Development of an environmental protection policy for air quality at Kwinana

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1. Introduction

The Environmental Protection (Kwinana) (Atmospheric Wastes) Policy 1992 was approved by the Minister for Environment on 17 July 1992 by order published in the Government Gazette of that date. In brief, this policy provides a basis for the establishment of ambient air quality objectives to protect the environment (including human health) in the municipalities of Cockburn, Kwinana and Rockingham and also provides a mechanism for effective achievement of sulphur dioxide and other objectives within the context of the multi-industry complex at Kwinana.

This report provides background information together with key determinations and results which arise out of the policy's implementation and are required by the policy to be published.

2. Air quality in the Kwinana area

Development of the Kwinana industrial area commenced in the mid 1950s. Kwinana today is a major heavy industrial area, with most industry concentrated in a strip of land about eight kilometres long adjacent to Cockburn Sound.

By far the most significant air quality issue to have arisen at Kwinana is the impact of sulphur dioxide caused by the combustion of sulphur-containing fossil fuels. In the late 1970s, total emissions of sulphur dioxide reached 300 tonnes per day. The most significant contributions to these emissions came from the combustion of heavy fuel oil at the Alcoa Alumina Refinery and the SECWA Kwinana Power Station, plus the processing of crude oil at BP Refinery without recovery of sulphur.

The Kwinana Air Modelling Study (KAMS, 1978-1982), was established by the then Department of Conservation and Environment in order to investigate the sulphur dioxide problem and develop procedures to manage it. The final report from this study (Paparo, 1982) summarised the results of sulphur dioxide monitoring in the Wattleup township, revealing a significant pollution problem. During January 1979, hourly averages of sulphur dioxide exceeded 1000 micrograms per cubic metre on 30 occasions, with a level of 1400 being exceeded nine times.

A key recommendation of KAMS was that a buffer zone be established between industry and areas of further urban expansion. This recommendation has influenced a number of planning decisions since that time and has more recently been accommodated within the Kwinana Region Strategy (1988).

The arrival of North West Shelf natural gas in 1984 vastly improved the air quality around Kwinana. The alumina refinery switched fully to this sulphur-free fuel. Due to the surplus supply of gas, SECWA also converted all units to burn gas. BP Oil Refinery remained the only large source of sulphur dioxide. During the mid 1980s, sulphur dioxide was much less of a pollution issue than odours. BP installed a sulphur recovery unit in 1989, further reducing the potential for high levels of sulphur dioxide in the environment.

North West Shelf gas has not proven to be a long-term solution to the sulphur dioxide problem in its own right. SECWA recommenced burning coal in significant quantities in 1988. Cockburn Cement has retained coal as a fuel and has recently been testing petroleum coke as a cheaper alternative to gas and coal. Western Mining Corporation is assessing coal as a fuel for the Kwinana Nickel Refinery, again for commercial reasons. BP intend to process higher sulphur crudes in coming years and, although hourly average emissions will not rise above previous maximum acceptable levels, they will be high for more of the time. Other small sources of sulphur dioxide are being added through new industries. Finally, although Alcoa have not decided to change from the use of gas, they clearly do not wish to be locked into using this fuel only, thereby potentially suffering commercial disadvantages.

In light of the above, the EPA has recognised the potential for the air quality around Kwinana to revert to a degraded state and has therefore moved to establish environmental objectives and associated procedures to maintain acceptable air quality.

Section III of the Environmental Protection Act provides for the establishment of an Environmental Protection Policy (EPP), which is a useful means of addressing the current situation at Kwinana. As described in Section 35 of the Act, an approved environmental protection policy may:

- identify the boundaries of the area, and the portion of the environment, to which the approved policy applies;

- identify and declare the beneficial uses to be protected under the approved policy;

- set out the indicators, parameters or criteria to be used in measuring environmental quality;

- specify the environmental quality objectives to be achieved and maintained by means of the approved policy; and

- establish a programme by which the environmental quality objectives are to be achieved and maintained, and may specify in that programme, among other things --

  - the qualities and maximum quantities of any waste permitted to be discharged into the relevant portion of the environment;

  - etc.

The EPP entitled Environmental Protection (Kwinana) (Atmospheric Wastes) Policy 1992, which is the subject of this report:

- identifies the area covered by the policy and three regions (industrial, buffer zone and rural/residential) within that area;

- establishes through associated regulations the air quality objectives for sulphur dioxide and particulates (with the opportunity for other pollutants to be added at later dates);

- allows the EPA to establish a procedure for determining and applying limits on the emissions from each industrial source so that the cumulative impact of all these emissions does not exceed the air quality objectives; and

- requires the industries to monitor pollutant levels at various locations in the environment (additional to the EPA's ongoing monitoring programme) and also to monitor emissions from the various industrial sources so that the achievement of policy objectives can be both verified and enforced.

It should be noted that, whilst the Policy Area includes an industrial zone which itself includes the land on which individual industrial premises are located, it is not the intention of this policy to set air quality objectives relating to occupational health in the workplace. In relation to the air quality within the boundaries of any industrial premises, the policy explicitly excludes from consideration that component of the concentration of any atmospheric waste which is caused by discharges of the waste from within that premises. In other words, the policy does apply to pollution from one industry affecting a neighbouring industry but does not apply to the pollution within an industry's boundary which the industry itself causes. The latter is the responsibility of the Department of Occupational Health, Safety and Welfare.

3. Air quality standards and limits

The EPP defines the terms "standard" and "limit" as follows:

- "standard" means the concentration of atmospheric waste which it is desirable not to exceed; and

- "limit" means the concentration of atmospheric waste which shall not be exceeded.

The EPP also defines three regions within the Policy Area for the purpose of establishing graded standards and limits. The regions are:

- Area A - the area of land on which heavy industry is located.

- Area B - an area surrounding industry, plus other outlying land zoned for industrial use.

- Area C - land beyond Areas A and B used predominantly for rural and residential purposes.

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Figure 3.1 is a map of a portion of the Policy Area showing the three regions and also showing the location of those industries which emit sulphur dioxide.

Initially the EPA has focussed on sulphur dioxide and particulates as being the two components of atmospheric waste requiring control. The EPA's rationale for setting standards and limits for these is outlined below.

3.1 Sulphur dioxide

Sulphur dioxide concentrations in the Kwinana area are caused predominantly by the combustion of fossil fuels which contain sulphur, with lesser amounts from sulphuric acid production and processing of other sulphur-containing materials. The largest industrial sources in Australia and world-wide are smelters and roasters which oxidise sulphide ores; there are no such industries at Kwinana.

Sulphur dioxide is a colourless, pungent, irritating gas that reacts on the surface of a variety of airborne solid particles. It is readily absorbed in the upper respiratory system and, at high concentrations, it causes acute bronchoconstriction and related effects. Individual sensitivity varies over a wide range, with some asthmatics being particularly susceptible to respiratory effects at quite low concentrations. Its effects are made worse in the presence of particulate matter which is of respirable size or present in the sub-micron range. Sulphur dioxide dissolves in moisture which is readily absorbed onto small particles, resulting in a dilute mist of sulphuric acid and sulphates. In this form, it can also cause leaf damage to plants, corrosion on metals, and deterioration of a wide range of building material. Acid rain caused by the atmospheric discharge of sulphur dioxide and oxides of nitrogen has caused major environmental damage to forests and lakes in the northern hemisphere.

The guidelines for sulphur dioxide which have been considered in arriving at the figures for Kwinana are set out in Table 3.1.

Table 3.1 Guidelines for ground level concentrations of sulphur dioxide (micrograms per cubic metre) for specified averaging periods

GUIDELINES	1-HOUR	24-HOUR	ANNUAL
NHMRC / ANZEC [1] goals	700		60
EPA of Victoria:			
- acceptable level [2]	486	171	
- detrimental level [3]	972	314	
World Health Organisation [4]	350	125 [5]	50 [5]
United States EPA:			
- primary standard		365 [6]	80

NOTES:

All values expressed as micrograms per cubic metre at 0 degrees Celsius and 101.3 kilopascals.

(1) NHMRC / ANZEC -- National Health and Medical Research Council / Australia and New Zealand Environment Council

(2) acceptable level is not to be exceeded on more than three days per year

(3) detrimental level is not to be exceeded

(4) WHO Air Quality Guidelines for Europe, 1987

(5) based on combined exposure to sulphur dioxide and particulate matter

(6) not to be exceeded more than once per year

Cockburn Cement

ALCOA Kwinana
Alumina Refinery

SECWA Kwinana
Power Station

HIsmelt Corporation

AREA A
Shaded

BP Refinery

TIWEST Kwinana
Pigment Plant

CSBP Kwinana

WMC Kwinana
Nickel Refinery

Thomsons Lake

PORTION OF AREA B

PORTION OF AREA C
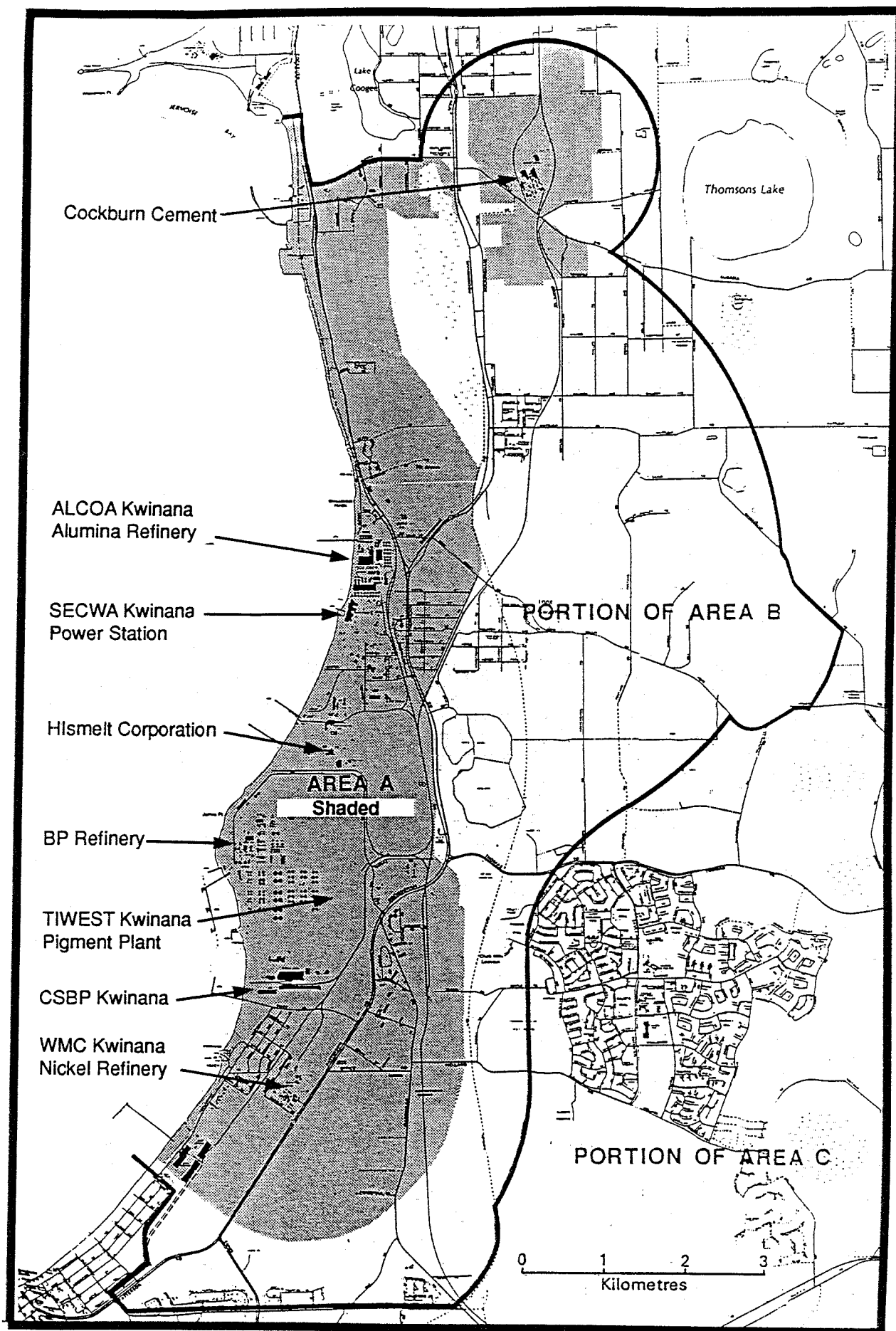
0   1   2   3
Kilometres

Figure 3.1. Portion of the Policy Area showing industries which emit sulphur dioxide.

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The selected standards and limits for the regions within the Policy Area are listed in Table 3.2.

Table 3.2 Sulphur dioxide standards and limits (micrograms per cubic metre) for the Policy Area for specified averaging periods

REGION	1-HOUR	24-HOUR	ANNUAL
AREA A standard limit	700 1400	200 365	60 80
AREA B standard limit	500 1000	150 200	50 60
AREA C standard limit	350 700	125 200	50 60

3.2 Particles - total suspended particulates

Airborne particulate matter represents a complex mixture of organic and inorganic substances. Mass and composition tend to divide into two principal groups: course particles larger than 2.5 micrometres in aerodynamic diameter, and fine particles smaller than 2.5 micrometres in aerodynamic diameter. The smaller particles include secondarily formed aerosols, combustion particles and recondensed organic and metal vapours. The larger particles usually comprise earth crustal materials and fugitive dust from roads and industries.

The method generally used to measure total suspended particles is high volume sampling which forms the base of Australian Standard 2724.3 - 1984. This measurement procedure measures particulate matter with an equivalent aerodynamic diameter of less than 50 micrometres. There are problems with this method however, in that the size range of particles sampled extends well beyond those particles that are able to penetrate the upper respiratory tract. This problem is now well recognised and measurement of particulate matter of less than 10 micrometres aerodynamic diameter (PM_{10}) is becoming widespread both nationally and internationally. Measurement of particles in this size range is achieved by a size selective head attached to a normal high volume sampler. It is now well recognised by national and international health authorities that the PM_{10} measurement provides a better indicator of health-related particles.

At present Australia's NHMRC recommends an annual mean of 90 micrograms per cubic metre (ug/m^3) for total suspended particulates (TSP). The PM_{10} fraction at present does not have an Australian air quality guideline. The United States Environmental Protection Agency's recommended standard has two components, namely an annual primary standard of 50 ug/m^3 and a 24-hour value of 150 ug/m^3. In his recent review of Victoria's air quality guidelines, Dr Streeton recommends the introduction of 24-hour and annual standards for inhalable particulate matter (PM_{10}) as follows :

    24-hour average:
        acceptable - 120 ug/m^3
        detrimental - 250 ug/m^3
    annual average:
        acceptable - 40 ug/m^3
        detrimental - 80 ug/m^3

The EPA has adopted a 15-minute average limit for total suspended particulates of 1000 ug/m^3, originally established to control nuisance-causing dust from stock holding paddocks.

The selected standards and limits for the regions within the Policy Area are listed in Table 3.3.

Table 3.3 Total suspended particulates standards and limits (micrograms per cubic metre) for the Policy Area for specified averaging periods

REGION	15 MINUTE	24-HOUR
POLICY AREA limit	1000	
AREA A standard limit		150 260
AREA B standard limit		90 260
AREA C standard limit		90 150

4. Developing an air quality management strategy

4.1 Rationale

Given a set of ambient air quality objectives (standards and limits), how can these be imposed and enforced in the context of a multi-industry complex such as the Kwinana industrial area?

The simplest means of imposing such objectives, from the EPA's viewpoint, would be to incorporate them in some form of subsidiary legislation (EPP or regulation) which makes it an offence not to comply with the objectives. The objectives could also be included in conditions of licence on each industry, making it an offence for an individual industry to cause or contribute to an exceedance of the objectives.

However, in the context of an industrial complex like Kwinana with a clear potential for air quality problems, compliance with such subsidiary legislation and/or licence conditions by industries, and enforcement of it by the EPA, would be extremely difficult for the following reasons:

• without some reliable means of prediction, the only way to assess whether the objectives were being met or not would be to install a dense and widespread system of pollutant monitoring stations, which would be prohibitively expensive and unmanageable;

• given the large number of variables which affect the ground level concentration pattern caused by a particular industrial source (eg stack height, stack gas flow rate, stack gas temperature, meteorological conditions etc.), individual industries would be hard pressed to know how to manage their emissions so as to control the ground level concentrations caused by themselves, let alone the concentration resulting from the combined emissions of many independent industries plus the emissions from non-industrial sources; and

• correspondingly, if an exceedance of the objectives was measured, the EPA's task of proving beyond reasonable doubt that one or more industries were contributors would be very difficult.

Each of the above reasons relate to the fact that the relationship between emissions of a pollutant from individual industrial sources and the cumulative concentration of that pollutant in the environment is exceedingly complex and, unfortunately, cannot be ignored or avoided. Rather than leaving individual industries to struggle with this complexity, the EPA has chosen to confront it directly by determining (to the best of our ability) limits on the emissions from each industrial source or measures to be taken to limit emissions, designed to achieve compliance with the air quality objectives. Individual industries will be held responsible, not for complying with the air quality objectives (over which they have limited and ineffective control), but rather for complying with limits on the discharge from their chimneys (over which they are obliged to have direct control) or for complying with specified emissions control measures.

For some air contaminants which do not currently constitute a significant problem in the environment, the task of setting emissions limits or control measures can be done in a simple fashion using the existing powers of the Act. For example, particulate levels in the environment around Kwinana are generally well within acceptable levels and, in any event, most of the particles in the atmosphere come from sources other than local industry (eg rural activity, bushfires, domestic fires etc). Hence we can set particulate emission limits on some sources and emissions control measures on others which require the respective industries to operate to a standard consistent with good engineering practice and environmental management (as required by Section 51 of the Environmental Protection Act). We can also require the industries to undertake monitoring at a few points in the environment (in addition to the EPA's own monitoring programme) to be satisfied that particulate levels are within the EPP objectives. Any exceedances of the objectives would be investigated on a case by case basis. The EPP gives the Chief Executive Officer the flexibility to decide, for each component of atmospheric waste included in its regulations, whether to control the emission of that waste via the general provisions of the Act or to follow the method outlined in Clause 7 and beyond, as discussed in detail below. We can note at this point that particulates will be handled via the general provisions of the Act, because:

(i) they do not currently warrant more complicated treatment; and

(ii) quantitative emissions limits can not be sensibly determined for some industrial sources like stockpiles and ship loading facilities.

The remainder of this report will refer to the development and implementation of a strategy to achieve the ambient air quality objectives for sulphur dioxide. This strategy is embodied in general terms in the EPP and may in the future also be applied, at the Chief Executive Officer's discretion, to control the discharge of other components of atmospheric waste which are amenable to the same type of management.

For air contaminants like sulphur dioxide which are potentially a problem and which are totally or predominantly emitted by industry, determining limits on source emissions in order to achieve the ambient air quality objectives is a necessary and critical step, requiring an application of the best available scientific theory for calculating ground level concentrations of pollutants. In the case of Kwinana, such theory has been developed and tested in the field at various stages over the past decade (particularly during the Kwinana Air Modelling Study) and has been incorporated into a computer model called DISPMOD. This model takes in data describing the industrial emissions and the meteorology for every hour of a year and provides predictions of the ground level concentrations over the Kwinana region for that year, summarised into various usable forms. For example, estimates of emissions limits for all sources can be put into the model to check that the predicted ground level concentrations do not exceed air quality objectives in any of the Policy Areas (this will be discussed in more detail later).

The EPA is acutely aware that the computer model is an approximation to the real world and should not be expected to give highly accurate predictions. Atmospheric turbulence which drives the dispersion of air pollutants is a highly random phenomenon which defies accurate prediction. Nevertheless, computer models such as DISPMOD represent the best available means of predicting the ground level concentration of pollutants from industrial sources, particularly if predictions of concentrations over averaging times as short as one hour are required (as is the case here). Any alternative prediction scheme which fails to account for the

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variables associated with individual sources (listed above), coupled with the effects of industry separation distances and orientations, will inevitably give less reliable predictions.

The overall strategy adopted by the EPA for sulphur dioxide and similar pollutants, which takes due account of the uncertainty of model predictions, is as follows (words in bold reflect terminology in the EPP):

- develop a **procedure**, customised for the component of **atmospheric waste** (air pollutant) in question, to **determine the maximum permissible quantities** of atmospheric waste from each significant industrial source (ie the emissions limits) so that the air quality objectives (standards and limits) can, **in the opinion of the Chief Executive Officer of the EPA**, be achieved and complied with; (EPP Clause 7(1));

- apply this procedure (which will almost certainly include the use of a computer model) to determine the emissions limits; (EPP Clause 7(3));

- enforce these emissions limits via licence conditions on industries in order to achieve and comply with the air quality objectives; (EPP Clauses 8, 9 and 10);

- require industries to undertake monitoring of the atmospheric waste at key locations in the Policy Area; (EPP Clause 11);

- require industries to undertake monitoring of their emissions to demonstrate compliance with licence conditions; (EPP Clause 11);

- investigate any exceedance of air quality objectives which appears in the monitoring data to see whether industries were complying with emissions limits at the time; and

  - if they were, review the adequacy of the procedure and decide whether a redetermination of emissions limits is necessary (EPP Clause 13); and

  - if they were not, take appropriate action (possibly recommending prosecution if there appears to have been a deliberate breach of conditions),

- use the combined monitoring results to improve the procedure (eg to improve the prediction capability of the model) and to assess the need for a redetermination of emission limits, either upward if measured concentrations indicate the model has over-predicted ground level concentrations, or downward if measured concentrations indicate the model has under-predicted (particularly if measurements show that the objectives have been exceeded).

In summary, the strategy employs best predictions coupled with feedback of data and corrective measures to provide a pollution control strategy which is manageable by both industry and the EPA and will ensure clean air in the surrounding environment.

4.2 Description of the computer model

The computer model DISPMOD was developed during the Kwinana Air Modelling Study (KAMS) and has subsequently been tested and upgraded as far as is reasonably possible with the data available at this time. The model is described in summary form in the KAMS final report (Paparo, 1982) and in more detail by Rayner (1987).

The following brief description of the model and its upgrades is necessarily technical. General readers may wish to skip to the next section.

DISPMOD, in the form used for this study, relies on the output data from two other models which process the available meteorological data, namely:

- a model called SOIL which takes in surface meteorological data and, by simulating the soil surface temperature and moisture variations, provides estimates of the surface layer turbulent fluxes of heat, moisture and momentum, which are key determinants of atmospheric stability (the positive or negative tendency for turbulent mixing and dispersion to occur);

- a model called WML which takes the output of the first model together with a dawn measurement of the atmospheric temperature profile, obtained from an airport radiosonde, and calculates the growing depth throughout each day of the turbulent mixed layer under off-shore winds. This model also calculates the strength of the capping inversion within the

thin layer immediately above the well mixed layer, for use in calculating the fraction of a plume which will penetrate the inversion.

Both of these model are described by Rayner (1987) and the second is verified against field data by Rayner and Watson (1991).

DISPMOD is a Gaussian plume model into which has been built the capability to simulate the dispersion of plumes from tall stacks near the coast under onshore winds. When onshore flows encounter the coastline, the sudden change in surface roughness, heating and evaporation rates leads to the formation of an internal boundary layer over the land, shown schematically in Figure 4.1. The situation of most significance occurs during daytime when a thermal internal boundary layer (TIBL) forms within cool onshore flow over warm land. In this case, the strength of turbulence (driven by convective heating) and hence also the dispersive capability of air within the TIBL is far greater than that of the marine air. Figure 4.1 shows a plume released in stable onshore flow, dispersing slowly downwind (possibly for several kilometres) until it intersects a growing TIBL, from where it is mixed rapidly to ground-level, resulting in higher short-term concentrations than would otherwise occur that far from the source (note the compressed horizontal scale in Figure 4.1). This phenomenon is called "shoreline fumigation" and is a major consideration in dispersion modelling for coastal sites.

If the meteorology of a coastal region is such that a regular pattern of onshore winds occurs over a season or longer, then a particular locality downwind of the industrial sources may experience fumigation events as frequently as daily over that time of the year. Such is the case at Kwinana where sea breezes occur on more than 50% of days during the months of October to March and less frequently in the remaining autumn and spring months. Unlike the transient fumigation events associated with the erosion of radiation inversions, the shoreline fumigation process may persist for a period of a few hours on any particular day. During this period the location of peak concentrations may move over a wide area downwind, as various meteorological and source parameters change. To simulate this phenomenon we need a model in which the TIBL and source plumes are accurately described in relation to each other and, since these are independent physical phenomena, each must be independently and accurately described. Specifically, a shoreline dispersion model must be able to describe the important features of the fumigation process which are:

- intersection of the rising or levelled plume with the growing boundary layer;

- subsequent entrainment of pollutants into the boundary layer;

- rapid vertical mixing of pollutants within the boundary layer, and

- enhanced lateral spread of pollutants within the boundary layer.

DISPMOD uses as input data the output of the model WML which includes all the necessary meteorological data in the form of 10-minute averages. It also takes in data describing the layout of the industrial area and the emissions from each industrial source. As it processes each meteorological record in turn, the model checks whether the wind is off-shore or on-shore; if it is the latter, the shoreline fumigation calculations are invoked. Ground level concentrations are calculated at gridpoints 1km (or less) apart over an area nominally 26km by 21km.

The model provides the following output options which may be plotted as contours on a base map of the Kwinana region:

- annual averages;

- number of times per year that a nominated ground level concentration is exceeded;

- maximum 24-hour average concentrations;

- maximum one hour average concentrations; and

- 99.9 percentile one hour average concentrations (ie ninth highest).

The 24 and one hour averages, as contoured, are values for each and every gridpoint which are unrelated in time (ie neighbouring values may have occurred on different days). The model also
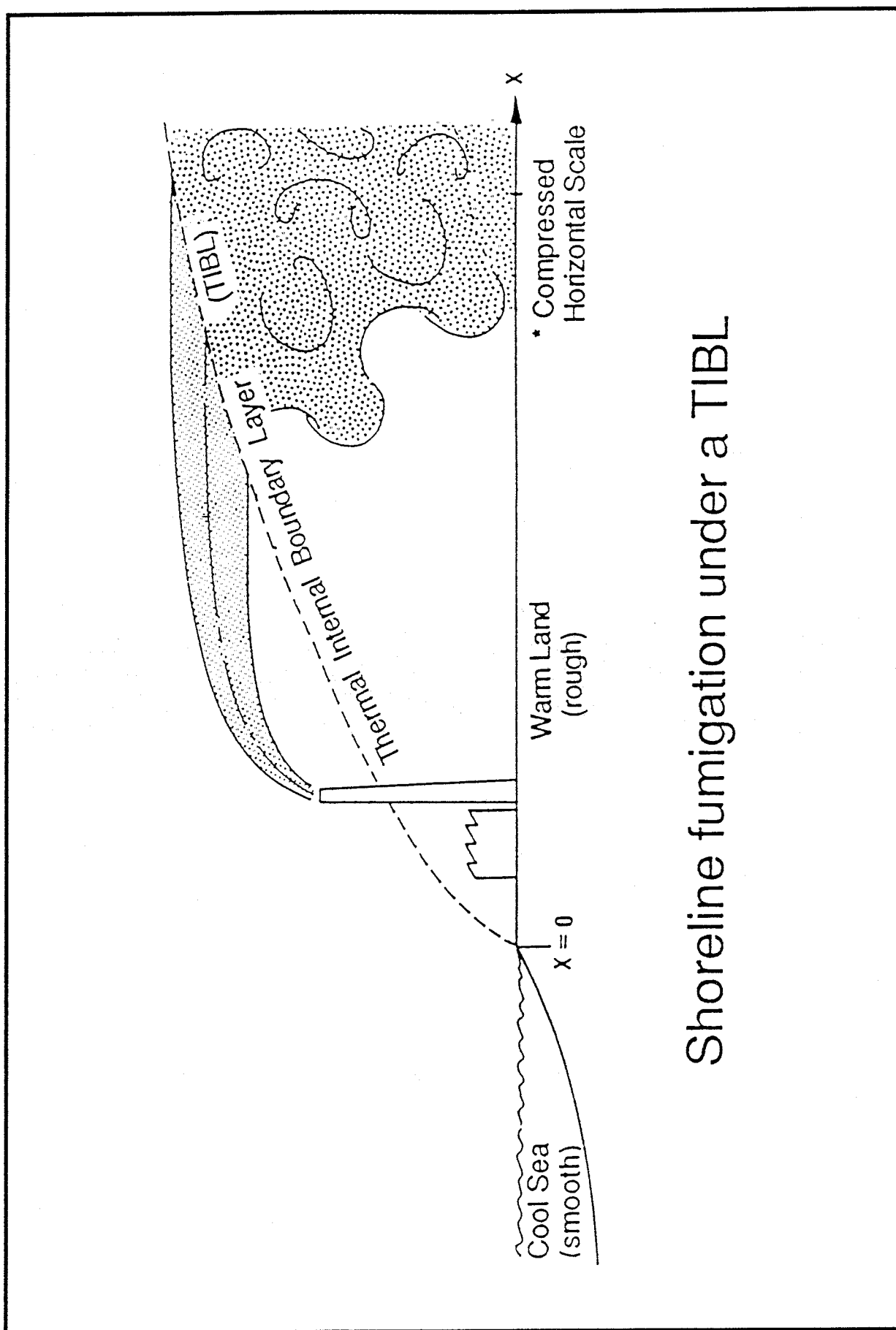
Figure 4.1. Shoreline fumigation under a thermal internal boundary layer.

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provides the option of storing the time series of ground level concentrations at nominated locations within the model grid, notably at the location of monitoring stations, so that the statistics of the model predictions may be compared directly to those of the measured ground level concentrations.

Many significant modifications have been made to DISPMOD subsequent to KAMS. These have been documented within the computer code and in working notes but, to date, a technical report describing the model in its current form has not been produced — this is an important task to be completed. The most significant aspects of the model requiring further investigation and possibly improvement are as follows:

(a)   The shape of the TIBL and therefore the downwind distance at which shoreline fumigation occurs is dependent on a variety of variables including the rate of change of temperature with height (lapse rate) within the onshore flow. Unlike the other variables, there is no presently available practical means of continuously measuring or estimating the lapse rate. It can be measured during field experiments via balloon-borne radiosondes or a spiralling aircraft fitted with a temperature sensor. For the purposes of the modelling work conducted to date we have had to utilise empirical relationships between lapse rate and other variables, derived by the CSIRO and the EPA from the results of several field experiments described by Rayner, Bell and Watson (1990). Such relationships are acknowledged to be tentative and need to be verified by further experiments; the EPA is proceeding to do this as resources allow.

(b)   In course of testing DISPMOD against available measurements it became apparent that the shoreline fumigation process is not yet well understood (by us or anyone else world-wide). Ground level concentrations measured at Wattleup during KAMS (notably 1979-80) exceed what we would expect on the basis of current theory and laboratory results. As an interim measure, these high values have been simulated by modifying the model to cause more rapid downward mixing of pollutants than the theory suggests. Further investigation of the structure of convective turbulence within the TIBL is needed to throw light on this issue.

A more general problem is the lack of complete data sets to use for model testing. A complete set comprises emissions data, meteorological data and ground level concentration monitoring data which are all coincident in time. A period of 12 months during KAMS (July 1979 to June 1980) is the only high quality set available, and even then there is data from one monitoring station only (Wattleup).

The 1979-80 data set has been employed to test and refine the model as far as is practicable. Figure 4.2 shows the results of this work in the form of plots of the cumulative frequency distribution of one-hour average ground level concentrations over this year:

(a)   as measured at Wattleup;

(b)   as modelled for Wattleup; and

(c)   as modelled for a location 700m SE of Wattleup.

In general terms, the agreement between measured and modelled distributions is pleasing. (The model results for the location 700m SE were included to examine the spatial sensitivity of results.) Despite the above-mentioned modification to achieve rapid fumigation (and hence higher concentrations) the modelled distributions still lie as much as 10% under the measured distribution for the range one to 20 hours per year. This needs to be borne in mind when applying the model.
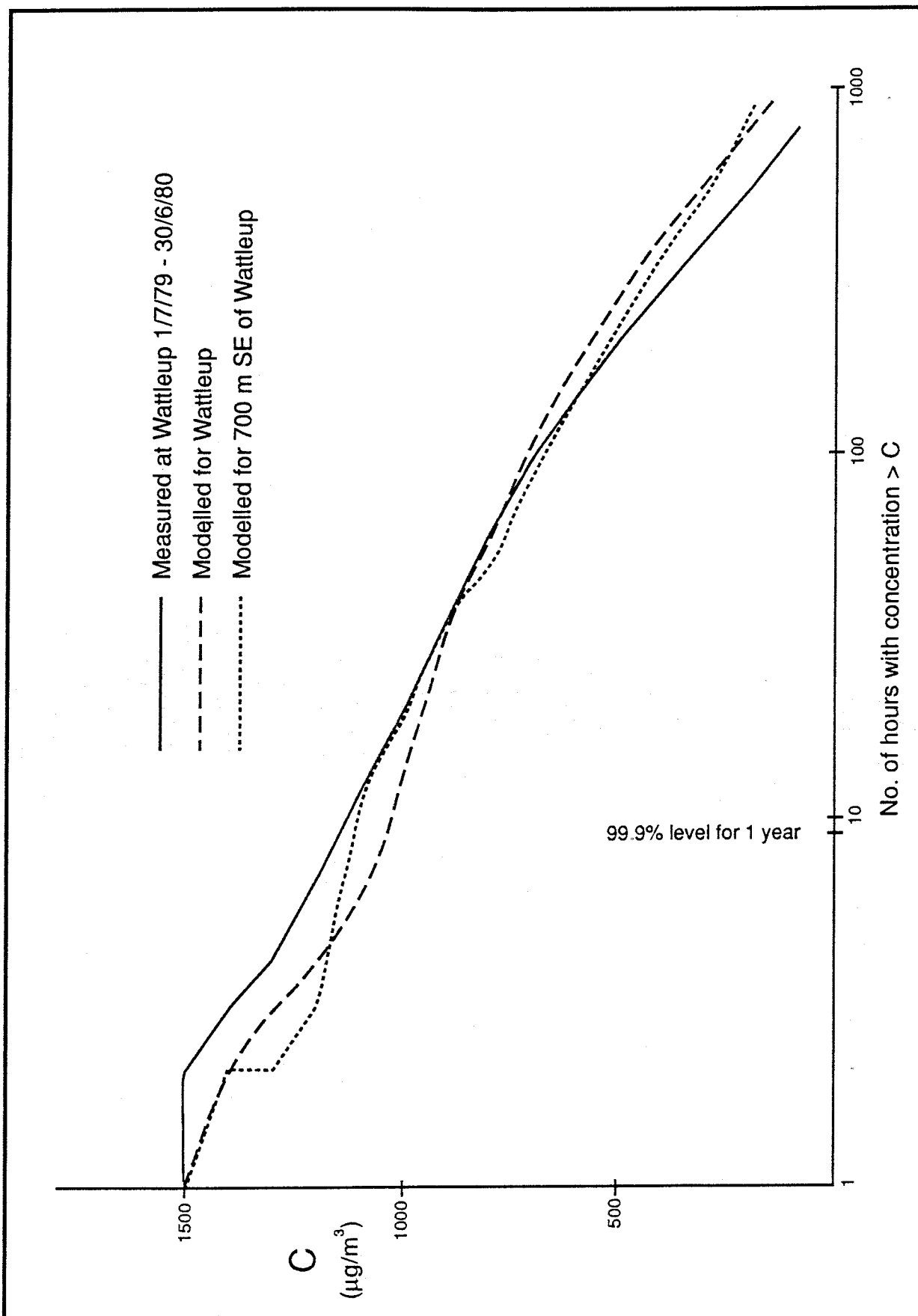
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Figure 4.2. Cumulative frequency distribution of the number of 1-hour averages per year with a concentration above the value C (for the year 1/7/79 to 30/6/80).

It should be noted that the model is not being used to obtain predictions of the ground level concentration occurring at a particular location at a particular time, ie the average for a particular hour. Accurate prediction in space and time is beyond the capability of most models except in tightly controlled circumstances. We have set aside any requirement to match predictions and measurements in time and we routinely relax the space matching requirement to the extent of checking measurements against model results for several nearby locations. Using the model in this way we can still obtain the important predictions required for the EPP and most other uses, as listed earlier, eg the **number of times** that a person living **at or near** a nominated location would experience, **within a year**, ground level concentrations in excess of the EPP standard. The actual dates on which these would occur are of little importance in the context of setting emissions limits on industry to ensure EPP compliance.

4.3   Relating model predictions to standards and limits

Scientists agree that a model should not be expected to accurately predict the actual value of the highest hourly concentration at a given location but it can be expected to give a reasonable estimate of, say, the 9th highest hourly concentration occurring at some time during the year at that location (ie the 99.9 percentile value). Model predictions of the 99.9 percentile value are frequently used for regulatory purposes because they are more stable and reliable than predictions of the peak value (eg Victorian Environmental Protection Authority, 1985). Other percentile values below 99.9 could also be predicted with an increasing level of confidence. This feature is important for the purposes of giving effect to the policy. We know from our analysis of the statistics of sulphur dioxide measurements at Wattleup that the highest hourly average measured in a given year is generally somewhat less than twice the value of the 9th highest hour. Since each of the EPP limit values for sulphur dioxide is twice the value of the standard for the same Policy Area, we may confidently assume that if the ground level concentration is below the standard for 99.9% of the year then the limit is unlikely to be exceeded even once. We could not be similarly confident if we lowered the above value to 99.8%. Hence, for the purposes of developing the procedure required under Clause 7, we will consider that the standards represent 99.9 percentile concentrations, ie the actual concentrations which occur should be below the standard for at least 99.9% of the year. We can then use the model to derive source emissions limits which achieve the standards in the three areas and be reasonably confident that the limit values will not be exceeded, without needing to rely on dubious model predictions of highest values.

As discussed in the previous section, the model has been tested on the high quality data set obtained in 1979-80, which includes source emissions, meteorological and sulphur dioxide measurements, and has proven capable of predicting the 99.9% value at Wattleup to within 10%, giving a reasonable basis for confidence.

4.4   Criteria for allocating emissions limits

There has never been any question that the combined industries at Kwinana can cause sulphur dioxide ground level concentrations which exceed the EPP limits by a large margin. Hence there is a need to allocate emissions limits which restrict these emissions to well less than the potential maximum.

The task of determining how the emissions limits are to be set for the various industries, and for individual sources within each industry, is not simply an exercise of dividing up a fixed amount. A kilogram of pollutant emitted from a tall chimney with a very buoyant plume causes a much lower concentration at ground level than a kilogram from a short stack with a weakly buoyant plume, so emission rates cannot be redistributed between industries in a simple fashion. Rather, any estimate of allocations must be tested via the model and modified, step by step, to achieve a set of emissions limits which the model confirms will comply with the policy objectives. However, within this procedure there is still the flexibility necessary to pre-determine the criteria which govern the relative sizes of emissions limits for the various industries, and then to determine the actual magnitude of emissions limits which meet these criteria.

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Early in the development of the EPP the EPA explained to industry, via the Confederation of WA Industry, the need for emissions limits in order to comply with the air quality objectives and the proposed strategy for establishing these. Two options for allocating the emissions limits between industries were suggested by EPA:

- Industry could propose a set of emissions limits which met the EPP objectives (as verified by the model in accordance with EPA's strategy). The obvious advantage of this approach was allowing industry to grapple with the commercial implications of emissions limits and to optimise the set of limits from their viewpoint, hopefully resulting in a cooperative and responsible approach to air quality management.

- EPA would develop a set of criteria defining how the emissions could be equitably allocated to the various industries, and apply these criteria in calculating the limits.

With regard to the second option, a set of draft criteria which EPA considered appropriate (and which were forwarded to industry for their information) is as follows:

- Consider only those emissions options which currently exist or have existed in the past. Any desire by an industry to use a new fuel or to increase the use of a sulphurous fuel above previous levels will be deferred for future consideration via the normal environmental assessment procedures.

- Given that some industries will clearly not be able to burn fuels containing high levels of sulphur, routine use of such fuels will not be considered acceptable for any industry. However exceptions could be made for industrial processes in which sulphur dioxide is removed by some means which is proven to be both efficient and very reliable.

- Section 51 of the Environmental Protection Act applies to all industries, ie any reasonable and practicable means of reducing emissions will be required. No decisions relating to this point will be taken without negotiation with the industry involved.

- Finally, the emissions of the largest emitters will be limited to meet a common maximum individual impact (eg maximum of 60% of the standard in any policy zone) such that the Policy standards and limits are met by the cumulative concentrations of sulphur dioxide. An example of this type of calculation was supplied to industry representatives on 20 July 1990.

The fourth criterion needs further explanation. If the EPA were to be left with the task of deciding how to allocate emissions limits (which amounts to deciding how to apportion the pain of restrictions on emissions) we would like to do so on the fairest possible basis. As previously explained it would not be fair to ignore the capital investment of some industries in tall chimneys which ensure that a given quantity of sulphur dioxide is dispersed much better than that from a short chimney. Perhaps the most equitable basis for comparison of industries (which could be the basis for a criterion to allocate emissions) is the ground level concentration impact of each industry considered in isolation. Following this reasoning, the EPA devised the following procedure (of which the fourth criterion is a summary):

- Run the model for each industry in isolation to provide a matrix of the 99.9 percentile hourly average ground level concentrations caused by that industry alone (which are unrelated to the 99.9 percentile concentrations for all industries combined).

- Select from the matrix the highest value in each of the Policy Areas A, B and C and express these as percentages of the standard for the respective areas.

- Complete the above steps for each industry in turn, resulting in a table showing percentages in each Policy Area for each industry.

- Estimate an upper limit on the allowable percentage (eg 60% in any of the areas) and, for any industry which has a percentage in any area exceeding this estimated limit, reduce the emissions of that industry by the ratio of the estimated limit to the highest percentage.

- Use the modified set of emissions in a model run for all industries combined in order to check whether the policy standards are anywhere exceeded by the 99.9 percentile predicted ground level concentrations. If so, reduce the estimate of the allowable percentage limit, recalculate the set of emissions and repeat the model run of all industries combined. If not,

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and if the predictions show that greater emissions could be comfortably accommodated, increase the estimated percentage and repeat the cycle.

There are clearly a number of variations which could be introduced into the above criteria. For example, it might be argued that a reduction of emissions should be across the board rather than restricting only those with large ground level concentration impacts. The criteria and associated calculation procedure could be altered as desired.

The above outline of the criteria proposed by the EPA is provided here as an indication of how the Chief Executive Officer could comply with the requirement under Clause 7 to develop a procedure and determine maximum permissible quantities in the event that industry were unable or chose not to propose a suitable set of emissions; it is an approach which may be used as necessary, both now and in the future when other pollutants are considered.

However, industry representatives have worked together to propose emissions limits which the model predicts will cause 99.9 percentile hourly average concentrations below the standards and peak concentrations below the limits. The proposal includes two sets of emissions limits, one based on the current situation under which the Alcoa Alumina Refinery is burning natural gas and one based on the possibility that Alcoa will exercise its right to a share of allowable emissions, in which case maximum emissions from other industries will reduce accordingly. There is a clear understanding amongst industries that the likelihood of Alcoa exercising this option in the foreseeable future is small, however industries and the EPA have agreed that the determination of maximum permissible quantities should fully protect Alcoa's options.

4.5 Procedure for determining maximum permissible quantities of sulphur dioxide

Clause 14 of the EPP requires the EPA to make details of the procedure for determining maximum permissible quantities of atmospheric waste (EPP Clause 7(1)) available for public inspection. The following summary of the procedure relating to sulphur dioxide is provided to fulfil this requirement.

(1) For the purpose of this procedure, define maximum permissible quantity to mean the mass of sulphur dioxide emitted per unit time, expressed in units of grams per second, kilograms per second or dimensionally equivalent units.

(2) Accept the computer model DISPMOD together with the data files listed or named in Appendix A as being the best available means of calculating ground level concentrations of sulphur dioxide in the Policy Area, noting that multiple calculations may be performed as necessary to exclude from the concentration within any industrial premises the concentration contribution from that premise's own discharges, in accordance with Clause 6 of the EPP.

(3) Provide the model and data files to representatives of Kwinana industry so that they, with the assistance of expert consultants, might propose maximum permissible quantities of sulphur dioxide for each industrial source which enable the ambient air quality standards and limits to be achieved and complied with.

(4) Use the model and data files to verify that the industry proposal is correct and acceptable and, if so, determine the maximum permissible quantities of sulphur dioxide to be those proposed by industry.

(5) In the event that the industry proposal is unsuitable, for whatever reason, develop this procedure further to include criteria for allocating emissions such as those suggested in Section 4.4 of this report and proceed to determine the maximum permissible quantities.

(6) Set in place via the provisions of the EPP a programme of monitoring the discharge of sulphur dioxide from all relevant industrial sources and of monitoring the ambient concentrations of sulphur dioxide at selected sites in the Policy Area and use this data to assess the adequacy of the model, the associated data and, therefore, the determination of (4) or (5).

5. Determination of maximum permissible quantities

Following the procedures outlined in Section 4.5, the maximum permissible quantities for sulphur dioxide have been determined.

As permitted by EPP Clause 7, two sets of maximum permissible quantities have been determined together with the circumstances in which, and the method by which, a change from one set to the other may occur.

The first set of maximum permissible quantities, called Set A, is contained in Table 5.1. The second set, called Set B, is contained in Table 5.2. The industrial sources listed in these tables are those which, in the opinion of the Chief Executive Officer, are likely to have a non-negligible effect on ground level concentrations in the relevant portion of the environment (as defined in the EPP). Further information on the location and height of sources is contained in Appendix A.

At the date of this determination coming into force, Set B shall be the set of maximum permissible quantities in force.

A change from Set B to Set A, or Set A to Set B may occur from time to time but only under the circumstances and according to the method detailed below:

(a) The Works Manager of the Alcoa of Australia Kwinana Alumina Refinery (hereafter called Alcoa) may from time to time decide that a change from Set A to Set B or Set B to Set A shall occur.

(b) A change from Set A to Set B or Set B to Set A will be made to occur by the Works Manager of Alcoa giving to the Chief Executive Officer of the EPA, via certified mail, notice of the change and the date at which it will occur which shall not, without the approval of the Chief Executive Officer, be less than 14 days after the date of posting of the notice. (It is also desirable that the Works Manager of Alcoa makes contact at the earliest opportunity via telephone or facsimile with the Director of the Pollution Control Division of EPA to advise of the pending change.)

(c) In the event that the Works Manager of Alcoa wishes, for emergency reasons, to increase the discharge of sulphur dioxide from that allowed under Set B to that allowed under Set A at a date sooner than the date of change of Set as per (b), the Chief Executive Officer of the EPA will, if he is satisfied that an emergency exists, grant an exemption under Section 75 of the Environmental Protection Act which will allow Alcoa to discharge sulphur dioxide in compliance with Set A until such time as Set A comes into force. Alternatively, if the period of such an emergency is expected to be less than 14 days in length, the Chief Executive Officer may, if so requested by Alcoa, grant such an exemption without having received a notice as per (b). A partial or total unforeseen loss of supply of natural gas to Alcoa would constitute such an emergency.

(d) The Chief Executive Officer will give notice via certified mail, to all occupiers of industrial premises affected by this determination, of any change from Set A to Set B or Set B to Set A and the date on which it is to occur.

(e) In relation to any one of the industrial premises affected by this determination, the Set to which the change has been made will come into force for that premises on the date specified in the notice referred to in (d), or four days after the mailing of that notice, whichever is later.

(f) The Works Manager of Alcoa may, after giving notice under (b) of a change of Set but prior to the date of change of Set, cancel the notice by advising the Chief Executive Officer via facsimile or mail. The Chief Executive Officer will give notice of this cancellation via certified mail to the occupiers notified under (d) and will also attempt to advise these occupiers via other means at the earliest opportunity. The Set to which the

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Table 5.1 Sulphur dioxide maximum permissible quantities: Set A

INDUSTRY SOURCES	SOURCE CODE	MAXIMUM PERMISSIBLE QUANTITIES (grams/sec)
SECWA Kwinana Power Station		
Stage A - Units 1 and 2	SEC STAGE A	Formula for Stages A, B and C:
Stage B - Units 3 and 4	SEC STAGE B	$Q_A+Q_B+Q_C/3.5=400$; Q_C not greater than 530,
Stage C - Units 5 and 6	SEC STAGE C	or, if $Q_B \approx 0$ (off-line or firing natural gas)
		$Q_A+Q_C/1.6=546$; Q_A not greater than 380 and
		Q_C not greater than 530,
		where Q_A, Q_B and Q_C are quantities
		from Stages A, B and C respectively.
Alcoa Kwinana Alumina Refinery		
Powerhouse Stage 1	ALC POWERHSE 1	28.5
Powerhouse Stage 2	ALC POWERHSE 2	32.3
Powerhouse Stage 3	ALC POWERHSE 3	36.1
Powerhouse Stage 4	ALC POWERHSE 4	36.1
Calciner 1	ALC CALCINER 1	17.1
Calciner 2	ALC CALCINER 2	19.0
Calciner 3	ALC CALCINER 3	21.9
BP Refinery (Kwinana) Pty Ltd		
Crude distillation unit 1	BP CDU 1	
Crude distillation unit 2	BP CDU 2	
Vacuum distillation unit 2	BP VDU 2	
Furfural unit	BP FURFURAL	Formula for combined sources:
Propane deashphalting unit	BP PDA	
Ferrofiner	BP FERROFINER	$A+B+C+D=298.0$;
Bitumen plant	BP BITUMEN	A (A not greater than 94.0)
Catalytic reformer 1	BP CAT REF 1	B not greater than 179.4
Catalytic reformer 2	BP CAT REF 2	C not greater than 250.0
Hydrofiner 1	BP HYDROFI 1	D not greater than 137.7
Hydrofiner 2	BP HYDROFI 2	
Hydrofiner 3	BP HYDROFI 3	the combined sources, as indicated
Alkylation plant	BP ALKY	by brackets, are:
Steam generation plant 1 and 3	BP SGA 1 & 3	A total of all furnaces
Steam generation plant 5	BP SGA 5	B flare
Flare	BP FLARE	B (C residue catalytic cracker)
Residue catalytic cracker unit	BP CRACKER	C (D two sulphur recovery units)
Sulphur recovery unit 1	BP SRU 1	
Sulphur recovery unit 2	BP SRU 2	D
TIWEST Kwinana Pigment Plant		
Bypass incinerator and stack	TIWEST BYPASS	77.0
HIsmelt Corporation Pty Ltd	HISMELT	35.0
CSBP Kwinana		
Sulphuric acid plant 2 and 3	CSBP SAP 2&3	60.0 during normal operation, or
		170.0 during start-up for winds from
		170 to 55 degrees clockwise, or
		340.0 during start-up for winds from
		55 to 170 degrees clockwise.
Western Mining Corporation Ltd Kwinana Nickel Refinery		
future coal	WEST MIN CORP	99.0
Cockburn Cement Limited		
Kiln 1 and 2	CC KILN 1&2	14.7
Kiln 3	CC KILN 3	21.5
Kiln 4	CC KILN 4	21.5
Kiln 5	CC KILN 5	7.3

Table 5.2 Sulphur dioxide maximum permissible quantities: Set B

INDUSTRY SOURCES	SOURCE CODE	MAXIMUM PERMISSIBLE QUANTITIES (grams/sec)

SECWA Kwinana Power Station

Stage A - Units 1 and 2	SEC STAGE A	Formula for Stages A, B and C:
Stage B - Units 3 and 4	SEC STAGE B	$Q_A+Q_B+Q_C/2.2=530$; Q_C not greater than 530,
Stage C - Units 5 and 6	SEC STAGE C	where Q_A, Q_B and Q_C are quantities from Stages A, B and C respectively.

Alcoa Kwinana Alumina Refinery

Powerhouse Stage 1	ALC POWERHSE 1	4.2
Powerhouse Stage 2	ALC POWERHSE 2	4.7
Powerhouse Stage 3	ALC POWERHSE 3	5.3
Powerhouse Stage 4	ALC POWERHSE 4	5.3
Calciner 1	ALC CALCINER 1	2.5
Calciner 2	ALC CALCINER 2	2.8
Calciner 3	ALC CALCINER 3	3.2

BP Refinery (Kwinana) Pty Ltd

Crude distillation unit 1	BP CDU 1	
Crude distillation unit 2	BP CDU 2	
Vacuum distillation unit 2	BP VDU 2	
Furfural unit	BP FURFURAL	Formula for combined sources:
Propane deashphalting unit	BP PDA	
Ferrofiner	BP FERROFINER	A+B+C+D=315.0;
Bitumen plant	BP BITUMEN (A)	A not greater than 94.0
Catalytic reformer 1	BP CAT REF 1	B not greater than 179.4
Catalytic reformer 2	BP CAT REF 2	C not greater than 290.0
Hydrofiner 1	BP HYDROFI 1	D not greater than 137.7
Hydrofiner 2	BP HYDROFI 2	
Hydrofiner 3	BP HYDROFI 3	the combined sources, as indicated
Alkylation plant	BP ALKY	by brackets, are:
Steam generation plant 1 and 3	BP SGA 1 & 3	A total of all furnaces
Steam generation plant 5	BP SGA 5	B flare
Flare	BP FLARE (B)	C residue catalytic cracker
Residue catalytic cracker unit	BP CRACKER (C)	D two sulphur recovery units
Sulphur recovery unit 1	BP SRU 1	
Sulphur recovery unit 2	BP SRU 2 (D)	

TIWEST Kwinana Pigment Plant

Bypass incinerator and stack	TIWEST BYPASS	77.0

HIsmelt Corporation Pty Ltd	HISMELT	35.0

CSBP Kwinana

Sulphuric acid plant 2 and 3	CSBP SAP 2&3	60.0 during normal operation, or 170.0 during start-up for winds from 170 to 55 degrees clockwise, or 340.0 during start-up for winds from 55 to 170 degrees clockwise.

Western Mining Corporation Ltd Kwinana Nickel Refinery

future coal	WEST MIN CORP	106.0

Cockburn Cement Limited

Kiln 1 and 2	CC KILN 1&2	24.0
Kiln 3	CC KILN 3	35.0
Kiln 4	CC KILN 4	35.0
Kiln 5	CC KILN 5	12.0

the change was made and then cancelled will not come into force for any occupier as per (e) irrespective of whether or not a notice of cancellation issued by the Chief Executive Officer has been received by that occupier. However, no action will be taken against an occupier who complies with a notice as per (d) and (e) prior to receiving a notice of cancellation as per this clause, provided that such an occupier complies with the notice of cancellation as soon as is practicable and, in any event, within four days of it being mailed.

The maximum permissible quantities for the SECWA Kwinana Power Station are shown in each of Tables 5.1 and 5.2 as formulae which allow the combination of discharges from the three stages to vary in a defined manner. For example, the discharge of 395 grams per second from Stage A, zero from Stage B and 297 from Stage C complies with the formula for Case B. Limits on the maximum allowable discharge from individual sources (where necessary) are specified as part of the formulae. For example, the discharge from Stage C is not allowed to exceed 530 grams per second under either Set A or Set B.

Similarly, the maximum permissible quantities for BP Refinery are expressed, for each Set, as a formula which limits the sum of the discharges to a specified maximum amount (eg 298 grams per second for Set A). In addition, each formula sets limits on the maximum allowable discharge from each of four specified groups of sources (eg under Set A the total discharge from the two sulphur recovery units, group D, may not exceed 137.7 grams per second).

The Chief Executive Officer has given an undertaking to industries at Kwinana affected by this determination that a re-examination and, as needs dictate, a redetermination of maximum permissible quantities will take place two years after this determination comes into force, as part of an informal assessment of all aspects of the implementation and operation of the EPP.

6. Model results

As required under the procedure of Section 4.5, the model DISPMOD was used to check the determination of maximum permissible quantities.

The meteorological data set used for all model runs was developed from data measured at Hope Valley in 1980. Turbulent heat and momentum fluxes were calculated via the model SOIL (see Section 4.2) for daytime hours and by flux-profile theory applied to meteorological tower measurements for night-time hours. The mixed layer model WML provided mixing heights and an estimate of the strength of the capping inversion which DISPMOD uses to assess the extent to which buoyant plumes penetrate the inversion.

All results below are presented as computer generated plots of contours, with contour intervals marked. The coastline and boundaries of Areas A, B and C appear as bold lines, whilst the various industrial sources appear as + signs. The industries can be identified by referring to Figure 3.1. The model results for the two sets of maximum permissible quantities are presented in turn. Unless otherwise stated, the model was run on a 1km by 1km grid indicated by tick marks on the boundaries of each plot.

For each of the model runs described below, the emissions from the SECWA Kwinana Power Station and BP Refinery were set to the following "base case" values which comply with the formulae for maximum permissible quantities in Tables 5.1 and 5.2:

- **SECWA Kwinana Power Station**

Set A:	$Q_A=357.2$	$Q_B=0.0$	$Q_C=300.8$
Set B:	$Q_A=395.0$	$Q_B=0.0$	$Q_C=297.0$

- **BP Refinery**

Set A:	A=19.2	B=49.2	C=164.6	D=65.0
Set B:	A=19.2	B=49.2	C=181.6	D=65.0

6.1 Set A

Figure 6.1 shows contours of the annual average ground level concentration. The highest value of 27.3 micrograms per cubic metre is well below standards and limits for all areas.

Figure 6.2 shows contours of the number of times in the year that the hourly average ground level concentration exceeded 350 micrograms per cubic metre. The highest value indicated for Area C is three hours per year which achieves the intent of the standard.

Figure 6.3 shows contours of the number of times in the year that the hourly average ground level concentration exceeded 500 micrograms per cubic metre. The highest value indicated for Area B is one hour per year which achieves the intent of the standard.

Figure 6.4 shows contours of the number of times in the year that the hourly average ground level concentration exceeded 700 micrograms per cubic metre. The highest value indicated for Area A is two hours per year which achieves the intent of the standard. The limit of 700 micrograms per cubic metre in area C is not exceeded.

Figure 6.5 shows contours of the number of times in the year that the hourly average ground level concentration exceeded 1000 micrograms per cubic metre. There were no such events.

Figure 6.6 shows contours of the 99.9 percentile hourly average ground level concentration. From inspection we can see that these values do not exceed the standards in any of the three Policy Areas.

Figure 6.7 shows contours of the maximum hourly average ground level concentration. From inspection we can see that these values do not exceed the limits in any of the three Policy Areas.

There is the potential for higher concentrations to occur at locations other than the gridpoints represented in the above plots, so it is necessary to check areas where high values might be expected. This is done by re-running the model on a finer grid over the area in question. For Set A, fine-scale model runs have been carried out for the area NNE of Cockburn Cement (where Area C commences), these runs (not plotted) confirm that the 99.9 percentile ground level concentration does not exceed 350 micrograms per cubic metre.

Figure 6.8 shows contours of the maximum 24-hour average ground level concentration. From inspection we can see that these values do not exceed the standards or limits in any of the three Policy Areas.

6.2 Set B

Figure 6.9 shows contours of the annual average ground level concentration. The highest value of 27.2 micrograms per cubic metre is well below standards and limits for all areas.

Figure 6.10 shows contours of the number of times in the year that the hourly average ground level concentration exceeded 350 micrograms per cubic metre. The highest value indicated for Area C is two hours per year which achieves the intent of the standard.

Figure 6.11 shows contours of the number of times in the year that the hourly average ground level concentration exceeded 500 micrograms per cubic metre. The highest value indicated for Area B is one hour per year which achieves the intent of the standard.

Figure 6.12 shows contours of the number of times in the year that the hourly average ground level concentration exceeded 700 micrograms per cubic metre. The highest value indicated for Area A is one hour per year which achieves the intent of the standard. The limit of 700 micrograms per cubic metre in area C is not exceeded.

Figure 6.13 shows contours of the number of times in the year that the hourly average ground level concentration exceeded 1000 micrograms per cubic metre. There were no such events.

Figure 6.14 shows contours of the 99.9 percentile hourly average ground level concentration. From inspection we can see that these values do not exceed the standards in any of the three Policy Areas.

Figure 6.15 shows contours of the maximum hourly average ground level concentration. From inspection we can see that these values do not exceed the limits in any of the three Policy Areas.

As for Set A, fine-scale model runs have been carried out for the area NNE of Cockburn Cement (where Area C commences), confirming that the 99.9 percentile ground level concentration does not exceed 350 micrograms per cubic metre.

Figure 6.16 shows contours of the maximum 24-hour average ground level concentration. From inspection we can see that these values do not appear to exceed the standards or limits in any of the three Policy Areas, although the high values ESE of BP Refinery warrant inspection on a finer scale.

Figure 6.17 shows the same results as 6.16 but on a 250 metre grid for the area of interest (as can be identified by the shape of the Policy Area boundaries). At this resolution it can be seen that the maximum 24-hour averages slightly exceed the standards in both Area C (125 micrograms per cubic metre) and Area B(150 micrograms per cubic metre). Under the definition of a standard, such a small exceedance is acceptable if it happens very rarely. Further investigation has revealed that the exceedance occurred on one day when the wind direction was remarkably constant for the whole day. To verify that this day was the cause, it was deleted from the model output and the results re-plotted (Figure 6.18); the second highest 24-hour ground level concentration seen in this plot are well below the standards. Hence the results of Figure 6.17 are considered acceptable.

6.3 SECWA Kwinana Power Station and BP Refinery formulae

SECWA has provided to the EPA the results of model runs performed to check the formulae for maximum permissible quantities in Tables 5.1 and 5.2. These model runs were performed at fine grid resolution for the most sensitive area (NNE of Cockburn Cement where Area C commences). Many combinations of discharge rates which fit the formulae were tested, including the allowable extremes for each source combination and several "mid range" combinations. This work verifies that the formulae are valid and may be used by SECWA in the management of power station emissions.

A corresponding effort has been carried out by BP Refinery, verifying that the formulae for maximum permissible quantities in Tables 5.1 and 5.2 are valid and may be used in the management of emissions from the refinery.

In both cases the EPA has carried out sufficient modelling to check and verify these results.

6.4 CSBP start-up emissions

CSBP have advised that they anticipate about two cold start-ups per year (taking about three hours each) and that, with good management, start-up emissions of sulphur dioxide can be kept to below 600kg per hour (170 grams per second). Higher emissions are possible if conditions are not optimum.

The total time of start-ups is a tiny fraction of the time in any year and the probability of the associated emission giving rise to high ground level concentration is correspondingly small. The model was run to assess whether a discharge rate of 170 grams per second would be expected to comply with the EPP standards and limits at all times (under all meteorological conditions within the data) assuming, in view of the extremely low probability, that this discharge would not coincide with other infrequent high discharges (ie neglecting the emergency discharges from TIWEST and HIsmelt as given in Tables 5.1 and 5.2). This model run confirmed compliance. Hence the determination of Section 5 allows CSBP to start up at any time (under any meteorological conditions) provided the discharge rate does not exceed 170 grams per second. Higher discharges up to a maximum allowable 340 grams per second are only permitted if the wind direction is off-shore and away from populated areas; Garden Island is sufficiently distant to avoid high concentrations.
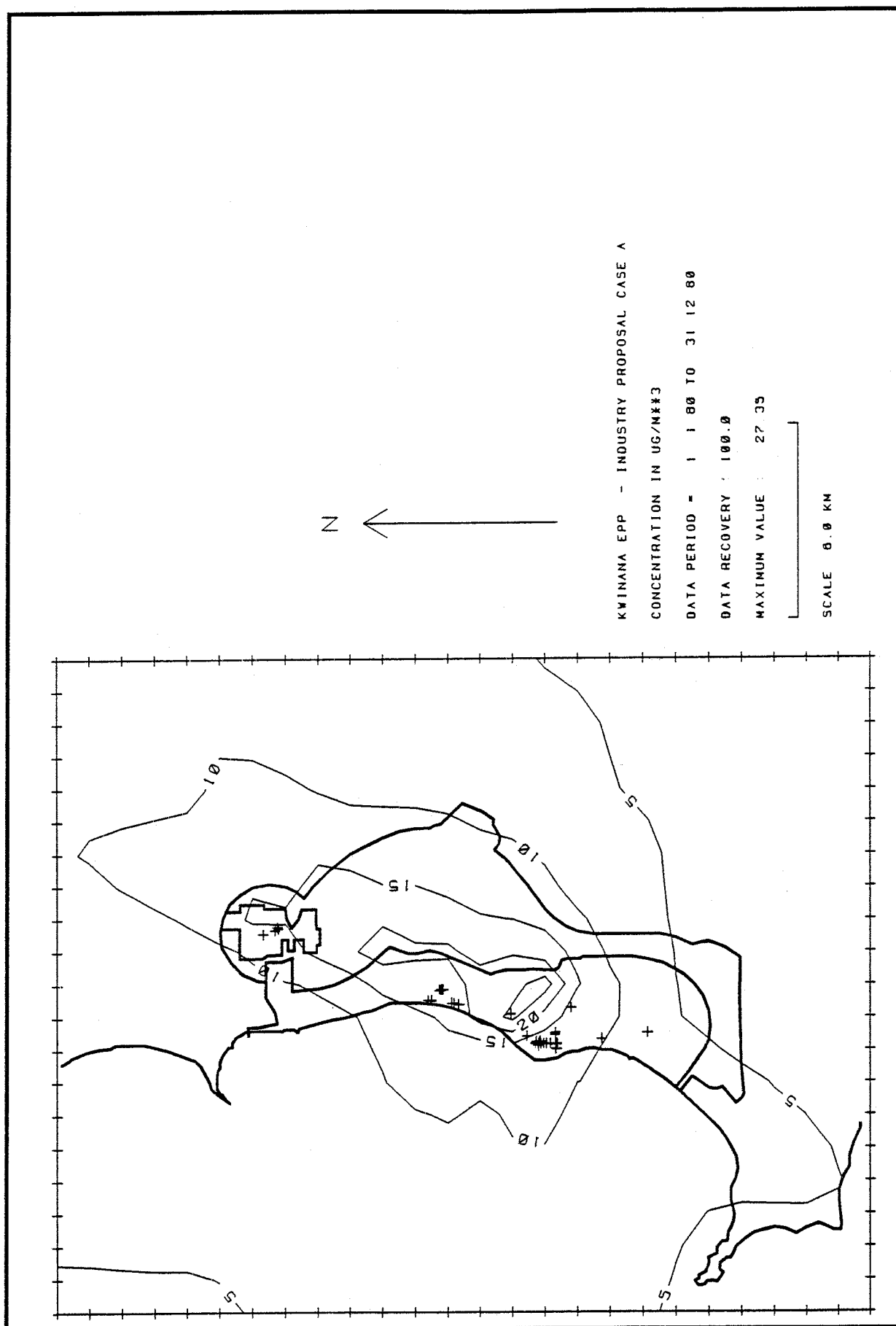
KWINANA EPP - INDUSTRY PROPOSAL CASE A

CONCENTRATION IN UG/M**3

DATA PERIOD = 1 1 80 TO 31 12 80

DATA RECOVERY : 100.0

MAXIMUM VALUE : 27.05

SCALE 8.0 KM

Figure 6.1. Annual average ground level concentration for Set A.

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KWINANA EPP - INDUSTRY PROPOSAL CASE A

HOURS GREATER THAN 350 UG/M**3

DATA PERIOD = 1 1 80 TO 31 12 80

DATA RECOVERY : 100.0

MAXIMUM VALUE 39.00

SCALE 0.0 KM
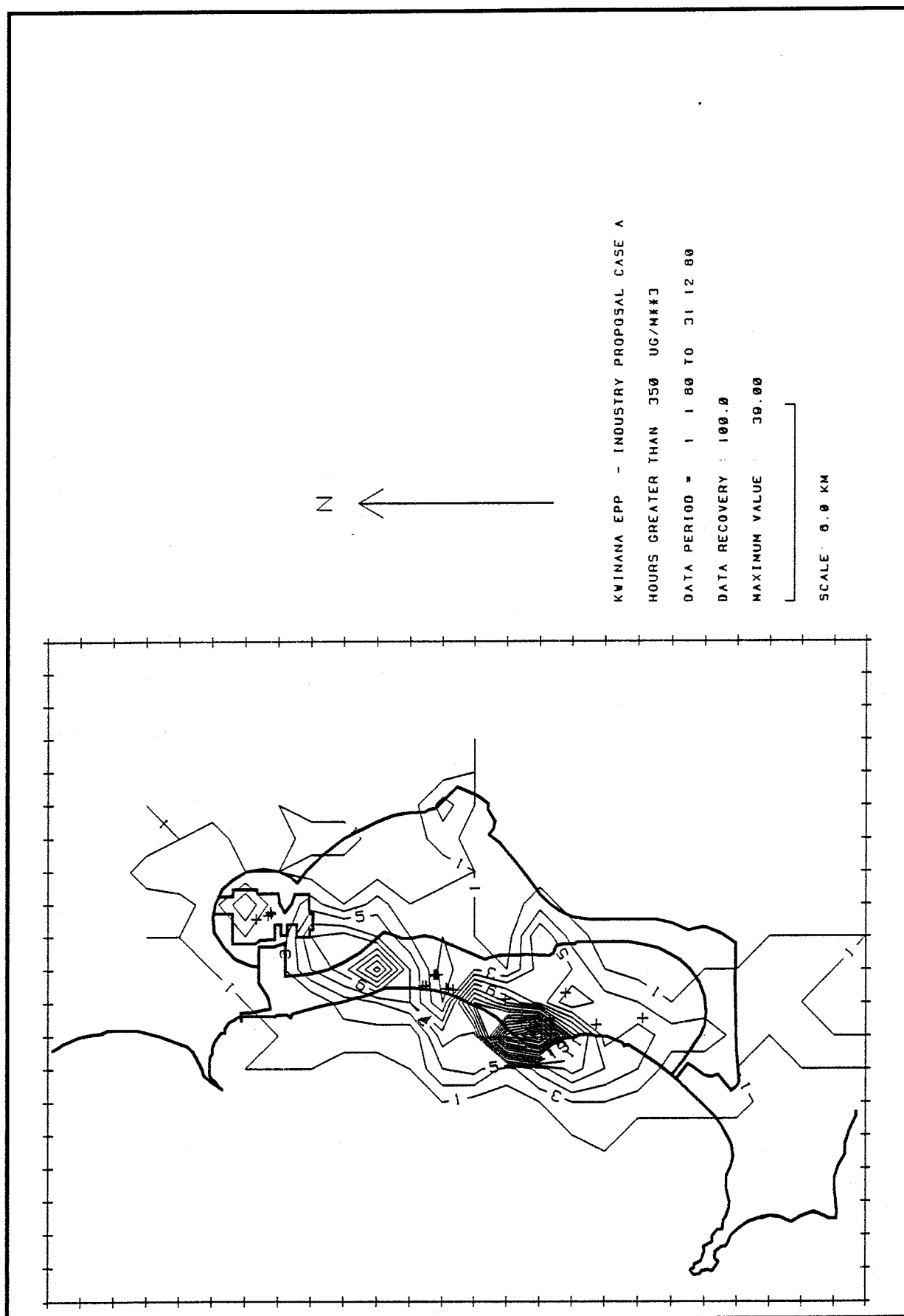
Figure 6.2. Number of hours greater than 350 micrograms per cubic metre for Set A.

KWINANA EPP - INDUSTRY PROPOSAL CASE A

HOURS GREATER THAN 500 UG/M**3

DATA PERIOD = 1 1 80 TO 31 12 80

DATA RECOVERY : 100.0

MAXIMUM VALUE : 9.00

SCALE 8.0 KM

N
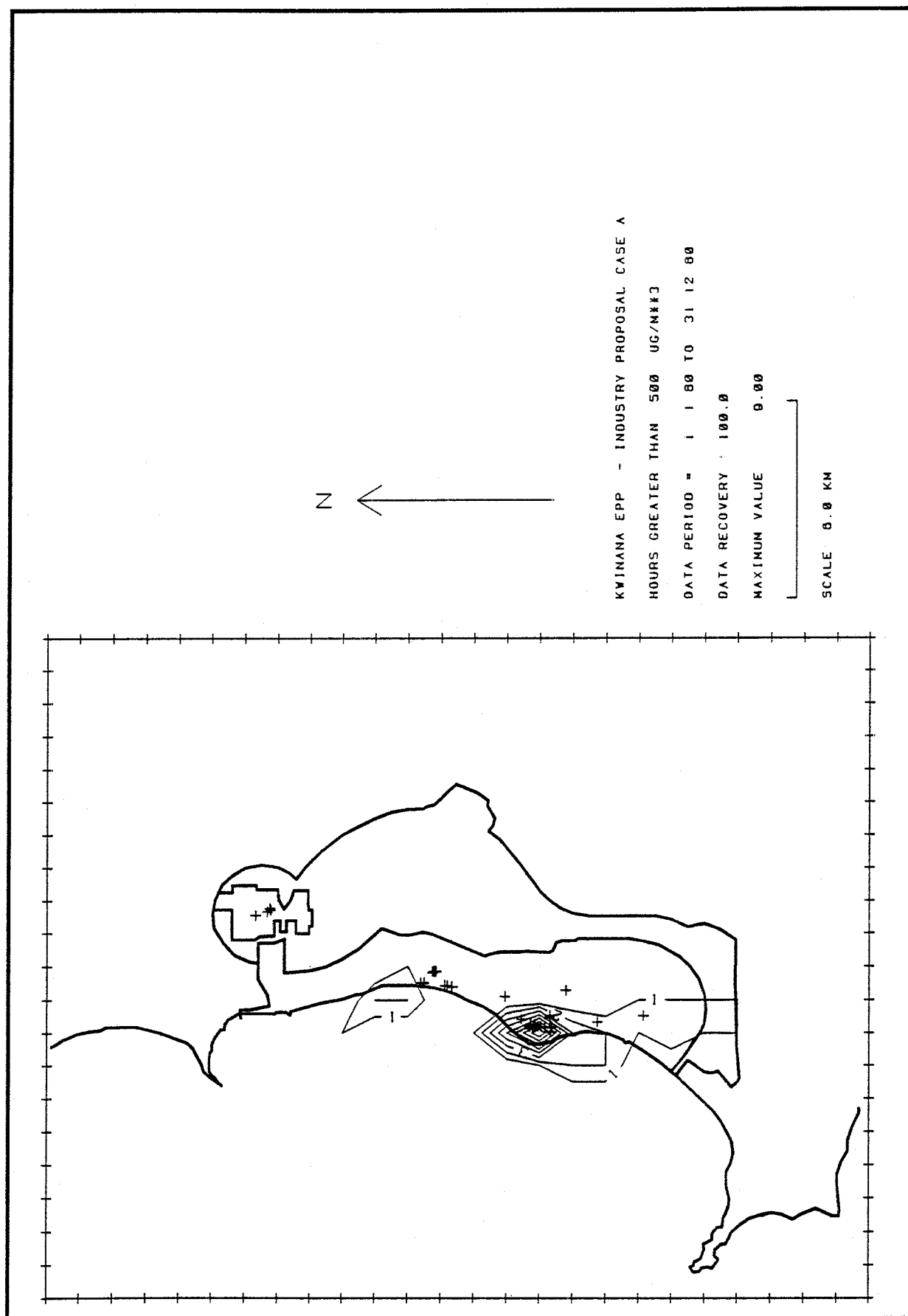
Figure 6.3. Number of hours greater than 500 micrograms per cubic metre for Set A.

KWINANA EPP - INDUSTRY PROPOSAL CASE A

HOURS GREATER THAN 700 UG/M**3

DATA PERIOD = 1 1 80 TO 31 12 80

DATA RECOVERY 100.0

MAXIMUM VALUE 2.00

SCALE 8.8 KM
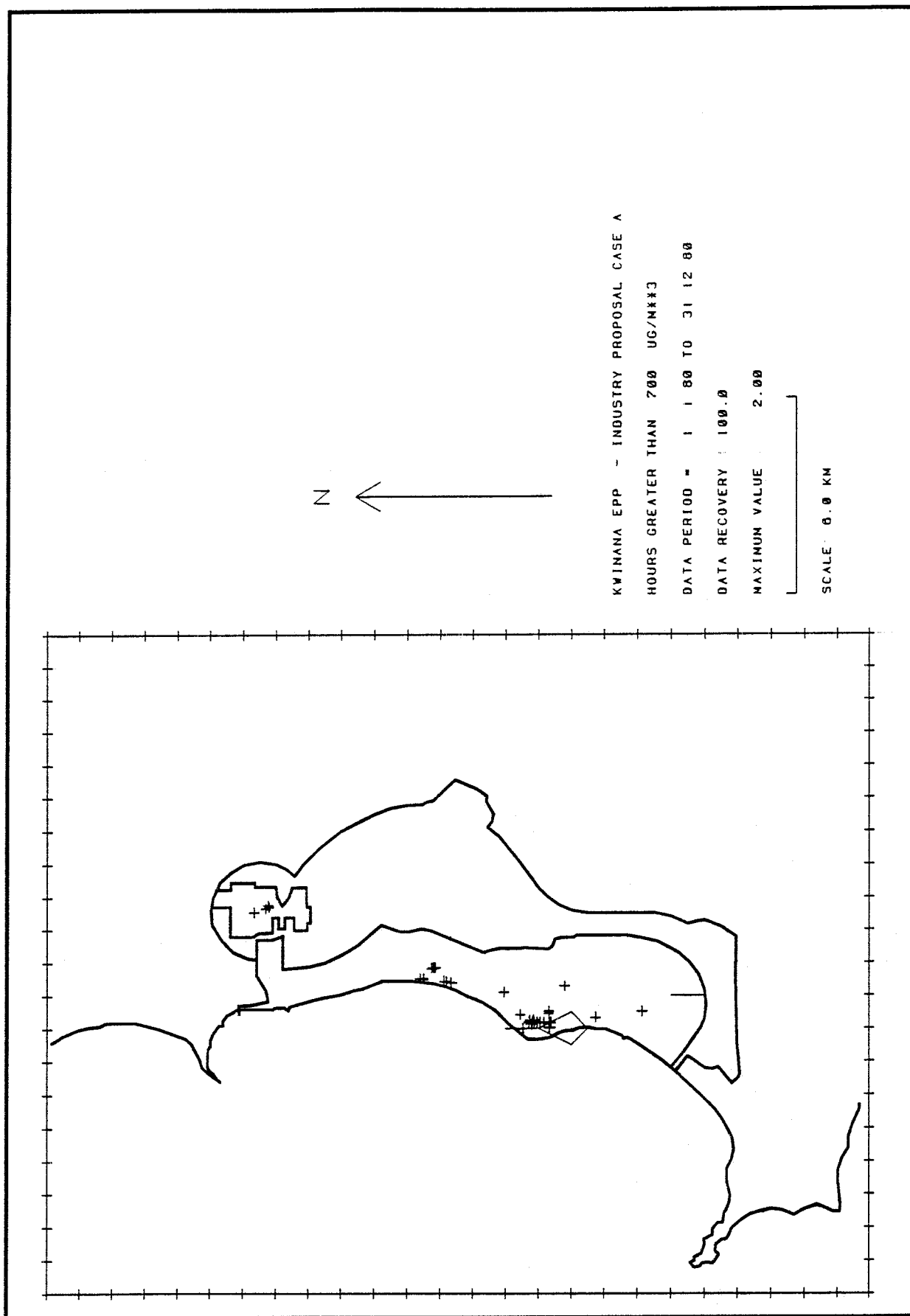
Figure 6.4. Number of hours greater than 700 micrograms per cubic metre for Set A.

KWINANA EPP - INDUSTRY PROPOSAL CASE A

HOURS GREATER THAN 1000 UG/M**3

DATA PERIOD = 1 1 80 TO 31 12 80

DATA RECOVERY : 100.0

MAXIMUM VALUE : 0.00

SCALE 6.0 KM

N ←
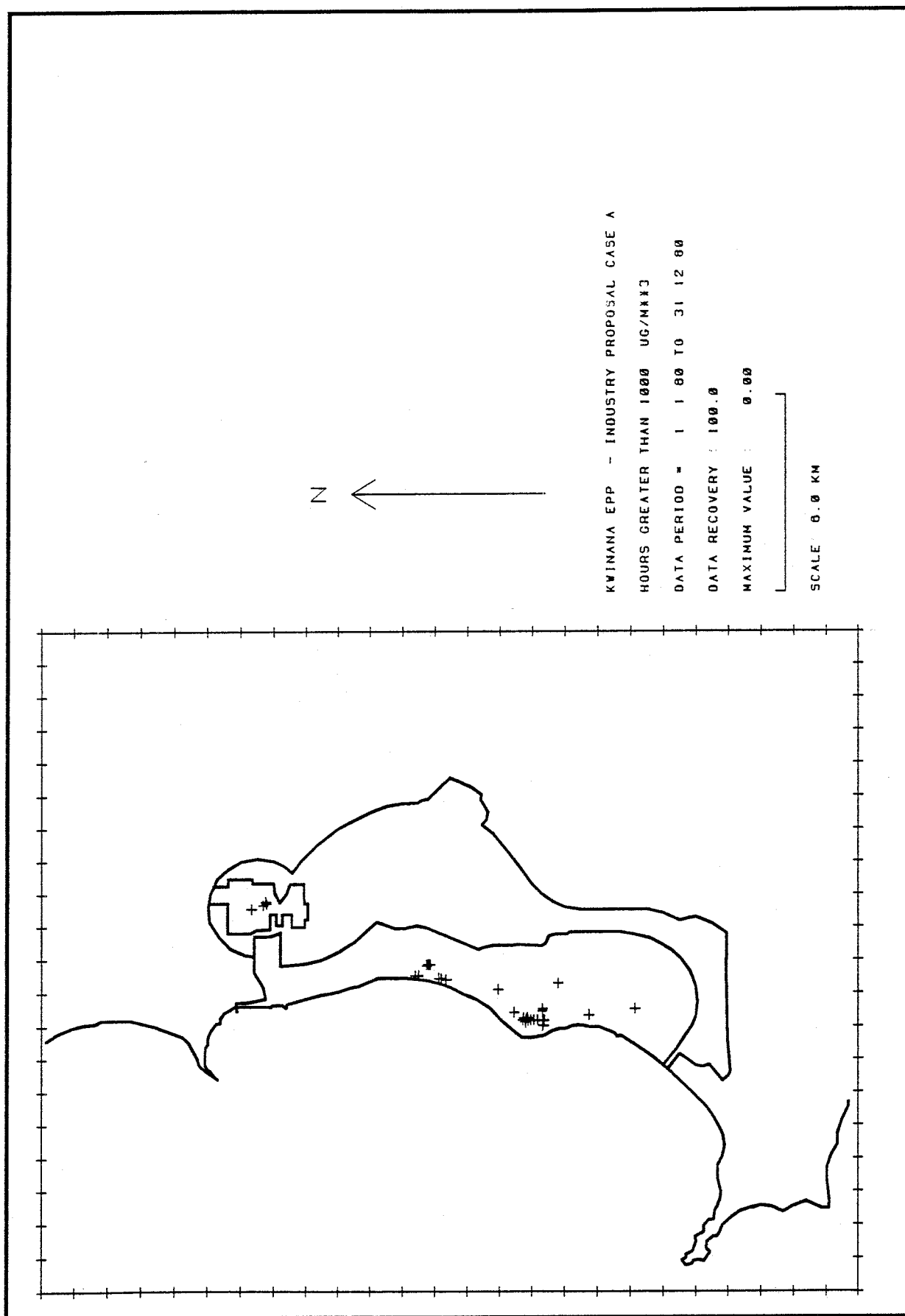
Figure 6.5. Number of hours greater than 1000 micrograms per cubic metre for Set A.

KWINANA EPP - INDUSTRY PROPOSAL CASE A

MAXIMUM HOURLY CONC. (99.9 PERCENTILE) IN UG/M**3

DATA PERIOD = 1 1 80 TO 31 12 80

DATA RECOVERY : 100.0

MAXIMUM VALUE : 545.

SCALE 8.0 KM

Figure 6.6. The 99.9 percentile hourly average ground level concentration for Set A.

KWINANA EPP - INDUSTRY PROPOSAL CASE A

MAXIMUM HOURLY CONC. IN UG/M**3

DATA PERIOD = 1 1 80 TO 31 12 80

DATA RECOVERY : 100.0

MAXIMUM VALUE : 898.

SCALE 8.0 KM

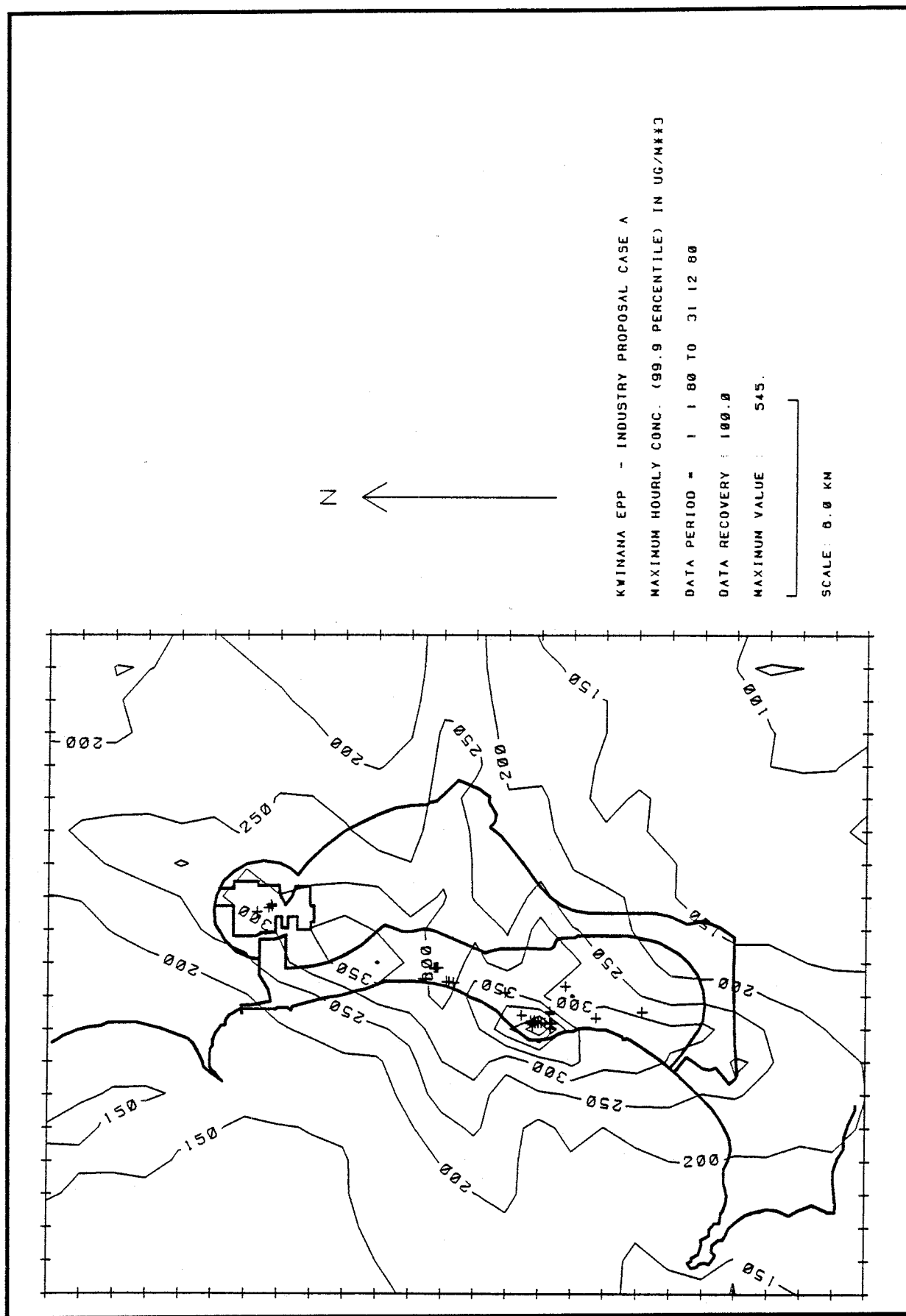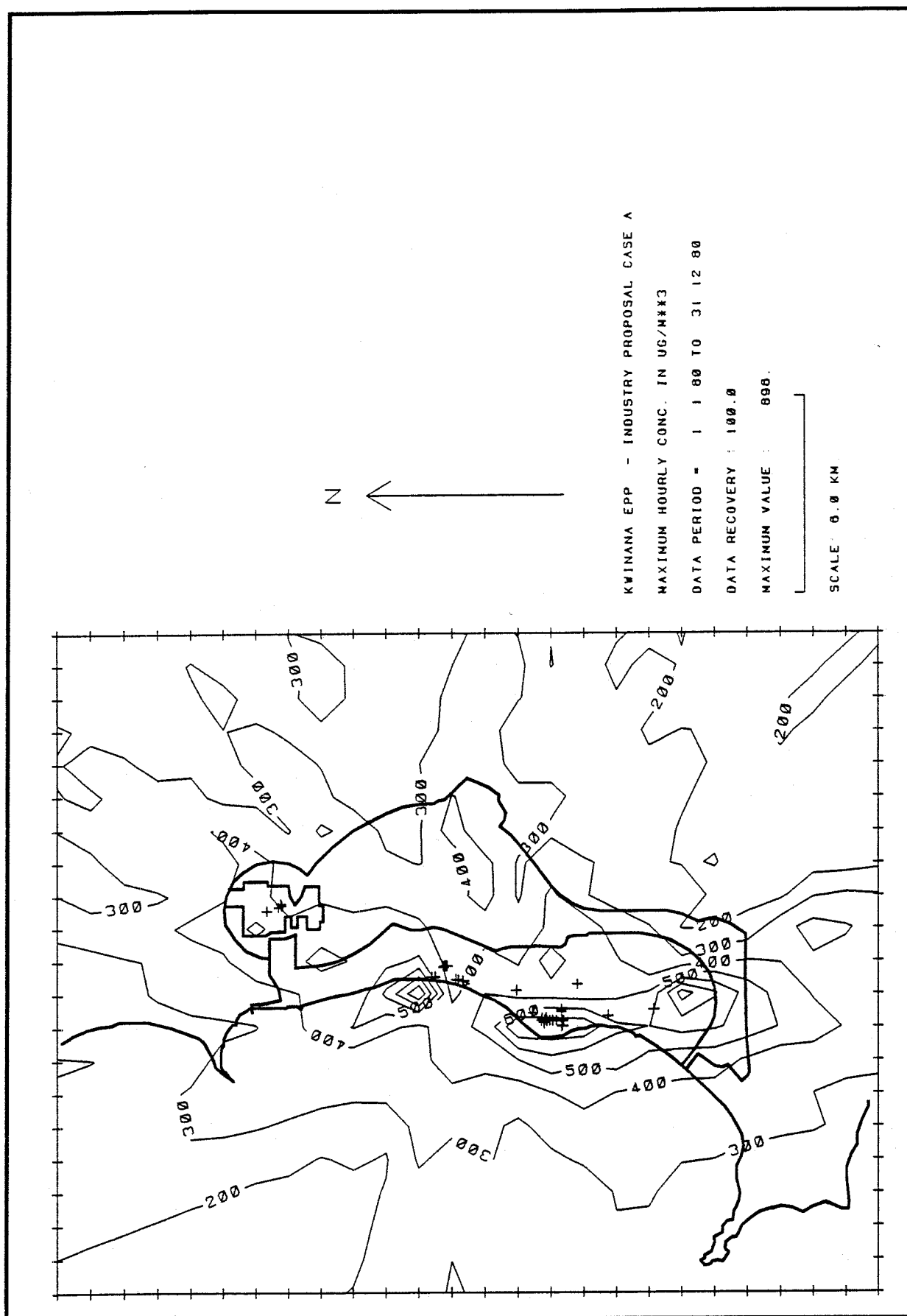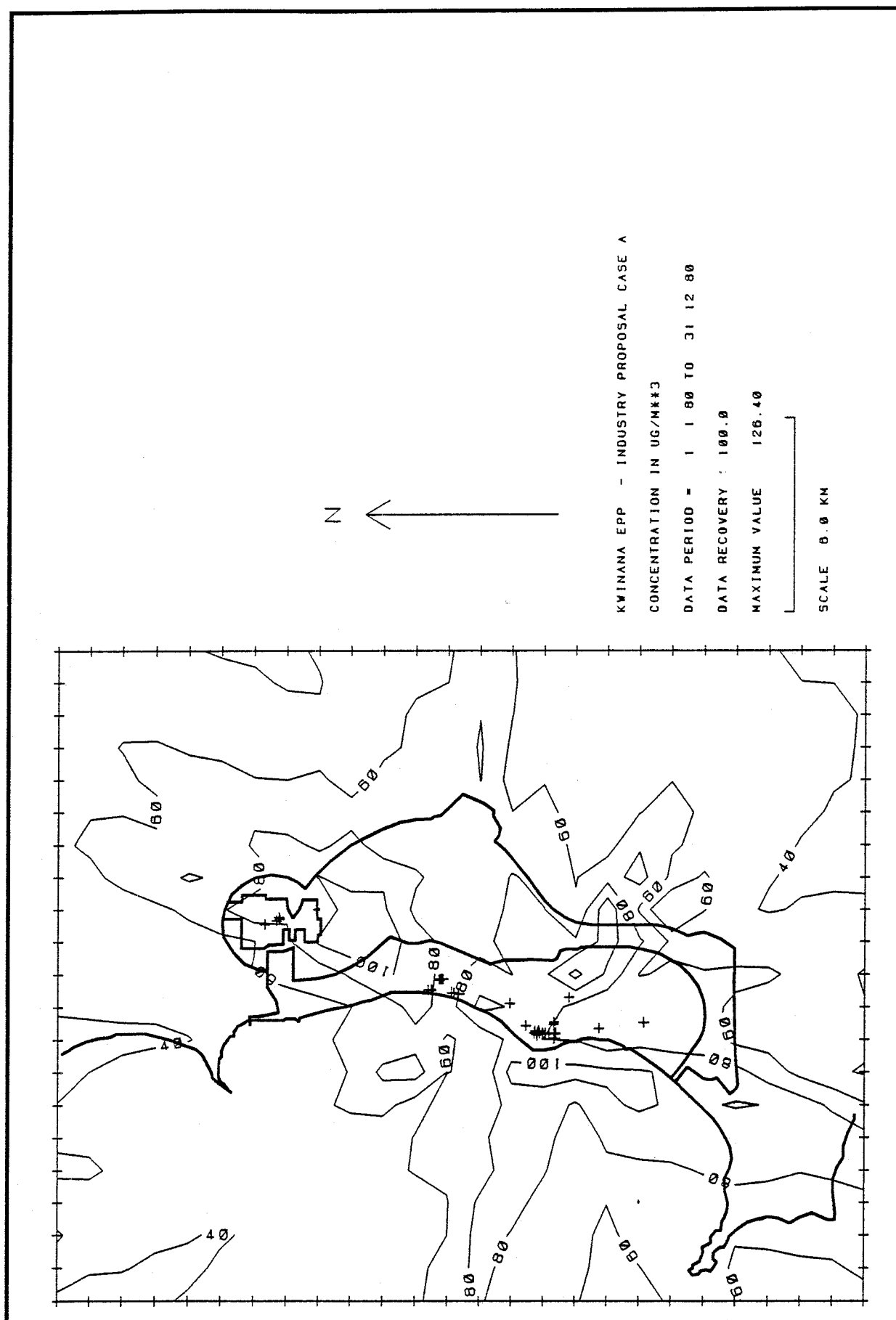*Figure 6.7. Maximum hourly average ground level concentration for Set A.*

Figure 6.8. Maximum 24-hour average ground level concentration for Set A.
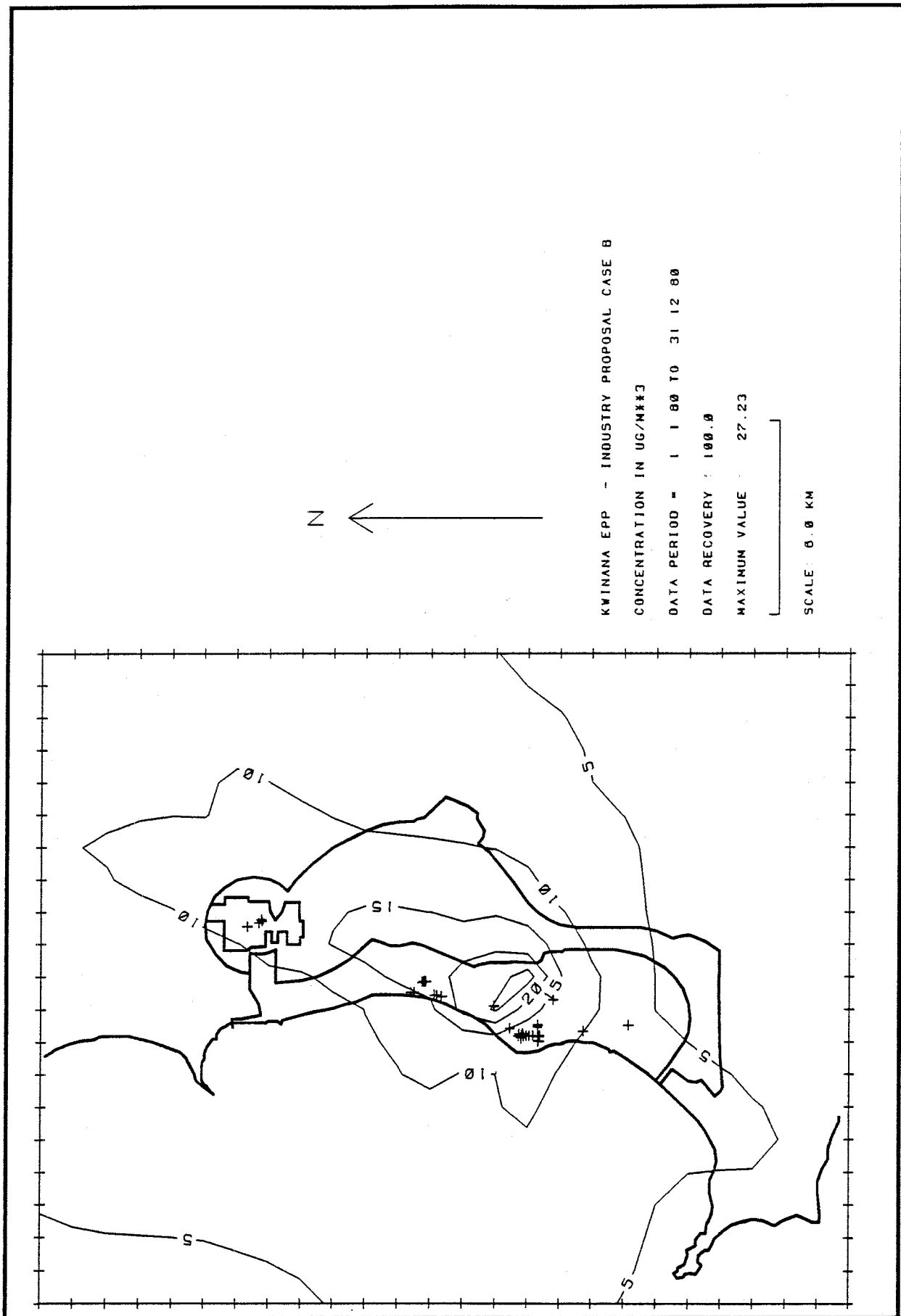
Figure 6.9. Annual average ground level concentration for Set B.

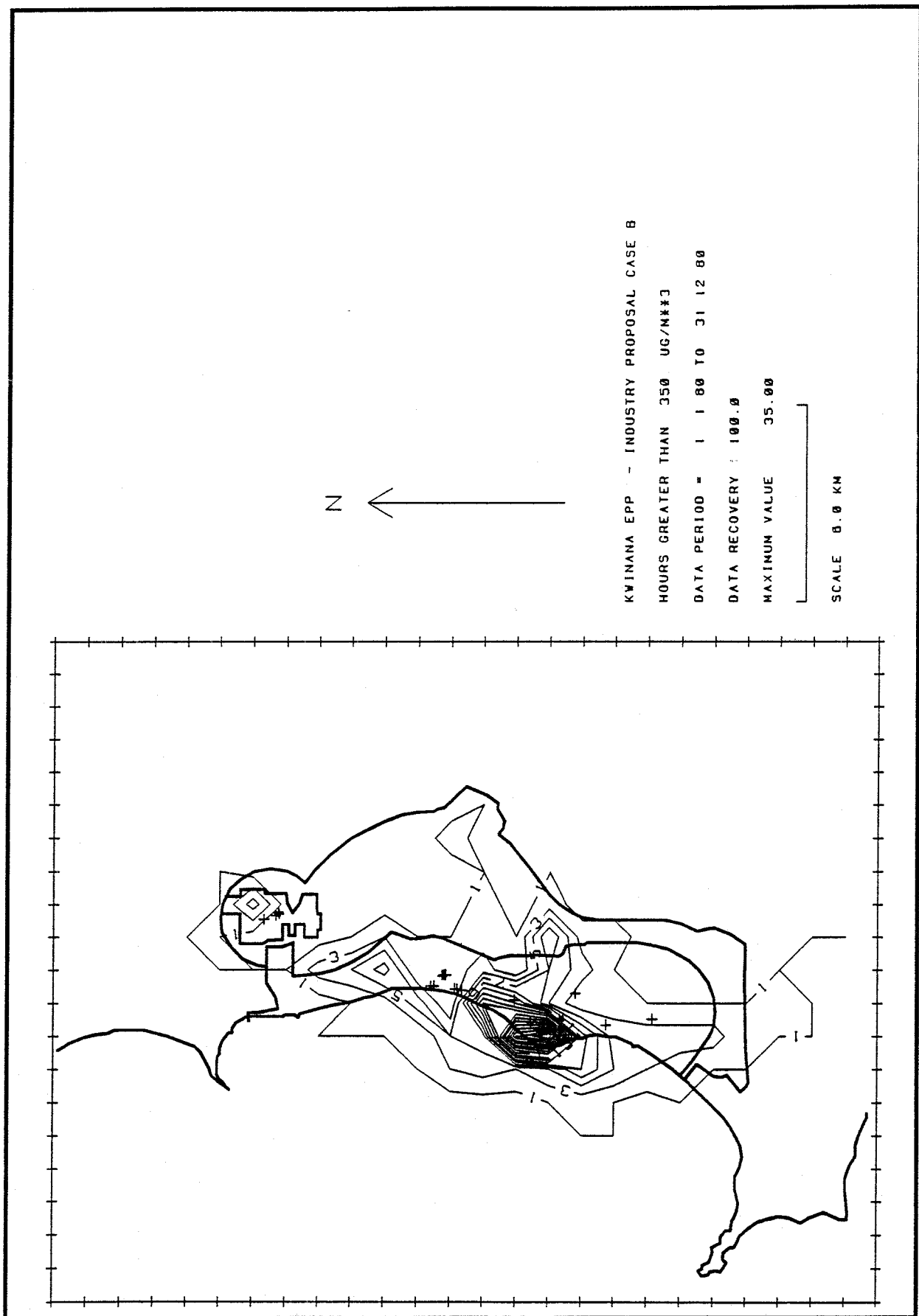KWINANA EPP - INDUSTRY PROPOSAL CASE B

HOURS GREATER THAN 350 UG/M**3

DATA PERIOD = 1 1 80 TO 31 12 80

DATA RECOVERY : 100.0

MAXIMUM VALUE 35.00

SCALE 8.0 KM

Figure 6.10. Number of hours greater than 350 micrograms per cubic metre for Set B.

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KWINANA EPP - INDUSTRY PROPOSAL CASE B

HOURS GREATER THAN 500 .UG/M**3

DATA PERIOD = 1 1 80 TO 31 12 80

DATA RECOVERY : 100.0

MAXIMUM VALUE   8.00

SCALE 8.0 KM

N

Figure 6.11. Number of hours greater than 500 micrograms per cubic metre for Set B.

KWINANA EPP - INDUSTRY PROPOSAL CASE B

HOURS GREATER THAN 700 UG/NM3 (XXXX)

DATA PERIOD = 1 1 80 TO 31 12 80

DATA RECOVERY : 100.0

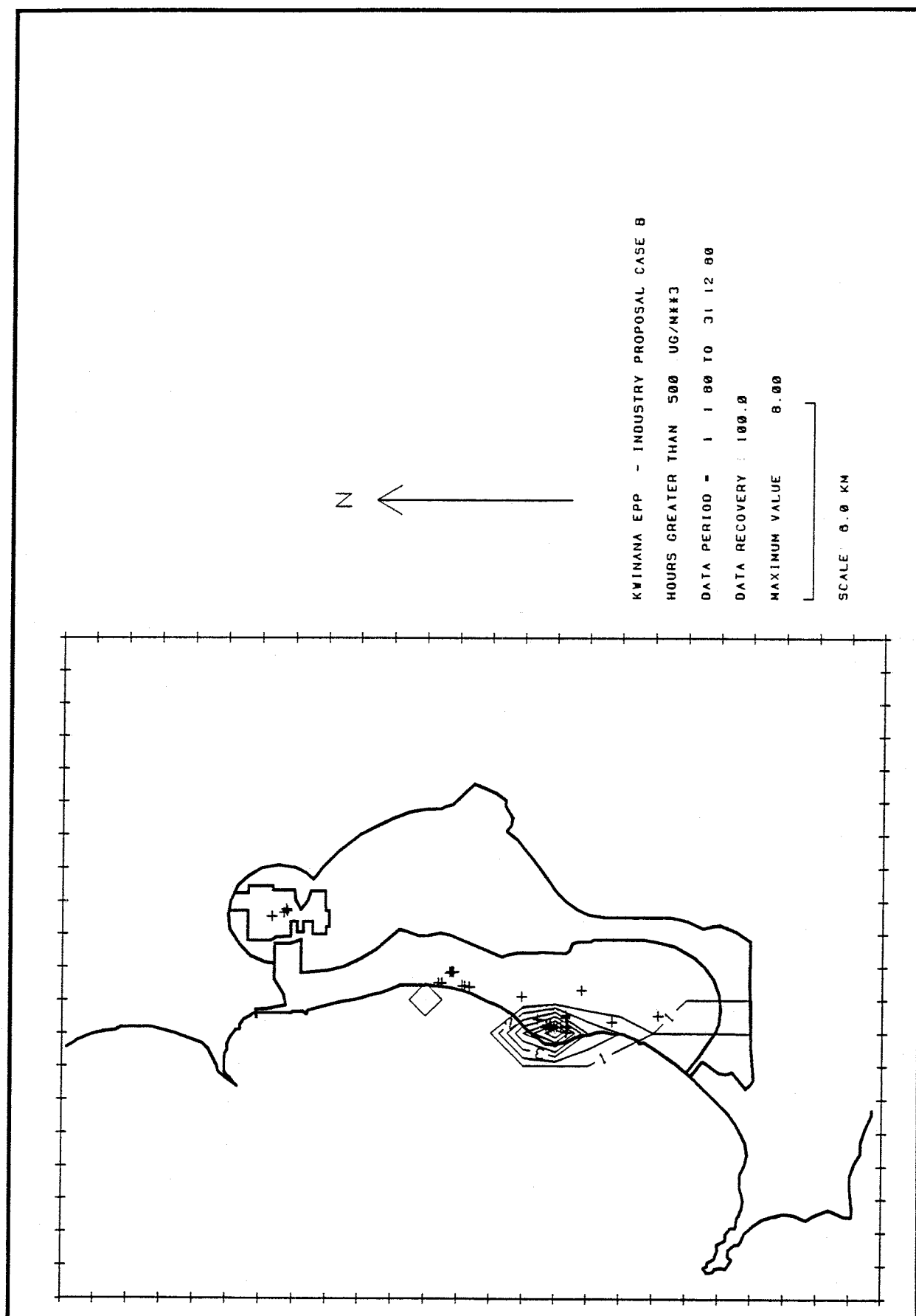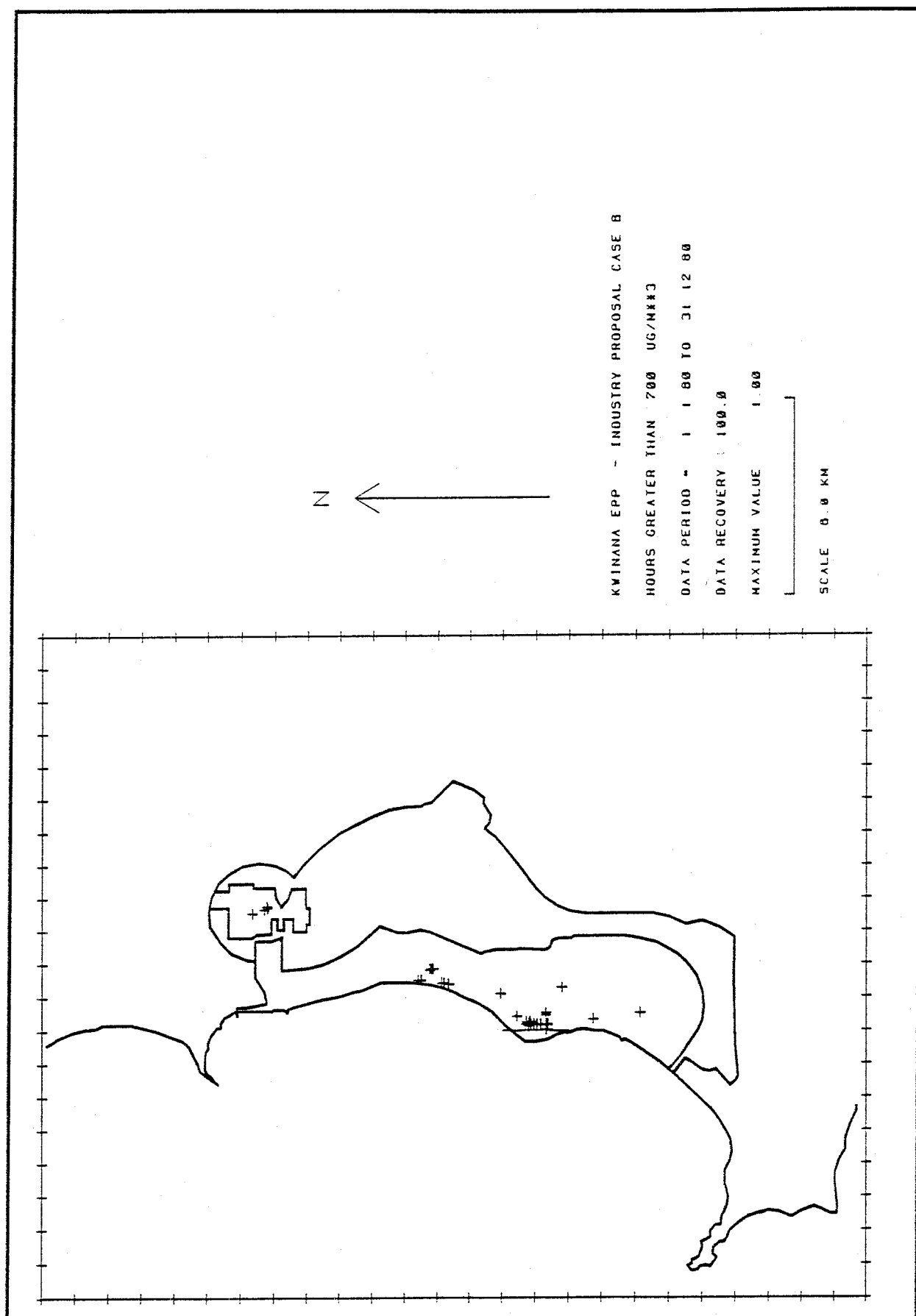MAXIMUM VALUE : 1.00

SCALE 8.0 KM

N

Figure 6.12. Number of hours greater than 700 micrograms per cubic metre for Set B.
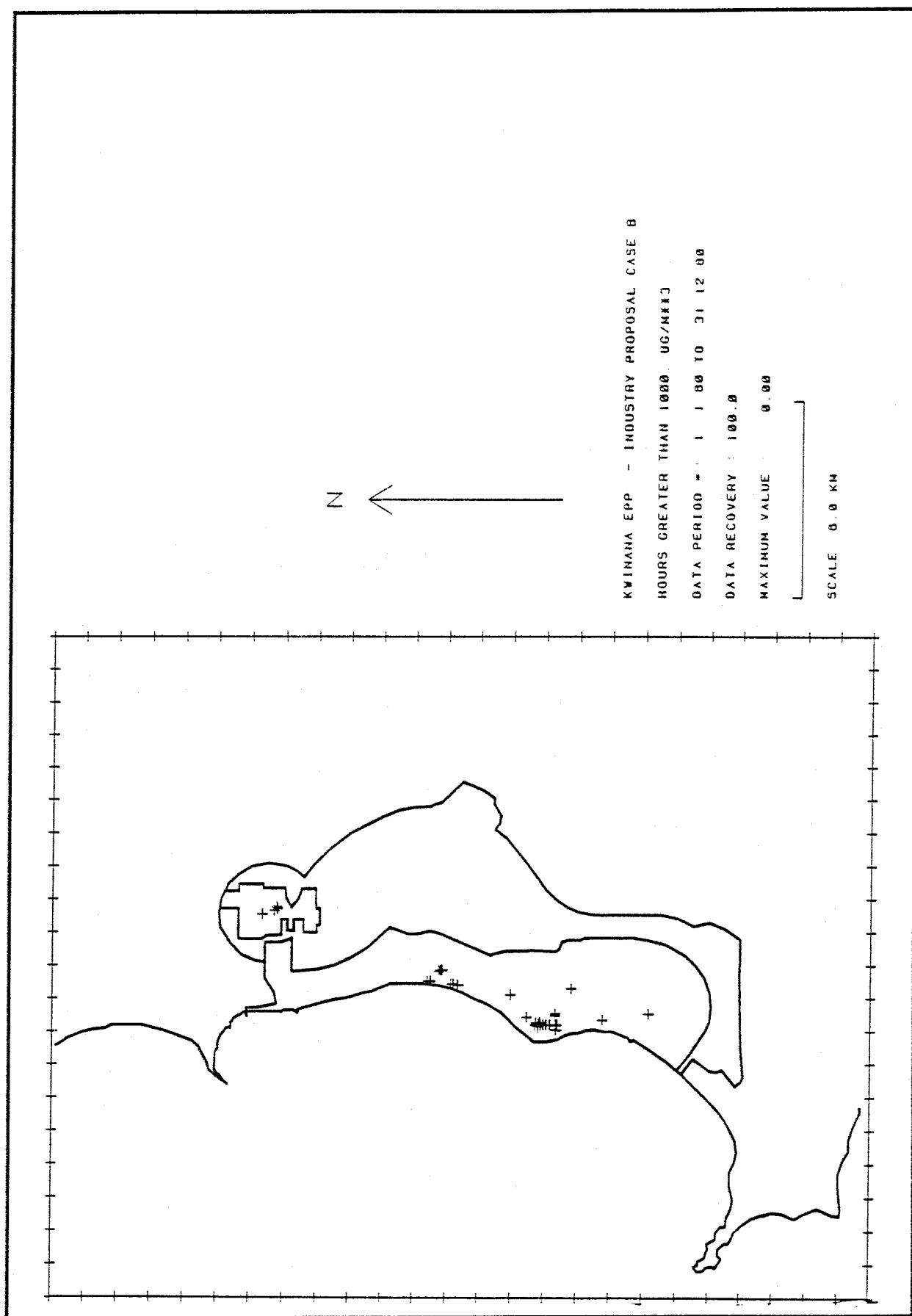
33

Figure 6.13. Number of hours greater than 1000 micrograms per cubic metre for Set B.

Figure 6.14. *The 99.9 percentile hourly average ground level concentration for Set B.*

KWINANA EPP - INDUSTRY PROPOSAL CASE B

MAXIMUM HOURLY CONC. IN UG/M**3

DATA PERIOD = 1 1 80 TO 31 12 80

DATA RECOVERY : 100.0

MAXIMUM VALUE   890

SCALE 0.0 KM

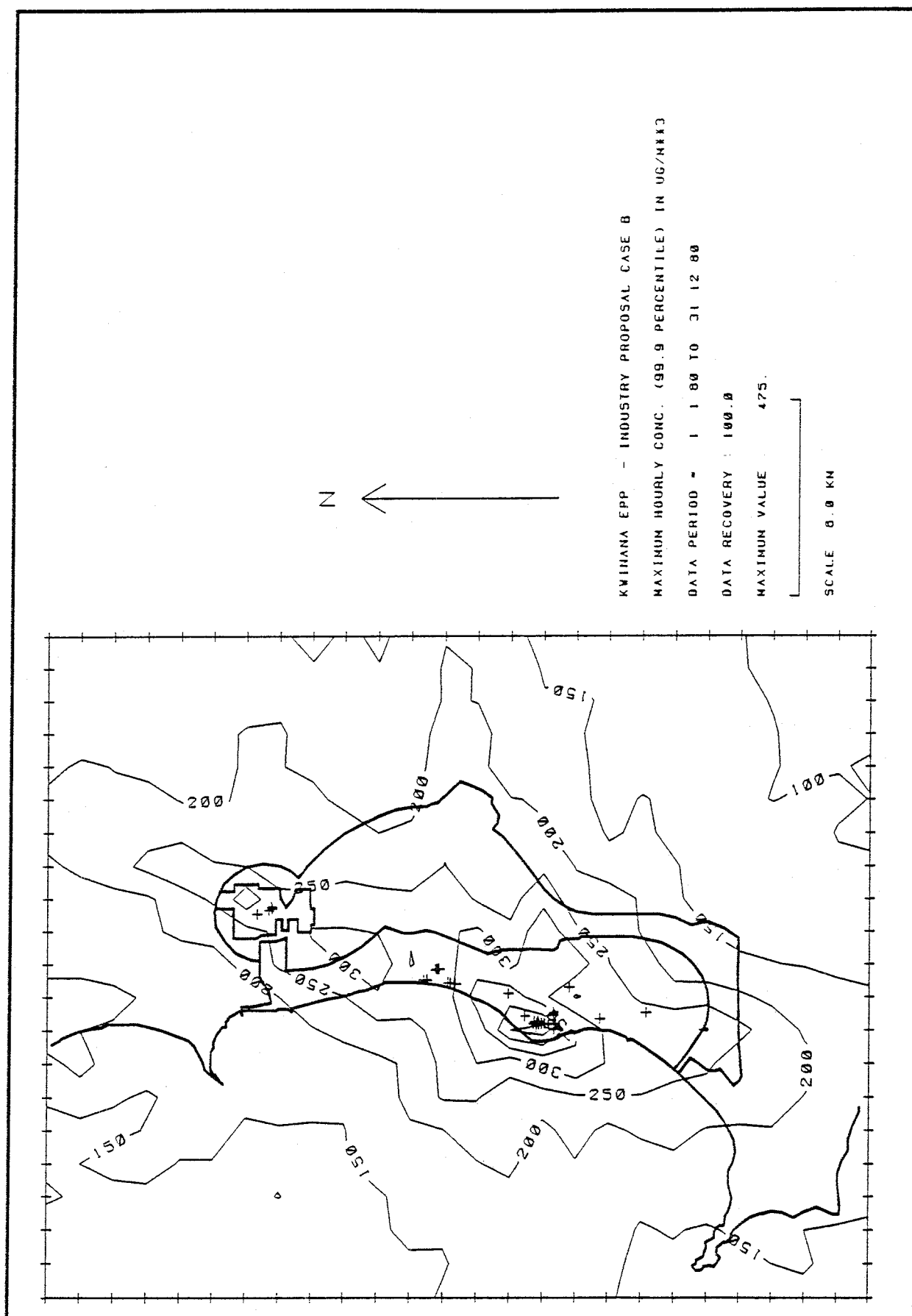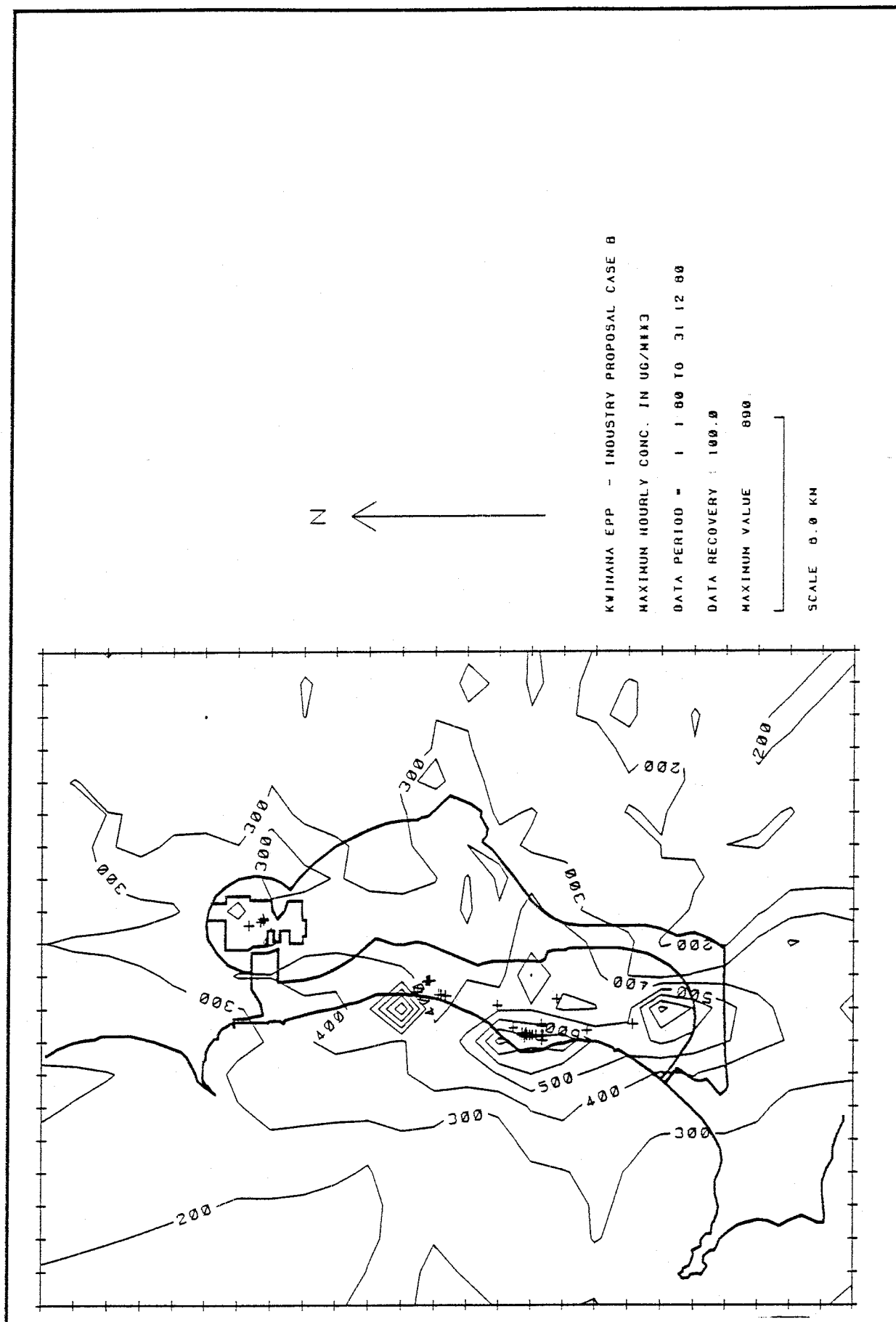*Figure 6.15. Maximum hourly average ground level concentration for Set B.*

36

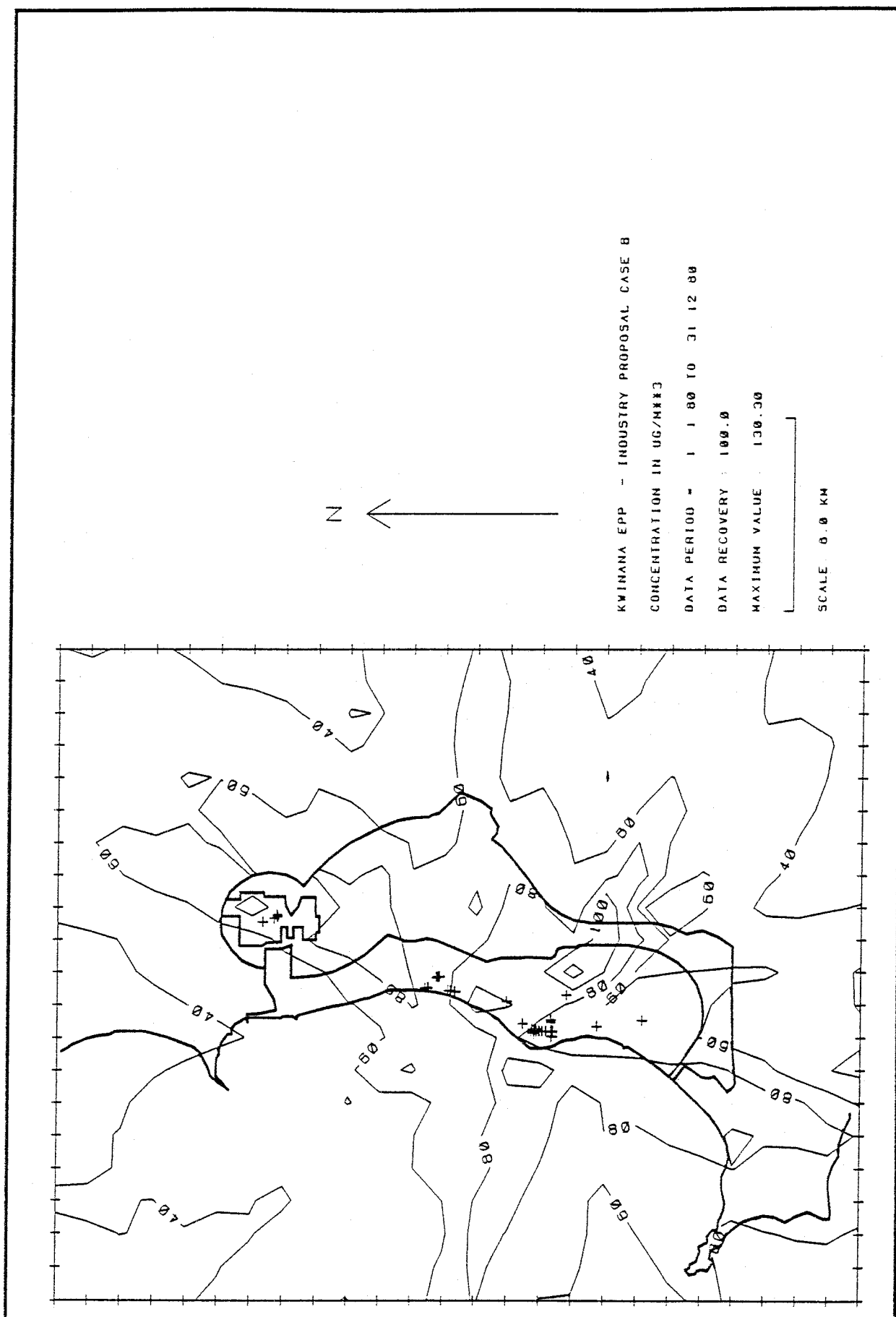*Figure 6.16. Maximum 24-hour average ground level concentration for Set B.*

Figure 6.17. Maximum 24-hour average ground level concentration for Set B (250m grid).

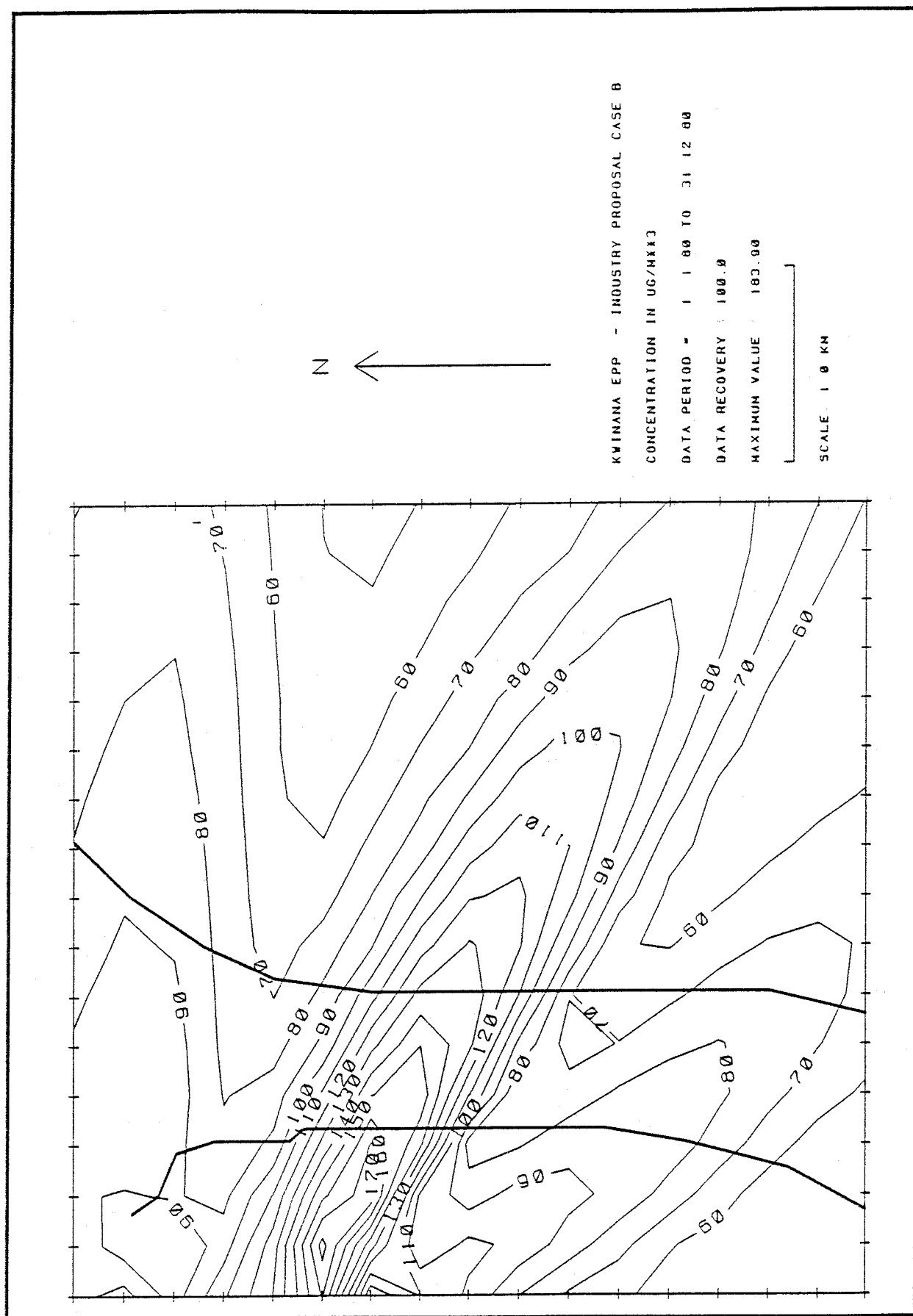KWINANA EPP - INDUSTRY PROPOSAL CASE B

CONCENTRATION IN UG/M××3

DATA PERIOD = 1 1 80 TO 31 12 80

DATA RECOVERY : 99.7

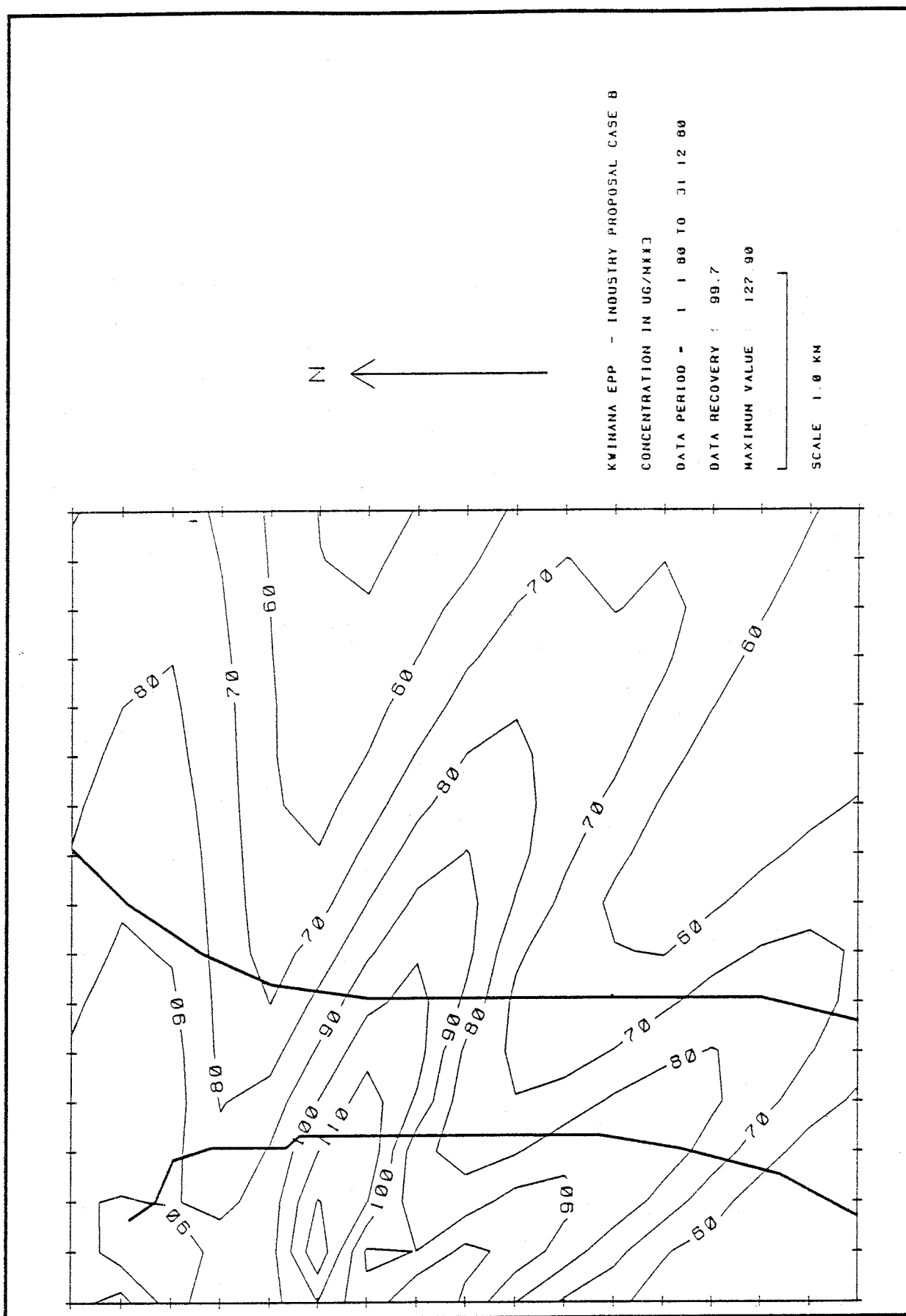MAXIMUM VALUE : 127 90

SCALE 1.0 KM

Figure 6.18. Second highest 24-hour average ground level concentration for Set B (250m grid).

7. Monitoring programme

7.1 Emissions monitoring

At the time of writing this report the details of emissions monitoring to be undertaken by the occupiers of industrial premises had not been finalised. All occupiers for whom a determination of maximum permissible quantities of sulphur dioxide has been made (Section 5) have received the letter contained in Appendix B, which indicates the basis on which emissions monitoring requirements will be determined.

7.2 Ambient air quality monitoring

The EPA has an existing network of monitoring stations in the Kwinana region which will be maintained for the foreseeable future. These stations are located at Wattleup, Hope Valley and East Rockingham, marked by the numbers 1, 2 and 3 respectively on the map in Figure 7.1. Sulphur dioxide and particulates are monitored at all three stations, whilst oxides of nitrogen, hydrocarbons, and visibility reduction are also measured at Hope Valley

The ambient monitoring requirements to be met by industry have been determined, in line with the strategy outlined in Section 4.1, by viewing the results of modelling and deciding the number and placement of monitors necessary to provide effective verification of the model results. The model results plotted in Figures 6.6 and 6.14 provide the best picture. The EPA originally considered that five additional monitoring stations would be necessary but have subsequently agreed with industry that the following programme will achieve all of the EPA's objectives.

Two stations to monitor sulphur dioxide and particulates will be established for the foreseeable future at the sites marked 4 and 5 on Figure 7.1. These sites have been chosen to coincide with areas in which relatively high concentrations are predicted. A third station measuring the same pollutants will be initially established at site 6 in Hillman, again in an area where the model predicted ground level concentrations a little higher than the surrounding area. The EPA anticipates, on the basis of our knowledge of the model's strengths and weaknesses, that the actual ground level concentrations at this site will be lower than predicted. If the monitoring data collected from this site over the first year or so indicates that the ground level concentrations are well within the EPP objectives, the station will be shifted to site 7, and subsequently to site 8 on the same proviso. Two alternatives for site 8 are shown in Figure 7.1; the actual locations of sites 7 and 8 will be chosen at a future date. Ultimately the station will be permanently sited at the most appropriate location, which may or may not be one of sites 6, 7 or 8. If, however, either of sites 6 or 7 prove to have ground level concentrations which are not clearly within the EPP objectives, the station will stay at that location and a new station will be installed at the next site in sequence. Hence it is conceivable (although unlikely) that there could ultimately be eight monitors in the region. There will not be less than six.

Some residents of Rockingham have expressed concern that there may be only one monitor in their area in the longer term. This concern is appreciated, however the situation will only arise in the context described above, in which case the EPA will be satisfied that our station at East Rockingham (site 3) provides a reliable indication for the whole area. Current industry could not at some future time cause a persistent pollution problem at, say, Hillman without also causing at least the same magnitude of problem at East Rockingham and prompting an appropriate response from the EPA. If additional industries were to be located in the area the adequacy of the monitoring network would need to be reviewed.

In addition to the above monitoring stations, industry will install a comprehensive meteorological station, providing data which may be used for ongoing assessment of compliance with the Policy, including computer modelling.
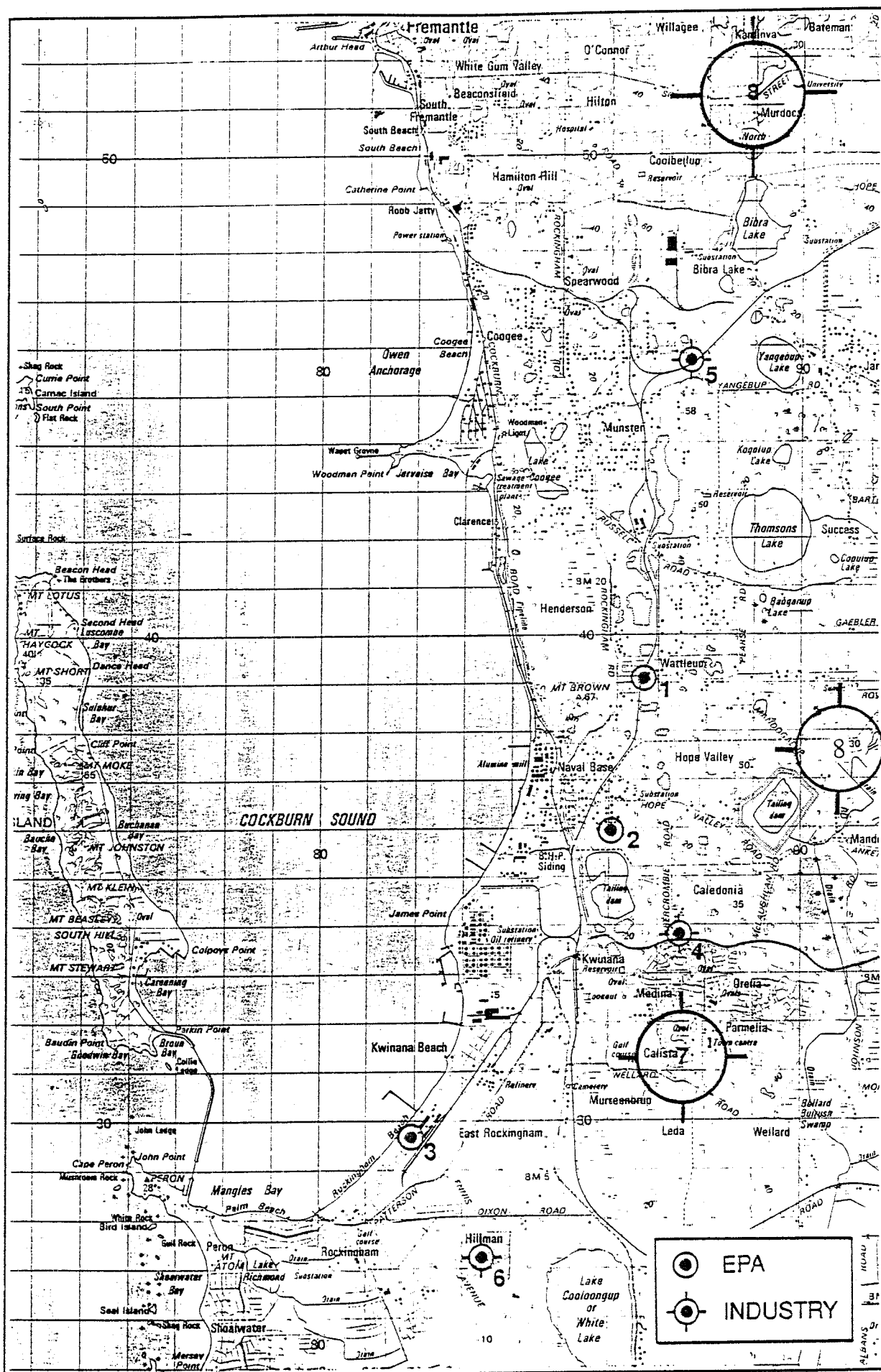
Figure 7.1. Ambient monitoring network.

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8. References

Paparo, V S (ed) (1982). Kwinana Air Modelling Study. Department of Conservation and Environment, Western Australia, Report 10, 96 pp.

Rayner, K N (1987). Dispersion of atmospheric pollutants from point sources in a coastal environment. PhD Thesis, Murdoch University, 249 pp.

Rayner, K N, Bell, B P and Watson, I D (1990). Coastal internal boundary layers and chimney plume dispersion. International Clean Air Conference, Auckland, NZ, 1990.

Rayner, K N and Watson, I D (1991). Operational prediction of daytime mixed layer heights for dispersion modelling. *Atmospheric Environment*, 25A, 1427-1436.

State Planning Commission (1988). Kwinana Regional Strategy.

Appendix A

This Appendix is included primarily as a record of the model parameters used in the determination of maximum permissible quantities. Much of the detail herein will make little sense to the general reader.

A copy of the control file for the model run using maximum permissible quantities Set A is included on page A2. The control file for Set B is identical except for the title. The industrial sources are listed in the same sequence as in Tables 5.1 and 5.2. As indicated in the explanatory notes at the bottom of the file, the values to the right of each source name are (in order):

- stack height;

- stack exit diameter;

- location of the stack, expressed in AMG coordinates (east and north);

- the next two figures are not used; and

- the final figure is the distance of the source eastward from the nominal coastline.

The computer command file is included on page A3 as a record of filenames and model parameters. HVWMLTHK10 is the name of the Hope Valley meteorological data file. PMKWIN79 is the name of a file of daily classifications of onshore flow type, used to determine a nominal value for the onshore flow temperature lapse rate. XCASEA.EMI is the emissions file (maximum permissible quantities) for Set A as per Table 5.1.

The model parameters listed in the command file are explained in the portion of the computer log file included on page A4.

```
KWINANA EPP  - INDUSTRY PROPOSAL CASE A
  375000. 6424000. 1000. 21 26 0.2833 -32.0 181.7   3.0  .083  .047  0.25
 010180 311280 0000 2400  3  1 77  1.9  2.3
37 0.00 0350. 0500. 0700. 1000. 0
  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22
 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37
  0        ! NUMBER OF STACKS THAT ARE NOT BEING USED
SEC STAGE A    114.3 4.27 384425 6436810 1.00  0. 250
SEC STAGE B    137.2 4.27 384450 6436880 1.00  0. 250
SEC STAGE C    189.0 5.33 384390 6436670 1.00  0. 250
ALC POWERHSE 1 68.6 1.96 384840 6437260 0.54 36. 500
ALC POWERHSE 2 71.6 1.96 384845 6437210 0.54 36. 500
ALC POWERHSE 3 99.7 1.98 384845 6437175 0.52 37. 500
ALC POWERHSE 4108.9 1.98 384845 6437140 0.51 37. 500
ALC CALCINER 1 49.9 3.05 384515 6437510 0.64 28. 250
ALC CALCINER 2 49.9 3.05 384505 6437510 0.64 28. 250
ALC CALCINER 3 37.7 3.05 384510 6437605 0.71 23. 250
BP CDU 1       63.1 2.59 383180 6433950 0.79 14. 400
BP CDU 2       65.5 1.61 383180 6433840 0.79 14. 400
BP VDU 2       48.8 1.07 383170 6434130 0.79 18. 400
BP FURFURAL    30.5 1.30 383260 6434150 0.85 11. 450
BP PDA         21.3 0.90 383250 6434265 0.86 11. 450
BP FERROFINER  18.3 0.46 383200 6434190 0.89 10. 400
BP BITUMEN     17.4 0.67 383120 6434230 0.90  7. 350
BP CAT REF1006 33.7 2.46 383500 6433690 0.86  8. 700
BP CAT REF1001 33.7 1.52 383520 6433675 0.85 10. 700
BP HYDROFI 601 15.2 1.07 383180 6433675 0.91  7. 400
BP HYDROFI 601 22.9 1.22 383180 6433650 0.88  8. 400
BP HYDROFI new 30.0 1.22 383180 6433625 0.88  8. 400
BP ALKY        70.5 1.07 383450 6433690 1.00  0. 700
BP SGA 1 & 3   27.6 1.90 383005 6433675 0.89  6. 250
BP SGA 5       27.6 1.90 383035 6433655 0.89  6. 250
BP FLARE       70.0 9.99 383415 6434550 1.00  0. 600
BP CRACKER     80.0 2.85 383185 6434040 1.00  0. 400
BP SRU         50.0 0.35 383170 6434300 1.00  0. 425
BP SRU 2       50.0 0.35 383200 6434300 1.00  0. 475
TIWEST BYPASS  27.0 1.20 384280 6433200 1.00  0.1300
HISMELT        64.0 2.50 384100 6435050 1.00  0. 600
CSBP SAP 2&3   91.5 3.84 383330 6432260 1.00  0. 350
WEST MIN CORP  93.5 1.88 383515 6430865 1.00  0.1500
CC KILN 1&2    58.5 2.22 386658 6442312 1.00  0.3000
CC KILN 3      62.7 3.00 386700 6442225 1.00  0.3000
CC KILN 4      82.5 2.18 386755 6442240 1.00  0.3000
CC KILN 5      82.3 3.60 386538 6442680 1.00  0.3000
0


TITLE
(A)
XREF,YREF,GINT,NUMX,NUMY,DTSL,ALAT,CSTDIR,ZLSB,SGTHSB,SGPHSB,TIBPEN
(2F9.1,F6.1,2I3,F7.4,3F6.1,3F6.0)
IDS,IMS,IYS,IDF,IMF,IYF,IT1,IT2,IAV,IDATAV,IY1,CSIGON,CSIGOF
(2(1X,3I2),2I5,3I3,2F5.1)
**** NOTE - IAV    = MODEL TIME STEP IN MULTIPLES OF 10 MINUTES (EG. 3 = 30 MIN
                     TIMESTEP.
           - IDATAV = INPUT MET DATA AVERAGING TIME IN MULTIPLES OF 10 MINUTES
                     (EG. 3 = 30 MIN INPUT DATA)
**** NOTE - IAV CANNOT BE LESS THAN IDATAV AND IDATAV MUST BE GREATER THAN 0
NUMSCE,QMIN,ALEV1,ALEV2,ALEV3,ALEV4,I
(I3,F5.1,4F6.0,I2)
**** NOTE - POLPOT MODE IS NOW FOR MULTIPLE SOURCES WITH FIXED EMISSIONS.
READ IN THE NUMBER OF STACKS PER SOURCE GROUP
KSCE(I),I=1,NUMSCE

(22I3)
READ IN THE STACK NUMBERS IN THE ORDER OF USE (.IE SOURCE GROUPING)
(ISTNUM(I),I=1,ISTTOT
READ IN THE NUMBER OF STACKS NOT TO BE USED
NSNTUS
READ IN STACK INFORMATION DATA
C STKHGT - HEIGHT OF STACK
C STKDIA - DIAMETER OF STACK
C STKX    - LATITUDE OF STACK AMG COORDS
C STKY    - LONGITUDE OF STACK AMG COORDS
C TEMSL   - SLOPE OF THE TEMPERATURE LOSS EQUATION FOR STACK
C TEMIN   - INTERCEPT OF THE TEMPERATURE LOSS EQUATION FOR STACK
C TEMSL AND TEMIN ARE USED TO AMKE ALLOWANCE FOR THE TEMPERATURE LOSS OF
C           FLUE GASES IN THE STACK WHEN GAS TEMPERATURES ARE MEASURED AT
C           THE BASE OF THE STACK
C DCOAST - ARRAY DISTANCE (METRES) FROM THE COAST OF EACH SOURCE GROUP
C Q       - SOURCE STRENGTH (KG/S)
C STKVOL - SOURCE VOLUME (M**3/S) AT STACK TEMP (IE. GAS FLOW RATE)
C STKRHO - EMISSION DENSITY (KG/M**3) AT STACK TEMP
C IBUILD - BUILDING EFFECTS FOR THIS SOURCE (1=YES, 0=NO)
C HBSTK   - HEIGHT OF BUILDING
C WBSTK   - WIDTH OF BUILDING
STKHGT(K),STKDIA(K),STKX(K),STKY(K),DCOAST(K),Q(K),STKVOL(K),STKRHO(K),
IBUILD(K),HBSTK(K),WBSTK(K)
(14X,F5.1,F5.2,F7.0,F8.0,F5.2,F4.0,F6.0,3F8.0,I2,2F4.0)
*** NOTE- WITH BUILDING EFFECTS IT IS ASSUMED THAT THE LAST SOURCE IN THE
          SOURCE GROUP HAS THE BUILDING DIMENSIONS. THIS LAST SOURCE ALSO
          CONTAINS THE LOGICAL (IBUILD) WHICH DETERMINE WHETHER BUILDING
          EFFECTS ARE TO BE USED.
```

```
$ SET NOON
$ set def [pi.rayner.kams]
$ RUN XDM4
XCASEA.CTL
XTEMP43.OUT
N
N
Y
2
Y
N
N
Y
1.
Y
N
N
HVWMLTHK10
PMKWIN79.DAT
XCASEA.EMI
$ @sumdisp xtemp43 010180,311280
$ RUN XDM4
XCASEB.CTL
XTEMP44.OUT
N
N
Y
2
Y
N
N
Y
1.
Y
N
N
HVWMLTHK10
PMKWIN79.DAT
XCASEB.EMI
$ @sumdisp xtemp44 010180,311280
```

```
DISPMOD -  GRID DISPERSION MODEL
                        Run time: 13:36:02 on 17-JUL-91


DISPMOD>Enter the name of the control file:
XCASEA.CTL
DISPMOD>Enter the name of the output file:
XTEMP43.OUT
DISPMOD>Do you want to use stability classes (Y/N <N>):
N
DISPMOD>Do you want only centre-line concentrations (Y/N <N>):
N
DISPMOD>Use fixed sea breeze depth of 1500 m? (Y/N <N>):
Y
DISPMOD> Choose an option for onshore flow lapse rate:
1 fixed value  2 Manins/Physick   3 Rye
2
DISPMOD> Apply standard seasonal lapse rate variation? (Y/N <N>):
Y
DISPMOD>Use measured sigma theta? (Y/N <N>):
N
DISPMOD>Do you want to reduced Sigma Theta at height in TIBLs (Y/N <N>):
N
DISPMOD>Do you want mixing into TIBLS to be sharper than SGPHI (Y/N <N>):
Y
  Enter new constant SGPHI for TIBLS
1.
DISPMOD> If met data is to be averaged, do you want to compare variance
due to direction meander to calculated variance and
select the greater? (Y/N <N>):
Y
DISPMOD> Do you want to get info to screen/log on events
with timestep conc. exceeding a nominated value?
N
DISPMOD>Do you want AUSPLUME plume penetration (Y/N <N>):
N
DISPMOD>Enter the name of the WML file (no extension for database)
        (RETURN TO END RUN):
HVWMLTHK10
  Enter name of file for onshore flow lapse rates
PMKWIN79.DAT
DISPMOD>Enter 1990 Emissions file:
XCASEA.EMI
 1 180   58907   22933
 2 180   54986   23483
 3 180   73324   27621
etc...
etc...
301280   62687   29349
311280   62922   24838

DATA RECOVERY FOR THIS RUN : 100.0

FORTRAN STOP
```

Appendix B

Mr J Day
Alcoa of Australia
PO Box 252
APPLECROSS WA 6153

P76/87/V4
Mr I Cameron

Dear Sir

SUBJECT: DRAFT ENVIRONMENTAL PROTECTION (ATMOSPHERIC WASTE) (KWINANA) POLICY - SULPHUR DIOXIDE MONITORING.

The Environmental Protection Authority (EPA) has prepared its final report on the Draft Environmental Protection (Atmospheric Waste) (Kwinana) Policy (EPP) which is to be submitted to The Hon: Minister for the Environment, Bob Pearce MLA in accordance with the requirements of the Environmental Protection Act (1986).

The EPA and industry representatives have developed and formalised a programme for ambient sulphur dioxide monitoring in the Kwinana region to satisfy the EPP's requirements.

The EPP also requires industries to undertake monitoring of emissions of sulphur dioxide at source. This emissions monitoring programme, which will be spelled out in licence conditions, will provide data for three purposes:

(i)   to verify compliance with licenced emission limits;
(ii)   to be used in the assessment of any exceedences of the EPP standards or limits;
(iii)   to be used as input data for further computer modelling, in order to evaluate the model against ambient monitoring data and thereby provide a sound basis for assessing future variations to emissions in the area.

The key EPP standards and limits are 1-hour averages. Therefore, we require measurements or acceptably accurate calculated estimates of emissions which resolve significant variations in emissions down to a timescale of 1 hour (and preferably half an hour, which is the model timestep). This means that half-hourly or hourly average data would be required for sources with emissions which vary often throughout the day whereas less frequent data would be required for sources with emissions which are nearly constant for several hours at a time . The data from all Kwinana sources will be processed by us to produce a single data base of half hourly values, including the following variables:

-   SO2 mass emission rate,
-   total volume flow rate at exit temperature,
-   exit temperature or density,
-   plume exit velocity.

Data of the frequency and quality we require for each source would obviously be available from a well maintained system comprising an in-situ stack monitor, calibration system, data logger with back-up chart recorder and software to provide processed emissions data on IBM diskette. The above is our default requirement, however we are happy to negotiate alternative systems to provide acceptably accurate emissions measurements or calculations (still to be provided on IBM diskette) if direct stack measurement is considered to be either too onerous or unnecessary in view of suitable alternatives. Any alternative system (e.g. SO_2 emissions calculated from fuel or feedstock sulphur content and other operational parameters) would need to include appropriately regular stack testing by the industry to confirm the calculated estimates. Independent auditing of emissions will be arranged by this Authority.

If you wish to propose a system which does not rely on in-situ stack monitoring, please provide details to me by 1 July 1991. I do not wish to be prescriptive as to what will or will not be acceptable, however I can say that any alternative systems will be closely scrutinised to determine whether the emissions estimates for each source are acceptably accurate in the context of the source's significance, i.e. its potential to contribute significantly to hourly average ambient SO_2 concentrations.

For further information or discussion on this matter, please contact:

- Mr Iain Cameron on telephone 222 7120 in relation to monitoring methods, equipment , etc.

- Dr Ken Rayner on telephone 222 7102 in relation to alternative systems.

Yours faithfully

SIGNED BY P BROWNE-COOPER

Peter Browne-Cooper
DIRECTOR

24 MAY 1991

REF: EPPSO₂ 220591 ICA