SPECIAL REPORT 246

RADON POTENTIAL IN WESTERN PLACER COUNTY, CALIFORNIA

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California
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California Geological Survey

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EXECUTIVE SUMMARY

This report documents the data and procedures used by the California Department of Conservation, California Geological Survey (CGS) to develop the 2020 radon potential zone map for western Placer County. CGS produced the map for the California Department of Public Health-Indoor Radon Program (CDPH-Indoor Radon Program) through an interagency agreement. The report includes radon potentials for individual geologic units and estimates the number of residents exposed to indoor-radon concentrations at or above the United States Environmental Protection Agency (U.S. EPA) recommended action level of 4.0 picocuries per liter (pCi/L).

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 from underlying soil and rock into homes, become concentrated in indoor air, and pose a significant lung cancer risk to the residents. The U.S. EPA estimates indoor radon exposure results in 21,000 lung cancer deaths annually in the United States.

Between December 2010 and June 2011, the CDPH-Indoor Radon Program conducted an indoor-radon survey of 677 homes in western Placer County. Radon was measured using short-term charcoal detectors and the contract laboratory directly informed survey participants of their test results. Survey test results range from less than 0.4 pCi/L, the reported detection limit, to 23.7 pCi/L.

An additional 63 indoor-radon measurements were available for the study area between April 2006 and September 2016. The finalized database contains 740 home radon data.

A radon potential zone map (Plate 1) was developed by the CGS using:

- CDPH-Indoor Radon Program survey test data.
- A geologic map compiled for this report, from geologic maps listed in the references section of this report.

Also consulted during map development were:

- The National Uranium Resource Evaluation (NURE) Program Airborne Survey Equivalent Uranium (eU) Data from the USGS.
- The NURE Program sediment/soil Uranium (U) data.
- Natural Resources Conservation Service (NRCS) soil unit data and maps.

The radon potential map development process involved using a geographic information system (GIS) to spatially link indoor-radon data, NURE Program airborne eU data, and NURE Program sediment and soil U data to geologic and soil units. Geologic units were then ranked for radon potential based on the characteristics of their associated radon data. Three radon potential categories, defined by the percentage of survey data equal to or exceeding (≥) 4.0 pCi/L, were used to rank western Placer County geologic units as follows:

- Moderate (5.0 to 19.9 percent)
- Low (< 5.0 percent)
- Unknown (for geologic units with few or no data)

No high radon potential units (20 percent or more ≥ 4 pCi/L) were identified in the study area.

Geologic units with the same radon potentials were grouped together to define radon potential zones for the western Placer County radon potential map (i.e., all geologic units with moderate

radon potential collectively define the moderate radon potential zone, etc.). Lack of indoor-radon data and eU data prevented us from mapping the sparsely populated eastern Placer County, except for the part near Lake Tahoe, which was mapped under *Special Report 211, Radon Potential in the Lake Tahoe Area, California*, prepared in 2009 by CGS (Churchill, 2009).

A final step in radon map development involved statistical comparison of indoor-radon data populations for the resulting radon potential zones to confirm that each zone represents a distinct radon potential.

Using the finalized radon potential zone map and the most recent U.S. Census data (from 2010), 8,400 people are estimated to live in residences with indoor-air radon concentrations ≥ 4.0 pCi/L in western Placer County. An estimated 1,888 people live in homes that will likely test ≥ 10 pCi/L, and about 342 people are estimated to live in homes that will likely test ≥ 20 pCi/L.

Indoor-radon testing should be encouraged in moderate radon potential zones and within unknown potential zones where insufficient data are currently available to estimate radon potential.

Those considering new home construction, particularly within moderate radon potential areas, may wish to consider radon resistant new construction practices. Post construction radon mitigation is possible but is more expensive than adding radon reducing features during construction.

Homes with basements tend to have increased incidence of indoor-radon concentrations exceeding the U.S. EPA action level of 4 pCi/L. Over 23 percent of the basements tested in western Placer County exceeded the U.S. EPA action level. Radon testing of existing basements in western Placer County should be encouraged and radon-resistant new construction practices should be considered for basement additions to existing homes.

INTRODUCTION

Purpose

This report documents the data and procedures used by the California Department of Conservation, California Geological Survey (CGS) to develop the 2020 radon potential zone map for western Placer County. CGS produced the map for the California Department of Public Health-Indoor Radon Program (CDPH-Indoor Radon Program) through an interagency agreement. The report includes radon potentials for individual geologic units and estimates the number of residents exposed to indoor-radon concentrations at or above (≥) 4 picocuries per liter (pCi/L). The report contains only minimal radon background, health, and testing information. No information on radon remediation of homes and buildings is included in the report.

The following websites have information about radon, related health issues, testing, and remediation:

https://www.cdph.ca.gov/Programs/CEH/DRSEM/Pages/EMB/Radon/Radon.aspx

http://www.epa.gov/radon/pubs/index.html

Background Information About 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 concentrations of five to several tens of ppm and occasionally higher.

All buildings have some potential for elevated indoor-radon levels because radon is always present in the underlying soils and rocks. Buildings on rocks and soils containing higher concentrations of uranium often have an increased likelihood of elevated indoor-radon levels. Breathing air with elevated radon gas over long periods 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, 2016) estimates 21,000 people die in the United States annually from lung cancer caused by radon exposure.

Indoor-radon concentrations are reported in pCi/L in the United States. The average indoor-radon concentration in American homes is about 1.3 pCi/L (U.S. EPA, 2016). Average outdoor air radon concentration is about 0.4 pCi/L. The U.S. EPA recommends avoiding long-term exposure to radon concentrations at or above the U.S. EPA recommended indoor-radon action level of 4.0 pCi/L. Based on long-term radon test statistics, the U.S. EPA estimates about 1 in 15 homes (6.7 percent) in the United States has radon levels ≥ 4.0 pCi/L.

Indoor-radon concentrations are used for determining potential exposure and for identifying buildings that require remedial action. However, it is inhalation of two radon decay products, polonium-218 and polonium-214, that most likely leads to lung cancer. These polonium isotopes have very short half-lives (see Table 1). When they enter the lungs, they attach to lung tissue or trapped dust particles and quickly undergo radioactive decay, emitting high-energy alpha particles. The alpha particles are thought to damage DNA in lung tissue cells, causing cancer (Brookins, 1990). In contrast, most longer-lived radon-222 is exhaled before undergoing radioactive decay.

Radon gas readily moves through rock and soil along micro-fractures and 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 underlying soil into a building when air pressure inside the building is lower than air pressure in the soil, and pathways for radon entry into the building are available. Heating indoor air, using exhaust fans, and wind blowing across a building will all lower a building's internal air pressure. Pathways include cracks in slab foundations or basement walls, pores and cracks in concrete blocks, through-going floor-to-wall joints, and openings around pipes. Because radon enters buildings from the adjacent soil, indoor-radon concentrations are typically highest in basements and ground floor rooms.

Radon can also enter a building in water from private wells. All groundwater contains some dissolved radon gas. The travel time of water from an aquifer to a home supplied by 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 1.0 pCi/L of radon to indoor air per 10,000 pCi/L of radon in water (Grammer and Burkhart, 2004).

The most common indoor-radon testing methods utilize either charcoal (for 2 to 3-day short-term tests) or alpha-track type detectors (for 90-day to one-year long tests). These tests are simple to perform, inexpensive, and homeowners can do this testing. Homeowners expose the radon detector following manufacturer instructions and then send it to a laboratory for analysis, which is included in the detector cost. Typical turnaround time for test results from the laboratory is one to two weeks. Alternatively, one may hire professional certified radon testers to do the testing. The CDPH-Indoor Radon Program maintains lists of currently certified radon testers, mitigators, and laboratories on its website:

https://www.cdph.ca.gov/Programs/CEH/DRSEM/Pages/EMB/Radon/Certified-Radon-Services-Providers.aspx

Table 1
Generalized Uranium-238 Radioactive Decay Series*

Nuclide (Isotope)	**Principal mode of radioactive decay**	**Half-life**
Uranium-238	Alpha	4.5 X 10^9 years
Thorium-234	Beta	24.1 days
Protactinium-234	Beta	1.2 minutes
Uranium-234	Alpha	2.5 X 10^5 years
Thorium-230	Alpha	7.5 X 10^4 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 X 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

*(Modified from Appleton, 2013, p. 241)

Long-term tests have advantages over short-term tests. Longer exposure times "average out" short-term fluctuations in radon levels, such as those caused by daily and seasonal weather changes. In addition, long-term tests utilize open-house conditions with windows and doors open or shut based on residents' preferences. Short-term tests utilize closed house conditions to maximize radon concentration during the measurement period. Consequently, long-term measurements should more accurately represent a person's exposure to indoor-radon. However, short-term measurements are more common because of the shorter time required. Often, if a short-term indoor-radon test result is several pCi/L above (>) 4.0 pCi/L, follow-up short-term and long-term tests will also be > 4.0 pCi/L.

Radon Potential Map Characteristics, Use and Limitations

Radon potential maps developed by CGS for the CDPH-Indoor Radon Program show areas where geologic conditions create higher or lower likelihoods for homes with radon concentrations ≥ 4.0 pCi/L. Also shown are areas lacking sufficient data for radon potential determination.

Radon potential maps are advisory, not regulatory. Their purpose is to help federal, state and local government agencies and private organizations target and prioritize radon program activities and resources.

A building's location on the map does not indicate it has excessive indoor-radon levels. In addition to geology, local variability in soil permeability, climatic conditions, and factors such as home design, construction, condition, and usage preferences may influence indoor-radon levels. Testing is the only way to determine the radon concentration in a specific building or home accurately, regardless of the radon zone. All radon zones typically have some buildings and homes with indoor-radon levels ≥ 4.0 pCi/L as well as some with radon levels below (<) 4.0 pCi/L.

Development of the Radon Potential Map

The radon potential zone development process for western Placer County utilized data from the following sources:

- Indoor-radon test data for 740 homes
    - 677 from the 2011 CDPH-Indoor Radon Program indoor-radon survey
    - 63 data from additional home tests conducted between April 2006 and September 2016.
- National Uranium Resource Evaluation (NURE) Program Aeroradiometric Survey data for equivalent uranium (eU) for the Sacramento and Chico 1X2 degree quadrangles.
- NURE Program sediment and soil Uranium (U) data for the Sacramento 1X2 degree quadrangle.
- A geologic map compiled for this report, from the geologic map sources listed in the References section.
- Natural Resource Conservation Service (NRCS) Soil Survey Geographic (SSURGO) databases and maps for Placer County, Western Part, California.
- U.S. Census Bureau 2010 census block data for Placer County, California.

The radon potential map development steps were:

1) Group indoor-radon survey data by geologic unit using a geographic information system (GIS).
2) Preliminarily assign geologic units a radon potential category based on the percentage of indoor-radon data ≥ 4.0 pCi/L and the total number of data (see step 7 for categories).
3) Group NURE eU data by geologic unit using GIS.
4) Rate geologic units as to their likelihood of having problem radon homes based on the percentage of NURE eU data ≥ 5.0-ppm uranium (twice the average crustal uranium abundance of 2.5 ppm).
5) Group indoor-radon survey data by NRCS soil unit using GIS.
6) Review soil permeability, shrink-swell character, and hydrologic soil group information for soil units and indoor-radon data to see if these soil characteristics relate to higher or lower indoor-radon concentrations in homes.
7) Considering the results from steps 2, 4, and 6, assign final indoor-radon potentials to all geologic units in the western Placer County study area using percentages of short-term tests ≥ 4.0 pCi/L as follows:
    - High—20.0 percent or more ≥ 4.0 pCi/L (not applicable to the study area at this time).
    - Moderate—5 to 19.9 percent ≥ 4.0 pCi/L.
    - Low—0 to 4.9 percent ≥ 4.0 pCi/L.
    - Unknown—units with insufficient indoor-radon data for estimating the percent ≥ 4.0 pCi/L.
8) Group geologic units with similar radon potentials to form radon potential zones using GIS.
9) Statistically compare assembled radon potential zones to confirm that each zone represents a distinct indoor-radon data population.
10) Estimate the number of people living in each radon potential zone using GIS to compare the census tract data to the radon zones and estimate the number of people residing in homes ≥ 4.0 pCi/L.

Portions of radon potential zones with faults and shear zones often have increased potential for elevated indoor-radon concentrations because such features provide pathways for radon flow. Fractures less than an inch wide can be significant radon pathways. However, the 1:100,000-scale western Placer County radon potential zone map does not show fault and shear zone locations. Accurate representation of such fractures on a 1:100,000-scale map is not possible. A feature must be at least 100-200 square feet in size to show on a map at this scale and the accuracy of that feature’s location is commonly +/- tens to hundreds of feet. Additionally, soil and alluvium may obscure faults and shear zones, especially smaller ones, or prevent their precise location. Consequently, at 1:100,000-scale mapping, it is better to base radon testing priorities on zone designation rather than attempt to target fault and shear zone locations.

Detailed investigations of indoor-radon and fault or shear zone relationships require use or development of 1:24,000 or more detailed scale geologic maps.

Western Placer County Geology Digital Layer

CGS radon potential map development requires appropriate geologic maps at 1:100,000-scale or larger (more detail). Geologic maps at smaller scales (less detail) typically do not work well for radon mapping. This is because geologic units from smaller-scale maps are more likely to be a composite of multiple rock types, and each lithology may have a distinctly different radon potential. Ideal geologic maps for radon potential map development are those with geologic units having a dominant lithology with relatively narrow ranges of variation in chemical and physical properties within the units.

Geologic mapping for this report was compiled and integrated from 21 different geologic maps (see References). Geologic mapping was compiled in GIS, from digital raster and vector GIS data, and field-checked to correlate discrepancies at the boundaries between different maps. This geologic map compilation is unpublished.

A Brief Note About Statistics

Preparing the radon potential map for western Placer County required comparisons of indoor-radon data populations for individual geologic units or groups of geologic units to see if they were statistically different. The nonparametric Mann-Whitney rank sum test was used for these comparisons. Many geologic unit radon data populations are not normally or lognormally distributed. Parametric statistical tests, such as the t-test, require normally distributed populations. Nonparametric tests, such as the Mann-Whitney rank sum test, do not have distribution requirements. Additionally, indoor radon data populations often contain censored data (i.e., data reported below an analytical detection limit, < 0.4pCi/L). The nonparametric Mann-Whitney rank sum test is a valid, simple, and better approach than substitution for missing data below the detection limit and using the t-test (Helsel, 2012).

SHORT-TERM INDOOR-RADON SURVEY AND OTHER INDOOR-RADON DATA

Overview

The CDPH-Indoor Radon Program conducted a radon survey of indoor radon in 677 homes in Placer County between December 2010 and June 2011. Each survey participant received a free charcoal detector with instructions for placement and exposure. After exposure, participants mailed their detector to the contract lab for measurement. The contract lab provided test results directly to survey participants within several weeks of detector receipt. The CDPH-Indoor Radon Program had an additional 63 voluntary indoor-radon measurements for western Placer County in their records, dating between April 2006 and September 2016, which were suitable for use and included in this study. The finalized database contains 740 indoor-radon data.

The primary goal of the survey was to obtain sufficient indoor-radon data for homes on specific geologic units to evaluate their radon potentials. The percentage of homes exceeding the U.S. EPA recommended radon action level of 4.0 pCi/L was used to assign a radon potential to a geologic unit.

Figure 1 shows the geographic distribution of homes with radon measurements in western Placer County used in this study. Areas of high and low survey sample densities reflect areas of high and low population densities in the county. Figure 2 shows the geographic distribution of the 23 homes with reported concentrations ≥4.0 pCi/L.

The CDPH-Indoor Radon Program survey found concentrations ranging from < 0.4 pCi/L, the reporting detection limit, to 23.7 pCi/L, the latter for a basement measurement in a home in Auburn. Table 2 provides test floor and test room information, and the name of the associated geologic unit for those homes with radon concentrations ≥ 10.0 pCi/L.

Table 3a summarizes CDPH-Indoor Radon Program survey results in western Placer County by Zip Code and city/region. For comparison, Table 3b summarizes CDPH online radon database test data for Placer County Zip Codes accumulated by CDPH since 1989. The CDPH online Zip Code radon data presented in Table 3b cannot be used for evaluating the radon potential of geologic units because the only available location information is the Zip Code. More precise test location information is needed for evaluating the radon potential of geologic units.

Another complication with Table 3b data is that it likely includes multiple radon measurements for some homes (e.g., follow-up measurements, simultaneous measurements in multiple rooms, or even measurements after radon mitigation) that cannot be identified as such. Despite these limitations, comparison of Zip Codes with 25 or more data in Table 3a and Table 3b often shows similar indoor-radon trends for western Placer County.

Table 3c shows that the percentage of indoor-radon measurements ≥ 4.0 pCi/L and the maximum radon concentration for basements are both significantly above those for other floors in western Placer County homes.

Figure 1. CDPH-Indoor Radon Program Test Locations, western Placer County.

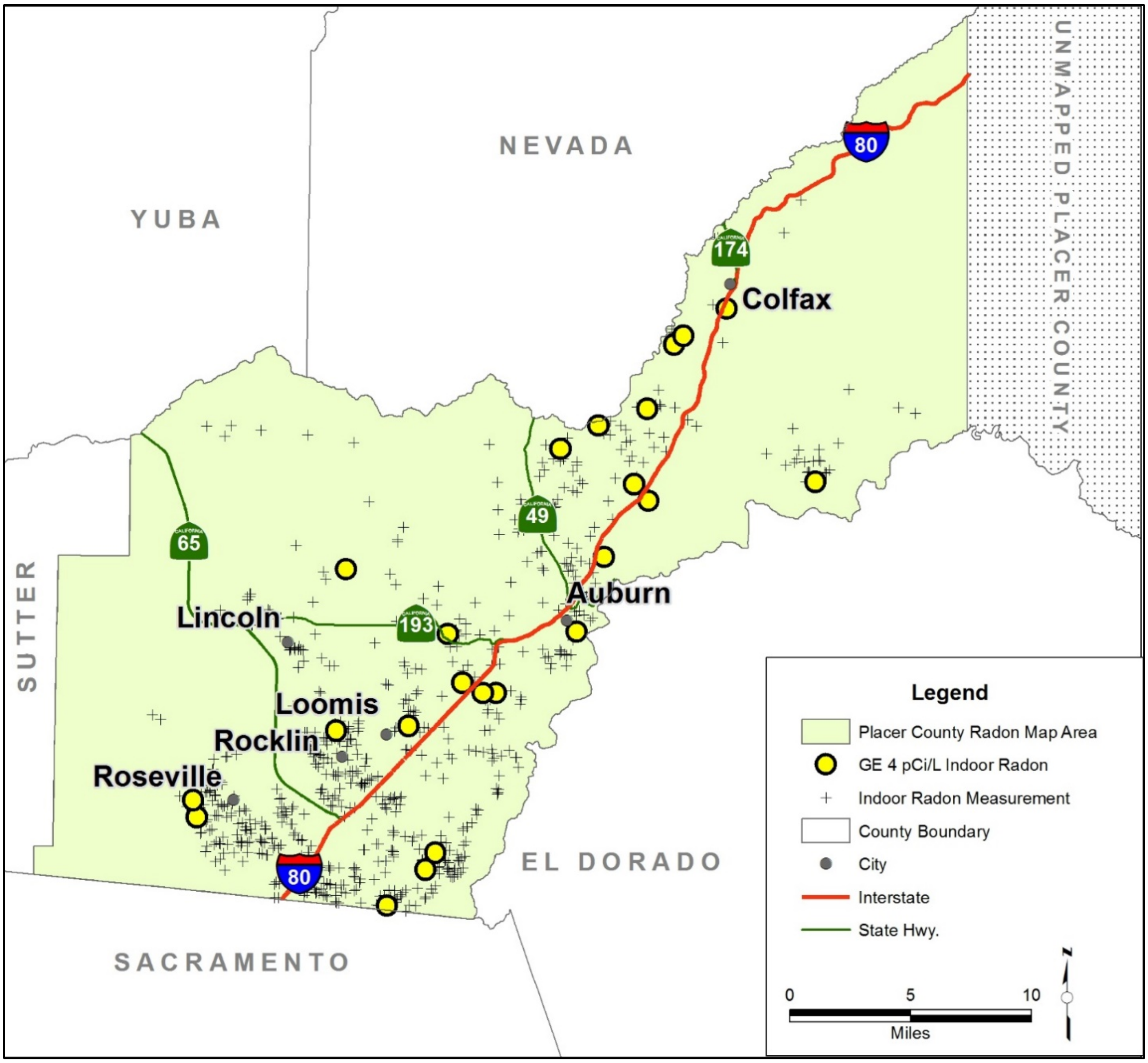

Figure 2. CDPH-Indoor Radon Program Test Locations, with ≥ 4.0 pCi/L Sites Identified (shown as yellow circles).
Note: GE means greater than or equal to.

Table 2 CDPH 2010-2011 Indoor Radon Survey Measurements ≥ 10 pCi/L						
Home	**Radon pCi/L**	**Zip Code**	**City**	**Floor**	**Room**	**Geologic Unit***
1	23.7	95603	Auburn	Basement	Basement	mvs
2	13.5	95602	Auburn	Basement	Basement	Mzg
3	10.7	95648	Lincoln	1st Floor	Dining Room	Jp
4	10.6	95746	Granite Bay	Basement	Basement	Kr
5	10.2	95713	Colfax	1st Floor	Living Room	mel-ms

* Geologic map unit symbols (e.g., mvs, Mzg etc.) referred to above are described in Appendix D.

Table 3a Radon Test Results CDPH 2010-2011 Radon Survey Results by Zip Code				
Zip Code	**City/Region**	**Number of Measurements**	**Number of Measurements ≥ 4pCi/L**	**Percent ≥ 4 pCi/L**
95602	Auburn	33	0	0
95603	Auburn	54	3	5.6
95631	Foresthill	26	1	3.8
95648	Lincoln	44	1	2.3
95650	Loomis	46	1	2.2
95658	Newcastle	38	3	7.9
95661	Roseville	40	0	0
95663	Penryn	12	0	0
95677	Rocklin	55	0	0
95678	Roseville	49	0	0
95681	Sheridan	3	0	0
95703	Applegate	3	0	0
95713	Colfax	10	2	20.0
95722	Meadow Vista	27	2	7.4
95746	Granite Bay	100	1	1.0
95747	Roseville	88	2	2.3
95765	Rocklin	49	0	0
Zip Code Totals from CDPH 2010-2011 Radon Survey				
All	Summary	677	16	2.4

Table 3b Radon Test Results CDPH Online Radon Zip Code Database				
Zip Code	**City/Region**	**Number of Measurements**	**Number of Measurements ≥ 4pCi/L**	**Percent ≥ 4 pCi/L**
95602	Auburn	106	11	10.4
95603	Auburn	175	12	6.9
95626	Elverta	8	1	12.5
95631	Foresthill	86	16	18.6
95648	Lincoln	129	10	7.8
95650	Loomis	91	3	3.3
95658	Newcastle	96	9	9.4
95661	Roseville	110	5	4.5
95663	Penryn	25	2	8.0
95677	Rocklin	116	5	4.3
95678	Roseville	122	1	0.8
95681	Sheridan	5	0	0
95703	Applegate	29	3	10.3
95713	Colfax	50	13	26.0
95722	Meadow Vista	87	12	13.8
95746	Granite Bay	198	12	6.1
95747	Roseville	182	9	4.9
95765	Rocklin	114	3	2.6
Totals from CDPH Online Zip Code Database				
All	Total	1729	127	7.3

Radon Survey Data—Exposure Duration and Data Quality

CDPH-Indoor Radon Program survey participants in western Placer County exposed their charcoal radon test kits for two days (554 homes), three days (114 homes) or four days (9 homes). Differences between two-day, three-day or longer test results should be negligible. Appendix A lists results for 93 concurrent tests. Review of Appendix A also provides a sense of the magnitude of radon variability between different rooms on the same floor and between rooms on different floors.

Table 3c
Comparison of Radon Survey Data by Building Floor

Floor	N	N ≥ 4	% ≥ 4	High
Basement	35	8	22.9	23.7
First Floor	650	13	2.0	10.7
Second Floor	14	0	0	2.5
Not Specified	41	2	4.9	5.4
Total	740	23	3.1	23.7

Appendix B shows the analytical results for 175 detector blanks, analyzed in batches on 12/14/2010, 01/17/2011, 2/15/2011, 3/15/2011, 4/12/2011, 5/18/2011, and 6/18/2011. The analytical results are typical of background ambient air radon concentrations in the United States, the average of which is 0.4 pCi/L.

In summary, blank sample test results support the validity of the CDPH-Indoor Radon Program's western Placer County radon survey data.

Follow-up Radon Testing Results

Appendix C compares six follow-up radon measurements for the same room and floor as the initial survey measurements in six different homes. The time between original and follow-up measurements range from 19 to 70 days. The highest measurement in Appendix C, a first-floor concentration of 10.7 pCi/L, tested 70 days later at 9.0 pCi/L. Four initial measurements above 4.0 pCi/L had follow-up measurements exceeding 4.0 pCi/L. These results confirm the magnitude of the first test and show that elevated radon concentrations likely exist over significant periods in certain rooms of these homes.

WESTERN PLACER COUNTY GEOLOGIC UNIT RADON POTENTIALS

Introduction

Radon data for homes located on 27 different geologic units were obtained for western Placer County. GIS software was used to determine which geologic unit is present at each radon test location.

The names of geologic units within the western Placer County radon map area, and their symbols (e.g., MPm, OMvs, Qr2, Qa, etc.), are listed in Appendix D. The availability of indoor-radon survey data for each geologic unit is also indicated in Appendix D. Appendix E summarizes radon survey data for the 27 geologic units with survey data. Appendix E shows the number of homes with radon data, the actual measurements, and the mean, median, low, and high radon data in pCi/L, and percentage ≥ 4.0 pCi/L for each geologic unit.

Preliminary Geologic Unit Radon Potentials Based Upon Indoor-Radon Data

Preliminary radon potentials were assigned to geologic units based on their associated indoor-radon data, listed in Appendix E, and the radon potential definitions in step 7 on page 5. Tables 4a, 4b, and 4c list geologic units likely to have moderate, low, and unknown radon potential, respectively. Some unit radon potentials listed in these tables are preliminary—less certain because they have less than 25 indoor-radon data. Radon potentials previously assigned to geologic units in Amador, Calaveras and Tuolumne Counties (Churchill, 2017) were also considered in assigning provisional radon potentials to geologic units in western Placer County. Provisional radon potential status is indicated in Tables 4a and 4b as follows: “Moderate (P)”, and “Low (P)”.

The presence or absence of known or likely radon source rocks was noted. Next, radon potentials were assigned to the occurrences based on the percentage of data ≥ 4.0 pCi/L. Tables 4a, 4b, and 4c shows occurrences of geologic units preliminarily identified as moderate, low, and unknown (respectively) radon potentials based on CDPH radon results.

Table 4a
Moderate Radon Potential
Geologic Units and Indoor-Radon Data

Geologic Unit	Indoor-Radon Data	Radon Potential Designation
Jp Penryn Pluton	R = 5.1% n = 138 n ≥ 4 pCi/L = 7 maximum = 10.7 pCi/L	Moderate 5% ≤ R < 20%
Mzg granite	R = 11.1% n = 9 n ≥ 4 pCi/L = 1 maximum = 13.5 pCi/L	Moderate (P) 5% ≤ R < 20%
ms metasedimentary rocks	R = 18.2% n = 11 n ≥ 4 pCi/L = 2 maximum = 8.6 pCi/L	Moderate (P) 5% ≤ R < 20%
mel-ms melange; metasedimentary	R = 11.4% n = 35 n ≥ 4 pCi/L = 4 Maximum = 23.7 pCi/L	Moderate 5% ≤ R < 20%
mel-mv melange; metavolcanic	R = 11.1% n = 27 n ≥ 4 pCi/L = 3 maximum = 6.8 pCi/L	Moderate 5% ≤ R < 20%
Qha alluvium, undivided	R = 5.3% n = 19 n ≥ 4 pCi/L = 1 maximum = 4.4 pCi/L	Moderate (P) 5% ≤ R < 20%
Qr2 Riverbank Formation, middle member	R = 5.3% n = 38 n ≥ 4 pCi/L = 2 maximum = 4.3 pCi/L	Moderate 5% ≤ R < 20%

R = The percent of indoor-radon data at or above 4 pCi/L.
n = Number of indoor-radon unit tests in the respective geologic unit.
(P) = Geologic unit radon potential is preliminary (less certain).

Table 4b Low Radon Potential Geologic Units and Indoor-Radon Data		
Geologic Unit	**Indoor-Radon Data**	**Radon Potential Designation**
Kr Rocklin Pluton	R = 1.3% n = 76 n ≥ 4 pCi/L = 1 maximum = 10.6 pCi/L	Low R < 5%
MPm Mehrten Formation, undivided	R = 0.0% n = 17 n ≥ 4 pCi/L = 0 maximum = 3.9 pCi/L	Low (P) R < 5%
MPmb Mehrten Formation, mudflow breccia	R = 0.0% n = 30 n ≥ 4 pCi/L = 0 maximum = 2.1 pCi/L	Low R < 5%
MPmc Mehrten Formation, conglomerate	R = 3.6% n = 28 n ≥ 4 pCi/L = 1 maximum = 6.2 pCi/L	Low R < 5%
mv metavolcanic rocks	R = 0.0% n = 28 n ≥ 4 pCi/L = 1 maximum = 3.6 pCi/L	Low R < 5%
OMvs Valley Springs Formation	R = 0.0% n = 17 n ≥ 4 pCi/L = 0 maximum = 2.7 pCi/L	Low (P) R < 5%
OMvs? Valley Springs Formation, queried	R = 0.0% n = 20 n ≥ 4 pCi/L = 0 maximum = 3.4 pCi/L	Low (P) R < 5%
Qoa Old alluvium	R = 0.0% n = 8 n ≥ 4 pCi/L = 0 maximum = 1.1 pCi/L	Low (P) R < 5%
Qr3 Riverbank Formation, upper member	R = 0.0% n = 27 n ≥ 4 pCi/L = 0 maximum = 1.9 pCi/L	Low R < 5%

Table 4b (Continued)
Low Radon Potential
Geologic Units and Indoor-Radon Data

Geologic Unit	Indoor-Radon Data	Radon Potential Designation
Qtl Turlock Lake Formation	R = 0.0% n = 131 n ≥ 4 pCi/L = 0 maximum = 2.5 pCi/L	Low R < 5%
sp serpentinite	R = 0.0% n = 9 n ≥ 4 pCi/L = 0 maximum = 1.0 pCi/L	Low (P) R < 5%
um ultramafic rocks	R = 0.0% n = 7 n ≥ 4 pCi/L = 0 maximum = 2.3 pCi/L	Low (P) R < 5%

R = The percent of indoor-radon data at or above 4 pCi/L.
n = Number of indoor-radon tests in the respective geologic unit.
(P) = Geologic unit radon potential is preliminary (less certain).

Table 4c
Unknown Radon Potential
Geologic Units and Indoor Radon Data

Geologic Unit	Indoor-Radon Data
Ei Ione Formation	R = 0.0% n = 1 n ≥ 4 pCi/L = 0 maximum = 0.9 pCi/L
Ei? Ione Formation, queried	R = 0.0% n = 1 n ≥ 4 pCi/L = 0 maximum = 3.6 pCi/L
gb gabbro	R = 0.0% n = 4 n ≥ 4 pCi/L = 0 maximum = 1.5 pCi/L
Mzd diorite	R = 0.0% n = 2 n ≥ 4 pCi/L = 0 maximum = 1.1 pCi/L

Table 4c (Continued) Unknown Radon Potential Geologic Units and Indoor Radon Data	
Geologic Unit	**Indoor-Radon Data**
Mzqd quartz diorite	R = 0.0% n = 1 n ≥ 4 pCi/L = 0 maximum = 0.8 pCi/L
Qm? Modesto Formation, queried	R = 0.0% n = 1 n ≥ 4 pCi/L = 0 maximum = 0.7 pCi/L
Tg auriferous gravels	R = 0.0% n = 1 n ≥ 4 pCi/L = 0 maximum = 0.8 pCi/L
Pl Laguna Formation	R = 0.0% n = 6 n ≥ 4 pCi/L = 0 maximum = 0.9 pCi/L
Jch Copper Hill Volcanics	R = 0.0% n = 5 n ≥ 4 pCi/L = 0 maximum = 0.8 pCi/L

R = The percent of indoor-radon data at or above 4 pCi/L.
n = Number of indoor-radon tests in the respective geologic unit.

Other Information Available for Geologic Unit Radon Potential Evaluation

Besides indoor-radon data, other data useful to consider when assessing geologic unit radon potentials are available for western Placer County. These are soil and sediment uranium data, airborne radiometric uranium data, and soil permeability data. For geologic units without indoor-radon measurements, uranium and soil permeability data may be sufficient to allow assignment of a radon potential. The next two report sections describe these data, indicate their degree of support for unit preliminary radon potentials based on indoor-radon data, and suggest radon potentials for units without indoor-radon data.

NURE PROJECT URANIUM DATA

Background

Because radon is a radioactive decay product of uranium, areas with higher natural background amounts of uranium are more likely to have higher quantities of radon in the subsurface. Buildings in such areas have a greater potential for indoor-radon problems. Consequently, background uranium data for rock units, soils, and sediments are valuable for assessing radon potential where indoor-radon measurements are sparse or absent.

Between 1975 and 1983, the United States government funded the NURE project. The goal of the National Uranium Resource Evaluation (NURE) was to identify new domestic sources (ore deposits) of uranium for energy production 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. Locations with unusually high uranium abundance were targets for additional work to determine whether economically recoverable uranium deposits were present. In parts of California, NURE project contractors collected soil and stream sediment samples for uranium determinations at various U.S. government laboratories. These data are available from the U.S. Geological Survey at: http://mrdata.usgs.gov/geophysics/nurequads.html and http://mrdata.usgs.gov/nuresed/.

Uranium in Soil Samples

NURE project sub-contractors collected 113 soil samples for uranium analysis within the western Placer County study area. The sample spacing generally ranges from about 0.8 to 3.8 miles. However, the NURE soil sample uranium data are only available in the portion of the study area within the Sacramento 1X2 degree quadrangle. Because of the spacing there are few samples per geologic unit. Only three units have more than 10 soil samples [Jp (21), Qr2 (24), and Qtl (13)]. Of the 43 geologic units in the study area, 21 of them have no associated NURE soil uranium data. This limits the usefulness of the data; however, the available NURE soil uranium data suggest a low radon potential for the associated geologic units.

Airborne Radiometric Data

The NURE project obtained uranium data for soil, sediments, and rocks using airborne radiometric surveys. These surveys utilized helicopters equipped with gamma-ray spectrometers to make measurements along a grid of flight lines within 1X2 degree quadrangles throughout the U.S. The spectrometers detect trace amounts of gamma radiation characteristic of several radioactive isotopes including bismuth-214. Because this isotope is a member of the uranium-238 radioactive decay chain (see Table 1), its gamma-ray data can be used to estimate uranium contents of the soils, sediments and rocks along the helicopter's flight paths. Such estimated uranium concentrations, in ppm, are referred to as "equivalent uranium" (eU) data, to distinguish them from uranium (U) data obtained by analyzing soil, sediment, or rock samples by various methods in a laboratory.

Uranium exploration studies view locations with anomalously high eU concentrations as targets for follow-up investigations to determine if economically viable uranium deposits are present. NURE airborne radiometric data used for developing the western Placer County radon potential map are from a compilation by Hill and others (2009). The NURE radiometric surveys covering the study area are the Sacramento and Chico 1X2 degree quadrangle surveys.

The radon isotope most often responsible for elevated indoor-radon concentrations is radon-222. It is a member of the uranium-238 decay chain, in a position between radium-226 and bismuth-214. Because bismuth-214 forms just a few minutes after radon-222 decays (see Table 1), it can be a good indicator of radon abundance within the interval of soil or rock from the surface to about 18 inches deep. However, soil moisture (Grasty, 1997), topography, atmospheric inversion and other local conditions can negatively affect airborne eU data accuracy. Radon entering buildings typically originates within several 10s of feet below the building but sometimes deeper. However, eU estimates are averages for only the uppermost 18 inches of the subsurface (High Life Helicopters 1980a and 1980b; U.S. DOE, 1980). Consequently, while generally helpful, eU measurements are not always good indicators of local subsurface radon availability. For these reasons, CGS radon mapping studies do not treat NURE airborne eU data as quantitative in defining anomalous radon areas as they do NURE laboratory uranium analyses of soil, sediment and rock samples. Instead, CGS studies treat airborne eU data as qualitatively suggestive of areas with higher or lower radon potentials.

Airborne radiometric data collection for western Placer County occurred at average elevations above ground surface of about 400 feet, and at flight speeds of about 60 to 95 miles per hour. Under such conditions, each measurement approximately represents the average uranium content within the upper 18 inches of surficial material over an area of approximately 48,000 square feet (or 1.1 acres; see High-Life Helicopters, 1980a and U.S. Department of Energy, 1980). Flight-line grid patterns for western Placer County consist of east-west flight lines, mostly 3 to 4 miles apart, and north-south flight lines, generally 10 to 15 miles apart. While helpful in the search for anomalous eU areas, this spacing may miss even moderate to relatively large anomalous eU areas.

Figure 3 shows the location of NURE project flight lines within western Placer County. Gamma-ray spectral measurements were recorded at 9,761 locations along these flight lines. Figure 3 also shows the location of eU concentrations within the study area that are at or above 5 ppm. These data appear to cluster in several areas in general agreement with our preliminary radon potential zones.

Appendix F contains the eU data tabulated by geologic unit. This data suggests the Mzg (granite) geologic unit is more likely to have high radon potential. The data suggest that all other geologic units with dataset coverage are more likely to have low radon potential.

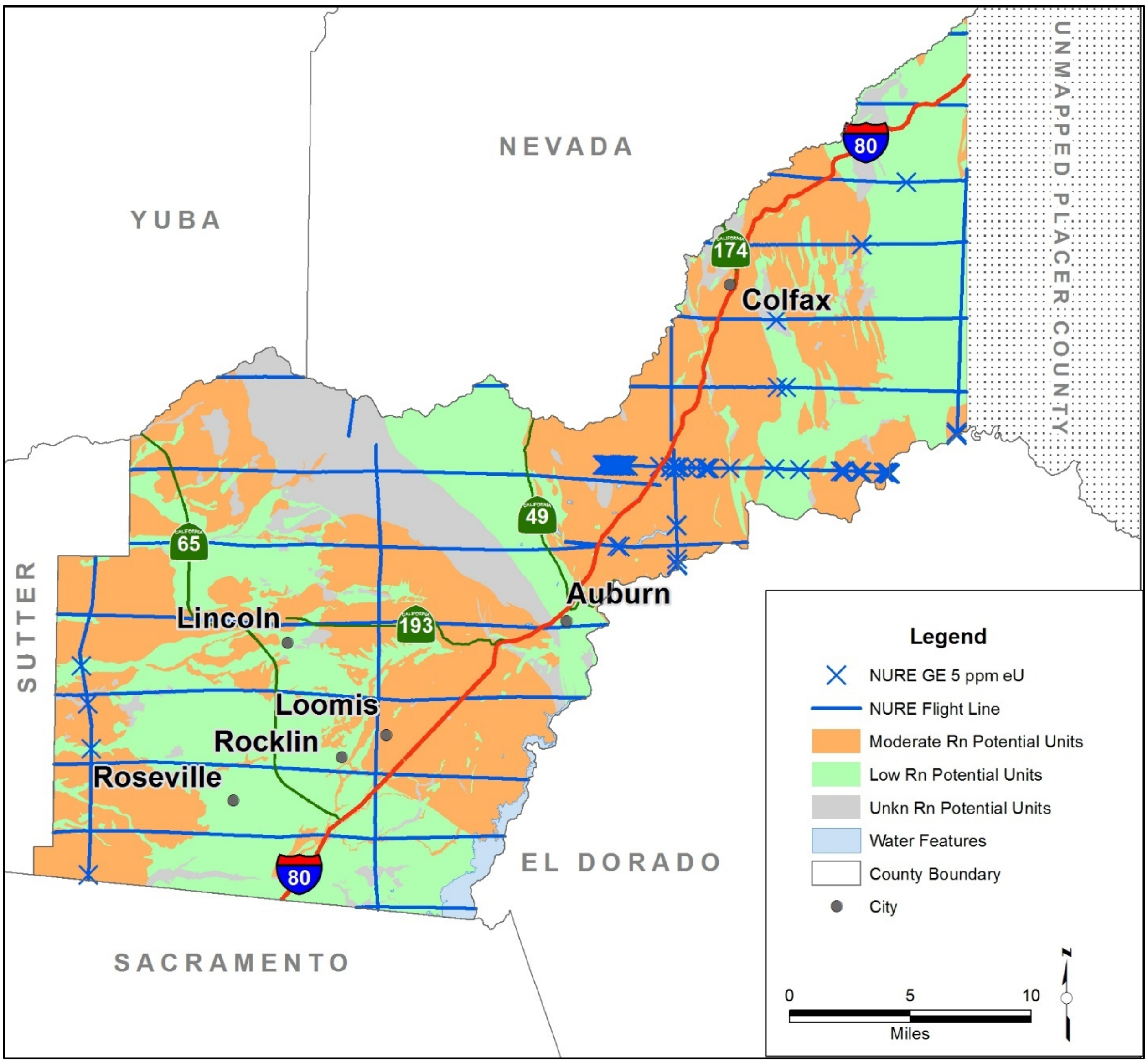

Figure 3. eU concentrations at or above 5 ppm, NURE flight lines, and preliminary radon potential zones in western Placer County.

NRCS SOIL DATA

Background

Natural Resource Conservation Service (NRCS) soil physical property data are sometimes useful in identifying areas with higher radon potential. Higher permeability soils facilitate radon release from host minerals and migration in the subsurface. Radon release and migration can be significantly restricted in soils with low permeability. Soil moisture also impacts radon availability and migration in the subsurface.

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. 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 water (Brookins, 1990). Appendix G provides information on the relationships between soil types, western Placer County geologic units, and indoor radon data.

Several factors limit the usefulness of soil data for radon potential mapping. One limitation is that it often is only available for soil from the surface to depths of five to seven feet. Typically, some or most of the radon entering buildings originates below this depth where permeability data are not available. Another limitation is uncertainty about how to interpret vertical permeability of radon in soil with multiple horizons, each having significant permeability differences. Finally, NRCS soil permeabilities are for water while radon is a gas. Although radon potential mapping projects routinely consider soil water permeabilities, these may not accurately represent radon soil permeability. Despite these limitations, soil permeabilities sometimes correlate with areas of higher or lower radon potential.

Soils in western Placer County often have multiple sub-layers with different thicknesses and permeabilities, which can make judgements about a soil's radon potential difficult. Using hydrologic soil groups (HSG) can help with assessing a soil's radon potential in these situations because each HSG treats its corresponding soil as a unit having a single overall permeability. The western Placer County project takes this approach.

HSG is determined by the water transmitting soil layer with the lowest saturated hydraulic conductivity and the depth to any layer that is water impermeable (e.g., fragipan or duripan), or depth to a water table if present (NRCS, 2007). The least transmissive layer is any soil horizon that transmits water at a slower rate relative to horizons above or below it. For simplicity in an HSG assessment, an impermeable horizon is one with a saturated hydrologic conductivity of 0.0 to 0.1 inches per hour (or 0.0 to 0.9 micrometers per second). Table 5 shows the NRCS HSG definitions with soil group A having the highest permeability and soil group D the lowest permeability for soils with depth to water impermeable layer >40 inches (>100 cm) and depth to high water table (during any month of the year) >40 inches (>100 cm).

Table 5 Definition of Hydrologic Soil Groups*				
Soil Property	NRCS Hydrologic Soil Group			
	A	B	C	D
Saturated hydraulic conductivity of the least transmissive layer	> 1.42 in/h (>10.0 µm/s)	≤1.42 to >0.57 in/h (≤10.0 to >4.0 µm/s)	≤0.58 to >0.06 in/h (≤4.0 to >0.40 µm/s)	≤0.06 in/h (≤0.40 µm/s)
Old permeability classification	Very high to moderate permeability	Moderate to moderately slow permeability	Moderately slow to slow permeability	Very slow permeability

* (Modified from NRCS, 2007)

Table 6 Comparison of Indoor-Radon Data by Hydrologic Soil Group (HSG)				
HSG	N Rn Data	Rn Median pCi/L	Rn Maximum pCi/L	% Rn ≥ 4 pCi/L
A	6	1.0	1.4	0.0
B	179	1.0	10.6	1.7
C	172	1.0	23.7	7.6
D	353	0.9	10.7	2.3

Table 6 compares indoor-radon data by HSG and shows HSG C soils have the highest percentage of indoor-radon data ≥ 4.0 pCi/L. The highest indoor radon concentration reported in the study area -- 23.7 pCi/L -- is also within the area mapped as HSG C by NRCS. Figure 4 shows HSG C soils generally correlate with preliminary moderate radon potential geologic units in the area north of Auburn and east of highway 49. HSG B soils between Rocklin and the southeastern county boundary on Figure 4 generally correlate with a preliminary moderate radon potential zone, although Table 6 indicates that only 3 out of the 179 indoor-radon data in HSG B soils were reported ≥ 4.0 pCi/L. The western third of the study area is largely mapped as HSG D soils that can change permeability by cracking during dry periods. Areas mapped with HSG D soils partially correlate with preliminary radon potential zones in the study area, with about half in the low radon potential zone and half in the moderate radon potential zone.

Comparing indoor-radon data to HSG permeabilities provides useful information for identifying radon potential areas in western Placer County that tends to support the preliminary radon potential zones. Appendix G provides information about soil unit properties in western Placer County including associated indoor-radon data, HSG, permeability, shrink-swell characteristics, and soil parent material (geologic unit).

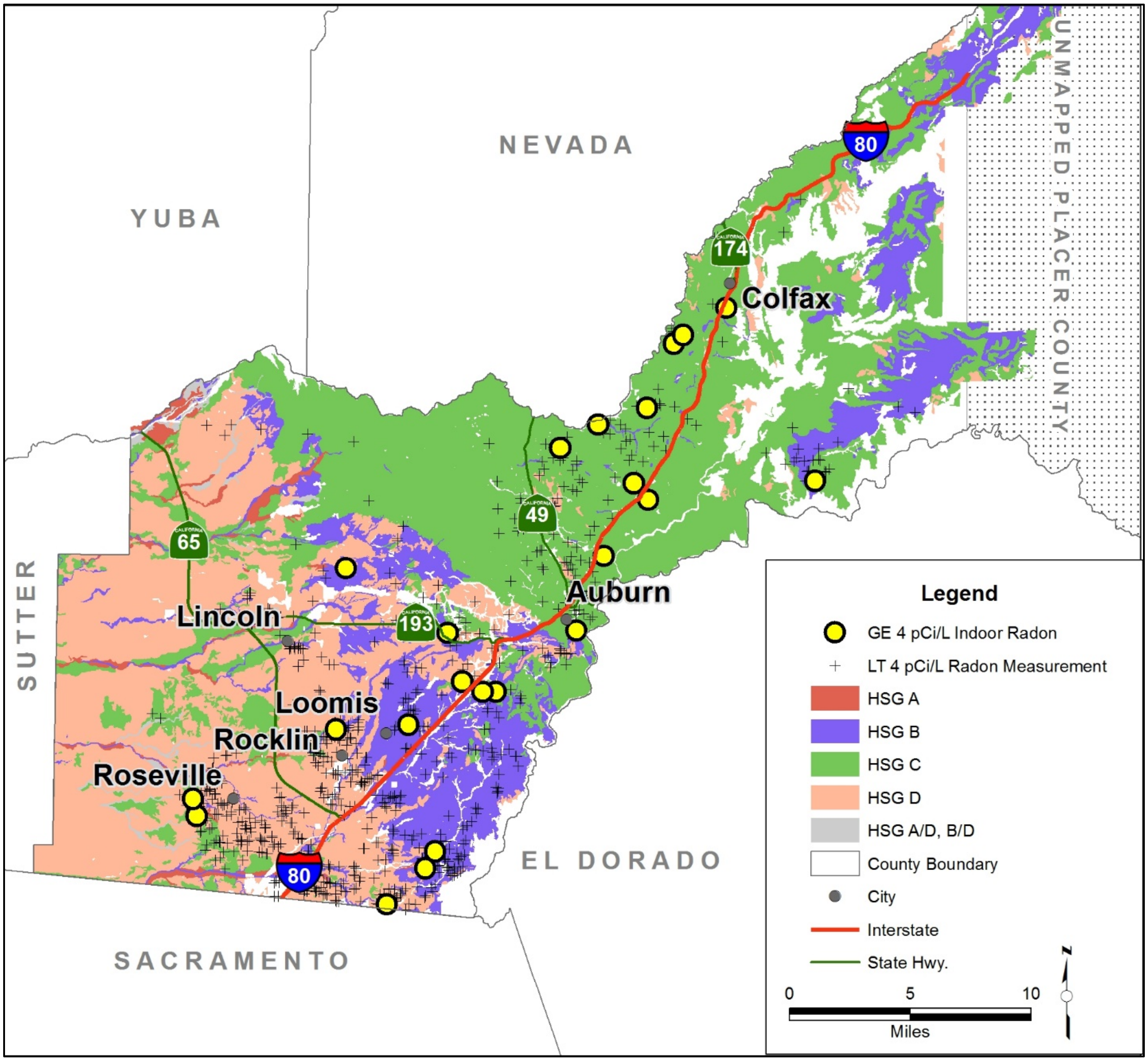

Figure 4. NRCS Hydrologic Soil Groups and Indoor Radon Data.

NRCS = Natural Resource Conservation Service
HSG = Hydrologic Soil Group
GE = Greater than or equal to
LT = Less than
(Areas in white have no hydrologic soil group assigned by NRCS.)

RADON POTENTIAL ZONES

Final Western Placer County Geologic Unit Radon Potentials

Western Placer County radon potential zones are based on the locations of geologic units classified as having moderate, low, or unknown radon potential. The final rankings of the western Placer County geologic units for this report and the associated radon potential map are based upon: 1) indoor-radon data; 2) NURE airborne eU data; and 3) Geologic unit radon potential information from previous CGS radon studies in areas with similar geology.

Table 7 shows the western Placer County geologic units assigned with moderate radon potential. This table provides information about which data support the assigned radon potential for individual geologic units. Figure 5 and Plate 1 show the western Placer County radon potential zones and Figure 6 shows the radon zones in relationship to CDPH Indoor Radon Program data and NURE airborne eU data.

Table 7
Geologic Units and Strength of Supporting Data for Moderate Radon Potential Designation

Geologic Unit	Indoor Radon Survey Data	NURE Airborne eU Data	Nearby Studies
Jp Penryn Pluton	supports moderate	supports low	no data
Mzg granite	weakly supports moderate (sparse data)	supports moderate or high	supports moderate
ms metasedimentary rocks	weakly supports moderate/high (sparse data)	supports moderate	supports high
mel-ms melange; metasedimentary lithologies dominant	supports moderate	supports moderate	no data
mel-mv melange; metavolcanic lithologies dominant	supports moderate	supports moderate	supports low
Qha alluvium	supports moderate	supports low	no data
Qr2 Riverbank Formation; middle member	supports moderate	supports low	no data

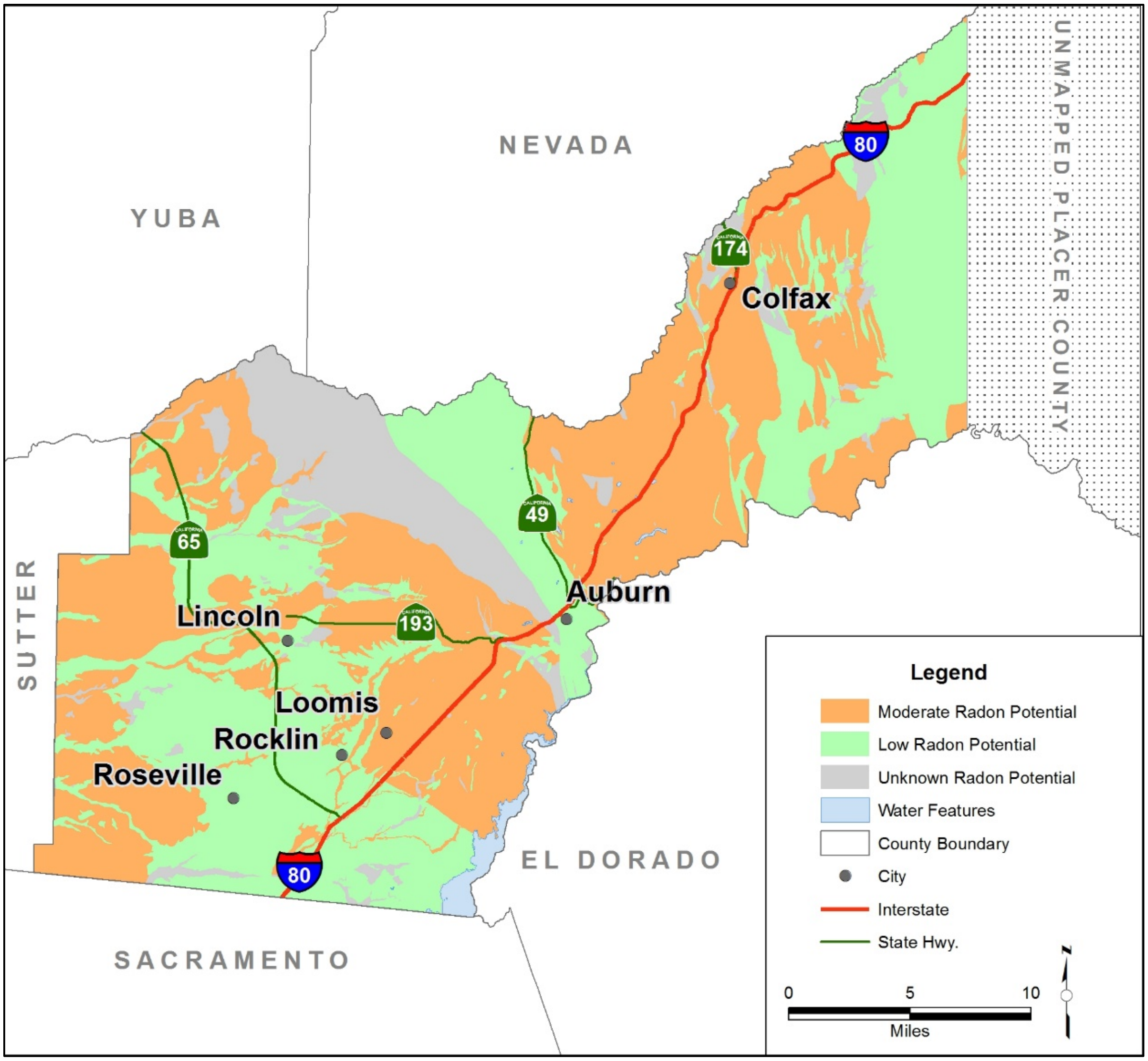

Figure 5. Western Placer County Radon Potential Zones.

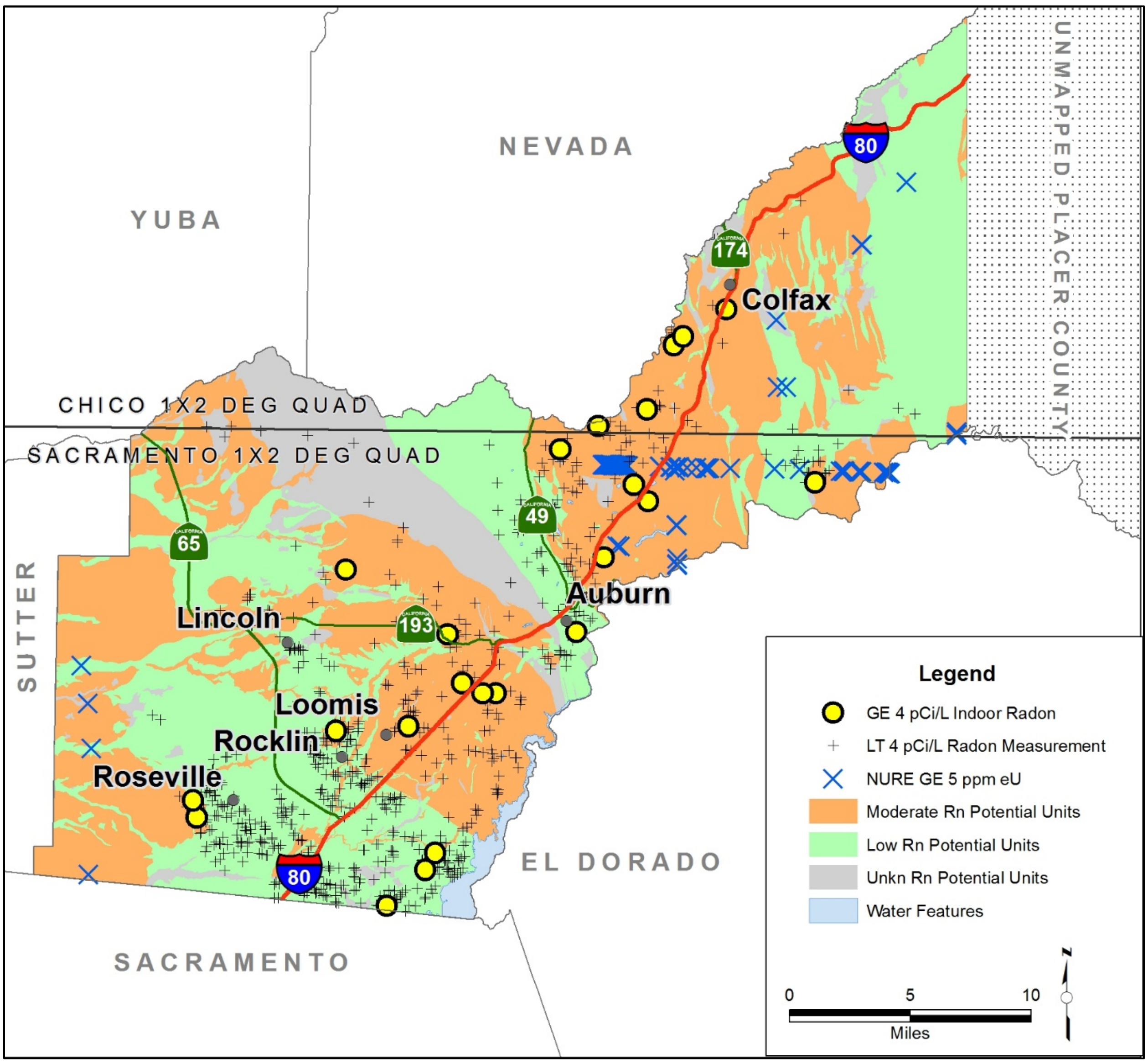

Figure 6. Western Placer County Radon Potential Zones, indoor radon measurements, and NURE airborne eU measurements above 5 ppm

GE = Greater than or equal to
LT = Less than

Tables 8 and 9 contain information about the radon data population characteristics for each radon potential zone. Tables 10 and 11 provide information about ≥ 4.0 pCi/L indoor concentration incidence rates for each radon potential zone and the density of indoor-radon survey data per zone. Table 10 shows that the moderate radon potential zone accounts for 47 percent of the western Placer County map area and contains 87% of measurements at or above 4.0 pCi/L. Table 11 shows that the western Placer County radon potential map area averages about 1.19 home indoor-radon measurements per square mile.

Table 8
Radon Zone Data Characteristics

Potential Zone	n	Median pCi/L	pCi/L at 25%	pCi/L at 75%	Minimum pCi/L	Maximum pCi/L
Moderate	277	1	0.8	1.6	0.4	23.7
Low	441	0.9	0.7	1.2	0.2	10.6
Unknown	22	0.75	0.6	1.05	0.5	3.6
All	740	0.95	0.7	1.3	0.2	23.7

Table 9
Number of measurements above 4.0, 10.0, and 20.0 pCi/L Per Radon Zone

Potential Zone	n	n ≥ 4.0 pCi/L	% data ≥ 4.0 pCi/L	n ≥ 10.0 pCi/L	% data ≥ 10.0 pCi/L	n ≥ 20.0 pCi/L	% data ≥ 20.0 pCi/L	Area-land only (mi2)
Moderate	277	20	7.22	4	1.44	1	0.36	292.2
Low	441	3	0.68	1	0.23	0	0.00	258.2
Unknown	22	0	0.00	0	0.00	0	0.00	71.9
All	740	23	3.11	5	0.68	1	0.14	622.3

Table 10 Percentage of measurements above 4.0, 10.0, and 20.0 pCi/L Per Radon Zone				
Zone	**% of all n ≥ 4.0 pCi/L data**	**% of all n ≥ 10.0 pCi/L data**	**% of all n ≥ 20.0 pCi/L data**	**% Mapped Area**
Moderate	87.0	80.0	100.0	47.0
Low	13.0	20.0	0.0	41.5
Unknown	0.0	0.0	0.0	11.6
All	100.0	100.0	100.0	100.0

Table 11 Radon Data Distribution by Radon Potential Zone		
Zone	**Average Rate: n ≥ 4.0 pCi/L Measurements per square mile**	**Average Rate: Total measurements per square mile**
Moderate	0.07	0.95
Low	0.01	1.71
Unknown	0.00	0.31
All	0.04	1.19

RADON POTENTIAL ZONE STATISTICS

Indoor-Radon Data Characteristics

Indoor-radon survey data population descriptive statistics for each final radon potential zone for untransformed and log-transformed data (i.e., data converted to natural logarithm values) are provided in Appendix H and Appendix I and are briefly discussed below.

Indoor-Radon Data Frequency Distributions

A lognormal frequency distribution is often the assumed statistical distribution for rock and soil trace element data, e.g., uranium and radon (Nero and others, 1986). However, because of the variety of geologic units and complex history of processes affecting them, geochemical data cannot always be fit to a specific frequency distribution (Rose and others, 1979, p. 33). Untransformed and log-transformed radon data for the final radon potential zones, and for the western Placer County radon map area overall, were tested for normality using the Shapiro-Wilk normality test. Appendix J contains the test results. Log-transformed and untransformed data populations all failed the normality test and vary significantly from the pattern expected if they were drawn from a normally distributed population. Each rock unit has its own unique radon population distribution. On an individual basis, the rock unit populations may be lognormal or normal, but the aggregate of several unit populations may not be either normal or lognormal in distribution.

Data non-normality has important implications for certain statistical operations. For example, t-test comparisons should not be used for comparing non-normal populations. For this reason, the Mann-Whitney rank sum test is used for comparisons of sub-populations of indoor-radon test data by radon zone in this study. Non-normality may 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 a radon data population.

Statistical Comparison of Indoor-Radon Data by Radon Potential Zone

Mann-Whitney rank sum test statistical comparisons of moderate, low, and unknown potential zone indoor-radon data populations are listed in Appendix K. Results of these comparisons show the indoor-radon data population for each of these radon zones is statistically distinct with P=0.001 and P=0.030. These results, along with the medians for each data population decreasing in rank order (moderate potential median > low potential median), are evidence supporting the validity of western Placer County radon potential zone definitions. Additional indoor-radon data are needed to identify which portions of the unknown potential zone should be assigned to moderate or low potential categories.

Estimated Western Placer County Population Exposed to 4.0 pCi/L or Higher Radon Concentrations in Indoor Air

Western Placer County radon potential map population estimates for each radon potential zone were obtained using GIS methods to overlay radon potential zones with 2010 census tract data (U.S. Department of Commerce, 2015). 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 12 lists the resulting population estimates and the estimated number of homes for different radon potential zones.

Table 12
Population and Home Estimates for Radon Potential Zones

Radon Potential Zone	Estimated Total Population within Zone—2010 Census Statistics	Estimated Total Homes within Zone—2010 Census Statistics	
		Average Household Population*	Estimated Number of Homes
Moderate	95,080	2.6	36,569
Low	225,697	2.6	86,807
Unknown	13,188	2.6	5,072
Total	333,965	2.6	128,448

*Persons per household, Placer County Community Facts from the U.S. Census Bureau https://factfinder.census.gov

Table 13 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 in each potential zone. Table 13 also contains estimates for individuals exposed to ≥ 4.0 pCi/L based upon:

- Radon zone ≥ 4.0 pCi/L percentages and populations (weighted)
- Overall CDPH Indoor-Radon Program, western Placer County radon data ≥ 4.0 pCi/L percentage and county population (unweighted)
- CDPH Zip Code data ≥ 4.0 pCi/L percentage for western Placer County and county population (unweighted).

Table 13
Estimates of Map Area Populations Exposed to 4.0 pCi/L or Greater Indoor-Radon Levels in Residences (using 2010 U.S. Census data).

Population Estimates by Radon Zone (does not include population within the unmapped portion of the county)						
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**	**Percent Area**	**Square Miles**
Moderate	95,080	6,865	1,369	342	47.0	292.2
Low	225,697	1,535	519	0	41.5	258.2
Unknown	13,188	0	0	0	11.5	71.9
Population Estimate Weighted by Radon Zone and Population Distribution (i.e., the sum of each zone's population estimates)						
Totals	333,965	8,400 (2.5%)	1,888 (0.6%)	342 (0.1%)	100	622.2
Population Estimates by Radon Survey Results Without Regard to Radon Zone or Population Distribution (i.e., ≥ 4.0 pCi/L rate, ≥ 10.0 pCi/L rate, and ≥ 20.0 pCi/L rate multiplied by total population)						
Totals for Western Placer County	333,965	10,386 (3.1%)	2,271 (0.68%)	468 (0.14%)	100	622.2

WESTERN PLACER COUNTY RADON MAPPING PROJECT SUMMARY

Procedures and Results

Short-term radon test data from the CDPH-Indoor Radon Program, NURE soil uranium, NURE airborne eU data, and NRCS soil data were reviewed to evaluate geologic units in western Placer County for their potential to be associated with homes at or above the U.S. EPA recommended radon action level of 4.0 pCi/L. Geologic units were classified as having moderate, low, or unknown radon potential based on the percentage of 4.0 pCi/L or higher indoor-radon test results. Radon potential mapping was completed for 42 percent of Placer County. The central portion of the county was not mapped because insufficient indoor-radon data were available (it is sparsely populated) and there are uncertainties regarding NURE airborne eU data accuracy within this portion of the county. Easternmost Placer County has already been mapped in CGS Special Report 211: Radon Potential in the Lake Tahoe Area, California (Churchill, 2009). Individuals in the unmapped central portion of Placer County concerned about radon should test their homes.

The final radon potential zones have the following characteristics:

Moderate Radon Potential Zone: comprises 47 percent (292 square miles) of western Placer County and contains 87 percent of the ≥ 4.0 pCi/L data and 100 percent of the ≥ 20 pCi/L data in western Placer County. The maximum indoor-radon measurement for a home in this zone is 23.7 pCi/L for a basement.

Low Radon Potential Zone: comprises 42 percent (258 square miles) of western Placer County and contains 13 percent of the ≥ 4.0 pCi/L data and 20 percent ≥ 10 pCi/L data in western Placer County. The maximum indoor-radon measurement for a home in this zone is 10.6 pCi/L for a basement.

Unknown Radon Potential Zone: comprises 11 percent (72 square miles) of western Placer County and contains no measurements ≥ 4.0 pCi/L. The maximum Indoor-Radon measurement for a home in this zone is 3.6 pCi/L.

Note that indoor-radon concentrations exceeding the U.S. EPA recommended action level of 4.0 pCi/L and indoor-radon concentrations below this action level were identified in moderate and low radon potential zones. The only way to know the indoor-radon concentration in a home or building is by testing the indoor-air for radon, regardless of the zone in which the building is located.

Statistical comparison of the indoor-radon data populations for the moderate, low, and unknown 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 the groups) listed in Appendix K are equal or less than 0.001 and 0.030. This is strong statistical support for the different western Placer County radon potential zones representing distinct groups of indoor-radon potentials.

RECOMMENDATIONS

Indoor-radon testing should be encouraged in western Placer County, particularly in the moderate radon potential zone which represents about 47 percent of the total county area. Additional indoor-radon measurements within unknown radon potential zones should also be encouraged because there are insufficient data currently available in these areas to estimate their radon potential.

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

ACKNOWLEDGEMENTS

Milton Fonseca and Anita Carney (CGS) produced the final GIS file of the Western Placer County Radon Potential Map, report figures, and provided GIS support during the development of this map and report. Fred Gius, Greg Marquis, and Ben Parrish (CGS) reviewed the map and report and provided helpful suggestions to improve the text and tables. Natalia Deardorff, CDPH-Indoor Radon Program manager, provided information about the western Placer County indoor-radon survey.

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APPENDIX A
Concurrent Indoor-Radon Test Data
(Multiple Short-Term Radon Tests in a Residence Conducted During Same Time Period)

High (pCi/L)	Low (pCi/L)	Difference (pCi/L)	Percent Difference[1]	Test Dates	City or Area	Test Floor and Room
0.6	0.6	0.0	0.0	2/22-2/24/2010	Newcastle	*1st Floor, Kitchen/Dining Room
0.6	0.5	0.1	16.7	3/13-16/2010	Meadow Vista	*1st Floor, Master Bedroom/Guest Room*
10.6	9.0	1.6	15.1	04/9-12/2010	Granite Bay	Basement
0.8	0.7	0.1	12.5	01/11-14/2011	Rocklin	1st Floor, Kitchen
2.0	1.2	0.8	40.0	1/11-13/2011	Granite Bay	1st Floor, Guest Room
0.9	0.8	0.1	11.1	01/11-14/2011	Granite Bay	1st Floor, Bedroom
2.4	1.8	1.6	25.0	01/11-14/2011	Colfax	2nd Floor, Living Room
1.0	0.9	0.1	10.0	1/12-14/2011	Granite Bay	1st Floor, Master Bedroom
0.9	0.9	0.0	0.0	1/12-14/2011	Granite Bay	1st Floor, Bedroom
4.2	3.3	0.9	21.4	1/13-15/2011	Meadow Vista	1st Floor, Bedroom

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Concurrent Indoor-Radon Test Data

(Multiple Short-Term Radon Tests in a Residence Conducted During Same Time Period)

High (pCi/L)	Low (pCi/L)	Difference (pCi/L)	Percent Difference[1]	Test Dates	City or Area	Test Floor and Room
2.0	2.0	0.0	0.0	1/14-16/2011	Roseville	1st Floor, Bedroom
0.8	0.6	0.2	25.0	1/14-18/2011	Roseville	2nd Floor, Great Room
1.0	1.0	0.0	0.0	1/14-16/2011	Rocklin	1st Floor, Dining Room
0.6	0.5	0.1	16.7	1/15-17/2011	Roseville	1st Floor, Dining Room
2.5	2.3	0.2	8.0	1/16-19/2011	Auburn	2nd Floor, Room not provided
0.5	0.5	0.0	0.0	1/16-19/2011	Roseville	1st Floor, Living Room
0.7	0.5	0.2	28.6	1/17-19/2011	Roseville	1st Floor, Kitchen
1.0	1.0	0.0	0.0	1/17-19/2011	Lincoln	1st Floor, Living Room
0.6	0.6	0.0	0.0	1/17-19/2011	Loomis	1st Floor, Bedroom
3.9	3.9	0.0	0.0	1/18-20/2011	Newcastle	Basement

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Concurrent Indoor-Radon Test Data
(Multiple Short-Term Radon Tests in a Residence Conducted During Same Time Period)

High (pCi/L)	Low (pCi/L)	Difference (pCi/L)	Percent Difference[1]	Test Dates	City or Area	Test Floor and Room
0.9	0.9	0.0	0.0	1/18-20/2011	Roseville	1st Floor, Room not provided
1.5	1.3	0.2	13.3	1/18-22/2011	Newcastle	2nd Floor, Living Room
1.2	1.2	0.0	0.0	1/20-22/2011	Auburn	1st Floor, Family Room
2.1	1.5	0.6	28.6	1/20-22/2011	Roseville	1st Floor, Room not provided
1.0	0.9	0.1	10.0	1/21-23/2011	Roseville	1st Floor, Home Office
1.2	1.1	0.1	8.3	1/21-23/2011	Granite Bay	2nd Floor, Room not provided
6.2	2.9	3.3	53.2	1/22-24/2011	Auburn	Basement
7.1	6.4	0.7	9.6	1/22-24/2011	Foresthill	1st Floor, Room not provided
0.8	0.8	0.0	0.0	1/22-24/2011	Roseville	1st Floor, Family Room
4.1	4.0	0.1	2.4	1/22-24/2011	Roseville	1st Floor, Kitchen

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Concurrent Indoor-Radon Test Data

(Multiple Short-Term Radon Tests in a Residence Conducted During Same Time Period)

High (pCi/L)	Low (pCi/L)	Difference (pCi/L)	Percent Difference[1]	Test Dates	City or Area	Test Floor and Room
1.4	0.9	0.5	35.7	1/22-25/2011	Loomis	1st Floor, Family Room
0.8	0.5	0.3	37.5	1/22-25/2011	Loomis	1st Floor, Family Room
1.2	1.1	0.1	8.3	1/22-25/2011	Granite Bay	1st Floor, Family Room
1.2	0.9	0.3	25.0	1/23-26/2011	Meadow Vista	1st Floor, Room not provided
0.7	0.7	0.0	0.0	1/23-25/2011	Newcastle	1st Floor, Office
1.6	1.6	0.0	0.0	1/24-26/2011	Roseville	Floor and Room not provided
1.0	0.8	0.2	20.0	1/24-26/2011	Newcastle	1st Floor, Family Room
0.5	0.4	0.1	20.0	1/24-27/2011	Foresthill	1st Floor, Living Room
1.6	1.6	0.0	0.0	1/24-27/2011	Granite Bay	Basement
0.6	0.6	0.0	0.0	1/24-27/2011	Granite Bay	2nd Floor, Room not provided

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(Multiple Short-Term Radon Tests in a Residence Conducted During Same Time Period)

High (pCi/L)	Low (pCi/L)	Difference (pCi/L)	Percent Difference[1]	Test Dates	City or Area	Test Floor and Room
2.0	1.4	0.6	30.0	1/25-28/2011	Granite Bay	1st Floor, Living Room
0.8	0.8	0.0	0.0	1/26-30/2011	Roseville	1st Floor, Dining Room
1.0	0.8	0.2	20.0	1/26-28/2011	Auburn	Basement
0.8	0.7	0.1	12.5	1/26-28/2011	Roseville	1st Floor, Living Room
1.0	1.0	0.0	0.0	1/28-30/2011	Meadow Vista	1st Floor, Dining Room
1.5	1.1	0.4	26.7	1/28-30/2011	Loomis	1st Floor, Living Room
1.0	0.9	0.1	10.0	1/30-2/2/2011	Roseville	1st Floor, Family Room
0.5	0.4	0.1	20.0	1/30-2/1/2011	Meadow Vista	1st Floor, Family Room
1.0	0.8	0.2	20.0	1/30-2/1/2011	Roseville	1st Floor, Family Room
0.8	0.7	0.1	12.5	1/30-2/1/2011	Roseville	1st Floor, Dining Room

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Concurrent Indoor-Radon Test Data
(Multiple Short-Term Radon Tests in a Residence Conducted During Same Time Period)

High (pCi/L)	Low (pCi/L)	Difference (pCi/L)	Percent Difference[1]	Test Dates	City or Area	Test Floor and Room
0.9	0.8	0.1	11.1	1/30-2/1/2011	Rocklin	1st Floor, Dining Room
0.9	0.8	0.1	11.1	1/31-2/2/2011	Roseville	1st Floor, Room not provided
0.9	0.8	0.1	11.1	2/1-3/2011	Auburn	1st Floor, Bedroom
1.2	1.0	0.2	16.7	2/4-6/2011	Roseville	1st Floor, Kitchen
1.2	0.8	0.4	33.3	2/4-7/2011	Foresthill	1st Floor, Dining Room
0.8	0.8	0.0	0.0	2/4-6/2011	Roseville	1st Floor, Family Room
3.7	3.2	0.5	13.5	2/5-8/2011	Newcastle	1st Floor, Family Room
0.9	0.8	0.1	11.1	2/6-9/2011	Rocklin	1st Floor, Family Room
0.8	0.6	0.2	25.0	2/6-9/2011	Granite Bay	1st Floor, Bedroom
1.1	0.7	0.4	36.4	2/7-10/2011	Roseville	1st Floor, Living Room

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Concurrent Indoor-Radon Test Data

(Multiple Short-Term Radon Tests in a Residence Conducted During Same Time Period)

High (pCi/L)	Low (pCi/L)	Difference (pCi/L)	Percent Difference[1]	Test Dates	City or Area	Test Floor and Room
1.3	0.7	0.6	46.2	2/9-11/2011	Auburn	2nd Floor, Room not provided
0.7	0.6	0.1	14.3	2/9-11/2011	Granite Bay	Floor and Room not provided
1.0	0.9	0.1	10.0	2/10-13/2011	Roseville	1st Floor, Dining Room
1.3	1.0	0.3	23.0	2/10-13/2011	Rocklin	1st Floor, Family Room
0.6	0.6	0.0	0.0	2/11-13/2011	Roseville	1st Floor, Room not provided
0.7	0.6	0.1	14.3	2/11-14/2011	Rocklin	Floor and Room not provided
1.2	0.8	0.4	33.3	2/12-14/2011	Roseville	1st Floor, Family Room
0.8	0.7	0.1	12.5	2/14-16/2011	Roseville	1st Floor, Dining Room
1.2	1.1	0.1	8.3	2/14-16/2011	Roseville	1st Floor, Office
0.9	0.5	0.4	44.4	2/14-16/2011	Granite Bay	1st Floor, Family Room/Master Bdrm

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Concurrent Indoor-Radon Test Data
(Multiple Short-Term Radon Tests in a Residence Conducted During Same Time Period)

High (pCi/L)	Low (pCi/L)	Difference (pCi/L)	Percent Difference[1]	Test Dates	City or Area	Test Floor and Room
2.0	1.5	0.5	25.0	2/18-21/2011	Roseville	1st Floor, bartop
0.7	0.7	0.0	0.0	2/18-21/2011	Newcastle	1st Floor, Room not provided
1.7	1.6	0.1	5.9	2/22-24/2011	Granite Bay	1st Floor, Room not provided
0.9	0.9	0.0	0.0	2/22-26/2011	Granite Bay	Floor and Room not provided
0.8	0.7	0.1	12.5	2/23-25/2011	Granite Bay	1st Floor, Family Room
0.6	0.6	0.0	0.0	2/25-27/2011	Granite Bay	2nd Floor, Room not provided
1.1	0.6	0.5	45.5	2/28-3/2/2011	Colfax	1st Floor, Sink counter
2.6	2.3	0.2	11.5	3/7-9/2011	Penryn	1st Floor, Sunroom
0.6	0.5	0.1	8.3	3/28-31/2011	Rocklin	1st Floor, Family Rm; 2nd Floor Rec Rm
2.1	1.6	0.5	23.8	4/3-5/2011	Rocklin	1st Floor, Bedroom

APPENDIX A Concurrent Indoor-Radon Test Data (Multiple Short-Term Radon Tests in a Residence Conducted During Same Time Period)						
High (pCi/L)	**Low (pCi/L)**	**Difference (pCi/L)**	**Percent Difference[1]**	**Test Dates**	**City or Area**	**Test Floor and Room**
1.0	0.8	0.2	20.0	4/6-9/2011	Roseville	1st Floor, Kitchen
0.5	0.5	0.0	0.0	4/11-14/2011	Auburn	1st Floor Master Bedroom
4.2	3.6	0.6	14.3	4/16-18/2011	Meadow Vista	2nd Floor, Bedroom -High; Dining Room- Low
0.6	0.6	0.0	0.0	4/30-5/2/2011	Rocklin	1st Floor, Living Room
10.2	8.3	1.9	18.6	5/7-9/2011	Colfax	1st Floor, Sunken Living Room
2.4	1.9	0.5	20.8	12/12-15/2011	Granite Bay	*1st Floor, In-Law Ste./Hallway
6.0	5.7	0.3	5.0	1/13-1/16/2012	Auburn	1st Floor, Kitchen/Family Room
3.5	2.2	1.3	37.1	3/11-13/2012	Rocklin	**Basement (H)/ 1st Floor(L)
3.7	2.3	1.4	37.8	4/7-9/2012	Newcastle	*1st Floor, Craft Room/Bedroom
1.4	1.3	0.1	7.1	7/8-11/2012	Meadow Vista	Basement

APPENDIX A

Concurrent Indoor-Radon Test Data
(Multiple Short-Term Radon Tests in a Residence Conducted During Same Time Period)

High (pCi/L)	Low (pCi/L)	Difference (pCi/L)	Percent Difference[1]	Test Dates	City or Area	Test Floor and Room
1.3	0.8	0.5	38.5	7/21-23/2012	Roseville	**1st Floor Kitchen (H)/2nd Floor Bedroom (L)
1.0	0.7	0.3	30.0	9/10-12/2013	Granite Bay	1st Floor, Room not provided
1.3	1.1	0.2	15.4	1/8-12/2015	Roseville	** Basement (H)/ Kitchen (L)

[1] = Percent difference (Difference ÷ High) x 100

* = Radon detectors placed in different rooms on same floor of residence.

** = Radon detectors placed on different floors of residence.

APPENDIX B
2010-2011 CDPH Indoor Radon Survey Laboratory Blanks
Western Placer County

Date Analyzed	Results pCi/L						
12/14/2010	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	0.5	0.5	0.4	0.4	0.4	0.4	0.4
	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	0.4	0.4	0.4	0.4			
1/17/2011	0.3	0.4	0.4	0.4	0.4	0.4	0.4
	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	0.4	0.5	0.5	0.5			
2/15/2011	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	0.4	0.4	0.5	0.5	0.5	0.5	0.5
	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	0.5	0.5	0.6	0.6			
3/15/2011	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	0.4	0.4	0.4	0.4	0.4	0.4	0.5
	0.5	0.5	0.5	0.5	0.5	0.5	
	0.5	0.5	0.5	0.5			
4/12/2011	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	0.4	0.4	0.4	0.4	0.4	0.5	0.5
	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	0.5	0.5	0.6	0.6			
5/18/2011	0.4	0.4	0.4	0.4	0.5	0.5	0.5
	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	0.5	0.5	0.6	0.6			
6/18/2011	0.4	0.4	0.4	0.4	0.5	0.5	0.5
	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	0.6	0.6	0.6	0.6			

APPENDIX C Follow-Up Radon Tests in Homes (Tests from same home at later date) CDPH Indoor-Radon Data Western Placer County						
Test 1 (pCi/L)	Test 2 (pCi/L)	Difference (pCi/L)	Percent Difference[1]	Days Between Tests	Date Test 1	Date Test 2
4.3	2.2	2.1	48.8	19	2/7/2009	2/26/2009
10.6	5.7	3.8	46.2	21	4/9/2010	4/30/2010
5.5	6.8	1.3	19.1	70	2/5/2011	4/16/2011
10.7	9.0	1.7	15.8	70	1/28/2011	4/8/2011
7.4	6.0	1.4	18.9	30	4/19/2014	5/19/2014

[1] = Percent Difference = (Difference ÷ High) X 100

APPENDIX D
Geologic Map Unit Descriptions
Western Placer County

Geologic Unit Symbol (PTYPE)	Unit Name	Unit Description	Radon Survey Data Available
af	artificial fill	artificial fill	N
Ei	Ione Fm.	Light-colored conglomerate, sandstone, and claystone (Eocene)	Y
Ei?	Ione Fm., queried		N
fz	fault-zone rocks	fault-zone rocks	N
gb	gabbro	gabbro and metagabbro	Y
Jch	Copper Hill Volcanics	Mafic to andesitic pyroclastic rocks, lava and pillow lava with subordinate felsic porphyritic and pyroclastic rocks (Jurassic)	Y
Jch?	Copper Hill Volcanics, queried		N
Jgo	Gopher Ridge Volcanics	Metamorphosed mafic to andesitic pyroclastic rocks, lava and pillow lava with subordinate felsic porphyritic and pyroclastic rocks (Jurassic)	N
Jp	Penryn Pluton	Medium- to coarse-grained quartz diorite. (Jurassic)	Y
Kc	Chico Fm.	Fossiliferous marine sandstone and minor siltstone (Cretaceous)	N
Kr	Rocklin Pluton	Light gray silicic quartz diorite (lower Cretaceous)	Y
ls	limestone	variably metamorphosed limestone	N

APPENDIX D

Geologic Map Unit Descriptions
Western Placer County

Geologic Unit Symbol (PTYPE)	Unit Name	Unit Description	Radon Survey Data Available
mel	melange	structurally mixed rocks; highly variable sizes and compositions of included blocks within a sheared matrix. Included blocks include mafic to intermediate metavolcanic rocks, gabbro, and serpentinite, among others.	N
mel-ms	melange-metasedimentary	area of melange dominated by metasedimentary block lithologies	Y
mel-mv	melange-metavolcanic	area of melange dominated by metavolcanic block lithologies	Y
MPm	Mehrten Fm.	Undivided mudstone, claystone, siltstone, minor sandstone and conglomerate, and tuff breccia derived from andesitic volcanic source areas near the crest of the Sierra Nevada (Miocene)	Y
MPmb	Mehrten Fm., mudflow breccia	Very hard caprock of volcanic mudflow tuff breccia	Y
MPmc	Mehrten Fm., conglomerate	Cemented, poorly bedded cobble and boulder conglomerate	Y
ms	metasedimentary rock	metasedimentary rock (Paleozoic and/or Mesozoic)	Y
mv	metavolcanic rock	metavolcanic rock (Paleozoic and/or Mesozoic)	Y
Mzd	diorite	diorite (Mesozoic)	Y
Mzg	granite	granite (Mesozoic)	Y
Mzqd	quartz diorite	quartz diorite (Mesozoic)	Y
OMvs	Valley Springs Fm.	Rhyolitic sandstone, ash, interbedded tuffs, and claystone. (Oligocene to earliest Miocene)	Y

APPENDIX D

Geologic Map Unit Descriptions
Western Placer County

Geologic Unit Symbol (PTYPE)	Unit Name	Unit Description	Radon Survey Data Available
OMvs?	Valley Springs Fm., queried		Y
Pl	Laguna Fm.	Cobble gravel, sand, and minor silt of mixed metamorphic, granitic, and volcanic source (Pliocene)	Y
py	pyroxenite and metapyroxenite	pyroxenite and metapyroxenite (Paleozoic and/or Mesozoic)	N
Qf	Alluvial fan deposits	Sand, gravel, silt, and clay mapped on gently sloping, fan-shaped, relatively undissected alluvial surfaces (Quaternary)	N
Qha	Alluvium, undivided	Alluvium deposited on fans, terraces, or in basins. Sand, gravel, and silt that are poorly to moderately sorted. Mapped where separate types of alluvial deposits are not delineated (Holocene).	N
Qhb	Basin deposits	Fine grained sediments of late Holocene age with horizontal stratification deposited by standing or slow-moving water in topographic lows	N
Qhc	Stream channel deposits	Deposits in active, natural stream channels consisting of loose alluvial sand, gravel, and silt	N
Qls	landslide deposit	Chaotic deposits of sand, silt, clay, boulders, and blocks of bedrock	Y
Qm?	Modesto Fm., queried	Arkosic alluvium, sand with minor gravel and silt, forming alluvial terraces, alluvial fans and abandoned channel ridges along streams and in valleys	N

APPENDIX D

Geologic Map Unit Descriptions
Western Placer County

Geologic Unit Symbol (PTYPE)	Unit Name	Unit Description	Radon Survey Data Available
Qm1	Modesto Fm., lower member	Unconsolidated, slightly weathered alluvium that forms terraces	N
Qoa	Old alluvium	Alluvial fan, stream terrace, basin, and channel deposits. Topography is gently rolling with little or no original alluvial surfaces preserved; moderately to deeply dissected	Y
Qr2	Riverbank Fm., middle member	Arkosic alluvium, sand with minor gravel and silt, forming alluvial terraces, and dissected alluvial fans along streams on the southeast side of the Sacramento Valley. Middle unit	Y
Qr3	Riverbank Fm., upper member	Arkosic alluvium, sand with minor gravel and silt, forming alluvial terraces, and dissected alluvial fans along streams on the southeast side of the Sacramento Valley. Upper unit	Y
Qtl	Turlock Lake Fm.	Arkosic alluvium, sand with some silt and minor gravel. Deeply weathered and dissected	Y
Qtl?	Turlock lake Fm., queried		Y
sp	serpentinite	serpentinite and peridotite	Y
t	dredge tailings	Gravel, cobbles, boulder, sand, silt, and clay resulting from historic dredging operations	N

APPENDIX D

Geologic Map Unit Descriptions
Western Placer County

Geologic Unit Symbol (PTYPE)	Unit Name	Unit Description	Radon Survey Data Available
Tg	Tertiary auriferous gravels	Sandstones, gravel conglomerates and siltstones. Clast lithologies are dominated by quartz (vein quartz, quartzite) with lesser metamorphic lithologies.	Y
um	ultramafic rocks	Igneous rocks composed chiefly of mafic minerals such as olivine, augite, or hypersthene. Dunite, peridotite, and pyroxenite are examples.	Y

PTYPE – Polygon type, a feature class in geographic information systems (GIS) used to describe polygons representing geologic map unit symbols.

? – Question marks are added to geologic map units to denote some uncertainty in the unit assignment.

APPENDIX E

CDPH-Indoor Radon Data By Geologic Unit
Western Placer County

Geologic Unit Name	N	Indoor Radon Data				Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% >= 4.0 pCi/L
CDPH Western Placer County Radon Data	**740**	**-**	**-**	**-**	**-**					
artificial fill	0					-	-	-	-	-
Ione Fm.	1	0.9				0.9	0.9	0.9	0.9	0.0
Ione Fm., queried	1	3.6				3.6	3.6	3.6	3.6	0.0
fault-zone rocks	0					-	-	-	-	-
gabbro	4	1.5	1.2	1.2	1.1	1.3	1.2	1.1	1.5	0.0
Copper Hill Volcanics	5	0.8 0.5	0.6	0.5	0.5	0.6	0.6	0.5	0.8	0.0
Copper Hill Volcanics, queried	0					-	-	-	-	-
Gopher Ridge Volcanics	0					-	-	-	-	-

APPENDIX E

CDPH-Indoor Radon Data By Geologic Unit
Western Placer County

Geologic Unit Name	N	Indoor Radon Data				Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% >= 4.0 pCi/L
		10.7	1.7	1.1						
		5.4	1.7	1.1	0.8					
		5.3	1.7	1.1	0.8					
		4.9	1.6	1.1	0.8					
		4.3	1.6	1.0	0.8					
		4.2	1.5	1.0	0.7					
		4.0	1.5	1.0	0.7					
		3.9	1.5	1.0	0.7					
		3.7	1.5	1.0	0.7					
		3.7	1.4	1.0	0.7					
		3.7	1.4	1.0	0.7					
		3.5	1.4	1.0	0.7					
		3.4	1.3	1.0	0.7					
		3.3	1.3	1.0	0.7					
		3.1	1.3	1.0	0.7					
		3.1	1.3	0.9	0.7					
		3.0	1.3	0.9	0.6					
Penryn Pluton	138	2.9	1.3	0.9	0.6	1.6	1.2	0.5	10.7	5.1
		2.8	1.3	0.9	0.6					
		2.7	1.3	0.9	0.6					
		2.6	1.3	0.9	0.6					
		2.6	1.3	0.8	0.6					
		2.6	1.3	0.8	0.6					
		2.5	1.2	0.8	0.6					
		2.4	1.2	0.8	0.6					
		2.4	1.2	0.8	0.6					
		2.3	1.2	0.8	0.6					
		2.3	1.2	0.8	0.6					
		2.2	1.2	0.8	0.6					
		2.1	1.2	0.8	0.5					
		2.0	1.2	0.8	0.5					
		1.9	1.2	0.8	0.5					
		1.8	1.2	0.8	0.5					
		1.8	1.2	0.8	0.5					
		1.7	1.1	0.8						

APPENDIX E

CDPH-Indoor Radon Data By Geologic Unit
Western Placer County

Geologic Unit Name	N	Indoor Radon Data				Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% >= 4.0 pCi/L
Chico Fm.	0					-	-	-	-	-
Rocklin Pluton	82	10.6 2.9 2.4 2.0 2.0 2.0 1.7 1.7 1.6 1.6 1.4 1.4 1.3 1.3 1.3 1.3 1.3 1.3 1.2 1.2 1.2	1.2 1.2 1.2 1.1 1.1 1.1 1.1 1.1 1.1 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.9 0.9 0.9 0.9	0.9 0.9 0.9 0.9 0.9 0.9 0.9 0.8 0.8 0.8 0.8 0.8 0.8 0.8 0.8 0.8 0.8 0.8 0.8 0.8 0.7	0.7 0.7 0.7 0.7 0.7 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.5 0.5	1.1	0.9	0.5	10.6	1.2
limestone	0					-	-	-	-	-
melange	0					-	-	-	-	-
melange-metasedimentary	35	23.7 10.2 4.8 4.1 3.8 2.6 2.5 2.4 1.8	1.5 1.3 1.3 1.2 1.2 1.2 1.1 1.1 1.1	1.1 1.1 1.0 1.0 1.0 0.9 0.9 0.9 0.7	0.7 0.7 0.7 0.7 0.7 0.7 0.6 0.5	2.3	1.1	0.5	23.7	11.4

APPENDIX E

CDPH-Indoor Radon Data By Geologic Unit
Western Placer County

Geologic Unit Name	N	Indoor Radon Data				Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% >= 4.0 pCi/L
melange-metavolcanic	27	6.8 6.0 4.2 3.8 3.0 2.6 2.6	1.5 1.5 1.4 1.2 1.1 1.0 1.0	1.0 1.0 1.0 1.0 0.9 0.9 0.8	0.7 0.6 0.6 0.5 0.5 0.4	1.8	1.0	0.4	6.8	11.1
Mehrten Fm.	17	3.9 3.2 2.3 2.3 1.5	1.3 1.2 0.9 0.9 0.8	0.8 0.7 0.7 0.6 0.6	0.6 0.5	1.3	0.9	0.5	3.9	0.0
Mehrten Fm., mudflow breccia	31	2.1 1.5 1.5 1.5 1.2 1.2 1.1 1.0	1.0 1.0 0.9 0.9 0.9 0.8 0.8 0.8	0.8 0.8 0.8 0.8 0.7 0.7 0.7 0.7	0.7 0.6 0.6 0.6 0.6 0.5 0.5	0.9	0.8	0.5	2.1	0.0
Mehrten Fm., conglomerate	37	6.2 3.5 3.4 2.8 2.5 2.4 2.1 1.7 1.4 1.3	1.3 1.2 1.2 1.2 1.1 1.1 1.1 1.0 1.0 1.0	1.0 1.0 0.9 0.9 0.9 0.9 0.9 0.7 0.7 0.7	0.7 0.7 0.6 0.6 0.6 0.6 0.5	1.4	1.0	0.5	6.2	2.7
metasedimentary rock	11	8.6 7.1 2.4	1.8 1.7 1.6	1.3 1.1 1.0	0.8 0.7	2.6	1.6	0.7	8.6	18.2

APPENDIX E

CDPH-Indoor Radon Data By Geologic Unit
Western Placer County

Geologic Unit Name	N	Indoor Radon Data				Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% >= 4.0 pCi/L
metavolcanic rock	29	3.6 3.4 2.2 2.1 1.5 1.5 1.3 1.2	1.0 1.0 1.0 0.9 0.9 0.9 0.9 0.8	0.8 0.8 0.8 0.7 0.7 0.7 0.7 0.7	0.7 0.6 0.6 0.5 0.5	1.1	0.9	0.5	3.6	0.0
diorite	2	1.1	0.5			0.8	0.8	0.5	1.1	0.0
granite	9	13.5 2.8 1.4	1.3 0.9 0.7	0.6 0.5		2.7	1.3	0.5	13.5	11.1
quartz diorite	1	0.8				0.8	0.8	0.8	0.8	0.0
Valley Springs Fm.	19	2.7 1.9 1.4 1.4 1.2	1.1 1.1 1.1 1.1 1.0	1.0 0.9 0.9 0.8 0.8	0.7 0.7 0.6 0.6	1.1	1.0	0.6	2.7	0.0
Valley Springs Fm., queried	23	7.4 3.4 2.2 2.1 1.2 1.2	1.2 1.1 1.1 1.1 1.0 1.0	1.0 0.9 0.8 0.8 0.7 0.7	0.7 0.7 0.6 0.6 0.6	1.4	1.0	0.6	7.4	4.3
Laguna Fm.	6	0.9 0.7	0.7 0.6	0.6 0.5		0.7	0.7	0.5	0.9	0.0
pyroxenite and metapyroxenite	0					-	-	-	-	-
Alluvial fan deposits	0					-	-	-	-	-
Alluvium, undivided	19	4.4 2.1 1.9 1.4 1.2	1.2 1.2 1.0 1.0 0.9	0.9 0.9 0.8 0.8 0.8	0.7 0.7 0.6 0.5	1.2	0.9	0.5	4.4	5.3

APPENDIX E

CDPH-Indoor Radon Data By Geologic Unit
Western Placer County

Geologic Unit Name	N	Indoor Radon Data				Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% >= 4.0 pCi/L
Basin deposits	0					-	-	-	-	-
Stream channel deposits	0					-	-	-	-	-
landslide deposit	0					-	-	-	-	-
Modesto Fm., queried	1	0.7				0.7	0.7	0.7	0.7	0.0
Modesto Fm., lower member	0					-	-	-	-	-
Old alluvium	8	1.1 1.1	1.0 1.0	1.0 0.9	0.8 0.7	1.0	1.0	0.7	1.1	0.0
Riverbank Fm., middle member	38	4.3 4.1 2.4 2.4 1.6 1.4 1.2 1.2 1.1 1.1	1.1 1.1 1.0 1.0 1.0 1.0 1.0 0.9 0.9 0.9	0.9 0.9 0.9 0.8 0.8 0.8 0.8 0.8 0.8 0.8	0.7 0.7 0.7 0.7 0.6 0.5 0.5 0.5	1.2	0.9	0.5	4.3	5.3
Riverbank Fm., upper member	29	1.9 1.9 1.5 1.5 1.5 1.3 1.3 1.3	1.2 1.1 1.1 1.1 1.0 1.0 1.0 1.0	0.9 0.9 0.8 0.8 0.8 0.8 0.7 0.7	0.6 0.6 0.5 0.5 0.5	1.0	1.0	0.5	1.9	0.0

APPENDIX E

CDPH-Indoor Radon Data By Geologic Unit
Western Placer County

Geologic Unit Name	N	Indoor Radon Data				Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% >= 4.0 pCi/L
Turlock Lake Fm.	150	3.1	1.2	0.9		1.0	0.9	0.2	3.1	0.0
		2.5	1.1	0.9	0.7					
		2.4	1.1	0.9	0.7					
		2.1	1.1	0.9	0.7					
		2.0	1.1	0.9	0.7					
		2.0	1.1	0.9	0.7					
		1.9	1.0	0.9	0.7					
		1.8	1.0	0.8	0.7					
		1.8	1.0	0.8	0.7					
		1.7	1.0	0.8	0.7					
		1.7	1.0	0.8	0.7					
		1.6	1.0	0.8	0.7					
		1.6	1.0	0.8	0.6					
		1.5	1.0	0.8	0.6					
		1.5	1.0	0.8	0.6					
		1.5	1.0	0.8	0.6					
		1.4	1.0	0.8	0.6					
		1.4	1.0	0.8	0.6					
		1.3	1.0	0.8	0.6					
		1.3	1.0	0.8	0.6					
		1.3	1.0	0.8	0.6					
		1.3	1.0	0.8	0.6					
		1.3	1.0	0.8	0.6					
		1.3	1.0	0.8	0.6					
		1.3	0.9	0.8	0.6					
		1.3	0.9	0.8	0.6					
		1.3	0.9	0.8	0.6					
		1.2	0.9	0.8	0.6					
		1.2	0.9	0.8	0.6					
		1.2	0.9	0.8	0.6					
		1.2	0.9	0.8	0.6					
		1.2	0.9	0.8	0.6					
		1.2	0.9	0.7	0.5					
		1.2	0.9	0.7	0.5					
		1.2	0.9	0.7	0.5					
		1.2	0.9	0.7	0.4					
		1.2	0.9	0.7	0.2					
		1.2	0.9	0.7						

APPENDIX E

CDPH-Indoor Radon Data By Geologic Unit
Western Placer County

Geologic Unit Name	N	Indoor Radon Data				Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% >= 4.0 pCi/L
Turlock lake Fm., queried	0					-	-	-	-	-
serpentinite	9	1.0 1.0 0.9	0.9 0.8 0.8	0.7 0.6 0.5		0.8	0.8	0.5	1.0	0.0
dredge tailings	0					-	-	-	-	-
Tertiary auriferous gravels	1	0.8				0.8	0.8	0.8	0.8	0.0
ultramafic rocks	7	2.3 0.8	0.7 0.7	0.7 0.6	0.6	0.9	0.7	0.6	2.3	0.0

APPENDIX F

NURE Airborne eU Data Statistics by Geologic Unit
Western Placer County

Geologic Unit Symbol	Geologic Unit Name	N	N ≥ 5 ppm eU	%N ≥ 5 ppm eU	Low ppm eU	High ppm eU	Median ppm eU
af	artificial fill	2	0	0.0	0.1	0.1	0.1
Ei?	Ione Fm., queried	15	0	0.0	1.3	3.5	2.8
fz	fault zone (?)	9	0	0.0	-0.7	2.8	2.3
gb	gabbroic rock	40	0	0.0	-0.7	3.2	0.7
Jch	Copper Hill Volcanics	580	0	0.0	-1.7	3.8	1.0
Jp	Penryn Pluton	1,337	0	0.0	-0.4	4.2	1.3
Kr	Rocklin Pluton	226	0	0.0	-0.3	4.6	1.1
mel	melange	42	1	2.4	-0.1	5.0	1.7
mel-ms	melange, dominated by metasedimentary lithologies	951	21	2.2	-0.7	7.6	2.1
mel-mv	melange, dominated by metavolcanic lithologies	309	9	2.9	-0.7	6.0	1.8
MPm	Mehrten Fm., undifferentiated	371	1	0.3	-0.3	5.0	1.4
MPmb	Mehrten Fm., volcanic breccia	144	0	0.0	0.1	4.5	1.3
MPmc	Mehrten Fm., conglomerate	236	0	0.0	-0.1	4.6	1.9
ms	metasedimentary	754	21	2.8	-1.1	11.0	2.0
mv	metavolcanic	856	3	0.4	-2.2	5.5	1.2
Mzd	diorite	46	0	0.0	1.1	3.8	2.3
Mzg	granite	30	23	76.7	3.5	7.6	5.7
Mzqd	quartz diorite	13	0	0.0	0.5	2.5	1.6
OMvs	Valley Springs Fm.	78	0	0.0	0.2	3.9	1.5
OMvs?	Valley Springs Fm., queried	88	0	0.0	-0.1	4.7	2.0
Pl	Laguna Fm.	52	0	0.0	0.4	3.4	1.2

APPENDIX F

NURE Airborne eU Data Statistics by Geologic Unit
Western Placer County

Geologic Unit Symbol	Geologic Unit Name	N	N ≥ 5 ppm eU	%N ≥ 5 ppm eU	Low ppm eU	High ppm eU	Median ppm eU
Qf	alluvial fan sediments	32	0	0.0	0.3	2.5	1.6
Qha	holocene alluvium	334	0	0.0	-0.6	4.0	1.3
Qhb	holocene basinal fill	55	0	0.0	0.5	3.4	1.6
Qhc	holocene channel sediments	31	0	0.0	0.1	2.7	1.0
Qm?	Modesto Fm., queried	22	0	0.0	0.0	3.9	1.8
Qoa	old alluvium	150	0	0.0	0.0	3.8	1.1
Qr2	Riverbank Fm., middle	1,434	2	0.1	-0.1	5.5	1.5
Qr3	Riverbank Fm., upper	540	2	0.4	0.0	5.3	1.4
Qtl?	Turlock Lake Fm., queried	501	0	0.0	-0.3	3.6	1.4
sp	serpentinite	25	0	0.0	-0.4	3.1	1.0
t	dredge tailings	17	0	0.0	-0.1	4.2	2.1
Tg	auriferous gravels	82	0	0.0	0.2	3.7	1.7
um	ultramafic rocks	359	1	0.3	-1.5	5.0	1.0

Total eU data points = 9,761

APPENDIX G

Soil Units and Indoor-Radon Data with associated Geologic Units
Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
100	Aiken loam, 2 to 9 percent slopes	M (21") M (27") MS (38")	B	Loam, clay loam, and clay Parent material: Residuum weathered from andesite. (MPm)	L M M	>80	9	0	0.0	0.9	3.9 3.2 1.2 0.9 0.9 0.8 0.7 0.6 0.6

APPENDIX G

Soil Units and Indoor-Radon Data with associated Geologic Units
Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
104	Alamo-Fiddyment complex, 0 to 5 percent slopes						1	0	0.0	1.9	1.9
	(Alamo)	S (9") VS (28") VS (4")	D	Alamo soil is a clay over indurated material. Parent material: Alluvium	H H ---	37-41					
	(Fiddyment)	M (12") M (16") --- (7") MS (4")		Fiddyment soil is loam, clay loam, and indurated material over weathered bedrock. Parent material: Alluvium derived from sed. rock (Qtl)	L L M ---	20-39					

APPENDIX G

Soil Units and Indoor-Radon Data with associated Geologic Units
Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
105	Alamo variant clay, 2 to 15 percent slopes	S (25") VS (11") MS (4")	D	Clay to sandy clay over weathered bedrock. Parent material: Alluvium (Omvs, MPmb, Qha)	H H ---	36-40	20	1	5.0	1.1	4.3 1.1 3.1 1.1 2.3 1.0 2.1 1.0 2.0 0.9 1.5 0.8 1.4 0.7 1.3 0.7 1.2 0.6 1.1 0.6
106	Andregg coarse sandy loam, 2 to 9 percent slopes	MR (15") MR (14") VS (4")	B	Coarse sandy loam over weathered bedrock. Parent material: Residuum weathered from granite. (Qr3, Kr, Jp, Ei, Qha, OMvs?)	L L ---	29-33	105	2	1.9	1.0	10.6

APPENDIX G

Soil Units and Indoor-Radon Data with associated Geologic Units Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
107	Andregg coarse sandy loam, 9 to 15 percent slopes	MR (15") MR (14") VS (4")	B	Coarse sandy loam over weathered bedrock. Parent material: Residuum weathered from granite. (Kr, Jp)	L L ---	29-33	7	0	0	0.8	2.3 1.1 0.8 0.8 0.7 0.7 0.5
108	Andregg coarse sandy loam, 15 to 30 percent slopes	MR (15") MR (14") VS (4")	B	Coarse sandy loam over weathered bedrock. Parent material: Residuum weathered from granite. (Jp)	L L ---	29-33	4	0	0	1.2	2.4 1.4 1.0 0.7

APPENDIX G

Soil Units and Indoor-Radon Data with associated Geologic Units
Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
109	Andregg coarse sandy loam, rocky, 2 to 15 percent slopes	MR (15") MR (14") VS (4")	B	Coarse sandy loam over weathered bedrock. Parent material: Residuum weathered from granite. (Kr, Jp, Qha)	L L ---	29-33	18	1	5.55	1.2	5.3 1.2 2.6 1.0 2.0 0.9 1.4 0.8 1.3 0.8 1.2 0.8 1.2 0.8 1.2 0.6 1.2 0.5
110	Andregg coarse sandy loam, rocky, 15 to 30 percent slopes	MR (15") MR (14") VS (4")	B	Coarse sandy loam over weathered bedrock. Parent material: Residuum weathered from granite. (Kr, Jp)	L L ---	29-33	3	0	0	0.9	0.9 0.9 1.7
111	Andregg coarse sandy loam, rocky, 30 to 50 percent slopes	MR (15") MR (14") VS (4")	B	Coarse sandy loam over weathered bedrock. Parent material: Residuum weathered from granite. (MPmc, Jp)	L L ---	29-33	3	0	0	1.9	3.9 1.9 0.6

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Soil Units and Indoor-Radon Data with associated Geologic Units Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
112	Andregg-Rock outcrop complex, 5 to 30 percent slopes	MR (15") MR (14") VS (4")	B	Coarse sandy loam over weathered bedrock. Parent material: Residuum weathered from granite. (Jp)	L L ---	29-33	8	0	0	0.7	2.9 1.0 0.7 0.7 0.6 0.6 0.5 0.5
113	Andregg-Shenandoah complex, 2 to 15 percent slopes						5	0	0	0.7	1.9 1.2 0.7 0.7 0.5
	(Andregg)	MR (15") MR (14") VS (4")	B	Andregg soils are coarse sandy loam over weathered bedrock. Parent material: Residuum weathered from granite. (Qha, Jp, Pl, Qr3)	L L ---	29-33					
	(Shenandoah)	M (16") VS (18) VS (4")	D	Shenandoah soils are sandy loam, clay over weathered bedrock. Parent material: Residuum weathered from granite. (Qha, Jp, Pl, Qr3)	L H ---	34-38					

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Soil Units and Indoor-Radon Data with associated Geologic Units
Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data	
114	Auburn silt loam, 2 to 15 percent slopes	M (20") VS (4")	C	Silt loam over unweathered bedrock. Parent material: Residuum weathered from metamorphic rock. (sp, Jch, mv, mel-ms)	L ---	20-24	20	0	0	0.8	2.6 2.1 1.5 1.3 1.2 1.0 0.9 0.9 0.9 0.8	0.8 0.8 0.7 0.7 0.7 0.7 0.6 0.5 0.5 0.5

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Soil Units and Indoor-Radon Data with associated Geologic Units Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
115	Auburn-Argonaut complex, 2 to 15 percent slopes						2	0	0	1.1	1.5 0.7
	(Auburn)	M (20") VS (4")	C	Auburn soils are silt loam over unweathered bedrock. Parent material: Residuum from weathered metamorphic rock. (mv)	L ---	20-24					
	(Argonaut)	M (4") M (5") M (7") VS (9") VS (4")	D	Argonaut soils are loam, silt loam, clay loam, and clay over weathered bedrock. Parent material: Residuum from weathered metamorphic rock. (mv)	L L L H ---	25-29					

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Soil Units and Indoor-Radon Data with associated Geologic Units
Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
116	Auburn-Argonaut Rock outcrop complex, 2 to 15 percent slopes						2	0	0	0.8	1.0 0.6
	(Auburn)	M (20") VS (4")	C	Auburn soils are silt loam over unweathered bedrock. Parent material: Residuum from weathered metamorphic rock.(mv)	L ---	20-24					
	(Argonaut)	M (9") MS (7") VS (9") VS (4")	D	Argonaut soils are silt loam, clay loam, and clay over weathered bedrock. Parent material: Residuum from weathered metamorphic rock. (mv)	L M H ---	25-29					
117	Auburn-Rock outcrop complex, 2 to 30 percent slopes	M (4") M (16") VS (59")	C	Silt loam over bedrock Parent material: Colluvium and residuum derived from metavolcanics. (sp, Jch, mv, mel-ms, um)	L L ---	12-20	14	0	0	0.8	1.3 0.8 1.1 0.8 1.0 0.7 1.0 0.6 0.9 0.6 0.9 0.5 0.8 0.5

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Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
118	Auburn-Sobrante silt loams, 15 to 30 percent slopes		C				5	0	0	0.7	1.3 1.1 0.7 0.6 0.6
	(Auburn)	M (20") VS (4")		Auburn soils are silt loam over unweathered bedrock. Parent material: Residuum weathered from metamorphic rock. (Jp, Jch, mel-ms)	L ---	20-24					
	(Sobrante)	M (16") M (17") VS (7") VS (4")		Sobrante soils are silt loam, loam, and weathered bedrock over unweathered bedrock. Parent material: Residuum weathered from metamorphic rock. (Jp, Jch, mel-ms)	L M --- ---	20-40					

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Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
119	Auburn-Sobrante Rock outcrop complex, 2 to 30 percent slopes		C	Auburn soils are silt loam over unweathered bedrock.Parent material: Residuum weathered from metamorphic rock. (Mzd, mv, mel-ms)			7	0	0	0.9	3.8 2.4 1.1 0.9 0.7 0.7 0.7
	(Auburn)	M (20") VS (4")			L ---	20-24					
	(Sobrante)	M (16") M (17") VS (7") VS (10")		Sobrante soils are silt loam, loam, and weathered bedrock over unweathered bedrock. Parent material: Residuum weathered from metamorphic rock. (Mzd, mv, mel-ms)	L M --- ---	0-40					

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Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
120	Auburn-Sobrante-Rock outcrop complex, 30 to 50 percent slopes						1	0	0	0.6	0.6
	(Auburn)	M (20") VS (4")	C	Auburn soils are silt loam over unweathered. Parent material: Residuum weathered from metamorphic rock. (Jch)	L ---	20-24					
	(Sobrante)	M (16") M (17") VS (7") VS (10")	D	Sobrante soils are silt loam, loam, and weathered bedrock over unweathered bedrock. Parent material: Residuum weathered from metamorphic rock. (Jch)	L M --- ---	40					

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Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
122	Boomer loam, 2 to 15 percent slopes	M (2") M (9") M (9") M (11") MS (19") M (9") VS (10")	C	Loam, clay loam, and gravelly clay loam to gravelly loam over cemented bedrock. Parent material: Colluvium derived from metavolcanics and/or residuum weathered from metavolcanics. (mel-ms, mel-mv)	L M M M M L ---	40-60	3	0	0	0.7	1.0 0.7 0.5
123	Boomer loam, 15 to 30 percent slopes	M (2") M (9") M (9") M (11") MS (19") M (9") VS (10")	C	Loam, clay loam, and gravelly clay loam to gravelly loam over cemented bedrock. Parent material: Residuum weathered from metavolcanics. (mel-mv)	L M M M M L ---	40-60	1	0	0	1.0	1.0

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Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
124	Boomer-Rock outcrop complex, 5 to 30 percent slopes	M (2") M (9") M (9") M (11") MS (19") M (9") VS (10")	C	Loam, clay loam, and gravelly clay loam to gravelly loam over cemented bedrock. Parent material: Colluvium derived from metavolcanics and/or residuum weathered from metavolcanics. (gb, mel-ms, mel-mv)	L M M M M L ---	40-60	6	0	0	1.2	2.6 2.5 1.2 1.1 1.0 0.6
125	Boomer-Rock outcrop complex, 30 to 50 percent slopes	M (2") M (9") M (9") M (11") MS (19") M (9") VS (10")	C	Loam, clay loam, and gravelly clay loam to gravelly loam over cemented bedrock. Parent material: Colluvium derived from metavolcanics and/or residuum weathered from metavolcanics. (mel-ms, mel-mv)	L M M M M L ---	40-60	4	1	25	2.3	23.7 3.4 1.2 0.7
127	Boomer variant stony sandy loam, 2 to 15 percent slopes	M (4") MS (32") S (24") VS (4")	C	Stony sandy loam, clay loam, and clay over weathered bedrock. Parent material: Residuum weathered from syenite. (Mzg, mel-ms)	L M M ---	60-64	3	0	0	0.7	0.9 0.7 0.6

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Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
128	Boomer variant very stony sandy loam, 15 to 50 percent slopes	M (4") MS (32") S (24") VS (4")	C	Very stony sandy loam, clay loam, and clay over weathered bedrock. Parent material: Residuum weathered from syenite. (Mzg)	L M M ---	60-64	6	1	16.67	1.4	13.5 2.3 1.4 1.3 0.7 0.5
129	Caperton gravelly coarse sandy loam, 2 to 30 percent slopes	MR (18") VS (4")	D	Gravelly coarse sandy loam over weathered bedrock. Parent material: Residuum weathered from granite. (Kr, OMvs?, Jp)	L ---	18-22	10	0	0	1.2	3.7 2.8 2.0 1.3 1.2 1.2 1.2 1.0 0.9 0.8

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Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
130	Caperton-Andregg coarse sandy loams, 2 to 15 percent slopes (Caperton) (Andregg)	 MR (18") VS (4") MR (15") MR (14") VS (4")	 D B	 Coarse sandy loam over weathered bedrock. Parent material: Residuum weathered from granite. (MPmc, OMvs?, Kr, Jp)	 L --- L L ---	 18-22 29-33	14	2	14.29	1.2	10.7 1.1 5.4 1.0 3.4 0.8 3.4 0.7 3.0 0.6 1.3 0.6 1.2 0.5
131	Caperton-Andregg coarse sandy loams, 15 to 30 percent slopes (Caperton) (Andregg)	 MR (18") VS (4") MR (15") MR (14") VS (4")	 D B	 Coarse sandy loam over weathered bedrock. Parent material: Residuum weathered from granite. (Jp)	 L --- L L ---	 18-22 29-33	5	0	0	1.0	3.7 3.3 1.0 0.8 0.6

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Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
132	Caperton-Rock outcrop complex, 2 to 30 percent slopes	MR (18") VS (4")	D	Gravelly coarse sandy loam over weathered bedrock. Parent material: Residuum weathered from granite. (Jp)	L ---	18-22	6	0	0	1.3	3.5 2.7 1.3 1.3 0.9 0.8
138	Cohasset cobbly loam, 15 to 30 percent slopes	M (18") M (39") VS (4")	B	Cobbly loam, cobbly clay loam over weathered granite. Parent material: Residuum from weathered conglomerate. (MPm, ms)	L M ---	57-61	5	0	0	1.8	2.3 2.3 1.5 1.8 1.0
140	Cometa sandy loam, 1 to 5 percent slopes	M (18") VS (11") S (31")	D	Sandy loam, clay, and sandy loam. Parent material: Alluvium derived from granite. (Qr2, OMvs, Qtl)	L H L	18	7	0	0	0.9	2.0 1.2 1.0 0.9 0.7 0.6 0.5

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Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
141	Cometa-Fiddyment complex, 1 to 5 percent slopes						86	0	0		3.1
	(Cometa)	M (18") VS (11") S (31")	D	Sandy loam, clay, and sandy loam. Parent material: Alluvium derived from granite. (Qtl, MPmc, Qr2, Qr3, Kr)	L H L	18					
	(Fiddyment)	M (12") VS (16") VS (7") VS (4")		Fiddyment soils are loam, clay loam, indurated, and weathered bedrock. Parent material: Alluvium derived from siltstone. (Qtl, MPmc, Qr2, Qr3, Kr)	L M --- ---	20-39					

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Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
142	Cometa-Ramona sandy loams, 1 to 5 percent slopes						51	0	0	1.0	1.9
	(Cometa)	M (18") VS (11") S (31")	D	Sandy loam, clay, and sandy loam. Parent material: Alluvium derived from granite. (Qha, Qoa, Qtl, Qr3, Qr2, MPmc, Kr, Jp)	L H L	18					
	(Ramona)	M (6") M (8") MS (41") MS (18")	C	Sandy loam, loam, sandy clay loam, and gravelly clay loam. Parent material: Alluvium derived from granite. (Qha, Qoa, Qtl, Qr3, Qr2, MPmc, Kr, Jp)	L L L L	80					
144	Exchequer very stony loam, 2 to 15 percent slopes	M (11") R (4")	D	Very stony loam over unweathered bedrock. Parent material: Residuum weathered from volcanic breccia. (MPmc, MPmb, um)	L ---	11-15	12	0	0	0.8	2.3 0.8 2.1 0.8 1.1 0.7 0.9 0.7 0.9 0.6 0.8 0.6

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Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
145	Exchequer-Rock outcrop complex, 2 to 30 percent slopes	M (11") R (4")	D	Very stony loam over unweathered bedrock. Parent material: Residuum weathered from volcanic breccia. (MPmc, MPmb, OMvs)	L ---	11-15	17	0	0	0.8	2.1 0.8 1.5 0.7 1.2 0.7 1.1 0.7 1.0 0.7 0.9 0.6 0.9 0.5 0.8 0.5 0.8
146	Fiddyment loam, 1 to 8 percent slopes	M (12") VS (16") VS (7") VS (4")	D	Loam, clay loam, indurated over weathered bedrock. Parent material: Alluvium derived from siltstone. (Qtl, Qm?)	L H --- ---	20-35	18	0	0	1.0	2.0 0.9 1.8 0.9 1.3 0.9 1.2 0.8 1.2 0.8 1.1 0.7 1.0 0.7 1.0 0.7 1.0 0.6

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Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data	
147	Fiddyment-Kaseberg loams, 2 to 9 percent slopes						26	0	0	0.8	1.6 1.5 1.3 1.2 1.1 1.1 1.0 1.0 1.0 0.9 0.9 0.8 0.8	0.8 0.7 0.7 0.7 0.7 0.6 0.6 0.6 0.6 0.5 0.5 0.5 0.5
	(Fiddyment)	M (12") M (16") VS (7") VS (4")	C	Fiddyment soils are loam, clay loam, indurated over weathered bedrock. Parent material: Alluvium derived from siltstone. (Qtl, Qr3, Qr2, MPmc)	L H M ---	20-39						
	(Kaseberg)	M (16") VS (1") MS (4")	D	Kaseberg soils are loam, indurated and weathered bedrock. Parent material: Alluvium derived from siltstone. (Qtl, Qr3, Qr2, MPmc)	L --- ---	16-21						

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Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
148	Henneke-Rock outcrop complex, 5 to 50 percent slopes	M (3") MS (15") R (4")	D	Gravelly loam, very gravelly clay loam over unweathered bedrock. Parent material: Residuum from serpentinite. (mel-ms, sp, um)	M M	18-22	9	0	0	0.8	1.2 1.0 0.9 0.9 0.8 0.8 0.7 0.7 0.6
152	Inks cobbly loam, 2 to 30 percent slopes	M (5") M (7") M (6") M (10")	D	Cobbly loam, very cobbly clay loam over bedrock. Parent material: Residuum weathered from conglomerate. (Qr3, Pl, MPm, MPmc, OMvs, Kr)	L L L	10-20	15	0	0	0.9	1.3 0.8 1.1 0.7 1.1 0.6 1.1 0.6 1.1 0.6 1.0 0.5 0.9 0.5 0.9

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Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
153	Inks cobbly loam, 30 to 50 percent slopes	M (6") M (4") M (3") M (10")	D	Very cobbly sandy clay loam, very gravelly clay loam, very cobbly loam over bedrock. Parent material: Colluvium derived from fanglomerate over tuff. (MPmc, MPmb, Omvs)	L L L	10-24	5	1	20	1.2	6.2 3.4 1.2 0.8 0.6

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Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
154	Inks-Exchequer complex, 2 to 25 percent slopes (Inks) (Exchequer)	 M (5") M (13") VS (4") M (11") R (4")	D	Inks soils are cobbly loam, very cobbly loam over unweathered bedrock. Parent material: Residuum weathered from conglomerate. (Qtl, MPmc, MPmb, Omvs) Exchequer soils are very stony loam over unweathered bedrock. Parent material: Residuum weathered from volcanic breccia. (Qtl, MPmc, MPmb, Omvs)	L L --- L ---	18-22 11-15	31	0	0	1.0	3.5 1.0 2.8 1.0 2.5 0.9 2.4 0.9 1.9 0.9 1.7 0.9 1.4 0.8 1.4 0.7 1.3 0.7 1.2 0.7 1.2 0.7 1.1 0.7 1.1 0.6 1.0 0.6 1.0 0.5 1.0
155	Inks variant cobbly loam, 2 to 30 percent slopes	M (17") M (34") VS (4")	B	Cobbly loam, very cobbly clay loam over weathered bedrock. Parent material: Residuum weathered from conglomerate. (MPmb)	L L ---	51-55	2	0	0	1.1	0.7 1.5

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Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
159	Josephine loam, 15 to 30 percent slopes	M (11") MS (25") MS (16") MS (4")	C	Loam, clay loam, silty clay loam over weathered bedrock. Parent material: Residuum weathered from metasedimentary rock. (mel-ms)	L M M	52-56	1	0	0	1.0	1.0
160	Josephine loam, 30 to 50 percent slopes	M (11") MS (25") MS (16") MS (4")	C	Loam, clay loam, silty clay loam over weathered bedrock. Parent material: Residuum weathered from metasedimentary rock. (ms)	L M M	52-56	1	0	0	1.6	1.6
162	Kilaga loam	M (19") MS (11") S (26") MS (24")	C	Loam, clay loam, clay, and sandy clay loam. Parent material: Alluvium (Qr3)	L M H M	>80	1	0	0	0.5	0.5
163	Mariposa gravelly loam, 5 to 30 percent slopes	M (6") M (22") VS (4")	C	Gravelly loam over weathered bedrock. Parent material: Residuum weathered from metasedimentary rock. (mv, ms)	L L ---	28-32	3	1	33.33	2.4	8.6 2.4 0.7

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Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
164	Mariposa-Josephine complex, 5 to 30 percent slopes						12	3	25	1.5	10.2 7.1 4.8 3.8 3.6 1.7 1.3 1.2 1.0 0.7 0.6 0.6
	(Mariposa)	M (6") M (22") VS (32")	C	Mariposa soils are gravelly loam, over weathered bedrock.Parent material: Residuum weathered from metasedimentary rock.(mv, ms, mel-ms, mel-mv)	L L ---	28-32					
	(Josephine)	M (11") MS (25") MS (16") MS (8")		Josephine soils are loam, clay loam, silty clay loam over weathered bedrock.Parent material: Parent material: Residuum weathered from metasedimentary rock.(mv, ms, mel-ms, mel-mv)	L M M ---	52-56					

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Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
165	Mariposa-Josephine complex, 30 to 50 percent slopes						3	1	33.33	3.0	6.8 3.0 1.2
	(Mariposa)	M (6") M (22") VS (32")	C	Mariposa soils are gravelly loam, over weathered bedrock. Parent material: Residuum weathered from metasedimentary rock. (mel-mv)	L L ---	28-32					
	(Josephine)	M (11") VS (25") MS (16") MS (8")	D	Josephine soils are loam, silty clay loam over weathered bedrock. Parent material: Parent material: Residuum weathered from metasedimentary rock. (mel-mv)	L M M ---	52-56					

APPENDIX G Soil Units and Indoor-Radon Data with associated Geologic Units Western Placer County											
Soil Unit	**Soil Unit Name**	**Permeability by Soil Sub-unit (unit thickness)**	**HSG**	**Soil Characteristics and Parent Materials (geologic map unit symbol)**	**SH-SW**	**Depth to Bed Rock (Inches)**	**N**	**N ≥ 4.0**	**% N ≥ 4.0**	**Median**	**Indoor Radon Data**
167	Mariposa-Rock outcrop complex, 5 to 50 percent slopes	M (6") M (22") VS (32")	C	Gravelly loam over weathered bedrock. Parent material: Residuum weathered from metasedimentary rock. (ms, mel-ms, mel-mv)	L L ---	28-32	11	1	9.1	1.1	4.1 1.0 1.8 1.0 1.5 0.8 1.4 0.7 1.1 0.4 1.1
172	McCarthy cobbly sandy loam, 30 to 50 percent slopes	MR (13") MR (26") VS (21")	B	Cobbly sandy loam, very cobbly sandy loam over weathered bedrock.Parent material: Residuum weathered from conglomerate.(MPm)	L L ---	39-43	1	0	0	1.3	1.3
174	Ramona sandy loam, 0 to 2 percent slopes	M (6") M (8") MS (41") MS (18")	C	Sandy loam, loam, sandy clay loam, and gravelly sandy loam. Parent material: Alluvium derived from granite. (Qr3)	L L M L	>80	1	0	0	0.6	0.6

APPENDIX G

Soil Units and Indoor-Radon Data with associated Geologic Units
Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
175	Ramona sandy loam, 2 to 9 percent slopes	M (6") M (8") MS (41") MS (18")	C	Sandy loam, loam, sandy clay loam, and gravelly sandy loam. Parent material: Alluvium derived from granite. (Qr3, Qtl)	L L M L	>80	6	0	0	0.9	2.5 1.2 1.0 0.8 0.6 0.6

APPENDIX G

Soil Units and Indoor-Radon Data with associated Geologic Units Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
176	Redding and Corning gravelly loams, 2 to 9 percent slopes		D				17	2	11.76	0.8	7.4 0.7 6.0 0.7 3.6 0.7 1.4 0.6 1.1 0.6 1.0 0.6 1.0 0.6 0.9 0.5 0.8
	(Corning)	M (22") VS (14") VS (4") S (18")		Corning soils are gravelly loam, clay, gravelly clay loam, and gravelly sandy clay loam. Parent material: Gravelly alluvium. (Qr2, Pl, OMvs?, Ei?, Kr, Mzqd)	L H H L	22					
	(Redding)	M (14") VS (14") VS (4")		Redding soils are gravelly loam, clay and indurated. Parent material: Gravelly alluvium. (Qr2, Pl, OMvs?, Ei?, Kr, Mzqd)	L M ---	28-32					

APPENDIX G

Soil Units and Indoor-Radon Data with associated Geologic Units
Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
177	Redding and Corning gravelly loams, 9 to 15 percent slopes (Corning) (Redding)	 M (22") VS (14") VS (4") S (18") M (14") VS (14") VS (4")	D	Corning soils are gravelly loam, clay, gravelly clay loam, and gravelly sandy clay loam. Parent material: Gravelly alluvium. (OMvs?) Redding soils are gravelly loam, clay and indurated. Parent material: Gravelly alluvium. (OMvs?)	 L H H L L M	 22 28-32	10	0	0	1.1	2.2 2.1 1.2 1.2 1.1 1.1 1.1 1.0 1.0 0.8
179	Rock outcrop	-	-	mv	-	0	1	0	0	0.5	0.5

APPENDIX G

Soil Units and Indoor-Radon Data with associated Geologic Units Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
180	Rubble land	VR (60")	-	Fragmental material Parent material: Residuum (Tg)	L	0	1	0	0	0.8	0.8
181	San Joaquin sandy loam, 1 to 5 percent slopes	M (15") VS (20") VS (15") S (10")	D	Sandy loam, clay loam, indurated, and stratified sandy loam to loam. Parent material: Alluvium derived from granite. (Qr2)	L H --- L	35-50	4	0	0	0.8	0.9 0.8 0.8 0.8
182	San Joaquin-Cometa sandy loams, 1 to 5 percent slopes (San Joaquin) (Cometa)	M (15") VS (20") VS (15") S (10") M (18") VS (11") MS (31")	D	Sandy loam, clay loam, indurated, and stratified sandy loam to loam. Parent material: Alluvium derived from granite. (Qr2, Qtl, MPmb) Cometa soils are sandy loam, clay, and sandy loam Parent material: Alluvium derived from granite. (Qr2, Qtl, MPmb)	L H --- L L H L	35-50 18	15	2	13.33	1.0	4.3 1.0 4.1 1.0 2.4 1.0 1.2 0.8 1.2 0.8 1.2 0.8 1.1 0.7 1.0

APPENDIX G

Soil Units and Indoor-Radon Data with associated Geologic Units Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
183	Sierra sandy loam, 2 to 9 percent slopes	M (23") MS (18") VS (4")	C	Sandy loam, loam over weathered bedrock. Parent material: Residuum weathered from granite. (Jp)	L M ---	40-80	4	0	0	1.3	3.7 1.3 1.3 1.2
184	Sierra sandy loam, 9 to 15 percent slopes	MS (23") MS (18") VS (4")	C	Sandy loam, loam over weathered bedrock.Parent material: Residuum weathered from granite.(Jp, Mzd)	L M ---	40-80	5	1	20	1.5	4.2 1.6 1.5 0.8 0.5
185	Sierra sandy loam, 15 to 30 percent slopes	MS (23") MS (18") VS (4")	C	Sandy loam, loam over weathered bedrock. Parent material: Residuum weathered from granite. (Jp)	L M ---	40-80	5	2	40	2.6	4.9 4.0 2.6 1.0 0.7
187	Sites loam, 9 to 15 percent slopes	M (16") M (10") MS (39") VS (4")	C	Loam, clay loam, clay over weathered bedrock. Parent material: Residuum weathered from metamorphic rock. (mv, mel-ms, mel-mv)	L M M ---	40-80	4	0	0	1.9	2.6 2.2 1.5 1.0

APPENDIX G

Soil Units and Indoor-Radon Data with associated Geologic Units
Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
188	Sites loam, 15 to 30 percent slopes	M (16") M (10") MS (39") VS (4")	C	Loam, clay loam, clay over weathered bedrock. Parent material: Residuum weathered from metamorphic rock. (gb, Mzg, mel-mv)	L M M ---	40-80	9	1	11.11	1.1	6.0 1.0 2.8 0.9 1.5 0.9 1.2 0.8 1.1
190	Sites-Rock outcrop complex, 15 to 30 percent slopes	M (16") M (10") MS (39") VS (4")	C	Loam, clay loam, clay over weathered bedrock. Parent material: Residuum weathered from metamorphic rock. (gb, mel-mv)	L M M ---	40-80	4	1	25	1.3	4.2 1.5 1.1 0.5
191	Sobrante silt loam, 2 to 15 percent slopes	M (16") M (17") VS (7") R (10")	C	Silt loam, loam, weathered bedrock over unweathered bedrock. Parent material: Residuum weathered from metasedimentary rock. (mv, mel-ms)	L M --- ---	20-40	2	0	0	1.0	1.1 0.9

APPENDIX G

Soil Units and Indoor-Radon Data with associated Geologic Units
Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
193	Xerofluvents, occasionally flooded	R (30") R (18") M (7")	A	Stratified loamy sand to fine sandy loam to silt loam to silty clay loam to clay. Parent material: Alluvium derived from mixed rocks. (Qha, Qtl)	M M M	>80	6	0	0	1.0	1.4 1.0 1.0 0.9 0.6 0.5
194	Xerofluvents, frequently flooded	R (15") R (22") M (18")	B	Stratified loamy sand to fine sandy loam to silt loam to silty clay loam to clay. Parent material: Alluvium (Qha, Qr3, Qr2, Jp)	M M M	>80	9	0	0	1.1	2.6 2.4 1.3 1.2 1.1 1.1 0.9 0.8 0.8

APPENDIX G

Soil Units and Indoor-Radon Data with associated Geologic Units
Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data
196	Xerorthents, cut and fill areas	-	-	Variable Parent material: Mine spoil or earthy fill. (Qha, Qr2, OMvs, Kr, um)	-	>80	11	0	0	0.9	2.7 0.9 1.4 0.8 1.2 0.8 1.1 0.7 1.0 0.7 0.9
197	Xerorthents, placer areas	-	-	Variable Parent material: Mine spoil or earthy fill. (Qha, Qoa, OMvs?, Kr, Jp)	-	>80	10	0	0	1.0	1.3 0.9 1.2 0.8 1.2 0.8 1.0 0.8 1.0 0.6
229 sa	Urban land-Xerarents-Fiddyment complex, 0 to 8 percent slopes	-	-	Variable Parent material: Alluvium derived from granite. (Qtl)	-	>80	7	0	0	0.8	1.3 0.9 0.9 0.8 0.8 0.8 0.7

APPENDIX G

Soil Units and Indoor-Radon Data with associated Geologic Units
Western Placer County

Soil Unit	Soil Unit Name	Permeability by Soil Sub-unit (unit thickness)	HSG	Soil Characteristics and Parent Materials (geologic map unit symbol)	SH-SW	Depth to Bed Rock (Inches)	N	N ≥ 4.0	% N ≥ 4.0	Median	Indoor Radon Data

Soil information summarized from United States Department of Agriculture, Natural Resources Conservation Service, 2018, Custom Soil Resource Report for Placer County, California, Western Part, March 1, 2018, 276p.
HSG = Hydrologic Soil Group (A, B, C, D)
SH-SW = Shrink Swell
Permeability:
VS = very slow
S = slow
M= moderate
MR=moderately rapid
R=rapid
VR=very rapid

Shrink-Swell classes based on change in length of an unconfined clod as moisture content is decreased.
L = Low = < 3 percent change
M = Moderate = 3 - 6 percent change
H = High = 6 - 9 percent change
VH = Very High = ≥ 9 percent change

APPENDIX H

Descriptive Statistics and Statistical Comparison of Indoor-Radon Data (Untransformed) by Western Placer County Radon Potential Zone

Zone	Size	Missing	Mean	Std Dev[1]	Std. Error[2]	C.I. of Mean[3]
ALL	740	0	1.303	1.443	0.053	0.104
MODERATE	277	0	1.67	2.074	0.125	0.245
LOW	441	0	1.091	0.799	0.0381	0.0748
UNKNOWN	22	0	0.927	0.656	0.14	0.291

Zone	Range*	Max	Min	Median	25%	75%
ALL	23.5	23.7	0.2	0.95	0.7	1.3
MODERATE	23.3	23.7	0.4	1	0.8	1.65
LOW	10.4	10.6	0.2	0.9	0.7	1.2
UNKNOWN	3.1	3.6	0.5	0.75	0.6	1.1

Zone	Skewness	Kurtosis	K-S Dist.[4]	K-S Prob.[5]	SWilk W[6]	SWilk Prob[7]
ALL	7.785	92.994	0.289	<0.001	0.426	<0.001
MODERATE	6.007	51.468	0.283	<0.001	0.475	<0.001
LOW	6.194	57.809	0.243	<0.001	0.525	<0.001
UNKNOWN	3.492	14.071	0.257	<0.001	0.586	<0.001

Zone	Sum	Sum of Squares
ALL	964.1	2793.81
MODERATE	462.5	1959.77
LOW	481.2	806.08
UNKNOWN	20.4	27.96

*pCi/L
[1]Standard Deviation
[2]Standard Error of the Mean
[3]Confidence Interval for the Mean
[4]K-S Distance (The Kolmogorov-Smirnov distance)
[5]K-S Probability (The Kolmogorov-Smirnov probability)
[6]Shapiro-Wilk W (The Shapiro-Wilk W-statistic)
[7]Shapiro-Wilk Probability

APPENDIX I

Descriptive Statistics and Statistical Comparison of Indoor-Radon Data (Ln-Transformed) by Western Placer County Radon Potential Zone

Zone	Size	Missing	Mean	Std Dev[1]	Std. Error[2]	C.I. of Mean[3]
ln ALL	740	0	0.0522	0.553	0.0203	0.0399
ln MODERATE	277	0	0.213	0.669	0.0402	0.0791
ln LOW	441	0	-0.036	0.442	0.021	0.0414
ln UNKNOWN	22	0	-0.206	0.462	0.0985	0.205

Zone	Range*	Max	Min	Median	25%	75%
ln ALL	4.775	3.165	-1.609	-0.0527	-0.357	0.262
ln MODERATE	4.082	3.165	-0.916	0	-0.223	0.5
ln LOW	3.97	2.361	-1.609	-0.105	-0.357	0.182
ln UNKNOWN	1.974	1.281	-0.693	-0.29	-0.511	0.0953

Zone	Skewness	Kurtosis	K-S Dist.[4]	K-S Prob.[5]	SWilk W[6]	SWilk Prob[7]
ln ALL	1.513	3.588	0.145	<0.001	0.886	<0.001
ln MODERATE	1.255	1.838	0.157	<0.001	0.905	<0.001
ln LOW	1.289	3.777	0.134	<0.001	0.911	<0.001
ln UNKNOWN	1.649	3.975	0.151	0.206	0.854	0.004

Zone	Sum	Sum of Squares
ln ALL	38.662	227.925
ln MODERATE	59.055	136.035
ln LOW	-15.869	86.482
ln UNKNOWN	-4.524	5.409

*pCi/L
[1]Standard Deviation
[2]Standard Error of the Mean
[3]Confidence Interval for the Mean
[4]K-S Distance (The Kolmogorov-Smirnov distance)
[5]K-S Probability (The Kolmogorov-Smirnov probability)
[6]Shapiro-Wilk W (The Shapiro-Wilk W-statistic)
[7]Shapiro-Wilk Probability

APPENDIX J

Results of the Shapiro-Wilk Normality Test for Untransformed and Ln-Transformed Indoor-Radon Data, by Radon Potential Zone

All Data -- untransformed	W-Statistic* = 0.426	P<0.001	Failed
All Data -- log transformed	W-Statistic = 0.886	P<0.001	Failed
Moderate Zone - untransformed	W-Statistic = 0.475	P<0.001	Failed
Moderate Zone - log transformed	W-Statistic = 0.905	P<0.001	Failed
Low Zone - untransformed	W-Statistic = 0.525	P<0.001	Failed
Low Zone - log transformed	W-Statistic = 0.911	P<0.001	Failed
Unknown Zone - untransformed	W-Statistic = 0.586	P<0.001	Failed
Unknown Zone - log transformed	W-Statistic = 0.854	P=0.004	Failed

*Shapiro-Wilk Statistic (W)—tests the null hypothesis that the data were sampled from a normal distribution. Small values of W indicate a departure from normality (SigmaPlot®12 Statistics User's Guide part 2, Systat Software, Inc., p. 23)

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 indicated that the data match the pattern expected if the data were drawn from a population with a normal distribution.

APPENDIX K

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

Zone	*N*	*Missing*	*Median*	*25%*	*75%*
Moderate	277	0	1	0.8	1.65
Low	441	0	0.9	0.7	1.2
Result	Mann-Whitney U Statistic= 48334.000 T = 112326.000 n(small)= 277 n(big)= 441 (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)				
Zone	*N*	*Missing*	*Median*	*25%*	*75%*
Moderate	277	0	1	0.8	1.65
Unknown	22	0	0.75	0.6	1.1
Result	Mann-Whitney U Statistic= 1765.000 T = 2018.000 n(small)= 22 n(big)= 277 (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)				
Zone	*N*	*Missing*	*Median*	*25%*	*75%*
Low	441	0	0.9	0.7	1.2
Unknown	22	0	0.75	0.6	1.1
Result	Mann-Whitney U Statistic= 3527.000 T = 3780.000 n(small)= 22 n(big)= 441 (P = 0.030) 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 = 0.030)				