SPECIAL REPORT 216

RADON POTENTIAL IN SANTA CRUZ COUNTY, CALIFORNIA

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CALIFORNIA GEOLOGICAL SURVEY
Department of Conservation

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By

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TABLE OF CONTENTS

FIGURES

TABLES

EXECUTIVE SUMMARY

Radon is a radioactive gas formed by decay of small amounts of uranium and thorium naturally present in rock and soil. Sometimes radon gas can move out from underlying soil and rock into houses and become concentrated in the indoor air, posing a significant lung cancer risk for the residents. The U.S. Environmental Protection Agency (EPA, 2007) estimates indoor radon exposure results in 21,000 lung cancer deaths annually in the United States.

Between December 2006 and April 2007, the California Department of Public Health Radon Program (CDPH-Radon Program) conducted an indoor-radon survey of 1,539 homes in Santa Cruz County using short-term charcoal detectors. Radon survey test results range from 0.2 picocuries per liter (pCi/L), the detection limit, to 89.3 pCi/L in a garage with a slab foundation. The highest first-floor measurement obtained within a room normally occupied in a residence, a first floor living room in a multi-level house, was 31.5 pCi/L. The U.S. EPA recommended radon action level is 4.0 pCi/L.

A radon potential zone map for Santa Cruz County, California, was developed by the California Geological Survey (CGS) utilizing:

- The 1:62,500 scale U.S. Geological Survey Geologic Map of Santa Cruz County, California compiled by Brabb (1997), 1:24,000 U.S. Geological Survey Miscellaneous Field Studies Maps for the Laurel, Loma Prieta, Los Gatos and Mt. Madonna quadrangles, and the 1958)CGS 1:250,000 Geologic Atlas--Santa Cruz Map Sheet

- 2006-2007 CDPH-Radon Program Santa Cruz County indoor-radon survey data

- Background uranium data from the National Uranium Resource Evaluation (NURE) project

- Soil property information from the Natural Resources Conservation Service (NRCS) soil report for Santa Cruz County

The indoor-radon, uranium and soil data were linked to Santa Cruz County geologic units using a geographic information system (GIS). The geologic units were then ranked for radon potential based on the characteristics of their associated data.

Four radon potential categories defined by the percentage of homes with indoor radon likely to equal or exceed 4.0 pCi/L were used: high (≥ 20 percent), moderate (≥ 5.0 to 19.9 percent), low (< 5 percent), and unknown (for geologic units with few or no data). Geologic unit occurrences with the same radon potentials were grouped to define the radon potential zones on the Santa Cruz County radon map. A final map development step involved statistical comparison of indoor-radon data for the resulting radon potential zones to confirm that each zone represents a distinct radon potential. The highest radon potentials found during the mapping process are generally located in or near the 95005 (Ben Lomond), 95018 (Felton) and 95033 (Los Gatos) Zip Code areas. High radon potential areas account for 10.6 percent of the Santa Cruz County radon potential map area. Moderate and low potential areas account for 42.1 percent and 36.6 percent respectively. Unknown radon potential areas account for 10.7 percent.

The radon potential zone map for Santa Cruz County, California, is informational, not regulatory. It is intended as a guide to prioritize areas for public education about radon, and for targeting additional indoor-radon testing activities. The map cannot be used to determine the indoor-air radon level of a particular building. All radon zones will contain some homes testing above 4 pCi/L and some homes testing below 4 pCi/L. The only way to identify specific buildings with indoor-radon levels exceeding 4 pCi/L is through testing.

Based on indoor-radon survey results, the radon potential zone map for Santa Cruz County developed by CGS in this study, and 2000 census data, an estimated 17,200 people in Santa Cruz County live in residences likely to equal or exceed 4.0 pCi/L. An estimated 5,000 people live in houses that will likely test at 10 pCi/L or more, and about 2,700 are estimated to live in houses that will likely test at 20 pCi/L or higher.

Because almost 53 percent of Santa Cruz County consists moderate to high radon potential areas, indoor-radon testing should be encouraged. Individuals planning new home construction in Santa Cruz County may wish to consider incorporating radon-resistant features into their building plans, particularly if the building site is located in a higher-radon potential area. If necessary, radon mitigation after construction is still possible but it will be more costly. Information on radon remediation and radon resistant construction is available on the CDPH-Radon Program website at: http://www.cdph.ca.gov/healthinfo/environhealth/Pages/Radon.aspx

INTRODUCTION

Purpose

This report describes radon potentials for geologic formations in Santa Cruz County. Additionally, this report documents the procedures and data used by the California Department of Conservation, California Geological Survey (CGS) to produce the 2010 radon potential zone map for Santa Cruz County. CGS produced the map for the California Department of Public Health Radon Program (CDPH-Radon Program) through an interagency agreement. Only minimal background information on radon and radon health issues is included in this report, and detailed radon testing and remediation practices are not discussed. The following websites contain information about radon and health issues, testing and remediation:

http://www.cdph.ca.gov/healthinfo/environhealth/Pages/Radon.aspx
and http://www.epa.gov/radon/pubs/index.html.

Background Information on Radon and Health

Radon gas is a naturally occurring odorless and colorless radioactive gas. It forms from the radioactive decay of small amounts of uranium and thorium naturally present in rocks and soils. The average uranium content for the earth's continental crust is about 2.5-2.8 parts per million (ppm). Typical concentrations of uranium and thorium for many rocks and soils are a few ppm. Certain rock types, such as organic-rich shales, some granitic rocks, and silica-rich volcanic rocks may have uranium and thorium present at levels of tens to hundreds of ppm. While all buildings have some potential for elevated indoor-radon levels, buildings located on rocks and associated soils containing higher concentrations of uranium often have an increased likelihood of elevated indoor radon levels. Breathing air with elevated radon gas abundance increases one's risk of developing lung cancer. Not everyone exposed to radon will develop lung cancer. However, the U.S. Environmental Protection Agency (U.S. EPA, 2007) estimated 21,000 people die in the United States annually from lung cancer attributed to radon exposure.

Radon in indoor-air is measured in units of picocuries per liter (pCi/L) in the U.S. The average radon concentration for indoor air in American homes is about 1.3 pCi/L (U.S. EPA, 2007). The average radon concentration in outdoor air is about 0.4 pCi/L. The U.S. EPA recommends that individuals avoid long-term exposures to radon concentrations ≥ 4.0 (*4.0 pCi/L is the U.S. EPA recommended indoor-radon action level*). Based on long-term radon test statistics, the U.S. EPA estimates about 1 out of 15 homes (6.7 percent) in the United States have radon levels ≥ 4.0 pCi/L.

Although radon levels are used as a guide for acceptable exposure and for remedial action, it is inhalation of two radon radioactive decay products that primarily lead to lung cancer: polonium-218 and polonium-214. These daughter elements have very short half-lives, and when they enter the lungs they attach to lung tissue or trapped dust particles and quickly undergo radioactive decay. In contrast, longer-lived radon-222 is mostly exhaled before it undergoes radioactive decay. Alpha particles emitted during decay of radon-222, polonium-218 and polonium-214 are thought to cause cancer by damaging the DNA (deoxyribonucleic acid) in lung tissue cells, resulting in abnormal or tumorous cell growth (Brookins, 1990).

Radon gas readily moves through rock and soil along micro-fractures and through interconnected pore-spaces between mineral grains. Radon movement away from its site of origin is typically limited to a few feet to tens of feet because of the relatively short half-lives of radon isotopes (3.8 days for radon-222, 55.6 seconds for radon-220 and 3.96 seconds for radon-219), but movement may be hundreds of feet in some cases. Additional conditions, such as soil moisture content, also affect how far radon can move in the subsurface. Because radon-222 (a radioactive-decay product of uranium-238, see Table 1) has the longest half-life of the several radon isotopes, it is usually the predominant radon isotope in indoor air rather than shorter lived radon-220 (a radioactive-decay product of thorium-232) or radon-219.

Radon gas moves from the soil into buildings in various ways. It can move through cracks in slab foundations or basement walls, pores and cracks in concrete blocks, through-going floor-to-wall joints, and openings around pipes. Radon enters buildings from the soil when air pressure inside the buildings is lower than air pressure in the soil. When exhaust fans are used, inside air is heated, or wind is blowing across a building, the building's internal air pressure is lowered. Because radon enters buildings from the adjacent soil, radon levels are typically highest in basements and ground floor rooms. Radon can also enter a building in water from private wells. All ground water contains some dissolved radon gas. The travel time of water from an aquifer to a home in a private well is usually too short for much radon decay so radon is available to be released in the house during water usage, for example through use of a bathroom shower. However, normal water usage typically adds only about 1 pCi/L of radon to indoor air per 10,000 pCi/L of radon in water (Grammer and Burkhart, 2004).

Nuclide (Isotope)	**Principal mode of radioactive decay**	**Half-life**
Uranium-238	Alpha	$4.5X10^9$ years
Thorium-234	Beta	24.1 days
Protactinium-234	Beta	1.2 minutes
Uranium-234	Alpha	$2.5X10^5$ years
Thorium-230	Alpha	$7.5X10^4$ years
Radium-226	Alpha	1,602 years
Radon-222	**Alpha**	**3.8 days**
Polonium-218	Alpha	3.1 minutes
Lead-214	Beta	26.8 minutes
Astatine-218	Alpha	1.5 seconds
Bismuth-214	Alpha	19.9 minutes
Polonium-214	Alpha	$1.6\text{-}10^{-4}$ seconds
Thallium-210	Beta	1.3 minutes
Lead-210	Beta	22.6 years
Bismuth-210	Beta	5.0 days
Polonium-210	Alpha	138.4 days
Thallium-206	Beta	4.2 minutes
Lead-206	Stable	Stable

Table 1. The uranium-238 radioactive decay series
(Generalized-doesn’t show branching or some short-lived isotopes. Modified from Appleton, 2005, p. 229)

The most common indoor-radon testing methods utilize either charcoal or alpha-track type detectors. These detectors are exposed to the air in a building according to the manufacturer's instructions and then sent to a laboratory for analysis. Charcoal detectors are usually exposed for a few days under closed building conditions (i.e., a short-term test), while alpha-track detectors are typically exposed for periods of weeks, months or as long as a year under normal (open) building conditions (i.e., a long-term test). These tests are simple and inexpensive and homeowners can do this testing themselves. Test results are reported in pCi/L. Long-term tests (alpha-track detector measurements) have an advantage because they "average out" short-term fluctuations in radon levels that relate to factors such as weather changes. Consequently, long-term measurements should be more representative of annual average indoor-radon levels. However, short-term measurements are more commonly used because of the shorter time required. More often than not, if a short-term indoor radon test is several pCi/L above 4 pCi/L, follow-up short-term tests or long-term tests will also be above 4 pCi/L (e.g. Appendix B).

Radon Potential Maps

Radon potential maps indicate areas where the likelihood of a house exceeding 4 pCi/L (the U.S. EPA recommended radon action level) is relatively higher or lower. They may also be used with population data to estimate the number of individuals exposed to excessive radon levels within the area of map coverage. Radon potential maps and related population estimates can help government agencies and private organizations identify priority areas for future radon testing and public education efforts.

Use and Limitations of Radon Potential Maps

Radon potential maps developed by CGS for the CDPH-Radon Program identify areas where geologic conditions are more likely to contribute to excessive indoor radon levels. They are advisory, not regulatory, intended to assist federal, state and local government agencies, and private organizations in targeting their radon program activities and resources. These maps are not intended for determining which buildings have excessive indoor radon levels. In addition to geology, local variability in soil permeability and climatic conditions, and factors such as building design, construction, condition, and usage may influence indoor radon levels. Radon levels for a specific building can only be determined accurately by indoor radon testing of that building, regardless of what radon zone it is located within. All radon zone categories will likely have some buildings with indoor radon levels ≥ 4.0 pCi/L.

Development of the Santa Cruz County Radon Potential Map

The Santa Cruz County radon potential zones were developed utilizing the following data:

- CDPH-Radon Program 2006-2007 Santa Cruz County indoor-radon survey test data for 1539 residences
- NURE Project Airborne Survey data for equivalent uranium (eU)
- NURE Project stream sediment and soil sample uranium data
- Santa Cruz County soil unit data and maps from the Natural Resources Conservation Service (NRCS)
- The 1:62,500 scale U.S. Geological Survey Geologic Map of Santa Cruz County, California (USGS OFR 97-489)
- The U.S. Geological Survey Miscellaneous Field Studies Map MF-2373(geologic maps for Laurel, Loma Prieta, Los Gatos and Mt. Madonna 1:24,000 quadrangles
- The California Geological Survey 1:250,000 Geologic Atlas Santa Cruz Sheet (1958)

The Santa Cruz radon potential map development steps are as follows:

1) Utilizing a geographic information system (GIS), 2006-2007 CDPH-Radon Program indoor-radon survey data (test measurements) for Santa Cruz County were grouped by geologic unit and soil unit.

2) Geologic units with associated indoor-radon data were preliminarily assigned to one of 4 radon potential categories based on the percentage of radon data at or exceeding 4 pCi/L, the number and magnitude of radon data per unit exceeding 10 pCi/L, and the total number of data.

3) Using GIS, NURE project airborne equivalent uranium (eU) data and soil and sediment uranium (U) data for Santa Cruz County were grouped by geologic unit.

4) Using NURE data, geologic units were rated as more likely or less likely to be related to problem radon homes based on the percentage of eU data and/or the percentage of soil, sediment or rock U data exceeding 5 ppm uranium (i.e., twice 2.5 ppm, the average crustal uranium abundance).

5) 2006-2007 CDPH-Radon Program indoor-radon survey data were grouped by NRCS soil units.

6) Permeability and shrink-swell character were reviewed for soil groups with indoor-radon data to see if these features are associated with higher or lower indoor radon concentrations.

7) Using the information from steps 2, 4 and 6, final radon potentials were assigned to all geologic units in Santa Cruz County, based on the percentages of short-term tests likely to exceed 4.0 pCi/L as follows:

- High--20 percent or more ≥ 4.0 pCi/L indoor measurements
- Moderate--5 to 19.9 percent ≥ 4.0 pCi/L indoor measurements
- Low--0-4.9 percent ≥ 4.0 pCi/L indoor measurements
- Unknown--areas with insufficient data for estimating the percent of ≥ 4.0 pCi/L indoor measurements

8) Geologic unit areas with similar radon potentials were grouped to form radon potential zones.

9) The indoor-radon data for each radon zone were compared statistically with other zones to confirm that each zone represents a statistically distinct indoor-radon data population.

10) The final radon zones were compared with 2000 census block data to estimate radon impacts on the Santa Cruz County population.
The data and information utilized and the results for each of these steps are provided and discussed in more detail in the following sections of this report.

Portions of radon potential zones underlain by faults and shear zones often have increased potential for elevated indoor-radon because such features provide pathways for radon flow. However, faults and shear zones are not identified on the 1:100,000 scale Santa Cruz County Radon Potential Zone map because the minimum fault or shear zone width that can be depicted on a map at this scale is about 150-200 feet whereas fractures of an inch width or less can be significant pathways for radon movement to a building's foundation. Soil and alluvium may obscure faults and shear zones or prevent their precise location on geologic maps, except where detailed site-specific investigations have been conducted. Consequently, at 1:100,000-scale mapping, it is better to base priority for indoor testing on zone designation rather than attempt to target fault and shear zone locations. Where situations require a local detailed investigation of indoor radon and fault or shear zone relationships, accurate fault or shear zone maps of 1:24,000 or a more detailed scale should be used or developed to guide testing.

THE SANTA CRUZ COUNTY SHORT-TERM INDOOR-RADON SURVEY

Overview

The CDPH-Radon Program conducted a survey of indoor-radon in Santa Cruz County homes between December 2006 and April 2007. The CDPH-Radon Program solicited participation via direct mailing to 30,503 homeowners in Santa Cruz County. Fifteen hundred and thirty nine homeowners (5.1 percent) participated in the survey. The survey participants received a free charcoal detector with instructions for placement and exposure, which they subsequently mailed to the Radon Program contract lab for measurement. Test results were provided directly to the survey participants by the contract lab within several weeks of detector receipt. The primary survey goal was to obtain sufficient indoor-radon data for homes located on specific geologic units to evaluate the radon potentials of these units. The percentage of homes exceeding the 4.0 pCi/L U.S. EPA recommended radon action level was used to evaluate geologic unit radon potential and the results are presented below in the section titled *Preliminary Geologic Unit Radon Potentials* (page 12).

Figure 1 shows the geographic distribution of the CDPH radon survey homes in Santa Cruz County. One hundred eight homes tested ≥ 4.0 pCi/L and their geographic distribution is shown in Figure 2. The survey radon concentrations range from 0.2 pCi/L, the detection limit, to 89.3 pCi/L-- a first floor garage with a slab foundation. The next highest measurements were 55.5 pCi/L in a first-floor pantry of a multi-level house and 31.5 pCi/L in the living room of a multi-level house. Table 2a summarizes survey results by Zip Code zone and City/Region. For comparison, Table 2b summarizes CDPH On-line Zip Code radon database test data for Santa Cruz County Zip Code zones accumulated by CDPH since 1989. The CDPH on-line database includes the 2006-2007 Santa Cruz County radon survey data in Table 2a. Table 2b data cannot be used for evaluating the radon potential of particular geologic units because, for much of its data, the only available location information is the Zip Code for the house tested. More precise test location information is need for geologic unit radon potential evaluation. Another complication with the Table 2b data is that it likely includes multiple radon measurements for some homes (e.g., follow-up measurements or simultaneous measurements in multiple rooms) that cannot be identified as such. In spite of these limitations, Table 2b data are still useful for identifying which Santa Cruz County Zip Codes may contain radon problem areas, and for suggesting general indoor-radon trends for Santa Cruz County. Both the 2006-2007 survey and the Zip Code radon data sets show reasonably close agreement on the overall percentage of

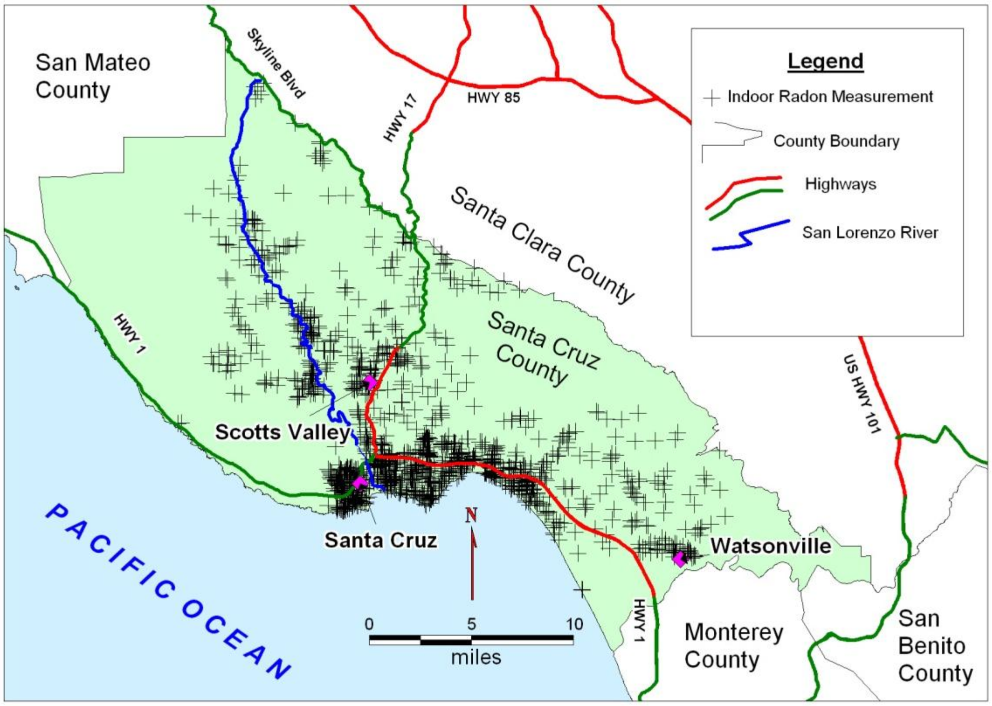

FIGURE 1. CDPH 2006-2007 Santa Cruz County radon survey test locations

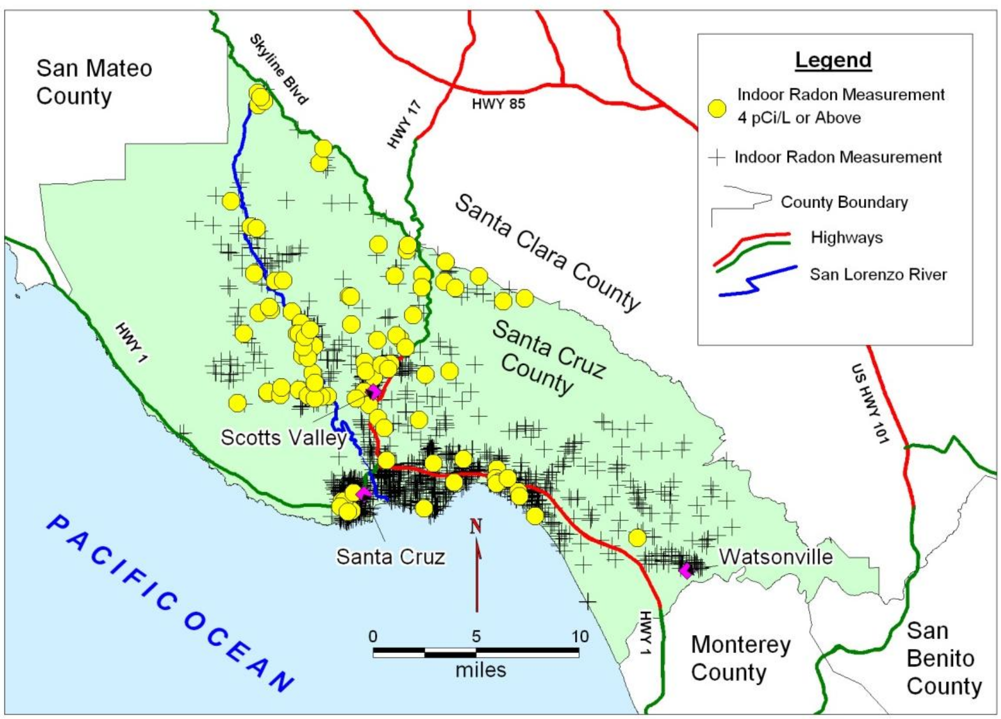

FIGURE 2. CDPH 2006-2007 Santa Cruz County radon survey test locations with 4.0 pCi/L or greater sites (shown as yellow circles)

homes in the Santa Cruz County ≥4 pCi/L (i.e., 7.0 percent for the 2006-2007 survey versus 6.2 percent for the online Zip Code data). Not surprisingly, there is general agreement on percentages between the two databases for Zip Codes with more than 25 tests. Both databases show the same Zip Codes as having high radon potential (percentages of ≥ 4 pCi/L homes at or exceeding 20 percent).

In summary, both the 2006-2007 indoor-radon survey data and the Zip Code radon data suggest significant high and moderate radon potential areas occur in northern and western Santa Cruz County. Zip code radon data also suggest the central and southeastern portions of the county are low radon potential areas.

Zip Code	City/Region	Number of Measurements	Measurements ≥ 4.0 pCi/L	Percent ≥ 4.0 pCi/L
95001*	Aptos	1	0	0
95003	Aptos	210	9	4.3
95005	**Ben Lomond**	**57**	**12**	**21.1**
95006	Boulder Creek	57	8	14.0
95010	Capitola	53	1	1.9
95017	Davenport	2	0	0
95018	**Felton**	**75**	**16**	**20.8**
95019	Freedom	4	0	0
95033**	**Los Gatos**	**53**	**17**	**32.1**
95060	Santa Cruz	356	21	5.9
95061*	Santa Cruz	1	0	0
95062	Santa Cruz	214	1	0.5
95063*	Santa Cruz	1	0	0
95064	Santa Cruz	7	0	0
95065	Santa Cruz	82	3	3.7
95066	Scotts Valley	123	17	13.8
95067*	Scotts Valley	2	0	0
95073	Soquel	78	2	2.6
95076***	Watsonville & Le Selva Beach	163	1	0.6
Totals for Zip Codes within Santa Cruz County				
		1539	108	7.0

Table 2a. CDPH indoor-radon short-term test results for the winter 2006-2007 Santa Cruz County radon survey--by Zip Code zone
*P.O. Box Only Zip Code.
**The portion of 95033 Zip Code area within Santa Cruz County.
***The portion of 95076 Zip Code area within Santa Cruz County.
Bold entries are Zip Codes with more than 20 percent ≥ 4.0 pCi/L measurements

Zip Code	City/Region	Number of Measurements	Measurements	Percent ≥ 4.0 pCi/L
95001*	Aptos	5	0	0
95003	Aptos	256	9	3.5
95005	**Ben Lomond**	**74**	**21**	**28.4**
95006	Boulder Creek	70	6	8.6
95010	Capitola	67	1	1.5
95017	Davenport	2	0	0
95018	**Felton**	**96**	**23**	**23.5**
95019	Freedom	8	0	0
95033**	**Los Gatos**	**112**	**37**	**33.0**
95060	Santa Cruz	482	28	5.8
95061*	Santa Cruz	2	0	0
95062	Santa Cruz	255	3	1.2
95063*	Santa Cruz	4	0	0
95064	Santa Cruz	19	2	10.5
95065	Santa Cruz	102	3	2.9
95066	Scotts Valley	154	20	13.0
95067*	Scotts Valley	1	0	0
95073	Soquel	94	2	2.1
95076***	Watsonville	223	1	0.5
Totals for Zip Codes within Santa Cruz County				
		1914	119	6.2

Table 2b. Radon test results for Santa Cruz County Zip Code zones from the CDPH on-line Radon Zip Code Database for California
(Results as of August 31, 2009; includes winter 2006-2007 CDPH survey results for Santa Cruz County)
*P.O. Box Only Zip Code.
**Data for the 95033 Zip Code area includes measurements from Santa Cruz County and Santa Clara County.
*** Data for the 95076 Zip Code area contains measurements from Santa Cruz County and may include measurements from Santa Clara and Monterey counties.
Bold entries are Zip Codes with more than 20 percent ≥ 4.0 pCi/L measurements

Radon Survey Data--Exposure Duration and Data Quality

Most Santa Cruz County CDPH radon survey participants exposed their radon tests for two days as instructed, but some exposed them for 3 days. Differences between two-day and three-day test results should be negligible.

Appendix A lists results for 108 duplicate (concurrent) tests made during the survey. These results are summarized in Table 2c and this table shows consistency between duplicate test results.

High Measurement Group Range pCi/L	**Associated Concurrent Group Measurement Ranges pCi/L**	**Differences pCi/L**
5.0-9.6	4.3-8.6	0.4-1.0
3.0-3.5	1.2-3.4	0.1-2.2
2.1-2.8	1.5-2.6	0.0-0.6
1.0-1.9	0.2-1.7	0.0-1.6
0.2-0.9	0.2-0.9	0.0-0.6

Table 2c. Comparison of Santa Cruz County radon survey duplicate (concurrent) test results

Appendices B and C show the analytical results for 10 field blank radon detectors (i.e., not exposed to radon) and eight spiked radon detectors (exposed to a known concentration of radon). The field blank samples measured below 0.5 pCi/L for 8 of 10 samples. One blank measures 0.7 pCi/L and one blank could not be analyzed. Seven of eight spiked samples differed by +/- 1.0 pCi/L or less from the mean chamber radon concentration of 6.0 pCi/L. One spiked sample measured 1.1 pCi/L below the minimum chamber radon concentration. All detectors exposed to air averaging 6.0 pCi/L radon measured above 4.0 pCi/L, the U.S. EPA recommended action level.

In summary, duplicate, blank and spiked sample test results support the validity of the CDPH-Radon Program Santa Cruz County radon survey data.

Follow-up Radon Testing Results

Twenty-three follow-up radon tests at 14 different locations were made and are shown in Appendix D. The number of days between tests range from 3 to 301. In 20 of the 23 instances, the follow-up tests confirmed the original test result of either > 4.0 pCi/L or < 4.0 pCi/L.

At one house initially testing 8.2 pCi/L, two follow-up tests 301 days later measured 3.1 and 1.0 pCi/L. There may be some detector exposure/placement issues with these two tests because two other follow-up tests made at the same time in this house measured 4.3 and 5 pCi/L and tests made 20 days, 255 days and 280 days after the initial 8.2 pCi/L test measured 6.8, 5.0 and 5.0 pCi/L respectively.

At another house initially testing 2.9 pCi/L, a second test 68 days later measured 6.0 pCi/L.

In summary, the follow-up tests related to the Santa Cruz Radon Survey usually (87% of the time) confirmed the initial test result of either > 4.0 pCi/L or < 4.0 pCi/L.

SANTA CRUZ COUNTY GEOLOGIC UNIT RADON POTENTIALS

Indoor Radon Data and Geologic Unit Information

Indoor-radon data from the CDPH Radon Program 2006-2007 survey of Santa Cruz County homes are tabulated by geologic unit in Appendix E for the 39 geologic units with indoor-data. The 1:62:500-scale Geologic Map of Santa Cruz County, California (Brabb, 1997), 1:24:000-scale geologic maps for the Laurel, Loma Prieta, Los Gatos and Mt. Madonna 1:24,000 quadrangles (McLaughlin and others, 2001), and the 1:250,000 Geologic Map of California-Santa Cruz Sheet (Jennings and Strand, 1959) were used to determine which geologic unit is present at each radon test location.

Preliminary Geologic Unit Radon Potentials

Tables 3a, 3b and 3c list 22 geologic units likely to have high, moderate, or low radon potential. Preliminary radon potentials are assigned to these units based on indoor-radon data and radon potential definitions listed in step 7 on page 6. The radon potential of 9 units listed in Tables 3a and 3b are provisional, less certain because they have fewer than 25 indoor-radon measurements. Provisional status is indicated in the following manor; “High?”, “Moderate?”, or “Low?”. Other data (airborne radiometric data, uranium data from soil and sediment samples, and soil data) were reviewed to see if they supported either high or moderate designations for the provisional units in Tables 3a and 3b, and to identify additional geologic units that have elevated radon potential but lack indoor-radon measurements. Following sections of this report discuss these data and their ramifications. Final geologic unit radon potentials are discussed with supporting information on pages 28 to 33 and listed in Appendix J-1.

The following radon potential classification categories for geologic units are based on indoor-radon survey results and geologic units as defined and located on the maps listed above. The bullets identify common rock and sediment types in each category.

<u>High radon potential units</u>:

- Semisiliceous organic mudstone and sandy siltstone with a few thick dolomite interbeds (Monterey Formation-Tm)
- Mudstone and arkosic sandstone with thick bed of glauconitic sandstone at base (San Lorenzo Formation-Rices Mudstone Member-Tsr)

- Pyritic siltstone (Butano Sandstone-Middle siltstone member-Tbm)
- Organic mudstone containing phosphatic laminae and lenses in lower part (Lambert Shale-Tla)
- Granite and adamellite-ga (quartz monzonite)

Moderate radon potential units:

- Siliceous organic mudstone (Santa Cruz Mudstone-Tsc)
- Quartz diorite-qd
- Calcareous arkosic sandstone (Lompico Sandstone-Tlo)
- Alluvial deposits-Qal (that Qal near to and derived from high radon potential and moderate radon potential rock units)
- Arkosic sandstone with interbeds of shale and mudstone (Vaqueros Sandstone-Tvq)
- Arkosic sandstone; locally calcareous and locally bituminous (Santa Margarita Sandstone-Tsm)
- Pelitic schist and quartzite-sch
- Arkosic sandstone containing thin interbeds of siltstone (Butano Sandstone-Upper sandstone member-Tbu)
- Micaceous siltstone (Locatelli Formation-Tl)

Low radon potential units:

- Surficial deposit-heterogeneous sequence of mainly eolian and fluvial sand, silt, clay and gravel (Aromas Sand, undivided-Qar)
- Surficial deposit-semiconsolidated well-sorted sand with a few thin, relatively continuous layers of gravel. Locally included many small areas of fluvial and colluvial silt, sand and gravel (Lowest emergent coastal terrace deposits-Qcl)
- Surficial deposit-semiconsolidated moderately well-sorted marine sand with thin, discontinuous gravel-rich layers. May be overlain by poorly sorted fluvial and colluvial silt, sand and gravel (coastal terrace deposits, undifferentiated-Qcu)
- Surficial deposits-unconsolidated, fine-grained, heterogeneous deposits of sand and silt, commonly containing relatively thin, discontinuous layers of clay. Gravel content increases toward the Santa Cruz mountains and is locally abundant within channel and lower point-bar deposits in natural levees and channels of meandering streams (Older flood-plain deposits-Qof)
- Surficial deposit-unconsolidated, heterogeneous deposits of moderately to poorly sorted silt, sand, and gravel (Colluvium-Qtl)
- Surficial deposits--Semiconsolicated, moderately to poorly sorted silt, sand, silty clay, and gravel. Gravel, approximately 50 feet thick, is generally present 50 feet below surface and is both a local aquifer and a significant source of gravel. The upper 5 to 15 feet is moderately indurated owing to clay and iron oxide cementation in

weathered zone (Terrace deposits of Watsonville-Fluvial facies-Qwf)

- Tuffaceous and diatomaceous siltstone containing thick interbetd of semifriable, fine-grained andesitic sandstone (Purisima Formation-Tp)

Geologic Unit	Incidence Rate (R) of CDPH ≥ 4 pCi/L Indoor Measurements (in Percent)	Radon Potential Designation
Monterey Formation [Tm]*(middle Miocene)**	R = 36.0% N = 25 N ≥ 4 pCi/L = 9 Maximum = 89.3 pCi/L	High R ≥ 20%
Rices Mudstone Member [Tsr](Oligocene and Eocene)	R = 33.3% N = 21 N ≥ 4 pCi/L = 7 Maximum = 11.0 pCi/L	High? Apparent R ≥ 20%
Middle siltstone member-Butano Sandstone [Tbm](Eocene)	R = 21.4% N = 14 N ≥ 4 pCi/L = 3 Maximum = 31.2 pCi/L	High? Apparent R ≥ 20%
Granite and adamellite [ga](Cretaceous)	R = 33.3% N = 12 N ≥ 4 pCi/L = 4 Maximum = 10.3 pCi/L	High?? Apparent R ≥ 20%
Lambert Shale [Tla](lower Miocene)	R = 75% N = 8 N ≥ 4 pCi/L = 6 Maximum = 26.8 pCi/L	High?? Apparent R ≥ 20%

Table 3a. High radon potential geologic units in Santa Cruz County based on 2006-2007 CDPH short-term indoor radon data N=the number of CDPH indoor-radon data available from houses located on the geologic unit indicated in the first column of the table. ?=Increased uncertainty because N<24

* [abc] = geologic unit abbreviation

** (xxx) = geologic unit formation time period-era, period or epoch

Geologic Unit	Incidence Rate (R) of CDPH ≥ 4 pCi/L Indoor Measurements (in Percent)	Radon Potential Designation
Santa Cruz Mudstone [Tsc]*(Upper Miocene)**	R = 17.9 % N = 28 N ≥ 4 pCi/L = 5 Maximum = 21.4 pCi/L	Moderate 5% ≥ R < 20%
Quartz diorite [qd](Cretaceous)	R = 15.4% N = 26 N ≥ 4 pCi/L = 4 Maximum = 8.8 pCi/L	Moderate 5% ≥ R < 20%
Lompico Sandstone [Tlo](middle Miocene)	R = 13.8% N = 29 N ≥ 4 pCi/L = 4 Maximum = 9.6 pCi/L	Moderate 5% ≥ R < 20%
Alluvial deposits, undifferentiated [Qal](Holocene)	R = 12.6% N = 127 N ≥ 4 pCi/L = 16 Maximum = 21.7 pCi/L	Moderate 5% ≥ R < 20%
Vaqueros Sandstone [Tvq](lower Miocene and Oligocene)	R=10.3 N=39 N ≥ 4 pCi/L = 4 Maximum = 28.5	Moderate 5% ≥ R < 20%
Santa Margarita Sandstone [Tsm](upper Miocene)	R = 6.3 % N = 111 N ≥ 4 pCi/L = 7 Maximum = 9.9 pCi/L	Moderate 5% ≥ R < 20%
Metasedimentary rocks [sch](Mesozoic or Paleozoic)	R = 15.0 % ? N = 20 N ≥ 4 pCi/L = 3 Maximum = 8.6 pCi/L	Moderate? Apparent 5% ≥ R < 20%
Upper sandstone member-Butano Sandstone [Tbu](Eocene)	R = 17.7 % ? N = 17 N ≥ 4 pCi/L = 3 Maximum = 8.4 pCi/L	Moderate? Apparent 5% ≥ R < 20%
Locatelli Formation [Tl](Eocene)	R = 12.5% ?? N = 8 N ≥ 4 pCi/L = 1 Maximum = 8.5 pCi/L	Moderate?? Apparent 5% ≥ R < 20%

Table 3b. Moderate radon potential geologic units in Santa Cruz County based on 2006-2007 CDPH short-term indoor radon data
N=the number of CDPH indoor-radon data available from houses located on the geologic unit indicated in the first column of the table. ?=Increased uncertainty because N<24
* [abc] = geologic unit abbreviation
** (xxx) = geologic unit formation time period-era, period or epoch

Geologic Unit	Incidence Rate (R) of CDPH ≥ 4 pCi/L Indoor Measurements (in Percent)	Radon Potential Designation
Coastal terrace deposits, undifferentiated [Qcu]*(Pleistocene)**	R = 4.8% N = 124 N ≥ 4 pCi/L = 6 Maximum = 26.5 pCi/L	Low R < 5%
Purisima Formation [Tp](Pliocene and upper Miocene	R = 3.7 % N = 161 N ≥ 4 pCi/L = 6 Maximum = 31.5 pCi/L	Low R < 5%
Lowest emergent coastal terrace deposits [Qcl](Pleistocene)	R = 2.7% N = 521 N ≥ 4 pCi/L = 14 Maximum = 6.0 pCi/L	Low R < 5%
Terrace Deposits of Watsonville-Fluvial Facies [Qwf](Pleistocene)	R = 1.8 % ? N = 56 N ≥ 4 pCi/L = 1 Maximum = 4.3 pCi/L	Low R < 5%
Older flood-plain deposits [Qof](Holocene) or Alluvial fan facies (Pleistocene)???	R = 1.7% N = 60 N ≥ 4 pCi/L = 1 Maximum = 6.2 pCi/L	Low R < 5%
Aromas sand, undivided [Qar](Pleistocene	R = 0 % N = 25 N ≥ 4 pCi/L = 0 Maximum = 1.7 pCi/L	Low R < 5%
Terrace deposits, undifferentiated [Qt](Pleistocene)	R = 4.4% N = 23 N ≥ 4 pCi/L = 1 Maximum = 5.8	Low? Apparent R < 5%
Colluvium [Qtl](Holocene)	R = 0.0 % N = 21 N ≥ 4 pCi/L = 0 Maximum = 1.4 pCi/L	Low? Apparent R < 5%
Aromas Sand-Fluvial lithofacies [Qaf](Pleistocene)	R = 0.0 % N = 17 N ≥ 4 pCi/L = 0 Maximum = 3.2 pCi/L	Low? Apparent R < 5%

Table 3c. Low radon potential geologic units in Santa Cruz County based on 2006-2007 CDPH short-term indoor radon data N=the number of CDPH indoor-radon data available from houses located on the geologic unit indicated in the first column of the table. ?=Increased uncertainty because N<24

* [abc] = geologic unit abbreviation

** (xxx) = geologic unit formation time period-era, period or epoch

Radon Potential and the Quaternary Alluvium (Qal) Problem

Quaternary alluvium is composed of sediments derived from various rock units upslope that have been transported and deposited by running water. Its uranium and radium composition and radon potential may vary significantly from place to place within a county because the source rocks for the alluvium vary within a county. Such details in compositional variability are not conveyed by standard geologic maps, such as the USGS map for Santa Cruz County used in this study. Intuitively, Qal areas down slope of geologic units with higher percentages of houses exceeding 4 pCi/L would be suspected of having higher radon potentials than Qal areas down slope of geologic units with few or no houses exceeding 4 pCi/L. This situation exists in Santa Cruz County with more moderate or high radon potential geologic units in the northwestern part of the county and lower radon potential units in the southeastern part of the county. The indoor-radon data populations associated with Qal from both areas (Table 3d) were compared using the Mann-Whitney Rank Sum Test and found to be significantly different (P=0.006). For this reason, Qal areas east of Soquel Creek and south of the Santa Cruz Mountains will be treated as having low radon potential for mapping purposes. Other Qal areas will be treated as having moderate radon potential.

Qal Population	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Minimum pCi/L	Maximum pCi/L	Median pCi/L
Qal-northwest	107	16	15.0	0.2	21.7	1.4
Qal-southeast	19	0	0.0	0.2	3.2	0.8
All Qal	126	16	12.7	0.2	21.7	1.25

Table 3d. Comparison of indoor-radon data from Qal areas in the northwestern and southeastern parts of Santa Cruz County.

NURE PROJECT URANIUM DATA

Background

Between 1975 and 1983, the United States government funded the National Uranium Resource Evaluation (NURE) project. The goal of NURE was to identify new domestic sources (ore deposits) of uranium for energy and national defense. NURE uranium exploration activities included airborne gamma-ray spectral surveys that estimated the uranium content of soils and rocks at points along a grid of flight-lines, and (in some parts of California) the collection and laboratory analysis of soil and stream sediment samples for uranium content. Locations with unusually high uranium abundance were considered targets for additional work to determine whether or not economically recoverable uranium deposits were present.

Airborne Radiometric Data

NURE airborne radiometric data used in this study were compiled from the original digital data files by Duval (2000). Santa Cruz County is covered by parts of three NURE airborne radiometric surveys: the Santa Cruz 1X2 degree quadrangle survey; the San Francisco 1X2 degree quadrangle survey; and the San Jose 1X2 degree quadrangle survey. A total of 175.7miles of flight-line data are available for Santa Cruz County from these surveys. The flight-line grid pattern, shown in Figure 3, consists of east-west flight lines 2-4 miles apart and north-south flight lines generally about 12 miles apart. A specially equipped helicopter flew a few hundred feet above the ground at about 90 miles per hour along these flight lines and recorded 7,745 gamma-ray spectral measurements. The average distance between data measurements is about 120 feet.

One of the gamma-ray energies measured during the NURE airborne radiometric survey is generated during the decay of bismuth-214. Bismuth-214 is a radioactive daughter product of uranium-238 which forms and decays quickly after radon-222 decay. The NURE program used bismuth-214 gamma-ray data to calculate estimates of the soil-rock uranium content, in parts-per-million (ppm), at each of the 7,745 flight line measurement locations. Under the NURE flight survey conditions, each airborne uranium measurement represents the average uranium content within the upper 18 inches of surficial material (rock or soil) over an area of approximately 48,000 square feet (approximately 1.1 acres; see High-Life Helicopters, 1980a and 1980b) . Because the uranium values are calculated from bismuth-214 gamma-ray data, they are referred to as equivalent uranium (eU) data to distinguish them from uranium data determined by direct chemical methods (i.e., laboratory determinations for uranium in rock and soil samples by delayed neutron activation, fluorescence or other laboratory methods).

Soil moisture, atmospheric inversion and other conditions can negatively impact airborne eU data measurements (Grasty, 1997). Consequently, eU data are treated as qualitative to semi-quantitative indicators of areas with increased uranium in rock or soil in the Santa Cruz County radon potential study.

Figure 3 shows flight-line data locations where eU data equal or exceed 10.0 ppm and where data range from 7.5 to 9.9 ppm eU. The average uranium content of the earth’s crust is about 2.5 ppm, so 10.0 ppm or higher data are about 4 times or greater than the uranium crustal average, and 7.5 to 9.9 is about 3 to 4 times crustal average. Equivalent uranium data of ≥ 7.5 ppm are considered anomalously high in this study.

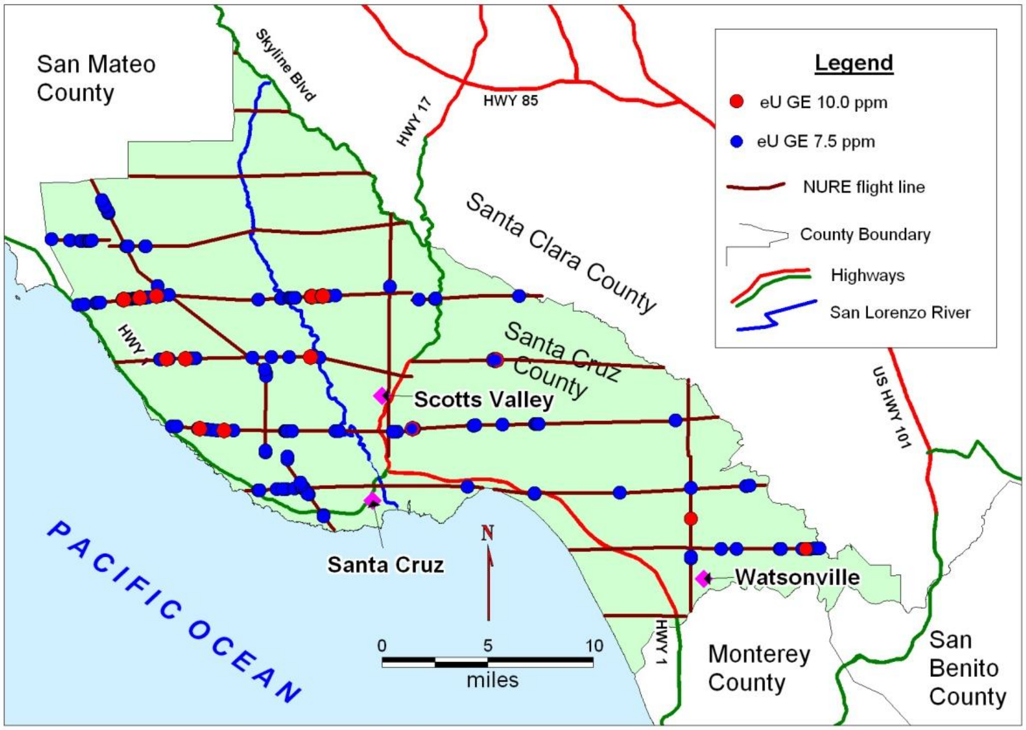

Figure 3. NURE project flight lines and elevated equivalent uranium locations

Santa Cruz County geologic units with higher percentages of ≥ 7.5 ppm eU data are assumed more likely to have houses with radon levels exceeding 4.0 pCi/L than geologic units with low percentages of ≥ 7.5 ppm eU data.

Appendices F-1, F-2, and F-3 summarize eU NURE aeroradiometric data for 52 geologic units in Santa Cruz County. These data suggest the following geologic units are more likely to have areas with elevated radon potentials (see Appendix E for geologic unit names):

- **Massive sandstone or arkosic sandstone, some of the latter with lesser amounts of siliceous shale and mudstone:** Tps, Tlo, Tsm, Tmm
- **Siliceous to semisilicious organic mudstone and sandy siltstone:** Tm, Tmp, Tsc

Note that indoor-radon data and eU data both support elevated (high or moderate) radon potentials for units: Tlo, Tm, Tsc and Tsm.

Airborne eU data in Appendix F also suggest the following geologic units are more likely to have lower radon potentials:

- **Arkosic sandstone:** Tlss
- **Shale, mudstone and arkosic sandstone with glauconitic sandstone:** Tsl, Tsr
- **Arkosic sandstone with siltstone, mudstone or shale interbeds, or lenses and interbeds of pebble and cobble conglomerate:** Tbu, Tvq, Tz
- **Laminated shale:** Tst
- **Organic mudstone containing phosphatic laminae and lenses:** Tla
- **Pyritic siltstone:** Tbm
- **Shale and sandstone (Cretaceous):** Kgs
- **Granite and adamellite:** ga
- **Quartz diorite:** qd
- **Marble:** m
- **Surficial deposits:** Qaf, Qar, Qb, Qbs, Qce, Qem, Qes, Qt, QTc, Qtl, Qwf, Qyf, Qyfo

Note that indoor-radon data and eU data both support low radon potentials for units: Qaf, Qar, Qt, and Qwf. Indoor-radon data do not support the eU data suggestions of low radon potentials for: ga, qd, Tbu, Tla and Tvq

Insufficient airborne eU data were available to rate the radon potentials of the following geologic units:

- **Micaceous siltstone:** Tl
- **Mudstone:** Tms
- **Sandy pebble conglomerate:** Tblc
- **Basalt:** Tbs
- **Surficial deposits:** Qbs, Qce, QTc

Uranium in Soil and Stream Sediment Samples

NURE project activities in Santa Cruz County also included collection of 3 soil and 25 stream sediment samples within the Santa Cruz 1X2 degree quadrangles for laboratory analysis of uranium content. Figure 4 shows NURE soil and stream sediment sample locations and groups them into two ranges of uranium abundance, sites greater than or equal to 5 ppm (GE 5 ppm) and sites less than 5 ppm (LT 5 ppm). Those sites greater than or equal to 5 ppm are two or more times the average crustal uranium abundance and have the potential for increased abundance of radon in the subsurface relative to sites where the soil uranium content is lower.

Appendix G lists the NURE soil and sediment uranium data by the geologic unit present at the sample location.

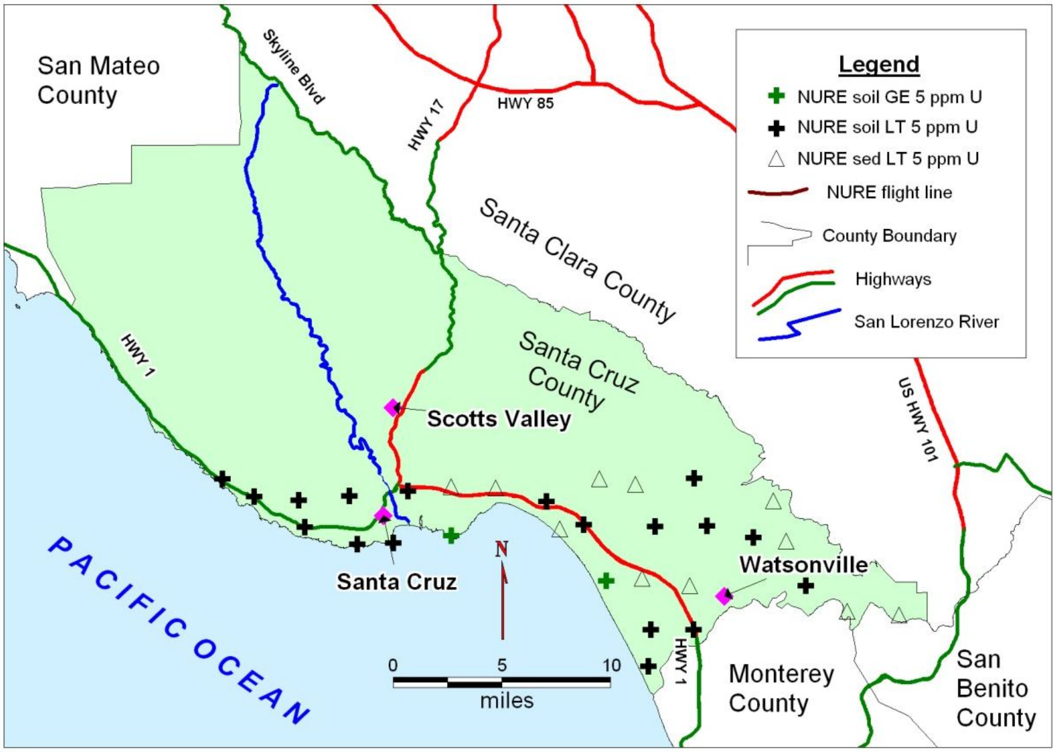

Figure 4. NURE project soil and stream sediment sample locations
GE 5 ppm U = greater than or equal to 5 ppm uranium
LT 5 ppm U = less than 5 ppm uranium

In general, soil uranium abundance is similar to that of the underlying rock from which the soil was developed (Otton, 1992), so soil uranium abundance should be somewhat representative of the radon potential of the underlying rock, barring major differences in radon emanation rates. Radon emanation is the ability of radon, once formed, to exit minerals and enter pore-space and fractures. Stream sediment uranium data are more complicated to interpret regarding their relationship to the radon potential of underlying geologic units. Stream sediment is a composite of debris derived both from rock units present at or near the sample site and farther upstream of the sample site. Consequently, stream sediment uranium abundance may be similar to the underlying bedrock, if the sediment is predominantly derived from that rock unit, or somewhat different if the sediment is predominantly derived from other rock units upstream. Detailed sediment source information is not available for the NURE data. However, sediment collected further downstream from the upstream contact of the underlying bedrock is more likely to have a greater component of sediment derived from that underlying rock type and, consequently, similar uranium abundance. For this study soil and sediment uranium analyses are considered anomalous if they equal or exceed 5.0 ppm (two times average crustal background).

Table 4a lists geologic units more likely to have elevated radon potentials, based on their highest single soil or stream sediment uranium analysis. Table 4b. lists geologic units less likely to have elevated radon levels based on their highest single soil or stream sediment uranium analysis and on relatively low median soil or stream sediment uranium values.

Geologic Unit and NURE Sample Type	Number of Samples	Median Uranium (ppm)	Highest Uranium Analysis (ppm)
Qb-soil (Basin deposits-Holocene)	2	4.2	5.9
Qem-soil (Eolian deposits of Manresa Beach-Pleistocene)	1		6.7

Table 4a. Geologic units with one or more associated NURE soil or stream sediment uranium analyses exceeding 5.0 ppm.

Geologic Unit and NURE Sample Type	**Number of Samples**	**Median Uranium (ppm)**	**Highest Uranium Analysis (ppm)**
Qcu-soil (Coastal Terrace deposits, undifferentiated, Pleistocene)	1		2.2
Qof-soil (Older flood-plain deposits, Holocene)	4	2.5	3.6
Qwf-soil (Fluvial facies, Pleistocene)	1		2.8
Qyf-soil (Younger flood-plain deposits, Holocene)	1		2.3
Qae-stream sediment (Eolian lithofacies-Aromas sand, Pleistocene)	1		3.4
Qcl-stream sediment (Lowest emerging coastal terrace deposits-Coastal terrace deposits, Pleistocene)	3	2.5	2.6
Qtl-1- stream sediment (Colluvium, Holocene)	1		3.7
Tmm- stream sediment (Sandstone of Mount Madonna area, Eocene?)	1		2.8
Tp- stream sediment (Purisima Formation (Pliocene and upper Miocene)	1		2.1
Tps- stream sediment (Predominantly massive sandstone, Pliocene and upper Miocene)	1		3.4
Ts- stream sediment (Siltstone and sandstone, Pliocene and upper Miocene)	1		2.2

Table 4b. Geologic units with all associated NURE soil or stream sediment uranium analyses less than 5.0 ppm.

SANTA CRUZ COUNTY SOIL DATA

Soil Properties and Indoor-Radon

Soil property data are sometimes useful in identifying areas with higher radon potential. Radon is more easily released from host minerals and can migrate further within higher permeability soils. In soils with low permeability, radon release and migration can be significantly restricted. Soil moisture is also an important factor. Soils exhibiting moderate to high shrink-swell character may be associated with indoor-radon problems. These soils change permeability, exhibiting low permeability during periods of precipitation and high permeability (cracks) during dry periods because they contain clays that expand or contract in relation to soil moisture content. High shrink-swell soils also stress and sometimes crack foundations, creating radon entry pathways into homes. Cracks in slabs and basement walls are pathways for radon moving from the soil into a home. However, radon is more readily released from its point of origin and may migrate further in dry soils than wet soils because it is captured (dissolved) and held in the water (Brookins, 1990, Appleton, 2005).

The Natural Resource Conservation Service (NRCS) soil map and report for Santa Cruz County by Bowman and Estrada, (http://www.ca.nrcs.usda.gov/mlra02/stcruz/index.html) were used to determine soil type at each indoor-radon radon survey site. Soil unit names and associated indoor-radon survey data are provided in Appendix H. Soil unit names, permeability, shrink/swell, depth to bedrock, a qualitative estimate of associated bedrock radon strength, and indoor-radon data are provided in Appendix I.

NRCS soil-permeability data, shrink-swell data and indoor-radon data for the houses in the CDPH Santa Cruz County radon survey are summarized in Tables 5a and 5b. Note that in Table 5a moderate permeability soils have the highest percentages of ≥ 4 pCi/L houses. Rapid to very rapid permeable soils and soils with a moderate permeable horizon overlying a moderately slow permeable horizon have relatively low percentages of ≥ 4 pCi/L houses. In Table 5b, soils with moderate or moderate over low shrink swell, and low or moderate over low shrink swell horizons have the highest percentage of ≥ 4 pCi/L houses. However, these apparent permeability, shrink-swell and indoor radon relationships do not consider the concentration of radon in the subsurface at these sites. Soils with a particular permeability or shrink-swell character may only develop in association with certain rock units. For example, a certain elevated uranium content rock unit may only weather to form a moderately permeable low shrink-swell soil. Another low uranium rock unit may only produce a low permeability high shrink-swell soil. In these examples, it would be wrong to conclude that all moderately permeability low shrink-

Soil Permeability	% all soil groups	N	N ≥ 4 pCi/L	% ≥ 4 pCi/L	Min. pCi/L	Max. pCi/L
Rapid to Very Rapid Soils						
Very Rapid	1.3	2	0	nd	0.8	0.8
Slow to very rapid	1.3	1	0	nd		0.4
Very slow to very rapid	1.3	2	0	nd	0.9	1.2
Rapid	9.3	139	6	4.3	0.2	9.9
Moderately slow to rapid	2.7	2	2	nd	5.1	26.8
Moderately Rapid Soils						
Moderately Rapid	9.3	118	14	11.9	0.2	28.5
Moderate Soils						
Moderately rapid/ Moderate	9.3	66	11	16.7	0.6	55.5
Moderately rapid; and Moderately rapid/ Moderately Slow/ Slow to Moderate	2.7	26	6	23.1	0.2	10.9
Moderately rapid/ moderate; Moderately rapid/ Moderate/Slow to Moderate	4.0	87	21	24.1	0.2	89.3
Moderate	13.3	99	11	11.1	0.2	26.3
Moderate; Moderately rapid over moderate	1.3	1	0	nd		3.5
Rapid/ slow/ moderate	1.3	2	0	nd	0.3	1.1
Moderate over Moderately Slow Soils						
Moderately rapid/ Moderately slow	5.3	243	12	4.9	0.2	6.7
Moderate over Moderately slow	8.0	111	12	10.8	0.2	21.7
Moderately slow/ Slow/ Moderately slow	2.7	42	1	2.4	0.2	4.0
Moderately Slow over Slow Soils						
Moderately rapid/ moderately slow over slow	1.3	3	0	nd	0.7	2.2
Moderate over slow	6.7	65	2	nd	0.2	5.8
Moderate/Very slow; Moderate/ Very slow/ Slow	9.3	503	10	2.0	0.2	26.5
Slow	4.0	23	0	0	0.2	3.6
Blank (no designation)	5.3	1535	108			

Table 5a Soil permeability and indoor-radon data

Data in the above table represent 75 different soil map units. Note: for soil units with multiple permeability horizons, permeability of units in the uppermost 12-16 inches were was ignored as likely to have been disturbed at house sites, subject to atmospheric dilution and unlikely to be as significant a control on radon entering a house than deeper soil horizons

Soil Characteristics*	Number	Number ≥ 4 pCi/L	Percent ≥ 4 pCi/L	Maximum pCi/L
High Shrink-Swell Soils				
High shrink-swell soils	29	1	3.5	5.8
High, High/ Moderate	81	1	2.1	22.3
Moderate/High	2	0	nd	1.9
Low/High	3	0	nd	1.2
Moderate Shrink-Swell Soils				
Moderate shrink-swell soils	525	42	8.0	31.5
High /Moderate	464	10	2.2	26.5
Moderate and Moderate/Low	87	20	23.0	89.3
Low/Moderate	2	2	nd	26.8
Moderate and Low	1	0	nd	3.5
Low Shrink-Swell Soils				
Low shrink-swell soils	309	24	7.8	55.5
Moderate/Low	5	0	nd	2.2
Low and Moderate/Low	26	6	23.1	10.9

Table 5b. Comparison of Santa Cruz County indoor-radon survey data with NRCS soil shrink-swell characteristics.

*****Soil characteristics example: “High, High/Moderate” = two soil types with different permeabilities within the soil map unit, one with high permeability throughout the horizon and one with a high permeability horizon overlying a moderate permeability horizon
**nd = no data, or insufficient data for a reliable ≥ 4 pCi/L percentage

swell soils have high radon potentials and all low permeability high shrink-swell soils have low radon potentials. To check this, indoor radon data were sorted into groups by soil permeability, shrink-swell characteristics, depth to bedrock, and likely radon potential (strong, moderate or weak) depending upon the radon potentials of the associated rock units. Summary indoor-radon information for these radon strength-soil characteristic groups is shown in Table 5c.

Not all possible combinations of radon strength and soil properties are shown in Table 5c (e.g., strong radon strength and slow permeability, or moderate radon strength and high shrink-swell) because some combinations have little or no indoor-radon data available (and some combinations may not exist in Santa Cruz County). To check the influence of permeability, shrink-swell characteristics and subsurface radon strength on indoor-radon concentrations, Table 6c shows only those soil types with bedrock at least 60 inches below the surface to minimize potential bedrock influence. Note that the highest percentages of ≥ 4 pCi/L houses are always associated with strong and moderate radon source strength areas no matter which of the three soil characteristics is considered. Note the inverse relationship between permeability and shrink-swell groups because sandy soils are higher permeability and lower

Estimated Geology Unit Rn Strength	Soil Property	Percent ≥ 4 pCi/L	Highest Indoor Rn Measurement
	Permeability (only soil units with bedrock depth > 60")		
Strong	Moderately Slow	11.9	21.7
Moderate	Moderate	7.1	8.0
Weak	Rapid	0.0	2.9
Weak	Moderately Slow	4.8	6.7
Weak	Slow Horizon over Moderately Slow Horizon	2.4	4.0
Weak	Slow	0.0	3.6
Weak	Very Slow Horizon over Slow Horizon	2.1	26.5
	Shrink-Swell Character (only soil units with bedrock depth > 60")		
Strong	Moderate	11.9	21.7
Strong	Low	6.6	9.9
Moderate	Low	11.3	9.3
Weak	High	0.0	3.6
Weak	Moderate	4.1	6.7
Weak	Low	0.0	2.9
	Depth to Bedrock		
Strong	Shallow (bedrock < 60")	19.1	89.3
Strong	Deep (bedrock > 60")	9.2	21.7
Moderate	Shallow	15.5	55.5
Moderate	Deep	8.0	8.0
Weak	Shallow	1.8	22.3
Weak	Deep	2.7	26.5

Table 5c. Comparison of estimated geologic unit radon strengths, soil permeabilities, shrink-swell characteristics, depth to bedrock and indoor-radon data.

shrink-swell and clayey soils are lower permeability and higher shrink swell. Of particular interest is that for strong and moderate subsurface radon sites, those with shallow bedrock have about twice the percentages of ≥ 4 pCi/L houses as those with deeper bedrock. One possibility for this relationship is increased dilution of subsurface radon by atmospheric air, but this would need to be confirmed by appropriate studies.

In Table 5c note that for a given radon potential, the soil properties may relate to higher or lower percentages of ≥ 4 pCi/L houses, but that the ≥ 4 pCi/L house percentages stay within the defined moderate radon potential (5.0 to 19.9%) and low radon potential ranges. For this reason, and because indoor radon data are not available for all combinations of permeability and shrink-swell characteristic soils, soil unit boundaries were not used to adjust radon zone boundaries based on indoor-radon survey data for the Santa Cruz radon potential map. However, within high and moderate radon zones areas Santa Cruz County, locations with shallow depth to bedrock may have higher ≥ 4 pCi/L house percentages than where bedrock is deeper.

RADON POTENTIAL ZONES

Final Santa Cruz County Geologic Unit Radon Potentials

Santa Cruz County radon potential zones are based on the locations of geologic units classified as having high, moderate, low or unknown radon potential. The data used for ranking Santa Cruz County geologic units are: 1) indoor-radon data; 2) NURE airborne eU data and NURE soil and sediment uranium data. NRCS soil data (permeability, shrink-swell character, and depth to bedrock) were not used in determining ranking of geologic units. This was because, although there is sometimes apparent correlation between these parameters and higher or lower incidences of ≥ 4 pCi/L indoor measurements within geologic unit areas, the correlations were not strong enough to warrant changing the radon potential of a portion of a geologic unit area to a different radon potential.

Appendix J-1contains the criteria used for low to high radon potential ranking of 52 Santa Cruz geologic units and identifies units having unknown radon potential because of insufficient data to allow ranking. Tables 6a and 6b summarize data support for geologic units ranked as having high or moderate radon potential respectively

Figure 5 shows the Santa Cruz radon zone locations, and Figure 6 shows the Santa Cruz radon zones in relationship to anomalous ≥ 4 pCi/L indoor measurements and NURE data. Tables 7a and 7b contain information about the radon data characteristics for each radon zone. Tables 8a and 8b provide information about the incidence rates of ≥ 4 pCi/L indoor measurements and the density of indoor -radon survey measurements per radon zone.

Geologic Unit (abbreviated unit names)	CDPH Indoor Radon Survey Data	NURE Airborne eU Data (% ≥ 7.5 ppm eU)	NURE Sediment and Soil Data for U; Other U data	Assigned Radon Potential
Tm-Monterey Formation	XXX	XXX(SF), nd(SJ)	nd	High
Tsr-- San Lorenzo Formation --Rices Mudstone Member-	X	---(SC), ---(SF), nd(SJ)	nd	High?
Tbm--Butano Sandstone -- Middle siltstone member	X	nd(SC), ---(SF), ---(SJ)	nd	High?
Tla-Lambert Shale	X	nd(SC), X(SF), ---(SJ)	nd	High?
ga-Granite and adamellite	X?	nd(SC), X(SF), nd(SJ)	nd	High?

Table 6a. Santa Cruz high radon potential geologic units--data supporting radon potential classification

nd = no data
XXX = data strongly support classification
X = data support classification
“-“ = data unsupportive of classification
“---“ = data strongly unsupportive of classification
? = less certain or uncertain
SC = Santa Cruz 1X2 degree quadrangle
SF = San Francisco 1X2 degree quadrangle
SJ = San Jose 1X2 degree quadrangle

Geologic Unit (abbreviated unit names)	**CDPH Indoor Radon Survey Data**	**NURE Airborne eU Data (% ≥ 7.5 ppm eU)**	**NURE Sediment and Soil Data for U; Other U data**	**Assigned Radon Potential**
qd-Quartz diorite	XXX	X?(SC), X(SF), nd(SJ)	nd	Moderate
Qal-Alluvial deposits, undifferentiated	XXX	X(SC), XXX(SF), X(SJ)	nd	Moderate (low in SE Santa Cruz County*
Tbu-Upper Sandstone Member-Butano Sandstone	X	nd(SC), ---(SF), X(SJ)	nd	Moderate
Tlo-Lompico Sandstone	XXX	XXX(SC), XXX(SF), -(SJ)	nd	Moderate
Tsc-Santa Cruz Mudstone	XXX	XXX(SC), XXX(SF), -(SJ)	nd	Moderate
Tsm-Santa Margarita Sandstone	XXX	XXX(SC), XXX(SF), nd(SF)	nd	Moderate
Tvq-Vaqueros Sandstone	XXX	nd(SC), ---(SF), ---(SJ)	nd	Moderate
sch-Metasedimentary Rocks	X	X?SC), XXX(SF), nd(SF)	nd	Moderate?
Tl-Locatelli Formation	X	nd(SC,SF,SJ)	nd	Moderate?

* See discussion of radon potential and Qal on page 17

Table 6b. Santa Cruz moderate radon potential geologic units--data supporting radon potential classification

nd = no data
XXX = data strongly support classification
X = data support classification
"-" = data unsupportive of classification
"---" = data strongly unsupportive of classification
? = less certain or uncertain
SC = Santa Cruz 1X2 degree quadrangle
SF = San Francisco 1X2 degree quadrangle
SJ = San Jose 1X2 degree quadrangle

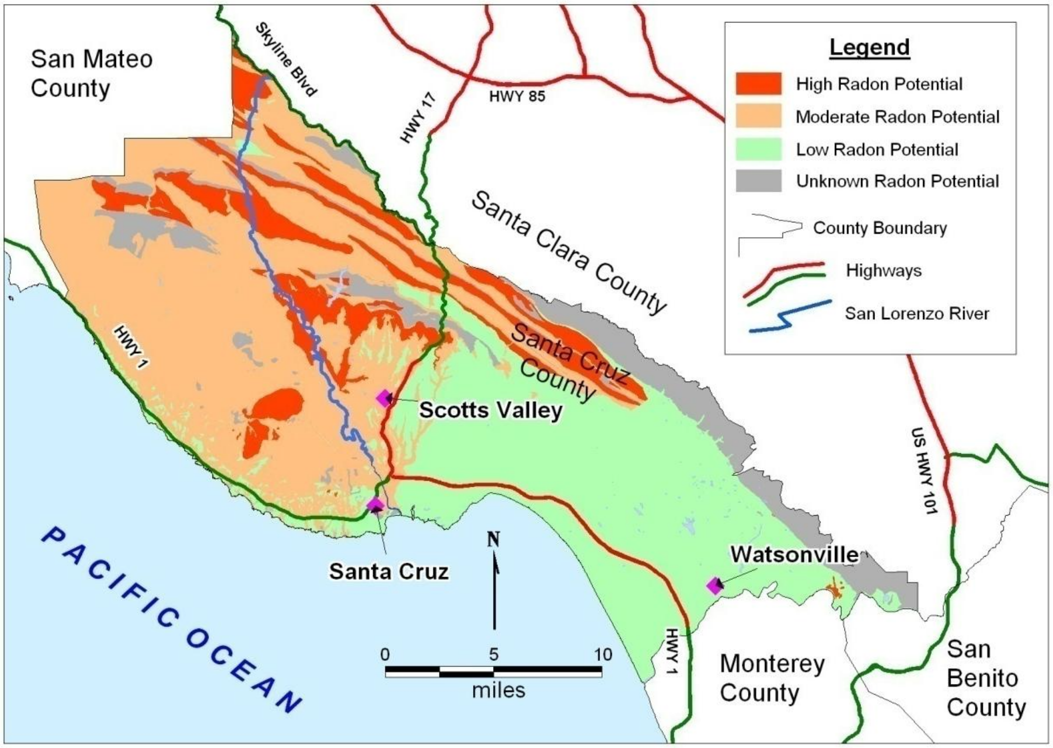

Figure 5. Santa Cruz County radon potential zones

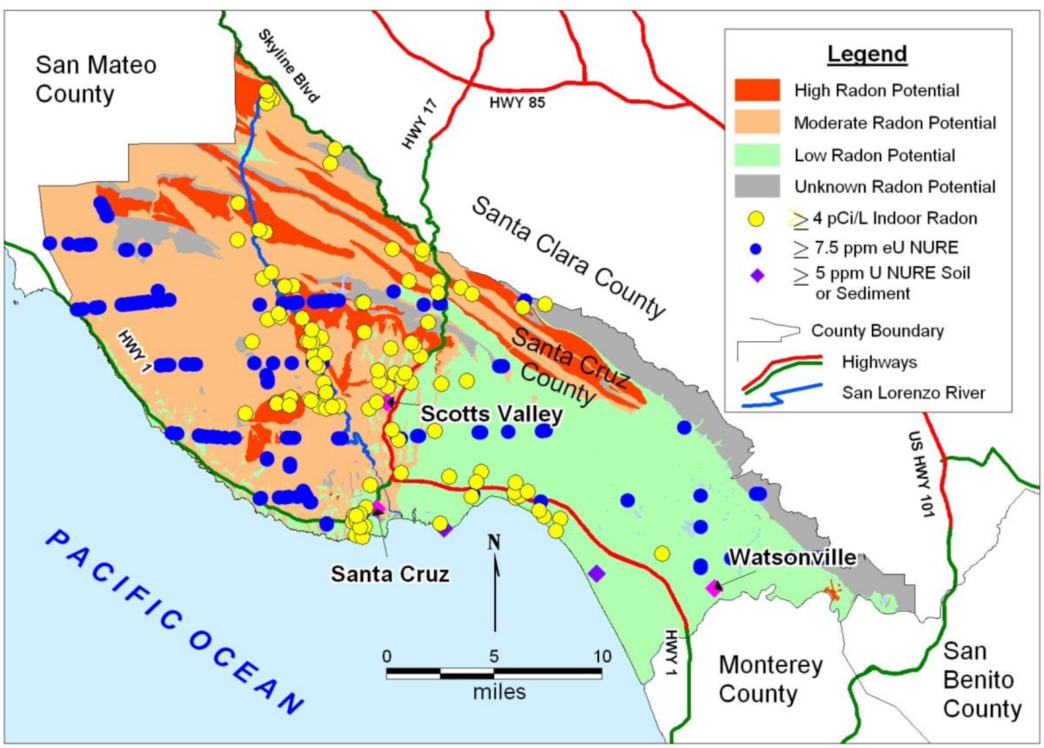

Figure 6. Santa Cruz County radon zones with supporting elevated indoor-radon survey data and NURE project data

Zone	n	Median pCi/L	pCi/L at 25%	pCi/L at 75%	Min pCi/L	Max pCi/L
High	80	2.7	1.5	7.6	0.2	89.3
Moderate	405	1.4	0.8	2.63	0.2	28.5
Low	1,042	0.8	0.4	1.4	0.2	31.5
Unknown*	12	1.6	0.8	3.25	0.2	55.5
All	1,548	1.85	0.9	1.8	0.2	89.3

*Only 12 of the 20 geologic units with unknown radon potential have indoor-radon measurements

Table 7a. Radon Zone data characteristics

Zone	n	n ≥ 4.0 pCi/L	% data ≥ 4.0 pCi/L	n ≥ 10.0 pCi/L	% ≥ 10.0 pCi/L	n ≥ 20.0 pCi/L	% ≥ 20.0 pCi/L	Area (sq-mi) land only
High	80	29	36.3	13	16.3	7	8.8	47.3
Moderate	405	47	11.6	7	1.7	3	0.74	187.7
Low	1,042	29	2.8	4	0.38	3	0.29	163.2
Unknown*	12	3	25.0	2	16.7	1	8.3	47.8
All	1,539	108	7.0	26	1.7	14	0.91	446.0

*Only 12 of the 20 geologic units with unknown radon potential have indoor-radon measurements

Table 7b. n ≥ 4.0 pCi/L incidence per radon potential zone

Zone	% of all n ≥ 4.0 pCi/L	% of all n ≥ 10.0 pCi/L	% of all n ≥ 20.0 pCi/L	% Area	Cumulative % of % of ≥ 4.0 pCi/L	Cumulative % of Santa Cruz County
High	26.9	50.0	50.0	10.6	26.9	10.6
Moderate	43.5	26.9	21.4	42.1	70.4	52.7
Low	26.9	15.4	21.4	36.6	97.3	89.3
Unknown*	2.8	7.7	7.1	10.7	100.1*	100.0
All	100.1**	100.0	99.9**			

*Only 12 of the 20 geologic units with unknown radon potential have indoor-radon measurements
**Does not sum to 100.0% due to rounding error

Table 8a. ≥ 4.0 pCi/L incidence rates for Santa Cruz County by radon potential zone

Zone	Average Rate: n ≥ 4.0 pCi/L measurements per square mile	Average Rate: All measurements per square mile
High	0.6131	1.6913
Moderate	0.2513	2.1577
Low	0.1777	6.3848
Unknown*	0.0628	0.2510
All	0.2422	3.4507

*Only 12 of the 20 geologic units with unknown radon potential have indoor-radon measurements

Table 8b. Radon data distribution by radon potential zone

RADON POTENTIAL ZONE STATISTICS

Indoor-Radon Measurement Data Characteristics

Descriptive statistics of indoor-radon survey data for each radon potential zone, non-transformed and log transformed, are provided in Appendix K and Appendix L.

Indoor-Radon Measurement Frequency Distributions

Frequency distributions of trace elements, such as uranium and radon, in rocks and soils are often approximated using the lognormal distribution. However, because of the variety of geologic units and complex history of processes affecting them, geochemical data such as radon data cannot always be fit to a specific frequency distribution (Rose and others, 1979, p. 33). The indoor radon data for Santa Cruz County are an example of this situation. Taken as a whole, the indoor radon test data from the CDPH Santa Cruz survey fail the Kolmogorov-Smirnov normality test in both untransformed and log-transformed modes (Appendix M). Consequently, the data population (of 1,539 measurements) is neither normally nor lognormally distributed. These data may be non-normally distributed because they are a combination of samples from several different populations--each rock unit radon population having its own unique distribution. On an individual basis, the rock unit radon populations may be lognormal, but the aggregate population is not lognormal.

Data non-normality has important implications for certain statistical operations. For example, T-test comparisons should not be used for comparing non-normal (non-parametric) populations. For this reason, the Mann-Whitney rank sum test is used for comparisons of sub-populations of the indoor-radon test data by radon zone in this study. The Mann-Whitney comparison results for the radon potential zones are discussed in the following section. Non-normality may also have negative consequences for predictions of percentages of homes with indoor radon levels exceeding 4.0 pCi/L where such predictions incorrectly assume a lognormal population distribution for radon data.

Statistical Comparison of Indoor Radon Data by Radon Potential Zone

The results of the statistical comparisons of indoor-radon data for Santa Cruz County High, Moderate and Low radon potential zones are listed in Appendix N. the indoor-radon data population for each radon potential zone is statistically distinct according to the Mann-Whitney rank sum test. This result, along with the medians for each radon zone population decreasing in rank order (high> moderate> low) is statistical evidence supporting the validity of the Santa Cruz County radon potential zone definitions.

Estimated Population Exposed to 4.0 pCi/L Radon or Greater Indoor air in Santa Cruz County.

Population estimated for each radon potential zone were obtained utilizing GIS methods to overlay Santa Cruz radon potential zones with 2000 census tract data (U.S. Census, 2000). For a census tract not completely within a radon potential zone, the population contribution from that tract was considered equal to the percentage area of the tract within the radon zone. Table 9 lists the resulting population estimates and estimated number of homes for the different radon potential zones. Table 10 contains population estimates for each radon potential zone and estimates for individuals exposed to ≥ 4.0 pCi/L, ≥ 10.0 pCi/L, and ≥ 20.0 pCi/L indoor radon concentrations. These estimates are based on the population estimated for each zone multiplied by the ≥ 4.0 pCi/L, ≥ 10.0 pCi/L, and ≥ 20.0 pCi/L percentages for each zone from Table 7b.

Table 10 contains two groups of population totals. Totals in the row titled “Population Estimates weighted by...” is obtained by summing the data for the individual radon zones. Totals in the row titled “Population Estimates by proportion...” are obtained by taking the total Santa Cruz County population and multiplying it by the percentages of CDPH Santa Cruz radon survey data that exceed ≥ 4.0 pCi/L, ≥ 10.0 pCi/L, and ≥ 20.0 pCi/L. These calculated results are designated with an (*). An estimate of the population exposed to ≥ 4.0 pCi/L indoor-radon levels derived from the percentage of ≥ 4.0 pCi/L measurements in the CDPH Zip Code database for Zip Codes in Santa Cruz County is also included and designated by a (**). The weighted and unweighted estimates for the Santa Cruz population exposed to various indoor-radon concentrations are similar in magnitude.

Radon Potential Zone	Estimated Total Population within Zone--2000 Census Statistics	Estimated Total Homes within Zone--2000 Census Statistics	
Santa Cruz County		Average Household Population*	Homes**
High	10,033	2.597	3,863
Moderate	55,938	2.485	22,510
Low	179,333	2.843	63,079
Unknown	10,302	2.682	3,841
Total	255,606	2.740	93,293

Table 9. Population and home estimates by radon potential zone
*Estimated using 2000 Census Tract Data and the Santa Cruz Area Radon Potential Zone Map. **Zone population ÷ average household population

Radon Potential Zone	Estimated Total Population for Zone	Estimated Population at ≥ 4.0 pCi/L Conditions	Estimated Population at ≥ 10.0 pCi/L Conditions	Estimated Population at ≥ 20.0 pCi/L Conditions	% Area	Sq. miles
High	10,033	3,642 36.3%	1,635 16.3%	883 8.8%	10.6	47.3
Moderate	55,938	6,489 11.6%	951 1.7%	414 0.74%	42.1	187.7
Low	179,333	5,021 2.8%	664 0.37%	520 0.29%	36.6	163.2
Unknown	10,302	2,060 20.0%	1,720 16.7%	855 8.3%	10.7	47.8
Population Estimate Weighted by Radon Zone and Population Distribution						
Totals (*weighted, i.e., sum of zone population estimates*)	255,606	17,212 (6.7%)	4,970 (1.9%)	2,672 (1.1%)	100.0	446.0
Population Estimate by Proportion to Radon survey Results Without Regard to Radon Zone or Population Distribution						
Totals for Santa Cruz County	255,606	17,895* (7.0%) 15,848** (6.2%)	4,345* (1.7%)	2,326* (0.91%)	100.0	446.0

Table 10. Estimates of Santa Cruz County population exposed to 4.0 pCi/L or greater indoor radon levels in residences (based on 2000 U.S. Census Data)

*estimated using 2006-2007 CDPH indoor-radon survey data

**estimated using CDPH Zip Code data for Santa Cruz County Zip Codes

SANTA CRUZ COUNTY RADON MAPPING PROJECT SUMMARY AND RECOMMENDATIONS

Procedures and Results

Short-term radon test data from CDPH, NURE project airborne radiometric data, NURE soil and stream sediment data were used to identify geologic units with relatively higher or lower radon potential in the Santa Cruz area. Geologic units were classified as having high, moderate, low or unknown radon potential based on the percentage of 4.0 pCi/L or higher indoor-radon measurements, the presence of anomalous airborne radiometric data for uranium, and the presence of soil and stream sediment whole rock uranium data exceeding 5.0 ppm.

The Final radon potential zones have the following characteristics:

High Radon Potential Zone: this zone comprises 10.6 percent (47.3 square miles) of Santa Cruz County and contains 26.9 percent of the ≥ 4.0 pCi/L measurements and 50 percent of the ≥ 20.0 pCi/L measurements in the Santa Cruz CDPH survey. The maximum radon measurement for this zone is 89.3 pCi/L (in a garage on a slab foundation). The maximum radon survey measurement for a room normally occupied in a home was 26.8 pCi/L (for a first floor bedroom in a multi-level house).

Moderate Radon Potential Zone: this zone comprises 42.1 percent (187.7 square miles) of Santa Cruz County and contains 43.5 percent of the ≥ 4.0 pCi/L measurements and 21.4 percent of the ≥ 20.0 pCi/L measurements in the Santa Cruz CDPH survey. The maximum radon survey measurement for a home in this zone was 28.5 pCi/L (for a first floor room in a house on a slab foundation).

Low Radon Potential Zone: this zone comprises 36.6 percent (163.2 square miles) of Santa Cruz County and contains 26.9 percent of the ≥ 4.0 pCi/L measurements and 21.4 percent of the ≥ 20.0 pCi/L measurements in the Santa Cruz CDPH survey. The maximum radon survey measurement for a home in this zone was 31.5 pCi/L (for a first floor living room in a multi-level house).

Unknown Radon Potential Zone: this zone comprises 10.7 percent (47.8 square miles) of Santa Cruz County. The CDPH indoor-radon survey was only able to obtain a total of 12 indoor radon measurements from 7 of the 20 geologic units within this zone. This zone contains 2.8 percent of the ≥ 4.0 pCi/L measurements and 7.1 percent of the ≥ 20.0 pCi/L measurements in the Santa Cruz CDPH survey. The maximum radon measurement for this zone is 55.5 pCi/L (in a pantry). A basement family room in a multi-level house tested 11.6 pCi/L. These results suggest moderate or high radon potential areas may be present in this zone.

Every radon zone contains short-term indoor-radon measurements equal to or above 4.0 pCi/L as well as below 4.0 pCi/L. The maximum measurement for each zone is: High, 89.3 pCi/L; Moderate, 28.5 pCi/L; Low, 31.5 pCi/L; and Unknown, 55.5 pCi/L.

Statistical comparison of the indoor radon data populations for the High, Moderate, and Low radon potential zones, using the Mann-Whitney rank sum test, shows the zones differ from each other statistically. Note the P values for these tests (the probability of being wrong in concluding that there is a true difference between groups) listed in Appendix O is less than 0.001. This is strong statistical support for the different Santa Cruz radon potential zones representing distinct groups of indoor-radon potentials.

Recommendations

Indoor-radon testing should be encouraged in Santa Cruz County as high and moderate radon potential zones account for 52.5 percent of the county. Additional indoor-radon measurements within unknown potential areas should be encouraged because 3 of the twelve available measurements for this zone exceed 4.0 pCi/L and one of these is 55.5 pCi/L.

Those considering new home construction, particularly at sites within high radon potential areas, may wish to consider radon resistant new construction practices. Post construction radon mitigation is still possible, if necessary, but will be more expensive than the cost of adding radon reducing features during house construction.

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Milton Fonseca (CGS) produced the final GIS file of the Santa Cruz County Radon Potential Map and provided GIS support during the development of this map and report. John Clinkenbeard (CGS) reviewed the map and report and provided helpful suggestions to improve the text. George Faggella, CDPHRP, provided information about the Santa Cruz indoor-radon survey and test results, survey QA/QC information, and helpful discussions throughout this project.

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APPENDIX A

Concurrent Indoor-Radon Test Data--In decreasing order by pCi/L

High (pCi/L)	Low (pCi/L)	Difference (pCi/L)	Percent Difference*
9.6	8.6	1.0	10.4
5.6	5.2	0.4	7.1
5.0	4.3	0.7	14.0
3.5	3.1	0.4	11.4
3.5	3.4	0.1	2.9
3.1	1.0	2.1	67.7
3.1	1.3	2.2	71.0
3.1	2.1	1.0	32.3
3.1	3.0	0.1	3.2
3.0	1.2	1.8	60.0
2.8	2.6	0.2	7.1
2.6	2.3	0.3	11.5
2.5	2.5	0.0	0.0
2.4	2.0	0.4	16.7
2.2	2.0	0.2	9.1
2.2	2.0	0.2	9.1
2.1	1.5	0.6	28.6
2.1	1.8	0.3	14.3
1.9	0.8	1.1	57.9
1.9	0.9	1.0	52.6
1.9	1.4	0.5	26.3
1.8	0.2	1.6	88.9
1.8	0.7	1.1	38.9
1.8	0.9	0.9	50.0
1.8	1.2	0.6	33.3
1.8	1.4	0.4	22.2
1.8	1.4	0.4	22.2
1.8	1.6	0.2	11.1
1.8	1.7	0.1	5.6
1.7	1.6	0.1	0.6
1.7	1.6	0.1	5.9
1.6	0.9	0.7	43.8
1.5	0.4	1.1	73.3
1.5	0.8	0.7	46.7
1.5	1.0	0.5	33.3
1.5	1.5	0.0	0.0
1.5	1.5	0.0	0.0
1.4	0.2	1.2	85.7
1.4	0.3	1.1	78.6
1.4	0.7	0.7	50.0
1.4	1.0	0.3	21.4
1.4	1.0	0.4	28.6
1.4	1.0	0.4	28.6

High (pCi/L)	Low (pCi/L)	Difference (pCi/L)	Percent Difference*
1.4	1.1	0.3	21.4
1.3	0.3	1.0	76.9
1.3	0.6	0.7	53.9
1.3	0.6	0.7	53.9
1.3	0.7	0.6	46.2
1.3	1.0	0.3	23.1
1.3	1.1	0.2	15.4
1.3	1.1	0.2	15.4
1.3	1.3	0.0	0.0
1.2	0.2	0.8	66.7
1.2	0.7	0.5	41.7
1.2	1.0	0.2	16.7
1.1	0.6	0.5	45.5
1.1	0.6	0.5	36.4
1.1	0.7	0.4	36.4
1.1	0.8	0.3	27.3
1.0	0.2	0.8	80.0
1.0	0.5	0.5	50.0
1.0	0.6	0.4	40.0
1.0	0.6	0.4	40.0
1.0	0.6	0.4	40.0
1.0	0.7	0.3	30.0
1.0	0.8	0.2	20.0
1.0	0.8	0.2	20.0
1.0	0.9	0.1	10.0
0.9	0.3	0.6	66.7
0.9	0.3	0.6	66.7
0.9	0.4	0.5	55.6
0.9	0.4	0.5	55.6
0.9	0.9	0.0	0.0
0.8	0.2	0.6	75.0
0.8	0.2	0.6	75.0
0.8	0.2	0.6	75.0
0.8	0.3	0.5	62.5
0.8	0.3	0.5	62.5
0.8	0.3	0.5	62.5
0.8	0.4	0.4	50.0
0.8	0.5	0.3	37.5
0.8	0.5	0.3	37.5
0.8	0.5	0.3	37.5
0.8	0.5	0.3	37.5
0.8	0.5	0.3	37.5
0.8	0.6	0.2	25.0
0.8	0.6	0.2	25.0
0.7	0.2	0.5	71.4
0.7	0.3	0.4	57.1
0.7	0.4	0.3	42.9

High (pCi/L)	**Low (pCi/L)**	**Difference (pCi/L)**	**Percent Difference***
0.7	0.4	0.3	42.9
0.7	0.5	0.2	28.6
0.7	0.5	0.2	28.6
0.7	0.6	0.1	14.3
0.6	0.4	0.2	33.3
0.6	0.4	0.2	33.3
0.6	0.5	0.1	16.7
0.5	0.2	0.3	60.0
0.5	0.2	0.3	60.0
0.5	0.3	0.2	40.0
0.5	0.4	0.1	20.0
0.5	0.5	0.0	0.0
0.5	0.5	0.0	0.0
0.4	0.2	0.2	50.0
0.4	0.2	0.2	50.0
0.4	0.4	0.0	33.3
0.3	0.2	0.1	33.3
0.2	0.2	0.0	0.0

* Percent Difference = Difference ÷ HighX100

APPENDIX B

Charcoal Detector Field Blanks

Date Analyzed	Results pCi/L
12/27/2006	<0.5
12/22/2006	0.2
12/27/2006	<0.5
12/22/2006	<0.5
12/22/2006	<0.5
12/27/2006	<0.5
--	error
12/27/2006	<0.5
12/27/2006	0.7
12/27/2006	<0.5

APPENDIX C

Laboratory Spikes of Charcoal Detectors

Charcoal detectors were exposed for 2-days (ending 11/29/2006) at 21.9 degrees C and 45.3 percent mean relative humidity						
Date	**Mean Chamber Radon Conc. pCi/L***	**Test Result pCi/L**	**Difference from Mean Chamber Conc. pCi/L**	**Minimum Chamber Conc. pCi/L**	**Maximum Chamber Conc. pCi/L**	**Test result within 10% of the Maximum and Minimum Radon Concentrations for the Chamber?**
12/5/06	6.0	6.4	0.4	5.4	6.5	Yes
12/5/06	6.0	7.0	1.0	5.4	6.5	Yes
12/5/06	6.0	6.5	0.5	5.4	6.5	Yes
12/5/06	6.0	4.3	1.7	5.4	6.5	No
12/5/06	6.0	5.3	0.7	5.4	6.5	Yes
12/5/06	6.0	6.6	0.6	5.4	6.5	Yes
12/5/06	6.0	6.4	0.4	5.4	6.5	Yes
12/5/06	6.0	5.7	0.3	5.4	6.5	Yes

* Minimum chamber concentration 5.4 pCi/L; Maximum chamber concentration 6.5 pCi/l

APPENDIX D

Results of Follow-up Tests in Homes

Test 1 (pCi/L)	Test 2 pCi/L)	Difference (pCi/L)	Percent Difference*	Days Between Tests	Dates Test 1	Dates Test 2
25.5	11.5	14.0	54.9	73	2/6/07	4/20/07
14.3	5.8	8.5	59.4	68	1/18/07	3/27/07
13.6	15.1	-1.5	-9.9	31	1/15/07	2/15/07
12.3	11.4	0.9	7.3	56	1/25/07	3/22/07
9.7	5	4.7	48.5	55	1/26/07	3/22/07
8.4	5.2	3.2	38.1	301	1/20/07	11/17/07
8.2***	6.8	1.4	17.1	20	1/12/07	2/1/07
8.2***	5	3.2	39.0	280	1/12/07	10/19/07
8.2***	5	3.2	39.0	301	1/12/07	11/9/07
8.2***	4.3	3.9	90.7	301	1/12/07	11/9/07
8.2***	3.1	5.1	62.2	301	1/12/07	11/9/07
8.2***	1.0	7.2	87.8	301	1/12/07	11/9/07
6.8***	5.0	3.8	55.9	255	2/1/07	10/14/07
6.8	11.0	-4.2	-38.2	41	1/18/07	2/28/07
3.2	1.0	2.2	68.8	13	1/26/07	2/8/07
3.1	3.8	-0.7	-20.2	291	1/23/07	11/10/07
2.9	6.0	-3.1	-51.7	68	1/10/07	3/19/07
2.4**	1.8	0.6	25.0	88	1/22/07	4/20/07
2.4**	1.4	1.0	41.7	88	1/22/07	4/20/07
2.4**	0.7	1.7	70.8	88	1/22/07	4/20/07
2.4**	0.2	2.2	91.7	88	1/22/07	4/20/07
0.6	0.5	0.1	16.7	3	1/16/07	1/19/07
0.5	0.5	0.0	0.0	17	1/5/07	1/22/07

*Percent Difference = Difference ÷ the higher of Test 1 or Test 2
** Multiple measurements at a house
*** Multiple measurements at a house

APPENDIX E

Geologic Map Units and Indoor Radon Data for Santa Cruz County

Geo Unit Description [unit symbol] (Age)	**N**	**N≥4 pCi/L**	**R (%)**	**Low pCi/L**	**High pCi/L**	**Cities**	**Zip Codes**
Granite and adamellite [ga](Cretaceous)	12	4	33.3?	1	10.3	Santa Cruz	95060
Hornblende-cummingtonite gabbro [hcg](Cretaceous)	2	1		3.2	11.6	Santa Cruz	95060
Shale and sandstone of Nibbs Knob area [Kgs](Upper Cretaceous)	2	1		0.9	55.5	Los Gatos	95033
Marble [m](Mesozoic or Paleozoic)	1	0			1.1	Santa Cruz	95060
Aromas sand--Eolian lithofacies [Qae](Pleistocene)	14	0	0?	0.2	2.1	Aptos, Watsonville	95003, 95076
Aromas sand--Fluvial lithofacies [Qaf](Pleistocene)	17	0	0?	0.2	3.2	Aptos, Watsonville	95003, 95076
Alluvial deposits, undifferentiated [Qal](Holocene)	127	16	12.6	0.2	21.7	Aptos, Ben Lomond, Boulder Creek, Capitola, Davenport, Felton, Santa Cruz, Scotts Valley, Soquel, Watsonville	95003,95005, 95006, 95010, 95017, 95018, 95060, 95062, 95065, 95066, 95073, 95076
Aromas sand, undivided [Qar](Pleistocene)	25	0	0	0.2	1.7	Aptos, Watsonville	95003, 95076
Basin deposits [Qb](Holocene)	5	0		0.5	1.3	Santa Cruz, Watsonville	95060, 95062, 95076

Geo Unit Description [unit symbol] (Age)	**N**	**N≥4 pCi/L**	**R (%)**	**Low pCi/L**	**High pCi/L**	**Cities**	**Zip Codes**
Coastal terrace deposits-- Eolian facies [Qce](Pleistocene)	1	0			0.6	Watsonville	95076
Coastal Terrace Deposits--Lowest emergent coastal terrace deposits [Qcl](Pleistocene)	521	14	2.7	0.2	6.0	Aptos, Capitola, Davenport, La Selva Beach, Santa Cruz, Soquel, Watsonville	95003, 95010, 95017, 95076, 95060, 95062, 95065, 95073, 95076
Coastal terrace deposits, undifferentiated [Qcu](Pleistocene)	124	6	4.8	0.2	26.5	Aptos, Santa Cruz, Soquel	95003, 95060, 95064, 95065, 95073
Quartz diorite [qd](Cretaceous)	26	4	15.4	0.2	8.8	Ben Lomond, Boulder Creek, Felton, Santa Cruz, Scotts Valley	95005, 95006, 95018, 95060, 95066
Eolian deposits of Manresa Beach [Qem](Pleistocene)	1	0			1.5	Watsonville	95076
Eolian deposits of Sunset Beach [Qes](Pleistocene)	3	0		0.2	0.8	Watsonville	95076
Older flood-plain deposits (Holocene) [Qof] or Terrace Deposits of Watsonville--Alluvial fan facies [Qof] (Pleistocene)???	60	1	1.7	0.2	6.2	Aptos, Capitola, Soquel, Watsonville	95003, 95010, 95073, 95076
Terrace deposits, undifferentiated [Qt](Pleistocene)	23	1	4.4	0.2	5.8	Aptos, Santa Cruz, Watsonville	95003, 95060, 95076
Continental deposits, undifferentiated [QTc](Pleistocene and Pliocene?)	1				0.9	Watsonville	95076
Colluvium [Qtl](Holocene)	21	0	0?	0.2	1.4	Aptos, Soquel, Watsonville	95003, 95073, 95076

46 CALIFORNIA GEOLOGICAL SURVEY SR 216

Geo Unit Description [unit symbol] (Age)	**N**	**N≥4 pCi/L**	**R (%)**	**Low pCi/L**	**High pCi/L**	**Cities**	**Zip Codes**
Terrace deposits of Watsonville--Fluvial facies [Qwf](Pleistocene)	56	1	1.8	0.2	4.3	Freedom, Watsonville	95019, 95076
Younger flood-plain deposits [Qyf](Holocene)	3			0.2	1.1	Watsonville	95076
Alluvial fan deposits [Qyfo](Holocene)	2	0		0.6	2.2	Watsonville	95076
Metasedimentary rocks [sch](Mesozoic or Paleozoic)	19	3	15.8?	0.2	8.6	Felton, Santa Cruz	95018, 95060
Butano Sandstone--Conglomerate [Tblc](Eocene)	4	1		0.2	4.5	Scotts Valley	95066
Butano Sandstone--Middle siltstone member [Tbm](Eocene)	14	3	21.4?	0.6	31.2	Los Gatos	95033
Butano Sandstone--Upper sandstone member [Tbu](Eocene)	17	3	17.7?	0.3	8.4	Boulder Creek, Felton, Los Gatos	95006, 95018, 95033
Locatelli Formation [Tl](Paleocene)	8	1	12.5?	0.3	8.5	Felton	95018
Lambert Shale [Tla](lower Miocene)	8	6	75.0?	1.4	26.8	Los Gatos	95033
Lompico Sandstone [Tlo](middle Miocene)	29	4	13.8	0.2	9.6	Ben Lomond, Boulder Creek, Felton, Santa Cruz	95005, 95006, 95018, 95065
Monterey Formation [Tm](middle Miocene)	25	9	36.0	0.2	89.3	Ben Lomond, Boulder Creek, Felton, Scotts Valley	95005, 95006, 95018, 95066

Geo Unit Description [unit symbol] (Age)	**N**	**N≥4 pCi/L**	**R (%)**	**Low pCi/L**	**High pCi/L**	**Cities**	**Zip Codes**
Shale of Mount Pajaro area [Tmp](Miocene and Oligocene)	3			0.2	3.3	Watsonville	95076
Purisima Formation [Tp](Pliocene and upper Miocene)	161	5	3.1	0.2	31.5	Aptos, Santa Cruz, Scotts Valley, Soquel, Watsonville	95003, 95060, 95062, 95065, 95066, 95073, 95076
Purisima Formation--Predominantly massive sandstone [Tps]	1				2.9	Watsonville	95076
Santa Cruz Mudstone [Tsc](Upper Miocene)	28	5	17.9	0.2	21.4	Santa Cruz, Scotts Valley	95060, 95065, 95066
San Lorenzo Formation, undivided [Tsl](Oligocene and Eocene)	1				0.8	Los Gatos	95033
Santa Margarita Sandstone [Tsm](upper Miocene)	111	7	6.3	0.2	9.9	Ben Lomond, Boulder Creek, Felton, Santa Cruz, Scotts Valley	95005, 95006, 95018, 95060, 95066
San Lorenzo Formation--Rices Mudstone Member [Tsr](Oligocene and Eocene)	21	7	33.3	0.2	11.0	Boulder Creek, Los Gatos	95006, 95033
Vaqueros Sandstone [Tvq](lower Miocene and Oligocene)	39	4	10.3	0.2	28.5	Boulder Creek, Los Gatos	95006, 95033
Zayanite Sandstone [Tz](Oligocene)	1				0.3	Felton	95018

39 geologic units of the 52 geologic units in Santa Cruz County have indoor-radon data

APPENDIX F-1

Santa Cruz 1X2 Degree Quadrangle NURE Airborne Radiometric Survey Equivalent Uranium (eU) Data for Santa Cruz County

Geologic Unit Symbol	Geologic Unit Name	N	N ≥ 7.5 ppm eU	% ≥ 7.5 ppm eU	Low ppm eU	High ppm eU	Median ppm eU
ga	Granite and adamellite (Cretaceous)	8	0	0	2.2	4.7	4.05
m	marble (Mesozoic or Paleozoic)	15	0	0	2	7.2	4.2
Qae	Aromas Sand-Eolian lithofacies (Pleistocene)	19	0	0	0.1	4.9	2.3
Qaf	Aromas Sand-Fluvial lithofacies (Pleistocene)	269	2	0.7	-0.5	7.7	3.1
Qal	Alluvial deposits, undifferentiated (Holocene)	78	0	0	1.1	7.1	3.85
Qar	Aromas Sand-undivided (Pleistocene)	71	0	0	0.2	6.1	2.7
Qb	Basin deposits (Holocene)	32	0	0	1.1	7.2	4.65
Qbs	Beach sand (Holocene)	12	0	0	2.1	5.8	4.35
Qce	Coastal terrace deposits-Eolian facies Pleistocene)	13	0	0	-0.6	4.2	2.7
Qcl	Lowest emergent coastal terrace deposits (Pleistocene)	195	1	0.5	0.2	7.7	3.5
Qcu	Coastal terrace deposits, undifferentiated (Pleistocene)	178	3	1.7	0.5	8.6	4.0
qd	Quartz diorite (Cretaceous)	10	0	0	1.5	6	4.6
Qem	Eolian deposits of Manresa Beach (Pleistocene)	13	0	0	1.7	5.8	4.2
Qes	Eolian deposits of Sunset Beach (Pleistocene)	49	0	0	0.8	6.9	3.3
Qof	Older flood-plain deposits (Holocene)	242	4	1.7	-0.2	7.9	3.4
Qt	Terrace deposits, undifferentiated (Pleistocene)	14	0	0	2.1	6.6	4.6

Geologic Unit Symbol	Geologic Unit Name	N	N ≥ 7.5 ppm eU	% ≥ 7.5 ppm eU	Low ppm eU	High ppm eU	Median ppm eU
QTc	Continental deposits, undifferentiated (Pleistocene and Pliocene?)	5	0	0	0.5	4.3	2.7
Qtl	Colluvium (Holocene)	36	0	0	-0.8	6	2.75
Qwf	Terrace deposits of Watsonville-Fluvial facies (Pleistocene)	221	2	0.9	-0.6	18	3.3
Qyf	Younger flood-plain deposits (Holocene)	100	0	0	1.5	6.4	3.6
Qyfo	Alluvial fan deposits (Holocene)	38	0	0	1.3	7.4	4.0
sch	Metasedimentary rocks (Mesozoic or Paleozoic)	18	0	0	2.2	6.8	4.35
Tlo	Lompico Sandstone (middle Miocene)	28	3	10.7	1	8.5	5.2
Tmm	Sandstone of Mount Madonna area (Eocene?)	24	2	8.3	0.5	9.2	4.25
Tmp	Shale of Mount Pajaro area (Miocene and Oligocene)	60	11	18.3	1.8	10	5.95
Tp	Purisima Formation (Pliocene and upper Miocene)	73	3	4.1	0.4	9.6	3.7
Tps	Purisima Formation-Predominantly massive sandstone (Pliocene and upper Miocene)	20	2	10.0	4	8.1	5.2
Tsc	Santa Cruz Mudstone (upper Miocene)	113	8	7.1	1.7	9.8	4.6
Tsm	Santa Margarita Sandstone (upper Miocene)	45	4	8.9	-0.4	9.5	4.6

Unit symbols and names reference: USGS OFR 97-489

APPENDIX F-2

San Francisco 1X2 Degree Quadrangle NURE Airborne Radiometric Survey Equivalent Uranium (eU) Data for Santa Cruz County

Geologic Unit Symbol	Geologic Unit Name	N	N ≥ 7.5 ppm eU	% ≥ 7.5 ppm eU	Low ppm eU	High ppm eU	Median ppm eU
ga	Granite and adamellite (Cretaceous)	68	0	0	-0.1	6.3	2.8
gd	Gneissic granodiorite (Cretaceous)	31	1	3.2	0.4	7.6	4.9
Qal	Alluvial deposits, undifferentiated (Holocene)	114	4	3.5	0.4	9.4	4.3
Qcl	Lowest emergent coastal terrace deposits (Pleistocene)	17	1	5.9	0.4	8.3	4.6
Qcu	Coastal terrace deposits, undifferentiated (Pleistocene)	29	0	0.0	1.1	6.9	4.1
qd	Quartz diorite (Cretaceous)	701	4	0.6	-0.6	8.9	2.6
Qt	Terrace deposits, undifferentiated (Pleistocene)	18	0	0	0.5	5.6	2.05
sch	Metasedimentary rocks (Mesozoic or Paleozoic)	173	4	2.3	0	8	3.9
Tbl	Butano Sandstone-Lower sandstone member (Eocene)	188	6	3.2	-1.3	9.4	3.3
Tblc	Butano Sandstone-Conglomerate in lower sandstone member (Eocene)	2	0	0	0	1.6	0.8
Tbm	Butano Sandstone-Middle siltstone member (Eocene)	100	0	0	-1.4	5	1.8
Tbs	Basalt (lower Miocene)	6	0	0	1.7	5.4	4.0
Tbu	Butano Sandstone-Upper sandstone member	255	0	0	-1.3	5.9	1.6
Tl	Locatelli Formation (Paleocene)	5	0	0	1.3	3	1.7

Geologic Unit Symbol	Geologic Unit Name	N	N ≥ 7.5 ppm eU	% ≥ 7.5 ppm eU	Low ppm eU	High ppm eU	Median ppm eU
Tla	Lambert Shale (lower Miocene)	39	0	0	0.4	5.6	3.0
Tlo	Lompico Sandstone (middle Miocene)	173	9	5.2	-0.8	9.9	4.3
Tlss	Locatelli Formation-Sandstone (Paleocene)	35	0	0	-0.8	3.9	1.1
Tm	Monterey Formation (middle Miocene)	263	31	11.8	-0.5	10.8	4.0
Tp	Purisima Formation (Pliocene and upper Miocene)	105	1	1.0	-0.1	7.5	2.3
Tsc	Santa Cruz Mudstone (upper Miocene)	773	69	8.9	-0.2	13	4.8
Tsl	San Lorenzo Formation, undivided (Oligocene and Eocene)	18	0	0	-0.7	4.8	2.1
Tsm	Santa Margarita Sandstone (upper Miocene)	428	15	3.5	-1.1	10.2	3.5
Tsr	Rices Mudstone Member (Oligocene and Eocene)	226	0	0	-0.7	6.8	2.3
Tst	Twobar Shale Member (Eocene)	62	0	0	-1	5.6	2.45
Tvq	Vaqueros Sandstone (lower Miocene and Oligocene)	460	0	0	-1.2	7	1.8
Tz	Zayante Sandstone (Oligocene)	113	1	0.9	-0.7	8.7	2.3

Unit symbols and names reference: USGS OFR 97-489

APPENDIX F-3

San Jose 1X2 Degree Quadrangle NURE Airborne Radiometric Survey Equivalent Uranium (eU) Data for Santa Cruz County

Geologic Unit Symbol	Geologic Unit Name	N	N ≥ 7.5 ppm eU	% ≥ 7.5 ppm eU	Low ppm eU	High ppm eU	Median ppm eU
Kgs	Shale and sandstone of Nibbs Knob area (Upper Cretaceous)	29	0	0	0.2	6.1	2.7
Qal	Alluvial deposits, undifferentiated (Holocene)	49	2	4.1	-0.4	9.1	2.8
Qcu	Coastal terrace deposits, undifferentiated (Pleistocene)	3	0	0	1.4	3.1	3.1
Qof	Older flood-plain deposits (Holocene)	8	1	12.5	1.4	8.2	2.75
QTc	Continental deposits, undifferentiated (Pleistocene and Pliocene?)	5	0	0	2	7.1	3.8
Qtl	Colluvium (Holocene)	9	0	0	1.5	4.7	3.1
Tblc	Butano Sandstone-Conglomerate in lower sandstone member (Eocene)	13	2	15.4	-0.9	15.5	2.9
Tbm	Butano Sandstone-Middle siltstone member (Eocene)	65	0	0	-2	5.1	2.4
Tbu	Butano Sandstone-Upper sandstone member	26	0	0	-0.5	6.3	2.25
Tla	Lambert Shale (lower Miocene)	23	0	0	-0.4	3.7	1.6
Tlo	Lompico Sandstone (middle Miocene)	13	0	0	0.7	4.8	2.35
Tm	Monterey Formation (middle Miocene)	1	0	0		3.2	3.2
Tmm	Sandstone of Mount Madonna area (Eocene?)	110	0	0	-0.8	6	2.0
Tmp	Shale of Mount Pajaro area (Miocene and Oligocene)	122	0	0	-1.7	7.2	2.05

Geologic Unit Symbol	Geologic Unit Name	N	N ≥ 7.5 ppm eU	% ≥ 7.5 ppm eU	Low ppm eU	High ppm eU	Median ppm eU
Tms	Mudstone of Maymens Flat area (Eocene and Paleocene)	12	0	0	0.5	5.8	2.8
Tp	Purisima Formation (Pliocene and upper Miocene)	651	14	2.2	-2.2	10.3	2.2
Tsc	Santa Cruz Mudstone (upper Miocene)	16	0	0	-0.5	4.1	2.6
Tsl	San Lorenzo Formation, undivided (Oligocene and Eocene)	51	0	0	-2.1	7.4	1.8
Tsm	Santa Margarita Sandstone (upper Miocene)	2	0	0	-0.3	3.1	1.55
Tsr	Rices Mudstone Member (Oligocene and Eocene)	20	0	0	0.1	4.8	2.6
Tst	Twobar Shale Member (Eocene)	7	0	0	1.8	5.3	2.6
Tvq	Vaqueros Sandstone (lower Miocene and Oligocene)	71	0	0	-1.7	6.1	1.5
Tz	Zayante Sandstone (Oligocene)	5	0	0	0.7	3.2	1.0

Unit symbols and names reference: USGS OFR 97-489

APPENDIX G

NURE Stream Sediment Sample (SS) and Soil Sample (SL) Uranium Data by Geologic Unit--Santa Cruz County

Geologic Unit	Geologic Unit Description	N	NURE U Data (ppm)				Mean (ppm)	Median (ppm)	Low (ppm)	High (ppm)
Qb-SL	Basin deposits (Holocene)	2	2.5	5.9			4.2	4.2	2.5	5.9
Qcu-SL	Coastal Terrace deposits, undifferentiated (Pleistocene)	1	2.2							2.2
Qem-SL	Eolian deposits of Manresa Beach (Pleistocene)	1	6.7							6.7
Qof-SL	Older flood-plain deposits (Holocene)	4	2.2	2.5	2.5	3.6	2.7	2.5	2.2	3.6
Qwf-SL	Fluvial facies (Pleistocene)	1	2.8							2.8
Qyf-SL	Younger flood-plain deposits (Holocene)	1	2.3							2.3
Qae-SS	Eolian lithofacies-Aromas sand (Pleistocene)	1	3.4							3.4
Qcl-SS	Lowest emerging coastal terrace deposits-Coastal terrace deposits (Pleistocene)	3	2.0	2.5	2.6		2.4	2.5	2.0	2.6
Qtl-1	Colluvium (Holocene)	1	3.7							3.7
Qwf-SS	Fluvial facies (Pleistocene)	1	2.8							2.8
Tmm-SS	Sandstone of Mount Madonna area (Eocene?)	1	2.8							2.8
Tp-SS	Purisima Formation (Pliocene and upper Miocene)	1	2.1							2.1
Tps-SS	Predominantly massive sandstone (Pliocene and upper Miocene)	1	3.4							3.4
Ts-SS	Siltstone and sandstone (Pliocene and upper Miocene)	1	2.2							2.2

NURE SL and SS data are only available for the portion of Santa Cruz County within the Santa Cruz 1X2 degree quadrangle

APPENDIX H

Geologic Units, NRCS Soil Units and Indoor Radon Data

Geologic Unit	Geologic Unit Name	Soil Unit	Soil Unit Name	N	N ≥ 4 pCi/L	R%	Low pCi/L	High pCi/L
ga	Granite and adamellite (Cretaceous)	154	Maymen variant sandy loam, 5-30% slopes	6	3	50.0	1.0	9.3
	Granite and adamellite (Cretaceous)	173	Sur-Catelli complex 50-75% slopes	1	1	100.0		10.3
hcg	Hornblende-cummingtonite gabbro (Cretaceous)	142	Lompico-Felton complex, 5-30% slopes	2	1	50.0	3.2	11.6
Kgs	Shale and sandstone of Nibbs Knob area (Upper Cretaceous)	141	Hecker gravelly sandy loam, 50-75% slopes	2	1	50.0	0.9	55.5
m	Marble (Mesozoic or Paleozoic)	123	Cropley silty clay, 2-9% slopes	1	0	0		1.1
Qae	Eolian lithofacies-Aromas sand (Pleistocene)	106	Baywood loamy sand, 15-30% slopes	4	0	0	0.4	1.4
	Eolian lithofacies-Aromas sand (Pleistocene)	112	Bend Lomond sandy loam, 50-75% slopes	2	0	0	0.2	1.5
	Eolian lithofacies-Aromas sand (Pleistocene)	133	Elkhorn sandy loam, 2-9% slopes	1	0	0		2.1
	Eolian lithofacies-Aromas sand (Pleistocene)	135	Elkhorn sandy loam, 15-30% slopes	1	0	0		2.0
	Eolian lithofacies-Aromas sand (Pleistocene)	136	Elkhorn-Pfeiffer complex, 20-50% slopes	1	0	0		0.7
	Eolian lithofacies-Aromas sand (Pleistocene)	159	Pfeiffer gravelly sandy loam, 15-30% slopes	1	0	0		1.0
	Eolian lithofacies-Aromas sand (Pleistocene)	183	Zayante coarse sand, 30-50% slopes	1	0	0		0.9
	Eolian lithofacies-Aromas sand (Pleistocene)	184	Zayante-Rock outcrop complex, 15-75% slopes	3	0	0	0.2	1.0

Geologic Unit	Geologic Unit Name	Soil Unit	Soil Unit Name	N	N ≥ 4 pCi/L	R%	Low pCi/L	High pCi/L
Qaf	Fluvial lithofacies-Aromas Sand (Pleistocene)	105	Baywood loamy sand, 2-15% slopes	1	0	0		0.7
	Fluvial lithofacies-Aromas Sand (Pleistocene)	159	Pfeiffer gravelly sandy loam, 15-30% slopes	1	0	0		0.8
	Fluvial lithofacies-Aromas Sand (Pleistocene)	162	Pinto loam, 2-9% slopes	2	0	0	0.2	0.7
	Fluvial lithofacies-Aromas Sand (Pleistocene)	163	Pinto loam, 9-15% slopes	2	0	0	0.5	0.9
	Fluvial lithofacies-Aromas Sand (Pleistocene)	174	Tierra-Watsonville complex, 15-30% slopes	2	0	0	0.6	1.3
	Fluvial lithofacies-Aromas Sand (Pleistocene)	175	Tierra-Watsonville complex, 30-50% slopes	2	0	0	1.3	3.5
	Fluvial lithofacies-Aromas Sand (Pleistocene)	177	Watsonville loam, 2-15% slopes	3	0	0	0.2	1.4
Qal	Alluvial deposits, undifferentiated (Holocene)	110	Ben Lomond sandy loam, 5-15% slopes	6	0	0	0.8	3.4
	Alluvial deposits, undifferentiated (Holocene)	116	Bonnydoon loam, 5-30% slopes	2	2	100.0	4.9	5.3
	Alluvial deposits, undifferentiated (Holocene)	125	Danville loam, 2-9% slopes	1	0	0		1.1
	Alluvial deposits, undifferentiated (Holocene)	129	Elder sandy loam, 0-2% slopes	4	1	25.0	0.5	4.4
	Alluvial deposits, undifferentiated (Holocene)	130	Elder sandy loam, 2-9% slopes	5	2	40.0	1.3	14.4
	Alluvial deposits, undifferentiated (Holocene)	131	Elder sandy loam, 9-15% slopes	4	0	0	0.2	1.1
	Alluvial deposits, undifferentiated (Holocene)	133	Elkhorn sandy loam, 2-9% slopes	7	0	0	0.2	1.4
	Alluvial deposits, undifferentiated (Holocene)	134	Elkhorn sandy loam, 9-15% slopes	3	1	33.3	0.4	6.7

Geologic Unit	Geologic Unit Name	Soil Unit	Soil Unit Name	N	N ≥ 4 pCi/L	R%	Low pCi/L	High pCi/L
Qal cont.	Alluvial deposits, undifferentiated (Holocene)	135	Elkhorn sandy loam, 15-30% slopes	1	0	0		1.4
	Alluvial deposits, undifferentiated (Holocene)	139	Fluvaquentic Haploxerolls-Aquic Xerofluvents complex, 0-15% slopes	2	0	0	0.9	1.2
	Alluvial deposits, undifferentiated (Holocene)	142	Lompico-Felton complex, 5-30% slopes	2	2	100.0	5.8	6.6
	Alluvial deposits, undifferentiated (Holocene)	144	Lompico-Felton complex, 50-75% slopes	1	0	0		0.5
	Alluvial deposits, undifferentiated (Holocene)	148	Los Osos loam, 30-50% slopes	2	0	0	0.2	0.8
	Alluvial deposits, undifferentiated (Holocene)	158	Nisene-Aptos complex, 50-75% slopes	1	0	0		1.4
	Alluvial deposits, undifferentiated (Holocene)	159	Pfeiffer gravelly sandy loam, 15-30% slopes	1	0	0		0.9
	Alluvial deposits, undifferentiated (Holocene)	170	Soquel loam, 0-2% slopes	28	0	0	0.2	3.8
	Alluvial deposits, undifferentiated (Holocene)	171	Soquel loam, 2-9% slopes	23	4	17.4	0.2	21.7
	Alluvial deposits, undifferentiated (Holocene)	172	Soquel loam, 9-15% slopes	3	0	0	0.8	3.2
	Alluvial deposits, undifferentiated (Holocene)	178	Watsonville loam, thick surface, 0-2% slopes	1	0	0		0.7
	Alluvial deposits, undifferentiated (Holocene)	179	Watsonville loam, thick surface, 2-15% slopes	5	0	0	0.2	2.8
	Alluvial deposits, undifferentiated (Holocene)	182	Zayante coarse sand, 5-30% slopes	8	1	12.5	0.8	4.7
	Alluvial deposits, undifferentiated (Holocene)	183	Zayante coarse sand, 30-50% slopes	2	1	50.0	1.1	5.2
Qar	Aromas Sand, undivided (Pleistocene)	106	Baywood loamy sand, 15-30% slopes	1	0	0		0.5

Geologic Unit	Geologic Unit Name	Soil Unit	Soil Unit Name	N	N ≥ 4 pCi/L	R%	Low pCi/L	High pCi/L
Qar cont.	Aromas Sand, undivided (Pleistocene)	107	Baywood loamy sand, 30-50% slopes	1	0	0		1.1
	Aromas Sand, undivided (Pleistocene)	133	Elkhorn sandy loam, 2-9% slopes	1	0	0		0.6
	Aromas Sand, undivided (Pleistocene)	134	Elkhorn sandy loam, 9-15% slopes	2	0	0	0.2	1.2
	Aromas Sand, undivided (Pleistocene)	135	Elkhorn sandy loam, 15-30% slopes	7	0	0	0.2	1.7
	Aromas Sand, undivided (Pleistocene)	136	Elkhorn-Pfeiffer complex, 20-50% slopes	10	0	0	0.2	1.1
	Aromas Sand, undivided (Pleistocene)	175	Tierra-Watsonville complex, 30-50% slopes	1	0	0		1.2
	Aromas Sand, undivided (Pleistocene)	177	Watsonville loam, 2-15% slopes	1	0	0		0.8
Qb	Basin deposits (Holocene)	161	Pinto loam, 0-2% slopes	1	0	0		1.2
	Basin deposits (Holocene)	170	Soquel loam, 0-2% slopes	2	0	0	0.5	1.3
	Basin deposits (Holocene)	174	Tierra-Watsonville complex, 15-30% slopes	1	0	0		0.6
Qce	Eolian facies-Coastal terrace deposits (Pleistocene)	106	Baywood loamy sand, 15-30% slopes	1	0	0		0.6
Qcl	Lowest emergent coastal terrace deposits (Pleistocene)	116	Bonnydoon loam, 5-30% slopes	1	0	0		1.1
Qcl	Lowest emergent coastal terrace deposits (Pleistocene)	124	Danville loam, 0-2% slopes	27	0	0	0.2	3.2
	Lowest emergent coastal terrace deposits (Pleistocene)	125	Danville loam, 2-9% slopes	8	1	12.5	0.2	4
	Lowest emergent coastal terrace deposits (Pleistocene)	127	Diablo Clay, 15-30% slopes	1	0	0		2.1
	Lowest emergent coastal terrace deposits (Pleistocene)	129	Elder sandy loam, 0-2% slopes	1	0	0		2.6

Geologic Unit	Geologic Unit Name	Soil Unit	Soil Unit Name	N	N ≥ 4 pCi/L	R%	Low pCi/L	High pCi/L
Qcl cont	Lowest emergent coastal terrace deposits (Pleistocene)	130	Elder sandy loam, 2-9% slopes	5	0	0	0.2	1.5
	Lowest emergent coastal terrace deposits (Pleistocene)	132	Elkhorn sandy loam, 0-2% slopes	10	0	0	0.2	3.4
	Lowest emergent coastal terrace deposits (Pleistocene)	133	Elkhorn sandy loam, 2-9% slopes	108	4	3.7	0.2	6
	Lowest emergent coastal terrace deposits (Pleistocene)	134	Elkhorn sandy loam, 9-15% slopes	5	0	0	0.6	1.5
	Lowest emergent coastal terrace deposits (Pleistocene)	135	Elkhorn sandy loam, 15-30% slopes	5	0	0	0.2	1.3
	Lowest emergent coastal terrace deposits (Pleistocene)	136	Elkhorn-Pfeiffer complex, 20-50% slopes	1	0	0		0.2
	Lowest emergent coastal terrace deposits (Pleistocene)	143	Lompico-Felton complex, 30-50% slopes	4	0	0	0.3	2.2
	Lowest emergent coastal terrace deposits (Pleistocene)	144	Lompico-Felton complex, 50-75% slopes	1	0	0		0.2
	Lowest emergent coastal terrace deposits (Pleistocene)	158	Nisene-Aptos complex, 50-75% slopes	1	0	0		2.2
	Lowest emergent coastal terrace deposits (Pleistocene)	161	Pinto loam, 0-2% slopes	23	0	0	0.2	1.8
	Lowest emergent coastal terrace deposits (Pleistocene)	162	Pinto loam, 2-9% slopes	6	2	33.3	0.2	1.4
	Lowest emergent coastal terrace deposits (Pleistocene)	163	Pinto loam, 9-15% slopes	2	0	0	0.2	0.8
	Lowest emergent coastal terrace deposits (Pleistocene)	170	Soquel loam, 0-2% slopes	2	0	0	0.9	0.9
	Lowest emergent coastal terrace deposits (Pleistocene)	175	Tierra-Watsonville complex, 30-50% slopes	3	1	33.3	0.2	4.5
	Lowest emergent coastal terrace deposits (Pleistocene)	176	Watsonville loam, 0-2% slopes	30	0	0	0.2	2.6

Geologic Unit	Geologic Unit Name	Soil Unit	Soil Unit Name	N	N ≥ 4 pCi/L	R%	Low pCi/L	High pCi/L
Qcl cont	Lowest emergent coastal terrace deposits (Pleistocene)	177	Watsonville loam, 2-15% slopes	36	0	0	0.2	3.2
	Lowest emergent coastal terrace deposits (Pleistocene)	178	Watsonville loam, thick surface, 0-2% slopes	138	3	2.2	0.2	5.9
	Lowest emergent coastal terrace deposits (Pleistocene)	179	Watsonville loam, thick surface, 2-15% slopes	81	1	1.2	0.2	4.1
Qcu	Coastal terrace deposits, undifferentiated (Pleistocene)	113	Ben Lomond-Catelli-Sur Complex, 30-75% slopes	3	0	0	0.4	0.9
	Coastal terrace deposits, undifferentiated (Pleistocene)	118	Bonnydoon-Rock outcrop complex, 50-85% slopes	1	0	0		0.8
	Coastal terrace deposits, undifferentiated (Pleistocene)	123	Cropley silty clay, 2-9% slopes	19	0	0	0.2	3.6
	Coastal terrace deposits, undifferentiated (Pleistocene)	125	Danville loam, 2-9% slopes	4	0	0	0.6	1.3
	Coastal terrace deposits, undifferentiated (Pleistocene)	133	Elkhorn sandy loam, 2-9% slopes	13	0	0	0.2	2.9
	Coastal terrace deposits, undifferentiated (Pleistocene)	134	Elkhorn sandy loam, 9-15% slopes	2	0	0	0.6	1.0
	Coastal terrace deposits, undifferentiated (Pleistocene)	135	Elkhorn sandy loam, 15-30% slopes	4	0	0	0.2	2.2
	Coastal terrace deposits, undifferentiated (Pleistocene)	136	Elkhorn-Pfeiffer complex, 20-50% slopes	3	0	0	0.2	1.0
	Coastal terrace deposits, undifferentiated (Pleistocene)	157	Nisene-Aptos complex, 30-50% slopes	1	0	0		0.8
	Coastal terrace deposits, undifferentiated (Pleistocene)	174	Tierra-Watsonville complex, 15-30% slopes	2	1	50.0	2.2	22.3
	Coastal terrace deposits, undifferentiated (Pleistocene)	176	Watsonville loam, 0-2% slopes	1	0	0		1.5

Geologic Unit	Geologic Unit Name	Soil Unit	Soil Unit Name	N	N ≥ 4 pCi/L	R%	Low pCi/L	High pCi/L
Qcu cont	Coastal terrace deposits, undifferentiated (Pleistocene)	177	Watsonville loam, 2-15% slopes	39	4	10.3	0.2	26.5
	Coastal terrace deposits, undifferentiated (Pleistocene)	179	Watsonville loam, thick surface, 2-15% slopes	28	0	0	0.2	3.4
	Coastal terrace deposits, undifferentiated (Pleistocene)	180	Watsonville loam, thick surface, 15-30% slopes	1	0	0		0.3
qd	Quartz diorite (Cretaceous)	110	Ben Lomond sandy loam, 5-15% slopes	3	0	0	0.2	1.5
	Quartz diorite (Cretaceous)	111	Ben Lomond sandy loam, 15-50% slopes	1	0	0		1.1
	Quartz diorite (Cretaceous)	113	Ben Lomond-Catelli-Sur Complex, 30-75% slopes	2	0	0	0.7	0.8
	Quartz diorite (Cretaceous)	130	Elder sandy loam, 2-9% slopes	1	1	100.0		8.0
	Quartz diorite (Cretaceous)	142	Lompico-Felton complex, 5-30% slopes	4	3	75.0	1.5	8.8
	Quartz diorite (Cretaceous)	143	Lompico-Felton complex, 30-50% slopes	3	0	0	0.2	1.4
	Quartz diorite (Cretaceous)	159	Pfeiffer gravelly sandy loam, 15-30% slopes	4	0	0	0.9	2.1
	Quartz diorite (Cretaceous)	160	Pfeiffer gravelly sandy loam, 30-50% slopes	2	0	0	1.0	1.3
	Quartz diorite (Cretaceous)	173	Sur-Catelli complex 50-75% slopes	3	0	0	0.7	1.2
	Quartz diorite (Cretaceous)	174	Tierra-Watsonville complex, 15-30% slopes	1	0	0		1.4
Qem	Eolian deposits of Manresa Beach (Pleistocene)	105	Baywood loamy sand, 2-15% slopes	1	0	0		0.3
Qes	Eolian deposits of Sunset Beach (Pleistocene)	107	Baywood loamy sand, 30-50% slopes	1	0	0		0.2
	Eolian deposits of Sunset Beach (Pleistocene)	128	Dune Land	2	0	0	0.8	0.8

Geologic Unit	Geologic Unit Name	Soil Unit	Soil Unit Name	N	N ≥ 4 pCi/L	R%	Low pCi/L	High pCi/L
Qof	Older flood-plain deposits (Holocene)	104	Baywood loamy sand, 0-2% slopes	3	0	0	0.2	0.8
	Older flood-plain deposits (Holocene)	105	Baywood loamy sand, 2-15% slopes	1	0	0		0.2
	Older flood-plain deposits (Holocene)	120	Conejo loam, 0-2% slopes	7	0	0	1.2	3.2
	Older flood-plain deposits (Holocene)	129	Elder sandy loam, 0-2% slopes	9	0	0	0.5	1.9
	Older flood-plain deposits (Holocene)	135	Elkhorn sandy loam, 15-30% slopes	3	0	0	0.4	0.9
	Older flood-plain deposits (Holocene)	136	Elkhorn-Pfeiffer complex, 20-50% slopes	1	0	0		0.7
	Older flood-plain deposits (Holocene)	143	Lompico-Felton complex, 30-50% slopes	2	0	0	0.9	1.8
	Older flood-plain deposits (Holocene)	158	Nisene-Aptos complex, 50-75% slopes	1	0	0		3.1
	Older flood-plain deposits (Holocene)	162	Pinto loam, 2-9% slopes	1	0	0		1.5
	Older flood-plain deposits (Holocene)	170	Soquel loam, 0-2% slopes	9	1	11.1	0.2	6.2
	Older flood-plain deposits (Holocene)	171	Soquel loam, 2-9% slopes	7	0	0	0.2	3.4
	Older flood-plain deposits (Holocene)	174	Tierra-Watsonville complex, 15-30% slopes	3	0	0	0.3	3.6
	Older flood-plain deposits (Holocene)	175	Tierra-Watsonville complex, 30-50% slopes	1	0	0		0.8
	Older flood-plain deposits (Holocene)	177	Watsonville loam, 2-15% slopes	7	0	0	0.3	1.4

Geologic Unit	Geologic Unit Name	Soil Unit	Soil Unit Name	N	N ≥ 4 pCi/L	R%	Low pCi/L	High pCi/L
Qt	Terrace deposits, undifferentiated (Pleistocene)	126	Diablo Clay, 9-15% slopes	1	0	0		0.7
	Terrace deposits, undifferentiated (Pleistocene)	130	Elder sandy loam, 2-9% slopes	1	0	0		0.4
	Terrace deposits, undifferentiated (Pleistocene)	133	Elkhorn sandy loam, 2-9% slopes	5	0	0	0.2	1.6
	Terrace deposits, undifferentiated (Pleistocene)	146	Los Osos loam, 5-15% slopes	2	1	50.0	1.8	5.8
	Terrace deposits, undifferentiated (Pleistocene)	158	Nisene-Aptos complex, 50-75% slopes	1	0	0		0.9
	Terrace deposits, undifferentiated (Pleistocene)	174	Tierra-Watsonville complex, 15-30% slopes	2	0	0	0.3	2.2
	Terrace deposits, undifferentiated (Pleistocene)	175	Tierra-Watsonville complex, 30-50% slopes	1	0	0		0.7
	Terrace deposits, undifferentiated (Pleistocene)	177	Watsonville loam, 2-15% slopes	4	0	0	0.3	0.9
	Terrace deposits, undifferentiated (Pleistocene)	179	Watsonville loam, thick surface, 2-15% slopes	2	0	0	0.5	3.5
	Terrace deposits, undifferentiated (Pleistocene)	182	Zayante coarse sand, 5-30% slopes	1	0	0		1.1
QTc	Continental deposits, undifferentiated (Pleistocene and Pliocene)	175	Tierra-Watsonville complex, 30-50% slopes	1	0	0		0.9
Qtl	Colluvium (Holocene)	105	Baywood loamy sand, 2-15% slopes	10	0	0	0.2	1.2
	Colluvium (Holocene)	106	Baywood loamy sand, 15-30% slopes	3	0	0	0.4	1.3
	Colluvium (Holocene)	107	Baywood loamy sand, 30-50% slopes	1	0	0		0.6
	Colluvium (Holocene)	108	Baywood variant loamy sand	1	0	0		0.3

64 CALIFORNIA GEOLOGICAL SURVEY SR 216

Geologic Unit	Geologic Unit Name	Soil Unit	Soil Unit Name	N	N ≥ 4 pCi/L	R%	Low pCi/L	High pCi/L
Qtl cont.	Colluvium (Holocene)	134	Elkhorn sandy loam, 9-15% slopes	1	0	0		1.2
	Colluvium (Holocene)	159	Pfeiffer gravelly sandy loam, 15-30% slopes	1	0	0		0.8
	Colluvium (Holocene)	171	Soquel loam, 2-9% slopes	3	0	0	0.6	1.4
Qwf	Fluvial facies (Pleistocene)	129	Elder sandy loam, 0-2% slopes	1	0	0		0.9
	Fluvial facies (Pleistocene)	135	Elkhorn sandy loam, 15-30% slopes	1	0	0		0.3
	Fluvial facies (Pleistocene)	161	Pinto loam, 0-2% slopes	9	0	0	0.2	1.4
	Fluvial facies (Pleistocene)	162	Pinto loam, 2-9% slopes	13	1	7.7	0.2	4.3
	Fluvial facies (Pleistocene)	174	Tierra-Watsonville complex, 15-30% slopes	5	0	0	0.2	2.2
	Fluvial facies (Pleistocene)	177	Watsonville loam, 2-15% slopes	22	0	0	0.2	3.4
	Fluvial facies (Pleistocene)	179	Watsonville loam, thick surface, 2-15% slopes	3	0	0	0.2	0.7
Qyf	Younger flood-plain deposits (Holocene)	108	Baywood variant loamy sand	1	0	0		1.1
Qyfo	Alluvial fan deposits (Holocene)	100	Aptos loam, warm, 15-30% slopes	1	0	0		2.2
	Alluvial fan deposits (Holocene)	121	Conejo loam, 2-9% slopes	1	0	0		0.6
sch	Medasedimentary rocks (Mesozoic or Paleozoic)	110	Ben Lomond sandy loam, 5-15% slopes	1	0	0		0.7
	Medasedimentary rocks (Mesozoic or Paleozoic)	113	Ben Lomond-Catelli-Sur Complex, 30-75% slopes	1	0	0		0.2
	Medasedimentary rocks (Mesozoic or Paleozoic)	115	Ben Lomond-Felton complex, 50-75% slopes	1	0	0		1.8
	Medasedimentary rocks (Mesozoic or Paleozoic)	125	Danville loam, 2-9% slopes	2	0	0	1.4	2.4
	Medasedimentary rocks (Mesozoic or Paleozoic)	133	Elkhorn sandy loam, 2-9% slopes	1	0	0		1.8
	Medasedimentary rocks (Mesozoic or Paleozoic)	142	Lompico-Felton complex, 5-30% slopes	9	2	22.2	0.2	10.8

Geologic Unit	Geologic Unit Name	Soil Unit	Soil Unit Name	N	N ≥ 4 pCi/L	R%	Low pCi/L	High pCi/L
sch cont.	Medasedimentary rocks (Mesozoic or Paleozoic)	143	Lompico-Felton complex, 30-50% slopes	1	0	0		3.2
	Medasedimentary rocks (Mesozoic or Paleozoic)	157	Nisene-Aptos complex, 30-50% slopes	1	0	0		1.6
	Medasedimentary rocks (Mesozoic or Paleozoic)	171	Soquel loam, 2-9% slopes	1	1	100.0		4.8
	Medasedimentary rocks (Mesozoic or Paleozoic)	174	Tierra-Watsonville complex, 15-30% slopes	1	0	0		0.8
Tblc	Conglomerate-Butano Sandstone (Eocene)	142	Lompico-Felton complex, 5-30% slopes	1	1	100.0		4.5
	Conglomerate-Butano Sandstone (Eocene)	151	Maymen stony loam, 30-75% slopes	1	0	0		2.3
	Conglomerate-Butano Sandstone (Eocene)	153	Maymen-Rock outcrop complex, 50-75% slopes	1	0	0		0.2
Tbm	Middle siltstone member-Butano Sandstone (Eocene)	115	Ben Lomond-Felton complex, 50-75% slopes	5	1	20.0	0.7	10.9
	Middle siltstone member-Butano Sandstone (Eocene)	140	Hecker gravelly sandy loam, 30-50% slopes	3	1	33.3	0.6	9.6
	Middle siltstone member-Butano Sandstone (Eocene)	142	Lompico-Felton complex, 5-30% slopes	1	1	100.0		31.2
	Middle siltstone member-Butano Sandstone (Eocene)	149	Modonna loam 15-30% slopes	6	0	0	0.6	3.5
Tbu	Upper sandstone member-Butano Sandstone (Eocene)	110	Ben Lomond sandy loam, 5-15% slopes	5	0	0	0.3	2.1
	Upper sandstone member-Butano Sandstone (Eocene)	111	Bend Lomond sandy loam, 15-50% slopes	2	0	0	2.5	3.0
	Upper sandstone member-Butano Sandstone (Eocene)	113	Ben Lomond-Catelli-Sur Complex, 30-75% slopes	3	0	0	0.9	1.4
	Upper sandstone member-Butano Sandstone (Eocene)	114	Ben Lomond-Felton complex, 30-50% slopes	2	0	0	0.7	0.9

66 CALIFORNIA GEOLOGICAL SURVEY SR 216

Geologic Unit	Geologic Unit Name	Soil Unit	Soil Unit Name	N	N ≥ 4 pCi/L	R%	Low pCi/L	High pCi/L
Tbu cont.	Upper sandstone member-Butano Sandstone (Eocene)	143	Lompico-Felton complex, 30-50% slopes	1	1	100.0		5.2
	Upper sandstone member-Butano Sandstone (Eocene)	158	Nisene-Aptos complex, 50-75% slopes	1	1	100.0		5.7
	Upper sandstone member-Butano Sandstone (Eocene)	173	Sur-Catelli complex 50-75% slopes	1	0	0		1.2
Tl	Locatelli Formation (Paleocene)	111	Bend Lomond sandy loam, 15-50% slopes	1	0	0		0.8
	Locatelli Formation (Paleocene)	143	Lompico-Felton complex, 30-50% slopes	7	1	14.3	0.3	8.5
Tla	Lambert Shale (lower Miocene)	115	Ben Lomond-Felton complex, 50-75% slopes	1	1	100.0		4.1
	Lambert Shale (lower Miocene)	143	Lompico-Felton complex, 30-50% slopes	2	1	50.0	2.3	21.5
	Lambert Shale (lower Miocene)	149	Modonna loam, 15-30% slopes	1	0	0		1.4
	Lambert Shale (lower Miocene)	151	Maymen stony loam, 30-75% slopes	2	2	100.0	15.1	26.3
	Lambert Shale (lower Miocene)	181	Xerothents-Rock outcrop complex, 50-100 percent slopes	2	2	100.0	5.1	26.8
Tlo	Lompico Sandstone (middle Miocene)	110	Ben Lomond sandy loam, 5-15% slopes	7	1	14.3	1.1	4.6
	Lompico Sandstone (middle Miocene)	111	Ben Lomond sandy loam, 15-50% slopes	6	1	16.7	0.8	4.6
	Lompico Sandstone (middle Miocene)	113	Ben Lomond-Catelli-Sur Complex, 30-75% slopes	3	2	66.7	2.8	9.6
	Lompico Sandstone (middle Miocene)	142	Lompico-Felton complex, 5-30% slopes	2	0	0	0.2	2.7
	Lompico Sandstone (middle Miocene)	143	Lompico-Felton complex, 30-50% slopes	2	0	0	2.2	2.8

Geologic Unit	Geologic Unit Name	Soil Unit	Soil Unit Name	N	N ≥ 4 pCi/L	R%	Low pCi/L	High pCi/L
Tlo cont.	Lompico Sandstone (middle Miocene)	156	Nisene-Aptos complex, 15-30% slopes	1	0	0		2.0
	Lompico Sandstone (middle Miocene)	157	Nisene-Aptos complex, 30-50% slopes	2	0	0	2.1	3.5
	Lompico Sandstone (middle Miocene)	182	Zayante coarse sand, 5-30% slopes	4	0	0	0.5	1.5
	Lompico Sandstone (middle Miocene)	184	Zayante-Rock outcrop complex, 15-75% slopes	1	0	0		0.2
Tm	Monterey Formation (middle Miocene)	110	Ben Lomond sandy loam, 5-15% slopes [MR]	1	1	100.0		6.6
	Monterey Formation (middle Miocene)	113	Ben Lomond-Catelli-Sur Complex, 30-75% slopes	1	1	100.0		7.0
	Monterey Formation (middle Miocene)	130	Elder sandy loam, 2-9% slopes	3	0	0	0.7	2.1
	Monterey Formation (middle Miocene)	134	Elkhorn sandy loam, 9-15% slopes	1	0	0		1.0
	Monterey Formation (middle Miocene)	142	Lompico-Felton complex, 5-30% slopes	1	1	100.0		7.2
	Monterey Formation (middle Miocene)	143	Lompico-Felton complex, 30-50% slopes	4	2	50.0	2.8	89.3
	Monterey Formation (middle Miocene)	151	Maymen stony loam, 30-75% slopes	2	1	50.0	1.0	6.9
	Monterey Formation (middle Miocene)	157	Nisene-Aptos complex, 30-50% slopes	2	1	50.0	2.1	26.0
	Monterey Formation (middle Miocene)	158	Nisene-Aptos complex, 50-75% slopes	7	3	42.9	2.4	12.3
	Monterey Formation (middle Miocene)	182	Zayante coarse sand, 5-30% slopes	3	0	0	0.2	1.8
	Monterey Formation (middle Miocene)	183	Zayante coarse sand, 30-50% slopes	1	0	0		2.7

Geologic Unit	**Geologic Unit Name**	**Soil Unit**	**Soil Unit Name**	**N**	**N ≥ 4 pCi/L**	**R%**	**Low pCi/L**	**High pCi/L**
Tm cont.	Monterey Formation (middle Miocene)	ScF2 es	*Not defined in soil report--RKC*	1	0	0		0.2
Tp	Purisima Formation (Pliocene and upper Miocene)	101	Aptos loam, warm, 30-50% slopes	2	0	0	0.6	0.8
	Purisima Formation (Pliocene and upper Miocene)	103	Aquents, flooded	1	0	0		0.4
	Purisima Formation (Pliocene and upper Miocene)	106	Baywood loamy sand, 15-30% slopes	1	0	0		1.3
	Purisima Formation (Pliocene and upper Miocene)	109	Beaches	2	0	0	0.3	0.4
	Purisima Formation (Pliocene and upper Miocene)	110	Ben Lomond sandy loam, 5-15% slopes	1	0	0		0.6
	Purisima Formation (Pliocene and upper Miocene)	112	Bend Lomond sandy loam, 50-75% slopes	1	0	0		0.6
	Purisima Formation (Pliocene and upper Miocene)	113	Ben Lomond-Catelli-Sur Complex, 30-75% slopes	1	0	0		1.9
	Purisima Formation (Pliocene and upper Miocene)	114	Ben Lomond-Felton complex, 30-50% slopes	2	1	50.0	1.0	9.0
	Purisima Formation (Pliocene and upper Miocene)	115	Ben Lomond-Felton complex, 50-75% slopes	5	0	0	1.0	2.9
	Purisima Formation (Pliocene and upper Miocene)	116	Bonnydoon loam, 5-30% slopes	8	0	0	0.2	2.4
	Purisima Formation (Pliocene and upper Miocene)	117	Bonnydoon loam, 30-50% slopes	10	1	10.0	0.2	5.4
	Purisima Formation (Pliocene and upper Miocene)	118	Bonnydoon-Rock outcrop complex, 50-85% slopes	1	0	0		0.2
	Purisima Formation (Pliocene and upper Miocene)	127	Diablo Clay, 15-30% slopes	1	0	0		1.1
	Purisima Formation (Pliocene and upper Miocene)	130	Elder sandy loam, 2-9% slopes	5	0	0	0.2	1.8

Geologic Unit	Geologic Unit Name	Soil Unit	Soil Unit Name	N	N ≥ 4 pCi/L	R%	Low pCi/L	High pCi/L
Tp cont.	Purisima Formation (Pliocene and upper Miocene)	133	Elkhorn sandy loam, 2-9% slopes	12	1	8.3	0.2	5.8
	Purisima Formation (Pliocene and upper Miocene)	134	Elkhorn sandy loam, 9-15% slopes	1	0	0		0.8
	Purisima Formation (Pliocene and upper Miocene)	135	Elkhorn sandy loam, 15-30% slopes	5	0	0	0.4	1.5
	Purisima Formation (Pliocene and upper Miocene)	136	Elkhorn-Pfeiffer complex, 20-50% slopes	3	0	0	0.7	1.4
	Purisima Formation (Pliocene and upper Miocene)	143	Lompico-Felton complex, 30-50% slopes	5	0	0	0.4	3.4
	Purisima Formation (Pliocene and upper Miocene)	144	Lompico-Felton complex, 50-75% slopes	8	0	0	0.2	1.6
	Purisima Formation (Pliocene and upper Miocene)	145	Lompico Variant loam, 5-30% slopes	1	0	0		0.6
	Purisima Formation (Pliocene and upper Miocene)	148	Los Osos loam, 30-50% slopes	2	0	0	0.2	0.6
	Purisima Formation (Pliocene and upper Miocene)	153	Maymen-Rock outcrop complex, 50-75% slopes	1	0	0		1.3
	Purisima Formation (Pliocene and upper Miocene)	156	Nisene-Aptos complex, 15-30% slopes	5	0	0	0.2	2.6
	Purisima Formation (Pliocene and upper Miocene)	157	Nisene-Aptos complex, 30-50% slopes	4	0	0	0.6	0.8
	Purisima Formation (Pliocene and upper Miocene)	158	Nisene-Aptos complex, 50-75% slopes	13	2	15.4	0.2	31.7
	Purisima Formation (Pliocene and upper Miocene)	159	Pfeiffer gravelly sandy loam, 15-30% slopes	1	0	0		0.7
	Purisima Formation (Pliocene and upper Miocene)	160	Pfeiffer gravelly sandy loam, 30-50% slopes	1	0	0		0.4
	Purisima Formation (Pliocene and upper Miocene)	161	Pinto loam, 0-2% slopes	1	0	0		0.2

Geologic Unit	**Geologic Unit Name**	**Soil Unit**	**Soil Unit Name**	**N**	**N ≥ 4 pCi/L**	**R%**	**Low pCi/L**	**High pCi/L**
Tp cont.	Purisima Formation (Pliocene and upper Miocene)	162	Pinto loam, 2-9% slopes	1	0	0		0.9
	Purisima Formation (Pliocene and upper Miocene)	171	Soquel loam, 2-9% slopes	7	0	0	0.2	1.4
	Purisima Formation (Pliocene and upper Miocene)	172	Soquel loam, 9-15% slopes	1	0	0		1.1
	Purisima Formation (Pliocene and upper Miocene)	174	Tierra-Watsonville complex, 15-30% slopes	6	0	0	0.6	2.2
	Purisima Formation (Pliocene and upper Miocene)	175	Tierra-Watsonville complex, 30-50% slopes	3	0	0	0.2	0.4
	Purisima Formation (Pliocene and upper Miocene)	176	Watsonville loam, 0-2% slopes	1	0	0		1.8
	Purisima Formation (Pliocene and upper Miocene)	177	Watsonville loam, 2-15% slopes	21	1	4.8	0.2	4.9
	Purisima Formation (Pliocene and upper Miocene)	178	Watsonville loam, thick surface, 0-2% slopes	2	0	0	0.2	1.8
	Purisima Formation (Pliocene and upper Miocene)	179	Watsonville loam, thick surface, 2-15% slopes	10	0	0	0.2	1.9
Tps	Perdominantly massive sandstone	100	Aptos loam, warm, 15-30% slopes	1	0	0		2.9
Tsc	Santa Cruz Mudstone (Upper Miocene)	116	Bonnydoon loam, 5-30% slopes	7	0	0	0.5	3.2
	Santa Cruz Mudstone (Upper Miocene)	118	Bonnydoon-Rock outcrop complex, 50-85% slopes	2	0	0	0.9	1.5
	Santa Cruz Mudstone (Upper Miocene)	133	Elkhorn sandy loam, 2-9% slopes	1	0	0		1.2
	Santa Cruz Mudstone (Upper Miocene)	142	Lompico-Felton complex, 5-30% slopes	1	0	0		2.1
	Santa Cruz Mudstone (Upper Miocene)	157	Nisene-Aptos complex, 30-50% slopes	1	0	0		3.0
	Santa Cruz Mudstone (Upper Miocene)	158	Nisene-Aptos complex, 50-75% slopes	9	3	33.3	0.8	21.4

Geologic Unit	Geologic Unit Name	Soil Unit	Soil Unit Name	N	N ≥ 4 pCi/L	R%	Low pCi/L	High pCi/L
Tsc cont.	Santa Cruz Mudstone (Upper Miocene)	170	Soquel loam, 0-2% slopes	2	2	100.0	5.2	11.3
	Santa Cruz Mudstone (Upper Miocene)	172	Soquel loam, 9-15% slopes	1	0	0		0.5
	Santa Cruz Mudstone (Upper Miocene)	179	Watsonville loam, thick surface, 2-15% slopes	2	0	0	0.2	0.4
Tsl	San Lorenzo Formation, Undivided (Oligocene and Eocene)	112	Bend Lomond sandy loam, 50-75% slopes	1	0	0		0.9
	San Lorenzo Formation, Undivided (Oligocene and Eocene)	144	Lompico-Felton complex, 50-75% slopes	1	0	0		0.8
Tsm	Santa Margarita Sandstone (upper Miocene)	106	Baywood loamy sand, 15-30% slopes	1	0	0		0.4
	Santa Margarita Sandstone (upper Miocene)	110	Ben Lomond sandy loam, 5-15% slopes	2	0	0	0.2	1.8
	Santa Margarita Sandstone (upper Miocene)	111	Ben Lomond sandy loam, 15-50% slopes	1	0	0		0.5
	Santa Margarita Sandstone (upper Miocene)	115	Ben Lomond-Felton complex, 50-75% slopes	4	2	50.0	0.2	6.5
	Santa Margarita Sandstone (upper Miocene)	116	Bonnydoon loam, 5-30% slopes	1	0	0		1.6
	Santa Margarita Sandstone (upper Miocene)	130	Elder sandy loam, 2-9% slopes	1	0	0		3.6
	Santa Margarita Sandstone (upper Miocene)	133	Elkhorn sandy loam, 2-9% slopes	2	0	0	0.7	1.0
	Santa Margarita Sandstone (upper Miocene)	138	Felton sandy loam, 5-9% slopes	3	0	0	0.7	2.2
	Santa Margarita Sandstone (upper Miocene)	157	Nisene-Aptos complex, 30-50% slopes	2	0	0	1.0	2.7
	Santa Margarita Sandstone (upper Miocene)	158	Nisene-Aptos complex, 50-75% slopes	1	0	0		2.4

Geologic Unit	Geologic Unit Name	Soil Unit	Soil Unit Name	N	N ≥ 4 pCi/L	R%	Low pCi/L	High pCi/L
Tsm cont.	Santa Margarita Sandstone (upper Miocene)	159	Pfeiffer gravelly sandy loam, 15-30% slopes	3	0	0	0.5	2.6
	Santa Margarita Sandstone (upper Miocene)	164	Pits-Dumps complex	1	1	100.0		7.4
	Santa Margarita Sandstone (upper Miocene)	171	Soquel loam, 2-9% slopes	1	1	100.0		9.4
	Santa Margarita Sandstone (upper Miocene)	174	Tierra-Watsonville complex, 15-30% slopes	9	0	0	0.2	3.4
	Santa Margarita Sandstone (upper Miocene)	175	Tierra-Watsonville complex, 30-50% slopes	3	0	0	0.4	2.3
	Santa Margarita Sandstone (upper Miocene)	177	Watsonville loam, 2-15% slopes	2	0	0	0.9	1.3
	Santa Margarita Sandstone (upper Miocene)	179	Watsonville loam, thick surface, 2-15% slopes	4	0	0	0.2	1.1
	Santa Margarita Sandstone (upper Miocene)	180	Watsonville loam, thick surface, 15-30% slopes	1	0	0		0.4
	Santa Margarita Sandstone (upper Miocene)	182	Zayante coarse sand, 5-30% slopes	55	3	5.5	0.2	4.4
	Santa Margarita Sandstone (upper Miocene)	183	Zayante coarse sand, 30-50% slopes	2	0	0	1.3	2.6
	Santa Margarita Sandstone (upper Miocene)	184	Zayante-Rock outcrop complex, 15-75% slopes	7	1	14.3	0.6	9.9
Tsr	Rices Mudstone Member (Oligocene and Eocene)	110	Ben Lomond sandy loam, 5-15% slopes	1	0	0		0.2
	Rices Mudstone Member (Oligocene and Eocene)	113	Ben Lomond-Catelli-Sur Complex, 30-75% slopes	2	1	50.0	1.6	5.1
	Rices Mudstone Member (Oligocene and Eocene)	115	Ben Lomond-Felton complex, 50-75% slopes	1	0	0		9.7
	Rices Mudstone Member (Oligocene and Eocene)	116	Bonnydoon loam, 5-30% slopes	4	1	25.0	1.2	11

Geologic Unit	Geologic Unit Name	Soil Unit	Soil Unit Name	N	N ≥ 4 pCi/L	R%	Low pCi/L	High pCi/L
Tsr cont.	Rices Mudstone Member (Oligocene and Eocene)	142	Lompico-Felton complex, 5-30% slopes	3	1	33.3	2.2	4
	Rices Mudstone Member (Oligocene and Eocene)	143	Lompico-Felton complex, 30-50% slopes	4	2	50.0	1.6	8.5
	Rices Mudstone Member (Oligocene and Eocene)	144	Lompico-Felton complex, 50-75% slopes	2	0	0	0.7	3.6
	Rices Mudstone Member (Oligocene and Eocene)	152	Maymen-Modonna complex, 30-75% slopes	1	0	0		3.5
	Rices Mudstone Member (Oligocene and Eocene)	171	Soquel loam, 2-9% slopes	2	0	0	18.	2.6
Tvq	Vaqueros Sandstone (lower Miocene and Oligocene)	110	Ben Lomond sandy loam, 5-15% slopes	8	0	0	0.4	3.9
	Vaqueros Sandstone (lower Miocene and Oligocene)	111	Ben Lomond sandy loam, 15-50% slopes	1	0	0		2.5
	Vaqueros Sandstone (lower Miocene and Oligocene)	112	Ben Lomond sandy loam, 50-75% slopes	3	1	33.3	1.1	28.5
	Vaqueros Sandstone (lower Miocene and Oligocene)	113	Ben Lomond-Catelli-Sur Complex, 30-75% slopes	3	0	0	1.1	2.0
	Vaqueros Sandstone (lower Miocene and Oligocene)	114	Ben Lomond-Felton complex, 30-50% slopes	2	0	0	0.7	3.9
	Vaqueros Sandstone (lower Miocene and Oligocene)	115	Ben Lomond-Felton complex, 50-75% slopes	4	1	25.0	0.5	9.2
	Vaqueros Sandstone (lower Miocene and Oligocene)	142	Lompico-Felton complex, 5-30% slopes	1	0	0		3.1
	Vaqueros Sandstone (lower Miocene and Oligocene)	143	Lompico-Felton complex, 30-50% slopes	5	0	0	0.4	1.5
	Vaqueros Sandstone (lower Miocene and Oligocene)	144	Lompico-Felton complex, 50-75% slopes	2	1	50.0	2.1	5.3
	Vaqueros Sandstone (lower Miocene and Oligocene)	151	Maymen stony loam, 30-75% slopes	1	0	0		2.6

Geologic Unit	Geologic Unit Name	Soil Unit	Soil Unit Name	N	N ≥ 4 pCi/L	R%	Low pCi/L	High pCi/L
Tvq cont.	Vaqueros Sandstone (lower Miocene and Oligocene)	153	Maymen-Rock outcrop complex, 50-75% slopes	4	0	0	0.2	3.9
	Vaqueros Sandstone (lower Miocene and Oligocene)	173	Sur-Catelli complex 50-75% slopes	5	0	0	0.3	2.2
Tz	Zayanite Sandstone (Oligocene)	144	Lompico-Felton complex, 50-75% slopes	1	0	0		0.3

APPENDIX I

NRCS Soil Units and Indoor-radon Measurements

(*WB=weathered bedrock; **UB=unweathered bedrock, "(2)" =number indoor radon measurements in the associated geologic map unit)

Soil Unit Symbol(s)	Soil Unit Name	Permeability by Soil Sub-unit	Substratum (based on 100K USGS Mapping)	Shrink -Swell	Depth to Bed Rock inches	N	N ≥ 4 pCi/L	R (%)	Min pCi/L	Max pCi/L
100, 101	Aptos loam, warm, 15-30% slopes and 30-50% slopes	Moderate 0-36"	Qyfo(1),Tps(1), Tp(2)	Mod	36-40 WB*	4	0	0	0.6	2.9
103	Aquents, flooded	Slow to very rapid+ 0-60"	Tp(1)	?	>60	1	0	0		0.4
104, 105, 106, 107	Baywood loamy sand, 0-2% slopes, 2-15% slopes, 15-30% slopes, 30-50% slopes	Rapid 0-61"	Qae(3),Qaf(4) Qal(7), Qar(2), Qce(1); Qcl(1), Qem(1), Qes(1), Qof(5), Qtl(15), Qyf(1),Tp(1), Tsm(2)	Low	>61	44	0	0	0.2	2.9
108	Baywood variant loamy sand	Rapid 0-38", slow 38"-55", moderate 55"-70"	Qtl(1), Qyf(1)	Mod to Low	>55-70	2	0	0	0.3	1.1
109	Beaches	---	Tp(2)	--		2	0	0	0.2	0.3
110, 111, 112	Ben Lomond sandy loam, 5-15% slopes, 15-50% slopes, 50-75% slopes	Moderately rapid 0-46"	Qae(3), Qal(5), qd(4), sch(1), Tbu(8), Tl(1), Tlo(14), Tm(1), Tp(2), Tsm(3), Tsr(1), Tvq(11)	Low	46-50 WB	54	5	9.3	0.2	28.5
113	Ben Lomond-Catelli-Sur Complex, 30-75 percent slopes	Ben Lomond-Moderately rapid 0-46", Catelli-Moderately rapid 0-37", Sur-Moderately rapid 0-35"	Qcu(3), qd(3), sch(1), Tbu(3), Tlo(3), Tp(1), Tsr(2), Tvq(3)	Low	46-50 WB or 37-41 WB or 35-39 UB**	19	3	15.8	0.2	9.6

Soil Unit Symbol(s)	Soil Unit Name	Permeability by Soil Sub-unit	Substratum (based on 100K USGS Mapping)	Shrink-Swell	Depth to Bed Rock inches	N	N ≥ 4 pCi/L	R (%)	Min pCi/L	Max pCi/L
114, 115	Ben Lomond-Felton complex, 30-50% slopes, 50-75% slopes	Ben Lomond-Moderately rapid 0-46”, Felton-Moderately rapid 0-11”, Moderately slow 11”-43”, slow to moderate 43”-63”	sch(1)Tbu(2), Tp(7), Tvq(6), Tbm(5), Tla(1), Tsm(3), Tsr(1),	Low and Mod to Low	46-50 WB or 63-67 WB	26	6	23.1	0.2	10.9
116, 117	Bonnydoon loam, 5-30% slopes, 30-50% slopes	Bonnydoon-Moderate 0-11”	Qal(2), Qcl(1), Tp(19), Tsc(8), Tsm(1), Tsr(5)	Mod	11-15 WB	36	5	13.9	0.2	11
118	Bonnydoon-Rock outcrop complex, 50-85% slopes	Bonnydoon-Moderate 0-11”, Rock complex- NA	Qcu(1), Tp(1), Tsc(2)	Mod	11-15 WB	4	0	0	0.2	1.5
120, 121	Conejo loam, 0-2% slopes, 2-9% slopes	Conejo-Moderate 0-7”, Moderately slow 7”-65”	Qof(7), Qyfo(1)	Mod	>65	8	0	0	0.6	3.0
123	Cropley silty clay, 2-9% slopes	Cropley-Slow 0-60”	m(1), Qcu(19)	High	>60	20	0	0	0.2	3.6
124, 125	Danville loam, 0-2% slopes, 2-9% slopes	Danville-Moderately slow 0-17”, Slow 17”-29”, Moderately slow 29”-65”	Qal(1), Qcl(35), Qcu(4), sch(2)	High and Mod	>65	42	1	2.4	0.2	4.0
126, 127	Diablo Clay, 9-15% slopes, 15-30% slopes	Diablo-Slow 0-59”	Qt(1), Qcl(1), Tp(1)	High	59-63 WB	3	0	0	0.7	2.1
128	Dune Land	Dune Land-Very rapid 0-24”	Qes(2)	Low	>24	2	0	0	0.8	0.8
129, 130, 131	Elder sandy loam, 0-2% slopes, 2-9% slopes, 9-15% slopes	Elder-Moderate 0-60”	Qal(11), Qcl(6), qd(1), Qof(10), Qt(4), Tm(3), Tp(6), Tsm(1)	Low	>60	42	3	7.1	0.2	8

Soil Unit Symbol(s)	Soil Unit Name	Permeability by Soil Sub-unit	Substratum (based on 100K USGS Mapping)	Shrink-Swell	Depth to Bed Rock inches	N	N ≥ 4 pCi/L	R (%)	Min pCi/L	Max pCi/L
132, 133, 134, 135	Elkhorn sandy loam, 0-2% slopes, 2-9% slopes, 9-15% slopes, 15-30% slopes	Elkhorn-Moderately rapid 0-21”, Moderately slow-21-61”	Qae(2), Qal(11), Qar(10), Qcl(140), Qcu(23), Qof(6), Qt(5), Qtl(1), Qwf(1), sch(1), Tm(1), Tp(18), Tsc(1), Tsm(2)	Mod	>61	222	11	4.95	0.2	6.7
136	Elkhorn-Pfeiffer complex, 20-50% slopes	Elkhorn-Moderately rapid 0-21”, Moderately slow-21-61”, Pfeiffer-Moderate rapid 0-66”	Qae(1), Qar(11), Qcl(2), Qcu(3), Qof(1), Tp(3)	Mod	66-70 WB	21	1	4.8	0.2	4
138	Felton sandy loam, 5-9% slopes	Felton-Moderately rapid 0-11”, Moderately slow 11-43”, Slow-43-63”	Tsm(3)	Mod and Low	63-67 WB	3	0	0	0.7	2.2
139	Fluvaquentic Haploxerolls-Aquic Xerofluvents complex, 0-15% slopes	Fluvaquentic Haploxerolls 0-60” Very slow-Very rapid Aquic Xerofluvents 0-60” Very slow-Very rapid	Qal(2)	Low and High	>60	2	0	0	0.9	1.2
140, 141	Hecker gravelly sandy loam, 30-50% slopes, 50-75% slopes	Hecker 0-9” Moderately rapid, 9”-41” Moderate	Tbm(3), Kgs(2)	Low	141-45 UB	5	2	40.0?	0.6	55.5

Soil Unit Symbol(s)	Soil Unit Name	Permeability by Soil Sub-unit	Substratum (based on 100K USGS Mapping)	Shrink -Swell	Depth to Bed Rock inches	N	N ≥ 4 pCi/L	R (%)	Min pCi/L	Max pCi/L
142, 143, 144	Lompico-Felton complex, 5-30% slopes, 30-50% slopes, 50-75% slopes	Lompico Moderately rapid 0-5”, Moderate 5”-37” Felton Moderately rapid 0-11”, Moderate 11”-43”, Slow to Moderate 43”-63”	hcg(2), Qal(3), Qcl(5), qd(8), Qof(2), sch(11), Tblc(1), Tbm(1), Tbu(3), Tl(7), Tla(2), Tlo(4), Tm(5), Tp(14), Tsc(1), Tsl(1), Tsr(9), Tvq(7) Tz(1)	Mod and Mod to Low	37-41 or 63-67	87	21	24.1	0.2	89.3
145	Lompico variant loam, 5-30% slopes	Lompico-Moderate 0-10”, Moderately slow 10”-14”, Slow 14”-28”	Tp(2)	Mod and High	29-32 WB	2	0	0	0.6	1.9
146, 148	Los Osos loam, 5-15% slopes, 30-50% slopes	Los Osos Moderate 0-19”, Slow 19-36”	Qt(2), Qal(2), Tp(2)	High	36-40 WB	6	1	16.7	0.2	5.8
149	Madonna loam, 15-30% slopes	Madonna Moderately rapid 0-16”, Moderate 16”-23”	Tbm(5), Tla(1)	Low		6	0	0	0.6	2.7
151	Maymen stony loam, 30-75% slopes	Maymen Moderate 0-14”	Tblc(1), Tla(2), Tm(2), Tp(1), Tvq(1)	Mod	14-18 UB	7	3	42.9 ?	1.0	26.3
152	Maymen-Madonna complex 30-75% slopes	Maymen Moderate 0-14”, Madonna Moderately rapid 0-16”, Moderate 16”-23”	Tsr(1)	Mod and Low	14-18 UB	1	0	0		3.5
153	Maymen-Rock outcrop complex, 50-75% slopes	Maymen Moderate 0-14” Rock outcrop NA	Tblc(1), Tp(1), Tvq(4)	Mod	14-18 UB or 0-4 B	6	0	0	0.2	3.9
154	Maymen variant sandy loam, 5-30 % slopes	Maymen Moderately rapid 0-19”	ga(11)	Low	19-23 WB	11	3	9.1	1	9.3
155	Mocho Silt Loam, 0-2% slopes		Qyf(1)	Mod	>60	1	0			0.2

Soil Unit Symbol(s)	Soil Unit Name	Permeability by Soil Sub-unit	Substratum (based on 100K USGS Mapping)	Shrink -Swell	Depth to Bed Rock inches	N	N ≥ 4 pCi/L	R (%)	Min pCi/L	Max pCi/L
156, 157, 158	Nisene-Aptos complex, 15-30% slopes, 30-50% slopes, 50-75% slopes	Nisene Moderately rapid 0-10”, Moderate 10”-58 Aptos Moderate 0-29”	Qal(2), Qcl(1), Qcu(1), Qof(1), Qt(1), sch(1), Tblc(1), Tlo(3), Tm(9), Tp(22, Tsc(10), Tsm(3)	Mod	29-33 WB or 58-62 WB	55	9	16.4	0.2	31.5
159, 160	Pfeiffer gravelly sandy loam, 15-30% slopes, 30-50% slopes	Pfeiffer gravelly sandy loam Moderately rapid 0-66”	Qae(1), Qaf(3), Qal(1), qd(6), Qtl(1), Tp(2), Tsm(3)	Low	66-70 WB	17	0	0	0.2	2.6
161, 162, 163	Pinto loam, 0-2% slopes, 2-9% slopes, 9-15% slopes	Pinto Moderate 0-21”, Slow 21”-65”	Qaf(4), Qb(1), Qcl(29), Qof(1) Qwf(22), Tp(2),	Mod	>65	59	1	1.7	0.2	4.3
164	Pits-Dumps complex	NA	Tsm(1)	NA		1	1	100 ?		7.4
170, 171, 172	Soquel loam, 0-2% slopes, 2-9% slopes, 9-15% slopes	Soquel Moderate 0-21”, Moderately slow 21”-62”	Qal(61), Qb(3), Qcl(3), Qof(16), Qtl(3), sch(1), Tp(8), Tsc(3), Tsm(1), Tsr(2)	Mod	>62	10 1	12	11.9	0.2	21.7
173	Sur-Catelli complex 50-75% slopes	Sur Moderately rapid 0-35”, Catelli Moderately rapid 0-37”	ga(1), qd(3), Tbu(1), Tlo(1) Tvq(7)	Low	35-39 UB	13	2	15.4	0.3	10.3

Soil Unit Symbol(s)	**Soil Unit Name**	**Permeability by Soil Sub-unit**	**Substratum (based on 100K USGS Mapping)**	**Shrink -Swell**	**Depth to Bed Rock inches**	**N**	**N ≥ 4 pCi/L**	**R (%)**	**Min pCi/L**	**Max pCi/L**
174, 175	Tierra-Watsonville complex 15-30% slopes, 30-50% slopes	Tierra Moderate 0-14”, very slow 14”-66” Watsonville Moderate 0-18”, very slow 18-39”, slow 39”-63”	Qaf(4), Qar(1), Qb(1), Qcl(2), Qcu(2), Qd(1), Qof(4), Qt(3), QTc(1), Qwf(6), sch(1), Tp(9), Tsm(12)	High and High to Mod	>66 or >63	47	1	2.1	0.2	22.3
176, 177	Watsonville loam, 0-2% slopes, 2-15% slopes	Watsonville Moderate 0-18”, very slow 18-39”, slow 39”-63”	Qaf(3), Qar(1), Qcl(69), Qcu(39), Qof(7), Qt(3), Qwf(23), Tp(21), Tsm (2)	High and Mod	>66 or >63	16 8	5	3.0	0.2	26.5
178, 179, 180	Watsonville loam, thick surface, 0-2% slopes, 2-15% slopes, 15-30% slopes	Watsonville Moderate 0-18”, very slow 18-39”, slow 39”-63”	Qal(6), Qcl(226), Qcu(29), Qt(2), Qwf(4), Tp(13), Tsc(3), Tsm(5)	High and Mod	>63	28 8	4	1.4	0.2	5.9
181	Xerothents-Rock outcrop complex, 50-100 percent slopes	Xerothents Moderately slow to Rapid 0-9” Rock outcrop NA	Tla(2)	Low and Mod	9-11 B	2	2	100 ?	5.1	26.8
182, 183	Zayante coarse sand 5-30% slopes, 30-50% slopes	Zayante Rapid 0-60”	Qae(1); Qal(12), Qt(2), Tlo(3), Tm(4), Tsm(62)	Low	>60	84	5	6.0	0.2	5.2
184	Zayante-Rock outcrop complex, 15-75% slopes	Zayante Rapid 0-60” Rock outcrop NA	Qae(3), Tlo(1), Tsm(7)	Low	>60 or 0-4 B	11	1	9.1	0.2	9.9
ScF2es (167,168, 169)	Santa Lucia shaly loam, 30-50% slopes		Tmp(2)	Low		2	0	0	0.2	3.3

APPENDIX J-1

Criteria for Radon Potential Ranking of 52 Santa Cruz County Geologic Units. Units are from the Geologic Map of Santa Cruz County, California, compiled by Brabb (1997). Symbols are defined at the end of the table.

Geologic Unit	Radon Survey Data		NURE Airborne eU Data		NURE Soil and Sediment Uranium Data		Radon Potential
	% ≥ 4 pCi/L	Max pCi/L	% ≥ 7.5 ppm	Max. ppm	Median ppm	Max. ppm	
db-Diabase (age unknown)	nd		0.0? (SC) nd (SF) nd (SJ)	4.7 -- --			Unkn
ga-Granite and adamellite (Cretaceous)	33.3?	10.3	nd (SC) 0.0 (SF) nd (SJ)	-- 6.3 --			High?
gd-Gneissic granodiorite (Cretaceous)	nd	--	nd (SC) 3.2 (SF) nd (SJ)	-- 7.6 --			Unkn
hcg-Hornblend-cummingtonite gabbro (Cretaceous)	fd	11.6	nd (SC) nd (SF) nd (SJ)	-- -- --			Unkn
Kcg-Conglomerate (Upper Cretaceous)	nd	--	nd (SC) nd (SF) nd (SJ)	-- -- --			Unkn
Kgs-Shale and sandstone of Nibbs Knob area (Upper Cretaceous)	fd	55.5	nd (SC) nd (SF) 0.0 (SJ)	-- -- 6.1			Unkn
m-Marble (Mesozoic or Paleozoic)	fd	1.1	0.0? (SC) nd (SF) nd (SJ)	7.2 -- --			Unkn
Qae-Aromas Sand-Eolian lithofacies	0.0?	2.1	0.0? (SC) nd (SF) nd (SJ)	4.9 -- --		3.4	Low?
Qaf-Aromas Sand-Fluvial lithofacies	0.0	3.2	0.7 (SC) nd (SF) nd (SJ)	7.7 -- --			Low?
Qal-Alluvial deposits, undifferentiated (Holocene)	12.6	21.7	0.0 (SC) 3.5 (SF) 4.1 (SJ)	7.1 9.4 9.1			Mod
Qar-Aromas Sand, undivided (Pleistocene)	0.0	1.7	0.0 (SC) nd (SF) nd (SJ)	6.1 -- --			Low
Qb-Basin Deposits (Holocene)	fd	1.3	0.0 (SC) nd (SF) nd (SJ)	7.2 -- --	4.2	5.9	Low?

Geologic Unit	**Radon Survey Data**		**NURE Airborne eU Data**		**NURE Soil and Sediment Uranium Data**		**Radon Potential**
	% ≥ 4 pCi/L	**Max pCi/L**	**% ≥ 7.5 ppm**	**Max. ppm**	**Median ppm**	**Max. ppm**	
Qbs-Beach sand (Holocene)	nd	--	0.0? (SC) nd (SF) nd (SJ)	5.8 -- --			Unkn
Qce-Coastal terrace deposits-Eolian facies	fd	0.6	0.0? (SC) nd (SF) nd (SJ)	4.2 -- --			Unkn
Qcf-Abandoned channel fill deposits (Holocene)	nd	--	nd (SC) nd (SF) nd (SJ)	-- -- --			Unkn
Qcl-Coastal terrace deposits-Lowest emergent coastal terrace deposits	2.7	6.0	0.5 (SC) 5.9? (SF) nd (SJ)	7.7 8.3 --	2.5	2.6	Low
Qcu-Coastal terrace deposits, undifferentiated (Pleistocene)	4.8	26.5	1.7 (SC) 0.0 (SF) fd (SJ)	8.6 6.9 3.1		2.2	Low
qd-Quartz diorite (Cretaceous)	15.4	8.8	0.0? (SC) 0.6 (SF) nd (SJ)	6 8.9 --			Mod
Qds-Dune sand (Holocene)	nd	--	nd (SC) nd (SF) nd (SJ)	-- -- --			Unkn
Qem-Eolian deposits of Manresa Beach (Pleistocene)	fd	1.5	0.0? (SC) nd (SF) nd (SJ)	5.8 -- --		6.7	Low??
Qes-Eolian deposits of Sunset Beach (Pleistocene)	fd	0.8	0.0 (SC) nd (SF) nd (SJ)	6.9 -- --			Low??
Qof-Older flood-plain deposits (Holocene)	1.7	6.2	1.7 (SC) nd (SF) fd (SJ)	7.9 -- 8.4	2.5	3.6	Low
Qt-Terrace deposits, undifferentiated (Pleistocene)	4.4	5.8	0.0? (SC) 0.0? (SF) nd (SJ)	6.6 5.6 --			Low?
QTc-Continental deposits, undifferentiated (Pleistocene and Pliocene)	fd	0.9	0.0? (SC) nd (SF) fd (SJ)	4.3 -- 7.1			Unkn
Qtl-Colluvium (Holocene)	0.0?	1.4	0.0 (SC) nd (SF) fd (SJ)	6.0 -- 4.7		3.7	Low?

Geologic Unit	Radon Survey Data		NURE Airborne eU Data		NURE Soil and Sediment Uranium Data		Radon Potential
	% ≥ 4 pCi/L	Max pCi/L	% ≥ 7.5 ppm	Max. ppm	Median ppm	Max. ppm	
Qwf-Terrace deposits of Watsonville-Fluvial facies (Pleistocene)	1.8	4.3	0.9 (SC) nd (SF) nd (SJ)	18.0 -- --		2.8	Low
Qyf-Younger flood-plain deposits (Holocene)	fd	1.1	0.0 (SC) nd (SF) nd (SJ)	6.4 -- --		2.3	Low??
Qyfo-Alluvial fan deposits (Holocene)	fd	2.2	0.0 (SC) nd (SF) nd (SJ)	7.4 -- --			Low??
sch-Metasedimentary rocks (Mesozoic and Paleozoic)	15.0?	8.6	0.0? (SC) 2.3(SF) nd (SJ)	6.8 8.0 --			Mod?
Tbl-Butano Sandstone-Lower sandstone member (Eocene)	nd	--	nd (SC) 3.2 (SF) nd (SJ)	-- 9.4 --			Unkn
Tblc-Butano Sandstone-Conglomerate (Eocene)	fd	4.5	nd (SC) fd (SF) 15.4? (SJ)	-- 1.6 15.5			Unkn
Tbm-Butano Sandstone-Middle siltstone member (Eocene)	21.4?	31.2	nd (SC) 0.0 (SF) 0.0	-- 5.0 5.1			High?
Tbs- Basalt (lower Miocene)	nd	--	nd (SC) fd (SF) nd (SJ)	-- 5.4 --			Unkn
Tbu-Butano Sandstone-Upper sandstone member (Eocene)	17.7?	8.4	nd (SC) 0.0 (SF) 0.0 (SJ)	-- 5.9 6.3			Mod?
Tl-Locatelli Formation (Paleocene)	12.5?	8.5	nd (SC) fd (SF) nd (SJ)	3.0 -- --			Mod?
Tla-Lambert Shale (lower Miocene)	75?	26.8	nd (SC) 0.0 (SF) 0.0? (SJ)	-- 5.6 3.7			High?
Tlo-Lompico Sandstone (middle Miocene)	13.8	9.6	10.7 (SC) 5.2 (SF) 0.0?	8.5 9.9 4.8			Mod
Tlss-Locatelli Formation-Sandstone (Paleocene)	nd	--	nd (SC) 0.0 (SF) nd (SJ)	-- 3.9 --			Unkn
Tm-Monterey Formation (middle Miocene)	36.0	89.3	nd (SC) 11.8 (SF) fd (SJ)	-- 10.8 4.8			High

Geologic Unit	Radon Survey Data		NURE Airborne eU Data		NURE Soil and Sediment Uranium Data		Radon Potential
	% ≥ 4 pCi/L	Max pCi/L	% ≥ 7.5 ppm	Max. ppm	Median ppm	Max. ppm	
Tmm-Sandstone of Mount Madonna area (Eocene?)	nd	--	8.3? (SC) nd (SF) 0.0 (SJ)	9.2 -- 6.0		2.8	Unkn
Tmp-Shale of Mount Pajaro area (Miocene and Oligocene)	fd	3.3	18.3 (SC) nd (SF) 0.0 (SJ)	10 -- 7.2			Low??
Tms-Mudstone of Maymens Flat area (Eocene and Paleocene)	nd	--	nd (SC) nd (SF) 0.0?	-- -- 5.8			Unkn
Tp-Purisima Formation (Pliocene and upper Miocene)	3.7	31.5	4.1 (SC) 1.0 (SF) 2.2 (SJ)	9.6 7.5 10.3		2.1	Low
Tps-Purisima Formation-Predominantly massive sandstone	fd	2.9	10.0? (SC) nd (SF) nd (SJ)	8.1 -- --		3.4	Unkn
Ts-Siltstone and sandstone (Pliocene and upper Miocene)	nd	--	nd (SC) nd (SF) nd (SJ)	-- -- --		2.2	Unkn
Tsc-Santa Cruz Mudstone (upper Miocene)	17.9	21.4	7.1 (SC) 8.9 (SF) 0.0? (SJ)	9.8 13.0 4.1			Mod
Tsl-San Lorenzo Formation, undivided (Oligocene and Eocene)	fd	0.8	nd (SC) 0.0? (SF) 0.0 SJ)	-- 4.8 7.4			Low?
Tsm-Santa Margarita Sandstone (upper Miocene)	6.3	9.9	8.9 (SC) 3.5 (SF) fd (SJ)	9.5 10.2 3.1			Mod
Tsr-San Lorenzo Formation-Rices Mudstone Member (Oligocene and Eocene)	33.3?	11.0	nd (SC) 0.0 (SF) 0.0 (SJ)	-- 6.8 5.3			High?
Tst-San Lorenzo Formation-Twobar Shale Member (Eocene)	nd	--	nd (SC) 0.0 (SF)	-- 5.6 --			Unkn
Tvq-Vaqueros Sandstone (lower Miocene and Oligocene)	10.3	28.5	nd (SC) 0.0 (SF) 0.0 (SJ)	-- 7.0 6.1			Mod

Geologic Unit	**Radon Survey Data**		**NURE Airborne eU Data**		**NURE Soil and Sediment Uranium Data**		**Radon Potential**
	% ≥ 4 pCi/L	**Max pCi/L**	**% ≥ 7.5 ppm**	**Max. ppm**	**Median ppm**	**Max. ppm**	
Tz-Zayante Sandstone (Oligocene)	fd	0.3	nd (SC) 0.9 (SF) fd (SJ)	-- 8.7 3.2			Low??

? = Somewhat uncertain because of limited data
??= Very uncertain because of limited data
SC = Santa Cruz 1X2 degree quadrangle
SF = San Francisco 1X2 degree quadrangle
SJ = San Jose 1X2 degree quadrangle

APPENDIX J-2

Santa Cruz County Geologic Units Without Indoor-Radon Measurements

Unit Symbol	Unit Name
db	Diabase (age unknown)
gd	Gneissic granodiorite (Cretaceous)
Kcg	Conglomerate (Upper Cretaceous)
Qbs	Beach sand (Holocene)
Qds	Dune sand (Holocene)
Qcf	Abandoned channel fill deposits (Holocene)
Tbs	Basalt (lower Miocene)
Tbl	Lower sandstone member-Bultano Sandstone (Eocene)
Tlss	Sandstone-Locatelli Formation (Paleocene)
Tmm	Sandstone of Mount Madonna area (Eocene?)
Tms	Mudstone of Maymens Flat area (Eocene and Paleocene)
Ts	Siltstone and sandstone (Pliocene and upper Miocene)
Tst	Twobar Shale Member (Eocene)

APPENDIX K

Descriptive Statistics and Statistical Comparison of Indoor Measurements (non-transformed) by Santa Cruz Radon Potential Zone

	All Indoor Radon Data	High Zone Radon Data	Moderate Zone Radon Data	Low Zone Radon Data	Unknown Zone Radon
Size	1548	80	393	1055	20
Mean	1.799	6.485	2.299	1.172	6.325
Std. Dev.	3.872	11.510	2.887	1.774	13.497
Std. Error	0.0984	1.287	0.146	0.0546	3.018
C.I. of Mean	0.193	2.561	0.286	0.107	6.317
Range	89.100	89.1	28.3	31.3	55.3
Maximum	89.300	89.3	28.5	31.5	55.5
Minimum	0.200	0.200	0.200	0.200	0.200
Median	1.000	2.700	1.400	0.800	1.600
25%	0.500	1.500	0.800	0.400	0.800
75%	1.800	7.600	2.700	1.300	3.250
Skewness	11.641	5.183	4.330	10.144	3.149
Kurtosis	2.5.469	34.247	27.587	143.571	10.050
K-S Dist.	0.340	0.293	0.234	0.292	0.404
K-S Prob.	<0.001	<0.001	<0.001	<0.001	<0.001
Sum	2784.800	518.800	903.400	1236.100	126.500
Sum of Squares	28200.940	13829.700	5343.880	4766.130	4261.230

APPENDIX L

Descriptive Statistics and Statistical Comparison of Indoor Measurements (Log(10)-transformed) by Santa Cruz Radon Potential Zone

	All Indoor Radon Data	High Zone Radon Data	Moderate Zone Radon Data	Low Zone Radon Data	Unknown Zone Radon
Size	1548	80	393	1055	20
Mean	-0.00628	0.500	0.157	-0.111	0.267
Std. Dev.	0.435	0.498	0.422	0.379	0.646
Std. Error	0.0111	0.0557	0.0213	0.0117	0.144
C.I. of Mean	0.0217	0.111	0.0418	0.0229	0.302
Range	2.650	2.650	2.154	2.197	2.443
Maximum	1.951	1.951	1.455	1.498	1.744
Minimum	-0.699	-0.699	-0.699	-0.699	-0.699
Median	0.000	0.431	0.146	-0.096	0.201
25%	-0.301	0.175	-0.0969	-0.398	-0.0969
75%	0.255	0.880	0.431	0.114	0.512
Skewness	0.390	0.308	-0.0131	0.167	0.665
Kurtosis	0.517	0.282	0.207	0.0603	0.504
K-S Dist.	0.0742	0.0928	0.0500	0.103	0.148
K-S Prob.	<0.001	0.085	0.020	<0.001	0.286
Sum	-9.725	40.024	61.510	-116.590	5.331
Sum of Squares	292.683	39.637	79.418	164.275	9.353

APPENDIX M

Results of the Kolmogorov-Smirnov Normality Test for Untransformed and Log(10) Transformed Indoor-Radon Data, by Radon Potential Zone

A test that fails indicates that the data vary significantly from the pattern expected if the data were drawn from a population with a normal distribution. A test that passes indicates that the data match the pattern expected if the data were drawn from a population with a normal distribution

Data	N	K-S Distribution	P	Result
All Data-Untransformed	1548	0.340	<0.001	Failed
All Data-Log(10) Transformed	1548	0.074	<0.001	Failed
High Zone-Untransformed	80	0.293	<0.001	Failed
High Zone-Log(10) Transformed	80	0.093	0.085	Passed
Moderate Zone-Untransformed	393	0.234	<0.001	Failed
Moderate Zone-Log(10) Transformed	393	0.050	0.020	Failed
Low Zone-Untransformed	1055	0.292	<0.001	Failed
Low Zone-Log(10) Transformed	1055	0.103	<0.001	Failed
Unknown Zone-Untransformed	20	0.404	<0.001	Failed
Unknown Zone-Log(10) Transformed	20	0.148	>0.200	Passed

Appendix N

Mann-Whitney Rank Sum Test Comparisons of Indoor-Radon Data Between the High, Moderate, Low and Unknown Radon Potential Zones

Mann-Whitney Rank Sum Test					
Group	*N*	*Missing*	*Median*	*25%*	*75%*
High Zone	80	0	2.70	1.50	7.60
Moderate Zone	393	0	1.40	0.80	2.70
Result	T = 25090.000 n(small)=80 n(big)=393 (P=<0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=<0.001)				
High Zone	80	0	2.70	1.50	7.60
Low Zone	1055	0	0.80	0.40	1.30
Result	T = 74357.500 n(small)=80 n(big)=1055 (p=<0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=<0.001)				
High Zone	80	0	2.70	1.50	7.60
Unknown Zone	20	0	1.60	0.80	3.25
Result	T = 806.000 n(small)= 20 n(big)=80 (p=0.079 The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=0.079)				
Moderate Zone	393	0	1.40	0.80	2.70
Low Zone	1055	0	0.80	0.40	1.30
Result	T = 361718.000 n(small)=393 n(big)=1055 (P=<0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=<0.001)				
Moderate Zone	393	0	1.40	0.80	2.70
Unknown Zone	20	0	1.60	0.80	3.25
Result	T = 4413.000 n(small)=20 n(big)=393 (P=0.601) The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P=0.601)				

Mann-Whitney Rank Sum Test					
Group	*N*	*Missing*	*Median*	*25%*	*75%*
Low Zone	1055	0	0.80	0.40	1.30
Unknown Zone	20	0	1.60	0.80	3.25
Result	T = 14747.000 n(small)=20 n(big)=1055 (P=0.004) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=<0.004)				