Alabama Karst Variability Study

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Introduction

Beginning with the FY 2001 grant year, EPA Region IV imposed "Special Karst Conditions" on three of its states' SIRG grants: Alabama, Tennessee, and Kentucky.[1] A modified version of those karst conditions has been in effect in these states since October 1, 2000 and continue to be in effect today. This grant condition requires the state radon programs to utilize special guidance for testing homes in karst areas. These karst areas are to be defined by each of the state programs with input from their state geologists. The authors believe that definitive studies consisting of same-house different-season test data should be performed to better establish whether special guidelines need to be enforced, and if used, which areas in Alabama should be defined as karst.

The Geological Survey of Alabama previously identified zip code areas in Alabama that are underlaid by 75% or greater carbonate rock.[2] These areas were utilized as the "Potential Karst Area" zip codes described in the *Final Report; Outcomes from the Workshop on Measuring Radon in Karst Geology*, May 6-7, 1999. The single short-term test per house data in Appendix A of the document shows: (1) that both the arithmetic and geometric means for the measured radon concentrations are greater in the potential karst areas than for non-karst areas; (2) that the ratio of the arithmetic and geometric means from winter to summer are greater for potential karst areas than for non-karst areas; and, (3) that both the arithmetic and geometric standard deviations in each of the four seasons are slightly greater in the potential karst areas.[3] The Alabama Radon Program has designated these same zip code areas as its karst areas, however, they question whether the single test per house data conclusively proves that seasonal variations exist in sufficient frequency and of sufficient magnitude to warrant that *all* karst areas be subjected to the use of special karst guidance.

In any given house there are many variables affecting the result of a short-term radon measurement. These include house foundation type, age of the house, and house construction, as well as the extent of connection to karst solution cavities, and the magnitude of soil gas pressure beneath the house. We know that susceptibility to elevated indoor radon varies with type of foundation utilized and that different types of foundations predominate in different areas.[4] These differences, as well as the different life styles of the occupants, produce differences in radon measurements.

An increase in the arithmetic or geometric standard deviation from one area to another means that the combination of all the factors results in an increased variation in one area compared to another. It cannot separate out which factor or factors vary from season to season, nor can it discern the expected magnitude of the seasonal variation of any one

factor. For that reason, Alabama chose to do a same-house different-season study as opposed to analyzing data consisting of a single short-term test per house.

The extent to which a house exhibits a temporal karst effect, or seasonal variation, would be dependent upon the extent to which the house is connected to solution cavities and the extent to which the difference between soil temperature and ambient temperature produces a seasonal gradient in the soil gas pressure exerted upon the house. If the latter is likened to the stack effect, and the pressure gradient of a stack is directly proportional to the stack height, then the pressure gradient of the karst effect is directly related to the soil's stack height. The soil "stack height" is essentially the relative change in elevation in the vicinity of the house. Thus the seasonal variation of soil gas pressure is related to *both* changes in temperature *and* the change in elevation in the vicinity of each individual house.

Applicant Solicitation

A letter describing the project and an application to participate was sent to 425 homeowners who had previously called the State Radon Hotline requesting information on radon and/or radon testing. From that solicitation, 84 homeowners signed the application or Agreement to Participate forms. From those 84, 65 participants were selected and sent acceptance letters. The 19 whose applications were rejected were sent a coupon for a free short-term radon test.

Conducting the tests

The study's measurements are performed by the homeowners since the majority of indoor radon tests in Alabama are performed by homeowners and it is the seasonal variability in homeowner-conducted tests that the study is designed to determine. The error induced by the study's homeowners performing the tests are no more likely than errors from homeowner-performed tests whose seasonal variation the study is trying determine. The cost of having the investigator individually place and retrieve each individual test out weighs the benefit of doing so.

The process began by obtaining quotes from certified laboratories to deliver the testing supplies directly to the study participants. AccuStar Labs was selected as the supplier and were provided with the names and addresses of the participants as well as a mailing schedule.

Beginning in January 2004, AccuStar sent each participant one short-term and two long-term test kits. One long-term was for a full year test and one for the first three months. The short-term was to be done during any two to four-day period of the month that was convenient to the homeowner; however, participants were asked to start the first quarterly test on or about Jan. 17 because this is, on average, the day having the coldest temperatures in north Alabama.

In February, March, May, June, August, September, November and December, each participant received another short-term test for that month, and in April, July, and

October they received a short-term as well as another long-term test for each three-month period.

Personal visits as well as periodic reminder letters were sent to participants to reinforce procedures, to clarify instructions and to encourage them to participate in the study as planned. The solicitation letter, the Agreement to Participate and each proceeding correspondence emphasized the need for all measurements to be made in the exact same location of the house, in the lowest lived-in level, and under normal house conditions. The only thing that changes from one measurement to the next are the dates on which the measurements are made. At the conclusion of the study, each homeowner-participant will be requested to sign written acknowledgement that the tests performed in their residence were in accordance with the Agreement to Participate. The results from participants who do not provide written assurance will not be included in the final data report.

Variables affecting test results

Mean Outside Temperature

The investigators will obtain the mean temperature for the start date, the stop date and every day in between from the closest reporting station to the test location from http://www.srh.noaa.gov/bmx/data/climate/climate.html, the Web site operated by the National Weather Service. A numerical average mean temperature will be calculated, giving one-half weight to the values of the starting and stopping dates and full-weighted value to each day in between. The calculated value determined will be assigned as the mean outside temperature for the test result.

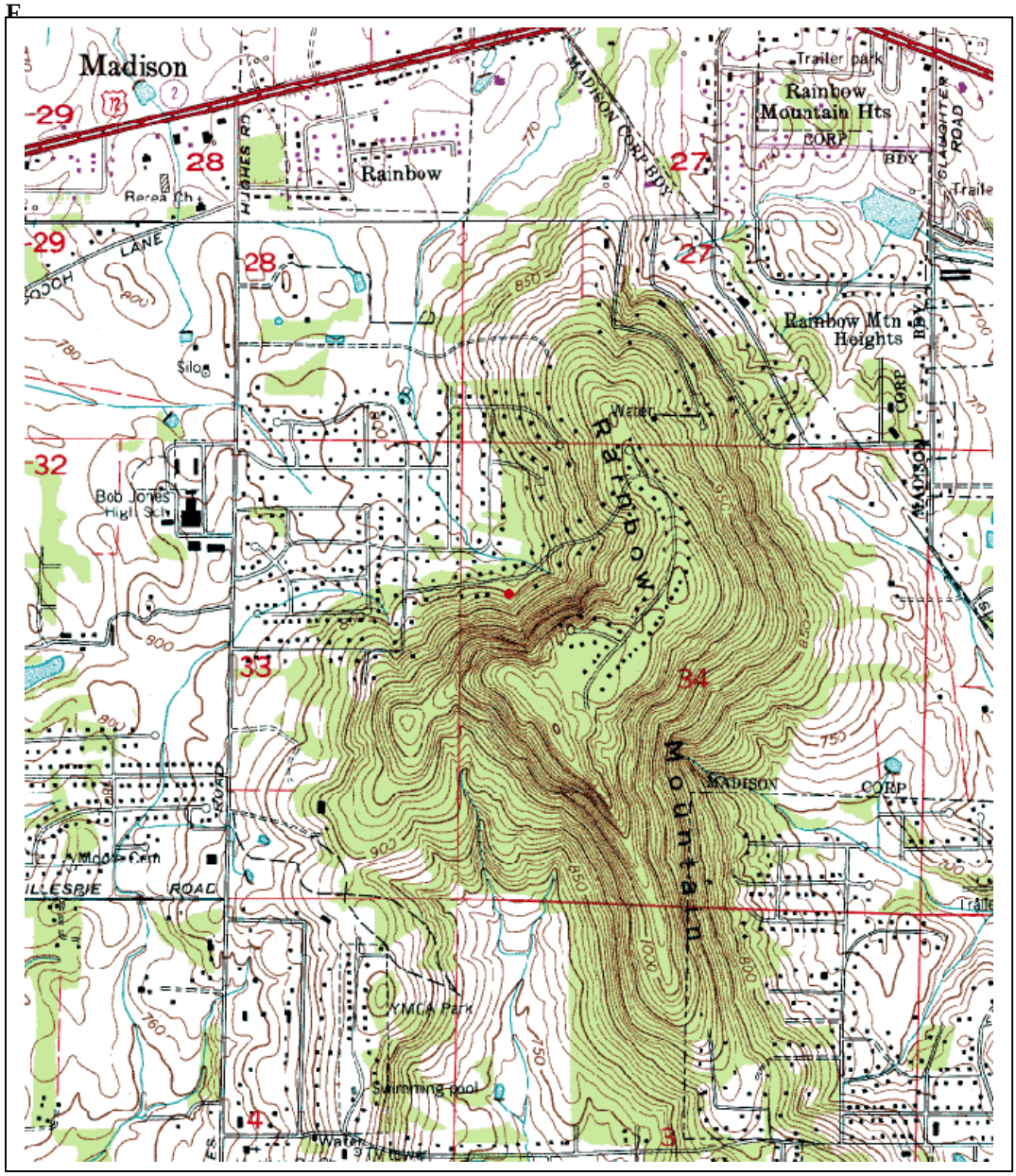
Adjacent Terrain Slope

Through personal visits, each house in the study is physically located and characterized. The latitude and longitude of each house is determined at a location near the front entrance utilizing a GPS locator. That latitude and longitude is entered into the Web site, http://www.topozone.com/viewmaps.asp, resulting in a topographical map plotted on a USGS quadrangle map. A circle of a quarter-mile scale radius will be drawn, centered on the location of the house. The maximum change in elevation from the house within the quarter-mile radius of the residence determined. One-tenth of the maximum change in elevation rounded to the nearest integer will be the Adjacent Terrain Slope (ATS) value assigned to that residence. For example: Test home #34 is located at 34^0 44.297' North and 86^0 43.833' West. The topographical map locates the residence at an elevation of 850 feet at the foot of Rainbow Mountain. The quarter-mile radius extends nearly to the top of Rainbow Mountain to an elevation of 1140 feet. The maximum change in elevation within the quarter-mile circle from the test residence is 290 feet. As shown in Figure 1, the ATS value for test home #34 is 29.

Location Characterization Code

Based upon on-site observations by the principle investigators and the topographical map location, each of the houses completing the Alabama Radon in Karst Variability Study will be characterized as hilltop (H), valley (V), side of slope (S), or level terrain (L). This designation shall be known as the Location Characterization Code (LCC). An ATS value of 4 or less will be characterized as level terrain.

Figure 1. The red dot in the center is the location of test house #34



Preliminary Results

Madison County karst area

With more than half of the data acquisition completed, results have been charted for 26 houses in Madison County. Six (23%) had short-term radon tests consistently greater than 4 pCi/l as the seasons changed. Six tested consistently less than 4 pCi/l, and 14 of the 26 (53%) produced short-term radon tests both above and below 4 pCi/l.

Of the 14 homes exhibiting variable test results, six (23% of the Madison County houses in the study) had highs less than 8 pCi/l with lows less than 4 pCi/l. The other eight (31% of the Madison County houses in the study) had highs greater than 8 pCi/l and lows less than 4 pCi/l. Only two appear to exhibit the summer, or valley, karst effect of significantly increased radon in the summer. Three strongly exhibited the winter, or hilltop, karst effect; one ranged from 35 pCi/l in January to less than 4 pCi/l in the summer, and two ranged from over 70 pCi/l in winter to at or below 4 pCi/l in the summer.

Florence, Sheffield, Muscle Shoals karst areas

Partial study results have been charted for 24 houses in Alabama's Tri-Cities area. Two had short-term radon tests consistently greater than 4 pCi/l as the seasons changed. Nine have tested consistently less than 4 pCi/l. Short-term radon tests in 13 (54%) varied from greater than 4 pCi/l to less than 4 pCi/l.

Of the 13 homes with variable readings, five (21% of the Tri-Cities houses in the study) had cold weather readings greater than 20 pCi/l and summertime readings of less than 4 pCi/l. No summer or valley karst effect was observed in this area.

Birmingham non-karst area

Partial study results have been charted for seven houses in the non-karst area in Birmingham. Three have tested consistently less than 4 pCi/l. Four produced radon measurements that varied from about 8 pCi/l to near or below 4 pCi/l. Of those four, one appears to exhibit the summer or valley effect of being higher in the summer. Three of the seven Birmingham houses appear to produce winter short-term radon measurements that are about twice as great as the summer measurements.

Work Continues

Work is still ongoing to characterize all the houses as (H), valley (V), side of slope (S), or on level terrain (L) and to determine the Adjacent Terrain Slope (ATS) value for each house. Observed seasonal variations will then be compared to these characteristics and to mean outside temperature.

Data results have been obtained through September 30, 2004. Three months of data are yet to be obtained.

Lessons learned and other factors affecting the study's results

A monetary reward or other incentive may be needed to promote full and complete participation by participants. With no monetary reward for satisfactory completion of the project, the study is plagued with testing inconsistencies by some of the homeowner participants. Eleven of the original 65 participants dropped out during the first seven months of the study. A significant number of participants did not promptly perform the test when the kit was received, and some participants decided to use study test devices to test other floors and rooms than their agreed-to test location.

Full funding should be secured prior to starting the study. The study was hampered by an unexpected delay in receipt of funding from EPA Region IV, although we were assured that the approval for the project had been granted. Funding that was anticipated to arrive in May did not occur until mid-August. This gap in funds caused the program to be without funds for contacting and visiting participants for several months which contributed to increased dropouts and inconsistent participation.

Study-specific instruction and data sheets should be enclosed with the test kits instead of the kit manufacturer's standard instructions. Confusion on the part of several participants concerning the placement and duration of the long-term tests could have been avoided had the state mailed out the kits to participants utilizing only instructions specifically prepared for the study.

Unexpected problems can occur. The vendor, AccuStar Labs, informed us that the third quarter alpha track long-term measurement devices mailed in mid-July did not pass their lab's quality control. Thus, there will be no valid long-term quarterly measurement for that period. The participants were provided a yearlong alpha track device which will capture the exposure for the third quarter as part of the full year.

Preliminary Conclusion

If one defines having high season short-term radon test values of greater than 20 pCi/l and low season short-term radon test values of less than 4 pCi/l as being a significant seasonal variability problem, then, according to the partial data thus far, 8 (20%) of the 40 karst area homes exhibit a significant seasonal variability problem. None of the non-karst area homes exhibit a significant seasonal variability problem.

Based upon the first nine months' preliminary data of the Alabama Karst Variability Study, temporal or seasonal variation is significant and widespread in the karst areas that were tested. Special karst specific guidance in addition to that in existing EPA publications appears to be justified for areas that are both high radon potential and high karst.

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References

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2. *Final Report, Outcomes from the Workshop on Measuring Radon in Karst Geology, May 6-7, 1999*, Karst Data Analysis: Additional Tasks, Page 2 of 8, Southern Regional Radon Training Center, June 21, 1999.

3. *Final Report, Outcomes from the Workshop on Measuring Radon in Karst Geology, May 6-7, 1999*, Karst Data Analysis: Additional Tasks, Page 5 of 8, Southern Regional Radon Training Center, June 21, 1999.

4. McNees, J. L., "Random vs. Self Select Participants in Radon Surveys," Thirteenth Annual National Radon Meeting, Nashville, TN, October 2003; also presented at Twentieth Annual National Conference on Radiation Control, Nashville, TN, May 1988.