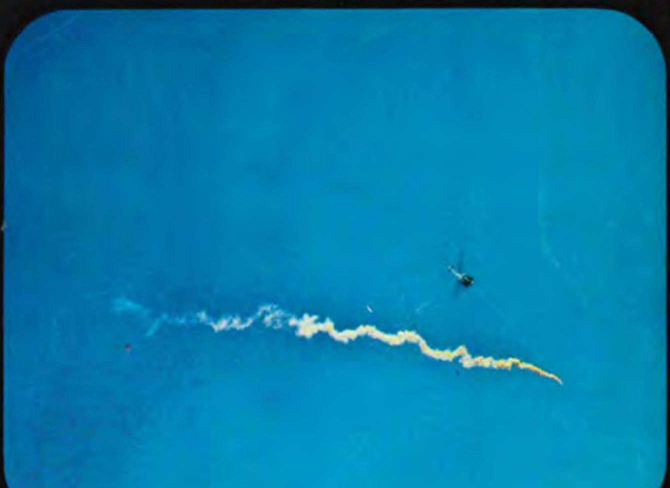
coogee air pollution study

may 1974

environmental protection authority



A VIEW TO THE FUTURE

* One of the Coogee Air Pollution Study stations monitoring sulphur dioxide levels north of the Kwinana industrial complex.
* Smoke patterns from coloured flares lowered from a helicopter were recorded to check the effect of Mt Brown on the flow of Kwinana chimney emissions.
* Children from the Bungaree Primary School at Rockingham were included in a task force to take air samples during tracer experiments.

COOGEE AIR POLLUTION STUDY

A REPORT PREPARED BY

The Coogee Air Pollution Study Working Group
representing the Department of Agriculture
Commonwealth Bureau of Meteorology, Department of
Environmental Protection, Kwinana Industry, Public
Health Department and the State Electricity Commission

for

THE WESTERN AUSTRALIAN
ENVIRONMENTAL PROTECTION COUNCIL

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To,

THE HON SIR CHARLES COURT, MLA
PREMIER OF WESTERN AUSTRALIA

COOGEE AIR POLLUTION STUDY

I have pleasure in forwarding to you a copy of the report resulting from the Coogee Air Pollution Study (CAPS). CAPS was set up by the Environmental Protection Council and was endorsed by the Environmental Protection Authority and Cabinet.

The study originated from the fact that the State Government, through its Industrial Lands Development Authority, possesses some 1500 acres (610 ha) of land presently zoned industrial at the northern end of the Kwinana industrial region.

The question arose and was presented to the Environmental Protection Council and the Environmental Protection Authority as to whether this land should be rezoned from industrial to urban. In other words, there was the unusual situation where the environmental bodies had to decide whether people would be placed near industry whereas in general the public controversy centres as to whether industry should be near people.

The study has been prepared as a result of cooperation between industry, Commonwealth and State Government departments and the University of Western Australia. It serves to answer on scientific grounds and with technical back-up data, what the present and the potential future position will be as regards air pollution in the 1500 acres in question.

It goes further than that, of course, because as a successful pilot study concerning the interaction of various sources of air pollution with human welfare, it makes recommendations as to research which should be undertaken in the future.

CAPS has been a unique study in Australia in the field of air pollution management. Indeed, the spirit of collaboration exhibited between the various participants in all phases of the study augers well for the future of environmental management in Western Australia.

Brian J O'Brien

Brian J. O'Brien
CHAIRMAN
COOGEE AIR POLLUTION STUDY
WORKING GROUP

May 1974

SYNOPSIS

The Coogee Air Pollution Study (CAPS) was initiated in November 1972 to evaluate levels of air pollution over 610 hectare of potential residential land just north of the Kwinana industrial complex. During the period of the study (1 January 1973 to 28 February 1974) a multidisciplinary team worked under the guidance of the Coogee Air Pollution Study Working Group.*

This "technical working group", comprising officers from the Department of Agriculture, Commonwealth Bureau of Meteorology, Department of Environmental Protection, Kwinana industry, Public Health Department, State Electricity Commission and the University of Western Australia carried out both regular data collection and special experiments with the aim of evaluating present, and predicting future, air pollution levels over the land in question.

The report of the CAPS Working Group was presented to the Environmental Protection Council on 8 May 1974 when it was recommended "..... that, at this stage, no residential development take place within the land defined by the Coogee Air Pollution Study and comprising Cockburn locations 1843 and 1738".

The EPC further recommended "..... that research be carried out to define buffer zones which should be developed and maintained around the Kwinana industrial area and the Woodman Point treatment plant".

In concurring with the EPC recommendations the Environmental Protection Authority agreed that research to define buffer zones should be extended to include all industrial areas and other sources of air pollution.

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* Personnel directly involved in the Coogee Air Pollution Study are listed in the Appendix to this Report.

ACKNOWLEDGEMENTS

Thanks must go to the many people who were involved in the Coogee Air Pollution Study, both in terms of material aid and valuable advice and criticism. These include officers and personnel of the Government instrumentalities directly and indirectly involved in CAPS as well as those outside the Government sphere.

Particular thanks must go to the staff and students of the Bungaree Primary School, men of the 22 Construction Squadron, staff and students of Churchlands Teachers College and the BP Kwinana Refinery Apprentice Training School, all of whom assisted in the collection of air samples during the tracer experiments.

Acknowledgement must also be made of the Government Chemical Laboratories and the Public Health Department Laboratories which carried out much of the great deal of analytical work that was necessary for CAPS, and members of the staff of the School of Chemistry, University of Western Australia who became involved in various facets of CAPS.

The high degree of cooperation and willing participation evident in all phases of CAPS played a major part in the successful completion of the study.

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1. INTRODUCTION

The Coogee Air Pollution Study (CAPS) had its genesis in a proposal put forward by the Industrial Lands Development Authority in 1970 to have some 610 hectare of land just to the north of the Kwinana industrial area zoned residential. The area in question is defined more fully in Figures 1 to 3.

Figure 1 indicates the locality and size of the CAPS area in relation to both the Kwinana industrial area and the coastal plain on which the Perth metropolitan area is situated.

Figure 2 shows the CAPS area in more detail as it relates to the various industries.

Figure 3 shows the CAPS area itself, its topography and the distribution of monitoring sites.

It is interesting to reflect back on some of the early history of this area, for it appears that as early as 1829 there was a proposal for residential development in the Coogee area. Amongst the new settlements planned by Captain James Stirling in 1829 was the Town of Clarence, near Woodman Point on the shore of Cockburn Sound. It is not clear how big the proposed settlement was to be but from some reports it could have been intended as the major settlement of the Colony. There is no doubt therefore that the area now under study was intended to be part of the Town of Clarence.

In fact, the proposed Town of Clarence never grew beyond the tent stage, the greener pastures of the Swan Valley holding by far the greater attraction for the early settlers. The only reminder we have today of the plans of Captain Stirling is the name of Clarence which lives on in the Clarence Railway siding on the Fremantle-Kwinana line.

In retrospect it is not hard to see why the early planners chose the Coogee area as a potential townsite, for it lies adjacent to the magnificent expanse of Cockburn Sound and itself is a pleasantly undulating wooded area bounded on the western side by a limestone ridge. Present day planners have also been aware of the potential of this site, as evidenced by the plans for residential development that have been put forward. Moreover, in view of the apparent unsuitability of the area for industrial development (because of the topography) housing development appeared to some to be an attractive alternative.

From another development point of view the Coogee area is attractive as it presently exists. The Metropolitan Water Board's siting of its waste water treatment plant at Woodman Point was in large part determined by the industrial zoning of the CAPS area and the presence of other "odour producing" industries to the north. The industrial area (both occupied and unoccupied) was seen as an area where people would only be present during working hours and would not therefore be subject to odours during evenings, nights and mornings.

However, the present proposal to rezone the land for residential development resulted in objections from various sources, including industry and some local government authorities. In particular, the Air Pollution Control Council (APCC) reported unfavourably on the project. The opinion of the Council was that the locations covering the area should remain as buffer zones between the Kwinana industrial area and residential areas further north.

The APCC considered that odours and dust from existing industries and possible future industries could be sources of nuisance. The Council noted that winds blowing over the locations from the south were prevalent for 20% of the time and that the topography had the potential to accentuate pollutant levels. Accidental emission of a toxic pollutant was also considered a potential hazard to any residential development. The accidental release of hydrated sulphur trioxide which occurred in February 1972 was cited in the report as an example.

The APCC further noted that a sulphur dioxide monitoring site* (established by the State Electricity Commission) near to the southern boundary of the area had already recorded ground level concentrations of sulphur dioxide approaching the maximum acceptable standards set by the Environmental Protection Agency in the United States of America(1).

At the commencement of the Coogee Air Pollution Study no ambient sulphur dioxide standards had been set for Australia, the United States EPA standards being taken only as a guideline.**

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* The site referred to above is 2 km northeast of the SEC Kwinana power station and 0.5 km south of the Coogee area. The maximum twenty-four hour average in 1972 was 230 microgram per cubic metre (9 parts per hundred million - pphm) while the average over ten months was 65 microgram per cubic metre (2.5 pphm).

** The United States EPA standards are as follow:

"<u>Primary standard</u>, designed to protect the Public Health:

a) 80 microgram per cubic metre (3 pphm) annual arithmetic mean

b) 365 microgram per cubic metre (14 pphm) as a maximum twenty-four hour concentration not to be exceeded more than once a year.

<u>Secondary standard</u>, designed to protect Public Welfare from any known or anticipated adverse effects of pollutant. This includes effects on soil, water, vegetation, materials, animals, weather, visibility and personal comfort and well being:

(cont'd over)

More recently the Environmental Health Committee of the National Health and Medical Research Council has recommended that the World Health Organisation air quality long term goals[2] be adopted as guidelines for air quality in Australia.***

The problem of whether the land should be zoned residential was referred to the Environmental Protection Council by the Director of Environmental Protection. After discussing the

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** a) 60 microgram per cubic metre (2 pphm) annual arithmetic mean

b) 260 microgram per cubic metre (10 pphm) maximum twenty-four hour concentration not to be exceeded more than once a year.

c) 1300 microgram per cubic metre (50 pphm) as a maximum three hour concentration not to be exceeded more than once a year."

*** <u>WHO Recommended Long Term Goals</u>

In presenting the levels below the WHO "committee specifically urged that the table should not be considered independently of the accompanying text." (2)

"Pollutant and measuring method		Limiting level
Sulfur oxides[a]	British standard procedure[b]	Annual mean 60 microgram per cubic metre. 98%[c] of observations below 200 microgram per cubic metre.
Suspended particulates[a]	British standard procedure[b]	Annual mean 40 microgram per cubic metre. 98%[c] of observations below 120 microgram per cubic metre.

a) Values of sulfur dioxide and suspended particulates apply only in conjunction with one another.

b) Methods are not those necessarily recommended but indicate those on which these units have been based. Where other methods are used an appropriate adjustment may be necessary.

c) The permissible 2% of observations over this limit may not fall on consecutive days."

matter fully the EPC in its report recommended that no decision should be made about rezoning the land as residential until a study had been made of the actual levels of pollution over the 610 hectare in question. This recommendation was endorsed by the Environmental Protection Authority and on 2 October 1972 was agreed to by Cabinet.

Following Cabinet's decision to defer the rezoning of the land a plan was put forward by the Minister for Environmental Protection to implement the suggested study. It was proposed that an ad hoc working group be established at a senior level to formulate definitive programmes for the air pollution studies over a period of one year. This recommendation was accepted by Cabinet on 23 October 1972.

The Coogee Air Pollution Study was thus initiated and its guidelines were determined by a working group of senior representatives from the Department of Environmental Protection, the Public Health Department, the Commonwealth Bureau of Meteorology, the State Electricity Commission, the Department of Agriculture, the Industrial Lands Development Authority and representatives of Kwinana industry.

This senior working group has been responsible for the policy guidance of the study while day to day management has been under the control of a technical working group comprising officers from the various bodies mentioned above and the University of Western Australia. The senior working group has been chaired by the Director of Environmental Protection while the technical working group was co-ordinated and chaired by an officer of the Department of Environmental Protection. (Participating personnel are listed in the Appendix.)

The primary objectives of CAPS were to measure and evaluate present air pollution levels and to predict possible future levels over the area of land which was under consideration for residential development.

However, it was also recognised at the outset of CAPS that the knowledge gained during the study would be of benefit to metropolitan planning in the future. For example, it was hoped that predictive models could be developed for application in other areas of future development, that basic knowledge of the interaction of air flows, topography and pollutant distributions would be gained, that basic data that could be used to verify theoretical models used for calculating stack heights and pollutant distributions over wider areas would be obtained and that some correlation between levels of pollutants in vegetation and ground level concentrations of pollutants might be determined.

At the conclusion of the study it is pleasing to note that some of these "spin off" aims have been achieved, in that basic knowledge about the areas discussed above has been obtained. These facets are amplified and discussed more fully in the body of this report. Moreover, in retrospect, the study has also delineated areas in which more work should have been done but which in many cases was not logistically possible to carry out. However, the co-operative teamwork and techniques developed in the CAPS work will enable accurate costing and manpower estimates to be made for future studies.

The roles of the authorities involved in CAPS have been as follow:

<u>Department of Environmental Protection</u> - co-ordination, liaison and review as necessary.

<u>Public Health Department</u> - monitoring of sulphur dioxide, smoke and dust levels.

Department of Agriculture - monitoring of native and introduced vegetation in an attempt to correlate levels of pollutants measured in plants with those obtained at chemical monitoring sites.

State Electricity Commission - operation of additional sulphur dioxide monitoring sites and use of the Kwinana power station in controlled experiments.

Commonwealth Bureau of Meteorology - regular collection of meteorological data; definition of atmospheric conditions relevant to the study area, and predictions of times of suitable meteorological conditions for controlled experiments.

Industrial Lands Development Authority - to be in a position to put the Coogee measurements into perspective against proposed development of the total area and its commercial value.

Kwinana Industry - technical liaison and input of data relating to stack emissions.

In addition staff members of the University of Western Australia have been involved in particular experiments and in an advisory capacity. The Government Chemical Laboratories have also carried out much behind the scenes work in the analysis of samples collected during the study.

The report now presents the results of the fourteen month study which took place from 1 January 1973 to 28 February 1974. The intent of the report is to present the data collected and its evaluation in as complete a form as possible, but at the same time to state the essential results and conclusions clearly and concisely.

For this reason, the report is presented at two levels. The first level is contained in the SUMMARY AND RECOMMENDATIONS, in which the results of the study are summarised, the important areas highlighted and recommendations made. The second level is contained in the DISCUSSION OF DATA, in which the results of the study are presented and discussed in more detail. This section attempts to present the bulk of the data collected during CAPS and the methods of evaluation used in arriving at the final conclusions. A third level is embodied in the data collected and the experience gained by the participants in the Study. All of this data on which the Report is based is freely available to interested parties, either through the Western Australian Department of Environmental Protection or through direct contact with the relevant participants.

2. SUMMARY AND RECOMMENDATIONS

2.1 Terms of Reference

On 23 October 1972 State Cabinet approved the formation of an ad hoc working group to formulate a definitive programme for an air pollution study over a period of twelve months, to ensure that Cabinet would be provided with a complete and accurate statement about air pollution levels in the area proposed for residential development.

2.2 Air Pollution

2.2.1 Health Standards

At present no health standards or guidelines exist in Australia for ambient levels of sulphur dioxide and particulates

Sulphur dioxide health standards and criteria in various other countries are summarised in Table 25 and discussed on pages 3 and 4 of the Introduction and Section 3.7.3 of this report

The United States Environmental Protection Agency standards (page 3) have been used as guidelines in Western Australia. As stated in the introduction (page 4) the Environmental Health Committee of the National Health and Medical Research Council has recommended that the World Health Organisation air quality long term goals be adopted as guidelines for air quality in Australia.

2.2.2 Meteorology

Collection of meteorological data was seen as central to the Coogee Air Pollution Study.

Over the study period, wind speed and direction have been measured at five sites while temperature and rainfall have been measured at a sixth site. Results from this monitoring are discussed in Section 3.1 and summarised in Figures 4 to 20.

It is emphasised that these measurements do not represent an average year (as discussed in Sub-section 3.1.2 and in the conclusions, Subsection 3.13.2). It is thus imperative that due care be taken in any attempt to extrapolate this data to yield an average or extreme case.

The conclusions drawn from the study and the summary given below have been framed in this context.

2.2.3 Measured Levels

Over the period of the Coogee Air Pollution Study (January 1973 to February 1974) sulphur dioxide ground level concentrations have been measured at thirteen twenty-four hour monitoring sites and two continuous recording monitoring sites (see Fig.3). Smoke levels have been measured at seven of these sites (PHD monitors 1 to 7).

The results of sulphur dioxide and smoke monitoring are summarised in Tables 1, 2 and 12 to 23. Tables 1 and 2 contain the essential data relating to the highest levels recorded during the study. Table 1 lists the seven highest sulphur dioxide (and the associated smoke level) ground level concentrations while Table 2 lists firstly, the three highest sulphur dioxide levels over half an hour, three hours and twenty-four hours as well as the maximum monthly and the yearly average for the continuous recording sites, and secondly, the maximum twenty-four hour average, the maximum one month average and the yearly mean for each twenty-four hour site.

All of the levels of sulphur dioxide and smoke measured within the study area fall well below those health standards recommended by the United States EPA and the long term goals recommended as guidelines by the World Health Organisation. At one site just outside the CAPS area (monitoring site 2, 300 m southwest of Mt Brown) there were four days when the United States EPA twenty-four hour secondary standard was exceeded (see Table 1).

Dust levels over the CAPS area, as measured by CERL dust gauges (Section 3.3) were acceptable when compared to other areas in the metropolitan region. Two dust gauges outside the area indicated levels of dust that could give rise to complaints.

2.2.4 Projected Levels

PART B of Section 3 (Sections 3.8 to 3.12) of this Report describes an attempt to mathematically model ground level concentrations of sulphur dioxide over the CAPS area. Although the model did not accurately predict ground level concentrations of sulphur dioxide it did suggest that in the event of increases in electric power output, the conversion of all industries to fuel oil and the operation of a large iron and steel industry in Kwinana, ground level concentrations of sulphur dioxide could be expected to treble throughout the CAPS area.

This forecast is dependent on meteorological factors observed in the 12 months study period; therefore as the weather pattern in subsequent years will vary so will this factor.

It should be noted that at the present time use of alternative fuels such as natural gas and coal is under active consideration, particularly in the light of the world shortage of fuel oil.

2.3 Other

2.3.1 Odours

The question of odours is discussed in Section 3.7.4.1. Odours from several Kwinana industries and the Metropolitan Water Board's waste water treatment plant at Woodman Point were apparent over the CAPS area at various times during the study. Persistent odours from industry were most obvious at the southern boundary.

The potential for odour from the Woodman Point plant is considered at least as serious as that at the Subiaco plant. It is the opinion of the Metropolitan Water Board that this problem cannot be eliminated or even considerably reduced in the future.

2.3.2 Noise

As discussed in Section 3.7.4.2 noise levels over the CAPS area do not appear to be higher than is general in residential areas.

2.3.3 Accidental Emissions

Examination of the data presented in this Report indicates that, given appropriate weather conditions, the CAPS area could be subject to "fallout" from accidental release of a toxic pollutant, if such an event occurred.

It is noted that Kwinana industries have a co-operative arrangement presently existing so that if an accidental emission of a toxic pollutant occurred, rapid action (commensurate with the nature and extent of the release) would be taken.

2.3.4 Aesthetic Considerations

As noted in Section 3.7.4.4 industrial emissions cause impairment to the clarity of the skies. In an area (such as the CAPS area) repeatedly subject to such intrusions they may arouse in residents adverse comment unrelated to health aspects.

The introduction of major new industries emitting gaseous effluents which could combine with presently existing pollutants to form new sources of particulate matter, could materially affect the clarity of the sky.

2.4 Recommendations

After discussion and endorsement of the report of the CAPS working group the Western Australian Environmental Protection Council on 8 May 1974 agreed to the following:

"The Environmental Protection Council:

NOTING that there are presently no formally adopted standards or guidelines in Australia for ambient levels of sulphur dioxide and particulates, but that the World Health Organisation long term goals are the leading guidelines for formulating such a policy:

NOTING the conclusions of the Coogee Air Pollution Study; in particular, the probability that the weather during the study period was not representative of an extreme for air pollution, the levels of sulphur dioxide measured at the southern end of the area and the potential of the Woodman Point waste water treatment plant for emission of odours, and in view of the possibility that expansion of industry using fuel oil would lead to increased levels of sulphur dioxide over the area in question:

RECOMMENDS that, at this stage, no residential development take place within the land defined by the Coogee Air Pollution Study and comprising Cockburn locations 1843 and 1738.

The EPC desires to convey to Hon Minister for Conservation and Environment that a review of the potential for residential development of this area be undertaken whenever the natural gas resources available to Western Australia are established and their use in the Kwinana industrial area determined.

The EPC further RECOMMENDS that research be carried out to define buffer zones which should be developed and maintained around the Kwinana industrial area and the Woodman Point treatment plant. Such research to be defined through continual collaboration of the CAPS group.

The EPC RESOLVES to advise Hon Minister for Conservation and Environment that it desires to convey to the industries and the Federal Government and State Government instrumentalities involved in the Coogee Air Pollution Study, an expression of appreciation for their willing participation in a study which should lead to optimum planning of air pollution management associated with industrial sites in Western Australia."

The Western Australian Environmental Protection Authority in endorsing both the CAPS report and the deliberations of the EPC said that it regarded the Coogee Air Pollution Study as a prototype for comprehensive studies in advanced air pollution planning associated with industrial sites and agreed that future studies of this type should be encouraged.

In concurring with the EPC recommendations the EPA agreed that research to define buffer zones should be extended and therefore -

"RECOMMENDS that further research be carried out to define buffer zones that should be developed around industrial areas and other sources of air pollution. Such research to be defined through continued collaboration of the CAPS group."

3. DISCUSSION OF DATA

PREAMBLE

As stated in the introduction to this report various monitoring programmes have been undertaken by several State instrumentalities as part of the Coogee Air Pollution Study. These programmes, their rationale and methodology are discussed in greater depth in the appendices to this Report.

This section embodies the results of the complete study. The various facets of the study are considered in turn and the data obtained are presented in summarised form. Some inter-relationships between the parts of the study are then discussed and predictions about the effect of variations in industrial output (from the Kwinana industrial area) on ground level concentrations of pollutants are made.

PART A deals in turn with each phase of the study. The results of monitoring are summarised, the emission levels of sulphur dioxide from industry are tabulated and the implications of the controlled experiments that have been carried out are discussed. Finally, some of the inter-relationships between the different facets of the study are presented and the relevance of this data to health and environmental standards is discussed.

PART B is concerned with model simulation of the ground level concentrations of sulphur dioxide under varying sets of emission conditions. A model relating ground level concentration of sulphur dioxide to source emission has been adapted using data obtained during the Coogee Air Pollution Study. Predictions of possible future ground level concentrations of sulphur dioxide are made assuming certain changes in the emission levels of Kwinana industries. These results are discussed in the light of the present pattern of industrial development and likely patterns of future development.

In PART C conclusions are drawn in the light of the evidence produced by the Coogee Air Pollution Study.

PART A - THE CAPS PROGRAMME

Locations were chosen to monitor meteorological data, sulphur dioxide ground level concentrations, smoke and dust levels, and levels of sulphur, alumina and chloride in introduced and native vegetation.

The monitoring sites were not confined specifically to the study area but were sited with regard to possible topographic effects and logistic constraints (see Fig.3). Results from locations outside the area have been integrated into the overall study with due regard being taken of their siting.

3.1 Meteorological

From the outset of CAPS it was recognised that a detailed knowledge of the meteorological conditions was essential to any attempt to evaluate levels of air pollution over the study area. In preliminary discussions questions had been raised as to the possible effects of the prevailing southwesterly winds, the frequency of low altitude temperature inversions and the nature of the topography on ground level concentrations of sulphur dioxide, smoke and dust.

Accordingly, various parts of the CAPS programme were designed to answer these questions, the meteorological data being seen as the connecting link.

Collection of meteorological data has been carried out by the Bureau of Meteorology. Five Woelfle long term recording anemometers(3) were set up. Siting of the instruments was determined by the location of the sulphur dioxide sampling equipment and the local topography (see Fig.3).

Hourly averages of wind speed and half-hourly averages of wind direction were obtained for the fourteen month study period. Servicing difficulties encountered during the winter months and vandalism produced some gaps in the data from the more exposed anemometers. Thermograph and hygrograph charts were obtained weekly from instruments exposed in a standard Stevenson Screen[4] on-site and in addition a long term pluviograph provided half-hourly rainfall totals.

3.1.1 Winds and Stability

It is quite clear that wind blowing from the Kwinana industrial complex over the CAPS area will be a factor affecting ground level pollution, the intensity of which will be determined by the ability of the atmosphere to disperse the pollution. The two major atmospheric parameters contributing to dispersion are wind speed and atmospheric stability.

The environmental[5] wind flow never attains steady state conditions. Variability or gustiness is a feature of the turbulent wind flow recorded near ground level. Thus, it is possible to obtain criteria for turbulence measurement based on the root-mean-square value of the wind direction variability. The wind figures quoted in the following tables are mean wind directions averaged over a half-hour period. Directional fluctuations have provided the stability figures using the technique outlined by Pasquill[5].

Wind data collected at anemometer site A2 were used wherever possible, as this site best satisfied the meteorological criteria for instrument exposure[6]. When site A2 was not operating data from anemometer site A1 were used.

Figures 4 to 17 are wind roses constructed for the months January 1973 to February 1974 inclusive, using data collected at site A2 (or site A1 if site A2 was out of order). Each wind rose indicates the percentage of wind blowing <u>from</u> the given direction over the whole month.

Figure 18 is the annual wind rose.

Figure 19 shows the percentage of wind blowing each day in the sector extending from 170^{o} to 230^{o} for the whole year. This is an indication of the percentage of the total wind flow which blows directly across the Kwinana industrial complex and on to the CAPS area. (See Fig.2.)

Figure 20 is a cumulative frequency diagram showing the percentage of days of the year in which the wind was blowing from the 170^{o} to 230^{o} sector for a given percentage of the day.

3.1.2 Temperature Inversions

Before the Coogee Air Pollution Study commenced it was suggested that levels of pollution over the area in question could be increased (over a period of some hours) by a strong and persistent low-level temperature inversion associated with either a gentle southerly air movement from the Kwinana industrial area or a light easterly drift from the other industrial works to the east[7].

When CAPS began it was anticipated that a more detailed investigation of the general inversion climatology of the area would be carried out using slow ascent radiosondes which were being developed in Australia. Unfortunately a delay in the production of these radiosondes and then technical difficulties precluded their use during the period of the study.

However, in general, the 1973 weather patterns favoured rapid and effective dispersion of pollutants as illustrated by the number of Air Dispersion Alerts issued by the Bureau of Meteorology in 1973.*

In 1972, the first year this service was made available, twenty-two alerts were issued compared to the two in 1973. Past meteorological data indicates that about 10 alerts could be expected on average per year.

Supporting this evidence are earlier measurements of oxides of nitrogen near the University of Western Australia and in Peppermint Grove. These results showed far fewer significant concentrations in the evening hours of 1973 when compared with data secured by the same techniques in 1972, thus reflecting the relative frequencies of Air Dispersion Alerts.

3.1.3 Topography

The CAPS area, as shown in Figure 3 comprises

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* An Air Dispersion Alert is given when light winds and stable conditions are expected to allow pollutants to accumulate in the lower atmosphere for a period of at least twelve hours(8). The forecast is intended to apply over the whole metropolitan area.

the western part of a shallow valley (less than ten metre above sea level at its lowest elevation) running parallel to the coast. About one-third of the area is low-lying and includes swamp areas and permanent water.

The western side is bounded by a limestone ridge which exceeds forty metre above sea level in places. This ridge protrudes eastwards at the southern boundary terminating in Mt Brown (70 metre).

Before the Coogee Air Pollution Study commenced it had been suggested [7, 9] that at least two local climatic effects (associated with topography) could lead to increased pollution levels over sections of the area in question, viz:

i) Valley Effect: Atmospheric pollutants could accumulate in low-lying areas at night following the drainage of cold moist air down the surrounding slopes under calm or very light wind conditions.

ii) Effect of Mt Brown: It was suggested that Mt Brown could have two effects on the air flow which would increase pollution levels over the area. First, it could act to divert or channel into the valley light southerly winds, and second, it could produce downwind eddies or downdraughts in fresh southerly winds. From aerodynamic theory it can be predicted that obstacles (such as Mt Brown) disrupt the normal air flow to a level up to three times above their height and downwind to the order of ten times their height [10].

As a result of these suggestions several controlled experiments were carried out during CAPS and monitoring equipment was set up at a special site to the north of Mt Brown to see if any effect could be detected and quantified (see Fig.3, site 7). The experiments which were carried out indicated that topography does have a role in the distribution of air pollution over the CAPS area. They are described in Section 3.6.

3.2 Monitoring of Sulphur Dioxide and Smoke

Monitoring of sulphur dioxide and smoke has been carried out by the Clean Air Section of the Public Health Department and of sulphur dioxide alone by the State Electricity Commission. As shown on Figure 3 there are thirteen sites* at which monitoring has been carried out on a twenty-four hour basis; seven of these sites have been operated by the Public Health Department while the remaining six have been operated by the State Electricity Commission.

All sites, except site 7, are based on a grid established by the Public Health Department[11]. Site 7 which commenced operation in July 1973 was specially set up to determine whether Mt Brown caused any increase in ground level concentrations in its northern lee.

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* Data from twelve of the thirteen sites noted above are recorded in figures and tables in this report. The thirteenth site (517) was located in the grounds of a small industry. Data from this site showed the influence of the adjacent low-level sulphur dioxide emission source and operation of the site was discontinued in July 1973.

In addition, two continuous sulphur dioxide monitors have been operated by the Public Health Department at the sites shown on Figure 3. These permit a time resolution to approximately five minutes.

Sulphur dioxide has been measured by the West-Gaeke colorimetric method which has been accepted by the United States Environmental Protection Agency as a standard method[12].

Smoke is measured by the British Standard method[13]. It should be noted that this method is designed to enable the concentration of smoke in a sample of air to be obtained in terms of a standard smoke, from observation of the darkness of the stain produced when the air is filtered through white paper. Hence, the method is limited in that a change in the colour of the smoke (ie the measured smoke level) may occur without any change in the quantity of smoke emitted, or conversely the absolute quantity of smoke may change without any apparent change in the "measured level".

In this context, airborne matter which is light in colour will give a much lower smoke reading than the "standard smoke" although the absolute quantity of material may be as great or greater than the standard smoke.

Figures 21 to 32 show graphically the levels of sulphur dioxide that have been recorded from January 1973 to February 1974 for each of the twelve twenty-four hour monitors. Each figure in this series records the level of sulphur dioxide in microgram per cubic metre for each day of the period.

Figures 33 to 44 are in turn cumulative frequency diagrams for each of the twelve twenty-four hour sulphur dioxide monitors.

Table 1 lists the seven highest ground level concentrations of sulphur dioxide and the associated smoke concentrations for each site. These seven values represent the two percent of days noted in the World Health Organisation guidelines for long term goals[2], for which the ground level concentration of sulphur dioxide should not exceed 200 microgram per cubic metre. It should be noted that the associated smoke levels are extremely low in comparison to the WHO long term goals.

Table 2 lists firstly, the three highest sulphur dioxide levels over half and hour, three hours and twenty-four hours as well as the maximum monthly and the yearly average for the continuous recording sites, and secondly, the maximum twenty-four hour average, the maximum one month average and the yearly mean for each twenty-four hour site.

3.3 Monitoring of Dust

Dust has been monitored at five sites (see Fig. 3) by the Public Health Department using CERL directional dust gauges[14]. The CERL gauge is designed to collect wind-borne dust from each quadrant.

Results for each gauge are expressed as "total dirtiness". Total dirtiness represents the soiling effect of particulate matter (including natural dust, vegetation debris, etc) which is blown to the location of the CERL directional dust gauge. The gauge collects the dust from all directions by means of four collectors facing north, south, east and west. The dust collected for a given time (one month in the case of CAPS) is measured using an optical obscuration method, whereby the amount of dust which obscures the intensity of a previously calibrated light path is computed. Pure water is taken as a reference level of zero. Table 3 below, lists the annual average values for total dirtiness obtained over the Perth metropolitan area in 1972[19]. The figures in brackets are the highest monthly values for each site. Those figures marked with an asterisk were associated with complaints which when investigated were found to be justified.

TABLE 3

Total Dirtiness Figures for the Metropolitan Area 1972

CERL Dust Gauge Site	CLASSIFICATION OF AREA		
	Residential	Commercial	Industrial
City Beach	1.5 (2.0)		
East Perth		1.4 (2.1)	
Lathlain Park	1.9 (2.5)		
Welshpool			
Site 1			2.1 (4.7)
Site 2			2.3 (3.1)
Site 3			2.2 (2.3)
Kewdale			
Site 1			3.3 (3.5)
Site 2			2.7 (3.2)
Site 3			3.1 (4.6)
Perth Airport		2.2 (3.9)	
Naval Base			3.1 (4.5)
Maddington			
Site 1			7.7 (19.0)*
Site 2			4.9 (8.6)*
Gosnells			3.3 (6.4)
Rivervale		2.9 (4.5)*	
Jandakot			
Site 1			3.0 (4.4)
Site 2			9.0 (12.7)
Site 3			6.1 (10.6)
Site 4			3.5 (5.8)

In the context of Table 3 it appears that a total dirtiness level that might result in a complaint in one area (residential or commercial) may not have the same effect in another area (industrial).

The results from sampling during the Coogee Air Pollution Study are summarised in Tables 4 to 8. In most cases the levels of total dirtiness are acceptable, both in comparison to the metropolitan area as a whole and for the nature of the Coogee area as it presently exists. The exceptions were the months of January, February and March at the Naval Base gauge and January and February at the gauge located at site 2, where the total dirtiness readings were such that complaints could be expected. It should be noted that both of these sites are outside the CAPS area (see Fig.3).

In addition to total dirtiness, CERL dust gauge samples have been analysed for iron oxide and aluminium. These results are summarised in Tables 4 to 8.

3.3.1 High Volume Sampling

It is known that particulate matter of around five micron (5 μ) or less is potentially harmful to humans from a health point of view[15]. Further, the harmful effect pollutants may be enhanced by the presence of particulate matter in this size range.

The synergistic effects of sulphur dioxide with smoke are well known from United Kingdom studies[16] and the synergistic effect of sulphur dioxide with other particulate matter has also been reviewed and described[16, 18]. The World Health Organisation long term goals also emphasise the relationship between particulate matter and sulphur dioxide[2].

At the outset of CAPS it was recognised that some information about particulate size and dust loading was necessary to identify any potential synergistic effect; for example, between sulphur dioxide and alumina dust.

In the current study particulate size could not be determined from the smoke or dust measurements described above.

Accordingly, attempts were made using high volume samplers and MRE gravimetric dust samplers to obtain levels of total dust and the proportion and nature of the dust below five micron in size, but these were unsuccessful.

Further research would be required to obtain sufficiently accurate data to determine if there were sufficient particles in the necessary size range to allow for the possibility of a synergistic effect.

3.4 Vegetation Survey

Chemical monitoring of sulphur dioxide and smoke, as described in Section 3.2, is limited in terms of the coverage it can give by problems of logistics and expense. Accordingly, when the Coogee Air Pollution Study was initiated a vegetation survey was undertaken in an attempt to extend monitoring in greater depth over the area.

The basic aim of the survey was to estimate the average, or long term sulphur dioxide levels at various locations in the CAPS area by measuring the sulphur content of vegetation and correlating these values with measured sulphur dioxide levels at chemical monitoring sites. Sampling of both native vegetation and introduced species (the latter to minimise variations due to soil) was carried out on a three monthly basis during the period of the study. Leaf samples were analysed (washed and unwashed) for chloride, aluminium and sulphur.

3.4.1 Methods and Techniques

a) Native Vegetation: Twenty sites were selected (see Fig. 45) using the State Electricity Commission Kwinana power station as a reference point. Depending on availability, the leaves of Blackboy (*Xanthorrea preissii*), Banksia (*Banksia attenuata*), Tuart (*Eucalyptus gomphocephala*) and Jarrah (*Eucalyptus marginata*) were sampled every three months and analysed for chloride, sulphur and aluminium. Only Blackboy and Banksia were found on all sites. Jarrah and Tuart were both prone to insect attack and leaf fall and both exhibited marked bursts of new growth, which characteristics made them unsuitable for sampling. Control was achieved by sampling all species at a site distant from the Kwinana industrial complex (site 20).

b) Introduced Vegetation (Maritime Pine - *Pinus pinaster*): Transplants were dug up in December 1972 from a seedbed and grown in cans in a nursery until stabilised. The young pines were then placed in the field (March 1973) in groups of five, at the twenty sites selected for vegetation sampling. Leaf samples were analysed as for native vegetation. Controls were taken from nursery stabilised pines.

3.4.2 Results

From experience in the field and the laboratory it became apparent that Blackboy was the preferred botanical species of those tested to measure levels of pollution at a particular site. Blackboy is a slow growing evergreen and thus accumulates pollutants over a considerable period of time. It was easy to sample quickly and accurately and did not present problems in washing. All of the other species tested exhibited shortcomings to some degree.

Banksia leaves were often sticky and difficult to wash while Tuart and Jarrah were prone to insect attack and leaf fall as mentioned above. In retrospect, the choice of young *Pinus pinaster* proved unsatisfactory as the young plants continually exhibited new growth which in many cases had to be sampled due to lack of more mature material. As a result analyses were variable and showed no observable correlation or trend. This experience indicates that more mature pines should be used in an experiment such as was carried out for CAPS.

Accordingly, results of sampling are presented only for Blackboy and Banksia in Tables 9 and 10. Discussion of the relationship of pollutant levels measured in vegetation, to those measured at chemical monitoring sites is contained in Section 3.7.2.

The following comments are made on the analytical results (Blackboy figures only).

a) Sulphur: These results may be graded as below:

i) Very low - under 0.10% sulphur (average) Sites - V2 and V12 which are exposed to the sea and V20 which is well to the south of the CAPS area.

ii) Low - between 0.10 and 0.12% sulphur (average) Sites - V1 which is exposed to the sea, V13, V14, V15 and V15A which are in the middle of the CAPS area and V18.

iii) Medium - between 0.12 and 0.14% sulphur (average)
Sites - V8 and V10 which are not exposed to prevailing southwest winds.

iv) High - between 0.14 and 0.16% sulphur (average)
Sites - V3, V4, V5, V6 and V11 which are all in the path of the prevailing wind and at the southern end of the CAPS area; V7, V9 V16 and V17.

v) Very High - above 0.16% sulphur (average)
Site - V19, 1300 m northeast of the CAPS area.

b) Chloride: High and consistent figures have been obtained where plants are exposed to the open sea and where sea spray and salt are most obviously responsible. Sites such as V1, V2, V3, V8, V11 and V16 show this trend. The possibility of the emission of industrial chloride cannot be ruled out. However, in the leaves of vegetation sampled, levels of chloride could have been raised by the presence of industrial pollutants, and conversely, the presence of chloride could have been a factor in increased levels of industrial pollutants. In turn, combinations of these factors with or without the addition of insect attack (and other natural conditions) may be responsible for some of the vegetation damage that is apparent in the area. More specific research would be needed before damage to vegetation could be linked to industrial pollution.

c) Alumina: It was assumed that the aluminium analysed was mainly due to alumina dust and not to contamination from other sources. Then, a combination of dust from ship loading and the alumina works itself seems responsible for the relatively high levels at sites V1, V2, V3, V4, V5 and V11.

The effect of alumina on vegetation is not known although this particulate material is alkaline (pH = 10.4) and contains about 0.35% of water soluble salts.

3.4.3 Conclusions

i) Blackboy tips (sampled at the recently mature stage) were found to be the most satisfactory plant indicator to measure the effect of long term levels of sulphur dioxide on vegetation. Correlation of the levels of sulphur measured in Blackboy with ground level concentrations of sulphur dioxide is considered more fully in Section 3.7.2.

ii) Generally, the sulphur content of plant samples decreased with increasing distance from the Kwinana industrial complex. In addition, the effects of two secondary sulphur dioxide emission sources was shown by analysis of vegetation for sulphur.

iii) Valuable experience in the methods and techniques of vegetation sampling and analysis was gained. This experience could be applied in future pollution studies.

3.5 Industrial Emissions

As shown on Figure 2 a total of eight industries, having between them fourteen emission sources, willingly contributed information to the Coogee Air Pollution Study. The data obtained from the industries included the total output of sulphur dioxide per half hour from each source as well as data relating to the condition of the flue gases. The depth of information obtained in this way allowed the use of modelling techniques to predict possible future ground level concentrations of sulphur dioxide. These results are discussed in PART B of this section.

Information as to the rate of emission of particulate matter was not obtained as measurements are not available at the present time.

Figure 46 shows graphically the total output of sulphur dioxide per day over the fourteen months of the study for all industries south of the CAPS area while Figures 47 to 49 show the daily emission rates for three of the emission sources nearest to the CAPS area.

Table 11 lists the average daily emission of sulphur dioxide for each of the eight industries for the whole period of the study as well as the average daily emission for each month of the study. The table thus gives an indication of the average amount of sulphur dioxide emitted by each industry as well as the way in which this amount varied during the year.

3.6 Controlled Experiments

3.6.1 Smoke Trail Experiments

As indicated in earlier discussion (see Section 3.1.3), it had been suggested that Mt Brown could modify air flow to increase ground level concentrations of pollutants over part of the CAPS area.

In an attempt to qualitatively determine the effect of Mt Brown on air flow two experiments were carried out as part of CAPS. The aim of the experiments was to detect downwind disturbances in the airflow pattern (by the use of smoke trails) which could indicate possible increases in ground level concentrations of pollutants.

The first experiment, carried out on 7 December 1972, involved the emission of puffs of black smoke from one of the State Electricity Commission Kwinana power station stacks. Each puff was of approximately thirty seconds duration, a total of five being emitted at two minute intervals. Beginning at the time of emission of the second puff, coloured smoke flares were set off from the top and bottom of Mt Brown. The complete exercise was photographed with still and movie cameras from six vantage point (see Fig.50).

This first experiment was rather inconclusive although a general downward movement of the puffs of smoke was observed both before and, more markedly, after Mt Brown, while the smoke from the flares showed a strong tendency to follow the topography.

A second experiment, carried out on 21 March 1973, was more informative. This time a single continuous plume of black smoke of three minutes duration was released from the SEC power station stack followed by the consecutive release of smoke flares at 300 m, 240 m, 180m, 120 m and 60 m above Mt Brown. Again, still and movie cameras were used to record the downwind movement of the smoke and flares.

Figure 51 is a composite representation of the behaviour of the smoke plume and the flares, being made up from the series of photographs taken from a position on Garden Island at right angles to the direction of wind flow.

In Figure 52 typical mountain flow patterns are depicted. The wind profile experienced at South Coogee during the experiment described above is shown in the final diagram, 6. Winds increased in strength in the levels above the summit of Mt Brown in much the same way as shown in the third diagram, 3. However, wind speeds were lighter and a wind flow pattern resembling a combination of the second and third diagrams would have been expected.

The results of the experiment, especially the continuous smoke plume tended to show the sinusoidal effect of the third diagram in Figure 52. The smoke flares also showed the disturbed flow pattern at lower levels as indicated in the second diagram. Turbulence in the smoke plume (as in the first experiment) appeared to occur both before and after Mt Brown.

In general, the results of the experiment showed agreement with the accepted theory of airflow over an obstruction; ie a degree of turbulence and abnormal vertical motion as confirmed by photographs, and added weight to the suggestion that increased levels of air pollution might occur over part of the CAPS area.

3.6.2 Tracer Experiments

At the outset of the Coogee Air Pollution study it was recognised that it would be relatively straight forward to collect data about particular levels of pollutants in particular places and further, to associate these levels with particular sets of meteorological conditions. However, it was also recognised that it would not be nearly so straightforward to determine accurately just which source, or combination of sources, was responsible for these levels.

One method by which it was hoped such correlations could be carried out was mathematical modelling. Such modelling has been completed and is described in PART B of this section. However, no logistically practicable model can completely replicate the real conditions and further, any model that is used must be verified against real data if it is to be meaningful.

Therefore, it was decided to use chemical tracers to define the fallout pattern of pollutants from the various industries. In this method a volatile chemical is injected into a stack under normal load conditions and a number of air samples are collected downwind of the stack before, during and after the period the chemical is being emitted. The air samples are then analysed for the presence of the chemical, which should be such as can be detected in extremely small concentrations. A contour map of the chemical fallout can then be produced from the results of the analysis.

A substantial amount of work has been carried out overseas on chemical tracers and their use to define pollutant fallout[20, 21]. In the present study it was intended to carry out a trial experiment to see if the method could be applied successfully in the Western Australian situation and then to proceed with further full-scale experiments as practicable.

Ideally, a single chemical tracer could be used under varying sets of weather conditions to define dispersion from several sources, and combinations of tracers could be used at the same time from several sources to define the contribution of each source to the overall ground level concentrations of pollutants.

In practice this total plan could not be achieved over the study period, mainly due to logistical difficulties and the vagaries of the weather. Nevertheless, the work that was carried out was informative and pointed to the importance and usefulness of this method for future air monitoring work.

After completion of a successful trial experiment to define and test the method, one full scale experiment was carried out. In this experiment sixty-five kilogram of "Freon 11" (tri-chlorofluoromethane) were used as the chemical tracer, being released from one of the State Electricity Kwinana power station stacks over a period of twenty minutes on the afternoon of 5 December 1973. Air samples were collected at sixty-six sites on a predetermined grid covering the CAPS area and its surrounds. The samples were collected over a period of four minutes at six minute intervals, the first sample being taken as a control before the release of the "Freon".

Analysis of the collected air samples was carried out using gas chromatographic facilities at the School of Chemistry, University of Western Australia. Measurements of wind speed and direction were made at a number of altitudes before, during and after the experiment by officers of the Bureau of Meteorology using theodolite tracked balloons.

The results of the experiment are shown in Figure 53. The contour lines on Figure 53 are a visual best fit to the data obtained and represent lines of equal ground level concentration of the "Freon" as detected. Due to logistical constraints it was not possible to carry out the tracer experiment at a time when the wind was blowing directely over the CAPS area. Nevertheless, certain conclusions can be drawn from the results that were obtained.

i) The maximum ground level concentration observed for the "Freon" fell within the range of theoretical predictions for the maximum ground level concentration of sulphur dioxide emitted under similar conditions.

ii) Perturbations in the concentration contours south and north of Mt Brown further confirmed the suggestion that topography at the southern end of the CAPS area plays a part in determining ground level concentrations of pollutants.

iii) Comparison of the results obtained with theoretical contours predicted by the mathematical model used in PART B of this section gives close agreement. The theoretical ground level contours for the tracer experiment are shown on the overlay to Figure 53.

iv) A general conclusion is that chemical tracers are a useful and informative environmental aid that can be successfully applied in the Western Australian industrial situation.

3.7 Discussion of Results

3.7.1 Correlation of Ground Level Concentrations of Sulphur Dioxide with Wind Conditions

Tables 12 to 23 give for each twenty-four hour monitor the five highest readings and the highest reading for each month of sulphur dioxide and smoke. (It should be noted that monitors numbered 501 to 517 have not been equipped to measure smoke.) Each table lists the percentage of wind blowing from the sector 170° to 230° (ie the sector in which the wind will blow from Kwinana industry over the CAPS area), the highest percentage of wind for the day and its direction, the average velocity and stability for each of the above directions, and the percentage calm for the day.

These tables give a qualitative idea of the relationship of ground level concentration and wind. In PART B of this section a mathematical model has been used in an attempt to more precisely correlate ground level concentration, wind and industrial output of sulphur dioxide.

Nevertheless, several useful comments can be made on the data as it is presented in Tables 12 to 23.

i) The highest twenty-four hour ground level concentrations of sulphur dioxide during the period of the study, occurred at the southern end of the CAPS area, and were recorded on days (most often in the months November to March) when the predominant wind direction was in the 170° to 230° sector.

The maximum twenty-four hour value of 283 microgram per cubic metre was recorded at site 2 (300 m southwest of Mt Brown; see Fig.3). This site had six days on which the twenty-four hour sulphur dioxide value exceeded 200 microgram per cubic metre. The State Electricity Commission site mentioned earlier (see site 501, Introduction, page 3) had three days on which the twenty-four hour sulphur dioxide value exceeded 100 microgram per cubic metre, the maximum of 189 being recorded in December 1973.

The maximum value recorded <u>on</u> the CAPS area was 126 microgram per cubic metre at site 7 (350 m northeast of Mt Brown). Other values greater than 100, were recorded at sites 1 and 3 outside the CAPS area and site 4 within the CAPS area (see Fig.3 and Table 1).

ii) Twenty-four hour ground level concentrations of sulphur dioxide recorded at sites further to the north (see Fig.3, sites 4, 5, 6, 514, 515 and 516) can be attributed to a combination of industry to the south and northeast of the CAPS area.

The maximum value recorded at these sites was 111 microgram per cubic metre at site 4, which is on top of the coastal limestone ridge (elevation above sea level approximately 30 m).

The maximum value recorded in the northern arc of monitors was 67 microgram per cubic metre at site 516 which is 600 m northeast of the northeastern corner of the CAPS area.

3.7.2 Correlation of Vegetation Survey Results with Ground Level Concentrations of Sulphur Dioxide

Table 24 lists for comparison the annual mean sulphur dioxide concentration and the average percentage of sulphur measured in Blackboy, for each monitoring site at which data is available.

Figure 45 contains a visual representation of the sulphur and sulphur dioxide levels listed in Table 24. There is an obvious relationship between the two and in fact the coefficient of linear correlation is 0.85 (0.94 if site 2 is excluded).

Sampling of vegetation (in particular Blackboy) has therefore proved a satisfactory indicator of atmospheric sulphur dioxide. The method could be extended to give a more detailed coverage of the CAPS area or it could be applied in other areas.

3.7.3 Relationship of Measured Sulphur Dioxide Levels to Health Standards

Table 25 lists some of the ambient air standards and criteria for sulphur dioxide that have been adopted in other countries. The following notes apply to this Table.

i) All figures are in microgram per cubic metre with the relevant value in parts per hundred million given in brackets. All standards are not to be exceeded more than once per year unless otherwise noted below.

ii) The World Health Organisation figure of 60 microgram per cubic metre is seen as a long term goal. An additional goal of ninety-eight percent of observations less than 200 microgram per cubic metre in a year is also recommended[2], (see also Introduction page 4).

iii) The United States EPA standards are given as both "primary" and "secondary" standards[1]. Under the Clean Air Amendments of 1970, primary standards to protect public health are required by 1975. More stringent standards, to protect aesthetics, property and vegetation (secondary standards) must be achieved within a "reasonable time", as determined by the US EPA[22].

iv) The USSR short term standard refers to a single incident.

v) The Swedish short term standard refers to the half hour average which can be exceeded fifteen times per month. The twenty-four hour average can be exceeded only once per month.

vi) The Japanese short term standard is the maximum value of hourly measurements, while the twenty-four hour level is the maximum daily average of hourly measurements.

It is apparent from examination of Table 25 that standards can vary quite considerably from country to country. As noted in the Introduction to this Report (page 3) the United States EPA standards have been used as guidelines for Western Australia. More recently it has been suggested that the World Health Organisation long term goals may be recommended for use as guidelines for air quality in Australia (page 4).

Tables 1 and 2 can be used to compare the measured ground level concentrations of sulphur dioxide over the CAPS area (during the period of the study) with the standards and criteria noted in Table 25. It is clear from examination of these tables that the maximum levels measured on and around the CAPS area during the fourteen months of the study were well below both the United States EPA standards and the World Health Organisation long term goals, with the exception of one site. This was site 2 which was situated 300 m southwest of Mt Brown and just outside the CAPS area.

As has already been noted (page 40) the maximum twenty-four hour value obtained at this site was 283 microgram per cubic metre. As listed in Table 1 there were four days on which the twenty-four hour ground level concentration of sulphur dioxide exceeded the United States EPA secondary standard and six days when the twenty-four hour ground level concentration of sulphur dioxide exceeded 200 microgram per cubic metre (for comparison to the WHO long term goal).

Predictions of possible future ground level concentrations of sulphur dioxide are given in PART B of this section.

3.7.4 Other Significant Areas Considered

3.7.4.1 Odours

Officers involved in the Coogee Air Pollution Study visited the area, both individually and as a "panel" in the daytime and at night, during the study period. It is well known that the human nose is extremely sensitive to certain odours and can often detect concentrations substantially below those detectable by physical or chemical means. In this sense it was appropriate that it was people who considered at first hand the question of odours.

The conclusions drawn as a result of these visits are that:

i) Several distinct odours are noticeable at the southern end of the CAPS area when the wind is blowing from the industrial complex. These are the so-called "alkali smell" (which is most often noticeable) from the alumina refinery, a "hydrocarbon" odour from the oil refinery, a "phenolic" odour from a chemical company manufacturing weedicides, and infrequent odours attributable to other industries.

ii) It was the experience of observing officers that sensitivity to these odours did not decrease over periods of several hours.

iii) A more complete picture of the extent of "odour penetration" into the CAPS area is given by observations of technicians who have been servicing monitoring equipment regularly. The majority of these observations have been made in the early morning.

The "alkali smell" has been most noticeable during light winds from the south and southwest and has been experienced as far as monitoring site 7 and occasionally at monitoring site 6.

The "oil refinery smell" was noticed on occasions at site 2 again in south and southwest winds while a "sulphur dioxide smell" has been observed at sites 2, 7 and 3. On a single occasion the same smell was noted at site 5 while an easterly wind was blowing.

Infrequently a "sewage smell" was observed at sites 5 and 6 with northerly winds and once under calm conditions a "superphosphate smell" was noted at site 5.

The Woodman Point waste water treatment plant which lies 900 m north of the north-west corner of the CAPS area has been suggested as a possible source of odours[26].

Sewage from this treatment plant has a potential for odour greater than other metropolitan sewage treatment works since the sewage to be treated is pumped long distances (as far away as Guildford) and undergoes some anaerobic decomposition in transit.

Generally, odour problems associated with treatment plants are worst in the evenings and early hours of the morning. Seasonally they are worst in the autumn and spring.

The Woodman Point plant at its present stage of development has reached approximately ten percent of its full potential development. More complete elimination of odour problems would involve the total enclosure of much of the plant and extraction and burning of gases. Not only would this be financially prohibitive but complete success could not be guaranteed irrespective of the amount of money spent.

The Metropolitan Water Board has received complaints concerning unpleasant odours from as far away as Hamilton Hill, although these odours have not been specifically linked to the Woodman Point plant. However, from the Board's experience with other metropolitan plants such complaints could be associated with the Woodman Point plant.

A new "odour burner" will be operating at the Woodman Point treatment works in the near future. While the Board is hoping that considerable improvement will result it certainly will not eliminate all odour sources.

3.7.4.2 Noise

Both Cockburn and Rockingham Roads are busy routes for cars and heavy haulage transport. However, Cockburn Road to the west is shielded from the CAPS area to some extent by a limestone ridge while Rockingham Road to the east is at present bordered by large trees and scrub.

Subjective comment from departmental officers who have worked regularly in the area (both early in the morning and during the day) is that present traffic noise levels are not unusually high.

Industrial noise is not apparent over the CAPS area except occasionally at the extreme southern end when the wind is blowing from the industrial complex.

3.7.4.3 Accidental Emissions

In the report of the Air Pollution Control Council[9] it was considered that accidental emission of a toxic pollutant would be a potential hazard to the residents of the proposed housing development at South Coogee. As an example, the APCC cited the accidental release of sulphur trioxide which occurred in February 1972.

The general question of hazard to neighbourhoods from the large scale use and storage of toxic flammable substances is discussed at length in the Report of the Committee on Safety and Health (chaired by Lord Robens and presented to the English Parliament in 1972)[27].

In the present study no direct attempt was made to ascertain the effect of, or potential for, an accidental emission of a toxic pollutant. However, it is evident from an examination of the data presented in this Report, that in the event of an accidental emission of a toxic pollutant occurring (without regard to the probability of such an occurrence), given the appropriate weather conditions, the CAPS area would be subject to "fallout".

The extent and effect of such fallout could only be determined if the amount and nature of the emission was known. In this context mathematical models, such as the one described in PART B of this section, could be used to predict ground level concentrations of an emission of toxic pollutant.

3.7.4.4 Aesthetic Considerations

In a community sense, Perth citizens are proud of and sensitive about the brilliance and clarity of our skies. Emissions from industry, both the visible plumes from the stacks and the general haze associated with the industrial processes cause deterioration in this characteristically Western Australian attraction.

Long lasting visible plumes from major industrial sources are caused by either or both, water droplets condensed around sulphur dioxide and sulphur trioxide nucleii and very finely divided solid particles which do not settle rapidly enough to be recorded by dust gauges. Very finely divided solid material, especially when strongly coloured or in a particular size range which has maximum optical effects, can produce very persistent trails.

Whether these persistent plumes are aesthetically objectionable is to some degree a matter for individual taste. However, in an area repeatedly subject to such intrusions they may arouse from residents adverse comment unrelated to health aspects.

3.7.4.5 Acid Smuts

The removal of soot from industrial chimneys by blowing steam through them is a potential source of acid smuts. Under suitable meteorological conditions these smuts could be carried into the CAPS area and would be expected to be a cause of complaint from residents.

PART B MATHEMATICAL MODELLING

3.8 The Model

A climatological mathematical dispersion model was chosen to determine and predict long term (seasonal or annual) pollutant concentrations at the seven, twenty-four hour sulphur dioxide monitoring sites (see Fig.3, sites 1 to 7) operated during CAPS by the Public Health Department. Validation of the model was possible by comparing the measured ground level concentrations of sulphur dioxide with those predicted by the model. Average emission rates from the point sources and a frequency distribution combining wind direction, wind speed and stability were the basic input to the model.

The atmospheric diffusion model used in this study was based on a model developed by Martin and Tickvart[28]. Basic output is in the form of a calculated long term average ground level pollutant concentration.

Pasquill diffusion equations[29] were used to calculate the downwind ground level concentrations from a set of point sources. Briggs' plume rise formula* was used to calculate the effective stack height (the height at which the plume centre line becomes horizontal).

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* The effective stack height (h_s) is the sum of the physical stack height and the plume rise. Plume rise is calculated using Briggs' plume rise formulae[30]:

$$\Delta h = 1.6F^{1/3}.u^{-1}.\ x^{2/3}$$

where : $F = 3.7.\ 10^{-5} Q_H$ (metre seconds)

Δh = plume rise

u = wind speed

X = downwind distance

Q_H = heat output of stack ($cal.sec^{-1}$)

Although change in wind direction is a continuous function over a long period, for computation purposes discrete wind directions of 45^{o} (corresponding to an eight-point compass) were used. Then, for seasonal or longer periods, all wind directions within a given 45^{o} sector are assumed to occur with equal frequency. Consequently air pollutants must be assumed to be uniformly distributed in the horizontal within the sector under consideration.

When a receptor is to one side of the receptor centre line the ground level concentration is composed of proportional contributions from both the sector containing the receptor and the nearest adjacent sector. The average ground level concentration at a receptor, due to all the sources is then given by a process of summation of the contributions of all the emission sources, taking into account the variability of the wind.

3.9 Data Input

3.9.1 Grid and Point Sources

Sources and receptors were located by X - Y coordinates referred to a rectangular grid having its origin at an arbitrary point approximately ten miles southwest of Rockingham.

3.9.2 Meteorological Parameters

Wind direction, speed and stability data were prepared in the form of a function which gave the joint frequency of occurrence of a wind direction sector k, with a wind speed class l and a stability index m.

3.9.2.1 Stability categories: Three stability categories, representing Turners classes B, C and D[31] were used. These were obtained from Pasquills categories[29] as shown below:

Pasquill	Turner	Model Category
1 2	B	1
3 4	C	2
5 6 7 8 9	D	3

3.9.2.2 Wind speed class: The representative wind speed for each class was taken as the mid-interval value for each of the six classes shown below:

Wind Speed Class	Speed Interval (m/sec)	Class Wind Speed (m/sec)
1	0 - 1.6	0.67
2	2.1 - 3.2	2.46
3	3.7 - 5.4	4.47
4	5.9 - 8.6	6.93
5	9.1 - 11.3	9.61
6	> 11.3	12.52

3.9.2.3 Dispersion Functions: An analytical approximation to the curves of Pasquill[29] and Gifford[32] for the vertical dispersion functions $\sigma_Z(\rho_n)$ was made using an empirical power law of the form:

$$\sigma_Z(\rho_n) = a.\rho_n^b$$

The variables a and b for the stability classifications were obtained from Turner's "Workbook of Atmospheric Dispersion Estimates"[31].

3.9.3 Emission Data

Average monthly and yearly emissions of sulphur dioxide were calculated from the hourly emission data available for each of the sources.

3.10 Limitations of the Model

3.10.1 The model used in this study was originally developed for point sources on a flat terrain and for distances of travel of no more than 10 kilometre. Hence, plume travel over distances greater than this cannot be accurately accounted for, especially in the case of rough terrain.

3.10.2 Only surface meteorological data was used for input to the model. Vertical wind and temperature soundings were not available.

3.10.3 Little is known about the mixing height over the coastal strip. Thus, the values used for mixing depth in the modelling are best available estimates only.

3.10.4 The sea breeze regime was difficult to model, due to the wide variation of vertical diffusion co-efficients from those predicted. Hence, in the case of the sea breeze the applied values could be significantly in error.

3.11 Results

Results of modelling are summarised in Figs. 54 to 61. Figs. 54 to 60 show the calculated and measured average monthly ground level concentrations of sulphur dioxide for the Public Health Department monitoring sites (Fig.3, sites 1 to 7) for the year March 1973 to February 1974. Fig.61 shows the calculated and measured annual mean ground level concentration and two predictions of future levels.

For the first prediction all major industries in the Kwinana and Coogee area are assumed to be using oil at 3.5% sulphur content, except the State Electricity Commission Kwinana power station which is rated at a generating capacity of 880 megawatts and using 2.5% sulphur oil.

The second prediction assumes the operation of a large iron and steel works in the Kwinana area, and all the major industries to be using oil at 3.5% sulphur content, except the SEC power station which is projected to 2000 megawatts using 2.5% sulphur oil.

3.11.1 "Freon" Release Tracer Experiment

As noted in Section 3.6.2 a tracer experiment was carried out as part of CAPS. This experiment was modelled using the dispersion parameters which were applied in the model discussed above.

At the time of the tracer experiment meteorological measurements were made of temperature and wind velocity to an altitude of 500 metre. Thus, in this case, data input for modelling was complete and predictions of ground level concentration profiles could be reliably prepared.

These theoretical "contours" are presented as an overlay to Fig.53.

3.12 Conclusions

Despite the limitations noted above, the model was developed to a degree where it was used to predict the effect of increased emissions of sulphur dioxide over the CAPS area. These predictions (see Fig.61) indicate that levels of sulphur dioxide could treble over the CAPS area in the future, given the assumptions made about fuel usage and industrial expansion (see 3.11).

The model would need to be further refined before it could be used to accurately predict short term and long term ground level concentrations under all seasonal conditions. The following conclusions are drawn in this context.

3.12.1 Results obtained from the model in its present stage of development indicate that it is unlikely that ground level concentrations can be modelled from emission data and surface meteorology on a short term basis. Vertical wind speed and temperature profiles are needed before this can reliably be attempted. In addition, a more detailed knowledge of the behaviour of the sea breeze is required as this represents a major proportion of the input to the model.

3.12.2 It is recognised that the stability classes used in the prototype model were over-simplified, and a more extensive classification is proposed.

3.12.3 45^{o} sectors, at first believed to simulate the variability of the local winds, are possibly too large for all wind conditions, and variable sector angles to suit different meteorological conditions are being considered.

3.12.4 In general, results predicted from the model will be low as the plume rise was calculated using surface wind data.

3.12.5 A more detailed knowledge of air movements in the region of Mt Brown is necessary to explain the consistently high readings of sulphur dioxide (greater than those predicted - especially from October to May) obtained at monitoring site 2 and to a lesser extent at monitoring site 7 (see Fig.3). Consideration of topography could also be important in this context as the model does not take this variable into account at the present time.

3.12.6 Even though the model is only at an early stage of development it has provided useful information about dispersion of pollutants in the Kwinana area. With further refinement and adequate input data it should prove an important tool in future air pollution management.

PART C CONCLUSIONS

3.13 The following conclusions, on which recommendations may be made, have been drawn from the study.

3.13.1 Atmospheric sulphur dioxide pollution has approached the figure for ground level concentrations recommended by the World Health Organisation as a long term goal and exceeded the United States EPA secondary standard at monitoring site 2 outside the CAPS area. The WHO criteria take into consideration both sulphur dioxide and smoke. Smoke levels measured during the study at site 2 are exceptionally low when compared to those experienced in the northern hemisphere.

All measurements at monitoring sites within the CAPS area have been well below these criteria.

3.13.2 Meteorological observations in the year of the study could not be classed as "average" and almost certainly do not represent an extreme potential for air pollution. It is thus considered possible that the WHO recommended levels for sulphur dioxide may be exceeded within an area south of an arc centred on the 180 m stack of the State Electricity Commission Kwinana power station (as a reference point) and passing through monitoring site 7, thus including the extreme southern part of the CAPS area.

3.13.3 Although computer modelling of the conditions prevailing in the area could not accurately predict ground level concentration of sulphur dioxide it does suggest that in the event of increases in power output using fuel oil, the conversion of all industries to fuel oil and the operation of a large iron and steel industry in Kwinana, ground level concentrations of sulphur dioxide can be expected to treble throughout the CAPS area.

The use of alternative fuels (such as natural gas and coal) which are under active consideration at the present time could lower this projected rise.

There is no evidence to suggest that sulphur dioxide pollution levels in the northern half of the area are likely to exceed the WHO recommended levels.

3.13.4 Sharp increases in ground level concentration with increasing altitude are predicted by all dispersion formulae. Measurements made during the study at monitoring sites 2 and 4 tend to support this theory.

3.13.5 The moderately dense vegetation surrounding stations 3 and 6 has apparently reduced the ground level concentration of sulphur dioxide below that which would be expected, and consequently levels could rise on clearing of vegetation for residential development.

3.13.6 Unpleasant odours from Kwinana industries and a nearby waste water treatment works are present in the area for some of the time. The offensiveness of the odours has been observed to persist over several hours.

3.13.7 There is a possibility of acid smuts being carried into the area from the burning of fuel oil.

3.13.8 Noise levels in the area do not appear to be higher than is general in residential areas.

3.13.9 Knowledge, expertise and techniques have been developed which will have wide-ranging applications for future air pollution studies. However, it has become apparent during the course of CAPS that future studies of this nature will require specific manpower, instrumentation and monetary budgets.

PAGE

4. TABLES AND FIGURES

4.1 Tables

4.2 Figures

TABLE 1 - Seven highest sulphur dioxide and associated smoke concentrations for each sulphur dioxide monitoring site (both values are in microgram per cubic metre).

MONITORING SITE 513			MONITORING SITE 1			MONITORING SITE 2		
Date	SO_2	Smoke	Date	SO_2	Smoke	Date	SO_2	Smoke
3.1.74	52	-	13.12.73	112	0	3.1.74	283	0
15.1.74	46	-	29.12.73	79	0	4.1.74	272	0
11.9.73	43	-	4.1.73	75	0	14.11.73	269	0
17.11.73	42	-	11.9.73	69	0	8.2.74	262	6
17.10.73	41	-	5.1.73	64	0	2.1.74	251	10
18.11.73	35	-	2.1.74	64	0	9.2.74	223	4
31.3.73	35	-	1.1.73	63	0	8.1.74	195	1
MONITORING SITE 3			MONITORING SITE 501			MONITORING SITE 7		
15.8.73	115	0	26.12.73	189	-	26.1.74	126	0
26.1.74	114	2	4.12.73	141	-	3.1.74	112	0
31.8.73	100	0	19.12.73	113	-	23.1.74	63	0
20.2.74	95	0	27.1.73	100	-	31.3.73	62	-
2.2.73	86	1	2.2.73	100	-	14.11.73	60	0
7.1.74	71	0	3.2.73	100	-	18.11.73	58	0
1.2.73	69	0	13.11.73	95	-	17.11.73	54	3

... Cont'd

TABLE 1 - (cont'd)

MONITORING SITE 4			MONITORING SITE 5			MONITORING SITE 6		
Date	SO_2	Smoke	Date	SO_2	Smoke	Date	SO_2	Smoke
31.3.73	111	1	31.3.73	62	-	24.1.73	61	-
3.1.74	58	2	14.11.73	60	0	25.1.73	36	-
14.11.73	54	0	26.1.73	44	1	31.1.73	31	0
18.1.74	51	0	11.1.73	36	0	4.1.73	29	0
30.11.73	48	1	10.1.73	34	1	27.1.73	22	0
17.10.73	47	0	14.2.74	34	0	26.1.73	21	-
29.12.73	45	0	6.4.73	32	0	12.10.73	21	0
MONITORING SITE 514			MONITORING SITE 515			MONITORING SITE 516		
15.1.74	81	-	17.1.74	57	-	6.1.74	67	-
11.1.74	77	-	12.12.73	52	-	16.1.74	64	-
31.12.73	76	-	6.1.74	38	-	24.12.73	57	-
26.1.74	72	-	16.1.74	37	-	31.12.73	55	-
23.1.74	69	-	21.3.73	36	-	22.12.73	53	-
21.1.74	46	-	30.7.73	35	-	4.1.74	53	-
5.1.74	46	-	24.12.73	35	-	28.3.73	52	-

TABLE 2 - Maximum recorded sulphur dioxide concentrations (microgram per cubic metre) January 1973 to February 1974.

Continuous Monitor	Half hour	Three hours	Twenty-four hours	One month	One Year March "73-February '74
701	1056 (5.10.73) 788 (23.12.73) 740 (5.1.74)	492 (5.10.73) 444 (5.1.74) 404 (9.12.73)	116 (5.10.73) 76 (5.1.74) 73 (18.1.74)	35 January 1974	22.8*
702	158 (19.3.73) 156 (7.3.73) 134 (4.3.73)	94 (8.3.73) 85 (4.3.73) 73 (7.3.73)	16 (17.10.73) 14 (4.3.73) 13 (8.3.73)	5 March 1973	1.2**

Twenty-four hour monitor	513	1	2	3	501	7	4	5	6	514	515	516
Twenty-four hours	52 3.1.74	112 13.12.73	283 3.1.74	115 15.8.73	189 26.12.73	126 26.1.74	111 31.3.73	62 31.3.73	61 24.1.73	81 15.1.74	57 17.1.74	67 6.1.74
One month	12 Jan'74	35 Dec '73	125 Jan'74	29 Jan'73	55 Dec '73	26 Jan '74	15 Dec '73	15 Feb '74	12 Jan '73	32 Jan '74	11 Jan '74	21 Jan '74
One Year (March '73 - Feb '74)	5.7	8.5	32.0	7.8	16.7	10.7	7.6	6.2	3.5	6.9	4.1	9.0

* Average taken for five months

** Average taken for eight months

TABLE 4

CERL DUST GAUGE - NAVAL BASE

	TOTAL DIRTINESS	PERCENTAGE Al_2O_3	PERCENTAGE Fe_2O_3
January 1973	4.3	43.4	-
February	4.2	17.8	-
March	6.9	-	-
April	-	-	-
May	-	-	-
June	3.5	36.5	7.1
July	1.1	3.6	1.7
August	2.5	1.7	2.5
September	1.3	13.8	5.6
October	-	-	-
November	3.2	35.0	4.0
December	2.1	32.3	5.2
January 1974	8.5	-	-
February	5.9	47.5	4.6

TABLE 5

CERL DUST GAUGE - MONITORING SITE NO.2

	TOTAL DIRTINESS	PERCENTAGE Al_2O_3	PERCENTAGE Fe_2O_3
January 1973	-	-	
February	-	-	
March	-	-	
April	-	-	
May	3.2	18.5	2.2
June	3.2	29.9	6.7
July	4.0	5.7	1.1
August	2.2	6.5	1.4
September	2.2	30.0	5.4
October	2.8	10.8	4.7
November	3.1	26.3	6.5
December	1.8	37.2	11.5
January 1974	9.3	7.8	13.5
February	3.9	30.2	13.4

TABLE 6

CERL DUST GAUGE - MONITORING SITE NO.4

	TOTAL DIRTINESS	PERCENTAGE Al_2O_3	PERCENTAGE Fe_2O_3
January 1973	-	-	-
February	-	-	-
March	-	-	-
April	-	-	-
May	2.6	13.3	5.1
June	1.3	24.2	4.4
July	1.8	2.5	1.7
August	0.5	0.8	1.1
September	1.5	3.0	2.5
October	2.5	5.0	3.8
November	1.6	9.3	13.3
December	0.9	4.5	8.9
January 1974	3.9	3.0	6.1
February	1.1	10.7	5.9

TABLE 7

CERL DUST GAUGE - MONITORING SITE NO.7

	TOTAL DIRTINESS	PERCENTAGE Al_2O_3	PERCENTAGE Fe_2O_3
January 1973	-	-	-
February	-	-	-
March	-	-	-
April	-	-	-
May	2.6	-	-
June	1.3	-	-
July	1.8	-	-
August	0.5	2.7	1.6
September	1.5	4.8	1.4
October	2.5	5.3	2.9
November	1.6	4.2	1.1
December	0.9	33.0	8.8
January 1974	3.9	6.7	14.3
February	1.1	19.8	9.2

TABLE 8

CERL DUST GAUGE - MONITORING SITE NO.701

	TOTAL DIRTINESS	PERCENTAGE Al_2O_3	PERCENTAGE Fe_2O_3
January 1973	-	-	-
February	-	-	-
March	-	-	-
April	-	-	-
May	-	-	-
June	1.2	32.1	6.5
July	1.4	4.1	2.4
August	1.1	2.6	4.2
September	1.2	5.8	3.4
October	3.6	5.8	4.9
November	1.9	12.7	6.2
December	1.6	12.8	9.0
January 1974	3.2	4.9	14.4
February	1.7	9.0	13.9

TABLE 9 - Vegetation Survey - Blackboy Tips (*Xanthorrea preissi*). Washed samples reported.

SITE NO.	SAMPLED FEBRUARY 1973			SAMPLED JUNE 1973		
	Chloride %	Sulphur %	Aluminium ppm	Chloride %	Sulphur %	Aluminium ppm
1	1.65	0.10	870	0.80	0.05	330
2	1.34	0.04	760	0.98	0.04	640
3	1.72	0.18	3,000	0.63	0.12	1,600
4	0.71	0.12	1,000	0.61	0.12	790
5	0.89	0.14	1,100	0.55	0.17	1,000
6	0.49	0.18	730	0.57	0.16	790
7	1.04	0.22	130	0.65	0.12	150
8	0.97	0.12	330	0.73	0.09	530
9	0.59	0.12	140	0.71	0.15	200
10	0.69	0.10	130	0.67	0.14	160
11	1.40	0.09	1,400	0.95	0.23	820
12	1.14	0.06	410	1.43	0.09	460
13	0.81	0.07	250	0.87	0.13	160
14	0.68	0.09	130	0.43	0.13	140
15	1.36	0.11	380	0.75	0.09	240
15A	1.08	0.15	560	0.35	0.11	550
16	0.85	0.15	290	0.75	0.14	460
17	1.16	0.15	250	0.89	0.16	220
18	0.51	0.05	90	0.71	0.13	170
19	0.43	0.19	120	0.73	0.24	220
20	0.93	0.09	130	0.61	0.08	80
	SAMPLED SEPTEMBER 1973			SAMPLED JANUARY 1974		
1	1.89	0.11	870	1.14	0.18	610
2	0.65	0.04	1,800	0.89	0.08	820
3	0.79	0.12	2,000	0.71	0.15	1,100
4	0.55	0.16	870	0.83	0.18	720
5	0.59	0.09	620	1.06	0.18	340
6	0.71	0.17	1,300	-	-	-
7	0.59	0.13	190	0.73	0.17	100
8	0.77	0.17	940	1.06	0.16	460
9	0,61	0.16	150	0.85	0.21	180
10	0.48	0.13	160	0.69	0.15	140
11	1.05	0.11	1,000	0.93	0.17	700
12	1.25	0.09	210	0.93	0.05	220
13	0.71	0.16	80	1.01	0.09	130
14	0.48	0.08	80	1.06	0.11	130
15	0.79	0.14	200	0.63	0.15	290
15A	1.35	0.04	250	0.97	0.13	160
16	0.91	0.14	240	1.14	0.16	380
17	1.25	0.12	280	0.87	0.15	210
18	0.87	0.09	150	0.89	0.16	160
19	0.67	0.22	180	0.83	0.18	120
20	0.81	0.05	70	0.86	0.06	60

TABLE 10 - Vegetation Survey - Narrow Leafed Banksia (*Banksia attenuata*). Washed samples reported.

SITE NO.	SAMPLED FEBRUARY 1973			SAMPLED JUNE 1973		
	Chloride %	Sulphur %	Aluminium ppm	Chloride %	Sulphur %	Aluminium ppm
1	0.43	0.06	2,300	0.37	0.07	1,100
2	0.58	0.03	2,500	0.39	0.08	2,100
3	0.71	0.13	4,200	0.71	0.10	1,800
4	0.41	0.27	1,300	0.24	0.16	1,300
5	0.73	0.14	1,200	0.26	0.07	2,400
6	0.26	0.09	4,000	0.33	0.06	1,800
7	0.45	0.21	710	0.45	0.14	770
8	0.77	0.12	330	0.67	0.08	1,700
9	0.57	0.15	200	0.37	0.11	990
10	0.35	0.27	360	0.41	0.15	390
11	0.75	0.07	1,600	0.39	0.15	1,200
12	0.51	0.03	240	0.61	0.05	1,200
13	0.57	0.05	140	0.35	0.09	160
14	0.53	0.21	1,600	0.49	0.17	1,200
15	-	-	-	-	-	-
15A	0.77	0.15	570	0.35	0.11	550
16	0.45	0.09	710	0.70	0.12	1,100
17	-	-	-	-	-	-
18	0.51	0.10	400	0.30	0.19	920
19	0.41	0.20	290	0.32	0.28	620
20	0.93	0.13	420	0.73	0.19	570
	SAMPLED SEPTEMBER 1973			SAMPLED JANUARY 1974		
1	0.28	0.07	1,100	0.63	0.06	1,100
2	0.28	0.12	3,900	0.32	0.11	3,000
3	0.67	0.11	2,600	0.51	0.20	3,000
4	0.16	0.20	1,900	0.18	0.17	1,500
5	0.22	0.07	5,100	0.20	0.23	680
6	0.48	0.14	5,300	0.88	0.18	3,300
7	0.28	0.13	990	0.59	0.11	670
8	0.30	0.20	1,500	0.67	0.24	800
9	0.24	0.17	920	-	-	-
10	0.10	0.18	410	0.34	0.19	420
11	0.46	0.04	4,400	0.49	0.23	2,700
12	0.40	0.06	1,000	0.41	0.08	790
13	0.20	0.12	270	0.36	0.15	210
14	0.38	0.13	2,400	0.81	0.14	1,800
15	-	-	-	-	-	-
15A	0.24	0.06	330	0.41	0.15	800
16	0.26	0.10	1,400	0.29	0.09	640
17	-	-	-	-	-	-
18	0.05	0.23	1,200	0.52	0.20	1,300
19	0.38	0.29	380	0.32	0.27	330
20	0.18	0.15	560	0.54	0.09	340

TABLE 11 - Average output of sulphur dioxide per day (tonnes) for each industry, for the study period and for each month of the study period (January 1973 to February 1974)

INDUSTRY	DAILY AVERAGE FOR STUDY PERIOD	DAILY AVERAGE OUTPUT OF SULPHUR DIOXIDE FOR EACH MONTH													
		JAN 1973	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN 1974	FEB
1	31.2	23.3	16.3	17.1	25.5	25.0	32.7	36.2	33.8	40.6	35.0	34.1	30.3	38.3	43.1
2	14.3	14.2	8.3	9.5	13.3	20.9	18.6	15.7	18.4	6.6	9.7	16.8	19.0	19.6	9.1
3	8.2	7.2	5.6	8.2	8.3	8.2	8.2	8.5	9.4	10.3	12.0	10.1	7.3	6.8	4.0
4	56.5	39.3	54.5	52.9	65.6	59.2	61.2	55.4	79.4	58.0	60.8	58.9	60.0	51.3	34.6
5	2.4	2.1	0.8	3.9	3.9	2.4	2.0	1.3	4.0	2.0	0.9	2.2	2.9	2.6	1.9
6	9.7	9.1	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
7	2.1	1.2	0.6	1.5	1.3	2.5	1.8	2.8	2.8	3.0	4.2	3.0	1.8	1.2	1.7
8	7.9	5.3	6.2	4.8	7.6	7.5	6.1	11.2	8.7	8.0	10.4	7.0	9.9	9.1	8.8

TABLE 12 : Monitoring Site 513 - Correlation of Ground Level Concentrations of Sulphur Dioxide and Wind Conditions

DATE	GLC*	SMOKE**	% DAILY WIND IN SECTOR 170	180	190	200	210	220	230	TOTAL % 170-230°	% CALM	HIGHEST % 0-360°	AVERAGE VELOCITY (m/sec)/MAJOR STABILITY 170	180	190	200	210	220	230
FIVE HIGHEST READINGS FOR STUDY PERIOD																			
3.1.74	52	-	2.1	18.7	8.3	6.2	18.7	6.2	-	60.2	-	180° 210° 18.7	5.0/4	6.9/3	8.5/4	9.3/4	12.1/4	10.3/4	-
15.1.74	46	-	2.1	2.1	10.4	8.3	22.9	14.6	-	60.4	-	140° 210° 22.9	6.0/4	5.0/3	6.6/4	9.3/4	10.7/4	8.4/4	-
11.9.73	43	-	2.1	4.2	4.2	2.1	-	-	-	12.6	-	180° 190° 4.2	7.0/4	7.5/4	8.0/4	8.0/4	-	-	-
17.11.73	42	-	4.2	8.3	10.4	-	2.1	22.9	12.5	60.4	-	220° 22.9	3.0/5	4.3/4	5.4/4	-	7.0/4	7.0/4	5.2/4
17.10.73	41	-	12.5	4.2	12.5	10.4	8.3	-	-	47.9	-	160° 27.1	4.5/6	5.5/6	8.0/4	8.8/9	9.0/6	-	-
HIGHEST READING FOR EACH MONTH																			
31.1.73	17	-	-	2.1	18.7	31.2	4.2	2.1	22.9	81.2	-	200° 31.2	-	3.0/3	4.2/5	4.7/4	7.5/4	8.0/4	8.7/4
5.2.73	22	-	4.2	2.1	18.7	8.3	8.3	4.2	31.2	77.0	-	230° 31.2	3.5/4	4.0/4	5.2/5	6.3/4	8.3/4	8.0/4	9.1/4
31.3.73	35	-	2.1	-	22.9	20.8	4.2	2.1	16.7	68.8	6.2	190° 22.9	1.0/5	-	3.4/4	3.8/4	4.5/4	4.0/4	4.8/4
5.4.73	24	-	2.1	-	8.3	31.2	2.1	4.2	12.5	60.4	-	200° 31.2	4.0/5	-	3.3/5	4.5/4	6.0/4	7.0/4	7.7/4
13.5.73	12	-	8.3	4.2	-	8.3	6.2	6.2	4.2	37.4	-	140° 16.7	3.0/5	3.0/4	-	5.0/3	5.0/3	5.7/2	7.5/4
Out of	Order														-				
15.7.73	12	-	-	-	-	-	2.1	2.1	-	4.2	6.2	40° 20.8	-	-	-	-	4.0/3	4.0/3	-
6.8.73	31	-	8.3	8.3	8.3	2.1	6.2	12.5	-	45.7	-	50° 16.7	4.0/5	5.0/3	5.3/4	4.0/3	5.3/3	6.8/4	-
11.9.73	43	-	2.1	4.2	4.2	2.1	-	-	-	12.6	-	180° 190° 4.2	7.0/4	7.5/4	8.0/4	8.0/4	-	-	-
17.10.73	41	-	12.5	4.2	12.5	10.4	8.3	-	-	47.9	-	160° 27.1	4.5/6	5.5/6	8.0/4	8.8/9	9.0/6	-	-
17.11.73	42	-	4.2	8.3	10.4	-	2.1	22.9	12.5	60.4	-	220° 22.9	3.0/5	4.3/4	5.4/4	-	7.0/4	7.0/4	5.2/4
14.12.73	32	-	2.1	4.2	8.3	2.1	10.4	6.2	12.5	45.8	-	240° 20.0	2.0/4	2.5/4	2.5/4	4.0/4	4.0/4	4.0/4	4.8/4
3.1.74	52	-	2.1	18.7	8.3	6.2	18.7	6.2	-	60.2	-	180° 210° 18.7	5.0/4	6.9/3	8.5/4	9.3	12.1/4	10.3/4	-
Out of	Order																		

* GLC - Ground level concentration of sulphur dioxide in microgram per cubic metre

** Smoke - microgram per cubic metre

TABLE 13 : Monitoring Site 1 - Correlation of Ground Level Concentrations of Sulphur Dioxide and Wind Conditions

DATE	GLC*	SMOKE**	% DAILY WIND IN SECTOR							TOTAL % 170-230°	% CALM	HIGHEST % 0-360°	AVERAGE VELOCITY (m/sec)/MAJOR STABILITY						
			170	180	190	200	210	220	230				170	180	190	200	210	220	230
FIVE HIGHEST READINGS FOR STUDY PERIOD																			
13.12.73	112	0	10.4	8.3	6.2	12.5	4.2	2.1	8.3	52.0	-	240° 22.9	3.4/4	4.5/9	5.0/4	4.7/6	7.0/6	7.0/9	6.0/6
29.12.73	79	0	2.1	22.9	10.4	4.2	8.3	16.7	20.8	85.4	-	180° 22.9	2.0/9	3.2/5	5.2/9	6.0/6	7.5/6	8.3/4	8.8/9
4.1.73	75	0	2.1	4.2	4.2	6.2	-	8.3	12.5	37.5	-	120° 130° 16.7	3.0/4	5.0/4	5.0/4	6.3/4	-	7.5/4	8.0/4
11.9.73	69	0	2.1	4.2	4.2	2.1	-	-	-	12.6	-	180° 4.2	7.0/4	7.5/4	8.0/4	8.0/4	-	-	-
2.1.74	64	0	4.2	16.7	22.9	8.3	6.2	29.2	-	87.5	-	220° 29.2	5.0/4	6.8/4	8.2/4	8.8/4	9.7/4	8.9/4	-
HIGHEST READING FOR EACH MONTH																			
4.1.73	75	0	2.1	4.2	4.2	6.2	-	8.3	12.5	37.5	-	120° 130° 16.7	3.0/4	5.0/4	5.0/4	6.3/4	-	7.5/4	8.0
Out of	Order																		
11.3.73	37	0	8.3	2.1	8.2	8.3	10.4	4.2	4.2	45.7	-	110° 140° 14.6	3.0/5	2.0/9	2.5/6	5.0/6	7.2/4	8.0/6	8.0/6
14.4.73	8	0	-	10.4	20.8	12.5	-	2.1	4.2	50.0	-	190° 20.8	-	3.2/4	3.8/4	4.2/4	-	5.0/4	5.0/4
8.5.73	6	-	-	-	-	-	-	-	-	0.0	-	270° 43.7	-	-	-	-	-	-	-
16.6.73	5	-	-	-	-	-	-	-	-	0.0	-	50° 30° 20.8	-	-	-	-	-	-	-
19.7.73	2	-	-	-	-	-	-	-	-	0.0	-	30° 25.0	-	-	-	-	-	-	-
28.8.73	35	6	6.2	4.2	4.2	-	2.1	2.1	8.3	27.11	2.1	160° 10.4	3.7/5	2.0/6	2.0/5	-	2.0/4	2.0/4	4.0/4
11.9.73	69	0	2.1	4.2	4.2	2.1	-	-	-	12.6	-	180° 4.2	7.0/4	7.5/4	8.0/4	8.0/4	-	-	-
3.10.73	26	0	2.1	33.3	10.4	18.7	6.2	4.2	8.3	83.2	-	180° 33.3	3.0/4	2.7/6	3.2/9	3.1/4	2.0/4	5.0/6	5.5/6
16.11.73	6	0	14.6	6.2	10.4	4.2	8.3	8.3	18.7	70.7	-	230° 18.7	3.3/5	3.3/5	3.8/4	5.5/4	5.5/4	5.8/4	7.0/4
13.12.73	112	0	10.4	8.3	6.2	12.5	4.2	2.1	8.3	52.0	-	240° 22.9	3.4/4	4.5/9	5.0/4	4.7/6	7.0/6	7.0/9	6.8/6
2.1.74	64	0	4.2	16.7	22.9	8.3	6.2	29.2	-	87.5	-	220° 29.2	5.0/4	16.8/4	8.2/4	8.8/4	9.7/4	8.9/4	-
9.2.74	19	0	12.5	25.0	4.2	2.1	4.2	29.2	10.4	87.6	-	220° 29.2	5.8/5	6.5/5	7.5/4	9.0/4	11.0/4	9.8/4	9.6/4

* GLC - Ground level concentration of sulphur dioxide in microgram per cubic metre

** Smoke - microgram per cubic metre

TABLE 14 : Monitoring Site 2 - Correlation of Ground Level Concentrations of Sulphur Dioxide and Wind Conditions

DATE	GLC*	SMOKE**	% DAILY WIND IN SECTOR							TOTAL % 170-230°	% CALM	HIGHEST % 0-360°	AVERAGE VELOCITY (m/sec)/MAJOR STABILITY						
			170	180	190	200	210	220	230				170	180	190	200	210	220	230
FIVE HIGHEST READINGS FOR STUDY PERIOD																			
3.1.74	283	0	2.1	18.7	8.3	6.2	18.7	6.2	-	60.2	-	180° 210° 18.7	5.0/4	6.9/3	8.5/4	9.3/4	12./4	10.3/4	-
4.1.74	272	0	8.3	4.2	8.3	6.2	14.6	4.2	2.1	47.9	-	120° 18.7	4.0/4	5.0/4	6.0/4	8.3/4	9.9/4	10.0/4	7.0/4
14.11.73	269	0	12.5	31.2	14.6	4.2	37.5	-	-	100.0	-	210° 37.5	4.3/4	5.2/4	6.9/4	9.0/4	11.0/4	-	-
8.2.74	262	6	2.1	-	14.6	4.2	27.1	33.3	2.1	83.4	-	220° 33.3	3.0/3	-	6.3/5	8.0/4	7.9/4	7.2/4	5.0/4
2.1.74	251	10	4.2	16.7	22.9	8.3	6.2	29.2	-	87.5	-	220° 29.2	5.0/4	6.8/4	8.2/4	8.8/4	9.7/4	8.9/4	-
HIGHEST READING FOR EACH MONTH																			
24.1.73	122	0	-	4.2	12.5	4.2	6.2	8.3	16.7	52.1	-	130° 18.7	-	4.0/4	4.5/4	7.0/4	8.7/4	10.5	9.0/4
Out of Order																			
26.3.73	37	0	-	4.2	6.2	6.2	4.2	12.5	4.2	37.5	-	130° 16.7	-	4.0/4	2.7/9	4.7/4	6.0/6	7.2/9	8.0/6
5.4.73	38	0	2.1	-	8.3	31.2	2.1	4.2	12.5	60.4	-	200° 13.2	4.0/5	-	3.3/5	4.5/4	6.0/4	7.0/4	7.7/4
25.5.73	23	0	4.2	-	-	-	4.2	2.1	-	10.5	-	130° 12.5	2.0/5	-	-	-	3.0/5	3.0/4	-
Out of Order																			
10.7.73	13	0	4.2	2.1	2.1	2.1	-	8.3	-	18.8	-	160° 22.9	3.0/5	5.0/5	5.0/5	6.0/4	-	5.8/4	-
Out of Order																			
20.9.73	9	4	-	-	16.7	4.2	2.1	4.2	14.6	41.8	20.8	230° 12.5	-	-	2.0/9	3.5/4	4.0/4	6.0/6	5.9/9
17.10.73	70	0	12.5	4.2	12.5	10.4	8.3	-	-	47.9	-	160° 27.1	4.5/6	5.5/6	8.0/4	8.8/9	9.0/6	-	-
14.11.73	269	0	12.5	31.2	14.6	4.2	37.5	-	-	100.0	-	210° 37.5	4.3/4	5.2/4	6.9/4	9.0/4	11.0/4	-	-
29.12.73	151	0	2.1	22.9	10.4	4.2	8.3	16.7	20.8	85.4	-	180° 22.9	2.0/9	3.2/5	5.2/9	6.0/6	7.5/6	8.3/4	8.8/9
3.1.74	283	0	2.1	18.7	8.3	6.2	18.7	6.2	-	60.2	-	180° 210° 18.7	5.0/4	6.9/3	8.5/4	9.3/4	12.1/4	10.3/4	-
8.2.74	262	6	2.1	-	14.6	4.2	27.1	33.3	2.1	83.4	-	220° 33.3	3.0/3	-	6.3/5	8.0/4	7.9/4	7.2/4	5.0/4

* GLC - Ground level concentration of sulphur dioxide in microgram per cubic metre

** Smoke - microgram per cubic metre

TABLE 15: Monitoring Site 3 - Correlation of Ground Level Concentrations of Sulphur Dioxide and Wind Conditions

DATE	GLC*	SMOKE**	% DAILY WIND IN SECTOR							TOTAL % 170–230°	% CALM	HIGHEST % 0–360°	AVERAGE VELOCITY (m/sec)/MAJOR STABILITY						
			170	180	190	200	210	220	230				170	180	190	200	210	220	230
FIVE HIGHEST READINGS FOR STUDY PERIOD																			
15.8.73	115	0	2.1	10.4	16.7	10.4	2.1	4.2	-	45.9	-	190° 16.7	4.0/5	5.6/5	7.5/4	8.2/4	11.0/4	11.0/4	-
26.1.74	114	2	-	12.5	20.8	8.3	29.2	29.2	-	100	-	210° 220° 29.2	-	5.3/4	6.4/4	8.5/4	9.9/4	10.4/4	-
31.8.73	100	0	2.1	12.5	2.1	-	10.4	14.6	10.4	52.1	-	240° 18.7	3.0/4	4.0/3	5.0/3	-	4.0/3	4.7/4	3.4/4
20.2.74	95	0	10.4	8.3	22.9	10.4	41.7			93.7	-	210° 41.7	3.8/5	4.3/5	7.3/5	9.0/4	10.4/4	-	-
2.2.73	86	1	-	4.2	2.1	2.1	-	-	56.2	64.6	-	230° 56.2	-/3	5.0/3	5.0/3	5.0/3	-	-	7.0/4
HIGHEST READING FOR EACH MONTH																			
31.1.73	66	0	-	2.1	18.7	31.2	4.2	2.1	22.9	81.2	-	200° 31.2	-	3.0/3	4.2/5	4.7/4	7.5/4	8.0/4	8.7/4
2.2.73	86	1	-	4.2	2.1	2.1	-	-	56.2	64.6	-	230° 56.2	-	5.0/3	5.0/3	5.0/3	-	-	7.0/4
18.3.73	64	0	-	-	-	-	-	-	-	0.0	-	120° 25.0	-	-	-	-	-	-	-
18.4.73	34	-	2.1	2.1	2.1	2.1	-	2.1	4.2	14.7	2.1	110° 16.7	2.0/3	2.0/3	2.0/3	2.0/3	-	2.0/4	4.0/4
26.5.73	10	1	2.1	6.2	-	-	2.1	-	4.2	14.6	-	40° 12.5	3.0/5	3.7/5	-	-	3.0/5	-	5.0/4
30.6.73	5	0	-	-	-	-	-	-	-	0.0	-	280° 37.5	-	-	-	-	-	-	-
15.7.73	1	2	-	-	-	-	2.1	2.1	-	4.2	6.2	40° 20.8	-	-	-	-	4.0/3	4.0/3	-
15.8.73	115	0	2.1	10.4	16.7	10.4	2.1	4.2	-	45.9	-	190° 16.7	4.0/5	5.6/5	7.5/4	8.2/4	11.0/4	11.0/4	-
3.9.73	46	0	10.4	14.6	4.2	8.3	6.2	12.5	-	56.2	-	180° 14.6	4.2/4	4.9/4	5.5/4	6.3/4	7.0/4	7.0/4	-
11.10.73	12	0	4.2	2.1	4.2	-	8.3	4.2	6.2	29.2	18.7	80° 14.6	2.5/4	3.0/4	2.0/4	-	4.0/4	4.0/4	3.7/4
30.11.73	25	2	31.2	16.7	12.5	2.1	16.7	20.0	-	100.0	-	170° 31.2	6.3/4	7.8/4	9.0/4	9.0/4	11.4/4	11.0/4	-
26.12.73	68	2	4.2	10.4	12.5	12.5	6.2	10.4	4.2	60.4	-	240° 29.2	1.5/9	2.6/9	2.2/6	3.5/4	6.3/9	8.2/4	9.0/6
26.1.74	114	2	-	12.5	20.8	8.3	29.2	29.2	-	100	-	210 220 29.2	-	5.3/4	6.4/4	8.5/5	9.9/4	10.4/4	-
20.2.74	95	0	10.4	8.3	22.9	10.4	41.3	-	-	93.7	-	210° 41.7	3.8/5	4.3/5	7.3/5	9.0/4	10.4/4	-	-

* GLC - Ground level concentration of sulphur dioxide in microgram per cubic metre

** Smoke - microgram per cubic metre

TABLE 16 : Monitoring Site 501 - Correlation of Ground Level Concentrations of Sulphur Dioxide and Wind Conditions

DATE	GLC*	SMOKE**	% DAILY WIND IN SECTOR							TOTAL % 170-230°	% CALM	HIGHEST % 0-360°	AVERAGE VELOCITY (m/sec)/MAJOR STABILITY						
			170	180	190	200	210	220	230				170	180	190	200	210	220	230
FIVE HIGHEST READINGS FOR STUDY PERIOD																			
26.12.73	189	-	4.2	10.4	12.5	12.5	6.2	10.4	4.2	60.4	-	240° 29.2	1.5/9	2.6/9	2.2/6	3.5/4	6.3/9	8.2/4	9.0/6
4.12.73	141	-	2.1	10.4	2.1	4.2	4.2	12.5	33.3	68.8	-	230° 33.3	1.0/5	3.2/4	5.0/4	3.5/4	6.0/4	6.3/4	8.1/4
19.12.73	113	-	6.2	12.5	18.7	6.2	8.3	16.7	2.1	70.7	-	240° 22.9	2.7/5	2.7/9	2.4/4	3.7/9	2.8/9	6.0/9	7.0/4
27.1.73	100	-	2.1	10.4	27.1	6.2	2.1	4.2	31.2	83.3	-	230° 31.2	5.0/4	5.0/4	5.2/4	8.3/4	10.0/4	9.5/4	9.0/4
2.2.73	100	-	-	4.2	2.1	2.1	-	-	56.2	64.6	-	230° 56.2	-	5.0/3	5.0/3	5.0/3	-	-	7.0/4
HIGHEST READING FOR EACH MONTH																			
27.1.73	100	-	2.1	10.4	27.1	6.2	2.1	4.2	31.2	83.3	-	230° 31.2	5.0/4	5.0/4	5.2/4	8.3/4	10.0/4	9.5/4	9.0/4
2.2.73	100	-	-	4.2	2.1	2.1	-	-	56.2	64.6	-	230° 56.2	-	5.0/3	5.0/3	5.0/3	-	-	7.0/4
15.3.73	82	-	6.2	14.6	20.8	16.7	14.6	8.3	4.2	85.4	-	190° 20.8	2.7/6	3.7/9	2.2/9	2.9/9	3.4/9	6.0/8	7.0/6
13.4.73	56	-	10.4	18.7	16.7	2.1	2.1	2.1	2.1	54.2	-	180° 240° 18.7	3.0/5	3.1/5	3.5/4	5.0/4	3.0/3	5.0/4	5.0/4
26.5.73	8	-	2.1	6.2	-	-	2.1	-	4.2	14.6	-	40° 12.5	3.0/5	3.7/5	-	-	3.0/5	-	5.0/4
23.6.73	18	-	4.2	-	4.2	4.2	10.4	12.5	16.7	52.2	-	230° 16.7	5.0/4	-	4.5/4	4.5/4	7.4/4	7.5/4	7.8/4
30.7.73	36	-	2.1	-	2.1	-	8.3	16.7	10.4	39.6	-	220° 16.7	7.0/4	-	7.0/4	-	8.0/4	9.4/4	11.0/4
31.8.73	39	-	2.1	12.5	2.1	-	10.4	14.6	10.4	52.1	-	240° 18.7	3.0/4	4.0/3	5.0/3	-	4.0/3	4.7/4	3.4/4
17.9.73	23	-	-	-	-	31.2	16.7	12.5	4.2	64.6	-	200° 31.2	-	-	-	6.4/4	6.5/6	6.3/6	8.0/6
27.10.73	59	-	-	-	-	-	-	39.6	4.2	43.8	-	220° 39.6	-	-	-	-	-	5.3/4	3.0/6
13.11.73	95	-	-	20.8	16.7	16.7	14.6	29.2	2.1	100.0	-	220° 29.2	-	7.6/4	9.3/4	10.9/4	11.0/4	11.1/4	12.0/4
26.12.73	189	-	4.2	10.4	12.5	12.5	6.2	10.4	4.2	60.4	-	240° 29.2	1.5/9	2.6/9	2.2/6	3.5/4	6.3/9	8.2/4	8.0/6
18.1.74	88	-	-	2.1	37.5	8.3	4.2	25.0	16.7	93.8	-	240° 29.2	-	4.0/3	5.3/4	7.5/4	8.0/4	8.0/4	7.4/4
22.2.74	61	-	8.3	6.2	2.1	2.1	-	35.4	-	54.1	-	220° 35.4	4.8/5	5.3/5	5.0/5	7.0/4	-	8.5/4	-

* GLC - Ground level concentration of sulphur dioxide in microgram per cubic metre

** Smoke - microgram per cubic metre

TABLE 17: Monitoring Site 7 - Correlation of Ground Level Concentrations of Sulphur Dioxide and Wind Conditions

DATE	GLC*	SMOKE**	% DAILY WIND IN SECTOR							TOTAL % 170-230°	% CALM	HIGHEST % 0-360°	AVERAGE VELOCITY (m/sec)/MAJOR STABILITY						
			170	180	190	200	210	220	230				170	180	190	200	210	220	230
FIVE HIGHEST READINGS FOR STUDY PERIOD																			
26.1.74	126	0	-	12.5	20.8	8.3	29.2	29.2	-	100.0	-	210° 220° 29.2	-	5.3/4	6.4/4	8.5/4	9.9/4	10.4/4	-
3.1.74	112	0	2.1	18.7	8.3	6.2	18.7	6.2	-	60.2	-	180° 210° 18.7	5.0/4	6.9/3	8.5/4	9.3/4	12.1/4	10.3/4	-
17.9.73	63	0	-	-	-	31.2	16.7	12.5	4.2	64.6	-	200° 31.2	-	-	-	6.4/4	6.5/6	6.3/6	8.0/6
23.1.74	63	0	2.1	8.3	18.7	6.2	2.1	35.4	8.3	72.8	-	220° 35.4	4.0/4	4.5/4	6.0/4	6.7/4	8.0/4	7.6/4	6.0/4
18.11.73	58	0	16.7	10.4	8.3	4.2	6.2	31.2	2.1	79.1	-	220° 31.2	3.4/5	4.4/5	6.8/4	7.5/4	7.7/4	7.1/4	7.0/4
HIGHEST READING FOR EACH MONTH***																			
15.7.73	8	2	-	-	-	-	2.1	2.1	-	4.2	6.2	40° 20.8	-	-	-	-	4.0/3	4.0/4	-
31.8.73	40	1	2.1	12.5	2.1	-	10.4	14.6	10.4	52.1	-	240° 18.7	3.0/4	4.0/3	5.0/3	-	4.0/3	4.7/4	3.4/4
17.9.73	63	0	-	-	-	31.2	16.7	12.5	4.2	64.6	-	200° 31.2	-	-	-	6.4/4	6.5/6	6.3/6	8.0/6
3.10.73	32	0	2.1	33.3	10.4	18.7	6.2	4.2	8.3	83.2	-	180° 33.3	3.0/4	2.7/6	3.2/9	3.1/4	2.0/4	5.0/6	5.5/6
18.11.73	58	0	16.7	10.4	8.3	4.2	6.2	31.2	2.1	79.1	-	220° 31.2	3.4/5	4.4/4	6.8/4	7.5/4	7.7/4	7.1/4	7.0/4
23/30.12.73	48	0	8.3	14.6	14.6	8.3	4.2	16.7	18.7	85.4	-	230° 18.7	3.8/9	3.1/4	3.6/9	5.0/6	8.0/6	9.8/6	9.4/4
26.1.74	126	0	-	12.5	20.8	8.3	29.2	29.2	-	100.0	-	210° 220° 29.2	-	5.3/4	6.4/4	8.5/4	9.9/4	10.4/4	-
2.2.74	36	0	18.7	6.2	6.2	4.2	6.2	8.3	2.1	51.9	2.1	170° 18.7	3.8/3	4.0/3	4.0/4	5.5/4	5.0/4	5.3/3	6.0/3

* GLC - Ground level concentration of sulphur dioxide in microgram per cubic metre

** Smoke - microgram per cubic metre

*** Monitoring Site 7 commenced operation in July 1973

TABLE 18: Monitoring Site 4 - Correlation of Ground Level Concentrations of Sulphur Dioxide and Wind Conditions

DATE	GLC*	SMOKE**	% DAILY WIND IN SECTOR							TOTAL % 170-230°	% CALM	HIGHEST % 0-360°	AVERAGE VELOCITY (m/sec)/MAJOR STABILITY						
			170	180	190	200	210	220	230				170	180	190	200	210	220	230
FIVE HIGHEST READINGS FOR STUDY PERIOD																			
31.3.73	111	1	2.1	2.1	2.1	33.3	6.2	2.1	12.5	60.4	6.2	200° 33.3	3.0/5	4.0/4	4.0/4	5.9/4	7.0/4	8.0/4	5.7/4
3.1.74	58	2	2.1	18.7	8.3	6.2	18.7	6.2	-	60.2	-	180° 210° 18.7	5.0/4	6.9/3	8.5/4	9.3/4	12.1/4	10.3/4	-
14.11.73	54	0	12.5	31.2	14.6	4.1	37.5	-	-	100.0	-	210° 37.5	4.3/4	5.2/4	6.9/4	9.0/4	11.0/4	-	-
18.1.74	51	0	-	2.1	37.5	8.3	4.2	25.0	16.7	93.8	-	190° 37.5	4.0/3	-	5.3/4	7.5/4	8.0/4	8.0/4	7.4/4
30.11.73	48	1	31.2	16.7	12.5	2.1	16.7	20.8	-	100.0	-	170° 31.2	6.3/4	7.8/4	9.0/4	9.0/4	11.4/4	11.0/4	-
HIGHEST READING FOR EACH MONTH																			
26.1.73	38	0	2.1	2.1	2.1	14.6	2.1	12.5	14.6	50.1	4.2	200° 230° 14.6	3.0/5	3.0/5	3.0/5	4.7/4	3.0/4	6.0/4	4.1/4
Out of	Order																		
31.3.73	111	1	2.1	2.1	2.1	33.3	6.2	2.1	12.5	60.4	6.2	200° 33.3	3.0/5	4.0/4	4.0/4	5.9/4	7.0/4	8.0/4	5.7/4
5.4.73	35	0	2.1	-	8.3	31.2	2.1	4.2	12.5	60.4	-	200° 31.2	4.0/5	-	3.3/5	4.5/5	6.0/4	7.0/4	7.7/4
13.5.73	4	0	8.3	4.2	-	8.3	6.2	6.2	4.2	37.4	-	140° 16.7	3.0/5	3.0/4	-	5.0/3	5.0/3	5.7/2	7.5/4
12.6.73	5	0	4.2	43.7	14.6	6.2	10.4	2.1	-	81.2	-	180° 43.7	5.0/4	5.7/4	6.7/4	7.0/4	7.4/4	6.0/3	-
10.7.73	3	0	4.2	2.1	2.1	2.1	-	8.3	-	18.8	-	160° 22.9	3.0/5	5.0/5	5.0/5	6.0/4	-	5.8/4	-
16.8.73	20	0	-	-	-	-	2.1	-	-	2.1	-	70° 31.2	-	-	-	-	2.0/2	-	-
29.9.73	28	0	8.3	8.3	16.7	14.6	12.5	-	-	60.4	29.2	90° 29.2	2.8/9	4.5/4	4.3/6	6.0/9	7.3/6	-	-
17.10.73	47	0	12.5	4.2	8.3	10.4	8.3	-	-	47.9	-	160° 27.1	4.5/6	5.5/6	8.0/4	8.8/9	9.0/6	-	-
14.11.73	54	0	12.5	31.2	14.6	4.2	37.5	-	-	100.0	-	210° 37.5	4.3/4	5.2/4	6.9/4	9.0/4	11.0/4	-	-
29.12.73	45	0	2.1	22.9	10.	4.2	8.3	16.7	20.8	85.4	-	180° 22.9	2.0/9	3.2/5	5.2/9	6.0/6	7.5/6	8.3/4	8.8/9
3.1.74	58	2	2.1	18.7	8.3	6.2	18.7	6.2	-	60.2	-	180° 210° 18.7	5.0/4	6.9/3	8.5/4	9.3/4	12.1/4	10.3/4	-
10.2.74	42	0	6.2	2.5	18.7	8.3	10.4	20.8	-	66.9	-	220° 20.8	4.0/5	6.7/5	8.3/4	9.0/4	9.8/4	9.6/4	-

* GLC - Ground level concentration of sulphur dioxide in microgram per cubic metre

** Smoke - microgram per cubic metre

TABLE 19 : Monitoring Site 5 - Correlation of Ground Level Concentrations of Sulphur Dioxide and Wind Conditions

DATE	GLC*	SMOKE**	% DAILY WIND IN SECTOR							TOTAL % 170–230°	% CALM	HIGHEST % 0–360°	AVERAGE VELOCITY (m/sec)/MAJOR STABILITY						
			170	180	190	200	210	220	230				170	180	190	200	210	220	230
FIVE HIGHEST READINGS FOR STUDY PERIOD																			
31.3.73	62	-	2.1	2.1	2.1	33.3	6.2	2.1	12.5	60.4	6.2	200° 33.3	3.0/5	4.0/4	4.0/4	5.9/4	7.0/4	8.0/4	5.7/4
14.11.73	60	0	12.5	31.2	14.6	4.2	37.5	-	-	100.0	-	210° 37.5	4.3/4	5.2/4	6.9/4	9.0/4	11.0/4	-	-
26.1.73	44	1	2.1	2.1	2.1	14.6	2.1	12.5	14.6	50.1	4.2	200° 230° 14.6	3.0/5	3.0/5	3.0/5	4.7/4	3.0/4	6.0/4	4.1/4
11.1.73	36	0	-	12.5	20.8	16.7	8.3	8.3	29.2	95.8	-	230° 29.2	-	3.7/4	5.0/4	6.0/4	8.5/4	11.5/4	8.9/4
10.1.73	34	1	-	-	33.3	14.6	8.3	2.1	20.8	79.1	-	190° 33.3	-	-	4.3/5	5.6/5	7.3/4	8.0/4	8.6/4
HIGHEST READING FOR EACH MONTH																			
26.1.73	44	1	2.1	2.1	2.1	14.6	2.1	12.5	14.5	50.1	4.2	200° 230° 14.6	3.0/5	3.0/5	3.0/5	4.7/4	3.0/4	6.0/4	4.1/4
Out of	Order																		
31.3.73	62	-	2.1	2.1	2.1	33.3	6.2	2.1	12.5	60.4	6.2	200° 33.3	3.0/5	4.0/4	4.0/4	5.9/4	7.0/4	8.0/4	5.7/4
6.4.73	32	0	12.5	6.2	6.2	2.1	2.1	6.2	4.2	39.5	-	240° 16.7	3.5/4	3.0/5	4.0/5	4.0/4	6.0/4	6.7/4	8.0/4
13.5.73	27	0	8.3	4.2	-	8.3	6.2	6.2	4.2	37.4	-	140° 16.7	3.0/5	3.0/4	-	5.0/3	5.0/3	5.7	7.5/4
Out of	Order																		
31.7.73	26	0	-	-	-	-	-	2.1	2.1	4.2	4.2	30° 25.0	-	-	-	-	-	2.0/3	2.0/3
Out of	Order																		
17.9.73	16	-	-	-	-	31.2	16.7	12.5	4.2	64.6	-	200° 31.2	-	-	-	6.4/4	6.5/6	6.3/6	8.0/6
23.10.73	7	0	-	-	-	-	-	-	-	0.0	2.1	260° 39.6	-	-	-	-	-	-	-
14.11.73	60	0	12.5	31.2	14.6	4.2	37.5	-	-	100.0	-	210° 37.5	4.3/4	5.2/4	6.9/4	9.0/4	11.0/4	-	-
Out of	Order																		
Out of	Order																		
14.2.74	34	0	2.1	2.1	4.2	8.3	18.7	50.0	-	85.4	-	220° 50.0	5.0/4	5.0/4	6.0/4	8.0/4	7.3/4	6.5/4	-

* GLC - Ground level concentration of sulphur dioxide in microgram per cubic metre

** Smoke - microgram per cubic metre

TABLE 20 : Monitoring Site 6 – Correlation of Ground Level Concentrations of Sulphur Dioxide and Wind Conditions

DATE	GLC*	SMOKE**	% DAILY WIND IN SECTOR							TOTAL % 170–230°	% CALM	HIGHEST % 0–360°	AVERAGE VELOCITY (m/sec)/MAJOR STABILITY						
			170	180	190	200	210	220	230				170	180	190	200	210	220	230
FIVE HIGHEST READINGS FOR STUDY PERIOD																			
24.1.73	61	–	–	4.2	12.5	4.2	6.2	8.3	16.7	51.9	–	130° 18.7	–	4.0/4	4.5/5	7.0/4	8.7/4	10.5/4	9.0/4
25.1.73	36	0	2.1	–	6.2	6.2	–	2.1	10.4	27.0	–	100° 20.8	3.0/4	–	4.7/4	6.7/4	–	8.0/4	7.6/4
31.1.73	31	0	–	2.1	18.7	31.2	4.2	2.1	22.9	81.2	–	200° 31.2	–	3.0/3	4.2/5	4.7/4	7.5/4	8.0/4	8.7/4
4.1.73	29	0	2.1	4.2	4.2	6.2	–	8.3	12.5	37.5	–	120° 130° 16.7	3.0/4	5.0/4	5.0/4	6.3/4	–	7.5/4	8.0/4
27.1.73	22	–	2.1	10.4	27.1	6.2	2.1	4.2	31.2	83.3	–	230° 31.2	5.0/4	5.0/4	5.2/4	8.3/4	10.0/4	9.5/4	9.0/4
HIGHEST READING FOR EACH MONTH																			
24.1.73	61	–	–	4.2	12.5	4.2	6.2	8.3	16.7	51.9	–	130° 18.7	–	4.0/4	4.5/5	7.0/4	8.7/4	10.5/4	9.0/4
Out of	Order																		
14.3.73	21	0	8.3	4.2	6.2	10.4	10.4	8.3	–	47.8	4.2	290° 20.8	3.0/6	3.0/6	3.3/9	4.4/4	6.2/9	6.3/6	–
23.4.73	16	0	–	–	–	–	–	–	–	0.0	–	300° 310° 25.0	–	–	–	–	–	–	–
6.5.73	10	–	2.1	8.3	2.1	10.4	–	8.3	14.6	45.8	–	100° 29.2	2.0/5	2.3/5	3.0/4	5.0/4	–	6.5/4	5.4/2
Out of	Order																		
2.7.73	4	–	–	–	–	–	–	–	–	0.0	8.3	110° 16.7	–	–	–	–	–	–	–
6.8.73	1	0	8.3	8.3	8.3	2.1	6.2	12.5	–	45.7	–	50° 16.7	4.0/5	5.0/3	5.3/4	4.0/3	5.3/3	6.8/4	–
29.9.73	13	0	8.3	2.1	10.4	10.4	25.0	–	–	56.2	–	90° 29.2	4.8/9	4.0/4	6.8/9	7.0/9	8.1/4	–	–
12.10.73	21	6	–	–	–	–	6.2	43.7	16.7	66.6	–	220° 43.7	–	–	–	–	3.3/4	4.1/4	4.0/4
28.11.73	12	3	6.2	20.8	27.1	–	25.0	20.8	–	99.9	–	190° 27.1	4.0/5	4.5/4	6.2/4	–	9.5/4	9.6/4	–
9(16,24).12.73	8	0	8.3	4.2	4.2	4.2	12.5	8.3	4.2	50.0	–	210° 240° 12.5	2.5/9	2.3/9	1.5/4	2.0/6	4.7/6	7.0/6	8.0/6
2.1.74	19	0	4.2	16.7	22.9	8.3	6.2	29.2	–	87.5	–	220° 29.2	5.0/4	6.8/4	8.2/4	8.3/4	9.7/4	8.9/4	–
23.2.74	16	0	8.3	2.1	4.2	–	2.1	14.6	2.1	33.4	–	80° 16.7	3.8/5	4.0/5	6.0/5	–	7.0/4	6.4/4	6.0/4

* GLC – Ground level concentration of sulphur dioxide in microgram per cubic metre

** Smoke – microgram per cubic metre

TABLE 21 : Monitoring Site 514 – Correlation of Ground Level Concentrations of Sulphur Dioxide and Wind Conditions

DATE	GLC*	SMOKE**	% DAILY WIND IN SECTOR 170	180	190	200	210	220	230	TOTAL % 170–230°	% CALM	HIGHEST % 0–360°
FIVE HIGHEST READINGS FOR STUDY PERIOD												
15.1.74	81	–	2.1	2.1	10.4	8.3	22.9	14.6	–	60.4	–	140° 210° 22.9
11.1.74	77	–	2.1	10.4	8.3	–	4.2	27.1	2.1	54.2	–	220° 27.1
31.12.73	76	–	–	4.2	8.3	2.1	10.4	2.1	6.2	33.3	–	100° 22.9
26.1.74	72	–	–	12.5	20.8	8.3	29.2	29.2	–	100.0	–	210° 220° 29.2
23.1.74	69	–	2.1	9.3	18.7	6.2	2.1	35.4	8.3	81.1	–	220° 35.4
HIGHEST READING FOR EACH MONTH												
31.1.73	17	–	–	2.1	18.7	31.2	4.2	2.1	22.9	58.3	–	200° 31.2
7.2.73	35	–	–	2.1	25.0	27.1	2.1	2.1	12.5	70.9	–	200° 27.1
1.3.73	27	–	–	8.3	4.2	4.2	6.2	10.4	16.7	50.0	–	130° 25.0
6.4.73	24	–	12.5	6.2	6.2	2.1	2.1	6.2	4.2	39.5	–	240° 16.7
13.5.73	12	–	8.3	4.2	–	8.3	6.2	6.2	4.2	37.4	–	140° 16.7
25.6.7	4	–	4.2	2.1	2.1	2.1	6.2	–	2.1	18.8	–	80° 18.7
11.7.73	8	–	–	–	–	–	–	–	–	0.0	–	40° 22.9
21.8.73	14	–	4.2	2.1	10.4	2.1	10.4	8.3	–	37.5	–	90° 160° 14.6
11.9.73	43	–	2.1	4.2	4.2	2.1	–	–	–	12.6	–	180° 190° 4.2
4.10.73	10	–	–	8.3	14.6	14.6	18.7	6.2	–	62.4	4.2	90° 31.2
28.11.73	34	–	6.2	20.8	27.1	–	25.0	20.8	–	99.9	–	190° 27.1
31.12.73	76	–	–	4.2	8.3	2.1	10.4	2.1	6.2	33.3	–	100° 22.9
15.1.74	81	–	2.1	2.1	10.4	8.3	22.9	14.6	–	60.4	–	140 210 22.9
Out of Order												

DATE	AVERAGE VELOCITY (m/sec)/MAJOR STABILITY 170	180	190	200	210	220	230
FIVE HIGHEST READINGS FOR STUDY PERIOD							
15.1.74	6.0/4	5.0/4	6.6/4	9.8/4	10.7/4	8.4/4	–
11.1.74	3.0/5	3.8/5	5.5/5	–	6.0/4	7.2/4	5.0/4
31.12.73	–	3.0/4	2.0/6	4.0/9	5.2/4	6.0/9	6.0/4
26.1.74	–	5.3/4	6.4/4	8.5/4	9.9/4	10.4/4	–
23.1.74	4.0/4	4.5/4	6.0/4	6.7/4	8.0/4	7.6/4	6.0/4
HIGHEST READING FOR EACH MONTH							
31.1.73	–	3.0/3	4.2/5	4.7/4	7.5/4	8.0/4	8.7/4
7.2.73	–	4.0/5	4.0/5	4.3/5	7.0/4	7.0/4	7.0/4
1.3.73	–	5.0/9	5.0/3	6.0/9	7.3/4	9.0/4	8.5/9
6.4.73	3.5/4	3.0/5	4.0/5	4.0/4	6.0/4	6.7/4	8.0/4
13.5.73	3.0/5	3.0/4	–	5.0/3	5.0/3	5.7/2	7.5/4
25.6.7	4.0/5	4.0/4	4.0/4	5.0/4	4.3/4	–	2.0/3
11.7.73	–	–	–	–	–	–	–
21.8.73	4.0/4	6.0/3	4.0/4	6.0/4	6.0/4	6.5/4	–
11.9.73	7.0/4	7.5	8.0/4	8.0/4	–	–	–
4.10.73	–	1.5/6	3.6/4	4.7/9	6.0/4	6.7/9	–
28.11.73	4.0/4	4.5/5	6.2/4	–	9.5/4	9.6/4	–
31.12.73	–	3.0/4	2.0/6	4.0/9	5.2/4	6.0/9	6.0/4
15.1.74	6.0/4	5.0/3	6.6/4	9.8/4	10.7/4	8.4/4	–
Out of Order							

* GLC – Ground level concentration of sulphur dioxide in microgram per cubic metre

** Smoke – microgram per cubic metre

TABLE 22 : Monitoring Site 515 - Correlation of Ground Level Concentrations of Sulphur Dioxide and Wind Conditions

DATE	GLC*	SMOKE**	% DAILY WIND IN SECTOR							TOTAL % 170-230°	% CALM	HIGHEST % 0-360°	AVERAGE VELOCITY (m/sec)/MAJOR STABILITY						
			170	180	190	200	210	220	230				170	180	190	200	210	220	230
FIVE HIGHEST READINGS FOR STUDY PERIOD																			
17.1.74	57	-	10.4	12.5	2.1	2.1	2.1	20.8	-	50.0	-	220° 20.8	4.0/4	4.2/4	5.0/4	5.0/4	5.0/4	6.0/4	-
12.12.73	52	-	10.4	2.1	2.1	6.2	-	4.2	12.5	37.5	-	250° 25.0	3.8/6	2.0/4	1.7/4	4.0/6	-	6.3/6	6.3/4
6.1.74	38	-	12.5	4.2	2.1	4.2	2.1	10.4	4.2	39.7	-	80° 22.9	3.7/4	5.5/4	6.0/4	6.0/4	6.0/4	6.4/4	5.0/4
16.1.74	37	-	-	-	-	-	-	-	-	0.0	-	120° 41.7	-	-	-	-	-	-	-
21.3.73	36	-	4.2	-	2.1	6.2	2.1	2.1	10.4	27.1	-	80° 29.2	2.0/6	-	3.0/9	4.3/4	6.0/9	6.0/4	6.0/6
HIGHEST READING FOR EACH MONTH																			
21.3.73	36	-	4.2	-	2.1	6.2	2.1	2.1	10.4	27.1	-	80° 29.2	2.0/6	-	3.0/9	4.3/4	6.0/9	6.0/4	6.0/6
5.4.73	19	-	2.1	-	8.3	31.2	2.1	4.2	12.5	60.4	-	200° 31.2	4.0/5	-	3.3/5	4.5/4	6.0/4	7.0/4	7.7/4
6.5.73	4	-	2.1	8.3	2.1	10.4	-	8.3	14.6	45.8	-	100° 29.2	2.0/5	2.3/5	3.0/4	5.0/4	-	6.5/4	5.4/2
24.6.73	1	-	12.5	18.7	-	-	-	-	-	31.2	-	110° 180° 18.7	5.5/4	5.8/4	-	-	-	-	-
30.7.73	35	-	2.1	-	2.1	-	8.3	16.7	10.4	39.6	-	220° 16.7	7.0/4	-	7.0/4	-	8.0/4	9.3/4	11.0/4
26.8.73	8	-	-	2.1	-	-	2.1	6.2	12.5	22.9	-	60° 22.9	-	3.0/4	-	-	4.0/4	4.7/4	4.7/4
28.9.73	5	-	4.2	6.2	2.1	2.1	2.1	-	2.3	19.0	-	310° 33.3	3.0/6	3.7/9	5.0/4	7.0/9	7.0/4	-	7.0/6
19.10.73	12	-	-	-	-	4.2	4.2	4.2	2.1	12.6	-	100° 22.9	-	-	-	4.0/6	5.0/6	5.0/9	5.0/4
17.11.73	23	-	4.2	8.3	10.4	-	2.1	22.9	12.5	60.4	-	220° 22.9	3.0/5	4.3/4	5.4/4	-	7.0/4	7.0/4	5.2/4
12.12.73	52	-	10.4	2.1	2.1	6.2	-	4.2	12.5	37.5	-	250° 25.0	3.8/6	2.0/4	1.7/4	4.0/6	-	6.3/6	6.3/4
17.1.74	57	-	10.4	12.5	2.1	2.1	2.1	20.8	-	50.0	-	220° 20.8	4.0/4	4.2/4	5.0/4	5.0/4	5.0/4	6.0/4	-
5.2.74	33	-	-	-	-	-	-	-	-	0.0	-	120° 62.5	-	-	-	-	-	-	-

* GLC - Ground level concentration of sulphur dioxide in microgram per cubic metre

** Smoke - microgram per cubic metre

TABLE 23 : Monitoring Site 516 - Correlation of Ground Level Concentrations of Sulphur Dioxide and Wind Conditions

DATE	GLC*	SMOKE**	% DAILY WIND IN SECTOR							TOTAL % 170-230°	% CALM	HIGHEST % 0-360°	AVERAGE VELOCITY (m/sec)/MAJOR STABILITY						
			170	180	190	200	210	220	230				170	180	190	200	210	220	230
FIVE HIGHEST READINGS FOR STUDY PERIOD																			
6.1.74	67	-	12.5	4.2	2.1	4.2	2.1	10.4	4.2	39.7	-	80° 22.9	3.7/4	5.5/4	6.0/4	6.0/4	6.0/4	6.4/4	5.0/4
16.1.74	64	-	-	-	-	-	-	-	-	0.0	-	120° 41.7	-	-	-	-	-	-	-
24.12.73	57	-	-	4.2	-	2.1	6.2	8.3	4.2	25.0	-	100° 29.2	-	3.0/5	-	3.0/9	5.0/6	6.5/6	7.0/6
31.12.73	55	-	-	4.2	8.3	2.1	10.4	2.1	6.2	33.3	-	100° 22.9	-	3.0/4	2.0/6	4.0/9	5.2/6	6.0/9	6.0/6
22.12.73	53	-	4.2	12.5	4.2	20.8	18.7	4.2	8.3	72.9	-	200° 20.8	3.0/6	3.2/6	2.0/6	2.5/9	4.1/4	6.0/6	4.5/9
HIGHEST READING FOR EACH MONTH																			
28.3.73	52	-	2.1	2.1	-	-	-	-	-	4.2	-	110° 31.2	2.0/5	1.0/5	-	-	-	-	-
5.4.73	20	-	2.1	-	8.3	31.2	2.1	4.2	12.5	60.4	-	200° 31.2	4.0/5	-	3.3/5	4.5/4	6.0/4	7.0/4	7.7/4
13.5.73	4	-	8.3	4.2	-	8.3	6.2	6.2	4.2	37.4	-	140° 16.7	3.0/5	3.0/4	-	5.0/3	5.0/3	5.7/2	7.5/4
12.6.73	3	-	4.2	43.7	14.6	6.2	10.4	2.1	2.1	83.3	-	180° 43.7	5.0/4	5.7/4	6.7/4	7.0/4	7.4/4	6.0/3	7.0/4
5.7.73	2	-	-	-	-	-	-	-	-	0.0	8.3	40° 27.1	-	-	-	-	-	-	-
15.8.73	15	-	2.1	10.4	16.7	10.4	2.1	4.2	-	45.9	-	190° 16.7	4.0/5	5.6/5	7.5/4	8.2/4	11.0/4	11.0/4	-
11.9.73	12	-	2.1	4.2	4.2	2.1	-	-	-	12.6	-	180° 190° 4.2	7.0/4	7.5/4	8.0/4	8.0/4	-	-	-
19.10.73	29	-	-	-	-	4.2	4.2	2.1	2.1	12.6	-	100° 29.2	-	-	-	4.0/6	5.0/6	5.0/9	5.0/4
17.11.73	41	-	4.2	8.3	10.4	-	2.1	22.9	12.5	60.4	-	220° 22.9	3.0/5	4.3/4	5.4/4	-	7.0/4	7.0/4	5.2/4
24.12.73	57	-	-	4.2	-	2.1	6.2	8.2	4.2	25.0	-	100° 29.2	-	3.0/5	-	3.0/9	5.0/6	6.5/6	7.0/6
6.1.74	67	-	12.5	4.2	2.1	4.2	2.1	10.4	4.2	39.7	-	80° 22.9	3.7/4	5.5/4	6.0/4	6.0/4	6.0/4	6.4/4	5.0/4
17.2.74	45	-	-	-	-	-	-	-	-	0.0	-	110° 35.4	-	-	-	-	-	-	-

* GLC - Ground level concentration of sulphur dioxide in microgram per cubic metre

** Smoke - microgram per cubic metre

TABLE 24 - Annual mean sulphur dioxide concentration and average percentage of sulphur measured in Blackboy tips (*Xanthorrea preissii*) at sulphur dioxide monitoring sites

MONITORING SITE	ANNUAL MEAN SO_2 (microgram per cubic metre)	AVERAGE SULPHUR %
513	5.7	0.11
1	8.5	0.05
2	32.0	0.14
3	7.8	0.145
501	16.7	0.145
7	10.7	0.15
4	7.6	0.07
5	6.2	0.11
6	3.5	0.10
514	6.9	0.10
516	9.0	0.11

TABLE 25 - Health standards and criteria for sulphur dioxide. Figures are given in microgram per cubic metre (*parts per hundred million*).

SOURCE	SHORT TERM	THREE HOUR	TWENTY-FOUR HOUR	ONE MONTH	ANNUAL
World Health Organisation[2]					60 (*2*)
United States Environmental Protection Agency[1]		1300 (*50*)	365 (*14*) 260 (*10*)		80 (*3*) 60 (*2*)
Sweden[24]	650 (*25*)		260 (*10*)	130 (*15*)	
Union of Soviet Socialist Republics (USSR)[23]	500 (*18.7*)		150 (*5.6*)		
Japan[25]	267 (*10*)		107 (*4*)		

FIG 1 : Coogee Air Pollution Study – Location

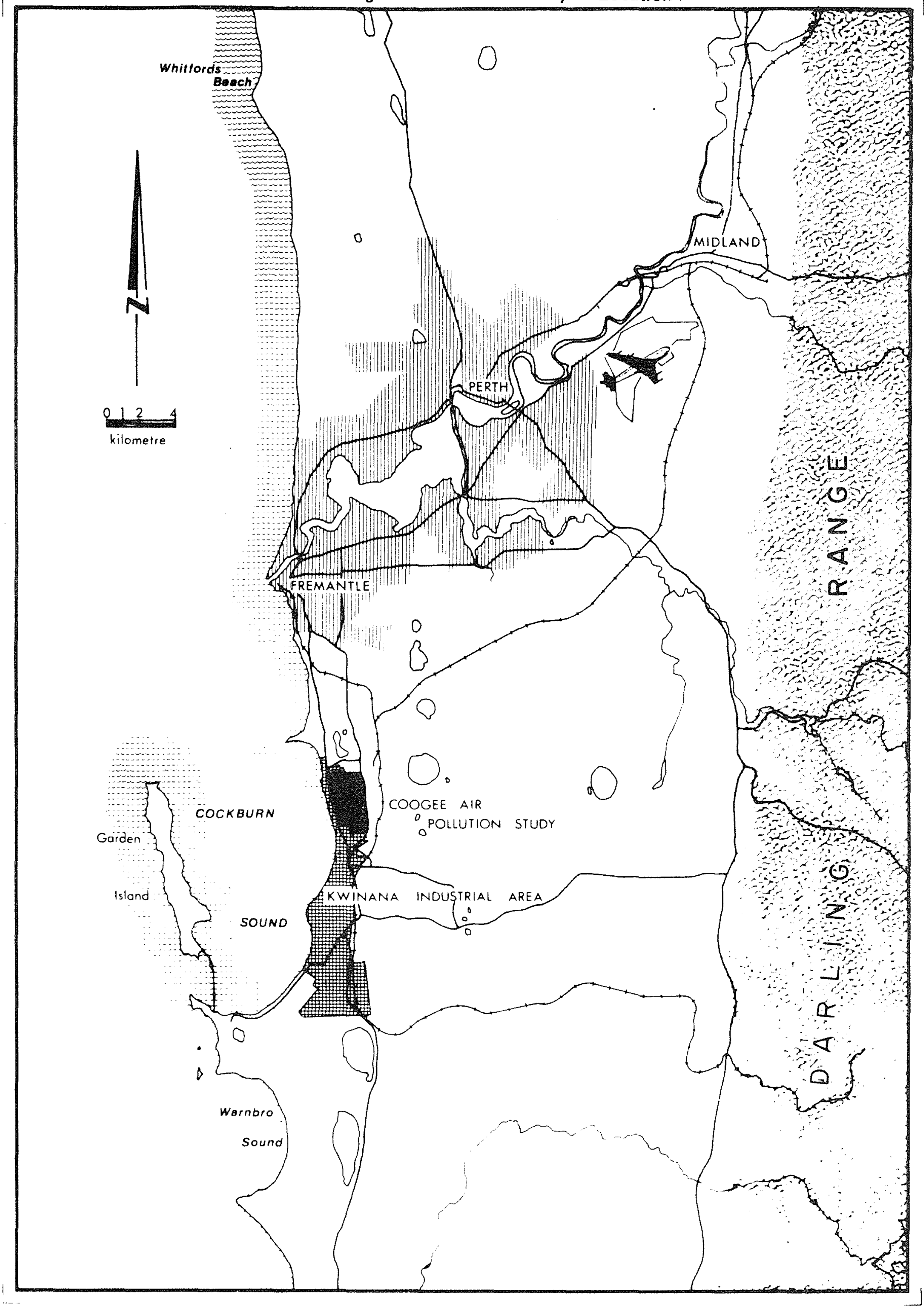


FIG 2 : Coogee Air Pollution Study — Relationship to Industrial Area

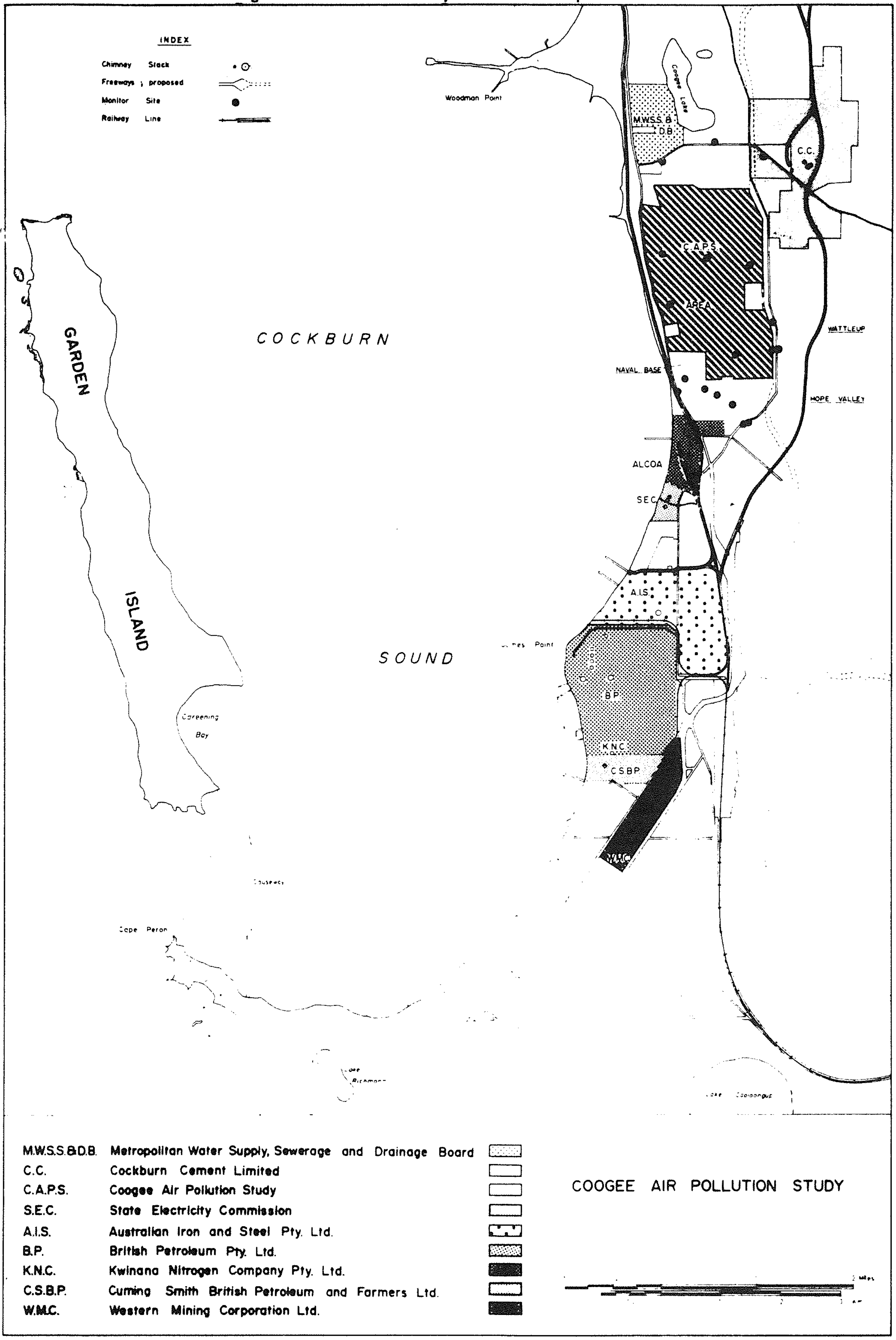


FIG 3: Coogee Air Pollution Study – Topography and Monitoring Sites

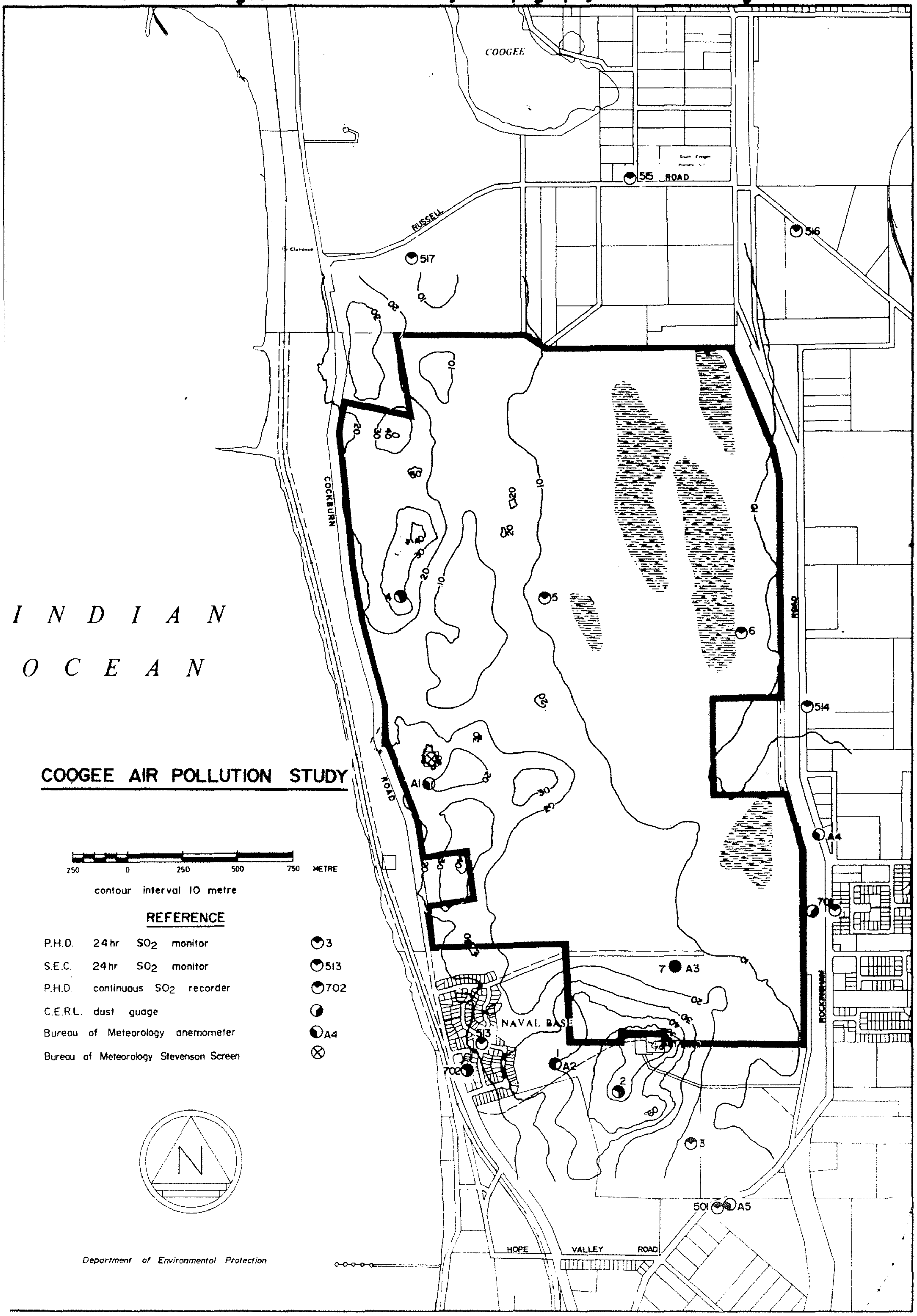
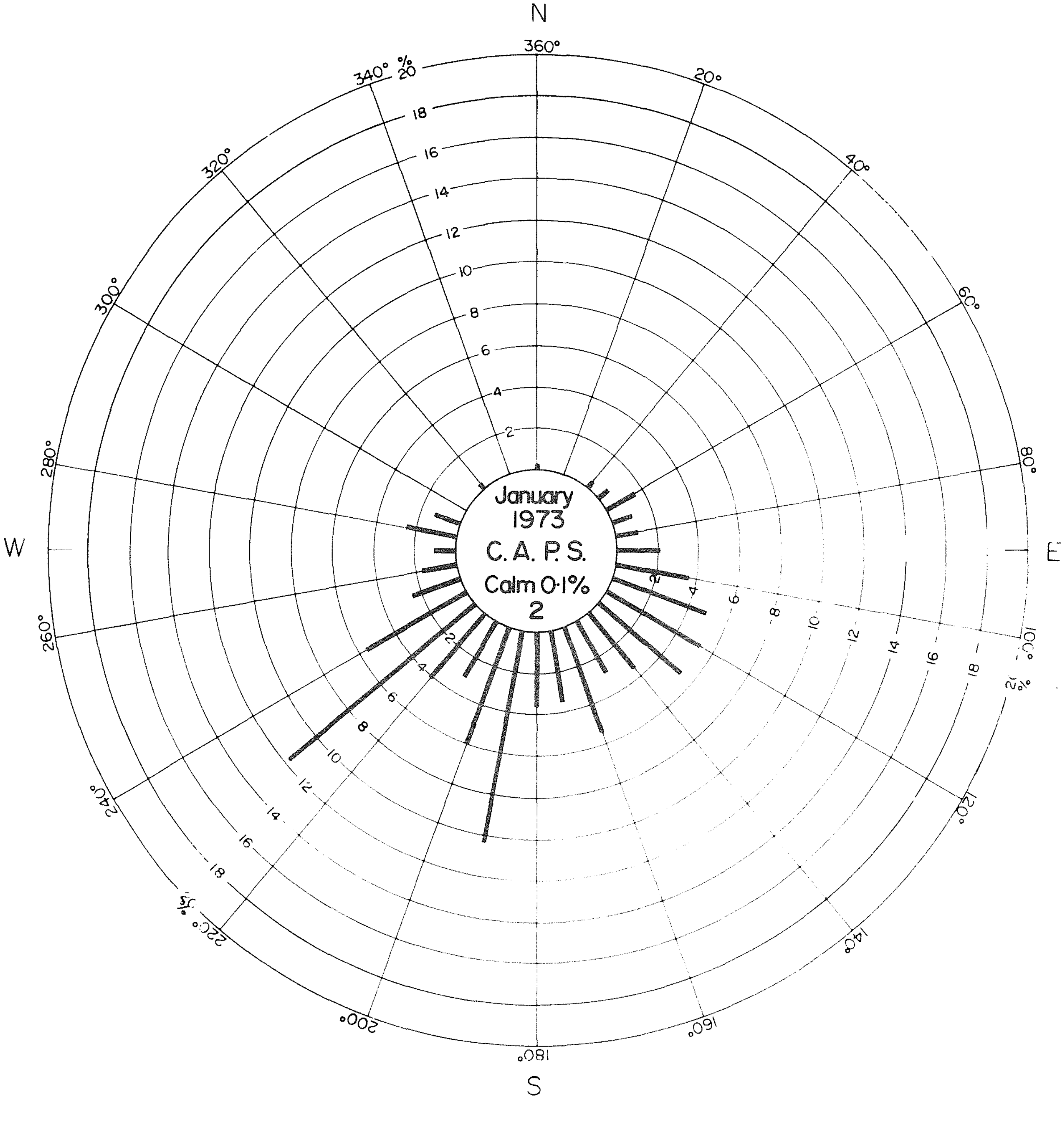
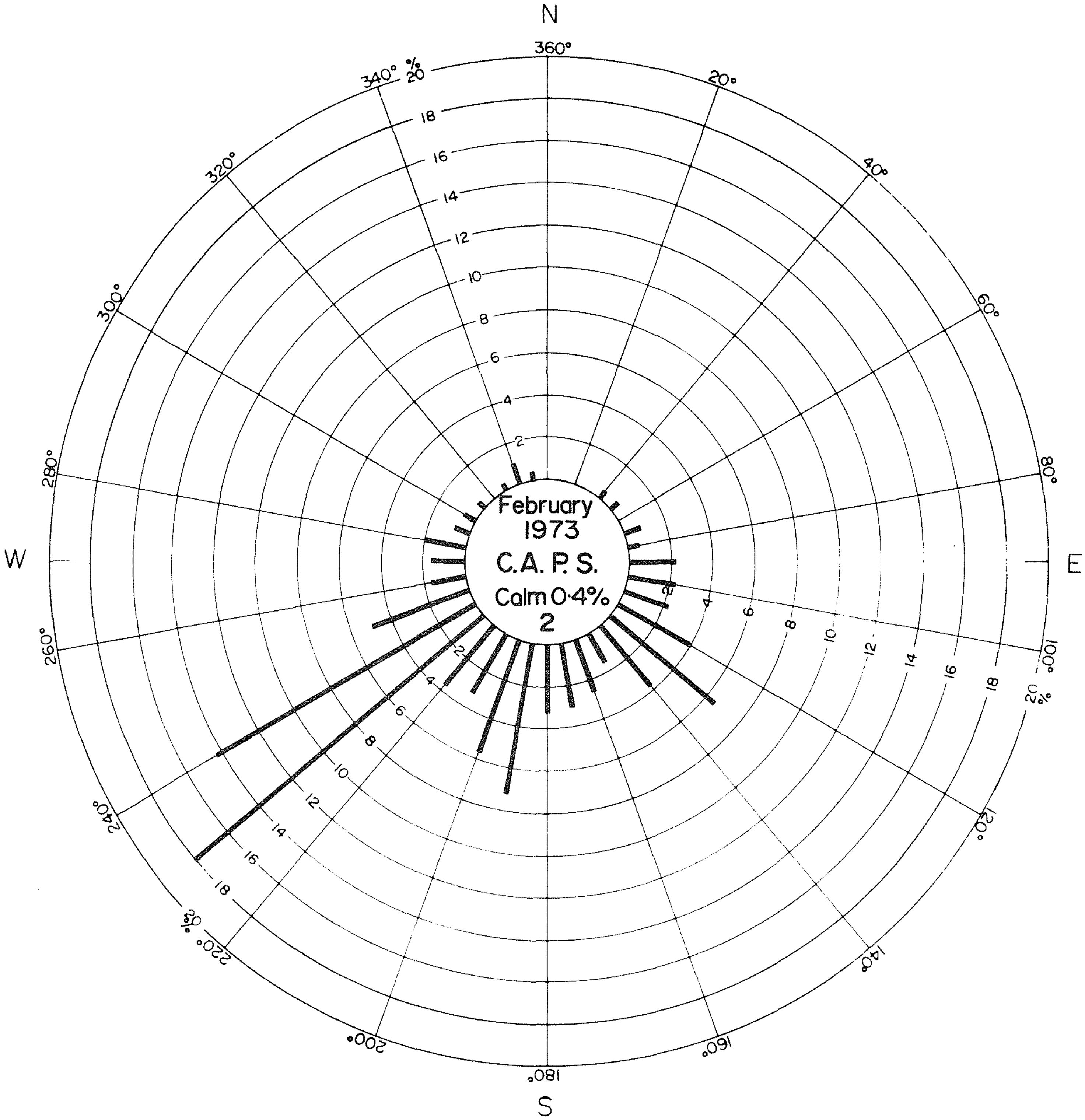


FIG 4: Wind Rose - January 1973



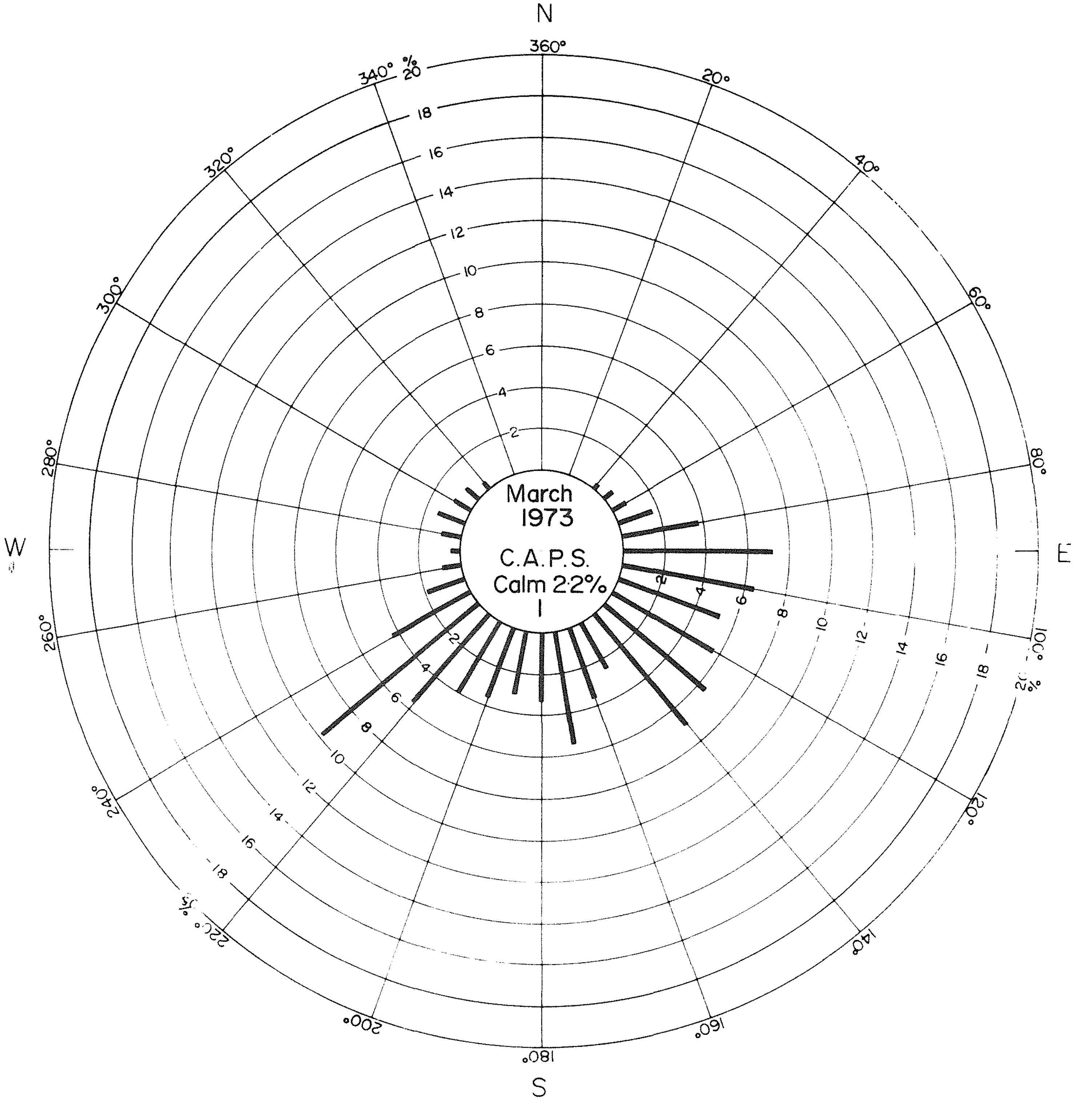
The length of the bars shows the percentage of the whole month during which the wind blew from the indicated direction

FIG 5: Wind Rose - February 1973



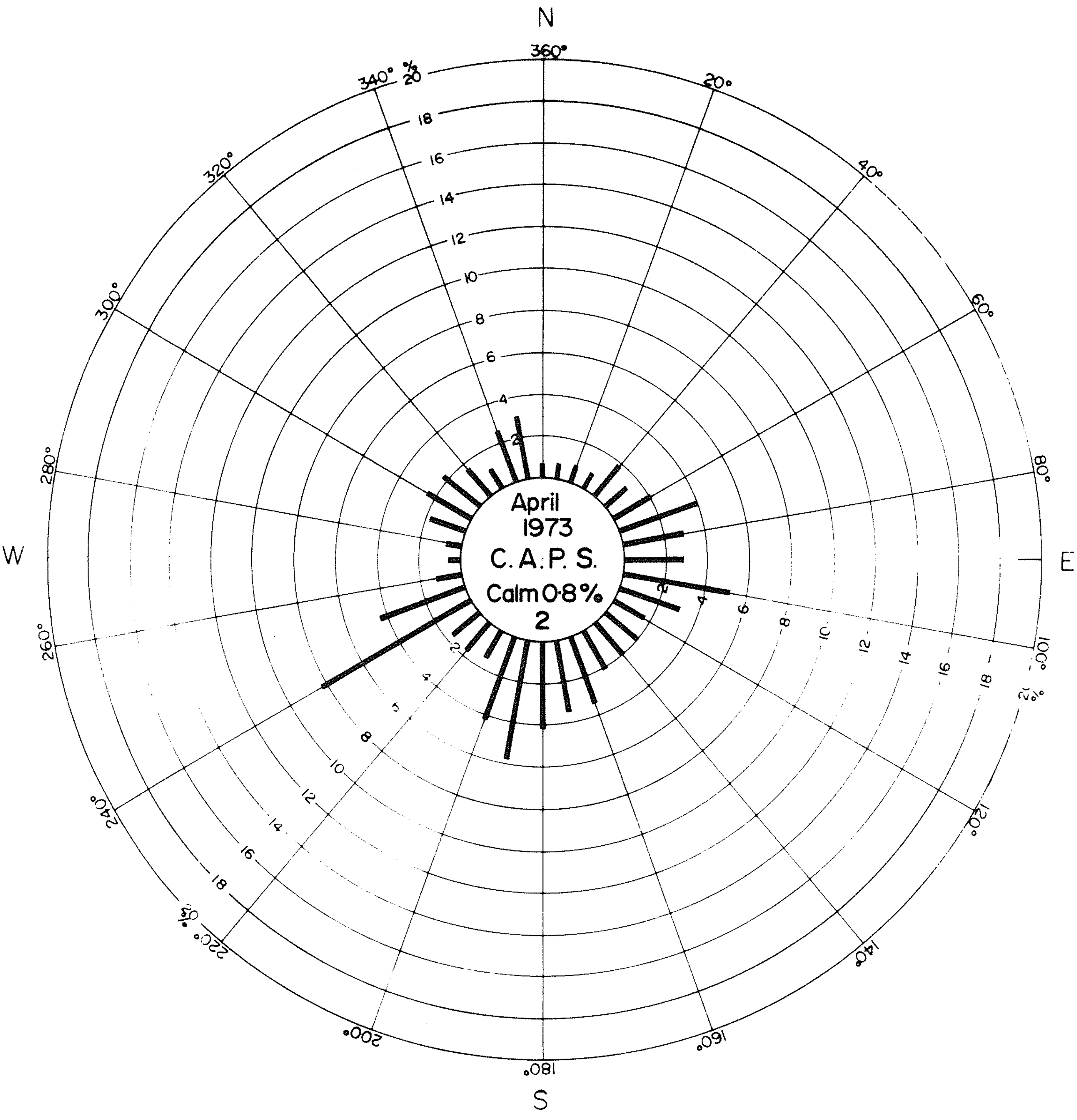
The length of the bars shows the percentage of the whole month during which the wind blew from the indicated direction

FIG 6: Wind Rose - March 1973



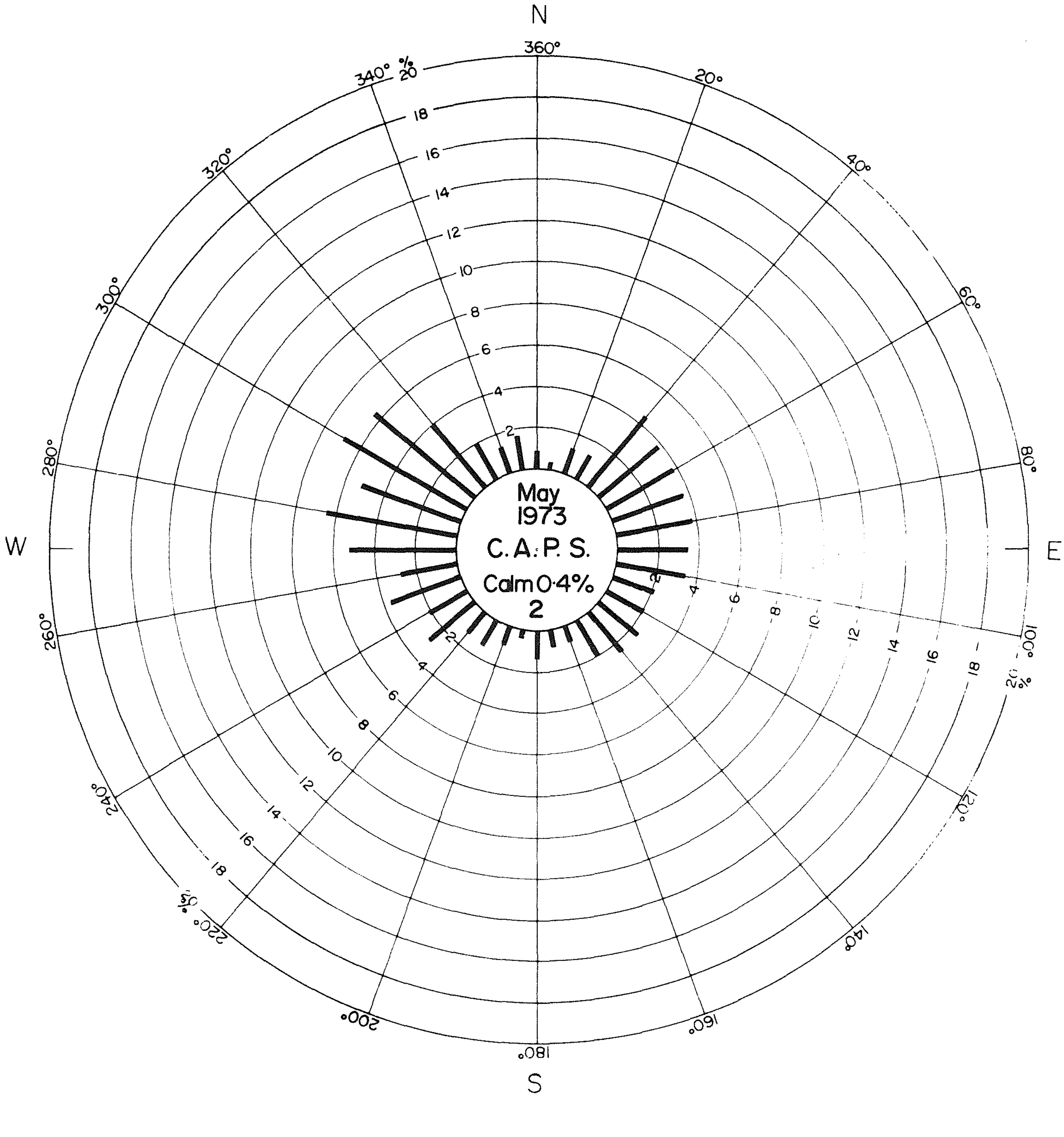
The length of the bars shows the percentage of the whole month during which the wind blew from the indicated direction

FIG 7: Wind Rose - April 1973



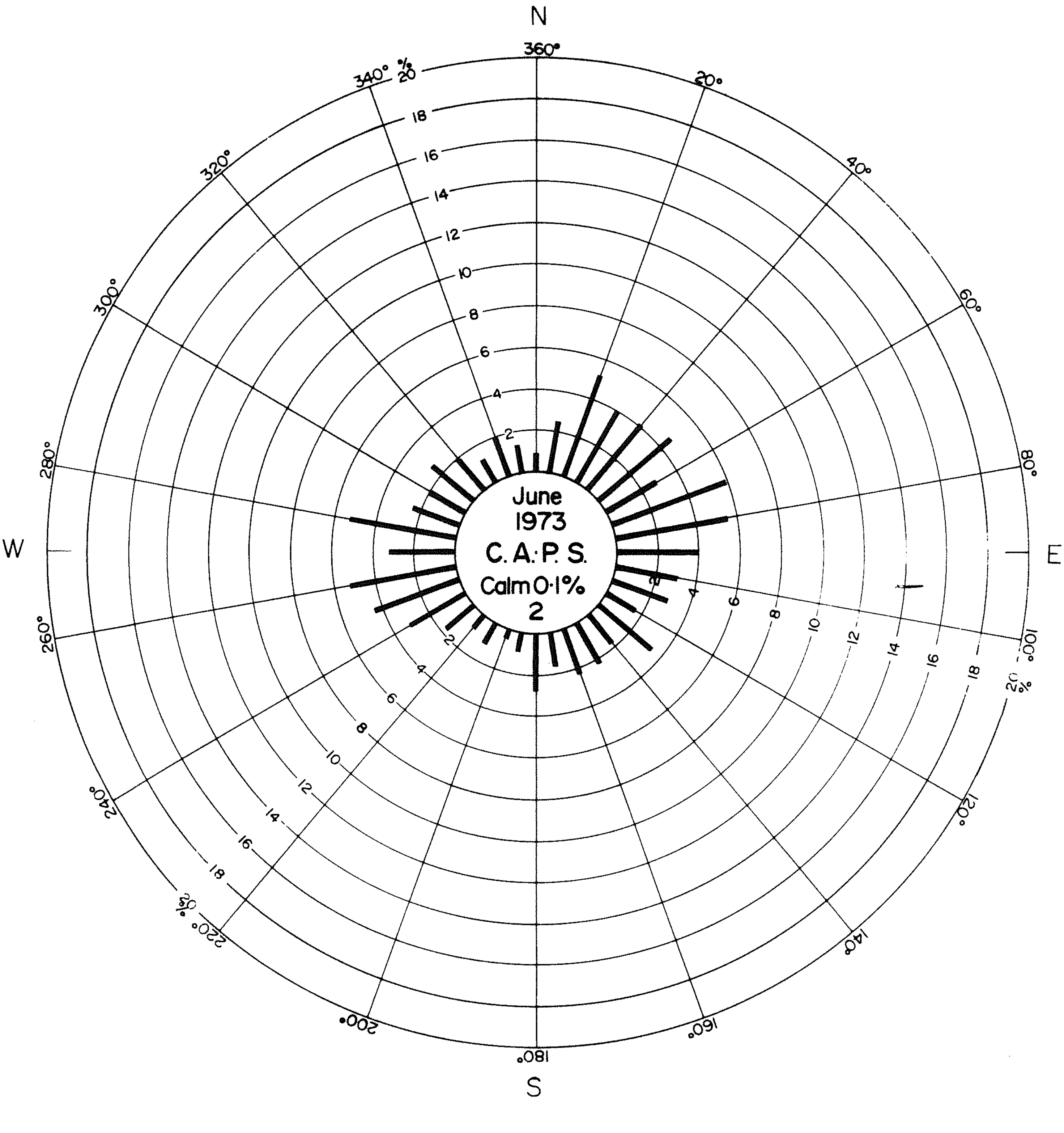
The length of the bars shows the percentage of the whole month during which the wind blew from the indicated direction

FIG 8: Wind Rose - May 1973



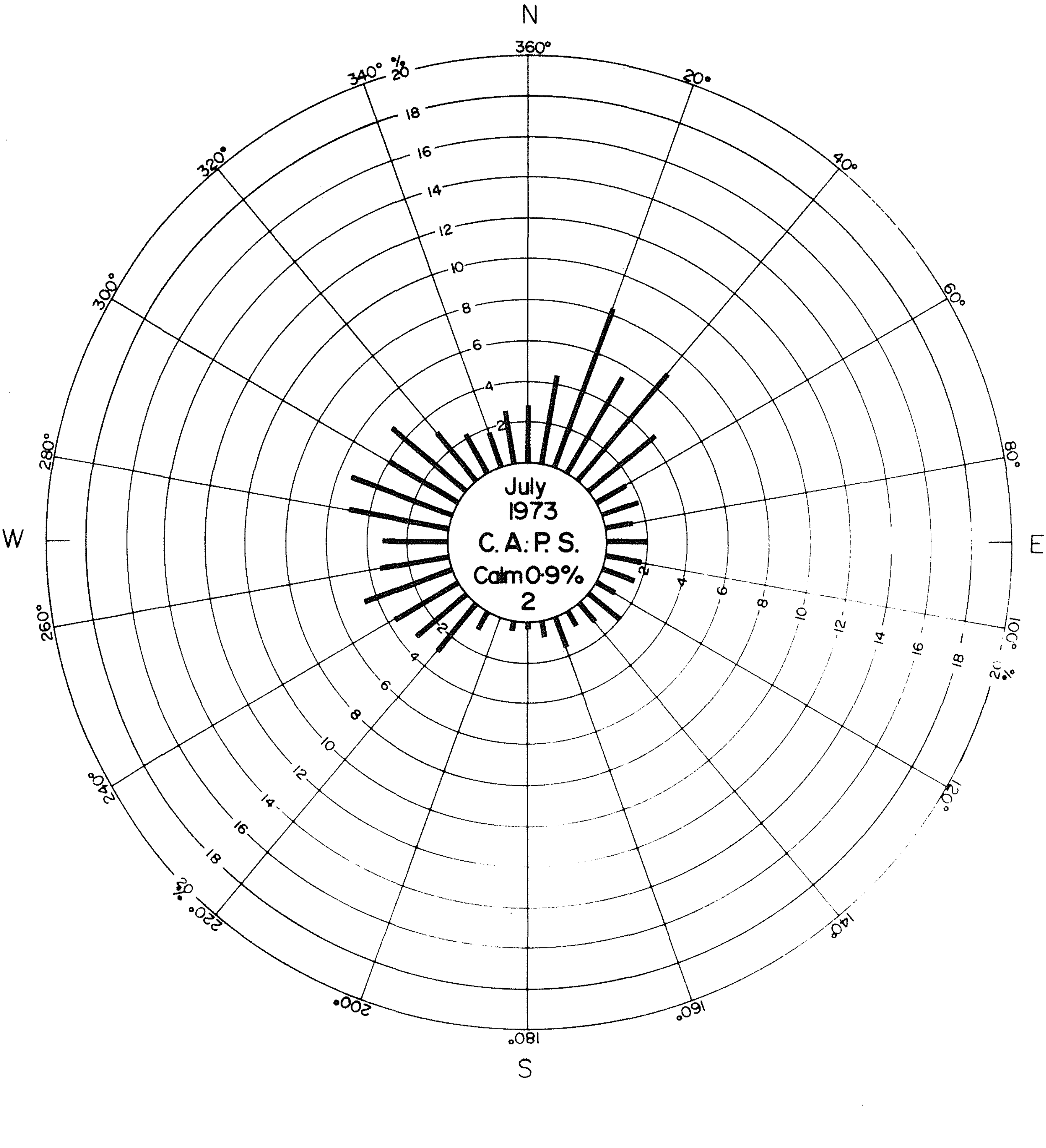
The length of the bars shows the percentage of the whole month during which the wind blew from the indicated direction

FIG 9: Wind Rose - June 1973



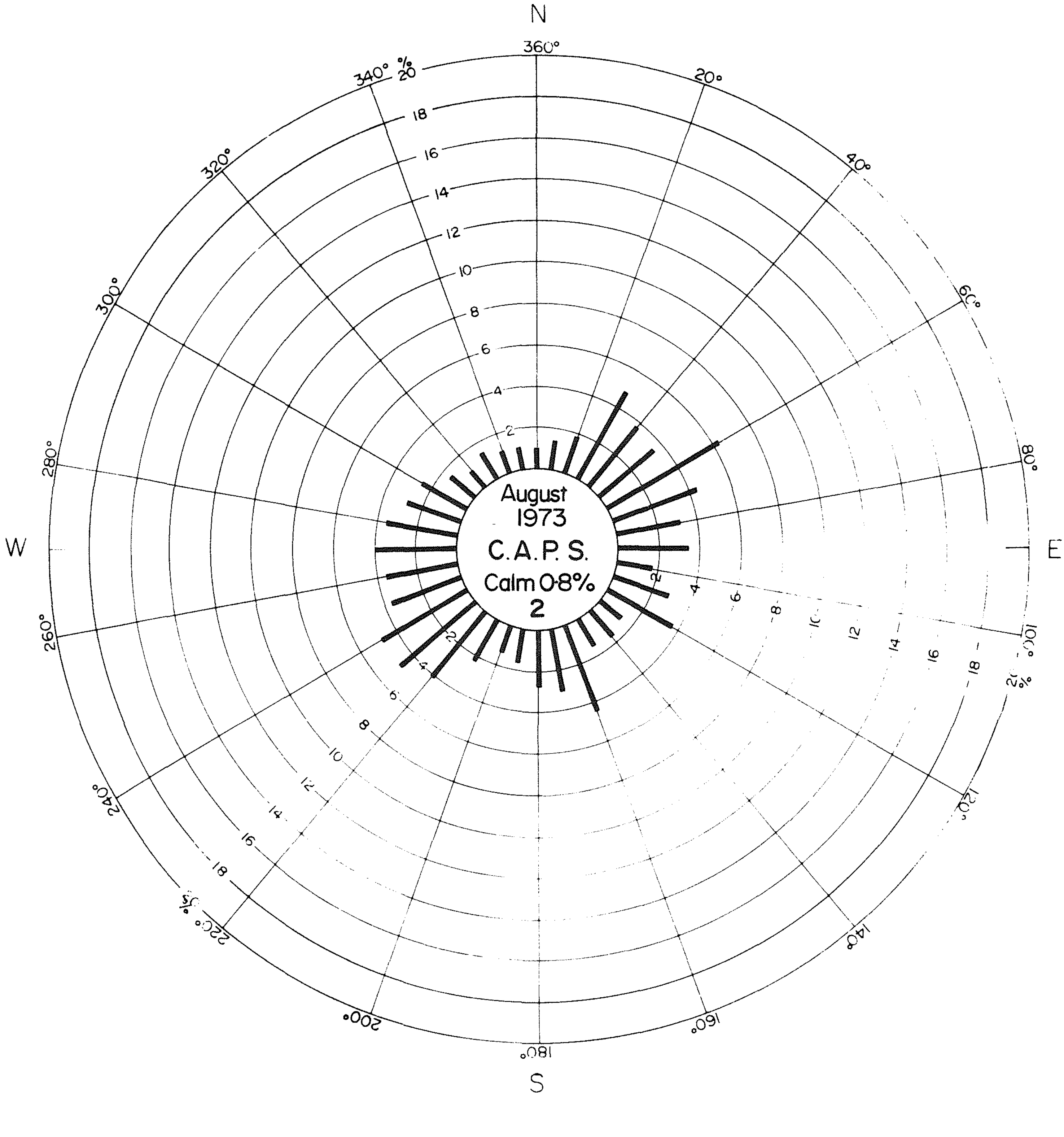
The length of the bars shows the percentage of the whole month during which the wind blew from the indicated direction

FIG 10: Wind Rose - July 1973



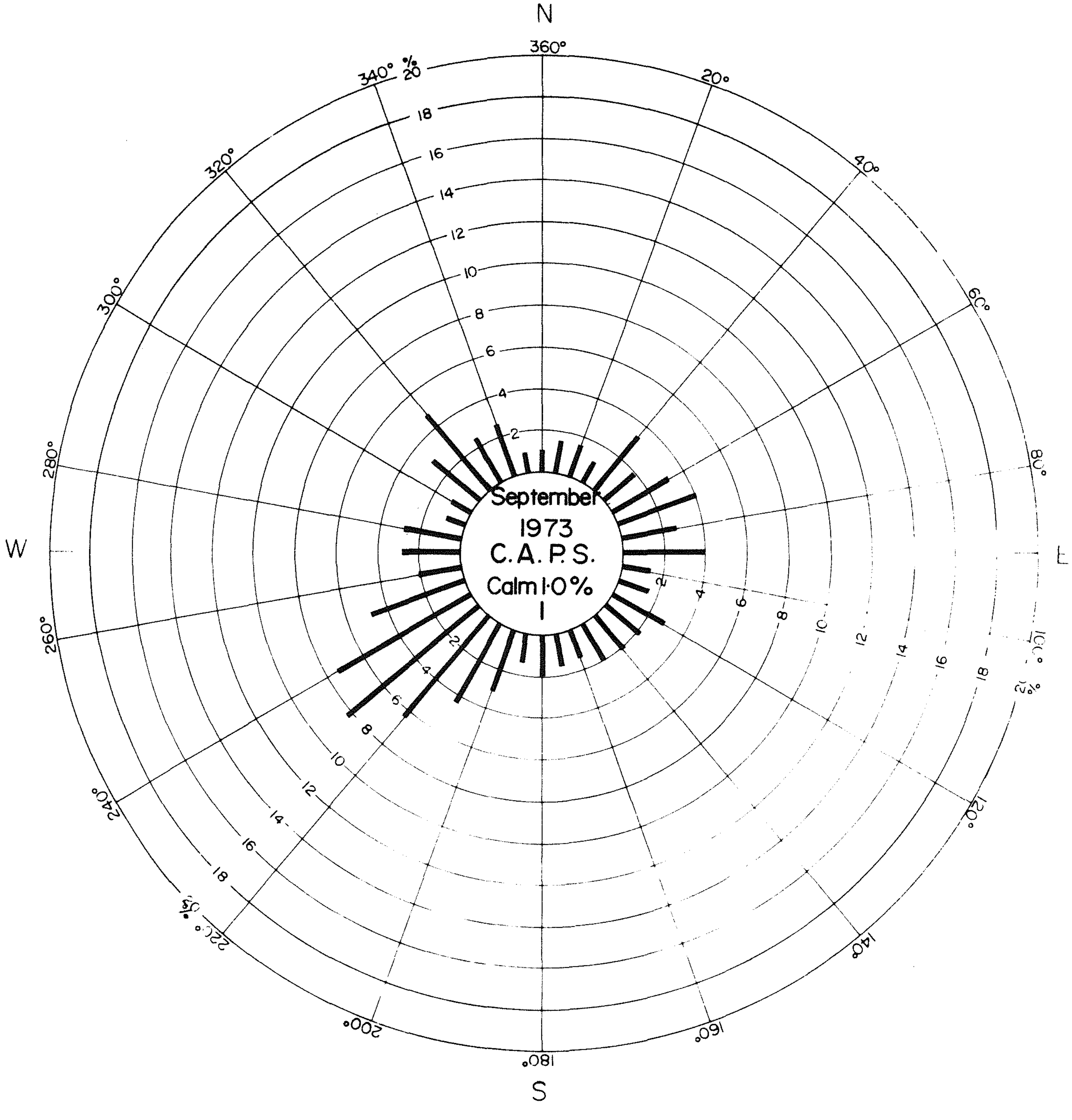
The length of the bars shows the percentage of the whole month during which the wind blew from the indicated direction

FIG II: Wind Rose - August 1973



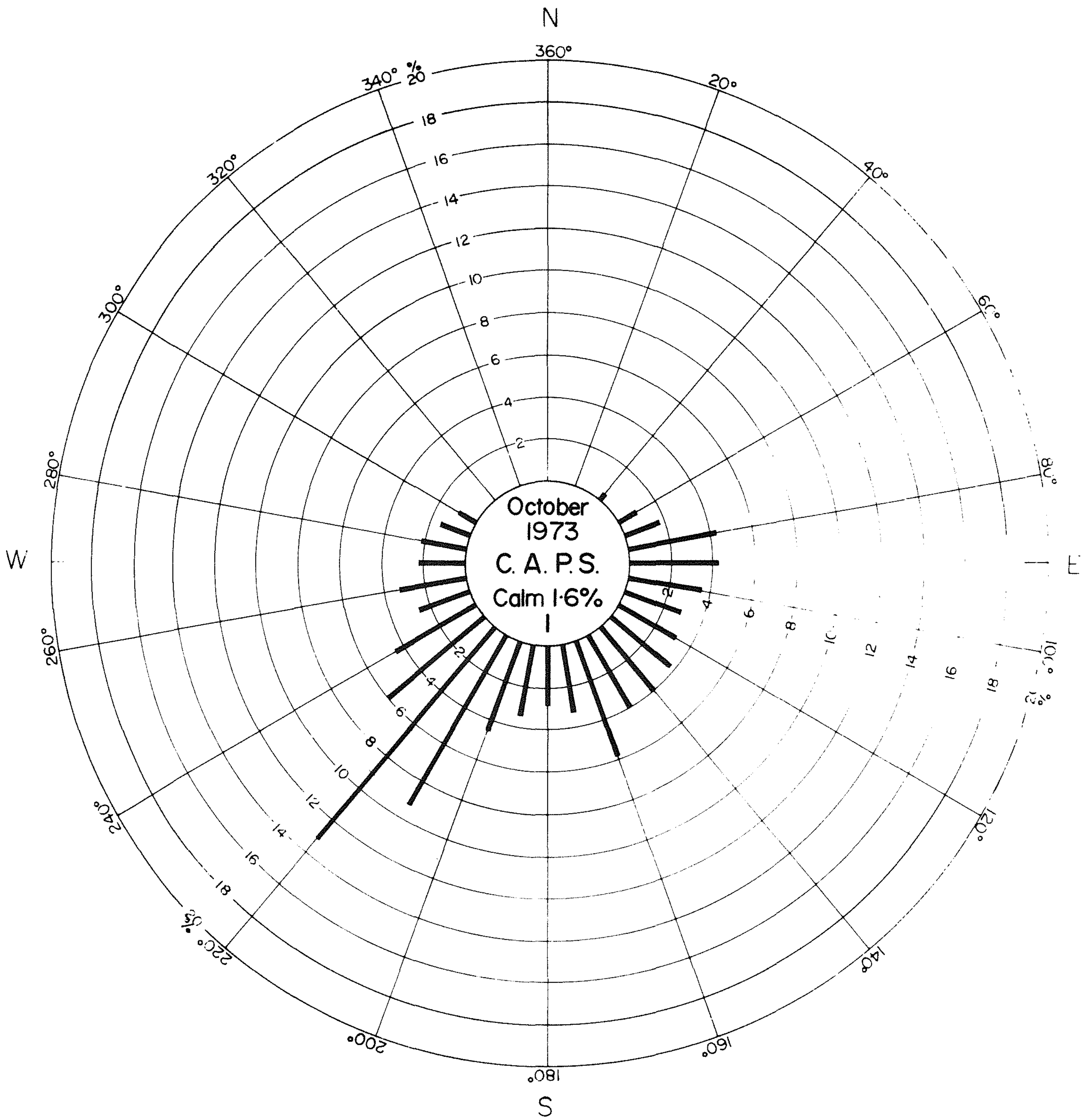
The length of the bars shows the percentage of the whole month during which the wind blew from the indicated direction

FIG 12: Wind Rose September 1973



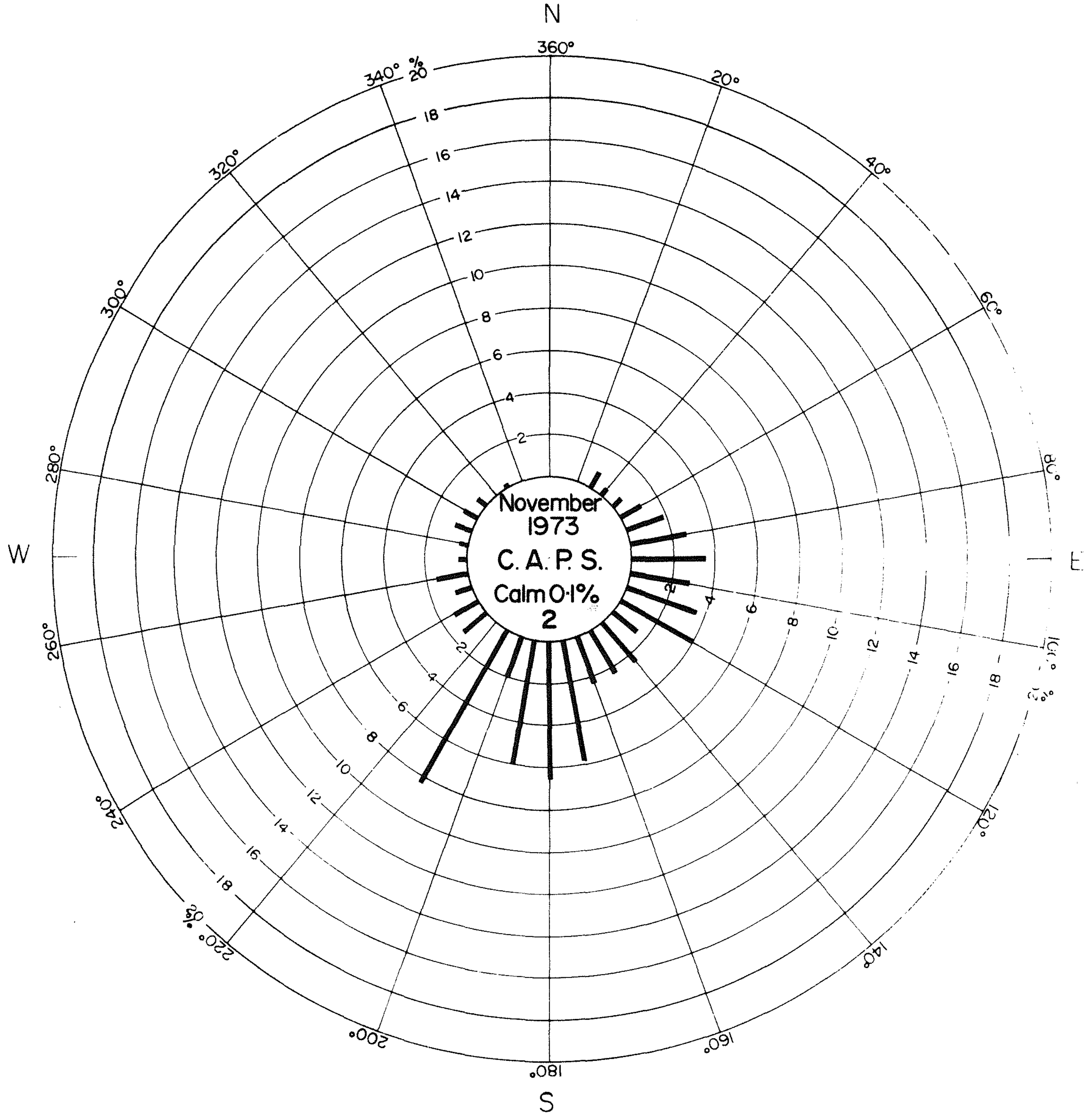
The length of the bars shows the percentage of the whole month during which the wind blew from the indicated direction

FIG 13: Wind Rose - October 1973



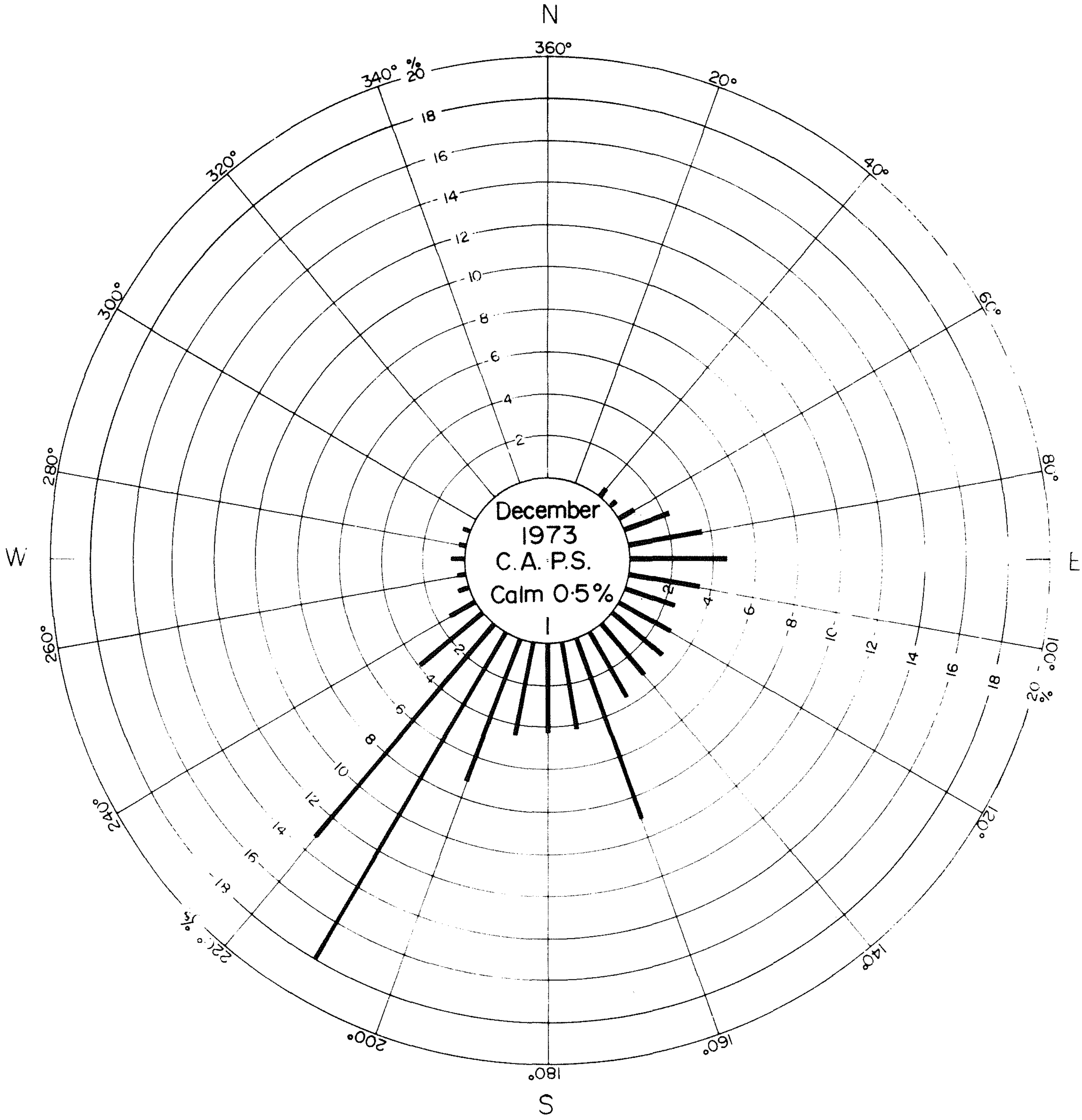
The length of the bars shows the percentage of the whole month during which the wind blew from the indicated direction

FIG 14: Wind Rose November 1973



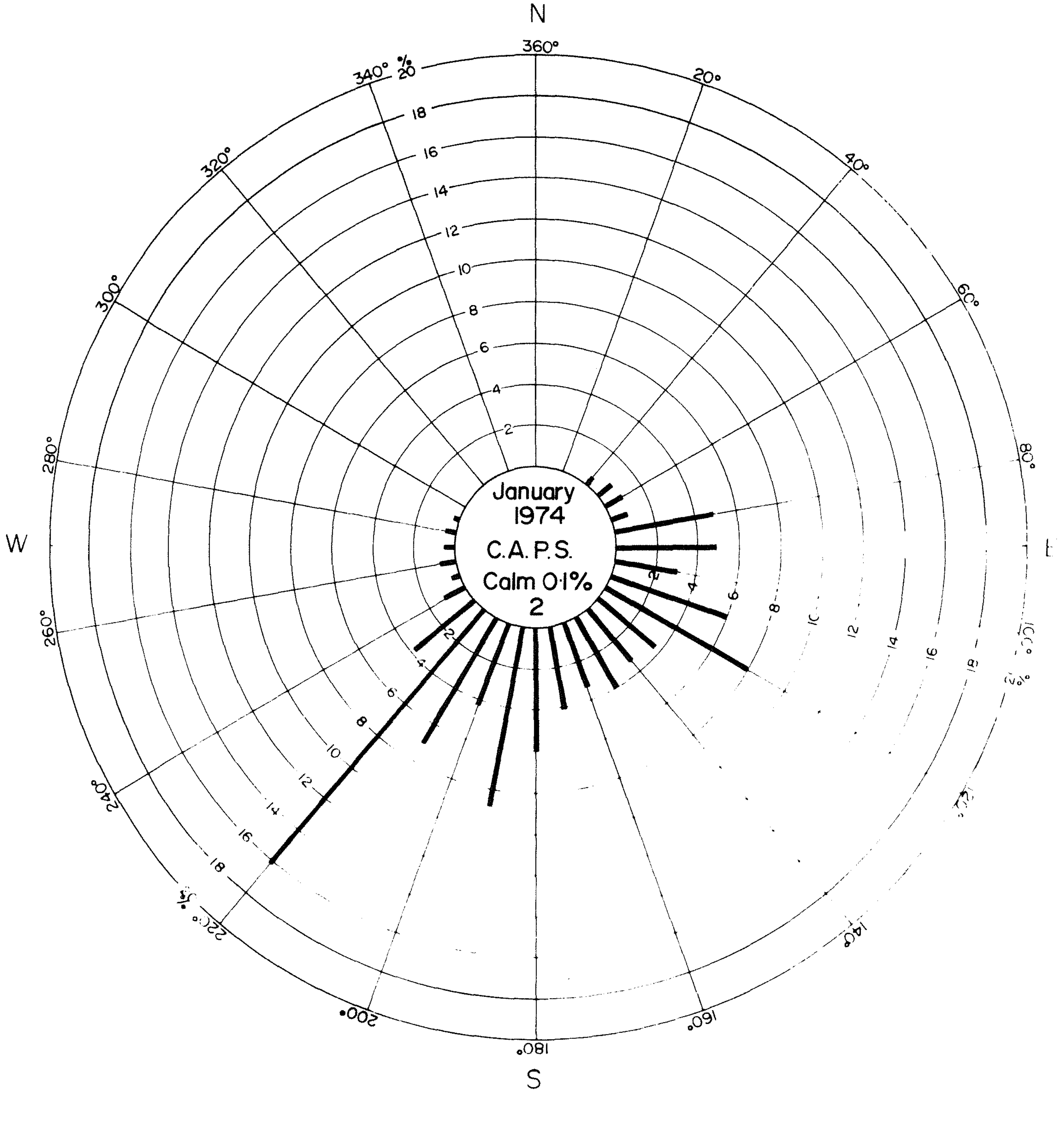
The length of the bars shows the percentage of the whole month during which the wind blew from the indicated direction

FIG 15: Wind Rose - December 1973



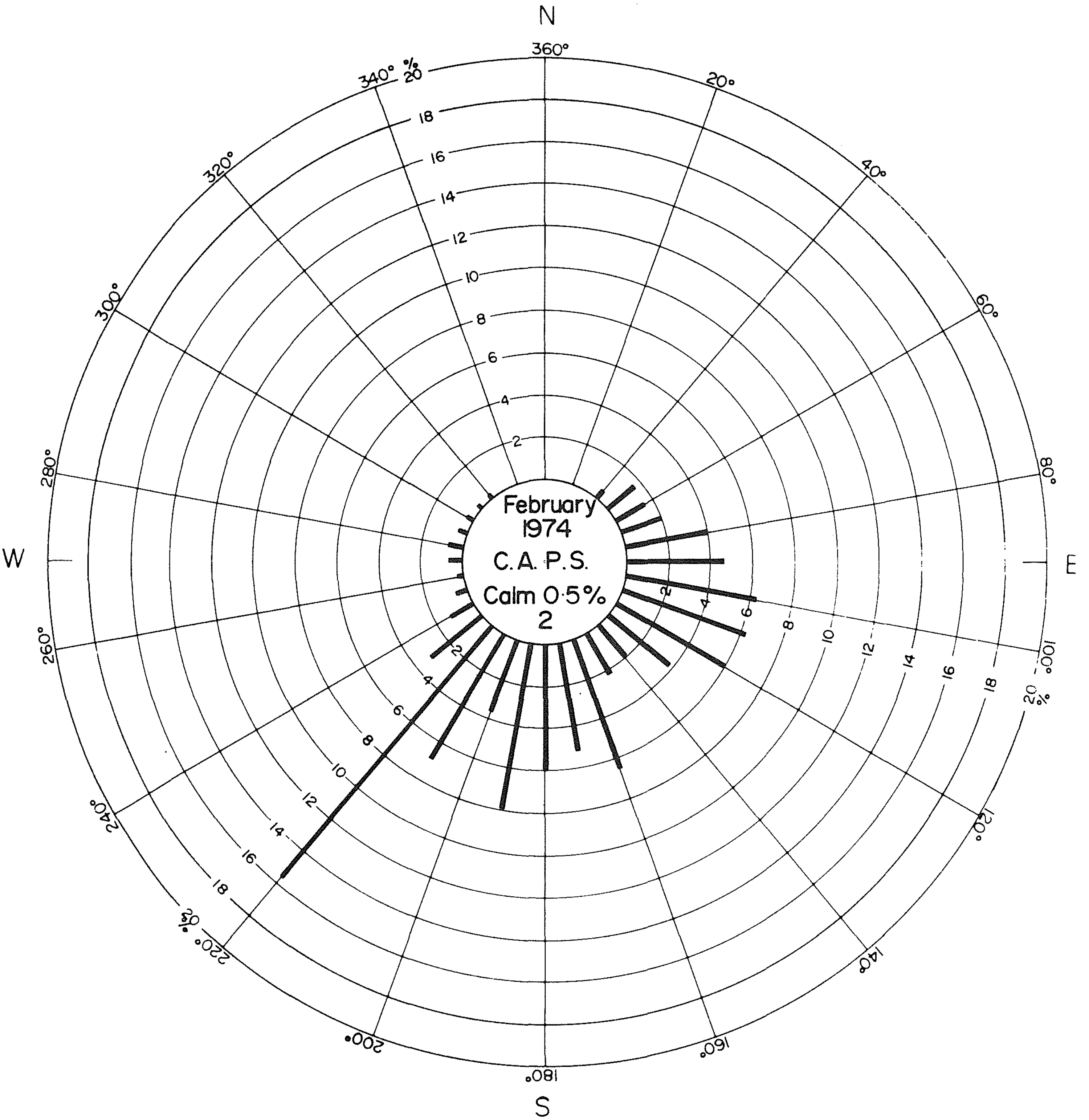
The length of the bars shows the percentage of the whole month during which the wind blew from the indicated direction

FIG 16: Wind Rose - January 1974



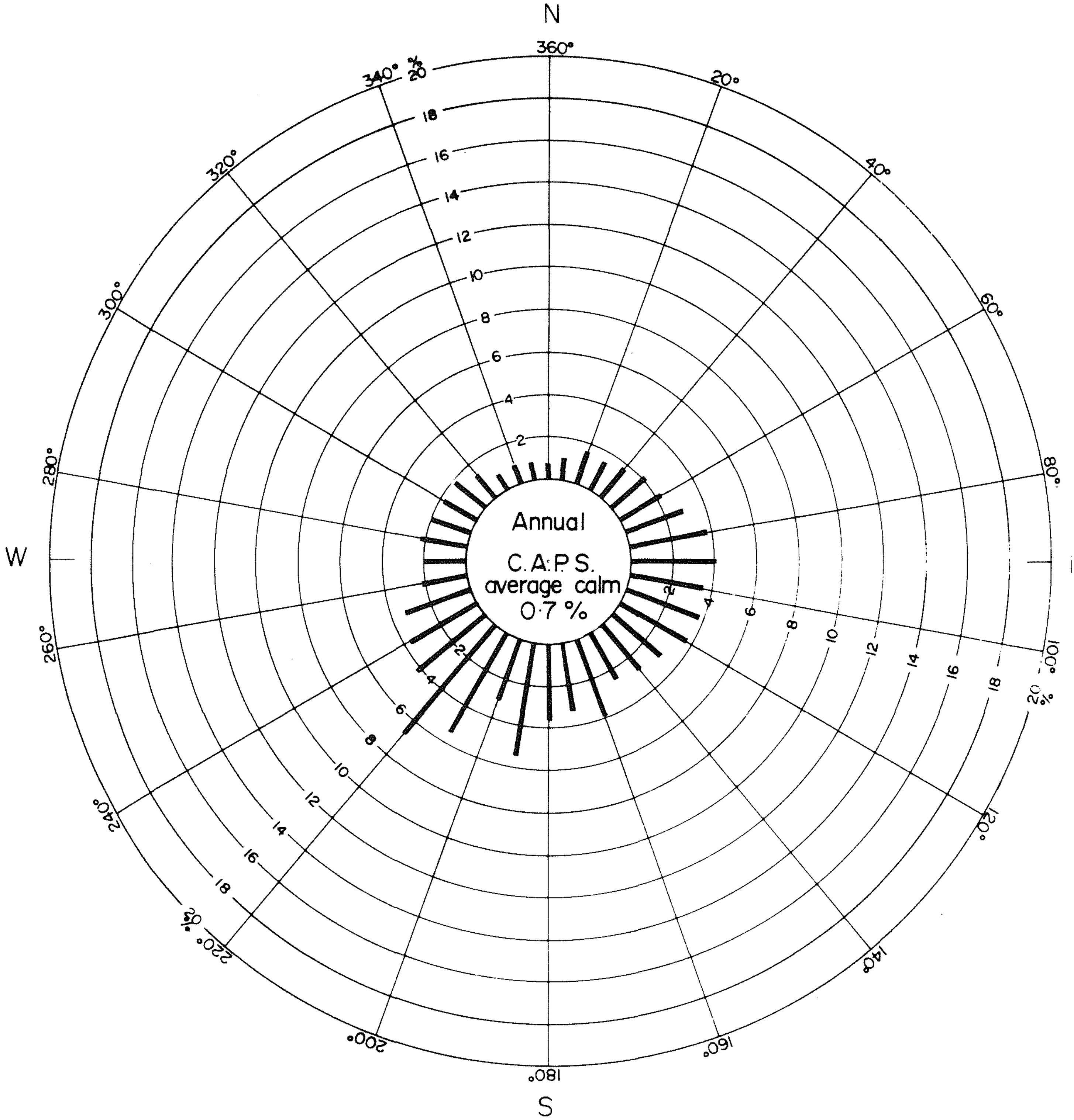
The length of the bars shows the percentage of the whole month during which the wind blew from the indicated direction

FIG 17: Wind Rose - February 1974



The length of the bars shows the percentage of the whole month during which the wind blew from the indicated direction

FIG 18: Annual Wind Rose - March 1973 to February 1974



The length of the bars shows the percentage of the whole month during which the wind blew from the indicated direction

FIG 19 : Percentage of wind blowing from 170° - 230° sector Anemometer A2

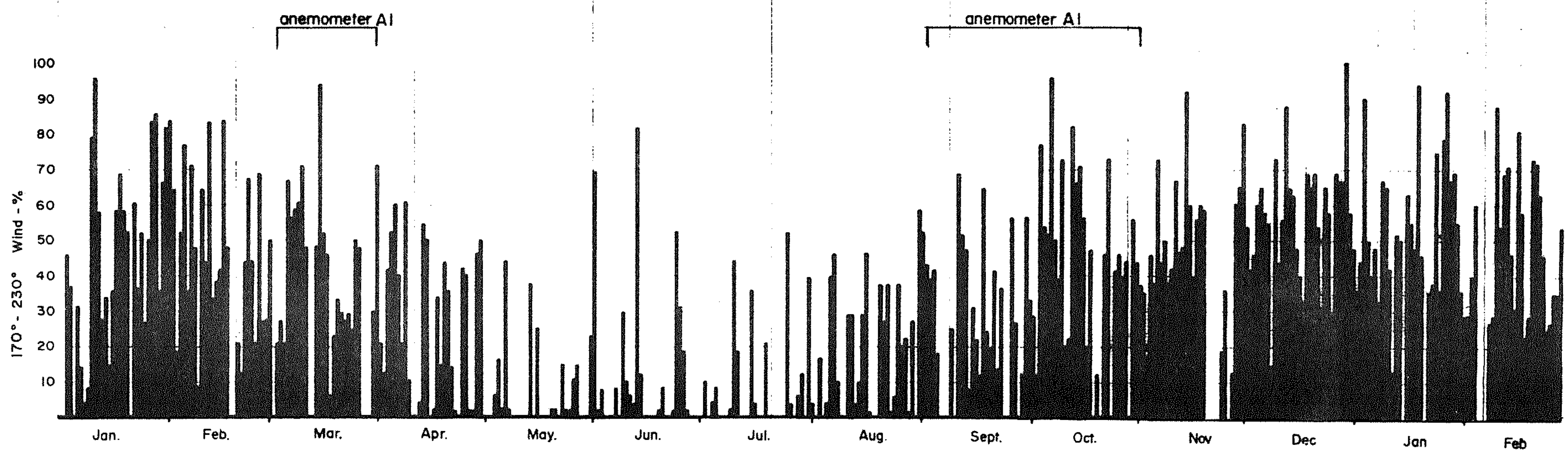


FIG 20 : Cumulative Frequency Diagram
Percentage of wind blowing from 170°-230° sector

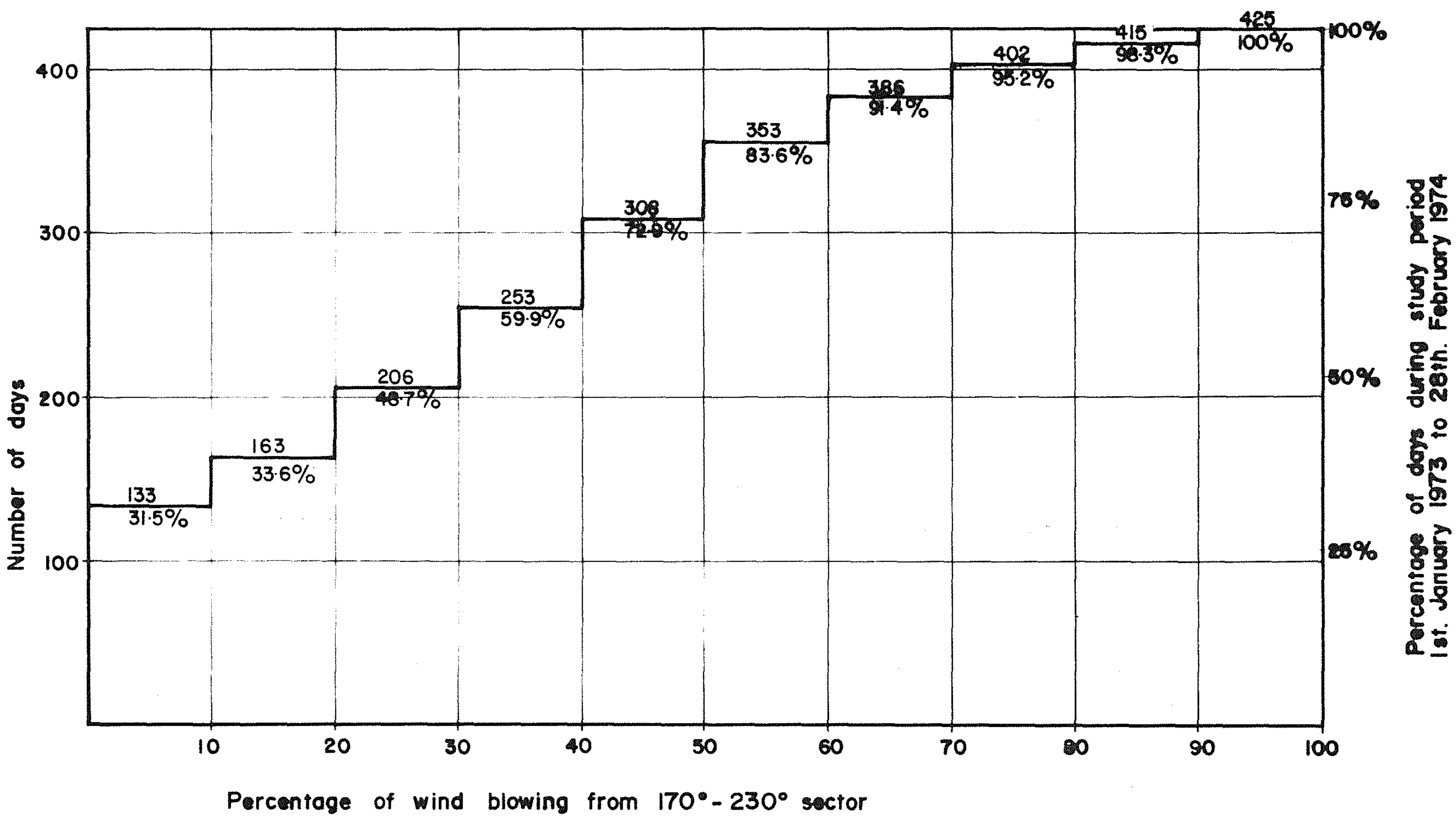


FIG: 21

Monitoring Site No. 513

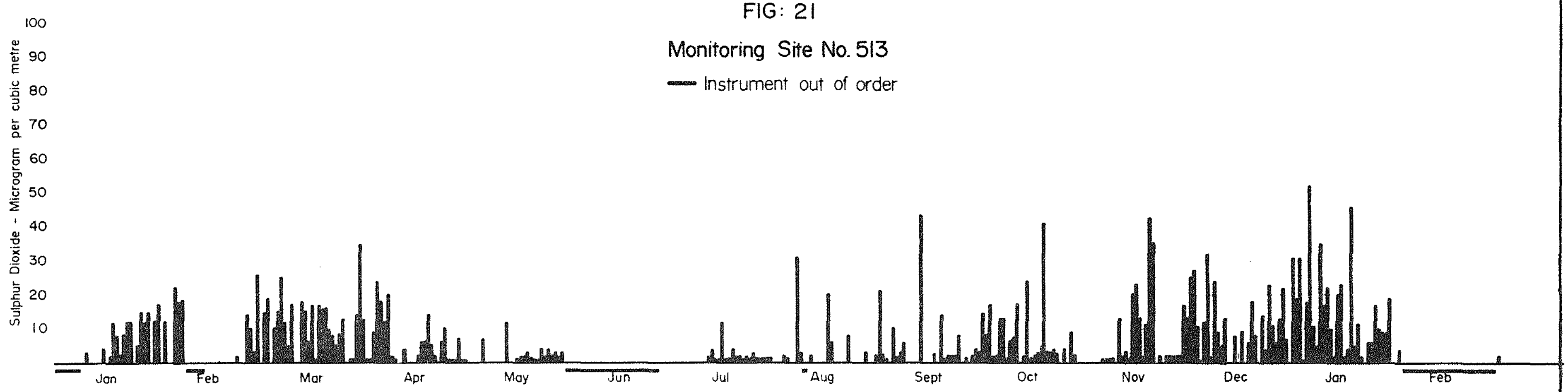


FIG: 22

Monitoring Site No I

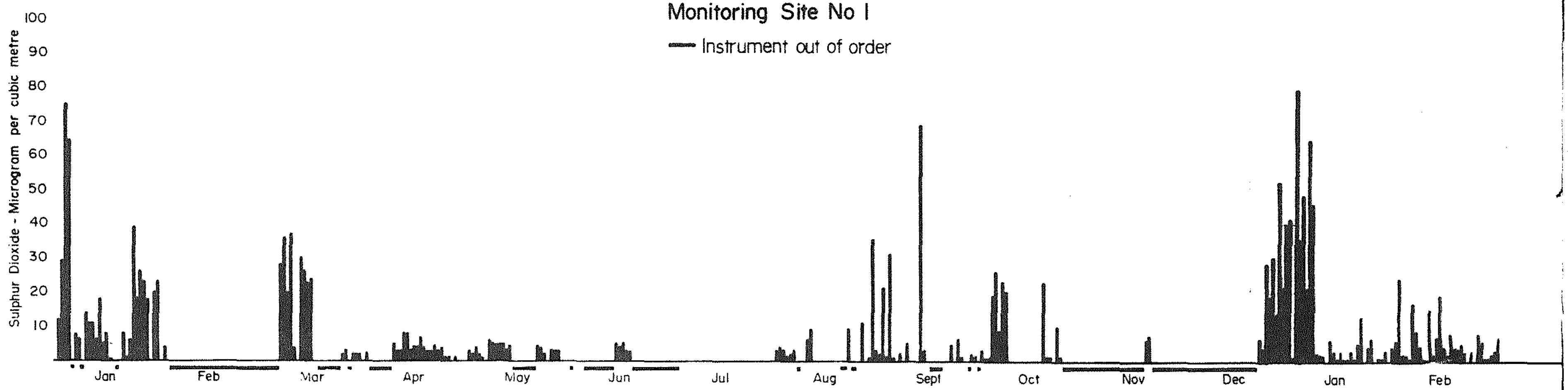


FIG: 23

Monitoring Site No. 2

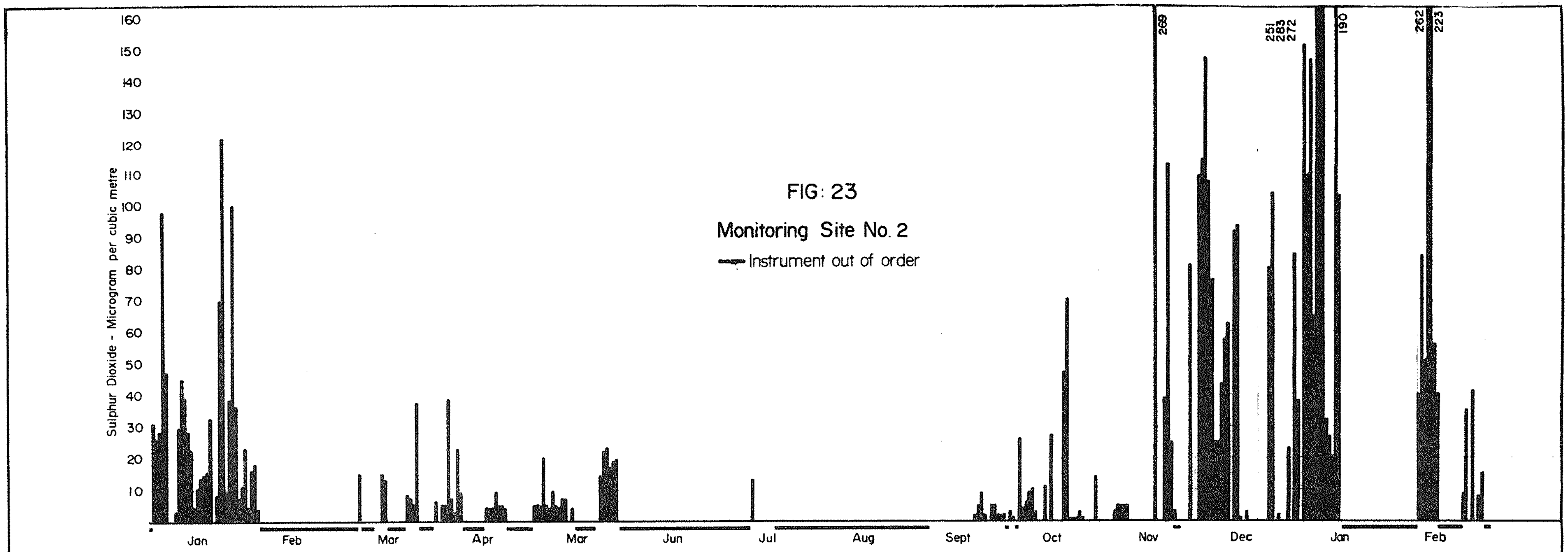
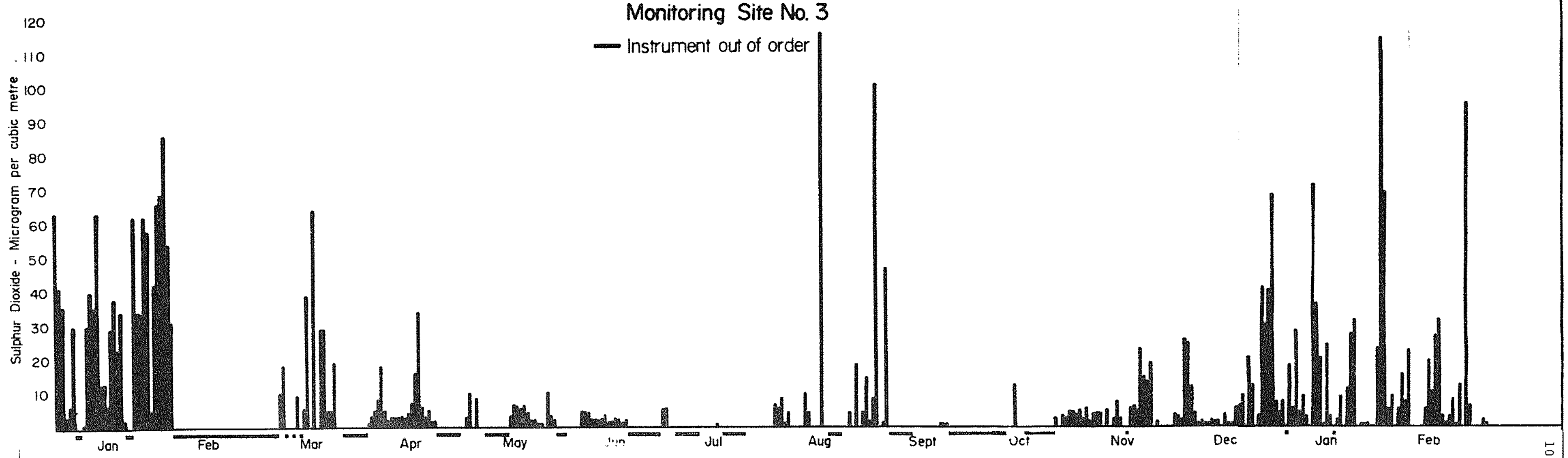


FIG: 24

Monitoring Site No. 3



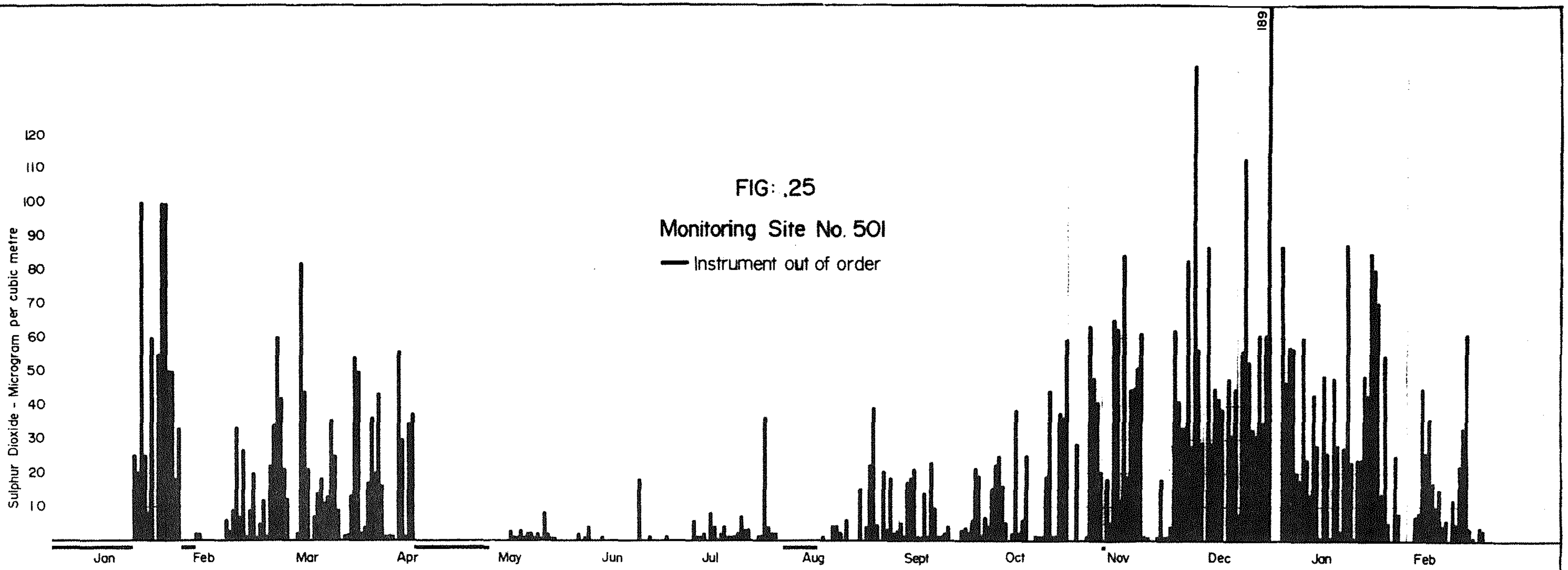


FIG: 25
Monitoring Site No. 501
— Instrument out of order

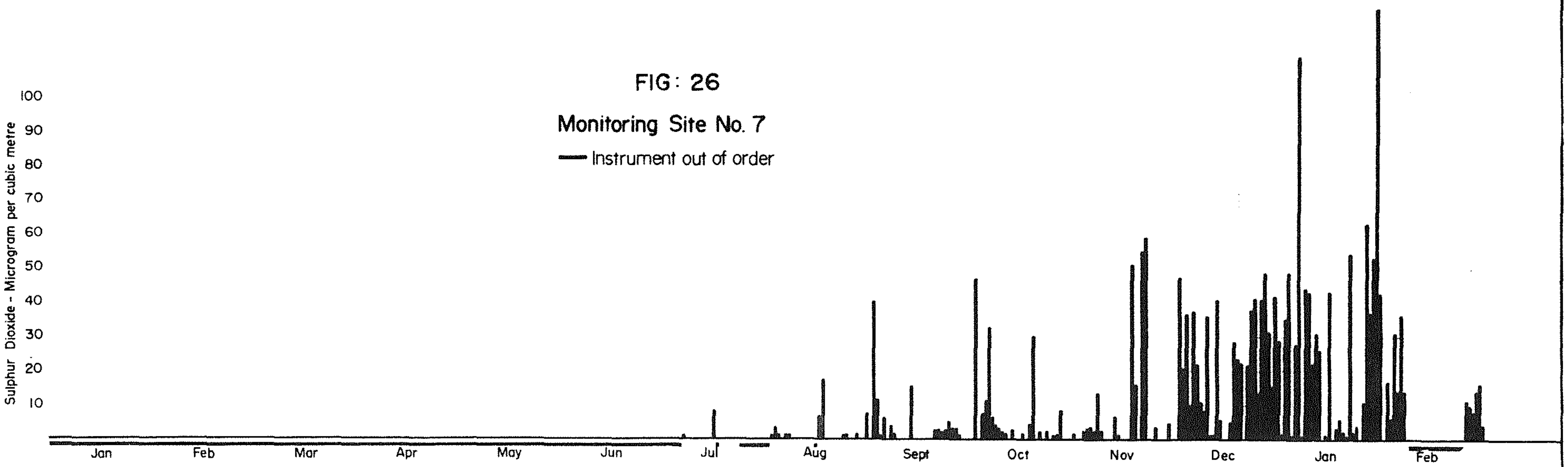


FIG: 26
Monitoring Site No. 7
— Instrument out of order

FIG: 27

Monitoring Site No 4

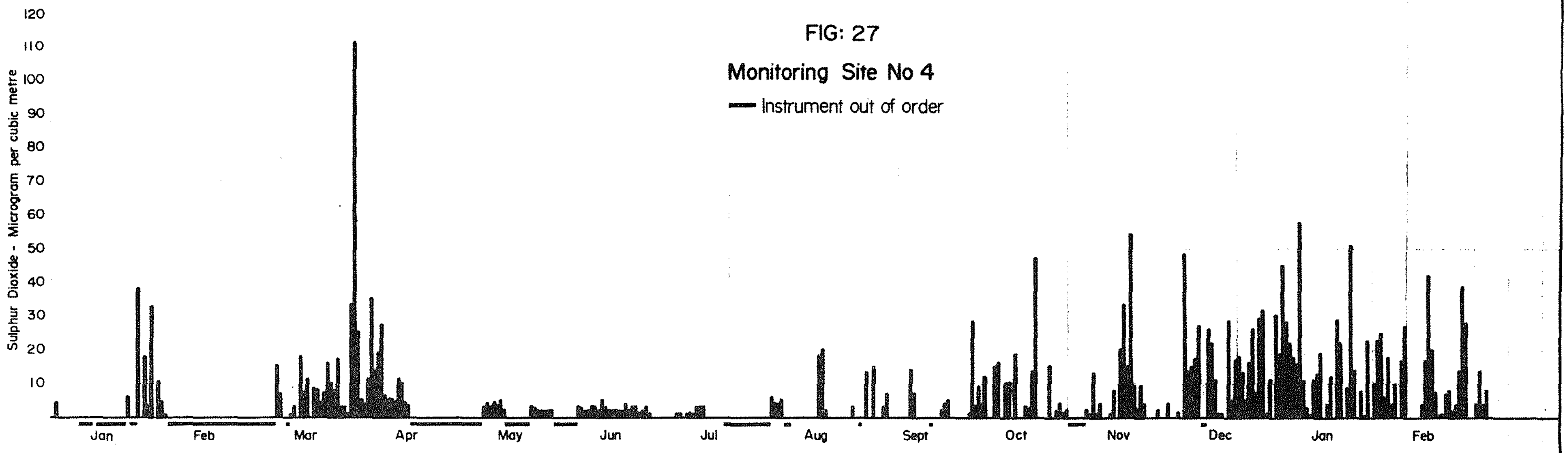


FIG: 28

Monitoring Site No. 5

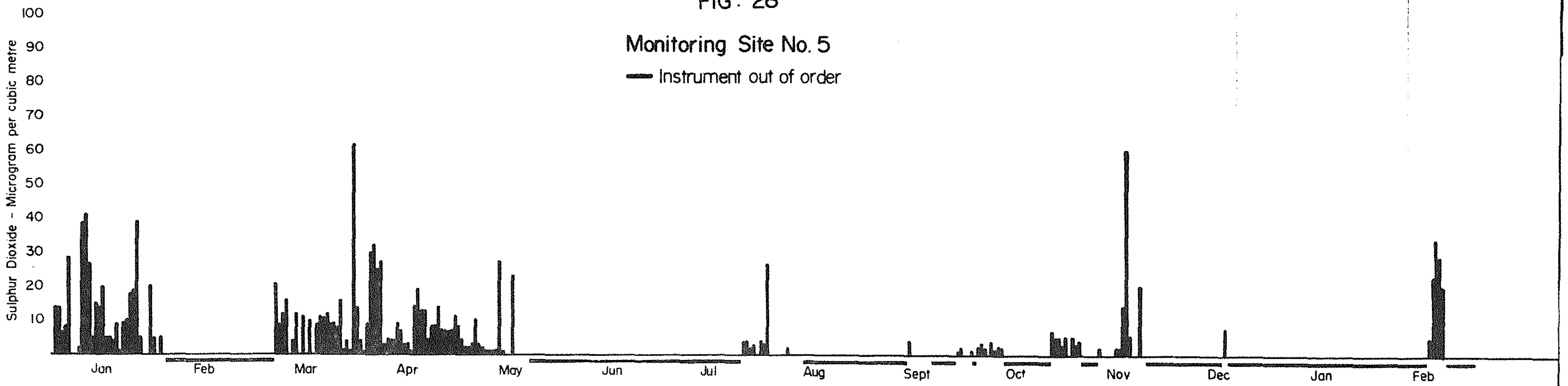


FIG: 29

Monitoring Site No. 6

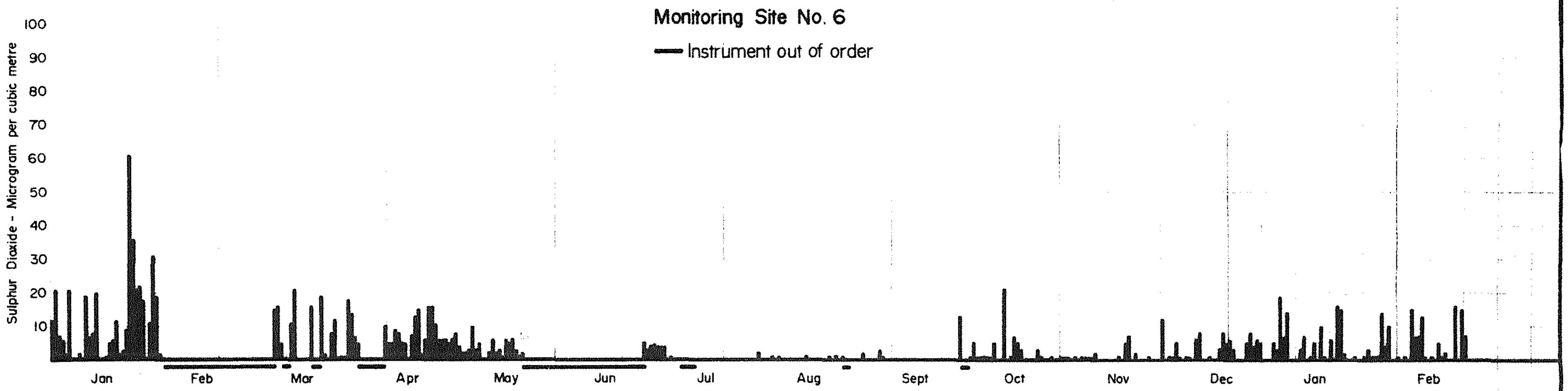


FIG: 30

Monitoring Site No 514

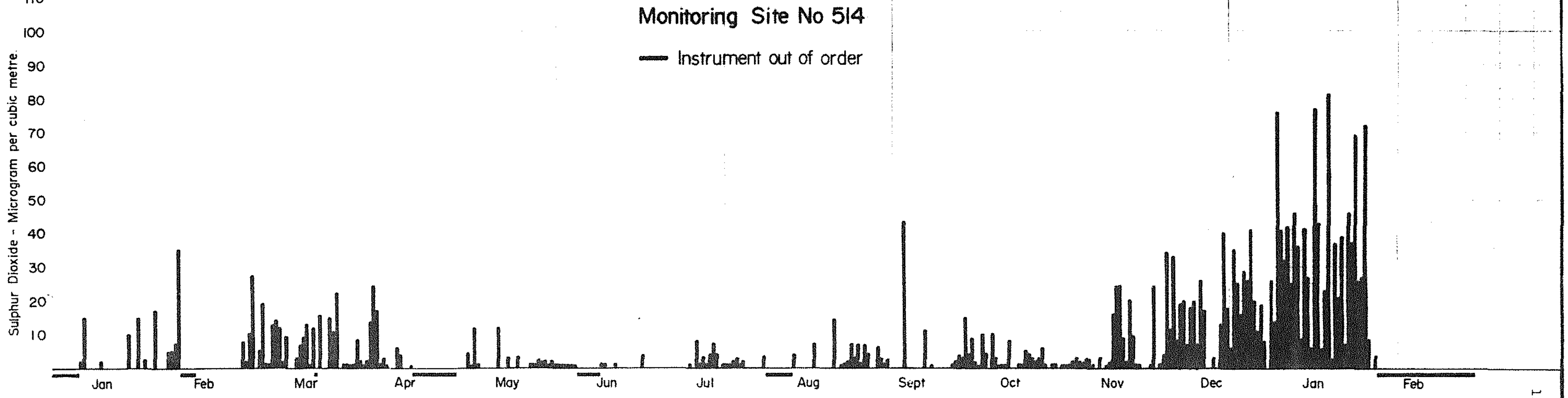


FIG: 31

Monitoring Site No. 515

— Instrument out of order

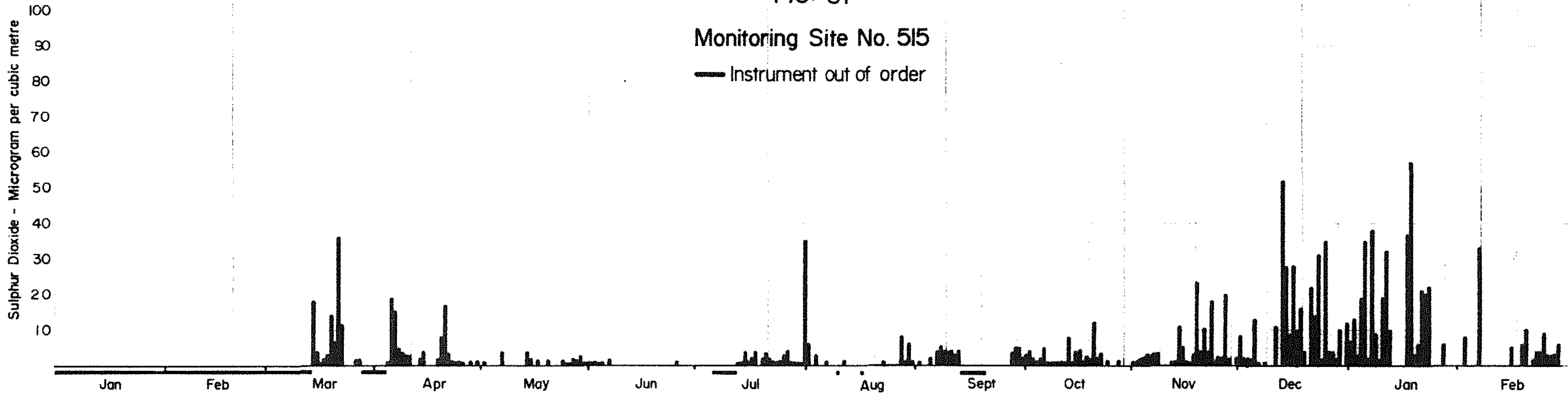


FIG: 32

Monitoring Site No 516

— Instrument out of order

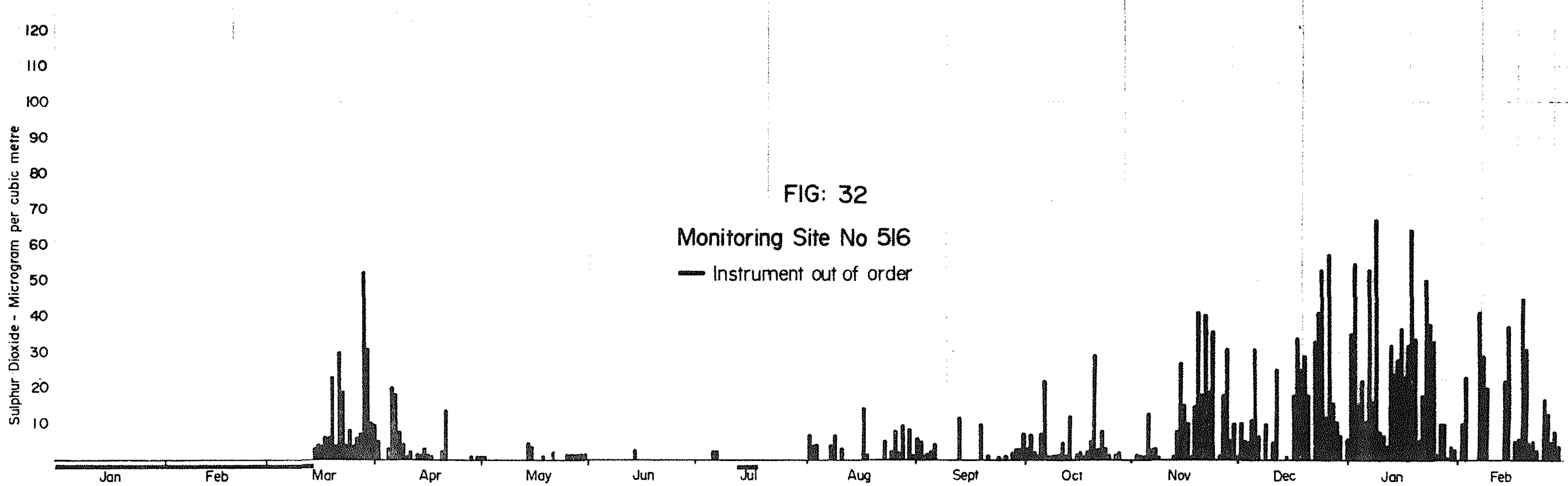


FIG 33: Cumulative Frequency Diagram
Monitoring Site No. 513

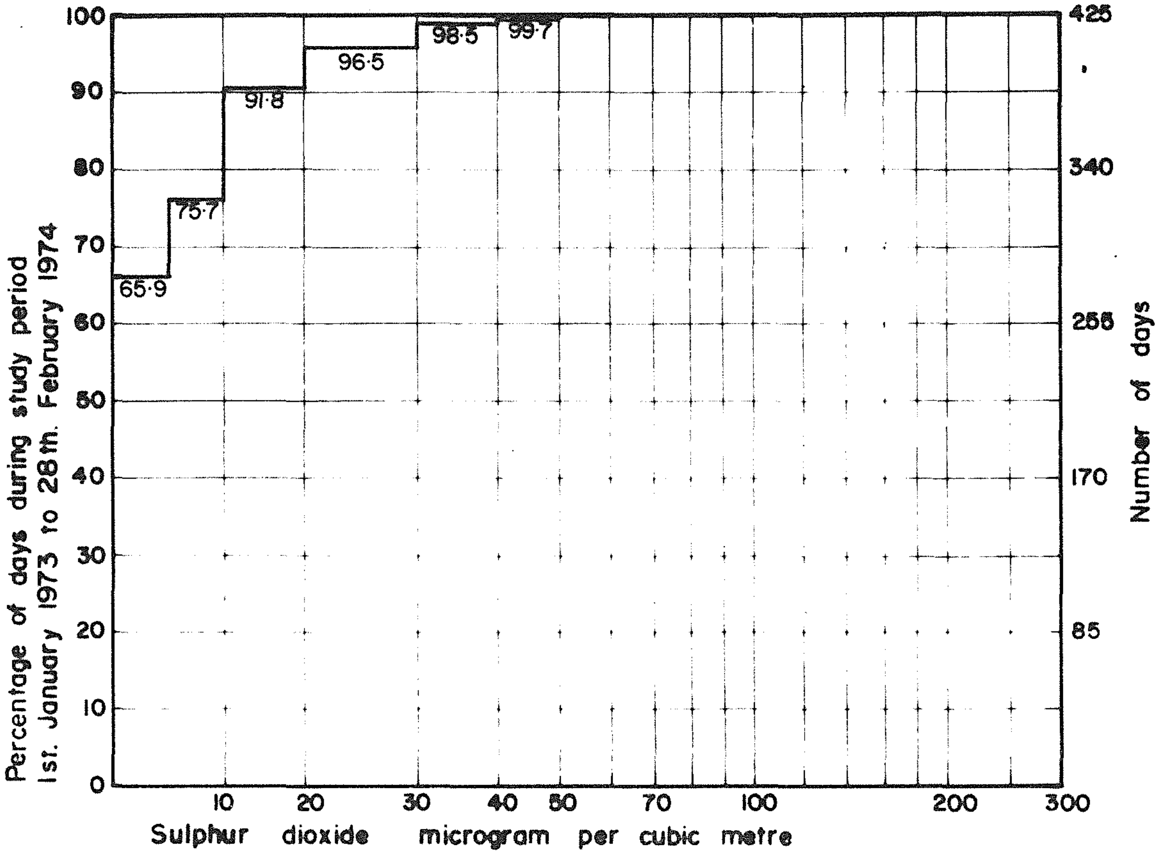


FIG 34: Cumulative Frequency Diagram
Monitoring Site No. 1

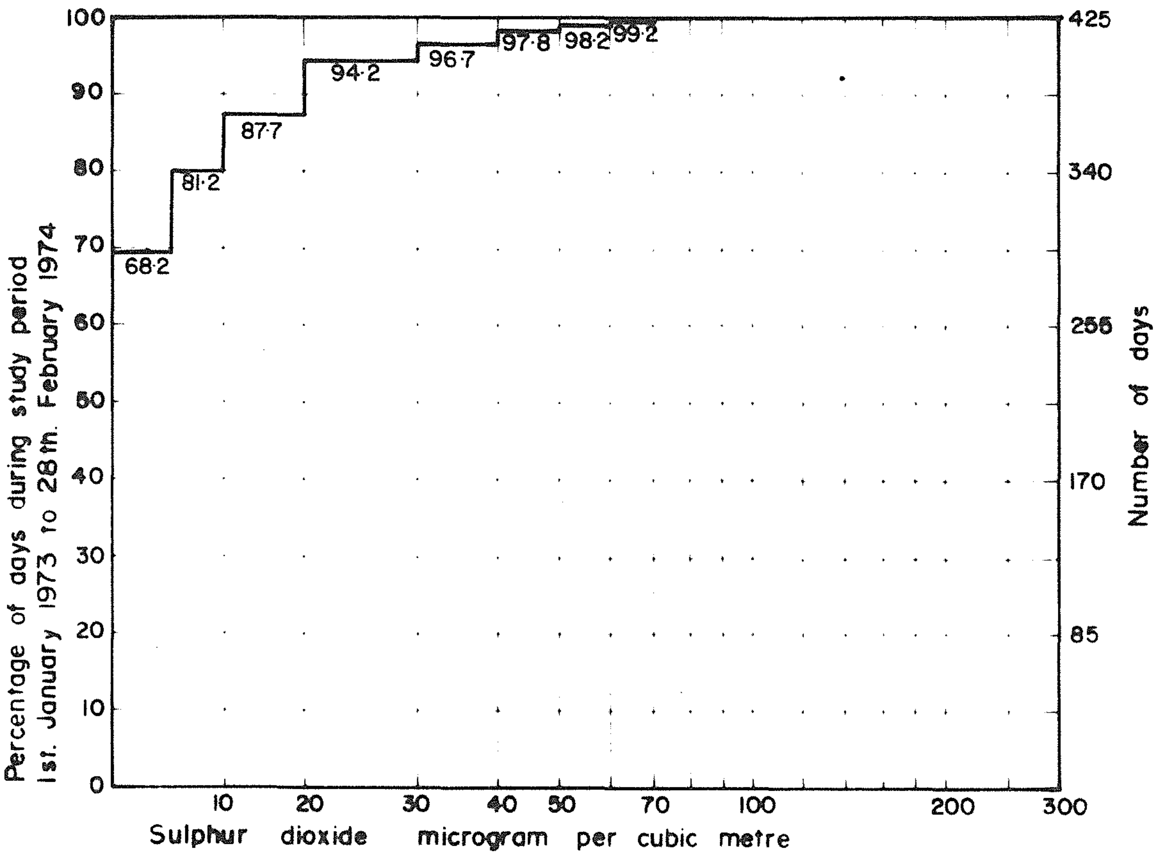


FIG 35: Cumulative Frequency Diagram
Monitoring Site No. 2

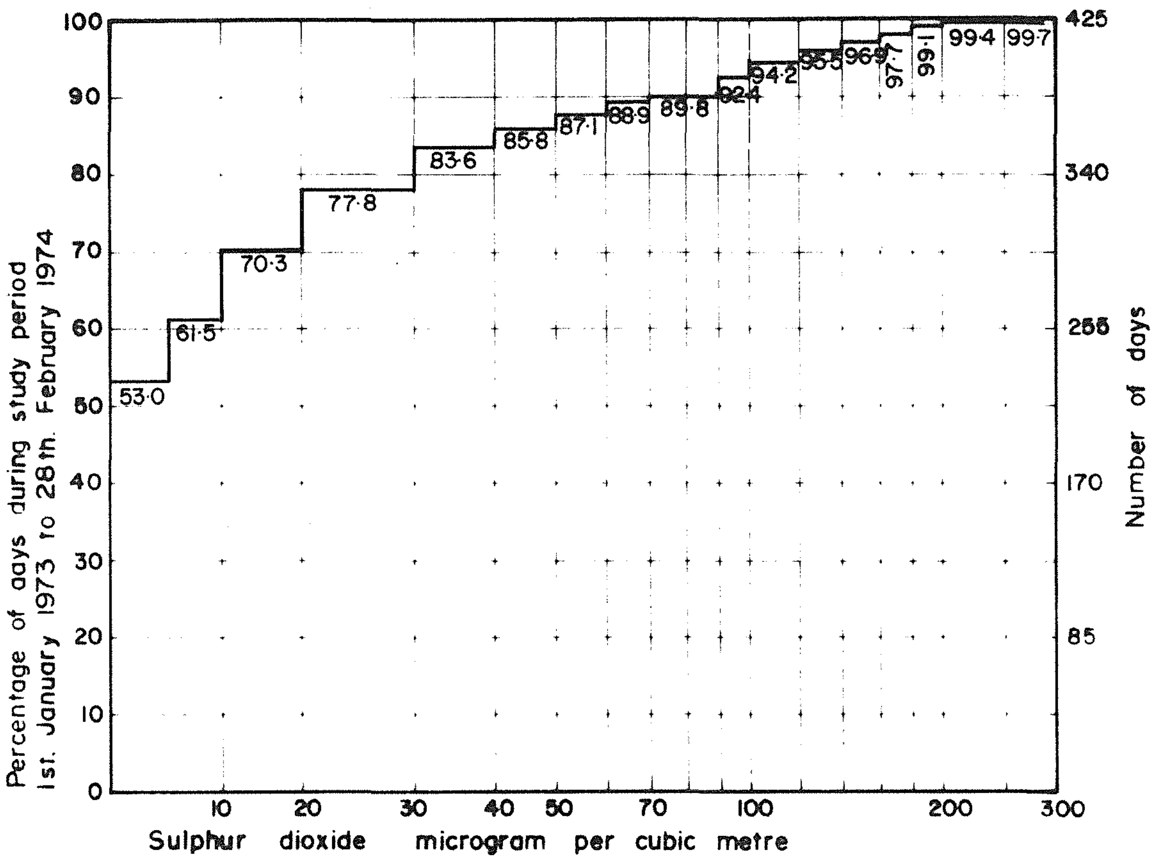


FIG 36: Cumulative Frequency Diagram
Monitoring Site No. 3

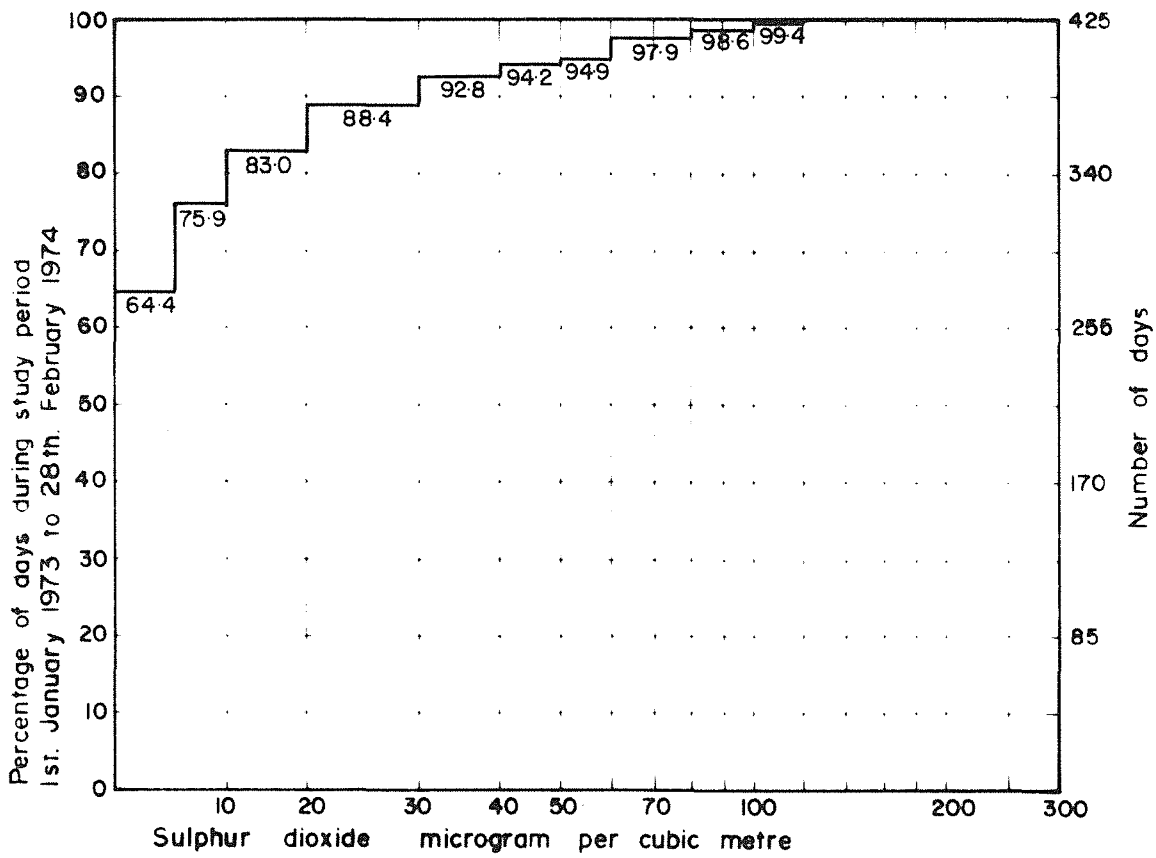


FIG 37: Cumulative Frequency Diagram
Monitoring Site No. 501

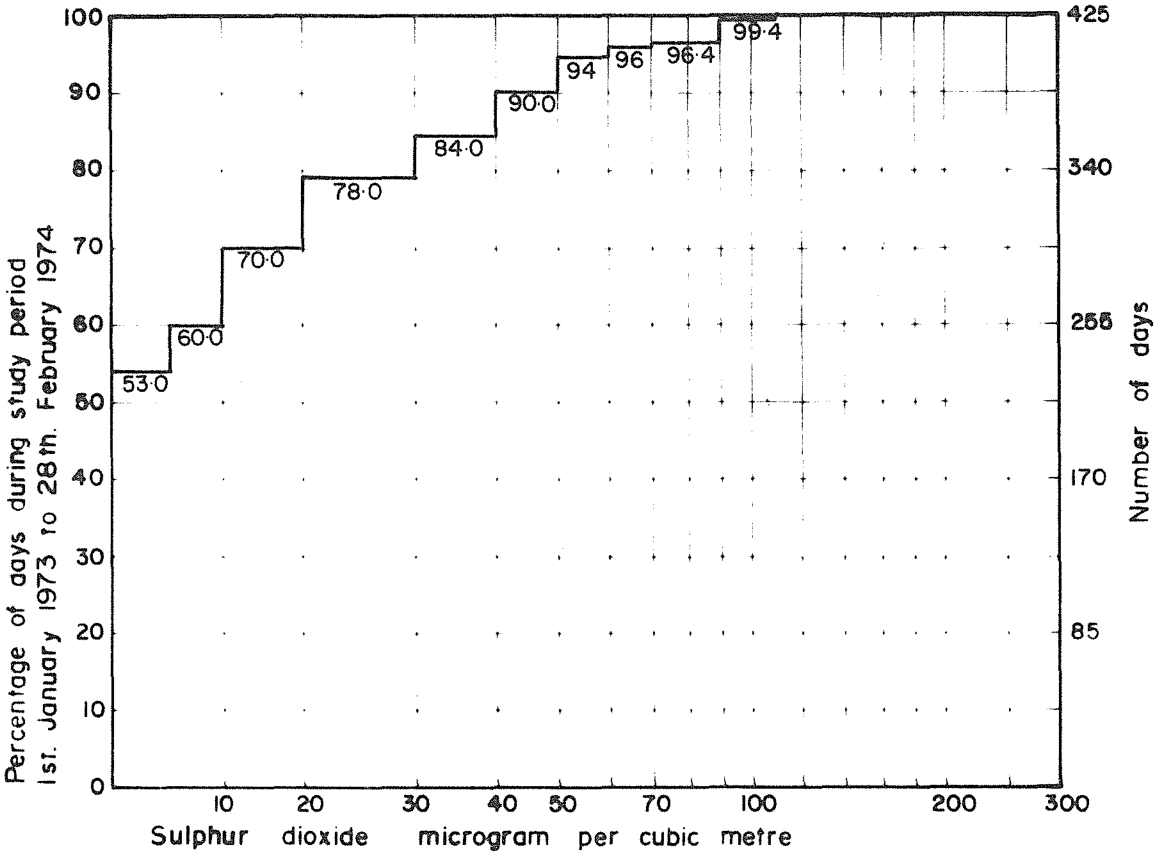


FIG 38: Cumulative Frequency Diagram
Monitoring Site No. 7

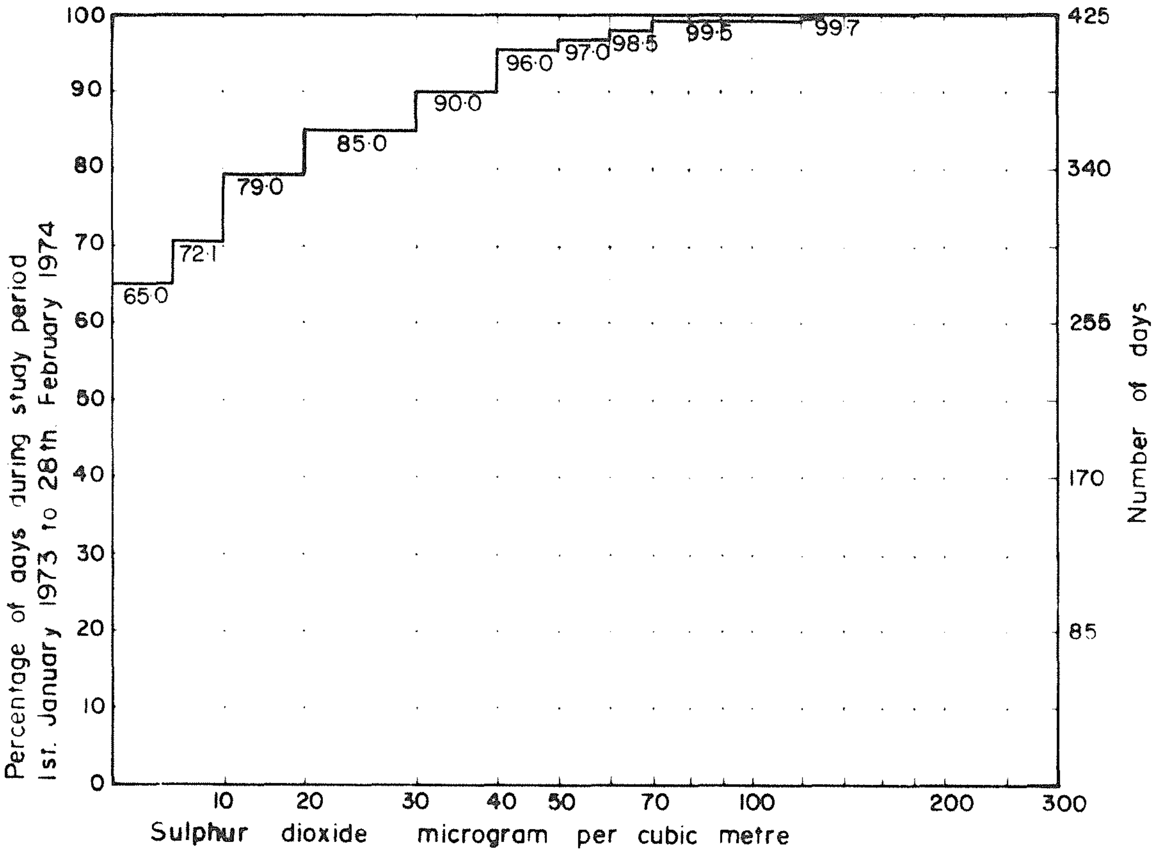


FIG 39: Cumulative Frequency Diagram
Monitoring Site No. 4

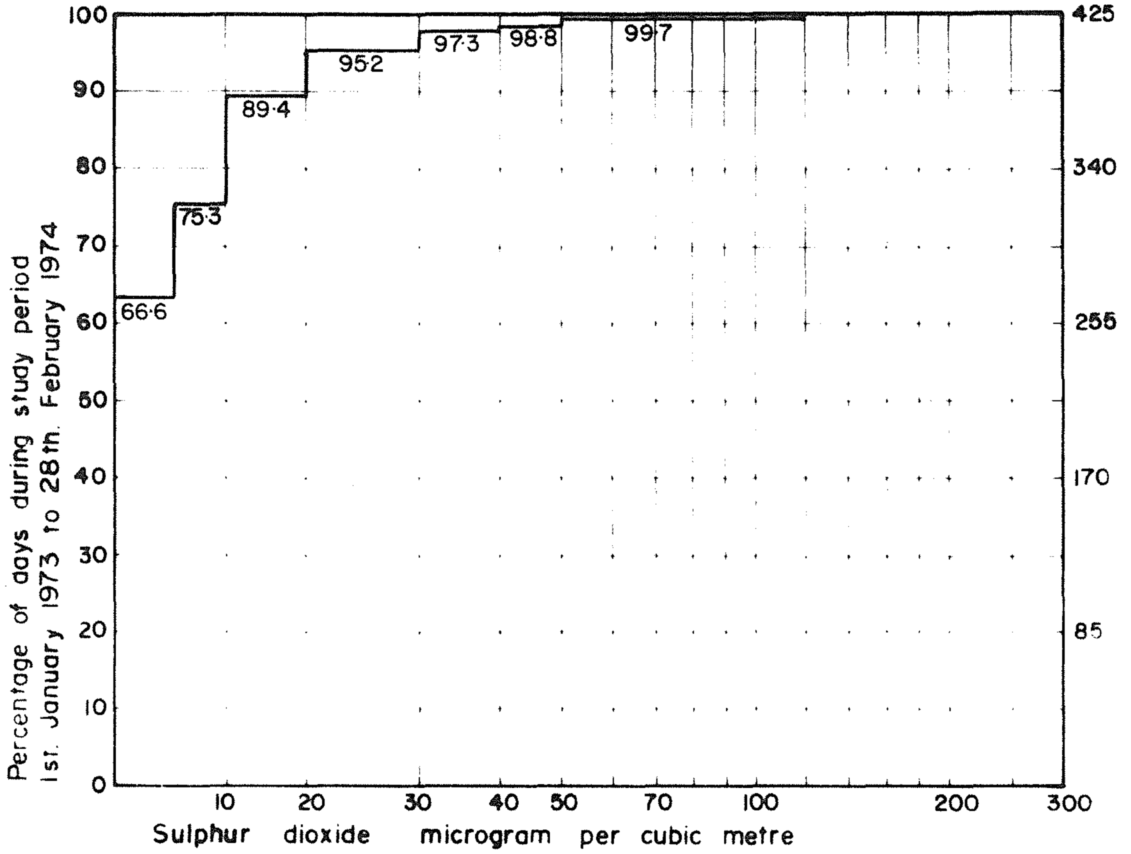


FIG 40: Cumulative Frequency Diagram
Monitoring Site No. 5

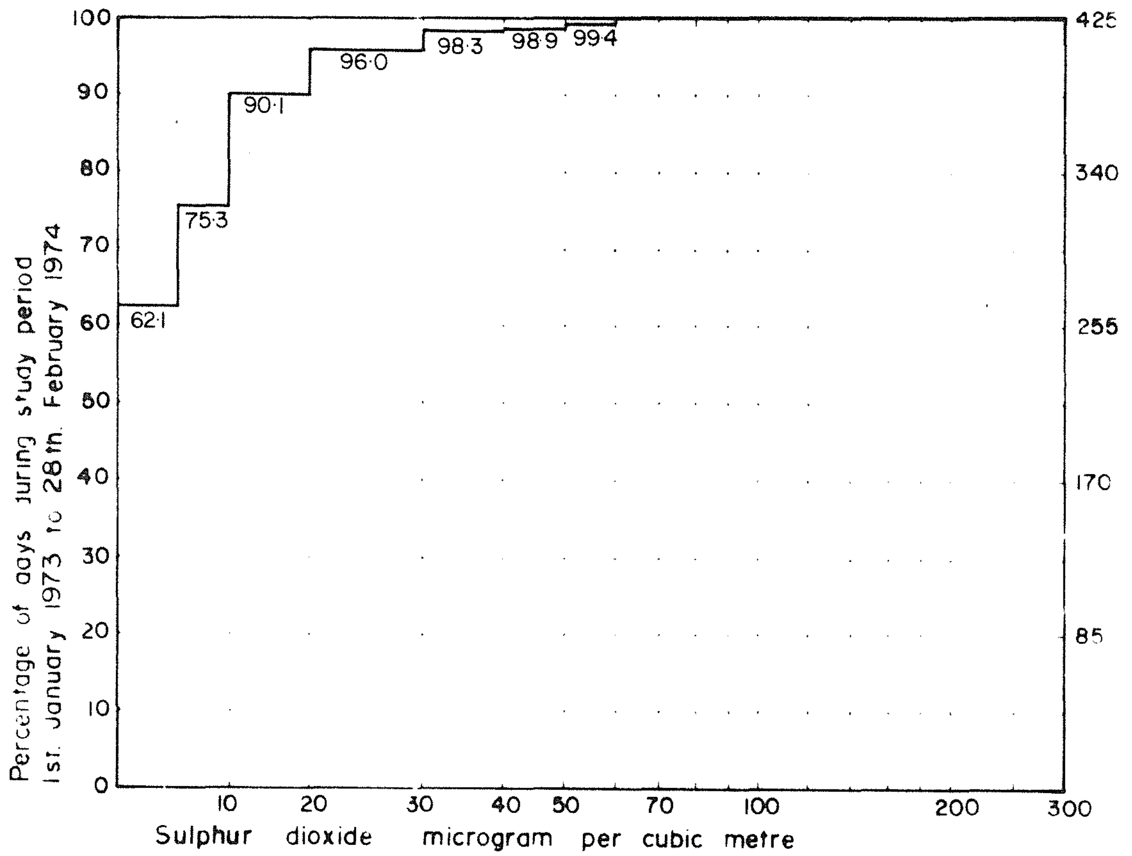


FIG 41 Cumulative Frequency Diagram
Monitoring Site No. 6

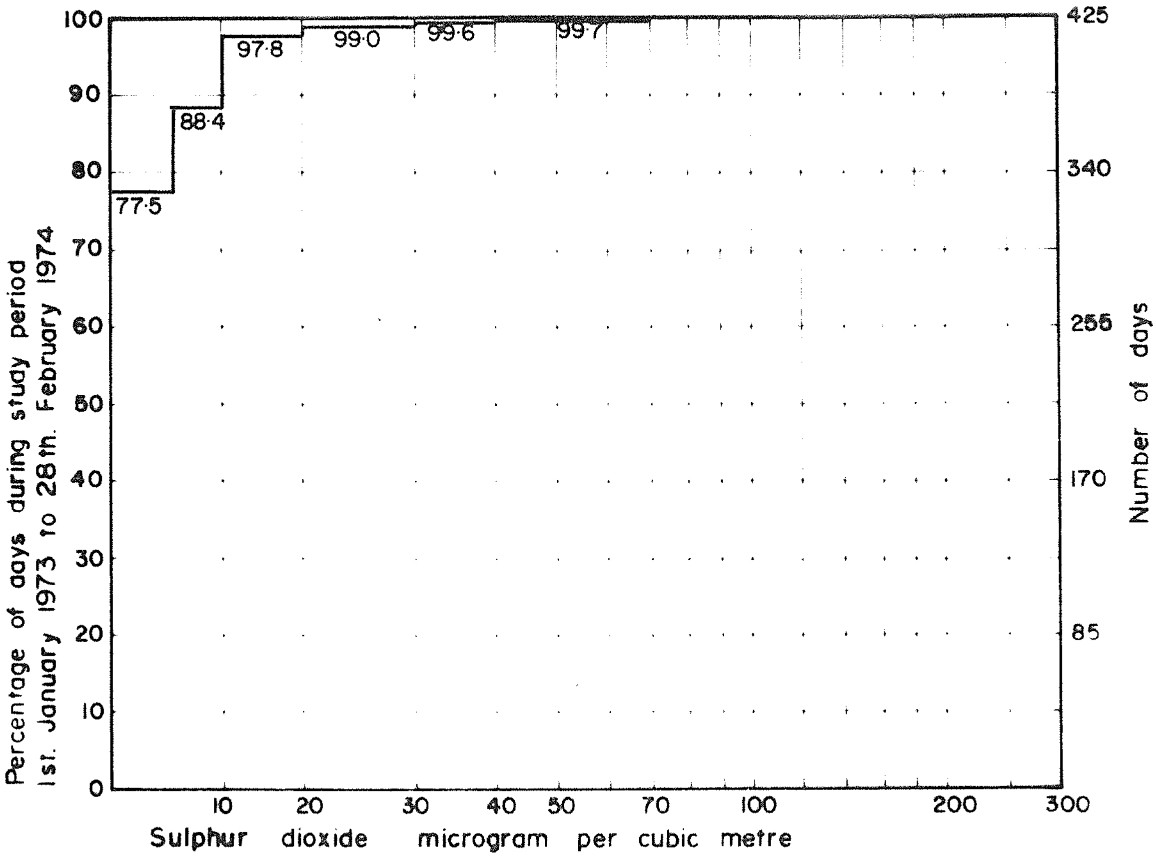


FIG 42 Cumulative Frequency Diagram
Monitoring Site No 514

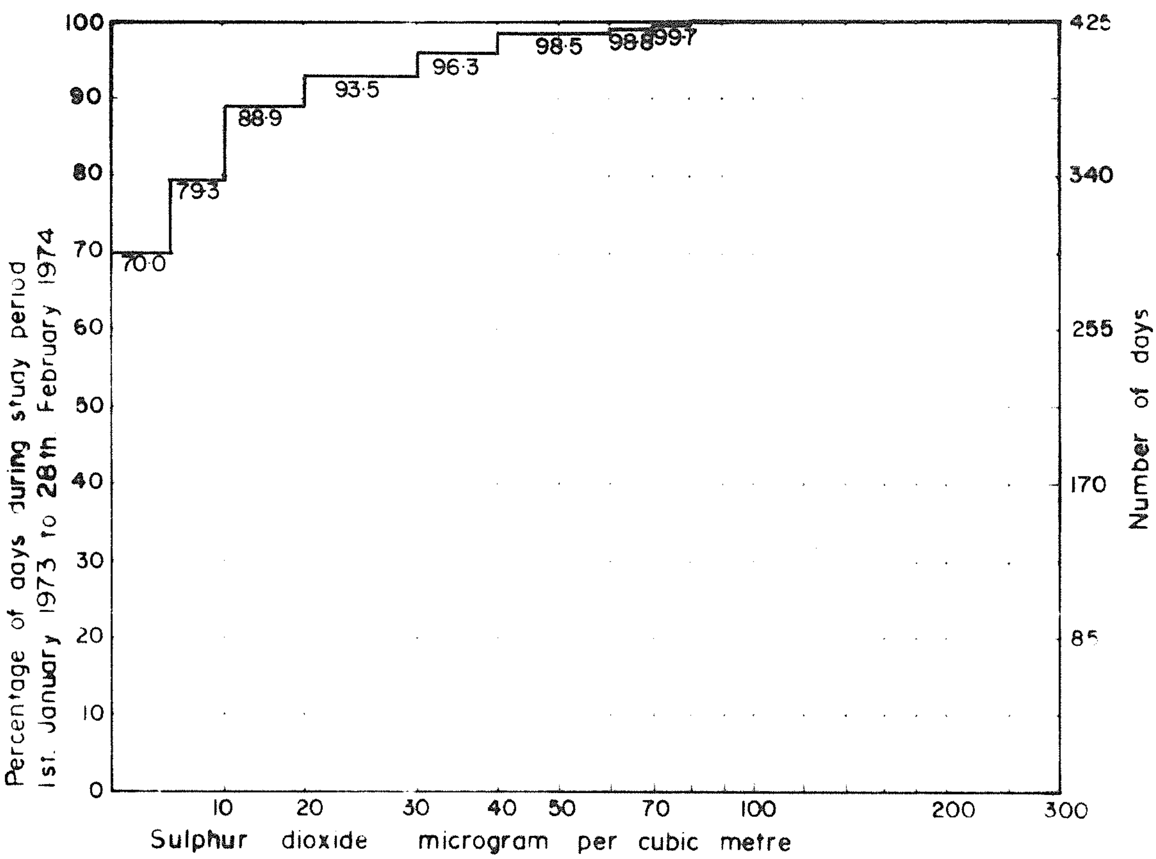


FIG 43 Cumulative Frequency Diagram
Monitoring Site No. 515

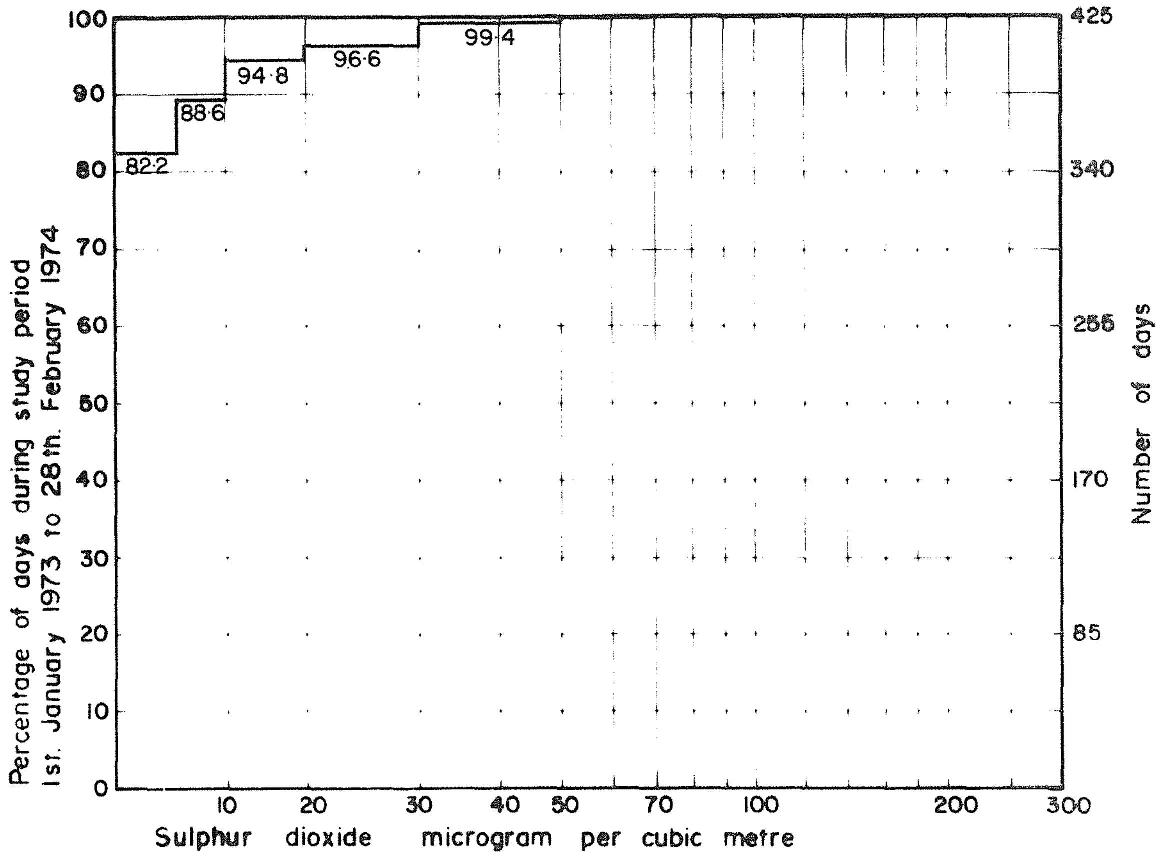


FIG 44 Cumulative Frequency Diagram
Monitoring Site No. 516

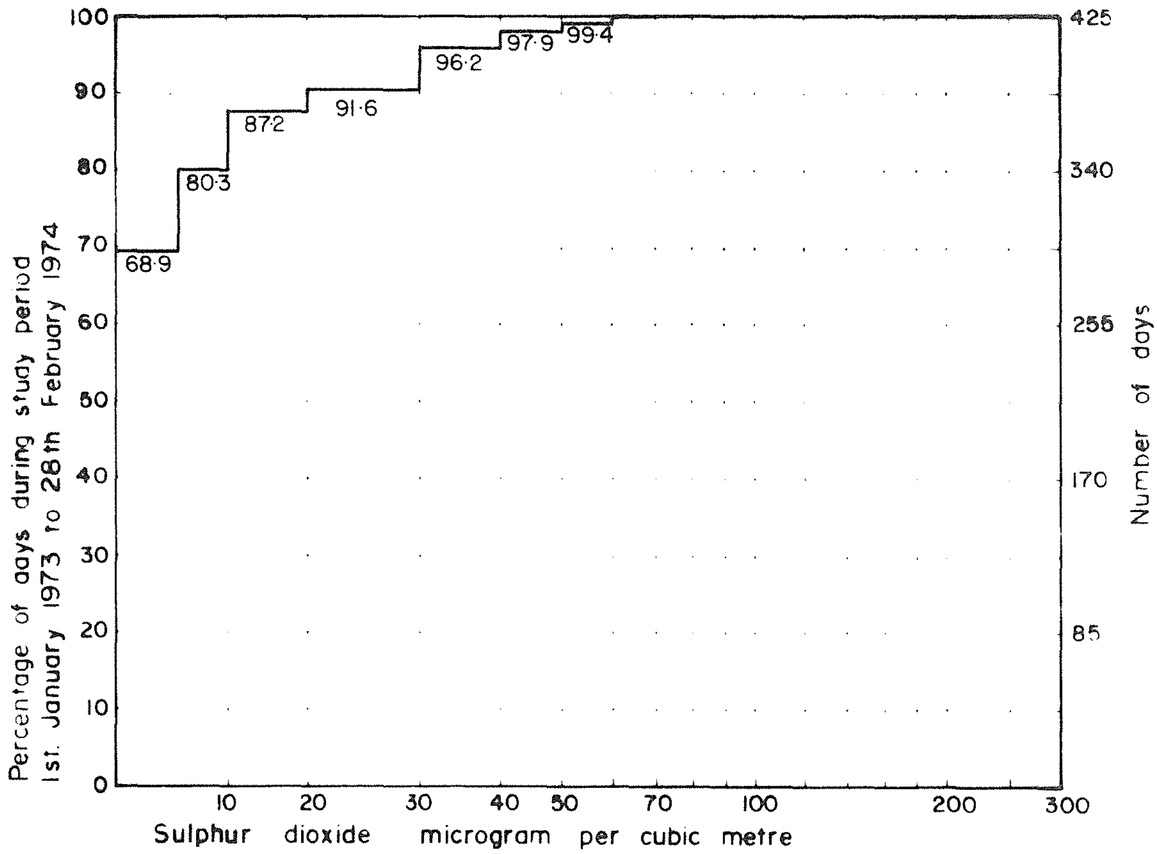


FIG 45: Vegetation Sampling Sites

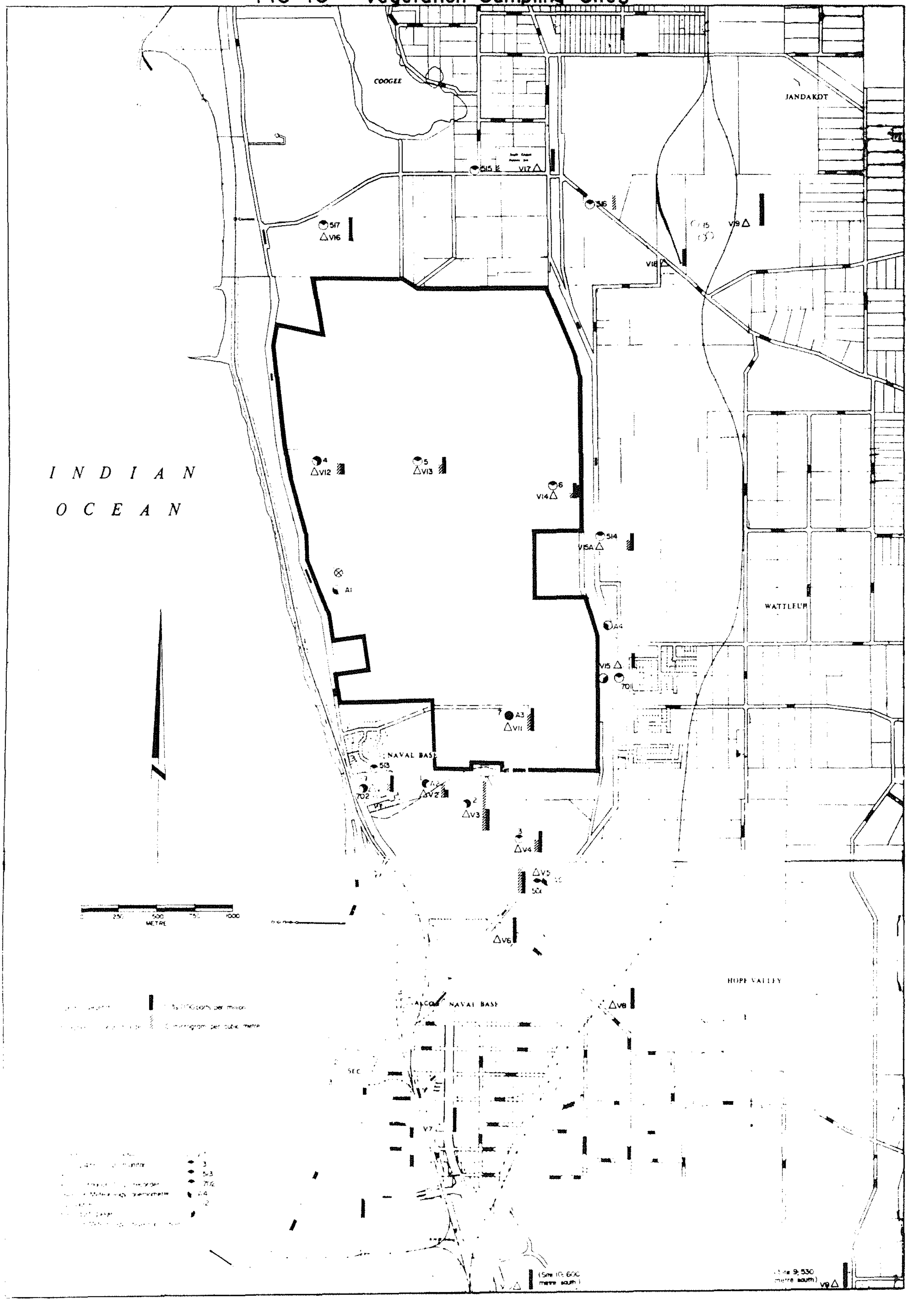


FIG: 46

Total Daily Output of
Sulphur Dioxide for all Industries South of C.A.P.S. Area
January 1973 to February 1974

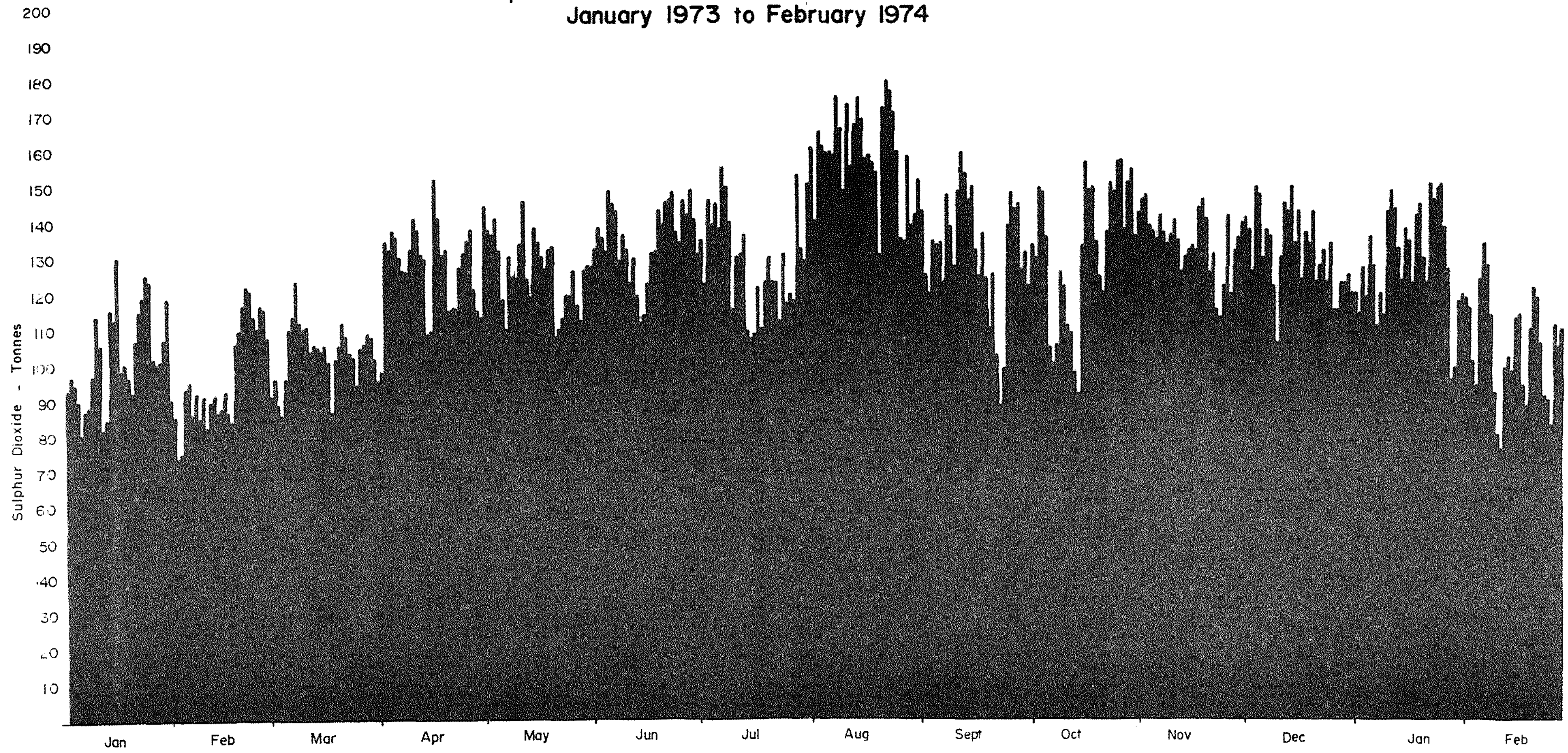


FIG: 47 Total Daily Output of Sulphur Dioxide for Industry 1 January 1973 to February 1974

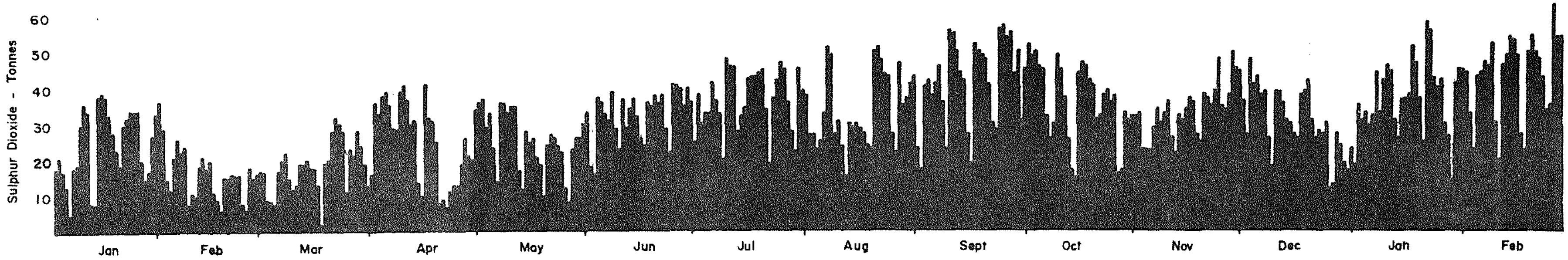


FIG 48 Total Daily Output of Sulphur Dioxide for Industry 2 January 1973 to February 1974

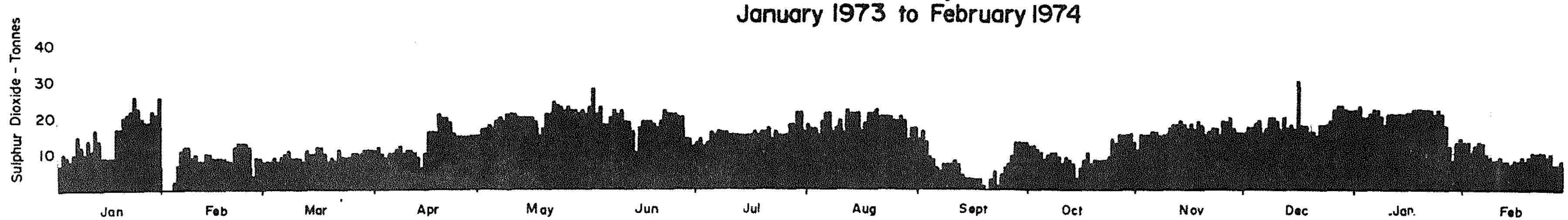


FIG 49 Total Daily Output of Sulphur Dioxide for Industry 8 January 1973 to February 1974

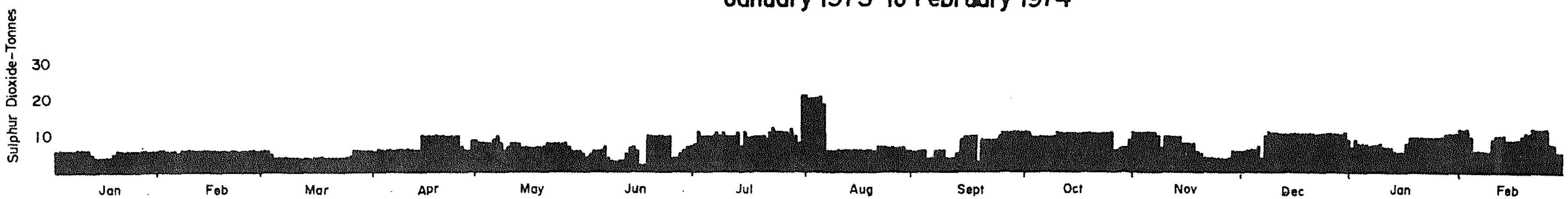


FIG 50: Camera Sites for Controlled Experiments

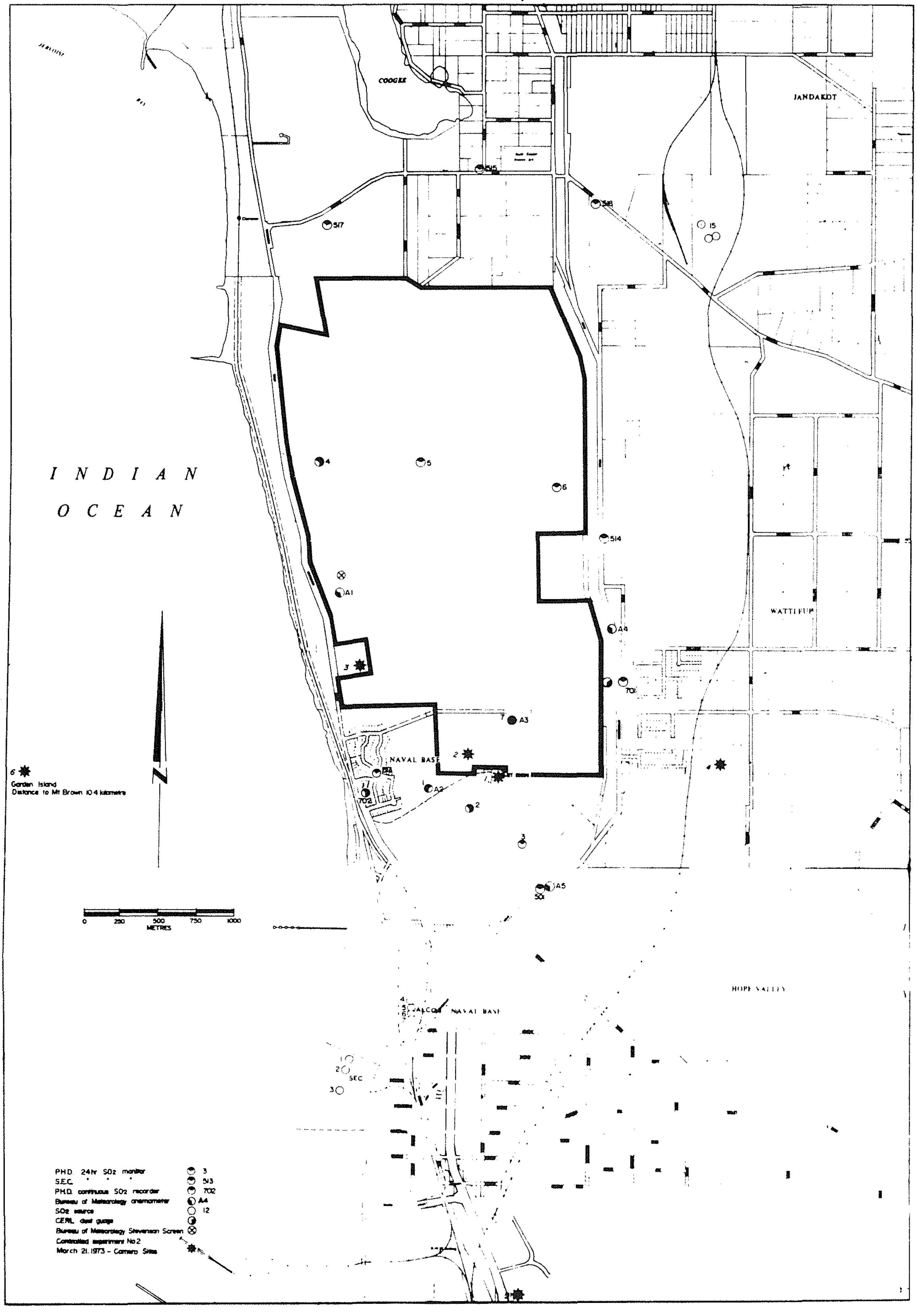
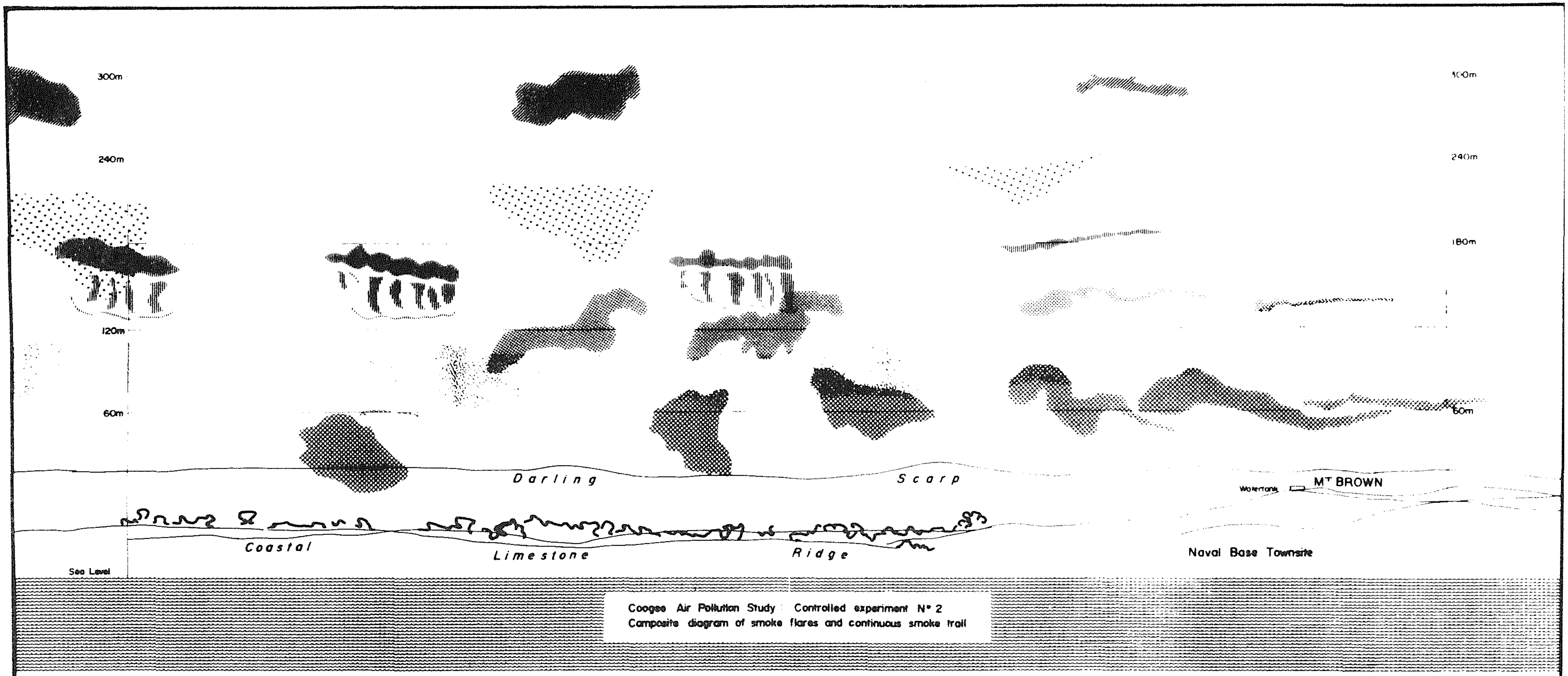
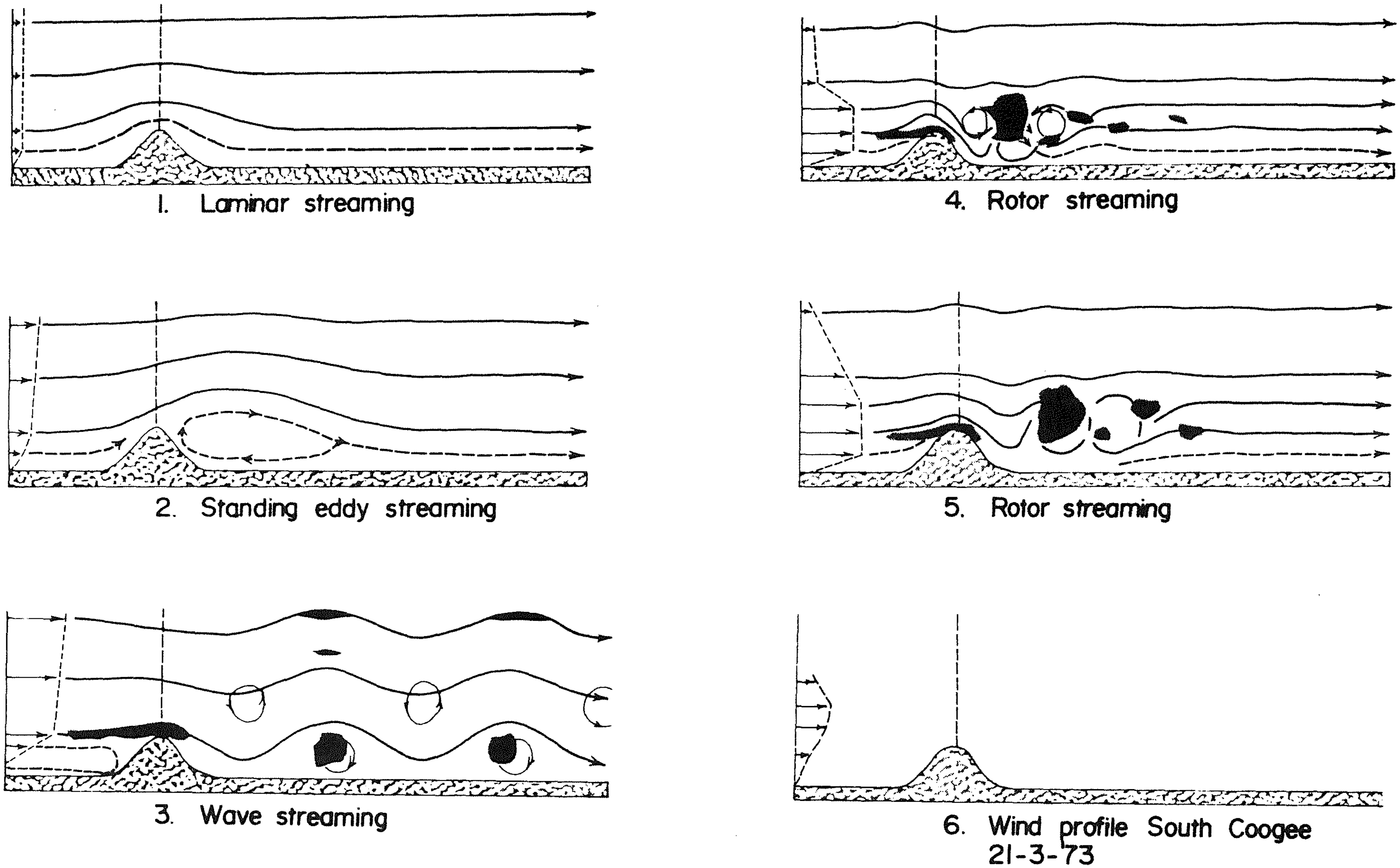


FIG 51



It is important to note that the smoke trails represented in this diagram do not indicate the position and magnitude of ground level concentration of sulphur dioxide. They represent only the visible part of the plume

FIG 52



CLASSIFICATION OF TYPES OF AIRFLOW OVER RIDGES. THE NATURE OF THE FLOW IS DETERMINED MAINLY BY THE WIND PROFILE INDICATED ON THE LEFT

FIG 53 : Ground Level Contours Obtained from Tracer Experiment

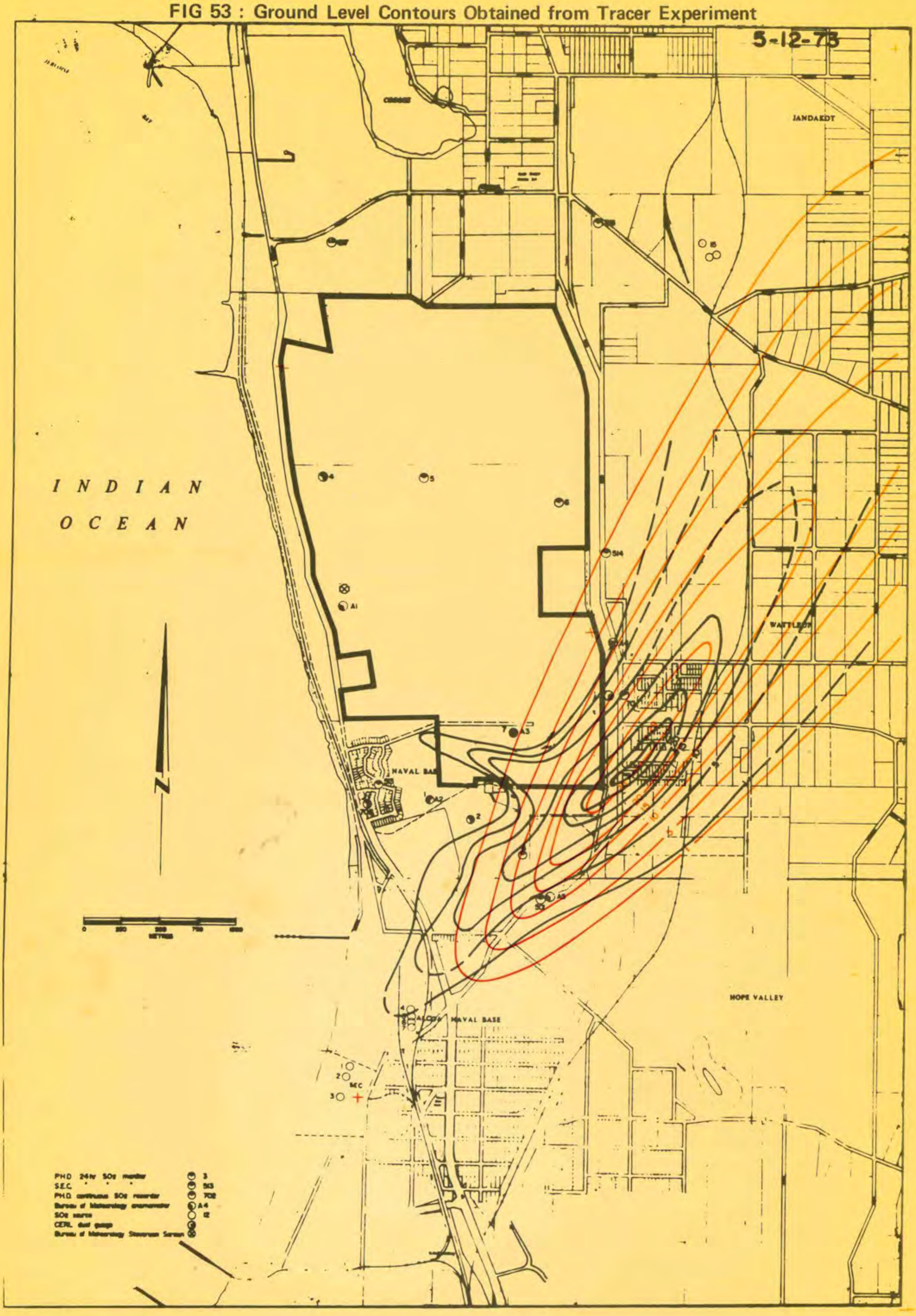


FIG 53 : Ground Level Contours Obtained from Tracer Experiment

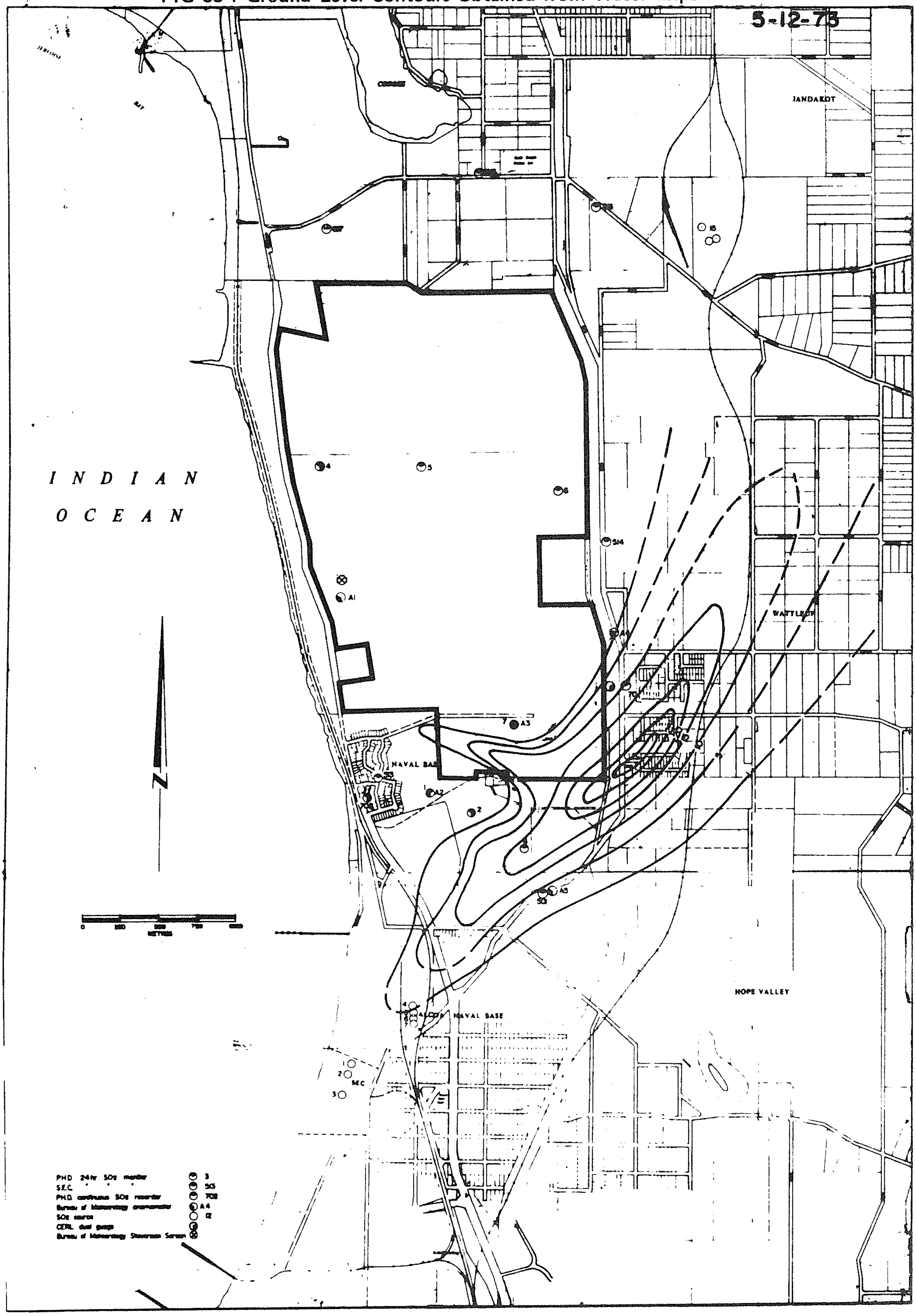


FIG. 54
Monitoring Site No. I

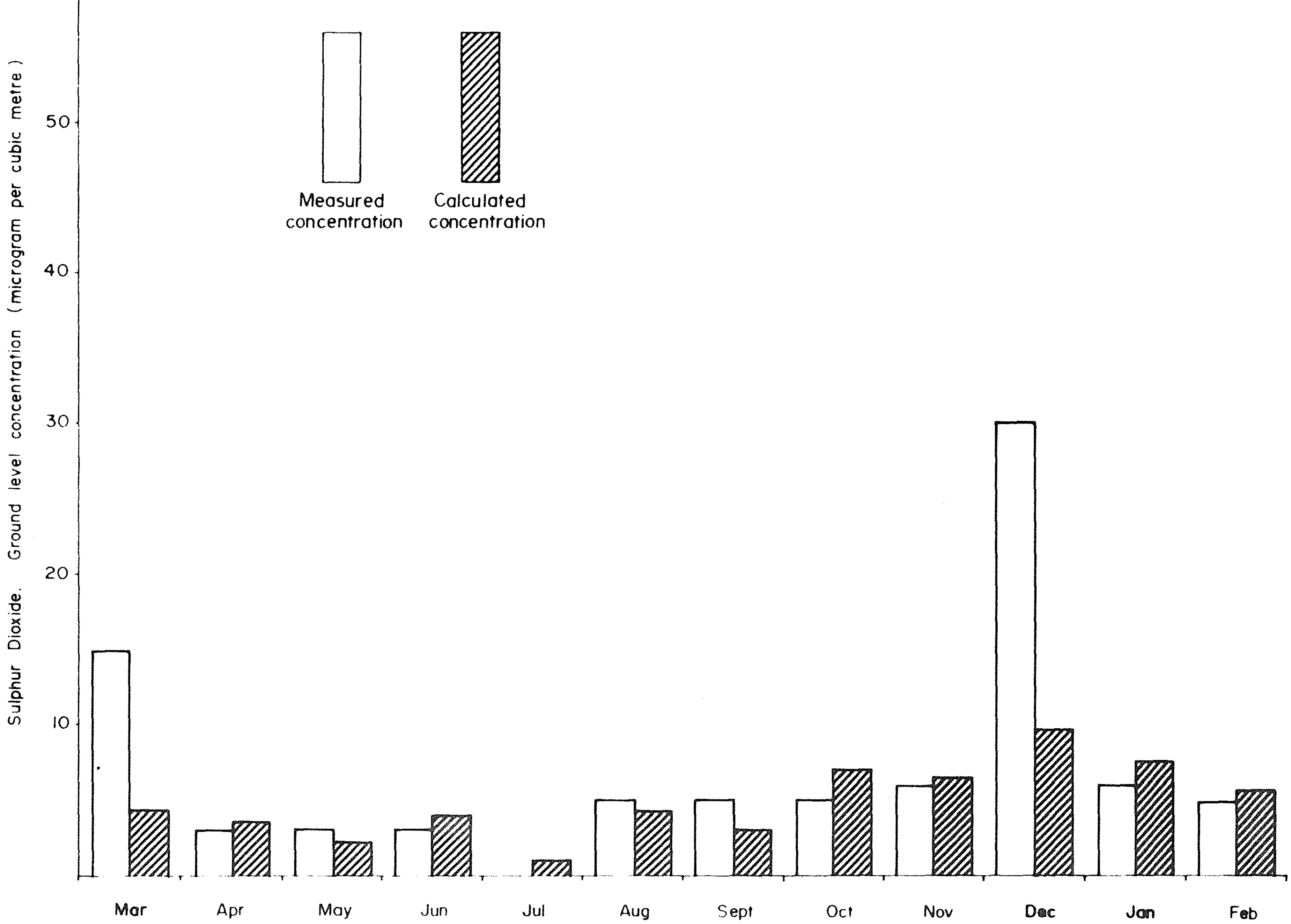


FIG. 55
Monitoring Site No. 2

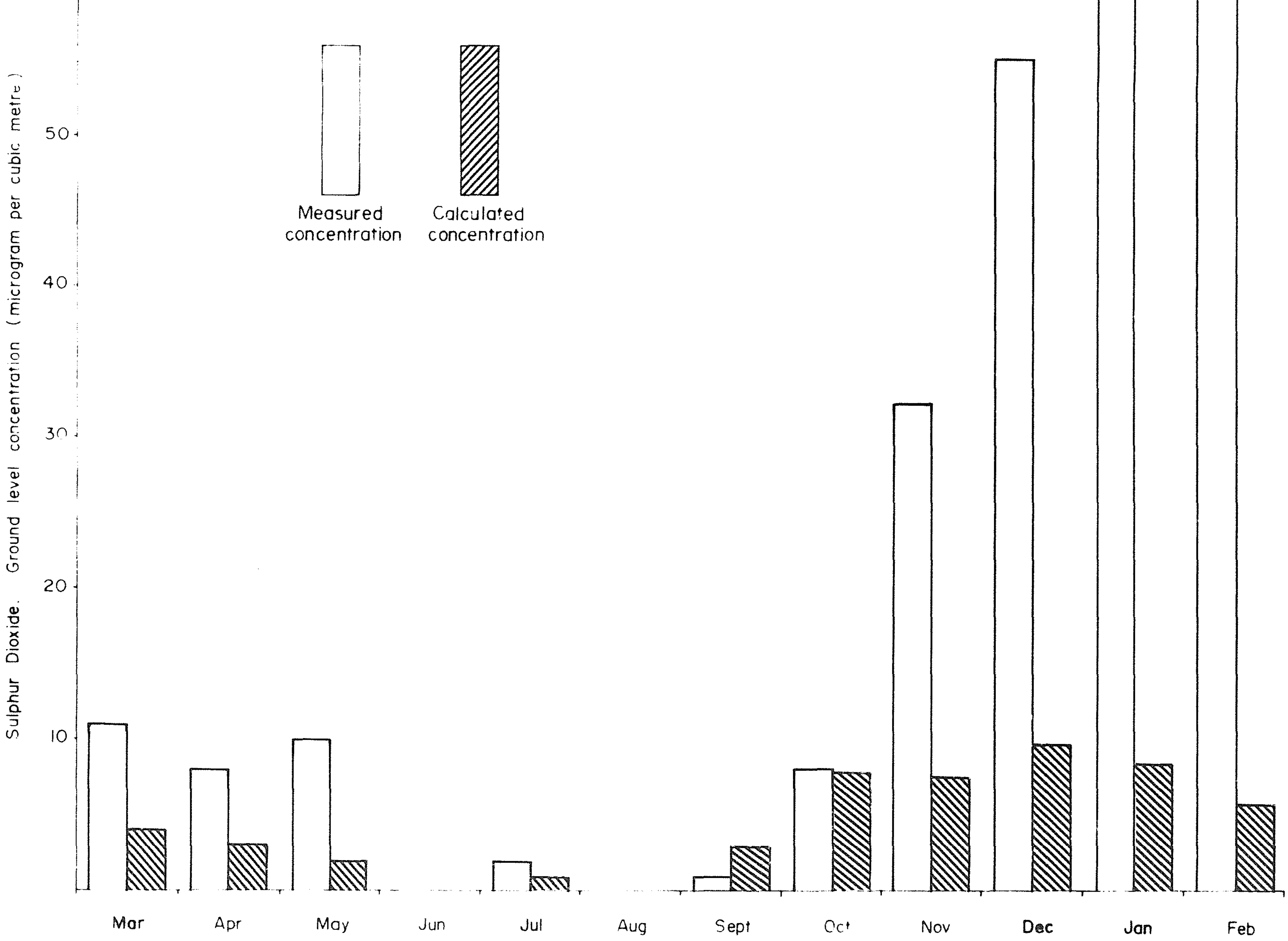


FIG. 56
Monitoring Site No. 3

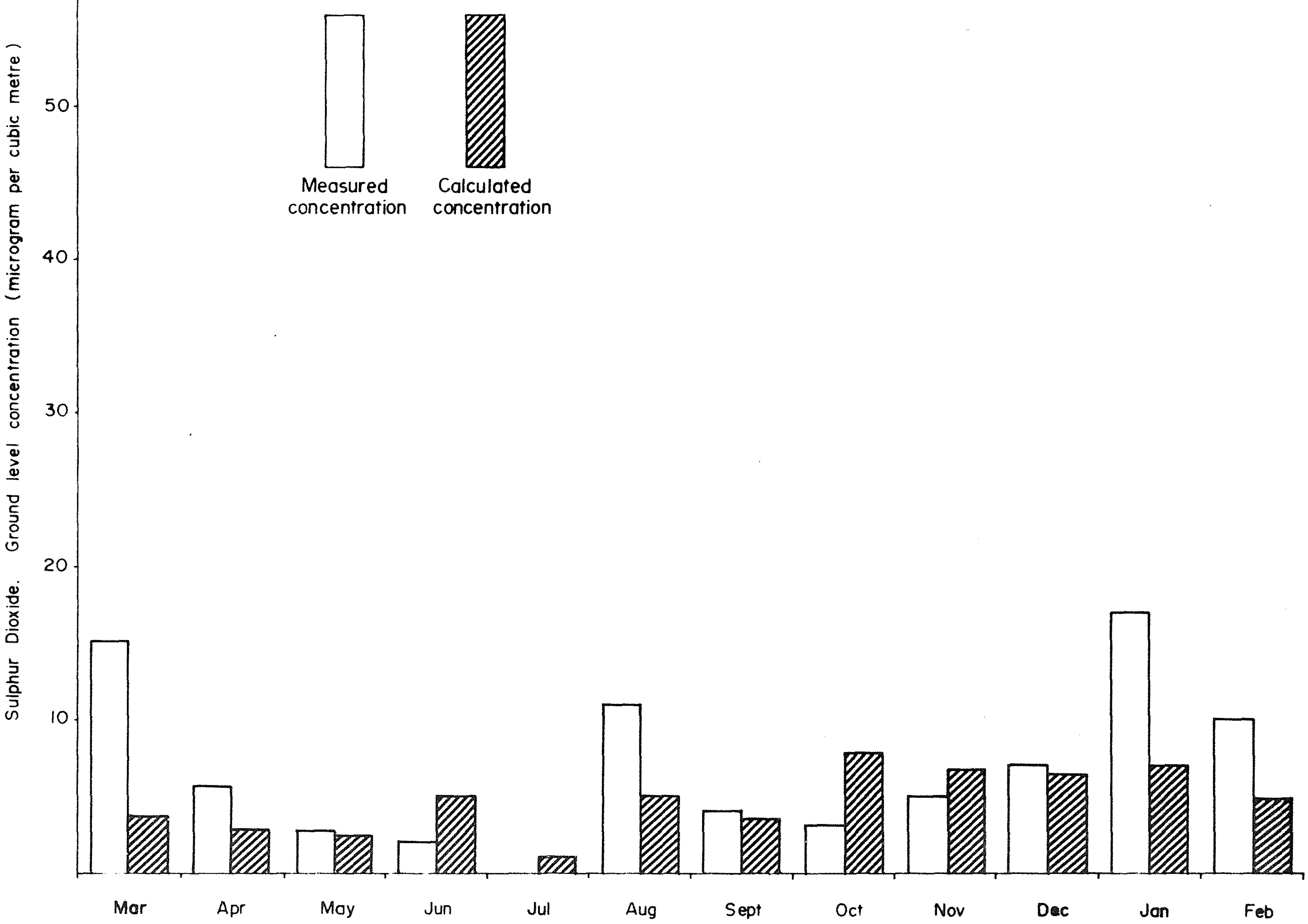


FIG. 57
Monitoring Site No. 4

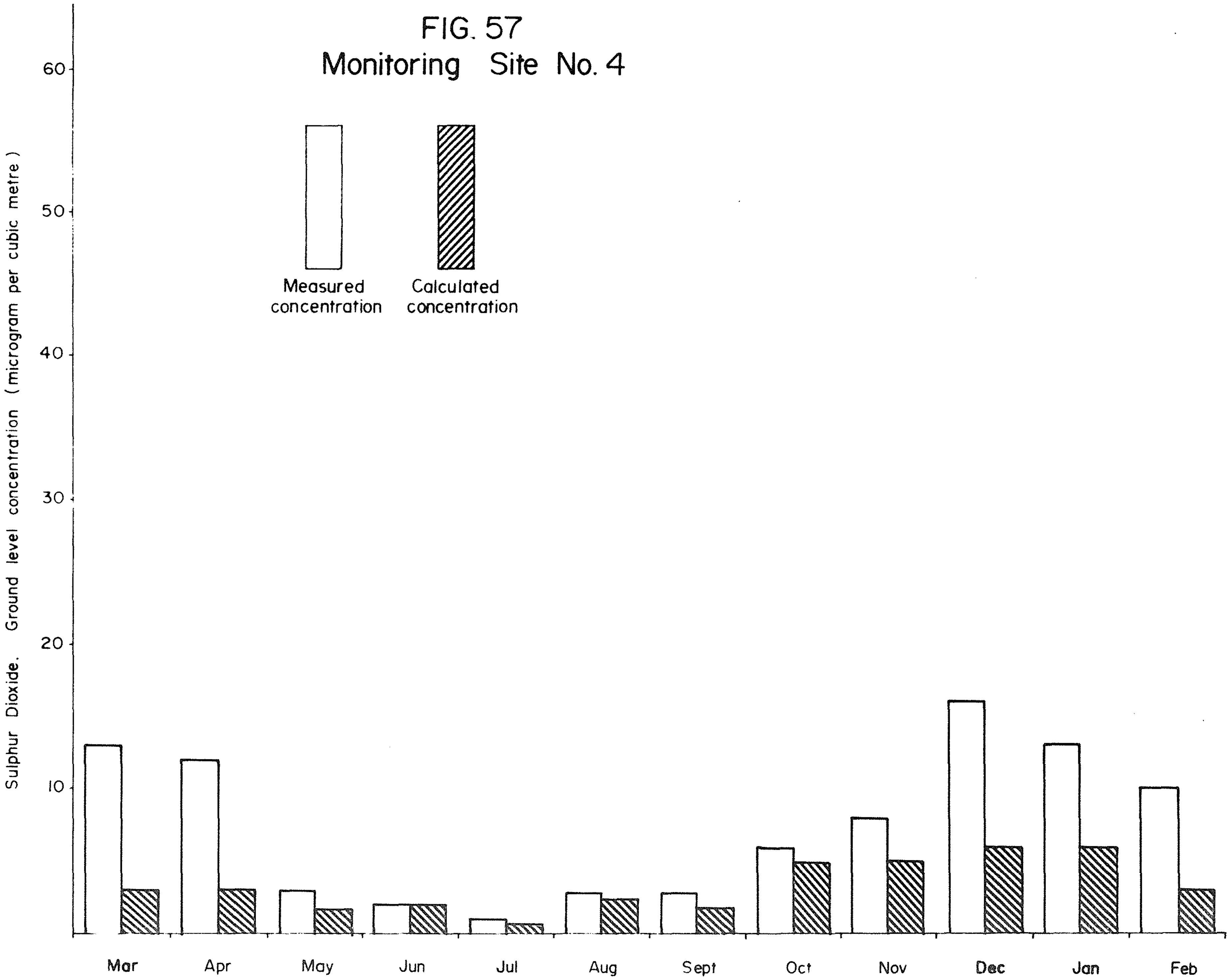


FIG. 58
Monitoring Site No. 5

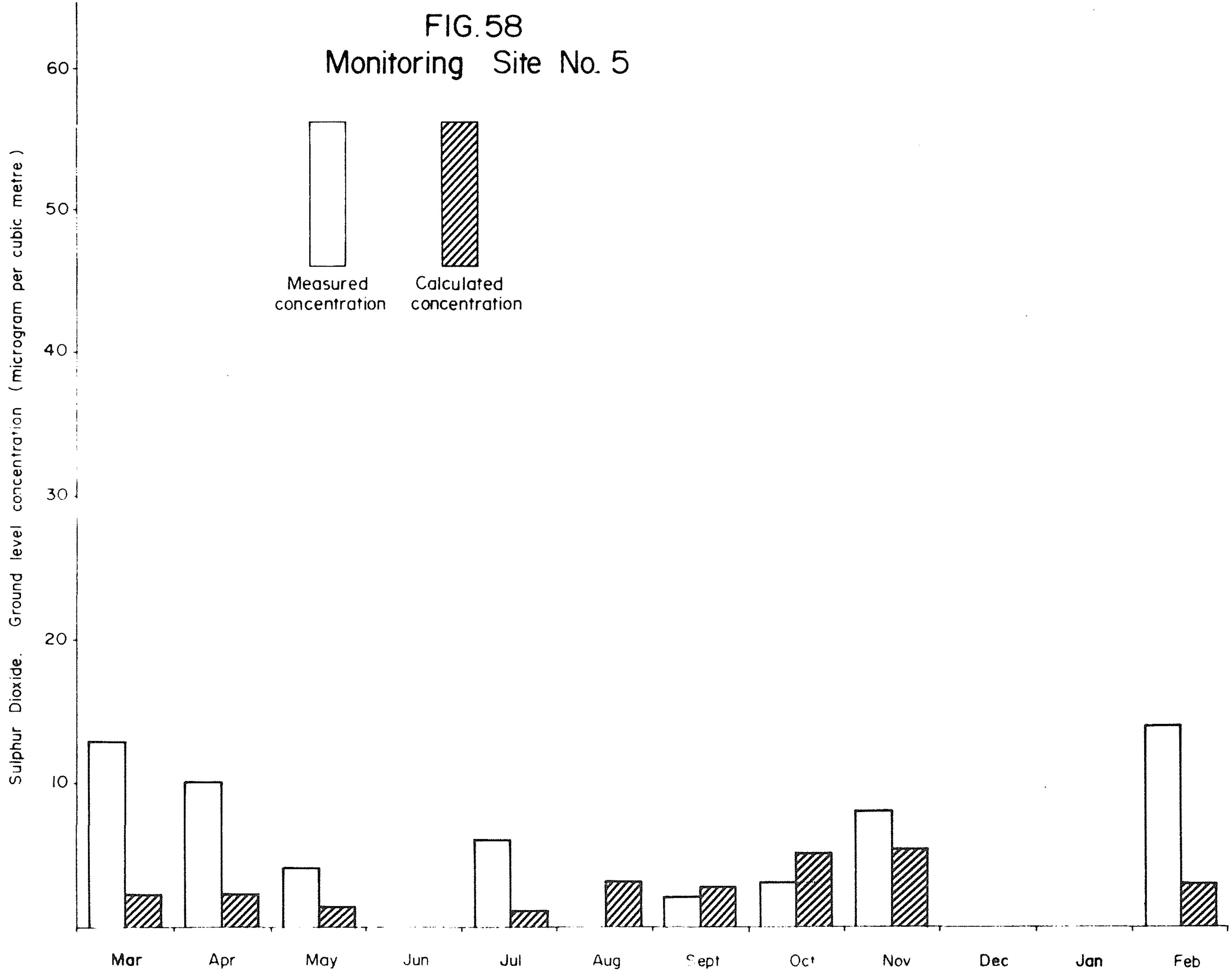


FIG. 59
Monitoring Site No. 6

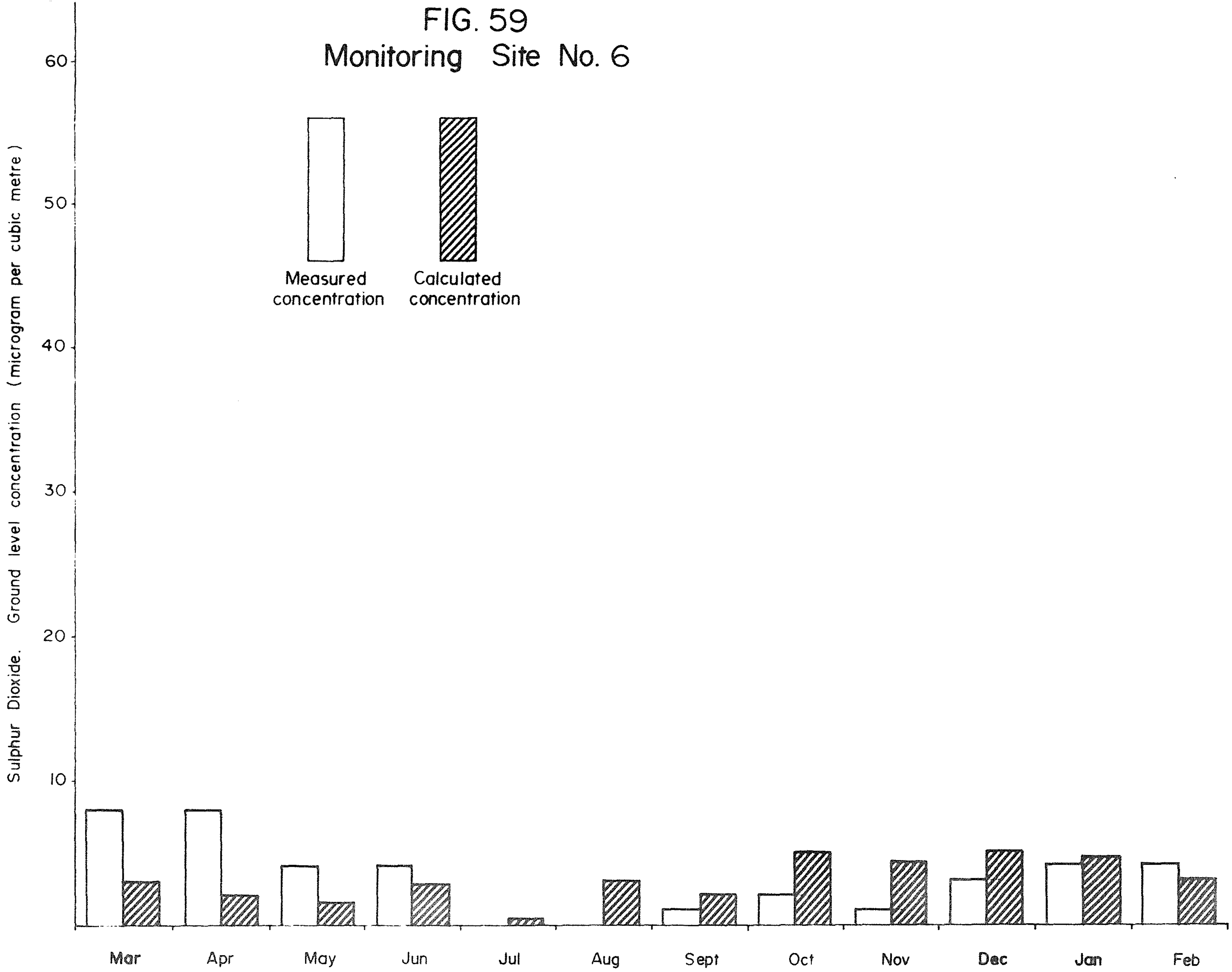
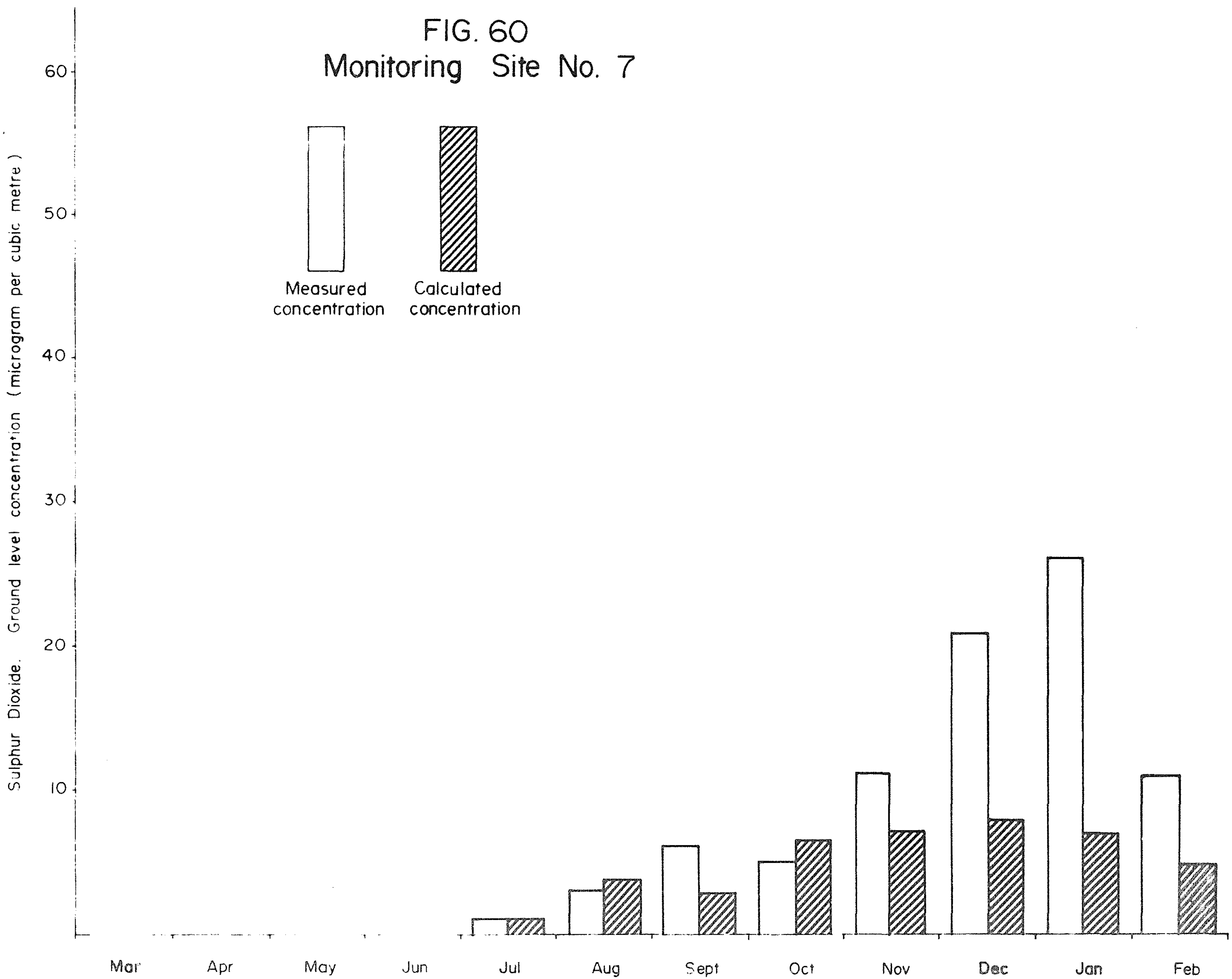


FIG. 60
Monitoring Site No. 7



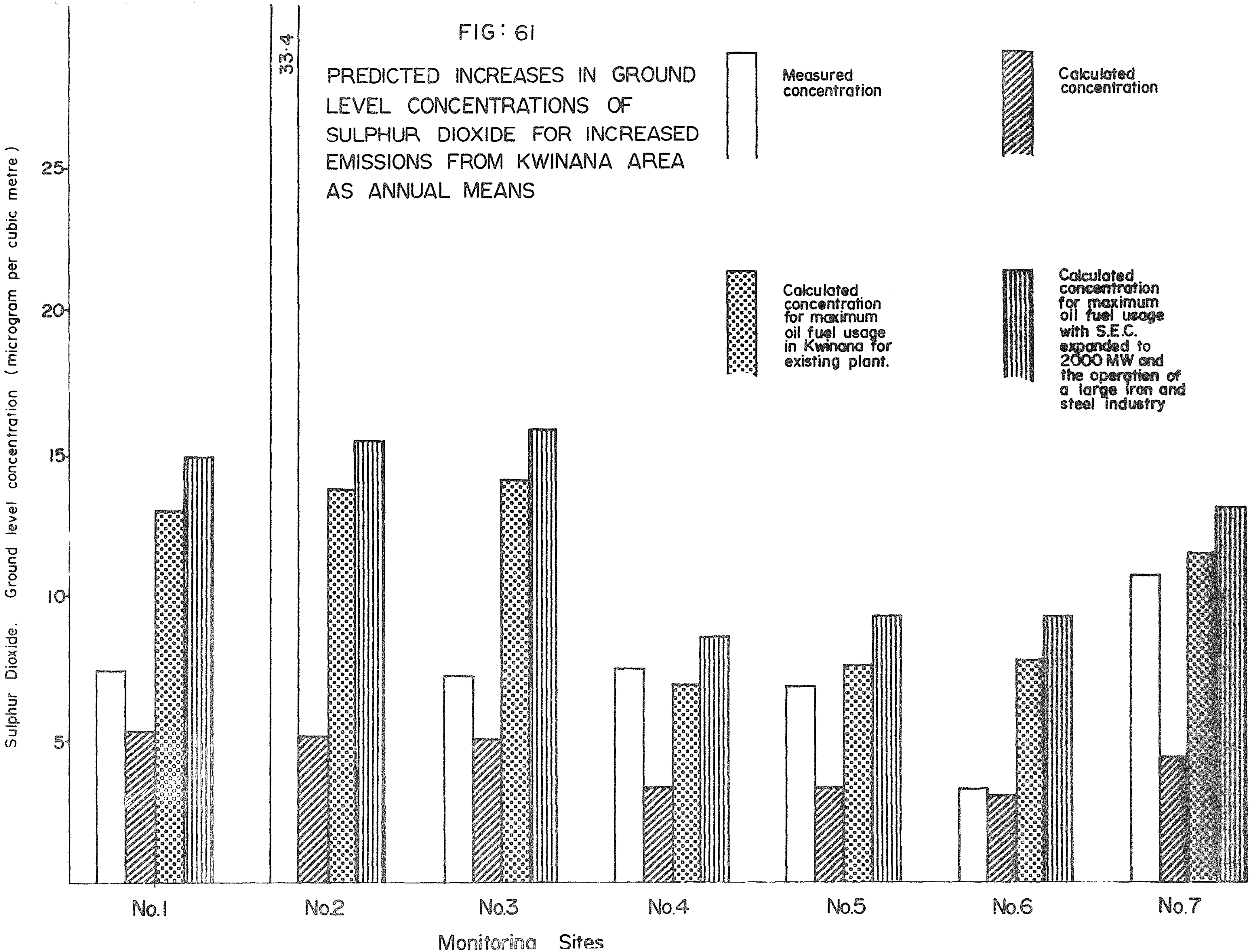


FIG: 61
PREDICTED INCREASES IN GROUND LEVEL CONCENTRATIONS OF SULPHUR DIOXIDE FOR INCREASED EMISSIONS FROM KWINANA AREA AS ANNUAL MEANS
Measured concentration
Calculated concentration
Calculated concentration for maximum oil fuel usage in Kwinana for existing plant.
Calculated concentration for maximum oil fuel usage with S.E.C. expanded to 2000 MW and the operation of a large iron and steel industry
33·4
Sulphur Dioxide. Ground level concentration (microgram per cubic metre)
25
20
15
10
5
No.1
No.2
No.3
No.4
No.5
No.6
No.7
Monitoring Sites

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APPENDIX

COOGEE AIR POLLUTION STUDY - PARTICIPATING PERSONNEL

Senior Working Group

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Members - Mr C.G. Carter, Deputy General Manager, State Electricity Commission

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Mr J.C.A. Hodgson, Secretary, Industrial Lands Development Authority

Dr J. McNulty, Physician in Charge, Occupational Health, Public Health Department

Mr L.F. Ogden, General Manager, BP Refinery, Kwinana

Mr R.L. Southern, Regional Director, Bureau of Meteorology

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Dr B.H. Hamilton, Department of Environmental Protection

Mr L.T. Jones, Department of Agriculture

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