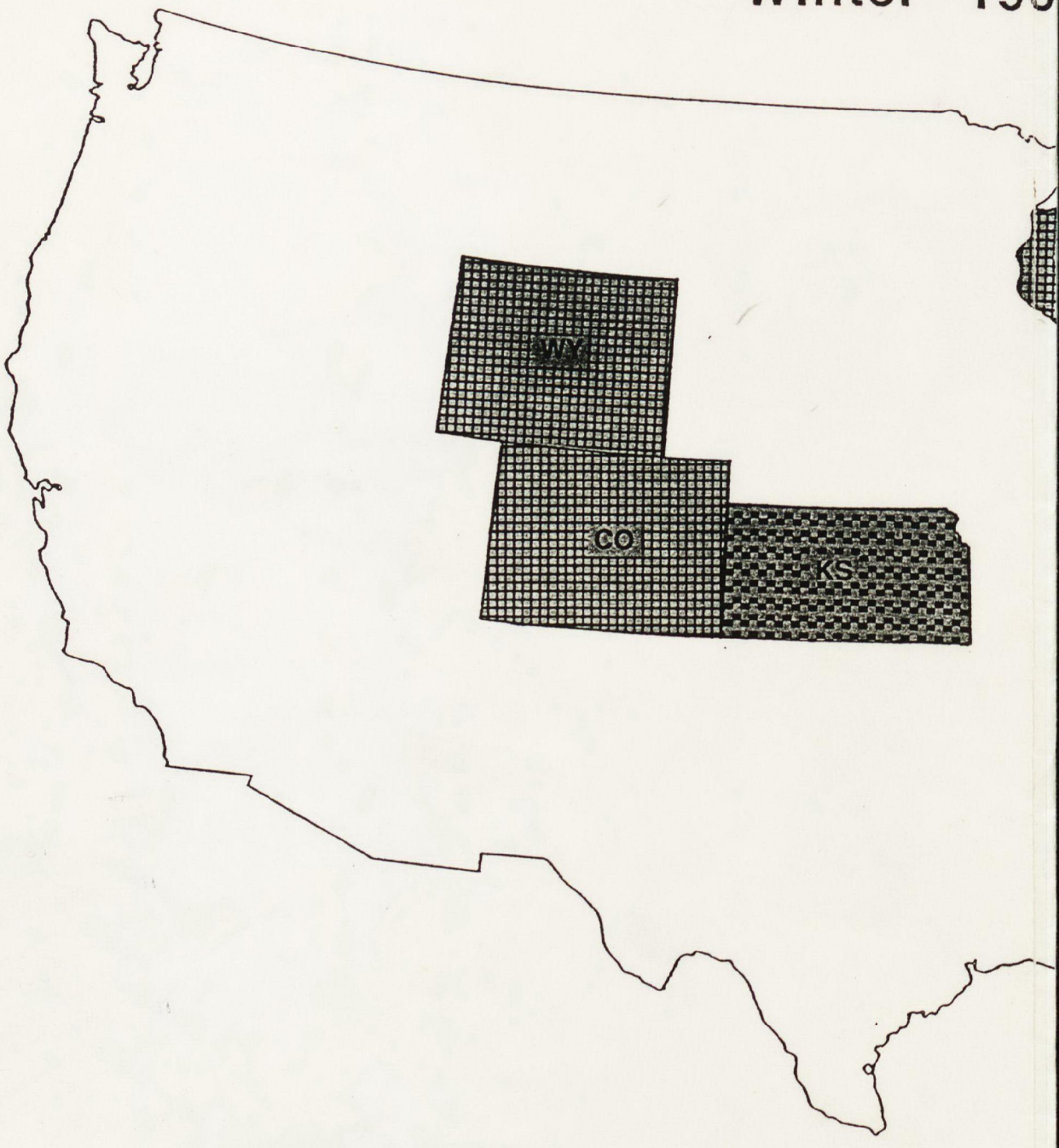
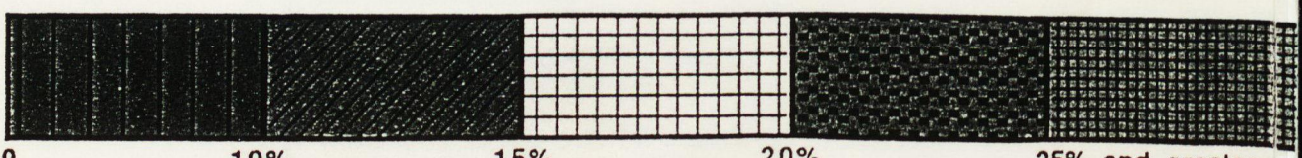
State/EPA Indoor Radc
Winter 198



Estimated Percent of Houses With Screening Levels Greater than 4 pCi/L



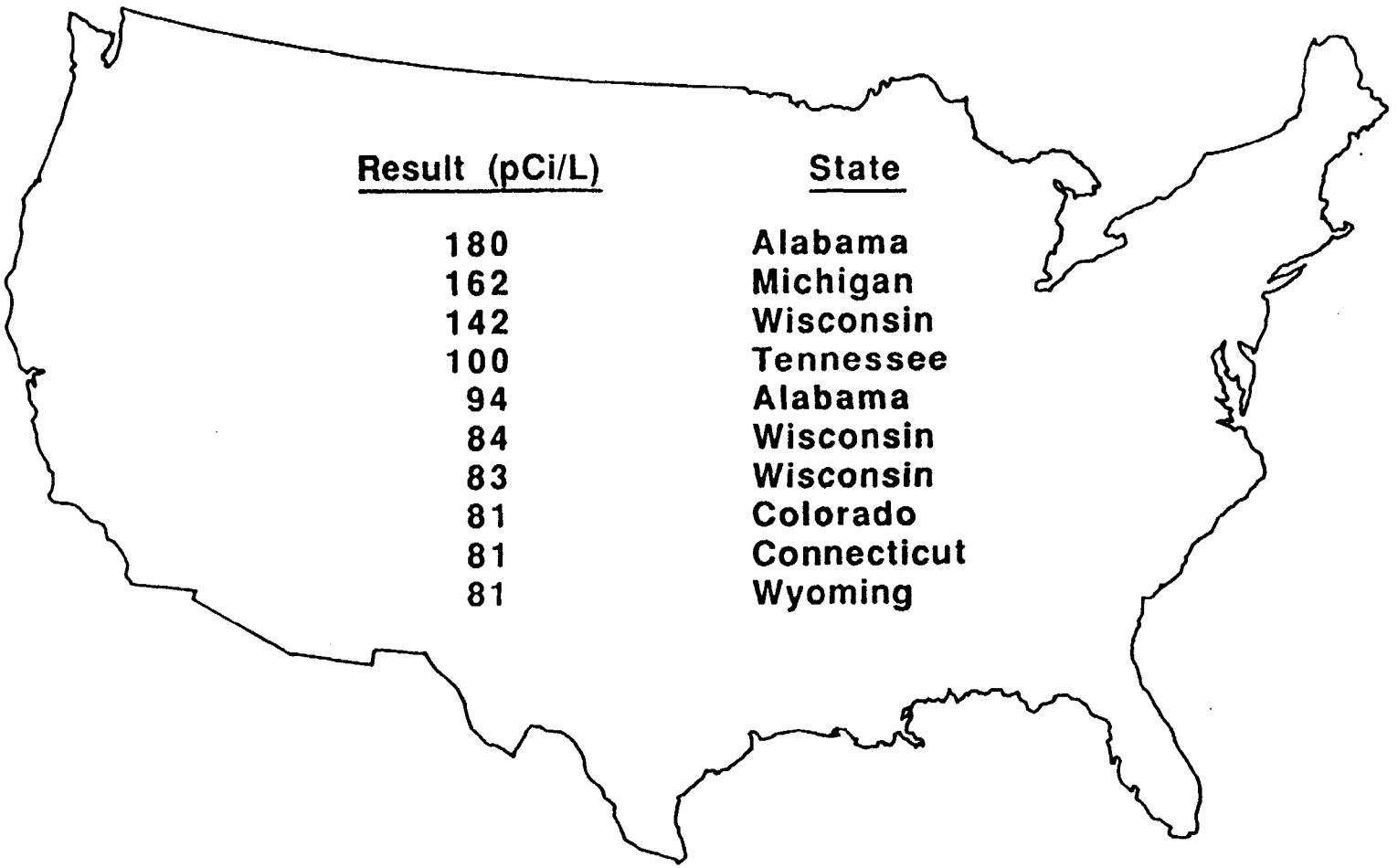
PAGE NOT

AVAILABLE

DIGITALLY

EPA 0489
c.2

Ten Highest Radon Measurements in the Surveys



Result (pCi/L)	State
180	Alabama
162	Michigan
142	Wisconsin
100	Tennessee
94	Alabama
84	Wisconsin
83	Wisconsin
81	Colorado
81	Connecticut
81	Wyoming

Survey Conclusions

- The Distribution of Radon Levels Varied Significantly Among States
- Elevated Radon Levels Were Found in Every State Surveyed
- Even the States with the Lowest Distribution of Radon Levels had Some Houses with Extremely High Radon Concentrations
- These Surveys Identified Radon Hot Spots
- Geology is a Good Indicator of High Risk Areas

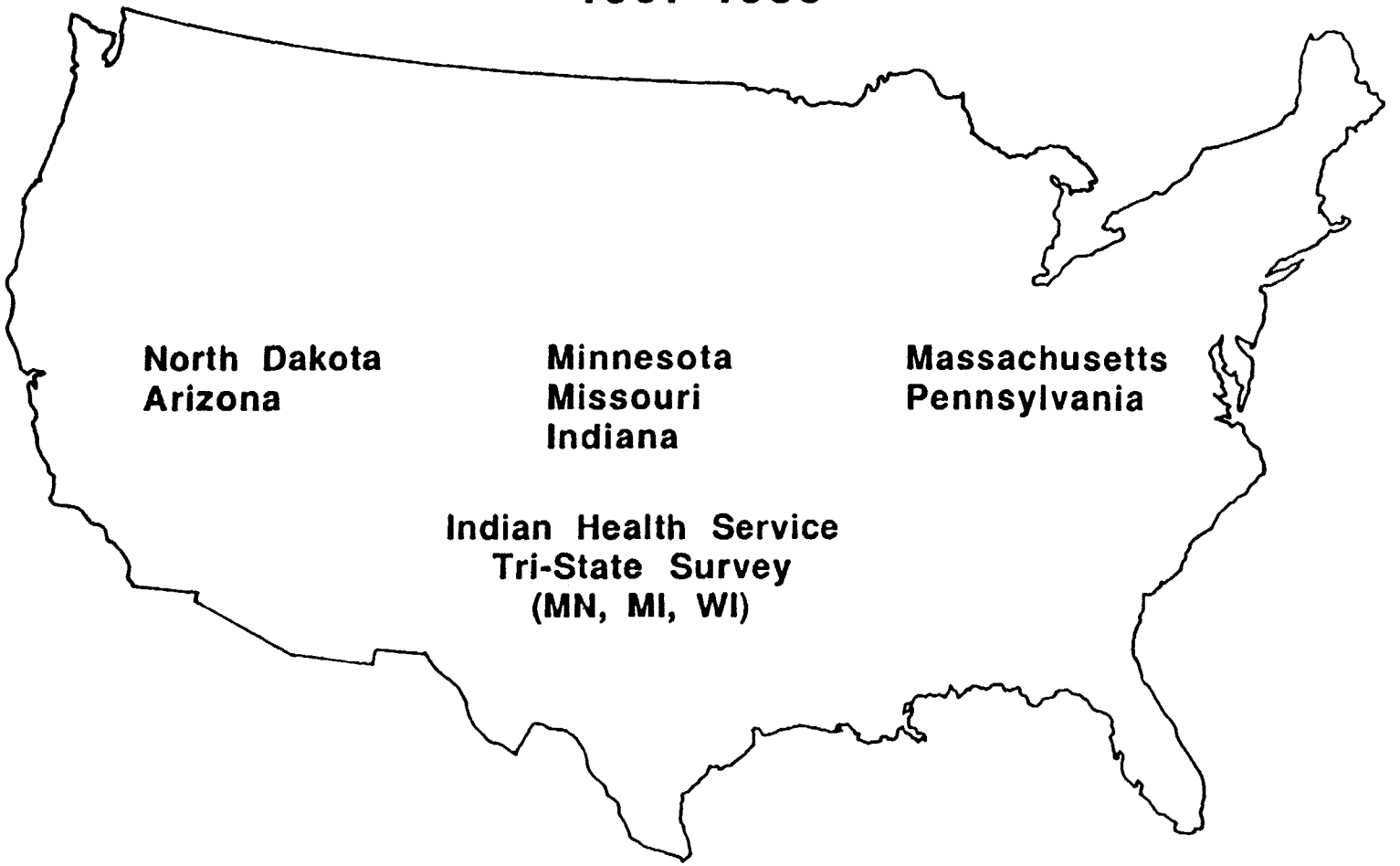
Radon Action Program
Major Accomplishments

- State Surveys
- Radon Measurement Proficiency Program
- Radon Mitigation Research Program
- House Evaluation Program
- Radon Diagnosis and Mitigation Training Course
- New Brochures

Radon Action Program
Key EPA and State Responsibilities

EPA Responsibilities	State Responsibilities
Problem Assessment • Provide Technical Assistance for State Surveys • Develop Uniform Measurement Protocols	• Conduct and Manage State Radon Surveys • Apply EPA Protocols
Mitigation and Prevention • Research and Demonstrate Mitigation and Prevention Techniques • Apply and Evaluate Mitigation Techniques	• Assist Homeowners with Radon Reduction • Transfer Knowledge to Local Govèrnments, Private Sector and Homeowners
Capability Development • Develop Technical Training Courses • Evaluate Public and Private Measurement Capability	• Establish State Radon Programs • Develop Private Sector Capability in Measurement and Mitigation • Provide Information to the Public on Measurement Firms
Public Information • Develop Public Information Materials • Initiate Cooperative Activities with States and National Organizations	• Respond to Homeowner Requests for Information • Distribute Public Information Materials • Conduct Public Education and Outreach Activities

Environmental Protection Agency
State Radon Survey Assistance Program
1987-1988



8/87

FOR RELEASE ON AUGUST 4

CONTACT: Aubrey Godwin
261-5315

According to a study conducted by the Alabama Department of Public Health with the assistance of the Environmental Protection Agency and the Alabama Geological Survey, 94 percent of the houses tested for radon exposure in the state met acceptable indoor radon screening measurements. Despite this, two of the 10 highest readings found in the entire U.S. were made in state homes.

Radon, a radioactive gas which occurs in nature, results from the natural breakdown or uranium. In an enclosed space such as a home, radon can accumulate because the gas enters through cracks and openings to the soil below. The only known health effect associated with exposure to elevated levels of radon is an increased risk of developing lung cancer.

Aubrey Godwin, director of the Radiological Health Branch of the Alabama Department of Public Health, stated, "In homes with elevated radon levels, homeowners are advised to take actions to reduce the amount of radon entering the structure. Although we recommend that any homeowner who is particularly concerned about exposure to indoor radon consider having his home tested, our survey findings indicate that there are a few areas of the state which are of particular concern."

These counties are Cleburne, Colbert, Coosa, Lauderdale, Limestone and Madison. Radon levels can vary greatly from season to season as well as from room to room.

For additional information contact the Radiological Health Branch, Alabama Department of Public Health at 261-5315.

-30-

7/31/87

FACT SHEET
RADON STUDY

The Alabama Department of Public Health recently conducted a survey with technical assistance provided by the U.S. Environmental Protection Agency and the Alabama Geological Survey. Funding was provided through a grant from the Alabama Department of Economic and Community Affairs.

PURPOSES: (1) To identify areas of the state having a potential for significantly elevated indoor radon levels.
(2) To determine the distribution of indoor radon screening measurements across Alabama.

MEASUREMENTS: Measurements were taken in a random sample of single-family owner-occupied homes statewide with charcoal canisters. These measurements for screening can be used to determine whether follow-up measurements are necessary.

- Alabama has made 1,200 measurements as a part of this survey.

- Based on preliminary analysis of the data, 6.4 percent of the homes surveyed had measurements above 4 pCi/l. Some 6.1 percent of the homes had measurements between 4 pCi/l and 20 pCi/l. The highest level found in the state was 180.0 pCi/l, while the average screening level was 1.8 pCi/l.

- Homeowners in the counties of Cleburne, Colbert, Coosa, Lauderdale, Limestone and Madison are advised to have their homes screened for indoor radon. These counties had data indicating that they had 20 percent or more homes above 4 pCi/l or 5 percent or more above 8 pCi/l in either the random sample or in the total data of the state. These included some volunteers.

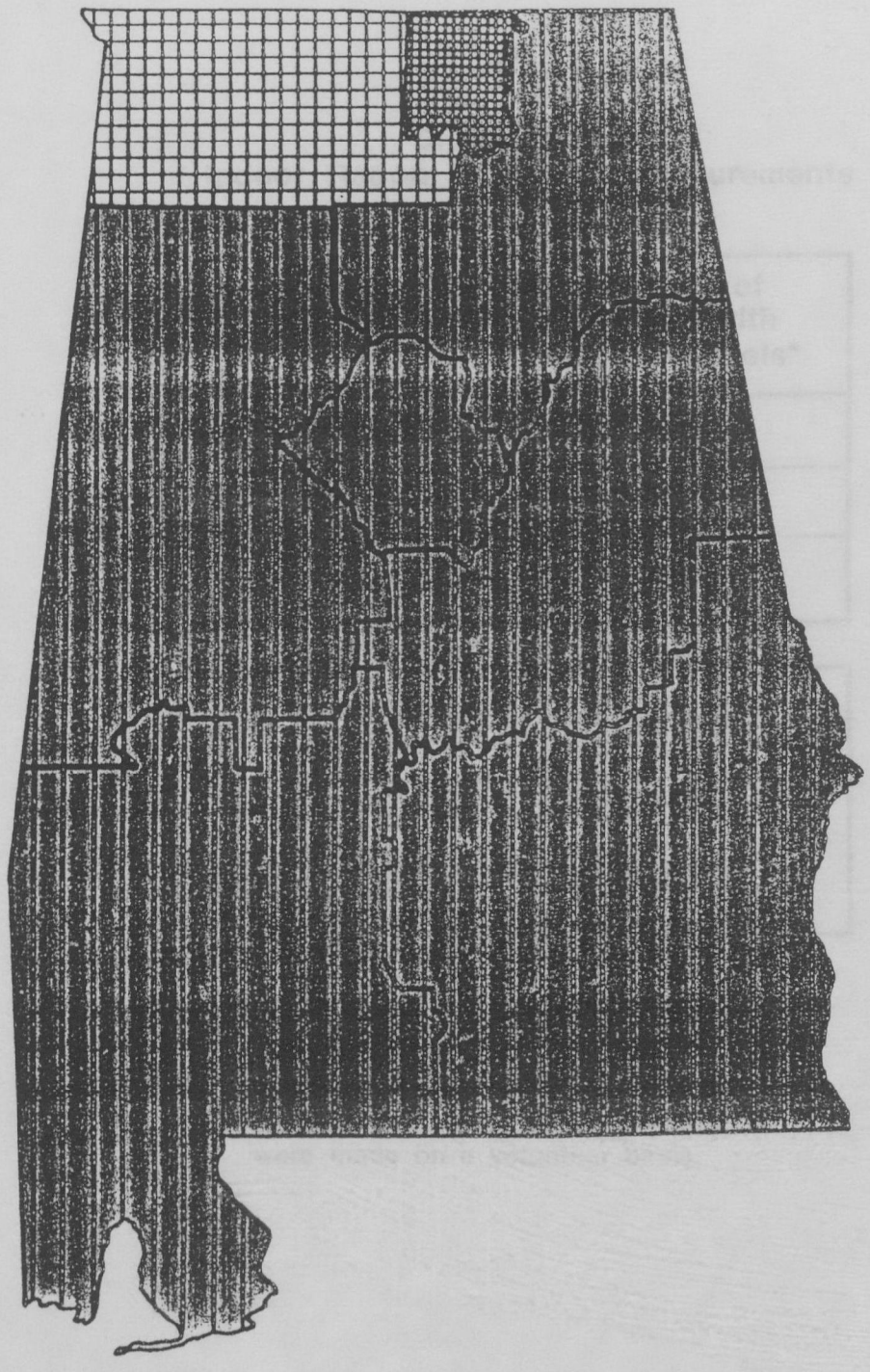
- Radon levels can vary greatly from season to season as well as from room to room; therefore, a screening measurement such as Alabama's only serves to indicate the potential for a radon problem.

- Any homeowner who is particularly concerned about exposure to indoor radon should consider testing; however, survey findings indicate there are few areas in the state which are of particular concern.

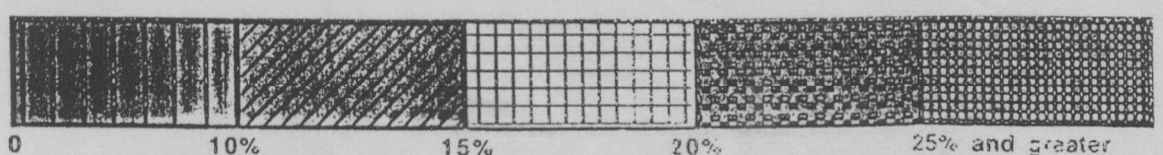
- For homeowners who have participated in the survey or who have had private screening measurements made in their homes, the Alabama Department of Public Health and the Environmental Protection Agency recommend that follow-up tests be made in homes with screening measurements above 4 pCi/l.

Released August 4, 1987

Radon Results in Alabama by Region



Estimated Percent of Houses With Screening Levels Greater than 4 pCi/L



Alabama

Distribution of Indoor Radon Screening Measurements

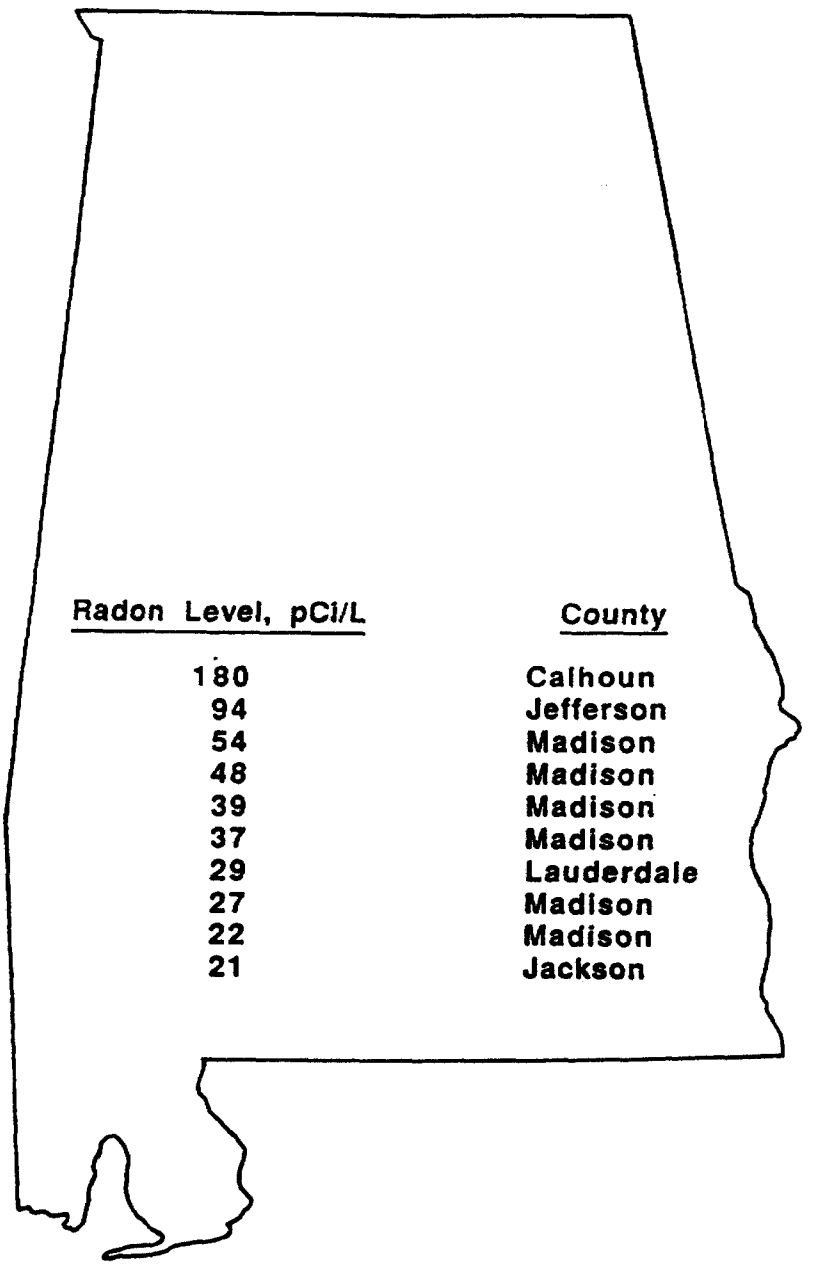
Radon Levels, pCi/L	Percent of Houses with These Levels*
0 - 4	94%
4 - 20	6%
> 20	<1%

Average Level	1.8 pCi/L
Number of Houses Measured**	1,200

* There is a 95% certainty that these values represent all houses in Alabama to within 2 percentage points.

** An additional 1000 measurements were made on a volunteer basis.

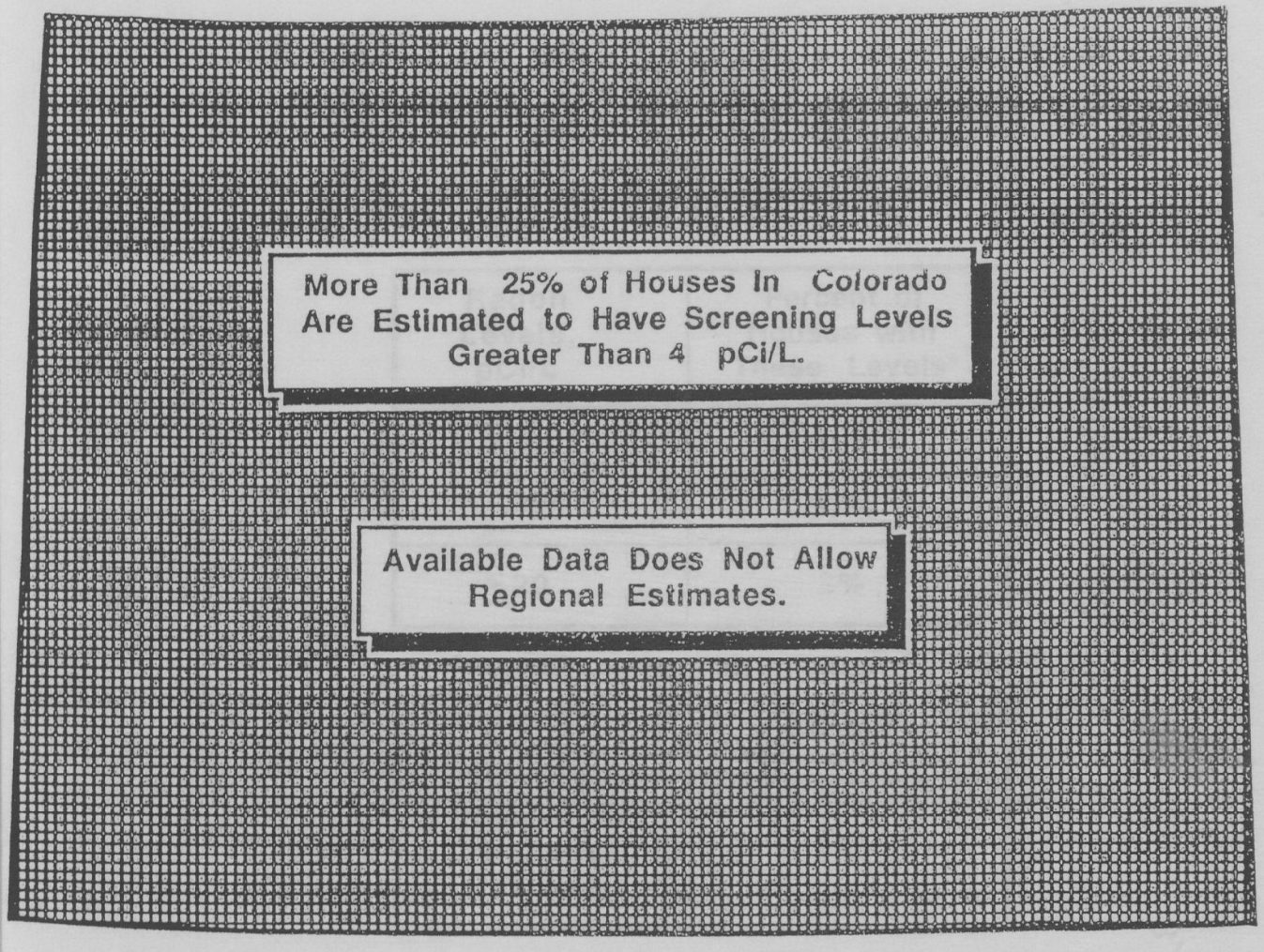
Ten Highest Radon Measurements in Alabama



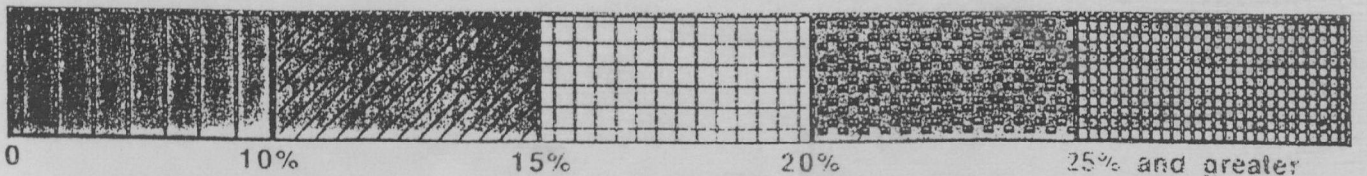
Radon Level, pCi/L	County
180	Calhoun
94	Jefferson
54	Madison
48	Madison
39	Madison
37	Madison
29	Lauderdale
27	Madison
22	Madison
21	Jackson

These single measurements may not be representative of all houses in these counties.

Radon Results in Colorado



Estimated Percent of Houses With Screening Levels Greater than 4 pCi/L



Colorado

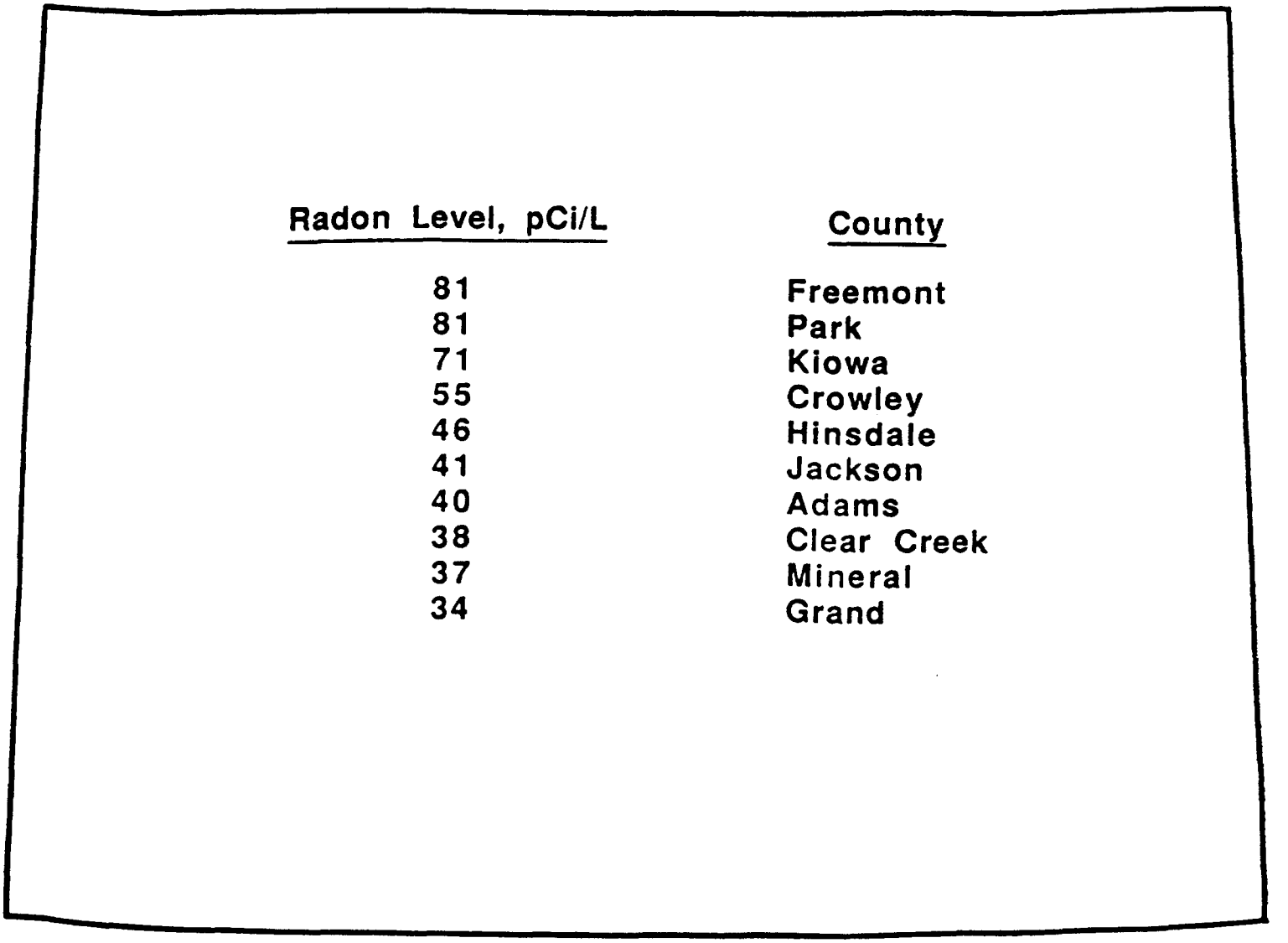
Distribution of Indoor Radon Screening Measurements

Radon Levels, pCi/L	Percent of Houses with These Levels*
0 - 4	61%
4 - 20	37%
> 20	2%

Average Level	4.6 pCi/L
Number of Houses Measured	900

* These values represent the actual measurements taken and may not be representative of all houses in Colorado.

Ten Highest Radon Measurements in Colorado



Radon Level, pCi/L	County
81	Freemont
81	Park
71	Kiowa
55	Crowley
46	Hinsdale
41	Jackson
40	Adams
38	Clear Creek
37	Mineral
34	Grand

These single measurements may not be representative of all houses in these counties.

8/87

EPA-CONNECTICUT RADON SURVEY PRESS RELEASE

The Connecticut Department of Health Services, with technical assistance from the U.S. Environmental Protection Agency, Connecticut Department of Environmental Protection and CONNSAVE, has conducted a survey to determine the distribution of indoor air radon levels across Connecticut.

Radon is a colorless, odorless, radioactive gas which is the natural product of uranium/radium decay. It is given off by rocks and soil which contain uranium, and is found in minute amounts almost universally in air and water. Radon gas can migrate into homes from the soil surrounding the basement and from other less significant sources. Radon exposure over a prolonged period of time has been shown to cause lung cancer in human beings.

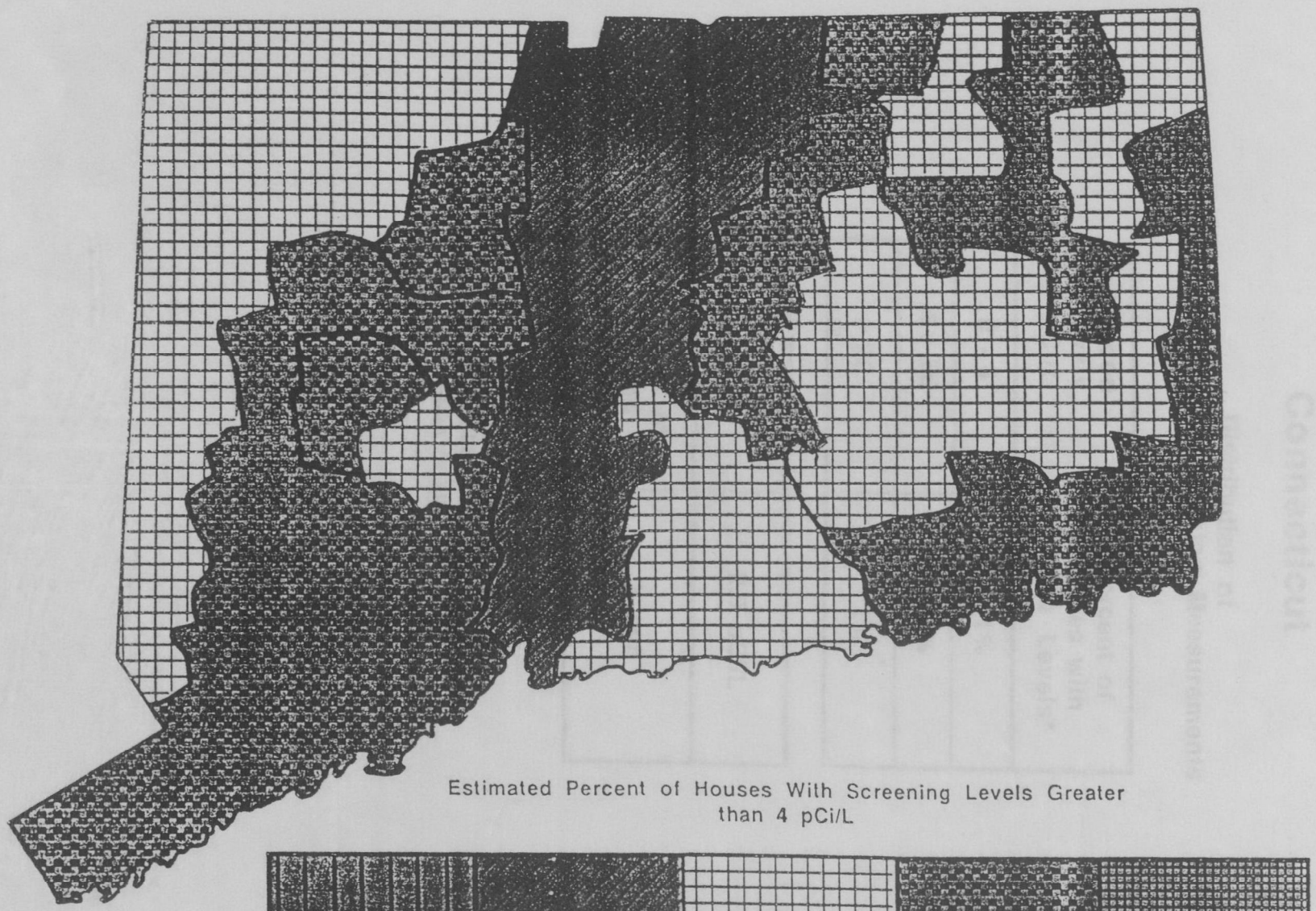
The state was divided into five (5) geologic regions to identify areas of the State that have the potential for significantly elevated indoor air radon levels. The EPA-Connecticut Radon Survey, conducted from December, 1986 through March, 1987, was based on measurements taken in a sample of single-family, owner-occupied homes across the state that had requested an energy audit by CONNSAVE. The short-term measurements that were taken with charcoal canisters in the basements of these homes are considered <u>screening tests</u> to determine the need for more extensive testing in those homes.

The indoor air radon measurements were taken from 1,500 homes in 167 of the 169 towns in Connecticut. Based on a preliminary analysis of the data, 19% of the homes surveyed in Connecticut (one in five) had radon measurements above the current EPA guideline of 4 picocuries per liter (pCi/l), and only 1% of the homes tested (one in a hundred) had radon measurements greater than 20 pCi/l. The average radon level detected in the State was 2.9 pCi/l, while the median measurement was 1.7 pCi/l. The highest radon level, 80.9 pCi/l, was found in a home in Glastonbury.

Homes with elevated levels of radon were found in most towns in Connecticut. Almost three quarters of the towns sampled (72%) had at least one house with a reading greater than 4 pCi/l. However there were no specific towns where consistently high levels were found. Radon occurrence is related to geology which does not follow town boundaries. A preliminary analysis of the data does indicate some differences in radon levels among the five geologic regions of the state. Compared to the rest of the state, the central valley region has a lower probability for homes with greater than 4 pCi/l of radon, while portions of both the eastern region and western central region of the state may have a higher potential for homes with elevated radon levels.

Due to this somewhat random distribution of radon, predictions on the risk from radon of a particular town or home cannot be made. Homeowners who are interested in finding out the radon levels in their house should have a radon test performed. Based upon the results of this survey the Connecticut Department of Health Services is recommending that all homeowners test their house for radon.

Radon Results in Connecticut by Region



Estimated Percent of Houses With Screening Levels Greater than 4 pCi/L

8/87

Connecticut

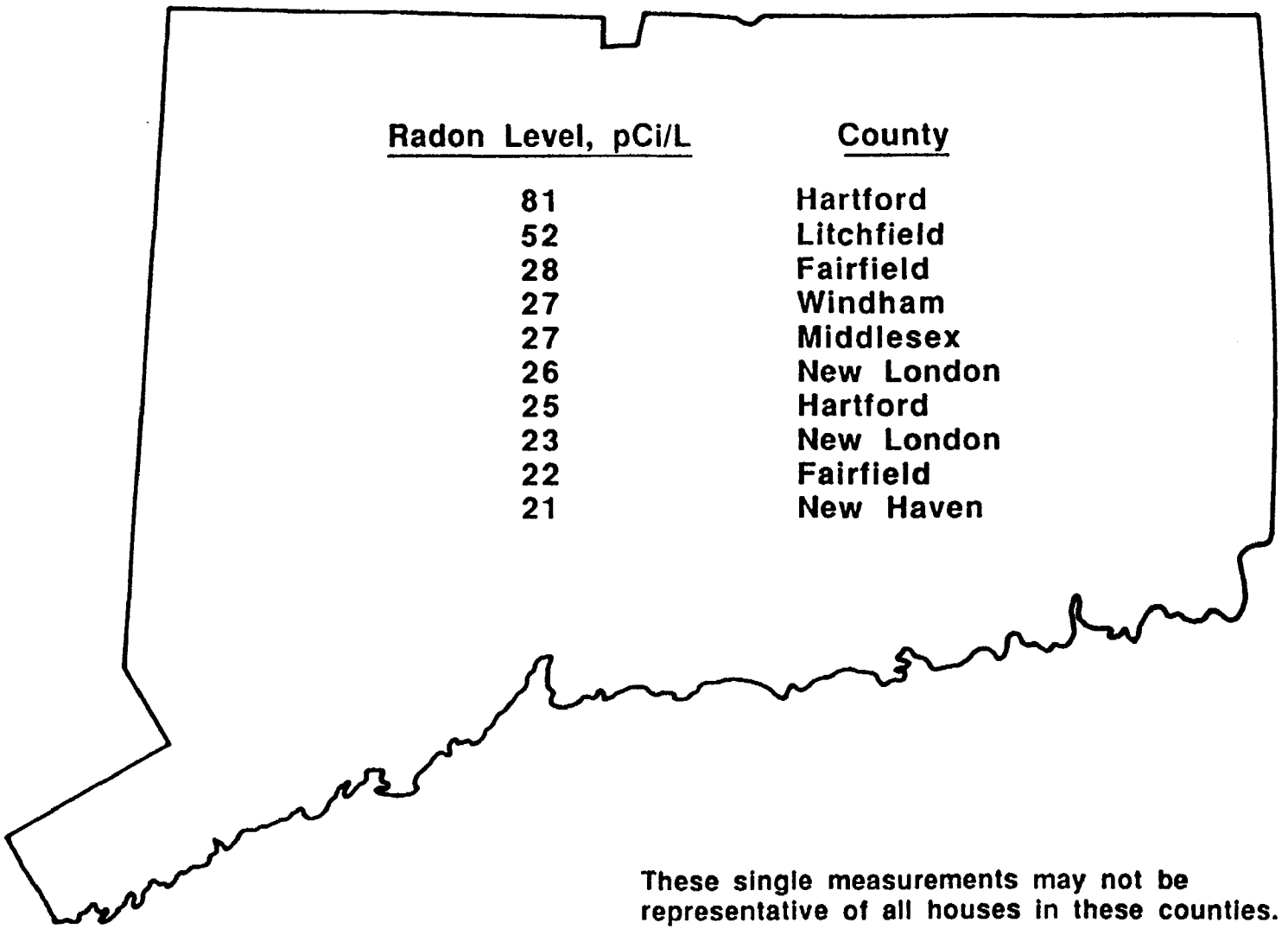
Distribution of Indoor Radon Screening Measurements

Radon Levels, pCi/L	Percent of Houses with These Levels*
0 - 4	81%
4 - 20	18%
> 20	1%

Average Level	2.9 pCi/L
Number of Houses Measured	1,500

* These values represent the actual measurements taken and may not be representative of all houses in Connecticut.

Ten Highest Radon Measurements in Connecticut



Radon Level, pCi/L	County
81	Hartford
52	Litchfield
28	Fairfield
27	Windham
27	Middlesex
26	New London
25	Hartford
23	New London
22	Fairfield
21	New Haven

These single measurements may not be representative of all houses in these counties.

State/EPA Indoor Radon Survey Results
Winter 1986-1987

Estimated Percent of Houses with Screening Levels Greater than 4 pCi/L

Alabama	6%
Colorado	39%
Connecticut	19%
Kansas	21%
Kentucky	17%
Michigan	9%
Rhode Island	19%
Tennessee	16%
Wisconsin	27%
Wyoming	26%

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

1

EPA

Radon Facts

SOURCES AND CHARACTERISTICS OF RADON

Radon is an invisible, odorless, radioactive gas produced by the decay of uranium in rock and soil. Radon decays into radioactive particles, which if inhaled may cause damage to lung tissues, increasing the risk of lung cancer.

- As uranium decays, it produces radium, which in turn releases radon gas. Once released, radon migrates through permeable rocks and soil, eventually escaping into the atmosphere or into buildings.

- High levels of naturally occuring radon are most likely to occur where there are significant amounts of uranium in the ground. Rocks that may have higher than average concentrations of uranium include black shales, phosphatic rocks and granites. Radon may also be found in areas which have been contaminated with certain types of industrial wastes, such as the byproducts from uranium or phosphate mining.

- Soils can also be a source of radon. Many soils are derived from the immediate underlying rock, and therefore tend to have similar mineral composition as the parent rock. Just as importantly, soils are the medium through which radon travels. Soil permeability plays an important role in determining whether or not radon will be able to move indoors.

- Outdoor radon levels generally do not pose a large health hazard. Indoor levels are normally about 5 to 10 times higher than outdoor levels, but they can be several thousand times higher.

- Radon gas can seep into a home through cracks in the foundation, areas around drainage pipes, sump pumps and other openings in the foundation or walls.

- Radon itself does not present a health hazard. It is the decay products that are the main sources of radiation exposure. Unlike radon, radon decay products are solid particles which can remain in the lungs. When the trapped particles decay, the surrounding lung tissue is damaged.

Virtually every house in the United States has some level of radon gas in its air (estimates suggest that average annual indoor levels range between about 1 to 2 pCi/L). Most homes will not have levels high enough to require any action to reduce them. Radon levels can vary substantially from house to house even among homes in the same area. The only way to be certain about the level of radon in a house is to have it measured. The Environmental Protection Agency has developed "A Citizen's Guide to Radon" to provide homeowners with the facts about radon, to help them determine whether and how to measure radon in their homes, and to help them evaluate their personal risk if they should find elevated levels.

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

2

EPA

Radon Facts

DISTRIBUTION OF RADON LEVELS ACROSS THE U.S.

While the Reading Prong area of Pennsylvania, New Jersey and New York is the best known high-radon area in the United States at this time, indoor radon is potentially a widespread problem.

- It is estimated that over 150,000 radon measurements have been made by both commercial firms and EPA. The number of measurements, however, is not equal to the number of houses tested since more than one detector is often used per house. Duplication aside, 150,000 still only represents considerably less than 1% of the single-family detached houses nationwide.

- Existing data is heavily concentrated in those states with known high radon levels (for example, Pennsylvania, New Jersey and New York). Measurements in the 2000-3000 pCi/L range have been observed in these areas. In almost every state, however, radon levels greater than 4 pCi/L have been documented.

- Available data indicate that perhaps 8-12% of the roughly 75 million houses existing in the United States may have annual average radon levels reaching or exceeding 4 pCi/L.

It will not be possible to refine these estimates until the national survey and national assessment are completed. This will take several years.

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

3

EPA

Radon Facts

POTENTIAL AREAS WITH
HIGH RADON LEVELS

At this time, there is no completely reliable method for predicting the locations of houses with high indoor radon levels. Indoor radon levels are affected by the uranium content of nearby rock and soil, soil permeability, house construction characteristics and other factors. The attached map is an updated version of one issued in August 1986 and includes more detailed information from a variety of sources. Shaded areas indicate where greater potential indoor radon problems exist, based solely on the uranium content of rocks near the surface. This map does not include information on other important factors, such as soil characteristics, for which nationwide data is not available. In some instances, these other factors may be most important in producing or alleviating radon problems since there is such a mixture of confirmed and nonconfirmed predictions.

- The data used for this map are based on geological reports, a modification of the National Uranium Resource Evaluation (NURE) data, and some indoor radon data. All shaded areas are only approximate, and boundaries should not be considered definitive. Not all portions within an area will have the same potential for elevated indoor radon levels.

- This updated map has many differences from the 1986 map. Data from the State/EPA radon survey and some commercial measurement companies have filled in gaps in certain areas. Granitic areas are now distinguished on the basis of uranium content, while all identified black shales are considered to be significantly uraniferous.

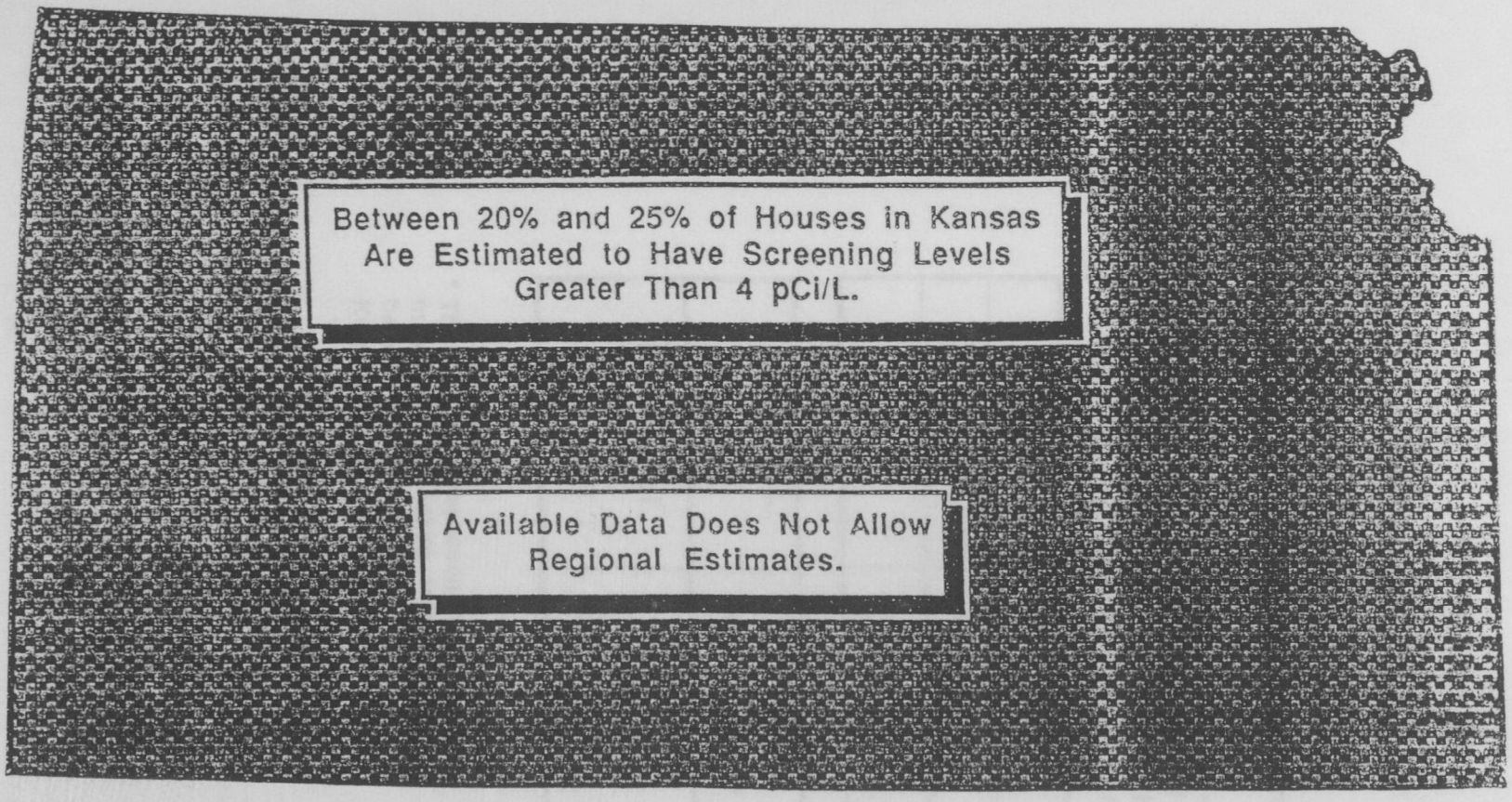
- Shaded areas of the map represent those areas which may have a higher percentage of homes with elevated radon levels, as compared to the nonshaded areas. An estimated 8-12% of homes nationwide may have annual average radon levels greater than 4 picocuries per liter. In the shaded areas, the percentage may be substantially higher, while in the nonshaded areas less than 10% of the houses may exhibit radon levels above 4 pCi/L.

- This map should not be used as the sole source for predicting elevated indoor radon levels. It is imperative to use the information from this map in conjunction with other factors (e.g., indoor measurements, soil permeability and housing types) to predict local radon levels.

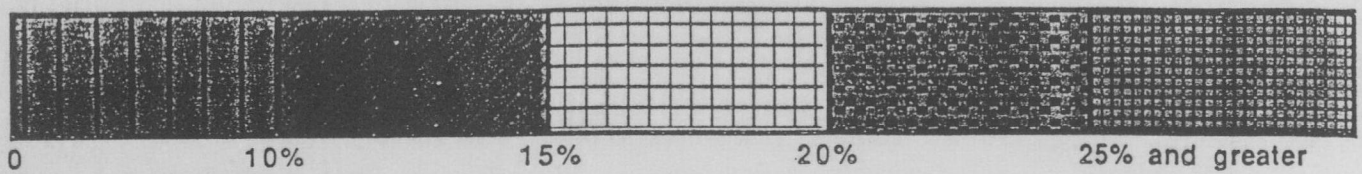
- This map cannot be used to determine specific houses or neighborhoods with low or elevated indoor radon levels. Because of differences in house characteristics, a house situated on a site with high radon potential will not necessarily have high indoor radon levels. Conversely, it is possible, but less likely, to have high indoor radon levels within areas of low radon potential. In order to determine if a particular house has a radon problem, it is necessary to make a measurement.

EPA is continuing to work with other Federal agencies and the States to improve our ability to understand the factors that influence radon levels, so that in the future we can better predict the geographical areas of concern.

Radon Results in Kansas



Estimated Percent of Houses With Screening Levels Greater than 4 pCi/L



8/87

Kansas

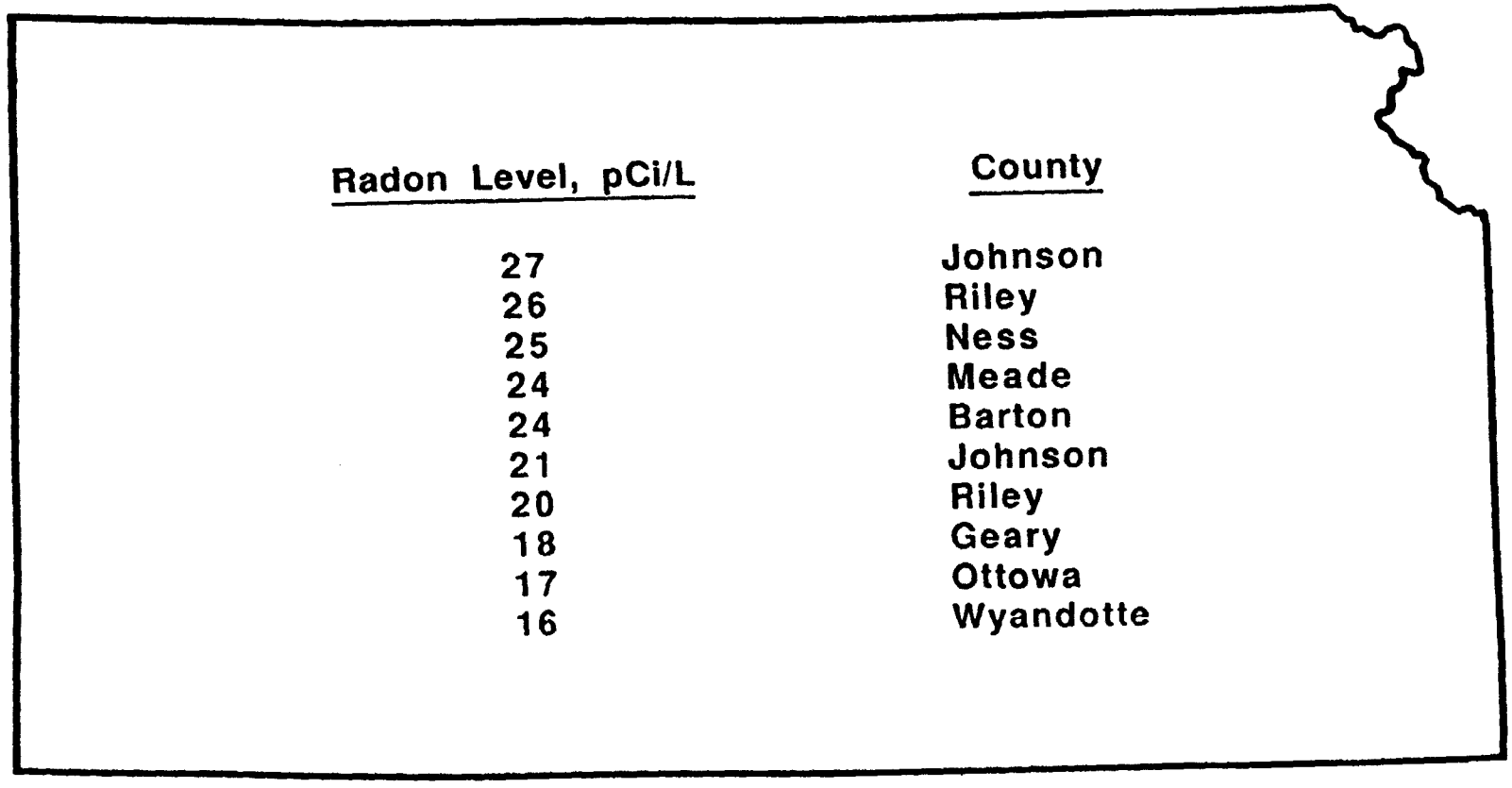
Distribution of Indoor Radon Screening Measurements

Radon Levels, pCi/L	Percent of Houses with These Levels*
0 - 4	79%
4 - 20	21%
> 20	<1%

Average Level	2.9 pCi/L
Number of Houses Measured	1,000

* These values represent the actual measurements taken and may not be representative of all houses in Kansas.

Ten Highest Radon Measurements in Kansas



Radon Level, pCi/L	County
27	Johnson
26	Riley
25	Ness
24	Meade
24	Barton
21	Johnson
20	Riley
18	Geary
17	Ottowa
16	Wyandotte

These single measurements may not be representative of all houses in these counties.

FACT SHEET INDEX

Kentucky Fact Sheet

The Kentucky Cabinet for Human Resources, with technical assistance from the U.S Environmental Protection Agency, conducted a survey to identify areas within the State that have the potential for significantly elevated indoor radon levels and to determine the distribution of indoor radon screening measurements across Kentucky. The Kentucky Indoor Radon Survey, begun in March, was based on measurements taken by random sample in single-family owner-occupied homes across the State. Measurements were taken with charcoal canisters, and represent screening measurements only. These measurements can be used to determine whether follow-up measurements are necessary.

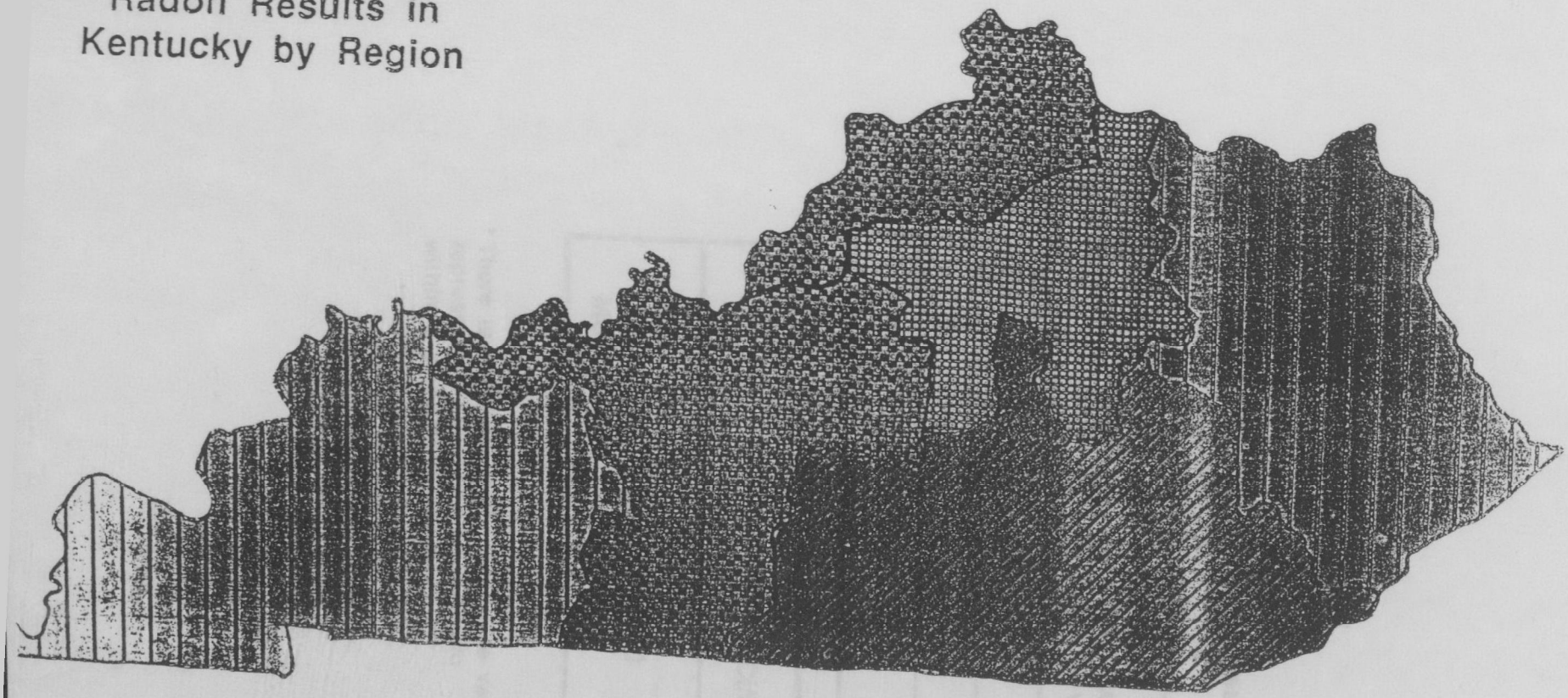
Kentucky has made 879 measurements as part of this survey. Based on preliminary analysis of the data, 17.1% of the homes surveyed in Kentucky had measurements above 4 pCi/l, with 15.6% of the homes tested having measurements between 4 pCi/l and 20 pCi/l. The highest level detected in the State was 65.5 pCi/l, while the average screening measurement was 2.88 pCi/l.

Although we recommend that any homeowner who is particularly concerned about exposure to indoor radon consider having their home tested, our survey findings indicate that 34.6% of the samples in Region IV (as indicated on the map) resulted in readings greater than the EPA recommended threshold of 4.0 pCi/l. We feel it is prudent to recommend that homeowners in this area have their homes screened for indoor radon.

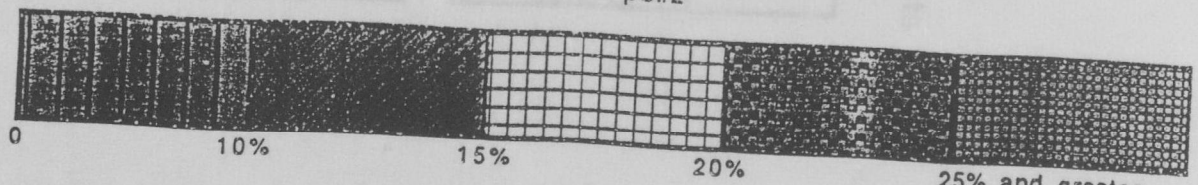
Because radon levels can vary greatly from season to season as well as from room to room, a screening measurement, such as those taken for the Kentucky survey, only serves to indicate the potential for a radon problem. Depending on the results of the screening measurement, follow-up tests are recommended. For homeowners who have participated in the survey or who have had private screening measurements made in their homes, the Kentucky Cabinet for Human Resources and the Environmental Protection Agency recommend that follow-up tests be made in homes with screening measurements above 4 pCi/l.

The Cabinet's Radiation Control Branch will be happy to answer questions individuals might have regarding radon and the testing for its presence. Individuals who decide to test their homes should be sure they deal with a reputable testing firm. Contact the Radiation Control Branch or your local health department for suggestions on how to select a radon testing company.

Radon Results in Kentucky by Region



Estimated Percent of Houses With Screening Levels Greater than 4 pCi/L



8/87

Kentucky

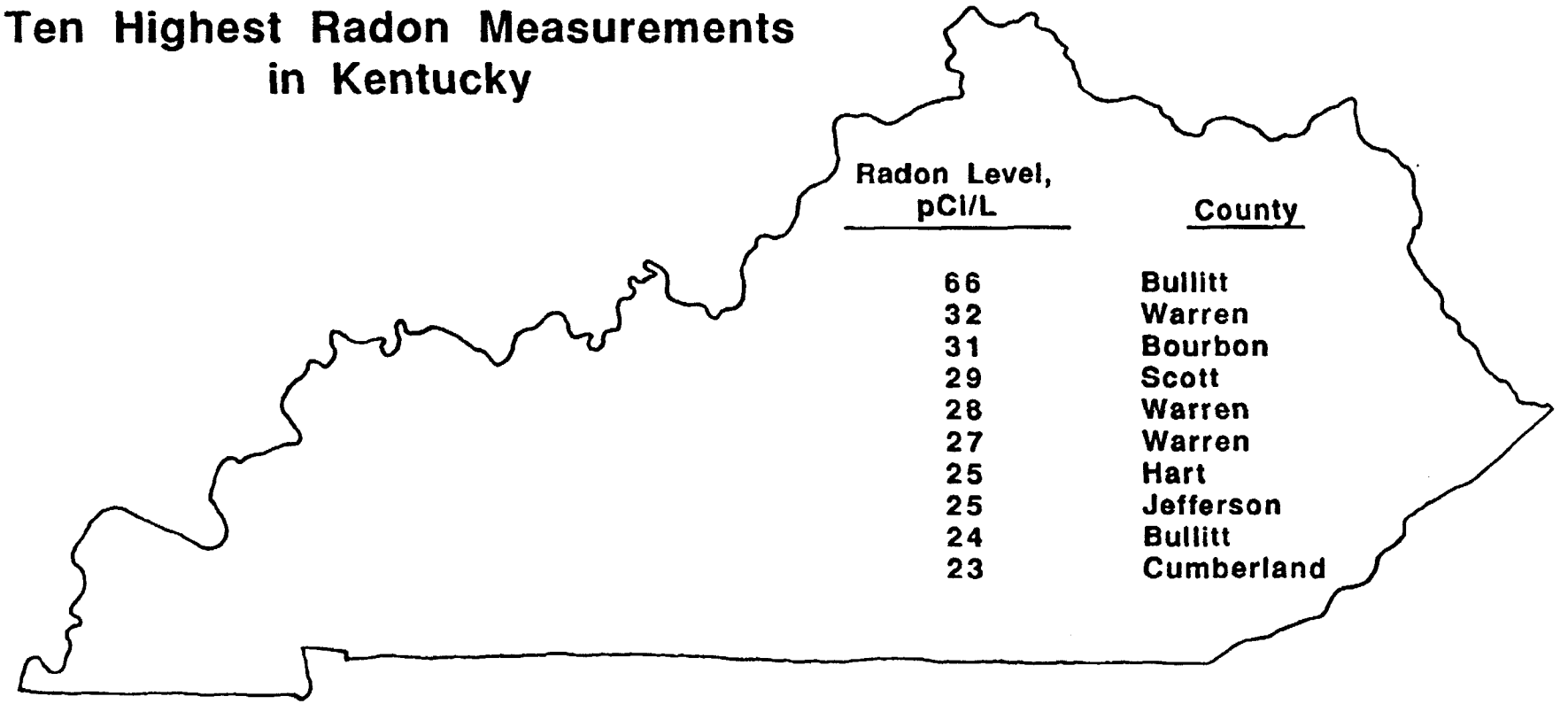
Distribution of Indoor Radon Screening Measurements

Radon Levels, pCi/L	Percent of Houses with These Levels*
0 - 4	83%
4 - 20	16%
> 20	1%

Average Level	2.8 pCi/L
Number of Houses Measured	900

* There is a 95% certainty that these values represent all houses in Kentucky to within 3 percentage points.

Ten Highest Radon Measurements in Kentucky



Radon Level, pCi/L	County
66	Bullitt
32	Warren
31	Bourbon
29	Scott
28	Warren
27	Warren
25	Hart
25	Jefferson
24	Bullitt
23	Cumberland

These single measurements may not be representative of all houses in these counties.

THE 1987 MICHIGAN INDOOR RADON SURVEY

SPRING SURVEY FACT SHEET

The Michigan Department of Public Health and 46 of Michigan's local health departments, with technical assistance from the U. S. Environmental Protection Agency, commenced a survey to identify areas within the state that have the potential for significantly elevated indoor radon levels and to determine the distribution of indoor radon screening measurements across Michigan. The survey was started in March and ran through May, 1987, when activities were suspended during the summer months. Restart of the survey is tentatively scheduled for October 1, 1987, with completion by early 1988. Screening measurements were taken in a random sample of single-family, owner-occupied homes across Michigan using charcoal canisters. The U. S. Environmental Protection Agency has recommended a remedial action level of 4 pCi/l as an annual average concentration. These screening measurements do not represent annual average concentrations, but they can be used to determine whether follow-up measurements are necessary.

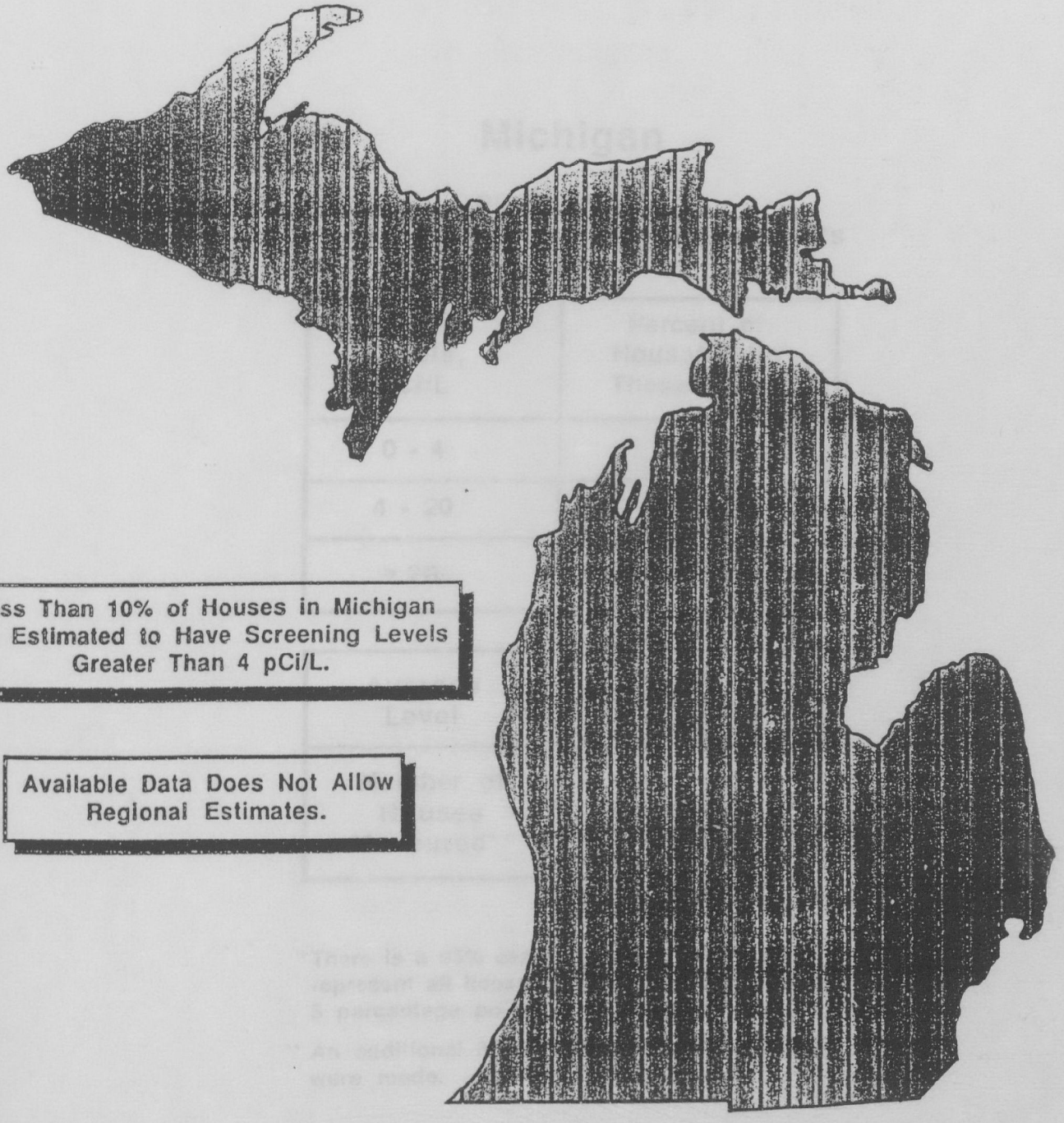
Michigan made 498 measurements this past spring during the initial phase of the survey. Based on a preliminary analysis of the data, 87.3% of the homes surveyed in Michigan had measurements below 4 pCi/l, and 12.5% of the homes tested had measurements between 4 pCi/l and 20 pCi/l. The highest level detected in the state was 162.1 pCi/l, while the average screening result was 2.7 pCi/l for homes with detectable levels of radon. Eighty-two of the homes tested had levels below the analytical minimum detectable level of 0.5 pCi/l, and the 2.7 pCi/l average did not include those measurements.

Since the Michigan survey is only about 20% complete, it is premature to conclude that any specific area of the state has a radon problem. During the completion of the survey additional measurements will be taken in the area surrounding the home with the state's highest survey measurement. This area and others which may become evident as a result of the survey continuation next fall, will be delineated at the completion of the survey. Until such time that we can provide more detailed information regarding areas within the state with significant potential for elevated indoor radon levels, we recommend that any homeowner who is particularly concerned about exposure to indoor radon consider having their home tested. A list of commercially available monitoring services can be obtained from state and local health department agencies in Michigan.

Because radon levels can vary greatly from season to season as well as from room to room, a screening measurement, such as those taken for the Michigan survey, only serves to indicate the potential for a radon problem. Depending on the results of the screening measurement, follow-up tests are recommended. For homeowners who have participated in the survey or have had private screening measurements made in their homes, the Michigan Department of Public Health and the Environmental Protection Agency recommend that follow-up tests be made in homes with screening measurements above 4 pCi/l.

RD:p
7/30/87

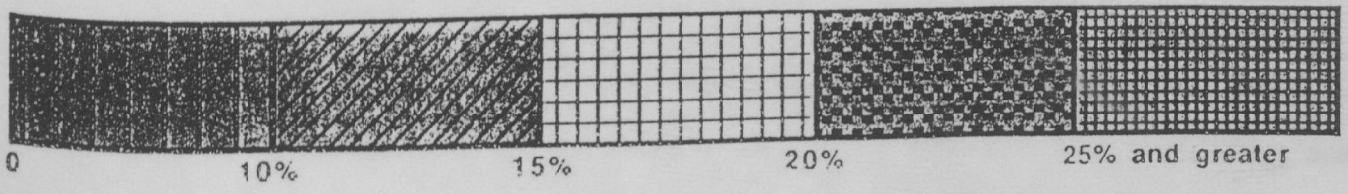
Radon Results in Michigan



Less Than 10% of Houses in Michigan Are Estimated to Have Screening Levels Greater Than 4 pCi/L.

Available Data Does Not Allow Regional Estimates.

Estimated Percent of Houses With Screening Levels Greater than 4 pCi/L



Michigan

Distribution of Indoor Radon Screening Measurements

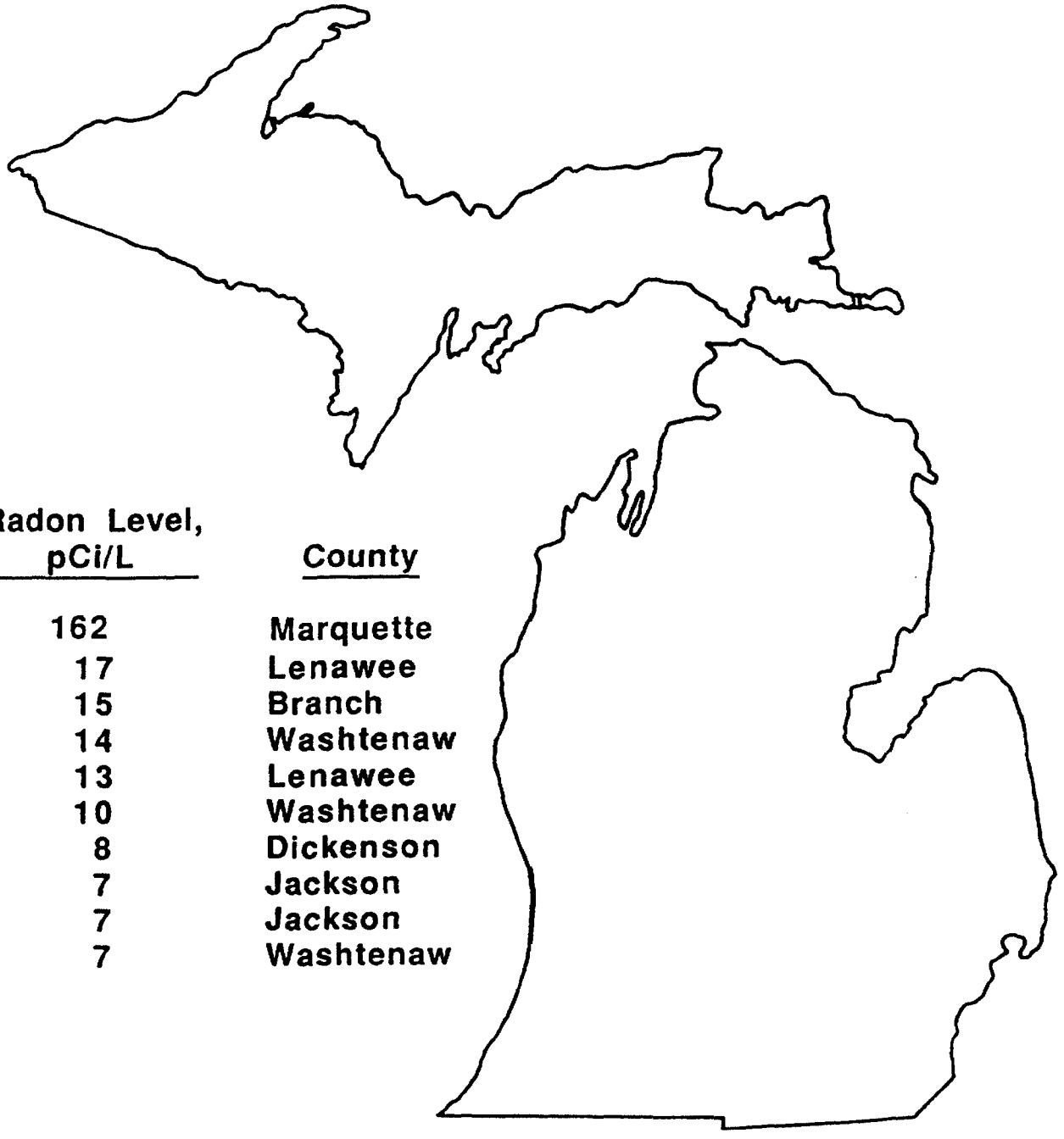
Radon Levels, pCi/L	Percent of Houses with These Levels*
0 - 4	91%
4 - 20	9%
> 20	<1%

Average Level	1.8 pCi/L
Number of Houses Measured**	200

*There is a 95% certainty that these values represent all houses in Michigan to within 5 percentage points.

** An additional 300 measurements were made.

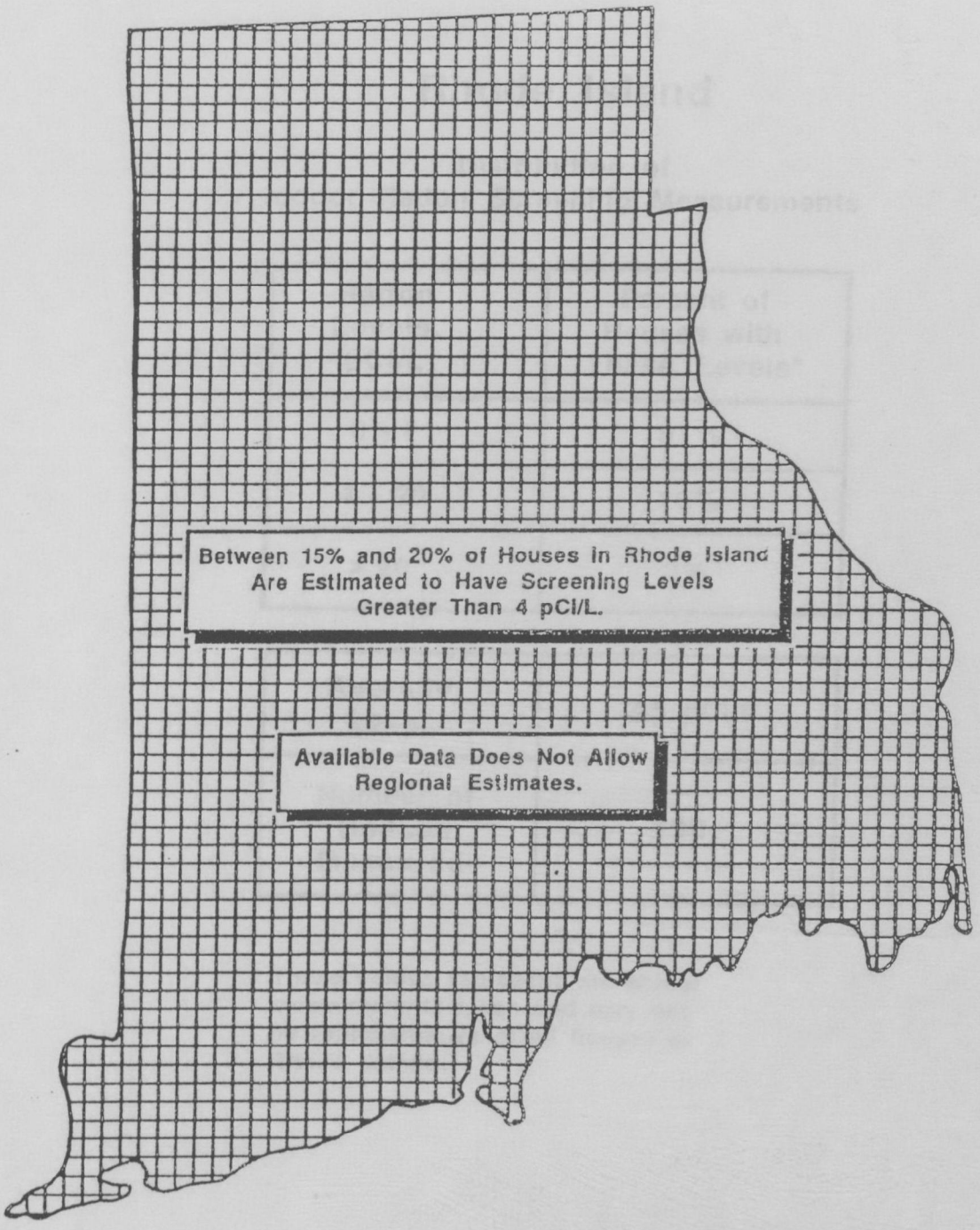
Ten Highest Radon Measurements In Michigan



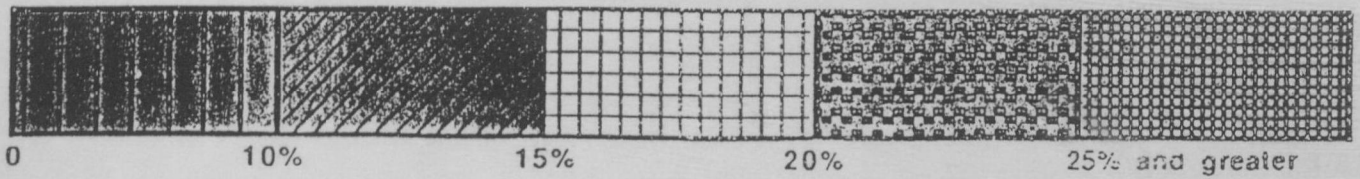
Radon Level, pCi/L	County
162	Marquette
17	Lenawee
15	Branch
14	Washtenaw
13	Lenawee
10	Washtenaw
8	Dickenson
7	Jackson
7	Jackson
7	Washtenaw

These single measurements may not be representative of all houses in these counties and were the highest in the total of 500 measurements made.

Radon Results in Rhode Island



Estimated Percent of Houses With Screening Levels Greater than 4 pCi/L



Rhode Island

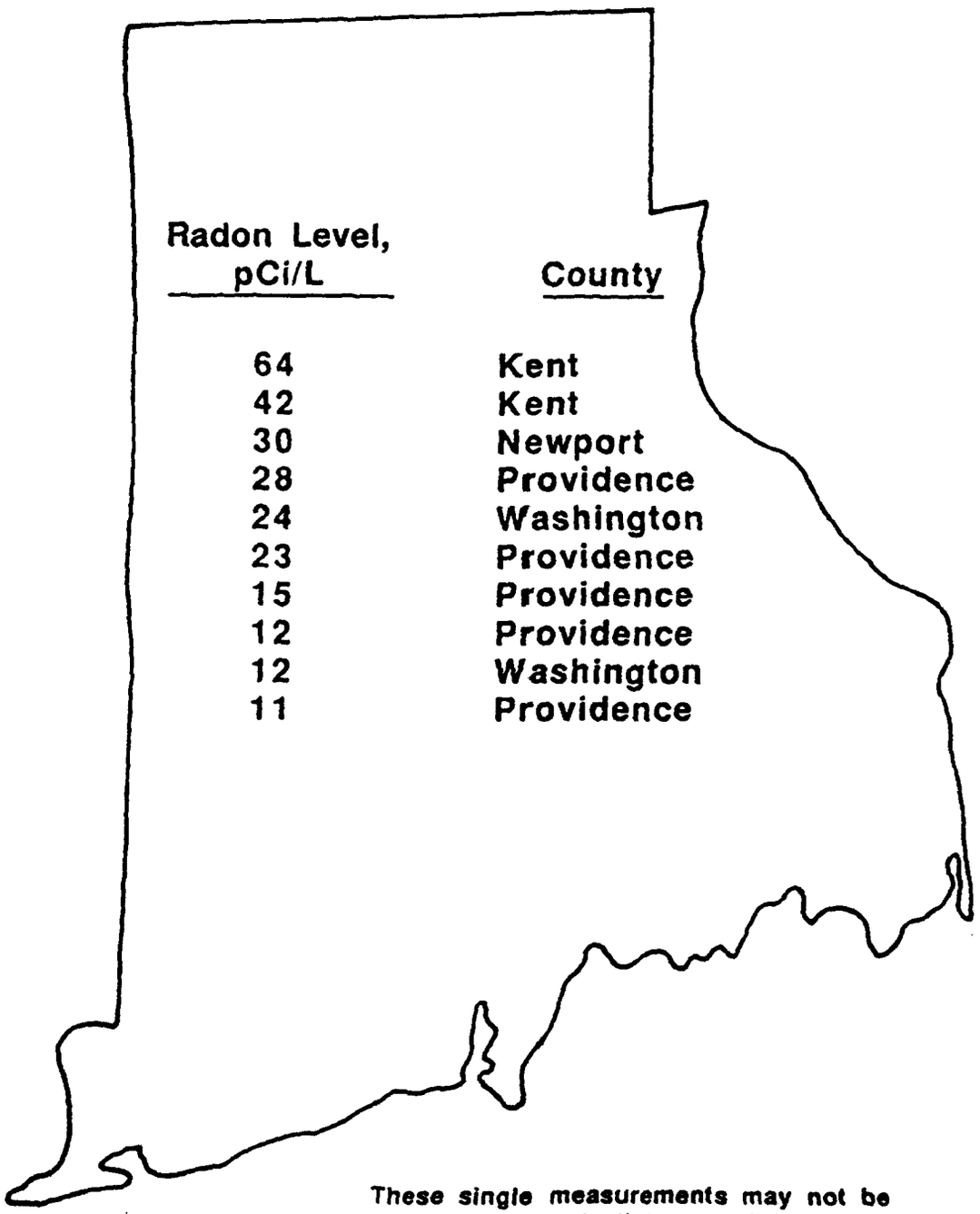
Distribution of Indoor Radon Screening Measurements

Radon Levels, pCi/L	Percent of Houses with These Levels*
0 - 4	81%
4 - 20	16%
> 20	3%

Average Level	3.5 pCi/L
Number of Houses Measured	190

* These values represent the actual measurements taken and may not be representative of all houses in Rhode Island.

Ten Highest Radon Measurements in Rhode Island



Radon Level, pCi/L	County
64	Kent
42	Kent
30	Newport
28	Providence
24	Washington
23	Providence
15	Providence
12	Providence
12	Washington
11	Providence

These single measurements may not be representative of all houses in these counties.

8/87

TENNESSEE RADON SURVEY

FACT SHEET

The State of Tennessee, in cooperation with the EPA, conducted a survey to identify areas within the State with the potential for significantly elevated indoor radon levels. The Tennessee Radon Survey was based on measurements taken in a random sample of 1,787 single-family, owner-occupied homes across the State. Measurements were taken with charcoal canisters, and represent screening measurements only. These test results should be used to determine whether or not follow-up measurements are necessary and should not be used to characterize citizens' exposure to radon in Tennessee.

The State plans to make a total of 3,000 measurements as part of this survey. To date, Tennessee has analyzed results from 60% of the measurements. Based on this preliminary analysis of the data, it has been estimated 84.2% of the single-family dwellings in the State have radon levels below 4 pCi/L, 14.5% have levels between 4 and 20 pCi/L, and 1.3% have levels equal to or greater than 20 pCi/L. The highest level detected in the State Survey was 99.9 pCi/L.

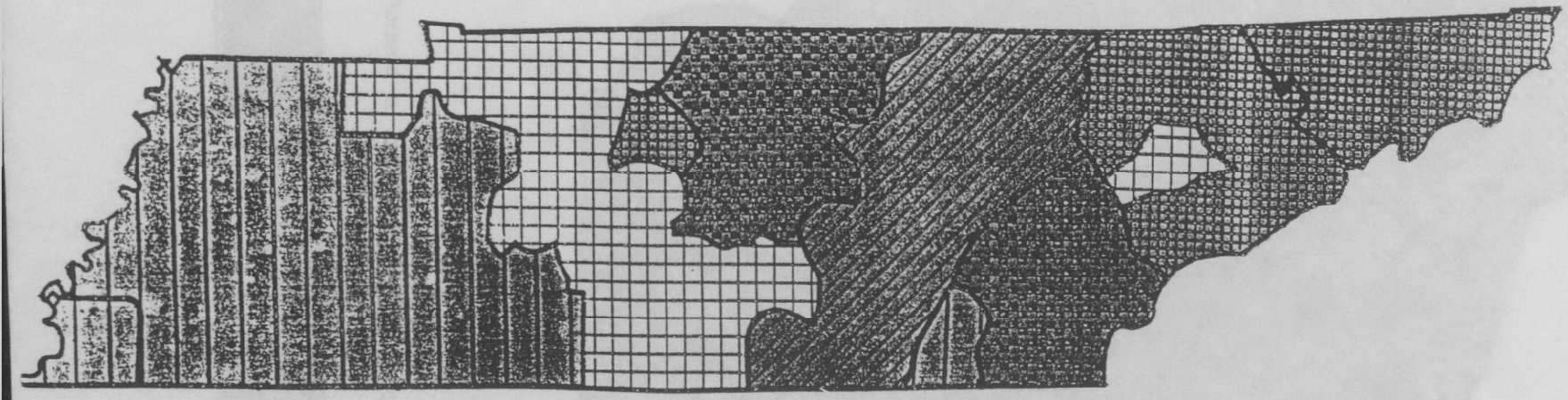
As a result of these findings, we feel it is prudent to recommend that homeowners throughout middle and east Tennessee have their homes screened for indoor radon.

For homeowners who have already had screening measurements made in their homes, the Tennessee Department of Health and Environment and the Environmental Protection Agency recommend that follow-up tests be made in homes with screening measurements above 4 pCi/L. As part of our ongoing efforts to address the radon problem in Tennessee, we plan to select a number of these homes in which screening measurements were made and ask homeowners to allow us to make follow-up long-term measurements. We also plan to conduct additional screening measurements in the State. We will concentrate in those areas of the State where it appears the extent of the radon problem needs to be investigated further.

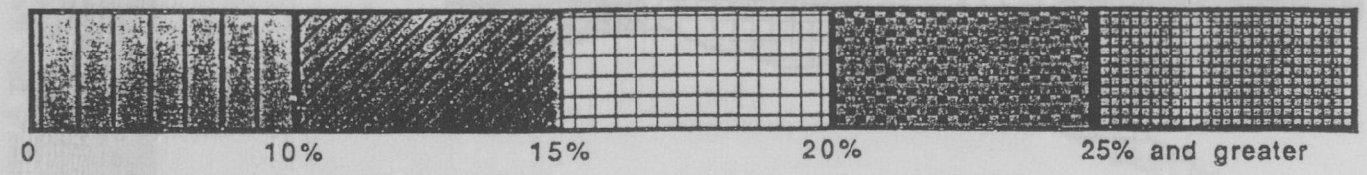
In the future, Tennessee plans to provide the following services to its citizens to help them address the radon problem:

- Study radon and issues related to it through a special committee established by the State legislature.
- Assist the EPA in conducting research on radon reduction techniques in a number of homes in the State.
- Sponsor training sessions in cooperation with the EPA on radon mitigation techniques.
- Provide literature on radon and radon reduction methods to the public.
- Provide lists of suppliers of radon detectors to citizens interested in making radon measurements.

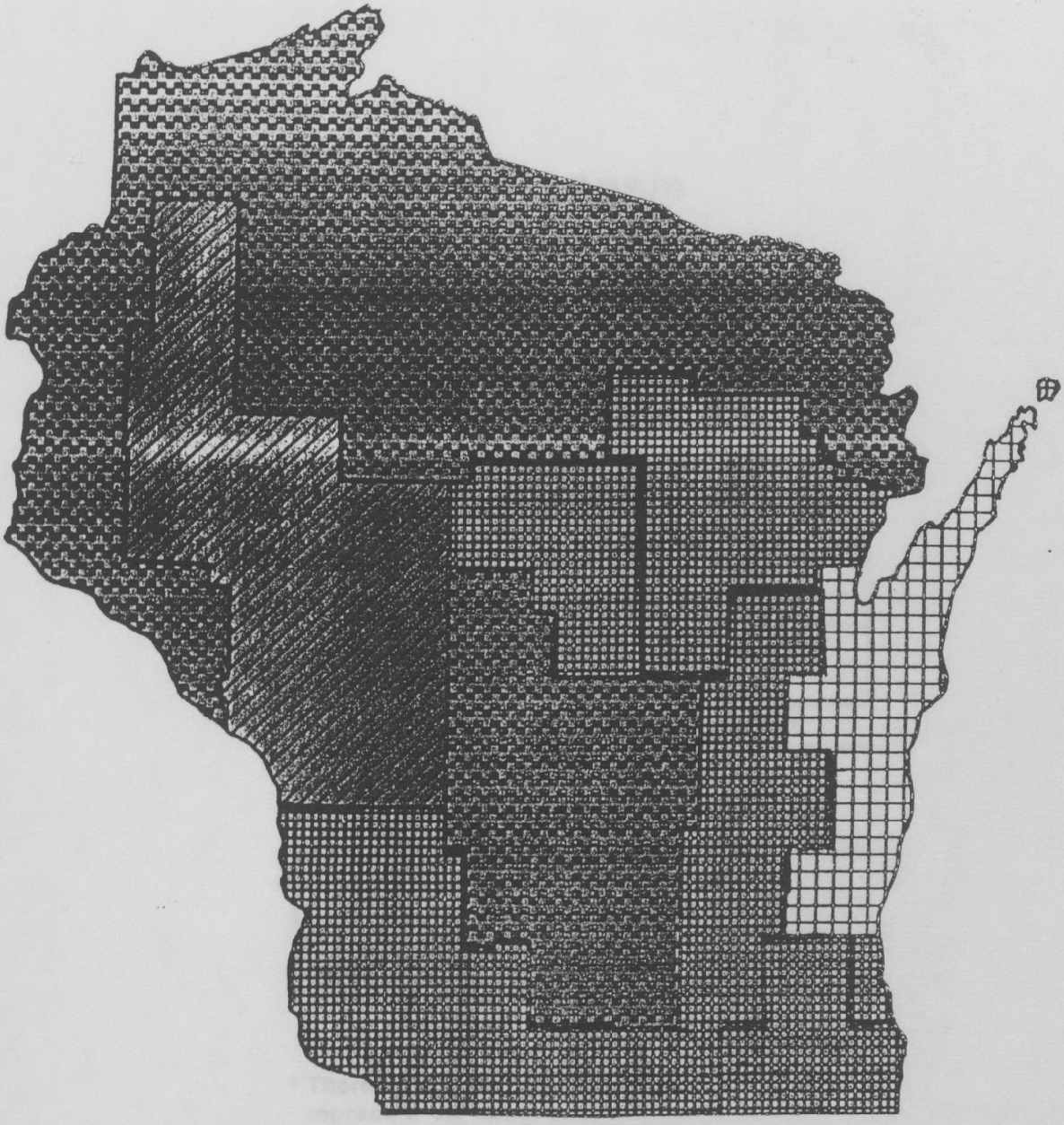
Radon Results in Tennessee by Region



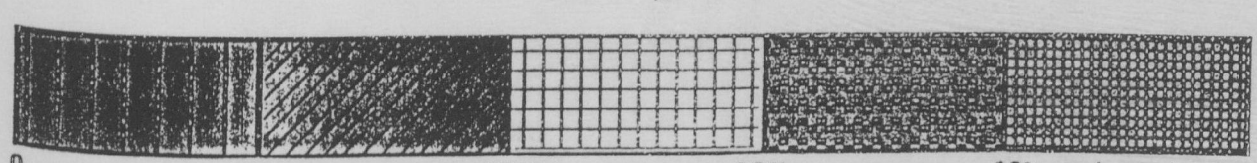
Estimated Percent of Houses With Screening Levels Greater than 4 pCi/L



Radon Results in Wisconsin by Region



Estimated Percent of Houses With Screening Levels Greater than 4 pCi/L



8/87

Wisconsin

Distribution of Indoor Radon Screening Measurements

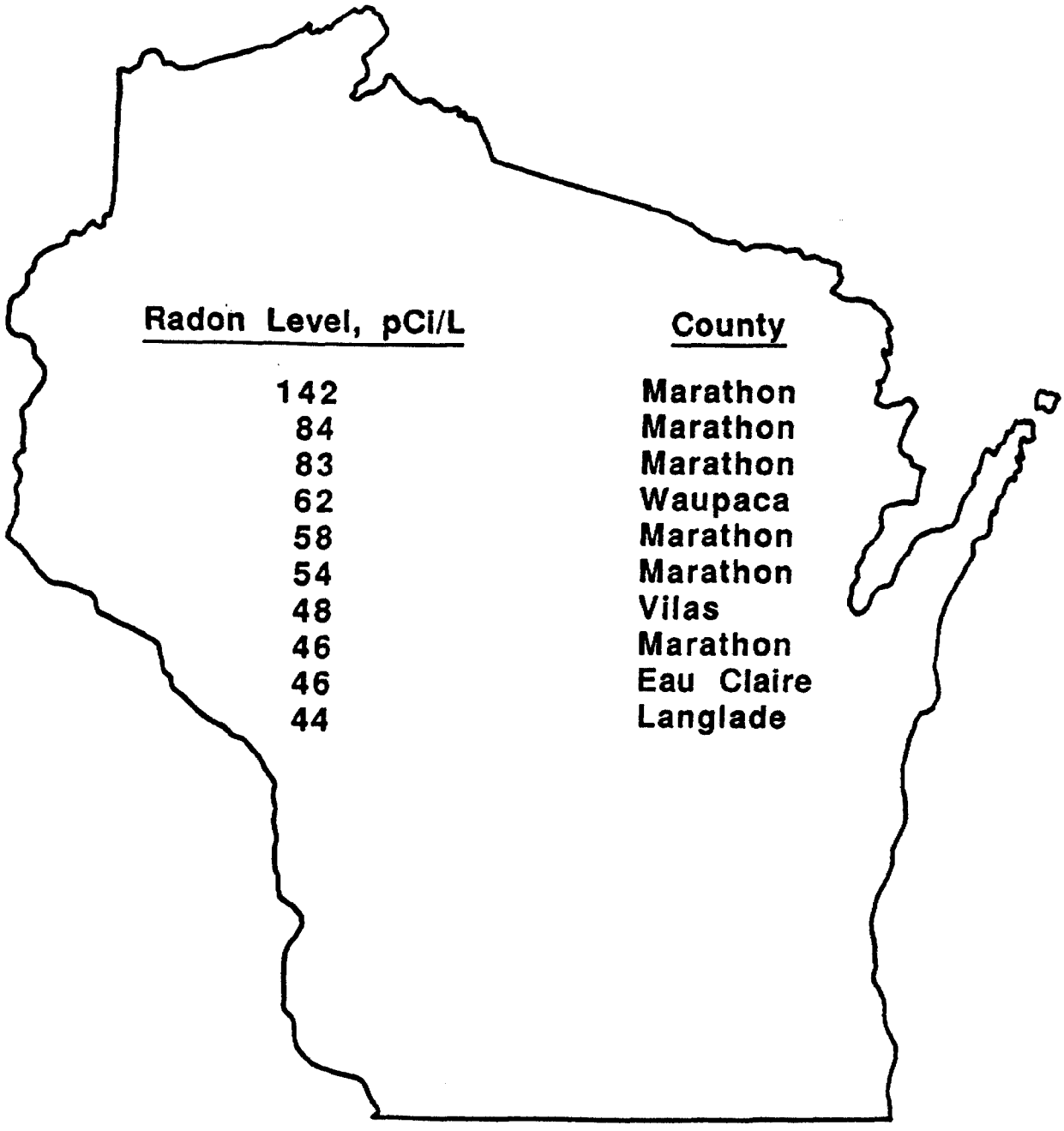
Radon Levels, pCi/L	Percent of Houses with These Levels*
0 - 4	73%
4 - 20	26%
> 20	1%

Average Level	3.4 pCi/L
Number of Houses Measured**	1,200

* There is a 95% certainty that these values represent all houses in Wisconsin to within 3 percentage points.

** An additional 500 measurements were made on a volunteer basis.

Ten Highest Radon Measurements in Wisconsin

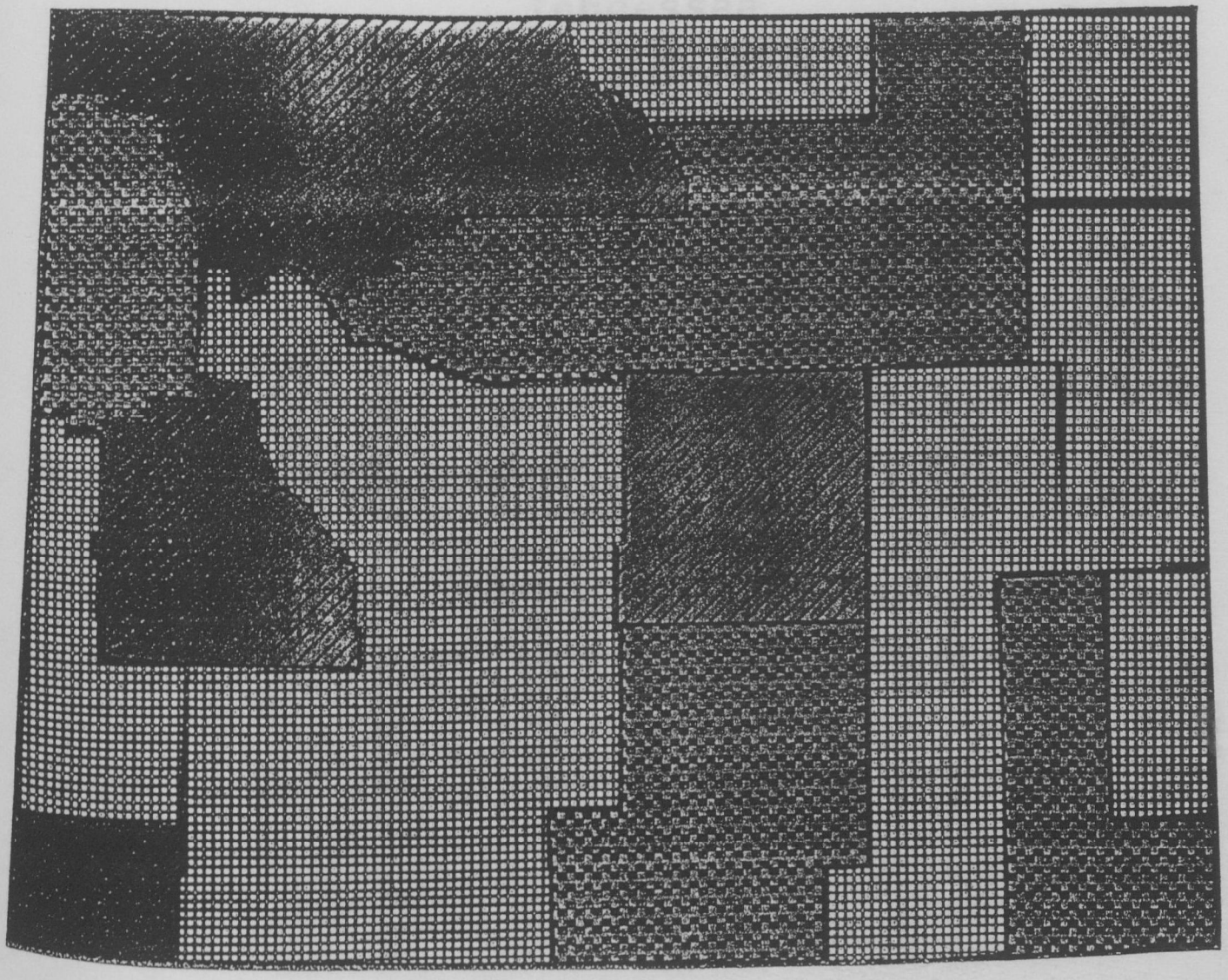


Radon Level, pCi/L	County
142	Marathon
84	Marathon
83	Marathon
62	Waupaca
58	Marathon
54	Marathon
48	Vilas
46	Marathon
46	Eau Claire
44	Langlade

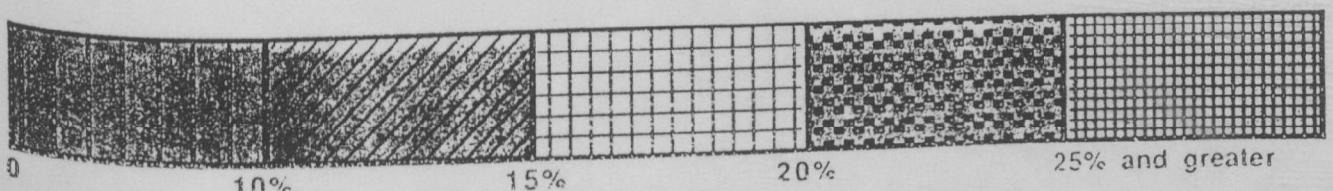
These single measurements may not be representative of all houses in these counties.

8/87

Radon Results in Wyoming By Region



Estimated Percent of Houses With Screening Levels Greater than 4 pCi/L



Tennessee

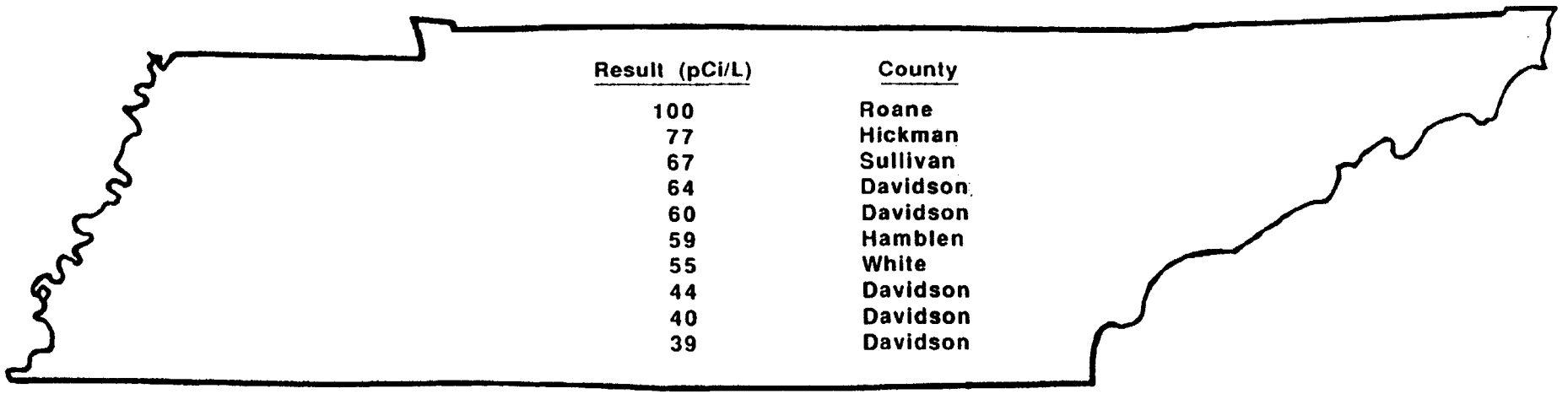
Distribution of Indoor Radon Screening Measurements

Radon Levels, pCi/L	Percent of Houses with These Levels*
0 - 4	84%
4 - 20	15%
> 20	1%

Average Level	2.7 pCi/L
Number of Houses Measured	1,800

*There is a 95% certainty that these values represent all houses in Tennessee to within 2 percentage points.

Ten Highest Radon Measurements in Tennessee



Result (pCi/L)	County
100	Roane
77	Hickman
67	Sullivan
64	Davidson
60	Davidson
59	Hamblen
55	White
44	Davidson
40	Davidson
39	Davidson

These single measurements may not be representative of all houses in these counties.

8/87

Wyoming

Distribution of Indoor Radon Screening Measurements

Radon Levels, pCi/L	Percent of Houses with These Levels*
0 - 4	74%
4 - 20	24%
> 20	2%

Average Level	3.6 pCi/L
Number of Houses Measured**	800

* There is a 95% certainty that these values represent all houses in Wyoming to within 4 percentage points.

** An additional 100 measurements were made on a volunteer basis.

PAGE NOT

AVAILABLE

DIGITALLY

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

4

EPA

Radon Facts

MEASURING RADON

The only way to know if a home contains a high level of radon is to test it. Since you cannot see, smell or taste radon, special equipment is needed to detect it. Homeowners can purchase radon detection equipment and do the tests themselves or they can employ a private contractor. Measurements must be made under specified conditions to ensure their accuracy. These conditions have been outlined in EPA's Radon Measurement Protocols.

Units of Measurements

- The concentration of radon in air is measured in units of picocuries per liter of air (pCi/L). One pCi/L represents the decay of two radon atoms per minute in a liter of volume of air.

- The concentration of radon decay products in air are measured in units of working levels (WL). One WL of radon decay products roughly corresponds to the amount of decay products released by 200 pCi/L of radon in air.

Testing Devices

Testing devices are available to the homeowner by mail or directly from private distributors. Proper placement of these devices is critical for obtaining accurate test results. Directions should describe the preferred locations and conditions for detector placement. At the end of the testing period, the devices must be sealed and returned to the distributor for analysis. Homeowners should contact State or local officials to obtain information on testing devices and private testing companies operating in their area. The two most widely used and least expensive detectors are:

- Charcoal Canister - Consists of a small container filled with activated charcoal. Radon is adsorbed in the charcoal. The radon decay products emit gamma rays. The radon concentration is estimated by counting the amount of gamma rays emitted.

- Alpha-track Detector - Consists of a small piece of plastic. Alpha particles, resulting from the decay of radon, strike the plastic and produce tracks. These tracks can be related to the concentration of radon.

Other testing devices used mostly by private contractors include:

- Continuous Radon Monitors - Air passes through a filter into a scintillation cell. Alpha particles are emitted and detected by a special electronic tube. This device can be programmed and measurements can be made at regular intervals.

- Continous Working Level Monitors - Radon decay products are measured by a solid-state alpha detector which counts the emitted alpha particles. This device can be programmed and measurements can be made at regular intervals.

- Grab Radon Sampling - A small sample of air is drawn into a flask. Emitted alpha particles produce light pulses which are counted by a special electronic tube.

- Grab Working Level Sampling - Radon decay products are collected in a known volume of air. Alpha particles emitted are then counted by a phosphor and photomultiplier tube assembly.

Testing devices are also available to measure radon in household water supplies:

- Liquid Scintillation Spectrometers - These devices utilize a liquid which emits light when struck by a nuclear particle. The water sample containing the radon is mixed with this liquid and the light flashes are counted on a liquid scintillation counting system.

- Alpha-track Detector - See description above.

Measurement Procedures

Taking a radon measurement is the first step in determining whether or not your house has a radon problem. EPA recommends a quick and inexpensive initial screening. If the results indicate the possibility of high radon levels, then follow-up measurements should be taken to provide a more precise picture of the average distribution and levels of radon throughout your home. Some vendors may offer special prices for multiple detectors and consumers may want to supplement the initial screening test and determine levels throughout the house.

- The EPA has developed testing protocols providing detailed information on proper testing procedures. These "Measurement Protocols" are available from EPA or from State or local officials.

- Once test results are received, homeowners should refer to the "Citizen's Guide to Radon" for assistance in interpreting their results.

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

5

EPA

Radon Facts

RADON RISK ASSESSMENT

As with other environmental pollutants, there is some uncertainty about the risks associated with radon. To account for this uncertainty, scientists generally express the risks associated with a particular radon level as a range of numbers. The risk estimates given in "A Citizen's Guide to Radon" are based on the advice of EPA's Science Advisory Board, an independent group of scientists established to advise the Agency on various scientific matters.

- Radon risk estimates are based on scientific studies of underground miners exposed to varying levels of radon. Consequently, the amount of uncertainty scientists feel about the risk estimates for radon is considerably less than if they had to rely on animal studies alone.

- An increased risk of lung cancer is the only known health effect associated with exposure to elevated radon levels. Not everyone exposed to elevated levels of radon will develop lung cancer, and the time between exposure and the onset of disease may be many years. Lung cancer usually does not occur until people are 45 or older.

- The short-lived radon decay products, and not radon itself, are responsible for the cancer risk associated with elevated radon levels. Radon decays into four short-lived radioactive elements known as decay products, which can be inhaled and trapped in a person's lung. As these decay products break down further, they release small bursts of energy which can damage lung tissues and lead to lung cancer.

- Scientists estimate that about 5,000 to 20,000 lung cancer deaths a year in the United States may be attributed to radon. (The American Cancer Society expects that about 136,000 people will die of lung cancer in 1987. The Surgeon General attributes roughly 85% of all lung cancer deaths to smoking.) Risk of lung cancer from radon exposure depends on both the concentration of radon and duration of exposure.

- Various assumptions are made in applying epidemiological data from underground miners to residential situations. EPA's risk assessments assume an individual is exposed to a given concentration of radon over a lifetime of roughly 70 years, and spends 75% of his or her time in the dwelling with elevated radon levels.

- Four epidemiological studies have been initiated or planned in the U.S. to further examine the link between lung cancer and radon exposure in residential structures. The National Cancer Institute is conducting studies with both New Jersey and Missouri; EPA is planning a study in Maine and the Argonne National Laboratory has a study in Pennsylvania.

While data from epidemiological studies will take a long time to both collect and interpret, the results should further understanding of the risks associated with exposure to elevated radon levels.

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

6

EPA

Radon Facts

RADON MITIGATION IN
EXISTING STRUCTURES

A variety of techniques exist for reducing indoor radon levels. The EPA's experience has shown that site and structural conditions play an important role in determining the success or failure of radon mitigation techniques. In general, the following approaches can be used:

- Sealing Off Entry Routes - to reduce gas entry into a house, barriers can be placed between the source material and the living space. This can include covering exposed earth with concrete or a gas-proof liner, sealing cracks and holes in concrete walls and floors, covering sumps and placing a removable plug in untrapped floor drains.

- House Ventilation - this method involves increasing a house's air exchange rate (the rate at which incoming fresh air replaces existing indoor air) either naturally by opening windows or vents, or mechanically through use of fans or heat recovery ventilators.

- Soil Ventilation - soil ventilation prevents radon from entering the house by drawing the gas away from the foundation before it can enter. Active ventilation techniques include hollow block wall ventilation, sub-slab ventilation using drain tile suction, as well as wall and sub-slab ventilation using selected suction points. Care must be taken when installing these methods to seal major openings that could reduce suction.

Mitigation techniques are also available for the less frequently encountered problem of radon in water:

- Granular Activated Carbon - when a household water supply is passed through a tank containing activated carbon, up to 99% of the waterborne radon will be captured. Investigation is continuing into safe and cost-effective disposal methods for the spent carbon.

- Aeration - Also known as air stripping, this method removes radon before water enters the house. Costs range from 10 cents to $1.70 per thousand gallons treated, depending on system size.

No one technique can be relied upon to consistently reduce radon levels in every house. Each house must be evaluated to determine the source and potential entry routes before an mitigation approach is adopted. EPA has successfully reduced radon levels in a number of houses and is continuing to research a variety of mitigation techniques. More information on these techniques is provided in EPA's booklet, "Radon Reduction Techniques: A Homeowner's Guide."

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

7

EPA

Radon Facts

Radon Action Program

Program Goals and Structure

The goal of EPA's Radon Action Program is to significantly reduce the health risks of radon through a partnership with other Federal Agencies and the States. To accomplish this goal, EPA is developing and disseminating technical knowledge to encourage, support and facilitate the development of State programs and private sector capabilities in the areas of radon assessment and mitigation. The program consists of four major elements:

- Problem Assessment: To identify areas with high levels of radon in homes and to determine the national distribution of radon levels and associated risks.
- Mitigation and Prevention: To identify cost-effective methods to reduce radon levels in existing structures and to prevent elevated radon levels in new construction.
- Capability Development: To stimulate the development of state and private sector capabilities to assess radon problems in homes, and to help people mitigate such problems.
- Public Information: To work with States to provide information to homeowners on radon, its risks, and what can be done to reduce those risks.

Activities

Problem Assessment:

- State Surveys: EPA will assist States in designing and conducting their own surveys to identify areas where indoor radon may be a problem.
- National Survey: The Superfund Amendments and Reauthorization Act (SARA) of 1986 requires a national assessment of radon in homes, schools, and places of employment. This effort is separate from the state survey program and will characterize the frequency distribution of indoor radon levels across the U.S.

- Land Evaluation Studies: The Agency is beginning efforts to identify those geological factors and characteristics which are most useful as indicators of high radon levels. EPA is also conducting preliminary work on the use of soil gas measurements to predict the radon potential for individual parcels of land.

- Health Studies: EPA is planning an epidemiological study in Maine. In addition, EPA is monitoring epidemiological and health studies being conducted by other organizations including the National Cancer Institute, universities, States and other Federal agencies.

Mitigation and Prevention:

- Radon Mitigation Demonstration Program: EPA is demonstrating selected mitigation techniques in homes in the Reading Prong and other areas.

- House Evaluation Program: This EPA program assists the States in providing house evaluations and mitigation recommendations to homeowners, as well as providing "hands-on" training to State personnel.

- New Construction Program: EPA is working closely with the housing industry to develop and demonstrate techniques to prevent radon entry in new construction. The Agency is also working to ensure that efforts in the area of radon prevention are reflected in local building codes.

Capability Development:

- Radon Mitigation Training: This technical training course on radon diagnosis and mitigation techniques was developed by EPA for States and private contractors designated by the States.

- Radon Measurement Proficiency Program: EPA established a voluntary program which allows private firms and other organizations to demonstrate their proficiency in measuring radon and its decay products.

- Technical Guidance: EPA's Office of Research and Development used the Agency's experiences in radon mitigation to publish "Radon Reduction Techniques for Detached Houses: Technical Guidance". Technical publications will be updated periodically as new information becomes available.

Public Information:

- Brochures: EPA has prepared two informational brochures: "A Citizen's Guide to Radon: What It Is and What to Do About It" and "Radon Reduction Methods: A Homeowner's Guide". Both brochures are available through State radiation control programs. Three new brochures will be released shortly: "Removal of Radon from Household Water", "Radon Reduction in New Construction: An Interim Guide" (produced in conjunction with the National Association of Home Builders), and a joint venture with the American Medical Association to provide information for doctors and other health professionals. In addition, the Homeowner's Guide will be updated.

- Public Inquiries: EPA staff answer general questions about radon and refer callers to state radiation control program staffs for additional information.

- Other Activities: EPA staff participate in many technical and general conferences and workshops on indoor radon. They also regularly provide information and give interviews to the news media and frequently brief members of Congress and their staffs.

While much of the Agency's recent activity has been directed at assisting States in the Reading Prong area, the Radon Action Program lays the groundwork for identifying and dealing with similar problems elsewhere in the country.

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

8

EPA

Radon Facts

MAJOR RADON ACTION PROGRAM ACCOMPLISHMENTS

The EPA's Radon Action Program is aimed at protecting public health by reducing people's radon exposures in their homes. During the past two years, the program has accomplished a great deal. Below is list of some of these accomplishments:

Problem Assessment

- Issued standardized measurement protocols for seven measurement methods. These protocols help ensure that measurements are comparable and assure the public that readings are made accurately.

- Developed a survey design to assist States with statewide surveys of high-risk areas. Ten States have now completed more than 12,000 measurements with EPA assistance. Seven additional States will conduct surveys in FY 1987-1988.

- Completed a preliminary design for a National Survey which was reviewed by EPA's Science Advisory Board in June 1987; detectors could be in place later this year. Resource limitations may restrict the survey to a sample size of between 2,000-5,000 residences nationwide.

- An Advance Notice of Proposed Rulemaking was published in September 1986 concerning the development of enforceable drinking water standards for radon and other radionuclides. This document contains much of the occurrence, exposure, risk, detection, treatment and cost information that will serve as the basis for proposed final standards.

Mitigation and Prevention

- EPA established the House Evaluation Program to assist States in evaluating causes of and mitigation approaches for elevated indoor radon levels. 80 houses have been evaluated in Pennsylvania, with additional projects set to begin in New York, New Jersey and several other States.

- As of July 1987, mitigation demonstration projects in existing and new homes have been completed or are ongoing in Pennsylvania, New Jersey, New York and Maryland. Additional demonstration projects are being initiated and planned in other States.

Capability Development

- The Agency established the Radon Measurement Proficiency Program (RMP) and completed four rounds of evaluations. The program has grown from 35 firms and 47 detection methods in the first round to 360 participants and 590 methods tested in the most recent round.

- Conducted 27 three-day radon diagnostician and mitigation training courses entitled "Reducing Radon in Structures" for States and private contractors. Over 1000 people from more than 40 States were trained.

- EPA is working with the National Association of Home Builders (NAHB) to provide technical guidance to builders interested in using radon prevention techniques in their new construction efforts.

Public Information

- Prepared and released two informational brochures: "A Citizen's Guide to Radon: What it is and What to Do About it," and "Radon Reduction Methods: A Homeowner's Guide."

- Developed and distributed a technical manual, "Radon Reduction Techniques for Detached Houses," for use by contractors and interested homeowners.

- Two new brochures are being developed for release in summer 1987: "Removal of Radon from Household Water," and "Radon Reduction in New Construction: An Interim Guide." In addition, a joint venture with the American Medical Association will provide information for use by doctors and other health professionals.

- Radon Action Program staff also participate in many technical and general conferences and workshops on indoor radon; provide information and interviews to the news media and briefings to Congressional members and their staffs; and respond to hundreds of public inquiries regarding indoor radon.

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

9

EPA

Radon Facts

RADON MITIGATION RESEARCH PROGRAM

The objective of EPA's Radon Mitigation Research Program is to develop and demonstrate cost-effective methods for reducing radon concentrations inside houses of all substructure types. The program addresses problems in both existing houses and new construction, and is national in scope. To encourage the development of information that will assist in the identification, design and implementation of additional demonstrations, EPA is working with public sector organizations (e.g., the Conference of State Radiation Control Program Directors) and private sector organizations (e.g., the National Association of Home Builders).

- EPA has successfully demonstrated mitigation techniques in approximately 40 houses in eastern Pennsylvania. All houses had initial radon levels ranging from 6 to 1200 pCi/L. Reductions of over 90% were achieved in most homes.

- In Clinton, New Jersey, ten houses with initial radon levels ranging from 400 to over 2000 pCi/L were selected for a demonstration project. Levels in all ten houses were reduced by more than 98%. In addition, 20 house-specific radon mitigation plans were developed for 20 different house designs in the Clinton area. Five town meetings were held with homeowners to explain the demonstration and results to them. Extensive assistance was also given to individual homeowners in the community who were not part of the demonstration.

- EPA is co-funding, with the Department of Energy and the State of New Jersy, a detailed diagnostic study of 14 piedmont homes to better understand the principles affecting radon entry into residences and appropriate mitigation techniques. Diagnostic protocols are being developed for use by researchers and ultimately, in simplified form, by mitigation contractors.

- Additional work is being carried out in the Oak Ridge, Tennessee, and northern Alabama areas in cooperation with the Tennessee Valley Authority and the Department of Energy focusing on detailed diagnostics and development of diagnostic protocols applicable to crawlspace houses.

- EPA and the New York State Energy Research and Development Authority are working together to examine radon reduction methods in 16 New York houses in the Orange/Putnam and Albany/Rensselaer areas. All houses have radon levels in the 20-200 pCi/L range. Diagnostic procedures similar to those used in Clinton are also being used on this project.

- Installations will be tested in up to 35 homes in Maryland under a joint project with the State that is currently underway. A project is being initiated in Nashville, Tennessee, and others are being planned in Florida, Ohio, Montana and Washington.

- Radon-resistent design features are being studied in new home construction projects in New Jersey and New York. Builders are being selected and plans drawn for radon prevention measures in the construction of 25 houses throughout the State of New Jersey and 15 houses in the Syracuse area of New York State. A cooperative project with a major builder has been initiated for the mid-Atlantic States.

- EPA has prepared a detailed manual, "Radon Reduction Techniques for Detached Houses" for contractors and those homeowners who are confident they have the tools, equipment and skills to do the job themselves. A revised and updated version of this manual will be published in late summer, as will a revised version of the brochure "Radon Reduction Methods: A Homeowner's Guide." A brochure on "Removal of Radon From Household Water" will also be published in late summer.

- EPA has developed test matrices for the selection of new and existing houses for study. Both matrices consider such factors as radon reduction or preventive techniques, house substructure, initial indoor radon concentration, geology, and climate. The EPA's Science Advisory Board has reviewed and endorsed these matrices.

In future demonstrations, EPA will expand activities into different States based upon the test matrix, and will consider other factors such as the radon survey data for the State, the project's cost-effectiveness, the possibility of cost-sharing by the State, and the severity of the State's radon problem.

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

10

EPA

Radon Facts

RADON MEASUREMENT
PROFICIENCY PROGRAM

The EPA established the Radon Measurement Proficiency Program (RMP) to test the capabilities of companies measuring indoor radon. Most major measurement companies in the United States now participate in the RMP, and all 50 States distribute the RMP list to local governments and the public. Some features of this highly successful program are:

- Semiannually, companies voluntarily submit measurement devices to the EPA for testing. Testing periods, referred to as test "rounds" consist of two tests -- a performance test and a follow-up test. A company must take part in the follow-up test if it fails any of the program requirements in the performance test. Successful completion of either the performance or follow-up test is considered as successful completion of the test round.

- Successful companies are listed in the RMP report which is issued to each State semiannually.

- To maintain a proficiency listing, companies must participate in every test round. These listings can be obtained from State Radiation Protection Offices, EPA's regional offices, or by calling Research Triangle Institute, EPA's contractor for the program, at 1-919-541-7131.

- Since February 1986, four test rounds have been conducted and participation in the program has grown 1000 percent. Approximately 360 companies using 590 detector methods were tested in Round 4. To accommodate growth, EPA built a larger radon chamber at its Eastern Environmental Radiation Facility in Alabama.

The RMP is not meant to certify, recommend or endorse participating companies. However, some States have passed or are considering legislation for measurement company certification programs. This year, both New Jersey and Pennsylvania established certification programs which require, among other things, successful participation in the RMP.

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

11

EPA

Radon Facts

HOUSE EVALUATION PROGRAM

EPA initiated the House Evaluation Program (HEP) to evaluate the cost and effectiveness of mitigation methods in the private sector and to train State and private sector personnel in diagnosing and mitigating radon in houses. State personnel, in cooperation with EPA, diagnose a house with elevated levels and offer the homeowner several alternative mitigation schemes. The homeowner then chooses the mitigation technique to be installed and selects the contractor. The responsiblities of the State, homeowner and EPA are outlined below:

- Participating States are responsible for the HEP's initial tasks which include contacting homeowners, selecting houses and drafting a Homeowner's Agreement to clarify State and homeowner responsibilities.

- Homeowners are responsible for providing access to their houses which allows for evaluation of mitigation activities in real-life situations. In addition, homeowners select the mitigation techniques to be installed, and hire and fund contractors. Through the HEP, homeowners receive a detailed evaluation of mitigation options and a final evaluation of the effectiveness of the mitgation methods employed.

- EPA is responsible for both the pre-mitigation evaluation (house diagnosis) and the post-mitigation evaluation. The house diagnosis determines radon entry routes and sources, and provides a list of mitigation techniques which may reduce the radon problem. The final evaluation determines the cost and effectiveness of the mitigation effort. EPA must also review the Homeowner's Agreement drafted by the States.

To date, over 100 houses have been evaluated in Pennsylvania, New Jersey and New York, and mitigation work is underway. EPA plans to expand its program into Tennessee, Ohio, and Virginia, as well as other States. An additional benefit of this program is that more than 40 State officials have been given field training in radon diagnosis and mitigation.

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

12

EPA

Radon Facts

STATE RADON ACTIVITIES

As awareness of the public health risks associated with indoor radon increases, States are establishing programs designed to address this problem. A number of States across the country are currently assessing and mitigating radon problems. Different approaches are used by States depending on the availability of resources, technical expertise, public concern and/or media attention and the estimated magnitude of the problem. For example, several States distribute EPA radon brochures and the Radon Measurement Proficiency Report to homeowners upon request. On the other hand, a few States are establishing comprehensive programs to distribute and develop public education materials as well as other activities, including: conducting surveys; providing training programs for State and local officials and private contractors; sponsoring mitigation demonstration and evaluation projects; and conducting research.

Provided below are examples of some State radon activities:

- Almost all States are distributing EPA radon brochures and technical information. To date, more than 300,000 copies of "A Citizen's Guide to Radon": What It Is And What To Do About It" and "Radon Reduction Methods: A Homeowner's Guide" have been distributed by EPA and the States.

- Ten States participated in the State/EPA Radon Survey program:

  Alabama
  Colorado
  Connecticut
  Kansas
  Kentucky
  Michigan
  Rhode Island
  Tennessee
  Wisconsin
  Wyoming

- Seven new States as well as some Indian tribes have been selected for participation in the 1987-1988 program:

  Arizona
  Indiana
  Indian Health Service (Tri-State survey)
  Massachusetts
  Minnesota
  Missouri
  North Dakota
  Pennsylvania

- Some States, including Indiana, Illinois, Pennsylvania and New Jersey, are taking radon measurements in schools.

- More than 40 States have been represented at EPA's radon training course on how to diagnose and mitigate indoor radon problems. Pennsylvania, New York and New Jersey are using EPA training materials, including a video-tape produced by the Agency, to conduct their own courses.

- Toll-free hotlines have been established by several States including Maryland, Minnesota, Wyoming, Illinois, Virginia, New Jersey, New York and Pennsylvania. Some States receive as many as 3,000 calls per month.

- Five States, with approximately 10 houses in each State, are participating in the EPA House Evaluation Program which provides free diagnosis and follow-up: Pennsylvania, New York, Tennessee, Virginia, and Ohio.

- Radon problems in approximately 50 houses in Pennsylvania and New Jersey were successfully mitigated through State participation in EPA's Radon Mitigation Research Program. Additional activities are underway or planned in Tennessee, Alabama, New York, Maryland, Florida, Ohio, Montana, and Washington.

- Several States are conducting health risk studies designed to correlate incidences of lung cancer with exposure to indoor radon. Idaho, South Carolina, Maine, New Jersey, New York and Pennsylvania are conducting various radon health risk studies.

EPA is providing a variety of technical assistance to States as they begin to establish their radon programs. One of the Agency's most important roles is to help States share information with other States as they develop their radon programs. Cooperative Agreements have been developed between EPA and the State Conference of Radiation Control Program Directors, and the National Conference of State Legislatures to develop information materials and to conduct national workshops for their members.

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

13

EPA

Radon Facts

STATE SURVEYS

In response to requests for aid from many States, EPA's Office of Radiation Programs established a program to help States conduct indoor radon surveys. This program will help States conduct surveys to identify high radon risk areas within States and to estimate State-wide frequency distributions of screening levels. These surveys, along with EPA's national survey, will help EPA assess the extent of the radon problem nationwide.

- Surveys conducted under the program use probability-based sample selection and geologic characterizations to determine areas of the State with high potential for elevated levels. States participating in the program are responsible for management of the survey and must commit sufficient resources to the survey.

- EPA will provide and analyze charcoal canister radon detectors and will assist the States with survey design, canister mailing, questionnaire development, training and data analysis.

- The ten States participating in the initial 1986-1987 program were:

  Alabama
  Colorado
  Connecticut
  Kansas
  Kentucky
  Michigan
  Rhode Island
  Tennessee
  Wisconsin
  Wyoming

- Seven States will be taking part in the 1987-1988 survey:

  Arizona
  Indiana
  Massachusetts
  Minnesota
  Missouri
  North Dakota
  Pennsylvania

In addition, a survey of selected Indian tribes in EPA's Region 5 will be conducted in conjunction with the Indian Health Service.

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

14

EPA

Radon Facts

NATIONAL SURVEY

The Superfund Amendments and Reauthorization Act (SARA) calls for EPA to conduct a national assessment of radon levels where people live and work, including educational institutions. The National Survey is part of this national assessment and addresses only residential structures. A separate feasibility study is now being done for schools and workplaces. Important aspects of the National Survey are outlined below.

- The objective of the National Survey is to determine the frequency distribution of annual average radon concentrations in residential structures nationwide. This will be accomplished by placing alpha-track detectors in living areas of selected residences for a one year period.

- It is estimated that the sample size will be between 2000 and 5000 houses across the United States.

- Data will also be gathered on geological factors and building characteristics.

Implementation of the National Survey is dependent upon review by the EPA's Science Advisory Board and the Office of Management and Budget (OMB). The Science Advisory Board reviewed comments on the survey in June 1987; a final report is expected in August 1987. The survey will begin once the final report has been approved.

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

15

EPA

Radon Facts

SUPERFUND AMENDMENTS AND
REAUTHORIZATION ACT OF 1986

The Superfund Amendments and Reauthorization Act of 1986 contains two provisions related to indoor radon:

- Section 118(k) deals specifically with radon assessment and mitigation, and requires EPA to conduct a national assessment of radon levels and a radon mitigation demonstration program.

- Under Section 118(k)(1), EPA must submit a report in October, 1987 which identifies and assesses locations where radon is found in the United States. In addition, EPA is to determine radon levels which pose health threats and to assess the extent of these threats. The report must also discuss methods to reduce or eliminate radon problems, and include guidance and public materials based on the results of mitigation work.

- Annual status reports on mitigation efforts, are due each February, required by Section 118(k)(2). The first of these reports was submitted to Congress earlier this year.

- Title IV addresses both radon gas and indoor air pollution. Under Title IV, the EPA Administrator is required to establish a program which assesses the problem; coordinates Federal, State, local and private sector efforts; and assesses appropriate Federal actions to mitigate the risk of indoor air pollution.

- Program requirements under Title IV include research and development concerning identification, characterization and monitoring of sources and levels of indoor air pollution (including radon); research relating to health effects; research, development and demonstration of mitigation measures; research (in conjunction with the Department of Housing and Urban Development) to assess radon potential in new construction; and dissemination of information to the public.

- Part I of the required implementation plan for indoor air and radon research programs within the EPA was submitted to Congress in April 1987. Part II of this plan was submitted on June 1987. A final report is required in October 1988 detailing progress and making appropriate recommendations.

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

16

EPA

Radon Facts

SUMMARY OF PENDING
RADON LEGISLATION

Several bills have been introduced in the Congress to address various aspects of the radon problem. These fall into three major categories: 1) EPA programs to provide grant assistance to the States, and technical assistance to States and the private sector to establish radon reduction programs, and to conduct a study of radon contamination in the nation's schools; 2) IRS/tax breaks for the costs of correcting radon problems in residences; 3) an HUD program to assist States and localities in modifying building codes to require testing for radon. The following summarizes these bills and their current status.

EPA Programs

- S. 744 The Radon Program Development Act of 1987: Approved by the Senate on July 8, 1987, by voice vote. S. 744 was introduced by Senator George Mitchell (D-ME) and includes other proposed radon legislation introduced by Senators John Chafee (R-RI) and Arlen Specter (R-PA), as well as an amendment by Senator Max Baucus (D-MT).

- S. 744 authorizes:
  - -- $10 million annually for fiscal years 1988, 1989 and 1990 for grants to help States establish radon reduction programs, conduct radon surveys, develop information on radon, and conduct demonstrations and mitigation projects.
  - -- $1 million for EPA to conduct a study of radon contamination in the nation's schools, plus an additional $500,000 for demonstrations of radon reduction techniques in schools.
  - -- $1.5 million for EPA training seminars for EPA to evaluate and report on the reliability (proficiency) of private radon control firms. This EPA-administered proficiency program would be funded through a user fee provision.
  - -- The Baucus amendment authorizes a study of radon contamination in buildings owned in high radon risk areas by the Interior, Defense, and Agriculture Departments, General Services and Veterans Administration.

- H.R. 2837, a House companion bill to S. 744, was introduced March 18 by Thomas Luken (D-OH). This bill was unanimously approved and reported out of the House Energy and Commerce Subcommittee on Transportation, Tourism and Hazardous Materials (chaired by Representative Luken). The bill is also referred to the Energy, Health and Environment Subcommittee (chaired by Representative Henry Waxman, D-CA). This Subcommittee has not yet taken any action on the bill.

IRS/Tax Breaks

- H.R. 1108 was introduced by Representative Don Ritter (R-PA) in February, 1987 and would amend the IRS code to provide tax credits for radon corrective measures. This provision would be limited to principal residences, cover 40% of costs up to a $2000 maximum, and only apply to residences where radon levels exceed 2 working level months per year. This bill has been referred to the House Ways and Means Committee.

- S. 756 was introduced by Senator Frank Lautenberg (D-NJ) in March, 1987 and would amend the IRS code to define radon mitigation costs as eligible medical expenses. This provision would be limited to "measured harmful levels" and amounts paid for home improvements. This bill was referred to the Committee on Finance.

- H.R. 1610 by Representative Yatron (D-PA) was introduced in March, 1987 and would direct HUD to provide technical assistance to States and localities to incorporate requirements for testing homes and other buildings for indoor radon. Testing would be performed by companies EPA determines are proficient. Funds would be authorized "as necessary" for FY 1988, 1989 and 1990, and activities would be covered in HUD's annual report. This bill was referred to the Committee on Banking, Finance and Urban Affairs.

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

17

EPA

Radon Facts

RADON IN SCHOOLS

As with residential structures, radon may become trapped in buildings such as schools. Currently there are about 100,000 public and private elementary and secondary schools in the United States. While EPA has not taken radon measurements in school buildings, the Superfund Amendments and Reauthorization Act (SARA) calls for the Agency to assess radon levels present in "structures where people normally live or work, including educational institutions."

- Children's exposure to radon in schools is a concern for 3 reasons. First, school buildings are often sprawling structures without basements that may capture significant amounts of radon gas. Second, research from the atom bomb experience suggests that children may be more susceptible to harm from certain types of radiation. Finally, exposure to elevated radon levels early in life could lengthen children's overall exposures to high levels and increase their risk of lung cancer.

- Preliminary information suggests that problems in schools are likely to be geographically localized and in specific building areas such as the ground floor or basement classrooms. Available information also suggests that radon in schools is probably not as large a problem as in residential structures.

- Pennsylvania has tested 140 schools and found 47 buildings with levels greater than 4 pCi/L. While 12 rooms initially had levels greater than 20 pCi/L, a three-month follow-up showed no rooms exceeding 20 pCi/L. New Jersey has found levels above 4 pCi/L in 41 schools with the majority having levels less than 10 pCi/L. An independent study of a New York school found levels of 50-60 pCi/L in the crawl space and equipment room, and 9 pCi/L in some classrooms.

- EPA feels that mitigation experience with residential structures will transfer to schools, with most difficulties arising from differences in scale. As with houses, EPA recommends 4 pCi/L as the guidance level for corrective action.

EPA has initiated a feasibility study to help design a survey which will fulfill the assessment requirements under SARA. Through a Federal-State partnership, EPA hopes to identify high risk areas and undertake some mitigation efforts.

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

18

EPA

Radon Facts

RADON REDUCTION IN
NEW CONSTRUCTION

"Radon Reduction in New Construction: An Interim Guide" is a booklet (developed in cooperation with the National Association of Home Builders Research Foundation) designed to give home builders some guidelines for building new homes that are radon-resistant. During the past few years, EPA has studied radon reduction techniques in more than one hundred existing homes. From this research, EPA has concluded that many successful radon reduction techniques can also be effective in minimizing radon entry into newly constructed houses.

Applying the techniques suggested in the "Interim Guide" to homes before they are built could reduce the number of homes that may need to be fixed in the future. These efforts can make a significant contribution to the long-term resolution of the indoor radon problem, without a major impact on construction cost.

- At least 80 new houses are being studied by the Office of Radiation Programs and more than 90 houses are under study by the Office of Research and Development. In addition, EPA is monitoring private industry new house projects in several States including Pennsylvania, New Jersey, Maryland, New York, Florida, Washington and Virginia.

- Most of the radon-resistant construction techniques outlined in the "Interim Guide" are common building practices. The techniques are not intrusive in the house and require little or no monitoring by the homeowner.

- About 1,250,000 new houses are built each year in the United States, many of them in areas where elevated indoor radon levels have been found.

- In most cases, it is cheaper to install radon-resistant features in a house during construction than it is to fix a home after it is built. EPA estimates that radon-resistant building techniques may cost from $400 to $600 per new house. The cost of installing the same features in an existing house can be four to five times higher.

- Some builders are already installing radon-resistant features into their new houses. For example, a builder in Michigan is using new construction techniques in 160 houses and will be working with EPA to assess the results.

EPA will continue working with States and the private sector to develop new approaches to radon reduction. Further results from ongoing research will be incorporated into a technical guidance document which should be available in 1988.

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

19

EPA

Radon Facts

RADON IN WATER

In addition to radon in soil and rock, radon can also be found in water. Public drinking water supplies drawing from surface sources contain very little radon and are a neglible source of indoor radon. Water supplies drawing from groundwater can contain signficant concentrations of radon, but are still often a small source of indoor radon. Radon enters groundwater that is next to or near uranium and radium deposits. When untreated water enters buildings, it can release the radon it contains into air. Uses in which the water is aerated or heated such as baths, showers, washing clothes or dishes, flushing toilets, or cooking, can increase release of radon in the home.

- EPA estimates that 10,000 pCi/L in water result in an air concentration of about 1 pCi/L. Radon concentrations in groundwater in the United States average 200-600 pCi/L, although in some areas, especially New England, high levels in well water have been found. Levels in excess of 1,000,000 pCi/L have been observed in some private wells.

- The primary health risk associated with radon in water is from the inhalation of the gas as it is released from the water. The health effects are the same from radon originating in both water and soil -- an increased risk of lung cancer.

- Generally radon in drinking water contributes only 1% to 7% of indoor air exposures, although it can be as much as 90% of the health risk from elevated levels of indoor radon. EPA estimates that between 100 and 1800 lung cancer deaths per year in the U.S. are attributable to radon inhaled from drinking water.

- Under the Safe Drinking Water Act, EPA must develop enforceable drinking water standards for radon and other radionuclides by June 1989. An Advance Notice of Proposed Rulemaking was published in September 1986 which contains much of the information that will serve as a basis for proposed maximum contaminant level goals (MCLGs) and maximum contaminant levels (MCLs).

- EPA is planning an extensive outreach program to educate water suppliers and consumers about what they can do to reduce the risks due to radon in water. In addition, pilot studies are being developed in New Hampshire which will determine the effectiveness and costs of installation and maintenance for water treatment methods to remove radon.

A brochure describing techniques for removal of radon from household water is scheduled for release this [illegible]

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

20

EPA

Radon Facts

INTERNATIONAL RADON ACTIVITIES

The United States is not alone in its concern about indoor radon. In the past few years, a number of countries have begun studying radon in homes and developing methods to reduce elevated levels when they are found.

- Most of the international activity involves national surveys to determine the general distribution of radon concentrations, the magnitude of individual exposures, and the number of dwellings which may require remedial action. Among the countries involved are Canada, the United Kingdom, Ireland, the Federal Republic of Germany, France, Luxembourg, Switzerland, Italy, Denmark, Norway, Sweden, Finland, Austria, the Netherlands, Greece and Japan.

- As a result of these efforts, several countries are developing objectives for action on indoor radon. Sweden, for example, has established the goal of reducing the average national radon level by one half during the next century.

- The National Radiological Protection Board of the U.K. issued a report providing recommended action levels of 10 pCi/L in existing buildings and 2.5 pCi/L in new dwellings. The report also included information from a national survey indicating that more than 20,000 dwellings in the U.K. may exceed their action level.

- Epidemiological studies of people exposed to radon in homes are underway in Sweden and Canada.

EPA continues to cooperate with other countries by attending scientific conferences and sharing information on health effects and mitigation techniques.

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

21

EPA

Radon Facts

STATE RADON SURVEY COORDINATORS

Alabama

Technical Contact: Aubrey Godwin
(205) 261-5113
Public Affairs Contact: Jim McVay
(205) 261-5095
Radiological Health Branch
Alabama Department of Public Health
State Office Building
Montgomery, AL 36130

Colorado

Technical Contact: Albert Hazle
(303) 320-8333
Public Affairs Contact: Ann Lockhart
(303) 331-4611
Radiation Control Division
Colorado Department of Health
4210 East 11th Avenue
Denver, CO 80220

Connecticut

Technical Contact: Brian Toal
(203) 566-8167
Public Affairs Contact: Wanda Rickerby
(203) 566-1060
Connecticut Department of Health Services
Toxic Hazards Section
150 Washington Street
Hartford, CT 06106

Kansas

Technical Contact: David Romano
(913) 862-9360
Public Affairs Contact: Bob Moody
(913) 862-9360, ext. 263
Kansas Department of Health and Environment
Forbes Field, Building 321
Topeka, KS 66620-0110

Kentucky

Technical Contact: Donald Hughes
(502) 564-3700
Public Affairs Contact: Brad Hughes
(502) 564-7130
Radiation Control Branch
Cabinet for Human Resources
275 East Main Street
Frankfort, KY 40621

Michigan

Technical Contact: George Bruchmann
(517) 373-1578
Public Affairs Contact: Ute Van Der Hayden
(517) 335-8002
Michigan Department of Public Health
Division of Radiological Health
3500 North Logan, P.O. Box 30035
Lansing, MI 48909

Rhode Island

Technical Contact: James Hickey
(401) 277-2438
Public Affairs Contact: John Faucett
(401) 277-6500
Division of Occupational Health and
Radiological Control
Department of Health
Cannon Bldg., Davis Street
Providence, RI 02908

Tennessee

Technical Contact: Harold Hodges
(615) 741-3931
Public Affairs Contact: Linda Tidwell
(615) 741-3111
Division of Radiological Health
Customs House
701 Broadway
Nashville, TN 37219-5403

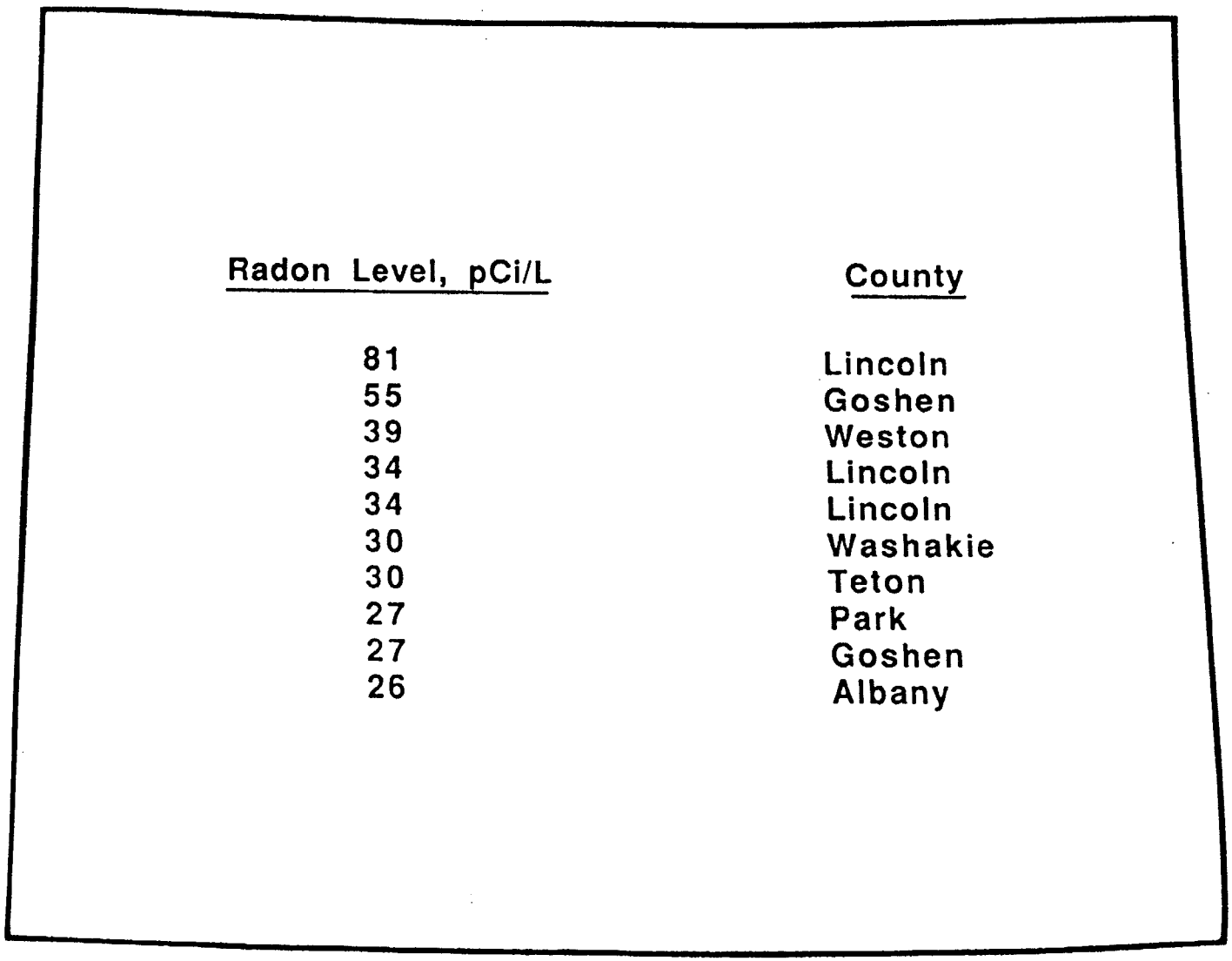
Wisconsin

Technical Contact: Lawrence McDonnell
(608) 273-5181
Public Affairs Contact: Sherry Kasper
(608) 266-8475
State Division of Health
Department of Health and Social Services
1 W. Wilson Street
P.O. Box 309
Madison, WI 53701-0309

Wyoming

Technical Contact: Julius Haes
(307) 777-7956
Public Affairs Contact: Helen Levine
(307) 777-6918
Division of Health and Medical Services
Radiological Health Services
Hathaway Building
Cheyenne WY 82002-0710

Ten Highest Radon Measurements in Wyoming



Radon Level, pCi/L	County
81	Lincoln
55	Goshen
39	Weston
34	Lincoln
34	Lincoln
30	Washakie
30	Teton
27	Park
27	Goshen
26	Albany

These single measurements may not be representative of all houses in these counties.

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

EPA

Radon Facts

STATE RADON CONTACTS

Alabama

James McNees
Radiological Health Branch
Alabama Department of Public Health
State Office Building
Montgomery, AL 36130
(205) 261-5313

Alaska

Sidney Heidersdorf
Alaska Department of Health
and Social Services
P.O. Box H-06F
Juneau, AK 99811-0613
(907) 465-3019

Arizona

Paul Weeden
Arizona Radiation Regulatory Agency
4814 South 40th Street
Phoenix, AZ 85040
(602) 255-4845

Arkansas

Greta Dicus/Bernard Bevill
Division of Radiation Control
and Emergency Management
Arkansas Department of Health
4815 W. Markham Street
Little Rock, AR 72205-3867
(501) 661-2301

California

Steve Hayward
California State Division
of Laboratories
2151 Berkeley Way
Berkeley, CA 94704
(415) 540-2134

California

John Hickman
Department of Health Services
Environmental Radiation Surveillance
714/744 P Street
P.O. Box 942732
Sacramento, CA 94234-7320
(916) 445-0498

California

A. Ferguson
Radiation Management
County of Los Angeles
Department of Health Services
2615 S. Grand Avenue
Los Angeles, CA 90007
(213) 744-3244

Colorado	Richard Gamewell Radiation Control Division Colorado Department of Health 4210 East 11th Avenue Denver, CO 80220 (303) 331-4812
Colorado	Lew Ladwig Colorado Geological Survey 1313 Sherman Street Room 715 Denver, CO 80203 (303) 866-2611
Connecticut	Laurie Grokey Connecticut Department of Health Services Toxic Hazards Section 150 Washington Street Hartford, CT 06106 (203) 566-8167
Delaware	John Hedden Division of Public Health Delaware Bureau of Environmental Health P.O. Box 637 Dover, DE 19903 (302) 736-4731
District of Columbia	Veronica Singh DC Department of Consumer and Regulatory Affairs 614 H Street, NW, Room 1014 Washington, DC 20001 (202) 727-7728
Florida	Harlan Keaton Florida Office of Radiation Control Building 18, Sunland Center P.O. Box 15490 Orlando, FL 32858 (305) 297-2095
Georgia	James Hardeman Georgia Department of Natural Resources Environmental Protection Division 205 Butler Street, SE Floyd Towers East, Suite 1166 Atlanta, GA 30334 (404) 656-6905

Hawaii

Environmental Protection and Health
Services Division
Hawaii Department of Health
591 Ala Moana Boulevard
Honolulu, HI 96813
(808) 548-4383

Idaho

Larry Boschult
Radiation Control Section
Idaho Dept. of Health and Welfare
Statehouse Mail
Boise, ID 83720
(208) 334-5879

Illinois

Greg Crouch
Illinois Department of Nuclear Safety
Office of Environmental Safety
1035 Outer Park Drive
Springfield, IL 62704
(217) 546-8100 or
(800) 225-1245 (in State)

Indiana

David Nauth
Division of Industrial Hygiene and
Radiological Health
Indiana State Board of Health
1330 W. Michigan Street, P.O. Box 1964
Indianapolis, IN 46206-1964
(317) 633-0153

Iowa

Richard Welke
Bureau of Environmental Health Section
Iowa Department of Public Health
Lucas State Office Building
Des Moines, IA 50319-0075
(515) 281-7781

Kansas

Craig Schwartz
Kansas Department of Health
and Environment
Forbes Field, Building 321
Topeka, KS 66620-0110
(913) 862-9360 Ext. 288

Kentucky

Donald R. Hughes
Radiation Control Branch
Cabinet for Human Resources
275 East Main Street
Frankfort, KY 40621
(502) 564-3700

Louisiana

Jay Mason
Louisiana Nuclear Energy Division
P.O. Box 14690
Baton Rouge, LA 70898-4690
(504) 925-4518

Maine

Gene Moreau
Division of Health Engineering
Maine Department of Human Services
State House Station 10
Augusta, ME 04333
(207) 289-3826

Maryland

Richard Brisson
Division of Radiation Control
Maryland Department of Health
and Mental Hygiene
201 W. Preston Street
Baltimore, MD 21201
(301) 333-3130
(800) 872-3666

Massachusetts

Bill Bell
Radiation Control Program
Massachusetts Department
of Public Health
23 Service Center
North Hampton, MA 01060
(413) 586-7525 or
(617) 727-6214 (Boston)

Michigan

Robert DeHaan
Michigan Department of Public Health
Division of Radiological Health
3500 North Logan, P.O. Box 30035
Lansing, MI 48909
(517) 335-8190

Minnesota

Bruce Denney
Section of Radiation Control
Minnesota Department of Health
P.O. Box 9441
717 SE Delaware Street
Minneapolis, MN 55440
(612) 623-5350
(800) 652-9747

Mississippi

Gregg Dempsey
Division of Radiological Health
Mississippi Department of Health
P.O. Box 1700
Jackson, MS 392215-1700
(601) 354-6657

Missouri

Kenneth V. Miller
Bureau of Radiological Health
Missouri Department of Health
1730 E. Elm
P.O. Box 570
Jefferson City, MO 65102
(314) 751-6083

Montana

Larry L. Lloyd
Occupational Health Bureau
Montana Department of Health
and Environmental Sciences
Cogswell Building A113
Helena, MT 59620
(406) 444-3671

Nebraska

Division of Radiological Health
Nebraska Department of Health
301 Centennial Mall South
P.O. Box 95007
Lincoln, NE 68509
(402) 471-2168

Nevada

Stan Marshall
Radiological Health Section
Health Division
Nevada Department of Human Resources
505 East King Street, Room 202
Carson City, NV 89710
(702) 885-5394

New Hampshire

Belva Mohle
New Hampshire Radiological
Health Program
Health and Welfare Building
6 Hazen Drive
Concord, NH 03301-6527
(603) 271-4674

New Jersey

New Jersey Department of
Environmental Protection
380 Scotch Road, CN-411
Trenton, NJ 08625
(609) 530-4000/4001 or,
(800) 648-0394 (in State) or,
(201) 879-2062 (N. NJ Radon
Field Office)

New Mexico

J. Margo Keele
Surveillance Monitoring Section
New Mexico Radiation Protection Bureau
P.O. Box 968
Santa Fe, NM 87504-0968
(505) 827-2957

New York	Bureau of Environmental Radiation Protection New York State Health Department Empire State Plaza, Corning Tower Albany, NY 12237 (518) 473-3613 (800) 458-1158 (in State) or (800) 342-3722 (NY Energy Research & Development Authority)
N. Carolina	Radiation Protection Section North Carolina Department of Human Resources 701 Barbour Drive Raleigh, NC 27603-2008 (919) 733-4283
N. Dakota	Dale Patrick/Jeff Burgess North Dakota Dept. of Health Missouri Office Building 1200 Missouri Avenue P.O. Box 5520 Bismarck, ND 58502 (701) 224-2348
Ohio	Debby Steva Radiological Health Program Ohio Department of Health 1224 Kinnear Road Columbus, OH 43212-0118 (614) 481-5800 (800) 523-4439 (in Ohio only)
Oklahoma	Radiation and Special Hazards Service Oklahoma State Dept. of Health P.O. Box 53551 Oklahoma City, OK 73152 (405) 271-5221
Oregon	Ray Paris Oregon State Health Department 1400 S. W. 5th Avenue Portland, OR 97201 (503) 229-5797
Pennsylvania	Tim Hartman Radon Monitoring Program Office PA-DER, Bureau of Radiation Protection 1100 Grosser Road Gilbertsville, PA 19525 (215) 369-3590 or 800-23-RADON (in State)

Puerto Rico
David Saldana
Puerto Rico Radiological Health Div.
G.P.O. Call Box 70184
Rio Piedras, PR 00936
(809) 767-3563

Rhode Island
James Hickey/Roger Marinelli
Division of Occupational Health
and Radiological Control
Rhode Island Department of Health
206 Cannon Bldg., 75 Davis Street
Providence, RI 02908
(401) 277-2438

S. Carolina
Nolan Bivens
Bureau of Radiological Health
South Carolina Dept. of Health
and Environmental Control
2600 Bull Street
Columbia, SC 29201
(803) 734-4700/4631

S. Dakota
Tammy LeBeau
Office of Air Quality and Solid Waste
South Dakota Dept. of Water & Natural Resources
Joe Foss Building, Room 217
523 E. Capital
Pierre, SD 57501-3181
(605) 773-3153

Tennessee
Jackie Waynick
Division of Air Pollution Control
Custom House
701 Broadway
Nashville, TN 37219-5403
(615) 741-4634

Texas
Gary Smith
Bureau of Radiation Control
Texas Department of Health
1100 West 49th Street
Austin, TX 78756-3189
(512) 835-7000

Utah
Bureau of Radiation Control
Utah State Department of Health
State Health Department Building
P.O. Box 16690
Salt Lake City, UT 84116-0690
(801) 538-6734

Radioactivity - Spontaneous release of energy by the nucleus of an atom which results in a chahge in mass.

Radon - A colorless, naturally occurring, radioactive, inert gaseous element formed by radioactive decay of radium atoms. Chemical symbol is RN, atomic weight 222, half-life 3.82 days.

Radon Decay Products - A term used to refer collectively to the immediate products in the radon decay chain. These include Po-218, Pb-214, Bi-214 and Po-214. They have an average combined half-life of about 30 minutes.

Soil Gas - Those gaseous elements and compounds that occur in the small spaces between particles of the earth and soil. Such gases can move through or leave the soil or rock depending on changes in pressure.

Uranium - Refers normally to U-238 which is the most abundant uranium isotope, although about 0.7 percent of naturally-occurring uranium is U-235.

Ventilation / Suction - Ventilation is the act of admitting fresh air into a space in order to replace stale or contaminated air, achieved by blowing air into the space. Similarly, suction represents the admission of fresh air into an interior space; however, the process is accomplished by lowering the pressure outside of the space thereby drawing the contaminated air outward.

Working Level (WL) - A unit of measure for documenting exposure to radon decay products. One working level is equal to approximately 200 pCi/L.

Working Level Month (WLM) - A unit of measure used for measuring cummulative exposure to radon. One WLM equals exposure to one WL for 173 hours.

Vermont	Division of Occupational and Radiological Health Vermont Department of Health Administration Building 10 Baldwin Street Montpelier, VT 05602 (802) 828-2886
Virginia	Bureau of Radiological Health Department of Health 109 Governor Street Richmond, VA 23219 (804) 786-5932 or, 800-468-0138 (in State)
Washington	Bruce Pickett/Robert Mooney Environmental Protection Section Washington Office of Radiation Protection Thurston AirDustrial Center Building 5, LE-13 Olympia, WA 98504 (206) 753-5962
W. Virginia	Bill Aaroe Industrial Hygiene Division West Virginia Department of Health 151 11th Avenue South Charleston, WV 25303 (304) 348-3526/3427
Wisconsin	Division of Health Section of Radiation Protection Wisconsin Dept. of Health and Social Services 5708 Odana Road Madison, WI 53719 (608) 273-5180
Wyoming	Radiological Health Services Wyoming Department of Health and Social Services Hathway Building, 4th Floor Cheyenne, WY 82002-0710 (307) 777-7956

United States
Environmental Protection
Agency

Office of Air
and Radiation
Washington DC 20460

EPA

Radon Facts

RADON GLOSSARY OF TERMS

Air Changes Per Hour(ach) - The movement of a volume of air in a given period of time; if a house has one air change per hour, it means that all of the air in the house will be replaced in a one-hour period.

Alpha Particle - A positively charged particle composed of 2 neutrons and 2 protons released by some atoms undergoing radioactive decay. The particle is identical to the nucleus of a helium atom.

Cumulative Working Level Months (CWLM) - The sum of lifetime exposure to radon working levels expressed in total working level months.

Curie (Ci) - A quantitative measure of radioactivity. One curie equals 3.7×10^{10} disintegrations per second.

Decay Series - The consecutive members of radioactive family of elements. A complete series commences with a long-lived parent such as U-238 and ends with a stable element such as Pb-206.

Depressurization - A condition that occurs when the air pressure inside a house is lower than the air pressure outside. Radon may be drawn more rapidly into a house under depressurization.

Equilibrium - The state at which the radioactivity of consecutive elements within a radioactive series is neither increasing nor decreasing.

Exposure - The amount of radiation present in an environment, not necessarily indicative of absorbed energy, but representative of potential health damage to the individual present.

Gamma Radiation - A true ray of energy in contrast to beta and alpha radiation. The properties are similar to x-rays and other electromagnetic waves.

Half-life - The time required for half of the atoms of a radioactive element to undergo decay.

Indoor Air - The part of the atmosphere or air that occupies the space within the interior of a house or other building.

Picocuries Per Liter (pCi/L) - A unit of measure used for expressing levels of radon gas. A picocurie is one-trillionth of a curie.

Qs/As
Table of Contents

STATE SURVEYS

QUESTION: What is the "worst" State?

There is no "worst" State. The surveys indicate that there are significant radon problems, of varying degrees, in each of these States. In some States, over 25% of the measurements taken were above 4 picocuries per liter (pCi/L). However, in other States where less than 10% of the measurements taken were above the action level, we found some of the highest single measurements. Both situations indicate significant public health risks. We believe that all of these States have reasons to be concerned. We also believe that all of these States can develop programs to effectively deal with their indoor radon problems.

QUESTION: Do you expect the results to change much in States where surveying ceased due to weather conditions?

In the few States where surveying stopped, we have enough measurements to provide a good estimate of indoor radon levels. We believe we can make good, sound conclusions based on this data. As these States finish their surveys, we may see slight changes; however, we expect final results to be fairly close to those which have been presented.

QUESTION: How are State surveys different from the National Survey?

The State surveys and the National Survey have different objectives. The purposes of the State surveys are to generally characterize indoor radon levels throughout the States surveyed, and to identify high risk areas within these States. The purpose of the National Survey is to generally determine the distribution of indoor radon throughout the United States.

The State survey program will benefit the National Survey because State survey data can complement National Survey data to allow us to better understand the variation of radon levels from region to region.

QUESTION: Why were different numbers of measurements taken in each State?

The surveys were designed to meet the specific needs of each individual State. The number of measurements taken by each State varied with the size of the State, the survey design, and available resources. As we have indicated, a few States intended to take more measurements, but due to weather conditions these measurements will be taken next year.

QUESTION: Do these survey results change your estimate of the number of houses in the nation above 4 pCi/L?

It is important to remember that it was not the purpose of the State surveys to characterize the National distribution of indoor radon. The National Survey is designed to address this issue. However, the State survey results do generally support our original estimate that 8-12% of houses across the Nation will have radon levels above 4 pCi/L. If anything, the State survey results show that our original estimate may have been slightly conservative.

QUESTION: Do the the survey results obtained for each State reflect the actual distribution of radon levels which can be expected for all houses in that State?

Yes, for those six States which have completed statistically valid surveys, the levels of indoor radon in surveyed houses will reflect, with 95% confidence, the levels of radon which we expect for all houses in each State. When the few remaining States complete their surveys, we expect the survey percentages and corresponding levels in each State will also reflect the distribution of indoor radon which can be expected for all houses across each individual State.

QUESTION Should everyone in these 10 States test for radon? Everyone in the Nation?

We recommend that people test who live in areas of these States that have been identified as potentially high risk; i.e., those areas that have a cluster of high measurements or an overall high distribution of radon levels. Further, we recommend that anyone who is at all concerned about radon should test. The test is relatively quick and inexpensive and testing is the only way for individual homeowners to be sure whether they have an indoor radon problem.

QUESTION: What is EPA going to do to further help these ten States?

EPA will continue to work with these ten States and others as they identify specific areas where they need assistance. In addition to survey assistance to the seven new States and the Indian Health Service, we will continue to work with Colorado, Kansas, Michigan and Rhode Island as they complete their surveys.

Beyond survey assistance, the Agency has already developed training videotapes, brochures and other materials which provide State officials with information on how to reduce elevated levels of radon in homes. EPA also has in place a number of programs to demonstrate mitigation techniques and to assist State officials in performing more extensive evaluations of houses with elevated levels of radon.

QUESTION: How much was spent on the State survey?

Approximately 1.3 million dollars have been spent in FY 1987 in support of the State survey program.

QUESTION: Can an average citizen generally predict radon risk using the geologic map?

The geologic map can be used to identify large areas with potentially high levels. The scale of the geologic map, however, does not allow for predicting high-risk areas at the county or city level. Further, we have found that the map does not permit us to predict low risk in non-shaded areas. In both shaded and non-shaded areas, factors such as local geology, soil permeability and climate also impact radon levels.

QUESTION: Based on these results, what other areas would you predict will have higher levels?

Areas with geology similar to States which had high indoor radon levels may have comparable problems. This is especially true for those States contiguous to States found to have generally high levels.

QUESTION: What is the difference between a screening measurement and an annual average measurement?

Screening measurements and annual average measurements have two different purposes. Screening measurements are designed to provide a quick and inexpensive evaluation of the potential for radon problems. These measurements are taken in the lowest livable area of a closed house over a period of two to seven days. Annual average measurements are designed to reflect the average radon concentrations to which occupants are exposed over the course of a year. These measurements are taken over a period of twelve months in the area of the house where occupants spend the greatest amount of their time. If a house has a lowest livable area screening measurement less than 4 pCi/L, it probably will not have an annual average measurement exceeding the EPA action level.

QUESTION: How did EPA arrive at the 4 pCi/L per liter level for its guideline for action by homeowners?

The 4 pCi/L that we have for the EPA guidance level was chosen after we evaluated the risks various radon levels pose and the amount of reduction that we thought most homeowners could achieve through today's radon control technologies. We did not consider 4 pCi/L as a safe level, but the safest level we could get most houses to achieve. We believe that any homeowners who see they can do better than that should consider doing so.

QUESTION: How does the risk from indoor radon compare to other risks that EPA regulates?

The risks from indoor radon may be higher in many homes--and often much higher--than the risks that EPA allows from the various activities regulated under the Agency's legislative mandates. However, these situations cannot be directly compared. Many of the risks that EPA is called upon to regulate arise from pollutants or waste materials that people may be involuntarily exposed to. On the other hand, the risks from indoor radon will be determined by the inherent characteristics of the house and land where an individual chooses to live. We believe that our most appropriate role with regard to the risks from indoor radon is to help the States provide citizens with information about how to determine, evaluate, and--if appropriate--reduce the risks they may face.

QUESTION: Is EPA planning to devote more resources to radon in light of its comparative risk report? If not, why not?

In the very near-term, EPA's resource allocations will not significantly change. Congress established FY 1987 priorities in the appropriations process last year. However, we see the comparative risk report as one useful piece of information that Congress can use in the future when it establishes our resource allocations. As we move to prepare recommendations for Congress in the President's FY 89 budget, we are internally using the report as a guide to where the bulk of our unfinished business to reduce risk remains. We are also using other important information on the public's environmental concerns. A complete answer to your question really needs to await the results of the upcoming budgetry process.

QUESTION: How much is EPA spending on radon in FY 1987 and FY 1988?

The total resources for programs specifically included in the Agency's Radon Action Program are as follows for FY 1987:

Office	Total Resources FTE's	$000*
Office of Radiation Programs	31	$4,400
Regional Offices	11	585
Office of Research and Development	19	2,510
Totals	61	$7,495

*Includes both extramural and personnel costs.

There are other parts of the Agency which address radon as one of a number of radionuclides of concern, such as the Office of Drinking Water (ODW). However, the level of investment solely in radon remediation cannot be determined. These programs generally provide technical assistance to States as part of the Drinking Water program and its State program grants. The grant amount allocated to radon is an individual State decision.

The FY 1988 budget request to the Office of Management and Budget (OMB), and the resultant level in the Administration's request to the Congress are as follows:

Budget Area	OMB Request FTE's	$000*	Cong. Request FTE's	$000*
Radiation Environmental Impact Assessment (ORP)	31	$4,350	31	$4,350**
Radiation Program Implementation (Regions)	24	1,190	14	560
Radiation Research and Development (ORD)	9	1,983	8	1,214
Totals	64	$7,523	53	$6,124

* Includes both extramural and personnel costs.

** To accommodate this level of radon funding in Headquarters (HQ), other ORP programs lose 14 FTE's.

** Although the FY 1988 Budget request had 31 FTE's for ORP the actual request put forth is 28 FTE's. There is currently confusion between the Program Office and the Comptrollers Office regarding the appropriate allocation of 3 FTE's.

QUESTION: What is the status of the National Survey?

The National Survey of residences has recently been reviewed by EPA's Science Advisory Board (SAB). Their report is expected shortly. After receiving their comments, the Agency will make appropriate changes in its design and then begin implementation of the survey as resources will permit.

In FY 1988, we hope to begin placement of radon detectors in houses for a one-year period to obtain the annual average radon concentration in each structure. The survey and the associated data analyses will take approximately two to three years to complete.

QUESTION: How is the real estate industry responding to radon problems in houses?

In areas where elevated indoor radon levels have been discovered, Realtors have responded with a variety of steps to protect themselves from potential damages from selling a house that might turn out to have elevated radon levels.

In Pennsylvania, the State Association of Realtors has developed a recommended set of forms for Realtors to use. The Association is not certain how widely these are being used, but reports that they are often added to agreements in the Harrisburg and Allentown areas.

The primary purpose of the Pennsylvania provisions is (1) to promote full disclosure of elevated radon concentrations, or (2) to allow the buyer to release the various parties from any liabilities concerning possible elevated levels, or (3) to allow the buyer to back out of a sale if post-purchase testing (within five days of purchase) reveals levels in excess of 4 pCi/L.

Almost all real estate contracts executed in areas of New Jersey with the potential for elevated radon levels now have some type of radon-related clause included in the contract. The New Jersey State Association of Realtors has developed a suggested radon disclosure form, but a wide variety of different provisions are being used in agreements by individual Realtors in areas where elevated indoor radon levels have been discovered. For example, some provisions call for radon testing before completing a sales agreement, while others have the seller set up an escrow account to cover potential mitigation expenses that may be indicated after a buyer obtains radon measurements.

Although sales prices sometimes are depressed when radon levels are discovered, the effect seems temporary--with prices rebounding to previous levels once the issue is better understood in the area.

QUESTION: Has EPA updated the National radon risk map that it issued last August?

Yes, we have updated the map. During the last year we have gathered geologic information as well as thousands of public and private indoor radon measurements which have enabled us to identify more areas with potentially high radon levels. The new map includes more shaded areas, especially in the Midwest and East.

STATE PROGRAMS

QUESTION: Are other States surveying for radon?

Yes, in addition to the EPA-assisted State Survey Program, several States have conducted surveys of widely varying designs and purposes. Nine States have initiated their own Statewide surveys: Alaska, Florida, Idaho, Illinois, New Jersey, New Mexico, New York, North Carolina and Virginia. Survey sites range from 500 houses in North Carolina to at least 7,500 houses in Florida.

QUESTION: How many States have developed comprehensive radon programs?

Five States--Florida, New Jersey, New York, Maine and Pennsylvania--have developed comprehensive radon programs. Several more are conducting radon surveys and considering expanding their programs beyond the provision of information to the public to include program assessment, training and mitigation demonstrations. Most States, however, are only responding to citizen requests for information by using EPA publications.

HOMEOWNER ISSUES

QUESTION: Are people mitigating their houses?

In addition to EPA and State mitigation and prevention programs, we have also observed mitigation work being performed by private citizens and contractors. We cannot provide a national estimate of the amount of ongoing activity.

QUESTION: How much does it cost to fix radon problems?

The installation costs of actions have ranged between $50 and $500 when homeowners performed the work themselves. The installation costs have been between $1,000 and $3,000 when homeowners contracted it out. However, it should be noted that these were typically higher level houses. We expect the cost to be lower for the majority of the houses that will require mitigation.

We will have additional details on the cost and effectiveness of mitigation techniques as we conduct more field research and collect more information from private contractors. Also, as more private firms get involved in this emerging field, we expect they will develop better techniques and price them competitively.

QUESTION: Are certain types of houses at greater risk?

Predicting the relationship of house structure to indoor radon levels is an important issue which EPA and the States are analyzing. We expect results from the State and National surveys as well as other studies will provide data so we can test these correlations.

QUESTION: Have homeowners participating in the surveys been notified of their results?

All homeowners will be notified of the results by the States. A few States are still in the process of notifying individual homeowners of their survey results.

QUESTION: How were private citizens selected to participate in the surveys, and what types of houses were included in the surveys?

States selected survey participants according to the specific needs of their survey designs. In general, potential participants were identified using randomized lists of residential telephone numbers. These potential participants were then screened to determine whether they were willing to participate in the survey, and to confirm that their house met the requirements of the survey. Single-family, owner-occupied houses were included in the survey.

QUESTION: What should these or other homeowners do once they find levels above 4 pCi/L in their home?

After the initial screening measurement is completed, homeowners should notify their State Radiation Office. We strongly recommend that follow-up measurements be made on the house. Further details on follow-up measurements are outlined in EPA's "Citizen's Guide To Radon." Before homeowners decide whether to undertake mitigation efforts, they should consult with their State Radiation Office. The State Radiation Office can provide specific advice and assistance.

There is increasing urgency for action at higher concentrations of radon. The higher the radon level in the house, the faster the homeowner should take action to reduce their exposure.

QUESTION: What is EPA doing to protect the homeowner?

Although States are primarily responsible for working directly with homeowners, EPA is helping States provide homeowner assistance. EPA has published two radon brochures which States are reproducing and distributing to citizens. "Citizen's Guide" summarizes what radon is, how it is detected, and associated radon health risks. "Radon Reduction Methods" describes low cost mitigation techniques which are available to reduce radon levels in houses. The Agency's voluntary Radon Measurement Proficiency Program assures that qualifed measurement companies are available to homeowners. EPA is also providing State officials and contractors with Radon and Mitigation training so that they can better serve homeowners. Legislation under consideration in the Congress would provide EPA and the States with greater ability to ensure that testing and mitigation companies provide responsible services.

QUESTION: How many houses across the Nation have been tested for indoor radon?

Including public and private tests, we estimate that over 150,000 houses have been tested.

RADON IN DRINKING WATER

Question: Has EPA checked for radon in drinking water?

Answer: Yes. In 1981, we began the National Inorganic and Radionuclides Survey. We sampled 990 sites from across the country. The water systems chosen were representative of the nation as a whole based on the size of populations served.

Question: What were the results?

Answer: Radon is present in 72% of the sites at concentrations greater than 100 pCi/L. The maximum concentration found is 25,700 pCi/L (100 pCi/L is the minimum reporting limit).

For supplies serving more than 1,000 people, the overall population weighted average concentration is approximately 200 pCi/L. For supplies serving less than 1,000 people, the overall population weighted average is approximately 700 pCi/L. The overall population weighted average radon concentration is approximately 250 pCi/L.

Table 1 on the next page summarizes the results from the NIRs survey for the ten States tested in the radon in air survey.

Table 1: Results of Testing for Radon in Drinking Water from the National Inorganic and Radionuclides Survey.

State	Number of Water Supplies Tested	Population Weighted Average Concentration pCi/L
Alabama	9	420
Colorado	11	330
Connecticut	24	1209
Kansas	10	369
Kentucky	9	206
Michigan	26	185
Rhode Island	1	1170
Tennessee	11	114
Wisconsin	26	367
Wyoming	3	558
Ten State total	130	not available
U.S. as a whole	990	250

Highest levels found in New England and Mid Atlantic/Appalachian (PA, MD, VA) regions

Question: What do these concentrations mean in terms of of risk to humans?

Concentration of Radon (pCi/L in water)	Individual Lifetime Risk	Number of Systems Exceeding This Level
10,000	10^{-3}	500-4000
1,000	10^{-4}	1000-10,000
100	10^{-5}	5000-30,000

Question: What are the next steps?

Answer: EPA published an advance notice of proposed rulemaking on September 30, 1986. This notice summarized our information on radon, radium, and uranium. It provides much of the basis for a forthcoming MCL goal and MCL. These will be proposed in early 1988 and become effective by the statutory deadline June 1989.

Question: What are the regulatory limits for radon in drinking water likely to be?

Answer: Although we have not yet proposed a standard for radon, we expect that the non-enforceable, health-based goal will be zero. This level is consistent with the way we treat all known human carcinogens. We have not yet determined what the MCL is likely to be. Under the Safe Drinking Water Act it will be set as close to the MCLG as is feasible. Generally, MCLs for carcinogens are set so that the individual lifetime risk falls within the range of 10^{-4} to 10^{-6}.

DRAFT

Summaries and Proposed Recommendations Concerning Air Quality Models

Submitted to Environmental Protection Agency

October 1980

United States Environmental Protection Agency
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

EPA 0496

Table of Contents

1.0 Introduction

1.1 Overview

In March 1980 EPA published a Federal Register notice entitled "Guidelines on Air Quality Models" (see Section 1.2). In that notice air quality models that can be considered refined analytical techniques and that have applicability to a general air quality problem were solicited. As a result of that solicitation, 17 models were submitted prior to September 1, 1980. Each of the models met six requirements listed in the Federal Register notice.

This document discusses 14 of the models. It briefly summarizes each model, proposes an action concerning the model, and indicates availability of the model for purposes of public comment. It is not appropriate to discuss, for the present, three of the models that were submitted.

The Federal Register notice indicates that one of three actions can be taken with regard to the models submitted. The first possible action is to recommend the model for routine use in specific applications. Such recommendations, with specific limits, are proposed for six of the models.

The second possible action is to recognize the model, but to require a case-by-case determination as to acceptability of the model. Such a position is proposed for eight of the models. These eight models fall into two subcategories. Six models are allowable with a simple demonstration that options in the models can be employed so that concentrations equivalent to those estimated by the recommended model can be obtained. The model can then be applied for a specific case as long as those same options

are used. The second subcategory includes these same six models plus the two remaining models. These eight models can be used on a case-by-case basis provided it is demonstrated, subject to requirements of Section 6 of the Guideline, that the model is applicable and reliable for the specific site and source.

The third possible action is to reject the model and return it to the developer. This action was not taken in any case.

In proposing the recommendations indicated above, three factors were considered: (1) the model is representative of the state-of-the-art for atmospheric simulation models; (2) the model is readily available to air pollution control agencies, and (3) the model fills a void in available models for a specific application and can be used without creating regulatory inconsistencies. These are the same criteria used for models recommended in the proposed revisions to the Guideline. Ideally these recommendations would have been based on prescribed standards of performance for particular applications and on specific evaluation procedures. Unfortunately, the technical community has not yet identified such standards and procedures for wide use. Also the very short time available to review these models precluded a detailed computational analysis.

The summaries provide a basis for public comment concerning proposed recommendations on use of air quality models for specific applications. It is likely that additional models will be submitted to EPA prior to the Conference on Air Quality Modeling in early 1981. Recommendations on those models will be made available for public comment at that time.

1.2 Federal Register Notice

[FRL 1447-7]

Guidelines on Air Quality Models

AGENCY: U.S. Environmental Protection Agency.

ACTION: Notice.

SUMMARY: In response to Clean Air Act requirements, EPA has published a Guideline on Air Quality Models and held a Conference on Air Quality Modeling. EPA currently is pursuing mechanisms by which (1) the technical community can take an active role in reviews and updates of the Guideline and (2) a wider range of models, including those developed by groups other than EPA, can be incorporated in the Guideline. To insure adequate public comment, revisions will be synchronized with the next Conference on Air Quality Modeling which must be held every three years and which is planned for early in 1981. This notice summarizes current activities and future plans regarding guidance and conferences on models. This notice also solicits well-documented models that can be considered refined analytical techniques for potential inclusion in planned revisions to the Guideline on Air Quality Models.

DATES: Letters of intent to provide refined air quality models that can be considered for inclusion in the Guideline on Air Quality Models should be submitted within sixty (60) days of the date of this notice.

ADDRESS: Letters of intent should be sent to: Source Receptor Analysis Branch (MD-14), Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, Attn: Jerome B. Mersch.

FOR FURTHER INFORMATION CONTACT: Joseph A. Tikvart, Chief, Source Receptor Analysis Branch (MD-14), Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, Phone: (919) 541-5261.

SUPPLEMENTARY INFORMATION:

Background

"Air quality modeling" is a mathematical technique for estimating the effect of an air pollution source (or group of sources) on air quality at various locations. Air quality modeling may provide the basis for approving or denying a proposed pollution source's application to construct. It may also provide the basis for determining the control level required for existing pollution sources. Modeling thus plays an important role in the administration of the Clean Air Act.

In response to the Clean Air Act requirements, EPA has published a Guideline on Air Quality Models[1] and held a Conference on Air Quality Modeling.[2] The preface to the Guideline on Air Quality Models states that the guide will be periodically reviewed and updated. EPA's plans for conducting this review and for obtaining public comment in conjunction with the next Conference on Air Quality modeling are presented in this notice. A means by which well-documented and refined models can be considered for inclusion in the Guideline is also identified and non-EPA models are solicited.

Review of Current Activities

EPA has already taken several steps to update the Guideline and conduct the next Conference. First, several workshops have been held within EPA to insure consistency in the use of the Guideline and in the application of Guideline models.

Secondly, a cooperative agreement has been initiated with the American Meteorological Society to receive comments from the scientific community on a variety of technical issues. The specific tasks of the cooperative agreement are: (1) review and make recommendations on previous work by EPA concerning air quality models; (2) conduct a general review of the state of knowledge on air quality modeling; (3) offer suggestions concerning recommended air quality models and criteria for their selection; and (4) evaluate data base requirements for use with models.

In addition, EPA has undertaken a series of projects concerning the development and application of modeling techniques to provide better understanding of several unresolved issues that are identified in the current Guideline. These include complex terrain, turbulence characterization and atmospheric dispersion, long-range transport of pollutants, visibility impairment, photochemical transformation of pollutants on urban and regional scales, and evaluation/improvement of models. EPA is also reviewing and participating in, where possible, activities of other agencies and scientific groups in these technical areas. For example, EPA staff participated in the Atmospheric Dispersion Modeling Panel conducted by the National Commission on Air Quality; recommendations of that Panel are being carefully evaluated for their relevance to EPA's guidance on modeling. However, while EPA has on-going programs in a variety of problem areas, the Agency recognizes that the efforts of others should also provide answers. Since many of these problems are on the frontiers of scientific knowledge and understanding, research by the scientific community-at-large is an important part of achieving sound solutions.

Finally, EPA has an on-going program to review, revise and expand the mathematical models that are available for general application. The standard models made available by EPA for routine use are being reviewed to insure internal consistency. Incorporation of more recent techniques and developments is a continuing process. Additional models will be incorporated to allow a wider range of applications, viz, the Industrial Source Complex Model.[3]

Status of Conference and Guideline Revision

EPA is required to hold a Conference on Air Quality Modeling every three years and has begun planning for the next Conference to take place in early 1981. The four general activities discussed in the above section will form a basis for the Conference and for public comments concerning a revised Guideline on Air Quality Models.

The Conference will be preceded by public meetings in the fall of 1980. The purpose of these meetings will be to receive comments on proposed revisions to the Guideline. The proposed revisions will be based heavily on recommendations of EPA's Regional Office workshops and preliminary findings resulting from the cooperative agreement with the American Meteorological Society. Proposed changes to selected air quality models and the addition of new models will also be identified for comment at these

[1] Environmental Protection Agency, "Guideline on Air Quality Models," *Publication No. EPA-450/2-78-027*, Environmental Protection Agency, Research Triangle Park, North Carolina 27711, April 1978.

[2] Environmental Protection Agency, "Conference on Air Quality Modeling," Acme Reporting Company, Washington, D.C. 20005, December 1977.

[3] J. F. Bowers, *et al.*, "Industrial Source Complex (ISC) Dispersion Model User's Guide: Volumes I and II," Volume I, *Publication No. EPA-450/4-79-030*; Volume II, *Publication No. EPA-450/4-79-031*, Environmental Protection Agency, Research Triangle Park, North Carolina 27711, December 1978.

public meetings. A progress report on current research efforts will be given. A complete report and review of all activities, findings and proposed changes will be presented for comment at the Conference in 1981.

Solicitation of Non-EPA Models

The activities outlined above are consistent with the intent of the Clean Air Act. They are also responsive to public comments received at the Conference on Air Quality Modeling held in December 1977. However, there is some concern, even though adequate precedent has been established for inclusion of non-EPA models in the Guideline on Air Quality Models, that few such models have been recommended for general use. The Texas Episodic Model and the Texas Climatological Model have been included in the Guideline from its earliest drafts. MULTIMAX, prepared by a private company, is included in the Guideline as a footnote. These models were incorporated as a result of their general consistency with models recommended in the Guideline and the availability of suitable documentation. Nevertheless, while some other non-EPA models have been utilized on a case-by-case basis for application to specific situations, there have been no firm requests from model developers that EPA consider and recommend such models for general use; nor in many cases do these models meet the requirements discussed in the following section of this notice. Thus, there is a need for a mechanism by which non-EPA models can be considered for inclusion in the Guideline.

This notice solicits models that can be considered refined analytical techniques and that have applicability to a general air quality problem. Models are sought that are applicable to issues associated with prevention of significant deterioration and new source review. Models applicable to a variety of stationary source categories with emissions of sulfur oxides and particulate matter in a range of terrain and climatic settings are of particular interest. However, models more generally applicable to SIP-revisions and non-attainment for multisource (urban) situations, for other criteria pollutants (CO, O_3, NO_2, Pb), and for hazardous or carcinogenic pollutants are also of interest. Models that can only be considered simple screening techniques or that do not directly consider atmospheric dispersion are not being requested at this time.

Refined models that are received will be reviewed by EPA and considered for inclusion in the Guideline. To be reviewed, the models submitted must meet the following requirements:

1. The model must be computerized and functioning in a common Fortran language suitable for use on a variety of computer systems.

2. The model must be documented in a user's guide which identifies the mathematics of the model, data requirements and program operating characteristics at a level of detail comparable to that available for currently recommended models, e.g., the Single Source (CRSTER) Model.[4]

3. The model must be accompanied by a complete test data set including input parameters and output results. The test data must be included in the user's guide as well as provided in computer-readable form.

4. the model must be useful to typical users, e.g., State air pollution control agencies, for specific air quality control problems. Such users should be able to operate the computer program(s) from available documentation.

5. The model documentation must include a comparison with air quality data or with other well-established analytical techniques.

6. The developer must be willing to make the model available to users at reasonable cost or make it available for public access through the National Technical Information Service; the model can not be proprietary.

EPA staff will review the models that are submitted and take one of the following actions: (1) Recommend that the model be included in the Guideline on Air Quality Models for routine use; (2) Recognize in the Guideline that the model exists, but require a case-by-case determination as to acceptability before the model can be used for a specific regulatory application. (3) Reject the model and return it to the developer. For the present it appears that criteria for selection of one of these actions are uncertain. this uncertainty results from a lack of performance standards that have been adopted by the scientific community, inadequate data bases for thorough model evaluation, and the need for regulatory consistency in the selection and use of models. EPA also solicits comment on the criteria that model developers believe to be appropriate in reviewing models.

Models that are candidates for inclusion in the Guideline will be identified and available for comment at the public meetings and Conference proposed above. The fact that a model has been submitted to the Agency or is being reviewed does not give it any particular status. The status of models will only be established by final revisions to the Guideline on Air Quality Models.

Letters of intent to submit refined air quality models that will be available in the next twelve (12) months are requested so that Agency resources can be planned for the necessary reviews. Letters of intent should be sent within sixty (60) days of the date of this notice to the Source Receptor Analysis Branch (MD-14), U.S. Environmental Protection Agency, Research Triangle Park, N.C. 27711, Attn: Jerome B. Mersch. Once work on the model is cocmpleted, formal submittal should consist of a magnetic tape containing the program source code for the model and the test data set written at 1600 bpi in EBCDIC, three copies of the user's guide, any related documentation concerning past applications and performance of the model, and a statement on what arrangements will be made for public access to the model. Formal submittal of the model and of criteria that model developers believe should be used in developing agency recommendations on specific models should also be sent to the above address.

Dated: March 21, 1980.

David G. Hawkins,

Assistant Administrator for Air, Noise and Radiation.

[FR Doc. 80-9319 Filed 3-26-80; 8:45 am].

BILLING CODE 6560-01-M

[4] Environmental Protection Agency. "User's Manual for Single Source (CRSTER) Model." *Publication No. EPA-450/2-77-013*, Environmental Protection Agency, Research Triangle Park, North Carolina 27711, July 1977.

2.0 Models Proposed for General Use

These models would be recommended for general use in certain well-defined situations. They would have the same status (after this public hearing process) as models currently recommended in the Guideline on Air Quality Models.

2.1 BLP (Buoyant Line and Point Source Dispersion Model)

Reference: Schulman, Lloyd L., and Joseph S. Scire. "Buoyant Line and Point Source (BLP) Dispersion Model User's Guide." Document P-7304B. Environmental Research and Technology, Inc., Concord, MA.

Abstract : A Gaussian plume dispersion model designed to handle unique modeling problems associated with aluminum reduction plants, and other industrial sources where plume rise and downwash effects from stationary line sources are important.

Equations:

for Point Sources

$$X = \frac{Q}{\pi \sigma_y \sigma_z U_s} \exp -\left[\frac{y^2}{2\sigma_y^2}\right] \exp -\left[\frac{H^2}{2\sigma_z^2}\right] \qquad (2\text{-}2)$$

where

X is concentration (g/m^3)

y is crosswind distance (m)

Q is pollutant emission rate (g/s)

U_s is mean wind speed (m/s) at stack height

σ_y is crosswind standard deviation of the concentration distribution (m)

σ_z is vertical standard deviation of the concentration distribution (m)

H is effective stack height (m)

The empirical dispersion coefficents, σ_y and σ_z, used in the BLP model are piecewise fits to the stability and distance dependent curves in Turner (1970). The effective stack height, H, is the sum of the physical stack height, H_s, and the plume rise, Δh. The equations used to calculate the plume rise are described in Section 2.4. The mean wind speed used in Equation 2-2 is the stack height wind speed as calculated by the stability dependent power law wind speed profile equation.

In the neutral atmospheric boundary layer, the vertical diffusion of a plume is sometimes limited by a stably stratified inversion layer above the mixed layer. The plume is assumed to be reflected at this interface as well as at the ground. The method of image sources is used to model these reflections (Turner 1970). The Gaussian equation for a ground-level receptor, with multiple reflections is:

$$\chi = \frac{Q}{\pi \sigma_y \sigma_z U_s} \exp\left[\frac{-y^2}{2\sigma_y^2}\right] \left\{ \sum_{n=-\infty}^{\infty} \exp\left[-\frac{1}{2} \left(\frac{H+2nD}{\sigma_z} \right)^2 \right] \right\} \qquad (2\text{-}3)$$

where D is the height of the base of the inversion (mixing height).

for Line Sources

$$\chi = \frac{(q_\ell)}{U} \int_0^L g \, dl \qquad (2\text{-}27)$$

where

q_ℓ is emission rate per unit length of the line, g s^{-1} m^{-1}
L is line length, m
g is dispersion function, m^{-2}

The dispersion function, g, consists of the lateral and vertical dispersion terms of the Gaussian point source equation (see Equation 2-2 to 2-8). For stable conditions, or if the mixing height is greater than 5,000 m,

$$g = \frac{1}{\pi \sigma_y \sigma_z} \exp\left[\frac{-y^2}{2\sigma_y^2}\right] \exp\left[\frac{-H^2}{2\sigma_z^2}\right] \qquad (2\text{-}28)$$

For unstable or neutral conditions,

$$g = \frac{1}{\pi \sigma_y \sigma_z} \exp\left[\frac{-y^2}{2\sigma_y^2}\right] F_1 \qquad (2\text{-}29)$$

$$F_1 = \sum_{N=-\infty}^{\infty} \exp\left[-\frac{1}{2}\left(\frac{H + 2nD}{\sigma_z}\right)^2\right]$$

unless the ratio σ_z/D is greater than 1.6,

$$g = \frac{1}{\sqrt{2\pi}\sigma_y D} \exp\left[\frac{-y^2}{2\sigma_y^2}\right]$$

a. Input Requirements

Emissions data: for point sources - stack location (x,y coordinates), elevation of stack base, physical stack height, stack inside diameter, stack gas exit velocity, stack gas exit temperature, and pollutant emission rate. For line sources - coordinates of the end points of the line, release height, emission rate, average line length, average building height, average line source width, average building width, average spacing between buildings, and average line source buoyancy parameter.

Meteorological data: can be input from either the EPA meteorological preprocessor output (up to 366 days) or from punched cards (up to 24 hours). The required data are: hourly stability class (derived in the EPA meteorological preprocessor from cloud ceiling, opaque cloud cover, and wind speed), hourly wind direction, and speed, hourly temperature, and daily mixing heights.

b. Output

Separate post-processing program produces:

- Total concentration or source contribution analysis
- Monthly and annual frequency distributions for 1-, 3-, and 24-hour average concentrations
- Tables of 1-, 3-, and 24-hour average concentrations at each receptor
- Table of the annual (or length of the BLP run) average concentrations at each receptor
- Five highest 1-, 3-, and 24-hour average concentrations at each receptor
- Fifty highest 1-, 3-, and 24-hour average concentration over the receptor field

c. Model Options

Coordinate system option (UTM or internal source coordinate system)
Source contribution
Wind shear effect on plume rise
Point source downwash
Transitional plume rise
Vertical potential temperature gradient option for E and F stabilities
Wind speed power law exponent option for user-defined values
Stability class restriction option allows up to a user-specified number of stability class changes per hour
Mixing height option (urban vs. rural)
Pollutant decay
Background concentration input terrain adjustment (includes any adjustment from horizontal plume, through "half-height," to terrain following plume

d. Limitations

Intended for aluminum reduction plants and other similar complex sources where buoyant line source plume rise, building downwash, and vertical wind speed shear effects are important

e. Pollutant Types

Treats a single inert pollutant

f. Source-Receptor Relationship

Up to 50 point sources, 10 parallel line sources, and 100 receptors, arbitrarily located
Unique topographic elevation for each stack

g. Plume Behavior

Briggs plume rise formulae with several enhancements by ERT
Transitional rise is optional for point sources, mandatory for line sources so that building downwash can be accounted for
Building downwash is a significant modification of the approach of Huber and Snyder

h. Horizontal Wind Field

User-supplied hourly winds
Wind speeds corrected for release height based on power law exponents used in CDM, CRSTER, and others
Constant, uniform wind assumed within each hour

i. Vertical Wind Speed

Assumed equal to zero

J. Horizontal Dispersion

Gaussian plume
Six stability classes used (Turner class 7 treated as 6)
Dispersion coefficients from Turner

k. Vertical Dispersion

Gaussian plume
Six stability classes used (Turner class 7 treated as class 6)
Dispersion coefficients from Turner

l. Chemistry/Reaction Mechanism

Not treated

m. Physical Removal

Not treated

n. Boundary Conditions

Lower boundary: perfect reflection
Upper boundary: perfect reflection
Multiple reflections handed by summation of series to a distance where σ_z = 1.6 times mixing height; uniform vertical distribution thereafter

o. Background

User input optional

p. Evaluation Studies

Studies described in Schulman, Lloyd L., and Joseph S. Scire. "Development of an Air Quality Dispersion Model for Aluminum Reduction Plants"

q. Proposed EPA Action

BLP is recommended to be included in the Guideline on Air Quality Models for routine application to aluminum reduction plant buildings that can be characterized as buoyant, elevated line sources.
BLP can also be used on a case-by-case basis for other source configurations if it can be demonstrated, using criteria in Section 6, that the model gives the same answers as a recommended model and will subsequently be executed in that mode.

r. Model Availability

The BLP model and accompanying user's guide and final report are available as a package from the Aluminum Association at a cost of $300. The user's guide and final report are available for $100.
Requests should be directed to:

Mr. Seymour G. Epstein
Technical Director
The Aluminum Association, Inc.
818 Connecticut Avenue, NW
Washington, DC 20006

2.2 CALINE3

Reference: Benson, Paul E."CALINE3 - A Versatile Dispersion Model for Predicting Air Pollutant Levels Near Highways and Arterial Streets." Interim Report. Report Number FHWA/CA/TL-79/23. Federal Highway Administration, November 1979.

Abstract : CALINE3 can be used to estimate the concentrations of nonreactive pollutants from highway traffic. This steady-state Gaussian model can be applied to determine air pollution concentrations at receptor locations downwind of "at-grade," "fill," "bridge," and "cut section" highways located in relatively uncomplicated terrain. The model is applicable for any wind direction, highway orientation, and receptor location. The model has adjustments for averaging time and surface roughness, and can handle up to 20 links and 20 receptors. It also contains an algorithm for deposition and settling velocity so that particulate concentrations can be predicted.

Equations:

$$C = \frac{1}{\sqrt{2\pi}U} * \sum_{i=1}^{n} \left\{ \frac{1}{SGZ_i} * \sum_{k=-CNT}^{CNT} \left[\exp\left(\frac{-(Z-H+2*k*L)^2}{2*SGZ_i^2} \right) + \exp\left(\frac{-(Z+H+2*k*L)^2}{2*SGZ_i^2} \right) \right] * \sum_{j=1}^{5} (WT_j * QE_i * PD_{ij}) \right\}$$

Where,

- n = Total number of elements
- CNT = Number of multiple reflections required for convergence
- U = Wind speed
- L = Mixing height (MIXH in coding)
- SGZ_i = σ_z as f(x) for ith element
- QE_i = Central sub-element lineal source strength for ith element
- WT_j = Source strength weighting factor for jth sub-element (WT_1 = 0.25, WT_2 = 0.75, ...)

$$PD_{ij} = \frac{1}{\sqrt{2\pi}} \int_{\frac{Y_j}{SGY_i}}^{\frac{Y_{j+1}}{SGY_i}} \exp\left(\frac{-p^2}{2}\right) dp$$

Y_j, Y_{j+1} = Offset distances for jth sub-element

SGY_i = σ_y as f(x) for ith element

a. Input Requirements

Meteorological data: Wind speed, wind angle (measured in degrees clockwise from the Y axis), stability class, mixing height, ambient (background to the highway) concentration of pollutant
Emissions data: Up to 20 highway links classed as At-grade, Fill, Bridge, or Depressed; coordinates of link end points; traffic volume; emission factor; source height; and mixing zone width.

b. Output

Concentration at each receptor for the specified meteorological condition

c. Model Options

Variable averaging times, variable surface roughness, deposition

d. Limitations

Mobile sources represented as multiple line sources
Relatively flat terrain
Not applicable to point and area sources

e. Pollutant Types

Treats a single inert pollutant

f. Source-Receptor Relationship

Up to 20 highway links
Unique location and emission rate for each link
Arbitrary receptor locations

g. Plume Behavior

Initial traffic induced dispersion handled implicitly by plume size parameters
No plume rise

h. Horizontal Wind Field

User-supplied hourly wind speed and direction
Constant, uniform wind assumed

i. Vertical Wind Speed

Assumed equal to zero

j. Horizontal Dispersion

Six stability classes
Gaussian plume
Six stability classes
Dispersion coefficients from Turner, with adjustment for roughness length and averaging time

k. Vertical Dispersion

Gaussian plume
Six stability classes used
Empirical dispersion coefficients which converge to F. B. Smith's curves at a distance of 10 kilometers - F. B. Smith's adjustment for roughness length is retained.
Adjustment to averaging time is included.

l. Chemistry/Reaction Mechanism

Not treated

m. Physical Removal

Deposition calculations are included

n. Boundary Conditions

Lower boundary: perfect reflection when deposition velocity is set to zero. Otherwise, lower boundary absorbs pollutant at a rate determined by the deposition velocity, settling velocity, and concentration
Upper boundary: perfect reflection. Multiple reflections accounted for when mixing heights are low

o. Background

Not treated

p. Evaluation Studies

Three studies reported in user's manual

q. Proposed EPA Action

CALINE3 is recommended to be included in the Guideline on Air Quality Models for routine use similar to HIWAY2. However, the use of the deposition option is subject to the demonstration requirements of Section 6 of the Guideline.

r. Model Availability

The CALINE3 model is available from the California Department of Transportation on an at-cost basis ($10 for documentation, approximately $50 for the model).

Requests should be directed to:

Mr. Ebert Jung
Chief, Office of Computer Systems
California Department of Transportation
1120 N Street
Sacremento, California 95814

2.3 MESOPUFF (Mesoscale Puff Model)

Reference: Benkley, Carl W., and Arthur Bass. "Development of Mesoscale Air Quality Simulation Models, Volume 3. User's Guide to MESOPUFF (Mesoscale Puff) Model. EPA 600/7-80-058. U. S. Environmental Protection Agency, Research Triangle Park, NC 27711.

Abstract : MESOPUFF is a mesoscale puff model designed to calculate concentrations of SO_2 and $SO_4^=$ over long distances. Plume growth is calculated by finite difference techniques with plume growth parameters fitted to Turner's plume size (sigma) curves.

Equations:

The conservation of pollutant mass in a puff transported a distance Δs is expressed by the mass balance equation:

$$\Delta Q = \int_0^\infty \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} G(r, \theta, z)\, dr\, d\theta\, dz \qquad \text{(B-1)}$$

$$= \frac{u}{\Delta s} \int_0^\infty \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} C\, dr\, d\theta\, dz \Bigg|_{s+\Delta s} - \frac{u}{\Delta s} \int_0^\infty \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} C\, dr\, d\theta\, dz \Bigg|_{s}$$

where r, θ, define points relative to the puff center in cylindrical coordinates, $G(r,\theta,z)$ (g m^{-3} s^{-1}) is the rate of change (gain-loss) of pollutant concentration $C(r,\theta,z)$ (g m^{-3}), ΔQ (g s^{-1}) is the resultant rate of change of pollutant mass, and u(m s^{-1}) is the wind speed. In the MESOPUFF model, $G(r,\theta,z)$ and u are constant for s to s + Δs, where s is defined as the total distance a puff has traveled since it was emitted.

For a discrete puff lying below the mixing height H, the circularly symmetric ground-level puff concentration C(r,0;s) is defined as

$$C(r,0;s) = \frac{Q(s)}{2\pi\, \sigma_y^2(s)\, g_1(z)} \exp\left(\frac{-r^2}{2\, \sigma_y^2(s)}\right) g_2(z) \qquad \text{(B-2)}$$

where Q(s) is the puff mass and $\sigma_y(s)$ the "radial" Gaussian plume dispersion coefficient at distance s. The use of a "radial" Gaussian dispersion coefficient is a convenient computational device.

nothing more. The functions $g_1(z)$ and $g_2(z)$ are dependent upon the vertical distribution of concentration in the puff. Replacing H by H_m, the maximum mixing depth encountered by a puff (see Section B.8), MESOPUFF permits the user to specify one of two possible algorithms for the distribution function g(z), namely

1) a uniform vertical distribution algorithm within H_m, such that $g_1(z) = H_m$ and $g_2(z) = 1.0$, and

2) a Gaussian, multiple reflection algorithm where:

   - if $\sigma_z < 2\ H_m$, $g_1(z) = \sqrt{2\pi}\ \sigma_z$ and $g_2(z)$ is a function that accounts for multiple reflection effects and
   - if $\sigma_z \geq 2\ H_m$, $g_1(z) = H$, and $g_2(z) = 1.0$.

For regional-scale transport, e.g., at distances from 100 to 1,000 km from a source, either algorithm will produce substantially similar results, as a rule, because at travel distances $\gtrsim$100 km σ_z is likely to be greater than $2H_m$.

Using the uniform vertical distribution function (1), the ground level puff concentration C(r,0;s) at distance s is

$$C(r,0;s) = \frac{Q(s)}{2\pi\ \sigma_y^2(s)\ H_m} \exp\left(\frac{-r^2}{2\ \sigma_y^2(s)}\right) \qquad \text{(B-3)}$$

At distance s+Δs, the ground level concentration becomes

$$C(r,0;s+\Delta s) = \frac{Q(s+\Delta s)}{2\pi\ \sigma_y^2(s+\Delta s)\ H_m} \exp\left(\frac{-r^2}{2\ \sigma_y^2(s+\Delta s)}\right) \qquad \text{(B-4)}$$

a. Input Requirements

Emission data: location (x and y coordinates), stack height, emission rate for SO_2, emission rate for $SO_4^=$, buoyancy flux for plume rise, multipliers, by hour of the day, for the emission rate and for the buoyancy flux; each for up to 10 sources
Meteorological data: Spatially variable, gridded fields of horizontal (u,v,) wind components, mixing height, and Pasquill stability class. These data are normally, though not necessarily, obtained from the output of the MESOPAC program (Volume 6, EPA-600/7-80-061). MESOPAC requires, as input, radiosonde observations from one or more stations, plus the wind components at the most relevant level.

b. Output

Options: Arrays of ground level concentrations of SO_2 and $SO_4^=$ for user-specified averaging times at user-specified intervals
Tables as above for specified receptors only
Arrays of maximum grid point concentration values for the period of the run
Maximum concentrations as above, but for specified receptors only
Table listing of the time when the first plume segment from each source reached the edge of the computational grid
The concentrations array may be output to disk for each time step

c. Model Options

Alternate plume growth coefficients
Exponential decay of SO_2 to $SO_4^=$
Dry deposition
Uses 24-hour cycle of emission rate multipliers
Uses 24-hour cycle of buoyancy flux multipliers
Through the MESOFILE postprocessing program (Volume 5, EPA 600/7-80-060) line printer plots and calcomp plots are available
Fumigation to produce immediate mixing or multiple reflection calculations at users option
Presence of mixing lid

d. Limitations

Relatively flat terrain
Model is designed primarily for calculating regional scale impacts
Not applicable to area or line sources

e. Pollutant Types

SO_2 and $SO_4^=$

f. Source-Receptor Relationship

Up to 10 point sources
Calculations made over a gridded network of receptors
Up to 10 arbitrary receptors are permitted

g. Plume Behavior

Briggs, with buoyancy flux, F, input to the model
Includes fumigation

h. Horizontal Wind Field

Derived gridded wind field specified for each grid square. MESOPAC derives the values by interpolation between stations and hours

i. Vertical Wind Speed

Assumed equal to zero

j. Horizontal Dispersion

Incremental plume growth over discrete time steps with plume growth parameters chosen to approximate Turner's σ_y curves to fill the mixing layer, as appropriate
Plume growth is a function of stability class

k. Vertical Dispersion

Incremental puff growth over discrete time steps, with puff growth parameters chosen to approximate σ_z curves of Turner
Puff growth is a function of stability class

l. Chemistry/Reaction Mechanism

SO_2 to $SO_4^=$ conversion by means of half-life formula. Half-life is supplied by the user

m. Physical Removal

See item 1. above

n. Boundary Conditions

Lower boundary: calculation of deposition is optional. Otherwise perfect reflection is assumed
Upper boundary: perfect reflection is assumed
Mixing height is input to the model as a function of time and grid location
Includes option to ignore upper boundary

o. Background

Optional user input

p. Evaluation Studies

Sensitivity tests and evaluation studies are described in "Development of Mesoscale Air Quality Simulation Models. Volume 1: Comparative Studies of Puff, Plume, and Grid Models for Long Distance Dispersion". EPA 600/7-80-056.

q. Proposed EPA Action

MESOPUFF is recommended to be included in the Guideline on Air Quality Models for routine use for long range transport (greater than 50 km) applications.

r. Model Availability

The MESO Models and accompanying user's guides and related studies are available from the National Technical Information Service. The models and related programs are on magnetic tape and the documentation is comprised of six volumes. The accession numbers and related costs are:

Magnetic tape:	PB 80-227 549	$720.00
Volume 1 :	PB 80-227 580	$ 13.00
Volume 2 :	PB 80-227 598	$ 10.00
Volume 3 :	PB 80-227 796	$ 9.00
Volume 4 :	PB 80-227 804	$ 9.00
Volume 5 :	PB 80-227 812	$ 7.00
Volume 6 :	PB 80-228 042	$ 7.00

Requests should be sent to:

National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

2.4 MESOGRID (Mesoscale Grid Model)

Reference: Morris, Charles S., Carl W. Benkley, and Arthur Bass. "Development of Mesoscale Air Quality Simulation Models. Volume 4: User's Guide to MESOGRID (Mesoscale Grid) Model." EPA-600/7-80-059. U. S. Environmental Protection Agency, Research Triangle Park, NC 27711.

Abstract : MESOGRID is a mesoscale k-theory grid model designed to calculate concentrations of SO_2 and $SO_4^=$ over long distances.

Equations:

The horizontal advection, vertical diffusion, linear decay, and dry deposition of sulfur dioxide (SO_2) and sulfate ($SO_4^=$) species on regional scales are represented in MESOGRID by a discrete-level numerical representation of the continuous equations describing the mass conservation of the respective pollutant species:

$$\frac{\partial C_1}{\partial t} = -u\frac{\partial C_1}{\partial x} - v\frac{\partial C_1}{\partial y} + \frac{\partial}{\partial z}\left[K_z\frac{\partial C_1}{\partial z}\right] - k_1C_1 - f_1C_1\delta(z,H,\Delta z_k) + \frac{Q_1}{\Delta z_k} \quad \text{(C-1)}$$

$$\frac{\partial C_2}{\partial t} = -u\frac{\partial C_2}{\partial x} - v\frac{\partial C_2}{\partial y} + \frac{\partial}{\partial z}\left[K_z\frac{\partial C_2}{\partial z}\right] + \frac{3}{2}k_1C_1 - f_2C_2\delta(z,H,\Delta z_k) \quad \text{(C-2)}$$

where

x is the east-west horizontal coordinate (m);

y is the north-south horizontal coordinate (m);

z is the vertical coordinate (m);

t is the time (s);

C_1, C_2 are the ambient concentrations of sulfur dioxide (SO_2) and sulfate ($SO_4^=$) respectively (g m^{-3});

Q_1 is the source emission rate of SO_2 (g $m^{-2}s^{-1}$) within a vertical cell of height Δz_k (the $SO_4^=$ emission rate is assumed to be zero);

$u(x,y)$, $v(x,y)$ are, respectively, the x and y components of horizontal wind velocity (m s^{-1});

K_z is the vertical eddy diffusivity (m^2 s^{-1});

k_1 is the rate (s^{-1}) of linear decay of SO_2 to $SO_4^=$;

f_1, f_2 are the dry deposition rate functions (s^{-1}) of SO_2 and $SO_4^=$, respectively. Dry deposition is considered only when the height z of a parcel of pollutant is below the mixing height H; and

$\delta(z,H,\Delta z_k) = 1$ for $z \leq$ and $k = 1$; $\delta(z,H,\Delta z_k) = 0$ for $z > H$ or $k \neq 1$.

a. Input Requirements

Emission data: location (x and y coordinates), stack height, emission rate for SO_2, emission rate for $SO_4^=$, buoyancy flux for plume rise, hourly multipliers for the emission rate and for the buoyancy flux; each for up to 10 sources

Meteorological data: Spatially variable, gridded fields of horizontal (u,v,) wind components, mixing height, and Pasquill stability class. These data are normally, though not necessarily, obtained from the output of the MESOPAC program (Volume 6, EPA 600/7-80-061). MESOPAC requires, as input, radiosonde observations from one or more stations, plus the wind components at the most relevant level.

b. Output

Options: Arrays of ground level concentrations of SO_2 and $SO_4^=$ for user-specified averaging times at user-specified intervals
Tables as above for specified receptors only
Arrays of maximum grid point concentration values for the period of the run
Maximum concentrations as above, but for specified receptors only
Table listing of the time when the first plume segment from each source reached the edge of the computational grid
The concentrations array may be output to disk for each time step

c. Model Options

Alternate plume growth coefficients
Exponential decay of SO_2 to $SO_4^=$
Dry deposition
Through the MESOFILE postprocessing program (Volume 5, EPA 600/7-80-060) line printer plots and calcomp plots are available
Background
Number of vertical layers

d. Limitations

Relatively flat terrain
Model is designed primarily for calculating regional scale impacts
Not applicable to area or line sources
Abrupt changes in wind flow over short distances can cause erroneous results in that vicinity

e. Pollutant Types

SO_2 and $SO_4^=$

f. Source-Receptor Relationship

Up to 10 point sources
Calculations made over a gridded network of receptors
Up to 10 arbitrary receptors are permitted

g. Plume Behavior

Briggs, with buoyancy flux, F, input to the model
Includes fumigation

h. Horizontal Wind Field

Derived gridded wind field specified for each grid square. MESOPAC derives the values by interpolation between stations and hours

i. Vertical Wind Speed

Assumed equal to zero

j. Horizontal Dispersion

Incremental plume growth over discrete time steps with plume growth parameters chosen to approximate Turner's σ_y curves
Plume growth is a function of stability class

k. Vertical Dispersion

Incremental plume growth over discrete time steps, with plume growth parameters chosen to approximate σ_z curves of Turner
Plume growth is a function of stability class

l. Chemistry/Reaction Mechanism

SO_2 to $SO_4^=$ conversion by means of half-life formula. Half-life is supplied by the user

m. Physical Removal

See item l. above

n. Boundary Conditions

Lower boundary: calculation of deposition is optional. Otherwise perfect reflection is assumed
Upper boundary: user input reflection coefficient at top boundary of highest grid

o. Background

Optional user input

p. Evaluation Studies

Sensitivity tests and evaluation studies are described in "Development of Mesoscale Air Quality Simulation Models. Volume 1: Comparative Studies of Puff, Plume, and Grid Models for Long Distance Dispersion". EPA 600/7-80-056.

q. Proposed EPA Action

MESOGRID is recommended to be included in the Guideline on Air Quality Models for routine use for long range transport (greater than 50 km) applications when more than 10 sources must be evaluated concurrently. For 10 sources or less, MESOPUFF is the recommended model.

r. Model Availability

The MESO Models and accompanying user's guides and related studies are available from the National Technical Information Service. The models and related programs are on magnetic tape and the documentation is comprised of six volumes. The accession numbers and related costs are:

Magnetic tape:	PB 80-227 549	$720.00
Volume 1 :	PB 80-227 580	$ 13.00
Volume 2 :	PB 80-227 598	$ 10.00
Volume 3 :	PB 80-227 796	$ 9.00
Volume 4 :	PB 80-227 804	$ 9.00
Volume 5 :	PB 80-227 812	$ 7.00
Volume 6 :	PB 80-228 042	$ 7.00

Requests should be sent to:

National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

2.5 SHORTZ

Reference: Bjorklund, J. R., and J. F. Bowers. "User's Instructions for the SHORTZ and LONGZ Computer Programs, Volumes 1 and 2" TR-79-181-01. H. E. Cramer Co., Inc. University of Utah Research Park, P. O. Box 8049, Salt Lake City, Utah 84108. December 1979.

Abstract: SHORTZ utilizes the steady state bivariate Gaussian plume formulation for both urban and rural areas in flat or complex terrain to calculate ground-level ambient air concentrations. It can calculate 1-hour, 2-hour, 3-hour, etc. averages for up to 300 arbitrarily located sources (stacks, buildings and areas) as total contribution to ambient air deterioration at each receptor. If the option for gravitational settling is invoked, analysis cannot be accomplished in complex terrain without violating mass continuity.

Equations: For gases and for particles with diameters equal to or less than 20 μm, the point-source and building source formulation consists of

$$\chi\{x,y\} = \frac{K\,Q}{\pi\,\bar{u}\{H\}\,\sigma_y\,\sigma_z}\ \{\text{Vertical Term}\}\ \{\text{Lateral Term}\}\ \{\text{Decay Term}\}$$

where

K = scaling coefficient to convert calculated concentrations to desired units (default value of 1×10^6 for Q in g/sec and concentration in $\mu g/m^3$)

Q = source emission rate (mass per unit time)

$u\{H\}$ = mean wind speed (m/sec) at the plume stabilization height H (transformed from wind measurement height via exponent law).

σ_y, σ_z = standard deviations (m) of the lateral and vertical concentration distributions at downwind distance x (σ_y and σ_z are also known as lateral and vertical dispersion coefficients); the σ's are those of Cramer.

and

$$\{\text{Vertical Term}\} = \left\{\exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] + \sum_{i=1}^{\infty}\left[\exp\left[-\frac{1}{2}\left(\frac{2i\,H_m + H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{2i\,H_m - H}{\sigma_z}\right)^2\right]\right]\right\} \quad (1)$$

where H_m is the depth of the surface mixing layer. Beyond the point at which the series exponentials are non-zero for i equal 3,

$$\{\text{Vertical Term}\} = \frac{\sqrt{2\pi}\,\sigma_z}{2H_m}$$

$$\{\text{Lateral Term}\} = \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$

where y is the crosswind distance from the plume centerline to the point at which the concentration is calculated.

$$\{\text{Decay Term}\} = \exp\left[-\psi\, x/\bar{u}\{H\}\right]$$

where

ψ = the washout coefficient $\Lambda(\text{sec}^{-1})$ for precipitation scavenging

= $\frac{0.692}{T_{1/2}}$, where $T_{1/2}$ is the pollutant half life (sec) for physical or chemical removal

= 0 for no depletion (ψ is automatically set to zero by the computer program unless otherwise specified)

The area source formulation is

$$\chi\{x,y\} = \frac{KQ}{\sqrt{2\pi}\,\bar{u}\{h\}\,\sigma_z\{x\}\,y_o}\ \{\text{Vertical Term}\}$$

$$\{\text{Lateral Term}\}\ \{\text{Decay Term}\} \qquad (2)$$

where

Q = area source emission rate (mass per unit time)

y_o = crosswind source dimension (m)

h = the characteristic height of the area source (m)

$$\{\text{Vertical Term}\} = \begin{cases} 1+2\sum_{i=1}^{3}\left\{\exp\left[-\frac{1}{2}\left(\frac{2iH_m}{\sigma_z\{x\}}\right)^2\right]\right\}; \exp\left[-\frac{1}{2}\left(\frac{6H_m}{\sigma_z}\right)^2\right] = 0 \\ \frac{\sqrt{2\pi}\,\sigma_z\{x\}}{2\,H_m} \qquad ; \exp\left[-\frac{1}{2}\left(\frac{6H_m}{\sigma_z}\right)^2\right] > 0 \end{cases}$$

where

H_m is mixing height

σ_z -- See instruction manual

$$\{\text{Lateral Term}\} = \left\{\text{erf}\left[\frac{y_o/2 + y}{\sqrt{2}\,\sigma_y\{x\}}\right] + \text{erf}\left[\frac{y_o/2 - y}{\sqrt{2}\,\sigma_y\{x\}}\right]\right\}$$

where

y_o = crosswind dimension of the area source (m)

y = crosswind distance from the centerline of the area source (m)

σ_y -- See instruction manual

For particles with diameters greater than 20 μm, Equation 1 or 2 is used with

$$\{\text{Vertical Term}\} = \sum_{n=1}^{N} \frac{\phi_n}{2} \left\{ \exp\left[-\frac{1}{2}\left(\frac{H - V_{sn}\, x/\bar{u}\{H\}}{\sigma_z} \right)^2 \right] + \exp\left[-\frac{1}{2}\left(\frac{2H_m - H + V_{sn}\, x/\bar{u}\{H\}}{\sigma_z} \right)^2 \right] \right\}$$

where

ϕ_n = the mass fraction of particulates with settling velocity V_{sn}, where V_{sn} is in meters per second

H = the effective stack height for stack sources, the building height for building sources and the characteristic emission height for area sources (m)

a. Input Requirements

Meteorological data (hourly, 2-hourly, etc.): wind speed and measurement height, wind profile exponents, wind direction, standard deviations of vertical and horizontal wind directions, mixing height, air temperature, vertical potential temperature gradient
Source data: point, building or area, total emission rate (optionally classified by gravitational settling velocity) and decay coefficient, stack height, effluent temperature, effluent exit velocity, stack radius (inner), actual volumetric emission rate, ground elevation (optional), coordinates, building height, length and width, and orientation, characteristic vertical dimension of area source, and length, width and orientation
Receptor data: coordinates, ground elevation

b. Output

Total concentration of all sources (optionally, with allowance for deposition).

c. Model Options

Point, building or area source, allowance for deposition and gravitational settling, terrain, Cartesian or polar receptor system, discrete receptors, time-dependent source characteristics, *exponential decay of pollutants, time periods for concentrations*

d. Model Limitations

Use of gravitational settling is not appropriate for complex terrain

e. Pollutant Types

Inert pollutants
Pollutants with simple exponential decay
Pollutants experiencing gravitiational settling and deposition

f. Source-Receptor Relationships

Sources and receptors can be arbitrarily located horizontally and vertically (but receptors always at ground level)

g. Plume Behavior

Briggs earlier formulae, modified by H. E. Cramer Company
Final rise attained at source
All plumes move horizontally and will fully intercept elevated terrain

Plumes above mixing height are ignored
Plume rise is limited when u at stack height approaches or exceeds stack exit velocity
Does not simulate fumigation
Tilted plume used for pollutants with fall velocity specified
Buoyancy-induced dispersion (source-specific)

h. Horizontal Wind Field

Homogeneous and steady-state

i. Vertical Wind Field

Zero vertical velocity
Homogeneous in direction
Exponential law defines speed

j. Horizontal Dispersion

Semi-empirical Gaussian plume
Cramer dispersion coefficients

k. Vertical Dispersion

Semi-empirical Gaussian plume
Cramer dispersion coefficients

l. Chemistry/Reaction Mechanism

Exponential decay (based upon time)

m. Physical Removal

Gravitational settling velocity
Dry deposition
Exponential washout (based upon time)

n. Boundary Conditions

Perfect vertical reflection at the level of the effective mixing height for all pollutants
Perfect vertical reflection at ground level for pollutants with zero settling velocity
Zero vertical reflection at ground level for pollutants with finite settling velocity
Actual mixing height is constant above sea level; effective mixing height is constant above terrain

o. Background

No provision

p. Evaluation Studies

Several such studies by H. E. Cramer Company, Inc.

q. Proposed EPA Action

SHORTZ is recommended to be included in the Guideline on Air Quality Models for routine use to estimate concentrations of 24 hours or less in complex terrain comprised of urban areas or industrialized valleys, meeting the urban criteria of Section 5.5, provided default values built into the computer code are used for the technical options. Vertical temperature gradients should be specified according to Table 2-4 of the User's Instructions.

r. Model Availability

The two-volume user's guide and magnetic tape containing the SHORTZ and LONGZ computer programs are available from H. E. Cramer Company at a cost of $250.
Requests should be directed to the attention of:

Mr. Harry V. Geary
H. E. Cramer Company, Inc.
Post Office Box 8049
Salt Lake City, Utah 84108

2.6 LONGZ

Reference: Bjorklund, J. R., and J. F. Bowers: "User's Instructions for the SHORTZ and LONGZ Computer Programs. Volumes 1 and 2." TR-79-131-01. H. E. Cramer Co., Inc. University of Utah Research Park, P. O. Box 8049, Salt Lake City, Utah 84108.

Abstract : LONGZ utilizes the steady-state, univariate, Gaussian formulation for estimating seasonal average concentrations due to emissions from stacks, buildings and area sources. The total concentration at each receptor due to all sources is output. An option which considers losses due to deposition is deemed inappropriate by the authors for complex terrain, and is not discussed herein.

Equations: For a single stack, the mean seasonal concentration at the point (r,θ) with respect to the stack is given by

$$\chi_\ell\{r,\theta,z\} = \frac{2K}{\sqrt{2\pi}\, r\, \Delta\theta'} \sum_{i,j,k} \left[\frac{Q_{i,k,\ell}\, f_{i,j,k,\ell}}{\bar{u}_i\, H_{i,k,\ell}\, \sigma_{z;i,k,\ell}} S\{\theta\}\, V_{i,k,\ell} \right. \quad (1)$$

$$\left. \exp\left[-\psi\, r/\bar{u}_i \left\langle H_{i,k,\ell} \right\rangle \right] \right]$$

where

$$V_{i,k,} = \sum_{n=-\infty}^{+\infty} \exp\left[-\frac{1}{2} \left(\frac{2nH_{m;i,k,\ell} + H_{i,k,\ell}}{\sigma_{z;i,k,\ell}} \right)^2 \right] \quad (2)$$

and

$\chi_\ell\{r,\theta\}$ = average concentration for season ℓ at the receptor located at radius r, direction θ

k = scaling factor to provide proper units for χ

$\bar{u}$ = mean wind speed (m/s) at plume height H

σ_z = standard deviation (m) of the vertical concentration distribution at distance r

H_m = effective mixing height

$Q_{i,k,\ell}$ = pollutant emission rate, which may be held constant or varied according to the i^{th} wind-speed category, k^{th} stability or time-of-day category and season (mass per unit of time)

$f_{i,j,k,\ell}$ = frequency of occurrence of the i^{th} wind-speed category, j^{th} wind direction category and k^{th} stability or time-of-day category for the ℓ^{th} season

$\Delta\theta'$ = the sector width in radians

$S\{\theta\}$ = a smoothing function between adjacent sector centerlines

$$S\{\theta\} = \begin{cases} \dfrac{\Delta\theta' - |\theta'_j - \theta'|}{\Delta\theta'} & ; \ |\theta'_j - \theta'| \leq \Delta\theta' \\ 0 & ; \ |\theta'_j \quad \theta'| > \Delta\theta' \end{cases}$$

θ'_j = the angle measured in radians from north to the centerline of the j^{th} wind-direction sector

θ' = the angle measured in radians from north to the point (r,θ)

i = wind-speed category

j = wind-direction category

k = stability or time-of-day category

ℓ = season

z = height above ground (always zero)

The Vertical Term given by Equation 2 is changed to the form

$$V_{i,k,\ell} = \frac{\sqrt{2\pi}\,\sigma_{z;i,k,\ell}}{2H_{m;i,k,\ell}}$$

when the exponential terms in Equation 2 become non-zero for $n = 3$.

$$V_{i,k,\ell} = \begin{cases} 1+2 \sum_{n=1}^{3} \exp\left[-\frac{1}{2}\left(\frac{2nH_{m;i,k,\ell}}{\sigma_{z;i,k}}\right)^2\right] ; \exp\left[-\frac{1}{2}\left(\frac{6H_{m;i,k,\ell}}{\sigma_{z;i,k}}\right)^2\right] 0 \\ \frac{\sqrt{2\pi}\,\sigma_{z;i,k}}{2H_{m;i,k,\ell}} \quad ; \exp\left[-\frac{1}{2}\left(\frac{6H_{m;i,k,\ell}}{\sigma_{z;i,k}}\right)^2\right] > 0 \end{cases}$$

where r" = the downwind distance, measured along the plume axis, from the upwind edge of the area source (m)

Equation 1 is used by LONGZ to calculate ground-level concentrations for building sources with the initial vertical dimension σ_{zo} given by the building height divided by 2.15 and the initial lateral dimension $4.3\,\sigma_{yo}$ given by the diameter of a circle with the same horizontal area as the building. A virtual point source is used to account for the initial lateral dimension of the source.

The seasonal average concentration within an area source attributable to the source's own emissions is given by

$$\chi_\ell\{r'' \leq r_o, \theta\} = \frac{2K}{\sqrt{2\pi}\,x_o y_o} \sum_{i,j,k} \left[\frac{Q_{i,k,\ell}\, f_{i,j,k,\ell}}{\bar{u}_i\{h\}\,\sigma'_{E;i,k}} \ln\left[\frac{\sigma'_{E;i,k}\,(r''+1) + h}{\sigma'_{E;i,k} + h}\right] V_{i,k,\ell}\right]$$

a. Input Requirements

Meteorological data: STAR type joint frequency distributions of meteorological conditions are utilized
Source data: See definition of Q above
Receptor data: Receptor loci are designated only in a polar coordinate system

b. Output

Same as SHORTZ

c. Model Options

Only seasonal average concentrations are output

d. - i. All items are the same as SHORTZ

j. Horizontal Dispersion

Homogeneous distribution of pollutants across sector is distributed

k - p. All items are the same as SHORTZ

q. Proposed EPA Action

LONGZ is recommended to be included in the Guideline on Air Quality Models for routine use to estimate long-term average concentrations in complex terrain comprised of urban or industrialized valleys, meeting the urban criteria of Section 5.5, provided default values built into the computer code are used for the technical options. Vertical temperature gradients should be specified according to Table 2-4 of the User's Instructions.

r. Model Availability

The two-volume user's guide and magnetic tape containing the SHORTZ and LONGZ computer programs are available from H. E. Cramer Company at a cost of $250.
Requests should be directed to the attention of:

Mr. Harry V. Geary
H. E. Cramer Company, Inc.
Post Office Box 8049
Salt Lake City, Utah 84108

3.0 Models Requiring a Demonstration of Equivalence

These models would not be recommended for general use. They would be identified in the Guideline on Air Quality Models, but would not be discussed in Appendix A -- Summaries of Recommended Air Quality Models.

Their use would be allowed if it could be demonstrated that they provide the same estimates as the recommended model for a specific application and they will subsequently be executed in that mode. They could also be used on a case-by-case basis with specific options not available in a recommended model if it could be demonstrated, using criteria in Section 6 of the Guideline, that they are more appropriate for a specific application.

3.1 MESOPLUME (Mesoscale Plume Segment Model)

Reference: Benkley, Carl W. and Arthur Bass. "Development of Mesoscale Air Quality Models: Volume 2. User's Guide to MESOPLUME (Mesoscale Plume Segment) Model." EPA-600/7-80-057. U. S. Environmental Protection Agency, Research Triangle Park, NC 27711.

Abstract : MESOPLUME is a mesoscale plume segment (or "bent plume") model designed to calculate concentrations of SO_2 and $SO_4^=$ over large distances. Plume growth is calculated by finite difference methods with plume growth parameters fitted to Turner's plume size (sigma) curves.

Equations:

$$\Delta Q = \left\{ \int_0^{\infty} \int_{-\infty}^{\infty} G(s,r,z)\, dr\, dz \right\} \Delta s \qquad \text{(A-1)}$$

$$+ \int_0^{\infty} \int_{-\infty}^{\infty} u\, C\, dr\, dz \Big|_{s+\Delta s} - \int_0^{\infty} \int_{-\infty}^{\infty} u\, C\, dr\, dz \Big|_{s}$$

where s, r, and z are the longitudinal, lateral, and vertical plume directions, $G(s,r,z)$ (g $m^{-3}s^{-1}$) is the rate of change (gain-loss) of pollutant concentration $C(s,r,z)$ (g m^{-3}) by conversion and removal processes, ΔQ (g s^{-1}) is the resultant rate of change of pollutant mass and u (m s^{-1}) is the wind speed. In the MESOPLUME model, $G(s,r,z)$ and u are considered to be constant from s to s + Δs, where s is the current distance of a plume segment endpoint from the emitting source, measured along the plume axis.

MESOPLUME permits the user to specify two possible vertical distribution functions; (1) a vertical Gaussian profile, ignoring any effects of the mixing lid H; or (2) a uniform vertical distribution below the mixing lid.

For Case 1, the ground-level axial plume concentration $C(s,r,0)$ is defined at the upwind edge of a plume segment by the expression:

$$C(s,r,0) = \frac{Q(s)}{\pi\, u\, \sigma_z(s)\, \sigma_y(s)} \exp\left[\frac{-r^2}{2\sigma_y^2}\right] \exp\left[\frac{-z^2}{2\sigma_z^2}\right] \qquad \text{(A-2)}$$

Plumes above mixing height are ignored
Plume rise is limited when u at stack height approaches or exceeds stack exit velocity
Does not simulate fumigation
Tilted plume used for pollutants with fall velocity specified
Buoyancy-induced dispersion (source-specific)

h. Horizontal Wind Field

Homogeneous and steady-state

i. Vertical Wind Field

Zero vertical velocity
Homogeneous in direction
Exponential law defines speed

j. Horizontal Dispersion

Semi-empirical Gaussian plume
Cramer dispersion coefficients

k. Vertical Dispersion

Semi-empirical Gaussian plume
Cramer dispersion coefficients

l. Chemistry/Reaction Mechanism

Exponential decay (based upon time)

m. Physical Removal

Gravitational settling velocity
Dry deposition
Exponential washout (based upon time)

n. Boundary Conditions

Perfect vertical reflection at the level of the effective mixing height for all pollutants
Perfect vertical reflection at ground level for pollutants with zero settling velocity
Zero vertical reflection at ground level for pollutants with finite settling velocity
Actual mixing height is constant above sea level; effective mixing height is constant above terrain

For Case 2, if the plume altitude (z) lies below the mixed lid H, the ground-level axial concentration is expressed at the upwind edge of the plume segment by the expression for uniform vertical mixing:

$$C(s,r,0) = \frac{Q(s)}{\sqrt{2\pi}\ u\ H_m\ \sigma_y(s)} \exp\left[\frac{-r^2}{2\sigma_y^2}\right] \qquad \text{(A-3)}$$

where H_m is the maximum mixing depth encountered by the plume segment (see Section A.8). If, rather, the plume centerline lies above the mixing lid, no ground-level concentrations are calculated. At the downwind edge (s+Δs) of the plume segment, the ground-level axial concentration (s+Δs,r,0) is expressed as:

$$C(s+ds,r,0) = \frac{\{Q(s)+(dQ/dt)\}\Delta t}{\sqrt{2\pi}\ u\ H_m\ \sigma_y(s+\Delta s)} \exp\left[\frac{-r^2}{2\sigma_y^2}\right] \qquad \text{(A-4)}$$

a. Input Requirements

Emission data: location (x and y coordinates), stack height, emission rate for SO_2, emission rate for $SO_4^=$, buoyancy flux for plume rise, multipliers, by hour of the day, for the emission rate and for the buoyancy flux; each for up to 10 sources
Meteorological data: Spatially variable, gridded fields of horizontal (u,v,) wind components, mixing height, and Pasquill stability class. These data are normally, though not necessarily, obtained from the output of the MESOPAC program (Volume 6, EPA 600/7-80-061). MESOPAC requires, as input, radiosonde observations from one or more stations, plus the wind components at the most relevant level.

b. Output

Options: Arrays of ground level concentrations of SO_2 and $SO_4^=$ for user-specified averaging times at user-specified intervals
Tables as above for specified receptors only
Arrays of maximum grid point concentration values for the period of the run
Maximum concentrations as above, but for specified receptors only
Table listing of the time when the first plume segment from each source reached the edge of the computational grid
The concentrations array may be output to disk for each time step

c. Model Options

Alternate plume growth coefficients
Up to 10 non-gridded receptors
Exponential decay of SO_2 to $SO_4^=$
Dry deposition
Uses 24-hour cycle of emission rate multipliers
Uses 24-hour cycle of buoyancy flux multipliers
Through the MESOFILE postprocessing program (Volume 5, EPA 600/7-80-060) line printer plots and calcomp plots are available
Presence of mixing lid

d. Limitations

Relatively flat terrain
Model is designed primarily for calculating regional scale impacts
Not applicable to area or line sources
Abrupt changes in wind flow over short distances can cause erroneous results in that vicinity

e. Pollutant Types

SO_2 and $SO_4^=$

f. Source-Receptor Relationship

Up to 10 point sources
Calculations made over a gridded network of receptors
Up to 10 arbitrary receptors are permitted

g. Plume Behavior

Briggs, with buoyancy flux, F, input to the model
Includes fumigation

h. Horizontal Wind Field

Derived gridded wind field specified for each grid square. MESOPAC derives the values by interpolation between stations and hours

i. Vertical Wind Speed

Assumed equal to zero

j. Horizontal Dispersion

Incremental plume growth over discrete time steps with plume growth parameters chosen to approximate Turner's σ_y curves
Plume growth is a function of stability class

k. Vertical Dispersion

Incremental plume growth over discrete time steps, with plume growth parameters chosen to approximate σ_z curves of Turner
Plume growth is a function of stability class

l. Chemistry/Reaction Mechanism

SO_2 to $SO_4^=$ conversion by means of half-life formula. Half-life is supplied by the user

m. Physical Removal

See item l. above

n. Boundary Conditions

Lower boundary: calculation of deposition is optional. Otherwise perfect reflection is assumed
Upper boundary: perfect reflection is assumed
Mixing height is input to the model as a function of time and grid location
Includes option to ignore upper boundary

o. Background

Not treated

p. Evaluation Studies

Sensitivity tests and evaluation studies are described in "Development of Mesoscale Air Quality Simulation Models. Volume 1: Comparative Studies of Puff, Plume, and Grid Models for Long Distance Dispersion". EPA 600/7-80-056.

q. Proposed EPA Action

MESOPLUME can be used for long range transport applications (beyond 50 km) if it can be demonstrated to give the same answers as the recommended model, MESOPUFF, and will be subsequently executed in that mode.

r. Model Availability

The MESO Models and accompanying user's guides and related studies are available from the National Technical Information Service. The models and related programs are on magnetic tape and the documentation is comprised of six volumes. The accession numbers and related costs are:

Magnetic tape:	PB 80-227 549	$720.00
Volume 1 :	PB 80-227 580	$ 13.00
Volume 2 :	PB 80-227 598	$ 10.00
Volume 3 :	PB 80-227 796	$ 9.00
Volume 4 :	PB 80-227 804	$ 9.00
Volume 5 :	PB 80-227 812	$ 7.00
Volume 6 :	PB 80-228 042	$ 7.00

Requests should be sent to:

National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

3.2 MULTIMAX

Reference: Moser, J. H. "MULTIMAX: An Air Dispersion Modeling Program for Multiple Sources, Receptors, and Concentration Averages." Shell Development Company, Westhollow Research Center, P. O. Box 1380, Houston, TX 77001, August 1979.

Abstract : MULTIMAX is a Gaussian plume model applicable to both urban and rural areas. It can be used to calculate highest and second-highest concentrations, for each of several averaging times due to up to 100 sources arbitrarily located.

Equations:

$$\chi = \frac{Q}{2\pi u\, \sigma_y\, \sigma_z}\, g_1\, g_3 \qquad \text{for } \sigma_z \leq 1.6L \qquad (1)$$

$$\chi = \frac{Q}{\sqrt{2\pi}\, uL\, \sigma_y}\, g_1 \qquad \text{for } \sigma_z > 1.6L \qquad (2)$$

L = mixing height (m)

H = (stack height + plume rise)-(difference in elevation between receptor and base of stack)

$$g_1 = \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$

$$g_3 = \sum_{n=-\infty}^{+\infty} \exp\left\{\left[-\frac{1}{2}\,\frac{2nL-H}{\sigma_z}^2\right] + \exp\left[-\frac{1}{2}\,\frac{2nL+H}{\sigma_z}^2\right]\right\}$$

a. Input Requirements

Emissions data: emission rate, physical stack height, stack gas exit velocity, stack inside diameter, stack gas temperature
Meteorological data:* hourly surface weather data including ceiling, wind direction, wind speed, temperature, opaque cloud cover. Daily mixing height is also required.

b. Output

Highest and second-highest concentrations for the year at each receptor for averaging times of 1, 3, and 24 hours
Annual arithmetic average at each receptor
Input and results saved on mass-storage

c. Model Options

Sampling time correction
Calibration
Choice of 3 terrain options or no terrain
Wind speed adjustment with height
Source contriibution
Specify receptors individually, define as circle or arc, or define as a line

d. Limitations

Not applicable to area and line sources
Use care when applying to low-level sources

e. Pollutant Types

Treats a single inert pollutant

f. Source-Receptor Relationship

Up to 100 point sources, no area sources
Point sources at arbitrary location
Unique stack height for each source
Unique topographic elevation for each receptor; must be below top of stack
Receptors can be described individually as lines or as arcs

---

*These data are input into a preprocessor program which prepares the data for input to the model. The same preprocessor program is used for CRSTER, RAM, MPTER, and ISC.

g. Plume Behavior

Briggs final plume rise formulae
Does not treat fumigation or downwash
If plume height exceeds mixing height, concentrations further downwind assumed equal to zero

h. Horizontal Wind Field

Uses user-supplied hourly wind speeds
Uses user-supplied hourly wind directions (nearest 10 degrees), internally modified by addition of a random integer value between -4 degrees and +5 degrees
Wind speeds corrected for release height based on power law variation exponents from DeMarrais, different exponents for different stability classes, reference height = 10 meters
Constant, uniform (steady-state) wind assumed within each hour

i. Vertical Wind Speed

Assumed equal to zero

j. Horizontal Dispersion

Semi-empirical/Gaussian plume
Six stability classes used; Turner Class 7 treated as Class 6
Dispersion coefficients from Turner; no further adjustments made for variations in surface roughness, transport
Averaging time adjustment optional

k. Vertical Dispersion

Semi-empirical/Gaussian plume
Six stability classes used; Turner Class 7 treated as Class 6
Dispersion coefficients from Turner; no further adjustments made for variations in surface roughness or transport

l. Chemistry/Reaction Mechanism

Not treated

m. Physical Removal

Not treated

n. Boundary Conditions

Lower boundary: perfect reflection at the same height as the receptor
Upper boundary: perfect reflection
Multiple reflections handled by summation of series until σ_z = 1.6 x mixing height
Uniform vertical distribution thereafter
Mixing height is constant and follows topographic variations;
Taken from base of stack for determining whether plume punches through
Taken from receptor elevation for determining vertical concentration distribution
Mixing height for a given hour is obtained by suitable interpolation using data from soundings taken twice a day. Interpolation technique dependent on mode of operation (urban or rural) and calculated stability class for the hour in question as well as the stability class for the hour just preceding sunrise

o. Background

Not treated

p. Evaluation Studies

With appropriate selection of options, can be made equivalent to CRSTER; therefore model evaluation studies for CRSTER apply

q. Proposed EPA Action

MULTIMAX can be used if it can be demonstrated to give the same estimates as the recommended model for the same application and will subsequently be executed in that mode.
MULTIMAX can also be used on a case-by-case basis with specific options not available in the recommended model if it can be demonstrated, using criteria in Section 6, to be reliable and applicable to the site and site source.

r. Model Availability

MULTIMAX: An Air Dispersion Modeling Program for Multiple Sources, Receptors, and Concentration Averages. PB 80-170-178, $12.50.
Computer tape for MULTIMAX: PB-80-170-160, $300.00.
Requests should be sent to:

National Technical Information Service
U. S. Department of Commerce
5825 Port Royal Road
Springfield, VA 22161

3.3 MPSDM (MULTIPLE POINT SOURCE DIFFUSION MODEL)

Reference: Environmental Research and Technology, Inc., User's Guide to MPSDM. ERT Document No. M-186-001-630. Environmental Research and Technology, Inc., Concord, MA. August 1980.

Abstract : MPSDM is a steady-state, univariate/bivariate, empirical, Gaussian model for calculating sequential/case-by-case concentrations of one/two case-by-case concentrations of one/two inert pollutants per run at user specified receptors in simple/complex terrain as a result of multiple point sources.

Equations:

$$\chi(0,0,z) = \frac{q(x, -y, H)}{2\pi\, \sigma_y \sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$

$$\left\{\exp\left[-\frac{1}{2}\left(\frac{z - H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z + H}{\sigma_z}\right)^2\right]\right\} \quad (1)$$

where

(x,y,z) are the (upwind, cross-wind, and vertical) components of a Cartesian Coordinate System, such that the receptor point is located at or vertically above the origin (expressed in units of length) and the source is at the point (x, -y, H);

$\chi(0,0,z)$ is the pollutant concentration at receptor location $(0,0,z)$ (mass/length^3);

H is the effective height (stack height plus plume rise) of emission, that is, the centerline height of the plume (length);

q is the source strength (mass/time); and

σ_y, σ_z are dispersion coefficients that are measures of cross-wind and vertical plume spread. These two parameters are functions of downwind distance (length) and atmospheric stability.

Hourly ground-level pollutant concentrations for unlimited mixing conditions can be obtained by setting z = 0 in Equation 1. The resulting equation is:

$$\chi(0,0,0) = \frac{q}{\pi \sigma_y \sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \cdot \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \quad (2)$$

An error function routine is used to calculate concentrations at centerline or off centerline of the user-specified plume width (i.e., sector-averaged concentrations).

a. Input Requirements

Emissions data: Hourly or constant emission rate, stack gas temperature and exit velocity.
Meteorological data: Hourly wind speed, wind direction, air temperature and mixing height; and vertical temeprature difference or stability class.
Air quality data: Observed concentrations at any monitor for any or all hours (case-by-case mode only) will be compared with estimates, or (sequential mode only) will be used to determine background levels.

b. Output

MPSDM produced hourly-averaged concentrations for the sequential mode of operation. A post-processing program, ANALYSIS, is used to produce averages for longer periods. The case-by-case mode produces statistics on each case, and a summary of all cases run together.

c. Model Options

Stacktip downwash
User-specified plume (sector) width and/or stability categories
Flat or complex terrain
Case-by-case or sequential analysis
Buoyancy-induced dispersion
Background levels from input monitoring data
Choice of dispersion parameters
Hourly or constant source data
Univariate or bivariate Gaussian distribution of pollutants in plume

d. Limitations

Stable pollutants only
No lower limit on distance for fumigation
Maximum of 15 km downwind distance

e. Pollutant Types

One or two inert pollutants

f. Source-Receptor Relationship

Arbitrary locations for sources and receptors
Actual terrain elevations may be specified and accounted for by plume-height adjustments
Actual separation between each source/receptor pair used
Receptors at ground level

g. Plume Behavior

Briggs plume rise formulas, including that for partial (or total) penetration of plume into elevated inversion
Stack-tip downwash
Fumigation
Total reflection at the mixing height of pollutant above or below top of mixing layer, and at ground level
Stack-tip downwash
A buoyancy-induced dispersion algorithm is optional

h. Horizontal Wind Field

User-supplied hourly wind speed and direction specify horizontally homogeneous, steady-state conditions
Wind speeds vary with height according to user-designated profiles for each stability
Specifiable in whole degrees from 1 degree to 360 degrees

i. Vertical Wind Field

Implied vertical velocities exist at tops of stacks and over rough terrain when the algorithms for downwash and plume-height adjustment are respectively invoked by the model; otherwise, implied value is zero

j. Horizontal Dispersion

Optionally uses input Gaussian diffusion coefficients or input angular horizontal plume width
Hourly stability (five classes -- very unstable through slightly stable) internally from input vertical temperature gradient and mean wind speed

k. Vertical Dispersion

Same as (j), except angular spread is not specifiable and not used

l. Chemistry/Reaction Mechanism

None

m. Physical Removal

None

n. Boundary Conditions

Ground is optionally a perfect reflector
No upper boundary

o. Background

Background concentrations are estimated internally, using input observed concentrations

p. Evaluation Studies

Two studies are available in the literature. The model was independently fit to the observed data in each case.

q. Proposed EPA Action

MPSDM can be used if it can be demonstrated to give the same estimates as a recommended model for the same application and will subsequently be executed in that mode.
MPSDM can be used on a case-by-case basis with specific options not available in the recommended model if it can be demonstrated, using the criteria in Section 6, to be reliable and applicable to the site and source.

r. Model Availability

Anyone wishing to review the MPSDM model should contact Environmental Research & Technology, Inc. At present no cost has been identified for the user's manual or the model.
Requests should be directed to:

Mr. Joseph A. Curreri
Air Quality Center
3 Militia Drive
Lexington, Massachusetts 01743

3.4 SCSTER (Multi-Source Model)

Reference: Program Documentation for Multi-Source SCSTER Model EN7408SS, Southern Company Services, Inc., Technical Engineering Systems, 64 Perimeter Center East, Atlanta, GA 30346.

Abstract : SCSTER is a modified version of the EPA CRSTER model. The primary distinctions of SCSTER are its capability to consider multiple sources that are not necessarily collocated, its enhanced receptor specifications, its variable plume height terrain adjustment procedures and plume distortion from directional wind shear.

Equations:

$$x = \frac{Q}{2\pi u\, \sigma_y\, \sigma_z}\, g_1\, g_3 \qquad \text{for } \sigma_z \leq 1.6L \qquad (1)$$

$$x = \frac{Q}{\sqrt{2\pi}\, uL\, \sigma_y}\, g_1 \qquad \text{for } \sigma_z > 1.6L \qquad (2)$$

L = mixing height (m)

H = (stack height + plume rise)-(difference in elevation between receptor and base of stack)

$$g_1 = \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$

$$g_3 = \sum_{n=-\infty}^{+\infty} \exp\left\{\left[-\frac{1}{2}\left(\frac{2nL-H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{2nL+H}{\sigma_z}\right)^2\right]\right\}$$

a. Input Requirements

Emissions data: emission rate, stack gas exit velocity, stack gas temperature, stack exit diameter , physical stack height, elevation of stack base, coordinates of stack location. The variable emission data can be monthly or annual averages
Meteorological data: hourly surface weather data including cloud ceiling, opaque cloud cover, wind direction, wind speed and temperature. A daily mixing height is required.

b. Output

Tables are given for each averaging time and the highest 50 concentrations or source contribution of individual point sources at up to 20 receptor locations for each averaging period.
Listing of daily maximum 1-hour and 24-hour concentrations
An option provides for a magnetic tape of all 1-hour concentrations
Tables of both highest and second-highest concentrations

c. Model Options

Four different terrain adjustment methods; variable averaging times, monthly emission data, half-life application, transitional plume rise, actual anemometer height, wind shear, wind profile, plume boundary indicator

d. Limitations

Not applicable to area or line sources

e. Pollutant Types

Treats a single pollutant

f. Source-Receptor Relationship

Can handle up to 60 separate stacks at varying locations and 15 receptor rings
Provides four terrain adjustments including the CRSTER full terrain height adjustment and a half-height for receptors above stack height

g. Plume Behavior

Briggs final plume rise formulae
Contains options to incorporate wind shear with a method developed by Maddukuri and Slawson
Applies a half-height correction in complex terrain
Provides for transitional plume rise at receptors close to source

h. Horizontal Wind Field

User-supplied hourly wind speeds
User-supplied hourly wind directions internally modified by addition of a random integer value between -4 and +5 degrees
Wind speeds corrected for release height based on power law variation exponents from DeMarrais, different exponents for different stability classes; reference height of 7 m
Steady-state wind assumed within each hour

i. Vertical Wind Speed

Assumed equal to zero

j. Horizontal Dispersion

Semi-empirical Gaussian plume
Uses 6 stability classes, Turner class 7 is treated as class 6
Pasquill-Gifford dispersion coefficients

k. Vertical Dispersion

Semi-empirical/Gaussian plume
Six stability classes used, Turner class 7 treated as Class 6
Pasquill-Gifford dispersion coefficients

l. Chemistry/Reaction Mechanism

Allows user input half-life

m. Physical Removal

Not treated

n. Boundary Conditions

Lower boundary: perfect reflection at the same height as the receptor
Upper boundary: perfect reflection
Multiple reflections handled by summation of series until σ_z = 1.6 x mixing height
Uniform vertical distribution thereafter

o. Background

Not treated

p. Evaluation Studies

See CRSTER discussion
Evaluation of certain individual options provided in user's manual
No evaluation studies of SCSTER provided

q. Proposed EPA Action

SCSTER can be used if it can be demonstrated to give the same estimates as a recommended model for the same application and will subsequently be executed in that mode.
SCSTER can be used on a case-by-case basis with specific options not available in a recommended model if it can be demonstrated, using criteria in Section 6, to be reliable and applicable to the site and source.

r. Model Availability

The SCSTER model and user's manual are available at no charge to a limited number of persons through Southern Company Services. A magnetic tape must be provided for those desiring the model. Requests should be directed to:

Mr. Bryan Baldwin
Research Specialist
Southern Company Services
Post Office Box 2625

3.5 TCM (TEXAS CLIMATOLOGICAL MODEL)

Reference: Staff of the Texas Air Control Board, Users' Guide to the TEXAS CLIMATOLOGICAL MODEL (TCM). Texas Air Control Board, Permits Section, 6330 Highway 290 East, Austin, TX 78723

Abstract : TCM is a climatological steady-state Gaussian plume model for determining long-term (seasonal or annual arithmetic) average pollutant concentrations of non-reactive pollutants.

Equations:

$$C_a(k,\rho) = \frac{32 \times 10^6 \, Q}{(2\pi)^{3/2}\rho} \left\{ \frac{\Phi(k,m)}{U^*(H,m)\,\sigma_z(m)} \exp\left[\frac{H^2}{-2\sigma_z(m)2}\right] \right\} \quad (1)$$

where

Q is the source emission rate, grams per second

ρ is the distance from the stack to the receptor, meters

$\Phi(k,m)$ is the meteorological joint frequency function

k is the index of wind direction sector which contains the vector from the source to the point considered

m is the index for the atmospheric stability class

$U^*(H,m)$ is the weighted averaged wind speed for stability class m at stack height H, meters per second

$\sigma z(m)$ is the standard deviation of the concentration distribution in the vertical direction, meters

H is the effective stack height, which is the sum of stack height and plume rise, meters

The vertical standard deviation function may be approximated by a power curve as follows: $\sigma_z = a(m)\,\rho^{b(m)}$

The equation for the pollutant concentration in the center of the square containing the area source is

$$\chi = \sqrt{\frac{2}{\pi}} \frac{Q\,(\Delta x/2)^{1-b(m)}}{U^*(m)a(m)\,[1-b(m)]}\ \Phi(k,m) \qquad (2)$$

where

$U^*(m)$ is the weighted average wind speed (measured at a height of 10 meters) for stability class m, meters/second

Δx is the receptor (calculation) grid spacing, meters

$a(m)$ and $b(m)$ are functions of atmospheric stability class m. Values used in this calculation were determined by Gifford and Hanna.

Q is the area source emission rate, gm/km^2-sec.

$\Phi(k,m)$ is the meteorological joint frequency function

k is the wind sector index

The pollutant concentration in the i th (i=1, 2, 3, 4) square from the area source is:

$$\chi = \sqrt{\frac{2}{\pi}} \frac{Q\,(\Delta x/2)^{1-b(m)}}{U^*(m)\,a(m)[1-b(m)]}\ [(2i+1)^{1-b(m)} - (2i-1)^{1-b(m)}]\ \Phi(k,m) \qquad (3)$$

The weighted average wind speed, U^*_m, for stability class m is defined as:

$$U^*_m = \frac{\sum_{k=1}^{16} \sum_{\ell=1}^{6} \Phi(k,\ell,m)}{\sum_{k=1}^{16} \sum_{\ell=1}^{6} \frac{\Phi(k,\ell,m)}{U_\ell}} \qquad (4)$$

Where:

$\Phi(k,\ell,m)$	is the meteorological joint frequency function
k	is the wind sector index
ℓ	is the wind speed class index
m	is the atmospheric stability class index
U_ℓ	is the central wind speed for wind speed class

a. Input Requirements

Meteorological data: stability wind rose and average temperature
Source data: point source coordinates emission rates (by pollutant), stack height, stack diameter, stack gas exit velocity, stack gas temeprature; area source coordinates (southwest corner), size, emission rate.
Air quality data: needed only for use of the calibration option

b. Output

Period average concentrations listed, displayed in map format, or punched on cards at the user's option
Culpability list option provides the contributions of the five highest contributors at each receptor
Maximum concentration option provides the maximum concentration for each scenario(run)

c. Model Options

Source culpability list
Exponential decay
Calibration
Urban or rural mode
Transitional plume rise

d. Limitations

Stationary point and area source with point source predominant
Flat, uncomplicated terrain
Steady state meteorology

e. Pollutant Types

Treats up to two inert pollutants

f. Source-Receptor Relationship

Arbitrary location of point sources and area sources
Arbitrary location and spacing of rectangular grid of receptors
(Area source grid is best defined in terms of the receptor grid, so that the receptors fall in the center of the area source)

g. Plume Behavior

Briggs' plume rise equations used for point sources
Momentum rise included
Two-thirds power law used when transitional rise (rising state) option is selected
Treats flares

h. Horizontal Wind Field

Characteristic wind speed is calculated for each direction-stability class combination
This characteristic speed is the inverse of the average inverse speed for the stability-wind direction combination
Wind speed is adjusted to stack height by a power law as in CDM

i. Vertical Wind Speed

Assumed zero

j. Horizontal Dispersion

Climatological approach, i.e., narrow plume assumption
Uniform distribution within each 22.5 degree sector

k. Vertical Dispersion

Gaussian plume as defined by Turner, with fit as used in CDM
Seven stability classes used
Pasquill "A" through "F" with daytime "D" and nighttime"D" given separately

l. Chemistry/Reaction Mechanism

Exponential decay, user input half-life

m. Physical Removal

Exponential decay only

n. Boundary Conditions

Lower boundary (ground): perfect reflection
Upper boundary (top of mixing layer): no effect

o. Background

Not explicit, but can by input as the "zeroth order" term in the calibration coefficient

p. Evaluation Studies

Studies underway

q. Proposed EPA Action

TCM can be used if it can be demonstrated to give the same estimates as a recommended model for the same application and will subsequently be executed in that mode.
TCM can be used on a case-by-case basis with specific options not available in the recommended model if it can be demonstrated, using criteria in Section 6, to be reliable and applicable to the site and source.

r. Model Availability

The TEM and TCM models are available from the Texas Air Control Board at a cost of $20.00 each for the user's manual and $80.00 each for the user's manual/model package.
Requests should be directed to:

Data Processing Division
Texas Air Control Board
6330 Highway 290 East
Austin, Texas 78723

3.6 TEM (TEXAS EPISODIC MODEL)

Reference: Staff of the Texas Air Control Board. User's Guide to the TEXAS EPISODIC MODEL. Texas Air Control Board, Permits Section, 6330 Highway 290 East, Austin, Texas 78723.

Abstract : TEM is a short-term, steady-state Gaussian plume model for determining short-term concentrations of non-reactive pollutants.

Equations: The ground level concentration χ (in micrograms per cubic meter) at the point (x,y) may be written as

$$\chi(x,y,0,H) = \frac{Q\ 10^6}{\pi\sigma_y\sigma_z\ U}\ \exp\left[-\tfrac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\ \exp\left[-\tfrac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right]$$

where:

Q is the source emission rate, grams per second
U is the average wind speed at stack height, meters per second
σ_y, σ_z are the standard deviations of the concentration distributions in the crosswind and vertical directions respectively, meters
H is the effective stack height, which is the sum of stack height and plume rise, meters
x is the distance downwind from the stack, meters
y is the crosswind distance from the plume centerline, meters
z is the vertical distance from ground level, meters

The equation for the pollutant concentration in the center of the square containing the area source is

$$\chi = \sqrt{\frac{2}{\pi}}\ \frac{Q\ (\Delta x/2)^{1-b(S)}}{U_0\ a(S)\ [1-b(S)]}$$

The pollutant concentration in the ith (i=1,2,3,4) square downwind of the area source is:

$$\chi = \sqrt{\frac{2}{\pi}} \frac{Q\ (\Delta x/2)^{1-b(S)}}{U_o\ a(S)[1-b(S)]} \left[(2i+1)^{1-b(S)} - (2i-1)^{1-b(S)}\right]$$

U_o is the surface wind speed (measured at a height of 10 meters) in meters/second

Δx is the receptor (calculation) grid spacing in meters

$a(S)$ and $b(S)$ are functions of atmospheric stability Class S. Values used in this calculation were determined by Gifford and Hanna.

Q is the area source emission rate in $gm/km^2/sec$.

a. Input Requirements

Meteorological data: one to 24 scenarios (usually, but not necessarily one hour each) of stability class, wind speed (or wind speed class), wind direction (or wind direction sector), ambient temperature, pollutant half-life, inversion penetration factor, and mixing height

Emissions data: locations, average emission rates and heights of emissions for both point and area sources; stack gas temperature, stack gas exit velocity, and stack inside diameter for point sources for plume rise calculations

b. Output

The user may specify any one or any combination of six output options:

(1) concentration list
(2) "spatial array (concentrations displayed as on a map)
(3) punched cards of the concentration list
(4) culpability list (percent contributions of the five highest contributors to each receptor
(5) maximum concentration, and
(6) point source list

c. Model Options

Source culpability list
Exponential decay
Averaging time adjustment to σ_y
Stack tip downwash
Treatment of flares
Automatic receptor grid selection

d. Limitations

Steady-state assumption
Flat terrain
Non-reactive pollutants
Area source emissions should be relatively small, not vary greatly between adjacent sources, and the size of the area source should be at least as large as the spacing between receptors if possible

e. Pollutant Types

Treats one or two non-reactive pollutants simultaneously

f. Source-Receptor Relationship

Arbitrary locations of point sources and area sources
Arbitrary location and spacing of rectangular grid of receptors
(Area source grid is best defined in terms of the receptor grid so that the receptors fall in the centers of the area sources

g. Plume Behavior

Briggs plume rise equations, including momentum rise, for point sources
Transitional rise is calculated
Does not treat plume rise for area sources
Does not treat fumigation of building downwash

h. Horizontal Wind Field

User-supplied wind speed and direction
Wind speeds adjusted to release height by power law formula
Steady-state wind assumed

i. Vertical Wind Speed

Assumed equal to zero

j. Horizontal Dispersion

Gaussian plume coefficients fitted to Turner

k. Vertical Dispersion

Gaussian plume coefficients fitted to Turner

l. Chemistry/Reaction Mechanism

Exponential decay only, user input half-life

m. Physical Removal

Exponential decay only, user-input half life

n. Boundary Conditions

Lower boundary: perfect reflection
Upper boundary; perfect reflection
For distances up to the distance x_m where σ_z = 0.47L (where L = mixing height), upper boundary reflection is ignored. Beyond $2x_m$, the plume is assumed to be well-mixed vertically through the mixing layer. Concentrations between x_m and $2x_m$ are found by linear interpolation of the vertical term in the diffusion equation

o. Background

Not considered

p. Evaluation Studies

Studies are available from the Texas Air Control Board

q. Proposed EPA Action

TEM can be used if it can be demonstrated to give the same estimates as a recommended model for the same application and will subsequently be executed in that mode.
TEM can be used on a case-by-case basis with specific options not available in the recommended model if it can be demonstrated, using criteria in Section 6, to be reliable and applicable to the site and source.

r. Model Availability

The TEM and TCM models are available from the Texas Air Control Board at a cost of $20.00 each for the user's manual and $80.00 each for the user's manual/model package.
Requests should be directed to:

Data Processing Division
Texas Air Control Board
6330 Highway 290 East
Austin, Texas 78723

4.0 Models Requiring a Case-By-Case Demonstration

These models would not be recommended for general use. However, their use would be allowed on a case-by-case basis if it could be demonstrated, using criteria in Section 6 of the Guideline, that they are more reliable than a recommended model for a specific application or they are applicable and reliable for a specific application for which there is no recommended model.

4.1 ERTAQ (ERT AIR QUALITY MODEL)

Reference: Environmental Research and Technology, Inc., ERTAQ User's Guide. ERT Document No. M-0186-0015. Environmental Research and Technology, Inc., Concord, MA. August 1980.

Abstract : ERTAQ is a multiple point, line and area source dispersion model which utilizes the univariate Gaussian formula for multiple reflections. Pollutant deposition and reentrainment are accountable. Offers an urban/rural option. Calculates long-term or worst-case concentrations due to arbitrarily located sources for arbitrarily located receptors above or at ground level. Background concentrations and calibration factors at each receptor can be user specified.

Equations: ERTAQ calculates hourly pollution concentrations according to the specific formula:

$$\chi(x,y,z) = \frac{Q}{u}\ hdf(x,y)\quad vdf(x,z,H)\quad df(x,u,T) \qquad (1)$$

where

- χ is the hourly average concentration ($\mu g/m^3$)
- x is the upwind distance (m) from receptor to source
- y is the crosswind distance (m) from receptor to plume centerline
- z is the height (m) of receptor above ground
- u is the average wind speed (m/sec)
- Q is the source strength (gm/sec), assumed constant
- H is the effective height (m) of source emissions
- T is the decay half-life (sec)
- hdf is a horizontal distribution function
- vdf is a vertical distribution function
- df is a decay function.

For point, line, and area sources there are two horizontal distributions. They are both defined as functions of c, the half-width of the appropriate sector at distance x downwind of the source.

$$c = x \tan \frac{\theta}{2}$$

where

- c is the half-width of sector (m)
- x is the downwind distance (m)
- θ is 22.5 degrees for uniform distribution, or 45 degrees for triangular distribution.

The default distribution is a uniform 22.5 degree distribution function. It is defined by the formula:

$$hdf(x,y) = \begin{cases} \frac{1}{2c} & |y| \leq c \\ 0 & |y| > c \end{cases}$$

where

c is 0.1989x.

The alternate distribution is a 45 degree triangular distribution. It is defined by the formula:

$$hdf(x,y) = \begin{cases} \frac{1}{c^2}\ (c - y) & |y| \leq c \\ 0 & |y| > c \end{cases}$$

where

c is 0.4142x.

The vertical distribution function used by ERTAQ is the well-known Gaussian distribution, adjusted to include perfect reflection off the ground surface at z = 0 and the mixing lid. The precise distribution is:

$$vdf(x,z,H) = \frac{1}{\sqrt{2\pi}\sigma_z} \sum_{j=-\infty}^{\infty} \left\{ e^{-\frac{1}{2}\left(\frac{(z+H - 2jD)}{\sigma_z}\right)^2} + e^{-\frac{1}{2}\left(\frac{(z-H - 2jD)}{\sigma_z}\right)^2} \right\}$$

where

D is the height (m) of mixing lid
σ_z is the vertical dispersion coefficient (m)
j is the summation index.

The vertical dispersion σ_z is calculated by the formula:

$$\sigma_z = ax^b + c + d.$$

a, b, and c are user-specified regression constants which define σ_z as a function of x. Default values result in Pasquill-Gifford σ_z. d represents an initial vertical mixing dimension for urban environments.

For pollutants with a half-life, T, of less than 100 hours, ERTAQ accounts for decay by multiplying the concentration by the factor:

$$df = 2^{-x/uT}$$

where

x is the effective downwind distance (m) from source to receptor
u is the mean wind speed (m/s)
T is the half-life of pollutant (seconds).

The effective downwind distance is equal to the actual downwind distance for point sources, the average downwind distance for line sources, and the weighted average downwind distance for area sources. For area sources, the average is weighted by the crosswind width of the area at the downwind distances which are evaluated.

When concentrations are calculated by ERTAQ to include deposition, the hourly concentration equation becomes:

$$\chi(x,y,z) = \sum_{i=1}^{NPTSZ} \frac{Q_{effi(x)}}{u} \; hdf(x,y) \; vdf(x,z,H) \qquad (2)$$

where

Q_{effi} is the effective emission rate (gm/sec) of particle size class i

NPTSZ is the number of particle size classes (up to 5)

The deposition function is used to account for gravitational settling and fallout of suspended particles. ERTAQ handles deposition by considering the total particulate emissions as being made up of five particle-size classes. Each particle size settles at a different rate, v_d, and therefore the distribution of particle sizes in the plume changes as distance from the source increases.

$$Q_{eff} = Q_o \, e^{-ax^b v_d/u}$$

where

Q_{eff} is the effective emission rate (gm/sec) at distance x downwind

Q_o is the actual emission rate (gm/sec) at the source

a,b are coefficients as functions of stability

x is the downwind distance (m)

v_d is the deposition velocity (cm/sec)

u is the wind speed (m/s).

In cases of emissions resulting from wind erosion, the emission rate can be defined as:

$$Q_o = q_o \, u^{WSFAC}$$

where Q_o is the actual emission rate (gm/sec)

q_o is the emission factor

WSFAC is the exponent of wind speed

= 1 for linear dependence on wind speed

= 2 for quadratic dependence on wind speed.

a. Input Requirements

Emissions data: Up to six pollutants may be specified, citing quantity and calibration factor for each (and particle size, if appropriate). Heat rate and height of emission per source for determining plume height.
Meteorological data: STAR-type, plus ambient air temperature and mixing height
Air Quality Data: Observed concentration may be input as factor in calculating background and for calibrating results.

b. Output

Mean concentrations at designated receptors for long-term mode. In worst-case mode, concentrations for user-specified meteorological conditions.

c. Model Options

Urban/rural
Long-term/worst-case
Nonreactive/first-order pollutant loss
Perfect reflection/deposition
Calibration Background concentration
Reentrainment from ground
Horizontal pollutant distribution either 22.5 (randomly distributed) or 45 degrees (triangularly distributed)
Logarithmic wind profile coefficients

d. Limitations

Simple topography and organized flow
Deposition algorithm appropriate only for near-ground sources

e. Pollutant Types

Up to six pollutants (simultaneously) and up to five size categories for particles

f. Source-Receptor Relationship

Up to 501 arbitrarily located point, area and line sources, and up to 128 arbitrarily located receptors
Arbitrary release heights for all sources
Simple terrain relief
Receptors at or above ground level

g. Plume Behavior

Plume rise is calculable for point and area sources
Briggs (1975) plume rise formulae (final rise only)
Briggs calm formula used when $\bar{u} < 1.37$ m/s
Does not treat fumigation or downwash
Top of mixed layer is perfect reflector (full or no plume penetration)
Ground surface is total or fractional reflector
No buoyancy-induced dispersion

h. Horizontal Wind Field

Climatological approach (steady state and homogeneous)
16 wind directions, 6 speed classes
Logarithmic vertical profile extrapolates observed wind to release height for plume rise and to plume height for downwind dilution (same exponents as ISC)

i. Vertical Wind Speed

Assumed to be zero

j. Horizontal Dispersion

Uniform distribution in 22.5 degree sector, or triangular distribution in 45 degree sector (user specified)
Independent of stability

k. Vertical Dispersion

Semi-empirical/Gaussian plume
Five stability categories (converts all stable to slightly stable category)
Pasquill-Gifford coefficients from Turner
Urban categories shifted one class toward unstable

l. Chemistry/Reaction Mechanism

Exponential decay (temporal)

m. Physical Removal

Particle deposition on ground accountable at user's option

n. Boundary Conditions

See g. Plume Behavior

o. Background

Calculate background for each pollutant for each receptor

p. Evaluation Studies

No field evaluation submitted
Two formal model comparisons are included in the ERTAQ User's Guide (comparisons made with CDM and PAL).

q. Proposed EPA Action

ERTAQ can be used on a case-by-case basis if it can be demonstrated, using the criteria in Section 6, that the model is reliable and applicable to the site and source.

r. Model Availability

Anyone wishing to review the ERTAQ model should contact Environmental Research & Technology, Inc. At present no cost has been identified for the user's manuals or the model.
Requests should be directed to:

Mr. Joseph A. Curreri
Air Quality Center
3 Militia Drive
Lexington, Massachusetts 01743

4.2 RTDM.WC (ROUGH TERRAIN DISPERSION MODEL:WORST CASE)

Reference: Environmental Research and Technology, Inc., User's Guide for RTDM.WC. ERT Report No. M-0186-000R. Environmental Research and Technology, Inc., Concord, MA. August 1980.

Abstract : RTDM.WC is a dispersion model specifically designed for estimating worst-case concentrations in areas where terrain elevations exceed stack top. The model uses a steady state, empirical Gaussian formulation; the expression for univariate Gaussian distribution (user specifies angle of sector) is used for stable atmospheres, and univariate or bivariate for nonstable. The model steps through a series of user specified meteorological conditions, calculating and outputting a concentration for each case for each receptor. The user then scans the output for the worst-case situation. A maximum of 35 receptors is assigned to each of 16 radials from a common point at which a maximum of ten point sources of different heights can be assigned.

Equations:

$$\chi = \text{MIN}\left\{ \frac{QR}{\sqrt{2\pi}\,\sigma_z\,SWu} , \frac{2Q}{\sqrt{2\pi}\,\sigma_z SWu}\ \text{EXP}\left[-\frac{1}{2}\left(\frac{H_a}{\sigma_z}\right)^2 \right] \right\}$$

where for designated univariate pollutant distributions

$$SW = 2x\cdot\tan(\phi/2)$$

and where for nonstable conditions with the optional bivariate pollutant distribution and using just the second expression in the brackets of the general formula above,

$$SW = 2\sqrt{2\pi}\,\sigma_y,$$

which provides centerline concentrations. Variables are defined as follows:

χ is 1-hour average concentration, $\mu g/m^3$

Q is pollutant emission rate, g/s

R is reflection factor,

H_a is the adjusted height above the local terrain, m

u is wind speed at plume height, m/s

σ_z is the dispersion rate that is a measure of the vertical plume spread, m

SW is sector width,

x is downwind distance of receptor, m

ϕ is the angular dimension of the sector (e.g., 45°), and

σ_y is the crosswind dispersion coefficient, m.

a. Input Requirements

Emissions data: physical stack height, stack inner radius, stack-gas temperature and exit velocity, and pollutant emission rate; a single ground elevation can be entered for the mandatorily colocated sources
Meteorological data: Range of atmospheric stability classes (maximum of six); range of wind directions (maximum of 16); range of wind speed classes (maximum of 6); wind speed for each speed class; mean ambient temperature; angular plume width for stable (optional for nonstable)
Air quality data: not applicable
Receptors: downwind distances; terrain elevations

b. Output

A concentration is output for any receptor(s) so designated for each of up to 6•6•16 = 576 meteorological conditions. The user sorts through these for maximum hourly concentration.

c. Model Options

Fraction of material available in stable plumes for total reflection from ground
Number of meteorological situations
Dispersion coefficients
Individual and/or total source contributions
Output type
Meteorological persistence factor for model-calculated 1-hour, 3-hour or 24-hour average concentrations
Stack-tip downwash

d. Limitations

Only for buoyant plumes
Elevated point sources only, collocated (or nearly so)
No building downwash
Treats nonreactive gases only
Significant separation of real sources can cause large errors in concentrations estimated

e. Pollutant Types

One nonreactive gaseous pollutant per analysis

f. Source-Receptor Relationship

All sources are co-located at the center of a single polar receptor grid; all receptors are located on radials emanating from source; 16 radials are possible, located directly downwind of sources for each allowable wind direction; ground elevation is required for the source and receptor locations; actual source-to-receptor distances are used; receptors are always at ground level and always at centerline of plume when impacted by the plume

g. Plume Behavior

"Half-height" correction imposed by model for nonstable cases in complex terrain; user controls correction for stable cases (from no correction to full impingement)
Briggs' (1975) formulae used; calm formula for wind speeds < 1.37 m/s
Plume path coefficient (user specified) determines portion of plume available for reflection from elevated terrain
No fumigation or building downwash
Stack-tip downwash available
Unlimited mixing height assumed

h. Horizontal Wind Field

Steady state and homogeneous for each of six wind speeds, six stabilities and 16 directions. Speed varies in vertical according to user-designated power-law relationship

i. Vertical Wind Field

Mathematically zero; an implied vertical velocity is utilized for plumes moving more or less parallel to slopes

j. Horizontal Dispersion

During stable, utilizes sector averaged concentration (angular width specified by user)
During nonstable, utilizes user-specified Gaussian, stability-dependent dispersion coefficients or user-specified constant angular sector width. Stabilities from very unstable to moderately stable are possible and are user specified

k. Vertical Dispersion

Gaussian stability-dependent dispersion coefficients are user-specified for very unstable through neutral stability classes
The dispersion coefficients for neutral are substituted by the model for user-designated stable cases
Stack-tip downwash
Buoyancy-induced dispersion by Pasquill ($\Delta h/\sqrt{10}$)

l. Chemistry/Reaction Mechanism

None

m. Physical Removal

None

n. Boundary Conditions

Lower boundary: perfect reflection for portion of plume designated by user to be available for reflection on slopes
Upper boundary: none

o. Background

Not treated

p. Evaluation Studies

Two validation studies documented in the user's guide

q. Proposed EPA Action

RTDM.WC can be used on a case-by-case basis if it can be demonstrated, using the criteria in Section 6, that the model is reliable and applicable to the site and source.

r. Model Availability

Anyone wishing to review the RTDM.WC model should contact Environmental Research & Technology, Inc. At present no cost has been identified for the user's manuals or the model.
Requests should be directed to:

Mr. Joseph A. Curreri
Air Quality Center
3 Militia Drive
Lexington, Massachusetts 01743

5.0 Models with No Recommendations

5.1 ELSTAR (ERT, Inc.)

This model was prepared to estimate concentrations of photochemical oxidants. For the present, detailed requirements for such models are not addressed in the Guideline. Therefore no recommendation concerning this model is made here.

5.2 GM Line Source (General Motors Corporation)

This is considered to be a screening model. Screening models were not requested in the Federal Register solicitation. Therefore no recommendation concerning its use as a refined model is made here. This model will be identified as a screening model for motor vehicle line sources in the Guideline.

5.3 VISIBILITY (ERT, Inc.)

This model was prepared to simulate visibility impairment. Such models are undergoing a separate review and comment process elsewhere in EPA and are not considered in detail in the Guideline. Therefore no recommendation concerning this model is made at this time.

6.0 Addendum to Appendix A of the Guideline on Air Quality Models

The summary of HIWAY-2 was not completed in time to meet the printing deadline for the Proposed Revisions to the Guideline on Air Quality Models. EPA considers HIWAY-2 to be a recommended model for carbon monoxide as stated on page 21 of the Proposed Revisions to the Guideline.

A.7 HIWAY-2 (A Highway Air Pollution Model)

Reference: Environmental Protection Agency. User's Guide for HIWAY-2, Publication No. EPA-600/8-80-018. Environmental Protection Agency, ESRL, Research Triangle Park, NC 27711, May 1980.

Abstract : HIWAY-2 can be used to estimate the concentrations of nonreactive pollutants from highway traffic. This steady-state Gaussian model can be applied to determine air pollution concentrations at receptor locations downwind of "at-grade" and "cut section" highways located in relatively uncomplicated terrain. The model is applicable for any wind direction, highway orientation, and receptor location. The model was developed for situations where horizontal wind flow dominates. The model cannot consider complex terrain or large obstructions to the flow such as buildings or large trees.

Equations: The calculation of concentration is made by a numerical integration of the Gaussian plume point-source equation over a finite length. The concentration χ (gm^{-3}), from the line source is given by:

$$\chi = \frac{q_\ell}{u} \int_0^D f d\ell$$

where

u = wind speed, m sec^{-1}
D = line source length, m
f = point source dispersion function (Equations 1 to 3), m^{-2}
q_ℓ = emission rate for line source, g m^{-1} sec^{-1}
ℓ = distance from point A to point R,S, m

For stable conditions, or if the mixing height is > 5000 meters:

$$f = \frac{1}{2\pi\sigma_y\sigma_z} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right]\right\} \quad (1)$$

where: σ_y = standard deviation of the concentration distribution in the crosswind direction, m

σ_z = standard deviation of the concentration distribution in the vertical direction, m

z = receptor height above ground, m

H = effective source height, m

y = crosswind distance, m

In unstable or neutral conditions, if σ_z is greater than 1.6 times the mixing height, L (meters), the distribution below the mixing height is uniform with height regardless of source or receptor height, provided both are less than the mixing height:

$$f = \frac{1}{\sqrt{2\pi}\sigma_y L} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \quad (2)$$

In all other unstable or neutral conditions:

$$f = \frac{1}{2\pi\sigma_y\sigma_z} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right]\right.$$

$$+ \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right] + \sum_{N=1}^{N=\infty}\left[\exp -\frac{1}{2}\left(\frac{z-H-2NL}{\sigma_z}\right)^2\right.$$

$$+ \exp -\frac{1}{2}\left(\frac{z+H-2NL}{\sigma_z}\right)^2 + \exp -\frac{1}{2}\left(\frac{z-H+2NL}{\sigma_z}\right)^2$$

$$\left.\left. + \exp -\frac{1}{2}\left(\frac{z+H+2NL}{\sigma_z}\right)^2\right]\right\} \quad (3)$$

a. Input Requirements

Meteorological data: one set at a time of hourly averages of wind speed, wind direction, and mixing height and the Pasquill-Gifford stability class are required input
Emissions data: a uniform emission rate must be specified for each line source; height of emission must also be determined; length, width, number of lanes and width of center strip are required

b. Output

One hourly average concentration at each specified receptor location

c. Model Options

User selects cut or at grade section
Can be run interactively or in batch mode

d. Limitations

Receptors should not be located on the highways or in the cut sections

e. Pollutant Types

Any non-reactive pollutant

f. Source Receptor Relationship

The coordinates (meters) of the end points of a line source of length D (meters), representing a single lane extending from point A to point B (see User's Guide Figure 2), are R_A,S_A and R_B,S_B. The direction of the line source from A to B from the north is β (degrees). The coordinates, R,S, of any point along the line at an arbitrary distance, ℓ (meters), from point A are given by:

$$R = R_A + \ell \sin \beta$$

$$S = S_A + \ell \cos \beta$$

Given a receptor at R_k, S_k, the downwind distance, x (meters), and the crosswind distance, y (meters), of the receptor from the point R,S for any wind direction θ (degrees), is given by:

$$x = (S - S_k) \cos \theta + (R - R_k) \sin \theta$$

$$y = (S - S_k) \sin \theta - (R - R_k) \cos \theta$$

g. Plume Behavior

Does not treat plume rise. Emission height and effective source height are the same.

h. Horizontal Wind Field

User-supplied hourly average wind direction
User-supplied hourly average wind speed
A wind speed and direction at 2 m is preferred
Constant steady-state winds assumed for an hour
An aerodynamic drag factor is applied when winds are parallel to the roadway and speeds are less than 2 m/sec

i. Vertical Wind Field

Assumed equal to zero

j. Horizontal Dispersion

A semi-empirical dispersion parameter is used
The total horizontal dispersion is that due to ambient turbulence plus the turbulence generated by the vehicles on the roadway
Beyond 300 m downwind total turbulence is considered to be dominated by atmospheric turbulence
Three stability classes are considered: unstable, neutral and stable

k. Vertical Dispersion

Three stability classes are considered
A semi-empirical dispersion parameter is used

l. Chemistry/Reaction Mechanism

None used, non-reactive pollutants only

m. Physical Removal

None used

n. Boundary Conditions

Initial vertical dispersion based on empirically derived formulae
Initial horizontal dispersion assigned a value twice the vertical dispersion
User-specified mixing height

o. Background

Not treated

p. Evaluation Studies

Some sensitivity analyses and evaluation included in the User's Guide