Community experiences and perceptions of geothermal venting and emergency preparedness in Lake County, California, November, 2012

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Executive Summary

Lake County, California is located on top of tectonic plate conjunctions and has had a long history of volcanic activity, with the last eruption having occurred 10,000 years ago (1). The geologic makeup of this region makes Lake County vulnerable to a variety of environment disasters and hazards such as earthquakes, volcanic eruptions, and geothermal venting of harmful gases such as hydrogen sulfide and methane. In addition, the area has also experienced frequent flooding and wild fires.

The California Department of Public Health (CDPH) and Lake County Public Health Division (LCPHD) requested the assistance of the Centers for Disease Control and Prevention (CDC) in conducting a Community Assessment for Public Health Emergency Response (CASPER) to assess disaster preparedness of the community and outdoor air measurement to determine the level of geothermal venting gases in the community. The Community Assessment for Public Health Emergency Response (CASPER) tool is an effective method to assess public health needs in both disaster and non-disaster settings. This information can then be used to initiate public health action during a disaster or for disaster planning in a non-disaster scenario.

The objectives of this CASPER were to assess and determine 1) the degree of disaster preparedness of the community, 2) the community experiences and perceptions associated with geothermal venting, 3) if hydrogen sulfide and methane are diffusing from the subsurface to help identify areas of potential concern for vapor intrusion and geothermal venting, and 4) the vulnerabilities of unregulated private well water use for drinking and household water testing practices.

On November 26-28, 2012, CDPH, LCPHD and CDC jointly conducted the CASPER and outdoor air sampling in Lake County. For the fourteen two-person CASPER interview teams and three two-person air sampling teams, this consisted of a half day just-in-time training for the field staff and two and half days of data collection in the field. Team members consisted of CDPH, LCPHD and CDC public health and environmental health staff. We conducted a total of 161 household interviews and collected a total of 510 air measurements in the 30 selected clusters. The key findings were:

- One in five households had experience with geothermal venting in or around their home, and one third have some concern regarding potential effects of geothermal gases.
- Households' preferred communication methods during a disaster were television, radio, cell phone, and internet.
- One third of the households had at least one communication barrier; of these, two-thirds had hearing problems.
- Half of the households have made a family disaster plan while 10% have participated in neighborhood emergency planning.
- Majority of the households will take pets and livestock with them during an evacuation.
- One in three households drinking private well water never examined or last examined their wells more than 1 year ago.
- No locations had elevated levels of high concern (≥30ppb of hydrogen sulfide or ≥50% LEL (≥2.5% in air) of methane).

Recommendations:

- Provide information to the community regarding geothermal venting.
- Consider documenting community concerns regarding geothermal venting.

- Utilize multiple means of communication to the community during a disaster or emergency to address communication barriers.
- Consider ways to increase the number of households with family disaster plans.
- Consider having pet friendly shelters in the event of a disaster or emergency.
- Increase community awareness regarding testing and examining private wells to protect their well water supply.
- Conduct long-term air monitoring to more thoroughly understand seasonal variation and exposure risk to hydrogen sulfide and methane.

This CASPER provided valuable information for emergency planners in the state and county and demonstrated the efficiency and usefulness of the methodology in a non-disaster setting. In this report, we describe details of the methodologies used for this CASPER, additional findings, and potential limitations of the data.

BACKGROUND

Lake County, California, with a population of 64,323 people, is located on top of tectonic plate conjunctions and has had a long history of volcanic activity, with the last eruption having occurred 10,000 years ago (1, 2). There are many small faults and old volcanoes in Lake County with one of the most well-known being Mount Konocti. The geologic makeup of this region makes Lake County vulnerable to a variety of environment disasters and hazards such as earthquakes, volcanic eruptions, and geothermal venting of harmful gases such as hydrogen sulfide and methane. Some areas such as Cobb Mountain experience daily small earthquakes and the United States Geological Survey (USGS) has also stated that future volcanic eruptions are likely in the Clear Lake field (3). In addition, this area has also experienced frequent flooding and wild fires. Despite these potential environmental threats, it is unknown how well prepared the community will be in the event of a large scale disaster.

Lake County is the home to the Geysers, the largest complex of geothermal power plants in the world (4). In this region, water in the earth's crust is continually heated by the mantle, and slowly leaks out in the form of steam through vents in the earth's crust. The steam from geothermal venting can contain gases such as hydrogen sulfide and methane, and high levels of exposure to these gases can have adverse health effects. Hydrogen sulfide is a toxic gas with a characteristic rotten egg odor, and exposure can cause headache, dizziness, nausea, and at high levels, death (5, 6). Methane is an odorless but highly flammable gas that can result in risk of explosion at 5-15% in air (7).

Localized venting of high levels of gaseous hydrogen sulfide and methane from geothermal venting has been detected in a neighborhood in the City of Clearlake, potentially increasing risk of exposure to the local community. California Department of Public Health (CDPH) first became aware of the problem in

March 2010 when gases were detected from previously unidentified vents in the Burns Valley neighborhood in the City of Clearlake. There are anecdotal accounts from the early 1990's of teachers and school children at the Burns Valley Elementary School experiencing possible health effects that were attributed to harmful effects of these gases (8). In the early 1990's, a home was demolished because of persistent intrusion of hydrogen sulfide (8). More recently, Lake County Health Services Department (LCHSD) recommended that a community-based organization vacate its building due to intrusion of hydrogen sulfide and methane. A nearby mobile home was deemed unsafe for occupancy due to accumulation of high levels of hydrogen sulfide and potentially explosive levels of methane in the enclosed crawl space. The Burns Valley Elementary School has historically experienced the odor of sulfur, leading to discontinued use of some classroom areas and engineering to prevent gas intrusion in others. Public health investigators were told of an explosion that occurred during digging activities when the new school library was built. Until now, levels of these harmful gases have been predominantly measured in the Burns Valley neighborhood. It is unknown if there are unidentified vents in other areas in Lake County that may also expose the local community to these harmful gases.

Other potential concerns in this community include the use of unregulated private wells for drinking water, given public and private wells are common in this community. It is unknown whether residents using unregulated private wells for drinking water are versed in water safety issues and recommendations for maintaining and testing the wells according to the United States Environmental Protection Agency guidelines (9).

To better understand the risks of these environmental hazards and the level of disaster preparedness in the community, CDPH and Lake County Public Health Division (LCPHD) requested the assistance of

the Centers for Disease Control and Prevention (CDC) in conducting a community survey combined with an assessment of outdoor levels of geothermal gases in selected areas in Lake County.

On November 25, 2012, EIS officers Cindy Chiu, PhD, MPH, and Matthew Lozier, PhD, MPH, along with CDC staff, Tesfaye Bayleyegn, MD, and Bryan Christensen, PhD, MEPC, departed for Clearlake, California. They joined California State EIS officer Jason Wilken, PhD, MPH, CSTE fellow, Rebecca Cohen, MPH, CDC/CDPH Public Health Associates, Olga Martinez, Alberto Aparicio, and Rebecca Lakew, CDPH staff, Rick Kreutzer, MD, Rachel Roisman, MD, Lori Copan, RPh, MPH, Tracy Barreau, REHS, Svetlana Smorodinsky, MPH, and LCPHD Health officer Karen Tait, MD in conducting a Community Assessment for Public Health Emergency Response (CASPER) and outdoor air sampling on November 26 – 28, 2012.

The CASPER tool is an effective method to assess public health needs in both disaster and non-disaster settings (10). This information can then be used to initiate public health action during a disaster or for disaster planning in a non-disaster scenario. The specific goals of this CASPER and assessment of outdoor levels of geothermal gases were to assess and determine: 1) the degree of disaster preparedness of the community, 2) community experiences and perceptions associated with geothermal venting, 3) if hydrogen sulfide and methane are diffusing from the subsurface to help identify areas of potential concern for vapor intrusion and geothermal venting, and 4) the vulnerabilities of unregulated private well water use for drinking and household water testing practices. This information will aid the CDPH and LCPHD health officials in preparedness planning and determining whether follow up actions will be necessary if high levels of hydrogen sulfide and methane are detected in the community.

METHODS AND MATERIALS

To accomplish these goals, CDPH, LCPHD and CDC conducted a CASPER and assessment of outdoor levels of geothermal gases in selected areas in Lake County on November 26 – 28, 2012. CASPER is an epidemiologic technique designed to provide household-based information about an affected community's needs in a timely and representative manner (10).

CASPER sample selection and data collection

We used a two-stage cluster sampling methodology (30 clusters, seven households design) modified from the World Health Organization's Expanded Program on Immunization to select a representative sample of –households to be approached for interviews (10-12). The sampling frame included all census blocks within or adjacent to the following cities and towns in Lake County: Clearlake Oaks, Spring Valley, City of Clearlake, Hidden Valley Lake, Cobb, Kelseyville, Lakeport, Middletown, Lower Lake, Lucerne, Nice, and Upper Lake (Figure 1). This sampling frame contained 26,730 housing units according to the 2010 Census. For the first stage of sampling, we selected 30 clusters (census blocks) within this sampling frame using the Geographic Information Systems CASPER tool, with a probability proportional to number of housing units within the clusters.

The goal of the sampling process was to obtain seven completed interviews from each of the 30 clusters (210 completed interviews). In the first round of the second stage of sampling, interview teams systematically selected seven households from each of the 30 clusters to approach for interviews. The interview teams were provided with street level and Google Earth maps of each selected cluster, and were instructed to select a random housing unit as the starting point, then

approach every n^{th} housing unit (n = total number of housing units in the cluster/7) to systematically select the first seven housing units to approach for interviews. It is very unlikely that the household approached in the first round resulted in an interview, additional rounds of each cluster were required to complete the required number of interview (11).

CDPH, LCPHD and CDC collaborated to develop a four-page data collection instrument (see Appendix I for the full questionnaire). The survey instrument included questions on the following: 1) household demographics; 2) household experiences with geothermal activities; 3) household disaster preparedness; and 4) unregulated drinking water from private wells.

We provided the two-person interview teams with a three-hour training session on the overall purpose of the CASPER, household selection, questionnaire, interview techniques, safety and logistics. There were a total of 14 teams on day 1, 13 teams on day 2, and 13 teams on day 3. The teams primarily consisted of CDPH, LCPHD and CDC public health staff. Teams conducted interviews between 8:30 am and 5 pm PST. Each team attempted to conduct seven interviews in each of the 30 clusters selected for the sample, with a goal of 210 total interviews over two and half days on November 26 – 28, 2012. One cluster was selected twice; therefore, 14 interviews were attempted in this cluster.

Interview teams also recorded observational data on evidence of geothermal venting outside the homes interviewed (Q32-34 in the questionnaire in Appendix I). All potential respondents approached were given an information sheet with contact telephone numbers for LCPHD, as well as public health educational material regarding emergency preparedness and other public health topics (e.g., well water information for homeowners, mercury in fish, quagga mussel information, radon, cyanobacteria,

indoor air quality, and flu vaccine clinic schedule). Eligible respondents were at least 18 years of age or older and resided in the selected household. Additionally, the interviewers were instructed to complete confidential referral forms whenever they encountered urgent physical or mental health needs, including those relating to possible effects of geothermal gases.

Outdoor air sampling

In addition to the CASPER interview, we also conducted an assessment of outdoor levels of geothermal gases in the same 30 selected clusters where we conducted the interviews. One cluster was selected twice so only one set of measurements was collected for this cluster. We measured levels of gaseous hydrogen sulfide and methane in water vaults and other public right-of-way areas in the community to identify areas of potential concern for vapor intrusion impacts and geothermal venting.

We provided the 3 two-person air sampling teams with a two-hour training session on the overall purpose of the air sampling, household selection, operation of the air sampling and GPS instruments, safety and logistics. Air sampling teams primarily consisted of CDPH, LCPHD and CDC environmental health staff. Each team was equipped with the following hand-held instruments: 1) a Jerome 631 Hydrogen Sulfide (H_2S) Analyzer with a detection limit of 1-50,000ppbv; 2) an EAGLE Combustible Gas Monitor (% LEL) for methane (CH_4); and 3) a handheld GPS instrument. Each team attempted to conduct spot air samples in at least five locations in each of the 30 selected clusters once during the three days of data collection on November 26 – 28, 2012.

In an effort to conduct systematic air sampling and best represent potential exposures to methane and hydrogen sulfide, we randomly selected one location for every 10 house in each cluster (range = 4–168; median = 32) or a minimum of 5 sampling location if there were <50 housing units in the cluster.

In addition the following factors were considered in designing the air sampling protocol: the number of teams, available equipment, geography of the area, and location of water vaults.

The air sampling teams were also provided with detailed maps of each selected cluster, and were instructed to select a random housing unit as the starting point and to go to every 10^{th} home if ≥50 housing units; and every kth home if <50 housing units (k=total number of housing units in the cluster/5) to systematically sample the household in the cluster where air measurement would be made.

For each selected household, the air sampling team took point measurements of hydrogen sulfide levels in the water vault (where available), 6 and 30 inches above ground level readings, and methane levels in the water vault only. Where water vaults were not available, methane was not measured, and hydrogen sulfide was measured at two different heights on public property in front of the selected household, above dirt surfaces free of pavement or other barriers.

In addition to measurements taken at the selected households, the air sampling teams also took measurements at areas with evidence of geothermal venting (i.e., areas with excessive corrosion, bubbling puddles, or smell of strong rotten egg odor). Duplicate measurements were taken at the first location in each cluster for quality assurance/control. The interview team also recorded observational data of evidence of geothermal venting in the immediate vicinity (see data collection form in Appendix II) as well as geocoded the location where the air sampling measurement was made using a handheld GPS device.

Data analysis

For the analysis of the CASPER interview data, we conducted a weighted cluster analysis to report the

estimated percent and projected number of households with a particular response in the assessment area. Calculation of weights were based on the total number of housing units in the sampling frame, the number of clusters selected, and the number of housing units interviewed within each cluster. Analysis was performed in SAS 9.3 (SAS Institute, Cary, NC) to calculate the unweighted frequencies and percentages, and weighted frequencies (projected number of households), percentages, and 95% confidence intervals.

Given that the completion rate is lower than 80%, the general cut-off level we use to consider the estimates to be reliable, the sample size may not be large enough to reliably project population estimates. Therefore, unless otherwise stated, throughout the text the percentages represent the unweighted percentages.

For the analysis of the air sampling data, for each cluster we calculated the maximum, minimum and median levels for the water vault; at 6 and 30 inches above ground; and overall above ground levels excluding the water vault readings using SAS 9.3 (SAS Institute, Cary, NC).

RESULTS

The 14 interview teams approached 514 houses, and 261 (50.7%) of the houses approached answered the door. The teams completed 161 interviews with a completion rate of 76.7% of the goal (Table 1). Of the household approached, there were 100 refusals or ineligible houses and 253 houses either were vacant, vacation home, inaccessible or no-one at home at the time of interview. The 3 air sampling teams took a total of 427 hydrogen sulfide measurements at 173 locations, and 83 methane measurements at 83 locations in 25 of the 30 selected clusters. The 3 air sampling teams took a total of 427 hydrogen sulfide measurements at 173 locations, and 83 methane measurements at 83

locations in 25 of the 30 selected clusters.

Household demographics and home characteristics of the surveyed households

The majority of the households interviewed had a household size of 2 to 4 people (64.0%), with 8.1% having at least one household member <2 years old, and 35.4% having at least one household member ≥65 years old (Table 2). The majority of the households lived in single family homes (70.8%), followed by mobile homes (25.5%). Forty-two percent (41.6%) of the homes were built before 1980. Many of the homes had a crawl space (42.9%) or were built on slab-on-grade (34.2%).

Community perceptions and experiences with geothermal venting

Sixty-eight percent (67.7%) of the households interviewed were aware of geothermal gases, and 36.0% had some concern about potential effects (Table 3). Thirty-four percent (34.2%) were concerned about potential health effects on their family, 23.6% were concerned about potential health effects on their pets and/or livestock, and 20.5% were concerned about potential effects on their property. Fifty-three percent (52.8%) of the households were aware of the health effects of radon, and 9.9% had been tested for radon. Twenty-one percent (20.5%) of the households had some experience with geothermal venting in or around their home. Fourteen percent (14.3%) noticed a rotten egg smell, 6.8% had seen unusual corrosion on metal surfaces, 3.1% had seen bubbling in puddles, and 0.6% encountered unexpected flames. The interview teams noted that 2.5% of the household interviewed had some evidence of geothermal venting outside home (i.e., signs of corrosion on metal surfaces, "rotten egg" smell outside home, or bubbling in puddles) (Table 4). Of the three confidential referral forms completed, two were related to potential geothermal venting activity in or around their homes.

Emergency and disaster preparedness of the community surveyed

Sixty-four percent (64.0%) of the households reported wildfires as one of their top three greatest emergency or disaster threats to their household (Table 5). This was followed by earthquakes (62.7%), floods (41.6%), and winter storms (40.4%). Sixty-one percent (60.9%) of the households had experienced earthquakes or tremors while living in their current neighborhood, and 22.4% had been affected by earthquakes in the past (Table 6). The most common effect was on their peace of mind (16.8%), followed by effects on their property (6.8%). The most common preferred method of receiving information during an emergency or disaster was television (34.2%), followed by AM/FM radio (17.4%), cell phone (14.3%), and internet (10.6%). Twenty-nine percent (29.2%) of the households had one or more household members with conditions that may create barriers to effective communication during an emergency or disaster (Table 7). The most common communication barrier reported was hearing problems (19.3%), followed by vision problems (10.6%).

Ninety-nine percent (98.8%) of households reported they had taken at least one action to prepare their household for an emergency or disaster and 87.0% reported having taken five or more actions (Table 8). The most common actions were "learned how to be safe during an earthquake" (91.3%) and "learned what supplies to have on hand" (85.7%).

The majority of the households had 10 days or more of supplies currently in their home (49.7%) (Table 9). Eighty-eight percent (87.6%) of the household had set at least five items aside for an emergency or disaster. The most common supplies to set aside were flashlights with batteries (85.1%), 3-day supply of non-perishable food (84.5%), and a first-aid kit (80.7%). When asked about possible reasons why the household may not have taken disaster or emergency preparedness steps, the top reason was that they thought that emergency responders would help them (37.3%) (Table 10).

When asked how confident the households were in their County's public health system to respond to an emergency or disaster to protect the health of their community, 56.5% were very confident or somewhat confident (Table 11). Fourteen percent (13.7%) were not at all confident. In the first 72 hours following a disaster, 85.1% of the household expected to rely on their household members for assistance, 84.5% expected to rely on fire, police, or emergency personnel, 81.4% expected to rely on their neighbors, 67.7% expected to rely on non-profit organizations, 62.1% expected to rely on the county, state, or Federal government, and 50.3% expected to rely on their faith community (Table 12).

When asked whether the households will evacuate in response to a mandatory evacuation due to a large-scale emergency or disaster, 85.1% reported they will evacuate, 9.9% reported they will not evacuate, and 4.3% reported being undecided (Table 13). When asked about possible reasons that may prevent evacuation, the most common reason was lack of transportation (18.6%), followed by concern about leaving property (17.4%). Twenty-two percent (22.4%) reported having 3 or more reasons that may prevent evacuation. Sixty-five percent (65.2%) of the households reported that they will go stay with family and friends, 11.8% reported that they will go to an American Red Cross or other community shelters, and 9.9% reported that they will go stay in a hotel or motel. Eighty-one percent (80.7%) reported owning pets and/or livestock (Table 14). When asked what they would do with their pets or livestock during an evacuation, 85.4% reported they would take the pets/livestock with them. Two percent (2.3%) reported that they will not evacuate because of pets.

Private well characteristics and testing practices in the community

The majority (75.2%) of households reported a town, city, or county water system as their main source

of home water supply, followed by a private well (11.2%), and a small water system (8.7%) (Table 15). 11.2% reported private well water as one of their drinking water sources at home, and 6.2% reported drinking exclusively private well water at home (Table 16). Of those that drink private well water at least some of the time, 61.1% of the households had wells 20 years or older, 22.2% had wells <50 feet deep, 16.7% examined their wells for possible problems more than one year ago, and 11.1% never examined their wells for possible problems. Seventy-eight percent (77.8%) of the households with private wells reported having tested the well water in the past.

Of the wells tested, 41.2% tested their water more than 1 year ago (Table 17). The primary reason reported for testing well water was that it was required by law (41.2%), followed by the household wanting to find out more about the water quality (23.5%). The most common test performed was the homeowner's package which included testing of coliform, as well as alkalinity and hardness (70.6%). Of the wells tested, only one household (5.9%) received a positive result indicating their well water was unsafe to consume.

Levels of hydrogen sulfide and methane in the community

A total of 427 readings of hydrogen sulfide were taken in 173 locations. We calculated the median reading of hydrogen sulfide at the water vault, 6" and 30" for each cluster. The median hydrogen sulfide reading in water vaults from all regions ranged from 0 to 0.5 ppb, the minimum reading was 0 ppb, and the maximum reading was 1 ppb (Table 18). The median hydrogen sulfide reading at either 6" or 30" height above ground from all regions ranged from 0 to 4 ppb, the minimum reading was 0 ppb, and the maximum reading was 5 ppb.

In city of Clearlake, the median hydrogen sulfide reading seen in either water vaults or above ground in the selected clusters ranged from 0 to 4 ppb, the minimum reading was 0 ppb, and the maximum reading was 5 ppb. In Clearlake Oaks, the median hydrogen sulfide reading seen in either water vaults or above ground ranged from 0 to 4 ppb, the minimum reading was 0 ppb, and the maximum reading was 4 ppb. In Nice and Lakeport, the median hydrogen sulfide reading seen in either water vaults or above ground ranged from 0 to 2 ppb, the minimum reading was 0 ppb, and the maximum reading was 2 ppb. In Cobb, Hidden Valley Lake, Middletown and Kelseyville, the median hydrogen sulfide reading seen in either water vaults or above ground ranged from 0 to 3 ppb, the minimum reading was 0 ppb, and the maximum reading was 4 ppb. No hydrogen sulfide measurements were ≥30 ppb.

A total of 83 methane readings were taken in 83 of the 173 sampling locations. Methane measurements were only taken in water vaults. Eighty-one of the methane readings were 0%LEL, and two readings were 1% LEL.

DISCUSSION

Disasters usually strike when people least expect with minimal warning. Being prepared at the governmental, community, and individual household levels are critical to minimize the risk of impact on their health and well-being. This community recently experienced wild fires and received a flood warning on day 3 of the CASPER survey. Therefore, this CASPER was extremely timely and relevant. We assessed the disaster preparedness in residents of selected cities and towns in Lake County, an area prone to various types of disaster and environmental hazards. Four topic areas formed the basis of this assessment: 1) community experiences with geothermal activities; 2) disaster and emergency

preparedness of the community; 3) levels of hydrogen sulfide and methane in the community; and 4) private well vulnerabilities and household well testing practices.

Knowledge of geothermal venting/Recommendations

We found that many people were aware of the geothermal venting phenomenon, 20% of households had experience with geothermal venting in or around their home, and a third of the households had some concern about potential effects. We recommend providing information to the community regarding geothermal venting, as well as documenting community concerns.

Knowledge of blue-green algae/Recommendations

We also asked questions about blue-green algae, since there was a concern that their smell could be mistaken for hydrogen sulfide from geothermal venting. Although this concern was alleviated once in the field, we found that many households reported having seen blue-green algae in a nearby lake. Therefore, we recommend continuing to provide public health education on the problem of blue-green algae in this community.

Preferred method of communication/Recommendations

We found that there is not one single universal communication method which all households preferred. Instead, the households' preferred communication media during a disaster included television, radio, cell phone, and internet. We also found that one third of the households had at least one communication barrier, with two thirds being hearing problems. We recommend using multiple means of communication to warn the community during a disaster or emergency to address communication barriers.

Household disaster plan/Recommendations

Half of the household had made a family disaster plan and 10% had participated in a neighborhood

emergency planning. We recommend LCPHD to encourage households to develop a family disaster plan. Nearly 90% of households had taken five or more actions to prepare for an emergency or disaster with half of the households having supplies currently in home that can sustain them for 10 days or more, indicating many households were prepared in this aspect. However, more households seemed to have a 3-day food supply than water supply. It is important to emphasize to the community the importance of having a 3-day water supply stored in the event of an emergency.

Knowledge on how to protect pets during a disaster/Recommendations

We found that most of the households in this community owned pets and/or livestock, and the majority of the households reported that they will take pets and livestock with them during an evacuation. Therefore, we recommend advanced planning for shelters that can accommodate pets.

Knowledge on how to protect private wells/Recommendations

We found that 1 in 10 households used private well as their main source of home water supply in this community. However, many households do not annually examine their well for problems or conduct annual testing of well water. We recommend increasing well owner's awareness for how to protect their well water supply.

Air Sampling

Finally, hydrogen sulfide and methane air sampling results from this assessment provided a snapshot of geothermal venting in Lake County. However, these results were only representative of the immediate areas that were sampled, and only during the times that the samples were taken. The median hydrogen sulfide level at 6 and 30 inches above ground was 2 ppb, with a mean of 1.9 and 2.0 ppb, respectively. In comparison, concentrations of hydrogen sulfide in urban areas were generally less than 1 ppb (5). All hydrogen sulfide levels were below the ambient California air quality standard

of 30 ppb (13). Lastly, the median hydrogen sulfide and methane levels in the water vaults were zero.

LIMITATIONS

The findings are subject to at least three limitations. First, logistically, door-to-door surveys were difficult to conduct. Despite the extensive outreach activities conducted and pre-arrangements made with gated communities to grant access for interview teams, interview teams still noted many homes (11.7%; 60 of 514 homes approached) that were inaccessible due to locked gates or unsafe to approach due to potentially dangerous dogs. Additionally, 33.3% (171 of 514 homes approached) of the homes either had nobody home after several visits or were likely vacation homes. We conducted interviews only during daylight hours until 5pm since this area had many unpaved roads in poor condition and with no street lamps. Therefore, we may have missed the optimal period to conduct interviews when people returned home from work.

Second, It is important to note that levels of geothermal gases measured can vary based on underground geothermal activities, temperature, humidity, and wind conditions, and can fluctuate from day to day even at the same location. Therefore, these results were only representative of the times that the samples were taken.

Third, based on our sampling methodology, we caution against generalizing these air sampling results to the entire county. To better understand the risk for exposure to hydrogen sulfide and methane, further air monitoring would be necessary. Longer monitoring periods throughout the year would provide a more thorough understanding of exposure risk and seasonal variations. Due to the nature of

geothermal venting and seismic activity in the region, new "hot spots" could form; thus, it is important that LCPHD be responsive to complaints of reports of "rotten egg" smell.

CONCLUSIONS

Conducting a CASPER in non-disaster environment may identify the needs and health concerns of the community related to major hazards of the area. Information obtained through these household level assessments will help the decision- makers to gauge the disaster preparedness level of the community and provide assistance or direct resources for planning for future disaster relief services. This was a successful joint exercise conducted by LCPHD, CDPH and CDC. CDPH and LCPHD demonstrated high level of expertise and resource capacity to conduct a CASPER to identify the public health needs of the local community in the event of a future emergency or disaster.

Figure 1. CASPER sampling frame (orange outline) and selected clusters (green outline) in Lake County, California.

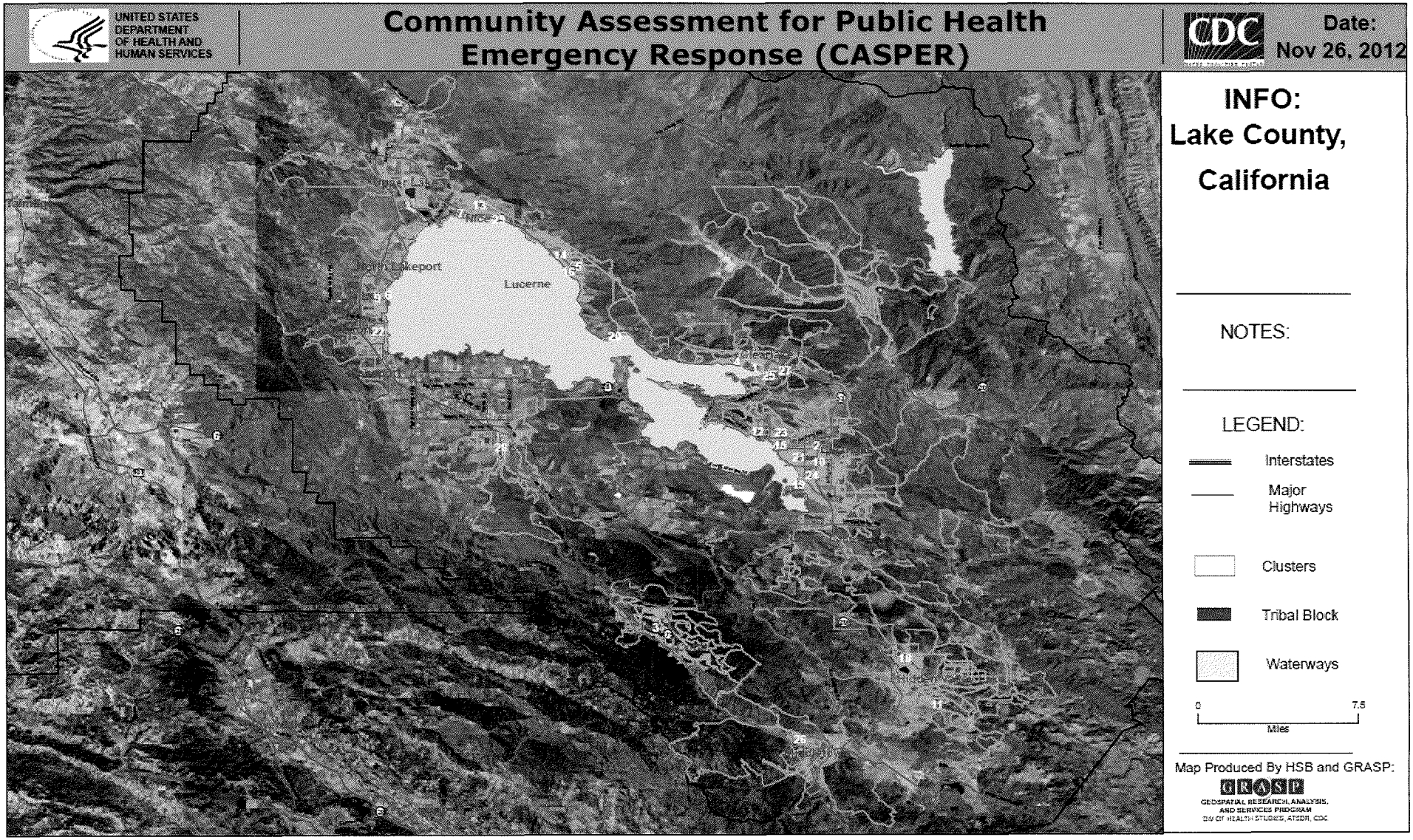

Table 1. Questionnaire response rates for CASPER conducted in Lake County, California.

Questionnaire response	Percent (n=161)	Rate
Completion*	76.7	161/210
Cooperation†	61.7	161/261
Contact‡	31.3	161/514

*Percent of surveys completed in relation to the goal of 210

†Percent of contacted households that were eligible and willing to participate in the survey

‡Percent of randomly selected households which completed an interview

Table 2. Demographics and home characteristics for interviewed households in Lake County, California.

	Frequency (n=161)	% of households	Projected number of households	Weighted % (95% CI)
Household size				
1	42	26.1	6, 570	24.6(16.0 – 33.1)
2 to 4	103	64.0	17, 712	66.3 (57.2 – 75.3)
5 or more	15	9.3	2, 321	8.7 (3.3 – 14.0)
Missing	1	0.6	127	0.5 (0 – 1.5)
Households with vulnerable age groups				
<2 years old	13	8.1	2,244	8.4 (3.1 – 13.7)
≥65 years old	57	35.4	9, 169	34.3 (24.6 – 44.0)
Main language spoken				
English	153	95.0	25,396	95.0 (91.3 – 98.7)
Spanish	8	5.0	1,334	5.0 (1.3 – 8.7)
Home type				
Mobile home	41	25.5	7,383	27.6 (17.5 – 37.8)
Single family home	114	70.8	18,512	69.3 (59.4 – 79.1)
Duplex	5	3.1	709	2.7 (0.4 – 4.9)
Multi-units complex	1	0.6	127	0.5 (0 – 1.5)
Year built (Home)				
2010 or later	0	0	0	0
2000 to 2009	18	11.2	3,488	13.0 (4.8 – 21.3)
1990 to 1999	16	9.9	2,228	8.3 (1.7 – 14.9)
1980 to 1989	24	14.9	3,880	14.5 (8.1 – 21.0)
Before 1980	67	41.6	11,755	44.0 (31.9 – 56.1)
Don't know	31	19.3	4,722	17.7(9.3 – 26.0)
Home foundation				
Slab-on-grade	55	34.2	9,252	34.6 (23.7 – 45.5)
Basement	5	3.1	636	2.4 (0.4 – 4.4)
Crawl space	69	42.9	11,806	44.2 (33.3 –55.0)
Other	22	13.7	3,522	13.2 (5.2 – 21.2)
Don't know	6	3.7	933	3.5 (0 – 7.3)

Missing: Household size (n=1); Year built (n=5).

Table 3. Perceptions and experiences regarding geothermal venting for interviewed households in Lake County, California.

	Frequency (n=161)	% of households	Projected number of households	Weighted % (95% CI)
Geothermal gases				
Aware of geothermal gases	109	67.7	18,106	67.7 (58.6 – 76.9)
Had at least one concern about potential effects*	58	36.0	8,664	32.4 (23.7 – 41.1)
Concerned about effects on health of family	55	34.2	8,231	30.8 (22.1 – 39.5)
Concerned about effects on health of pets/livestock	38	23.6	5,995	22.4 (14.8 – 30.1)
Concerned about effects on property	33	20.5	5,287	19.8 (12.3 – 27.2)
No concerns about effects of gases	97	60.2	17,251	64.5 (54.9 – 74.2)
Radon				
Aware of health effects of radon	85	52.8	14,023	52.5 (41.6 – 63.3)
Home have been tested for radon	16	9.9	2,841	10.6 (4.9 – 16.3)
Experiences in or around home				
Have had at least one experience with geothermal venting in or around home†	33	20.5	5,626	21.0 (12.3 – 29.8)
Noticed rotten egg smell	23	14.3	4,311	16.1 (7.5 – 24.8)
Encountered unexpected flames	1	0.6	127	0.5 (0 – 1.5)
Seen unusual corrosion on metal surfaces	11	6.8	1,634	6.1 (1.7 – 10.5)
Seen bubbling in puddles	5	3.1	849	3.2 (0.3 – 6.1)
Seen blue-green algae in nearby lake	128	79.5	21,112	79.0 (67.9 – 90.0)

*Any household that reported concerns about effects on health of family, health of pets/livestock, or concern about effects on property.

†Any household that reported that they have noticed rotten egg smell, encountered unexpected flames, seen unusual corrosion on metal surfaces, or seen bubbling in puddles.

Table 4. Evidence of geothermal venting outside home for interviewed households in Lake County, California.

	Frequency (n=161)	% of households	Projected number of households	Weighted % (95% CI)
Had at least one evidence of geothermal venting outside home*	4	2.5	849	3.2 (0 – 7.9)
Signs of corrosion on metal surfaces				
Corrosion seen on metal surfaces	4	2.5	849	3.2 (0 – 7.9)
No visible corrosion seen	148	91.9	23,955	89.6 (81.1 – 98.1)
No metal surfaces outside home	6	3.7	1,443	5.4 (0 – 12.6)
Rotten egg smell outside home	0	0	0	0 (0)
Bubbling in puddles				
Bubbling seen in puddles	0	0	0	0 (0)
No bubbling seen in puddles	49	30.4	9,451	35.4 (20.1 – 50.7)
No puddles outside home	109	67.7	16,795	62.8 (47.5 – 78.2)

*Any household where the interview teams noted signs of corrosion on metal surfaces, rotten egg smell, or bubbling in puddles outside home.
Missing: Bubbling in puddles (n=2).

Table 5. Perceived greatest emergency or disaster threats for interviewed households in Lake County, California.

	Frequency (n=161)	% of households	Projected number of households	Weighted % (95% CI)
Accidental chemical releases	25	15.5	4,561	17.1 (8.9 – 25.2)
Earthquakes	101	62.7	17,101	64.0 (53.2 – 74.8)
Floods	67	41.6	11,288	42.2 (29.6 – 54.8)
Heat waves	24	14.9	4,249	15.9 (10.1 – 21.7)
Terrorist attacks	10	6.2	1,447	5.4 (1.9 – 9.0)
Tornadoes	5	3.1	806	3.0 (0.2 – 5.8)
Volcanic eruptions	40	24.8	6,199	23.2 (15.5 – 30.9)
Wild fires	103	64.0	17,540	65.6 (55.0 – 76.3)
Winter storms	65	40.4	10,319	38.6 (28.3 – 48.9)
Other	18	11.2	2,822	10.6 (4.1 – 17.0)

Table 6. Experiences with earthquakes for interviewed households in Lake County, California.

	Frequency (n=161)	% of households	Projected number of households	Weighted % (95% CI)
Experienced earthquakes or tremors while living in this neighborhood	98	60.9	17,618	65.9 (56.2 – 75.6)
Had been affected by earthquakes in the past*	36	22.4	5,350	20.0 (13.7 – 26.3)
Finances	6	3.7	785	2.9 (0.7 – 5.2)
Property	11	6.8	1,443	5.4 (2.4 – 8.4)
Peace of mind	27	16.8	3,993	14.9 (9.5 – 20.4)
Health	3	1.9	647	2.4 (0.0 – 5.3)
Other	3	1.9	403	1.5 (0.0 – 3.7)
No effects	119	73.9	20,425	76.4 (69.9 – 82.9)

*Any household that reported having had their finances, property, peace of mind or health affected by earthquakes in the past.

Table 7. Communication during an emergency or disaster for interviewed households in Lake County, California.

	Frequency (n=161)	% of households	Projected number of households	Weighted % (95% CI)
Preferred method of receiving information				
Television	55	34.2	8,800	32.9 (24.9 – 40.9)
AM/FM Radio	28	17.4	5,066	19.0 (9.4 – 28.5)
Text message	9	5.6	1,854	6.9 (1.2 – 12.7)
Cell phone	23	14.3	3,486	13.0 (6.6 – 19.5)
Landline telephone	11	6.8	1,981	7.4 (2.3 – 12.5)
Internet	17	10.6	3,042	11.4 (5.9 – 16.8)
Printed newspaper	1	0.6	127	0.5 (0.0 – 1.5)
Word of mouth	7	4.3	963	3.6 (0.7 – 6.5)
Church/community center	0	0	0	0
Bulletin board	0	0	0	0
Child's school	1	0.6	127	0.5 (0.0 – 1.5)
Ham radio	4	2.5	509	1.9 (0.1 – 3.7)
Work	0	0	0	0
Other	3	1.9	520	1.9 (0.0 – 4.7)
Households with at least one communication barriers*	47	29.2	7,217	27 (18.2 – 35.8)
Hearing problems	31	19.3	4,739	17.7 (10.9 – 24.6)
Vision problems	17	10.6	2,567	9.6 (3.7 – 15.5)
Problems understanding written material	12	7.5	2,087	7.8 (2.2 – 13.4)
Problems understanding English	7	4.3	1,112	4.2 (0.7 – 7.6)
Other	5	3.1	806	3.0 (0.2 – 5.8)
No barriers	111	68.9	19,131	71.6 (62.5 – 80.6)

*Any household that reported someone in the household with a hearing problem, vision problem, problem understanding written material, or problem understanding English.

Table 8. Action taken to prepare for an emergency or disaster for interviewed households in Lake County, California.

	Frequency (n=161)	% of households	Projected number of households	Weighted % (95% CI)
Actions taken				
Have taken at least 1 action*	159	98.8	26,454	99.0 (97.5 – 100)
Have taken at least 3 actions*	149	92.5	25,012	93.6 (89.8 – 97.4)
Have taken 5 or more actions*	140	87.0	23,696	88.7 (83.5 – 93.8)
Learned to shut off utilities	128	79.5	22,040	82.5 (74.9 – 90.0)
Learned what supplies to have on hand	138	85.7	23,200	86.8 (81.1 – 92.5)
Made family disaster plans	79	49.1	12,822	48.0 (37.5 – 58.4)
Participated in neighborhood emergency or disaster planning	17	10.6	3,233	12.1 (3.7 – 20.5)
Made disaster plans for pets	57	35.4	9,633	36.0 (25.5 – 46.6)
Made disaster plans for livestock	5	3.1	857	3.2 (0.3 – 6.2)
Learned first aid	131	81.4	21,919	82.0 (75.2 – 88.8)
Learned how to be safe during an earthquake	147	91.3	24,418	91.3 (85.6 – 97.1)
Learned how to make home contents safe during an earthquake	129	80.1	21,980	82.2 (77.0 – 87.5)
Learned how to make building structure safer during an earthquake	94	58.4	16,424	61.4 (51.9 – 71.0)
Stored hazardous materials safely	133	82.6	22,631	84.7 (77.7 – 91.6)
Learned how to safeguard finances	97	60.2	15,936	59.6 (48.9 – 70.4)
Purchased earthquake insurance for home	25	15.5	4,071	15.2 (8.4 – 22.1)
Purchased earthquake insurance for home contents	24	14.9	4,196	15.7 (9.0 – 22.4)

*Actions as listed in the table.

Table 9. Emergency supplies for an emergency or disaster for interviewed households in Lake County, California.

	Frequency (n=161)	% of households	Projected number of households	Weighted % (95% CI)
Numbers of days of supplies currently in home				
1 to 3 days	23	14.3	4,056	15.2 (8.7 – 21.7)
4 to 6 days	22	13.7	3,004	11.2 (5.7 – 16.8)
7 to 9 days	34	21.1	5,668	21.2 (13.3 – 29.1)
10 days or more	80	49.7	13,704	51.3 (41.9 – 60.7)
Supplies set aside for emergency/disaster				
Had at least 1 item set aside*	157	97.5	26,200	98.0 (94.9 – 100)
Had at least 3 items set aside*	153	95.0	25,691	96.1 (92.7 – 99.6)
Had 5 or more items set aside*	141	87.6	23,773	88.9 (83.5 – 94.4)
3-day supply for non-perishable food	136	84.5	22,716	85.0 (78.6 – 91.3)
3-day supply of water	102	63.4	17,655	66.0 (56.2 – 75.9)
Battery-operated radio	108	67.1	17,837	66.7 (56.8 – 76.6)
First-aid kit	130	80.7	21,435	80.2 (72.2 – 88.2)
3-day supply of prescription medication	117	72.7	19,021	71.2 (61.2 – 81.2)
Special medical equipment or supplies	58	36.0	8,634	32.3 (23.4 – 41.2)
Flashlights with extra batteries	137	85.1	23,170	86.7 (79.8 – 93.6)
Dust masks	80	49.7	13,609	50.9 (40.7 – 61.1)
Eye glasses	104	64.6	17,990	67.3 (57.0 – 77.7)
Important financial documents	113	70.2	18,970	71.0 (61.8 – 80.1)
Cash	82	50.9	14,655	54.8 (44.5 – 65.2)
Copies of personal identification	110	68.3	18,658	69.8 (60.8 – 78.8)
Other	30	18.6	4,612	17.3 (8.6 – 25.9)
Generator	11	6.8	1,538	5.8 (0 – 11.6)
Guns/Ammo	3	1.9	477	1.8 (0 – 3.9)
Clothing/Blankets	6	3.7	955	3.6 (0.3 – 6.8)
No supplies set aside	3	1.9	382	1.4 (0 – 4.4)

*Items as listed in the table.

Missing: Number of days of supplies currently in home (n=1). Refused: Number of days of supplies currently in home (n=1).

Table 10. Reasons for not preparing for an emergency or disaster for interviewed households in Lake County, California.

	Frequency (n=161)	% of households	Projected number of households	Weighted % (95% CI)
Don't know what to do	25	15.5	3,746	14.0 (7.7 – 20.3)
Haven't had the time	23	14.3	3,751	14.0 (8.0 – 20.0)
Don't want to think about it	33	20.5	5,248	19.6 (13.2 – 26.1)
It costs too much	42	26.1	6,150	23.0 (13.9 – 32.2)
Don't think it will make a difference	19	11.8	3,152	11.8 (6.2 – 17.3)
Don't think will be able to	19	11.8	3,199	12.0 (5.6 – 18.3)
Think that emergency responders will help	60	37.3	9,865	36.9 (26.5 – 47.3)
Other reasons	16	9.9	3,114	11.7 (4.9 – 18.4)
None of these reasons	22	13.7	3,657	13.7 (6.5 – 20.9)

Table 11. Confidence in the County's public health system to respond and protect the community for interviewed households in Lake County, California.

	Frequency (n=161)	% of households	Projected number of households	Weighted % (95% CI)
Very confident	23	14.3	4,124	15.4 (6.9 – 24.0)
Somewhat confident	68	42.2	10,609	39.7 (28.7 – 50.7)
Not too confident	34	21.1	6,377	23.9 (14.9 – 32.8)
Not at all confident	22	13.7	3,360	12.6 (6.9 – 18.3)
Don't know	13	8.1	2,111	7.9 (3.2 – 12.6)

Missing: Confidence in the County's public health system (n=1).

Table 12. Assistance expected in the first 72 hours following a disaster for interviewed households in Lake County, California.

	Frequency (n=161)	% of households	Projected number of households	Weighted % (95% CI)
Household members				
Expected to rely on*	137	85.1	22,844	85.5 (80.0 – 90.9)
Expected to rely on a great deal†	119	73.9	19,625	73.4 (66.7 – 80.2)
People in your neighborhood				
Expected to rely on*	131	81.4	21,229	79.4 (70.7 – 88.2)
Expected to rely on a great deal†	44	27.3	6,430	24.1 (16.4 – 31.7)
Non-profit organizations				
Expected to rely on*	109	67.7	18,251	68.3 (58.3 – 78.3)
Expected to rely on a great deal†	27	16.8	4,313	16.1 (9.1 – 23.1)
Faith community				
Expected to rely on*	81	50.3	12,396	46.4 (37.4 – 55.3)
Expected to rely on a great deal†	28	17.4	4,633	17.3 (11.0 – 23.6)
Fire, police, emergency personnel				
Expected to rely on*	136	84.5	21,802	81.6 (72.7 – 90.4)
Expected to rely on a great deal†	49	30.4	8,753	32.7 (23.2 – 42.3)
County, State or Federal Government				
Expected to rely on*	100	62.1	16,950	63.4 (53.2 – 73.6)
Expected to rely on a great deal†	17	10.6	3,507	13.1 (5.4 – 20.8)

*Any household that reported a score of 2, 3, 4, or 5 to the corresponding question.

†Any household that reported a score of 5 to the corresponding question.

Missing: Household members (n=8); People in your neighborhood (n=3); Non-profit organization (n=8); Faith community (n=9); Fire, police, emergency personnel (n=4); County, State or Federal Government (n=7).

Table 13. Response to mandatory evacuation and shelter locations for interviewed households in Lake County, California.

	Frequency (n=161)	% of households	Projected number of households	Weighted % (95% CI)
Likely response to mandatory evacuation				
Will evacuate	137	85.1	22,831	85.4 (79.8 – 91.1)
Will not evacuate	16	9.9	2,491	9.3 (4.2 – 14.4)
Don't know if will evacuate	7	4.3	1,260	4.7 (0.8 – 8.7)
Reasons preventing evacuation				
Had at least 1 reason that may prevent evacuation*	90	55.9	14,547	54.4 (46.0 – 62.9)
Had 3 or more reasons that may prevent evacuation*	36	22.4	5,342	20.0 (12.9 – 27.1)
Had 5 or more reasons that may prevent evacuation*	13	8.1	2,109	7.9 (2.6 – 13.2)
Lack of transportation	30	18.6	4,480	16.8 (9.9 – 23.6)
Lack of trust in public officials	24	14.9	3,797	14.2 (7.3 – 21.1)
Concern about leaving property	28	17.4	4,489	16.8 (10.0 – 23.6)
Concern about getting gas for vehicle	25	15.5	3,768	14.1 (8.0 – 20.2)
Nowhere to go	15	9.3	2,393	9.0 (3.6 – 14.3)
Concern about personal safety	22	13.7	4,300	16.1 (8.1 – 24.0)
Concern about leaving livestock or pets	20	12.4	3,696	13.8 (5.9 – 21.8)
Inconvenient	11	6.8	1,663	6.2 (2.3 – 10.1)
Expensive	17	10.6	2,720	10.2 (4.2 – 16.1)
Health problems	16	9.9	2,253	8.4 (4.0 – 12.9)
Other	16	9.9	2,491	9.3 (4.6 – 14.1)
Road Problems	6	3.7	785	2.9 (0 – 5.9)
Shelter locations				
Friends/ family/ second home	105	65.2	18,181	68.0 (59.9 – 76.1)
Hotel or motel	16	9.9	2,174	8.1 (4.0 – 12.2)
American Red Cross/ church/ community shelter	19	11.8	2,715	10.2 (5.1 – 15.2)
Would not evacuate	4	2.5	870	3.3 (0 – 7.4)
Other	12	7.5	1,793	6.7 (2.5 – 10.9)
Don't know	4	2.5	849	3.2 (0 – 6.9)

*Reasons as listed in the table.

Missing: Likely response to mandatory evacuation (n=1); Shelter locations (n=1).

Table 14. Pet ownership and pet evacuation of interviewed households in Lake County, California.

	Frequency (n=161)	% of households	Projected number of households	Weighted % (95% CI)
Pet ownership and pet evacuation				
Own pets	126	78.3	22,080	82.6 (75.9 – 89.3)
Own livestock	4	2.5	1,443	5.4 (0.0 – 12.6)
Own pets and/or livestock	130	80.7	22,589	84.5 (77.8 – 91.2)
Take pets/livestock with them*	111	85.4	19,784	87.6 (82.0 – 93.1)
Find a safe place for them*	3	2.3	433	1.9 (0.0 – 4.2)
Leave behind with food/ water*	9	6.9	1,337	5.9 (2.1 – 9.7)
Would not evacuate because of pet*	3	2.3	505	2.2 (0.0 – 4.8)
Would not evacuate because of livestock*	0	0.0	0	0.0 (0.0 – 0.0)
Would not evacuate for other reasons*	2	1.5	276	1.2 (0.0 – 3.0)

*Of those who have pets and/or livestock.

Missing: What to do with pets during an evacuation (n=2);

Table 15. Main source of home water supply in Lake County, California.

	Frequency (n=161)	% of households	Projected number of households	Weighted % (95% CI)
Town, city or county water system	121	75.2	20,081	75.1 (62.1 – 88.2)
Small water system operated by property owner/ homeowner association	14	8.7	1,782	6.7 (0.4 – 12.9)
Private well	18	11.2	3,755	14.0 (3.0 – 25.1)
Other	3	1.9	454	1.7 (0.0 – 3.7)
Don't know	4	2.5	509	1.9 (0.1 – 3.7)

Missing: Main source of home water supply (n=1);

Table 16. Home drinking water and private well characteristics of households that drink private well water in Lake County, California.

	Frequency (n=161)	% of households	Projected number of households	Weighted % (95% CI)
Home drinking water				
Private well water	18	11.2	2,726	10.2 (2.5 – 17.9)
Only drank private well water	10	6.2	1,612	6.0 (0.0 – 12.5)
Tap/faucet water	100	62.1	15,211	56.9 (44.7 – 69.2)
Bottled water	93	57.8	15,983	59.8 (48.7 – 70.9)
Lake water collected by household	0	0.0	0	0.0 (0.0 – 0.0)
Other	21	13.0	3,411	12.8 (4.1 – 21.4)
Age of well				
<10 years*	2	11.1	255	9.3 (0.0 – 19.8)
10 to <20 years*	2	11.1	424	15.6 (0.0 – 34.1)
≥20 years*	11	61.1	1,665	61.1 (47.0 – 75.2)
Don't know*	3	16.7	382	14.0 (0.0 – 33.4)
Depth of well				
<50 ft.*	4	22.2	774	28.4 (7.3 – 49.5)
50 to <100 ft.*	4	22.2	509	18.7 (0.0 – 38.5)
≥100 ft.*	4	22.2	679	24.9 (6.1 – 43.7)
Don't know*	6	33.3	764	28.0 (0.0 – 56.7)
Last examined well				
Never*	2	11.1	255	9.3 (0.0 – 21.4)
Within the last year*	10	55.6	1,538	56.4 (34.6 – 78.3)
More than 1 year ago*	3	16.7	552	20.2 (0.0 – 41.7)
Don't know*	2	11.1	255	9.3 (0.0 – 21.4)
Private well tested in the past*	14	77.8	2,217	81.3 (53.6 – 100.0)

*Of those using private well water as one of their drinking water sources at home (n=18).
Missing: Last examined well (n=1);

Table 17. Well water testing practices in households in Lake County, California.

	Frequency (n=17)	% of households	Projected number of households	Weighted % (95% CI)
Well tested within the last year†	10	58.8	1,368	40.7 (0.0 – 81.9)
Well tested more than 1 year ago†	7	41.2	1,994	59.3 (18.1 – 100.0)
Primary reason for testing well				
It was required by law†	7	41.2	1,061	31.5 (0.0 – 70.8)
Wanted to know about water quality†	4	23.5	509	15.1 (0.0 – 38.4)
It tasted or smelled bad†	1	5.9	127	3.8 (0.0 – 12.1)
Someone recommended testing†	1	5.9	127	3.8 (0.0 – 11.2)
Other†	4	23.5	1,538	45.7 (5.2 – 86.2)
Testing performed				
Bacteria/Coliforms†	8	47.1	2,121	63.1 (27.4 – 98.8)
Homeowner's package†	12	70.6	1,962	58.4 (18.8 – 97.9)
Other special tests†	5	29.4	636	18.9 (0.0 – 39.2)
Don't know†	2	11.8	255	7.6 (0.0 – 17.3)
Received positive results indicating water is unsafe to consume†	1	5.9	127	3.8 (0.0 – 12.1)
Actions taken after receiving positive results				
Action taken‡	1	100.0	127	100.0 (100.0 – 100.0)

†Of those well tested (n=17), n=3 may be public wells

‡Of those who received positive results (n=1)

Table 18. Water vault and ground level readings of hydrogen sulfide (ppb) in selected areas in Lake County, California.

Location	Cluster numbers	Measurement location	n (Total n=427)	Median	Minimum	Maximum	IQR	Quantity ≥ 30 ppb
Clearlake	2	Water vault	3	0	0	0	0	0
		6"	6	3	1	4	1	0
		30"	6	4	2	5	1	0
Clearlake	10	Water vault	3	0	0	0	0	0
		6"	5	2	2	2	0	0
		30"	5	2	2	2	0	0
Clearlake	12	Water vault	5	0	0	0	0	0
		6"	5	2	1	2	0	0
		30"	5	2	1	2	0	0
Clearlake	15	Water vault	5	0	0	0	0	0
		6"	5	2	1	2	1	0
		30"	5	2	2	2	0	0
Clearlake	19	Water vault	5	0	0	0	0	0
		6"	16	1	1	2	0	0
		30"	16	1	1	2	0	0
Clearlake	21	Water vault	7	0	0	0	0	0
		6"	7	2	1	2	0	0
		30"	7	2	1	2	1	0
Clearlake	23	Water vault	NA	NA	NA	NA	NA	NA
		6"	5	1	0	2	1	0
		30"	5	0	0	2	0	0
Clearlake	24	Water vault	5	0	0	0	0	0
		6"	5	0	0	1	1	0
		30"	5	1	0	1	1	0
Clearlake Oaks	1	Water vault	12	0	0	0	0	0
		6"	15	4	3	4	0	0
		30"	15	4	2	4	0	0
Clearlake Oaks	4	Water vault	5	0	0	0	0	0
		6"	5	3	2	4	0	0
		30"	5	4	3	4	1	0
Clearlake Oaks	8	Water vault	2	0	0	0	0	0
		6"	5	4	3	4	0	0

Location	Cluster numbers	Measurement location	n (Total n=427)	Median	Minimum	Maximum	IQR	Quantity ≥ 30 ppb
		30"	5	4	3	4	1	0
Clearlake Oaks	17	Water vault	4	0	0	0	0	0
		6"	5	4	2	4	1	0
		30"	5	4	3	4	1	0
Clearlake Oaks	25	Water vault	3	0	0	0	0	0
		6"	5	0	0	1	1	0
		30"	5	0	0	1	0	0
Clearlake Oaks	27	Water vault	NA	NA	NA	NA	NA	NA
		6"	13	2	2	3	0	0
		30"	13	2	1	3	0	0
Lucerne	14	Water vault	NA	NA	NA	NA	NA	NA
		6"	NA	NA	NA	NA	NA	NA
		30"	NA	NA	NA	NA	NA	NA
Lucerne	5	Water vault	NA	NA	NA	NA	NA	NA
		6"	NA	NA	NA	NA	NA	NA
		30"	NA	NA	NA	NA	NA	NA
Lucerne	16	Water vault	NA	NA	NA	NA	NA	NA
		6"	NA	NA	NA	NA	NA	NA
		30"	NA	NA	NA	NA	NA	NA
Paradise Cove	20	Water vault	5	0	0	0	0	0
		6"	5	3	2	4	0	0
		30"	5	3	2	4	0	0
Nice	7	Water vault	4	0	0	0	0	0
		6"	14	1	0	1	0	0
		30"	14	1	0	2	0	0
Nice	13	Water vault	2	0	0	0	0	0
		6"	2	1	1	1	0	0
		30"	2	1	1	1	0	0
Nice	29	Water vault	NA	NA	NA	NA	NA	NA
		6"	NA	NA	NA	NA	NA	NA
		30"	NA	NA	NA	NA	NA	NA
Lakeport	6	Water vault	2	0	0	0	0	0
		6"	5	0	0	1	1	0
		30"	5	1	0	1	0	0

Location	Cluster numbers	Measurement location	n (Total n=427)	Median	Minimum	Maximum	IQR	Quantity ≥ 30 ppb
Lakeport	9	Water vault	2	0	0	0	0	0
		6"	5	1	0	2	2	0
		30"	5	2	1	2	1	0
Lakeport	22	Water vault	3	0	0	0	0	0
		6"	5	0	0	0	0	0
		30"	5	0	0	1	0	0
Cobb	3	Water vault	3	0	0	0	0	0
		6"	13	3	2	3	0	0
		30"	13	3	2	4	0	0
Hidden Valley Lake	11	Water vault	1	0	0	0	0	0
		6"	5	2	1	2	0	0
		30"	5	1	1	2	1	0
Hidden Valley Lake	18	Water vault	2	0.5	0	1	1	0
		6"	7	2	1	2	1	0
		30"	7	2	1	2	1	0
Middletown	26	Water vault	NA	NA	NA	NA	NA	NA
		6"	5	1	0	2	1	0
		30"	5	0	0	2	1	0
Kelseyville	28	Water vault	NA	NA	NA	NA	NA	NA
		6"	4	3	3	4	0.5	0
		30"	4	3	3	3	0	0

Table 19. Water vault readings of methane (%LEL) in selected areas in Lake County, California.

Location	Cluster numbers	Measurement location	n (Total n=83)	Median	Minimum	Maximum	IQR	Quantity ≥ 50 %LEL
Clearlake	2	Water vault	4	0	0	1	0.5	0
Clearlake	10	Water vault	3	0	0	0	0	0
Clearlake	12	Water vault	5	0	0	0	0	0
Clearlake	15	Water vault	5	0	0	0	0	0
Clearlake	19	Water vault	5	0	0	0	0	0
Clearlake	21	Water vault	7	0	0	1	1	0
Clearlake	23	Water vault	NA	NA	NA	NA	NA	NA
Clearlake	24	Water vault	5	0	0	0	0	0
Clearlake Oaks	1	Water vault	12	0	0	0	0	0
Clearlake Oaks	4	Water vault	5	0	0	0	0	0
Clearlake Oaks	8	Water vault	2	0	0	0	0	0
Clearlake Oaks	17	Water vault	4	0	0	0	0	0
Clearlake Oaks	25	Water vault	3	0	0	0	0	0
Clearlake Oaks	27	Water vault	NA	NA	NA	NA	NA	NA
Lucerne	5	Water vault	NA	NA	NA	NA	NA	NA
Lucerne	14	Water vault	NA	NA	NA	NA	NA	NA
Lucerne	16	Water vault	NA	NA	NA	NA	NA	NA
Paradise Cove	20	Water vault	5	0	0	0	0	0
Nice	7	Water vault	3	0	0	0	0	0
Nice	13	Water vault	2	0	0	0	0	0
Nice	29	Water vault	NA	NA	NA	NA	NA	NA
Lakeport	6	Water vault	2	0	0	0	0	0
Lakeport	9	Water vault	2	0	0	0	0	0
Lakeport	22	Water vault	3	0	0	0	0	0
Cobb	3	Water vault	3	0	0	0	0	0
Hidden Valley Lake	11	Water vault	1	0	0	0	0	0
Hidden Valley Lake	18	Water vault	2	0	0	0	0	0
Middletown	26	Water vault	NA	NA	NA	NA	NA	NA
Kelseyville	28	Water vault	NA	NA	NA	NA	NA	NA

Appendix I: Questionnaire used in the CASPER household interviews in Lake County, California.

To be completed by interview team BEFORE the interview	
Q1a. Date (MM/DD/YY): **Q1b.** Time: □ am □ pm	**Q3.** Survey Number:
Q2. Cluster Number:	**Q4.** Team Member Initials:

First, we would like to ask you some general questions about your household and your home. Please respond for all members of your household.

Q5. Including yourself, how many people live in your household? _____

Q6. Including yourself, how many people living in your household are: (list number)
Less than 2 years old? _____ 2-17 years old? _____ 18-64 years old? _____ 65 years or older? _____ □ DK □ R

Q7. What is the MAIN language spoken in your household? □ English □ Spanish □ Other, specify _____ □ DK □ R

Q8. Is your home a: □ Mobile home □ Single family home (detached) □ Duplex □ Multi-units complex (e.g., apartments) □ DK □ R

Q9. When was your home built? (write year) _____ □ DK □ R

Q10. Is your home built on top of: □ Slab-on-grade (e.g., concrete slab) □ Basement □ Crawl space □ Other, _____ □ DK □ R

You may know Mt. Konocti is a volcano. Because of this, some areas of Lake County have hydrogen sulfide, methane, and other naturally occurring gasses seeping out of the ground. We would like to ask you some questions about your household's experience with these gasses. Please respond for all members of your household.

Q11. Are you and members of your household aware of these naturally occurring gasses that come up through the ground?
□ Yes □ No □ DK □ R

Q12. Are you and members of your household concerned about potential effects of these naturally occurring gasses on: **(check all that apply)**
□ The health of you and your family? □ The health of your pets/ livestock? □ Your property? □ None of the above □ DK □ R

Q13a. Are you and members of your household aware of the health effects of radon? □ Yes □ No □ DK □ R
Q13b. Has your home been tested for radon levels? □ Yes □ No □ DK □ R

Q14. In or around your home, have you or members of your household ever:
Noticed a rotten egg smell? □ Yes □ No □ DK □ R
Have you encountered unexpected flames during activities such as digging? □ Yes □ No □ DK □ R
Have you seen unusual corrosion on metal surfaces? (e.g., fence, door hinges **[Show photo]**) □ Yes □ No □ DK □ R
Have you seen bubbling in puddles? **[Show photo]** □ Yes □ No □ DK □ R
Have you seen blue-green algae in nearby lakes? (i.e., visibly discolored water, surface scum **[Show photo]**) □ Yes □ No □ DK □ R

Now, we would like to ask you some questions about how your household might prepare for a disaster or emergency. Please respond for all members of your household.

Q15. Of the following, which do you view as the three greatest emergency or disaster threats to your household? **(check three)**
□ Accidental chemical releases □ Earthquakes □ Floods □ Heat waves □ Terrorist attacks □ Tornados
□ Volcanic eruptions □ Wild fires □ Winter storms □ Other, specify: _____ □ DK □ R

Q16a. What is your household's preferred method for receiving information during an emergency or disaster? **(check one)**
□ TV □ AM/FM Radio □Text message □Cell phone □Landline telephone □Internet □ Printed newspaper □ Word of mouth
□Church/community center □ Bulletin board □ Your child's school □ Ham radio □ Work □ Other, _____ □ DK □ R

Q16b. Does anyone in your household have any of the following conditions that could be barriers to effective communication during an emergency or disaster: **(check all that apply)**

□ Hearing problems □ Vision problems □ Problems understanding written material

□ Problems understanding English Language □ Other, _____ □ None □ DK □ R

Q17a. Have you or members of your household experienced earthquakes or tremors while living in this neighborhood? □ Yes □ No □ DK □ R

Q17b. Have earthquakes affected your: **(check all that apply)**

□ Finances □ Property □ Peace of Mind □ Health □ Anything else, specify _____ □ None of these □ DK □ R

Now we want to ask you about steps your household may have taken to prepare for a disaster or emergency. Please respond for all members of your household.

Q18a. There are many reasons why people do not prepare for an emergency or disaster. Please tell me if any of the following are reasons why you have not taken disaster or emergency preparedness steps?

You don't know what you're supposed to do	□ Yes	□ No	□ DK	□ R
You haven't had the time	□ Yes	□ No	□ DK	□ R
You don't want to think about it	□ Yes	□ No	□ DK	□ R
It costs too much	□ Yes	□ No	□ DK	□ R
You don't think it will make a difference	□ Yes	□ No	□ DK	□ R
You don't think you'll be able to	□ Yes	□ No	□ DK	□ R
You think that emergency responders, such as fire, police will help you.	□ Yes	□ No	□ DK	□ R
□ Other, specify_____				
□ None of the these			□DK	□R

Now we want to know if you have done any of the following things. This will be a series of yes or no questions about actions people can take to prepare for an emergency or disaster.

Q19. In order to prepare for an emergency or disaster, have you done the following things:

Learned how to shut off utilities such as gas or propane? (if all-electric home, check N/A)	□ Yes	□ No	□ DK	□ R	□ N/A
Learned what supplies and equipment to have on hand?	□ Yes	□ No	□ DK	□ R	
Made family disaster plans?	□ Yes	□ No	□ DK	□ R	
Participated in neighborhood emergency or disaster planning?	□ Yes	□ No	□ DK	□ R	
Made disaster plans for pets?	□ Yes	□ No	□ DK	□ R	□N/A
Made disaster plans for large animals or livestock?	□ Yes	□ No	□ DK	□ R	□N/A
Learned first aid?	□ Yes	□ No	□ DK	□ R	
Learned how to be safe during an earthquake?	□ Yes	□ No	□ DK	□ R	
Learned how to make the things inside your home safer during an earthquake?	□ Yes	□ No	□ DK	□ R	
Learned how to make the structure of your building safer during an earthquake?	□ Yes	□ No	□ DK	□ R	
Stored hazardous materials safely?	□ Yes	□ No	□ DK	□ R	
Learned how to safeguard your finances in case there is an emergency or disaster?	□ Yes	□ No	□ DK	□ R	
Purchased earthquake insurance to cover your home's structure?	□ Yes	□ No	□ DK	□ R	
Purchased earthquake insurance for the things inside your home?	□ Yes	□ No	□ DK	□ R	

Q20. Think about what you have in your home right now. For how many days would you be able to stay in your home without anyone shopping for additional supplies? □1 to 3 days □ 4 to 6 days □ 7 to 9 days □ 10 days or more □ DK □ R

Q21. Do you have the following supplies set aside in your home to be used only in the case of an emergency or disaster? **(check all that apply)**

□ 3-day supply of non-perishable food □ 3-day supply of water (1 gallon/person/day) □ Battery-operated radio
□ First-aid kit □ 3-day supply of prescription medication for each person who needs it □ Special medical equipment or supplies
□ Flashlights w/ extra batteries □ Dust masks □ Eye glasses □ Important financial documents □ Cash
□ Copies of personal identification □ Other, specify _____ □ None □ DK □ R

Q22. How confident are you that your county's public health system can respond in a way to protect the health of your family and neighbors **(check one)**

□ Very confident □ Somewhat confident □ Not too confident □ Not at all confident □ DK □ R

Q23. In the first 72 hours following a disaster, please indicate how much you would expect to rely on the following for assistance. Please use a scale of 1 to 5, with 5 being "expect to rely on a great deal" and 1 being "do not expect to rely on at all.

Household members	□ 1=Not at all	□2	□3	□4	□ 5=A great deal	□ DK	□ R
People in your neighborhood	□ 1=Not at all	□2	□3	□4	□ 5=A great deal	□ DK	□ R
Non-profit organizations, such as the American Red Cross or the Salvation Army	□ 1=Not at all	□2	□3	□4	□ 5=A great deal	□ DK	□ R
Your faith community, such as a congregation	□ 1=Not at all	□2	□3	□4	□ 5=A great deal	□ DK	□ R
Fire, police, emergency personnel	□ 1=Not at all	□2	□3	□4	□ 5=A great deal	□ DK	□ R
County, State or Federal Government agencies	□ 1=Not at all	□2	□3	□4	□ 5=A great deal	□ DK	□ R

Now, we would like to ask you some questions about what you and your household may do during a mandatory evacuation.

Q24. If public authorities announced a mandatory evacuation from your community due to a large-scale emergency or disaster (such as a wildfire), would you and your household evacuate? □ Yes □ No □ DK □ R

Q25. What would be reasons that might prevent you from evacuating if asked to do so? **(check all that apply)**

□ I will evacuate no matter what □ Lack of transportation □ Lack of trust in public officials □ Concern about leaving property
□ Concern about getting gas for vehicle □ Nowhere to go □ Concern about personal safety
□ Concern about leaving livestock or pets □ Inconvenient □ Expensive □ Health problems (e.g., could not be moved)
□ Other_____ □ DK □ R

Q26. If your household had to evacuate due to a large-scale disaster or emergency, where would you go? **(check one)**

□ Friends/family/2nd home outside your area □ Hotel or motel □ American Red Cross, church or community shelter
□ Would not evacuate □ Other _____ □ DK □ R

Q27a. Do you have any pets or large animals? □ Yes □ **No (proceed to Q28.)** □ DK □ R

Q27b. What kind? **(check all that apply)**

□ Pets such as dogs or cats □ Large animals or livestock □ Other _____ □ DK □ R

Q27c. If your household was asked to evacuate, what would you do with your pets or animals? **(check one)**

□ Take it/them with you □ Find a safe place for it/them □ Leave behind with food and water
□ Would not evacuate because of pets □ Would not evacuate because of large animals or livestock
□ Would not evacuate for reasons other than pets/livestock, specify _____ □ NA □ DK □ R

Finally, we are going to ask some questions about the drinking water in your household.

Q28. What is the main source of your home water supply? **(check only one)**

□ Town, city, or county water system □ Small water system operated by property owner or homeowner association □ Private well

□ Other _____ □ DK □ R

Q29a. What water do you drink at home? **(check all that apply)**

□ Private well **(go to next question)** □ Tap/Faucet water □ Bottled water □ Lake water you collect yourself (e.g., Clear Lake)

□ Other _____ □ DK □ R **(thank participant and end interview)**

Q29b. How old is your well? □ Less than 10 years old □ 10 to less than 20 years old □ 20 years or older □ DK □ R

Q29c. How deep is your well? □ Less than 50 feet □ 50 to less than 100 feet □ 100 feet or deeper □ DK □ R

Q29d. When did you last examine your well for possible problems? □Never □Within the last year □More than 1 year ago □DK □R

Q30. Has your well water ever been tested? □ Yes □ **No (thank participant and end interview)** □ DK □ R

Q31a. When was the last time your well water was tested? □ Within the last year □ More than 1 year ago □ DK □ R

Q31b. What was the primary reason you tested your water? **(check only one)**

□ It was required by law (e.g., new well, refinance, regulation)
□ The water tasted or smelled bad
□ You heard a news story about testing your well
□ Water was discolored or cloudy
□ Flooding near well
□ Wanted to know more about the quality of the water
□ Small child or a pregnant woman in your house
□ Someone with an illness in the household
□ Someone recommended testing
□ Other, specify _____ □ DK □ R

Q31c. Did you test your well for: **(check all that apply)**

□ Bacteria/Coliforms only □ Homeowner's package (including pH, hardness) □ Other special tests, _____ □ DK □ R

Q31d. Did you ever receive results indicating your well water was unsafe to drink? □ Yes □ **No (thank participant, end interview)** □DK □R

Q31e. (If ***YES***) What did you do about it? Specify, _____ □ DK □ R

(The interview is complete. Please thank the interviewee for their time)

To be completed by interview team AFTER the interview

Q32. Are any signs of corrosion on metal surfaces outside the home: *(Check all that apply)*

□ Water pipes □ Outdoor faucets □ Door hinges □ Metal fences □ Cars □ Street signs
□ Light fixture □ Door handle □ Stair railing □ Outdoor metal furniture □ Mail box
□ Street lamp □ Other metal surfaces, specify _____ □ No visible corrosion seen □ NA

Q33. Is there a rotten egg smell outside the home? □ Yes □ No □ DK

Q34. Do you see any bubbling in puddles outside the home? □ Yes □ No □ DK □ NA (No puddles)

Appendix II: Air sampling data collection form used in the air sampling assessment in Lake County, California.

Team initials:____________________ Cluster #: __________				Hydrogen Sulfide (ppb)			Methane (% LEL)	Observations
ID	Geocode Location	Date (MM/DD/YY)	Time (24hr)	Water Vault	6"	30"	Water Vault	
__a	Systematically sampled location: □ Yes □ No Latitude:_______________				□ Dirt/Grass □Asphalt/Concrete			□ Unusual corrosion of metal objects, specify: _______________ ____________________________ □ mild □ mod □ severe
__b	Longitude:_______________							□ Rotten egg odor □ Bubbles in puddles
__a	Systematically sampled location: □ Yes □ No Latitude:_______________				□ Dirt/Grass □Asphalt/Concrete			□ Unusual corrosion of metal objects, specify: _______________ ____________________________ □ mild □ mod □ severe
__b	Longitude:_______________							□ Rotten egg odor □ Bubbles in puddles
__a	Systematically sampled location: □ Yes □ No Latitude:_______________				□ Dirt/Grass □Asphalt/Concrete			□ Unusual corrosion of metal objects, specify: _______________ ____________________________ □ mild □ mod □ severe
__b	Longitude:_______________							□ Rotten egg odor □ Bubbles in puddles
__a	Systematically sampled location: □ Yes □ No Latitude:_______________				□ Dirt/Grass □Asphalt/Concrete			□ Unusual corrosion of metal objects, specify: _______________ ____________________________ □ mild □ mod □ severe
__b	Longitude:_______________							□ Rotten egg odor □ Bubbles in puddles

Air Sampling Data Collection Form (Back)

ID	Additional Comments

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