INTERSTATE AIR POLLUTION STUDY

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PHASE II PROJECT REPORT

IV. ODORS—RESULTS OF SURVEYS

INTERSTATE AIR POLLUTION STUDY
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IV. ODORS — RESULTS OF SURVEYS

prepared by

H. Neff Jenkins
T. O. Harris

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

U. S. Public Health Service

Division of Air Pollution, Technical Assistance Branch
Robert A. Taft Sanitary Engineering Center
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Copies of this report are available from the cooperating agencies listed on the cover of this report and from the Technical Assistance Branch, Division of Air Pollution, Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati, Ohio.

FOREWORD

The Interstate Air Pollution Study was divided into two phases. Phase I, a general study of the overall air pollution problems in the St. Louis - East St. Louis Metropolitan area, was conducted to determine specific activities that would require further study in Phase II of the project. The effort was divided into two phases to provide a logical stopping point in the event that interest and resources for proceeding further might not materialize. The necessary impetus did continue, however, and the Phase II operation was also completed.

The Phase I operation resulted in a detailed report, designed primarily for use of the Executive Committee members and their agencies in making decisions concerning the Phase II project operation. A Phase I summary report was also prepared; it received wide distribution.

Numerous papers, brochures, and reports were prepared during Phase II operations, as were some 18 Memorandums of Information and Instruction concerning the project. All of these documents were drawn upon in the preparation of the Phase II project report. The Phase II project report consists of eight separate volumes under the following titles:

I. Introduction
II. Air Pollutant Emission Inventory
III. Air Quality Measurements
IV. Odors - Results of Surveys
V. Meteorology and Topography
VI. Effects of Air Pollution
VII. Opinion Surveys and Air Quality Relationships
VIII. Proposal for an Air Resource Management Program.

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CONTENTS

IV. ODORS—RESULTS OF SURVEYS

INTRODUCTION

Preliminary information obtained from two odor surveys conducted during Phase I of the Interstate Air Pollution Study indicated the need for a further investigation of the odor problems in the St. Louis Metropolitan Area. The two earlier surveys were limited in geographical coverage, number of observers, and number of observations recorded.

The first of the Phase I surveys took place during the 2-week period from May 25 to June 7, 1963, and utilized St. Louis City firemen as observers. During the course of this study 307 observations were made at six fire stations in the south St. Louis area.

The second survey was conducted by the air pollution inspectors of the St. Louis Division of Air Pollution Control, and covered the periods June 10 through 14 and June 17 through 21, 1963. Eight observers were used, and 207 observations resulted from the study. In contrast to the survey performed by the firemen, in which observations were made at 7 a.m., 8 p.m., 10 p.m., and 12 midnight, the survey performed by the air pollution inspectors covered normal working hours only, with observations at 9 a.m., 12 noon, and 3 p.m. Observation sites were not fixed locations, and observations were made by each inspector at the street intersection nearest him at a particular observation time.

During the Phase I surveys, odors were detected in 40 percent of the observations made by the firemen, and in 38 percent of those made by the air pollution inspectors. The most frequently detected odors were those associated with chemical manufacturing; they represented 25 percent of the total. The next three most frequently detected and potentially undesirable odors were food processing, 16 percent; burning refuse, 16 percent; and putrid odors, 6 percent.

During the Phase I surveys, odors were detected in over 40 percent of all of the observations made in inspector territories 2, 7, and 10. Within these three territories are large tracts of industrially zoned land, which undoubtedly contain many of the sources responsible for the high response frequencies observed in these territories.

The Phase II survey reported on herein was greatly expanded in terms of the number of observation stations (79), the geographical area encompassed, and the total number of observations made (5,022). (For the location, elevation, and zoning of the stations, see Appendix A.) The results of the current survey will, therefore, give a more definitive picture of the odor problems encountered in the Interstate Air Pollution Study Area.

The objective of the Phase II Odor Survey was to provide answers to the following questions:

1. What areas in Metropolitan St. Louis have odor problems?

2. What types of odors affect each area?

3. What odor types are the most undesirable?

4. When are odors prevalent?

5. What are the meteorological conditions associated with the occurrence of odors?

6. Where are the potential odor sources located?

7. Are there interjurisdictional and interstate problems related to odor control?

SURVEY DESCRIPTION

Selection of Odor Observers

Firemen were selected as the principal odor observers for the Phase II Odor Survey. Experience with these men during Phase I showed them to be reliable, conscientious observers. In addition, the firehouse locations are distributed relatively uniformly throughout the area and are staffed 24 hours a day. Excellent cooperation was received from all fire departments that participated in the survey.

To obtain information in areas in which fire department personnel were not present, an attempt was made to use private citizens as odor observers. This effort, for the most part, was a failure. Of the five citizens selected as observers, only three returned the odor observation folders, one of which was used incorrectly.

Each potential odor observer was given an odor sensitivity test to check his capability for detecting odors. (See Appendix B for the test description and sample forms.) The test also gave the observers a relative feeling of what was considered to be a strong or faint odor. At the same time the odor sensitivity test was given, each observer was instructed in the procedure for making and recording the odor observations. The test and instruction were administered by project staff members.

Odor Observation Locations

The odor observation locations were fixed points determined in most cases by the addresses of the fire stations. The data presented in this report were gathered from a total of 79 locations, 37 in St. Louis, 29 in St. Louis County, and a total of 13 in the Illinois communities of East St. Louis, Alton, Cahokia, Brooklyn, National City, Hartford, and Wood River. Because fire stations were used primarily, the observation locations are related more to population density than area. Although the number and distribution of observation stations were greatly expanded for this study, the number of sites available in Illinois, especially in East St. Louis Monsanto, and Granite City, was limited because of fewer cooperating fire stations in these areas. Figure 1 shows the odor observation locations on a grid map.

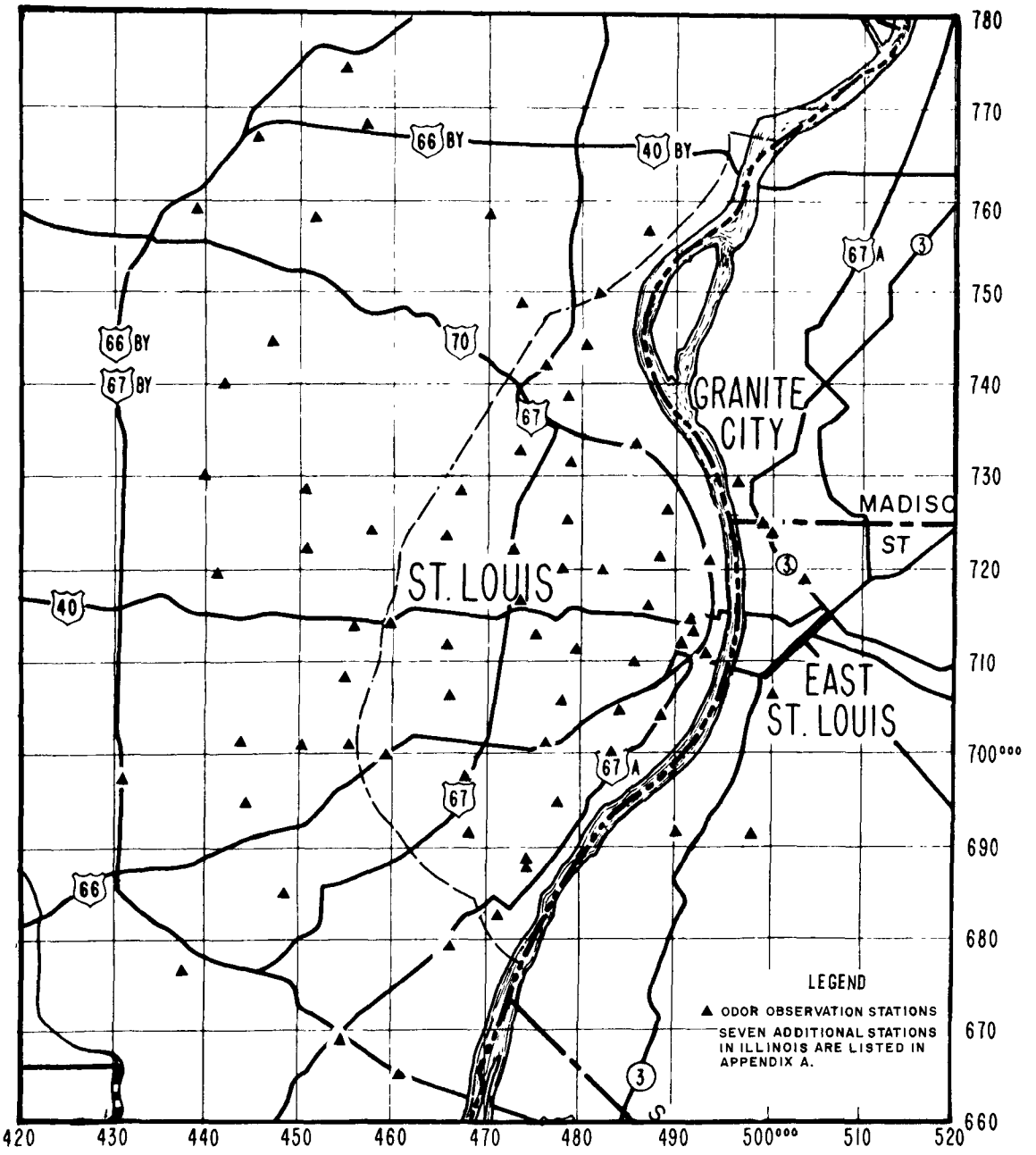

Figure 1. Odor observation locations.

Dates and Times

The Phase II Odor Survey was conducted continuously during 2 weeks from November 18 through December 1, 1963. Five odor observations were made each day at 79 locations in St. Louis, St. Louis County, and Illinois. The odor observation times were 7 a.m., 2 p.m., 8 p.m., 10 p.m., and 12 midnight.

Procedure

Except for the difference in observation times, the procedures employed and the forms used for this survey were the same as for Phase I.

The firemen at each firehouse were given a manila folder containing a schedule of assignments for the odor observers, an observer instruction sheet, 14 observation forms, and an addressed return envelope. Copies of these forms are in Appendix C.

Space was allocated on the observation form to permit the observer to describe the various odors in his own words. It was felt that the use of this method would produce more valid results than would have been obtained through the use of preselected odor categories. The use of such preselected categories could bias the observers' decisions because of limiting the number of descriptive terms. As might be expected, however, this approach produced a wide variety of odor descriptions; and to adapt these to data processing, each odor description had to be characterized as belonging to one of nine particular odor types. This classification, together with the number of odor observations pertaining to each type, for each of the three geographical areas is presented in Table 1.

FREQUENCY OF ODOR DETECTION

Metropolitan Area

The odor survey results for the Metropolitan St. Louis Area were evaluated separately for the three primary political parts, St. Louis, St. Louis County, and Illinois. St. Louis observers recorded the highest frequency of both total and unpleasant odors (Table 2 and Figure 2). Illinois results were only slightly lower than for St. Louis; whereas, St. Louis County experienced significantly lower frequencies. For the entire metropolitan area, 29.6 percent of all observations indicated the presence of odors, 66 percent of which were unpleasant.

Four of the five daily odor observations were at times when the meteorological conditions are relatively poor for odor dispersal. The frequencies of odor detection given above are, therefore, more representative of what might be expected in the evening and early morning rather than during the whole day. (See Table 3). The fact that odors were detected in 29.6 percent of the observations, however, indicates that odors are a significant air pollution problem in metropolitan St. Louis.

St. Louis

Since the Phase I odor survey data were summarized by air pollution inspector territories, the Phase II data had to be treated in a similar manner to permit comparison of the results. Figure 3 shows the areas encompassed by the inspector territories; Table 4 summarizes the Phase II data; and Figure 4 compares the results of the two studies.

The fact that the percentage of positive odor* responses was higher for the Phase I survey was expected and results from at least the following factors: (1) The

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*As used in this report, "positive odors" are odors detected by the observers during the observation periods.

Table 1. ODOR TYPES BY PRINCIPAL AREA IN PHASE II ODOR SURVEY

Category	Odor type	Number reported		
		St. Louis	St. Louis County	Illinois
1. Chemical	Chemical	140	13	16
	Sulfurous	37	6	2
	Soap or detergent	2	-	0
	Refinery	0	8	11
	Medicinal	14	-	1
	Vanilla or coumarin	7	-	0
	Other	22	15	4
	Unknown	2	-	1
	Total	224	42	35
2. Food processing	Coffee roasting	-	-	-
	Bakery	11	6	-
	Brewery	17	-	-
	Restaurant	3	3	-
	Grain	3	0	3
	Other	2	1	-
	Unknown	-	0	-
	Total	36	10	3
3. Combustion	Gasoline and diesel engine exhaust	55	52	9
	Coke-oven and coal gas odors (steel mills)	2	7	2
	Maladjusted heating systems	-	3	-
	Coal smoke	98	55	19
	Smokey	95	42	32
	Other	2	3	-
	Unknown	-	2	-
	Total	252	164	62
4. General industrial	Asphalt	1	5	-
	Plastics	1	-	-
	Solvents	2	-	-
	Fertilizer plants	2	-	-
	Paint and related industries	11	3	-
	Oily	3	3	13
	Foundry odors	-	-	-
	Other	-	1	8
	Unknown	-	-	8
	Total	20	12	30
5. Animal	Rendering	10	2	-
	Stockyards	6	-	30
	Poultry	-	-	-
	Other	-	-	-
	Unknown	-	-	-
	Total	16	2	30
6. Combustible waste	Open dump fires	8	2	6
	City incinerators burning garbage	1	3	2
	Home incinerators, backyard trash fires, wood smoke, and burning leaves	135	136	33
	Burning rubber	8	3	2
	Other	9	-	-
	Unknown	1	-	-
	Total	162	144	43
7. Decomposition	Sewage	11	26	1
	Nonburning garbage	25	1	1
	Other	9	1	-
	Unknown	0	-	-
	Total	45	28	2
8. Vegetation		5	22	2
9. Miscellaneous	General	17	15	2
	Foul - not specified	0	1	1
	Putrid - source not specified	11	0	1
	Not pleasant	1	1	-
	Smog	1	4	3
	Clean or fresh	93	60	3
	Total	123	81	10
No description		3	27	36

Table 2. FREQUENCY OF ODOR DETECTION IN PHASE II ODOR SURVEY
(November 18 - December 1, 1963)

Area	Pleasant	Unpleasant	No reaction[a]	Positive observations	Total observations
St. Louis	94	546	147	787	2,446
% of positive observations	11.9	69.4	18.7		
% of total observations	3.8	22.3	6.0	32.2	
St. Louis County	101	274	75	450	1,784
% of positive observations	22.4	60.9	16.7		
% of total observations	5.7	15.4	4.2	25.2	
Illinois	32	166	50	248	792
% of positive observations	12.9	66.9	20.2		
% of total observations	4.0	21.0	6.3	31.3	
Metropolitan Area	227	986	272	1,485	5,022
% of positive observations	15.2	66.4	18.3		
% of total observations	4.5	19.6	5.4	29.6	

[a]No reaction as to whether odor was pleasant or unpleasant.

Table 3. ODORS BY TIME OF DAY IN PHASE II ODOR SURVEY
(November 18 - December 1, 1963)

Area	7 a.m.	2 p.m.	8 p.m.	10 p.m.	12 M
St. Louis					
Positive observations	126	136	192	176	157
Total observations	483	494	490	491	488
% positive	26.1	27.5	39.2	35.8	32.2
St. Louis County					
Positive observations	66	85	119	106	74
Total observations	371	370	372	360	311
% positive	17.8	23.0	32.0	29.4	23.8
Illinois					
Positive observations	43	39	54	56	56
Total observations	164	161	162	161	144
% positive	26.2	24.2	33.3	34.8	38.9
Metropolitan Area					
Positive observations	235	260	365	338	287
Total observations	1,018	1,025	1,024	1,012	943
% positive	23.1	25.4	35.6	33.4	30.4

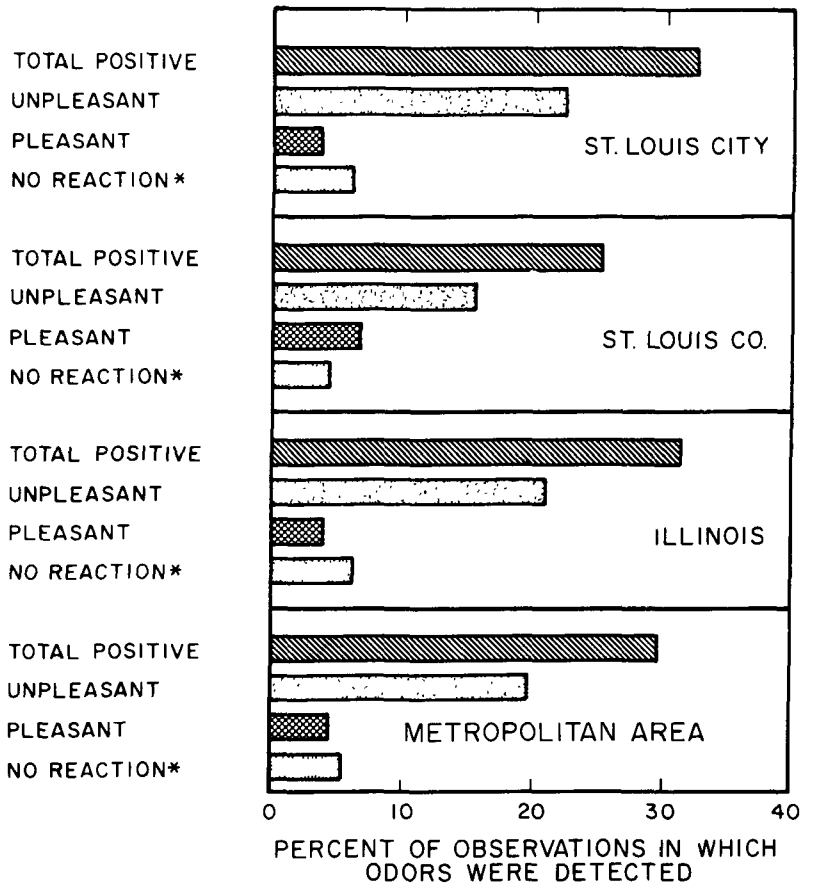

Figure 2. Odor frequency summary for Phase II Odor Survey (*indicates no reaction as to whether odor was pleasant or unpleasant).

sampling times were different, particularly in the case of the survey conducted by the inspectors. (2) The nature of the air pollution inspectors' work would be apt to cause them to be in areas where odors are highly prevalent. (3) Since the surveys were carried on at different seasons of the year, the meteorological conditions were different. (4) Many more observations were made in the Phase II survey. (5) Certain types of odors are more prevalent in the fall than in the spring, and vice versa.

TIMES WHEN ODORS ARE PREVALENT

Most frequently detected in the evening hours, odors reached a maximum at 8 p.m. in St. Louis and St. Louis County, and at 12 midnight in Illinois. Odors were at a minimum at 7 a.m. in St. Louis and St. Louis County, and at 2 p.m. in Illinois. A graphical summary of the variation in odor frequencies at different times of the day is presented in Figure 5.

The decrease in odors after 8 p.m. in St. Louis and St. Louis County is probably attributable to a reduction in the amount of combustible waste burning late in the evening and a decrease in transportation activities.

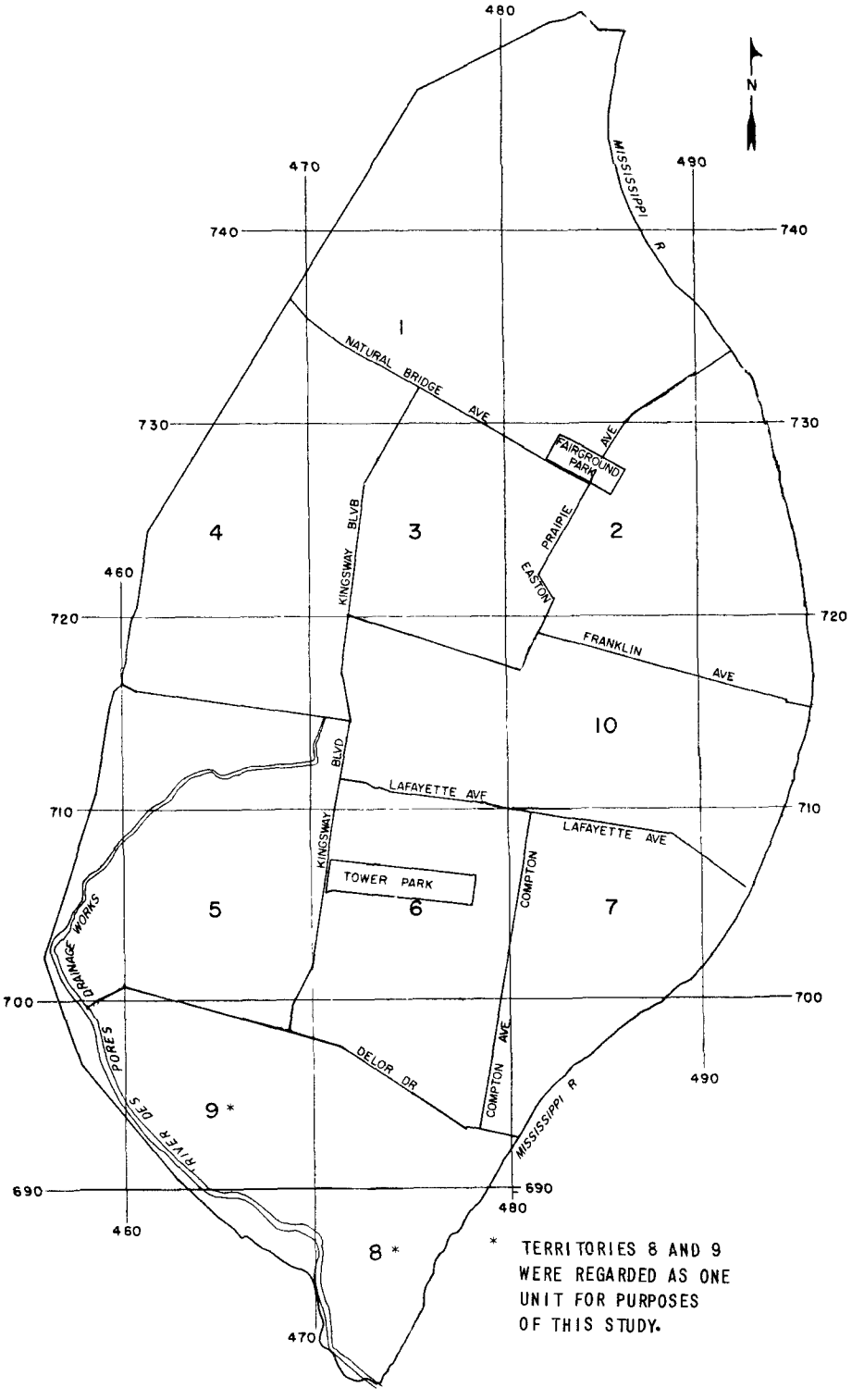

Figure 3. Inspector territories in St. Louis Phase II Odor Survey.

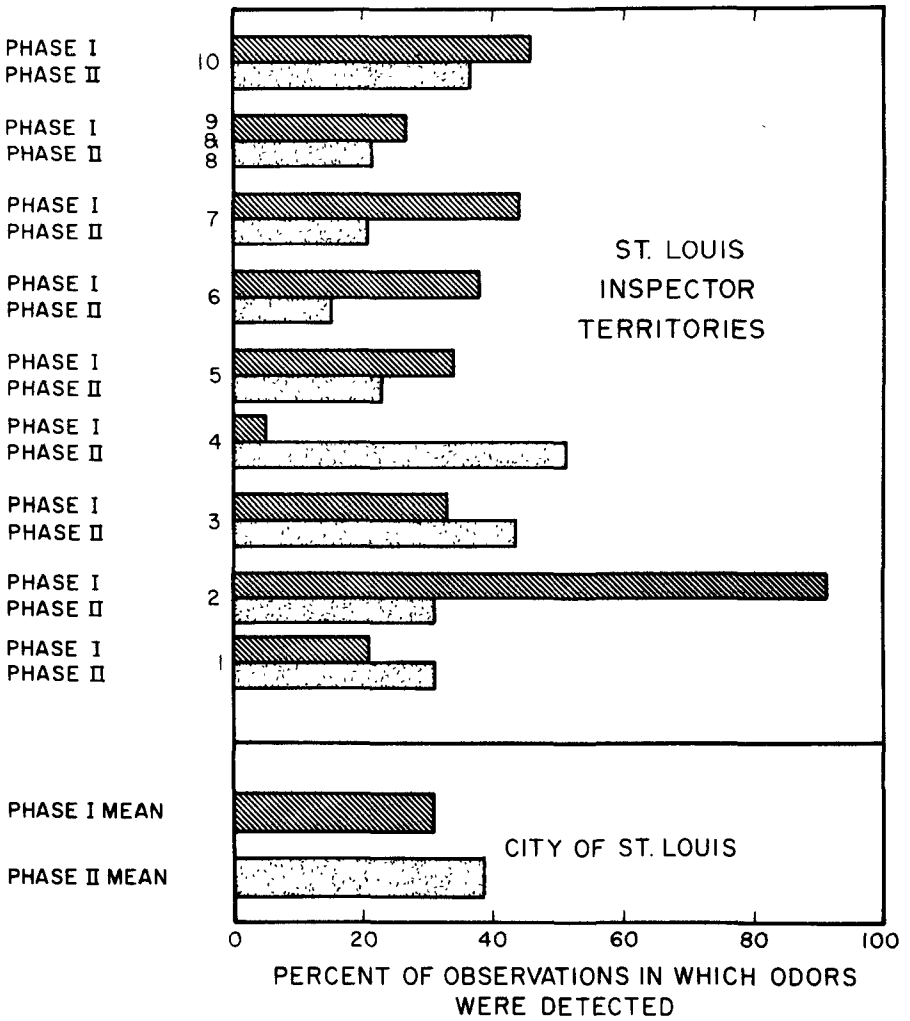

Figure 4. Odor frequencies by St. Louis Inspector Territories - Phase I and II Odor Surveys.

Table 4. FREQUENCY OF ODOR DETECTION IN ST. LOUIS INSPECTOR TERRITORIES - PHASE II ODOR SURVEY

Inspector territory	Pleasant odor	Unpleasant odor	No reaction by observer	Total positive	Total observations	Percent occurrence of odors
No. 1	7	71	20	98	308	31.8
No. 2	11	51	16	78	254	30.7
No. 3	20	50	16	86	197	43.7
No. 4	2	58	18	78	132	51.5
No. 5	14	35	12	61	264	23.1
No. 6	5	16	9	30	194	15.5
No. 7	8	34	4	46	216	21.3
No. 8 and 9	8	31	2	41	190	21.6
No. 10	18	151	42	211	580	36.4
Total	93	497	139	729	2,335	31.2

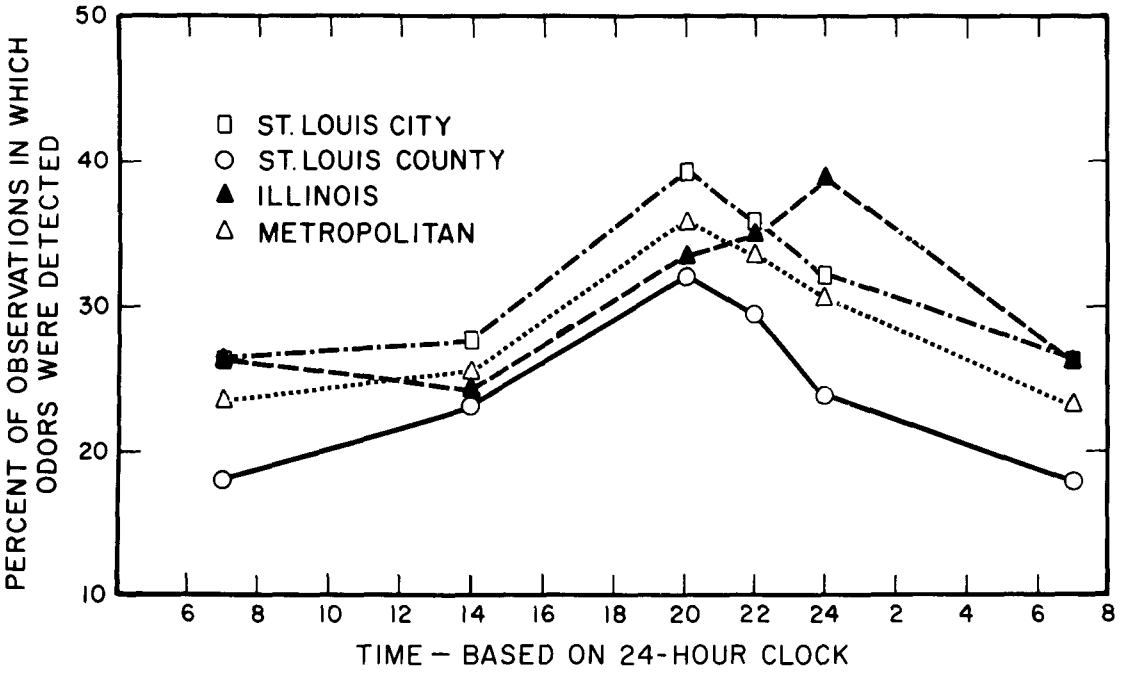

Figure 5. Odor frequencies by time of day during Phase II Odor Survey.

In Illinois the frequency of positive odors increased from 8 p.m. to 12 midnight instead of decreasing. This increase may be a result of low-level atmospheric temperature inversions coupled with the existence of numerous ground-level sources, such as burning dumps. These inversions, which occur most often at night, tend to keep pollutants released from ground-level sources close to the ground and in high concentrations.

The low percentage of positive odors at 7 a.m. in St. Louis is probably related to the low rate of community activity at this time of day. Transportation activities are just beginning to increase, and many industrial operations have not yet begun.

The observed positive odor frequency at 2 p.m. in Illinois is low because the meteorological conditions at this time of day are usually the most favorable for the dilution of air pollutants. Odors from industrial plants operating on an 8-hour daytime shift could have been detected only at this observation time since the other four daily observations were not during the daily work period.

KINDS OF ODORS

Metropolitan Area

The percentage frequency of positive odor response by type for each geographic area is presented in Table 5 and graphically in Figures 6 through 8. The two most frequently detected types were combustion and combustible waste odors. The av-

Table 5. PHASE II ODOR SURVEY, FREQUENCY OF ODORS BY CATEGORY

Area	Odor type										
	Chemical	Food processing	Combustion	General industrial	Animal	Combustible waste	Decomposition	Vegetation	Miscellaneous[a]	No description	Total positive observations
St. Louis											
(Total observations = 2,446)											
Positive observations	224	36	252	19	16	162	45	5	30	3	792
Unpleasant observations	178	10	180	13	15	88	42	2	18	2	
Unpleasant observations ÷ positive observations, %	79.5	27.8	71.4	68.4	93.8	54.3	93.3	4.0	60.0	66.7	
Positive observations÷total positive observations, %	28.3	4.5	31.8	2.4	2.0	20.5	5.7	0.6	3.8	0.4	
Positive observations ÷ total observations, %	9.2	1.5	10.3	0.8	0.6	6.6	1.8	0.2	1.2	0.1	
St. Louis County											
(Total observations = 1,784)											
Positive observations	42	10	164	12	2	144	28	22	21	27	472
Unpleasant observations	33	0	119	7	2	72	27	3	8	6	
Unpleasant observations÷positive observations, %	78.6	0	72.6	58.3	100	50	96.4	13.6	38.1	22.2	
Positive observations ÷ total positive observations, %	8.9	2.1	34.7	2.5	0.4	30.5	5.9	4.7	4.4	5.7	
Positive observations ÷ total observations, %	2.4	0.6	9.2	0.7	0.1	8.1	1.6	1.2	1.2	1.5	
Illinois											
(Total observations = 792)											
Positive observations	35	3	62	30	30	43	2	2	7	36	250
Unpleasant observations	30	0	30	18	30	20	1	0	4	33	
Unpleasant observations ÷ positive observations, %	85.7	0	48.4	60	100	46.5	50	0	57.1	91.7	
Positive observations ÷ total positive observations, %	14.0	1.2	24.8	12.0	12.0	17.2	0.8	2.8	2.8	14.4	
Positive observations ÷ total observations, %	4.4	0.4	7.8	3.8	3.8	5.4	0.3	0.3	0.9	4.5	
Metropolitan Area											
(Total observations = 5,022)											
Positive observations	301	49	478	61	48	349	75	29	58	66	1,514
Unpleasant observations	241	10	329	38	47	180	70	5	30	41	
Unpleasant observations ÷ positive observations, %	80.1	20.4	68.8	62.3	97.9	51.6	93.3	17.2	51.7	62.1	
Positive observations ÷ total positive observations, %	19.9	3.2	31.6	4.0	3.2	23.1	5.0	1.9	3.8	4.4	
Positive observations ÷ total observations, %	6.0	1.0	9.5	1.2	1.0	6.9	1.5	0.6	1.2	1.3	

[a]Odors described as clean or fresh were removed for this tabulation.

erage temperature for the study period was 43.7° F, which requires a significant amount of space heating, especially at the observation times of 7 a.m., 8 p.m., 10 p.m., and 12 midnight. These odors would be greatly reduced during the warm months. Motor vehicle odors were also included within the combustion category, but are not seasonal. Odors resulting from the use of home incinerators, backyard trash fires, wood smoke, and burning leaves were considered as a single subcategory (see Table 1), and accounted for by far the greatest number of combustible waste odors. The small number of observations attributed to open dump fires is probably related to the fewer number of observation stations on the Illinois side of the river, where most of the open dumps in the Study area are operated. Many of the combustible waste odors were from burning leaves, a significant source for about 2 months during the late fall. Slightly less than 50 percent of the combustible waste odors were described as unpleasant.

Chemical odors were the third most common odor type detected in the metropolitan area, and the second most frequently detected odor in St. Louis. Chemical odors, detected in St. Louis in more than 9 percent of the observations, represent 28 percent of all odors observed there. In this survey 80 percent of all chemical odors were described as unpleasant. Chemical odors are often detected at great

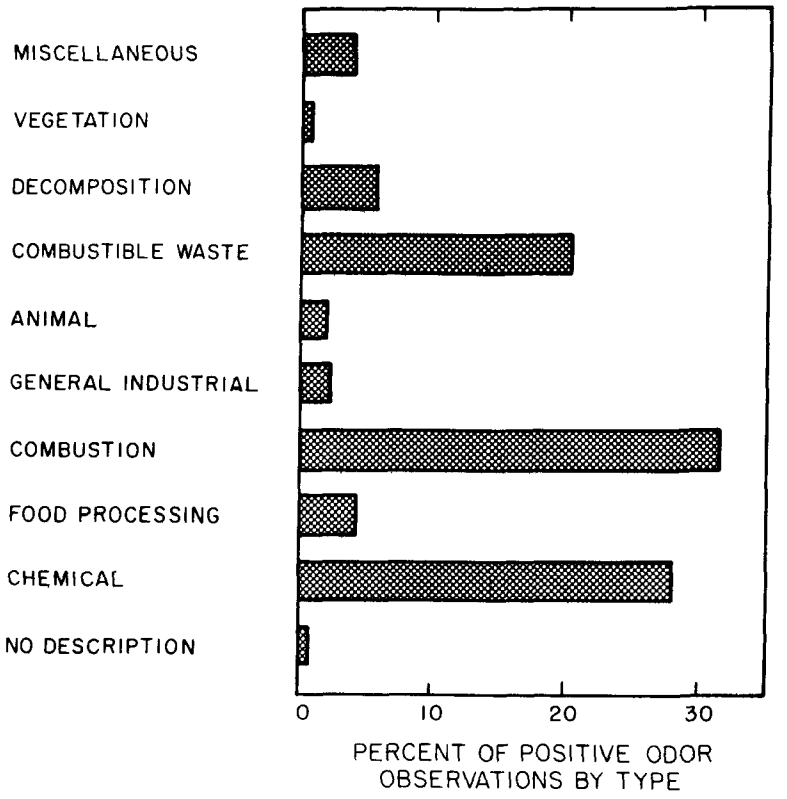

Figure 6. Odor types in St. Louis - Phase II Odor Survey.

distances from their sources so that one point source can often affect a large area. During the odor episode described later in this report, an odor originating in Illinois was detected in Missouri at places 12 miles from the source.

Odors from animals, decomposition of sewage and vegetation, food processing, and the general industrial categories were not widespread, but were detected frequently in areas close to their sources. Animal odors were most frequently detected in Illinois because an observation station was located in the stockyards area at National City. Animal odors are a more severe problem during the warm summer months because of the increased decomposition resulting from higher temperatures. Animal and decomposition odors were described as unpleasant over 90 percent of the time. St. Louis and Illinois both have rendering plants and stockyards, which can be sources of unpleasant odors, especially during the warmer months of the year. St. Louis County and Illinois have some open sewage ditches, septic tanks, and open dumps that can be sources of objectionable odors.

Food processing odors originate from many sources and were described as unpleasant about 20 percent of the time. They do not usually travel very far, with the exception of the brewery malt smell and a few other odors typical of large operations.

Figures 9, 10, and 11 compare graphically the frequency of kinds of odors detected during the 2-week period for St. Louis, St. Louis County, Illinois, and the

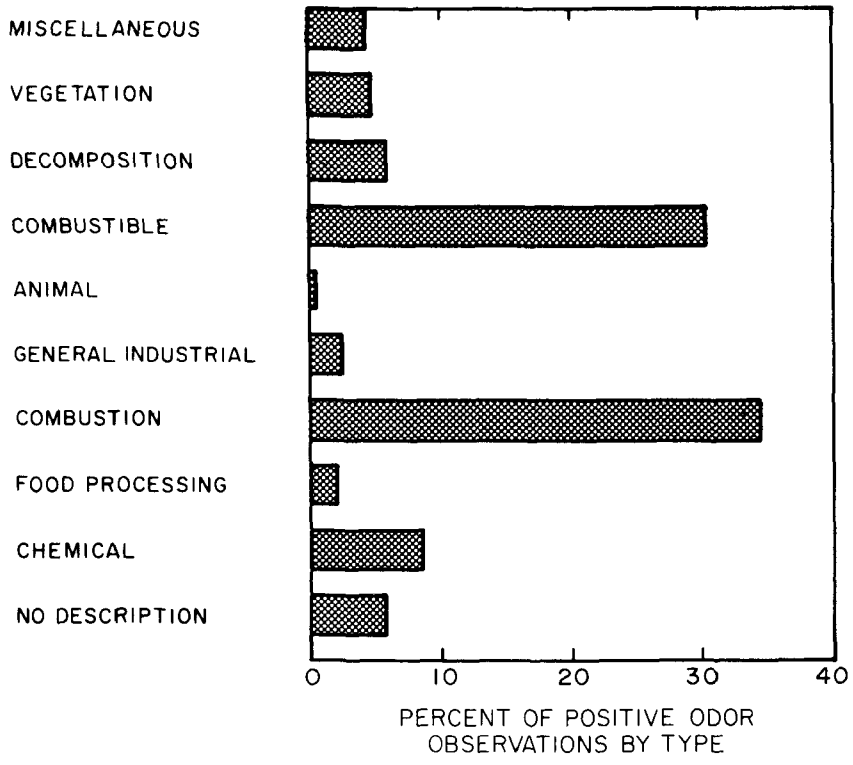

Figure 7. Odor type in St. Louis County - Phase II Odor Survey.

entire metropolitan area as a whole. Figure 12 indicates the frequency of occurrence of the different types of odors that were described as unpleasant.

St. Louis

Table 6 reports the number of odors of each category by inspector territory. Based on percent of total observations, chemical odors are most prevalent in territories 2, 8, 9, and 10; whereas, combustion odors prevail in territories 1, 3, and 4. Other odors also vary among territories, but not so markedly. The prevalence of combustion odors causes territories 3 and 4 to have the two highest percent frequencies of total odors. Territory 10 experienced the third highest percent frequency of total odors, primarily because of the large number of chemical odors reported.

METEOROLOGICAL CONDITIONS

Wind Speed

Figure 13 shows graphically how the frequency of odor detection decreases with an increasing wind speed; a more detailed analysis is given in Table 7. The reasons for the comparatively high frequency of odors in the 20-to-30-mile-per-

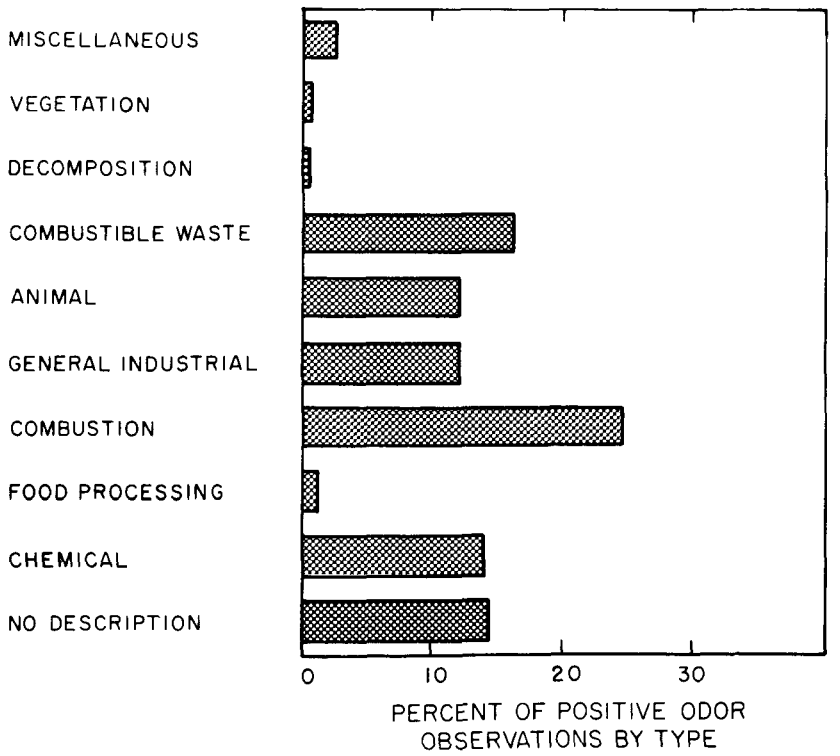

Figure 8. Odor type in Illinois - Phase II Odor Survey.

Table 6. KINDS OF ODORS DETECTED IN ST. LOUIS - PHASE II ODOR SURVEY

Inspector territory	Total observations	Chemical	Food processing	Combustion	General industrial	Animal	Combustible waste	Decomposition	Vegetation	Miscellaneous
No. 1	308	19	1	35	8		18	9		8
No. 2	254	24		14		5	30		1	9
No. 3	197		2	50			18	10	1	68
No. 4	132	2		58			18			1
No. 5	264	9	4	15	2		25	6	1	9
No. 6	194	1	4	9	1		12	3		
No. 7	216	9	15	6	1		9	5		9
No. 8 and 9	190	17	1	5			8	4		7
No. 10	580	110	9	52	2	10	14	8	1	11

hour range in the Illinois area is not clear. The data indicate that wind speeds of less than 15 mph accompany a rapid increase in odors detected to a high of 43 percent at 0 to 5 mph. Above 10 mph the frequency of odors detected decreases, but at a slower rate. When the wind speed drops below 10 mph, a condition that

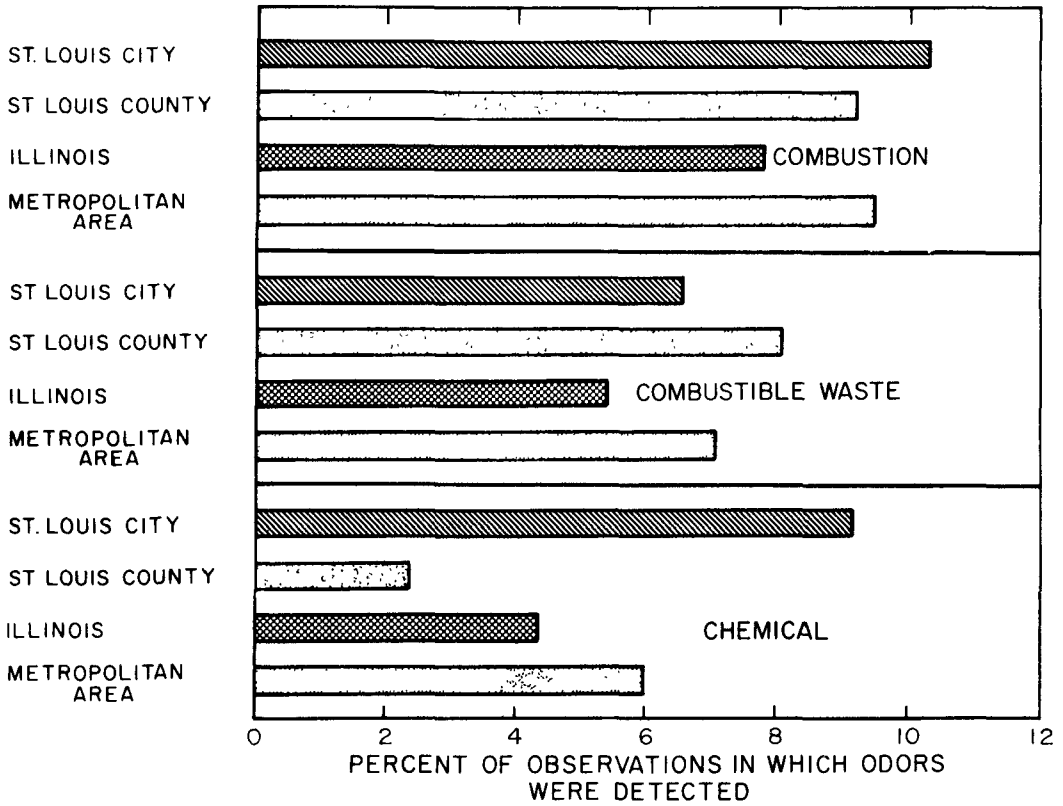

Figure 9. Variation of combustion, combustible waste, and chemical odors in different parts of Study area - Phase II Odor Survey.

Table 7. ODOR VARIATIONS WITH WIND SPEED - PHASE II ODOR SURVEY

Area	Wind speed, mph					
	0-5	5-10	10-15	15-20	20-25	25-30
St. Louis						
Positive observations[a]	220	325	121	83	34	4
Total observations	464	875	487	380	206	34
% positive	47.4	37.1	24.8	21.8	16.5	11.8
St. Louis County						
Positive observations	119	197	63	51	18	2
Total observations	329	645	353	282	148	27
% positive	36.2	30.5	17.8	18.1	12.2	7.4
Illinois						
Positive observations	66	97	39	28	15	3
Total observations	148	282	159	125	66	12
% positive	44.6	34.4	24.5	22.4	22.7	25.0
Metropolitan area						
Positive observations	405	619	223	162	67	9
Total observations	941	1,802	999	787	420	73
% positive	43.0	34.4	22.3	20.6	16.0	12.3

[a]Positive observation means odor detected.

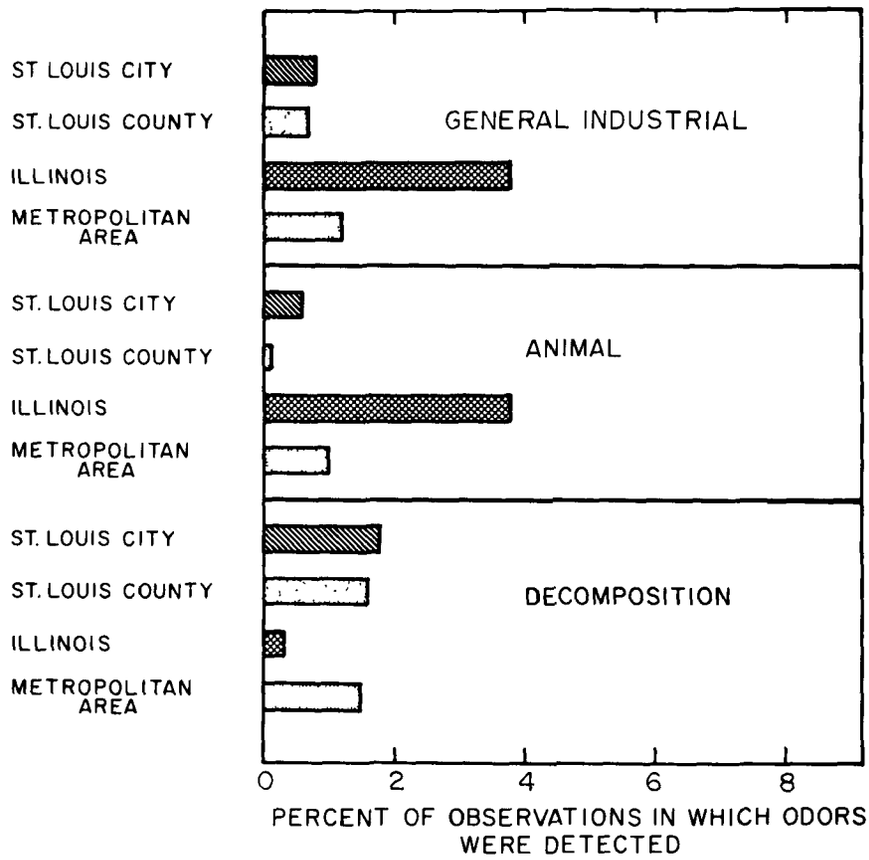

Figure 10. Variation of general industrial, animal, and decomposition odors in different parts of Study area - Phase II Odor Survey.

occurs 58 percent of the time, the potential for a community odor episode increases greatly.

Atmospheric Stability

Figure 14 and Table 8 present a comparison of odor frequencies as related to the Pasquill-Gifford-Turner stability classes. An explanation of these classes is given in Appendix D.

Because of the low solar altitude during the late fall, moderate to strong insolation conditions do not exist (see Table D-1, Appendix D). Stability class 1 is associated solely with moderate and strong insolation conditions, and class 2 also involves these insolation conditions. It is not surprising, therefore, that stability classes 1 and 2 did not occur during the study period.

An examination of Figure 14 reveals that the lowest frequency of odor detection occurred with the neutral condition 4 rather than with the more unstable condition 3. The reason for this is apparently due to the higher wind speeds that accompany con-

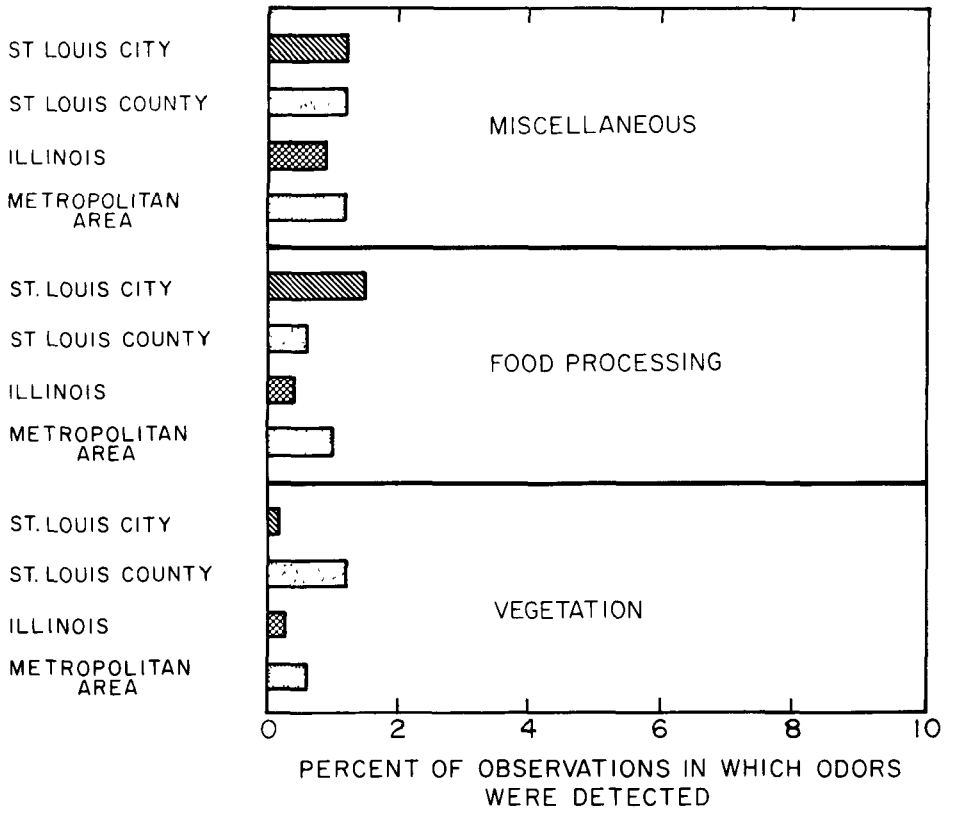

Figure 11. Variation of miscellaneous, food processing, and vegetation odors in different parts of Study area - Phase II Odor Survey.

dition 4. These higher wind speeds are evidently more effective in diluting odors than are the slightly unstable conditions of class 3 accompanied by lower wind speeds. This situation is also illustrated in Figure 15, which points to the high occurrence of odor detections with the low wind speeds accompanying the more stable conditions 5 and 6.

Under conditions 5 and 6 odors can travel for long distances at high concentrations, partially because these are the most stable of the atmospheric conditions and partially because of the low wind speeds accompanying them.

Precipitation

The relationship between occurrence of rain and the frequency of odor detection is illustrated in Figure 16. During rainy conditions the frequency of odor detection in the metropolitan area was 20 percent as against 31 percent for no-rain conditions.

One of the main factors contributing to this decrease would be the reduction in the amount of combustible wastes burned when it raining. Also, during this period of the year precipitation often occurs with a frontal movement, which tends to force out the existing air mass and replace it with cleaner air. In addition, these frontal movements are generally accompanied by higher than average wind speeds and increased instability, which also aid in the dispersal of pollutants.

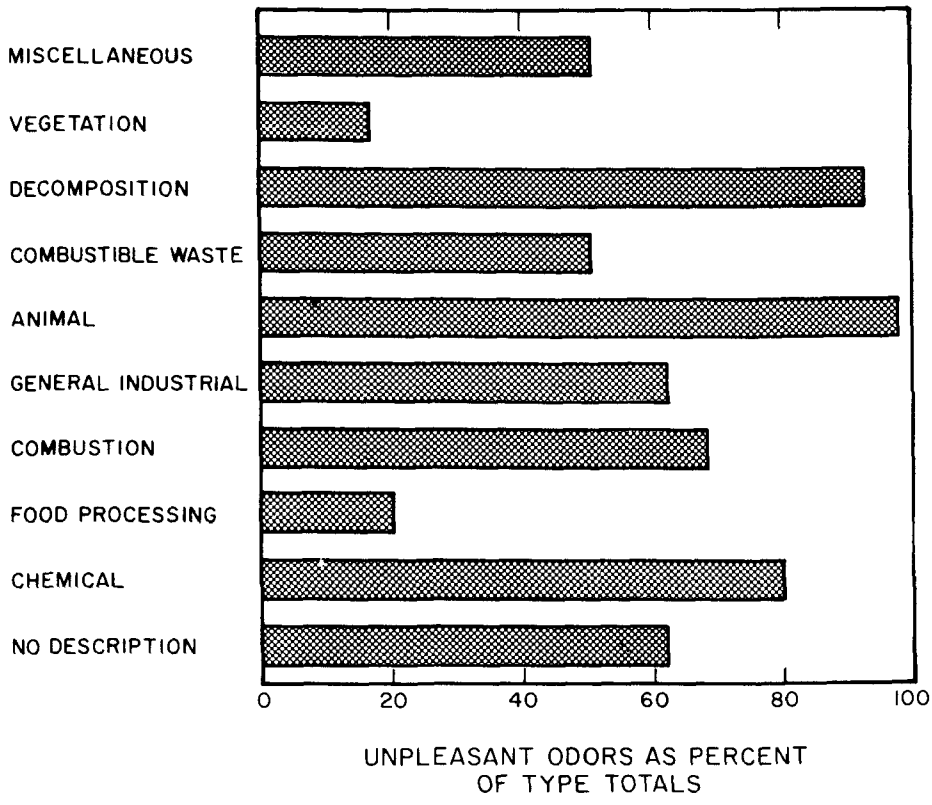

Figure 12. Percent of each odor type considered unpleasant by observers in St. Louis Metropolitan Area - Phase II Odor Survey.

Table 8. ODOR VARIATION WITH STABILITY - PHASE II ODOR SURVEY

Area	Stability class					
	1	2	3	4	5	6
St. Louis						
Positive observations[a]	-	-	83	231	95	378
Total observations	-	-	249	1,072	274	851
% positive	-	-	33.3	21.5	34.7	44.4
St. Louis County						
Positive observations	-	-	60	122	68	200
Total observations	-	-	191	779	207	607
% positive	-	-	31.4	15.7	32.9	32.9
Illinois						
Positive observations	-	-	21	83	34	110
Total observations	-	-	83	348	96	265
% positive	-	-	25.3	23.9	35.4	41.5
Metropolitan Area						
Positive observations	-	-	164	436	197	688
Total observations	-	-	523	2,199	577	1,723
% positive	-	-	31.4	19.8	34.1	39.9

[a]Positive observation means odor detected.

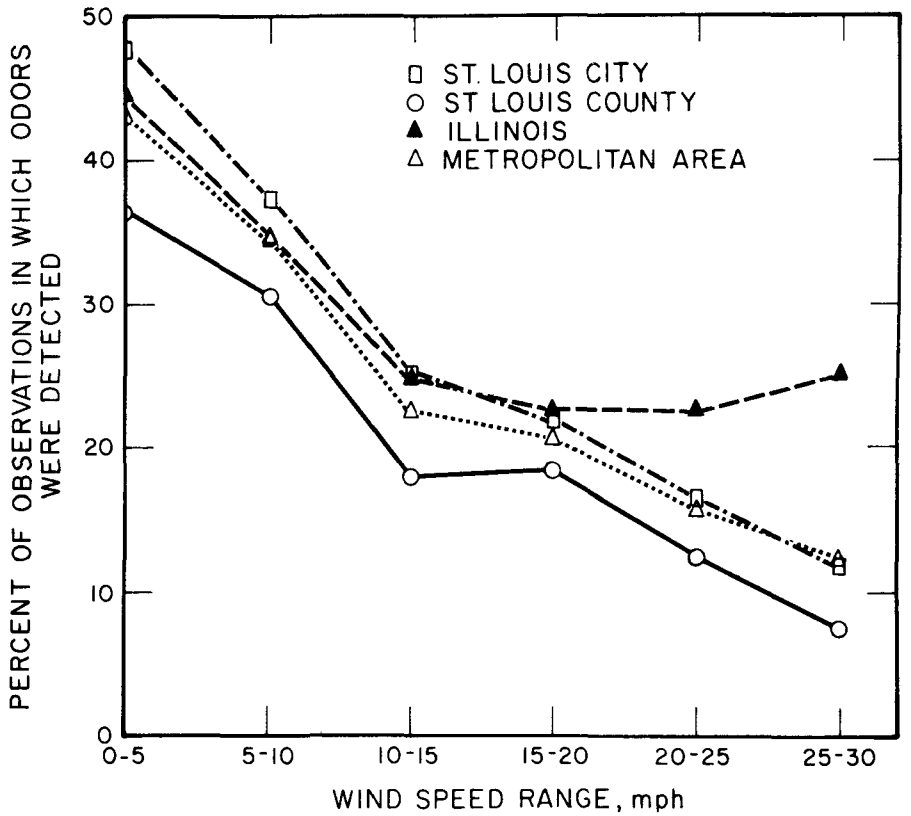

Figure 13. Odor variations with wind speed - Phase II Odor Survey.

LOCATION OF ODORS

Odors can be detected in almost every type of area - residential, commercial, and industrial. Although the majority of the most objectionable odors are usually produced in the industrial and commercial areas, residential zones are the source of various odors; these odors most often originate from food preparation and the disposal of solid wastes by combustion and in the form of sewage.

Odors are expected to be more prevalent in industrial areas than they would be in commercial or residential areas. The frequency of odors by zoning classification of the area in which the observation points were located was determined and is reported in Figure 17. It shows that the commercial and industrial zones* in the St. Louis Metropolitan Area had 46.5 percent positive odor observation compared to 28.5 percent for the business zones and 25.2 percent for the residential area. The percentage of positive odor observations that were reported as unpleasant ranged from 71 for commercial and industrial zones to 58 for residential zones (Figure 18). Figure 19 shows the industrial parts of the St. Louis Metropolitan Area. These areas and the neighborhoods surrounding them would have odors most frequently detected in them.

*The Revised Code of St. Louis, 1948, was used as a guide in establishing the zoning classifications used in this report.

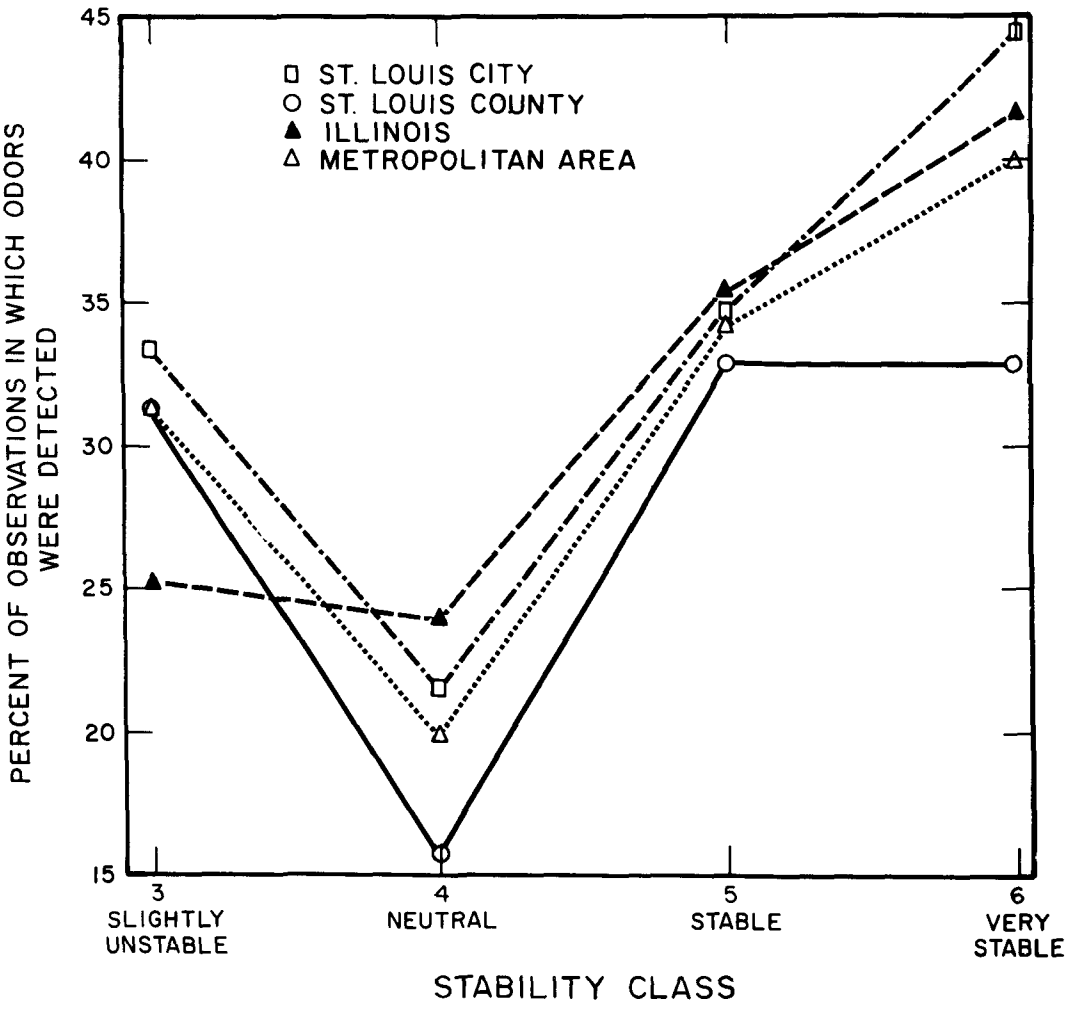

Figure 14. Odor variations with stability classes - Phase II Odor Survey.

A few characteristic odor types familiar to most residents of metropolitan St. Louis were selected for further study. The first was chemical odors. The area affected is shown in Figure 20. The darker area on the figure has the higher level of odors. Chemical odors are a significant problem in the cities of St. Louis and East St. Louis, but St. Louis County is relatively free from them.

The second odor type selected for further study was rendering and meat packing. Figure 21 shows the areas affected by odors from the meat processing industries. The areas shown here are relatively small compared to those affected by the chemical odors, but because of their extreme unpleasantness they are of major importance. Here again this problem is found only in St. Louis and Illinois.

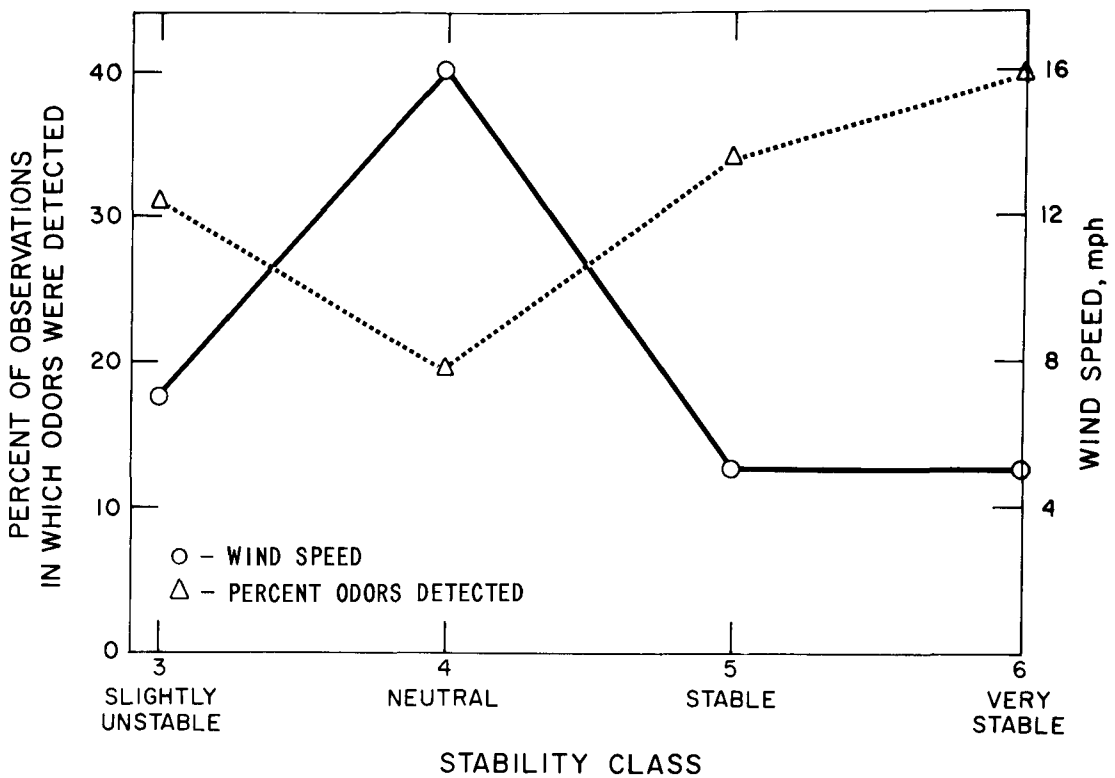

Figure 15. Comparison of odor detection and wind velocity with stability class - Phase II Odor Survey.

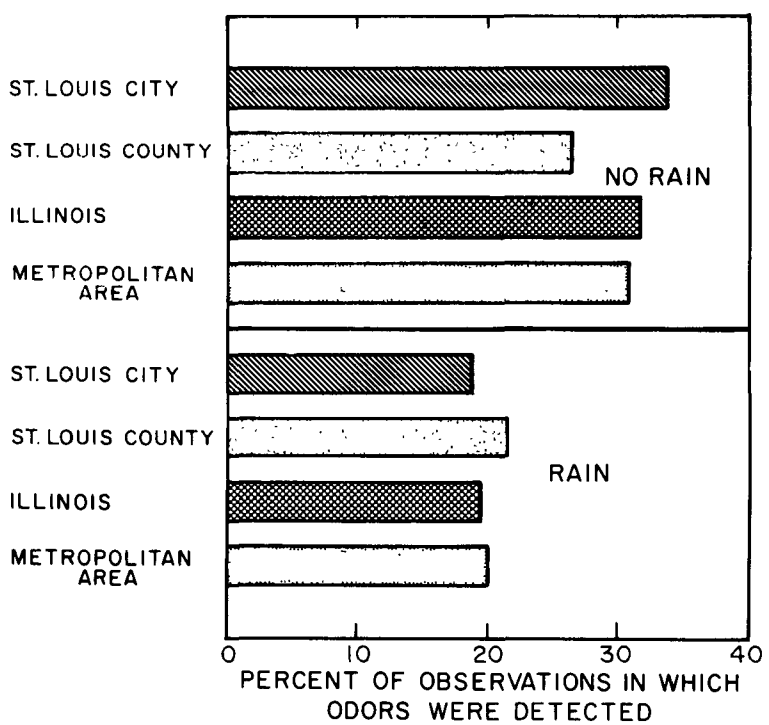

Figure 16. Odor variations with precipitation - Phase II Odor Survey.

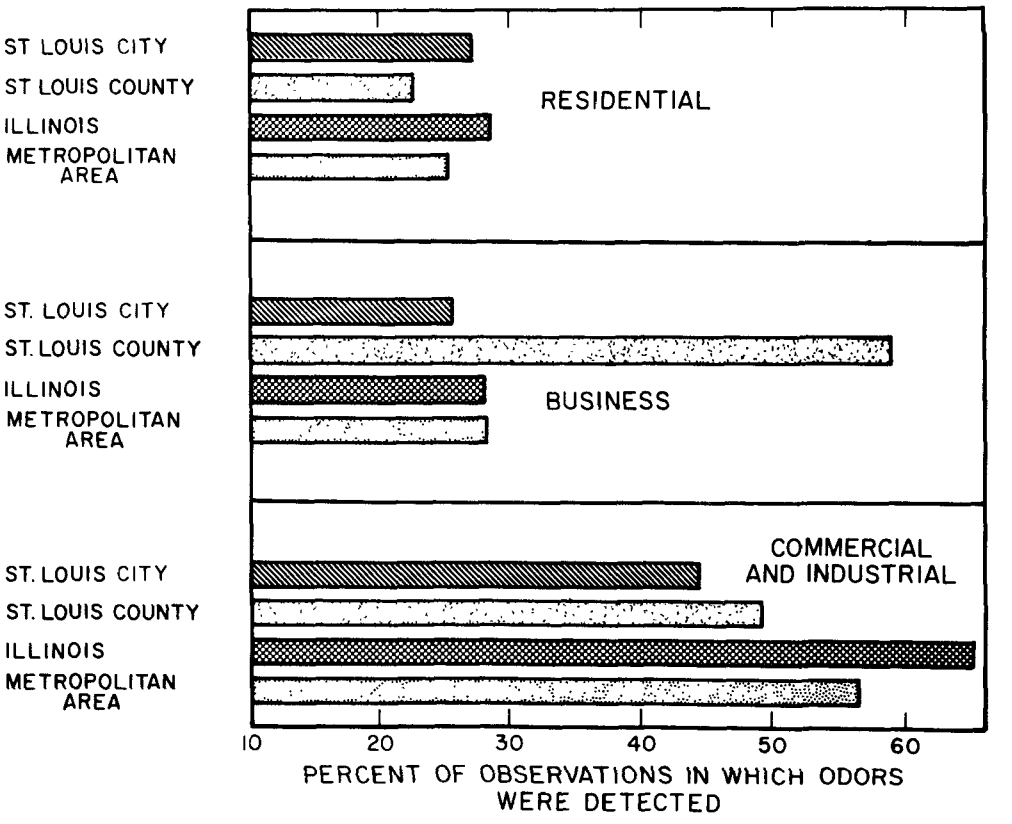

Figure 17. Odor variations associated with land use - Phase II Odor Survey.

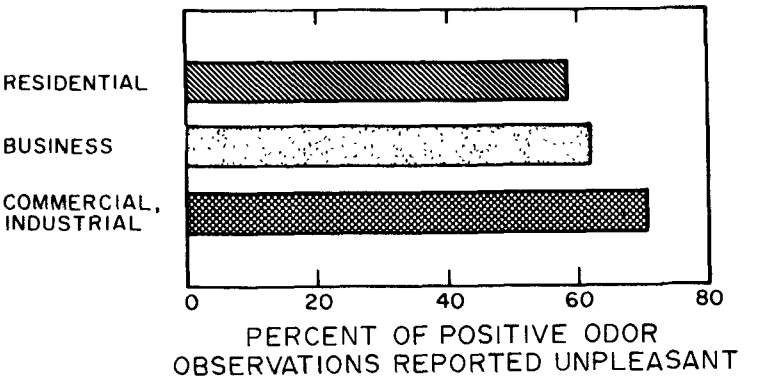

Figure 18. Unpleasant odor variations associated with land use in Study area - Phase II Odor Survey.

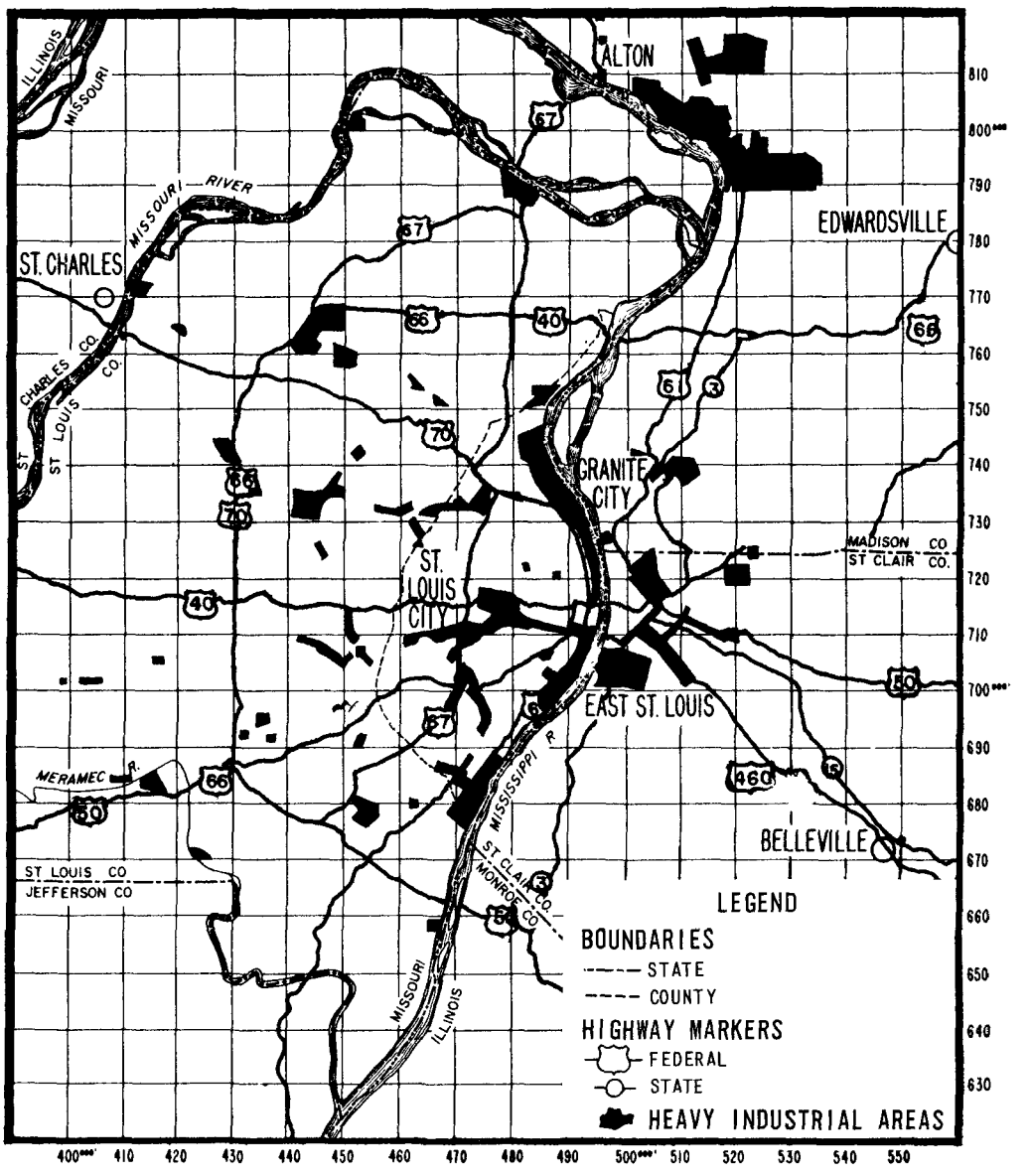

Figure 19. Heavy industrial areas.

Odors produced by burning dumps are a problem of considerable magnitude to the residents of the Illinois area and St. Louis County. Because the contaminants from these sources are released at ground level, they are capable of affecting a considerable geographical area before being dissipated. Since odors produced by burning dumps are very similar to those produced by burning garbage and rubbish in alleys and back yards, the areas affected by these two types of sources could not be separated and were, therefore, not mapped.

EFFECT OF METEOROLOGY ON ODOR OBSERVATION FREQUENCY

Although each of the meteorological elements considered in this section has some bearing on the frequency of positive odor observations, none is as important

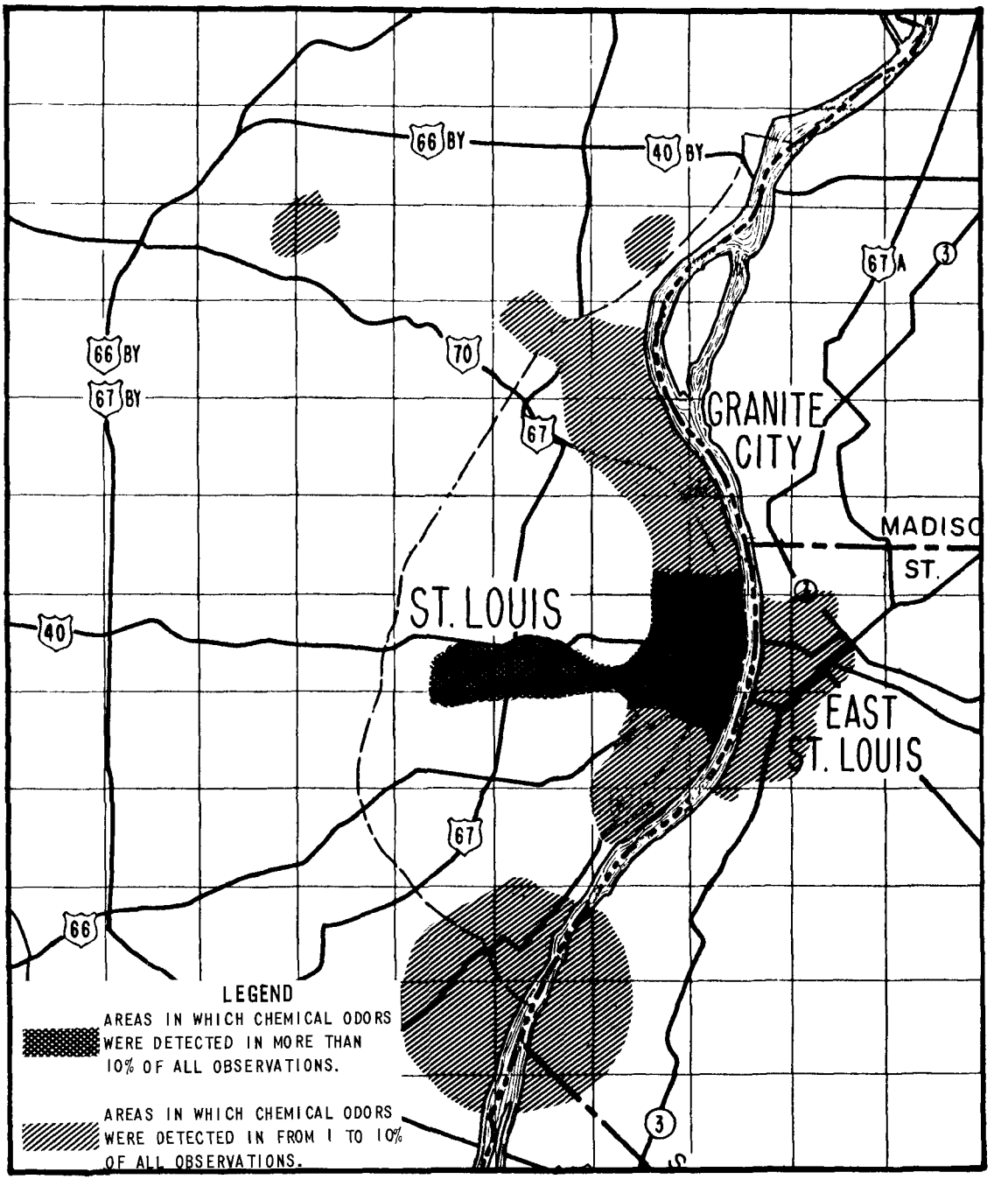

Figure 20. Areas where chemical odors were detected relatively frequently.

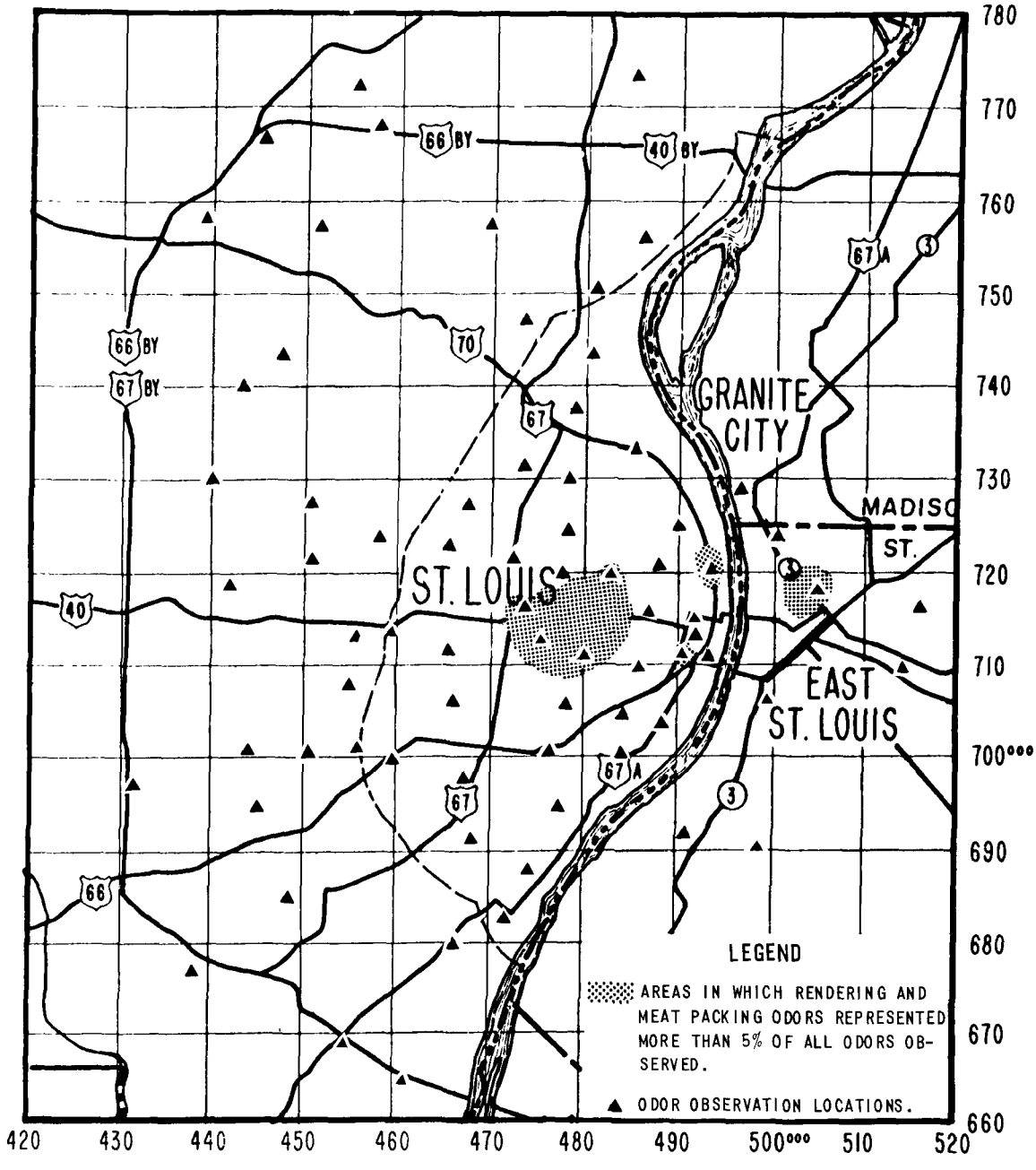

Figure 21. Area affected by rendering and meat packing odors.

as wind direction. It not only controls where the odor will be observed but also gives a very good indication of the source. The relationship between percent positive odor observations and wind direction is shown in Figure 22. Table 9 gives a detailed breakdown of these same data. Note that the east wind is associated with higher odor levels in all areas except Illinois.

Tables 10 through 12 show, respectively, the influence that would be expected on the frequency of odor detection from the meteorological factors of wind speed,

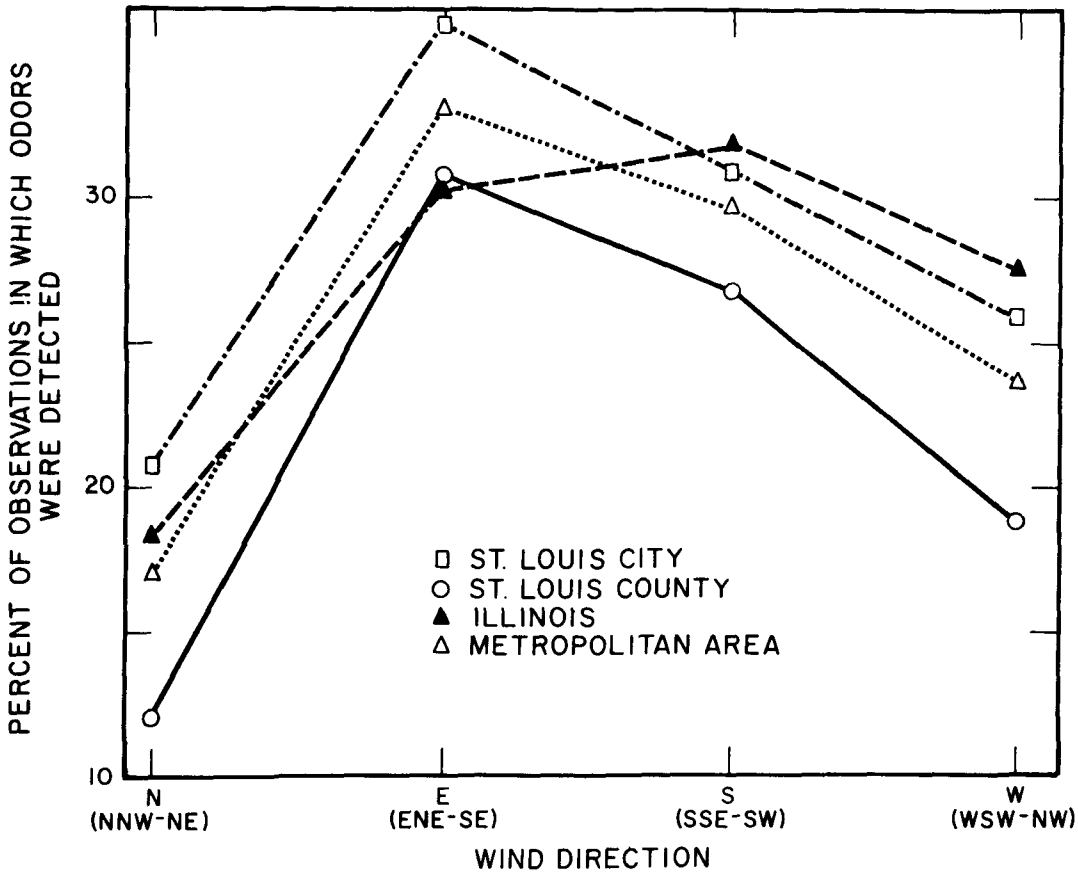

Figure 22. Odor variations with wind direction - Phase II Odor Survey.

atmospheric stability, and precipitation. The data for the northerly directions are very meager; however, for the sake of completeness the data for this direction have been included. Table 10 indicates that the percentage of winds less than 10 mph was zero for northerly winds, 47 for easterly winds, 80 for southerly winds, and 41 for westerly winds. If wind speed were the only factor influencing the frequency of positive odors, the expected order of decreasing frequencies would be S, E, W, and N because odors would be detected more frequently with winds of less than 10 mph.

The effect that atmospheric stability would have on the frequency of odor detection is shown in Table 11. Stability condition 6 produced the highest frequency of positive odor observations during the study (Figure 15). The percentages of observation times with class 6 stability for the E, S, W, and N direction were 41, 20, 19, and 0, respectively.

The occurrence of precipitation during the study period, on a percentage basis (Table 12), was highest when winds came from the easterly and southerly directions; therefore, on the basis of precipitation it should be expected that the overall frequency of positive odor observations with winds stemming from these directions would be lower.

Table 9. ODOR VARIATIONS WITH WIND DIRECTION - PHASE II ODOR SURVEY

Area	Wind direction				
	NNW-NE N	ENE-SE E	SSE-SW S	WSW-NW W	Calm
St. Louis					
Positive observations[a]	7	215	108	287	170
Total observations	34	599	351	1,106	356
% positive	20.6	35.9	30.8	25.9	47.8
St. Louis County					
Positive observations	3	137	62	155	93
Total observations	25	446	232	824	257
% positive	12	30.7	26.7	18.8	36.2
Illinois					
Positive observations	2	58	36	99	53
Total observations	11	193	113	360	115
% positive	18.2	30.1	31.9	27.5	46.1
Metropolitan Area					
Positive observations	12	410	206	541	316
Total observations	70	1,238	696	2,290	728
% positive	17.1	33.1	29.6	23.6	43.4

[a]Positive obersvation means odor detected.

Table 10. WIND SPEEDS AND WIND DIRECTION

Wind direction	Wind observations		Total	% of times wind is < 10 mph	Expected order of decreasing frequencies of odor occurrence
	0-10 mph	10-30 mph			
N (NNW-NE)	0	1	1	0	4
E (ENE-SE)	8	9	17	47	2
S (SSE-SW)	8	2	10	80	1
W (WSW-NW)	13	19	32	41	3

Summarizing the meteorological factors of wind speed and stability associated with the various wind directions as they occurred during the survey (Table 13) should have given the highest frequency of positive odor observations from a southerly direction, with the second highest from the east. Precipitation as it occurred indicated that the southerly and easterly wind directions would produce the lowest frequency of odors. The actual frequency of positive odor observations for St. Louis and St. Louis County, however, occurred with easterly winds instead of southerly winds, as predicted by the meteorological variables. It is concluded, therefore, that source location coupled with wind direction causes the odor frequency maximum

Table 11. STABILITY AND WIND DIRECTION

Wind direction	Stability class observations				Total	% 6	Expected order of decreasing frequencies of odor occurrence
	3	4	5	6			
N (NNW-NE)	-	1	-	-	1	0	4
E (ENE-SE)	2	8	-	7	17	41	1
S (SSE-SW)	4	3	1	2	10	20	2
W (WSW-NW)	2	20	4	6	32	19	3

Table 12. PRECIPITATION AND WIND DIRECTION

Wind direction	Weather observations accompanied by rain		Total	% rain	Expected order of decreasing frequencies of odor occurrence
	Rain	No rain			
N (NNW-NE)	-	1	1	0	1
E (ENE-SE)	3	14	17	18	3
S (SSE-SW)	2	8	10	20	4
W (WSW-NW)	3	29	32	9	2

Table 13. SUMMARY OF RANKINGS OF ACTUAL AND EXPECTED FREQUENCIES BASED ON METEOROLOGICAL CONDITIONS EXISTING FOR WIND DIRECTIONS

Wind direction	Expected order of decreasing frequencies				Actual order of decreasing frequencies			
	Wind speed	Stability	Precipitation	Combined effect	Metro	St. Louis	St. Louis County	Ill.
N (NNW-NE)	4	4	1	4	4	4	4	4
E (ENE-SE)	2	2	3	2	1	1	1	2
S (SSE-SW)	1	1	4	1	2	2	2	1
W (WSW-NW)	3	3	2	3	3	3	3	3

with the easterly direction in these areas. The Illinois area ranking does follow the expected order, and, therefore, indicates the proximity of sources to observation points. An example of the importance of wind speed and stability, as well as direction, was shown by the odor episode that occurred on the evening of November 24, 1963. It was accompanied by stability class 6 and winds of 8 miles per hour or less.

Figure 23 emphasizes the importance of wind direction in connection with the detection of chemical odors. The data concerning this type of odor were correlated with wind direction for each of the sampling stations, and for each station the wind direction corresponding to the greatest number of chemical odor observations was selected and plotted on the map. The length of the arrow is proportional to the number of times chemical odors were observed. With but two exceptions, these odor vectors are associated with winds blowing from the ESE to SSE directions; and as is indicated on the map, the majority of the observation stations experiencing frequent chemical odors are located within the City of St. Louis. The figure defines the odor relationship between the large chemical manufacturing complex on the east side of the Mississippi River and the downtown area of St. Louis, where unpleasant chemical odors are often observed.

ODOR SOURCES

Figure 24 through 26 show the location of potential sources of odors in St. Louis, St. Louis County, and Illinois, respectively. The sources are classified into nine (five general and four specific) types. The type of odor indicated for a particular potential source was determined from the nature of the activities responsible for the emissions. Figure 27 shows the locations of the solid waste disposal sites and municipal incinerators for the metropolitan area.

The figures show that most of the potential odor sources are located along the Mississippi River on the east side of St. Louis, and in and around East St. Louis, Illinois. Only a few potential odor sources exist in St. Louis County.

ODOR EPISODE

A severe odor episode was experienced during the Phase II Odor Survey on Sunday evening, November 24, 1963. The St. Louis Police Department and the Laclede Gas Company received over 100 complaints before 8:00 p.m. An inspector for the St. Louis Division of Air Pollution Control was called in to investigate the complaints. By traversing the area in his automobile, he was able to trace the odor all the way back to the edge of the Mississippi River. Since the wind was from a southeasterly direction, he concluded that the odor was originating across the river in Illinois.

The data collected by the odor survey network the evening of the odor episode are presented in three maps, Figures 28, 29, and 30, one for each observation time. The chemical odor observations made during the episode, according to the category established in Table 1, were used to draw rough boundary lines around the area affected. The 8:00 p.m. map (Figure 28) shows the odors extending all the way from the Mississippi River to Lindberg Road, a distance of more than 10 miles. The cone-shaped path expanding out in the direction of the wind is the normal diffusion pattern for emissions from a point source with a steady wind. The 10:00 p.m. and midnight maps are almost identical, except that by midnight the

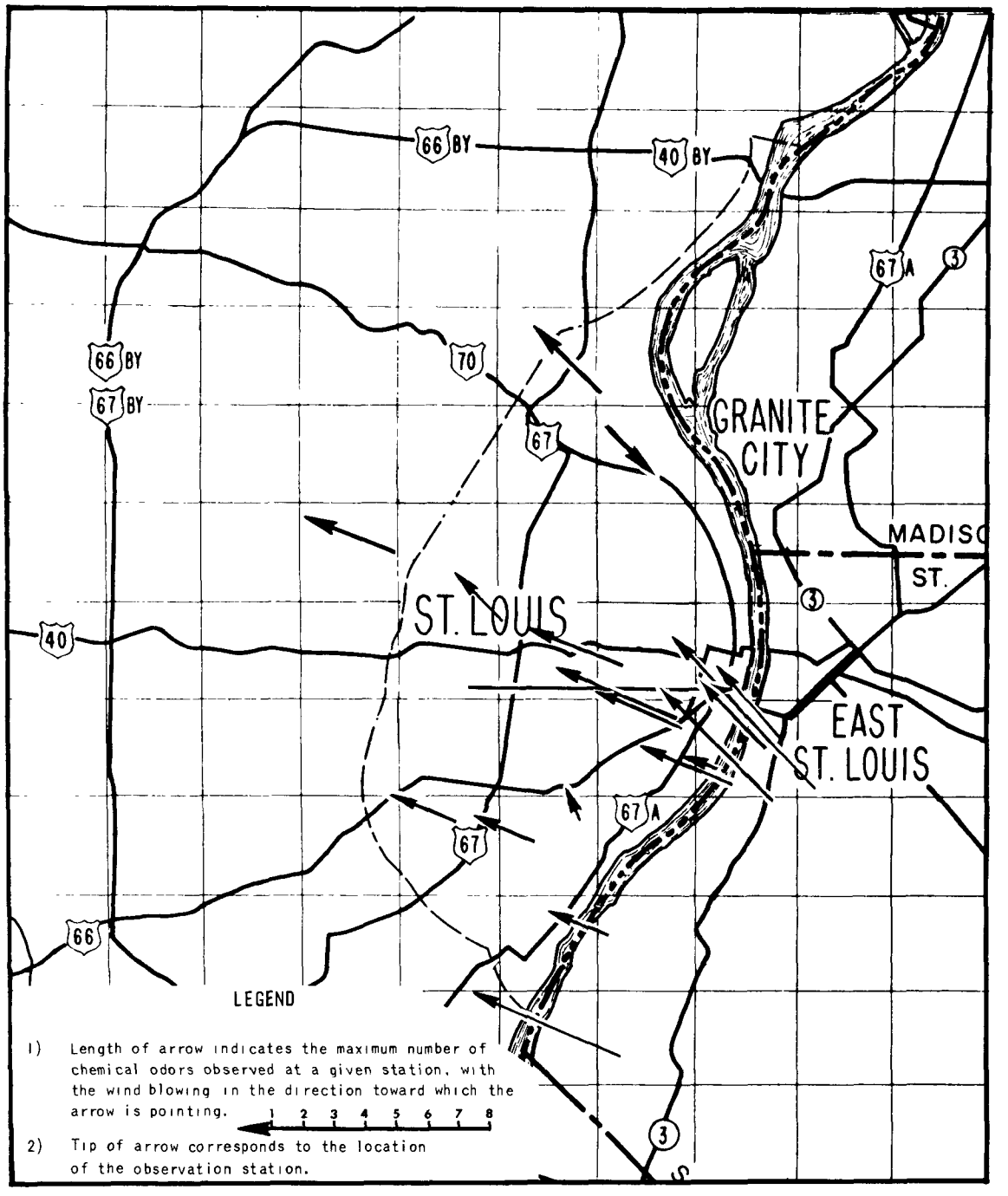

Figure 23. Association of chemical odor observations with wind direction.

GPO 828-153-5

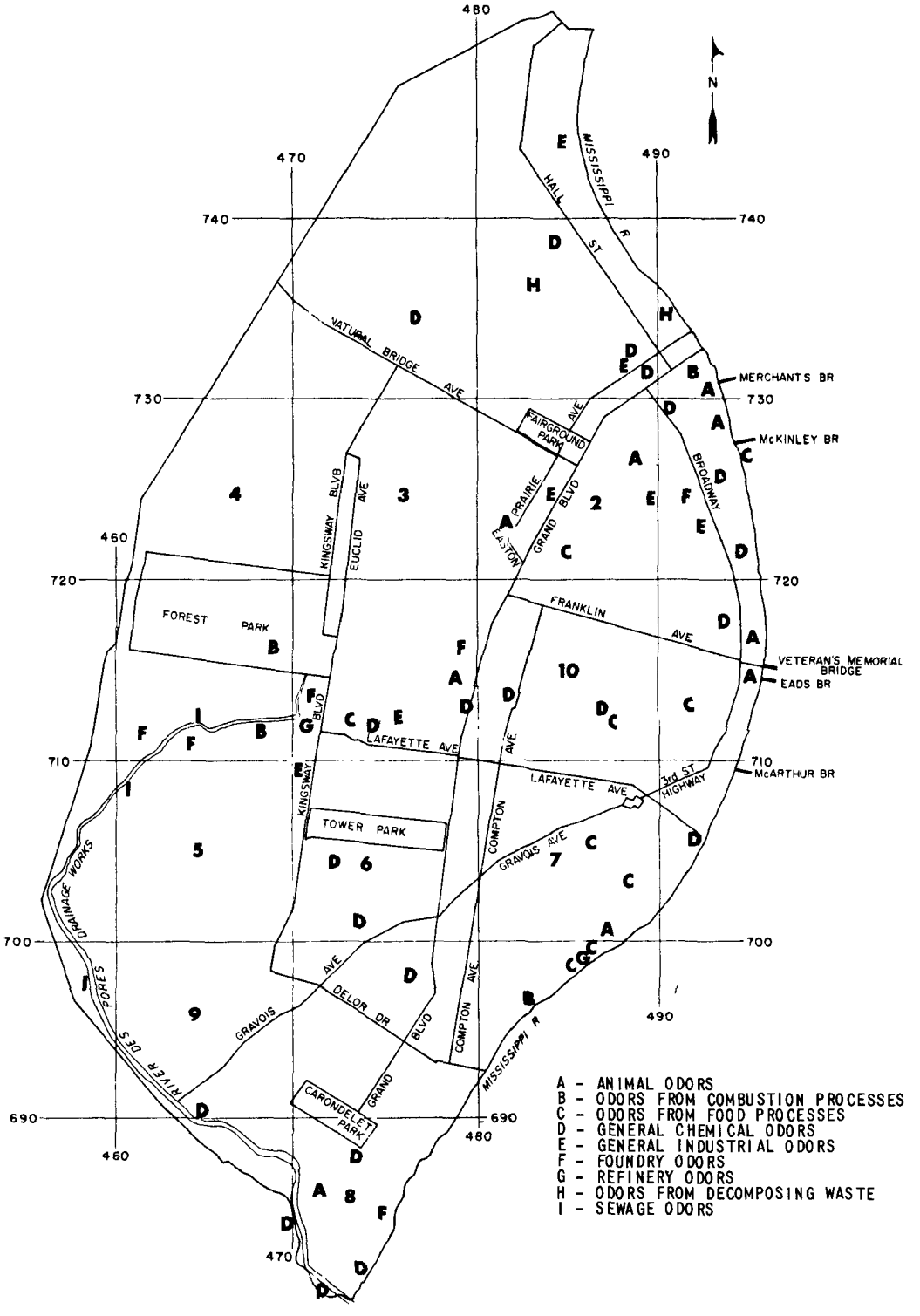

Figure 24. Location of potential odor sources in St. Louis.

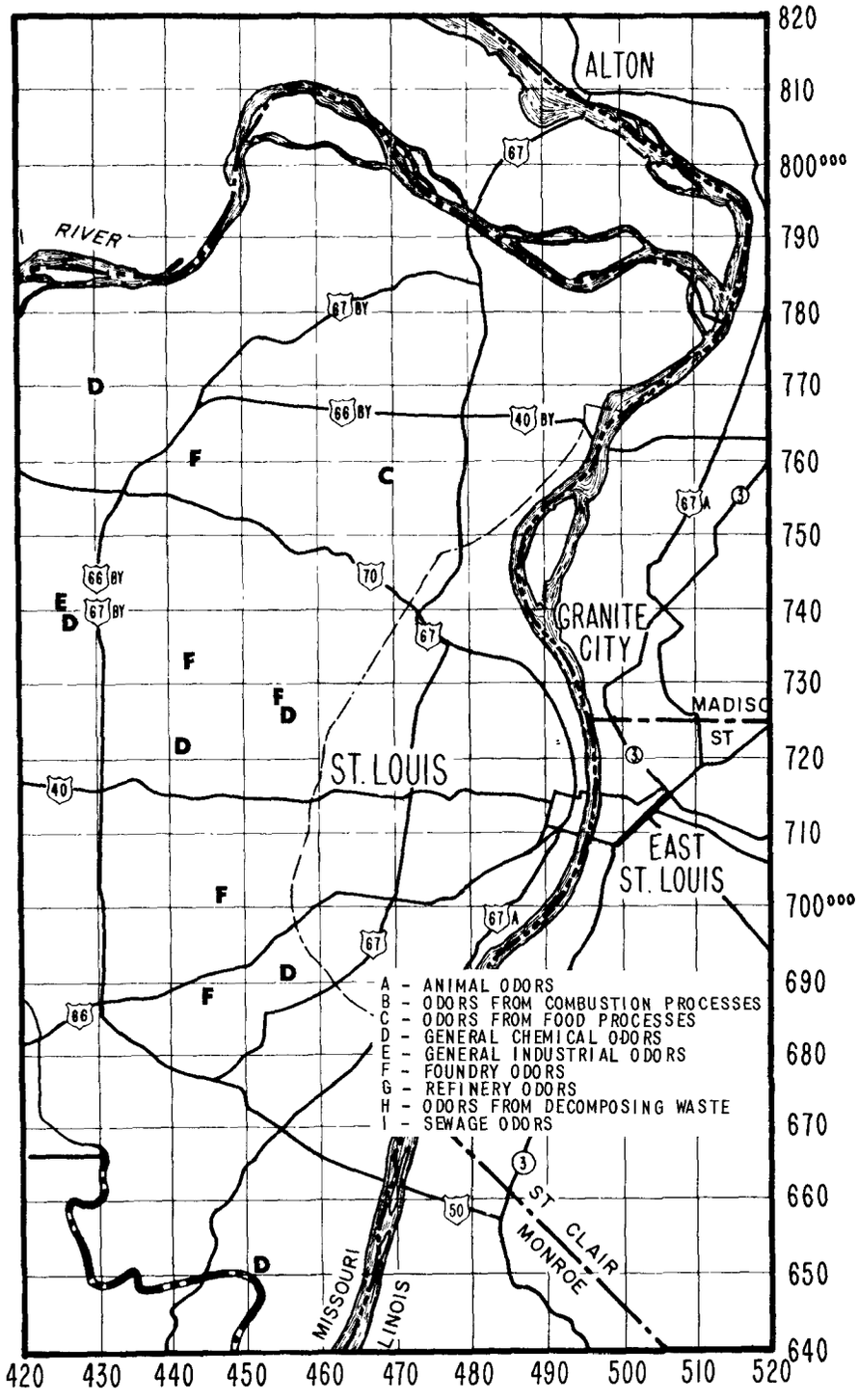

Figure 25. Potential odor sources in St. Louis County.

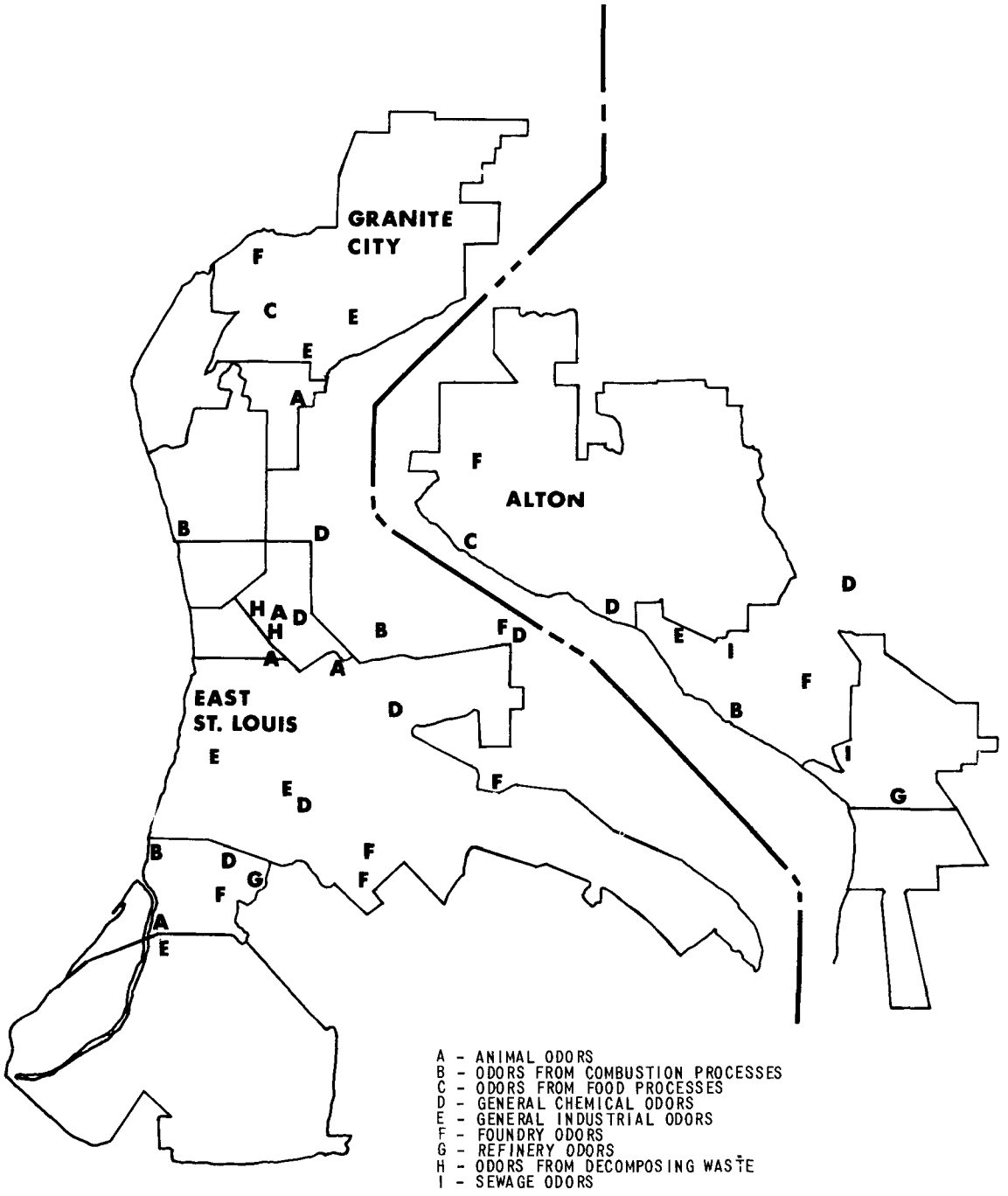

Figure 26. Potential odor sources in Illinois portion of Study area.

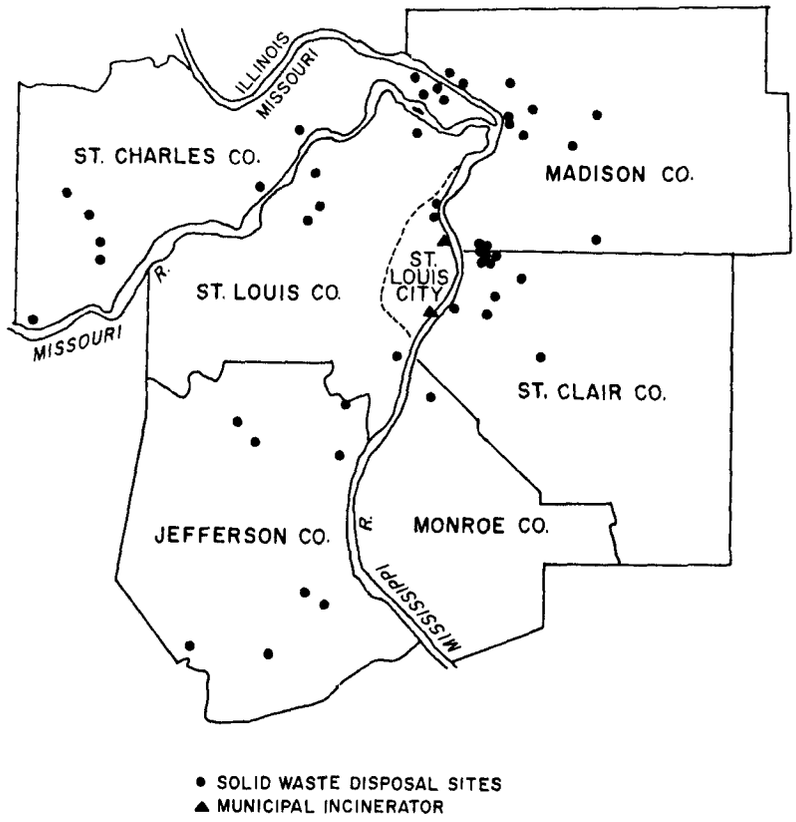

Figure 27. Solid waste disposal sites.

wind had shifted a little more to the east and had caused the diffusion cone to shift to the south. In addition, odors of a similar nature were detected in a circular band along the St. Louis boundary in the south. This circular path follows the low area of South St. Louis along the River des Peres drainage channel. The slight shift in wind direction appears to have caused the diffusion cone to shift enough to the south so that it split in two directions on an east-west ridge that extends along the south of Forest Park. Although the odor path in South St. Louis does not follow the wind direction, such an occurrence is not impossible with the existing topography and meteorological conditions. It is also possible that the odors detected in South St. Louis along the boundary between St. Louis and St. Louis County may have originated from another source located near the mouth of the River des Peres. None of the observers in Illinois experienced any odors that could be associated with this episode.

As expected, the actual descriptions used by the odor observers to describe what was probably the same odor or two odors for the 10:00 p.m. and 12 midnight observations varied considerably. All descriptions seemed to be similar enough for the odor to have been from the same source.

On the evening of November 24, 1963, the winds ranged from 6 to 8 mph from a southeasterly direction. The stability condition was 6 (very stable condition),

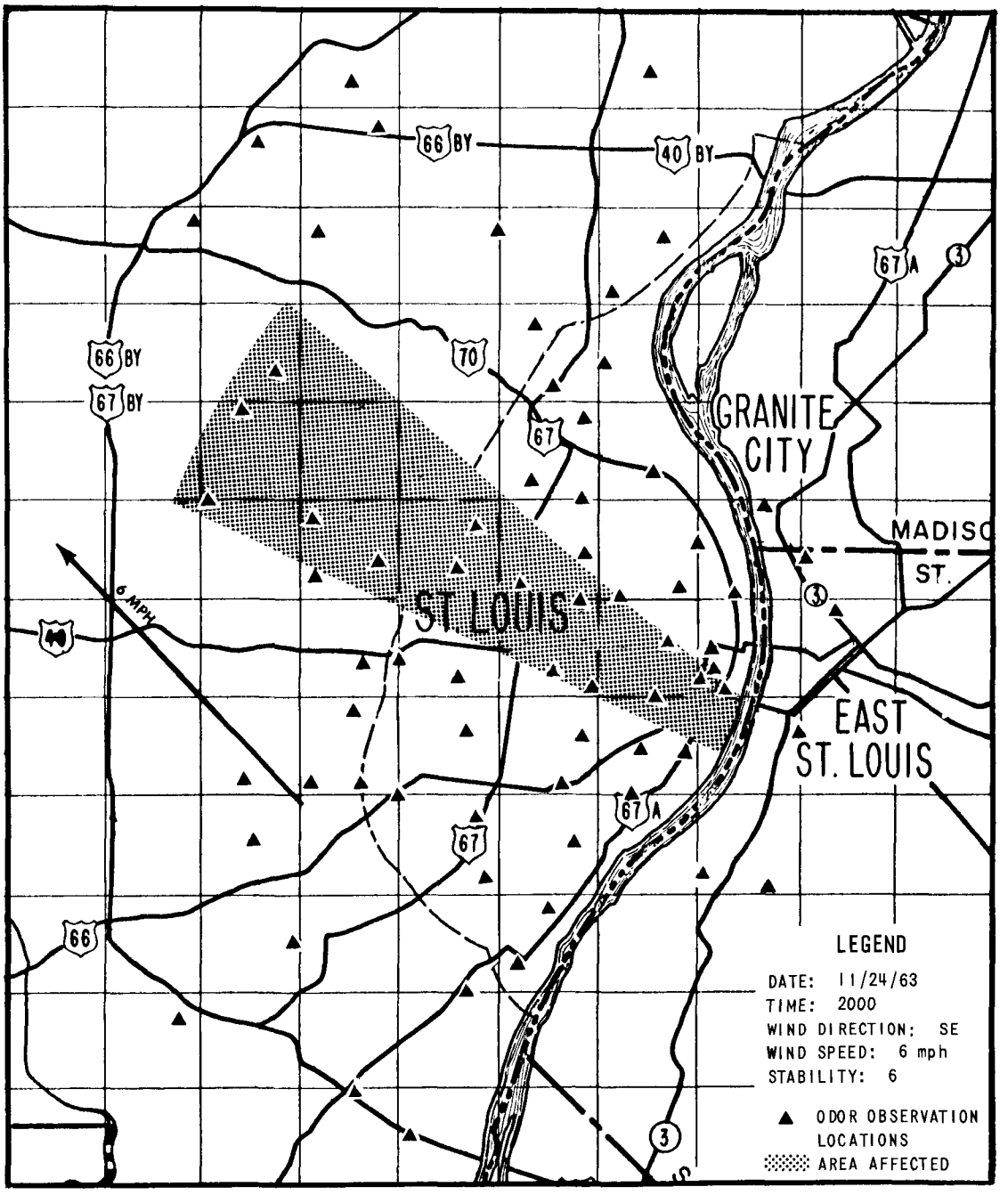

Figure 28. Odor episode, 8 p.m. map.

and there was no rain. Although these conditions are very favorable for an odor episode, they are in no sense unusual and may occur fairly frequently, particularly when an anticyclone passes with its highest pressure zone just to the north of the St. Louis area.

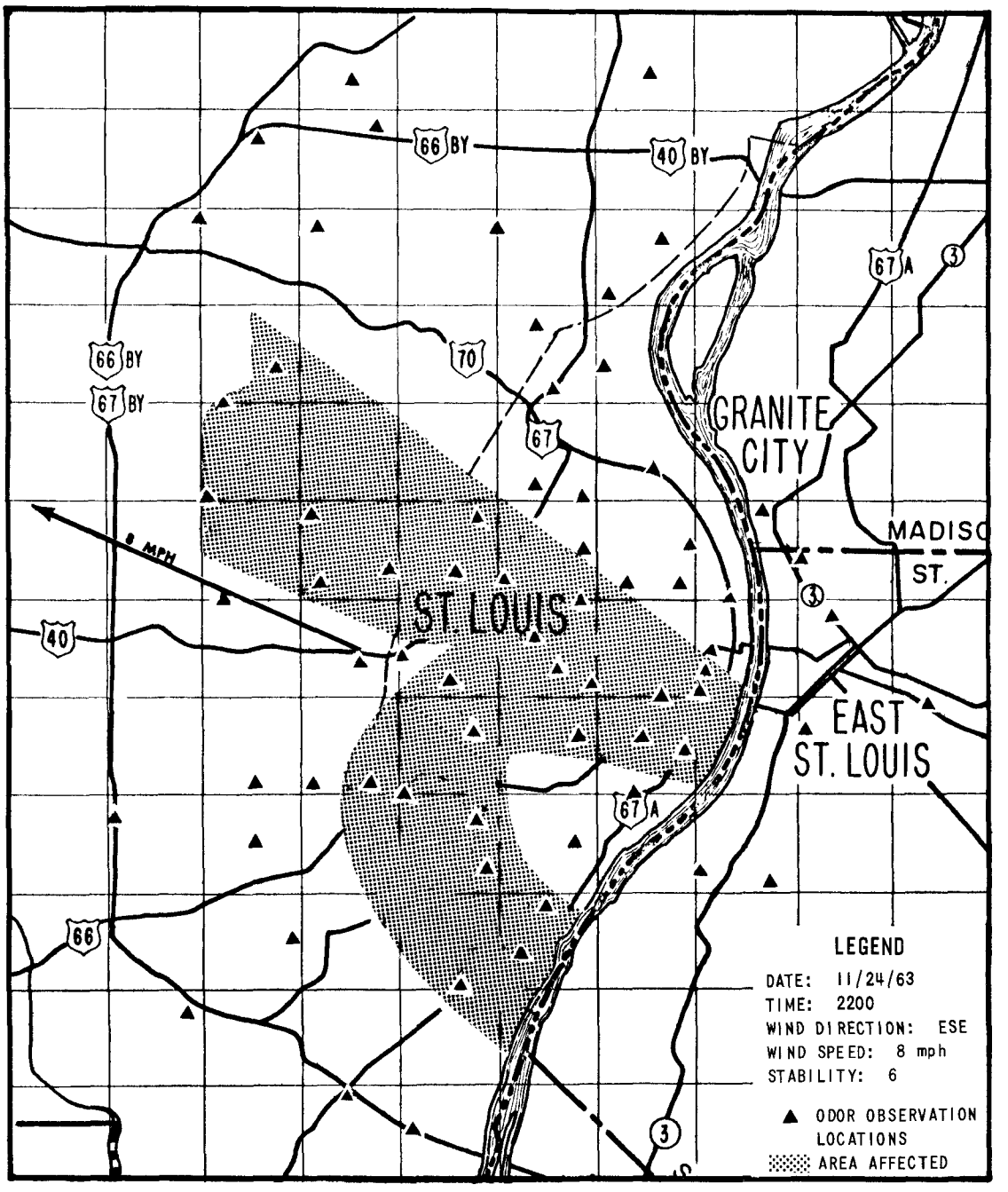

Figure 29. Odor episode, 10 p.m. map.

Although the odor episode of November 24 was probably a result of an industrial breakdown or spill, it clearly illustrates the nature of the interstate chemical odor problem. An odor originating in Illinois resulted in discomfort to a considerable number of people in both St. Louis and St. Louis County in Missouri in an area in excess of 25 square miles.

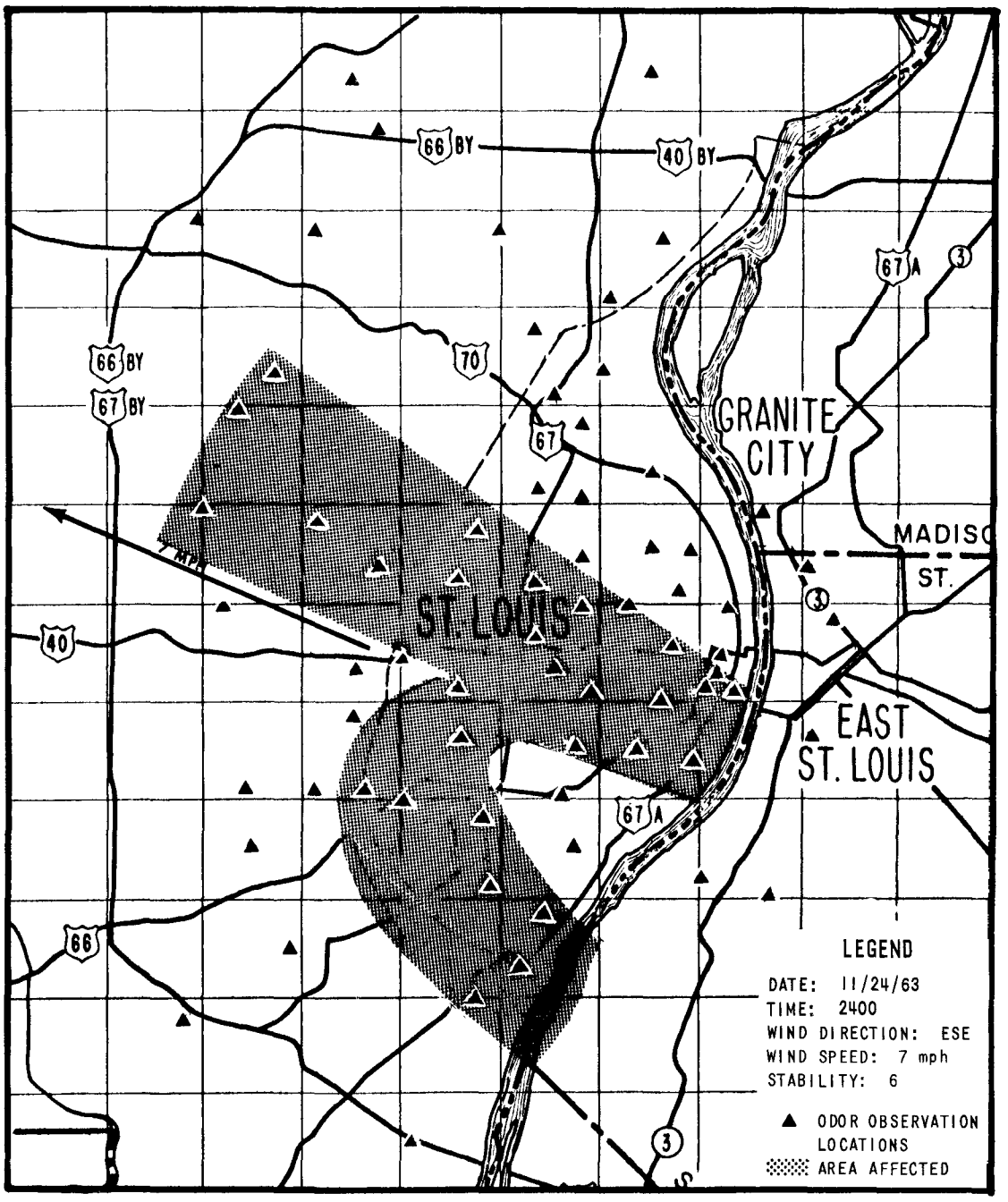

Figure 30. Odor episode, midnight map.

SUMMARY AND CONCLUSIONS

The object of the Phase II Odor Survey was stated in the form of seven questions. Each of these questions is answered and discussed below along with some conclusions drawn from the survey data.

1. What areas in metropolitan St. Louis have odor problems?

Odors were detected more often in St. Louis and Illinois than in St. Louis County. The most objectionable and intense odors occur near the location of large chemical plants and rendering plants. Areas frequently affected by such odors are shown in Figures 20 and 21. The most odorous areas found in metropolitan St. Louis tend to be within or very near commercial and industrial areas (see Figures 18 and 19).

2. What types of odors affect each area?

The occurrence of combustion and combustible waste odors was quite similar for the three areas (Table 14). Chemical odors, on the other hand, were considerably higher in St. Louis than in Illinois or St. Louis County. Combustible waste odors were probably abnormally high because of seasonal leaf burning.

Table 14. PERCENT OF OBSERVATIONS IN WHICH ODORS WERE DETECTED

Type of odor	St. Louis	St. Louis Co.	Illinois
Combustion odors	10.3	9.2	7.8
Combustible waste	6.6	8.1	5.4
Chemical	9.2	2.4	4.4

3. What odor types are the most undesirable?

All types of odors other than food processing and vegetation were described by the observers as being unpleasant over 50 percent of the time. Animal, decomposition, and chemical odors were described as unpleasant most frequently, with 97.9, 93.3, and 80.1 percent, respectively. See Figure 12.

4. When are odors prevalent?

The percent positive odor observations were the highest for the 8:00 p.m. observation time. More odors were generally detected at night than during the day. See Figure 5.

5. What are the meteorological conditions associated with odors?

The meteorological conditions associated with a high frequency of positive odor observations were as follows:

a. Wind speeds less than 10 mph (Figure 13).

b. Stable atmospheric conditions (Figure 15).

GPO 828-153-4

c. No rain (Figure 16).

d. Winds out of the east for odors detected in St. Louis and St. Louis County (Figure 22).

e. Winds out of the south for odors in Illinois (Figure 22).

6. Where are the potential odor sources located?

Many of the major odor sources in the St. Louis City area are on strips of industrially zoned properties adjacent to the Mississippi River. An additional strip of industrially zoned property runs west from the middle of downtown St. Louis County border, and it, too, is a frequent source of odors. On the Illinois side there are considerable concentrations of industry in the East St. Louis, Alton, Granite City, and Monsanto areas, which give rise to objectionable odors.

7. Are there interjurisdictional and interstate problems related to odor control?

The odor episode experienced during the survey was caused by odors that originated in Illinois, crossed the Mississippi River, and extended all the way west across St. Louis and into St. Louis County almost to the St. Louis Municipal Airport. This episode clearly indicated that severe interstate odor problems do exist in the metropolitan area.

Further indication of the existence of interstate and interjurisdictional odor problems is presented in Figure 23, which strongly indicates that the chemical odors so frequently observed in St. Louis arise from the industrial complexes on the Illinois side of the Mississippi River.

The results of the survey described here indicate that unpleasant odors are of relatively frequent occurrence in the St. Louis Metropolitan Area. The existence of these odors is a source of considerable discomfort to the multitude of persons forced to breathe this contaminated air during the course of their everyday activities. Future increases in population and industrialization will surely cause the odor situation to become even more undesirable if steps are not taken to alleviate present conditions and prevent the occurrence of future odor problems.

APPENDICES

APPENDIX A - ODOR OBSERVATION LOCATIONS

LOCATION	Grid coordinates[a]		Elevation, ft	Zoning[b]
St. Louis City				
No. 1	485	705	550	1
2	491	712	450	5
3	484	700	520	1
4	478	695	510	1
5-25	489	721	520	1
6	492	713	460	3
7-33	487	710	510	1
8	490	726	470	1
9	494	720	460	4
10	479	725	510	1
11-16	489	704	430	5
12	479	738	510	2
13	468	728	560	1
14	479	706	550	1
15-39	493	711	460	4
17	483	720	550	1
18	474	717	500	1
19	460	692	450	1
20	486	733	430	1
21	480	711	510	3
22	460	714	550	1
23	475	688	460	2
24	474	732	500	2
26	479	730	510	1
27	476	742	510	1
28	479	720	490	1
29	476	713	490	3
30	466	723	490	3
31	460	700	480	1
32	488	716	490	4
34	472	683	450	2
35	467	706	600	1
36	468	698	460	1
37	481	744	420	3
38	477	701	550	1
40-41	492	715	460	3
42	466	712	450	2
43	473	722	510	1
44	439	759	530	4

[a]See Figure 1.
[b]Zoning code: 1, residential; 2, business; 3, commercial; 4, industrial; and 5, unrestricted.

LOCATION	Grid coordinates		Elevation, ft	Zoning
St. Louis County				
Kirkwood	431	697	640	1
Florissant Valley No. 1	455	773	570	1
Florissant Valley No. 2	458	768	600	1
Ladue No. 1	442	719	600	1
Lemay Fire Dept.	467	680	480	1
Riverview No. 1	487	757	550	1
Riverview No. 2	482	751	480	1
Jennings, Mo.	474	748	530	1
Pine Lawn	467	738	560	1
Spanish Lake, Mo.	486	774	570	1
Moline	470	758	530	1
Hazelwood	445	768	520	4
Berkeley	452	758	550	1
Community No. 1	447	744	650	1
Community No. 2	443	740	650	1
Olivette	440	730	650	1
University City No. 1	458	724	550	1
University City No. 3	451	728	570	1
Clayton	451	722	590	2
Richmond Heights	456	714	530	1
Maplewood	455	708	510	1
Shrewsbury	456	701	450	1
Webster Groves No. 1	444	701	550	3
Webster Groves No. 2	451	701	530	1
Affton	449	685	560	1
Mehlville Dist. No. 1	455	669	620	1
Mehlville Dist. No. 2	461	665	500	1
Mehlville Dist. No. 3	438	677	640	1
Illinois				
Cahokia	491	692	410	1
Alton No. 1[c]	494	811	440	2
Cahokia	498	691	410	1
Alton No. 4[c]	504	815	540	2
Alton No. 5[c]	509	811	540	1
Wood River[c]	520	799	440	2
Hartford[c]	520	790	430	2
Venice	497	729	400	2
Brooklyn	500	724	410	1
National City	504	718	420	4
E. St. Louis - McCallough[c, d]	527	704	410	1
E. St. Louis - Chanselor[c, d]	523	701	410	1
E. St. Louis - Brown[d]	501	707	410	1

[c]These stations not included on Figure 1.
[d]Not a fire station.

APPENDIX B - ODOR SURVEY ST. LOUIS - EAST ST. LOUIS METROPOLITAN AREA

ODOR SENSITIVITY TEST

As an odor observer, you will be taking observation simultaneously along with about 100 other firemen in the metropolitan area. The odor survey covers about 400 square miles; this means that each observer is essentially representing a four-square-mile area. The data from each observation will be keypunched on cards to be analyzed by a Honeywell "400" digital computer located at the Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio. The importance of each observation makes it necessary for us to give an odor sensitivity test to all the participants of the study, to make sure they are capable of detecting odors.

Description of Test

The chemicals used to determine your ability to detect odors will be vanillin, amyl acetate, and butyric acid. The first two odorants are pleasant, but the third, butyric acid, has a stench much like rancid butter. Three dilutions will be prepared of each odorant -- one is considered to be below the normal threshold or detection level, one is detectable by a majority of the normal population, and one is a factor of 10 higher than the normal detectable level. Each participant will be asked to select the odorous container from a group of three, two of which are only distilled water.

Instructions

Three containers will be passed among the group for each test. One contains an odorous fluid, while the others simply contain distilled water. The observers should take short sniffs of the samples to insure that the odorant reaches the olfactory receptor surfaces that are high up in the nasal passages. Select the container A, B, or C that appears to have even the slightest odor and mark an (X) in the appropriate block on the test sheet.

ODOR STUDY OF ST. LOUIS - E. ST. LOUIS METROPOLITAN AREA

ODOR SENSITIVITY TEST RECORD

Fire House _____ Folder Location _____

Location _____ Pay Telephone No. _____

Captain: Even _____ Odd _____

Grid Coordinates

X Y

cc. 2-6

Pollutant Code

cc. 7-8

Odorant Strength Odorous Container

VSC	BFA	AMB	VFA	BMC	AFC	VMB	ASA	BSB
1	2	3	4	5	6	7	8	9

Observer Number — Observer Name

cc. 17-19

Odd Test Date — Day, Mo., Yr. — cc. 9-14

Even Test Date — Day, Mo., Yr. — cc. 9-14

TEST SHEET

Name ______________________________

Test No.	A	B	C
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

TEST SHEET

Name ______________________________

Test No.	A	B	C
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

TEST SHEET

Name ______________________________

Test No.	A	B	C
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

TEST SHEET

Name ______________________________

Test No.	A	B	C
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

PHASE II

ODOR SURVEY ST. LOUIS - E. ST. LOUIS METROPOLITAN AREAS

OBSERVATION FORM

Location: _____

Grid Coordinates X [ ][ ][ ] Y [ ][ ][ ] cc. 1-6

Pollutant Code [0][4] cc. 7-8

Date YR [ ][ ] MO [ ][ ] DAY [ ][ ] cc. 9-14

Time		Strength[1] of Odor (None 0, Faint 1, Strong 2)	Description of Odor	Odor[2] Code	Observer's Name	Observer[2] Number	Observer's Reaction (None 0, Pleasant 1, Not Pleasant 2)	Do you have a cold? (No 0, Yes 1)	Rain (No 0, Yes 1)
7 A.M.	0 7								
	15-16	17		18-19		20-22	23	24	25
2 P.M.	1 4								
8 P.M.	2 0								
10 P.M.	2 2								
12 P.M.	2 4								

[1]Check only 1 box.

[2]Do not use these boxes.

APPENDIX C - PHASE II ODOR SURVEY ST. LOUIS - EAST ST. LOUIS METROPOLITAN AREA

OBSERVER INSTRUCTIONS

1. START SURVEY at 7 a.m. on Monday, November 18, 1963.

2. Make daily observations at 7 a.m., 2 p.m., 8 p.m., 10 p.m., and 12 midnight.

3. If the scheduled observer is not available, the next man in line under the appropriate odd or even shift should make the observation.

4. Observers preferably should not smoke, chew gum, or chew tobacco for at least 30 minutes prior to observations.

5. Go outside the fire house and immediately take a few SHORT SNIFFS of the air. It is preferable to take observations at the back of the fire house, away from the street in an open area (avoid the detection of odors originating at the fire house).

6. Record the results on the Observation Form.

    1. Strength (Mark with X)

    2. Description (Use own words - avoid looking at terms used by other observers).

    3. Name (Last name only is sufficient).

    4. Observers reaction (Mark with X).

    5. Do you have a cold (Mark with X).

    6. Rain (Mark with X).

7. Return folder to specified folder location.

8. SURVEY FINISHED Midnight, Sunday, December 1, 1963. Place folder in the provided addressed envelope and drop in mail box (No postage necessary).

9. Thanks for your cooperation.

GPO 828-153-3

PHASE II

ODOR SURVEY ST. LOUIS - E. ST. LOUIS METROPOLITAN AREAS

SCHEDULE

Fire House_____

Location_____

Folder Location_____

Grid Coordinates [ ][ ][ ] X

[ ][ ][ ] Y

cc. 1-6

ODD			EVEN		
	Obs. No.			Obs. No.	
Captain		_____	Captain		_____
Observers	[ ][ ][ ]	1._____	Observers	[ ][ ][ ]	1._____
	[ ][ ][ ]	2._____		[ ][ ][ ]	2._____
	[ ][ ][ ]	3._____		[ ][ ][ ]	3._____
	[ ][ ][ ]	4._____		[ ][ ][ ]	4._____

DATE	TIME	OBSERVER
11/18	7 A. M.	
	2 P. M.	
	8 P. M.	
	10 P. M.	
	12 M. N.	
11/19	7 A. M.	
	2 P. M.	
	8 P. M.	
	10 P. M.	
	12 M. N.	

APPENDIX D - STABILITY CLASSES--ST. LOUIS ODOR SURVEY

For the St. Louis odor survey, the Pasquill-Gifford-Turner stability classes were used; however, these stability classes were modified somewhat by use of data obtained from instruments located at different heights on towers in St. Louis.

Table D-1 gives the six classes of stability in terms of the surface wind, the solar insolation for the daytime, and the cloud cover at night. Strong insolation corresponds to a solar altitude greater than 60° with clear skies, and slight insolation corresponds to a solar altitude from 15° to 35°F with clear skies. Cloudiness, which decreases insolation, was considered along with solar altitude in determining insolation. Insolation that would be strong with clear skies was classified as moderate with broken middle clouds and as slight with broken low clouds. The neutral category, 4, was assumed for conditions with cloud cover greater than 6/10 and a ceiling less than or equal to 10,000 feet during day or night.

Table D-1. PASQUILL-GIFFORD-TURNER KEY TO STABILITY CLASSES

Surface wind speed (at 10 m.), mph	Insolation			Night	
	Strong	Moderate	Slight	Thinly overcast or > 5/10 low cloud	< 4/10 cloud
< 4.5	1	1-2	2	-	-
4.5- 6.7	1-2	2	3	5	6
6.7-11.2	2	2-3	3	4	5
11.2-13.4	3	3-4	4	4	4
13.4	3	4	4	4	4

Definitions of stability classes: 1, extremely unstable; 2, unstable; 3, slightly unstable; 4, neutral; 5, stable; 6, very stable.

GPO 828-153-2