequences of such incidents should not, however, be viewed solely in terms of human life. Factors such as environmental pollution and property damage are also pertinent issues, as is the potential for chaos brought about by the possible need to evacuate whole communities in certain instances.

Accident risk due to the transportation of such materials is an inherent problem and South Africa has so far been fortunate in not having been exposed to any major incidents. However, in relation to total accident costs due to general transportation it would appear to be a minor one. Accident probability is related to exposure, and the case of hazardous cargoes is no exception. Public concern, though, has been fueled by the much publicised incidents on Van Reenen's and Majuba Passes in 1987, and such fears need to be allayed.

Up until July 1987 only two classes of hazardous substances were controlled by South African law, these being explosives and radio-active materials. The transportation of flammable liquids in most areas are subject to Municipal by-laws but these regulations lacked uniformity as well as clarity.

Regulations governing the conveyance of dangerous commodities, other than explosive and radio active ones, were published in the Government Gazette No. 10818 on 10th July 1987 after some 10 years of deliberation. These regulations cover such aspects as labelling, driver fitness training and the reporting of accidents.

The Government's policy of transport deregulation will allow more operators to become involved in the handling of hazardous substances. Such operators may be difficult to trace and thus train in the proper handling of hazardous materials. Since deregulation in the United States, the number of trucking companies increased by 61 per cent between 1980 and 1985 and is still growing (2). There is no reason to think that the situation will be any different in South Africa. Deregulation tends to foster fierce competition, and one result could clearly be neglect in maintaining safety. To compound this, some safety experts argue that temptations to cut corners on safety are attractive due to the fact that enforcement is likely to be inconsistent and the proposed penalties for infringement are relatively light.

New chemicals are becoming more complex and potentially more dangerous every year and are being generated at an accelerated pace. Approximately 700 substances are covered by the new regulations, whilst the Port Authority of New York, USA Hazmat Regulations Manual has recorded over 500 new entries since the Bophal incident in India in 1983 (3).

In order that a community can assess the potential risk and prepare itself to deal with the emergencies which result from vehicular accidents involving these materials, it is imperative that the what, where and how of hazardous substance transportation be established.

The methodology adopted for the study centred around a practical approach in which physical surveys were undertaken rather than relying on existing resources, which were potentially unreliable and far from complete.

The project report has been divided into four sections namely:

Section 1	-	Data Collection.
Section 2	-	Modelling of flows.
Section 3	-	Risk Assessment Model.
Section 4	-	Overall Conclusions.

Section 1 documents the study goals, methodology and initial findings of the surveys, including the level of compliance with the regulations.

Section 2 documents the construction of a computer model of the study area, the presentation of origin/destination matrices and the graphical production of a network of routes indicating the flow rates of such hazardous commodities along these routes.

In Section 3 a model is developed which will assess on a rational basis the risk of a specific cargo on a specific route. The data requirements for the model are minimal thus allowing both smaller communities and transporters to determine the risk associated with a route with relative ease.

SECTION 1

DATA COLLECTION SURVEY

2. STUDY GOALS AND OBJECTIVES

The goal of the project was to provide a data base on the movement of hazardous cargoes on the roads of the PWV area.

The objectives of the study were to:

i. Identify the type and quantity of materials being transported.

ii. Ascertain the methods of containment and/or packaging as well as the types of vehicle being used.

iii. Establish the origin and destination of the different materials being transported.

iv. Identify the routes most commonly used.

v. Test the compliance and effectiveness of current regulations as per Government Gazette R1462 of 10th July 1987.

3. STUDY METHODOLOGY

3.1 STUDY AREA

As noted earlier, the study focused on the PWV area. The reason for this is that the major industrial and commercial centres together with high densities of populations are located in this area. A majority of the major inter-urban links are surrounded by major developments and thus offer a high risk of exposure to a major incident.

The Study Area consisted of the greater PWV area. The reason for this is that the major industrial and commercial centres together with high densities of populations are located in this area. A majority of the major inter urban links are surrounded by major developments thus increasing the exposure to a major incident.

The Study Area consisted of the greater PWV area extending from Zambezi Drive on the northern outskirts of Pretoria to Sasolburg in the South and from Randfontein in the West to Putfontein in the East. A map of the Study Area is shown in Figure 1.

This area contains a multitude of different land uses whose economic structure includes:

i. The Central Areas of Johannesburg and Pretoria.

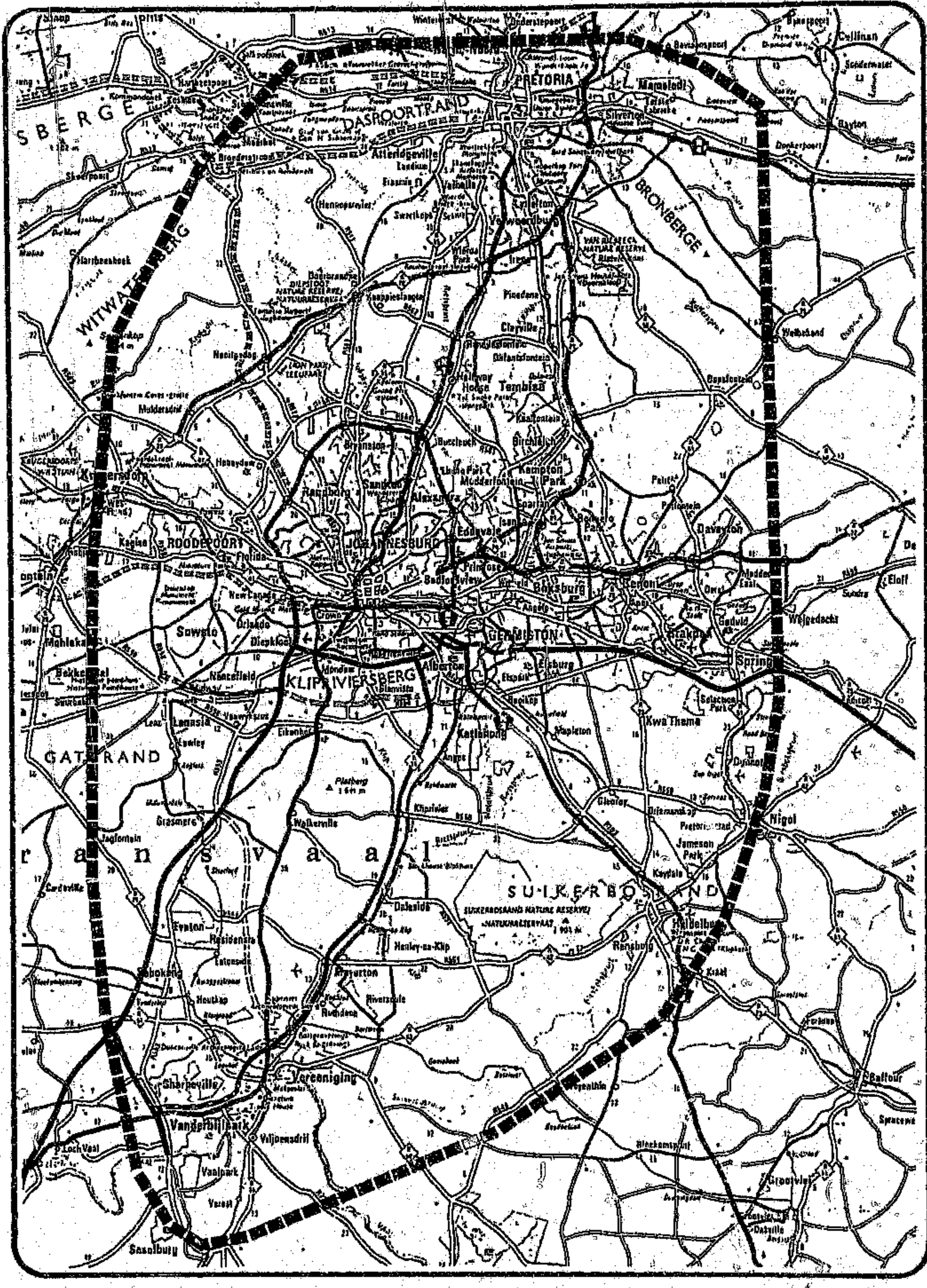
   These areas have the greatest concentration of offices and retail outlets.

ii. Industrial/Commercial Corridors.

   These areas contain significant concentrations of manufacturing industries and allied activities such as Sasolburg, Vanderbijl Park, Spartan, Isando, Germiston, Modderfontein and Industria. The corridors are served by major transport routes (roads and railway).

iii. Major Town Centres Outside the Central Area.

   These areas are retailing and office centres, principally serving the needs of the suburbs although some also serve a wider national or international role. The centres are also related to major road and rail links.



	STUDY AREA	**Figure No.** 1

iv. Rural Areas.

These rural areas are characterised by low density agricultural land such as Bapsfontein.

In recent years the process of decentralisation has led to the larger national companies relocating from the central areas to more rural areas alongside the major inter-urban routes. Examples of this type of situation can be seen in Midrand.

v. High Density Residential Developments.

These satellite the major town centres and include such townships as Soweto and Tembisa.

The number of persons residing in these areas is a matter of speculation and the areas are poorly serviced in terms of fire services etc.

As can be seen in Figure 1 the whole area is well developed and presents a number of problems to the transportation engineer in terms of hazardous material accident mitigation.

3.2 DATA COLLECTION

As stated in the introduction, the basic modus operandi of the Study was to take a practical approach.

Limited information with respect to origin and destination and chemicals moved could be obtained from certain responsible chemical and oil companies but, in general, response rates to information surveys are low. A request for such information was published by the CHEMSA magazine in 1982 achieved a nil return.

To date no previous work has ever measured the extent of the movement of these hazardous commodities on the roads of South Africa. Previous work on the subject had relied on information tendered by industry which has largely been incomplete and unspecific because of such factors as the unknown number of smaller operators involved and the restriction on information concerning strategic materials such as fuels.

However, one of the objectives of the Study was to test compliance with the recently introduced legislation. The only way to accurately determine the compliance was to intercept these vehicles by means of a roadside interview.

Once the method of data collection had been decided upon, there arose the problem of where to survey. There are thousands of routes within the Study Area all of which could be selected if a random selection procedure was followed.

However, owing to the increased travel costs on urban routes, operators tend to keep to the major routes. With this in mind a coarse network of routes was identified, in which the major chemical industrial areas were superimposed on the network.

In order to intercept the Internal-Internal and the Internal-External movements, roadside interview stations were placed at the major access points to the industrial centres of Modderfontein, Chloorkop, Sasolburg and Industria.

To sample the External-External and the External-Internal movements, roadside interview stations were placed on major routes known to be frequented by vehicles carrying hazardous chemicals.

From the above it can be deduced that the sampling process was in fact biased, as a random sampling procedure could have selected routes which carry little or no hazardous material.

In addition to the roadside interviews, manual classification counts were made in order to determine the composition of traffic on the routes and also to provide control totals so that estimates could be made of the total number of vehicles carrying hazardous material in any given mix of traffic.

Roadside interviews and manual classifications were conducted at 13 points. The positions of the roadside interview stations are detailed in Table 1 and illustrated on Figure 2.

In addition to these 13 stations, three additional manual classifications were made where the type of vehicle and United Nations Hazchem number displayed were recorded. At these three stations, roadside interviews should have been conducted, but owing to road rehabilitation and the volume of traffic using the routes the roadside interview technique became impossible on the grounds of safety.

3.3 SURVEY DURATION

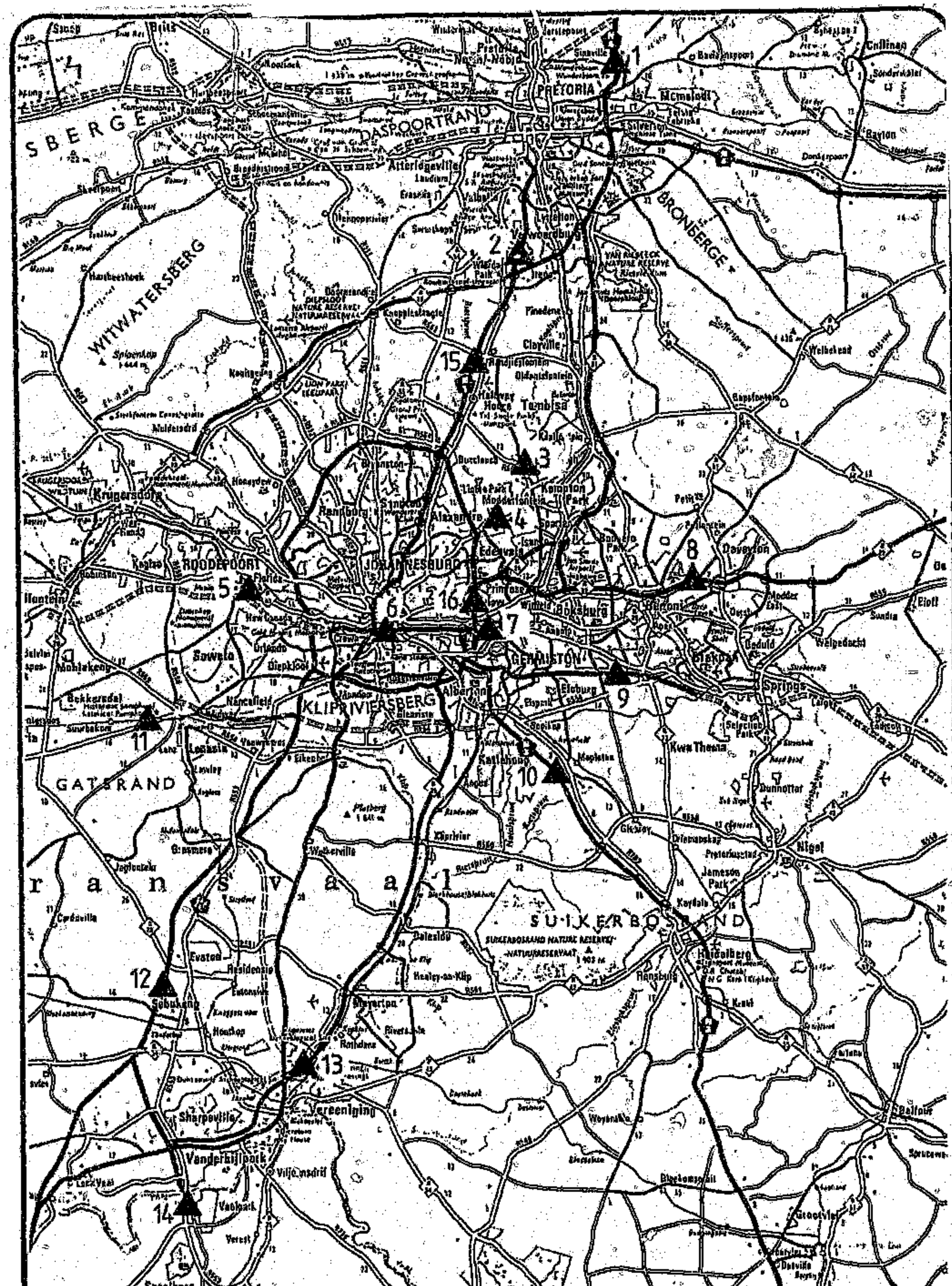
The roadside interviews and manual classifications were undertaken on a "light to dark" basis which approximates to 06h00 to 18h00 - a 12 hour period. All stations with the exception of Station 5 were conducted during these times.

At Station 5 on the R41 near Roodepoort permission could only be gained during the off-peak period as it was necessary to close a lane in each direction to facilitate the interviewing.

With the assistance of the local traffic authorities, traffic in both directions was sampled.

TABLE 1 : POSITION OF SURVEY STATIONS

Station No.	Date	Road Route	Location
1	Nov 25 1987	N1	2km North of the Zambesi Drive Interchange
2	Dec 01 1987	R28	1km North of the N1 Brakfontein Interchange
3	Oct 29 1987	R56	0,5km South of the Halfway House/ Tembisa Intersection
4	Oct 29 1987	R25	0,5km East of N3 Modderfontein Interchange
5	Nov 04 1987	R41	1km East of Randfontein/Roodepoort Intersection
6	Nov 24 1987	M2	Between the Eloff Street and Harrow Road Interchanges
7	Oct 18 1987	M2	1km East of N3 Interchange
8	Oct 28 1987	R22	1,9km East of Benoni/Brakpan Interchange
9	Oct 27 1987	R77	1km West of Brakpan Interchange
10	Nov 05 1987	N3	4km South of Leondale Interchange
11	Nov 04 1987	R29	0,5km East of R558 Intersection
12	Nov 26 1987	N1	2km South of the R28 Sebokeng Interchange
13	Nov 03 1987	R26	1km North of Redan Interchange
14	Nov 03 1987	R568	1,5km South of Vaal River Crossing
15	Nov 24 1987	N1	1km North of the Kyalami Interchange
16	Nov 24 1987	N3	Between Gilloolys and Geldenhuis Interchange



LOCATION OF SURVEY STATIONS

Figure No. 2

The survey was undertaken in the mid-week period i.e. Tuesday, Wednesday or Thursday. These were considered as average days thus avoiding the large "directional" traffic between the major centres which tends to occur on the first and last days of the week.

3.4 DATA COLLECTED

The data collected from each surveyed truck carrying a hazardous material included:

i. Origin of trip.
ii. Destination of trip.
iii. Vehicle type.
iv. Method of containment (tank, drum, cylinder, bag).
v. Hazchem label displayed.
vi. Emergency Action Code displayed.
vii. United Nations Substance Number displayed.
viii. Number of sides of vehicle hazardous signs displayed.
ix. Positioning, fixing, conditions of signs.
x. Availability of delivery documentation.
xi. Substance/s carried.
xii. Quantity of hazardous materials carried by type.
xiii. Availability of a scale card.
xiv. Date of driver's last medical examination.
xv. Date of training to handle substance carried.
xvi. Availability of Tremcard or other information of product carried.
xvii. Direction of travel.

In addition to the above, the driver was requested to plot the route used, enabling a network of routes used to be defined.

A proforma of the questionnaire used is shown in Appendix A.

3.5 DATA ANALYSIS

The completed questionnaires were captured on the computer and manipulated using the programs General Survey Analysis Program (GASP) (4) and MINITRAMP (5). The results are presented in a graphical and tabular manner.

4. RESULTS

The results of the analysis of the truck survey data are divided into four elements namely:

Sample statistics,
Method of containment.
Substances and quantities transported.
Compliance with regulations:

- labeling.
- medical.
- training.

4.1 SAMPLE STATISTICS

At the 13 roadside interview stations, 19519 trucks were surveyed of which 1068 were found to be carrying hazardous substances. Of these 86% were found to carry sufficient quantity of hazardous material to meet the current regulations published in the Government Gazette of 10th July 1987.

In terms of the composition of the total traffic the percentage of vehicles carrying hazardous materials varied from 0,07% to 2,4% dependent on the location of the station.

The results from each of the stations can be seen in Table 2. The station with the highest concentration of hazardous vehicle traffic was Station 16 which was situated on the N3 between Gilloolys and Geldenhuis interchanges where 283 vehicles carrying hazardous materials were recorded between 06h00 and 18h00.

Considerable research has been undertaken by the Vehicle Safety Section of the NITRR into the safety of articulated vehicles against rigid vehicles. In terms of the type of vehicle used to transport hazardous materials it can be seen in Table 2 that the articulated vehicle accounts for 79% of the total vehicles used, 21% were rigid vehicles and 12% of vehicles carrying hazardous materials also had a "pup" trailer.

TABLE 2 : SURVEY STATISTICS

Station No.	Direction	Total Traffic During Period Surveyed	Trucks Without Hazardous Materials		Trucks With Hazardous Materials		
			Rigid	Art	Rigid	Art	Trailer
1	N	3868	372	214	-	11	2
	S	3410	357	227	2	9	2
2	N	13086	570	204	4	2	-
	S	11694	641	155	5	7	-
3	N	8124	350	365	2	27	6
	S	9012	439	243	6	25	9
4	N	10660	422	238	7	19	2
	S	9494	406	86	5	54	7
5	E	5074	425	185	2	32	1
	W	6583	539	252	12	12	1
6	E	Not Recorded	2531	1043	33	70	17
	N	Not Recorded	1653	874	10	56	7
7	E	16156	789	273	38	26	5
	W	12906	848	168	35	41	5
8	E	9946	511	521	11	51	2
	W	10742	467	402	14	22	4
9	E	8286	386	340	6	17	2
	W	6784	362	377	-	20	1
10	N	3490	224	468	-	26	15
	S	3319	173	280	-	10	8
11	E	3282	349	278	-	12	2
	W	5851	603	381	4	23	2
12	N	2462	165	194	1	18	1
	S	2727	201	146	2	21	2
13	N	7078	530	572	-	52	5
	S	7763	498	327	-	44	11
14	N	5048	390	58	33	94	14
	S	4711	260	220	15	72	8
15	N	Not Recorded	1055	441	8	18	4
	S	Not Recorded	900	345	9	18	3
16	N	Not Recorded	2621	1735	19	109	19
	S	Not Recorded	2438	1580	12	110	14
Percentage (%)			63	37	21	79	12

4.2 METHOD OF CONTAINMENT

The method in which a hazardous material is contained whilst being transported has serious consequences on the magnitude of an incident. However, only substances carried in a tank containing more than 500 litres are required to comply with the hazardous materials regulations. The classification of the method of containment was divided into four categories, namely tank, drum, cylinder and bag.

Table 3 shows the method of containment of hazardous material vehicles at each of the roadside interview stations.

It can be seen that 86% of hazardous materials were carried in a tank, 9% in cylinders, 3% in drums and 1% in bags.

Some difficulty was experienced in defining whether the material carried was in fact hazardous, especially in the case of materials contained in bags.

4.3 TYPE AND QUANTITY OF MATERIALS TRANSPORTED

A great variety of hazardous materials are transported through the PWV on a daily basis, these include fuels, solvents, lubricants, corrosives, flammable, radio-active and explosive substances. For clarity, the substances were placed into the following categories:

- Flammable Liquid.
- Flammable Solid.
- Flammable Gas.
- Poison Gas.
- Compressed Gas.
- Poison.
- Corrosive.
- Organic Peroxide.
- Oxidising Agent.
- Dangerous when wet.
- Spontaneously combustible.
- Other hazards.

TABLE 3 : METHOD OF CONTAINMENT

STATION	DIRECTION	TANK	DRUM	CYLINDER	BAG
		METHOD OF CONTAINMENT			
1	N	6	0	1	0
	S	9	0	0	0
2	N	3	0	0	0
	S	10	0	1	0
3	N	25	1	2	0
	S	25	3	2	0
4	N	23	0	0	0
	S	33	6	5	5
5	E	22	0	2	0
	W	14	1	10	0
6		Not Recorded			
7	E	40	0	12	0
	W	51	1	18	1
8	E	32	0	1	3
	W	31	1	1	1
9	E	[illegible]	1	2	0
	W	13	0	3	2
10	N	24	1	0	0
	S	14	0	0	0
11	E	15	1	0	0
	W	27	0	0	0
12	N	18	1	0	0
	S	21	2	0	0
13	N	50	1	0	0
	S	55	0	1	0
14	N	93	2	2	0
	S	62	0	3	0
15		Not Recorded			
16		Not Recorded			

An additional category of hazardous substance entitled "not covered" was made which refers to quantities of hazardous materials which are not required to comply with the requirements of the Hazardous Substances Act 1973 (Act 15 of 1973). These regulations govern the conveyance of hazardous substances by road tanker and were published in the Government Gazette of 10th July 1987. The regulations state that quantities of less than 500 litres in a single compartment are not required to comply. This category was found to be made up mainly of cylinders of liquid and welding gases. These cylinders typically contain approximately 10 kgs gas each.

Table 4 shows the various categories of material at each station.

TABLE 4 : INCIDENCE OF MATERIAL CATEGORIES TRANSPORTED THROUGH EACH OF THE SURVEY STATIONS (No. of vehicles)

STATION	SUBSTANCE												
	a	b	c	d	e	f	g	h	i	j	k	l	m
01	09	-	01	-	-	-	-	-	02	-	-	-	04
02	02	01	-	-	01	-	01	-	03	-	-	04	02
03	07	-	-	-	-	-	36	01	01	-	-	-	13
04	10	-	02	03	10	-	23	-	06	-	-	01	18
05	17	-	05	-	01	01	01	-	01	-	01	-	21
06	54	-	05	01	05	04	12	-	03	-	-	01	83
07	29	02	-	02	17	02	08	-	15	-	-	01	34
08	30	01	03	-	-	-	11	-	07	-	-	01	20
09	14	-	-	-	02	-	11	-	02	-	-	01	10
10	19	-	02	-	-	-	04	-	-	-	-	01	12
11	20	-	01	-	03	03	11	01	-	-	01	00	03
12	07	-	06	04	04	03	07	01	01	-	-	02	07
13	43	-	01	02	14	06	21	-	08	01	-	-	09
14	109	-	03	02	04	16	12	-	06	-	-	01	12
15	10	-	03	-	07	-	01	-	-	-	-	01	31
16	143	-	13	04	19	05	35	-	02	-	-	10	78
TOTAL	523	04	45	18	87	40	194	03	57	01	02	24	357
%	39	-	03	01	06	03	14	-	04	-	-	02	26

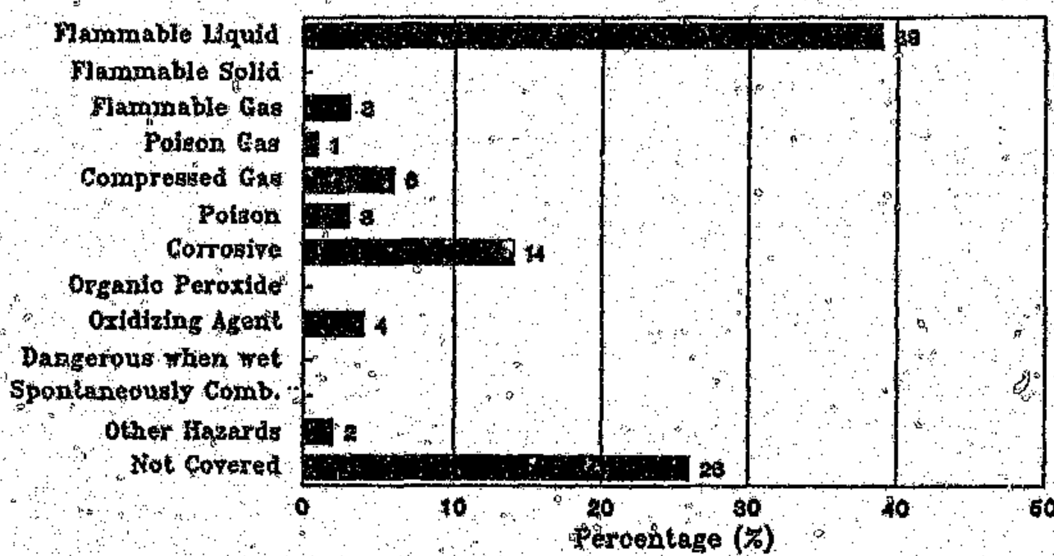
LEGEND:

a Flammable Liquid
b Solid
c Gas
d Poison Gas
e Compressed Gas
f Poison
g Corrosive
h Organic Peroxide
i Oxidising Agent
j Dangerous When Wet
k Spontaneously Combustible
l Other Hazards
m Not Covered

The category "Other Hazards" refers to substances which may cause pollution of the environment, air or water, and result in damage to plant and wildlife while not necessarily causing an immediate hazard to the surrounding populace.

The percentage of each category is shown graphically in Figure 3.

FIGURE 3 : PERCENTAGE OF VEHICLES CARRYING HAZARDOUS MATERIALS AVERAGE ALL STATION.

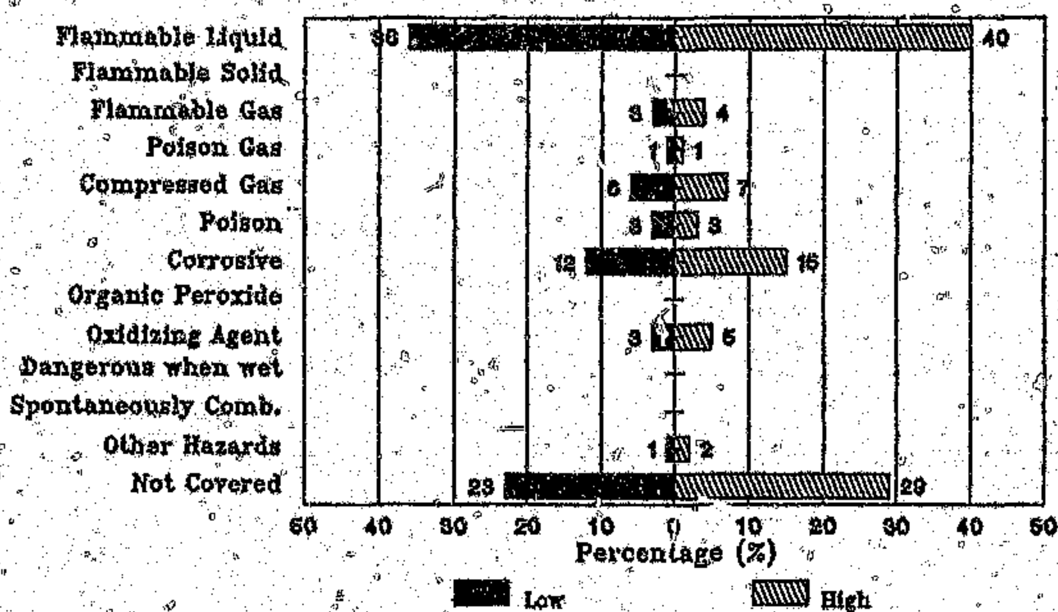


As noted in the study methodology, the selection of the interview stations was made in order to review the maximum number of vehicles. The selection was therefore not random and the sample is subject to bias.

In a case such as this where there is a lack of reliable detailed knowledge of the overall system, a theoretical approach to the calculation of the bias of the estimate may be precluded. Therefore in order to verify the estimates, a "jack-knife" (6) type analysis had to be undertaken. Jackknife methods provide direct numerical approximations of bias and can give reasonably reliable confidence limits. The standard jackknife procedure that was used in this analysis is related to certain theoretical characteristics of estimators, including the influence function familiar in robust estimation ; this relation leads to useful generalisations and variants of the standard jackknife. The jackknife is a relative of cross-validation and of various nonparametric models.

In basic terms, the technique as used in this application, checks ~~the~~ sensitivity of the results to the omission of one survey station; in this way a bias produced by a single station can be identified. A detailed description of the technique is given in Appendix C. The band of results produced by this technique is shown in Figure 4 and it can be seen that the results obtained are consistent.

FIGURE 4 : PERCENTAGE OF VEHICLES CARRYING HAZARDOUS MATERIALS "JACK KNIFE ANALYSIS



If the tonnage of hazardous materials carried is now considered, it can be seen in Table 5 that the percentage of each type of material remains similar to the above apart from the not covered category.

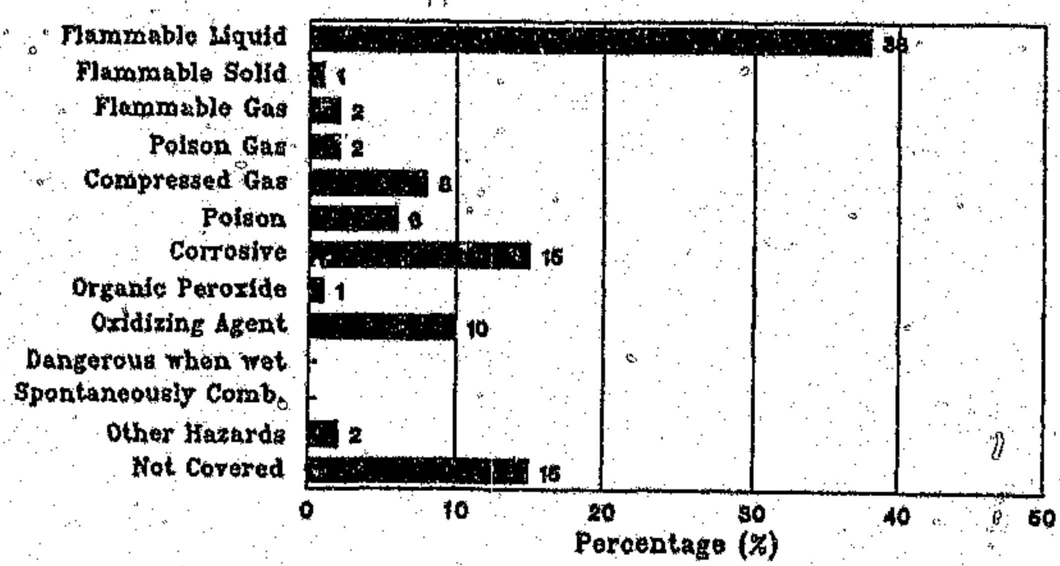
TABLE 5 : MATERIALS TRANSPORTED THROUGH THE SURVEY STATIONS (TONS)

SUBSTANCE	QUANTITY (Tons)	PERCENTAGE
Flammable Liquid	2482	38,0
Flammable Solid	54	1,0
Flammable Gas	156	2,4
Poison Gas	108	1,7
Compressed Gas	506	7,8
Poison	373	5,7
Corrosive	1001	15,3
Organic Peroxide	37	0,6
Oxidising Agent	689	9,8
Dangerous When Wet	25	0,3
Spontaneously Combustible	7	0
Other Hazards	153	2,3
Not Covered	987	15,1
		100,0

The tonnage carried is also illustrated graphically in Figure 5.

The high tonnage of flammable liquids recorded can be ascribed to the large number of fuel tankers on the roads.

FIGURE 5 : MATERIALS TRANSPORTED THROUGH THE SURVEY STATIONS (TONS)



4.4 COMPLIANCE WITH EXISTING REGULATIONS

As noted earlier in this report, regulations covering the transportation by road of over 500 litres in a single vehicle came into force on the 10th July 1987 covering such items as labelling, driver fitness and training and reporting of accidents.

At the roadside interview stations, all vehicles carrying sufficient quantities of hazardous material to warrant compliance with the existing regulations were checked for compliance on four items:

i. Labelling.

ii. Driver fitness.

iii. Driver training, and

iv. The possession of a Hazchem scale card and/or product information.

Labelling

In the event of a collision or leakage of a hazardous substance, major delays have been experienced as the result of the Emergency Service's inability to correctly determine the substances involved. Inappropriate action on the part of these services has in some cases escalated the potential hazard.

The regulations required vehicles, that carry over 500 litres of hazardous substance, to be labelled on three sides of the vehicle (one on each side and one at the rear). Each label conveys four items of information - UN substance number, Hazchem emergency code, International warning diamond, and contact telephone number.

Each vehicle interviewed was inspected for positioning of label, method of fixing, condition and validity of information displayed.

4.4.1.1 Information Displayed on Label

Difficulties were experienced in identifying certain substances as manufacturers tended to use trade names or in-house code numbers to identify their products on the delivery documents. The questioning of drivers proved fruitless, as a majority of drivers had no idea what substances they were carrying.

Approximately 11% of vehicles who were required to comply with the regulations displayed no labelling at all.

The information displayed on the labels was checked against the substance using the computer program HAZDATA(7) which is a hazardous material data base developed by a local transportation training company.

With respect to the United Nations (UN) substance number it was found that 8% of vehicles displaying a label had incorrect UN numbers for the substances carried.

The Emergency Action Code used by the fire brigade to identify the correct technique to be used to contain the incident was found to be incorrect on 11% of vehicles displaying labels.

4.4.1.2 Positioning and Condition of Labels

All vehicles carrying hazardous materials were inspected for correct number of labels displayed, positioning, fixing and general condition of labels.

The interviewers were instructed to make a note of the vehicle if the information contained on the labels was not legible at close inspection.

The method by which the labels were fixed to the vehicles also raised some concern. Vehicles were inspected where the labels were "flapping in the wind" or "attached by a piece of Sellotape" or the "information written in Koki pen".

48% of vehicles were found to be defective on at least one of the above accounts.

4.4.2 **Driver Fitness**

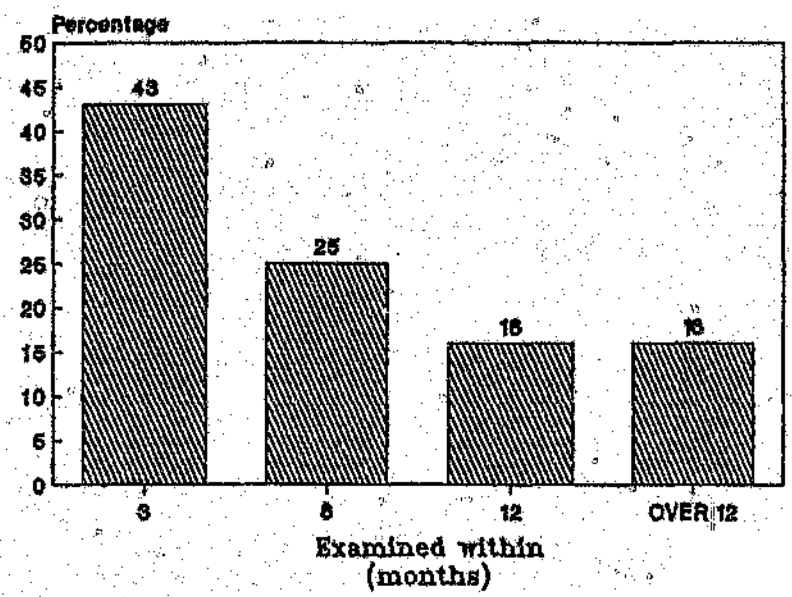
Drivers were questioned as to when they last underwent a medical examination, as the current regulations require that a driver is examined by a medical practitioner every 12 months.

The current regulations make no provision however for the driver to carry any documentation to prove the date given as being valid. As a result of this some drivers may have given incorrect information.

The interviewer noted whether the examination had occurred within the last 3, 6, 12 or over 12 months. This classification was made in order to determine which companies are examining drivers on a regular basis and those who examine only to comply with the regulations.

The distribution of medical examinations undergone by the drivers of hazardous vehicles is shown in Figure 6.

FIGURE 6 : DISTRIBUTION OF MEDICAL EXAMINATIONS AMONG DRIVERS



84% of drivers indicated that they had been examined by a medical practitioner within the last 12 months, with 43% of these examined within the last three months.

A total of 16% of drivers indicated that they had either never been examined or were examined over 12 months ago.

4.4.3 **Driver Training**

In the event of an incident, until the emergency services arrive, the only person with any knowledge of the potential hazard is the driver. Improper action on the part of the driver can expose a large proportion of the population at risk, therefore it is imperative that the proper steps are taken on driver training in order to reduce the risk.

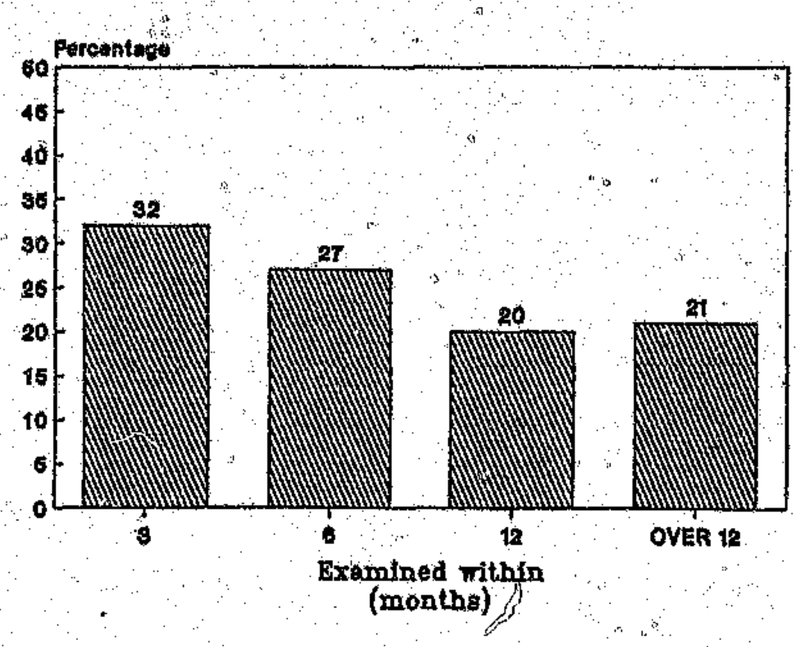
The regulations published in the Government Gazette of 11th January 1985 made provision for practical training with regard to the safe handling of a road tanker conveying various hazardous substances in a single consignment and action and steps to be taken in the event of an accident or breakdown.

The current regulations only makes a vague reference to any form of training under regulation 10(1) (bb) (iii) in which it states that the carrier should ensure that the driver of a vehicle "is aware of and has access to information supplied by the consignor of such grouped hazardous substance, pertaining to these regulations and to aspects concerning the safe handling of the specific grouped hazardous substance or substances being conveyed".

In order to determine the distribution of driver training, drivers were asked to indicate when they underwent a hazardous materials handling training course.

The distribution of driver training can be seen in Figure 7.

FIGURE 7 : DISTRIBUTION OF DRIVER TRAINING



79% of drivers indicated that they had received training within the last 12 months, of these 32% had attended a training course within the last three months. 21% of drivers conceded that they had not received any training or the course was undertaken over 12 months ago.

4.4.4 Overall Compliance with Current Regulations

Only 22% of vehicles which were transporting sufficient quantities of hazardous material to require compliance with the current regulations complied on all accounts.

Of the vehicles which were not required to comply as the quantity carried was less than 500 litres in a single tank, very little attempt appears to have been made to protect either the public or the operators' investment by ensuring driver fitness and proper training.

5. CONCLUSIONS OF SECTION 1

The results of the survey of the 16 stations have identified a number of important issues.

In terms of the total vehicular flows on the major routes, the percentage of vehicles carrying hazardous substances is relatively low in comparison with first world experience. A value of approximately 13% is experienced in the United States of America, whereas this study found that the composition varied between 0,07 and 2,4% dependent on location. However, this should not denigrate the requirement for safety measures as an accident involving a vehicle carrying hazardous substances tends to be low probability but high consequence incident.

The relatively low number of vehicles carrying hazardous substances should also not result in a lack of interest by the carriers in ensuring proper safety procedures which are plainly evident from the results of the roadside interviews.

The current regulations, by first world standards, can be considered as being very lax, offering the minimum protection to the general public. By taking into consideration all the aspects covered by the existing legislation only 22% of vehicles required to comply with the existing regulation actually complied. This is an extremely low compliance rate which may have resulted from two factors;

i. the regulations being unclear and ambiguous to the operator, and

ii. the lack of enforcement.

Although the regulations have been criticized by the transport industry as being difficult to understand, the regulations are however clear on a number of issues which a large proportion of operators have failed to comply with.

The enforcement of the regulations presents a difficult problem for the authorities. The traffic authorities are presently under-manned and the recognition of a specific substance as found in this study is difficult as manufacturers tend to use trade names to define specific substances. Even if the substance is defined, the checking of the information on the labels can be tedious unless computer facilities are available. No information to prove compliance on such issues as driver training and medical examinations need be carried and, experience at the different survey stations showed that drivers learn to say the "right thing", especially with respect to training and medical examinations.

SECTION 2

MODELLING OF FLOWS

6. INTRODUCTION

This, the second section of the report, outlines the methodology employed in the modelling and evaluation of a network of routes used by vehicles carrying hazardous substances.

This section is divided into two parts, namely:

1. Network Description.

2. Assignment.

7. NETWORK DESCRIPTION

The initial stage of the network description was to define a suitable zoning system and to code the associated road network. Wherever appropriate, the Study Area boundaries were made co-incidental to major administrative boundaries and/or the JOMET road network in order to facilitate the provision of input data and the identification of output summaries.

Journeys with origins (or destinations) outside of the Study Area boundary were allocated to a number of much larger external zones. The advantage of using external zones is that if a coarse external network is used, the possibility of long distance strategic traffic diverting to alternative routes can be assessed.

The main criteria used in defining the zones was:

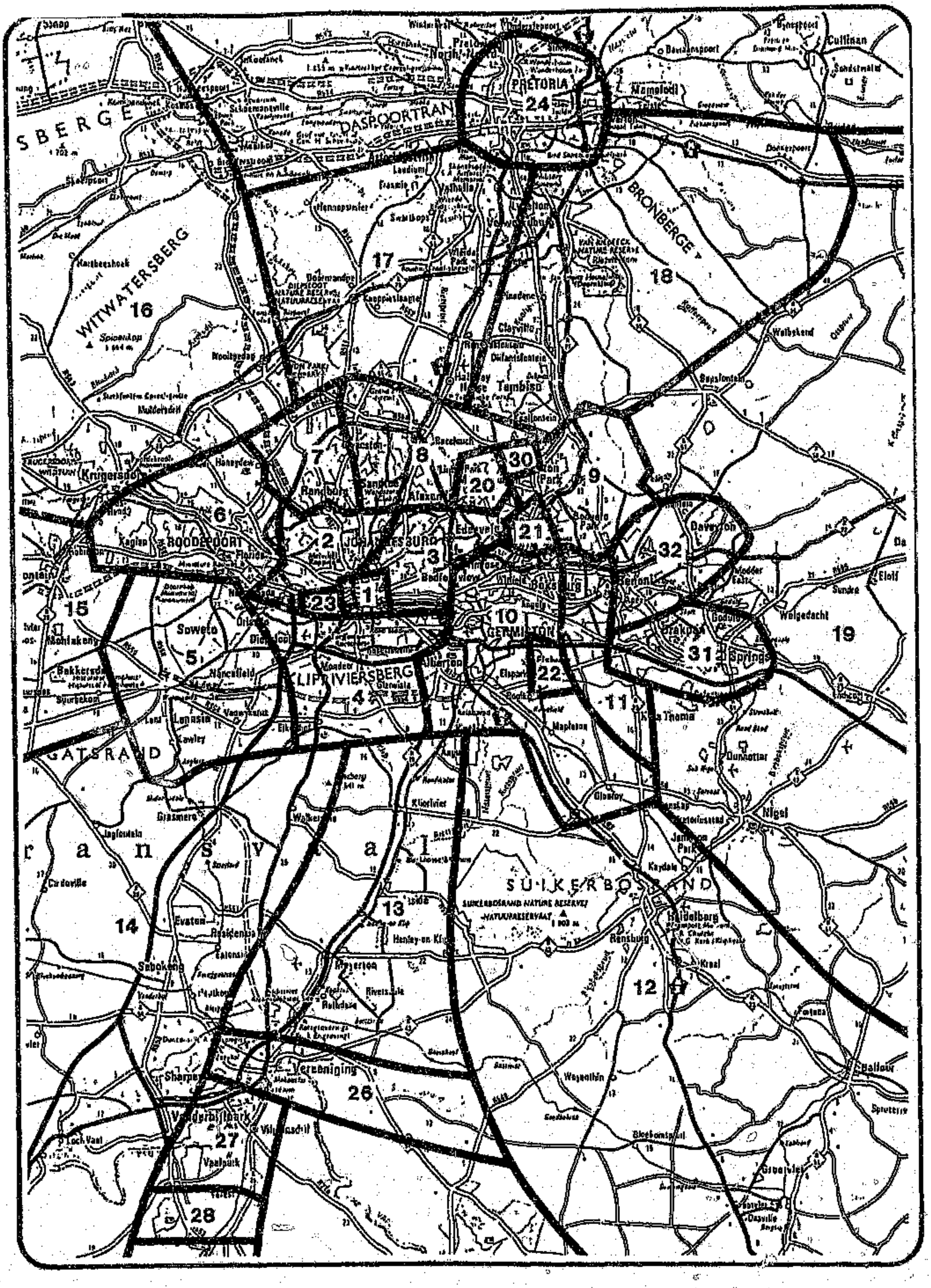
i. The size of the zones should be consistent with the population density of the modelled network.

ii. Zones should not be larger than is necessary to allow traffic to be loaded on the transport network with adequate accuracy.

iii. Boundaries should be drawn to include, wherever possible, consistent types of development with each zone (e.g. residential, industrial, etc.).

iv. Zones should not contain well spaced out areas of development each with a different point of access to the network and poor intra-zonal linkages.

The definition of the zone boundaries was, as often is the case, a compromise between conflicting requirements (e.g. between the desire to "improve" the model by increasing its size and complexity and the practical consideration of keeping costs down and meeting targets of time scale and accuracy), however, 32 zones were defined in all and these are illustrated in Figure 8. There are 25 internal zones and 7 external zones.



STUDY AREA ZONING SYSTEM

Figure No. 8

The most noteworthy zones are:

Zone Number	Description
1	Central Johannesburg
20	Modderfontein
21	Isando
23	Industria
24	Pretoria
28	Sasolburg
30	Chloorkop

The road network itself was described in terms of nodes (usually representing junctions) and the road links connecting them. In addition, certain nodes were required to represent zone centroids, the points where trips start and finish, which are connected to the network by notional links known as "centroid connectors".

The level of detail to be included in the network description is a difficult decision as clearly the more roads are included, the closer is the representation to the network on the ground but the more data input is needed. As the Study Area covers the whole of the PWV area it was necessary to adopt a fairly coarse network definition.

The network was classified according to its operational characteristics and the following classification was adopted:

Road Class	Description
00	Zone Connectors
01	Freeway
02	Main and Provincial
03	Secondary Main

The following is a breakdown of the total length of roads coded in the network:

Type of Road	Length (km)
Freeway	693,30
Main and Provincial	1128,00
Secondary Main	1342,00
TOTAL	3163,30

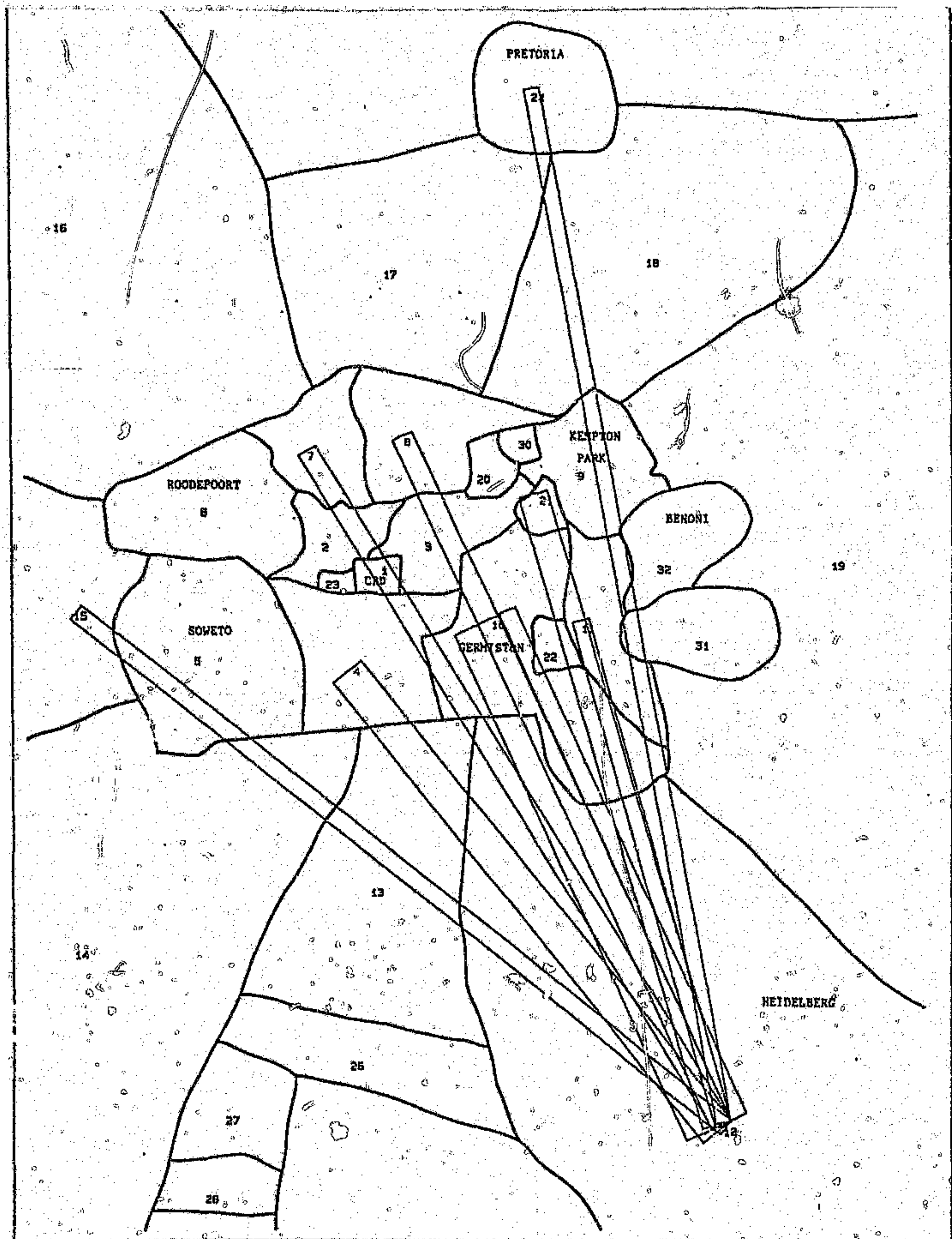
Average travelling times were coded for the three types of road defined above and overall route costs and paths checked by plotting minimum cost paths for each zone.

Travelling times were based on speed and delay studies undertaken on roads of similar type and with similar traffic flows.

8. TRIP MATRICES

The General Analysis Survey Program (GASP) (4) was used to produce trip matrices for the 13 categories of hazardous substances defined in Section 1. The matrices were produced in tons for the 12 hour period between 06h00 and 18h00 and these can be seen in Appendix D.

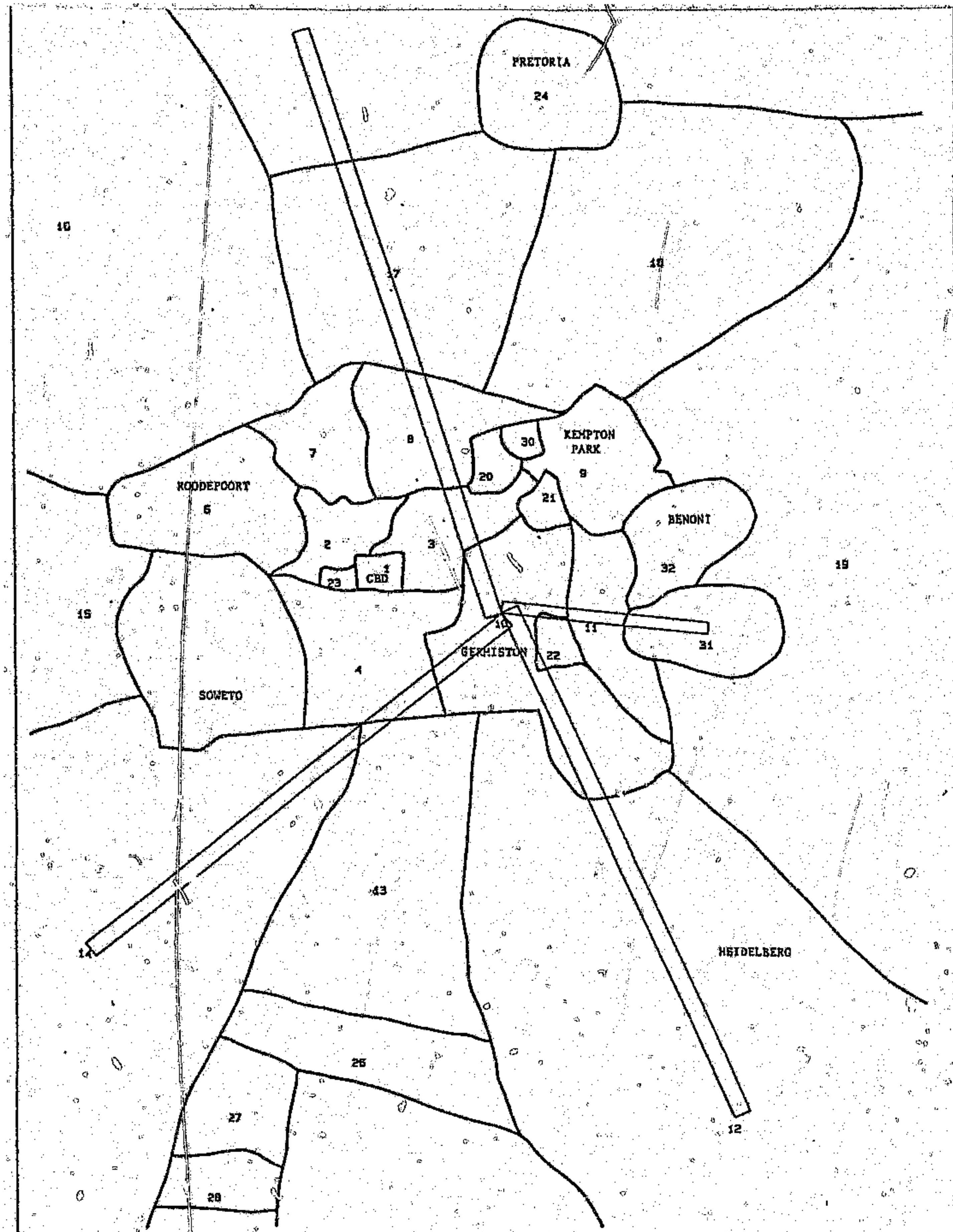
The major movement of hazardous materials has been represented graphically as "desire lines". Desire lines are straight lines connecting the survey zones. Such lines are drawn without reference to the existing road network and provide a picture of inter-zonal travel demands. The width of each line is proportional to tonnages of material which moves between the zones. For reasons of illustrative clarity only desire lines representing a minimum of 10 tons of hazardous material per 12 hour period are given. Although only flows of 10 tons per 12 hour period have been illustrated, flows of materials less than this amount could result in extensive damage if involved in an incident. Figures 9 to 14 illustrate the desire lines for the major movement of materials.



HAZCHEM DESIRE LINES - UNREGULATED MATERIAL FROM ZONE 12

SCALE 1: 100000 DATE 22.4. 88

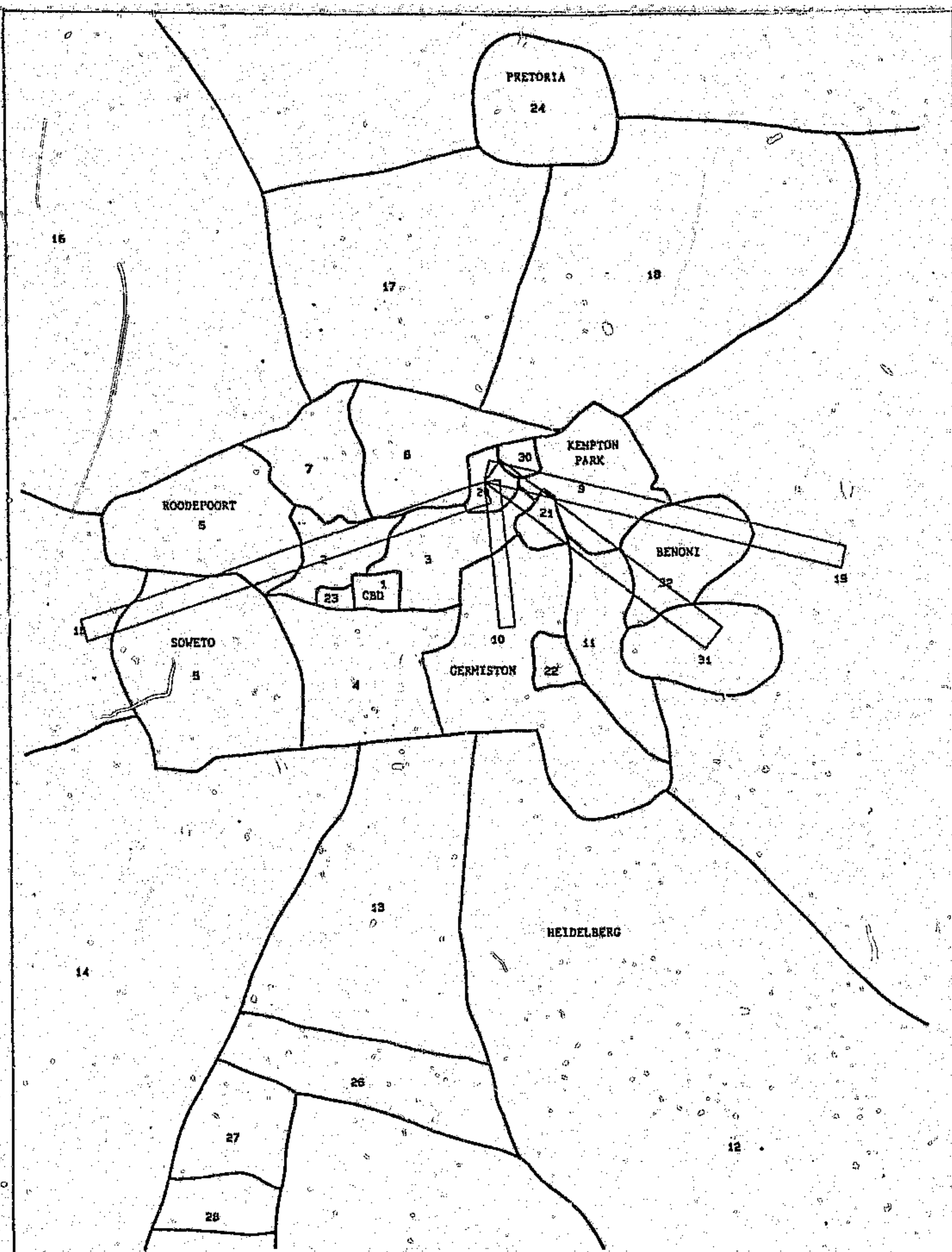
| | REPRESENTS 40 TONS MINIMUM FLOW PLOTTED 10 FIGURE 9



HAZCHEM DESIRE LINES - UNREGULATED MATERIAL FROM ZONE 10

SCALE 1: 100000 DATE 22.4. 88

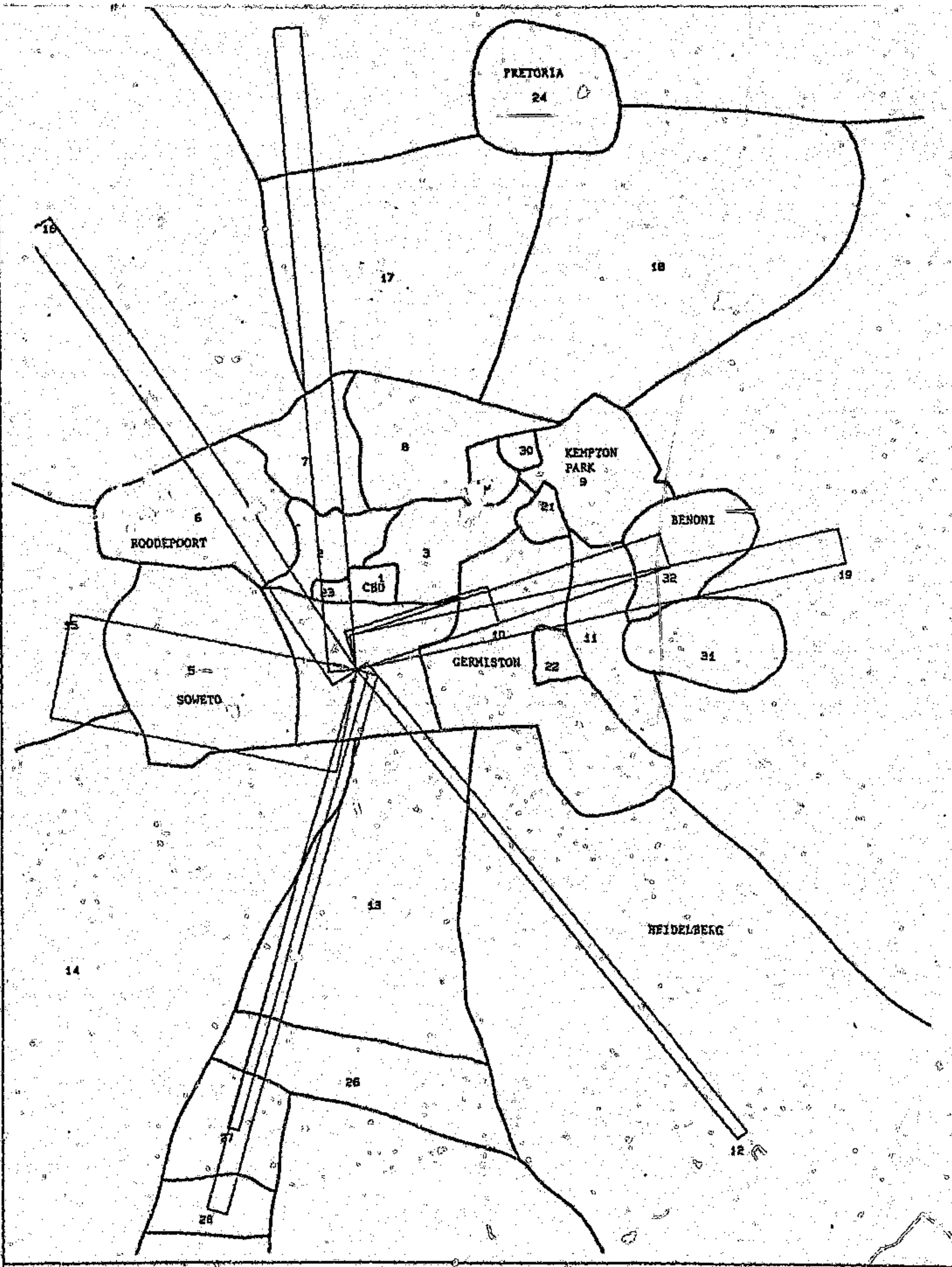
| | REPRESENTS 40 TONS MINIMUM FLOW PLOTTED 10 FIGURE 10



HAZCHEM DESIRE LINES - UNREGULATED MATERIAL FROM ZONE 20

SCALE 1: 100000 DATE 22.4. 88

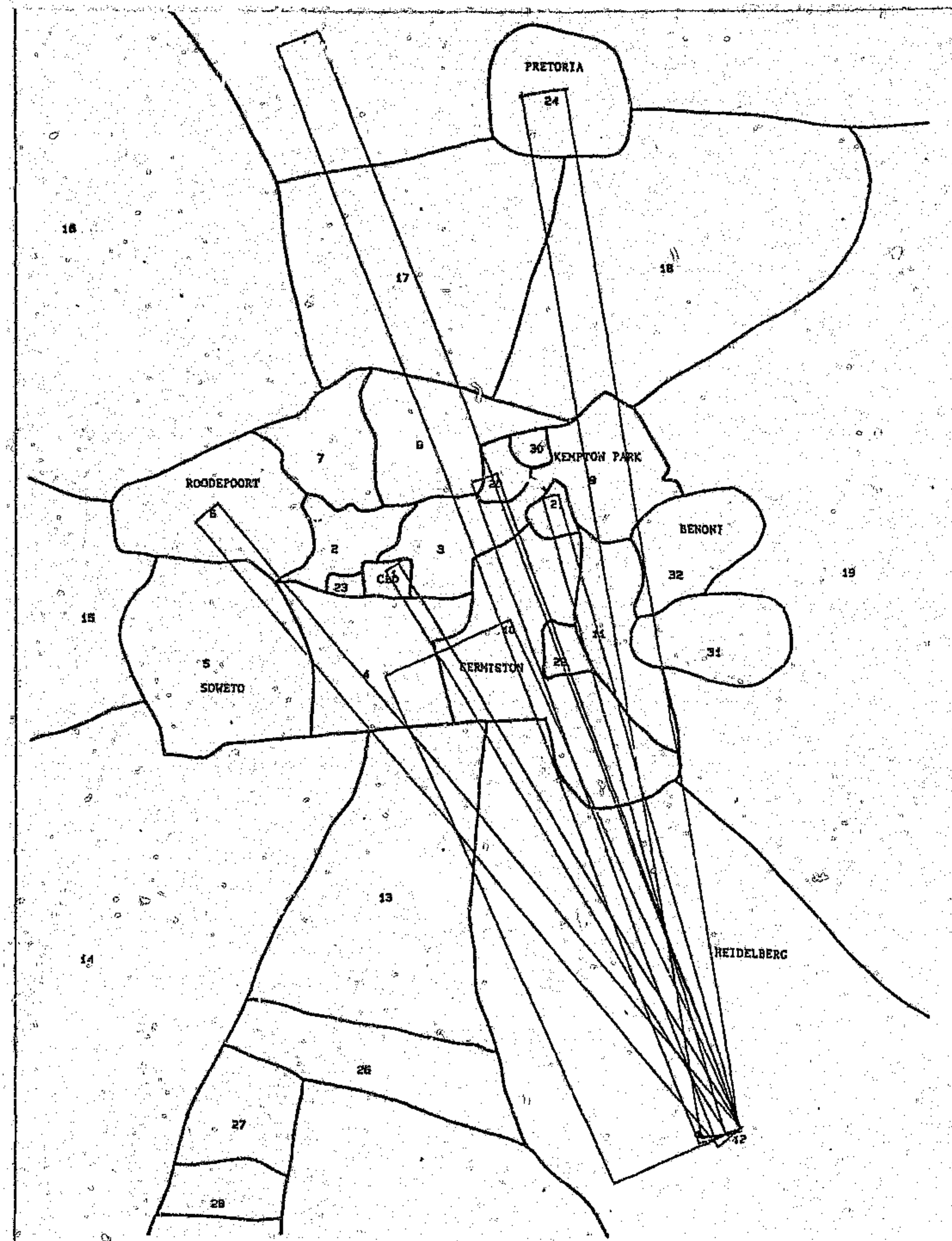
[ ] REPRESENTS 40 TONS MINIMUM FLOW PLOTTED 10 FIGURE 11



HAZCHEM DESIRE LINES -FLAMMABLE LIQUID FROM ZONE 4

SCALE 1: 100000 DATE 22.4. 88

| | REPRESENTS 40 TONS MINIMUM FLOW PLOTTED 10 FIGURE 12

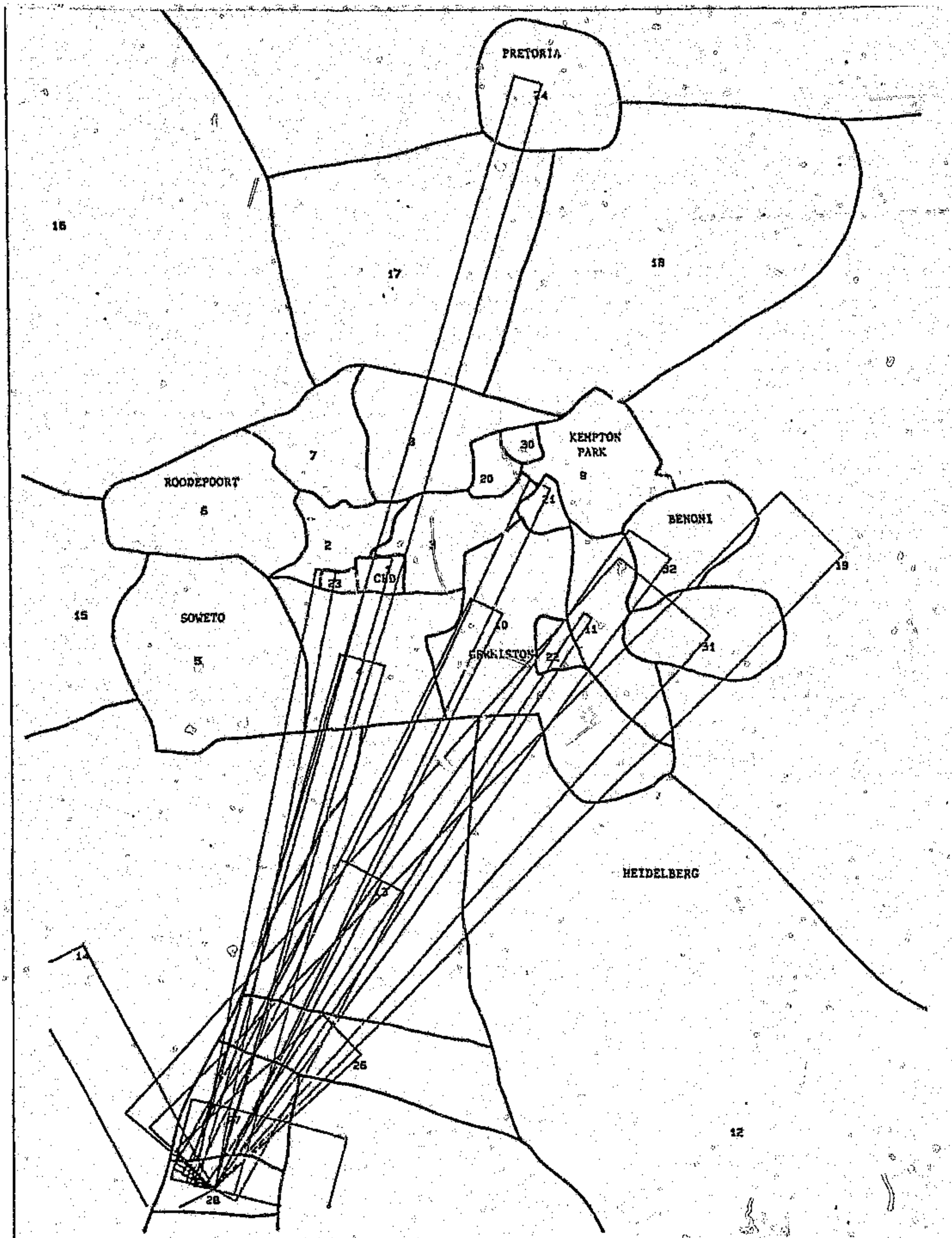


HAZCHEM DESIRE LINES -FLAMMABLE LIQUID FROM ZONE 12

SCALE 1: 100000

DATE 22.4. 88

| | REPRESENTS 40 TONS MINIMUM FLOW PLOTTED 10 FIGURE 13



HAZCHEM DESIRE LINES -FLAMMABLE LIQUID FROM ZONE 28

SCALE 1: 100000 DATE 22.4. 88

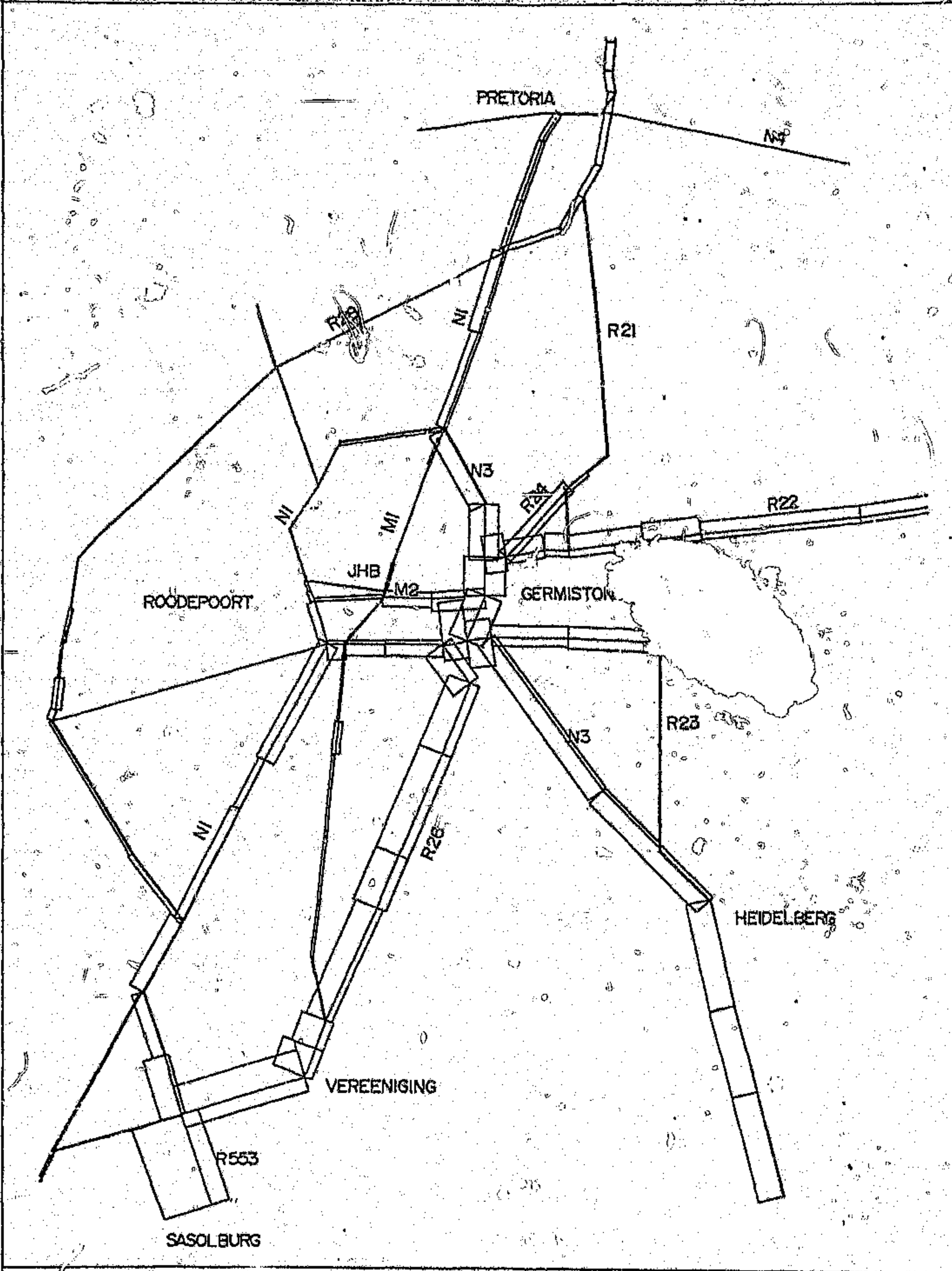
| | REPRESENTS 40 TONS MINIMUM FLOW PLOTTED 10 FIGURE 14

9. HAZARDOUS MATERIAL FLOWS

During the roadside interview, drivers were requested to detail their route taken on the network. These routes were encoded by means of a link and node technique.

A series of computer programs were written in DBase3 to provide the amount of hazardous material transported during the survey period on each link. These tonnages were converted into Minitramp(5) format for plotting. The major routes in the study area were then digitised and the tonnage per 12 hour period for each material plotted using Minitramp program HPPLOT.

The completed plots are given in Figures 15 to 25.



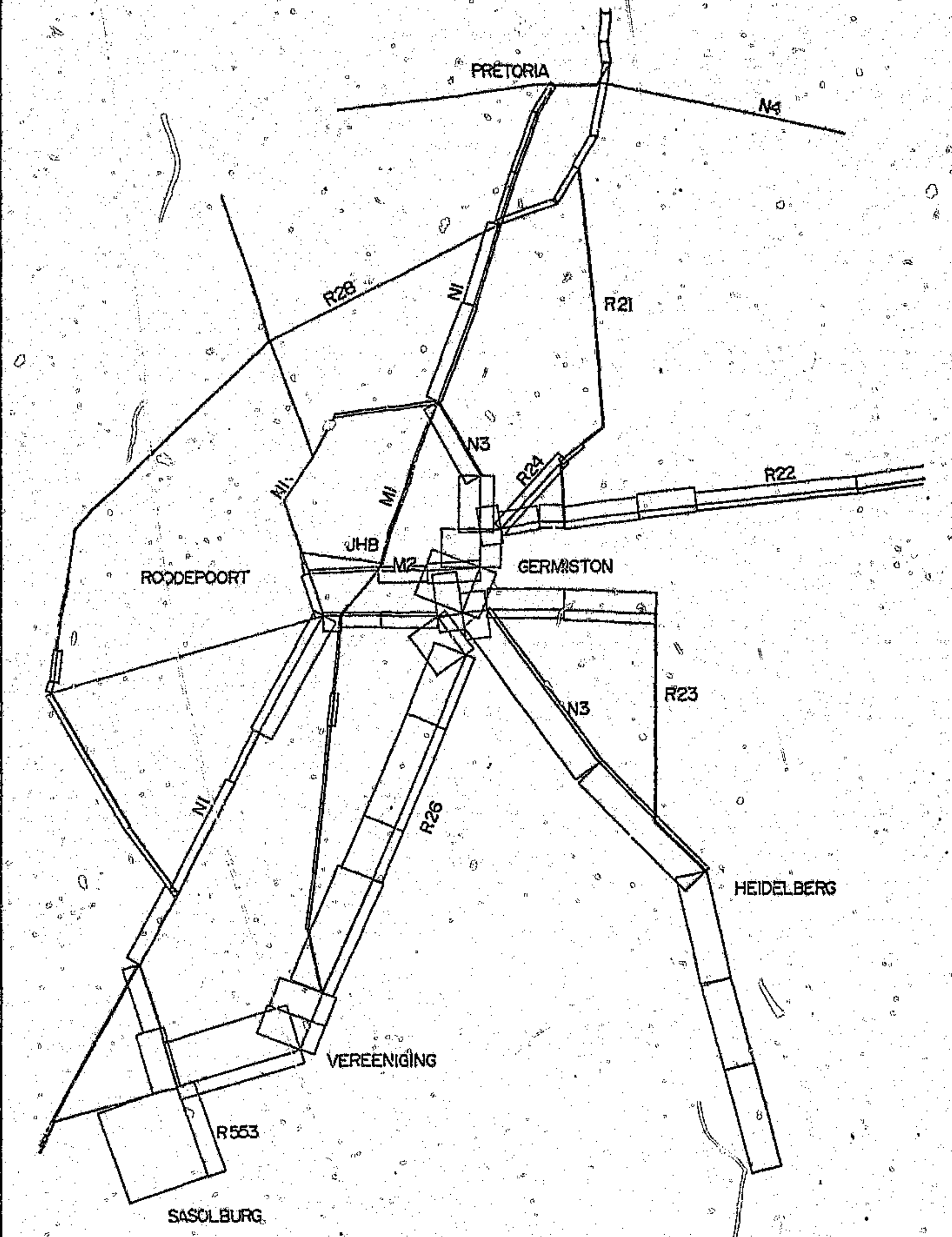
HAZCHEM LOADED NETWORK - UNREGULATED MATERIAL.

SCALE 1: 100000

DATE 21.7. 88

| | REPRESENTS 600 TONS

FIGURE 15



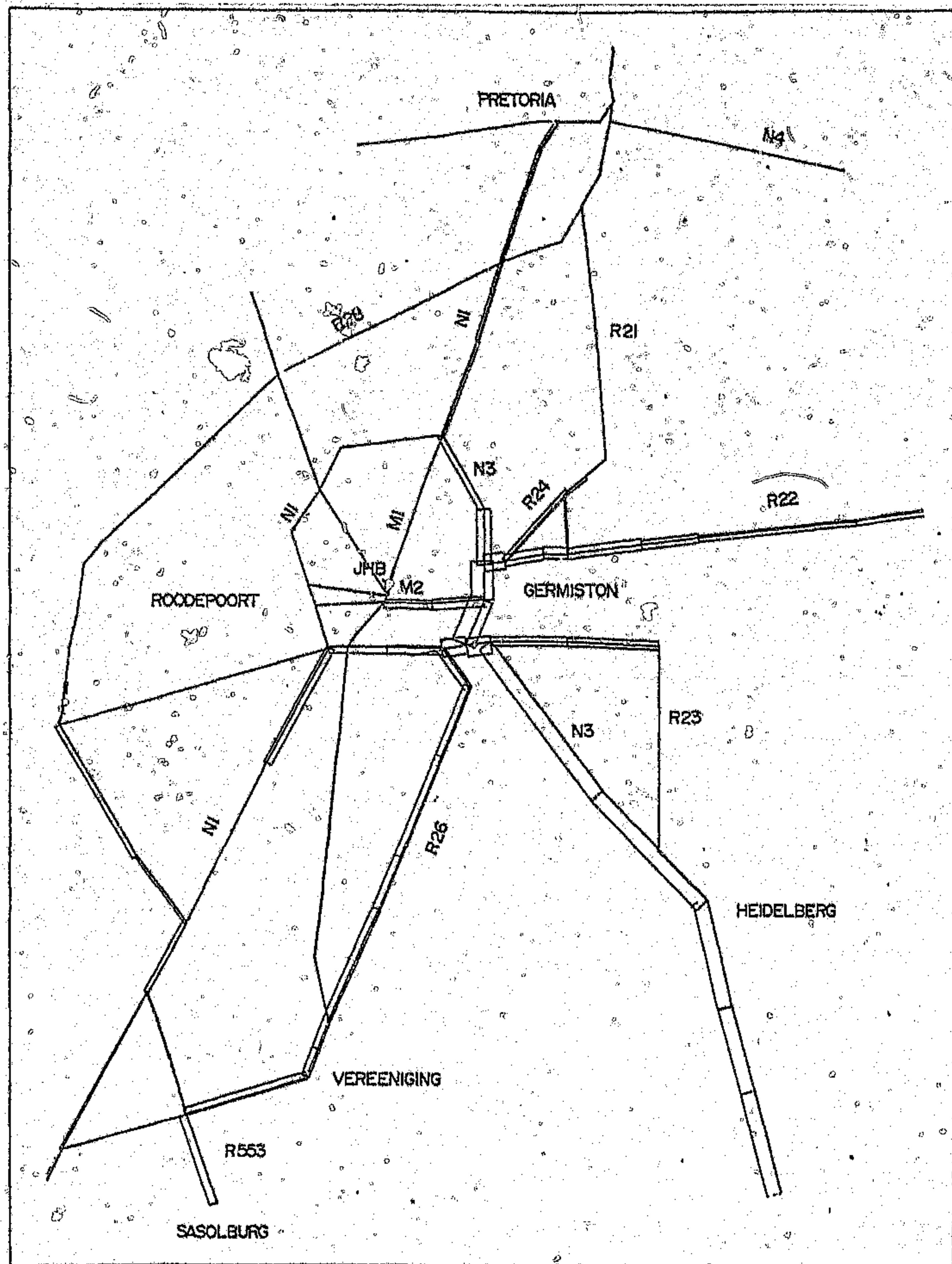
HAZCHEM LOADED NETWORK - FLAMMABLE LIQUIDS

SCALE 1: 100000

[ ] REPRESENTS 666 TONS

DATE 8. 8. 88

IGURE 16



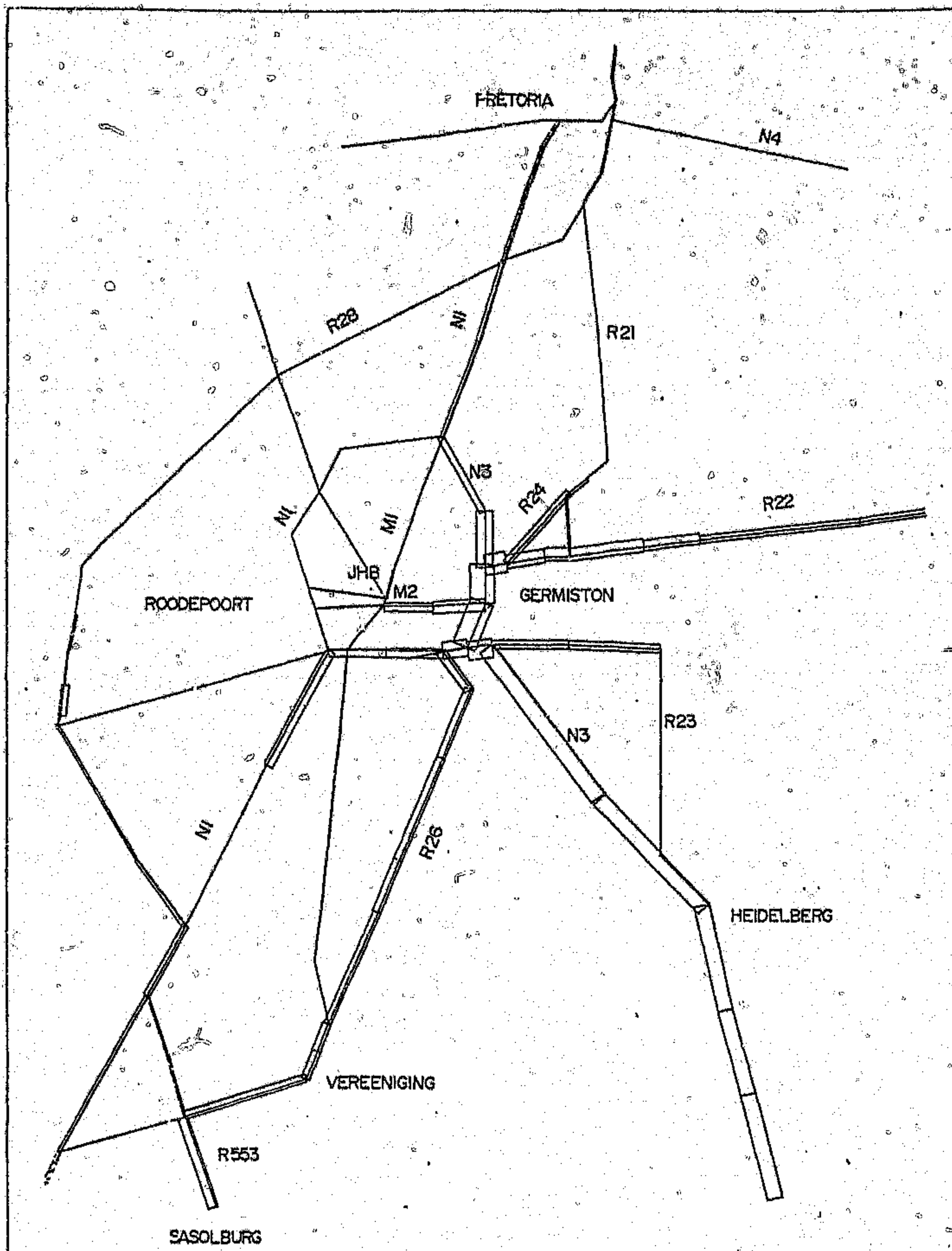
HAZCHEM LOADED NETWORK – FLAMMABLE SOLIDS

SCALE 1: 100000

| | REPRESENTS 000 TONS

DATE 8. 8. 88

FIGURE 17



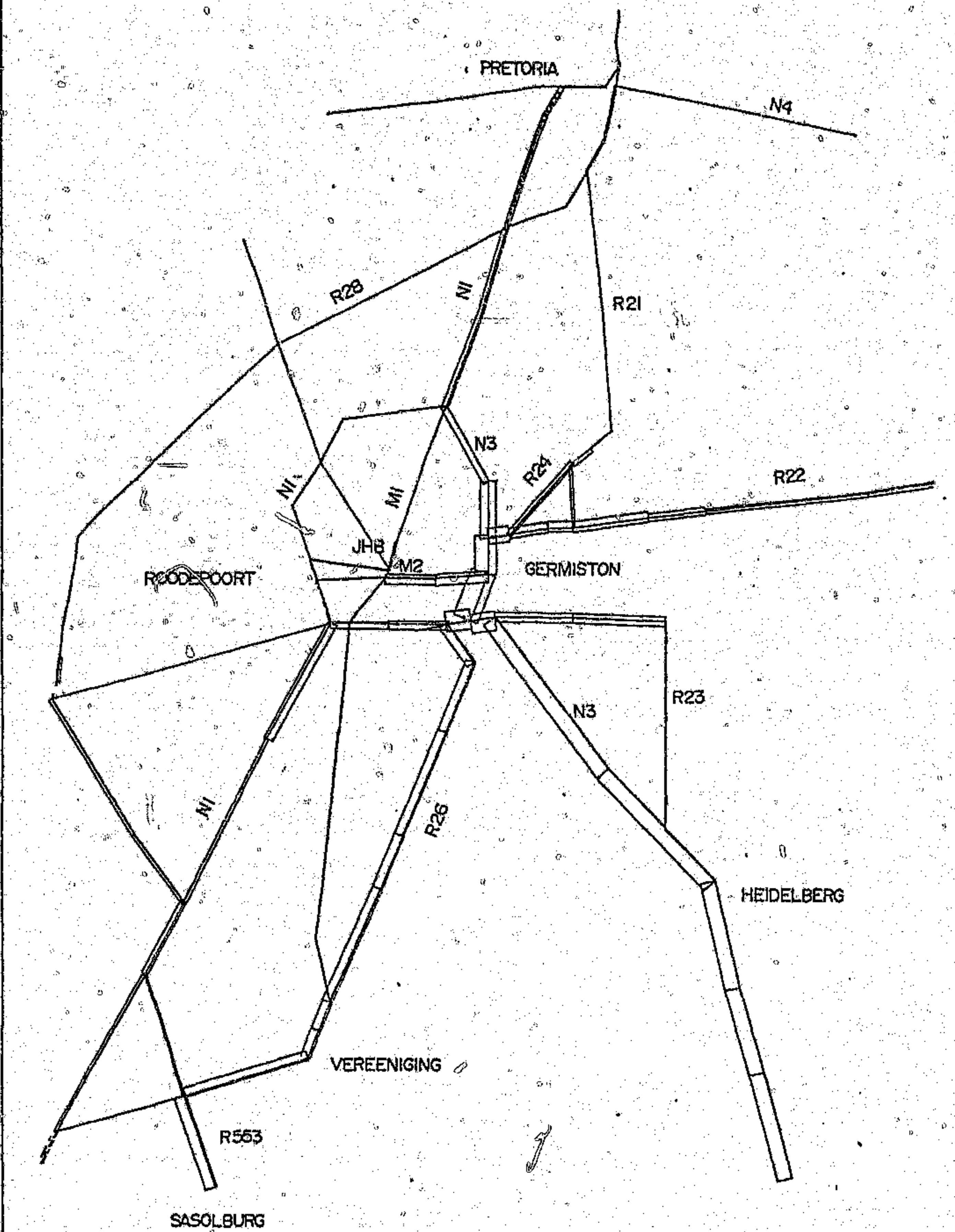
HAZCHEM LOADED NETWORK - FLAMMABLE GAS

SCALE 1: 100000

| | REPRESENTS 666 TONS

DATE 8. 8. 88

FIGURE 18



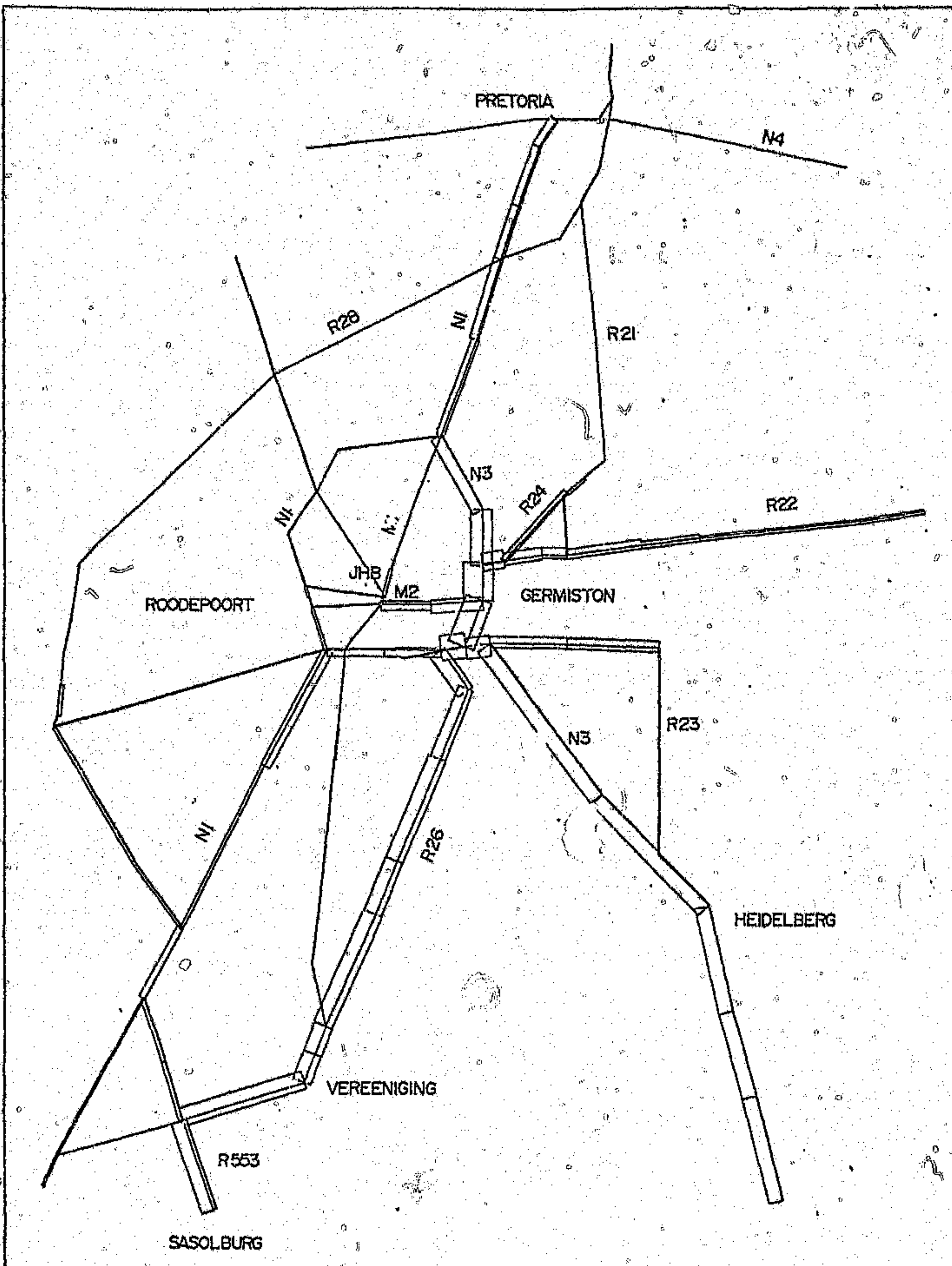
HAZCHEM LOADED NETWORK - POISON GAS

SCALE 1: 100000

| | REPRESENTS 666 TONS

DATE 8. 8. 88

FIGURE 19



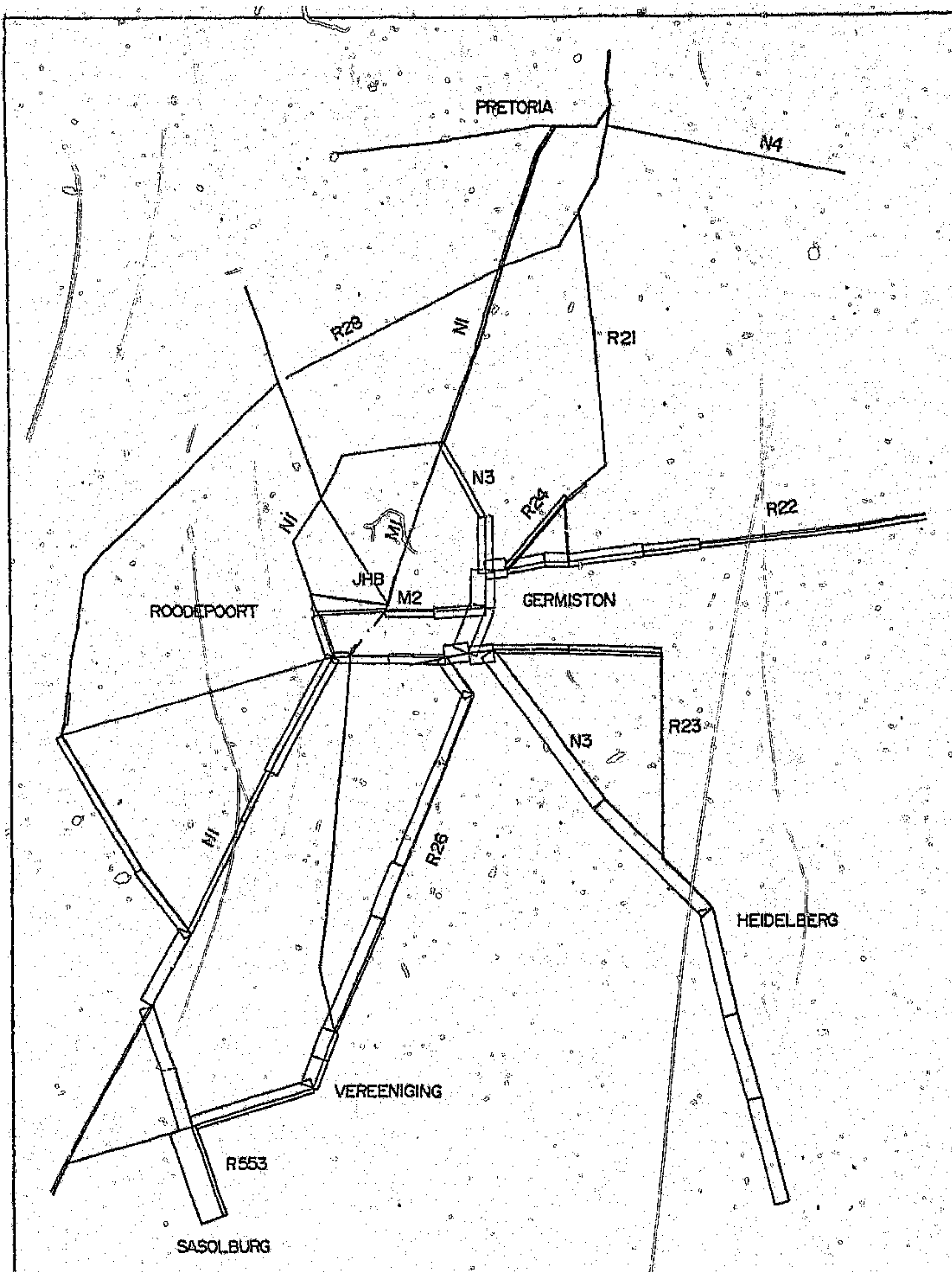
HAZCHEM LOADED NETWORK - COMPRESSED GAS

SCALE 1: 100000

DATE 8. 8. 88

[ ] REPRESENTS 666 TONS

FIGURE 20



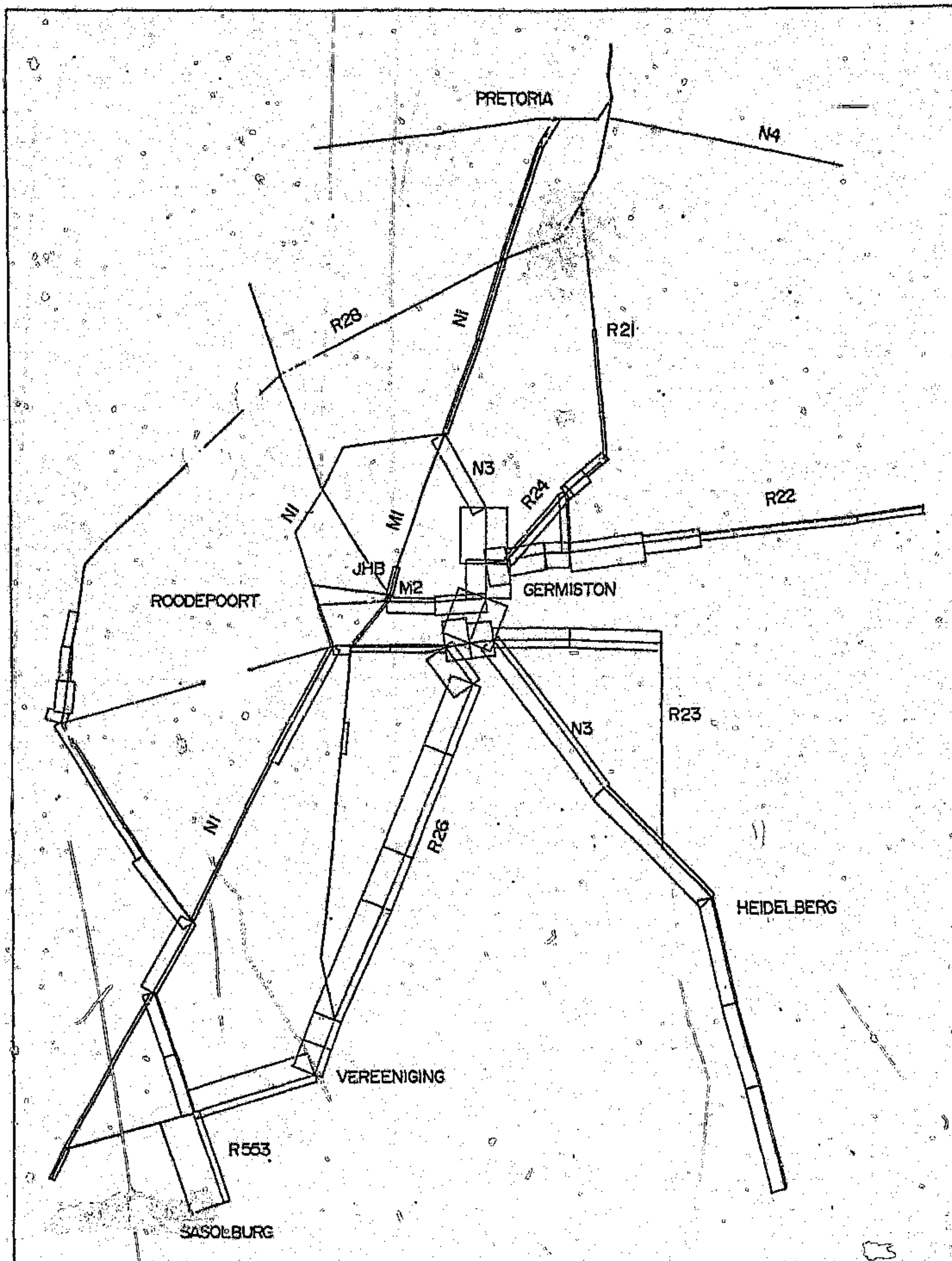
HAZCHEM LOADED NETWORK - POISON

SCALE 1: 100000

DATE 8. 8. 88

| | REPRESENTS 666 TONS

FIGURE 21



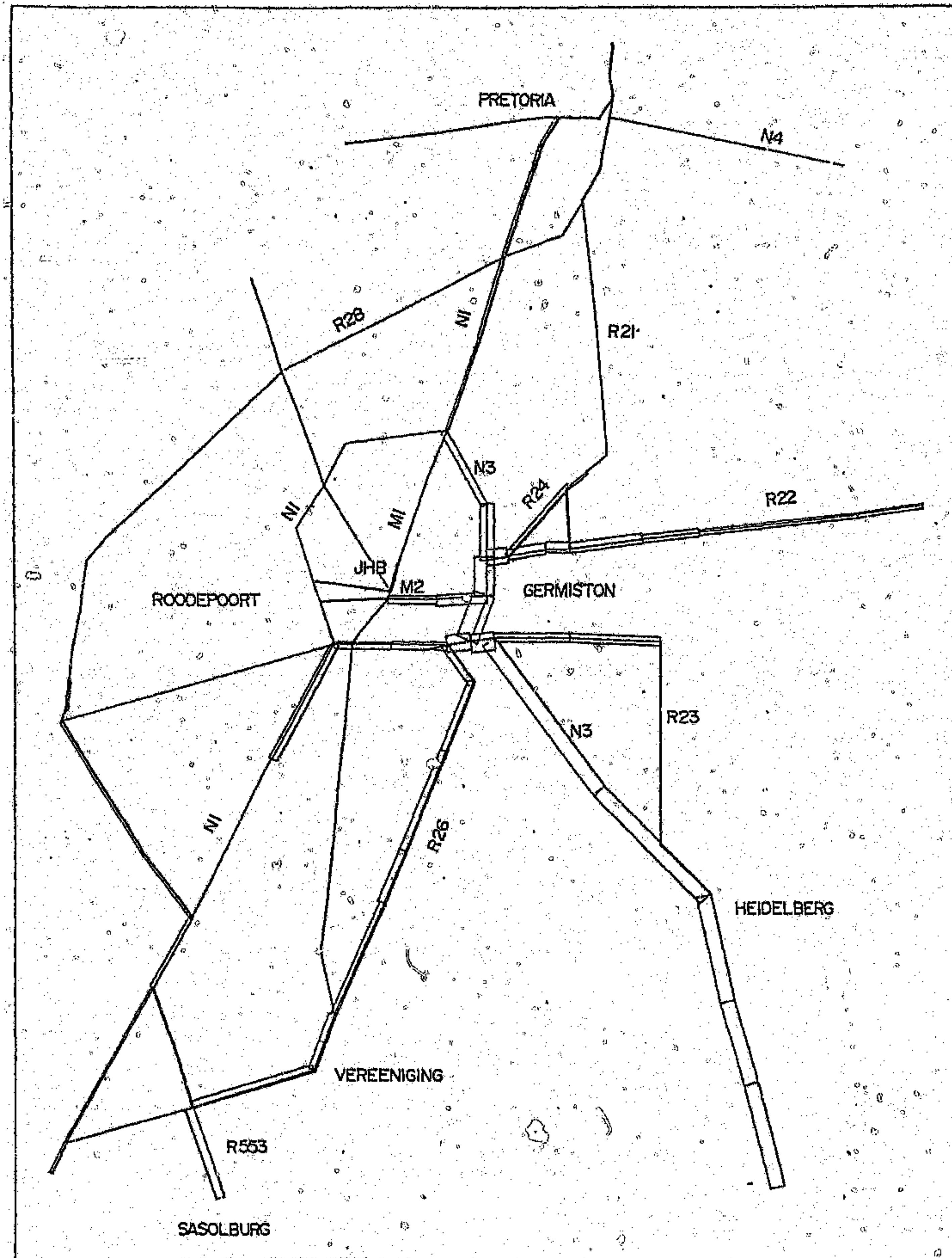
HAZCHEM LOADED NETWORK - CORROSIVE

SCALE 1: 100000

DATE 8. 8. 88

| | REPRESENTS 666 TONS

FIGURE 22



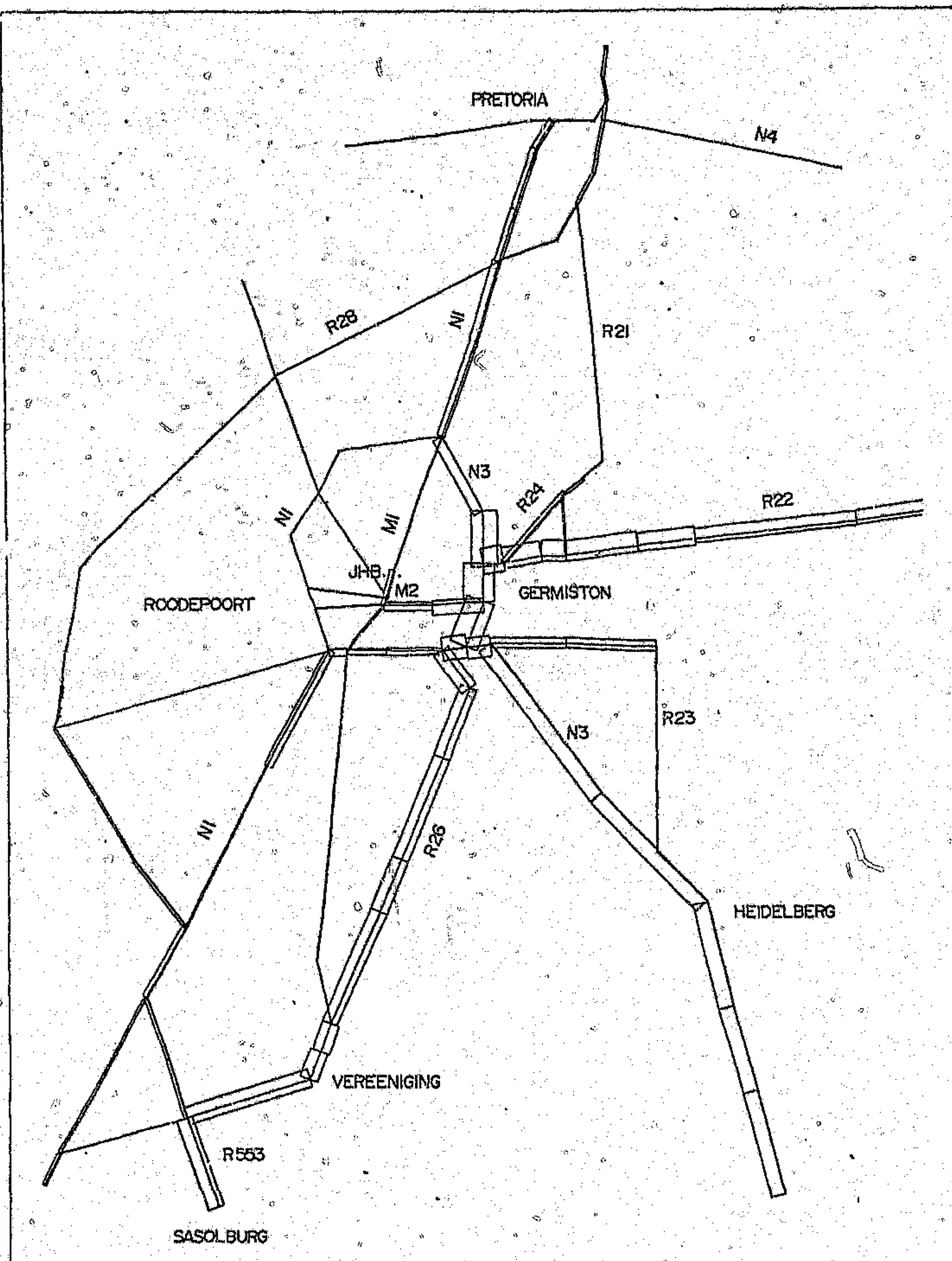
HAZCHEM LOADED NETWORK - ORGANIC PEROXIDE

SCALE 1: 100000

DATE 8. 8. 88

| | REPRESENTS 666 TONS

FIGURE 23



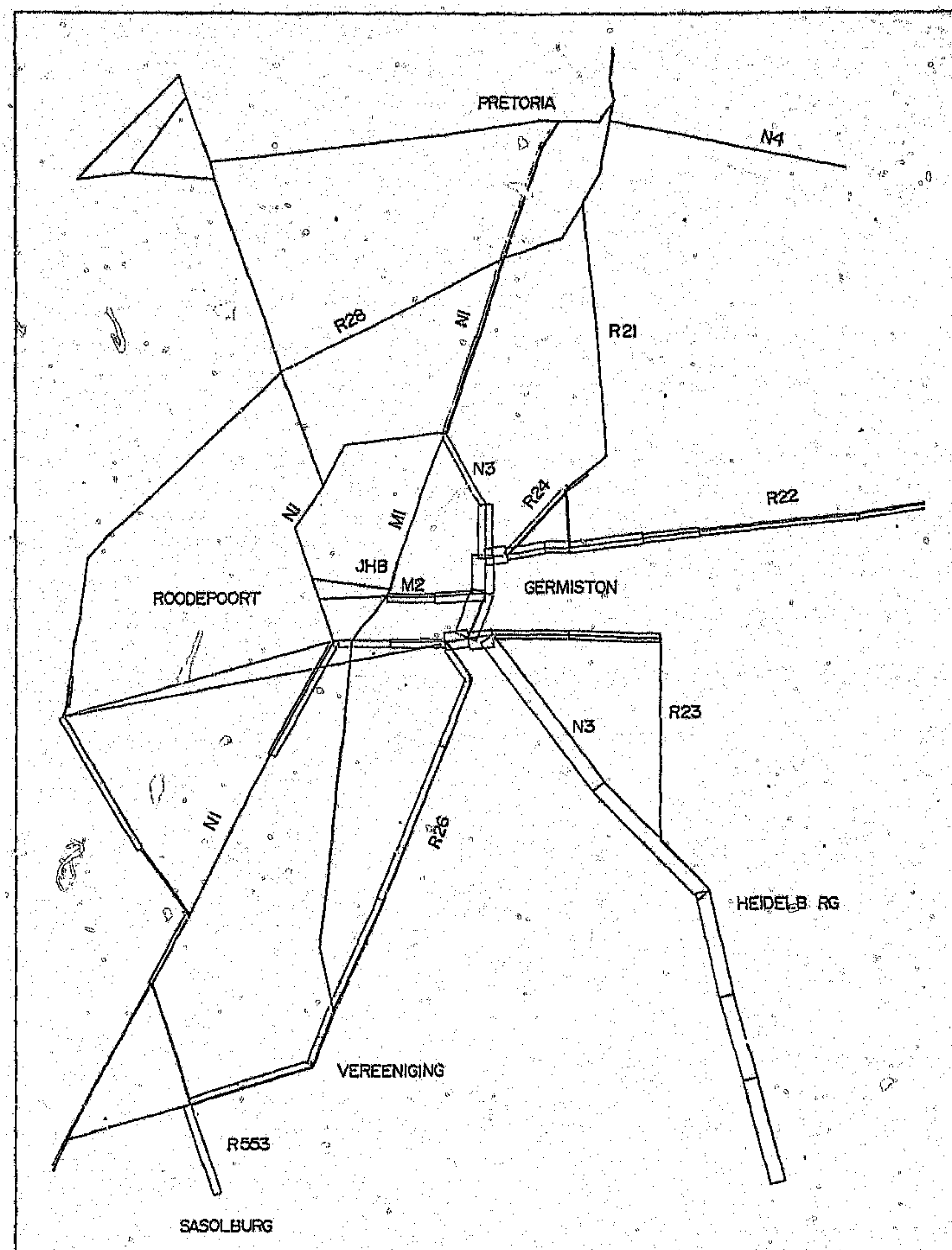
HAZCHEM LOADED NETWORK - OXIDIZING AGENT

SCALE 1: 100000

DATE 8. 8. 88

| | REPRESENTS 666 TONS

FIGURE 24



HAZCHEM LOADED NETWORK - OTHER HAZARDS (TONS)

SCALE 1: [illegible]

DATE 21.7. 89

[illegible] FLOW UNITS

FIGURE 25

10. CONCLUSIONS OF SECTION 2

The plots of the tonnage of hazardous materials carried on the major routes within the PWV show definite areas of concentration. The following routes have a high concentration and also carry large volumes of other traffic.

N3	-	between Gilloolys and Geldenhuis
M2	-	between Geldenhuis and Kaserne
R26	-	between Alberton and Vereeniging.

As the probability of an incident is related to exposure, the quantities of hazardous materials carried on these routes are a matter of great concern. In addition, a number of these routes pass in close proximity to residential areas. Considering the lack of compliance with the current regulations it is clear that, should an incident occur, the authorities would be presented with some serious problems.

Desire line and bandwidth diagrams were plotted for each category of material carried. The most striking factor of these diagrams is the substantial amount of hazardous material carried which, owing to the quantity of material carried, is unregulated and can be considered considerable.

The routes linking the eastern industrial areas are heavily trafficked by hazardous material vehicles carrying a variety of categories of material.

As expected the movement of flammable liquids, in particular petroleum products, represent the large movement of hazardous materials in the PWV. Processing of these products occurs in Sasolburg with the major distribution being undertaken via the M1 and R26 to the Johannesburg/Pretoria area.

SECTION 3

RISK ASSESSMENT MODEL

11. INTRODUCTION

The safe transportation of hazardous materials involves minimising the risk to the public. The vast majority of materials defined as "hazardous" are inexorably intertwined in the fabric of South Africa's society. Accepting that the materials have to be transported through our cities, towns, and neighbourhoods over the country's transportation network, how can the attendant risks be reduced?

The severity of an incident involving a specific substance is dependent on a number of issues, one of the major issues being the environment in which it occurs. Clearly an incident occurring in an urban area is potentially more dangerous than one occurring in a rural area, but there are other environmental factors that can affect the outcome of an incident.

One of the most commonly used techniques of reducing the effects of hazardous material incident is the routing of vehicles carrying hazardous materials away from damage sensitive areas. Routing is a tool available to communities that limits community exposure to a hazardous materials incident. The proper routing of hazardous material cargoes to preferred routes limits the exposure of a community to an incident and should increase the effectiveness of the response to an incident. However, this process raises the issue of quantifying the risks of removing the risk from one segment of the community to another segment of the community.

In this section of the report a model is developed which estimates the risks on a particular route. The description of the model has been divided into three sections. Firstly, the concept of risk is described in terms of hazardous material transportation, and use of the model. Secondly, an evaluation of the various types of risk assessment models used overseas is presented and this then followed by the development of a model for South African application with an example of its use.

12. REQUIREMENTS OF A RISK ASSESSMENT MODEL

The requirements for risk assessment can vary widely dependent on the different kinds of user. One may need a methodology for assessing the risks of a given hazardous material transport operation under conditions that express representative nationwide factors. Another may need a detailed capability for modelling the risks of specific alternative cargo routes, modes or containers for a given material. A third may need to be able to assess in detail the effectiveness of some possible risk reduction measure. Local authorities may need to assess the risk of cargoes of one or all hazardous materials into or through their area, as specifically as possible to the conditions on their present routes and possible alternatives to them. Operators may require similar assessment capabilities to support their cost-safety optimisation decision-making, which may in the future become increasingly explicit.

While the basic concepts and general techniques must be common to all such applications, it is evident that considerable variability is possible in the particular form and specific details of risk analyses appropriate to different user's needs.

The model described below, endeavours to provide a methodology, which addresses the needs of the local authorities and transporters for determining route choice, but requires the minimum of data input that is applicable to both the local and national situation.

13. ESTIMATION OF RISKS

Before any attempt is made to develop a model it is important to define the concept of risk as used in the application of hazardous material transport.

Most approaches to risk assessment to date are of the relative variety, that is, a numerical assessment by which one route or even one mode can be evaluated against another. The end result of such an assessment is that Route A can only be stated as being better or worse than Route B or safer or less safe than Route B.

Absolute risk is a direct measure of hazard, that is, an estimate of the number of persons who might be killed or injured, the financial amount of potential economic loss, or the physical extent (quantitatively expressed) of possible environmental and ecological damage. Although this approach is the most desirable one it is difficult to achieve.

The model developed below provides a risk measure that tends toward the absolute. It provides the practitioner with a feel for the condition of safety in which the community finds itself as a result of exposure to potential catastrophe by the use of a particular route.

14. EXISTING RISK ASSESSMENT MODELS

Before attempting to develop a risk assessment model it is important to review some of the models developed overseas. Existing methods of risk estimation as applied to hazardous material transportation risk analysis can be classified by the use of four categories. The four categories are statistical inference, fault-free modelling, analytical-simulation modelling and subjective estimation of risk parameters.

The discussion of the four methodologies is oriented around their utility in the estimation of the likely occurrence of an accident and the determination of the possible consequences. Data and methodological problems, their implications to uncertainties of concern to the user and possible approaches for development of a route risk assessment model are noted. The following brief synthesis of the various categories of models based on the work of E R Russell et al (8), TRB Special Report 195 (9) and NCHRP Report 103 (10).

A summary of the main factors utilised in the four categories of the model is given in Section 14.5.

Following the selection of the most appropriate category of model, the various approaches in the application of the model are discussed.

14.1 STATISTICAL INFERENCE

Statistical inference is the most regularly employed procedure for estimating accident or incident occurrence probabilities. The main drawback of this technique is the significant sample required of the specific hazardous conditions of concern.

However, it is directly usable only if an adequate accident data base exists, with significant sample sizes at the various levels of the specific hazardous conditions of concern. Also, it has to be able to be assumed that the past record satisfactorily represents (or can be modified so as to represent) what the future will hold.

Statistical inference models attempt to use measurable parameters (such as average daily traffic, number of heavy volume intersections, number of signals, type of road, road or rail condition) in order to develop a value for the probability of an accident per million vehicle kilometres, or some other similar probabilistic form, for a specific vehicle type. The probability is combined with a consequence valuation by determining the population density of those at risk. The Peat, Marwick, Mitchell model (11,12) for example, uses this approach.

These methods are route specific since the data come from specific routes that are generally independent of the type of cargo. The method uses actual data for its variables; however, constants for equations are either set arbitrarily (as weights) or are correlated with actual conditions and accident history for specific routes. Although the latter approach seems most appropriate to determine the average number of accidents expected over a given route, it does not account for the magnitude of the consequences of an accident. For rare events, historic data regarding a specific route, or even national averages, will not reflect the actual potential for large accidents.

The method assumes that accidents or incidents occur independently and with constant probabilities and develops estimates of these probabilities. Past records of such accidents and incidents then provides the frequency of their occurrences over a particular time period.

This results in an inference of the future probability of occurrence of an accident or incident per shipment.

A number of important problems arise in this superficially simple process, however. First, the estimation of the exposure requires that records are kept and accessible on shipments of the hazardous material. Such records are not generally available. Thus, estimates must usually be made by employing samples of shipment data, often of uncertain accuracy or even validity, with liberal judgmental interpretation.

Second, adequate data for a meaningful statistical inference may also not exist on the accident-incident occurrences. This is always the case for the rare, catastrophic events that are usually of greatest interest. If the record of exposure (e.g. number of shipments) is great enough, it may be possible nevertheless to estimate credible upper bounds on the probabilities of such events, but these are often too conservative (that is, too large) to support practical decision making on the control of future shipments with just as large or larger rates of exposure.

Instead of generating such upper bounds on the probabilities of accident-incident occurrence, it is sometimes attempted to establish a "surrogate" sample of recorded data larger than the real one of interest and sufficiently large to permit direct inferences to be made. Thus, the record of accidents with liquid natural gas (LNG) tankers, with no significant entries and a relatively limited exposure, is expanded by use of the record for oil tankers modified subjectively in various ways to reflect the differences between oil tanker and LNG tanker operations. With somewhat greater refinement, a record for a given hazardous material transported in a particular container in a particular mode is extended by incorporating all accidents-incidents for other materials that employ the same container and mode - it being agreed that as far as the occurrence (per shipment, kilometre, etc) of an accident or incident is concerned, the material makes no difference. Lastly, a most common use of the "surrogate" approach is the application of the nationwide modal accident statistics, on a per kilometre basis, to inferences of the probabilities of accident occurrences on particular routes for which adequate route specific accident records do not exist. Clearly, this neglects the potentially significant differences in the physical and environmental characteristics of specific routes from nationwide averages of these conditions.

Another problem area in statistical inference is the principle that the conditions at the time of measurement are the same at the time of the analysis. That is, it must be assumed that the past record also represents the future (or it is understood how to modify it so that it will). There are many reasons why this may not be the case, e.g. if a major accident occurs once, significant actions may be taken to decrease the chance of occurrence of such an accident in the future. Alternatively "familiarity breeds contempt", or at least lack of concentration, among human operators so that the chance of a major accident where humans are involved may gradually increase over time. Increase in accident frequency may also be due to wear of equipment under inadequate maintenance. The validity of statistical inferences that do not, or cannot, reflect such considerations is clearly questionable.

A number of important problems arise in this process.

i. As noted above, accurate records must be kept of hazardous cargo shipments.

ii. Accidents involving hazardous cargoes which are of use in the model are rare, catastrophic events.

iii. The process assumes that the past record of events also represents the future.

Overcoming fully the problems that have been noted is not always possible but the situation could be improved by first, making the uncertainties that the inference procedure gives rise to as explicit as possible so that the user can incorporate them into the decision process. Second, steps for improving the accident and exposure record keeping procedures should be defined comprehensively, and carried out.

These methods are applicable to the risk of specific shipments over alternative routes and provide a community with guidance on either the overall risk or specific risk problems.

14.2 FAULT-TREE MODELLING (14)

The fault-tree methodology is based on the systems engineering approach in which hazards are identified not only in the roadway environment element of the man-machine-environment system, but also in the driver and the vehicle aspects.

The possible sequence of events are synthesised, culminating in a particular consequence to people, property, or the environment.

If this technique is to be used to its full potential, its application requires that all significant consequences will have been tracked back through all possible event sequences to their initiating basic events. To realise the full power of fault-tree modelling, the probabilities of occurrence of the initiating events and all related action initiations (e.g. a successful or unsuccessful activation of a corrective action) need to be estimated with adequate precision, and the magnitude of the consequences accurately predicted. If these requirements are met, a series of combined probability calculations results in assessments of the probabilities of occurrence of specified consequences with given magnitudes, i.e. the risks deriving from the hazards under analysis.

The principal difficulties with the fault-tree procedures are the uncertainty that all significant event sequences have been considered and the acquisition of sufficiently precise data necessary for predicting, with reasonable accuracy, the initiating and related action event probabilities. These difficulties are central to the controversies on the application of logic tree methods in nuclear power plants and other fixed-facility risk assessments and their generally complete failure in transportation accident probability determinations. Because there are so many possible kinds of accidents and because interactions of possible accident causal factors exist in the dynamic operations environment of transportation systems, descriptions in terms suitable for probability analysis of all important sequences of events culminating in transportation accidents are not able to be meaningfully accomplished. However, fault-trees, in particular, have been effectively applied to post-accident events analysis - most notably in analyses of nuclear material container failure under accident stresses - and to mishandling and normal operations incidents.

Despite these severe difficulties, some potential has lately appeared for the application to transportation problems of computer-based fault-tree synthesis and analysis methods that have very recently been developed for nuclear and chemical processing plants.

This methodology has three important advantages not provided by statistical inference methods.

i. The data acquisition would be changed from that of obtaining meaningful samples of accident data for all sets of conditions to that of obtaining only basic event data.

ii. The methodology lends itself to the evaluation of the effectiveness of given mitigating measures.

iii. Qualitative analyses of fault-trees can provide significant insights on accident-initiating event sequences that are potentially most important to system safety.

To gain these advantages, fault-tree modelling techniques need to be deepened to better reflect accident dynamics, including human operator actions. Improved means are required for acquiring data on the probabilities of initiating events, equipment and human faults or failures, and control action time delays. Comprehensive testing, experimentation, and simulation programs will be needed for this.

Models utilising fault-tree analysis modelling were developed at the Pacific Northwest Laboratories (14,15).

14.3 ANALYTICAL AND SIMULATION MODELLING

Analytical and simulation modelling approaches to risk analysis begin with functional descriptions of the system under study. The operations of the system are then expressed in terms of appropriate performance parameters that express the functions and the interaction of the functions, system components (human and equipment), and interfacing external factors. The conditions under which accidents and incidents occur, or when particular consequences arise, are associated with specific combinations of the values of these parameters. Their probabilities of occurrence and/or the effects of their occurrence are then assessed by means of probability or effects formulas (if analytical models) through numerical accumulations from repeated runs of system operation "scenarios" (in simulation models), or by combinations of both procedures.

The main problem with analytical models is the need for assumptions to be made which in some instances differ considerably from the direct physical conditions. Simulations are better in these regards in that they usually tend to replicate real-world factors in a fairly recognisable way. However, to the extent that they avoid arbitrariness of their simplifications, their complexity and computational requirements increase. The need to repeat many runs of simulated operations in order to derive usable accident statistics (as in Monte Carlo simulations) exacerbates the computational requirements. Simulations are, therefore, expensive means for risk analysis (other than in specific and limited data development support roles).

Analytical models have been applied primarily in assessments of normal operations, incident occurrences, and post-accident effects and consequences, especially in the marine mode. Simulations have been used, but without great success, for estimating marine-mode accident probabilities.

14.4 SUBJECTIVE ESTIMATION

When all else fails, an approach to augmenting sparse data in developing statistical inference and estimates of other forms of model parameters is that of subjective estimation by panels of experts. These experts are assumed to be sufficiently familiar with the detailed circumstances of operations similar to those of interest that they can meaningfully extrapolate their experience to new conditions, employing only their individual judgements in combination with those of the other experts.

Two approaches can be considered in applying this process in hazardous materials transportation risk analysis. The first is exemplified by a "Delphi" procedure (13) that was carried out in developing risk parameter estimates for hydrogen sulphide transport as extrapolations from general experience with the material and from a "baseline" set of specific experience data for a more common hazardous material, propane.

The second is typified by an attempt that was made to estimate oil tanker spill risks. It developed numerical estimates from rankings of the likelihoods of possible causative events as these rankings derived from the experience of a team of circumstances were not so rare as to require some basis for comparison with experience with another material.

Subjective estimation is perceived as inherently a relatively low confidence risk analysis methodology. However, this perception may be at least in part a result of the general lack of appreciation of the perhaps more subtle but sometimes just as significant subjective elements of the other possible methodologies. This has been evidenced to some extent in the preceding discussions of these methodologies. To improve the subjective estimation process may therefore be a worthwhile endeavour, even if less formal procedures than Delphi are considered. The objective of this improvement effort would be to enhance the selection, control, and input information development of expert panels.

14.5 SUMMARY OF EXISTING RISK ASSESSMENT MODELS

Table 6 summarises the methodologies adopted in existing models described in the literature. The characteristics of the existing models are given in terms of the type of category and main features of model. It can be seen that a majority of the existing risk assessment models are of the absolute statistical inference type.

Table 7 gives an overview of the four general types of risk estimation methodologies that have thus far evolved and been applied to the various aspects of transport risk analysis. Though the actual approach of the four categories of models differ they all consider two basic elements these being:

i. The probability or likelihood of a vehicle being ~~involved~~ in an incident which results in the release of the material carried and

ii. The possible consequences of the release of the material.

Each of these techniques has advantages and disadvantages, which must be evaluated in any given case. For example, the primary limitation of statistical inference techniques is that one must assume the process generating the accident frequencies to remain constant over time. Otherwise the estimates obtained from past data could not be used to predict future occurrences.

Unlike statistical inference methods, fault-tree analysis attempts to model the incident occurrence process in great detail. Although this has scientific appeal, there are difficulties associated with the acquisition of data for predicting basic event probabilities and the uncertainty that all significant event sequences have been considered. Nevertheless, fault-tree analysis as applied to the estimation of the risk of transporting hazardous materials has been used in several studies.

In analytical and simulation modelling, various scenarios are examined indicating a range of values describing the best and worst conditions. These techniques are more applicable to situations where regulations on a national scale need to be tested and are of little benefit to the transporter or local authority in determining route choice.

The use of the subjective estimation is the writers option based on "educated guesswork" and should only be used in exceptional cases where no data whatsoever is available or where situation considered is extremely unusual and the other models are not applicable.

Of the various techniques discussed in the literature, statistical inference was considered to be the most appropriate for this project in terms of the overall project objectives of examining the determination of the risk of a particular route.

As the statistical inference analysis uses generally available information and is easily comprehensible, its application is within the reach of greater proportion of professionals and transporters.

TABLE 6 : CHARACTERISTICS OF EXISTING RISK ASSESSMENT MODELS

REFERENCE	TYPE: RELATIVE/ABSOLUTE	CATEGORY OF MODEL	MAIN FEATURES OF MODEL
8	-	-	Synthesis of models available
9	-	-	Synthesis of models available
10	-	-	Synthesis of models available
11	Absolute	Statistical inference	Developed incident probability and exposure factor for each section of route
12	Absolute	Statistical inference	Based on work undertaken in reference 11
13	Relative	Subjective estimation	This reference illustrates the use of the Delphi Model in various applications
14	Absolute	Fault tree	Develops a series of probabilities for each event in the man-machine-environment system. Numerous assumptions are made.
15	Absolute	Fault tree	Develops a series of probabilities for each event in the man-machine-environment system. Numerous assumptions are made.
16	Absolute	-	Develops a procedure for relating risk assessment model results to incident reporting
17	Absolute	-	Develops a procedure for relating risk assessment model results to incident reporting
18	Absolute	Analytical and simulation modelling	This approach, though systems oriented, considers the events leading to an incident and the possible consequences
19	-	-	Develops a release rate model for eight container classes based on an incident occurrence model and a fraction released model
20	-	-	Synthesis of techniques
21	Absolute	Statistical inference	A crude model with numerous simplifications based on historical data
22	Relative	Subjective estimation	No details given

23	Absolute	Statistical inference
24	Absolute	Statistical inference
25	Absolute	Statistical inference
26	Absolute	Statistical inference
27	Absolute	Statistical inference
28	Absolute	Statistical inference

A risk management model is developed wherein vulnerability is a product of risk reduction and preparedness

National level model utilising gross estimates of distance and speed to select minimum paths

Utilising a series of algorithms in terms of consequential effect, individual risk rate, societal risk

The approach emphasises the risk attributable to large release accidents using risk profiles based on probability distributions

Conditional probabilities are combined with traffic data to give accident probabilities. These are complemented by dispersion and density population evaluations

Based on FWHA guidelines. For each segment accident probability and consequence are combined to establish total risk

TABLE 7 : SUMMARY OF CATEGORIES OF RISK ASSESSMENT MODELS

CATEGORY	METHOD	ASSUMPTIONS	DATA REQUIREMENTS	CRITIQUE
Statistical Inference	Assumes that incidents occur independently, with constant probabilities. Past records provide frequency of occurrences and then extrapolated to future years.	Assumes historical data relates to present day conditions.	Vary from requiring detailed information for analysis of of certain section to global information for coarse route appraisals.	Most used technique for bot relative and absolute approaches. As hazardous incidents are rare the occurrence of a major accident can significantly affect historical trends assumed.
Fault Tree	Based on systems engineering approach in which all the elements of the man-machine-environment system are synthesised culminating in a particular consequence.	To realise the full benefit of this approach the probabilities of occurrence of each element of the system needs to be determined to an adequate precision. Such information is rarely available.	Substantial data requirements. Data not readily available to the practitioner.	Very detailed analysis of every element of the system. Has scientific appeal. Difficulty in acquiring required data. Application not very practical for the practitioner.
Analytical Simulation	Develops scenarios which consider the conditions under which incidents occur in the functions and inter-action of functions, system components and interfacing external factors.	Requires estimates and simplifications to be made of physical occurrences.	Analysis based solely on global data. Requirements dependent on the accuracy required in formulating the scenarios.	More applicable for regulatory evaluations on a national scale. Used with little success for individual risk assessment analyses.
Subjective Estimations	Subjective estimates are made by a panel of experts based on personal knowledge as to the possible consequences of an event.	Complete analysis based on a series of assumptions.	Specific methodology designed around available data. Particularly useful when available data is limited.	Inherently low confidence methodology. Completely dependent on expertise of panel. Only to be used in exceptional cases where none of the above models are applicable or data limited.

15. DEVELOPMENT OF RO[illegible]E SELECTION RISK MODEL

15.1 CONCEPTUAL ACTIVITIES

In this section of the report a risk assessment model is developed which will enable the practitioner to assess the risk of transporting a specific hazardous material cargo on a specific route.

Before developing the model in detail it is worth reviewing the main activities required.

As borne out in all the models considered (8-28), risk assessment of hazardous material transpo[illegible]tation can be conceptualised as a series of activities. These activities can be illustrate[illegible] in the form of a flow chart as shown in Figure 26.

The major ste[illegible]s being:

i. **Possible number of incident**

Fundamental to the calculation of the risk associated with hazardous material cargoes on a section of road is the estimation of the probability of an accident.

ii **Possible consequences/disutility of incident**

Should an incident occur, the effect of the release of the hazardous material on the surrounding population is of primary importance.

iii. **Network statement**

To enable the comparison of the alternative routes it is necessary to obtain certain physical/operational information relating to the routes, such as travel times, speed limits, type of facility, etc.

iv. **Calculation of total risk for each route**

The total risk of the release of the hazardous material to the public is the combination of the possibility of an incident and the possible consequences of the release of the hazardous material. This measure is determined by multiplying the possible number of incidents by the possible consequence on a particular link segment.

v. **Calculation of risk for comparable routes**

By summing these link specific risk measures along each alternative route, a total risk value can be established for each route. The calculation of risk for each alternative route considered can then be undertaken. This will enable the determination of lowest risk route.

vi. **Calculation of minimum travel costs for routes considered**

Using the network evaluation information it is possible to calculate the travel cost of utilising the alternative routes. Cost is probably the major determining factor in the route choice of the operator.

vii. **Performance report/comparison of routes**

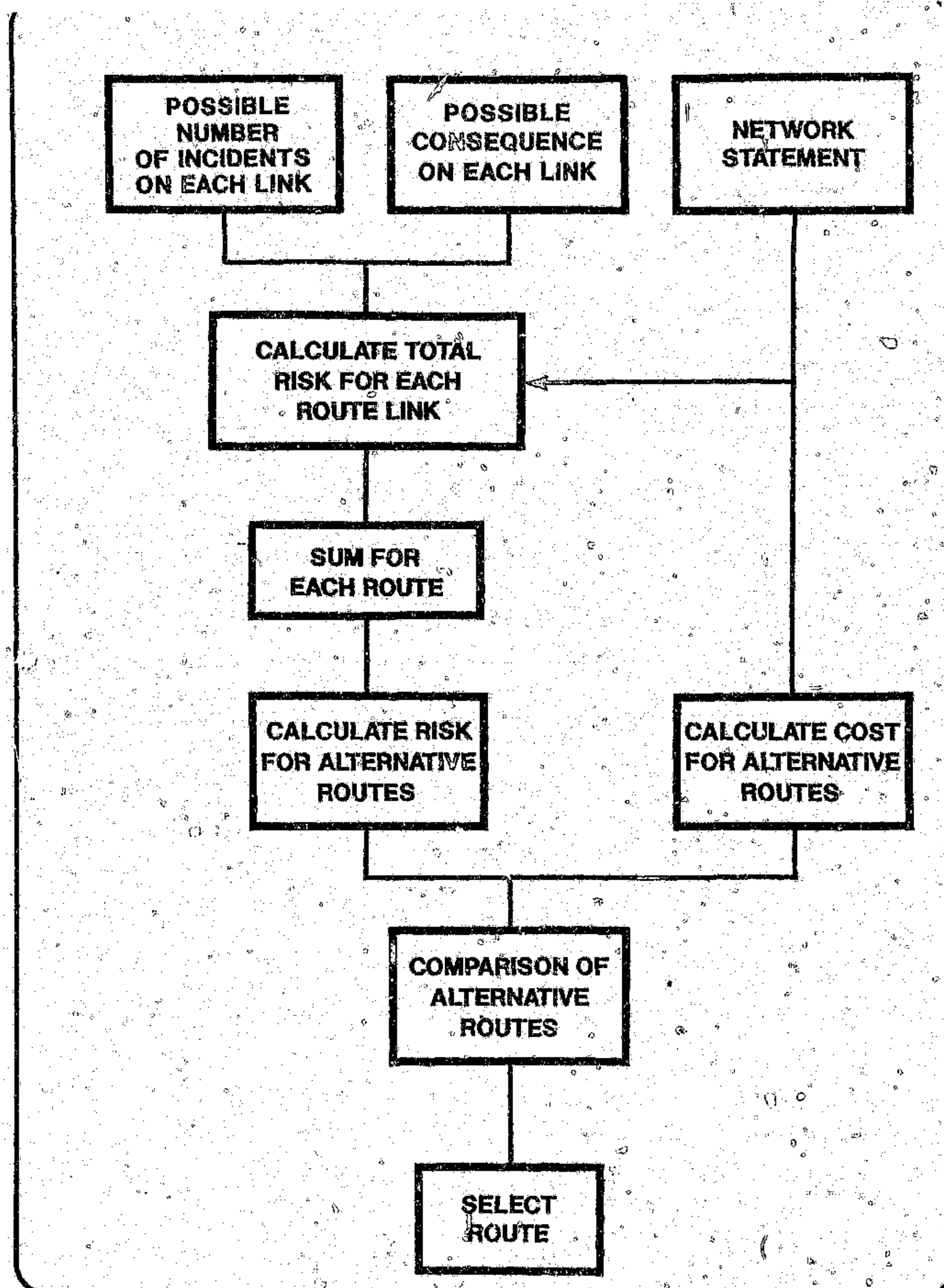
By comparing the risks of each route with the cost of utilising the route a direct comparison between the routes can be made.

viii. **Route selection**

It is then possible to select a preferred route based on the criteria assumed.

In summary, the critical element in the development of a risk assessment model for the transportation of hazardous materials can be described as the product of the number of a vehicle carrying a hazardous materials accidents and the consequences of that accident i.e.

Risk = Incident Likelihood x Consequence Factor



HAZARDOUS MATERIAL ROUTING
RISK-ASSESSMENT METHODOLOGY

Proj.

Fig. 26

STANWAY EDWARDS ASSOCIATES Inc Ing

15.2 DEVELOPMENT OF RISK ASSESSMENT MODEL

If we consider the route under consideration as divided into $l_{1\text{-}n}$ segments of length $L_{l_{1\text{-}n}}$.

Considering a small element of segment l of length δl_i which is occupied by the vehicle carrrying a hazardous substance at time T.

$I_{\delta l_i} = AR_i$ x Amount of Travel $_{l_{1\text{-}n}}$

where

$I_{\delta l_i}$ = Incident Likelihood on δl_i

AR_i = Average Accident Rate for Segment l

Amount of Travel $_{l_{1\text{-}n}}$ = Volume of vehicles travelling on δl_i at the same time as the hazardous vehicle under consideration x length of element δl_i;

$= (q_i \times t_i) \times \delta l_i$

$= q_i \times \frac{\delta l_i}{s_i} \times \delta l_i$

where

q_i = Flow rate on segment (Veh/hr)
t_i = Travel time (hr)
s_i = Average speed on segment l (km/hr)

It is assumed that over the small length of segment considered that the speed of the vehicle carrying hazardous material approximates to the average vehicle speed on the route.

The consequence or disutility (U_{ikT}) in terms of persons exposed per accident on segment i at time T resulting from the release of a hazardous material k is:

$$U_{ikT} = E_k \times C_i \times D_{iT}$$

where

E_k = Exposure area of material k (km^2)

C_i = Dispersion co-efficient

D_{iT} = Population density adjacent to section i_{1-n} at time T (persons/km^2)

The risk of an incident can be calculated as the product of the number of accidents on the selected route section and the number of persons exposed.

Therefore the risk ($R_{\delta l_i}$) in persons of an incident on element δl_i at time T can be described as:

$$R_{\delta l_i} = I_{\delta l_i} \times U_{ikT}$$

$$R_{\delta l_i} = AR_i \times q_i \times \frac{\delta l_i}{s_i} \times \delta l_i \times (E_k \times C_i \times D_{iT})$$

By taking the second integral, we obtain the risk (R_{ikT}) over the length of $L_{i_{1-n}}$ of section l_i giving

$$R_{ikT} = \frac{AR_i \times q_i \times L^2_{i_{1-n}} \times E_k \times C_i \times D_{iT}}{s_i}$$

Over the whole length of route j the risk is therefore

$$R_j = \Sigma[R_{ikT}]$$

where

R_j = set of segments i_{1-n} in route j

15.3 INCIDENT LIKELIHOOD

Accidents are stochastic events and as such it is reasonable to assume that vehicles with greater exposure or utilisation should show a relatively higher rate of involvement in transportation accidents.

Recorded accidents related to hazardous materials transportation are numerically only a small portion of all reported transportation related accidents. This is due to, essentially, three reasons, namely:

i. Actual happenings are rare.

ii. Though not nearly adequate, there is a marginally greater care exhibited by operators in transporting hazardous material than in the transportation of non-hazardous material.

iii. Until June 1987 there was no requirement to record whether a vehicle involved in a collision was carrying hazardous materials.

Incident probability measures the chance that one incident could occur to a particular vehicle on a particular route under a given set of circumstances.

15.3.1 Factors Affecting Incident Likelihood

In developing the incident likelihood of a particular route section a number of factors contribute to this likelihood, the major ones being;

- Type of facility and physical characteristics
- Volume of vehicles utilising facility
- Accident history of section
- Time of day
- Meteorological conditions
- Vehicle characteristic and condition
- Driving training, medical condition and state of mind
- Law enforcement/compliance.

Whilst all these factors could contribute to the incident, values are obtainable for a few of them.

It is therefore necessary to simplify the data requirements in order to take account of the dearth of information in South Africa. As such it is believed that a major portion of these factors can be ascribed to the type of facility and operating conditions experienced. Below, the variables which describe the Incident Likelihood, are evaluated.

15.3.2 Overall Accident Rate (AR_{ij})

Various incident probability models have been developed overseas which determine accident rates for specific facilities based on deterministic and stochastic influences. (29). These models are extremely "data hungry" and in the writer's view impractical for normal use.

The use of overall accident rates for a specific type of facility whilst not giving the degree of accuracy found in the more complex models, implicitly contain the factors which affect an incident as described above.

Owing to a lack of detailed data it is proposed that accident rates be based on the type of facility divided in terms of the urban/rural condition.

In terms of urban conditions accident rates for various routes in Johannesburg and Pretoria (30) were obtained. From these it was possible to determine accident rates (number of accidents per 100 million vehicle kilometres) for three types of facility these being:

i. Freeway.
ii. Major Arterial.
iii. Minor Arterial.

For rural conditions rates were obtained from a study undertaken by the Cape Provincial Authority (31).

Both sets of accident rates are shown in Table 8.

<u>TABLE 8 : ACCIDENT RATES</u> [acc/100 X 10^6 Vehicle km]

	<u>URBAN</u>	**<u>RURAL</u>**
Freeways	248 (i)	26 (ii)
Major Roads	1464 (iii)	111 (ii)
Minor Roads	2912 (i)	192 (ii)

(i)	Johannesburg City Council	19[illegible] - 1984
(ii)	Cape Provincial Authority	1983
(iii)	Pretoria City Council	1983 - 1985

It can be seen that the likelihood of an accident in an urban area is over 10 times greater than in a rural area.

15.3.3 <u>Flow Rate(q)</u>

In order to determine the number of accidents that are likely to occur whilst the hazardous vehicle is utilising the route under consideration if necessary to determine the flow rate (q) on the particular facility.

However, the flow rate tends to vary considerably depending on the time of day in which the journey is undertaken. This situation is particularly critical when urban conditions are considered.

In the major centres hourly traffic counts on the major routes are normally readily available and no corrections are necessary for the variations in flows.

However, in the rural areas and on minor routes, hourly traffic counts are unlikely to be available. In these cases Average Daily Traffic Volumes (ADT) are normally estimated by the local authority or the Department of Transport in the case of the rural areas.

Table 9 indicates a typical suburban street, business and rural area, the correction factors (32,33) in percentage terms (C_2), in which the flow rate on a particular route section may be estimated for a specific time of day from ADT volumes.

TABLE 9 : TYPICAL HOURLY PERCENTAGE OF AVERAGE DAILY TRAFFIC IN DIFFERENT OPERATING ENVIRONMENTS AT VARIOUS TIMES OF THE DAY (32,33)

PERIOD	PERCENTAGE ADT		
	SUBURBAN	BUSINESS	RURAL
Early Morning	1	1	2
Morning Peak	13	8	5
Midday	5	6	7
Afternoon Peak	12	10	5
Evening	2	1	3

15.3.4 **Average Speed** (S_i)

The number of vehicles, a vehicle transporting hazardous materials is likely to encounter on a section of the route depends on the time spent in that section of route and the flow rate.

The time spent in the section under consideration will depend on the average speed and the length of section.

Table 10 gives a series of default speeds for different types of facility (34).

TABLE 10 : DIFFERENT TYPES OF FACILITIES

TYPE OF FACILITY	URBAN (km/hr)	RURAL (km/hr)
Freeway	75	90
Arterial	45	65
Minor Road	30	45

It is assumed that the vehicles carrying the hazardous material will travel at the section's operating speed for the purpose of calculating time spent on the road.

15.4 CONSEQUENCE FACTOR OR DISUTILITY (U_k)

Three types of damages are assumed to result from the consequent impacts of a hazardous material incident;

i. Damages to individuals directly involved in each accident (this includes drivers and passengers of all vehicles involved and adjacent vehicles).

ii. Damages to individuals not directly involved in the accident but who reside in proximity to the incident site

iii. General property damages that result directly or indirectly from an incident (this includes vehicles and other properties).

However, in the development of this model it was assumed that when a substantial quantity of a lethal hazardous material is released in an incident the most important consequence of concern is the loss of human life and thus the damage to general property has been ignored.

15.4.1 Factors Affecting the Consequence of an Incident

The consequence of an incident is dependent on a number of factors, the prominent factors are:

- Type of material released
- Rate of release
- Amount of material released
- Surrounding population
- Surrounding vehicle occupants
- Fuel storage facilities in vicinity
- Nearby waterways
- Preparedness of protection services
- Driver training
- Correct Hazchem signage/loading of vehicle.

Whilst all these factors have an influence on the consequence, a number of these factors are difficult to quantify and are not considered in the model. As the focus of the model is on the protection of human life and the risk is most effectively calculated by considering the expected population at risk within the hazard area of the spill. Thus, time of day at which the shipment takes place should be taken into account when estimating the number of exposed individuals in the general public.

To be precise, the population density should include any on-scene professionals (fire brigade, traffic officials and related emergency personnel) and the degree to which persons in the lethal area are vulnerable (depending on the fire protection services preparedness, mobility, protection and so forth) should be reflected. However, these elements are difficult to quantify and have been excluded from the model.

15.4.2 Exposure Area (E_a)

In the event of a release of a hazardous substance the escaping material will spread, evaporate and mix with the air surrounding the spill forming a cloud. (If flammable, the air-fuel mixture will burn if a suitable ignition source is present).

The details of the spreading and cloud formation, among other things, depend on the rate of release of the material, its density, vaporisation rate and buoyancy, meteorological conditions, and terrain. The cloud that is formed is characterised by its size and concentration at any location relative to the release point and at any time after release.

Actual information of this type is difficult to obtain. In the mess and turmoil of an accident, the magnitude of a release is understandably difficult to determine, and subjectivity in making judgements about the size of an impacted area or the value of damage may be unavoidable. Assessments of injury also are subject to interpretation. The guidelines are not always clear, and the motives are not always pure when accident consequences are being reported (35).

A number of mathematical models have been developed (35,36,37) that attempt to describe these complex events. The models differ significantly from one another in sophistication, because of their approximations and assumptions, in characterisation of the source (point of area source, instantaneous or continuous release), or in the manner of spreading and air entrainment. For the majority of materials, input data on material properties are lacking and data for similar materials are used, which gives rise to errors of uncertain magnitude.

The zone of impact of the release of a hazardous material is affected by a number of factors which vary from incident to incident and are not properly described in the mathematical models. To illustrate the above the release rate of a chlorine tanker is considered. Table 11 illustrates the estimated hazardous area of four major release scenarios as given by Andrews et al (38).

TABLE 11 : ESTIMATED RADIUS OF IMPACT FOR RELEASE OF CHLORINE FROM A SINGLE TANK (38)

RELEASE SCENARIO	RADIUS OF IMPACT (m)
1. A continuous release of chlorine vapour at 4 kg/second	42
2. A continuous release of liquid chlorine at 10 kg/second	[illegible]
3. Extreme rapid to instantaneous release of all contents	620
4. Instantaneous and catastrophic failure of tank	720

It can be seen that there is considerable variation in the radius of impact resulting from just one of the many factors affecting the cloud formation.

As a result most estimates of evacuation distance have been based on the "worst possible scenario" approach, which have factors of safety of up to 10. This is evident when the values estimated in Table 11 are compared with those by the USA Department of Transport given in Table 12.

15.4.3 Evacuation Distances (r_e) Utilised

The most utilised source of evacuation distances is those given in the DOT Emergency Response Guidebook, (39), Table of Isolation and Evacuation Distances. In absence of more reliable information these figures have been used in the following analysis and are illustrated in Table 12.

TABLE 12 : AVERAGE EVACUATION DISTANCES (r_i) FOR EACH CLASS OF HAZARDOUS MATERIAL FROM SOURCE (39)

Hazardous Material	Average Evacuation Distance (r_i) (km)
Class A explosive	0,8
Class B explosive	0,8
Class C explosive	0,5
Flammable liquid	2,1
Combustible liquid	3,5
Flammable gas	1,6
Flammable solid	1,3
Non-flammable gas	3,4
Poison A	N/A
Poison B	3,2
Corrosive	2,1
Oxidiser	3,2

However, the evacuation distances presented in Table 12 take no cognisance of preparedness and are the distances within which the materials released are hazardous to human life.

15.4.4 Zone of Impact/Dispersion of Hazard Material

In the model a point event corresponding to a circular zone of impact for each spill, is assumed. The point event is then integrated over the length of the link to obtain the risk.

The assumption of a circular zone of impact may not reflect a realistic dispersal of toxic contaminants. As noted by Schulze (40) the shape of dispersion cloud may vary considerably, depending on wind speed and direction.

The circular dispersion formula utilised in this study is a centre line of plume estimate, with no wind blowing. As such, the impact zone estimated for each road link tends to over-estimate the area that is likely to be affected in a real spill situation. The area of impact for each link depends on the nature of damage from a potential spill.

The zone that is likely to be affected can be obtained from the expression:

$$E_k = \pi r_k^2$$

where

E_k = Explosive area on section i of route j from material k (km²)
r_k = evacuation distance (km).

This equation assumes that all persons within the exposure area are exposed to the same degree which is clearly not the case.

Abkowitz and Cheng (41) estimated that the concentration of substances released in the air can be represented by an equation that forms a cone of concentration, where the concentration is greater nearer the point of release. This concept is developed further below in Section 15.4.5

15.4.5 Dispersion Co-efficient (C_i)

As exposure to each potential incident varies with distance from the incident site, the more distant points are not contained within the range of potential damage for the same duration time as nearby points. In order to take cognisance of this fact, Saccomanno et al (42) recommended that the exposure area has been multiplied by a factor of $\pi/4$ (23), to standardise the range for exposure variations with distance. Within this reduced range, all locations are assumed to be equally affected by a hazardous material incident.

The circular dispersion assumed in this study is estimated from the centre line of the link, with no wind blowing. As such, the impact zone estimated for each road link tends to overestimate the area that is likely to be affected in a real incident situation. However, the distortion of the circular dispersion resulting from uneven wind directions will most likely produce a minimal reduction of the area of exposure and will not affect the accuracy of the model.

15.4.6 Population Density (D_{ii})

On any particular route being considered, the population density can vary considerably. Whilst these densities can be determined, the calculation can be tedious and may not be that accurate owing to variations in density at specific times of the day. For expediency in the calculation, population densities have been categorised into five groups as shown in Table 13.

TABLE 13 : POPULATION DENSITIES (D_{ii})

CATEGORY	TYPE OF DEVELOPMENT	DENSITY (D_{ii}) Non-Worktime	Worktime
Central Business Districts	Office	20 people/hect. (2000 people/km^2)	600 people/hect.
High Urban Residential	Flats/Apartments	200 people/hect. (20 000 people/km^2)	20 people/hect.
Urban Residential	Detached Houses High Income Townhouse	20 people/hect. (2000 people/km^2)	2 people/hect.
Rural Residential	Minimum 1 hect. plot	2 people/hect. (200 people/km^2)	2 people/hect.
Agricultural	Farms	0,2 people/hect. (20 people/km^2)	0,2 people/hect.

(Ref. 43)

16. COMPARISON OF OPERATING COST OF ROUTE CONSIDERED

Once the minimum risk route has been identified it is necessary to consider the difference in operating cost in using the normal (unrestricted route) which is normally the minimum cost route to that of the minimum risk route. The calculation of operating costs have been well documented, the most comprehensive being NITRR manual on the Economic Evaluation of Transportation Projects Parts 1 and 2, K64 (44). Commercial vehicles are divided into three categories:

Light	1,0 - 1,5	ton payload
Medium	7,0 - 9,0	ton payload
Heavy	15,0 - 20,0	ton payload

16.1 THE COMPONENTS OF TOTAL RUNNING COST

In Figure 27 the components of total running cost (measured at market prices) for HGV's are shown for travel speeds ranging from 10 km/h to 120 km/h. Tyres and oil for HGV's constitute between 13% and 25% of total running cost, whilst fuel constitutes between 39% and 52% of total costs. Depreciation constitutes between 10% and 25% of total costs for HGV's.

A single average speed for each facility was assumed in running cost calculation for each type of facility. These speeds were derived from Table 10 and are indicated in Table 14.

TABLE 14 : ASSUMED SPEED FOR EACH TYPE OF FACILITY

TYPE OF FACILITY	SPEED (km/hr)
Freeway	80
Major Arterial	60
Minor Arterial	45

FIGURE 27:

Components of total running cost (market price) at different travel speeds: HGVs

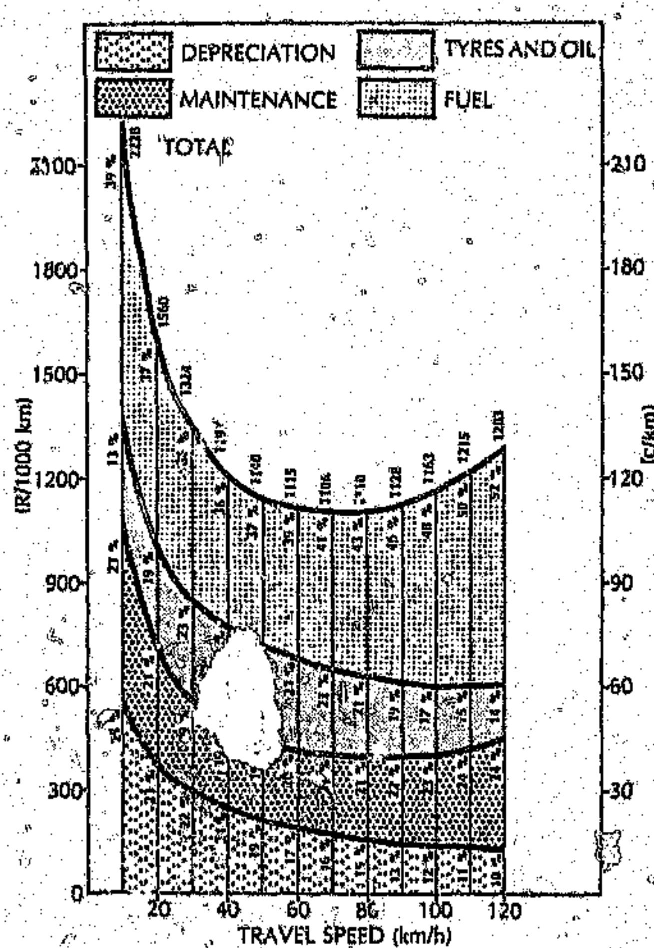


FIGURE 28:

The cost of travel time at different travel speed

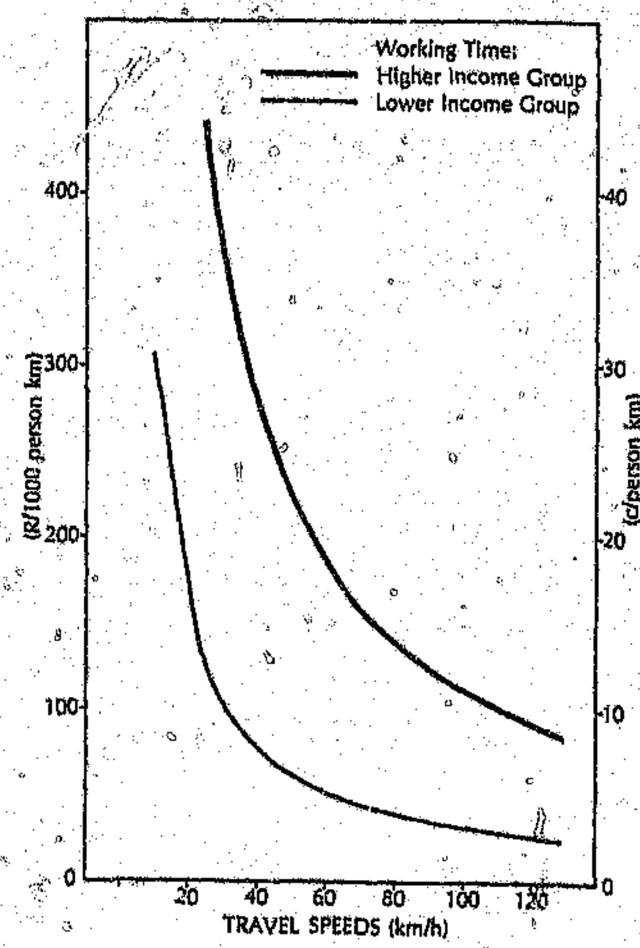


Table 15 indicates the total running costs for vehicles carrying hazardous materials utilised in the analysis.

TABLE 15 : TOTAL RUNNING COSTS

Speed (km/h)	Cost (cents/km)
80	111,0
60	111,5
45	116,6

16.2 THE COST OF TRAVEL TIME

In Figure 28 the cost of travel time at travel speeds ranging from 10km/h to 120km/h is shown. The four curves relate to time costs for high and low income groups as well as to working time and leisure time for each income group. The costs will obviously increase in multiples of the occupancy rate should the driver have an assistant. Leisure time is rated at 25% of working time and, in general, the PWV cost rate is 1,1 times that of the national cost rate.

The curves in Figure 28 are based on the following values:

TABLE 16 : VALUE OF TRAVEL TIME IN RANDS PER VEHICLE OCCUPANT's HOUR

	INCOME GROUP	
	Higher (R/hr)	Lower (R/hr)
Working Time:		
- PWV Area	12,20	3,48
- National	11,06	3,14

The following assumptions were made in order to calculate the cost of the travel time of a hazardous material vehicle given in Table 17, these being:

i. a vehicle occupancy of two persons/vehicle was assumed i.e. driver plus mate.

ii. both occupants were of a low income group.

iii. PWV area work time was assumed.

TABLE 17 : COST OF TRAVEL TIME

Speed (km/h)	Cost (cents/km)
80	8,7
60	11,6
45	15,5

Practitioners who require a more detailed analysis of vehicle operating costs are referred to the Road Freight Association's vehicle cost schedule (45). Their analysis is based on an annual survey of their membership and consider each axle configuration of commercial vehicles, however no consideration is given to staff costs.

17. EVALUATION

It is clear that one of the impediments to the successful implementation of risk assessment for the problems of transporting hazardous materials is the inadequacy of the data, in both scope and detail.

The most controversial aspect of the implementation of risk assessment is the evaluation and interpretation of the predicted risks. This aspect of the problem involves judgements based on factors that are difficult to quantify. They include the hazards, risks, costs and benefits, business and political risks etc. There is the lack of concurrence as to what attributes should be included in these factors. Even if all the attributes could be defined and agreed to, their quantification is not readily achieved.

However, it is necessary to obtain a comparison of the routes under consideration which is logical and systematic.

The output from the model endeavours to provide a level of risk based on the potential number of persons "involved" in an incident for each trip. As a hazardous material vehicle incident tends to be relatively rare, as they make up only a small proportion of the total traffic on a route, the number of persons likely to be involved in an incident tends to be low. This makes the decision to use a lower risk route which may incur higher operational costs on the part of the operator more difficult as the operator is generally not in a position to appreciate the risk to the community as a whole and the subsequent social costs incurred by such an incident.

Where this decision to utilise a lower risk route may affect the competitive position of the carrier and/or the shipper and/or the availability of the commodity in a timely manner there is bound to be considerable resistance to its use. This promotes the question, can business risks be accounted for and somehow be balanced against the risk reduction of the hazard? From the operator's point of view travel cost is his only consideration, as the social cost of an incident is borne by the whole community. However, certain operators may feel that the cost of adverse publicity as a result of an incident may mar the operators image as a safe carrier and therefore utilise a lower risk route.

18. CASE STUDY

18.1 COMPARISON OF ALTERNATIVE ROUTES

To illustrate the application of the model three routes between Alrode in the southern industrial belt of Johannesburg and Sasolburg were analysed. This origin/destination pair was shown to be most common during the data collection surveys.

In this application it is assumed that a single tanker load of 32 tons of petroleum is to be transported between the origin/ destination pair during the mid-morning period.

The most probable routes between the two areas are:

Route 1: M1 motorway/R568.
Route 2: M27.
Route 3: R26.

These routes are illustrated in Figure 29.

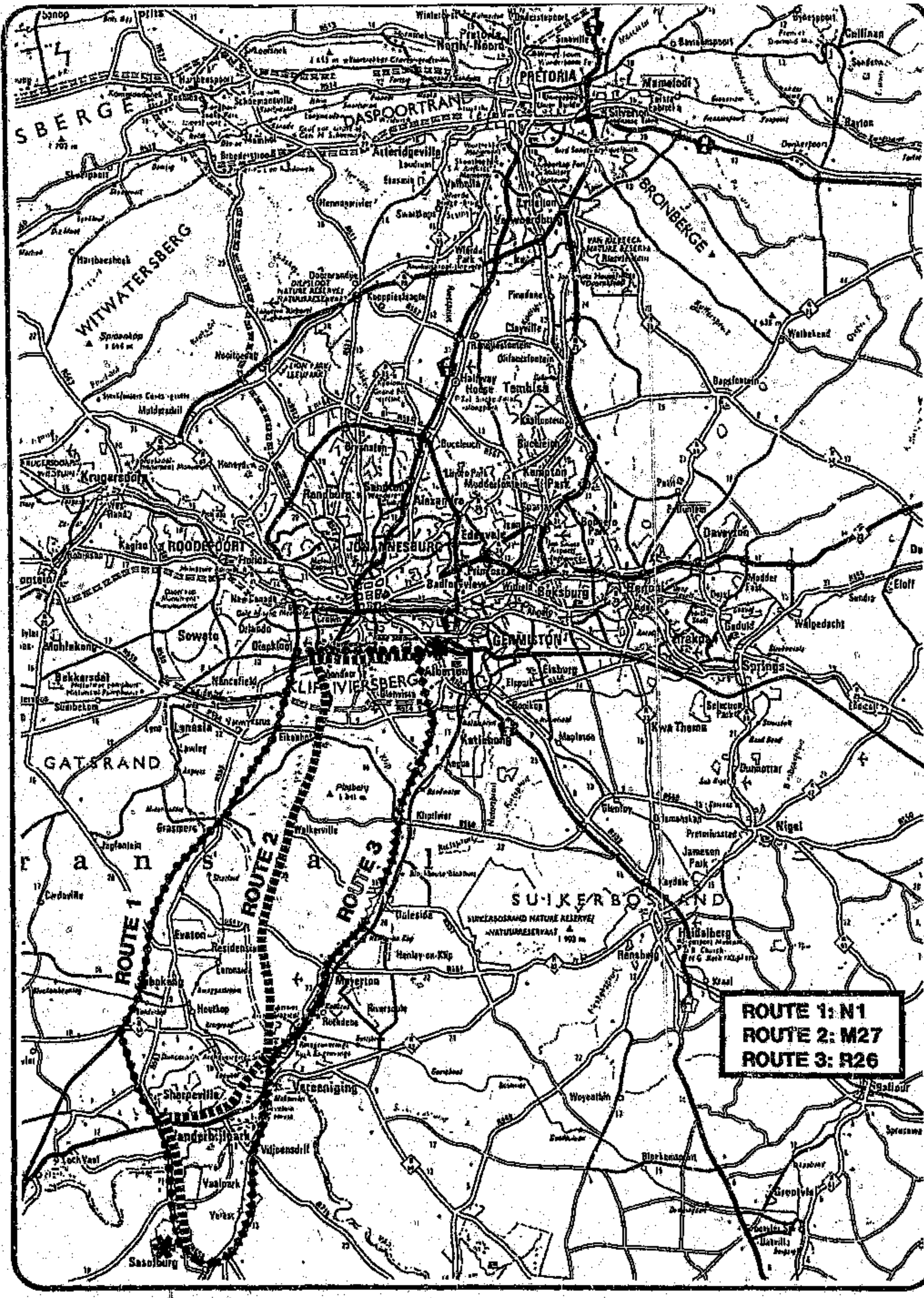
All routes differ in both types of facility utilised and length of route. Some of the routes travel through urban areas and city centres.

Table 18 summarises the results of the analysis into the categories i.e. likely number of accidents and consequence.

The complete analysis is given in Appendix E.

TABLE 18 : SUMMARY OF RESULTS OF CASE STUDY

CRITERIA	ROUTE 1 (N1)	ROUTE 2 (M27)	ROUTE 3 (R26)
Distance (km)	66	69	63
Likely number of accidents (acc)	$4,87 \times 10^{-3}$	$33,96 \times 10^{-3}$	$7,11 \times 10^{-3}$
Consequence Exposure (Persons)	43 534	43 512	43 727
Risk (Persons)	66	566	106



	CASE STUDY ROUTES CONSIDERED BETWEEN SASOLBURG AND ALRODE	Figure No. 29

From Table 18 we can see that the type of facility used by the hazardous vehicle has a large influence on the likelihood of an accident where Route 1, which utilises the N1 motorway, has the lowest accident likelihood even though it is not the shortest route. Whereas the length of the route and the adjacent population densities tend to affect the consequence.

In terms of the route which is least likely to be involved in an incident it can be seen that Route 1, closely followed by Route 3 are considered to be most appropriate.

The operating cost of using the three alternatives routes is given in Table 19.

TABLE 19 : THEORETICAL COST ANALYSED BASED ON K64

ROUTE	ROUTE TYPE	DISTANCE (km)	SPEED (km/hr)	THEORETICAL TRAVEL TIME (min)	RUNNING COST (R/trip)	TIME COST (R/trip)	TOTAL (R/trip)
1 (N1)	1	57	80	43	63,27	4,96	68,23
	2	9	60	19	10,04	1,04	11,08
	3	-	45	-	-	-	-
		66					79.31
2 (M27)	1	2	80	2	2,22	0,23	2,45
	2	67	60	67	74,70	7,73	82,43
	3	-	45	-	-	-	-
		69					84.88
3 (R26)	1	55	80	41	61,05	4,79	65,84
	2	3	60	3	3,35	0,35	3,7
	3	5	45	7	5,58	0,76	6,34
		63					75.88

It can be seen that owing to the directness of the route and the high operating speed, Route 3 has the least operating cost.

18.2 DISCUSSION

Table 20 compares the trip cost of the alternative routes with the potential person injured.

TABLE 20 : COMPARISON OF TRIP COST AND POTENTIAL PERSONS INJURED

ROUTE	POTENTIAL PERSONS INJURED PER TRIP	TOTAL COST (R)/TRIP
1	66	79,31
2	566	84,88
3	106	75,88

In terms of total cost it can be seen that with a marginal increase in operating cost, the potential person injured can be reduced substantially i.e. utilising route 1 (which has the lowest risk) instead of route 3 (which has the lowest operating cost).

As the consequence factor is largely dependent on the population density adjacent to the link, which varies throughout the day, the model could also be used to ascertain the most appropriate time of the day to move hazardous materials in order to reduce the potential risk.

19. CONCLUSION OF SECTION 3

The modelling of rare hazardous vehicle incidents implies that subjective evaluations and estimates must be made and some uncertainty is bound to exist. The range of attributes which could be included in the model are large and some important factors which may relate to a specific failure or damage mode may have been overlooked. However, the need to provide a practical, comprehensible methodology for quantifying risk is needed. These simplifications do not mean that the results of the model are of poor quality or are useless for practical decision making. Variations are bound to occur in the application of the model by different users as its simplicity requires a certain amount of judgement, however these errors are relative and likely to occur throughout the whole analysis and to each route.

Clearly the routing of hazardous material vehicles to low risk routes can enhance public safety. While these low risk routes may reduce the potential extent of damage associated with an incident its effectiveness must be viewed in relation to possible higher operating costs which in most instances will outweigh the benefits to society.

SECTION 4

CONCLUSIONS

20. **OVERALL CONCLUSIONS**

The study clearly shows a lack of compliance by heavy vehicle operators of the regulations governing road transportation of hazardous materials. Only 22% of vehicles carrying hazardous materials complied with regulations in all respects. The reasons for this low compliance can be ascribed to weak law enforcement and indifference and negligence among operators. A majority of drivers had no idea what substances they were carrying, an extremely dangerous situation should an incident occur. It can be argued that South African heavy-vehicle operators are under tremendous pressure to contain costs within a highly inflationary and competitive environment, but this cannot be sufficient excuse for presenting such a serious threat to the public.

Heavy vehicle band width diagrams were constructed for the PWV area in which the busiest road section was found to be on the N3 between Gillooly's and Geldenhuis Interchanges. Excluding explosive trucks, 283 vehicles carrying hazardous materials pass through this section during a 12 hour period. Ironically, this is considered to be one of the potentially most dangerous sections of the entire N3 because it passes through a residential area.

A risk assessment model which tends towards the absolute, i.e. where the risk is expressed in quantifiable terms such as persons injured, was developed. Representing rare accidents implies that subjective evaluations and estimates be made, and numerical values calculated which are bound to be uncertain. Important parameters may have been overlooked but this does not mean the model is of limited use. It is believed that the safe transportation of hazardous materials can be enhanced through effective routing strategies and that the model developed can assist in their developments. The case study shows that a minimum risk routing strategy can reduce the potential damage associated with hazardous material incidents, with a marginal increase in operating cost. The effectiveness of such a strategy must be viewed in relation to possibly higher vehicle operating costs. From the operator's point of view the introduction of a routing strategy based solely on minimum risk in all but a few instances may not be cost effective as incidents are rare and the probability of an incident is very low.

Whilst endeavouring to provide a model which can be used by both operator and local authority certain simplifications were made. Generalised assumptions as to traffic conditions in urban and rural areas have been made which need to be honed to local conditions.

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APPENDICES

APPENDIX A

PROFORMA OF QUESTIONNAIRE

NITRR TRANSPORTATION OF HAZARDOUS MATERIALS

ROADSIDE INTERVIEW SURVEY

STATION NO. [ ] DIRECTION: [ ] DATE: [| | | | |]

[illegible]	[illegible] - 06h15	09	08h00 - 08h15	17	10h00 - 10h15	25	12h00 - 12h15	33	14h00 - 14h15	41	16h00 - 16h15
[illegible]	06h15 - 06h30	10	08h15 - 08h30	18	10h15 - 10h30	26	12h15 - 12h30	34	14h15 - 14h30	42	16h15 - 16h30
[illegible]	06h30 - 06h45	11	08h30 - 08h45	19	10h30 - 10h45	27	12h30 - 12h45	35	14h30 - 14h45	43	16h30 - 16h45
[illegible]	06h45 - 07h00	12	08h45 - 09h00	20	10h45 - 11h00	28	12h45 - 13h00	36	14h45 - 15h00	44	16h45 - 17h00
[illegible]	07h00 - 07h15	13	09h00 - 09h15	21	11h00 - 11h15	29	13h00 - 13h15	37	15h00 - 15h15	45	17h00 - 17h15
[illegible]	07h15 - 07h30	14	09h15 - 09h30	22	11h15 - 11h30	30	13h15 - 13h30	38	15h15 - 15h30	46	17h15 - 17h30
[illegible]	07h30 - 07h45	15	09h30 - 09h45	23	11h30 - 11h45	31	13h30 - 13h45	39	[illegible] - 15h45	47	17h30 - 17h45
[illegible]	07h45 - 08h00	16	09h45 - 10h00	24	11h45 - 12h00	32	13h45 - 14h00	40	15h45 - 16h00	48	17h45 - 18h00

TYPE OF VEHICLE

RIGID	FLATBED	1
	TANKER	2
	OTHER	3
ARTICULATED	FLATBED	4
	TANKER	5
	OTHER	6

METHOD OF CONTAINMENT

TANK	1
DRUM	2
CYLINDER	3
BAGS	4

DOES THE VEHICLE HAVE A TRAILER? [YES | NO]

WHERE DID YOU START YOUR JOURNEY? ______________________ [| | |]

WHERE IS YOUR DESTINATION? ______________________ [| | |]

LABELLING

WHICH HAZCHEM SIGNS ARE DISPLAYED ON THE VEHICLE?

NUMBER OF SIDES OF VEHICLE HAZCHEM SIGNS DISPLAYED? [ ]

EMERGENCY ACTION CODE [| |]

CORRECTLY POSITION / FIXED / CLEARLY VISIBLE [ ]

UN SUBSTANCE NUMBER DISPLAYED? [| | |]

CONSIGNMENT DOCUMENTS

PRODUCT/S IDENTIFICATION RECORDED ON DELIVERY DOCUMENTS? ______________________

____

QUANTITY TRANSPORTED? [ ] m^3 [ ] liters [ ] tons [ ] empty

ARE YOU IN POSSESSION OF A SCALE CARD? [|]

WHEN WAS THE LAST TIME YOU UNDERWENT A MEDICAL EXAMINATION? 3 MONTHS [ ] 6 MONTHS [ ] 12 MONTHS [ ] OVER 12 MONTHS [ ]

HAVE YOU RECEIVED TRAINING ON HOW TO HANDLE THE SUBSTANCE YOU ARE CARRYING? - WITHIN THE LAST
3 MONTHS [ ]
6 MONTHS [ ]
12 MONTHS [ ]
OVER 12 MONTHS [ ]

TREMCARD / INFORMATION ON PRODUCT CARRIED [YES | NO]

APPENDIX B

MANUAL CLASSIFICATION COUNTS

NITRE HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 1 DATE 25/11/87

TIME	DIRECTION : NORTH						DIRECTION : SOUTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
06h00	41	3		2			15	2		1		4
06h15	57	1		3			32	4		5		8
06h30	76	5		6	1		30	1		2		4
06h45	81	6		4	1		55	1		1		5
07h00	115	11		1		1	51	6		2		8
07h15	120	12		5		2	48	5		3		3
07h30	100	3		5			51	6		4		1
07h45	100	7		3	1		64	8		9		1
08h00	83	3		7	1	1	52	3		8		1
08h15	56	7		2			58	4		6		1
08h30	65	7		3			45	3		8		
08h45	67	8		4		3	41	6		5		1
09h00	95	5		3		1	50	15		3	1	2
09h15	62	9		2	1	1	50	11		3		
09h30	68	10		4			51	8	1	3	2	2
09h45	64	7		5			52	4		2		1
10h00	65	5		4	1		50	5		4		
10h15	58	3		8	2	1	42	3		2		
10h30	75	7		5	1	2	47	9		5		
10h45	50	5		3		1	41	6		5		
11h00	56	12		6			67	10		3		2
11h15	61	10		3			60	6		2		1
11h30	60	12		8			55	9		5		1
11h45	63	12		6			62	7		4		
12h00	51	6		9			52	12		6		
12h15	59	6		3			55	7		5		
12h30	69	8		8	1		55	7		1		1
12h45	41	8		4			53	8		5		

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 1 DATE 25/11/87

TIME	DIRECTION : NORTH						DIRECTION : SOUTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
13h00	61	7		4			74	13		1		
13h15	52	10		3		1	91	12		9		
13h30	65	16		4			49	5		4		
13h45	58	14		5			60	14		3		
14h00	41	14		4			48	11		7		
14h15	47	9		7		2	42	3		8		
14h30	60	5		1		1	48	12		5		1
14h45	58	8		4			50	6		6	1	
15h00	58	7		3		1	47	13		5		1
15h15	56	7		5	1	2	68	7		7		
15h30	67	16		4		2	88	8	1	8		
15h45	41	3		3			91	13		6		
16h00	58	8		3			58	8		9	1	
16h15	45	9		3		5	52	9		4		
16h30	64	4		7		3	60	8		7		1
16h45	74	9		6		11	59	4		7	2	
17h00	100	5		7		7	101	6		8		1
17h15	79	6		3		3	85	10		7		2
17h30	75	8		4		11	126	10		2		1
17h45	82	9		8		10	77	9		2	2	2
TOTAL	3199	372	0	214	11	72	2759	357	2	227	9	56

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 2

DATE 01/12/87

TIME	DIRECTION : NORTH						DIRECTION : SOUTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
06h00	27						43	3		1		
06h15	145	2		2			120	1		1		
06h30	265	6		1		2	155	8				
06h45	453	4		3			182	13		5		
07h00	605	7				1	192	5		1		
07h15	555	4		1			315	2		1		1
07h30	425	10	2	2			[illegible]	8		1		2
07h45	380	5		3			[illegible]	[illegible]		3		
08h00	295	13		3			[illegible]	[illegible]		9		
08h15	361	15		3			[illegible]	[illegible]		2		1
08h30	352	14		4		1	200	[illegible]		2		
08h45	334	21		6			164			3		
09h00	305	19		2			196	11	1			
09h15	310	15		10			204	10				
09h30	320	25		10		2	188	16				
09h45	285	18		7			276	35		2	1	
10h00	266	18	1	3			172	14		4	1	
10h15	237	18		4	1		208	14		7		
10h30	345	31		2		1	195	7		7		1
10h45	349	16		3		1	226	13		6		
11h00	310	15		3			196	9	1			
11h15	270	12		7			214	26				
11h30	[illegible]	10		4			285	17				
11h45	245	10		6			247	19		2	1	1
12h00	209	14		3			254	31		4		2
12h15	206	25		5			223	13		4		1
12h30	253	16		5			294	14		8		1
12h45	207	16	1	6			250	9		6		

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION : NORTH

DATE 01/12/87

TIME	DIRECTION : NORTH						DIRECTION : SOUTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
13h00	222	16		10			241	16		1	1	
13h15	196	13		6			232	11		2		
13h30	225	6		2		1	244	13		3	2	
13h45	160	13		2			287	19	1	2		
14h00	257	9		5		2	291	24		8		
14h15	224	6		8			247	11		3		
14h30	220	13		11	1	1	237	18		9	1	
14h45	207	12		3			286	18		3		
15h00	240	7		8			256	16		2		
15h15	191	7		4			260	8		5		
15h30	205	4		3		1	273	10	1	2		1
15h45	157	8		[illegible]			302	13		7		
16h00	233	12		2			301	20		3		
16h15	210	11		2			353	17		4		
16h30	237	13		5			484	12		4		1
16h45	278	11		7		3	385	14		1		2
17h00	300	6		6			344	18		1		
17h15	255	13		2		1	403	12		5		2
17h30	240	7		3		1	205	12		5		
17h45	215	4		2			195	8	1	4		
TOTAL	13 086	570	4	204	2	18	11 694	641	5	155	7	17

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 3 DATE 29/10/87

TIME	DIRECTION : NORTH						DIRECTION : SOUTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
06h00	125	16		7		3	205	4		1		17
06h15	187	12		15			320	5		7		13
06h30	230	5		4		11	370	6		1		9
06h45	271				2	9	361	7		2	1	11
07h00	170	1		4		4	295	5		4	1	5
07h15	246			10	1	3	280	5		3	1	6
07h30	310	7		3	1	8	275	2		4		6
07h45	244	5		10		4	248	8		4	1	10
08h00	193	7		9	1	4	213	9		7	1	3
08h15	170	13		3			170	11		3		4
08h30	131	10		7			142	8		6		1
08h45	126	17		4	1	3	123	11		9	1	2
09h00	152	7		11		3	125	7	1	4		1
09h15	138	9		8		2	118	7		6	1	3
09h30	115	8		9	1	2	88	8	1	4	1	
09h45	111	4	1	12		1	134	12		9		
10h00	109	7		13	1	1	128	13		11		
10h15	90	6		16	2	1	126	7		9		3
10h30	81	10		8		2	101	10		5		
10h45	92	6		16		3	111	12	1	4		
11h00	102	7		8	1	1	116	11	1	5		1
11h15	94	11		7	2		117	11		4	1	1
11h30	121	3		3	1		97	13		8		
11h45	105	7		5	2	7	104	13		6	1	1
12h00	115	12		8		4	112	11		9		2
12h15	125	6			1	1	137	15		6		1
12h30	112	11		17	1	4	133	11		3	1	2
12h45	117	11		10	1	1	121	14		2		

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 3 DATE 29/10/87

TIME	DIRECTION : NORTH						DIRECTION : SOUTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
13h00	103	15		8		3	135	11		3		2
13h15	111	9		11	1	5	158	10	1	4		
13h30	87	4		9		1	141	11		4	1	2
13h45	117	12		6	2	2	112	5		3	1	2
14h00	119	12		6	1		115	14	1	4		
14h15	127	14		10		2	123	7		7	1	1
14h30	148	7		16		2	150	10		5	1	
14h45	140	4		19		1	162	6		5	1	2
15h00	128	11		2		1	113	11		11	1	3
15h15	116	5		3	1	3	129	19		8	2	1
15h30	131	4		2		1	138	13		4		4
15h45	140	11		13		1	156	12		2	1	3
16h00							198	13		7	1	4
16h15							147	18		2	1	7
16h30							238	8		5		4
16h45							256	6		8	1	6
17h00	372	5		5		6	300	8		4	1	9
17h15	390	5	1	6	1	6	268	6		3		7
17h30	560	4		8		20	225	5		5	1	4
17h45	402	10			2	10	143	4		2		3
TOTAL	7377	350	2	365	27	152	8287	453	6	242	25	125

NITRE HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 4 DATE 29/10/87

TIME	DIRECTION : SOUTH						DIRECTION : NORTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
06h00	60	5			1	9	111	3				3
06h15	110	5		1	1	6	158	3		1		4
06h30	250	4		2	3		200	2		1		2
06h45	362	9		1	4		214					
07h00	390	7			6		273	6		3		5
07h15	480	5		1	1	5	312	11		2		4
07h30	400	7		1	2	1	380	7		4		
07h45	380	4			1	2	407	5		4		2
08h00	150	6	1			3	240	6		5	1	1
08h15	160	7	1	1	3	2	222	12	1	3	1	
08h30	155	16		3		1	203	10	3	4	1	2
08h45	165	12		2		1	172	5		4	1	
09h00	120	7		1		2	153	11		6	2	2
09h15	130	10	1	5	1	2	165	10	1	4		1
09h30	123	8	1	2	2	5	141	8	1	2	1	1
09h45	129	5		6	3		135	8		4		
10h00	115	9		2			120	12		8	1	2
10h15	140	7	1	1	2	1	143	11		3		
10h30	105	11					189	7		4	1	1
10h45	200	14		2	1		157	8		4	3	1
11h00	110	6			1		173	13		5		2
11h15	125	8		3		1	204	10		8	1	3
11h30	107	4		1			177	10		11		1
11h45	130	15		5			188	13		8		4
12h00	210	11				1	153	11		15		2
12h15	165	9			5	1	137	8		8		3
12h30	170	6		2			133	10		3		1
12h45	160	4		4			157	6		2		

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 4 DATE 29/10/87

TIME	DIRECTION : SOUTH						DIRECTION : NORTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
13h00	180	8		2	2		197	4		3	1	1
13h15	140	6		1	1		206					
13h30	157	13		4	3	1	159	19		4		
13h45	180	8		3		2	190	18		2		1
14h00	180	6		1			170	9		5	1	1
14h15	170	11		1	3		177	8		4		3
14h30	160	9			4		147	5		9		2
14h45	165	7		1	1		169	14		12	1	1
15h00	160	10		5			203	14		10		1
15h15	150	9		3			192	11	1	7		5
15h30	154	9		4		1	217	15		7		3
15h45	227	9		3	3	2	268	14		16		7
16h00	260	6				2	286	6		17		4
16h15	300	9				1	324	5		3	1	4
16h30	290	5		1		2	342	8				5
16h45	260	6		2		2	453	7		5		2
17h00	240	11		3		3	386	9		6	2	
17h15	280	12		4		3	272	8		2		8
17h30	240	11		2		5	234	3		2		3
17h45												
TOTAL	9174	386	5	86	54	67	10 009	413	7	240	19	98

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 5

DATE 4/11/87

TIME	DIRECTION : EAST						DIRECTION : WEST					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
06h00												
06h15												
06h30												
06h45												
07h00												
07h15												
07h30												
07h45												
08h00	280	5				2	113	16	1	7	2	3
08h[illegible]	240	9		3		1	165	20	1	8		2
08h30	220	12		2	2	1	163	19		9		2
08h45	200	15		4	1		164	17		14	1	2
09h00	220	8		3			137	10		8	1	1
09h15	190	11		7		2	128	12	1	9		2
09h30	180	10		7	2		187	18		9		4
09h45	180	12		8	1		166	31	1	11	1	3
10h00	130	17	1	5	1	2	157	18	1	6		1
10h15	150	15		4	2		130	13		6		
10h30	163	17		6	2		204	18		4	1	1
10h45	144	24	1	8	1		210	18		7	1	
11h00	140	15		6	1		199	15		5	2	
11h15	120	17		8			181	17	1	7		1
11h30	160	19		11	1		186	13		4	1	
11h45	140	12		7			205	21		6		3
12h00	140	12		7			190	15		5		3
12h15	130	14		8			187	32	1	10		2
12h30	150	13		11			207	18	2	8		1
12h45	140	11		8		3	180	17		11		3

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 5 DATE 4/11/87

TIME	DIRECTION: EAST						DIRECTION: WEST					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
13h00	102	13		7		2	197	26		8		5
13h15	83	12		4		4	178	24	1	9		2
13h30	100	16		7	1	3	204	20	1	15		1
13h45	93	11		1		2	180	18		11		2
14h00	140	7		3		2	188	9		6		1
14h15	120	11		2		1	201	12	1	7		5
14h30	110	14		1			189	14		9	1	3
14h45	90	9		4		1	162	10		10		3
15h00	110	12		6	2	3	149	13		4		3
15h15	100	11		3		4	150	16			1	4
15h30	100	13		6	1	2	200	8		7		3
15h45	140	15		8		3	240	11		7		5
16h00												
16h15												
16h30												
16h45												
17h00												
17h15												
17h30												
17h45												
TOTAL	4 390	425	2	185	32	40	5 697	539	12	252	12	71

RIVER HAZGUEH STUDY

VEHICLE CLASSIFICATION

STATION

DATE 24/11/87

TIME	DIRECTION : EAST						DIRECTION : WEST					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
06h00		38	1	8				10		11		
06h15		32		5				15		7		
06h30		56		9				15		8	2	
06h45		23	2	12				24	1	13	1	
07h00		28		12				20		11	1	
07h15		35		8	1			23		10		
07h30		38	1	12	1			33	1	19	2	
07h45		37		8	1			43		19	3	
08h00		39	1	9	2			43	2	23	2	
08h15		34	1	16	1			58		28		
08h30		46		33	2			46		24	2	
08h45		69		17	4			45		24	1	
09h00		56	1	29				36		32	1	
09h15		52		23	3			48		24	1	
09h30		47		22				47	2	26	1	
09h45		45	1	18	1			47		21	1	
10h00		47	1	22	2			34		17	1	
10h15		54	2	34	1			32	2	17	2	
10h30		50	1	22	3			30	1	19	4	
10h45		68	2	28	3			36		18	2	
11h00		76	1	27				37		18		
11h15		73		31				42		9		
11h30		91	1	29	2			41		24	2	
11h45		71		30				35		27	2	
12h00		70		22	2			42		25	2	
12h15		71		31	2			47		22	1	
12h30		65	1	31	9			44		22	2	
12h45		61	2	38				45		22		

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 6

DATE 24/11/87

TIME	DIRECTION : EAST						DIRECTION : WEST					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
13h00		63		26				34		24	1	
13h15		41	2	15	6			28		16	3	
13h30		37		22	2			34		17	3	
13h45		35		18	1			38		19	3	
14h00		43	1	13				38		19		
14h15		47	1	28	3			41	1	17	1	
14h30		45	1	33	2			43		22	1	
14h45		85	2	38	2			45		31	2	
15h00		76	1	32				40		22		
15h15		53	1	20	1			38		24	1	
15h30		67	2	27	2			42		22	2	
15h45		75	1	25	3			47		28	1	
16h00		90	1	33	1			33		7		
16h15		83		29	1			25		13		
16h30		47		22				27		15	1	
16h45		48		18	1			30		8		
17h00		33		15	1			16		7	1	
17h15		38		17	3			18		11		
19h30		30		15	1			16		10		
17h45		23		11				3		2		
TOTAL		2531	33	1043	70			1653	10	874	56	

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 7 DATE 28/10/87

TIME	DIRECTION : WEST						DIRECTION : EAST					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NR	R	NR	R			NR	R	NR	R	
06h00	37	5	1			1	38					
06h15	107	4	1				122	2		3		
06h30	463	6	1				255	5		3		1
06h45	156	4	1	1		1	420	4		3		
07h00	272	3	2	2			350	5		4		1
07h15	420	12	1	5			392	5		4		
07h30	430	18	1	3			580	6		1		
07h45	335	14	6	4	1	2	590	10		7	1	2
08h00	310	27		5		1	359	5	2	2		2
08h15	300	21	1	7	3	1	364	14	3	1		
08h30	253	20	3	2	1		317	11		4	1	
08h45	190	28	1	7			292	17		5	2	
09h00	204	22		5	1		278	16		4	1	1
09h15	160	22		4			307	21		10		2
09h30	260	32		5	1	2	278	16		10		1
09h45	260	26		3	3		264	22	1	6		1
10h00	220	25	1	6			280	16	8	1		
10h15	240	19		3			260	7	4	3		
10h30	260	17	1	3	1		253	12		4		
10h45	200	21		3	1		221	14		4		
11h00	177	20		2	2		251	21		6	3	
11h15	182	24	2	2	1	1	271	28		5	2	
11h30	260	29	1	5			307	24	6	1	1	
11h45	240	16	4	1			395	15		9		
12h00	280	20		6			310	23		8	2	
12h15	260	18		6	1	1	233	22		4		
12h30	220	20		6	2	1	336	22		7		
12h45	180	17		3	1		287	25	1	5		

NITUR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 7

DATE 28/10/87

TIME	DIRECTION : WEST						DIRECTION : EAST					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
13h00	180	13	2	1	1		253	26		5	2	2
13h15	160	24		4			217	22	1	8		
13h30	260	13	1	6			257	25		11		
13h45	280	21		4			273	19	2	6	1	2
14h00	260	19	2	3	3		282	19		4	1	
14h15	280	17		3			305	26		11		3
14h30	240	21		3	2		355	20		8	1	
14h45	240	21		3	3		330	22		4	4	
15h00	220	15		5			317	25		6		
15h15	240	16		2	1		310	16		3	1	
15h30	250	17		2	2	2	298	20		10	1	
15h45	240	19		3	2		357	11		9		
16h00	220	13	2	7	1		244	21	2	11		1
16h15	240	19		5	1		287	12		2		
16h30	280	18		3	2		258	30	1	17		1
16h45	520	9		4	1		493	23	1	10		1
17h00	360	9		3	1		437	24	1	10		1
17h15	380	18		4		1	339	31	1	7	1	
17h30	200	11		3	1	3	236	11	1	1		
17h45	190	5		3	1	1	243	10	3	6	1	
TOTAL	11796	824	35	168	41	18	14701	801	38	273	26	22

NITRO HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 8 DATE 26/10/87

TIME	DIRECTION : EAST						DIRECTION : WEST					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
06h00	42	4		3			145	5		6		2
06h15	103	10	1	9		1	182	5		7		3
06h30	123	11		5	1	1	350	4		7		3
06h45	200	4		4	1	2	330	3		10	1	4
07h00	190	7		6		1	475	14		8		1
07h15	200	7		7	2		460	8		10		1
07h30	260	14	2	12			495	10	1	12		5
07h45	300	10	2	9	1		360	9		9		2
08h00	171	11		10	1	1	291	8		8		1
08h15	188	12		12	1	1	203	7	1	7		1
08h30	220	20		19	1		180	7		8	1	1
08h45	187	22		12	1		160	7		10	2	
09h00	210	8		8			165	13		8		1
09h15	178	12		6		1	127	8	1	7	1	
09h30	157	16		9	1		180	12	1	11	1	
09h45	0	10	1	8			141	9		13	2	
10h00	80	5		5	1		135	7		6		5
10h15	65	8		6		1	150	6		11	1	
10h30	85	9		3			149	9	1	3		
10h45	90	4		2	1		145	8		10	2	
11h00	100	9		11			157	13		8		
11h15	146	13		10	1	1	175	13		9		
11h30	146	11		17			141	9		7	1	
11h45	155	10	1	14		2	142	12		10		
12h00	163	12		18	1		155	8	1	8	1	
12h15	152	9	1	9	1		176	5		5	2	1
12h30	186	11	1	17	1		161	8	1	4	1	
12h45	178	16		17	1	3	123	6		5		

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION ~ DATE 2[illegible]/10/87

TIME	DIRECTION : EAST						DIRECTION : WEST					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
13h00	130	9	1	13	4		156	7	1	7		
13h15	129	8		12			145	10	1	10	2	
13h30	142	11		18	2	2	179	17		7		
13h45	134	11		11			172	10		12	1	
14h00	125	11		3	1	1	195	5	1	7		
14h15	115	12		8			198	11		10		1
14h30	165	16		14		4	182	8	1	8		1
14h45	148	9	1	13	1	2	231	12		15		
15h00	152	11		20			172	17		11		
15h15	156	10		10			184	25		10	1	2
15h30	163	13		12	1	5	176	9		[illegible]		2
15h45	158	16		15		4	148	9	2	12		1
16h00	208	12		7	1	5	224	13		10		
16h15	229	20		18		1	202	13		9		
16h30	430	[illegible]		12		1	191	20		6		5
16h45	440	12		16	1		214	11		7		
17h00	503	8		11		2	210	9	1	10		2
17h15	421	8		4		7	200	12		9		
17h30	281	5		14		1	211	13		10		1
17h45	197	5		6		1	124	8		2		1
TOTAL	8830	511	11	505	28	51	9795	467	14	409	25	48

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 9 DATE 27/10/87

TIME	DIRECTION : TO JHB						DIRECTION : FROM JHB					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
06h00	86	3		2	1		24			3		
06h15	173	1		3	1		57	1		4		
06h30	278	6		2	1		100	11		5		
06h45	311	2		7			73	5		4		
07h00	378	3		5			141	8		8		
07h15	353	4		6	1		137	3		1	1	
07h30	380	8		6		1	149			3		1
07h45	232	15		13		1	172	8	1	4		
08h00	208	5		5			105	8		10	1	3
08h15	126	2		9			105	5	1	18		
08h30	113	8		9			94	5		10	1	
08h45	89	7		12	1		97	11		10		
09h00	78	7		9			83	10	1	9	1	
09h15	107	13		11		1	77	6	1	5	1	
09h30	92	9		6			97	10		5	1	
09h45	84	10		6			101	15		3		
10h00	73	5		7	1		61	7		9	1	
10h15	85	9		10			71	1		6	1	
10h30	93	10		7			55	11		8		
10h45	78	7		8			66	10		8		
11h00	94	12		9			104	16		12	1	
11h15	73	9		15	1		73	11		7		
11h30	94	7		8	2		95	5		7	1	
11h45	97	12		6	1		97	15		9	1	
12h00	95	6		8	3		52	13		2	1	
12h15	91	2		10			85	4		1		
12h30	81	9		6			65	9		12		1
12h45	94	8		9			80	6		14		

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 9 DATE 27/10/87

TIME	DIRECTION : TO JHB						DIRECTION : FROM JHB					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
13h00	94	11		11			87	11		9		
13h15	89	2		7			98	6		5	1	
13h30	107	10		8	1		92	18		7	1	
13h45	79	10		8			95	13		9		
14h00	70	5		11	1		50	6		9		
14h15	106	8		17	1		68	6		7		
14h30	105	5		7	1		71	7		8		
14h45	83	7		9	2		95	5		4		1
15h00	123	6		8			61	6	1	5		
15h15	72	14		17			85	10	1	12		1
15h30	92	9		15			91	9		14		1
15h45	75	15		10		3	80	17		1		
16h00	150	11		5			110	6		3	1	
16h15	89	3		3			170	10		7		
16h30	137	9		7			280	5		12		
16h45	160	7		8	1		310	4		10	1	
17h00	1[illegible]2	11		9			304	12		4		
17h15	150	7		2			346	12		5		
17h30	118	2		6			260	3		9	1	
17h45	49	2		1			130	5		3		
TOTAL	6186	353	0	383	20	6	5399	385	6	340	17	8

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 10 DATE 3/11/87

TIME	DIRECTION : NORTH						DIRECTION : SOUTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
06h00	34	4		8	1	1	45			4		
06h15	67	6		12	1	1	63			7	2	
06h30	72	5		9		2	77	1		5		
06h45	96	5		13		2	70	3		7		
07h00	82	5		17			73	3		5		
07h15	105	1		14	1		74	3		5	1	1
07h30	96	2		7			88	4		5		
07h45	64	4		6	2		71	5		6		
08h00	71	5		12			73			6		1
08h15	66	3		10	1		67	1		8		1
08h30	53	4		10	2		66	4		6		
08h45	33	6		7			53	5		4		
09h00	65	3		5			64	4		2		
09h15	75	5		10			57	2		2		
09h30	53	1		7	1		53	3		4		
09h45	47	2		10	1		60	7		8		
10h00	61	3		10			85	4		8		4
10h15	49	7		12			59	6		7		
10h30	55	6		7			74	4		6		
10h45	51	5		13			68	6		7	2	
11h00	48	7		13	1		79	7		7	1	
11h15	55	4		8			89	3		8		
11h30	50	5		16	2		60	3		4	1	1
11h45	53	9		14			78	3		8	1	
12h00	57	3		8			53	3		8		
12h15	62	5		11	2		52	4		5		
12h30	74	6		10			57	4		6		
12h45	52	8		4		1	49	5		7		

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 10 DATE 5/11/87

TIME	DIRECTION : NORTH						DIRECTION : SOUTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
13h00	55	4		11			56	5		4		
13h15	43	2		7			53	5		7		
13h30	61	3		16		3	47	4		6		
13h45	52	5		13			51	5		4		
14h00	62	4		6	2		43	6		7		
14h15	57	6		11	1		59	3		6		
14h30	67	9		7	1		64	6		5		1
14h45	48	7		13	3		47	4		7		
15h00	59	4		7	2		57	2		7	1	1
15h15	52	9		18			68	3		5		1
15h30	68	7		11			74	3		6		
15h45	61	5		13	1		62	5		6		
16h00	68	5		12			54	4		6		
16h15	57	3		10	1		49	3		6		
16h30	61	6		18			52	5		7		
16h45	72	7		9			78	4		6	1	
17h00	76	7		4			77	9		7		
17h15												
17h30												
17h45												
TOTAL	2765	224		468	26	7	2848	173		280	10	8

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 1E DATE 4/11/87

TIME	DIRECTION : WEST						DIRECTION : EAST					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
06h00	44	6		4			[illegible]	10		3		1
06h15	85	8	1	3			[illegible]	4		4		
06h30	93	8		10		2	[illegible]	4		3		1
06h45	119	8		6		2	120	4		2		5
07h00	116	1		1			142	9		7		
07h15	163	10		5			120	6		7		
07h30	127	8		3			59	9		10	3	2
07h45	98	11		2								
08h00	102	9		2		1	49	6		4		
08h15	89	7		6			87	13		8		1
08h30	106	4		3			95	15		5		2
08h45	108	8	1	3	3		59	5		7		2
09h00	94	11		6			59	3		7		2
09h15	105	21		12	1		43	6		8	2	
09h30	97	23		13			55	9		2	1	
09h45	71	17		8			60	10		10		1
10h00	117	15		19	3		58	17		15		
10h15	112	16		12			33	23		17		
10h30	123	24		5	1		88	6		24		
10h45	124	18		24	1		72	6		16		
11h00	129	12		9			98	13		7		1
11h15	97	16		11	1		57	7		4		
11h30	126	13		13	4		49	8		6	2	
11h45	102	11	1	8			56	12		10		
12h00	111	18		22	1		15	3		2	2	
12h15	102	7		4	1							
12h30	90	6	1	4	1	1	100	3		2	1	
12h45	108	23		10		1	6	3		1	1	

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 11 DATE 4/11/87

TIME	DIRECTION : WEST						DIRECTION : EAST					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
13h00	117	13		19	1							
13h15	117	17		2	1							
13h30	100	14		5	1							
13h45	93	15		9	1							
14h00	79	11		6								
14h15	106	22		9	2							
14h30	85	14		6	1							
14h45	91	12		8	1							
15h00	107	8		3								
15h15	98	12		6		1						
15h30	98	7		5								
15h45	66	10		8	1							
16h00	89	10		13			155	23		11		2
16h15	104	12		9		2	113	18		8		2
16h30	115	19		11		1	82	9		4		
16h45	123	21		6			123	27		23		2
17h00	135	13		5		1	108	13		15		3
17h15	159	16		13			112	17		12		
17h30							158	22		14		2
17h45												
TOTAL	4840	585	4	381	23	12	2603	343	0	278	12	29

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 12 DATE 26/11/97

TIME	DIRECTION : NORTH						DIRECTION : SOUTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
06h00	17			1	1							
06h15	30	1		1		1	49	2		2	1	
06h30	47			2	1		69	9		4	3	
06h45	37	2		2		1	55	1		4	1	
07h00	71			4			24	5		2		
07h15	55	1		3			74			1		
07h30	56	5		8	1	1	90	1			1	
07h45	58	3		2			86	2		1		
08h00	46	5		2			82	5		2		
08h15	59	1		5			75	5			1	4
08h30	53	1		4		1	59	2		5		1
08h45	42	2		3			74	5		2	1	1
09h00	43	6		5			53	6		1	1	2
09h15	52	1		1	1		63	9		3	1	1
09h30	40	3		1	2		48	5		6		1
09h45	48	1		2	1		50	5		2		1
10h00	46	8		2			62	10		4	1	
10h15	43	5		3			55	5		5		
10h30	47	1		6		2	51	6		1		
10h45	48	2		4		1	61	10		3	3	
11h00	37	3		1	3		33	6		3		
11h15	48	1		6	1		51	7		4		
11h30	40	3		6	1		45	6		3		
11h45	64	3		3	1		57	8		2		
12h00	48	3		2	3		55	7		4	2	
12h15	61	3		6		1	55	3		5	1	1
12h30	31	5		8		1	64	3			1	
12h45	42	2		1	2		51	4		4		

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 12 DATE 26/11/87

TIME	DIRECTION : NORTH						DIRECTION : SOUTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
13h00	55	7		6			55	5		2		1
13h15	66	1		2			56	5		5		
13h30	64	5		6	1		65	1		2	1	
13h45	59	2		5			65	5		5	1	
14h00	52	2		3	1		61			1		
14h15	50	3		2			50	5		3		1
14h30	43	8		3			40	3		2		
14h45	42	5		3		1	52	6		5		1
15h00	53	5		2			43				1	
15h15	82	7		6	2		57	2		2		
15h30	52	1		4			48	4		2		
15h45	65	1		9			42	1		8		
16h00	52	3		5		1	85	2		5	3	2
16h15	61	11		7		1	60	2		4		
16h30	66	7		16			61	7		7	2	2
16h45	49	8		9			46	6		5		
17h00	74	6		5			92	5		4	1	
17h15	85	11		7	2		68	4		6	1	
17h30	83	7		4			54	3		2		
17h45	76	8		3			56	2		3		
TOTAL	2538	173		206	24	12	2727	203	1	146	28	22

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 13 DATE 3/11/87

TIME	DIRECTION: NORTH						DIRECTION: SOUTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
06h00	78	1		8	2		40	4				
06h15	90	6		9	2	1	60	6			1	1
06h30	144	5		9	3		100	10			4	
06h45	162	2		8			150	6		4		3
07h00	189	10		8			130	5		7		1
07h15	153	7		10	1		170	6		7	3	
07h30	126	9		10			160	5		7		
07h45	125	10		7			180	5		10		
08h00	133	8		8		2	140	9		2	2	
08h15	89	17		12	3		120	15		12		
08h30	107	17		15	6	1	100	8		5	1	
08h45	117	15		16		1	120	9		3	1	
09h00	135	15		18			120	11		9		
09h15	98	14		20	2	3	110	11		8		
09h30	119	17		22		1	120	10		12	3	
09h45	84	12		17		2	110	9		8		
10h00	77	4		5	1		100	14		5	1	
10h15	99	10		10	3		120	8			1	
10h30	129	12		17	3		90	11		3	1	
10h45	136	9		9	1		140	14		7		
11h00	117	6		13	1	1	120	11		9	2	1
11h15	103	7		9	1		110	11		12	1	
11h30	120	10		10			120	9		11	3	
11h45	127	7		12	3		120	13		11		
12h00	109	16		19	2	2	100	7		3	4	
12h15	97	12		15	1		80	12		5		
12h30	104	14		11			60	21		9	2	1
12h45	77	13		17	3	1	70	12		15	1	2

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 13 DATE 3/11/87

TIME	DIRECTION: NORTH						DIRECTION: SOUTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
13h00	71	10		9	1		90	17		8		
13h15	80	12		10			80	14		9		
13h30	90	14		13			100	13		11		
13h45	93	10		15	2		90	10		11		
14h00	99	7		11	1		60	12			5	
14h15	126	10		9	2		105	12		9	2	
14h30	142	6		5	2		80	10		7	1	
14h45	148	8		10	2		100	6		9	4	
15h00	156	16		9	2		100	7		5		
15h15	150	9		6			100	9		5		
15h30	130	6		7		1	90	11		7		
15h45	153	11		13			110	9		8		
16h00	137	13		11		2	120	18		12	1	
16h15	155	16		16		1	90	5		7		
16h30	178	14		12			150	8		3		
16h45	197	20		18	2	3	120	12		5		
17h00	157	11		17		1	160	12		8		
17h15	133	13		12			150	14		9		
17h30	127	13		10			170	13		11		
17h45	133	13		11		3	140	12		9		
TOTAL	5899	520	0	572	52	25	5365	496	0	335	44	9

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 14 DATE 3/11/87

TIME	DIRECTION: NORTH						DIRECTION: SOUTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
06h00	34	1			1		30	1			1	2
06h15	33	2	4	2	5	4	104	3			1	2
06h30	94	3	1	1	1	2	155	6			3	
06h45	111	3		4	6	3	85			1	1	2
07h00	95	4	1	1	1	2	82	3		3		
07h15	110	1	3		3	2	108	2		6		
07h30	106	4	1	4		3	108	2		2	1	4
07h45	77	10		1	4	2	159	7		3	2	2
08h00	43	1	2	1	3		100	5	1	3		
08h15	63	4	4		5	3	70	4		1		
08h30	64	1		4	4	2	75	3		5	1	
08h45	68	5		2	1		88	3		3	2	
09h00	50	4	1	4	2		81	5		4	1	
09h15	62	8	4	3	3		83	5		5	1	1
09h30	68	2	1	7	3		66	5		2		
09h45	82	3	3	4	3		68	5		5	3	
10h00	73	4	2	1	1		100	4		2	1	
10h15	92	9		2			45	5		2	2	
10h30	67	4		2			70	6		2	3	
10h45	60	8		8	8		85	9		5	4	
11h00	88	8		1			74	6	1	7	2	
11h15	79	10	3	5			80	8	2	3	2	
11h30	76	7	1	1			67	6		6	2	
11h45	75	5		2	1		66	6		9		
12h00	68	11			6		87	8	2	7		
12h15	87	7		8	3		7	3	5	2		
12h30	100	3		1	2		76	7		5	2	
12h45	91	11	3	4	3		64	5		5	2	

NITEX HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 14 DATE 3/11/87

TIME	DIRECTION: NORTH						DIRECTION: SOUTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
13h00	95	8		9	7		62	7		6	3	1
13h15	52	6		2	2		73	8		5		3
13h30	87	8		4	1		86	7	1	4	3	2
13h45	100	5		5		1	79	7		3	3	4
14h00	97	10		7	1	1	76	8		6	1	2
14h15	123	8		4	3	1	73	5		5	2	
14h30	92	8	1	2	3		73	3		4	2	2
14h45	92	5	-	5			58	7		5	3	1
15h00	132	13		5		2	84	7		6	1	
15h15	84	5		2	1	3	82	6		5	3	1
15h30	103	13		3	1	1	76	7		7	1	2
15h45	77	6			1		73	5		6	2	2
16h00	81	9		5	2		66	5	1	7	3	2
16h15	130	8		1			88	7		4	1	2
16h30	190	6		3			137	5	3	4		1
16h45	147	12		3	1	3	120	7	1	12	1	1
17h00	228	5		8	1	1	124	6		11	2	2
17h15	203	7		3		5	132	4		6	2	1
17h30	118	4	1	8	1	5	93	4		5		1
17h45	79	5		6		3	73	5		1		6
TOTAL	4426	294	33	158	94	49	4097	255	15	213	73	49

NITRR HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 15 DATE 29/11/87

TIME	DIRECTION : NORTH						DIRECTION : SOUTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
06h00		8		5				12		4		
06h15		7		3	1			10				
06h30		16	1	4	1			7		3		
06h45		7		5				16		2		
07h00		5		2				12		1		
07h15		18		4				17	2	7	1	
07h30		11	1	5	1			7		4		
07h45		17		5	1			11		4		
08h00		31	1	11				16		9	1	
08h15		35	1	14	2			18	1	1		
08h30		15	1	3	1			20	1	3		
08h45		27		5				12		8		
09h00		35	1	11	3			23	1	7		
09h15		31		12				14		4	1	
09h30		23		15				12		8	1	
09h45		34		14				7		5		
10h00		22		9	1			19		7	1	
10h15		27		9				20		8		
10h30		25		7				27		15		
10h45		35		9				11		8		
11h00		23		12	1			36		10	1	
11h15		29		8	1			12		8	1	
11h30		22		16				20		13	1	
11h45		22		9	1			10		4		
12h00		25		12				12		4		
12h15		27		9	1			14		10		
12h30		26		16				39		6	1	
12h45		23		11				34		9		

NITER HAZCHEH STUDY

VEHICLE CLASSIFICATION

STATION 15 DATE 29/11/87

TIME	DIRECTION : NORTH						DIRECTION : SOUTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
13h00		23		8				27		15	2	
13h15		27		16				30		10		
13h30		17		10				27	1	7		
13h45		19		8				26		6		
14h00		40		8	1			25		3		
14h15		18	1	7				17		13	1	
14h30		27		18				24		8		
14h45		21		11				18	1	9		
15h00		26	1	5	1			21		7		
15h15		21		8				15		7	1	
15h30		23		6				12		12		
15h45		17		7				20		12	1	
16h00		27		13				18	1	16		
16h15		28		15				25		6		
16h30		22		7				20		7		
16h45		13		13				18		7	2	
17h00		12		4	1			15		5		
17h15		28		9				40		13	1	
17h30		14		12				17	1	7	1	
17h45		16		11				22		3		
TOTAL		1055	8	441	18			900	9	345	18	

NITRR HARCHEM STUDY

VEHICLE CLASSIFICATION

STATION 16 DATE 24/11/87

TIME	DIRECTION : NORTH						DIRECTION : SOUTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
06h00		7	1	15	3			5		7	1	
06h15		15		17	1			12		11	2	
06h30		16		15	3			18		11		
06h45		21		23	4			24		18	2	
07h00		23		25	3			28		14	2	
07h15		27		32	5			24		15		
07h30		30	1	32	4			32		17		
07h45		61		39	2			40		21	2	
08h00		50		35	2			51		30	2	
08h15		59		48	3			54		42	2	
08h30		61		39	1			49		29	1	
08h45		64		47	3			52		36	1	
09h00		59		42	1			62		28	6	
09h15		69		45	2			55	1	31	5	
09h30		59	2	49	1			66		44	4	
09h45		72		36	2			65		35	1	
10h00		58	1	36	2			68		46	1	
10h15		61		43	4			68		41	3	
10h30		67	2	46	3			61	2	39	3	
10h45		63	2	51	2			51		37	6	
11h00		65	1	48	3			48		40	1	
11h15		60		41	1			45		41		
11h30		57	1	46	5			48		33	5	
11h45		54	1	37	2			46		28	2	
12h00		58		36	5			52	1	36	4	
12h15		60		31	1			54	1	28	2	
12h30		60		28	1			57		34	2	
12h45		56		40	3			48		32	4	

METRA HAZCHEM STUDY

VEHICLE CLASSIFICATION

STATION 16 DATE 24/11/87

TIME	DIRECTION : NORTH						DIRECTION : SOUTH					
	LIGHT	RIGID		ARTICULATED		BUS	LIGHT	RIGID		ARTICULATED		BUS
		NH	H	NH	H			NH	H	NH	H	
13h00		47		33	3			46		29	3	
13h15		55	2	32	2			50	1	31	1	
13h30		51		30	4			48		33	2	
13h45		48		29	1			45	1	36	5	
14h00		51	1	32	1			52	1	29	3	
14h15		48		37	1			50		36	1	
14h30		50		42	4			52		35	3	
14h45		57	1	39	1			49		33	2	
15h00		61		32	3			54		42	2	
15h15		61		48	2			50	1	42	1	
15h30		72		42	3			59	1	43	1	
15h45		76		46	1			64		51	5	
16h00		80		37	2			69	1	42	3	
16h15		85		38	2			82		37		
16h30		81		47	1			78		41	4	
16h45		77		42				81		39	4	
17h00		62	2	26	3			68		41	1	
17h15		56		26	1			56		32	1	
17h30		49		32	1			57		42	2	
17h45		42	1	34	1			46	1	42	2	
TOTAL		2621	19	1735	109			2438	12	1589	110	

APPENDIX C

JACK-KNIFE TECHNIQUE

J

JACKKNIFE METHODS

In certain problems of statistical estimation*, theoretical complexity or lack of reliable detailed knowledge of the model may preclude a theoretical approach to calculation of the standard error and the bias* of an estimate. Jackknife methods provide direct numerical approximations of both bias and standard error, and can give reasonably reliable confidence limits. The standard jackknife procedure that we shall describe first turns out to be related to certain theoretical characteristics of estimators, including the influence function* familiar in robust estimation*; this relation leads to useful generalizations and variants of the standard jackknife. The jackknife is a relative of cross-validation* and of various nonparametric methods*.

ONE-SAMPLE JACKKNIFE

To begin with a rather simple problem, suppose that we have a sample of n independent observations $x_1, \ldots, x_n$ from a population that possesses a well-defined characteristic θ, whose unknown value is of interest. We have an estimate t of θ, based on the sample, and we wish now to determine the bias and standard error of our estimate. In addition, we should like to calculate probable limits for θ, e.g., a 95% confidence interval. However, suppose that we are uncertain as to the distribution of X, or that we are incapable of suitable theoretical approximation of the required moments of T. What can be done? A reasonable starting point in many problems is to assume that the first two moments of T have expansions of the forms

$$E(T) = \theta + \frac{a_1(\theta)}{n} + \frac{a_2(\theta)}{n^2} + \cdots$$
$$\operatorname{var}(T) = \frac{\sigma_1^2(\theta)}{n} + \frac{\sigma_2^2(\theta)}{n^2} + \cdots, \tag{1}$$

and that for large sample size n

$$\{T - E(T)\}/\sqrt{\operatorname{var}(T)} \tag{2}$$

is approximately standard normal. Even without knowledge of the functions $a_1, \ldots, \sigma_1^2, \ldots$ the structure in (1) can be used.

One very elementary approach is to split the data randomly into two equal pieces, supposing for the moment that n is even; calculate the corresponding estimators T_1 and T_2 of θ; and then estimate the lead-

J

JACKKNIFE METHODS

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is approximately standard normal. Even without knowledge of the functions $a_1, \ldots, \sigma_1^2, \ldots$ the structure in (1) can be used.

One very elementary approach is to split the data randomly into two equal pieces, supposing for the moment that n is even; calculate the corresponding estimators T_1 and T_2 of θ; and then estimate the leading bias and variance terms of (1) by $-T + \frac{1}{2}(T_1 + T_2)$ and $\frac{1}{4}(T_1 - T_2)^2$, respectively. These estimates are unbiased for $a_1(\theta)/n$ and $\sigma_1^2(\theta)/n$ to first order, meaning that terms in higher powers of n^{-1} are ignored. However, these naive estimates are unreliable.

The standard jackknife methods developed by Quenouille [22] and Tukey [26] provide a sophisticated way of extending the half-sample idea. Define

$$I_j = (n-1)(T - T_{(-j)}), \tag{3}$$

where $T_{(-j)}$ means T computed from $\{X_i : i \neq j\}$; i.e., the sample with X_j omitted. Then the leading terms for bias and variance in (1) are estimated by $-\bar{I}. = -n^{-1}\sum_{j=1}^n I_j$ and $\sum_{j=1}^n (I_j - \bar{I}.)^2/\{n(n-1)\}$, respectively. The bias-adjusted form of T is therefore

$$\tilde{T} = T + \bar{I}. , \tag{4}$$

and

$$S = \sqrt{\sum_{j=1}^{n} (I_j - \bar{I}.)^2 \Big/ \{n(n-1)\}} \tag{5}$$

estimates both SE(T) and SE($\tilde{T}$), ignoring terms beyond first order in (1). The validity of the bias correction is easily checked by using (1) to calculate

$$E(I_j) = (n-1)\left[\left(\frac{1}{n} - \frac{1}{n-1}\right)a_1(\theta) + \cdots\right]$$

$$= -\frac{a_1(\theta)}{n} + O(n^{-2}),$$

where $O(n^{-k})$ means a term essentially bounded by a constant times n^{-k}, so that for large n, $O(n^{-2})$ is negligible relative to $O(n^{-1})$.

The validity of the standard error S is somewhat more subtle. But for a very large class of problems where (1) and (2) do apply, S is valid *and* one can justify the standard normal approximation for both $(T-\theta)/S$ and $(\tilde{T}-\theta)/S$ for large n. Thus the jackknife method for calculating approximate $100(1-\alpha)\%$ confidence limits for θ is

$$T \pm k_{1-(1/2)\alpha}S, \tag{6}$$

or $\tilde{T} \pm k_{1-(1/2)\alpha}S$ if the bias correction is made, where k_ϵ is the upper $100\epsilon\%$ point of the standard normal distribution.

The simple test case $T = \bar{X}$ shows that $I_j = X_j - \bar{X}$, $\bar{I}. = 0$ (no bias adjustment is needed, of course), and S is the usual sample standard error. Because $T + I_j = X_j$ here, some authors generally refer to

$$P_j = nT - (n-1)T_{(-j)} = T + I_j \quad (j = 1, \ldots, n) \tag{7}$$

as *pseudo-values*, and for some purposes the analogy with data values is apt. In general, the P_j are correlated.

Example 1. As an illustration, suppose that ρ is the correlation* for pairs $X = (Y, Z)$. The second and third columns of Table 1 give example data for $n = 15$ law schools,

- Y = average score on test A for new admissions
- Z = average score on test B for new admissions.

Because (1) and (6) are probably more reliable for $T = \tanh^{-1}r$ than for r = sample correlation itself, we first obtain confidence limits for $\theta = \tanh^{-1}\rho$ and then reexpress these limits on the ρ scale. However, a bias correction for r must be obtained by jackknifing r directly, and *not* by reexpressing the bias-adjusted estimate $\tilde{T}$, since transformation affects bias. Columns 4 and 5 in Table 1 give values of $r_{(-j)}$ and $I_j^{(r)} = (n-1)(r - r_{(-j)})$; columns 6 and 7 give values of $t_{(-j)} = \tanh^{-1}r_{(-j)}$ and $I_j^{(t)}$. From the calculations at the foot of the table we find that the bias-adjusted correlation estimate is

$$\tilde{r} = r + \bar{I}. = 0.776 + 0.008 = 0.784,$$

and that approximate 95% two-sided confidence limits for θ are

$$1.0352 \pm 1.96 \times 0.438,$$

equivalent to 0.175 and 0.956 on the correlation scale. These limits are somewhat wider than one would obtain under an assumption

Table 1 Jackknife Calculations for Correlation with Law School Data[a]

j	y_j	z_j	$r_{(-j)}$	$I_j^{(r)} = (n-1)(r - r_{(-j)})$	$t_{(-j)} = \tanh^{-1} r_{(-j)}$	$I_j^{(t)} = (n-1)(t - t_{(-j)})$
1	576	3.39	0.892	−1.624	1.432	−5.549
2	635	3.30	0.763	0.182	1.003	0.446
3	558	2.81	0.755	0.294	0.984	0.711
4	578	3.03	0.776	0.	1.035	0.
5	666	3.44	0.731	0.630	0.931	1.461
6	580	3.07	0.780	−0.056	1.045	0.142
7	555	3.00	0.784	−0.112	1.056	−0.286
8	661	3.43	0.736	0.560	0.942	1.310
9	651	3.36	0.751	0.130	0.975	0.840
10	605	3.13	0.776	0.	1.035	0.
11	653	3.12	0.818	−0.588	1.151	−1.617
12	575	2.74	0.785	−0.126	1.058	−0.322
13	545	2.76	0.740	0.504	0.950	1.187
14	572	2.88	0.767	0.126	1.013	0.311
15	594	2.96	0.779	−0.042	1.043	−0.106

$$r = 0.776, \quad T = \tanh^{-1} r = 1.0352$$

Jackknife calculations

$$\begin{cases} r \text{ scale: } \bar{I}_{\cdot} = 0.008 \\ T \text{ scale: } \bar{I}_{\cdot} = -0.098, \ \sum I_j^2 - n\bar{I}_{\cdot}^2 = 40.2449, \ S = \sqrt{\dfrac{40.2449}{15 \times 14}} = 0.438 \end{cases}$$

[a]Table entries have been rounded off.
Source. Efron [5].

of bivariate normality for X, which assumption would clearly be inappropriate for these data.

The class of problems in which the limits (6) are valid corresponds essentially to those where T is accurately approximable by an average; indeed, it is this fact which leads to (1) and (2). Thus T can be a function of sample moments or of U-statistics* (as long as the function has nonzero derivative), or an estimate of maximum likelihood type [i.e., solution of an equation of the form $\sum a(X_j, T) = 0$ where a is smooth]; but T cannot be a single sample quantile such as a median or extreme value. Miller [16] reviews the validity of the jackknife; Reeds [23] and Miller [18] add useful postscripts.

What makes the jackknife appealing is that the limits (6) are quite robust in the *validity* sense, so that in the correlation example they will be valid for a reasonably large sample from any bivariate distribution. Of course, this should not be confused with *efficiency robustness* or *resistance* to aberrant values, which the jackknife does not have.

One suggestion for obtaining more reliable confidence limits is to replace the normal percentile k in (6) by the Student-t percentile for $m-1$ degrees of freedom, where m is the number of distinct I_j values [20, 26]. There is no theoretical support for this. Very often S has a positive bias [5, IV] which tends to correct for variability in S.

With very large samples it may be helpful to make initial (random) groupings of the data, say into g groups each of size $m = n/g$, and then to let X_j represent the jth data group in the earlier discussion. This has the defect of giving an analysis that is not uniquely defined.

For problems where the bias is of special interest, it is useful to know that more refined bias adjustments are possible. Relevant methods are described by Gray et al. [7] and Schucany et al. [24].

APPENDIX D

12 HOUR TRIP MATRICES

HAZCHEM MATRIX O : MATERIALS NOT COVERED (TONS)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	2	17	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
10	5	0	1	2	0	4	1	0	1	0	2	20	0	19	3	1
11	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0
12	0	0	0	41	0	0	23	25	0	56	20	0	0	0	20	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
14	16	0	0	0	0	1	0	0	0	0	0	0	0	25	25	0
15	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0
16	0	0	0	0	0	1	0	0	0	34	20	0	0	8	0	0
17	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	11	12	0	0	0	0	15	0	0	0	0	1	20
20	0	0	1	0	0	0	0	0	0	18	0	0	0	0	26	0
21	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
22	0	0	0	0	30	[illegible]	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0
24	0	0	0	2	[illegible]	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	14	0	13	0	0	0	0	0	0	0	0	0	0	0	0	9
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

17	.18	.19	.20	.21	.22	.23	.24	.25	.26	.27	.28	.29	.30	.31	.32 .
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	3	0	0	24	0	0
1	0	1	2	0	0	3	0	20	0	3	0	0	0	13	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
0	0	0	0	34	0	0	18	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	0	0	24	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0
0	0	25	0	0	0	0	0	0	0	0	0	0	0	31	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	14	0	0	0	39	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

HAZCHEM MATRIX I : FLAMMABLE LIQUID (TONS)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0	0	0	0	0	0	0	0	0	7	0	32	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	7	45	0	14	0	0	119	32	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	6	0	1	0	0	0	0	0	0	0	0	0	0	17	14	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	17	0	0	0	0	33	0	0	0	158	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0	38	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	14	0	0	0	0	0	20	0	5	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	5	0	0	0	0	0	32	7	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	16	0	0	0	[illegible]	0	0	0	29	61	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	20	0	0	28	0	0	0	0	0	41	11	0	53	77	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	0	0	0	0
31	0	0	0	0	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	[illegible]	[illegible]	0	0	0	0	0	0

18	.19	.20	.21	.22	.23	.24	.25	.26	.27	.28	.29	.30	.31	.32
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	40	0	0	0	0	0	32	0	13	24	0	0	0	39
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	0	0	0	0	0	22	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	2	0	0	0	21	6
0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
0	66	4	15	0	15	32	0	0	0	9	0	0	35	0
0	0	0	0	0	0	0	0	0	0	8	0	0	0	0
0	0	32	19	0	0	51	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	28	0	0	0	0
0	0	0	0	0	0	0	0	0	0	21	0	0	0	0
0	0	0	0	0	0	0	0	0	0	24	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	27	0	0	0	55	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0	40	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	54	0	0	0	0	0
0	0	0	0	0	0	14	16	0	0	0	0	0	0	0
0	13	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	132	0	3	0	0
0	103	0	26	0	23	33	0	64	51	0	0	0	134	56
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

HAZCHEM MATRIX 2 : FLAMMABLE SOLID (TONS)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

HAZCHEM MATRIX 3 : FLAMMABLE GAS (TONS)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	18	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	18	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

HAZCHEM MATRIX 4 : POISON GAS (TONS)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	21	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

7	.18	.19	.20	.21	.22	.23	.24	.25	.26	.27	.28	.29	.30	.31	.32
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0

HAZCHEM MATRIX 5 : COMPRESSED GAS (TONS)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	20	21	0	0	43	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	[illegible]	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	17	0	0	0	0	0	0	103	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	2	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
20	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	9	0	0	0	0	0	0	10	19	12	0	0	0	0	21	0	0	0	3	0	0	0	0	0	0	0	20	0	0	0	0
28	0	0	0	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

HAZCHEM MATRIX 6 : POISON (TONS)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	39	0	0	0	0	0	0	0	0	0	0	0	0	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	13	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	0
28	0	0	0	25	0	0	0	0	0	0	0	37	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

HAZCHEM MATRIX 7 : CORROSIVE (TONS)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	0	0	0	0	0	0	0	6	0	0	20	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	11	0	0	0	26
10	0	0	0	0	0	0	0	0	0	0	0	20	0	6
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	20	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	5	9	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	8	0	0	17	0	0	0	0	0	0	0	0	0	17
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	7	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	20	0	0	20	0	0	0	0	0	74	0	0	0	11
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0

.15	.16	.17	.18	.19	.20	.21	[illegible]	[illegible]	[illegible]	.25	.26	.27	.28	.29	.30	.31	.32
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	11	0	0	0	0	0	0	0	14	50	0	0	31	0
0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	41	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	76	0	0	15	0	15	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	66	0	0	44	22	0	0	27	0	0	0	0	0	0	20	101	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

HAZCHEM MATRIX 8 : ORGANIC PEROXIDE (TONS)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

16	.17	.18	.19	.20	.21	.22	.23	.24	.25	.26	.27	.28	.29	.30	.31	.32 .
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	22.	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

HAZCHEM MATRIX 9 : OXIDIZING AGENT (TONS)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	7	16	0	15	0	0	0	6	0	0	0	0	0	20	0	22
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	6	0	0	0	0	0	0	0	10	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	35	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	6	0	0	0	0	0	0	0	0	0	21	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

17	.18	.19	.20	.21	.22	.23	.24	.25	.26	.27	.28	.29	.30	.31	.32 .
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	20	0	0	21	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	25	0	0	0	0	47	0	15	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0
0	0	0	19	0	0	0	0	0	0	0	44	0	0	0	0
0	0	53	0	0	0	0	0	34	0	0	0	0	15	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	42	0	0	0	0	0	0	0	0	0	0	0	15
0	0	0	37	0	8	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

HAZCHEM MATRIX 10 : DANGEROUS WHEN WET

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

.17	.18	.19	.20	.21	.22	.23	.24	.25	.26	.27	.28	.29	.30	.31	.32
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

HAZCHEM MATRIX 11 : SPONTANEOUSLY COMBUSTIBLE (TONS)

	1	2	3	4	5	6	7	9	9	10	11	12	13	14	15	16	17
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

18	.19	.20	.21	.22	.23	.24	.25	.26	.27	.28	.29	.30	.31	.32 .
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

HAZCHEM MATRIX 12 : OTHER HAZARDS (TONS)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	28	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	23	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

17	.18	.19	.20	.21	.22	.23	.24	.25	.26	.27	.28	.29	.30	.31	.32 .
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	15	0	0	0	0	0	34	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	32	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX E

CASE STUDY ANALYSIS

FACILITY TYPE		LENGTH (km)	ACCIDENT RATE/10-8	A D T	C2	FLOW RATE q	AVERAGE SPEED S	LAND USE TYPE	DENSITY (Persons/km^2) D_{ir}	EXPOSURE AREA (km^2) E_x	C1	RISK (Persons) R_{hr}
ROUTE 1 (N1)												
1	URBAN	13	248	8000	0,05	400	75	URBAN RESIDEN.	2000	13,85	0,785	48,70
	RURAL	44	26	4500	0,07	315	90	AGRICULTURAL	20	13,85	0,785	0,04
2	URBAN	4	1464	2950	0,05	150	45	URBAN RESIDEN.	2000	13,85	0,785	17,00
	RURAL	5	111	3100	0,07	215	65	AGRICULTURAL	20	13,85	0,785	0,01
												65,75
ROUTE 2 (M27)												
1	URBAN	2	248	5900	0,05	295	75	URBAN RESIDEN.	2000	13,85	0,785	0,87
	RURAL	0	26	-			90	-				0
2	URBAN	20	1464	4050	0,05	200	45	URBAN RESIDEN.	2000	13,85	0,785	565,40
	RURAL	47	111	3000	0,07	210	65	AGRICULTURAL	20	13,85	0,785	0,17
												566,40
ROUTE 3 (R26)												
1	URBAN	7	248	6000	0,05	300	75	URBAN RESIDEN.	2000	13,85	0,785	10,4
	RURAL	48	26	4800	0,07	335	90	AGRICULTURAL				0,05
2	URBAN	0	1464	-	0,05	-	45	-				0
	RURAL	3	111	3000	0,07	210	65	RURAL RESIDEN.	200	13,85	0,785	0,01
3	URBAN	5	2912	3000	0,06	180	30	URBAN RESIDEN.	2000	13,85	0,785	95,00
	RURAL	0	192	-	0,07	-	45	-				-
												105,50

$$R_{hr} = \frac{AR_i \times q_i \times L^2_{i_{hr}} \times E_x \times C_i \times D_{ir}}{S_i}$$