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A TECHNIQUE FOR ASSESSMENT OF AIR POLLUTION FOR THE NEEDS PROGRAM FOR THE CITY OF TULSA, OKLAHOMA

APPROVED BY

James M. Robertson

Dan E. Gruger

Robert Y. Nelson

Geo. W. Re

Raymond A. Mill.

DISSERTATION COMMITTEE

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A TECHNIQUE FOR ASSESSMENT OF AIR POLLUTION FOR THE NEEDS PROGRAM FOR THE CITY OF TULSA, OKLAHOMA

CHAPTER I

INTRODUCTION

The air which envelopes the Earth is the life-supporting medium for man, just as water is the medium in which fish exist. It is required in the combustion of fuels whereby man generates heat and power. Air is used in manufacturing processes and service activities, such as chemical and biological oxidation processes, cooling and spray painting. The air supply of the Earth's atmosphere is limited and as other natural resources must be reused. In the course of natural and artificial ventilation, used air, along with any waste products, mixes with the surrounding ambient air which is thereby polluted. Many waste products in the air are damaging both to man and various elements of his environment. Fortunately, polluted air is subject to natural cleansing and rejuvenation. When these cleansing systems become overloaded and the tolerance of man and his environment is excluded, man must either suffer the consequences or initiate action to preclude the resulting damage and loss. (1)*

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*Number in parenthesis refers to reference.

Air pollution control has been carried out from time to time and to various levels of sophistication for hundreds of years. Until the relatively recent episodes of death-dealing smog in London, the Meuse Valley of Belgium, and Donora, Pennsylvania, actions were generally for the purpose of lessening a nuisance. Today there is a substantial and growing realization that the ecology is changing rapidly and that man's existence as a species of this planet is threatened. Damaging air pollution is the principal result and indicator of this ecological change. Air pollution is a regional problem. Therefore, county-wide, multi-county and interstate programs have been established in various parts of the United States. Mounting effective air quality management is complex, difficult, and expensive. It involves major considerations and actions in the technologic, sociologic, economic, political and judicial areas. Society has now deemed that air pollution control must be achieved in order to preserve and promote man's total health and well being.

The mission of air pollution control agencies is to reduce to a minimum the amount of pollutants emitted from existing sources and to minimize the introduction of additional pollutants from new sources. Control programs should be operated as efficiently and effectively as possible. Under the complex and difficult circumstances that prevail, a thoughtful and thorough planning effort is demanded.[2]

Despite the spectacular increased effort in the 1960's to control air pollution, the best that can be said. in most areas of the nation, is they've barely been able to hold the line. Both population and standard of living continue to increase and with these there is a resulting increase in the production and use of goods and services. Each year there are more automobiles, more power-generating facilities, more new chemical compounds, more manufacturing plants, and more use of fertilizers and pesticides, all resulting in more sources of atmospheric emissions. Air pollution is considered to be a major factor in respiratory ailments such as lung cancer, emphysema, chronic bronchitis, and common colds. It appears to be a factor in heart disease and abnormal human behavior. It causes eye irritation. Economic loss from air pollution is most visible due to damage to vegetation, materials, animals and diminished visibility. Agricultural productivity and the salability of fruits, flowers, and vegetables are reduced by air pollution. It adversely affects normal growth and function of domestic animals. Air contaminants not only damage paint and erode metals and masonry but art sculptures are severely deteriorated. Fabrics are caused to fade and deteriorate by these pollutants and the connections and switches of electrical systems are damaged. Air pollution reduces visibility and thus spoils or obliterates vistas, causes airplane and vehicular accidents, delays airline schedules and reduces property values.[(3)]

Air pollutants are in the form of solid and liquid particulates and gases. They occur in the air in varying particle sizes, concentrations and combinations. Problems result after variable exposure times depending upon the nature of the pollutant and the sensitivity of the receptor. Odor problems occur almost instantaneously when a very low concentration of a single gaseous pollutant comes in contact with a human nose, while noticeable damage to a stone sculpture may require years of exposure to relatively high concentrations of sulfur dioxide particles and humidity. Significant problems for a small area may be limited to those caused by emissions from a single "point" source such as a smelter, power plant, paper mill or chemical manufacturing plant. Air pollution for regional areas with an urban core, however, is caused by the emissions from a large number of sources, both stationary and mobile. Identification and quantification of the problem requires an evaluation of the pollutant source-receptor system of the area with thorough consideration of such factors as the nature and location of pollutant sources, quantities of source emissions, topography, meteorology, and measured and predicted levels of air quality. These evaluations serve as the basis for subsequent monitoring, emission inventory studies, and regulatory activities.[4]

CHAPTER II

REVIEW OF THE LITERATURE

General

Every living thing contaminates its environment. To live, organisms must react with their environment, and in the process of reacting, by the very fact of living and reacting, waste is produced and cast off. Any environment must be self-cleansing in order to sustain life. Unless the environment can dispose of life's by-products, life will cease. When wastes are produced so rapidly, or when they accumulate in such concentrations that the normal self-cleansing or dispersive propensities of the atmosphere cannot cope with them, the air is called "polluted." Some kinds of pollution affect visibility. These same pollutants, in sufficient concentration, may cause discomfort to man or animals, may damage property, or may actually injure man, animals, and plants. Even when levels of concentration are so low that they cannot be detected except with special instruments, certain pollutants may harm living creatures exposed for long periods of time.[5]

Pollutants and Their Effects

The Federal Environmental Protection Agency recognizes the following five air pollutants as being among the most serious nationally:

1. Carbon monoxide--An invisible gas produced primarily by incomplete combustion of gasoline in automobile engines.

2. Sulfur oxides--Primarily sulfur dioxide, a product arising from burning high-sulfur coal and fuel oil.

3. Nitrogen oxides--Principally nitrogen dioxide, a gas in exhausts from motor vehicles and from other high temperature combustion systems. It is also present in coal and oil smoke and reacts with sunlight and hydrocarbons to form oxidants.

4. Particulate matter--Solid matter carried in the air: fly ash and other discharges from smokestacks and motor vehicles; agricultural and industrial dust; etc.

5. Hydrocarbons--A large class of organic chemicals. Certain hydrocarbons react with sunlight to form oxidants. Because the total hydrocarbon level present in the atmosphere is derived largely from natural sources, the total concentration is corrected by subtracting the naturally-occurring inert and non-toxic hydrocarbons such as methane.

Carbon Monoxide

Carbon monoxide is one of the three most common products of fuel combustion. Carbon dioxide and water vapor are the other two. Most of the carbon monoxide in the atmosphere results from the incomplete combustion of carbonaceous materials. Automobiles are especially notorious for producing this gas. In Los Angeles County, more than three million motor vehicles each day pollute the air with 8,000 tons of carbon monoxide, which amounts to an average of more than five pounds per vehicle per day. The mass emissions of carbon monoxide as a result of fuel combustion in the United States was estimated, as of June 1962, at about 100 million tons per year, a quantity that approximately equals the combined total of all other industrial contaminants.[1][6]

Carbon monoxide is a poisonous inhalant and no other toxic gaseous air pollutant is found at such relatively high concentrations in the urban atmosphere.[7] The gas is dangerous because it has a strong affinity for hemoglobin, which carries oxygen to body tissues. The effect of carbon monoxide is to deprive the tissues of necessary oxygen.

At a concentration of slightly more than 1,000 ppm, carbon monoxide kills quickly.[7] One hundred parts per million is generally considered the upper limit of safety in industry for healthy persons within certain age ranges when exposure may continue for an eight-hour period.[8] Los Angeles has set its three alert levels for carbon monoxide at 100, 200, and 300 ppm. Most people experience dizziness, headache, lassitude, and other symptoms at approximately 100 ppm.[9]

Present measurements show that the level of 100 ppm is seldom exceeded in cities of the United States.[10] In the commercial and industrial districts of Cincinnati, the concentrations of carbon monoxide have ranged from 0 to 55 ppm with an average of 9.5 ppm.[11] During extensive measurements in the Los Angeles area the highest concentration was 72 ppm.[5] Higher concentrations than this occasionally occur locally in garages, tunnels, behind automobiles, or in the open atmosphere. For example, maximum instantaneous concentrations of more than 100 ppm were found during several months of observation in Detroit in 1960.[12] Some researchers believe that even small amounts of carbon monoxide are likely to produce some detectable response.[13] Although, there may be a difference between a "response" and a "harmful effect," the question is of particular concern because of the increasing number of automobiles in our cities.

Most American scientists believe that carbon monoxide is not a cumulative poison.[7] When exposure is discontinued, the gas that combines with hemoglobin is spontaneously released and the blood is cleared of one-half of its carbon monoxide, at least in healthy subjects, in three to four hours.[9] Carbon monoxide can cause acute poisoning as a result of exposure to high concentrations of the gas, but chronic poisoning does not occur as a result of long-continued exposure to relatively low concentrations. However, some European scientists maintain that chronic carbon monoxide poisoning does occur.[10] In the adopting its "serious" level of standards for carbon monoxide in 1960, the California Department of Public Health indicated that exposure to 30 ppm for eight hours, or exposure to 120 ppm for one hour may be a serious risk to the health of sensitive people.[14]

Oxide of Sulfur

Oxides of sulfur, primarily sulfur dioxide, are produced by the combustion of sulfur-containing fuels, such as coal and fuel oils in sulfuric acid plants and in metallurgical processes involving ores containing sulfur. One and one-half million tons of sulfur dioxide are discharged yearly in New York City from the burning of coal alone, and in Great Britain five million eight hundred tons.[15] The annual worldwide emission of sulfur dioxide, based on statistics available from some of the industrialized countries in recent years, totals about eighty million tons--fifty to sixty million tons from coal, about eleven million tons from crude oil refining (most of this in the United States), eleven to twelve million tons from copper smelters, and three and one-half to four million tons from lead and zinc smelters.[11] The burning of wood and solid wastes, such as paper, cardboard, and rubber tires, also adds sulfur dioxide to the atmosphere.

Sulfur oxides can injure man and plants and interfere with visibility. At sufficiently high concentrations, sulfur dioxide irritates the upper respiratory tract of human beings because of its high solubility in body fluids. Although the concentration of sulfur dioxide has been measured regularly for many years and in many places, the concentration was determined during only one of the three well-known dramatic air pollution disasters (London, Meuse Valley and Donora). The average concentration of sulfur dioxide during a two day period at the height of the London smog of December 1952 was 1.34 parts per million.[18] Higher concentrations may have existed for shorter periods of time, but this average figure is well below the maximum that has been measured in other cities not in the midst of a disaster. Concentrations of up to 3.2 ppm have been recorded in the commercial and industrial sections of cities that use a great deal of solid fuel, for example, Chicago and Pittsburg.[18]

The more usual concentrations for community air pollution are about a few parts per hundred million. Although these levels are far below those regarded as hazardous to the industrially employed, there is growing evidence that lower concentrations may adversely affect health in special cases.[19] A discernible physiological response, produced by concentrations as low as 1 ppm has been reported, but there is disagreement with the findings.[9] A concentration of 0.6 ppm of sulfur dioxide will produce no detectable response in healthy human beings, but in the range between 1 and 5 ppm most persons will begin to show a detectable response.[9] Most people can detect 5 ppm which produces a distinctive gross physiological response, and exposure for one hour causes choking.[24] Most people find 10 ppm quite unpleasant because an exposure for one hour to this concentration produces severe distress. A study of people who, because of the occupations, were regularly exposed indicates that a moderate degree of resistance may develop from continuous exposure to sulfur dioxide concentrations of 5 ppm and above.[9] They can scarcely smell the gas at these concentrations, and experience little or no irritation of the respiratory tract. Pattle and Cullumbine reported that repeated exposure may also be associated with increased sensitivity.[20]

In an experiment, unanesthetized guinea pigs that were exposed to a mixture of sulfur dioxide and sodium chloride at near air pollution levels experienced greater difficulty in breathing than did those exposed to a corresponding concentration of sulfur dioxide alone.[7] Many believe that the illnesses and deaths in the Meuse Valley episode must be attributed primarily to a mixture of sulfur dioxide and sulfuric acid mist, and to other aerosols in conjunction with sulfur dioxide. Others attribute the Meuse Valley disaster to hydrogen fluoride that accidentally escaped from a zinc factory.[21] Lawther recently reported that mortality in London increased significantly when 750 micrograms per cubic meter of suspended smoke were present at the same time that sulfur dioxide was in excess of 0.25 ppm. He also reported that with 300 micrograms of smoke per cubic meter, 0.21 ppm of sulfur dioxide was associated with a deterioration in health of patients with chronic bronchitis.[22]

Experimental exposure of both animals and man to sulfur dioxide--or, rather, its hydrate, sulfuric acid--shows that it is a very strong irritant, much stronger than sulfur dioxide, and can cause choking at relatively low levels of concentration.[10] Unfortunately, there are few data concerning levels and particle sizes of sulfuric acid as a community air pollutant. Sulfuric acid must have been the principal cause of the air pollution disasters in the Meuse Valley, Donora, and London.[9] It produces, on a molar basis, from 4 to 20 time the physiological response in animals as sulfur dioxide.[9] Sulfur dioxide causes both acute and chronic injury to the leaves of plants. The gas is phytotoxic to some species in concentrations above 0.1 to 0.2 ppm; the effect depends upon the length of exposure.[23] Chronic injury to plants is caused either by rapid absorption of an amount of sulfur dioxide somewhat less than the amount needed to cause acute symptoms, or by exposure over a long period of time to sublethal concentrations (usually under 0.4 ppm). The leaves gradually turn yellow, and later become white; areas affected are half as active as normal areas.[24] The presence of nontoxic concentrations of sulfur dioxide has been found to lessen the oxidant damage to plants in the Los Angeles area.[25] At higher concentrations, however, this protective effect has not been noticed.[26]

Both sulfur dioxide and sulfuric acid are responsible for accelerating the corrosion and deterioration of certain materials. Especially when moisture is present, they attack iron and steel, copper, nickel, and aluminum, although the latter appears to be fairly resistant to the concentrations of the sulfur oxides that are normally found in polluted atmospheres.[27] Sulfur dioxide and sulfur trioxide also attack building materials, particularly limestone, marble, roofing slate, and mortar, all of which contain carbonates that are converted to relatively soluble sulfates that can be leached away by rainwater.

Oxides of Nitrogen

Oxides of nitrogen are one of the most important groups of atmospheric contaminants in many communities. They are produced during the high-temperature combustion of coal, oil, gas, or gasoline in power plants and internal combustion engines. Total emissions of nitrogen oxides from moving sources--mostly automobiles, trucks, and buses--were 500 tons per day, approximately 1.5 to 2.3 times the emissions from stationary sources, depending on the time of year.(5) Most determinations of oxides of nitrogen combine nitric oxides and nitrogen dioxide, with a typical range of concentrations being 0.02 to 0.9 ppm.(28)

Of the oxides of nitrogen, nitrogen dioxide is considerably more toxic than nitric oxide, acting as an acutely irritating substance. In equal concentrations, it is more injurious than carbon monoxide. Since the smoke from cigarettes, pipe tobacco, and cigars contain several hundred parts per million of nitrogen dioxide,(7) its effects on the respiratory system deserve attention. Chronic lung disease has been produced experimentally by subjecting animals to nitrogen dioxide, and there is some evidence that exposure to the nitrogen dioxide released during the filling of silos has caused a chronic pulmonary condition.[9] The Cleveland Clinic fire of May 1929 illustrated the insidious nature of nitrogen dioxide as a poison; a large number of people died after inhaling nitrogen dioxide produced by burning x-ray film.[29] However, exposures of this severity are rare. Nitrogen oxides, at levels found in air pollution, are only potentially irritating and potentially related to chronic pulmonary fibrosis.[5]

Nitrogen dioxide has received considerable attention as an air pollutant because it is a hazard in numerous industries. The threshold limit (established by the American Conference of Governmental Industrial Hygienists) for an 8-hour working day has been tentatively set at 5 ppm. However, a report that a three- to five-year exposure of Russian workmen to concentrations of nitrogen dioxide generally below 2.8 ppm resulted in chronic changes in the lung has contributed to the belief that 5 ppm of nitrogen dioxide may not be safe for daily exposure.[7] Concentrations of 25 ppm near factories handling large amounts of nitric acid have caused injury to plants.[24] In recent years Los Angeles County recorded its first instances of nitrogen oxide concentrations that exceeded the first alert level: 3.17 ppm on December 19, 1960 and 3.93 ppm on January 13, 1961.[30] A concentration of 8 to 10 ppm would probably reduce visibility to about one mile.[31]

No standards have been set for oxides of nitrogen with regard to their part in the formation of noxious substances in the photochemical oxidation of organic material. The permissible level for this indirect adverse effect is likely to be much lower than for the direct affect--perhaps as low as 0.1 to 0.2 ppm.[32] Control efforts at the power plants may result in an overall reduction of approximately 50 percent.[33] In trying to control emissions from automobiles, attention has been given hydrocarbons and carbon monoxides rather than to the oxides of nitrogen. The goal of present devices to control automobile exhaust emissions is to reduce hydrocarbons by up to 80 percent and carbon monoxide by 60 percent. Little has been done with the oxides of nitrogen and extensive engineering research and development are necessary.[34]

Particulate Matter

Both organic and inorganic particles emanate from a number of sources: industrial operations, modern transportation facilities, and domestic combustion processes. Major sources of dust include coal- and oil-burning power plants, iron and steel mills, and oil refineries. In addition, small sources, such as automobiles and incinerators, contribute significantly to the dust load of the atmosphere because they are so numerous. Smoke (dust and droplets) is produced during combustion or destructive distillation, and fume (dust) is formed by high-temperature volatilization or by chemical reactions.

A large number of extremely fine particles are emitted from automobile exhaust systems, with approximately 70 percent in the size range of 0.02 to 0.06 micron.[34] For a car population such as that of Los Angeles, the latest estimate of aerosol emission from gasoline-powered vehicles, made by the County of Los Angeles Air Pollution Control District, is 40 tons per day.[5]

Distribution of lead in the air of some cities is usually correlated with the density of vehicular traffic.[9] (Another source of lead pollutants is the melting of scrap metals in foundries.)

One of the most important consequences of pollution of the air by fine particles is the reduction of visibility. Meteorological conditions will greatly affect the reduced visibility that results from a given rate of emissions of particulate pollutants. With very low wind speeds and low turbulence, high concentrations accumulate near the source, thereby reducing visibility. Substantially higher wind velocities will also cause low visibility if surface dust and debris are picked up from vacant lots and streets. The wind velocity that will give the greatest visibility during continuous emission of man-made pollutants will depend, therefore, not only upon atmospheric stability and other factors relating to pollutant dispersal, but also upon soil moisture, vegetation cover, and other surface characteristics in the immediate vicinity.(35)(36)

A portion of the particles in urban atmospheres collects substantial quantities of absorbed water at humidities well below water saturation.(39) The California Department of Public Health has established a standard for particulate matter at the "adverse" level: "Sufficient to reduce visibility to less than three miles when relative humidity is less than 70 percent."(14) Many houses in urban areas, as well as newly painted automobiles, require repainting because discoloring particles accumulate on their surfaces.(27) Acid aerosols that are associated with fog have been found to produce a "pock mark" type of injury on plants, particularly on the upper surfaces of table beets and Swiss chard.(23)

The effect of particles on human health is determined not only by their chemical composition but also by their size. Community air pollution produces more eye irritation than can be accounted for by the additive effects of its known gaseous components, which suggests that particulate matter may also play a role. There is some evidence that mechanical filtration of particles down to 0.05 micron does not reduce eye irritation, whereas activated carbon filtration of gas does reduce irritation.(40) During times of heavy pollution, the average individual breathes about 1 milligram of suspended matter per day.(38) Because the air in the respiratory tract usually has a higher temperature than the inspired air and is virtually saturated with water vapor, an inhaled particle that can absorb water increases in size as it progresses down the respiratory tract.[37] Particles may also modify the response to simultaneously inhaled gases. The combination of gases with particles has been shown to cause toxicity changes in rodents, respiratory resistance in air flow, and bactericidal action.[41]

Sulfur dioxide, in concentrations of about 1 ppm, increases the airway resistance of guinea pigs when it is inhaled simultaneously with a sodium chloride aerosol, which, of itself, has no effect.[42] Airway resistance increases in human beings when they are exposed to a number of so-called inert particles.[9] This also includes the particles in cigarette smoke. In Great Britain, it has been known for many years that smoke and the smaller soot particles aggravate the symptoms of those who have chronic bronchitis. Larger soot particles give up the absorbed organics more easily.[9]

Hydrocarbons

Numerous investigators have examined urban atmospheres, gasoline and diesel engine exhaust, and other combustion effluents, such as incineration and open-dump burning, for carcinogens.[62][63][64][65][66] A significant portion of the airborne aromatic hydrocarbons and other organic pollutants are often adsorbed on soot particles in the atmosphere. The size of the soot particles has an important bearing on their entry into and retention in the lung and on the degree of elusion of harmful materials by body fluids within the bronchus and pulmonary area.[67]

Incomplete combustion of organic materials is a primary source of airborne carcinogenic aromatic hydrocarbons. The airborne carcinogens that have been identified are mostly polynuclear aromatic hydrocarbons. Some forty aromatic hydrocarbons have been identified in polluted atmospheres, including benzo [a] Pyrene, which is a potent carcinogen, and approximately five other compounds that are classed as weakly carcinogenic.[68] The tars and asphalt used in road surfacing are another source of aromatic hydrocarbons, but, because of their low vapor pressure and relatively limited dust production, this source is probably minor.[70]

Although several carcinogenic heterocyclic nitrogen-containing compounds have been identified in cigarette smoke, they have not been reported in urban polluted atmospheres or in engine exhausts.[69] Kotin and Falk presented indirect evidence for the presence of oxygenated tumor agents by using ozonized gasoline to produce pulmonary tumors in mice.[71]

Benzene extracts of the particulate phase of air pollutants, obtained from eight cities in the United States, were each resolved into three fractions: aromatic hydrocarbons, aliphatic hydrocarbons, and oxygenated compounds. These fractions, as well as the benzene extracts themselves, all exhibited carcinogenic activity to varying degrees.[56] The amount of carcinogens to which urban dwellers are exposed is a significant factor in determining the potential dangers of air pollutants. The U. S. Public Health Service measured the concentration of aromatic hydrocarbons per 1,000 cubic meters of atmosphere over 14 American cities.(62) The total amount ranged in various locations from 146 micrograms down to approximately 5 micrograms.

In 1775, the British surgeon, Percivall Pott, published a report that described "The Cancer of the Scrotum," and attributed its occurrence to the exposure of chimney sweeps to soot.(43) The carcinogenicity of coal tar was established by Yamagiwa and Ichikawa who produced carcinomas by painting coal tar on the inner surface of the ears of domestic rabbits.(44) Later Kennaway showed that the pyrolysis of a number of organic substances produced the carcinogenic tars, and he isolated the first pure carcinogenic chemical, dibenz [a,h] anthracene.(45)(46) Cook and his co-workers tested the carcinogenicity of a number of polynuclear aromatic hydrocarbons and it was shown that benzo [a] Pyrene and related hydrocarbons are produced by incomplete combustion of organic compounds.(47)

Epidemiological evidence is usually the first indication of the presence of environmental carcinogens. The study of the eipdemiological relationship between lung cancer and exposure to air pollutants is difficult because of: (1) the long period of latency between exposure to a carcinogen and a recognizable tumor, (2) population mobility that results in a change of exposure and loss of contact with the subjects, and (3) difficulty in obtaining accurate occupational and personal histories. The problem is further complicated by cigarette smoke, which, through its prevalence, tends to mask other factors.[48]

Studies in this country and abroad have shown that the rates of lung cancer in metropolitan areas are higher than in rural areas, and in small towns they are intermediate.[49] These differences suggest that there is a possible correlation between lung cancer and air pollution. In studies made on smokers and nonsmokers, the lung cancer rate was higher in urban than in rural populations.[50][51]

Recently Dean reported that, although white South Africans are the world's heaviest smokers, their incidence of lung cancer is less than half that of Great Britain.[52] Eastcott has reported similar findings from New Zealand.[53] Haenszel and Shimkin related mortality from lung cancer in white males to residence and smoking histories and showed that persons who moved from rural to urban areas experienced an increase in the rate of lung cancer that was greater than could be explained by smoking histories alone, which again suggests that some factor associated with urban living was responsible.[54]

Studies have shown that atmospheric pollutants can induce several types of cancer in experimental animals. In

1942, tars collected in a number of American cities produced subcutaneous sarcomata in mice.[55] More recently, an extensive survey of the biological activity of extracts of particulate air pollutants showed that they could produce cancer in experimental animals.[56] These and other studies show that air pollutants contain biologically active tumor factors.[57]

Early studies on the induction of pulmonary tumors by inhalation were made by Campbell, who exposed mice in dust chambers to asphalt road sweepings: benign lung tumors were produced.[59][60] Kotin and Falk produced malignant lung tumors in mice that were exposed to both influenza virus and carcinogenic hydrocarbons, a finding consistent with the concept that lung cancer generally involves the interaction of several factors.[63]

Evaluation of all the above pollutants is necessary for an urban area before any air pollution control program can be established. A good evaluation is based on a workable technique, community cooperation, availability of equipment, and continual support from governmental agencies.

Modeling has been used many times as a tool to determine air pollution levels. The Gaussian Model is one example to describe the plume from a continuous ground-level point source developed by Gifford.[77] This model assumes perfect reflection at the ground. The following equation was the simplest form to determine the ground level concentration:

$$\frac{C_L}{Q} = \frac{1}{\pi\sigma_y\sigma_z U} \exp(-y^2/2\sigma_y^2)$$

Where:

C_L = ground-level concentration (gram/m^3)

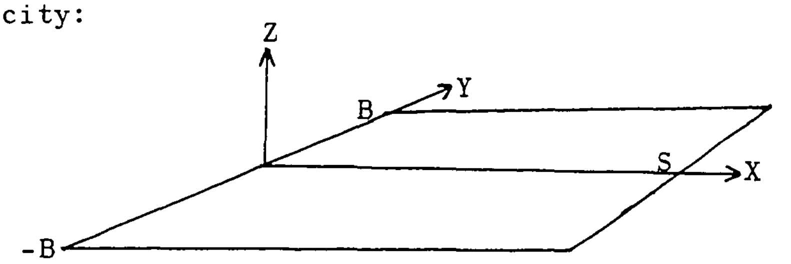
Q = Source Strength (gram/sec.)

U = Average Wind Speed (meter/sec.)

y = lateral distance from the plume axis (m)

$\sigma_y \sigma_z$ = lateral and vertical standard deviation of plume concentration (m); these parameters are functions of source-receptor distance and atmospheric stability

George C. Holzworth developed an urban dispersion model which was more appropriate to use for larger than 10 km cities.(76) He considered a city with along-wind length S (meters m) and cross-wind with 2B located in a rectangular coordinate system with the wind along the x-axis and the origin at ground-level of the midpoint along the upwind side of the city:



He then assumed an average area emission rate $\overline{Q}(gm^{-2}sec^{-1})$ at ground-level over the city, perfect reflection from the ground, and no restriction on vertical mixing. The ground-level concentration $\chi(gm^{-3})$ was determined as follows:

$$\chi(x,0,0) = \int_0^x \int_{-B}^{B} \frac{2\overline{Q}}{2\pi\sigma_y\sigma_z U} \exp\left[\frac{-(y_0)^2}{2\sigma_{y2}}\right] dy_0 dx_0$$

where

x_0, y_0 = downwind and lateral distances (m) of infinitesimal area source $dx_0 dy_0$ from origin.

σ_y, σ_z = lateral and vertical diffusion functions--lateral and vertical standard deviations (m) of Gaussian concentration distribution at downwind distance $x-x_0$ from source

U = average wind speed (m sec^{-1}) through the mixing layer.

For situations where x and thus σ_y is not large compared to 2B, the error in concentration at (x,0,0) will not be large if in equation (1) -B and B are replaced by ∞ and ∞, yielding

$$\chi(x,0,0) = \int_0^x \frac{2\overline{Q}}{\sqrt{2\pi}\,\sigma_z U}\,dx_0$$

CHAPTER III

PURPOSE AND SCOPE

The Tulsa City-County Health Department in cooperation with the Tulsa Community Development Agency (Model Cities Agency), Tulsa Area Health and Hospital Planning Council, and the Bureau of Community Environmental Management (BCEM) of the U. S. Department of Health, Education and Welfare has implemented the Neighborhood Environmental Evaluation Decision System (NEEDS) Program for the City of Tulsa, Oklahoma. The NEEDS Program technique is a five-stage computerized technique designed by the Bureau of Community Environmental Management to provide local agencies with a method for evaluating their environmental profile. The baseline data on the quality of the environment provides the means by which a community can re-evaluate the environmental health conditions at various intervals of time. Community officials and citizens groups can have data necessary to plan for more effective utilization of manpower and other resources. Air pollution is one of the environmental problems evaluated in the NEEDS Program.

The Air Pollution evaluation for the NEEDS Program in Tulsa was made on reasonable estimates of air pollutant emissions from limited air sampling data. The community was divided into four air pollution level categories (no problem, moderate pollution, considerable pollution and extreme pollution) and assessed on a sample block basis in each neighborhood. The following suggested emission values from an average annual space-heating day were used:

Moderate:
Suspended particulates--0.5 to 1.0 tons/day/sq. mile
Carbon monoxide--0.5 to 1.0 tons/day/sq. mile
Sulfur dioxide--0.5 to 1.0 tons/day/sq. mile

Considerable:
Suspended particulates--1.0 to 2.0 tons/day/sq. mile
Carbon monoxide--1.0 to 4.0 tons/day/sq. mile
Sulfur dioxide--1.0 to 2.0 tons/day/sq. mile

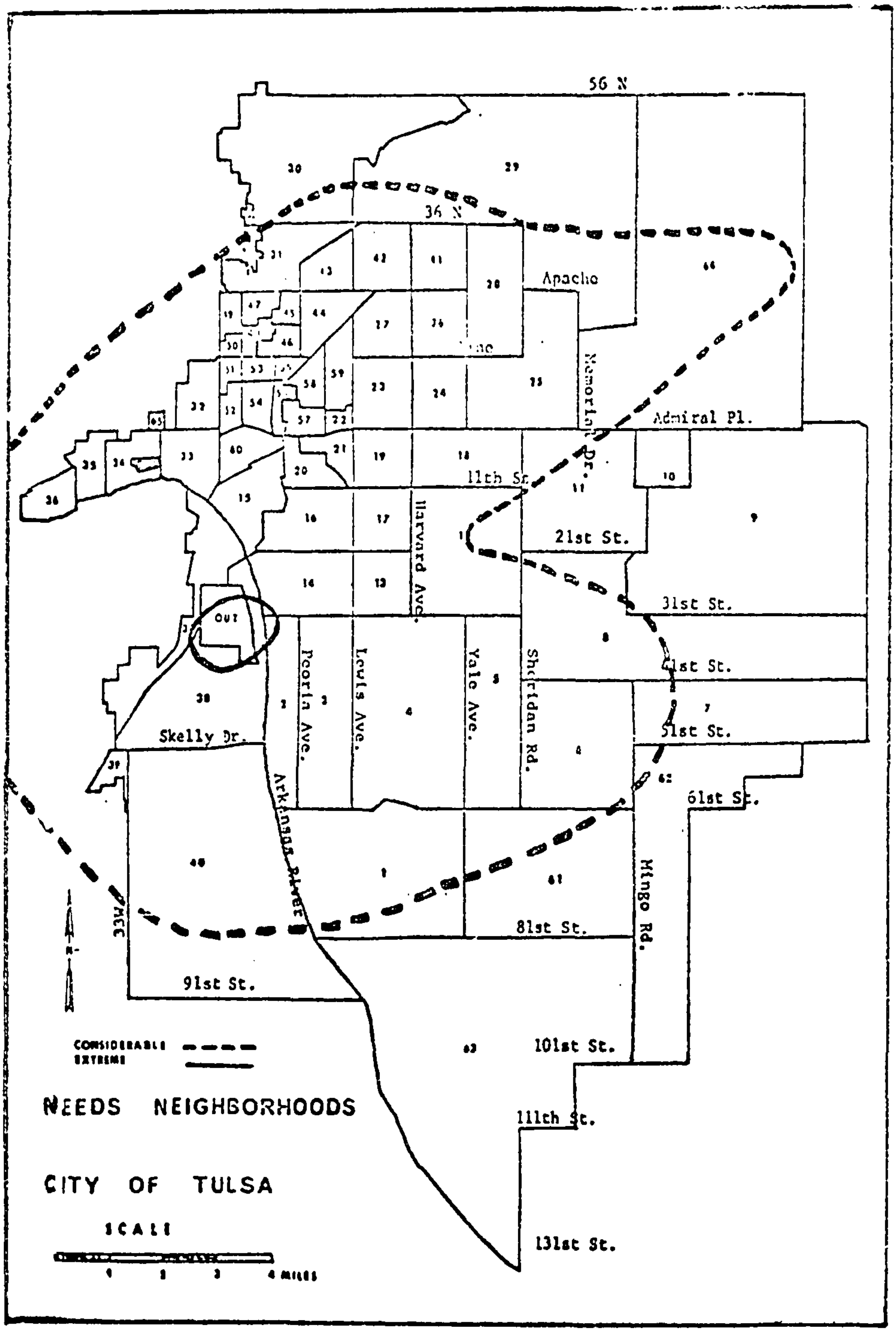
Extreme:
Suspended particulates greater than 2.0 tons/day/sq. mile
Carbon monoxide--greater than 4.0 tons/day/sq. mile
Sulfur dioxide--greater than 2.0 tons/day/sq. mile

The Director of Air Pollution Control for the City of Tulsa determined upon completion of the NEEDS Program that the Air Pollution Evaluation was inadequate and misleading. Therefore, the City-County Health Department left the air pollution evaluation out of the NEEDS Program report of results until further and more detailed study could be made. (See Figure 3-1.)

The purpose of this study was to develop a method to more accurately estimate the levels of air pollution in each of the NEEDS neighborhoods. This research combined the Region Number Two--Northeastern Oklahoma Emission Inventory data of the Environmental Protection Agency and Traffic Count data of the Tulsa Metropolitan Area Planning Council in order to

FIGURE 3-1

EVALUATED AIR POLLUTION ON THE BASIS OF THREE LEVELS MENTIONED IN CHAPTER V


56 N
36 N
Apache
Admiral Pl.
Memorial Dr.
11th St.
21st St.
31st St.
41st St.
51st St.
61st St.
81st St.
91st St.
101st St.
111th St.
131st St.
Harvard Ave.
Peoria Ave.
Lewis Ave.
Yale Ave.
Sheridan Rd.
Mingo Rd.
Skelly Dr.
Arkansas River
33W
OUT
CONSIDERABLE
EXTREME
NEEDS NEIGHBORHOODS
CITY OF TULSA
SCALE
4 MILES

project estimated pollution levels. The study also demonstrates through computer Symaps (systems mapping) the pollutant concentrations by neighborhood and the relationship to health problems such as tuberculosis, infant mortality, etc. The Symaps further demonstrate the presentation of NEEDS Program weighted variables such as housing and premise conditions for city officials and citizen groups with non-technical education. The Symaps were developed as visual aids to assist in the presentation of NEEDS Program data. The air pollution Symaps are being used to determine the most appropriate location for sample stations to effectively monitor the air quality of Tulsa. The maps on tuberculosis and infant mortality will provide the public health authorities a means of demonstrating to citizens the need for improved or expanded testing for tuberculosis case finding and care for expectant mothers and infants. The Symaps on Total Penalty Index, Housing Condition, Premises Condition and Auxiliary Housing Conditions were used by citizen decision making groups to establish environmental improvement programs such as Urban Renewal and Housing Code Enforcement and set priorities for these programs by neighborhood.

The scope of this study was necessarily limited to available data on point sources and area sources and the NEEDS Program results.

CHAPTER IV

SOURCES OF POLLUTION AND METHODS

Sources

Air emission inventory, provided by the Oklahoma Air Pollution Control Agency, was used to identify the major emissions in the City of Tulsa, Oklahoma. The emission inventory contains all sources of pollution in Region Number Two--Northeastern Oklahoma. This study considered only the contaminants emitted in large quantities from numerous sources located within the City of Tulsa. The contaminants included are carbon monoxide, hydrocarbons, nitrogen oxides, sulfur oxides and particulates. Other emissions of contaminants were not included in the Source Inventory and therefore were not considered.

The sources of air pollution for purposes of this study were divided into two major categories:

1. Point sources--includes all types of industries in the City of Tulsa (see Appendix A-1 to A-3)
2. Area sources--includes vehicles (autos, buses, trucks, etc.), open burning, incinerators, residential, commercial and institutional heating systems (see Table 4-1 and Appendix A-4)

Point Source Emissions

These emissions from industrial and commercial establishments are attributable to two general types of operations--

TABLE 4-1

TOTAL VEHICLE PASSES IN TWENTY-FOUR HOUR PERIODS FOR PRIMARY AND SECONDARY ARTERIAL WAYS AND EXPRESSWAYS FOR THE CITY OF TULSA, OKLAHOMA--1972

Neighborhood No.	Primary and Secondary Arterial Ways		Expressways		Total Vehicle Passes Per Sq. Mile for Neighborhood	Neighborhood Area Square Mile
	Total Vehicle Passes	Vehicle/Sq. Mile Passes	Total Vehicle Passes	Vehicle/Sq. Mile Passes		
1	102,247.0	17,041.2	0.0	0.0	17,041.2	6.00
2	182,280.5	121,520.3	0.0	0.0	121,520.3	1.50
3	228,279.0	76,093.0	49,889.0	16,629.7	92,722.0	3.00
4	457,688.0	76,281.3	88,861.0	14,810.2	91,091.5	6.00
5	269,386.5	89,795.5	85,880.0	28,626.7	117,422.2	3.00
6	148,496.0	37,120.0	0.0	0.0	37,124.0	4.00
7	41,596.0	6,932.6	0.0	0.0	6,932.6	6.00
8	376,002.5	37,600.2	254,548.0	25,454.8	63,005.0	10.00
9	191,087.5	11,374.2	87,082.0	5,183.5	16,447.7	16.80
10	37,088.5	37,088.5	28,901.0	28,901.0	65,989.5	1.00
11	350,766.0	82,533.2	0.0	0.0	82,533.2	4.25
12	509,180.5	127,295.1	50,495.0	12,623.8	139,918.9	4.00
13	103,387.5	103,387.5	49,657.0	49,657.0	153,041.5	1.00
14	190,692.0	8,966.9	0.0	0.0	8,966.9	1.75
15	465,790.0	465,790.5	0.0	0.0	465,790.5	1.00
16	303,789.5	189,868.4	0.0	0.0	189,868.4	1.60
17	185,912.0	185,912.0	36,741.0	36,741.0	222,653.0	1.00
18	285,442.0	147,721.0	30,880.0	15,440.0	163,161.0	2.00
19	202,205.0	202,205.0	47,870.0	47,870.0	250,075.0	1.00
20	157,690.0	242,600.0	0.0	0.0	242,600.0	0.65
21	108,306.0	180,510.0	0.0	0.0	180,510.0	0.60
22	27,958.5	111,834.0	0.0	0.0	111,834.0	0.25
23	93,339.0	93,339.0	0.0	0.0	93,339.0	1.00
24	83,775.5	83,775.5	0.0	0.0	83,775.5	1.00
25	206,528.0	59,008.0	54,306.0	15,516.0	74,520.0	3.50

TABLE 4-1--Continued

Neighbor-hood No.	Primary and Secondary Arterial Ways		Expressways		Total Vehicle Passes Per Sq. Mile for Neighborhood	Neigh-borhood Area Square Mile
	Total Vehicle Passes	Vehicle/Sq. Mile Passes	Total Vehicle Passes	Vehicle/Sq. Mile Passes		
26	46,892.0	46,892.0	0.0	0.0	46,892.0	1.00
27	42,394.0	44,625.3	0.0	0.0	44,625.3	0.95
28	77,999.0	38,999.5	0.0	0.0	38,999.5	2.00
29	63,302.5	6,330.3	0.0	0.0	6,330.3	10.00
30	173,090.0	28,848.3	0.0	0.0	28,848.3	6.00
31	133,103.0	106,482.4	0.0	0.0	106,482.4	1.25
32	19,830.5	26,440.7	0.0	0.0	26,440.7	0.75
33	57,885.5	64,317.2	0.0	0.0	64,317.2	0.90
34	40,655.5	50,819.4	0.0	0.0	50,819.4	0.80
35	19,865.5	33,109.2	0.0	0.0	33,109.0	0.60
36	58,164.0	83,091.4	0.0	0.0	83,091.4	0.70
37	184,411.5	122,941.0	0.0	0.0	122,941.0	1.50
38	91,881.0	36,752.4	0.0	0.0	36,752.4	2.50
39	9,184.0	36,736.0	0.0	0.0	36,736.0	0.25
40	37,782.5	3,598.3	98,028.0	9,336.0	12,934.3	10.50
41	13,103.5	13,103.5	0.0	0.0	13,103.5	1.00
42	35,063.5	35,063.5	0.0	0.0	35.063.5	1.00
43	41,914.0	59,877.1	0.0	0.0	59,877.1	0.70
44	65,043.0	81,303.8	0.0	0.0	81,303.8	0.80
45	14,087.5	70,437.5	0.0	0.0	70,437.5	0.20
46	24,289.5	80,965.0	0.0	0.0	80,965.0	0.30
47	24,690.0	82,300.0	0.0	0.0	82,300.0	0.30
48	15,901.5	63,606.0	0.0	0.0	63,606.0	0.25
49	27,607.5	92,025.0	0.0	0.0	92,025.0	0.30
50	19,500.0	130,000.0	0.0	0.0	130,000.0	0.15
51	27,068.0	108,272.0	0.0	0.0	108,272.0	0.25
52	26,836.0	67,090.0	0.0	0.0	67,090.0	0.40
53	18,409.0	73,636.0	0.0	0.0	73,636.0	0.25
54	4,370.5	10,926.3	0.0	0.0	10,926.3	0.40

TABLE 4-1--Continued

Neighbor-hood No.	Primary and Secondary Arterial Ways		Expressways		Total Vehicle Passes Per Sq. Mile for Neighborhood	Neigh-borhood Area Square Mile
	Total Vehicle Passes	Vehicle/Sq. Mile Passes	Total Vehicle Passes	Vehicle/Sq. Mile Passes		
55	41,180.0	274,533.3	0.0	0.0	274,533.3	0.15
56	1,620.0	8,100.0	0.0	0.0	8,100.0	0.20
57	52,721.0	131,802.5	0.0	0.0	13,802.5	0.40
58	21,486.0	42,972.0	0.0	0.0	42,972.0	0.50
59	50,381.0	77,509.2	0.0	0.0	77,509.2	0.65
60	155,633.0	389,082.5	0.0	0.0	389,082.5	0.40
61	89,466.5	14,911.1	0.0	0.0	14,911.1	6.00
62	27,928.0	4,296.6	23,382.0	3,597.2	7,893.8	6.50
63	66,737.0	4,171.1	0.0	0.0	4,171.1	16.00
64	210,287.5	12,369.9	80,244.0	4,720.2	17,090.1	17.00
65	8,723.0	174,460.0	0.0	0.0	174,460.0	0.05

the contaminants generated by the combustion of fuels and the contaminants produced and discharged from manufacturing processes. Emission factors for fifty-eight point sources are shown in Table 4-2. These sources were located in the NEEDS Neighborhoods according to their addresses or x-axis and y-axis.

Types of contaminants.--Essentially two types of contaminants occur in the air--particulates and gases.[72] The particulates are classified as suspended and settleable. The suspended particulates vary in size from less than one to approximately 100 microns, and may remain suspended in the atmosphere for long periods of time. The settleable particles are much larger in size which causes them to settle out of the air relatively close to the source.[72] The gaseous contaminants, which are molecular in size, remain mixed in the atmosphere indefinitely, since they have approximately the same density as the air itself.[72] In this study both suspended and settleable contaminants are referred to as particulates.

Four major gaseous contaminants recognized as most important and harmful were considered. They are carbon monoxide, hydrocarbons, nitrogen oxides, and sulfur dioxide. The point source emission inventory lists carbon monoxide, nitrogen oxides and hydrocarbons as uncontrolled contaminants from point sources. Other contaminants such as sulfur dioxide

TABLE 4-2

POINT SOURCES EMISSIONS INVENTORY FOR
THE CITY OF TULSA, OKLAHOMA--1972

Neighbor-hood No.	Source No.	SO_2 Emissions Tons/Yr.				Particulate Emissions Tons/Yr.				CO Emissions Tons/Yr.		NO_2 Emissions Tons/Yr.		Hydro-Carbons Tons/Yr.	
		Comp. or Hand Cal.	Uncon-trolled	Con-trolled	Allow-able	Comp. or Hand Cal.	Uncon-trolled	Con-trolled	Allow-able	Comp. or Hand Cal.	Uncon-trolled	Comp. or Hand Cal.	Uncon-trolled	Comp. or Hand Cal.	Uncon-trolled
1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
6	216	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	0.0	0.0	c3.0	3.0	c1.0	1.0
7	27	0.0	0.0	0.0	0.0	H12.0	12.0	12.0	62.0	0.0	0.0	0.0	0.0	0.0	0.0
8	234	0.0	0.0	0.0	0.0	H1.0	1.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
	229	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
	235	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0	0.0	0.0	c4.0	4.0	c1.0	1.0
9	218	0.0	0.0	0.0	0.0	H8.0	8.0	8.0	58.0	0.0	0.0	0.0	0.0	0.0	0.0
10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
14	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
15	16	0.0	0.0	0.0	0.0	H1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
16	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
18	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
20	26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	c1.0	1.0	0.0	0.0
	25	0.0	0.0	0.0	0.0	H1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 4-2--Continued

Neighbor-hood No.	Source No.	SO_2 Emissions Tons/Yr. Comp. or Hand Cal.	Uncon-trolled	Con-trolled	Allow-able	Particulate Emissions Tons/Yr. Comp. or Hand Cal.	Uncon-trolled	Con-trolled	Allow-able	CO Emissions Tons/Yr. Comp. or Hand Cal.	Uncon-trolled	NO_2 Emissions Tons/Yr. Comp. or Hand Cal.	Uncon-trolled	Hydro-Carbons Tons/Yr. Comp. or Hand Cal.	Uncon-trolled
21	29	0.0	0.0	0.0	0.0	c45.0	47.0	47.0	2.0	0.0	0.0	c876.0	876.0	c5.0	7.0
						H2.0								H2.0	27.0
	272	0.0	0.0	0.0	0.0	H2.0	2.0	2.0	4.0	0.0	0.0	0.0	0.0	H27.0	27.0
	28	H32.0	32.0	32.0	0.0	H68.0	68.0	68.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
22	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
23	117	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	c2.0	2.0	0.0	0.0
	245	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	c1.0	1.0	0.0	0.0
24	34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0	0.0	0.0	c3.0	3.0	c1.0	1.0
25	33	c3.0	3.0	3.0	0.0	c81.0	81.0	81.0	711.0	c2.0	2.0	c788.0	788.0	c180.0	180.0
26	118	c12.0	12.0	12.0	0.0	c3.0	3.0	3.0	36.0	0.0	0.0	0.0	0.0	c4.0	4.0
	31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	c2.0	2.0	0.0	0.0
27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
28	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
29	238	0.0	0.0	0.0	0.0	c3.0	3.0	3.0	76.0	0.0	0.0	c32.0	32.0	c7.0	7.0
	239	0.0	0.0	0.0	0.0	c3.0	3.0	3.0	76.0	0.0	0.0	c32.0	32.0	c7.0	7.0
	211	0.0	0.0	0.0	0.0	c5.0	5.0	5.0	122.0	0.0	0.0	c47.0	47.0	c11.0	11.0
	221	c14.0	14.0	14.0	0.0	c7.0	7.0	7.0	123.0	0.0	0.0	c66.0	66.0	c15.0	15.0
30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
31	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
32	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
33	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
34	224	0.0	0.0	0.0	0.0	H15.0	15.0	15.0	10.0	H68.0	68.0	c5475.0	5477.0	c30.0	45.0
												H2.0		H15.0	
	230	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0	0.0	c2.0	2.0	0.0	0.0
	233	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	c1.0	1.0	0.0	0.0
	223	0.0	0.0	0.0	0.0	H3.0	3.0	3.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 4-2--Continued

Neighbor-hood No.	Source No.	SO_2 Emissions Tons/Yr. Comp. or Hand Cal.	SO_2 Uncon-trolled	SO_2 Con-trolled	SO_2 Allow-able	Particulate Emissions Tons/Yr. Comp. or Hand Cal.	Particulate Uncon-trolled	Particulate Con-trolled	Particulate Allow-able	CO Emissions Tons/Yr. Comp. or Hand Cal.	CO Uncon-trolled	NO_2 Emissions Tons/Yr. Comp. or Hand Cal.	NO_2 Uncon-trolled	Hydro-Carbons Tons/Yr. Comp. or Hand Cal.	Hydro-Carbons Uncon-trolled
35	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
36	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
37	219	0.0	0.0	0.0	0.0	c1.0	1.0	1.0	18.0	0.0	0.0	c5.0	5.0	c1.0	1.0
	227	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0	c1.0	1.0	1.0	38.0	0.0	0.0	c13.0	13.0	c3.0	3.0
	1	0.0	0.0	0.0	0.0	H22.0	22.0	22.0	75.0	0.0	0.0	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0	H70.0	70.0	70.0	62.0	0.0	0.0	0.0	0.0	0.0	0.0
	264	0.0	0.0	0.0	0.0	H266.0	266.0	266.0	74.0	0.0	0.0	H2810.0	2810.0	0.0	0.0
38	271	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	c1.0	1.0	0.0	0.0
	158	H1522.0	1522.0	1522.0	0.0	H177.0	177.0	0.0	224.0	H39730.0	39730.0	H638.0	638.0	H183.0	183.0
	18	0.0	0.0	0.0	0.0	H1.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
39	32	0.0	0.0	0.0	0.0	c1.0	1.0	1.0	24.0	0.0	0.0	c7.0	7.0	c2.0	2.0
40	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
41	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
42	14	0.0	0.0	0.0	0.0	c2.0	2.0	2.0	35.0	0.0	0.0	c17.0	17.0	c4.0	4.0
	13	0.0	0.0	0.0	0.0	c3.0	3.0	3.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
43	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
44	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
45	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
46	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
47	228	0.0	0.0	0.0	0.0	c2.0	2.0	2.0	55.0	0.0	0.0	c17.0	17.0	c4.0	4.0
48	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
49	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
50	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	6	0.0	0.0	0.0	0.0	c6.0	6.0	6.0	62.0	0.0	0.0	0.0	0.0	0.0	0.0
51	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 4-2--Continued

Neighbor-hood No.	Source No.	SO_2 Emissions Tons/Yr. Comp. or Hand Cal.	SO_2 Uncon-trolled	SO_2 Con-trolled	SO_2 Allow-able	Particulate Emissions Tons/Yr. Comp. or Hand Cal.	Particulate Uncon-trolled	Particulate Con-trolled	Particulate Allow-able	CO Emissions Tons/Yr. Comp. or Hand Cal.	CO Uncon-trolled	NO_2 Emissions Tons/Yr. Comp. or Hand Cal.	NO_2 Uncon-trolled	Hydro-Carbons Tons/Yr. Comp. or Hand Cal.	Hydro-Carbons Uncon-trolled
52	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
53	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
54	9	0.0	0.0	0.0	0.0	c113.0 H1.0	114.0	114.0	7.0	H5.0	5.0	c2191.0	2191.0	c12.0 H1.0	13.0
	8	0.0	0.0	0.0	0.0	H2.0	2.0	2.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
55	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
56	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
57	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
58	220	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	c1.0	1.0	0.0	0.0
	222	c1.0	1.0	1.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	c1.0	1.0	c1.0	1.0
59	119	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	c1.0	1.0	0.0	0.0
	11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	c3.0	3.0	c1.0	1.0
60	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
61	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
62	270	0.0	0.0	0.0	0.0	H1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	15	0.0	0.0	0.0	0.0	H12.0	12.0	12.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0
63	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
64	5	0.0	0.0	0.0	0.0	H3.0	3.0	3.0	62.0	0.0	0.0	0.0	0.0	0.0	0.0
	10	0.0	0.0	0.0	0.0	H2.0	2.0	2.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
	134	0.0	0.0	0.0	0.0	H1575.0	1575.0	394.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0
	19	0.0	0.0	0.0	0.0	H272.0	272.0	272.0	31.0	0.0	0.0	0.0	0.0	0.0	0.0
	20	0.0	0.0	0.0	0.0	H120.0	120.0	120.0	31.0	0.0	0.0	0.0	0.0	0.0	0.0
	214	0.0	0.0	0.0	0.0	H47.0	47.0	47.0	3.0	0.0	0.0	c1.0	1.0	0.0	0.0
	21	c87.0	87.0	87.0	0.0	c5.0	5.0	5.0	32.0	0.0	0.0	c25.0	25.0	c2.0	2.0
	135	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0	0.0	0.0	c4.0	4.0	c1.0	1.0
65	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

and particulates are listed in the inventory as controlled from the point of release. Therefore, this study evaluation considered only the uncontrolled contaminants. The author assumed that no problem exists as such for those contaminants and sources listed in the Emission Inventory as controlled.

Area Source Emissions

The emissions from area sources are attributed to three general types--transportation, domestic and institutional, and commercial.

Transportation.--The emission inventory for area sources calculated the tons per year of vehicle pollution at twenty-five miles per hour and forty-five miles per hour. Therefore, the volume of vehicles for the purpose of calculation were categorized as follows:

1. Expressways--form the basic framework of the street system, and to carry large volumes of traffic safely, quickly, and smoothly through the area or over considerable distances within the area. The usual vehicle speeds are over fifty miles per hour.

2. Arterial streets--to bring traffic at moderate speeds to and from expressways and facilitate trips of moderate distances. Vehicle speeds are between thirty and forty miles per hour with stop and go signals resulting in heavy pollution at the low speeds.

3. Collector streets--to facilitate traffic to and from arterial streets; to provide circulation of traffic within neighborhoods and to link local streets together. Vehicle speeds are approximately twenty-five miles per hour.

4. Local streets--to provide direct access to individual properties with speeds of 25 miles per hour or less.

The latter two groups were assumed to be the most important relative to air pollution, because of the greater pollution by vehicles at low speeds within the neighborhood. The peak periods of normal weekday traffic flow on arterial streets in the City of Tulsa are from 7:00 a.m. to 9:00 a.m. and from 4:00 p.m. to 6:00 p.m.[73] The average travel speed in the central business district is seventeen miles per hour during peak hours and twenty miles per hour during off-peak hours. One of the major reasons for the increase in speed was the decline in the number of vehicle stops in the moving lanes to deposit passengers. The remaining arterial streets and most collector streets have an average speed of between twenty and thirty miles per hour. This speed is reduced from five to seven miles per hour on streets with strip-commercial or other property with frequent access points.[73]

Domestic and institutional.--Natural gas is the principal fuel used in Tulsa. Although the combustion of fuel (natural gas) emits approximately 40 percent of the total oxides of nitrogen, there was insufficient information available at this time to calculate the concentration of pollution by neighborhood due to domestic and institutional units. Other domestic sources of pollution, such as open burning and backyard incineration, have been effectively restricted or eliminated through ordinance enforcement by the Tulsa City-County Health Department. In as much as 40 percent of total oxides of nitrogen emissions are space heating fuels (natural gas), this parameter should be included in future studies.

Commercial.--This group of sources, outside of negligible amounts of fuel combustion, are made up of commercial incinerators. Effective control by the Tulsa City-County Health Department has eliminated the use of single-chamber incinerators and restricted the use of multi-chamber incinerators to approved types and operational procedures to maintain emissions within approved limits. (See Appendix A-4.)

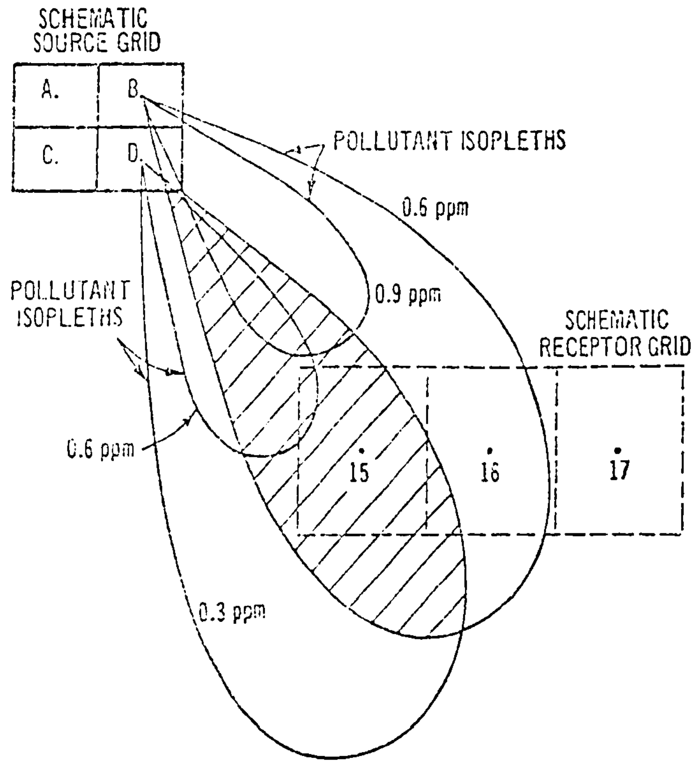
Methods

Box Model

"Physical and Meteorological Basis for Mathematical Models of Urban Diffusion Processes," by Heinz H. Littau was utilized in this study to determine the neighborhood concentration of pollutants. The author discussed some general aspects of processes taking place in the atmospheric boundary layer when wind passes over urban terrain. He started in Figure 4-1 with the "Vector Model" of diffusion from multiple sources which was developed by Moses.[74] He then contrasted (Figure 4-2) the Vector Model with a "scalar model" in which the volume of city air is somewhat crudely defined.

FIGURE 4-1

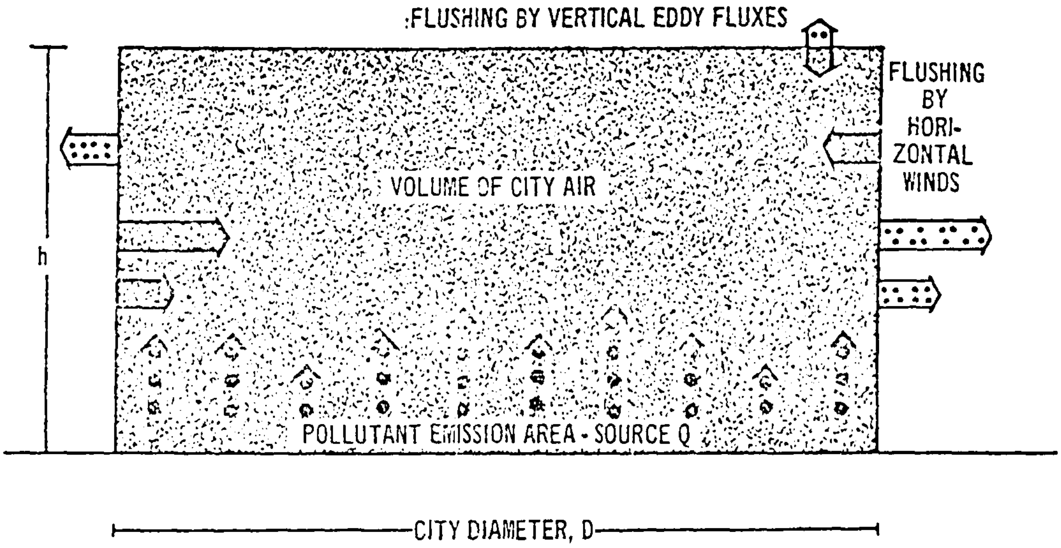
ILLUSTRATION OF CONVENTIONAL OR VECTOR MODEL OF URBAN DIFFUSION



Sources are located at A, B, C and D of source grid. A section of the monitoring grid is given by squares 15, 16 and 17. The concentration enclosed by the 0.6 ppm isopleth of source B and 0.3 ppm isopleth of source D contribute a concentration exceeding 0.9 ppm for square 15.

FIGURE 4-2

SCHEMATIC ILLUSTRATION OF BOX OR SCALAR MODEL OF URBAN DIFFUSION



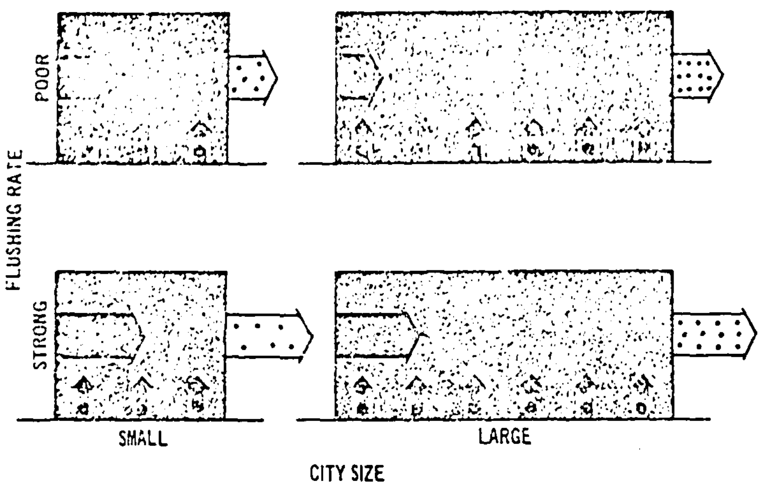
Pollutant emission is attributed to a quasi-uniform area source at the lower boundary. The major flushing agent is horizontal air motion, additionally supported by vertical eddy flux at the level h that taps the volume. If no other city is immediately upstream, the wind enters the volume relatively clean but leaves it loaded with emission products. The level h may coincide with an inversion of temperature, in which case vertical exchange through this level will be of minor importance.[75]

It is assumed in Figure 4-3 that the source strength of pollutant release per unit area of the lower boundary is the same for two cities of different size; and two different flushing ratios are applied to both cities. These rates could correspond to two weather situations, one with relatively strong versus one with weak winds. The particle loading of a comparable unit volume of air is illustrated in Figure 4-3 by the "dots" carried by the outgoing air current, which in each case equals the number of "dots" released by the area sources into the volume of city air. Obviously, a small city with a weak flushing rate would be no worse off than a big city with a good flushing rate. For example, an innocent activity like the burning of leaves could be well tolerated in a small city, but could generate intolerable smog conditions once the city became large.[75]

To define the quantitative answer consideration should be made on the basic fluid dynamic equations.[75]

FIGURE 4-3

EFFECTS OF CITY DIAMETER AND ATMOSPHERIC FLUSHING RATE ON POLLUTANT CONCENTRATION IN BOX MODEL OF URBAN DIFFUSION



Dots (•) indicate output of pollutant sources to city air volume.

Arrows indicate ingoing (shaded) and outgoing (white) volumes of air per unit time.

Forcing function, Q.

Let

s = specific admixture to air, (g meter^{-3})

$\vec{v}$ = $\vec{i}u + \vec{j}v + \vec{k}w$ (meter sec^{-1})

S = strength of internal source, or sink if negative, of considered admixture (sec^{-1} meter^{-3})

ν = molecular diffusion coefficient (meter^2 sec^{-1})

The principle of conservation yields

$$\frac{\delta s}{\delta t} + \nabla \cdot \vec{v}s - \nu\nabla^2 s = S \qquad (1)$$

Eddy fluctuations are removed from the instantaneous values by time averaging and by introducing $s-s'=\bar{s}$, $S-S'=\bar{S}$, and $\vec{V}-\vec{V}'=\vec{\bar{V}}$, whereupon the primitive equation (1) transforms into

$$\frac{\delta \bar{s}}{\delta t} + \nabla \cdot \overline{\vec{V}s} + \nabla \cdot \overline{V's'} - \nu\nabla^2\bar{s} = \bar{S} \qquad (2)$$

Molecular diffusion and eddy fluxes can be neglected in the horizontal direction, and the transport by mean vertical motion, in comparison with vertical eddy flux and the transport divergence by mean horizontal wind components.[75] This amounts to saying that

$$[(\bar{w}\bar{s})_z + (\overline{u's'})_x + (\overline{v's'})_y - \nu\nabla^2\bar{s}] \ll [(\bar{u}\bar{s})_x + (\bar{v}\bar{s})_y + (w's')_z] \qquad (3)$$

where subscripts denote partial derivatives with respect to the three independent spatial variables (x, y, z).[75]

From equations (2) and (3), the simplified version of the primitive equation becomes

$$\frac{\delta s}{\delta t} + (\bar{u}\bar{s})_x + (\bar{v}\bar{s})_y = \bar{S} - (\overline{w's'})_z \qquad (4)$$

It is characteristic for the box model of urban diffusion that we are primarily interested in representative area average over the city or neighborhood diameter D (m) and thickness h (m) of the boundary layer (Figure 4-2). Let such an average of any function, be denoted by the following symbol:[75]

$$[\phi] = \frac{1}{h\ D} \int_h \int_D \phi \, dxdz \tag{5}$$

The area source is represented by the boundary value $(\overline{w's'})$ that is the vertical eddy flux of pollutant at height, z = 0.

In air pollution climatology, the forcing function is the effective strength of the area source, Q (per meter, per unit time), a function only of time, t,

$$Q(t) = [(\overline{w's'})_0] + [h\overline{S}] \tag{6}$$

that is, the effective release qualified by effective internal sources. The response function is the bulk value of pollutant concentration in the volume of city air, $q(m^{-3})$, also a function only of time, where

$$q(t) = [\bar{s}] \tag{7}$$

With the aid of q and D, the controlling process of horizontally advection is expressed by a bulk value of wind speed, $U(m\text{-}hr.^{-1})$

$$U(t) = \frac{D}{q}\,(\bar{u}\bar{s})_x + (\bar{v}\bar{s})_y \tag{8}$$

The "flushing frequency," f, of the volume of city air, is another controlling parameter U and eddy flux value $(\overline{w's'})$ at z = h.[75]

$$F = \frac{U}{D} + \frac{1}{h\ q}\left[(\overline{w's'})\right] \quad \text{or} \quad F = \frac{U}{D} \tag{9}$$

Horizontal advection will significantly control the flushing frequency, especially when the level h coincides with a "lid" such as an inversion layer.[75]

The author assumed that each neighborhood was shaped like a box (Figure 4-4), with each side of the box measured in meters. Thus the volume of each box was defined from equation (10) as follows:

$$\text{Volume} = y \cdot z \cdot y(m^3) \tag{10}$$

where
y = cross lateral (neighborhood diameter)
z = vertical lateral (mixing depth)

Flushing frequency which is the force needed to move the volume of air in the neighborhood was previously defined in equation (9). Therefore, this is a dot product to the equation (10).

$$\text{Moving volume} = \frac{U(m/hr.)}{D(m)} \cdot y^2 z(m^3) = Uzy\ (m^3/hr.) \tag{11}$$

but D and y are both the same (width).

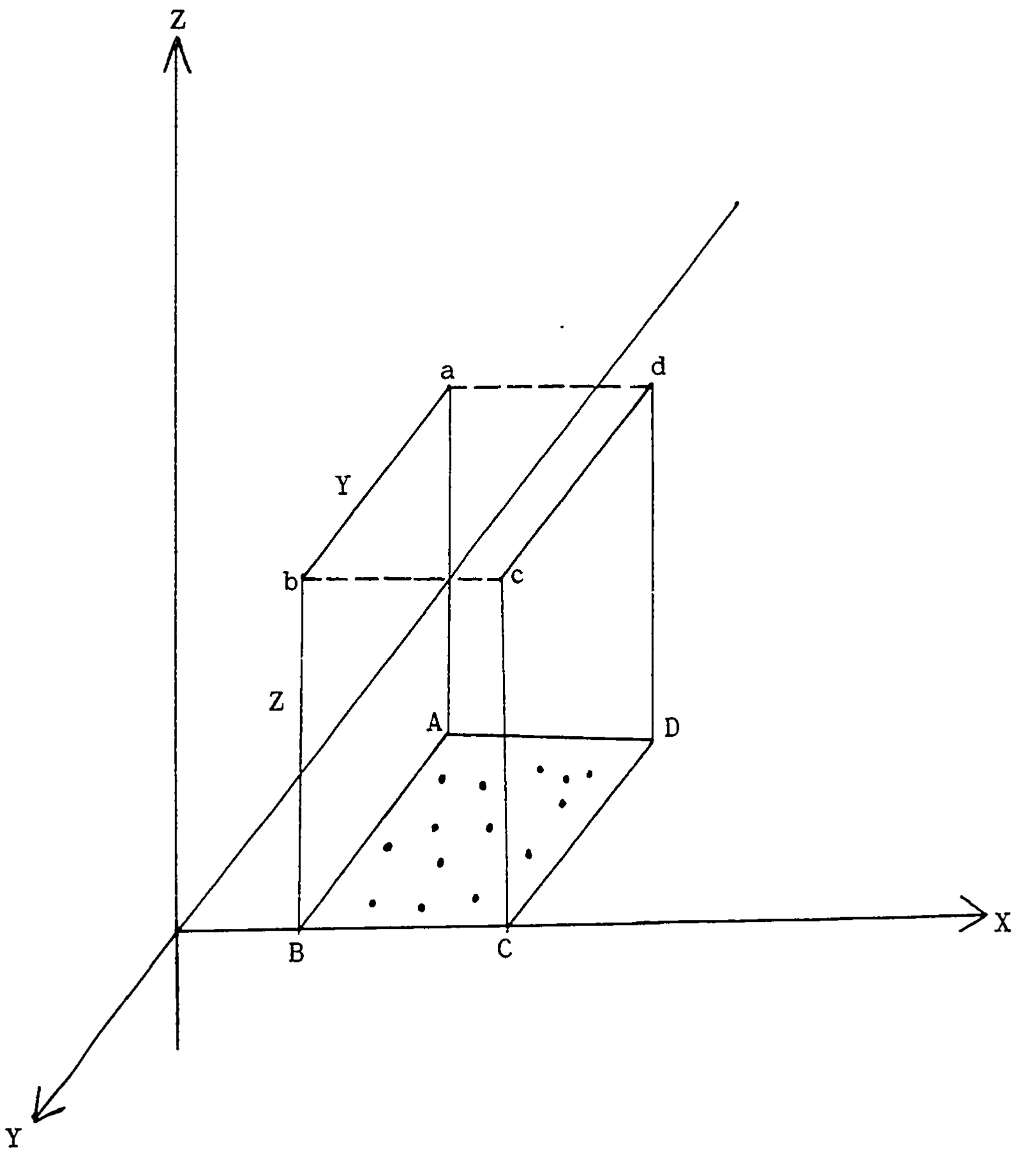
$$\therefore \text{Moving volume} = yzU\ (m^3/hr.) \tag{12}$$

Suppose one unit of contaminant is released into the above volume of air in the box, since the concentration is measured by units per volume, then the concentration of this one unit would be determined from the equation

$$\chi = \frac{1\ \text{unit}}{yz\overline{U}} \tag{13}$$

FIGURE 4-4

ILLUSTRATION OF URBAN AIR DIFFUSION BOX MODEL



ABCD = area of city or neighborhood

Dot (•) = source of pollution or Q

Z = mixing depth (in this study seasonal mixing depth)

Y = width of city or neighborhood

$\overline{U}$ = mean wind (in this study seasonal mean wind) where $\overline{U}$ mean wind $\left(\frac{U+U_2+U_3+...U_n}{n}\right)$

χ - concentration (m^{-3})

The units of each of the point sources and area sources for each pollutant were added to define the total quantity of a pollutant or Q value. These values were substituted for the numerator and the equation becomes

$$\chi = \frac{Q}{yz\overline{U}} \tag{14}$$

This determines the concentration of the various pollutants. This practical technique only determines the concentration of pollutants for each neighborhood for comparison purposes, which is one of the goals of the NEEDS Program.

Point Sources

Each emission source was located on the NEEDS Neighborhood map according to address and x and y coordinates, given in the point sources emission inventory. This was done in order to determine the contaminant concentration for each neighborhood. The point sources evaluated in this study are listed by source number, neighborhood number and pollutant in Table 4-4. The concentration of each pollutant was calculated by adding the quantities of a particular pollutant for the sources in each neighborhood. The sum of each pollutant for each neighborhood was used for the Q value in equation 14 above.

Vehicles

The volume of traffic in each NEEDS Neighborhood was determined by use of a traffic count map. The number of vehicle passes per neighborhood was determined for expressways, primary and secondary arterial streets. (See Table 4-1.) Expressway speeds for vehicles was determined to be in excess of 45 miles per hour. Since the information on emissions released by vehicle speeds of 45 miles per hour and over was not available, they have been marked zero in area source emission inventory and assumed to be of no problem by NEEDS Program. Because these emissions are as important as the others, they should be evaluated in future studies.[78] The primary and secondary arterial street traffic counts provide the only available data on the traffic volume per neighborhood. The number of vehicle passes for each neighborhood are shown in Table 2-1. The area of each neighborhood was measured by a planometer from an official map of Tulsa, Oklahoma. The area of each neighborhood in square miles divided into the number of vehicle passes equals the vehicle passes per square mile in each neighborhood (Table 4-1). Because many arterial streets were between neighborhoods, the traffic count was divided equally into each neighborhood regardless of meteorological effect. The primary and secondary arterial streets and internal street vehicle volume was recognized as the major area source of pollution in the City of Tulsa because of the high volume and low speeds.

Information was not available on internal vehicle volume or local street traffic counts. These vehicles are of importance in terms of the contribution to pollution in the City air. Therefore, a means to predict the number of vehicle passes on internal or local neighborhood streets was necessary.

The Tulsa Transportation Study was used to predict the number of vehicle passes made internally.[73] Table 4-3 shows the internal trips made in a 24-hour period in the City of Tulsa in 1954 and 1964.

TABLE 4-3

TOTAL TRIPS MADE INTERNALLY IN 24 HOURS IN 1954 AND 1964

Item	1954	1964	% Changed
1. Total transit trips daily*	39,294	43,000	+9.4%
2. Total trips, other modes daily (auto, truck, taxi)	176,819	319,526	+81.0%
3. Total auto passenger trips daily	216,113	362,526	+68.0%
4. Vehicle entering and leaving CBD daily	252,120	276,528	+9.7%

*Include extra school bus trips per weekday.

There has been an increase in volume of trips during the 10-year period. If it is assumed that everything stays approximately the same from 1964 through 1971, a seven-year period, the percentage increase can be calculated as follows:

1. % increase in 1971 = $\frac{9.4\% \times 7}{10}$ = 6.5%

2. = 65.1%

3. = 47.6%

4. = 6.8%

Therefore, Table 4-4 was prepared to show the number of trips for 1964 and 1971 accordingly.

TABLE 4-4

TOTAL NUMBER OF TRIPS MADE IN 24 HOURS IN 1971

Item	1964	No. of Increase	Predicted 1971
1.	43,000	2,795	45,795
2.	319,526	179,254	498,780
3.	362,526	172,562	535,088
4.	252,120	17,144	269,264
Total for 1971			1,348,927

The amount of pollution from these vehicle trips (1,348,927) was calculated as follows:

The Emission Inventory gives a total of 102,983 tons/year carbon monoxide released from 7,450,000 vehicle passes through the sixty-five neighborhoods per 24 hours.

Therefore: $\frac{1{,}348{,}927 \text{ vehicles} \times 102{,}983 \text{ tons CO/yr.}}{7{,}450{,}000 \text{ vehicles}}$ =

18,645 tons CO/yr.

A more realistic value of internal neighborhood vehicle emissions was determined by determining the average of the calculated carbon monoxide emissions (18,645 tons/yr.) and the "additional emissions" given in the area source inventory (16,447 tons/yr.). Thus, the quantity of carbon monoxide released from 1,348,927 internal vehicle trips was determined as follows:

$$\frac{16,447 + 18,645}{2} = 17,546 \text{ tons/yr. CO}$$

The same procedure was used to determine the quantity of hydrocarbons, nitrogen oxide, sulfur dioxide and particulates. These quantities are as follows:

Hydrocarbons	=	18,284 tons/yr.
Nitrogen oxide	=	752 tons/yr.
Sulfur dioxide	=	205 tons/yr.
Particulates	=	311 tons/yr.

The total quantity of each contaminant was predicted for vehicular pollution as follows:

Carbon monoxide	=	120,524 tons/yr.
Hydrocarbons	=	32,094 tons/yr.
Nitrogen oxides	=	8,087 tons/yr.
Sulfur dioxide	=	523 tons/yr.
Particulates	=	656 tons/yr.

The quantity of each pollutant per neighborhood in tons per year was determined by multiplying each of the above quantities by the number of vehicle passes per neighborhood and dividing by the total vehicle passes for all neighborhoods (see Table 4-5).

The concentration of each pollutant was calculated for both point sources and area sources, and the sum of the

TABLE 4-5

AREA AND POINT SOURCES EMISSION INVENTORY TONS/YEAR
FOR THE CITY OF TULSA, OKLAHOMA--1972

Neighbor-hood No.	Vehicles With 25 MPH					Point Sources				
	CO	Hydro-carbons	NO_2	SO_2	Partic-ulate	CO	Hydro-carbons	NO_2	SO_2	Partic-ulate
1	1654	440	111	7	9	--	--	--	--	--
2	2949	785	198	13	16	--	--	--	--	--
3	3693	983	248	16	20	--	--	--	--	--
4	7405	1972	509	32	40	--	--	--	--	--
5	4358	1160	292	19	24	--	--	--	--	--
6	2402	640	161	10	13	--	1	3	--	--
7	672	179	45	3	4	--	--	--	--	--
8	6083	1620	408	26	33	--	1	4	--	--
9	3091	823	207	13	17	--	--	--	--	--
10	600	160	40	3	3	--	--	--	--	--
11	5675	1511	381	25	31	--	--	--	--	--
12	8238	2194	523	36	45	--	--	--	--	--
13	1672	445	112	7	9	--	--	--	--	--
14	3085	821	207	13	17	--	--	--	--	--
15	7536	2007	506	33	40	--	--	--	--	--
16	4915	1309	330	21	27	--	--	--	--	--
17	3008	801	202	13	16	--	--	--	--	--
18	4618	1230	310	20	25	--	--	--	--	--
19	3271	871	219	14	18	--	--	--	--	--
20	2551	679	171	11	14	--	--	1	--	--
21	1752	467	118	8	10	--	61	876	--	--
22	452	120	30	2	2	--	--	--	--	--
23	1510	402	101	7	8	--	--	3	--	--
24	1355	361	91	6	7	--	1	3	--	--
25	3341	890	224	14	18	2	180	788	--	--
26	759	202	51	3	4	--	4	2	--	--
27	686	183	46	3	4	--	--	--	--	--
28	1262	336	85	5	7	--	--	--	--	--
29	1024	273	69	4	6	--	40	177	--	--

TABLE 4-5--Continued

Neighbor-hood No.	Vehicles with 25 MPH					Point Sources				
	CO	Hydro-carbons	NO_2	SO_2	Partic-ulate	CO	Hydro-carbons	NO_2	SO_2	Partic-ulate
30	2800	746	188	12	15	--	--	--	--	--
31	2153	573	144	9	12	--	--	--	--	--
32	321	85	22	1	2	--	--	--	--	--
33	936	249	63	4	5	--	--	--	--	--
34	658	175	44	3	4	68	45	5480	--	--
35	321	86	22	1	2	--	--	--	--	--
36	941	251	63	4	5	--	--	--	--	--
37	2993	794	200	13	16	--	4	2828	--	--
38	1486	396	100	6	8	39730	183	639	--	--
39	149	40	10	1	1	--	2	7	--	--
40	611	163	41	3	3	--	--	--	--	--
41	212	56	14	1	1	--	--	--	--	--
42	567	151	38	2	3	--	4	17	--	--
43	678	181	45	3	4	--	--	--	--	--
44	1052	280	71	5	6	--	--	--	--	--
45	228	61	15	1	1	--	--	--	--	--
46	393	105	26	2	2	--	--	--	--	--
47	399	106	27	2	2	--	4	17	--	--
48	257	69	17	1	1	--	--	--	--	--
49	447	119	30	2	2	--	--	--	--	--
50	315	84	21	1	2	--	--	--	--	--
51	438	117	29	2	2	--	--	--	--	--
52	434	116	29	2	2	--	--	--	--	--
53	298	79	20	1	2	--	--	--	--	--
54	71	19	5	0	0	5	13	2191	--	--
55	666	177	45	3	4	--	--	--	--	--
56	26	7	2	0	0	--	--	--	--	--
57	853	227	57	4	5	--	--	--	--	--
58	348	93	23	2	2	--	1	2	--	--
59	815	217	55	4	4	--	1	4	--	--
60	2518	670	169	11	14	--	--	--	--	--

TABLE 4-5--Continued

Neighbor-hood No.	Vehicles with 25 MPH					Point Sources				
	CO	Hydro-carbons	NO_2	SO_2	Partic-ulate	CO	Hydro-carbons	NO_2	SO_2	Partic-ulate
61	1447	385	97	6	8	--	--	--	--	--
62	452	120	30	2	2	--	--	--	--	--
63	1080	287	72	5	6	--	--	--	--	--
64	3402	906	228	15	19	--	3	30	--	--
65	141	38	9	1	1	--	--	--	--	--

two was substituted for Q in equation 14 to determine the concentration of each pollutant for each neighborhood. The Q values were converted to pounds per year and y, z and $\overline{U}$ to meters. Therefore, the concentration of each pollutant was calculated in terms of pounds per cubic meter per year [pounds (10^{-4}) (m^{-3})/year].

Meteorology

The City of Tulsa, Oklahoma is located on the Arkansas River at an elevation of 600 to 800 feet. The topography of the city is relatively flat to the east with the west section consisting of small hills and valleys. The eastern part of the city has little effect on wind flows; while the western hills and valleys may turn the winds. Buildings of considerable height are located in the center of the business district which may change wind flow patterns in the small central business area.[72]

Wind velocity or air movement is the most important meteorological factor in air pollution. This factor of wind movement provides the means for the mixing and distribution of air contaminants over the city. Examination of wind data[72] indicated that the most frequent occurrence for low wind speeds (≤ 7 mph) was south to southeast. The per cent of low wind speeds from all directions was highest in Summer and Fall. The persistence of winds of less than 5 mph would be conducive to air stagnation or the lack of ventilation.

This condition occurs very infrequently in Tulsa. High winds that persist in this region are not necessarily helpful to air quality control in that heavy contamination can occur from aerodynamic downwash of stack effluents in high winds.[72]

Major air pollution episodes usually occur in urban areas when low wind speeds continue for periods of four or more days allowing the air contaminants to concentrate in or near the source neighborhood. This condition has only been reported twice in Tulsa over a twenty-year period.[72]

The stability of the air mass is of importance in air pollution because unstable air moves contaminants on vertical currents upward and out of the mass of air on the ground. However, stable air keeps contaminants in the air near the ground and increases the concentration of pollutants. If the temperature increases with increases in altitude, a condition known as an "inversion" occurs. This layer of air is stable and prevents the vertical dispersion of air pollutants.[72]

In a study by Gerard DeMarrais, "Meteorology for Land Development Planning in the Tulsa Metropolitan Area," it was demonstrated that the monthly temperature differences between 25 feet and 91 feet had large temperature decreases with height during the day or superadiabatic conditions prevailed. Night observations during winter were near isothermal and observations in late winter and summer showed that superadiabatic conditions occurred most frequently. Spring, early summer, and most of the fall seasons showed average conditions between adiabatic and isothermal.

Mixing Height (Mixing Depth or z)

The determination of the seasonal depth for calculation in equation 14 (Chapter 4) used concepts and computation methods developed by George C. Halzworth.[76] He determined the seasonal mixing depth in forty-eight states of the United States for both morning and afternoon. The morning mixing height was calculated as the height above ground at which the day adiabatic extension of the morning minimum surface temperature plus five degrees centigrade intersected the vertical temperature profile observed at 1200 Greenwitch Median Time (GMT). The minimum temperature was determined from the regular hourly airways reports from 0200 through 0600 Local Standard Time (LST). The "plus 5°C" was intended to allow roughly for the usual effects of nocturnal and early morning urban heat island, since National Weather Service upper air measuring stations are located in rural or suburban surroundings. Thus, the urban morning mixing height was more nearly calculated.[76]

The afternoon mixing height is less complicated than the morning, but was calculated in the same way, except that instead of the minimum temperature plus 5°C, the maximum surface temperature observed from 1200 through 1600 LST was used. Urban-rural differences of maximum surface temperature was assumed to be negligible. The typical time of the afternoon mixing height may be considered to coincide approximately with the usual midafternoon minimum concentration of slow-reacting urban pollutants. The morning and afternoon mixing heights for the United States are shown on diagrams in Appendix A-5 to A-12.[76]

The average of the morning and afternoon mixing height was used for the seasonal mixing height for calculations in equation 14 for this study. The four seasons mixing height calculations are shown below:

1. Summer $z = \dfrac{400 + 1800}{2} = 1100$ meters
2. Fall $z = \dfrac{1325 + 350}{2} = 867$ meters
3. Winter $z = \dfrac{950 + 400}{2} = 675$ meters
4. Spring $z = \dfrac{500 + 1550}{2} = 1025$ meters

Width Measurement of the Neighborhoods (y)

The East-West width of each of the sixty-five NEEDS Neighborhoods was measured on the official Tulsa map with a scale of 2 inches per mile (see Table 4-6). The width of each neighborhood was then multiplied by 1609 meters per mile. The width (East-West) of each neighborhood in meters was used for y in equation 14.

Average Wind (Mean Wind or $\overline{U}$)

Seasonal wind velocity was determined by averaging the wind speeds for the three months of each season for use

TABLE 4-6

WIDTH OF THE NEIGHBORHOODS BY METER FOR THE CITY OF TULSA, OKLAHOMA--1972

Neighborhood No.	Width	Neighborhood No.	Width
1	4827.0	34	1609.0
2	804.5	35	2011.25
3	1609.0	36	1609.0
4	3218.0	37	804.5
5	1609.0	38	3218.0
6	3218.0	39	804.5
7	9654.0	40	4827.0
8	12872.0	41	1609.0
9	9654.0	42	1609.0
10	1609.0	43	1609.0
11	3218.0	44	1609.0
12	3218.0	45	804.5
13	1609.0	46	1206.75
14	2413.5	47	804.5
15	2413.5	48	804.5
16	2413.5	49	804.5
17	1609.0	50	804.5
18	3218.0	51	804.5
19	1609.0	52	804.5
20	1609.0	53	804.5
21	1609.0	54	804.5
22	804.5	55	804.5
23	1609.0	56	804.5
24	1609.0	57	1206.75
25	3218.0	58	804.5
26	1609.0	59	804.5
27	1609.0	60	1609.0
28	1609.0	61	4827.0
29	8045.0	62	1609.0
30	3218.0	63	7240.5
31	3218.0	64	11263.0
32	1206.75	65	402.25
33	1609.0		

as $\overline{U}$ in equation 14. The mean wind for each season ($\overline{U}$) are shown below:

1. Summer $\overline{U}$ = 14,159 meters/hour
2. Fall $\overline{U}$ = 14,803 meters/hour
3. Winter $\overline{U}$ = 16,734 meters/hour
4. Spring $\overline{U}$ = 18,664 meters/hour

CHAPTER V

RESULTS AND DISCUSSION

A summary of the results of the "Box Model" method of determining pollution concentrations for each of the sixty-five NEEDS Program neighborhoods is shown in Table 5-1. The table presents the quantities of each pollutant in tons per year and in tons per day per square mile. Utilizing the suggested ranges for the three major air pollutants, particulates, carbon monoxide and sulfur dioxide, given in the NEEDS Program Manual, ranges for the other two pollutants, hydrocarbons and nitrogen oxide can be predicted for use in this study. The suggested emission values for an average annual space-heating day were predicted as follows:

Moderate:	
Particulates	0.5 to 1.0 tons/day/sq. mile
Carbon monoxide	0.5 to 1.0 tons/day/sq. mile
Sulfur dioxide	0.5 to 1.0 tons/day/sq. mile
Hydrocarbons	0.5 to 1.0 tons/day/sq. mile
Nitrogen oxides	0.5 to 1.0 tons/day/sq. mile
Considerable	
Particulates	1.0 to 2.0 tons/day/sq. mile
Carbon monoxide	1.0 to 4.0 tons/day/sq. mile
Sulfur dioxide	1.0 to 2.0 tons/day/sq. mile
Hydrocarbons	1.0 to 4.0 tons/day/sq. mile
Nitrogen oxides	1.0 to 4.0 tons/day/sq. mile
Extreme	
Particulates	greater than 2.0 tons/day/sq. mile
Carbon monoxide	greater than 4.0 tons/day/sq. mile
Sulfur dioxide	greater than 2.0 tons/day/sq. mile
Hydrocarbons	greater than 4.0 tons/day/sq. mile
Nitrogen oxides	greater than 4.0 tons/day/sq. mile

TABLE 5-1

TOTAL POLLUTANTS (TONS/YEAR) AND TOTAL POLLUTANTS (TONS/DAY/SQ. MILE) IN EACH NEIGHBORHOOD FOR THE CITY OF TULSA, OKLAHOMA--1972

Neighbor-hood No.	Pollutants (Tons/Year)					Pollutants (Tons/Day/Sq. Mile)					
	CO	Hydro-carbon	NO_2	SO_2	Part.	Area (SqMi)	CO	Hydro-carbon	NO_2	SO_2	Part.
1	1654	440	111	7	9	6.00	0.76	0.20	0.05	0.00	0.00
2	2947	785	198	13	16	1.50	5.38	1.40	0.36	0.02	0.03
3	3693	983	248	16	20	3.00	3.37	0.89	0.23	0.01	0.02
4	7405	1972	509	32	40	6.00	3.38	0.90	0.23	0.01	0.02
5	4358	1160	292	19	24	3.00	3.98	1.10	0.27	0.02	0.02
6	2402	641	164	10	13	4.00	1.65	0.44	0.11	0.00	0.00
7	673	179	45	3	4	6.00	0.31	0.08	0.03	0.00	0.00
8	6083	1621	412	26	33	10.00	1.67	0.44	0.11	0.00	0.00
9	3091	823	207	13	17	16.80	0.50	0.13	0.03	0.00	0.00
10	600	160	40	3	3	1.00	1.60	0.43	0.10	0.08	0.08
11	5675	1511	381	25	31	4.25	3.66	0.97	0.25	0.02	0.02
12	8238	2194	523	36	45	4.00	5.60	1.50	0.36	0.02	0.03
13	1673	445	112	7	9	1.00	4.60	1.20	0.31	0.02	0.02
14	3085	821	207	13	17	1.75	4.80	1.30	0.32	0.02	0.03
15	7536	2007	506	33	40	1.00	20.60	5.50	1.40	0.09	0.11
16	4915	1309	330	21	27	1.60	8.50	2.20	0.56	0.04	0.04
17	3008	801	202	13	16	1.00	8.20	2.20	0.55	0.04	0.04
18	4618	1230	310	20	25	2.00	1.30	1.70	0.42	0.03	0.03
19	3271	871	219	14	18	1.00	9.00	2.40	0.60	0.04	0.05
20	2551	679	172	11	14	0.65	10.80	2.90	0.72	0.05	0.06
21	1752	528	994	8	10	0.60	8.00	2.40	4.50	0.04	0.05
22	452	120	30	2	2	0.25	5.00	1.30	0.33	0.02	0.02
23	1510	402	104	7	8	1.00	4.10	1.10	0.28	0.02	0.02
24	1355	362	94	6	7	1.00	3.70	1.00	0.26	0.02	0.02
25	3343	1070	1012	14	18	3.50	2.60	0.84	0.79	0.01	0.01
26	759	206	53	3	4	1.00	2.10	0.56	0.15	0.00	0.00
27	686	183	46	3	4	0.95	1.90	0.53	0.13	0.00	0.00

TABLE 5-1--Continued

Neighbor-hood No.	Pollutants (Tons/Year)					Pollutants (Tons/Day/Sq. Mile)					
	CO	Hydro-carbon	NO_2	SO_2	Part.	Area (SqMi)	CO	Hydro-carbon	NO_2	SO_2	Part
28	1262	336	85	5	7	2.00	1.70	0.46	0.12	0.00	0.00
29	10241	313	246	5	6	10.00	2.80	0.09	0.07	0.00	0.00
30	2800	746	188	12	15	6.00	1.30	0.34	0.09	0.00	0.00
31	2135	573	144	9	12	1.25	4.70	1.30	0.32	0.02	0.03
32	321	85	22	1	2	0.75	1.20	0.31	0.08	0.00	0.00
33	936	249	63	4	5	0.90	2.80	0.76	0.19	0.01	0.01
34	726	220	5524	44	3	0.80	2.50	0.75	18.90	0.15	0.01
35	321	86	22	1	2	0.60	1.50	0.39	0.10	0.00	0.00
36	941	251	63	4	5	0.70	3.70	0.98	0.25	0.02	0.02
37	2993	798	3028	13	16	1.50	5.50	1.50	5.50	0.02	0.03
38	41816	579	739	6	8	2.50	45.80	0.63	0.81	0.00	0.00
39	149	42	17	1	1	0.25	1.60	0.46	0.19	0.01	0.01
40	611	163	41	3	3	10.50	0.16	0.04	0.01	0.00	0.00
41	212	56	14	1	1	1.00	0.58	0.15	0.03	0.00	0.00
42	567	155	55	2	3	1.00	1.60	0.42	0.15	0.00	0.00
43	678	181	45	3	4	0.70	2.70	0.71	0.18	0.01	0.02
44	1052	280	71	5	6	0.80	3.60	0.96	0.24	0.02	0.02
45	228	61	15	1	1	0.20	3.12	0.84	0.20	0.01	0.01
46	393	105	26	2	2	0.30	3.60	0.96	0.24	0.02	0.02
47	399	110	44	2	2	0.30	3.60	1.00	0.40	0.02	0.02
48	257	69	17	1	1	0.25	2.80	0.76	0.19	0.01	0.01
49	447	119	30	2	2	0.30	4.10	1.10	0.27	0.02	0.02
50	315	84	21	1	2	0.15	5.80	1.50	0.38	0.02	0.02
51	438	117	29	2	2	0.25	4.80	1.30	0.30	0.02	0.02
52	434	116	29	2	2	0.40	3.00	0.79	0.20	0.01	0.01
53	298	79	20	1	2	0.25	3.30	0.87	0.22	0.01	0.01
54	76	32	2196	0	0	0.40	0.52	0.22	5.04	0.00	0.00
55	666	177	45	3	4	0.15	12.20	3.20	0.82	0.05	0.05
56	26	7	2	0	0	0.20	0.36	0.10	0.03	0.00	0.00
57	853	227	57	4	5	0.40	5.80	1.60	0.39	0.03	0.03
58	349	93	25	2	2	0.50	1.90	0.51	0.14	0.01	0.01

TABLE 5-1--Continued

Neighbor-hood No.	Pollutants (Tons/Year) CO	Hydro-carbon	NO_2	SO_2	Part.	Pollutants (Tons/Day/Sq. Mile) Area (SqMi)	CO	Hydro-carbon	NO_2	SO_2	Part.
59	815	218	59	4	4	0.65	3.40	0.92	0.25	0.02	0.02
60	2518	670	169	11	14	0.40	17.20	4.60	1.20	0.08	0.10
61	1447	385	97	6	8	6.00	0.66	0.18	0.04	0.00	0.00
62	452	120	30	2	2	6.50	0.19	0.05	0.01	0.00	0.00
63	1080	287	72	5	6	16.00	0.18	0.05	0.01	0.00	0.00
64	3402	909	258	15	19	17.00	0.55	0.15	0.04	0.00	0.00
65	141	38	9	1	1	0.05	7.70	2.00	0.49	0.05	0.05

Any value below the moderate values was considered to constitute no air pollution problem.

The calculated levels of particulates and sulfur dioxide were below the suggested moderate pollution value of 0.5 tons/day/square mile. Therefore these contaminants were judged not to be a problem. The levels of pollution for each neighborhood are shown in Table 5-2 for carbon monoxide, Table 5-3 for hydrocarbons, and Table 5-4 for nitrogen oxides.

In order to determine the seasonal variation of pollution per neighborhood, refer to Table 5-6. Seasonal variations are further demonstrated by line graphs for carbon monoxide concentrations by neighborhood in Winter and Spring (Figure 5-1), Summer and Fall (Figure 5-2); for hydrocarbons in Summer and Winter (Figure 5-3), Fall and Spring (Figure 5-4). It is readily visualized in these figures that carbon monoxide and hydrocarbons concentrations are highest in Winter and lowest in Spring. This is due to the meteorological variables of mixing depth and mean wind speed. Neighborhood relationships--one to another--are shown in Figures 5-5 and 5-6. These figures illustrate the maximum annual concentration of carbon monoxide and hydrocarbons respectively by neighborhood.

Symaps in Appendix B-1, B-2, and B-3 show the pollution levels of carbon monoxide, hydrocarbons, and nitrogen oxides respectively. These levels were determined according to the suggested emission values for an average annual space-heating day which was predicted in Chapter V. An example of

TABLE 5-2

RANGES OF CARBON MONOXIDE NEIGHBORHOOD BY NEIGHBORHOOD FOR THE CITY OF TULSA, OKLAHOMA--1972

Classification	Neighborhood Number
No Problem	7, 40, 56, 62, 63
Moderate	1, 9, 41, 54, 61, 64
Considerable	3-6, 8, 10-11, 24-30, 32-36, 39, 42-48, 52-53, 58-59
Extreme	2, 12-23, 31, 37-38, 49-51, 55, 57, 60, 65

TABLE 5-3

RANGES OF NYDROCARBONS NEIGHBORHOOD BY NEIGHBORHOOD FOR THE CITY OF TULSA, OKLAHOMA--1972

Classification	Neighborhood Number
No Problem	1, 6-10, 28-30, 32, 25, 39-42, 54, 56, 61-64
Moderate	2-5, 11, 24-27, 33-34, 36, 38, 43-48, 52-53, 57-59
Considerable	12-14, 16-23, 31, 37, 49-51, 55, 65
Extreme	15, 60

TABLE 5-4

RANGES OF NITROGEN OXIDE NEIGHBORHOOD BY NEIGHBORHOOD FOR THE CITY OF TULSA, OKLAHOMA--1972

Classification	Neighborhood Number
No Problem	1-15, 18, 22-24, 26-33, 35-36, 39-40, 42-53, 56-59, 61-65
Moderate	16-17, 19-20, 25, 38, 55, 60
Considerable	
Extreme	21, 34, 37, 54

TABLE 5-5

COMPARISON OF AIR POLLUTION EVALUATED BY TULSA AND EVALUATION DETERMINED IN THIS STUDY

Classification	City-County Health Dept. Air Pollution Evaluation by Neighborhood	Air Pollution Evaluation Determined in this Study, by Neighborhood		
		CO	Hydrocarbons	NO_2
No Problem	7, 9-11, 29-30, 61-63	7, 40, 56, 62-63	1, 6-10, 28-30, 32, 35, 39-42, 54, 56, 61-64	1-15, 18, 22-24, 26-36, 39-40, 42-53, 56-59, 61-65
Moderate	Not determined	1, 9, 41, 54, 61, 64	2-5, 11, 24-27, 33-34, 36, 38, 43-48, 52-53, 57-59	16-17, 19-20, 25, 38, 55, 60
Considerable	1-6, 8, 12-28, 31-37, 39-60, 64-65	3-6, 8, 10-11, 24-30, 32-36, 39, 42-48, 52-53, 58-59	12-14, 16-23, 31, 37, 49-51, 55, 56	
Extreme	38	2, 12-23, 31, 37-38, 49-51, 55, 57, 60, 65	15, 60	21, 34, 37, 54

TABLE 5-6

CONCENTRATION OF POLLUTANTS, LB(10^{-4})(M^{-3}) BY SEASON FOR THE CITY OF TULSA, OKLAHOMA--1972

Neighbor-hood No.	Fall			Winter			Spring			Summer		
	CO	Hydro-carbon	NO_2	CO	Hydro-carbon	NO_2	CO	Hydro-carbon	NO_2	CO	Hydro-carbon	NO_2
1	0.13	0.03	0.00	0.15	0.03	0.00	0.18	0.03	0.00	0.10	0.03	0.00
2	1.40	0.38	0.08	1.60	0.43	0.10	0.95	0.25	0.05	1.18	0.30	0.08
3	0.87	0.23	0.05	1.00	0.25	0.05	0.58	0.15	0.03	0.73	0.18	0.03
4	0.87	0.23	0.05	0.63	0.25	0.05	0.60	0.15	0.03	0.73	0.18	0.03
5	1.05	0.28	0.05	1.18	0.30	0.08	0.70	0.18	0.03	0.85	0.23	0.05
6	0.28	0.08	0.00	0.33	0.08	0.00	0.18	0.05	0.00	0.23	0.05	0.03
7	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.18	0.03	0.00	0.20	0.05	0.00	0.10	0.03	0.00	0.15	0.03	0.00
9	0.10	0.03	0.00	0.13	0.03	0.00	0.18	0.00	0.00	0.10	0.03	0.00
10	0.11	0.03	0.00	0.15	0.03	0.00	0.18	0.03	0.00	0.10	0.03	0.00
11	0.68	0.18	0.03	0.78	0.20	0.05	0.33	0.10	0.03	0.55	0.15	0.03
12	0.98	0.25	0.05	1.13	0.30	0.05	0.65	0.18	0.03	0.80	0.20	0.05
13	0.40	0.10	0.03	0.45	0.10	0.03	0.25	0.05	0.00	0.33	0.08	0.00
14	0.48	0.13	0.03	0.55	0.15	0.03	0.33	0.08	0.00	0.40	0.10	0.03
15	1.20	0.30	0.08	1.38	0.35	0.08	0.80	0.20	0.05	1.00	0.25	0.05
16	0.78	0.20	0.05	0.90	0.23	0.05	0.53	0.13	0.03	0.65	0.15	0.03
17	0.73	0.18	0.03	0.83	0.20	0.05	0.48	0.13	0.03	0.60	0.15	0.03
18	0.55	0.13	0.03	0.63	0.15	0.03	0.38	0.08	0.03	0.45	0.10	0.03
19	0.78	0.20	0.05	0.88	0.23	0.05	0.53	0.13	0.03	0.65	0.15	0.03
20	0.60	0.15	0.03	0.70	0.18	0.03	0.40	0.10	0.03	0.50	0.13	0.03
21	0.40	0.13	0.23	0.48	0.13	0.25	0.28	0.08	0.00	0.33	0.08	0.00
22	0.20	0.05	0.00	0.23	0.05	0.00	0.13	0.03	0.00	0.18	0.03	0.00
23	0.35	0.08	0.00	0.40	0.10	0.03	0.23	0.05	0.00	0.30	0.08	0.00
24	0.33	0.08	0.00	0.35	0.08	0.03	0.20	0.05	0.00	0.25	0.05	0.00
25	0.40	0.13	0.10	0.45	0.13	0.13	0.25	0.08	0.08	0.30	0.10	0.10
26	0.17	0.03	0.00	0.20	0.05	0.00	0.10	0.03	0.00	0.15	0.03	0.00
27	0.15	0.03	0.00	0.18	0.05	0.00	0.10	0.03	0.00	0.13	0.03	0.00
28	0.30	0.08	0.00	0.33	0.08	0.00	0.20	0.05	0.00	0.25	0.05	0.00

TABLE 5-6--Continued

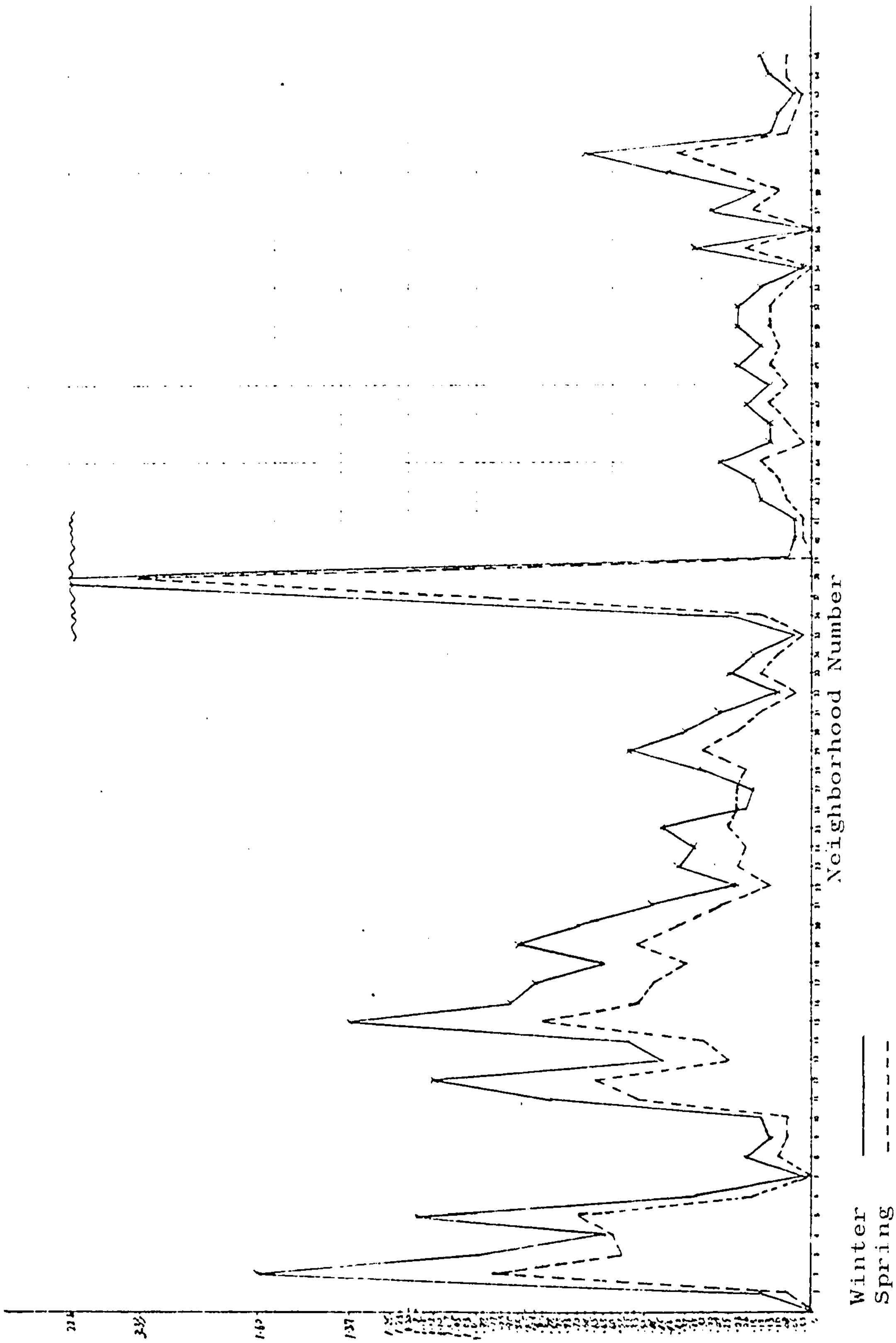
Neighbor-hood No.	Fall			Winter			Spring			Summer		
	CO	Hydro-carbon	NO_2	CO	Hydro-carbon	NO_2	CO	Hydro-carbon	NO_2	CO	Hydro-carbon	NO_2
29	0.47	0.00	0.00	0.55	0.00	0.00	0.33	0.00	0.00	0.40	0.00	0.00
30	0.33	0.08	0.00	0.38	0.10	0.03	0.23	0.05	0.00	0.28	0.05	0.00
31	0.25	0.05	0.00	0.28	0.08	0.00	0.15	0.03	0.00	0.20	0.05	0.00
32	0.10	0.03	0.00	0.10	0.03	0.00	0.05	0.00	0.00	0.08	0.00	0.00
33	0.23	0.05	0.00	0.25	0.05	0.00	0.15	0.03	0.00	0.18	0.03	0.00
34	0.18	0.05	1.33	0.18	0.05	1.50	0.10	0.03	0.88	0.13	0.03	1.10
35	0.05	0.00	0.00	0.05	0.00	0.00	0.03	0.00	0.00	0.05	0.00	0.00
36	0.23	0.05	0.00	0.25	0.05	0.00	0.15	0.03	0.00	0.18	0.05	0.00
37	1.40	0.38	1.45	1.60	0.43	1.65	0.95	0.25	0.98	1.18	0.30	1.20
38	4.98	0.05	0.08	5.65	0.08	0.10	3.33	0.03	0.05	4.10	0.05	0.05
39	0.05	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
40	0.03	0.00	0.00	0.05	0.00	0.00	0.03	0.00	0.00	0.03	0.00	0.00
41	0.05	0.00	0.00	0.05	0.00	0.00	0.03	0.00	0.00	0.03	0.00	0.00
42	0.13	0.03	0.00	0.15	0.03	0.00	0.18	0.03	0.00	0.10	0.03	0.00
43	0.15	0.03	0.00	0.18	0.03	0.00	0.10	0.03	0.00	0.13	0.03	0.00
44	0.25	0.05	0.00	0.25	0.08	0.00	0.15	0.03	0.00	0.20	0.05	0.00
45	0.10	0.00	0.00	0.13	0.03	0.00	0.03	0.00	0.00	0.08	0.00	0.00
46	0.13	0.03	0.00	0.13	0.03	0.00	0.18	0.03	0.00	0.10	0.03	0.00
47	0.18	0.03	0.00	0.20	0.05	0.00	0.13	0.03	0.00	0.15	0.03	0.00
48	0.10	0.00	0.00	0.13	0.03	0.00	0.18	0.00	0.00	0.10	0.00	0.00
49	0.20	0.05	0.00	0.23	0.05	0.00	0.13	0.03	0.00	0.18	0.03	0.00
50	0.15	0.03	0.00	0.15	0.03	0.00	0.10	0.03	0.00	0.13	0.03	0.00
51	0.20	0.05	0.00	0.23	0.05	0.00	0.13	0.03	0.00	0.15	0.03	0.00
52	0.20	0.05	0.00	0.23	0.05	0.00	0.13	0.03	0.00	0.15	0.03	0.00
53	0.13	0.03	0.00	0.15	0.03	0.00	0.18	0.03	0.00	0.10	0.03	0.00
54	0.03	0.00	1.05	0.03	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.88
55	0.30	0.08	0.00	0.35	0.08	0.00	0.20	0.05	0.00	0.25	0.05	0.00
56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
57	0.28	0.05	0.00	0.30	0.08	0.00	0.18	0.03	0.00	0.23	0.05	0.00
58	0.15	0.03	0.00	0.18	0.05	0.00	0.10	0.03	0.00	0.13	0.03	0.00
59	0.38	0.10	0.03	0.43	0.10	0.03	0.25	0.05	0.00	0.33	0.08	0.00

TABLE 5-6--Continued

Neighborhood No.	Fall			Winter			Spring			Summer		
	CO	Hydrocarbon	NO_2	CO	Hydrocarbon	NO_2	CO	Hydrocarbon	NO_2	CO	Hydrocarbon	NO_2
60	0.60	0.15	0.03	0.68	0.18	0.03	0.40	0.10	0.03	0.50	0.13	0.03
61	0.10	0.03	0.00	0.13	0.03	0.00	0.18	0.00	0.00	0.08	0.03	0.00
62	0.10	0.03	0.00	0.10	0.03	0.00	0.05	0.00	0.00	0.08	0.03	0.00
63	0.05	0.00	0.00	0.05	0.00	0.00	0.03	0.00	0.00	0.03	0.00	0.00
64	0.10	0.03	0.00	0.13	0.03	0.00	0.18	0.00	0.00	0.08	0.03	0.00
65	0.13	0.03	0.00	0.15	0.03	0.00	0.18	0.00	0.00	0.10	0.00	0.00

FIGURE 5-1

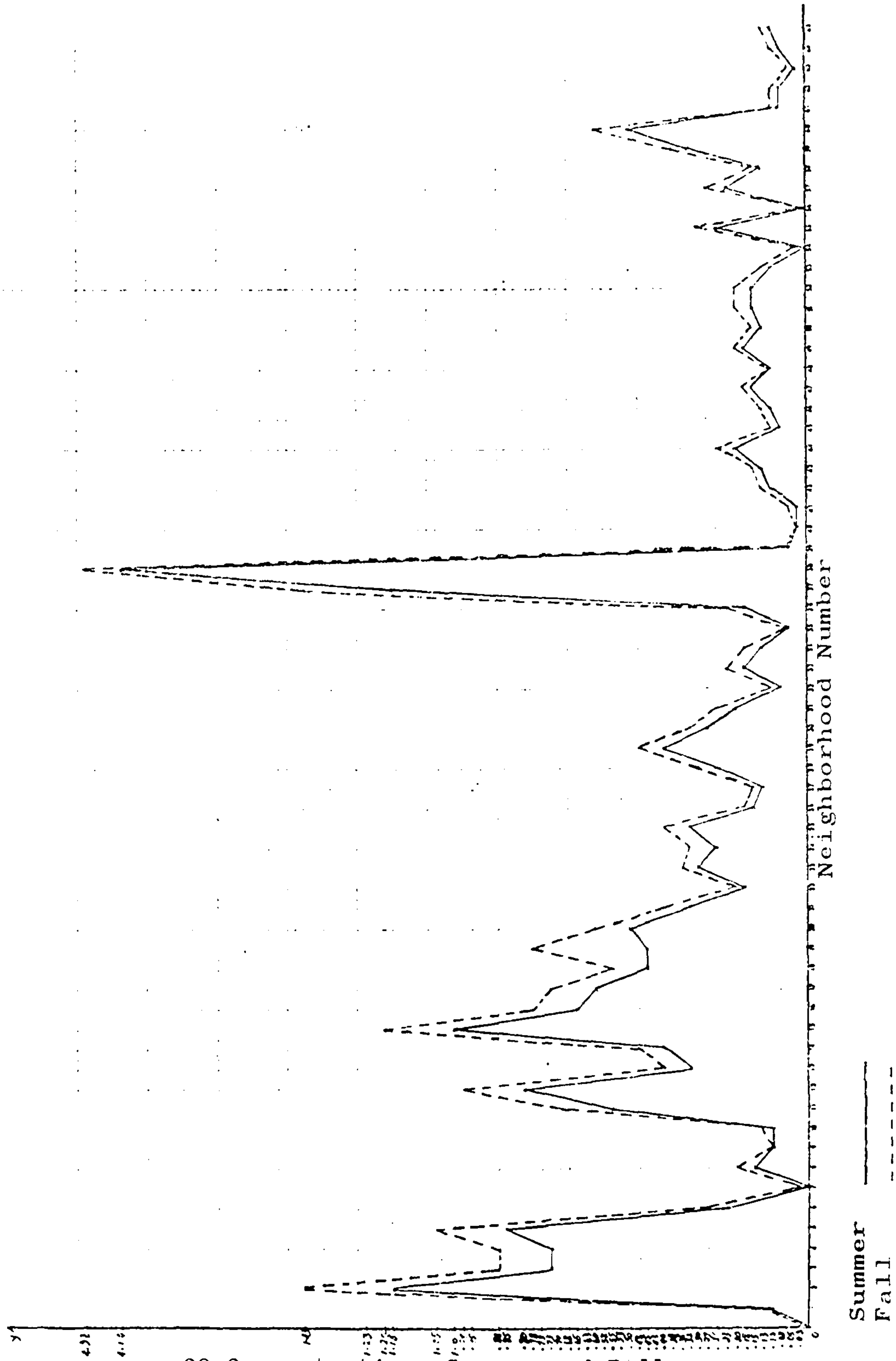
CARBON MONOXIDE CONCENTRATION LB(10^{-4})(M^{-3})
FOR THE SEASONS OF WINTER AND SPRING 1972
FOR THE CITY OF TULSA, OKLAHOMA



CO Concentration--Winter and Spring

FIGURE 5-2

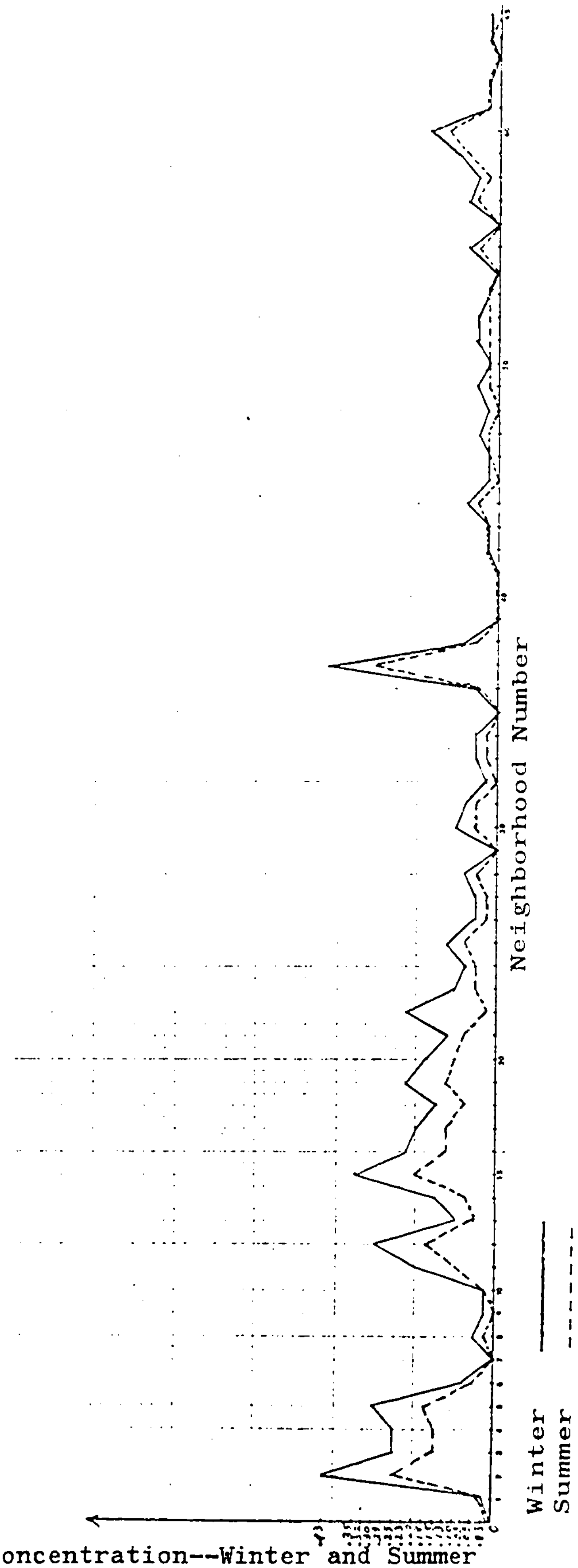
CARBON MONOXIDE CONCENTRATION LB(10^{-4})(M^{-3})
FOR THE SEASONS OF SUMMER AND FALL 1972
FOR THE CITY OF TULSA, OKLAHOMA



CO Concer-ration--Summer and Fall

FIGURE 5-3

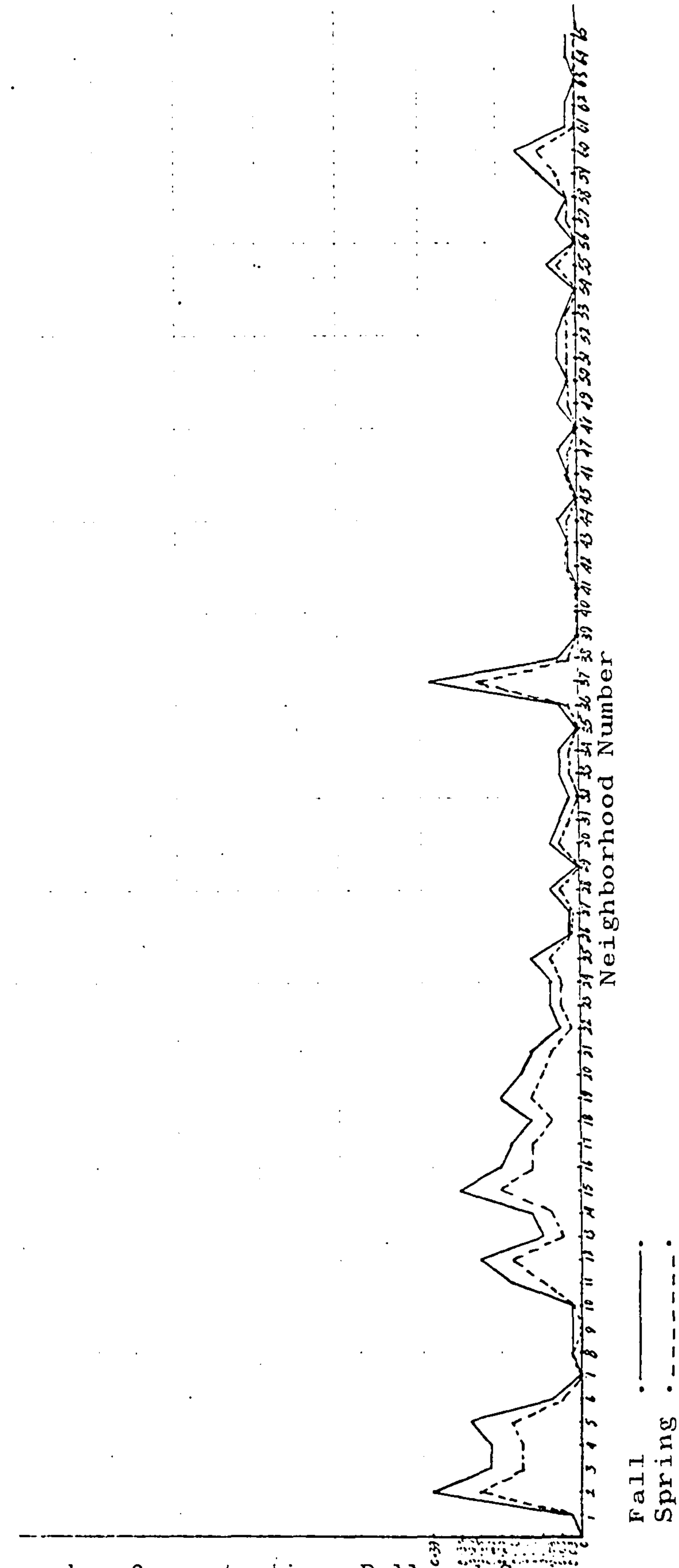
HYDROCARBONS CONCENTRATION LB(10^{-4})(M^{-3}) FOR
THE SEASONS OF WINTER AND SUMMER 1972
FOR THE CITY OF TULSA, OKLAHOMA



Hydrocarbon Concentration--Winter and Summer

FIGURE 5-4

HYDROCARBONS CONCENTRATION LB$(10^{-4})(M^{-3})$ FOR THE SEASONS OF FALL AND SPRING 1972 FOR THE CITY OF TULSA, OKLAHOMA



Hydrocarbon Concentration--Fall and Spring

FIGURE 5-5

MAXIMUM ANNUAL CARBON MONOXIDE CONCENTRATION
LB(10^{-4})(M^{-3}) FOR THE CITY OF
TULSA, OKLAHOMA--1972

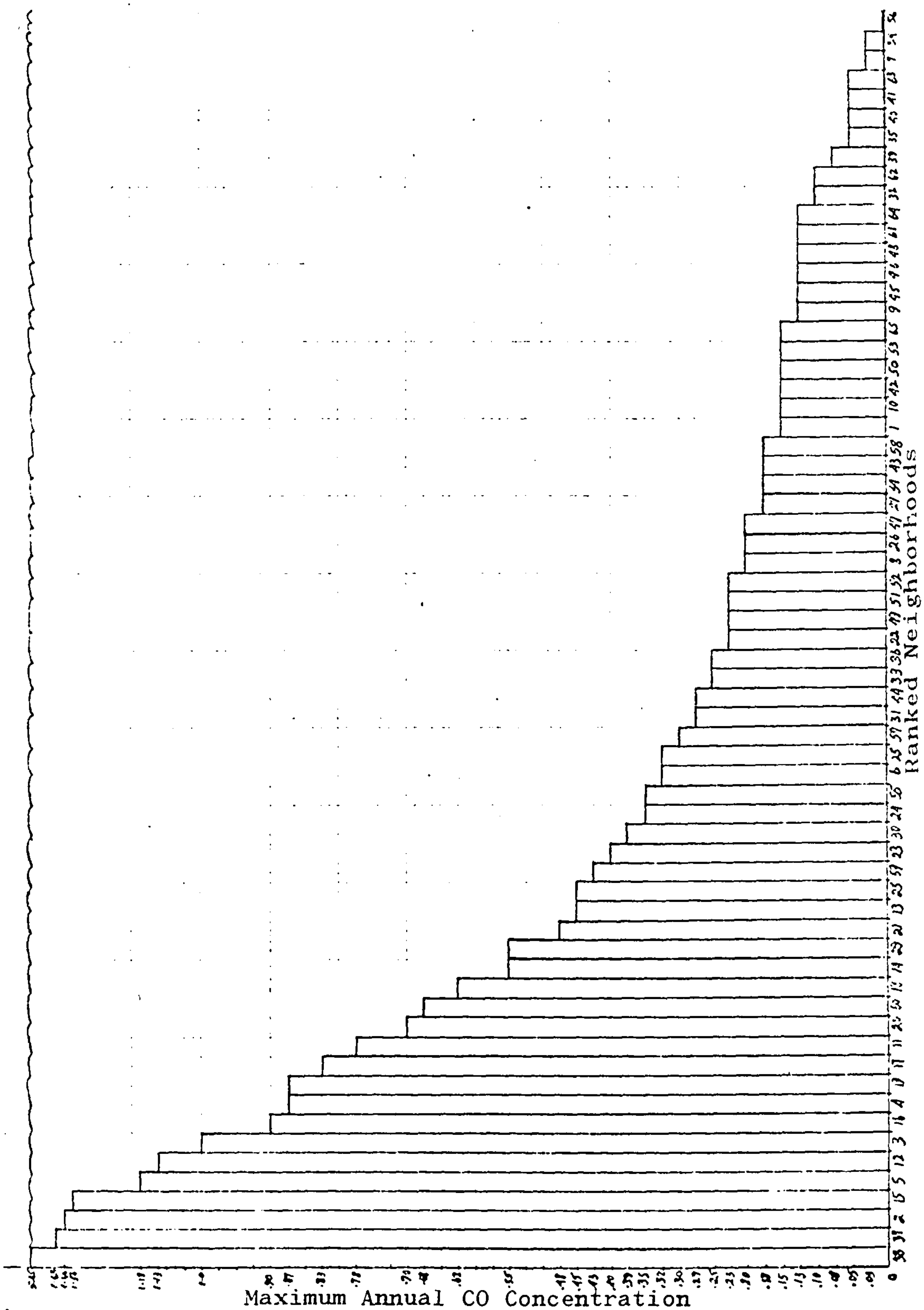
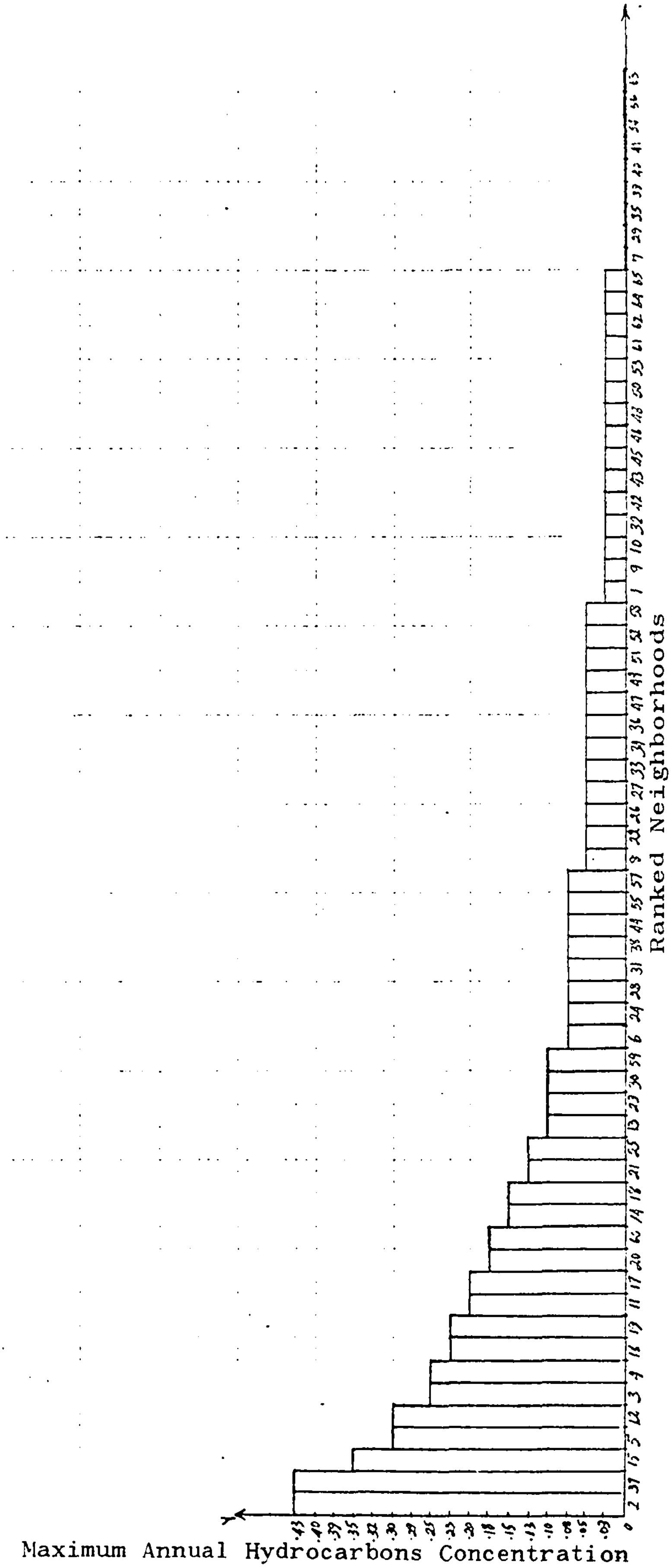

Maximum Annual CO Concentration
Ranked Neighborhoods

FIGURE 5-6

MAXIMUM ANNUAL HYDROCARBONS CONCENTRATION
LB(10^{-4})(M^{-3}) FOR THE CITY OF
TULSA, OKLAHOMA--1972


Ranked Neighborhoods
Maximum Annual Hydrocarbons Concentration

the levels of hydrocarbons for visual evaluation is presented in Appendix B-2. The minimum and maximum quantities of hydrocarbons are 0-5.50 tons/day/square mile (Table 5-1) for the neighborhoods. According to the suggested emission levels the following distribution can be made:

	Level	Tons/day/sq. mi.	Symbol
1.	No problem	0.00-0.50	-
2.	Moderate pollution	0.50-1.00	0
3.	Considerable pollution	1.00-4.00	⊠
4.	Extreme pollution	4.00-5.50	■

The same procedure was followed for other pollutants in this study.

Variables such as housing condition, street condition, tuberculosis rate for 1968-70, 1970 residence trash fire rate/1000 premises, etc. can be visualized by considering the following examples. The lowest and highest rate for 1970 residence and trash fires for the neighborhoods were 0-45.10 (Appendix B-4). Therefore the distribution can be set up as follows:

Level	Rate/1000 Premises	Symbol
1	0-10.99	-
2	11-20.99	X
3	21-30.99	0
4	31-40.99	⊠
5	41-45.99	■

(See Symap in Appendix D-8.) Comparison of pollutant symaps with symaps on tuberculosis rate per 100,000 population (Appendix C-1) and infant mortality rate per 1000 live births (Appendix C-2) reveals no direct relationship of these factors. However, it should be pointed out that the tuberculosis rates encompass only three years, and the infant mortality rate covers only one year. Air pollution levels in the neighborhoods have been increasing for a number of years. It would be revealing to make a correlation analysis of these and other health problems, especially upper respiratory diseases and chronic respiratory conditions, if morbidity and mortality data were available for a period of five or more years. Health Agencies in Tulsa, and other areas for that matter, should make a concerted and coordinated effort to tabulate morbidity and mortality data for future study.

A program of Synagraphic Computer Mapping, "Symap," developed by L. O. Degelman of the Department of Architectural Engineering, Pennsylvania State University, was used to visually demonstrate the penalty weighted variables of the Tulsa Neighborhood Environmental Evaluation System (NEEDS) Program for report presentation to City Officials and citizens groups. The neighborhoods of Tulsa which have the greatest problems are easily ascertained by non-technically educated citizens by viewing the Total Penalty Index Symap (Appendix D-1). A study of maps showing carbon monoxide levels (Appendix B-1) and Housing Condition--Main Structure (Appendix D-2) and Premises Condition (Appendix D-3) reveals an inverse relationship of these factors, i.e., the lower the penalty score for housing conditions and premises conditions the higher the level of air pollution with the obvious exception of industrial neighborhoods. This fact leads to the belief that the better the housing condition and premises condition the higher air pollution caused primarily from vehicles was found to be greater in areas of higher socio-economic status due to a larger number of vehicles per family and more frequent use of vehicles for short trips. In addition to the symaps discussed above others were programmed to assist officials and citizen task force groups of the model cities area to determine the need and location of low rent apartment projects (Crowding of Structure and Crowding of Population, Appendix D-4 and D-5). General sanitation enforcement programs were established using the Symap on Auxiliary Structure Housing Condition (Appendix D-6) and priorities were assigned for street improvement with the Symap on Street Condition (Appendix D-7).

CHAPTER VI

SUMMARY AND CONCLUSIONS

This research was designed to investigate a method of calculating air pollution concentrations which would take into account a means of projecting vehicular traffic volumes. It was necessary to consider vehicular pollution because it has been known for some time (1967) that the gasoline-powered motor vehicle is the largest source of emissions of air contaminants, based on total tons of the percentages of all contaminants emitted in the City of Tulsa, Oklahoma.[72]

While the Box Model utilized the meteorological variables of mixing depth and mean wind speed, the very important variable of wind direction was not taken into account. Further research and development of this model is needed to incorporate a dispersion equation to determine and demonstrate wind direction effects on pollutants and the resultant relationships of neighborhood pollution levels. The difference between the air pollution levels estimated for the NEEDS Program and levels calculated by this research method can be seen in Table 5-6. It is readily observed in the table that Tulsa has far greater pollution than was indicated by the NEEDS Program. Many neighborhoods are affected by moderate pollution which was not estimated for the NEEDS Study. The neighborhood area affected by extreme pollution levels is expanded ten fold through the more accurate model calculations of pollution levels.

Efforts to correlate morbidity and mortality data with air pollution levels and NEEDS penalty factors was unsuccessful due to insufficient tabulations of the occurence of disease, causes of deaths and the complete lack of data on respiratory diseases and chronic conditions. It is recommended that a coordinated system be established to tabulate by resident address or census tract all mortality caused by emphysemia, lung cancer, chronic bronchitis and other diseases and chronic health conditions for future use.

The use of "Symap" has been demonstrated to be a feasible tool for simple illustration of NEEDS Program weighted factors. The symapping of the Tulsa NEEDS data has created interest by officials of the Bureau of Community Environmental Management in the development of a "Symap" program for analysis of future NEEDS Programs. Factor analysis of the data is presently being completed by the Bureau.

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APPENDICES

APPENDIX A

APPENDIX A-1

POINT SOURCES

Source No.	Name of Industry	Source No.	Name of Industry
1	McMichael Concrete	223	Empire Foundry Co.
2	McMichael Concrete	224	Empire Foundry Co.
3	McMichael Concrete	227	Flint Steel Corp.
4	Millcreek LBR. Supply	228	FO MAC, Inc.
5	Mid-Continent Conc.	229	Farm Corp.
6	Mid-Continent Conc.	230	F.W.I., Inc.
7	Mid-Continent Conc.	233	Jakes Foundry, Inc.
8	Memco Casting Co.	234	Kaiser Magnesium
9	Memco Casting Co.	235	Kaiser Magnesium
10	Oil Cap. Conc.	238	McDonnell Douglas
11	Patterson Steel	239	McDonnell Douglas
13	Progressive Brass	245	Con. Rad. Div., US Ind.
14	Progressive Brass		
15	Poly Version, Inc.	264	Nipak, Inc.
16	R. D. Patterson Foundry	270	American Castings
18	Sentinal Mfg. Co.	271	Sentinel Mfg. Co.
19	Standard Ind., Inc.	272	Service Paint Mfg.
20	Standard Ind., Inc.		
21	Standard Ind., Inc.		
25	Tulsa Bronze Work, Inc.		
26	Tulsa Bronze Work, Inc.		
27	Tulsa Concrete Co.		
28	Tulsa Iron Work		
29	Tulsa Iron Work		
31	Tulsa Tallow Feed Co.		
32	Unit Rig Equipment Co.		
33	Vickers Spery RND		
34	YUBA Heat Transfer		
117	Abbott Heat Exchange		
118	Acme Brick Co.		
119	Aluminum Hardcoat		
134	Standard Inc., Inc.		
135	Standard Inc., Inc.		
158	Texaco Refinery		
211	American Airlines		
214	AVCO Corp.		
216	Byron Jackson Pump		
218	Concrete Ind. of Tulsa		
219	Creamer Dunlap		
220	Custom Chrome Plating		
221	Douglas Aircraft		
222	Dowel Div. DDW Chem.		

APPENDIX A-2

PROCESS TYPE OF INDUSTRIES AND THEIR CHARACTERISTICS CITY OF TULSA, OKLAHOMA--1972

Neighbor-hood No.	Source No.	Stack Parameter Height Feet	Diameter Feet	Temp. F°	Velocity Feet/Sec.	Maximum Process Weight Rate Pounds/Hr.	Normal Process Weight Rate Pounds/Hr.	Shift Per Day
1	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--
7	27	0	0	0	0	260,000.0	76,923.0	1.07
8	234	0	0	0	0	4,326.0	4,326.0	0.71
9	218	0	0	0	0	53,846.0	53,846.0	1.07
10	--	--	--	--	--	--	--	--
11	--	--	--	--	--	--	--	--
12	--	--	--	--	--	--	--	--
13	--	--	--	--	--	--	--	--
14	--	--	--	--	--	--	--	--
15	16	0	0	0	0	173.0	173.0	0.71
16	--	--	--	--	--	--	--	--
17	--	--	--	--	--	--	--	--
18	--	--	--	--	--	--	--	--
19	--	--	--	--	--	--	--	--
20	25	0	0	0	0	104.0	104.0	0.71
21	272	0	0	0	0	1,572.0	1,572.0	0.78
	28	0	0	0	0	692.0	692.0	0.71
22	--	--	--	--	--	--	--	--
23	--	--	--	--	--	--	--	--
24	--	--	--	--	--	--	--	--
25	--	--	--	--	--	--	--	--

APPENDIX A-2 --Continued

Neighbor-hood No.	Source No.	Stack Parameter: Height Feet	Diameter Feet	Temp. °F	Velocity Feet/Sec.	Maximum Process Weight Rate Pounds/Hr.	Normal Process Weight Rate Pounds/Hr.	Shift Per Day
26	--	--	--	--	--	--	--	--
27	--	--	--	--	--	--	--	--
28	--	--	--	--	--	--	--	--
29	--	--	--	--	--	--	--	--
30	--	--	--	--	--	--	--	--
31	--	--	--	--	--	--	--	--
32	--	--	--	--	--	--	--	--
33	--	--	--	--	--	--	--	--
34	223	0	0	0	0	227.0	227.0	0.71
35	--	--	--	--	--	--	--	--
36	--	--	--	--	--	--	--	--
37	1	0	0	0	0	600,000.0	230,769.0	1.28
	2	0	0	0	0	900,000.0	461,538.0	1.07
	264	0	0	0	0	16,438.0	16,438.0	3.00
38	158	0	0	0	0	196,882.0	196,882.0	3.00
	18	0	0	0	0	750.0	750.0	0.71
39	--	--	--	--	--	--	--	--
40	--	--	--	--	--	--	--	--
41	--	--	--	--	--	--	--	--
42	13	0	0	0	0	397.0	397.0	0.71
43	--	--	--	--	--	--	--	--
44	--	--	--	--	--	--	--	--
45	--	--	--	--	--	--	--	--
46	--	--	--	--	--	--	--	--
47	--	--	--	--	--	--	--	--
48	--	--	--	--	--	--	--	--
49	--	--	--	--	--	--	--	--
50	6	0	0	0	0	480,000.0	80,000.0	1.07
51	--	--	--	--	--	--	--	--

APPENDIX A-2 --Continued

Neighbor-hood	Source No.	Stack Parameter Height Feet	Diameter Feet	Temp. F°	Velocity Feet/Sec.	Maximum Process Weight Rate Pounds/Hr.	Normal Process Weight Rate Pounds/Hr.	Shift Per Day
52	--	--	--	--	--	--	--	--
53	--	--	--	--	--	--	--	--
54	8	0	0	0	0	4,375.0	1,875.0	0.71
55	--	--	--	--	--	--	--	--
56	--	--	--	--	--	--	--	--
57	--	--	--	--	--	--	--	--
58	--	--	--	--	--	--	--	--
59	--	--	--	--	--	--	--	--
60	--	--	--	--	--	--	--	--
61	--	--	--	--	--	--	--	--
62	270	0	0	0	0	58.0	58.0	0.71
	15	0	0	0	0	685.0	685.0	3.00
63	--	--	--	--	--	--	--	--
64	5	0	0	0	0	160,000.0	66,800.0	1.07
	10	0	0	0	0	200,000.0	36,364.0	0.98
	134	0	0	0	0	0.0	0.0	0.29
	19	0	0	0	0	1,395,385.0	1,395,385.0	0.53
	20	0	0	0	0	307,692.0	307,692.0	0.53
65	--	--	--	--	--	--	--	--

APPENDIX A-3

BOILER TYPE OF INDUSTRIES AND THEIR CHARACTERISTICS
CITY OF TULSA, OKLAHOMA--1972

Neighbor-hood No.	Source No.	Boiler Capacity MMBTU/HR.	Coal Ton/YR.	Dist. Oil MGAL/Yr.	Natural Gas MMCF/YR.	Heat Content			Sulfur Content			% Ash Coal
						Coal MMB/T	Dist Oil MB/GA	Natural Gas BTU/CF	Coal	Dist. Oil	Natural Gas	
1	--	--	--	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--	--	--	--	--
6	216	15.0	0.0	0.0	29.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
7	--	--	--	--	--	--	--	--	--	--	--	--
8	229	1.0	0.0	5.0	1.0	0.0	140.0	1050.0	0.0	0.0	0.0	0.0
	235	21.0	0.0	0.0	41.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
9	--	--	--	--	--	--	--	--	--	--	--	--
10	--	--	--	--	--	--	--	--	--	--	--	--
11	--	--	--	--	--	--	--	--	--	--	--	--
12	4	0.0	0.0	0.0	1.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
13	--	--	--	--	--	--	--	--	--	--	--	--
14	--	--	--	--	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--	--	--
16	--	--	--	--	--	--	--	--	--	--	--	--
17	--	--	--	--	--	--	--	--	--	--	--	--
18	--	--	--	--	--	--	--	--	--	--	--	--
19	--	--	--	--	--	--	--	--	--	--	--	--
20	26	3.0	0.0	0.0	6.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
21	29	3.0	240.0	0.0	0.0	26.0	0.0	0.0	0.0	0.0	0.0	25.0
22	--	--	--	--	--	--	--	--	--	--	--	--
23	117	5.0	0.0	0.0	24.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
	245	3.0	0.0	0.0	12.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
24	34	6.0	0.0	0.0	37.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0

APPENDIX A-3 --Continued

Neighbor-hood No.	Source No.	Boiler Capacity MMBTU/HR.	Coal Ton/YR.	Dist. Oil MGAL/YR.	Natural Gas MMCF/YR.	Heat Content Coal MMB/T	Heat Content Dist. Oil MB/GA	Heat Content Natural Gas BTU/CF	Sulfur Content Coal	Sulfur Content Dist. Oil	Sulfur Content Natural Gas	% Ash Coal
25	33	4543.0	0.0	0.0	9000.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
26	118	132.0	0.0	84.0	218.0	0.0	140.0	1050.0	0.0	2.0	0.0	0.0
	31	4.0	0.0	0.0	20.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
27	--	--	--	--	--	--	--	--	--	--	--	--
28	--	--	--	--	--	--	--	--	--	--	--	--
29	238	84.0	0.0	0.0	360.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
	239	84.0	0.0	0.0	360.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
	211	65.0	0.0	0.0	540.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
	211	185.0	0.0	97.0	720.0	0.0	140.0	1050.0	0.0	2.0	0.0	0.0
30	--	--	--	--	--	--	--	--	--	--	--	--
31	--	--	--	--	--	--	--	--	--	--	--	--
32	--	--	--	--	--	--	--	--	--	--	--	--
33	--	--	--	--	--	--	--	--	--	--	--	--
34	224	19.0	1500.0	0.0	0.0	26.0	0.0	0.0	0.0	0.0	0.0	0.0
	230	3.0	0.0	0.0	24.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
	233	6.0	0.0	0.0	12.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
35	--	--	--	--	--	--	--	--	--	--	--	--
36	--	--	--	--	--	--	--	--	--	--	--	--
37	219	15.0	0.0	0.0	59.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
	227	2.0	0.0	0.0	4.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
	3	48.0	0.0	0.0	144.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
38	271	9.0	0.0	0.0	17.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
39	32	21.0	0.0	0.0	82.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
40	--	--	--	--	--	--	--	--	--	--	--	--
41	--	--	--	--	--	--	--	--	--	--	--	--
42	14	100.0	0.0	0.0	198.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
43	--	--	--	--	--	--	--	--	--	--	--	--
44	--	--	--	--	--	--	--	--	--	--	--	--
45	--	--	--	--	--	--	--	--	--	--	--	--
46	--	--	--	--	--	--	--	--	--	--	--	--

APPENDIX A-3 --Continued

Neighbor-hood No.	Source No.	Boiler Capacity MMBTU/HR.	Coal Ton/YR.	Dist. Oil MGAL/Yr.	Natural Gas MMCF/YR.	Heat Content: Coal MMB/T	Heat Content: Dist. Oil MB/GA	Heat Content: Natural Gas BTU/CF	Sulfur Content: Coal	Sulfur Content: Dist. Oil	Sulfur Content: Natural Gas	% Ash Coal
47	228	32.0	0.0	0.0	192.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
48	--	--	--	--	--	--	--	--	--	--	--	--
49	--	--	--	--	--	--	--	--	--	--	--	--
50	7	0.0	0.0	3.0	0.0	0.0	140.0	0.0	0.0	2.0	0.0	0.0
51	--	--	--	--	--	--	--	--	--	--	--	--
52	--	--	--	--	--	--	--	--	--	--	--	--
53	--	--	--	--	--	--	--	--	--	--	--	--
54	9	12.0	600.0	0.0	8.0	26.0	0.0	1050.0	0.0	0.0	0.0	25.0
55	--	--	--	--	--	--	--	--	--	--	--	--
56	--	--	--	--	--	--	--	--	--	--	--	--
57	--	--	--	--	--	--	--	--	--	--	--	--
58	220	5.0	0.0	0.0	10.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
	222	19.0	0.0	10.0	36.0	0.0	140.0	1050.0	0.0	2.0	0.0	0.0
59	119	3.0	0.0	0.0	10.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
	11	16.0	0.0	0.0	32.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
60	--	--	--	--	--	--	--	--	--	--	--	--
61	--	--	--	--	--	--	--	--	--	--	--	--
62	--	--	--	--	--	--	--	--	--	--	--	--
63	--	--	--	--	--	--	--	--	--	--	--	--
64	214	5.0	0.0	0.0	11.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
	21	107.0	0.0	603.0	78.0	0.0	140.0	1050.0	0.0	2.0	0.0	0.0
	135	26.0	0.0	0.0	45.0	0.0	0.0	1050.0	0.0	0.0	0.0	0.0
65	--	--	--	--	--	--	--	--	--	--	--	--

APPENDIX A-4

INCINERATORS LOCATED IN THE CITY
OF TULSA--JANUARY 1, 1972

Neighborhood No.	Name and Address	Rated Cap. lb/hr	# of Hrs. Operated	Est. Amount lb/day
1	Oral Roberts Association 7777 South Lewis Avenue	450	2	300
2	Row Lee Red Bud 4404 South Peoria Avenue	250	3	50
3	Sams Trif-T-Wise 4933 South Peoria Avenue	300	2	100
	Humpty Dumpty 5155 South Peoria Avenue	500	2	100
4	Howards Discount Center 5130 South Harvard Avenue	500	6	300
	Pan American Research Center 4502 East 41 Street	750	6	600
	Humpty Dumpty 4004 South Yale Avenue	500	2	500
	Humpty Dumpty 330 East 51 Street	400	2	1,000
	Katz Drugs 3328 East 51 Street	475	12	800
5	McDonald's Hamburgers 4301 South Yale Avenue	150	4	450
	Sheridan Red Bud 5046 South Sheridan Road	500	2	150
	Woolco Department Store 4903 East 41 Street	1,000	16	4,000
6	Royal Thrif-T-Wise 4830 South Memorial Drive	350	2	100
	Safeway Stores, Inc. 4477 South 70 East Avenue	350	3	100
	Bryan Manufacturing 9120 East 43 Street	150	1	100
7	Cousins Furniture 4417 South Mingo Road	150	2	50

Neighbor-hood No.	Name and Address	Rated Cap. lb/hr	# of Hrs. Op-erated	Est. Amount lb/day
8	Oertle's, Inc. 2625 South Memorial Drive	1,100	12	2,600
9	Humpty Dumpty 1926 South Garnett Road	500	5	450
	A. & C. Thrif-T-Wise 10122 East 11 Street	500	4	?
	Rolling Hills Red Bud 19296 East Admiral Place	300	4	200
10	--	--	--	--
11	Gulf Mart, Inc. 2029 South Sheridan Road	500	4	400
	Colonial Market 7004 East Admiral Place	500	3	30
12	Howards Discount Center 1750 South Sheridan Road	500	6	300
	Shoppers Fair at Tulsa 2150 South Sheridan Road	500	4	200
	Doctors Hospital 2323 South Harvard Avenue	25	2	50
13	--	--	--	--
14	Humpty Dumpty 1740 Utica Square	500	4	250
	Wolferman Fred, Inc. 1964 Utica Square	--	--	--
15	Glencliff Dairy 519 East 7th Street	750	3	200
16	--	--	--	--
17	--	--	--	--
18	C & R Cousins Furniture 5308 East Admiral Place	250	1	50
19	Tulsa University Oliphant Hall 600 South College Avenue	100	3	50
	Bama Pie Company 2745 East 11 Street	450	3	400

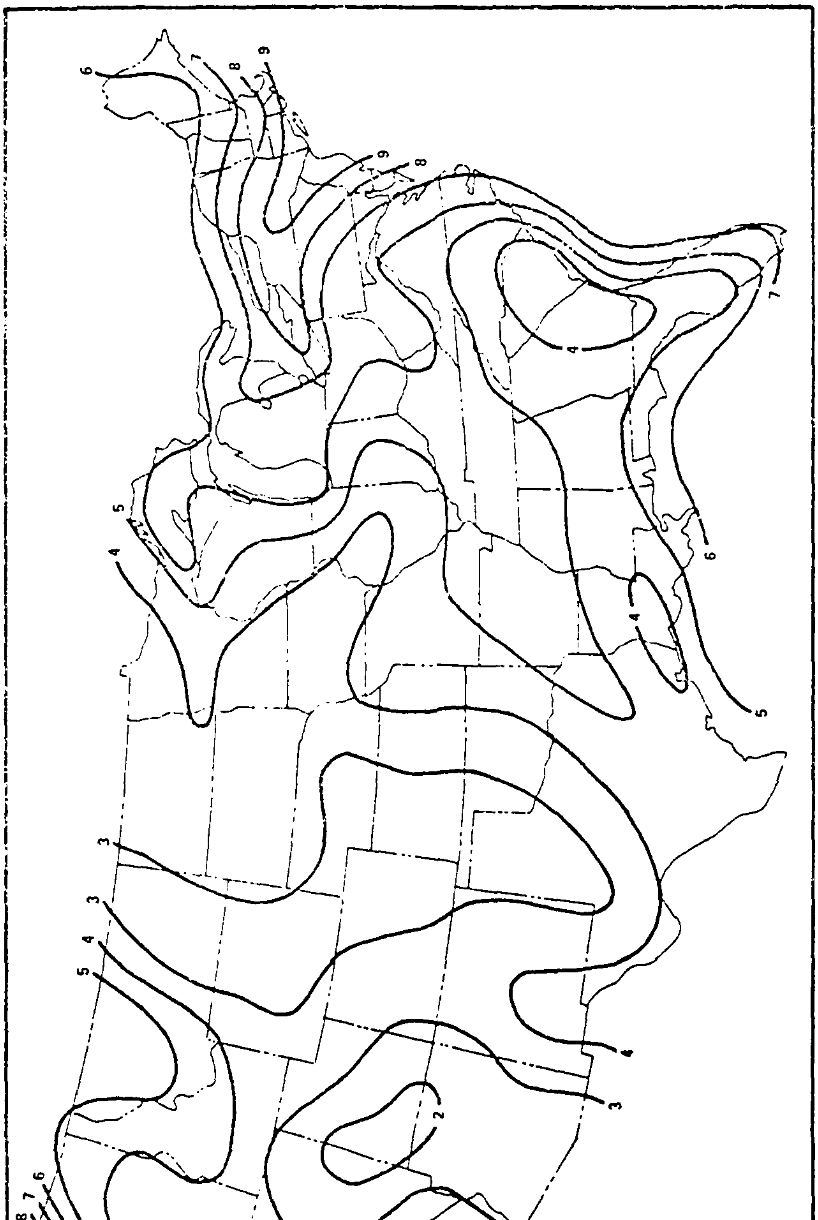
APPENDIX A-4 --Continued

Neighbor-hood No.	Name and Address	Rated Cap. lb/hr	# of Hrs. Op-erated	Est. Amount lb/day
20	--	--	--	--
21	Allied Bearing Supply 416 South Utica Avenue	150	4	30
22	--	--	--	--
23	--	--	--	--
24	--	--	--	--
25	Belscot Department Store 6921 East Admiral Place	400	4	700
26	--	--	--	--
27	--	--	--	--
28	--	--	--	--
29	--	--	--	--
30	Mini-Max 4601 North Peoria Avenue	400	3	700
31	Warehouse Market 1125 East 36 Street North	450	3	700
32	--	--	--	--
33	Safeway 472 Charles Page Blvd.	350	3	100
34	--	--	--	--
35	--	--	--	--
36	--	--	--	--
37	--	--	--	--
38	--	--	--	--
39	--	--	--	--
40	--	--	--	--
41	--	--	--	--
42	--	--	--	--
43	--	--	--	--
44	--	--	--	--
45	--	--	--	--
46	--	--	--	--

Neighborhood No.	Name and Address	Rated Cap. lb/hr	# of Hrs. Operated	Est. Amount lb/day
47	--	--	--	--
48	--	--	--	--
49	--	--	--	--
50	--	--	--	--
51	--	--	--	--
52	--	--	--	--
53	--	--	--	--
54	Charles Johnson School 507 East Easton Street	--	--	--
55	--	--	--	--
56	--	--	--	--
57	--	--	--	--
58	--	--	--	--
59	--	--	--	--
60	--	--	--	--
61	--	--	--	--
62	--	--	--	--
63	University Village Rest Home 8555 South Lewis Avenue	600	2	400
64	--	--	--	--
65	--	--	--	--

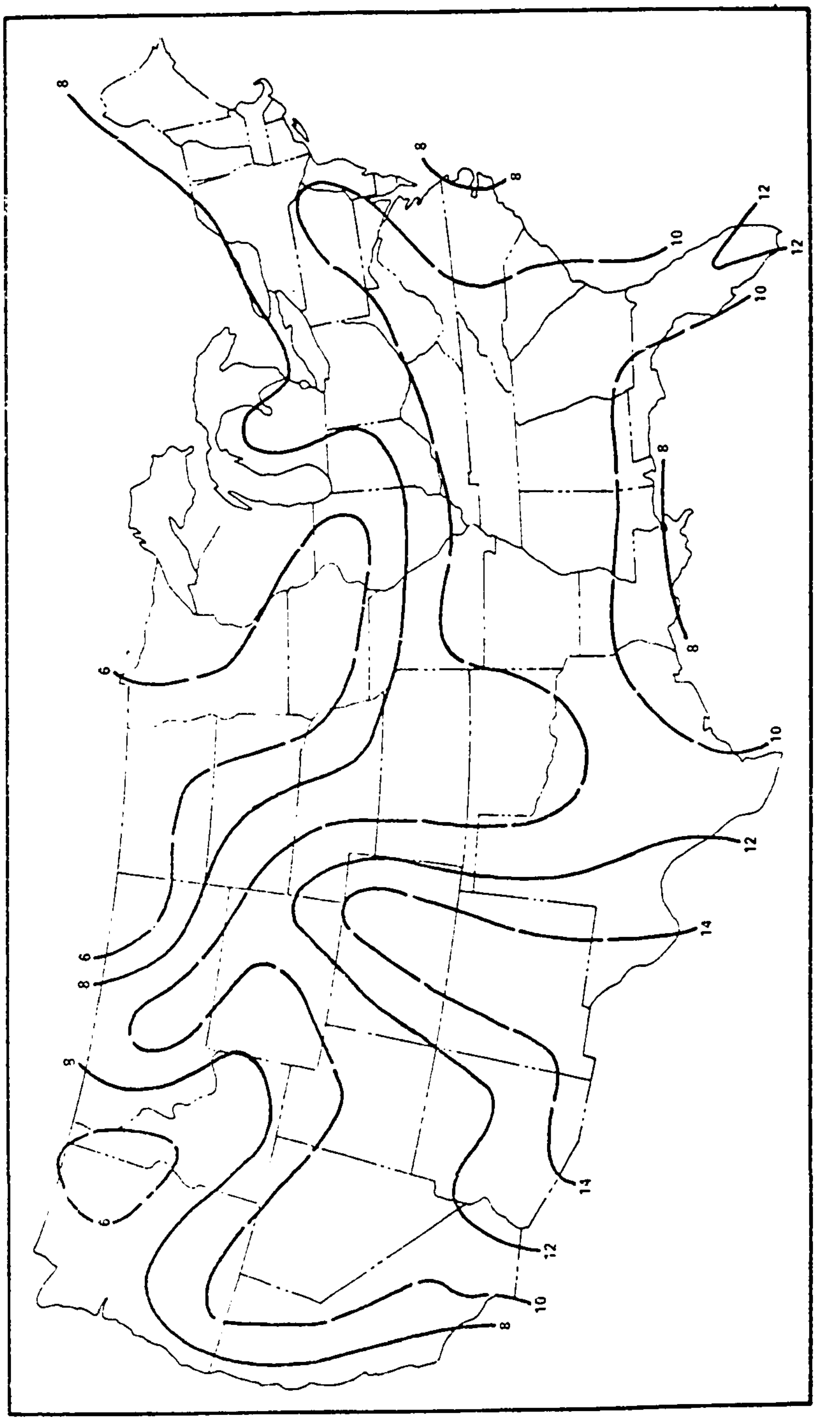
APPENDIX A-5

ISOPLETHS (M x 10^2) OF MEAN WINTER MORNING MIXING HEIGHTS FOR THE UNITED STATES



APPENDIX A-6

ISOPLETHS (M x 10^2) OF MEAN WINTER AFTERNOON MIXING HEIGHTS FOR THE UNITED STATES



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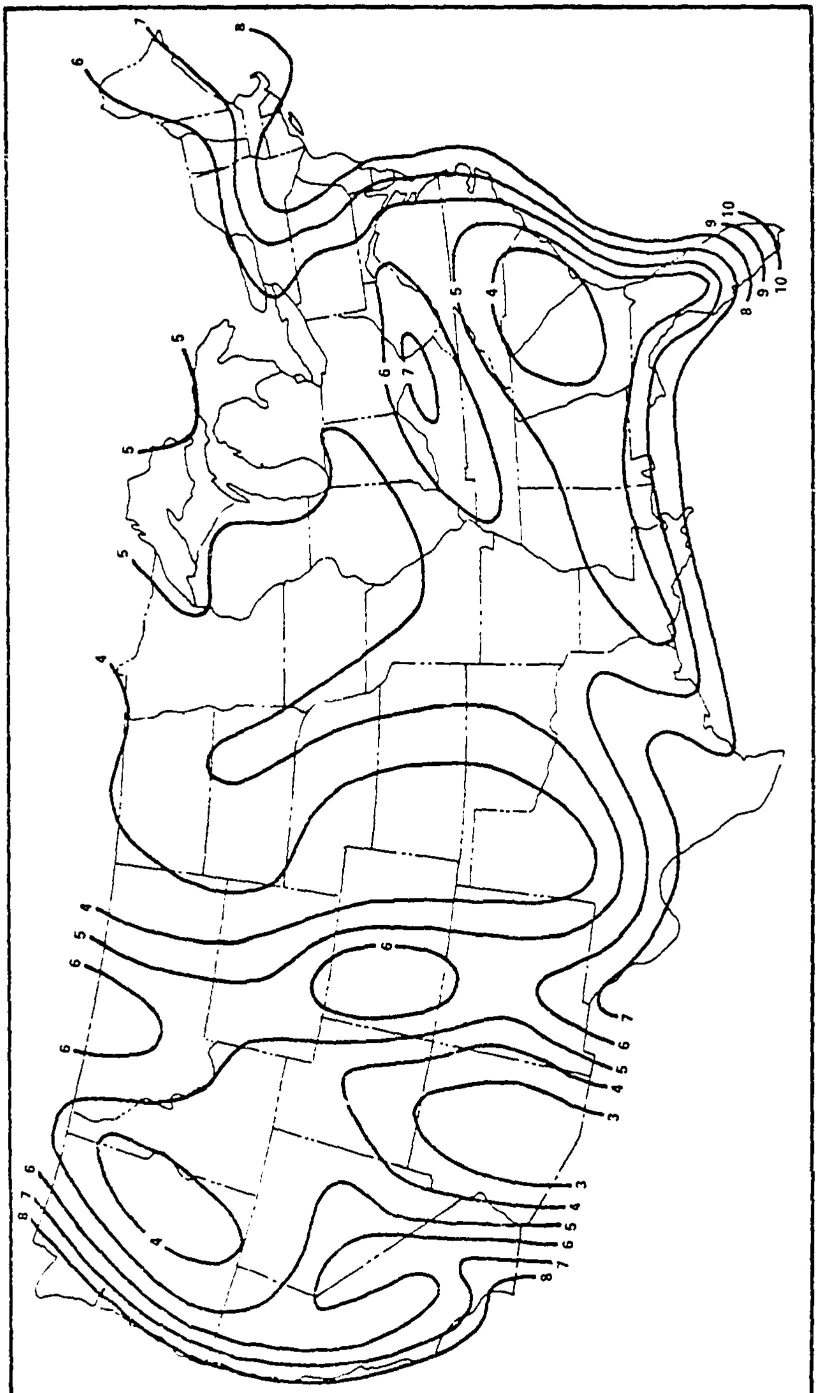
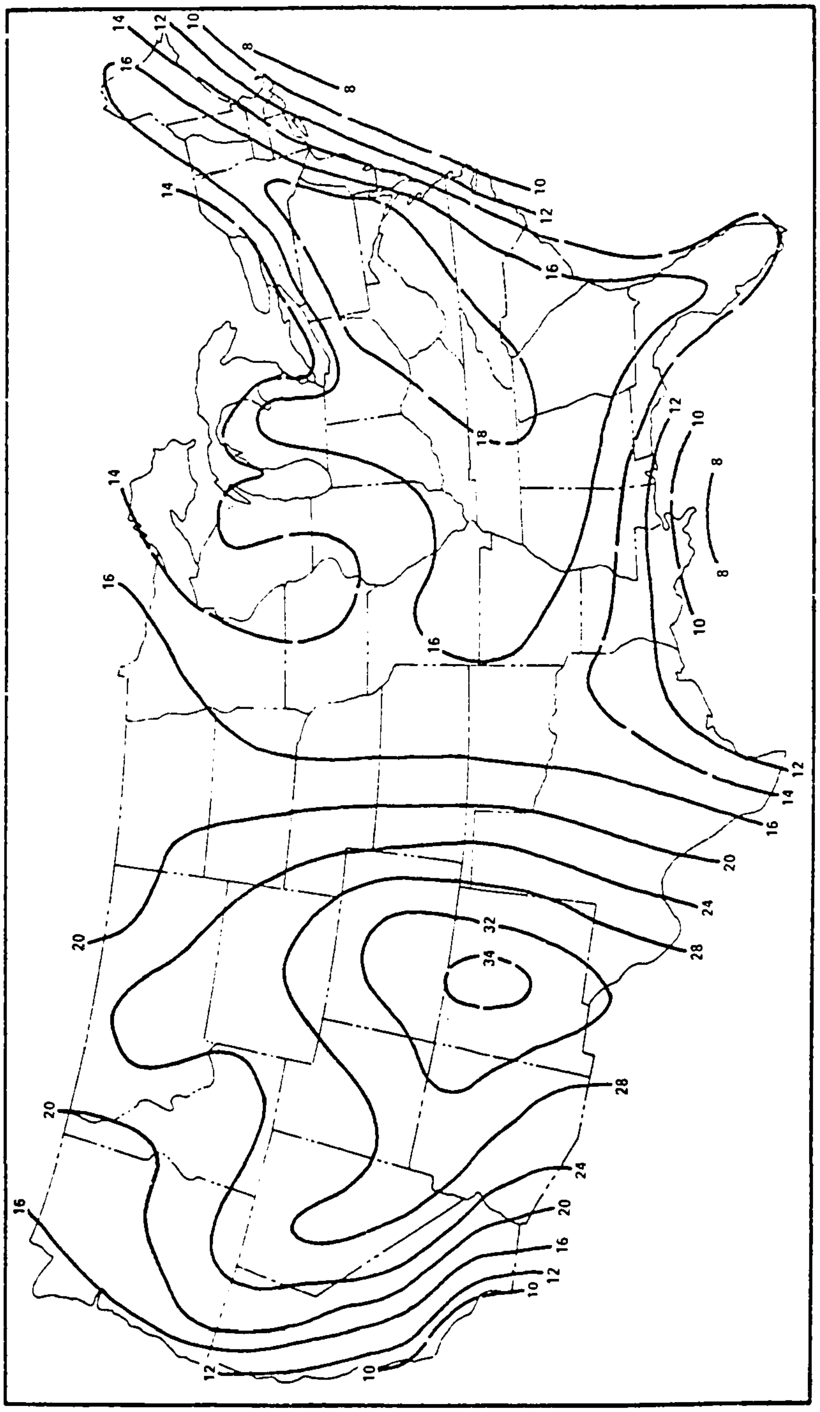
APPENDIX A-7

ISOPLETHS (M x 10^2) OF MEAN SPRING MORNING MIXING HEIGHTS FOR THE UNITED STATES



APPENDIX A-8

ISOPLETHS (M x 10^2) OF MEAN SPRING AFTERNOON
MIXING HEIGHTS FOR THE UNITED STATES



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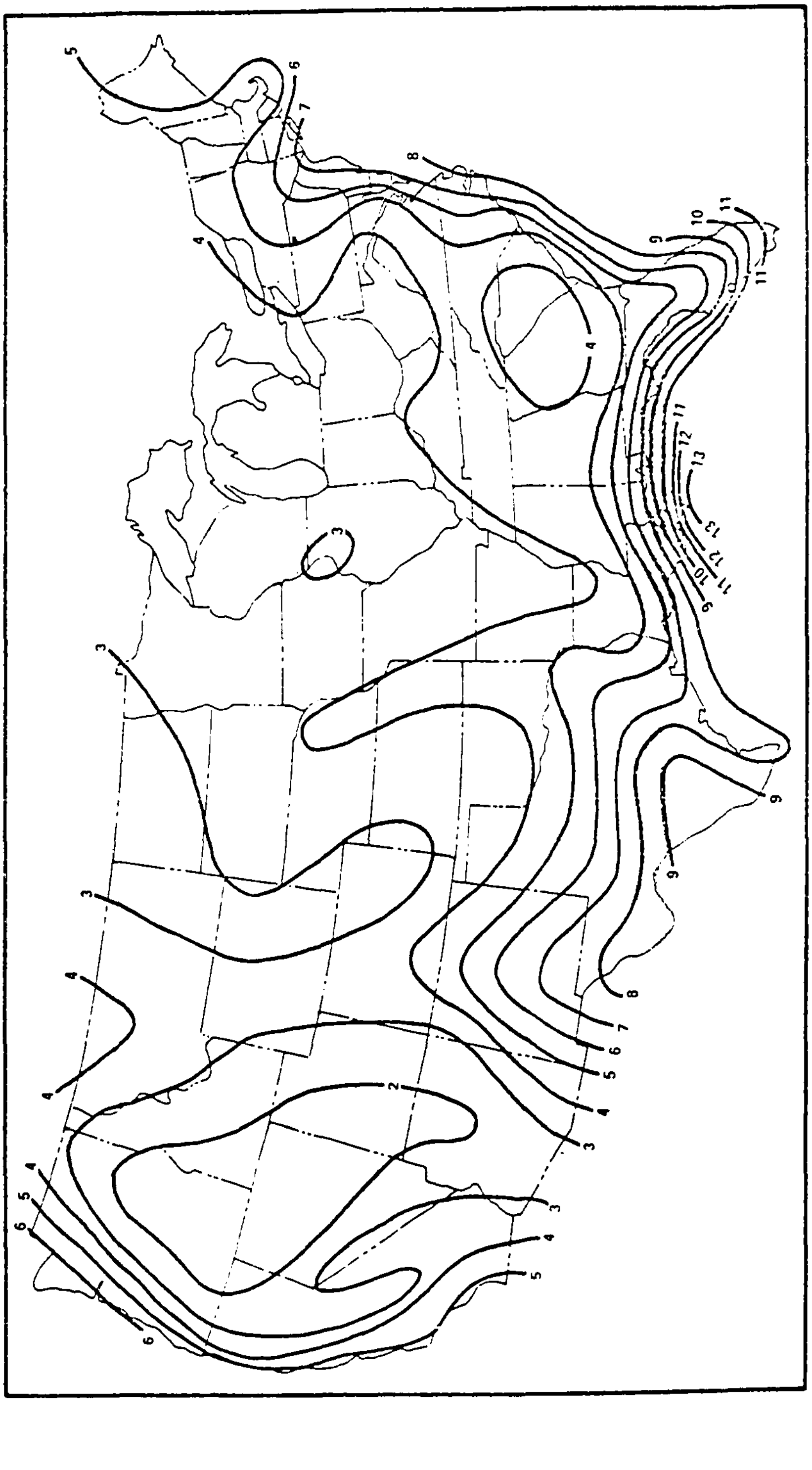
APPENDIX A-9

ISOPLETHS (M x 10^2) OF MEAN SUMMER MORNING MIXING HEIGHTS FOR THE UNITED STATES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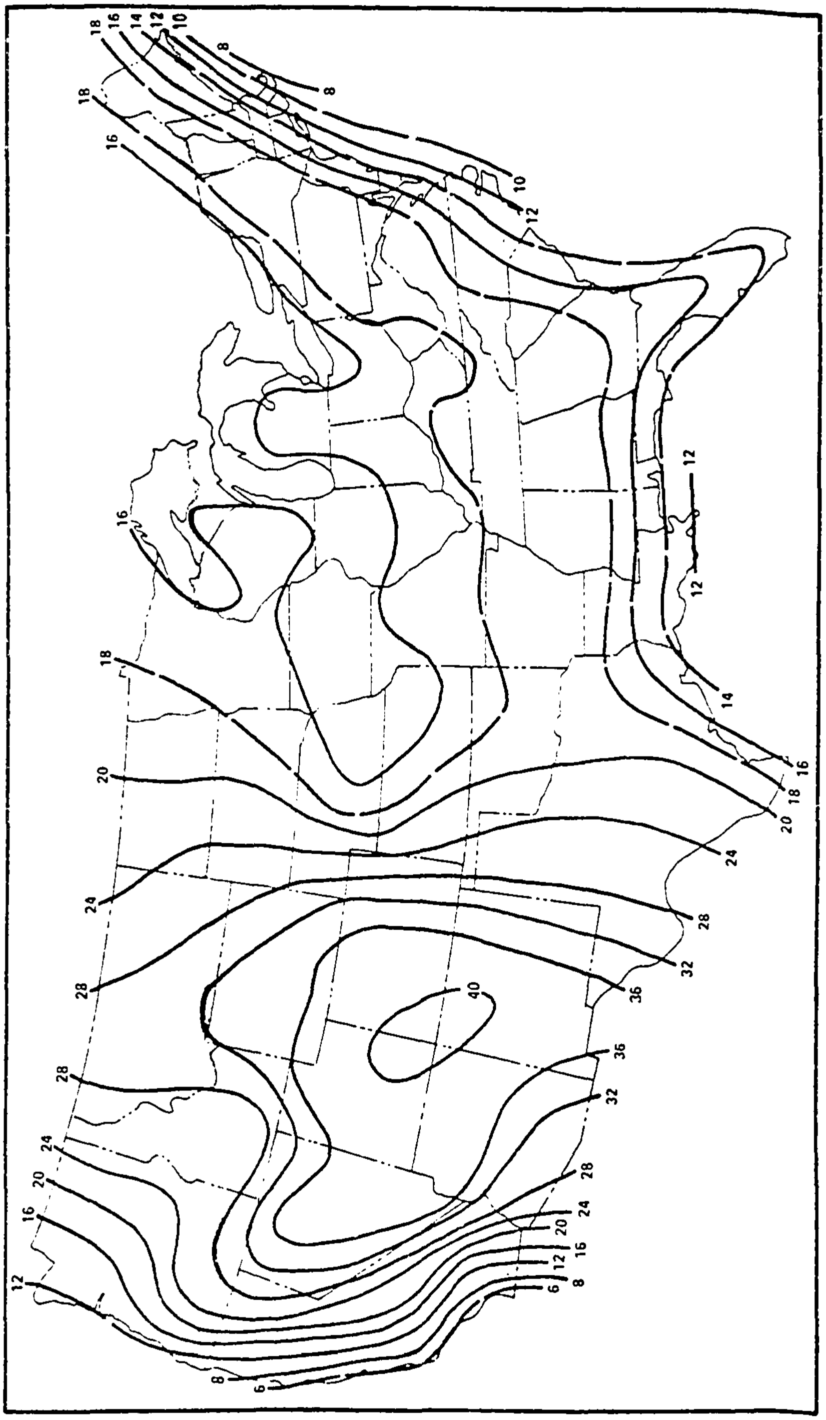
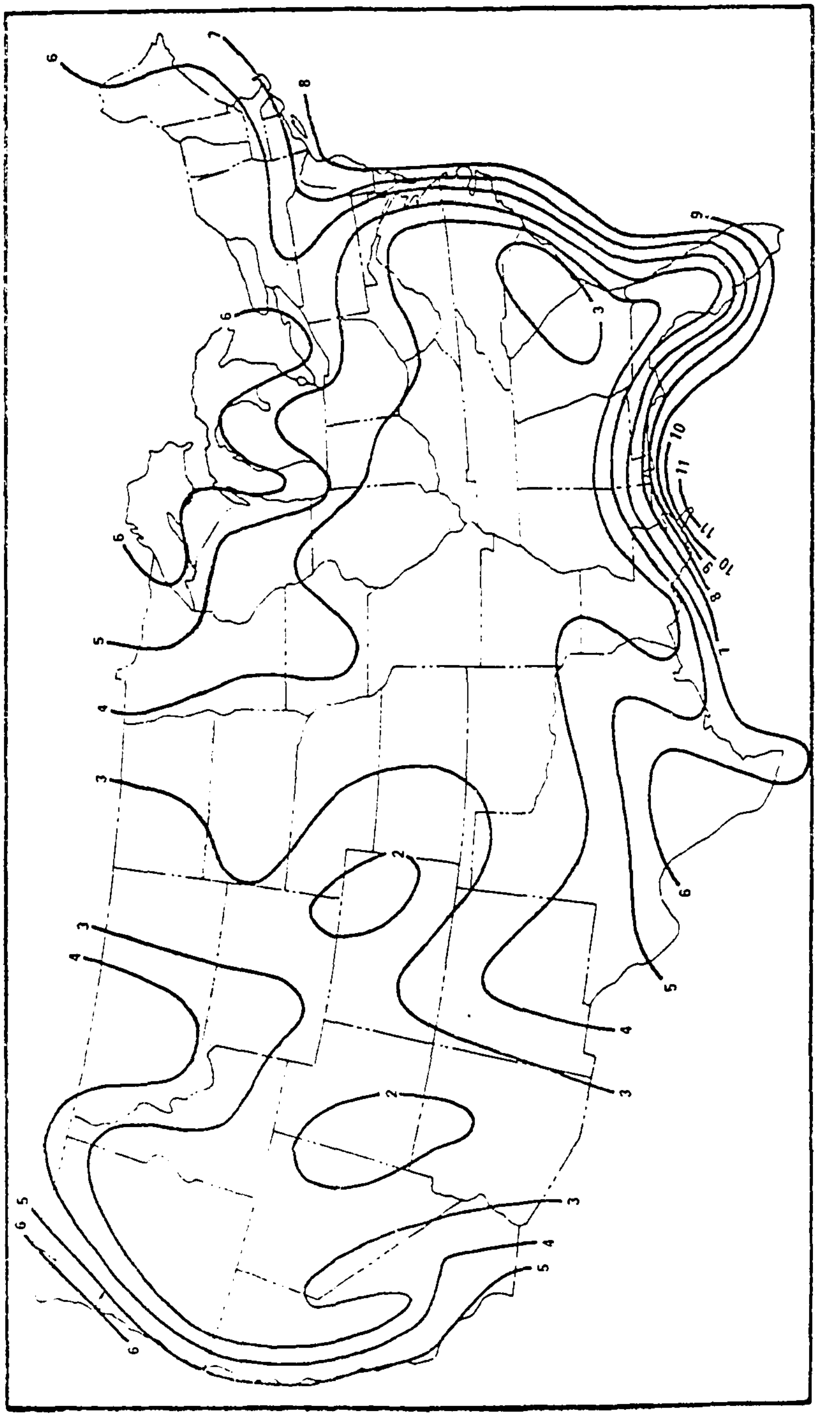
APPENDIX A-10

ISOPLETHS (M x 10^2) OF MEAN SUMMER AFTERNOON MIXING HEIGHTS FOR THE UNITED STATES



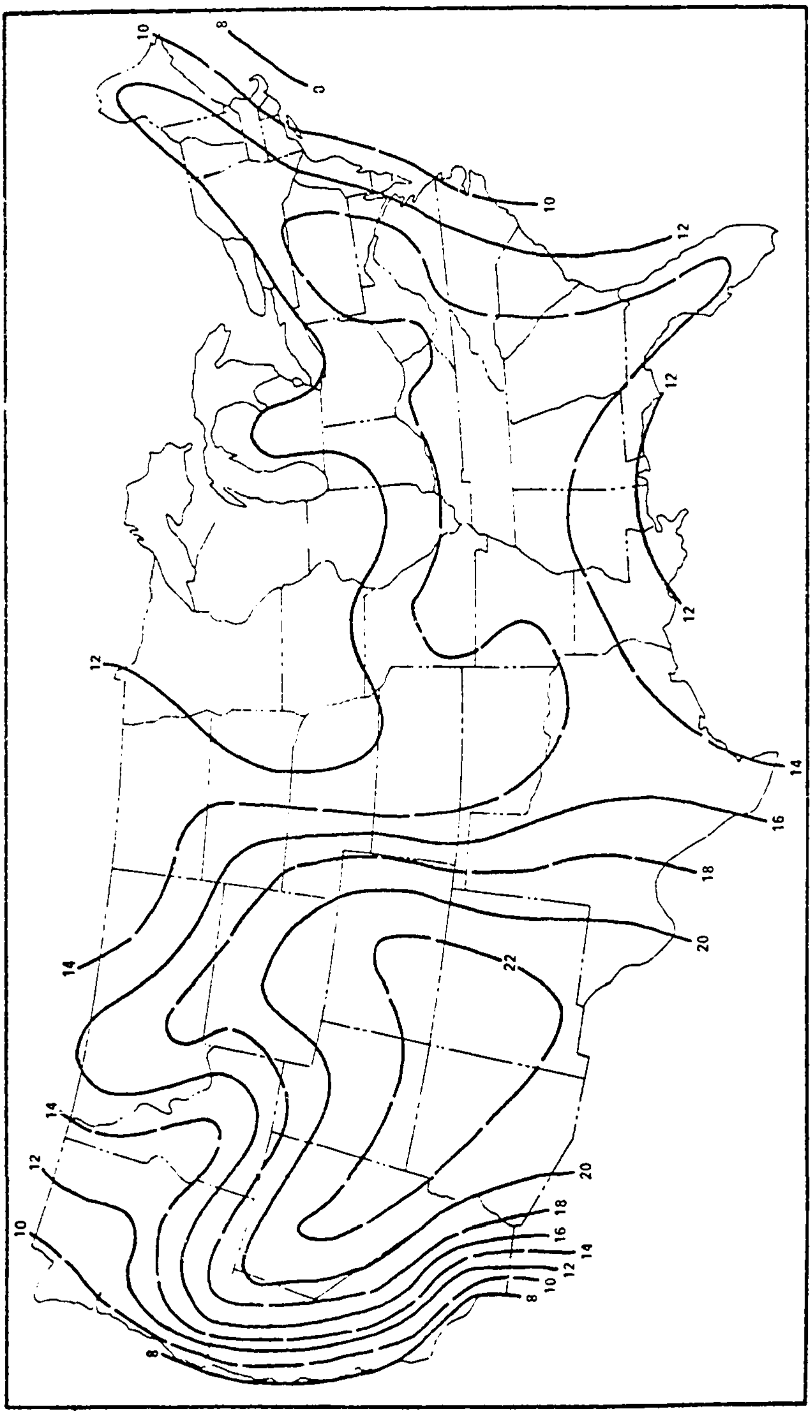
APPENDIX A-11

ISOPLETHS (M x 10^2) OF MEAN FALL MORNING MIXING HEIGHTS FOR THE UNITED STATES



APPENDIX A-12

ISOPLETHS (M x 10^2) OF MEAN FALL AFTERNOON MIXING HEIGHTS FOR THE UNITED STATES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APPENDIX B

APPENDIX B-1

NEEDS NEIGHBORHOODS CARBON MONOXIDE TONS/DAY/SQ. MI.

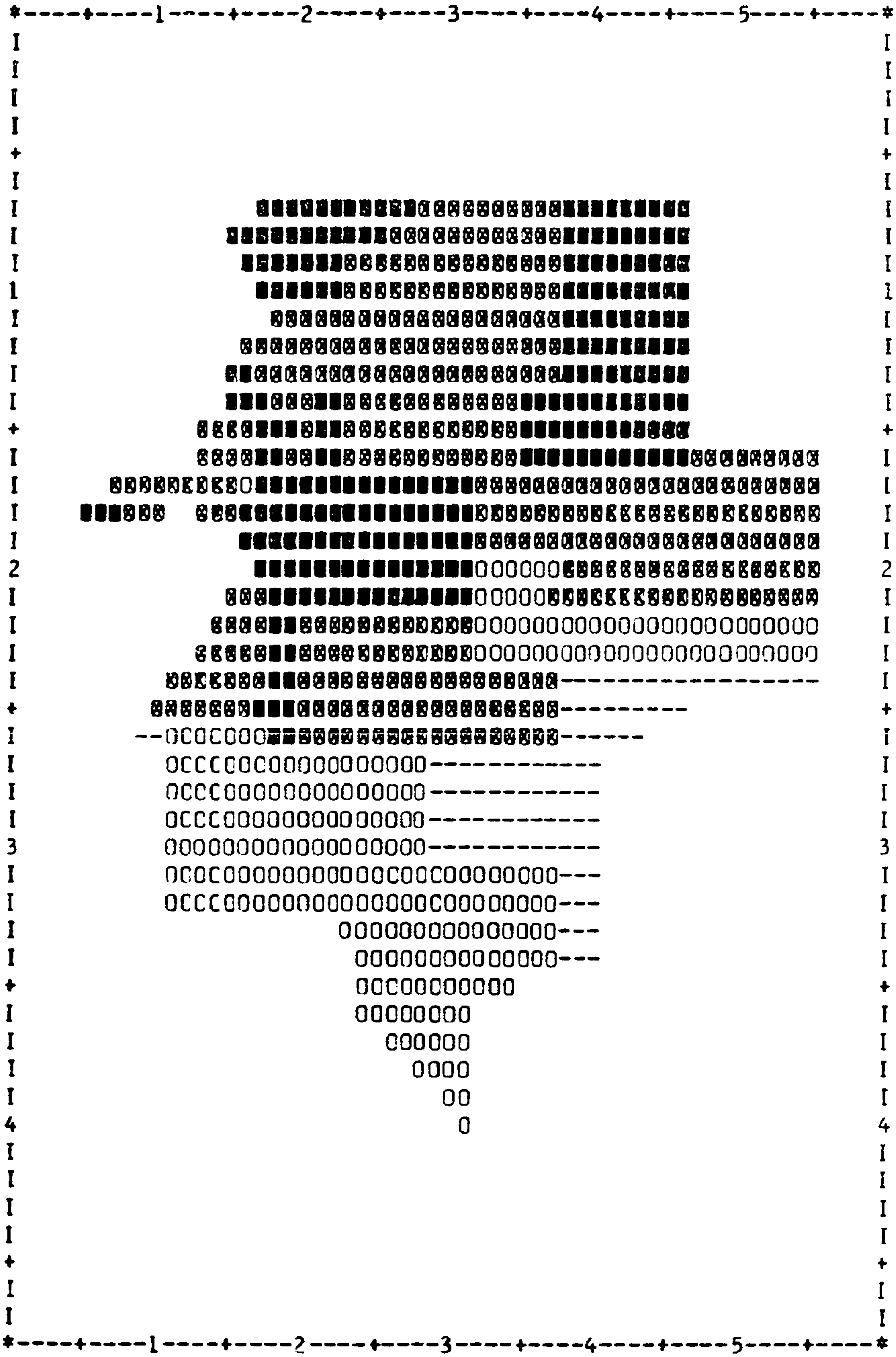
Data value extremes are: 0.00 45.80

Absolute value range applying to each level ('maximum' included in highest level only):

Level	1	2	3	4
Minimum	0.00	0.50	1.00	4.00
Maximum	0.50	1.00	4.00	45.00

Frequency distribution of data point values in each level:

```
Level         1          2          3          4
          ========================================
           --------- OOOOOOOOO █████████ █████████
           --------- OOOOOOOOO █████████ █████████
Symbols    ---- ---- OOOO OOOO ████ ████ ████ ████
           --------- OOOOOOOOO █████████ █████████
           --------- OOOOOOOOO █████████ █████████
          ========================================
Freq.         6          6         31         22
```



SYMAP

APPENDIX B-2

NEEDS NEIGHBORHOODS HYDROCARBONS TONS/DAY/SQ. MI.

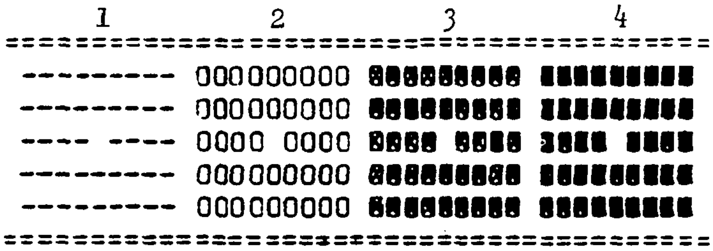
Data value extremes are: 0.04 5.50

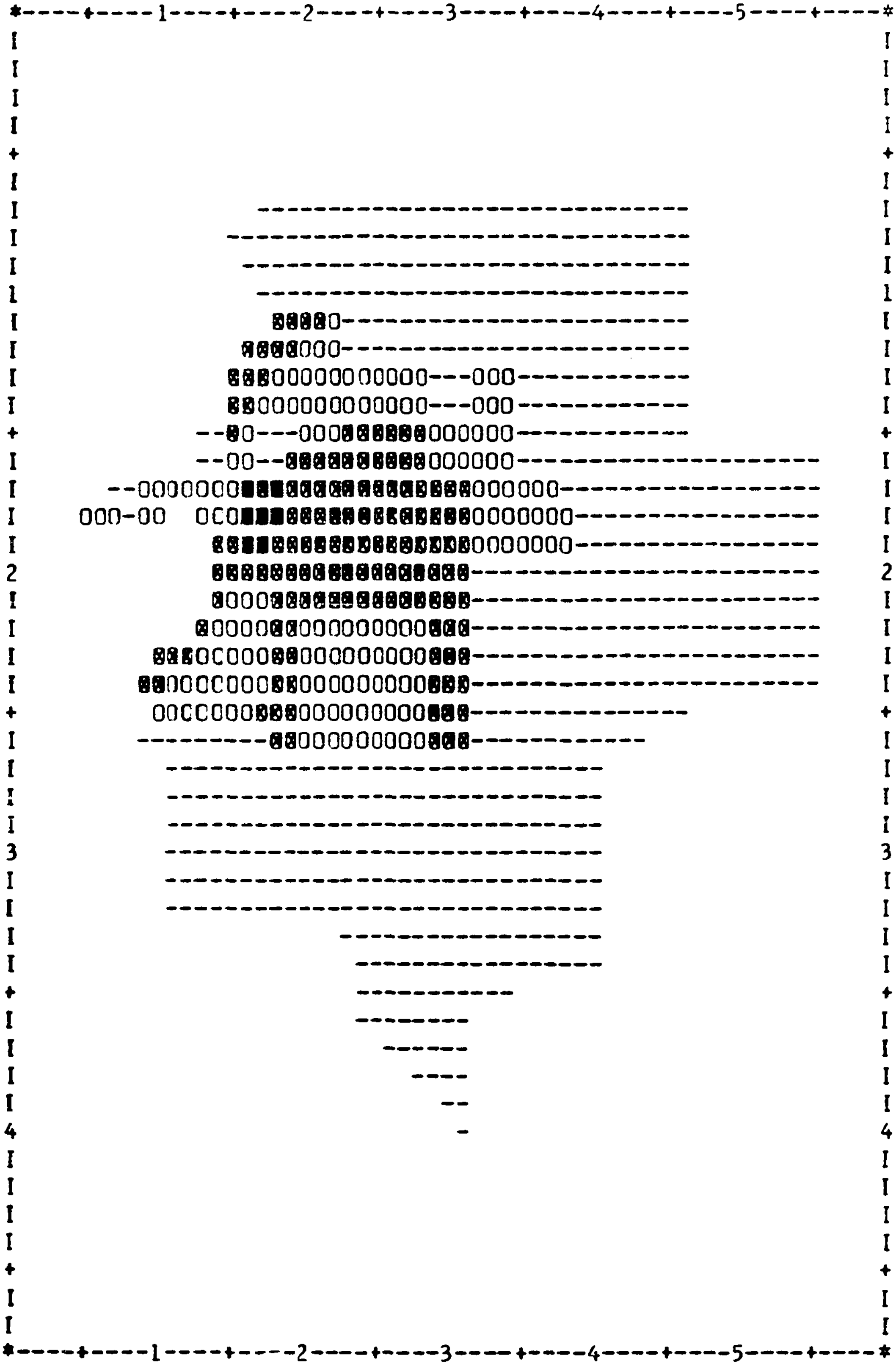
Absolute value range applying to each level ('maximum' included in highest level only):

Level	1	2	3	4
Minimum	0.00	0.50	1.00	4.00
Maximum	0.50	1.00	4.00	5.50

Frequency distribution of data point values in each level:

Level	1	2	3	4
Symbols				
Freq.	21	19	23	2





SYMAP

APPENDIX B-3

NEEDS NEIGHBORHOODS NITROGEN OXIDES TONS/DAY/SQ. MI.

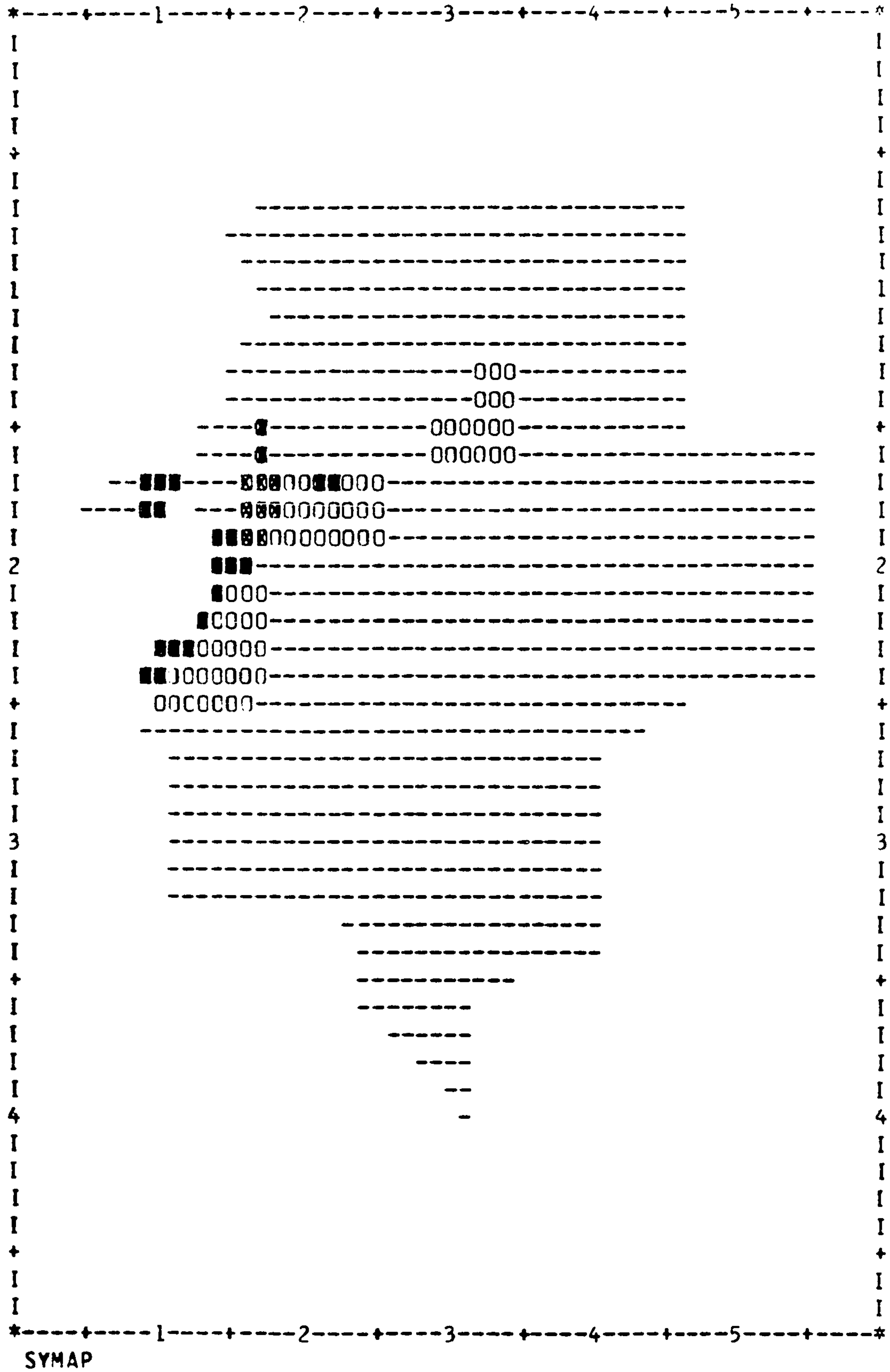
Data value extremes are: 0.01 18.90

Absolute value range applying to each level ('maximum' included in highest level only):

Level	1	2	3	4
Minimum	0.00	0.50	1.00	4.00
Maximum	0.50	1.00	4.00	18.90

Frequency distribution of data point values in each level:

Level	1	2	3	4
Symbols	---------	OOOOOOOOO	▮▮▮▮▮▮▮▮▮	█████████
Freq.	52	7	2	4


1
2
3
4
5
SYMAP

APPENDIX B-4

E-VALUES USED IN DEVELOPMENT OF SYMAPS

Neighborhood Number	CO Tons/Day/ Square Mile	Hydrocarbons Tons/Day/Sq. Mi.	NO_2 Tons/Day/ Square Mile	Infant Mortality Rate/1000 Live Births	1970 Residence & Trash Fires Rate/ 1000 Premises	Penalty Points: Condition Auxiliary Structure	Crowding of Structure	Housing Conditions	Premises Condition	Street Condition	Crowding of Population	TB Rate/ 100,000 Population	Total Penalty Index
1	0.76	0.20	0.05	15.50	15.30	14.00	0.00	2.00	5.00	52.00	2.00	6.18	92.50
2	5.38	1.40	0.36	24.10	8.63	6.00	1.00	1.00	5.00	33.00	1.00	8.13	60.80
3	3.37	0.89	0.23	34.50	12.20	5.00	2.00	1.00	3.00	22.00	2.00	2.26	52.10
4	3.38	0.90	0.23	19.30	14.00	0.00	1.00	1.00	2.00	32.00	6.00	14.20	66.80
5	3.98	1.10	0.27	5.55	11.50	6.00	3.00	0.00	0.00	39.00	0.00	7.74	71.10
6	1.65	0.44	0.11	4.56	8.51	0.00	1.00	0.00	2.00	24.00	0.00	0.00	70.50
7	0.31	0.08	0.03	0.00	2.87	20.00	0.00	22.00	17.00	38.00	19.00	0.00	150.10
8	0.50	0.44	0.11	19.70	7.43	0.00	1.00	0.00	2.00	38.00	1.00	1.91	85.40
9	1.60	0.13	0.03	8.66	4.77	14.00	0.00	3.00	6.00	39.00	2.00	3.73	61.70
10	3.66	0.43	0.10	0.00	6.19	0.00	2.00	0.00	0.00	21.00	1.00	34.20	45.70
11	3.66	0.97	0.25	21.30	8.95	6.00	1.00	1.00	9.00	33.00	6.00	7.35	94.40
12	4.66	1.50	0.36	23.00	11.40	6.00	1.00	1.00	10.00	21.00	2.00	12.60	54.70
13	4.86	1.20	0.31	15.40	8.87	0.00	0.00	1.00	1.00	39.00	0.00	0.00	66.00
14	20.60	1.30	0.32	16.40	15.30	6.00	0.00	1.00	1.00	26.00	0.00	30.88	54.30
15	8.40	5.50	1.40	23.40	17.70	27.00	12.00	9.00	5.00	22.00	1.00	81.30	86.10
16	8.20	2.20	0.56	28.40	16.20	29.00	8.00	9.00	6.00	16.00	0.00	34.30	73.10
17	6.30	2.20	0.55	7.93	9.54	10.00	1.00	1.00	2.00	22.00	0.00	5.99	53.70
18	9.00	1.70	0.42	9.30	10.04	5.00	1.00	0.00	1.00	26.00	1.00	16.80	53.60
19	10.80	2.40	0.60	4.08	14.50	30.00	3.00	8.00	8.00	19.00	15.00	5.05	86.50
20	8.00	2.90	0.72	16.40	19.30	41.00	10.00	14.00	13.00	14.00	11.00	43.30	87.90
21	5.00	2.40	4.50	51.30	12.90	51.00	15.00	12.00	11.00	12.00	7.00	26.30	86.10
22	4.10	1.30	0.33	58.80	14.00	48.00	2.00	9.00	8.00	14.00	5.00	85.70	64.20
23	3.70	1.10	0.28	12.50	9.28	39.00	2.00	11.00	14.00	29.00	6.00	5.60	104.20
24	2.60	1.00	0.26	14.90	14.30	24.00	0.00	4.00	12.00	33.00	8.00	19.70	88.80

APPENDIX B-4--Continued

Neighborhood Number	CO Tons/Day/ Square Mile	Hydrocarbons Tons/Day/Sq. Mi.	NO_2 Tons/Day/ Square Mile	Infant Mortality Rate/1000 Live Births	1970 Residence & Trash Fires Rate/ 1000 Premises	Penalty Points: Condition Auxiliary Structure	Crowding of Structure	Housing Conditions	Premises Condition	Street Condition	Crowding of Population	TB Rate/ 100,000 Population	Total Penalty Index
25	2.10	0.84	0.79	16.07	12.02	13.00	0.00	4.00	7.00	31.00	14.00	13.99	92.00
26	1.90	0.56	0.15	17.80	18.00	11.00	0.00	2.00	7.00	25.00	3.00	6.14	75.60
27	1.70	0.53	0.13	31.10	6.92	24.00	2.00	2.00	9.00	28.00	4.00	27.20	81.60
28	2.80	0.46	0.12	56.90	9.98	29.00	4.00	4.00	11.00	24.00	10.00	13.90	97.40
29	1.30	0.09	0.07	5.23	22.60	25.00	0.00	4.00	25.00	43.00	8.00	6.46	118.60
30	4.70	0.34	0.09	12.30	20.50	4.00	0.00	1.00	4.00	27.00	4.00	20.10	48.90
31	1.20	1.30	0.32	13.90	27.60	45.00	1.00	10.00	19.00	34.00	15.00	19.60	136.10
32	2.80	0.31	0.08	0.00	18.02	9.00	0.00	2.00	8.00	27.00	1.00	23.40	64.60
33	2.50	0.76	0.19	13.90	10.10	40.00	0.00	20.00	8.00	22.00	19.00	48.40	126.60
34	1.50	0.75	18.90	9.74	5.42	51.00	0.00	3.00	10.00	35.00	19.00	33.80	95.90
35	3.70	0.39	0.10	9.74	7.95	8.00	0.00	5.00	16.00	36.00	15.00	30.40	103.40
36	5.50	0.98	0.25	11.80	12.10	40.00	0.00	12.00	12.00	43.00	15.00	10.30	128.10
37	45.80	1.50	5.50	40.00	17.10	26.00	2.00	11.00	12.00	23.00	18.00	25.30	97.60
38	1.60	0.63	0.81	24.00	4.80	30.00	0.00	5.00	6.00	32.00	4.00	21.20	79.20
39	0.16	0.46	0.19	9.80	0.00	50.00	0.00	13.00	24.00	44.00	38.00	166.70	152.00
40	0.58	0.04	0.01	9.80	45.10	30.00	0.00	14.00	17.00	71.00	15.00	0.00	148.50
41	1.60	0.15	0.03	32.30	3.78	67.00	0.00	7.00	35.00	77.00	11.00	0.00	185.40
42	2.70	0.42	0.15	32.30	12.20	56.00	0.00	9.00	21.00	51.00	10.00	0.00	140.50
43	3.60	0.71	0.18	32.30	10.00	41.00	0.00	11.00	14.00	43.00	14.00	25.80	135.30
44	3.12	0.96	0.24	8.58	20.30	21.00	0.00	2.00	3.00	23.00	16.00	58.50	86.30
45	3.60	0.84	0.20	17.20	9.61	58.00	1.00	11.00	11.00	29.00	9.00	76.10	119.50
46	3.60	0.96	0.24	17.20	16.30	71.00	0.00	20.00	14.00	29.00	13.00	140.00	132.90
47	2.80	1.00	0.40	22.70	30.90	64.00	1.00	13.00	17.00	52.00	4.00	17.40	134.60
48	4.10	0.76	0.19	22.70	20.80	60.00	0.00	8.00	13.00	30.00	17.00	82.50	114.80
49	5.80	1.10	0.27	33.30	8.21	19.00	0.00	3.00	14.00	33.00	3.00	79.20	89.20
50	4.80	1.50	0.38	33.30	20.90	40.00	1.00	4.00	8.00	31.00	10.00	52.90	96.20

APPENDIX B-4--Continued

Neighborhood Number	CO Tons/Day/ Square Mile	Hydrocarbons Tons/Day/Sq. Mi.	NO_2 Tons/Day/ Square Mile	Infant Mortality Rate/1000 Live Births	1970 Residence & Trash Fires Rate/ 1000 Premises	Penalty Points: Condition Auxiliary Structure	Crowding of Structure	Housing Conditions	Premises Condition	Street Condition	Crowding of Population	TB Rate/ 100,000 Population	Total Penalty Index
51	3.00	1.30	0.30	13.00	33.90	63.00	2.00	4.00	5.00	19.00	5.00	0.00	62.80
52	3.30	0.79	0.20	13.00	22.90	63.00	2.00	8.00	12.00	15.00	7.00	117.10	71.30
53	0.52	0.87	0.22	19.40	33.20	59.00	1.00	24.00	18.00	25.00	14.00	150.50	131.00
54	12.20	0.22	5.04	19.40	13.20	24.00	1.00	32.00	11.00	24.00	36.00	144.70	172.70
55	0.36	3.20	0.82	24.40	11.40	59.00	3.00	28.00	21.00	28.00	9.00	100.40	143.00
56	5.80	0.10	0.03	24.40	32.80	62.00	0.00	24.00	19.00	32.00	22.00	101.90	140.00
57	1.90	1.60	0.39	28.40	22.80	50.00	1.00	16.00	10.00	18.00	23.00	23.30	115.00
58	3.40	0.51	0.14	28.40	34.30	50.00	0.00	16.00	9.00	22.00	29.00	22.80	148.40
59	17.20	0.92	0.25	58.80	13.80	50.00	0.00	14.00	18.00	50.00	17.00	32.40	142.40
60	0.66	4.60	1.20	23.40	32.30	16.00	22.00	9.00	13.00	27.00	2.00	383.50	131.40
61	0.19	0.18	0.04	32.30	7.37	0.00	1.00	0.00	2.00	32.00	2.00	11.90	77.10
62	0.18	0.05	0.01	9.59	3.49	45.00	0.00	22.00	25.00	65.00	3.00	0.00	167.80
63	0.55	0.05	0.01	0.00	6.76	21.00	0.00	16.00	9.00	83.00	14.00	0.00	147.90
64	7.70	0.15	0.04	16.50	0.63	10.00	4.00	11.00	12.00	34.00	38.00	6.55	182.20
65		2.00	0.49	0.00	6.80	0.00	0.00	0.00	2.00	24.00	0.00	105.20	51.80

APPENDIX C

APPENDIX C-1

NEEDS NEIGHBORHOODS TB RATE /100,000 POPULATION

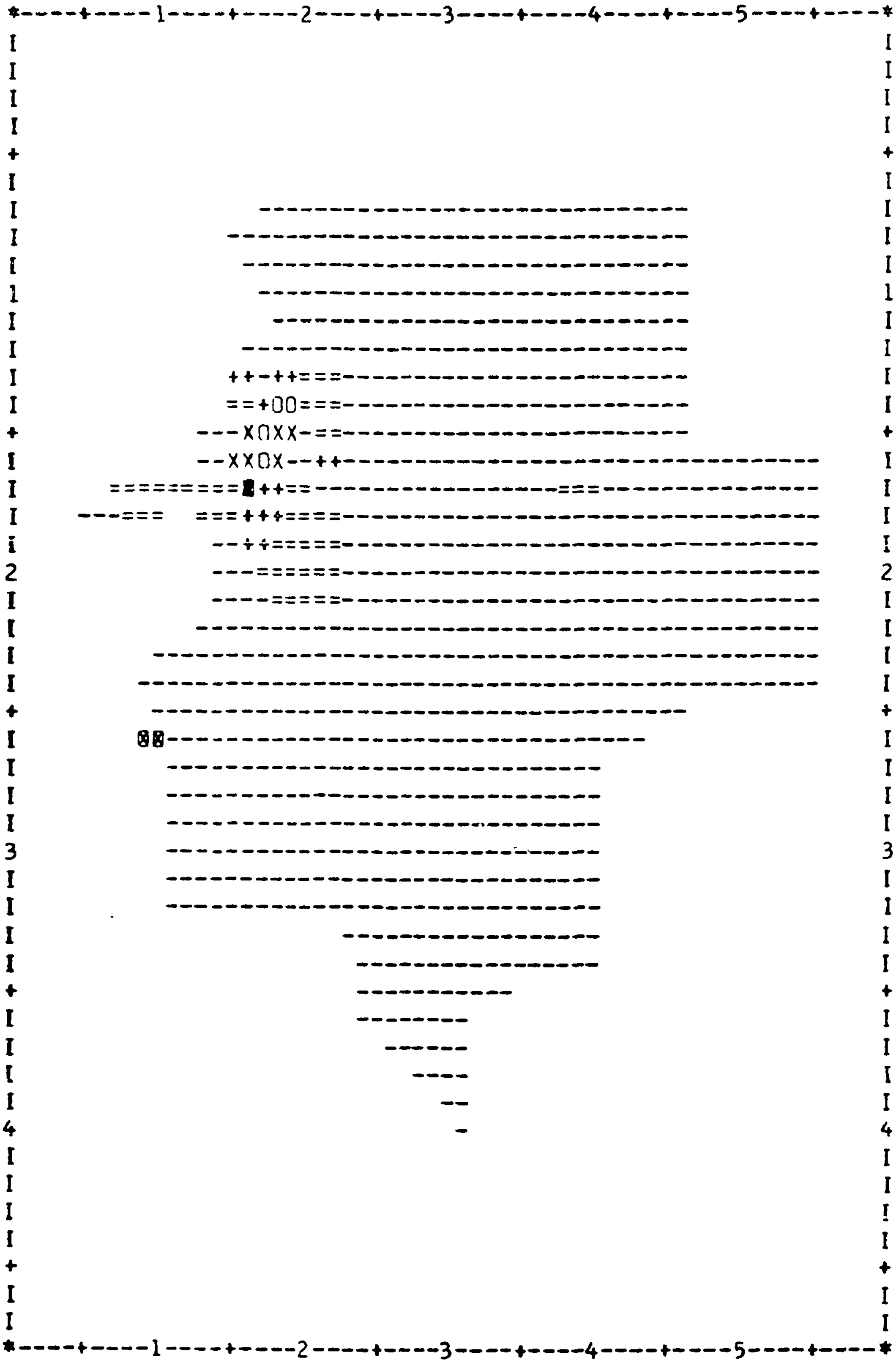
Data value extremes are: 0.00 383.50

Absolute value range applying to each level ('maximum' included in highest level only):

Level	1	2	3	4	5	6	7
Minimum	0.00	27.83	64.93	92.75	120.58	153.04	180.87
Maximum	27.83	64.93	92.75	102.58	153.04	180.87	384.00

Frequency distribution of data point values in each level:

Level	1	2	3	4	5	6	7
Symbols	---------	=========	+++++++++	XXXXXXXXX	OOOOOOOOO	[illegible]	[illegible]
Freq.	41	10	5	4	3	1	1



SYMAP

APPENDIX C-2

NEEDS NEIGHBORHOODS 1970 INFANT MORTALITY
RATE/1000 LIVE BIRTHS

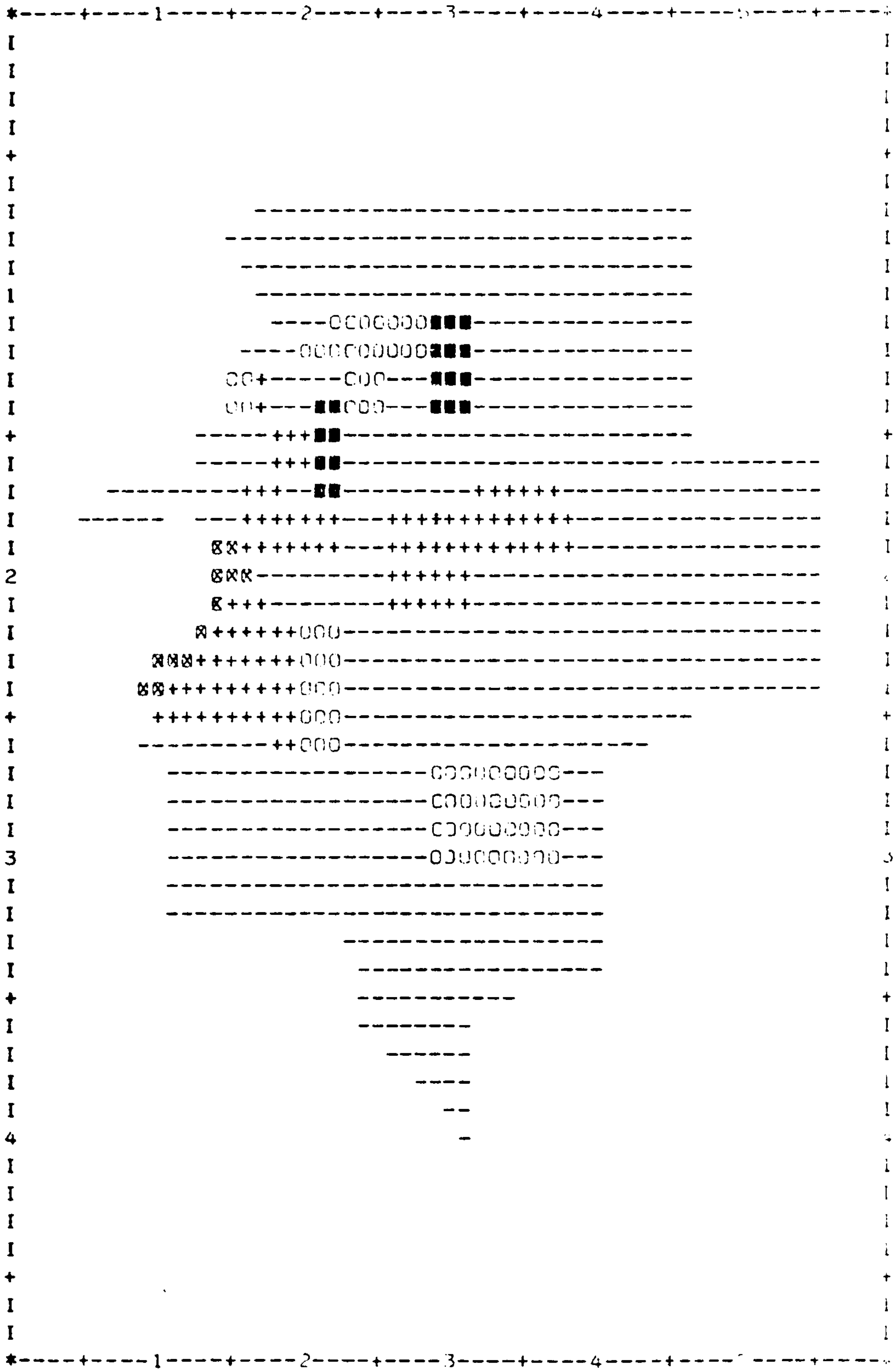
Data value extremes are: 0.00 58.80

Absolute value range applying to each level ('maximum' included in highest level only):

Level	1	2	3	4	5
Minimum	0.00	20.00	29.90	39.90	49.90
Maximum	20.00	29.90	39.90	49.90	59.90

Frequency distribution of data point values in each level:

Level	1	2	3	4	5
Symbols	---------	+++++++++	OOOOOOOOO	XXXXXXXXX	■■■■■■■■■
Freq.	39	13	8	1	4



SYMAP

APPENDIX D

APPENDIX D-1

NEEDS NEIGHBORHOODS TOTAL PENALTY INDEX

Data value extremes are: 45.70 185.40

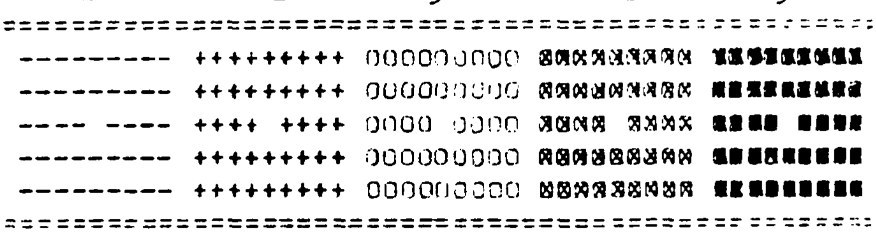
Absolute value range applying to each level ('maximum' included in highest level only):

Level	1	2	3	4	5
Minimum	0.00	59.90	99.90	139.90	179.90
Maximum	59.90	99.90	139.90	179.90	199.90

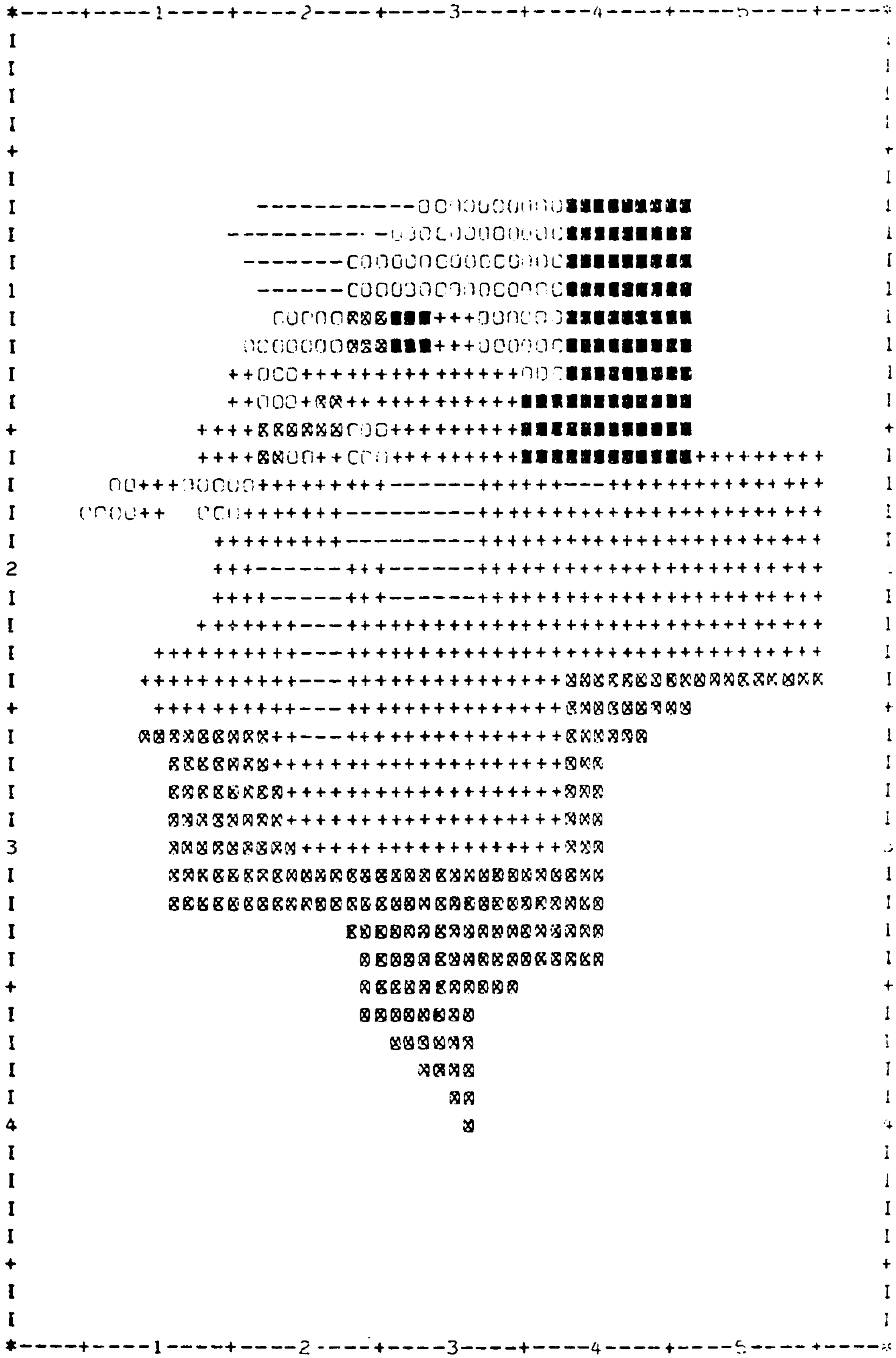
Frequency distribution of data point values in each level:

Level	1	2	3	4	5

Symbols



Freq.	8	30	14	11	2



SYMAP

APPENDIX D-2

NEEDS NEIGHBORHOODS HOUSING CONDITION MAIN STRUCTURE

Data value extremes are: 0.00 32.00

Absolute value range applying to each level ('maximum' included in highest level only):

Level	1	2	3	4	5	6
Minimum	0.00	4.90	9.90	12.90	19.90	27.90
Maximum	4.90	9.90	12.90	19.90	27.90	32.90

Frequency distribution of data point values in each level:

Level	1	2	3	4	5	6
Symbols	---------	=========	XXXXXXXXX	OOOOOOOOO	⊗⊗⊗⊗⊗⊗⊗⊗⊗	■■■■■■■■■
	---------	=========	XXXXXXXXX	OOOOOOOOO	⊗⊗⊗⊗⊗⊗⊗⊗⊗	■■■■■■■■■
	---- ----	==== ====	XXXX XXXX	OOOO OOOO	⊗⊗⊗⊗ ⊗⊗⊗⊗	■■■■ ■■■■
	---------	=========	XXXXXXXXX	OOOOOOOOO	⊗⊗⊗⊗⊗⊗⊗⊗⊗	■■■■■■■■■
	---------	=========	XXXXXXXXX	OOOOOOOOO	⊗⊗⊗⊗⊗⊗⊗⊗⊗	■■■■■■■■■
Freq.	30	11	8	8	6	2

SYMAP

APPENDIX D-3

NEEDS NEIGHBORHOODS PREMISES CONDITION

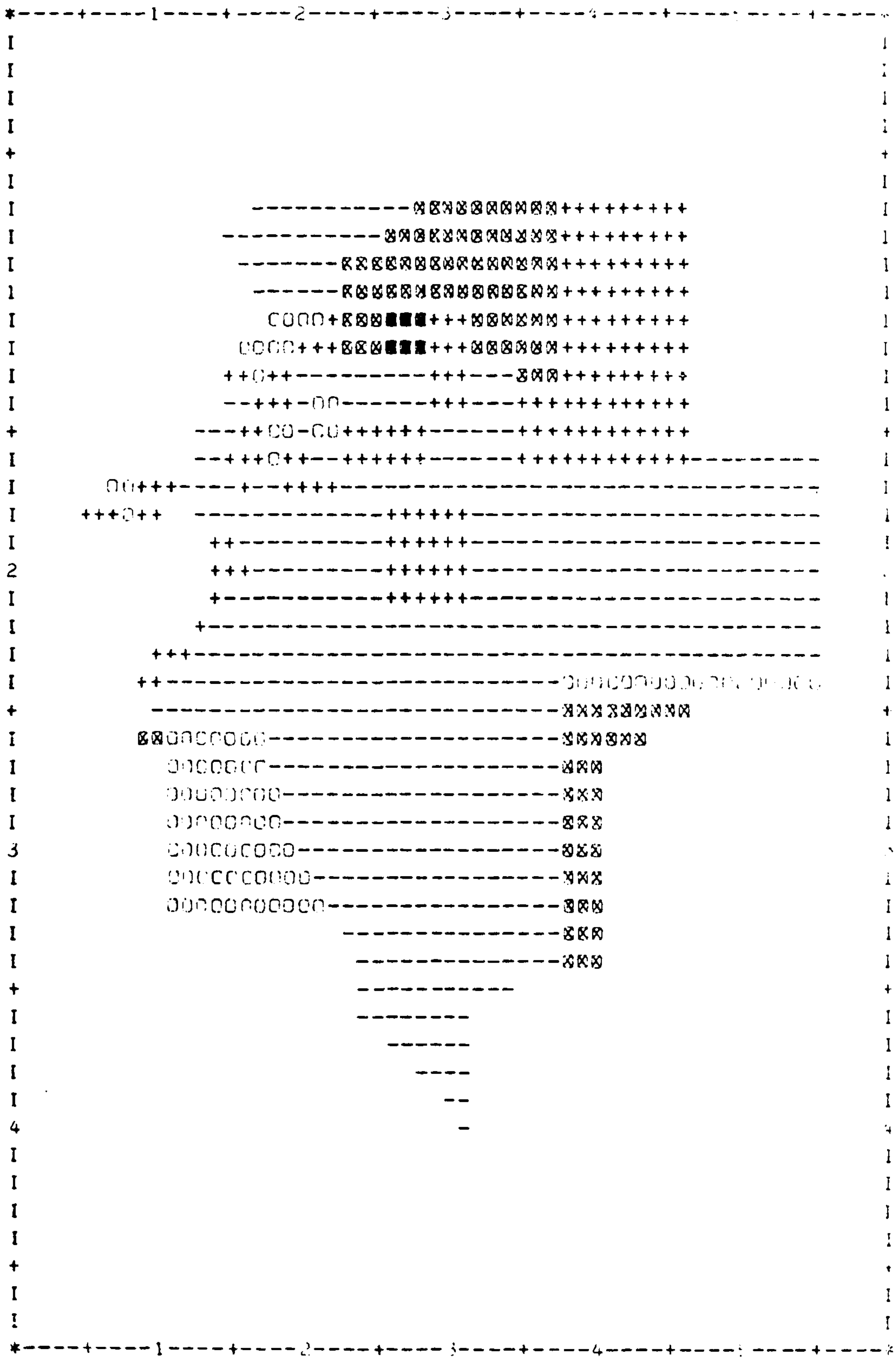
Data value extremes are: 0.00 35.00

Absolute value range applying to each level ('maximum' included in highest level only):

Level	1	2	3	4	5
Minimum	0.00	9.90	14.90	19.90	29.90
Maximum	9.90	14.90	19.90	29.90	35.90

Frequency distribution of data point values in each level:

Level	1	2	3	4	5
	---------	+++++++++	000000000	▓▓▓▓▓▓▓▓▓	█████████
	---------	+++++++++	000000000	▓▓▓▓▓▓▓▓▓	█████████
Symbols	---- ----	++++ ++++	0000 0000	▓▓▓▓ ▓▓▓▓	████ ████
	---------	+++++++++	000000000	▓▓▓▓▓▓▓▓▓	█████████
	---------	+++++++++	000000000	▓▓▓▓▓▓▓▓▓	█████████
Freq.	32	19	8	5	1



SYMAP

APPENDIX D-4

NEEDS NEIGHBORHOODS CROWDING OF STRUCTURE

Data value extremes are: 0.00 22.00

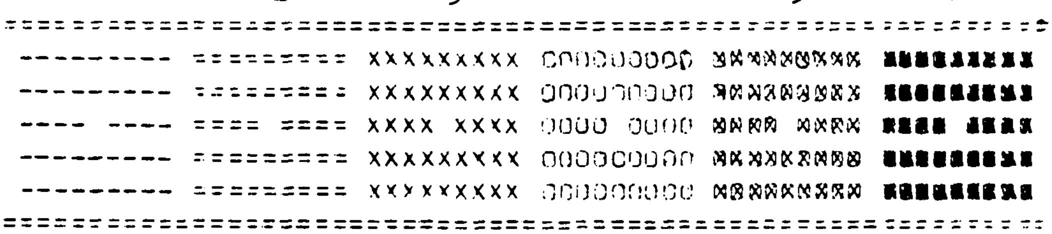
Absolute value range applying to each level ('maximum' included in highest level only):

Level	1	2	3	4	5	6
Minimum	0.00	0.90	2.90	4.90	10.90	15.90
Maximum	1.90	2.90	4.90	10.90	15.90	22.90

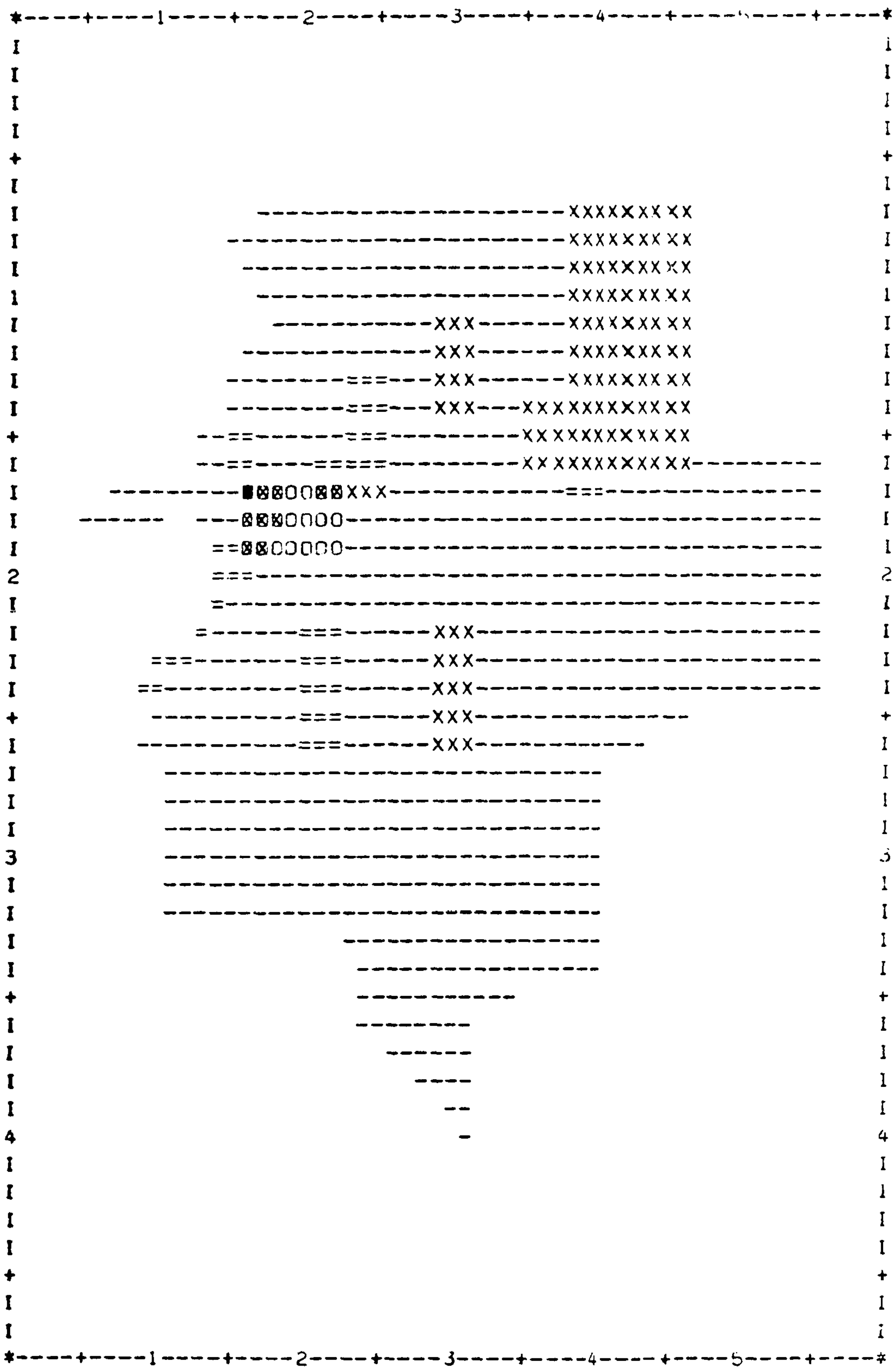
Frequency distribution of data point values in each level:

Level	1	2	3	4	5	6

Symbols



Freq.	47	8	5	2	2	1



SYMAP

APPENDIX D-5

NEEDS NEIGHBORHOODS CROWDING OF POPULATION

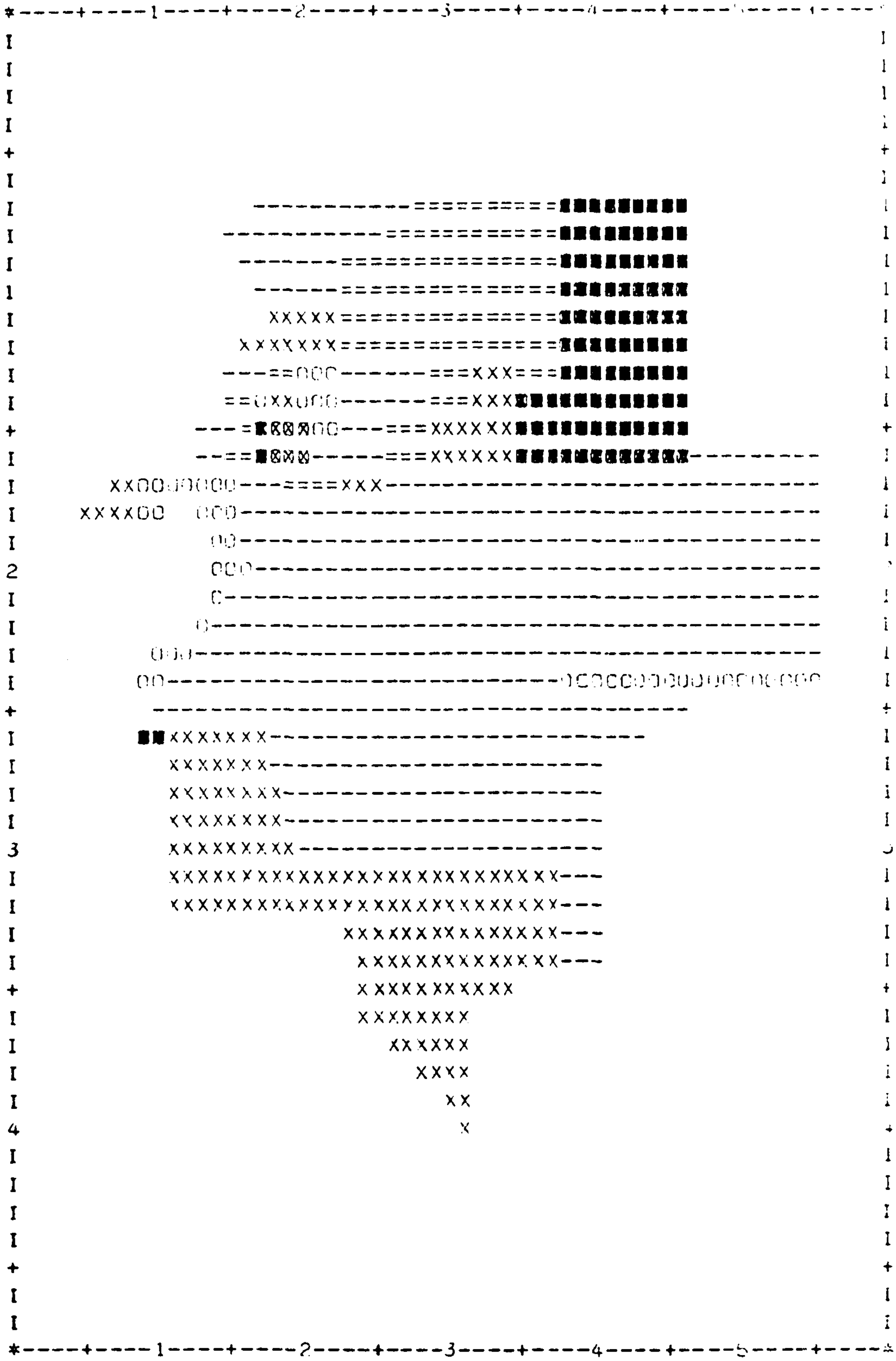
Data value extremes are: 0.00 38.00

Absolute value range applying to each level ('maximum' included in highest level only):

Level	1	2	3	4	5	6
Minimum	0.00	6.90	12.90	15.90	21.90	29.90
Maximum	6.90	12.90	15.90	21.90	29.90	38.90

Frequency distribution of data point values in each level:

Level	1	2	3	4	5	6
	---------	=========	XXXXXXXXX	OOOOOOOOO	⊗⊗⊗⊗⊗⊗⊗⊗⊗	■■■■■■■■■
	---------	=========	XXXXXXXXX	OOOOOOOOO	⊗⊗⊗⊗⊗⊗⊗⊗⊗	■■■■■■■■■
Symbols	---- ----	==== ====	XXXX XXXX	OOOO OOOO	⊗⊗⊗⊗ ⊗⊗⊗⊗	■■■■ ■■■■
	---------	=========	XXXXXXXXX	OOOOOOOOO	⊗⊗⊗⊗⊗⊗⊗⊗⊗	■■■■■■■■■
	---------	=========	XXXXXXXXX	OOOOOOOOO	⊗⊗⊗⊗⊗⊗⊗⊗⊗	■■■■■■■■■
Freq.	31	11	10	7	3	3



SYMAP

APPENDIX D-6

NEEDS NEIGHBORHOODS HOUSING CONDITION--AUXILIARY

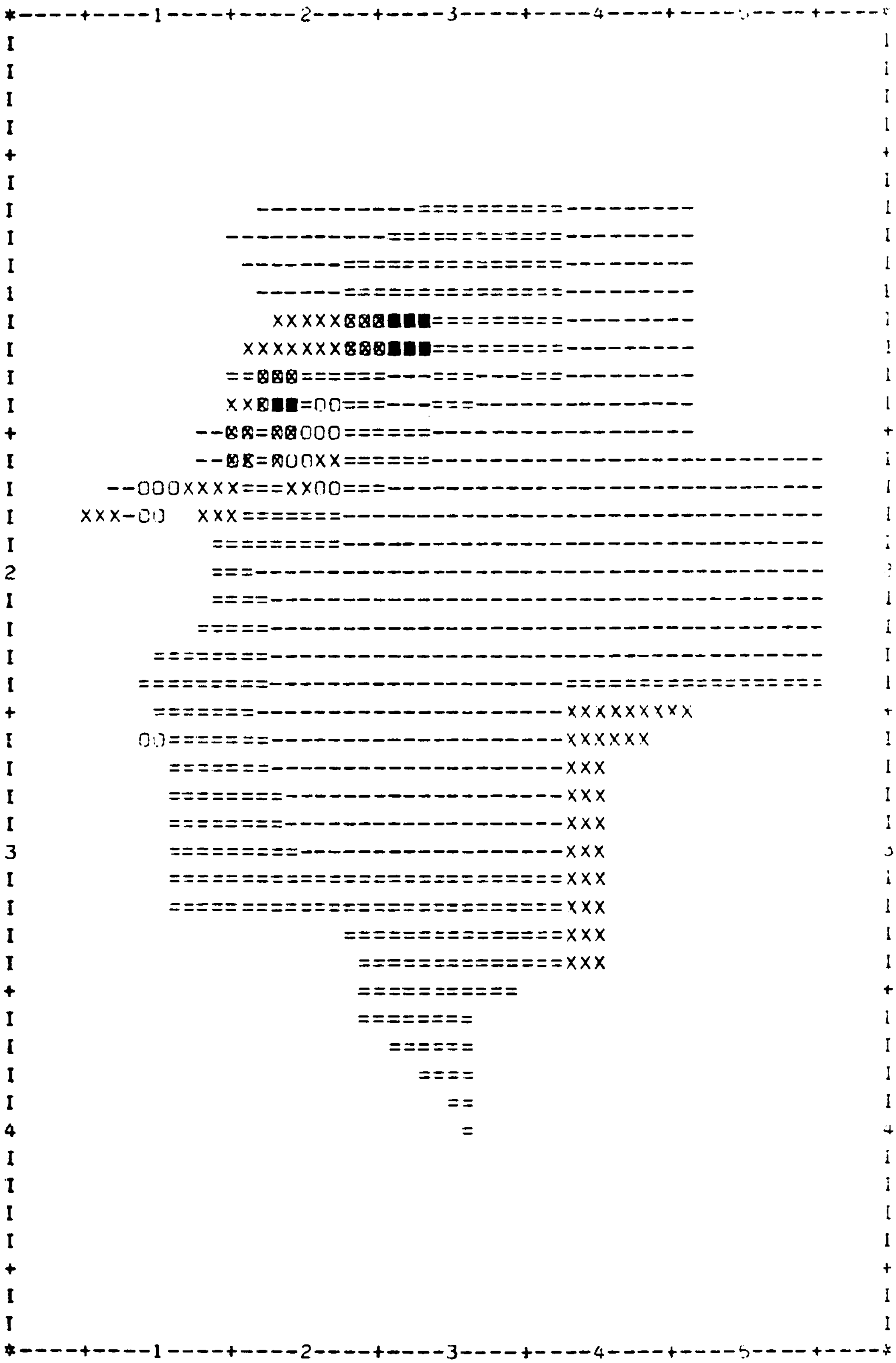
Data value extremes are: 0.00 71.00

Absolute value range applying to each level ('maximum' included in highest level only):

Level	1	2	3	4	5	6
Minimum	0.00	15.90	39.90	49.90	54.90	66.90
Maximum	15.90	39.90	49.90	54.90	66.90	71.90

Frequency distribution of data point values in each level:

```
Level        1           2           3           4           5           6
        ======================================================================
          ---------   =========   XXXXXXXXX   OOOOOOOOO   XXXXXXXXX   ■■■■■■■■■
          ---------   =========   XXXXXXXXX   OOOOOOOOO   XXXXXXXXX   ■■■■■■■■■
Symbols   ---- ----   ==== ====   XXXX XXXX   OOOO OOOO   XXXX XXXX   ■■■■ ■■■■
          ---------   =========   XXXXXXXXX   OOOOOOOOO   XXXXXXXXX   ■■■■■■■■■
          ---------   =========   XXXXXXXXX   OOOOOOOOO   XXXXXXXXX   ■■■■■■■■■
        ======================================================================
Freq.       23          17           8           6           9           2
```



SYMAP

APPENDIX D-7

NEEDS NEIGHBORHOODS STREET CONDITION

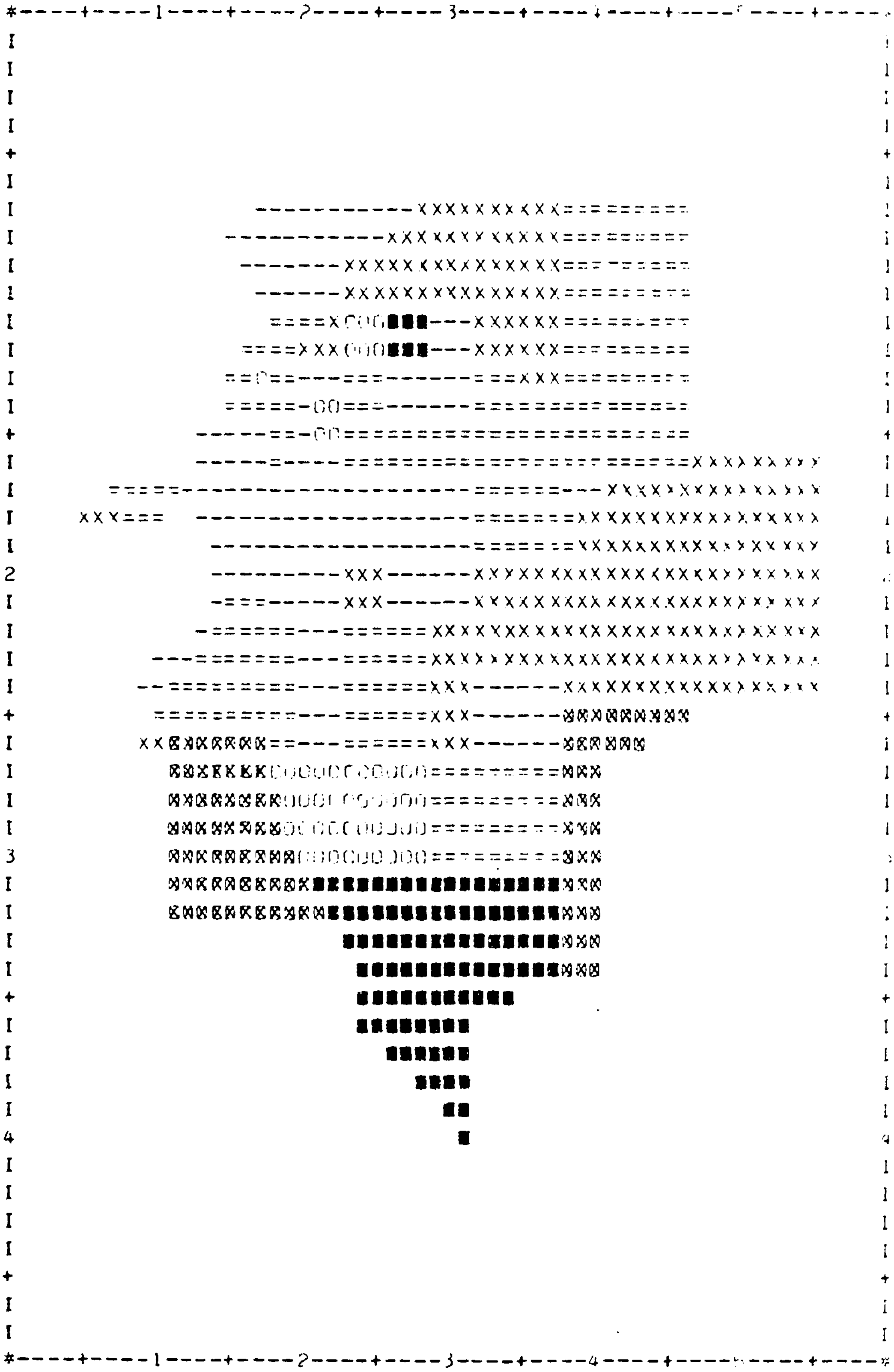
Data value extremes are: 12.00 83.00

Absolute value range applying to each level ('maximum' included in highest level only):

Level	1	2	3	4	5	6
Minimum	0.00	27.90	37.90	49.90	64.90	76.90
Maximum	27.90	37.90	49.90	64.90	76.90	83.90

Frequency distribution of data point values in each level:

Level	1	2	3	4	5	6
Symbols	---------	=========	XXXXXXXXX	OOOOOOOOO	XXXXXXXXX	█████████
	---------	=========	XXXXXXXXX	OOOOOOOOO	XXXXXXXXX	█████████
	---- ----	==== ====	XXXX XXXX	OOOO OOOO	XXXX XXXX	████ ████
	---------	=========	XXXXXXXXX	OOOOOOOOO	XXXXXXXXX	█████████
	---------	=========	XXXXXXXXX	OOOOOOOOO	XXXXXXXXX	█████████
Freq.	28	20	9	4	2	2



SYMAP

APPENDIX D-8

NEEDS NEIGHBORHOODS 1970 RESIDENCE AND TRASH FIRES RATE/1000 PREMISES

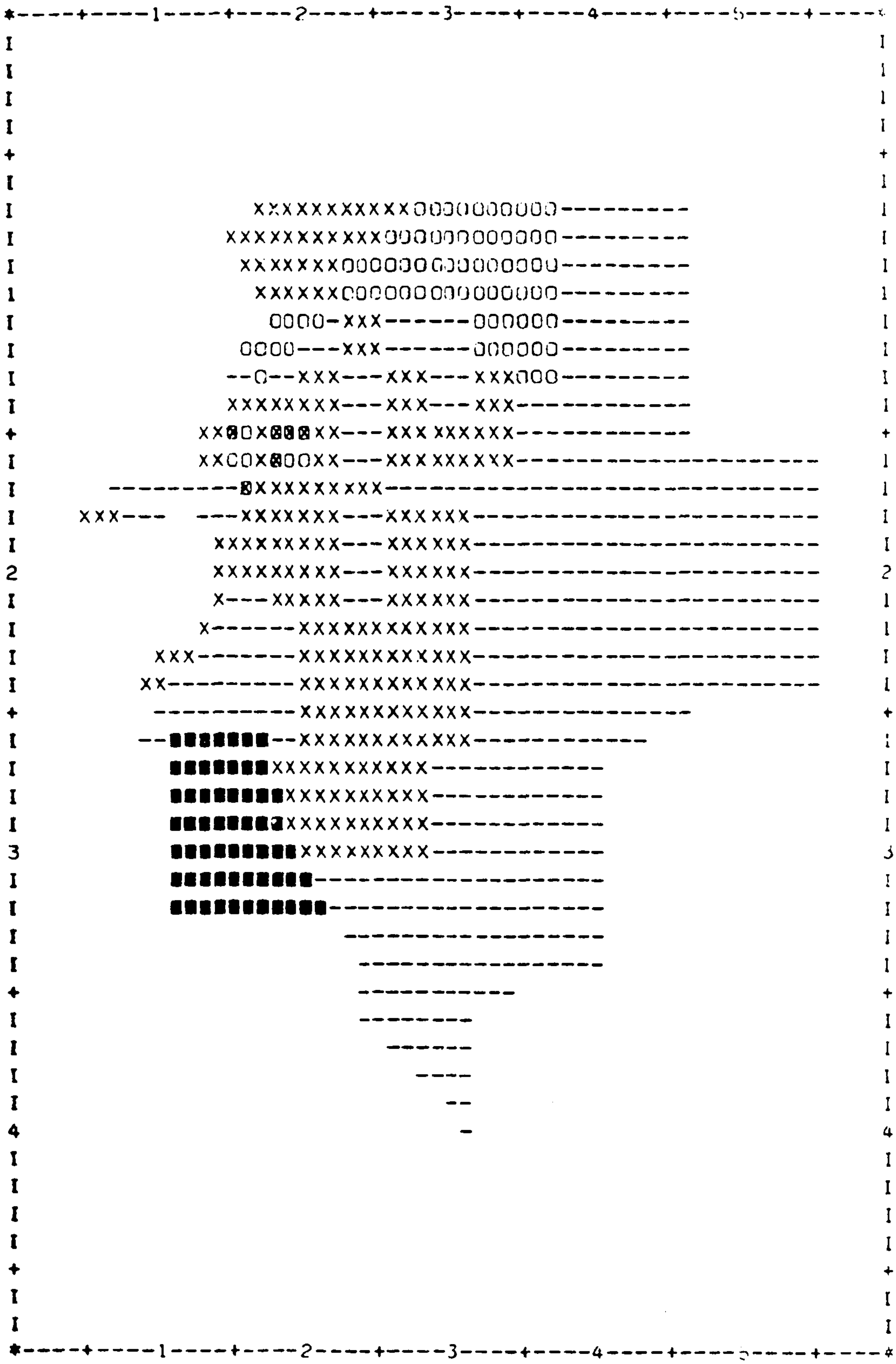
Data value extremes are: 0.00 45.10

Absolute value range applying to each level ('maximum' included in highest level only):

Level	1	2	3	4	5
Minimum	0.00	10.99	20.99	30.99	40.99
Maximum	10.99	20.99	30.99	40.99	45.99

Frequency distribution of data point values in each level:

Level	1	2	3	4	5
Symbols	--------- --------- ---- ---- --------- ---------	XXXXXXXXX XXXXXXXXX XXXX XXXX XXXXXXXXX XXXXXXXXX	OOOOOOOOO OOOOOOOOO OOOO OOOO OOOOOOOOO OOOOOOOOO	[illegible]	[illegible]
Freq.	27	27	5	5	1



SYMAP