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Health Risk Assessment of Hydrogen Sulfide Emissions During the 2011 Startup Operations at the Updated Novato Treatment Plant

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Acronyms and Abbreviations

AAQS	Ambient Air Quality Standard
AEGL	Acute Exposure Guideline Levels
ATSDR	Agency for Toxic Substances and Disease Registry
CARB	California Air Resources Board
EPA	U.S. Environmental Protection Agency
H_2S	hydrogen sulfide
HSDB	Hazardous Substances Data Bank
MRL	Minimal Risk Levels
NRC	National Research Council
REL	Reference Exposure Level

Health Risk Assessment of Hydrogen Sulfide Emissions During the 2011 Startup Operations at the Updated Novato Treatment Plant

Exponent conducted an evaluation of potential human health and nuisance effects associated with emissions of hydrogen sulfide (H_2S) gas during startup operations at the new Novato Treatment Plant (NTP) in the summer of 2011.[1] The NTP is located in Novato, California, and is operated by the Novato Sanitary District. Concerns were expressed regarding odor and potential health effects associated with the release of H_2S from the NTP during the startup operations in the summer of 2011. An evaluation of the odor control systems at the NTP was conducted in response to the detected odors and a report was produced in October 2011 by V&A Consulting Engineers. In addition to the systems evaluation, an odor assessment was conducted and found that the malfunctioning biofilter system was releasing foul air into the atmosphere, which was then being transported into the neighboring residential development along Lea Drive to the north of the NTP.

As discussed below, our evaluation showed that H_2S concentrations in the residential neighborhood would have reached levels perceptible by residents, but both acute (1-hour) and longer-term (3-month) exposures were well below levels at which health effects would be expected. The H_2S concentrations were estimated using conservative approaches and were calculated using agency-approved models and site-specific data. The modeled air concentrations used in the evaluation of potential health effects were higher than the levels we think people near the NTP actually experienced. The conclusions reached in this evaluation are based on modeling results that were substantiated by the H_2S monitoring data collected both at the NTP and in the residential neighborhood by NSD staff and the distance at which odor complaints were received.

Health and Nuisance Effects of Inhaled Hydrogen Sulfide

H_2S is a colorless gas that commonly causes the "rotten egg" odor and can be emitted from a variety of agricultural and industrial operations. H_2S has a low odor threshold—in the microgram per cubic meter ($\mu g/m^3$) range for humans. However, classic toxicological effects (e.g., respiratory irritation, irreversible effects) occur at concentrations that are orders of magnitude higher than the level of perception by the human olfactory system. The U.S. Environmental Protection Agency (EPA), State of California, and other agencies have developed a series of exposure guidelines intended to address the toxic effects of H_2S. However, as shown in Figure 1, these levels are often well above the level of odor detection, and they account for a series of safety factors that are intended to protect sensitive individuals in a potentially exposed population.

[1] This analysis focused on the summer months, when odor complaints were being received and when exposure concentrations were likely the highest.

Odor Detection

The range of odor detection for H_2S is highly variable between individuals. The average odor threshold, which is defined as detection by 50% of the population, is reported to be 11 to 14 $\mu g/m^3$ (Amoore and Hautala 1983; Amoore 1985; Ruth 1986). Amoore (1985) also estimated that 96% of individuals would detect H_2S at concentrations below 140 $\mu g/m^3$.

Toxicity and Exposure-Response Thresholds for Hydrogen Sulfide

Classic acute toxicological effects of H_2S, including respiratory irritation and less severe neurological effects, severe pulmonary and respiratory irritation, and death, occur at concentrations thousands of times higher than odor detection levels. Eye irritation (including conjunctivitis), cough, sore throat, hoarseness, runny nose, and chest tightness occur at levels between 7,000 to 350,000 $\mu g/m^3$; Hazardous Substances Data Bank [HSDB] 2011. Fatalities have been reported from exposures in excess of 700,000 $\mu g/m^3$ (ATSDR, 2006).

This summary focuses on the acute (e.g., 1 hour) and short-term (3 months) effects of H_2S, the applicable published thresholds from regulatory agencies and authorities (and their bases), and corresponding regulatory levels discussed below. The thresholds discussed below are federal and state recommendations and guidelines based on peer-reviewed literature and processes. These values are intended to provide context for the concentrations that were modeled in the vicinity of the NTP and potential human health effects.

EPA and the National Research Council (NRC) of the National Academy of Sciences have developed a series of exposure levels, denoted acute exposure guideline levels (AEGLs), that are intended to be protective of the "general public, including susceptible subpopulations, such as infants, children, the elderly, persons with asthma, and those with other illnesses" (NRC 2010). AEGLs are delineated in three tiers related to increasing severity of effect, as follows:

> **AEGL-1**. Airborne concentration above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. Effects are not disabling and are transient and reversible on cessation of exposure.
>
> **AEGL-2**. Airborne concentration above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
>
> **AEGL-3**. Airborne concentration above which it is predicted that the general population, including susceptible individuals, could experience life-threatening adverse health effects or death.

The State of California has also developed acute, 1-hour thresholds intended to be protective of the general public. The 1-hour reference exposure level (REL) and ambient air quality standard (AAQS) for California are set at a concentration of 42 $\mu g/m^3$. This REL is based on nausea, headache, and physical responses to odor in humans (Amoore 1985; Cal/EPA 2008). These effects are considered transient and reversible. The AAQS is reported to be based on consideration of odor effects (Amoore 1985; Collins and Lewis 2000).

The ATSDR has developed sub-chronic minimal risk levels (MRLs) for the evaluation of short-term exposures. MRLs represent an estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are intended to serve as a screening tool to help public health professionals decide where to look more closely. The sub-chronic MRL for H_2S is 28 $\mu g/m^3$ and is based on respiratory effects derived using animal data.

H_2S is not listed as a cancer causing chemical by EPA or Cal/EPA (EPA 2012, Cal/EPA 2012).

Modeling Approach

The CALPUFF air dispersion model was used to estimate offsite concentrations of H_2S. CALPUFF is an EPA guideline model for both far-field and complex meteorological conditions. It was developed under the sponsorship of the California Air Resources Board (CARB) and was selected for this modeling study due to its ability to model low wind-speed conditions, which are common at the site.

Meteorological data, including wind speeds and direction, temperature, pressure, humidity, and cloud cover were used to drive the dispersion model. Both wind speed and direction were recorded on site, while other parameters were measured at the nearby Gnoss Field. Meteorological data from the onsite station and Gnoss Field were merged and processed using the EPA-approved AERMET code.

The maximum possible source emission rate was estimated based on H_2S concentration measurements in the headworks and at primary clarifier 1. These measured values were summarized in a report produced by V&A Consulting Engineers in October 2011. In this assessment, we assumed that 3% of the measured H_2S backed up and was released from two storm drains located on the facility property. The initial dilution of this release was calculated taking into account the locational dimensions of nearby NTP buildings. This release rate represents a conservative assumption, because modeled levels are higher than the measured levels discussed below.

Hydrogen Sulfide Monitoring Data

Concentrations of H_2S were monitored by the NSD staff during normal operating conditions and during some odor complaint events. Concentrations of H_2S were monitored using a hand-held, direct-reading meter, and were recorded. Monitoring occurred both on the NTP site and in the residential neighborhood. The monitoring data were used to calibrate the air dispersion model assumptions. The monitoring data was summarized and provided to Exponent by the NSD for use in this analysis.

Results and Conclusions

The modeled H_2S concentrations in the residential neighborhood reached levels perceptible by residents, but both acute (1-hour) and longer-term (3-month) exposures were well below levels at which health effects would be expected. Further, we believe the modeled H_2S concentrations are higher than the levels actually experienced in the neighborhood during the NTP startup period. This conclusion was reached using conservative, agency-approved modeling approaches, site-specific data, and model calibration using monitoring data collected during the H_2S release period and associated odor complaints.

As shown in Figure 2, the maximum 1-hour H_2S concentration is above levels at which people would perceive the odor in the residential neighborhood. The area of odor perception by one-half the local population would have extended well into and beyond the extent shown in Figure 3. This figure supports the assertion that the air dispersion modeling approach that was used was conservative, because one-half the population would have perceived odors out to 700 m from the NTP boundary. Based on NTP records, odor complaints were isolated to the residential neighborhood along Lea Drive to the north of the plant and were well within the extent shown in Figure 3. There would likely have been more odor complaints had the offsite concentrations actually reached the levels estimated by the modeling.

As shown in Figures 4 through 7, both acute (1-hour) and sub-chronic (3-month) exposures were well below concentrations at which residents could have incurred medical harm or respiratory effects associated with acute or sub-chronic exposures, respectively.

The modeling approach used in this assessment was calibrated using available monitoring data by comparing the modeled 1-hour concentrations to the monitored concentrations provided by the NSD. The maximum offsite modeled concentration (340 $\mu g/m^3$) was over 4-fold higher than the maximum monitored concentration (82.6 $\mu g/m^3$) recorded in the residential neighborhood. Further, the maximum onsite 1-hour concentration modeled at the site (1,438 $\mu g/m^3$) was over 2-fold higher than the maximum monitored concentration (588 $\mu g/m^3$) recorded at the site. While it is possible that the peak H_2S concentrations were not captured by the monitoring program, either on the NTP site or in the residential neighborhood, this comparison between modeled and monitored concentrations, in concert with the distribution and density of odor complaints received from residents, supports the conservativeness of this analysis.

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Figures

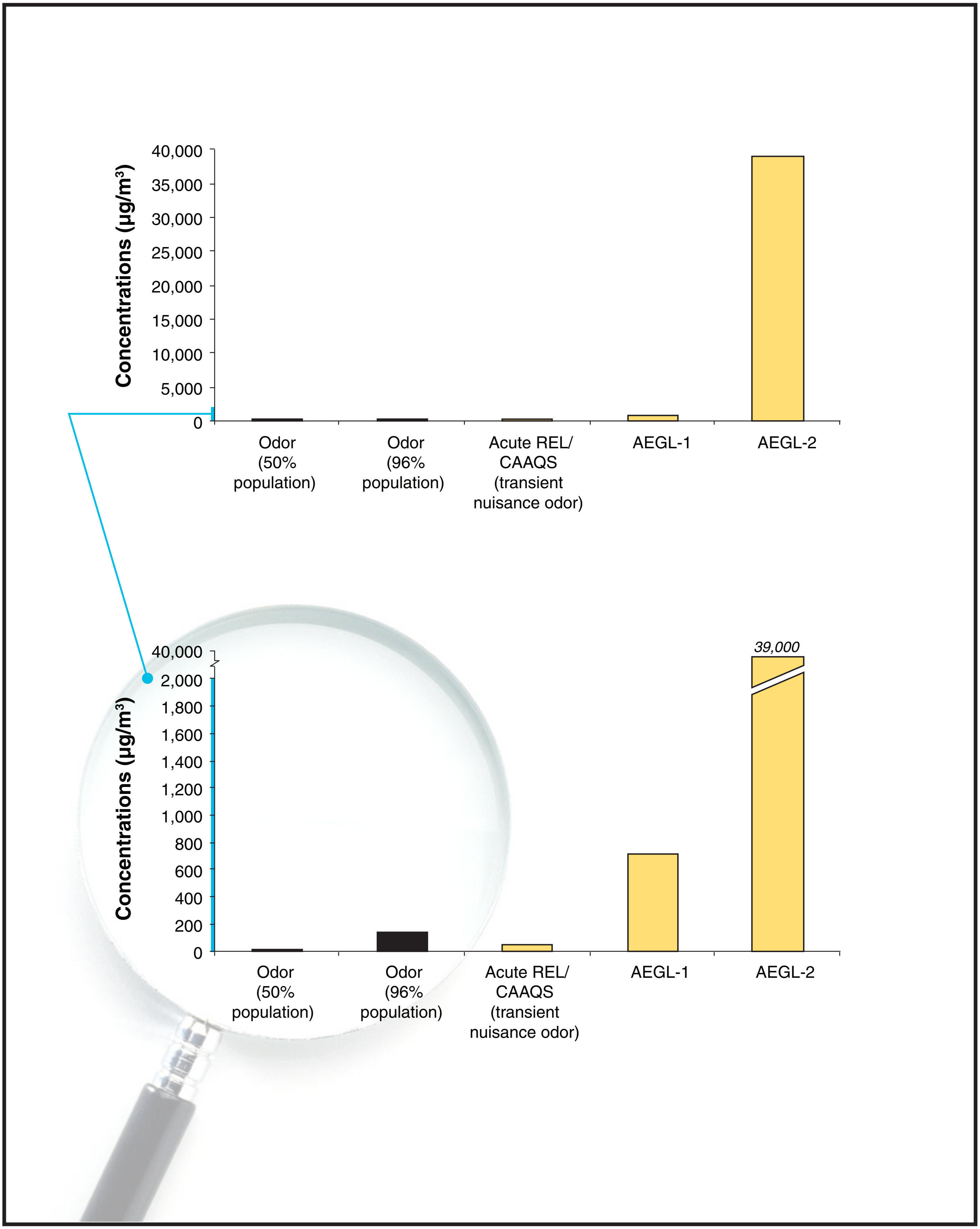

Figure 1. Comparison of odor concentrations and exposure levels for H_2S

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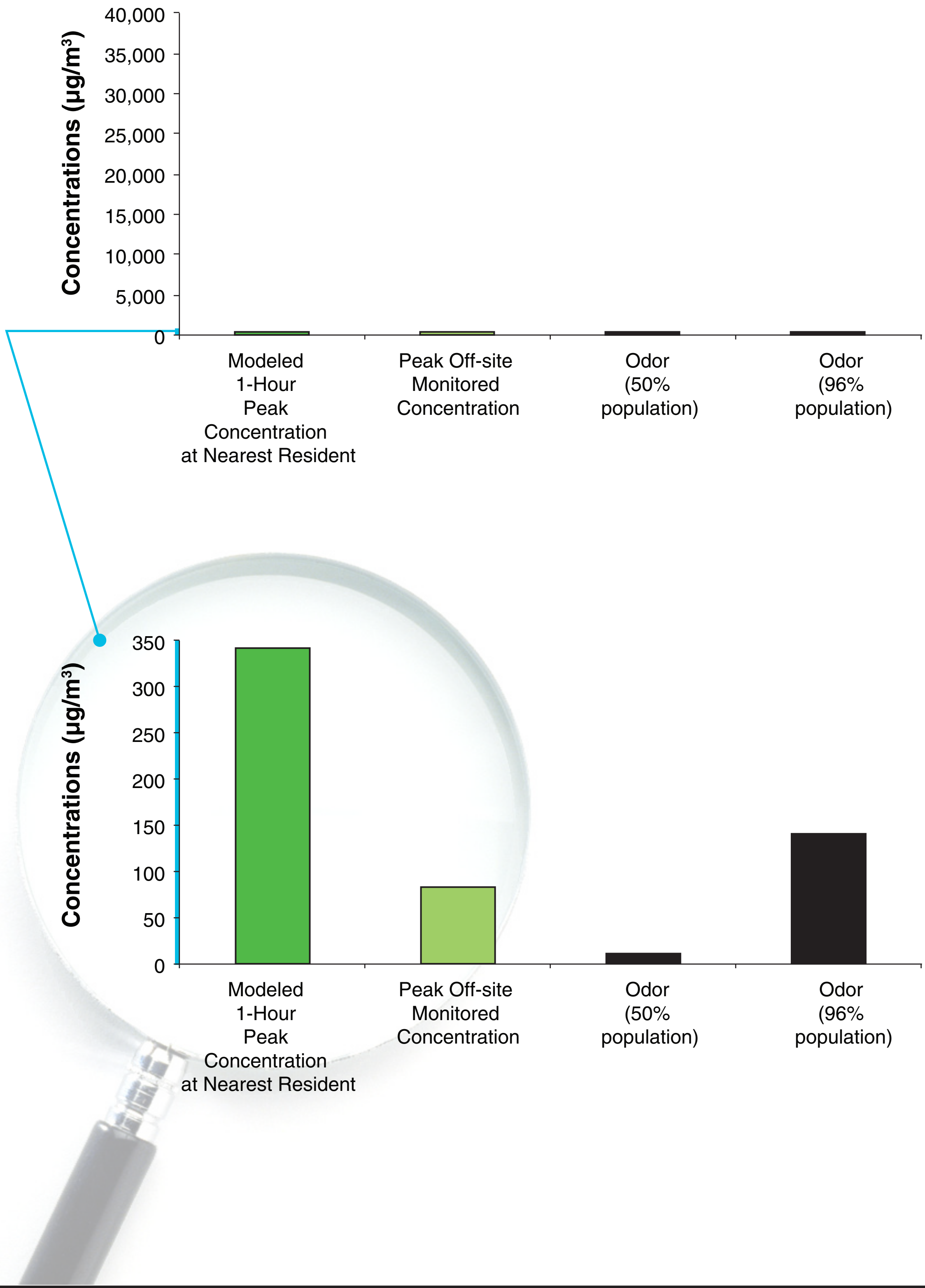

Figure 2. Comparison of maximum modeled (1-hour), monitored, and odor H_2S concentrations

Figure 3. Isopleth for 1-hour H_2S concentrations of ≥140 μg/m^3 and ≥11 μg/m^3

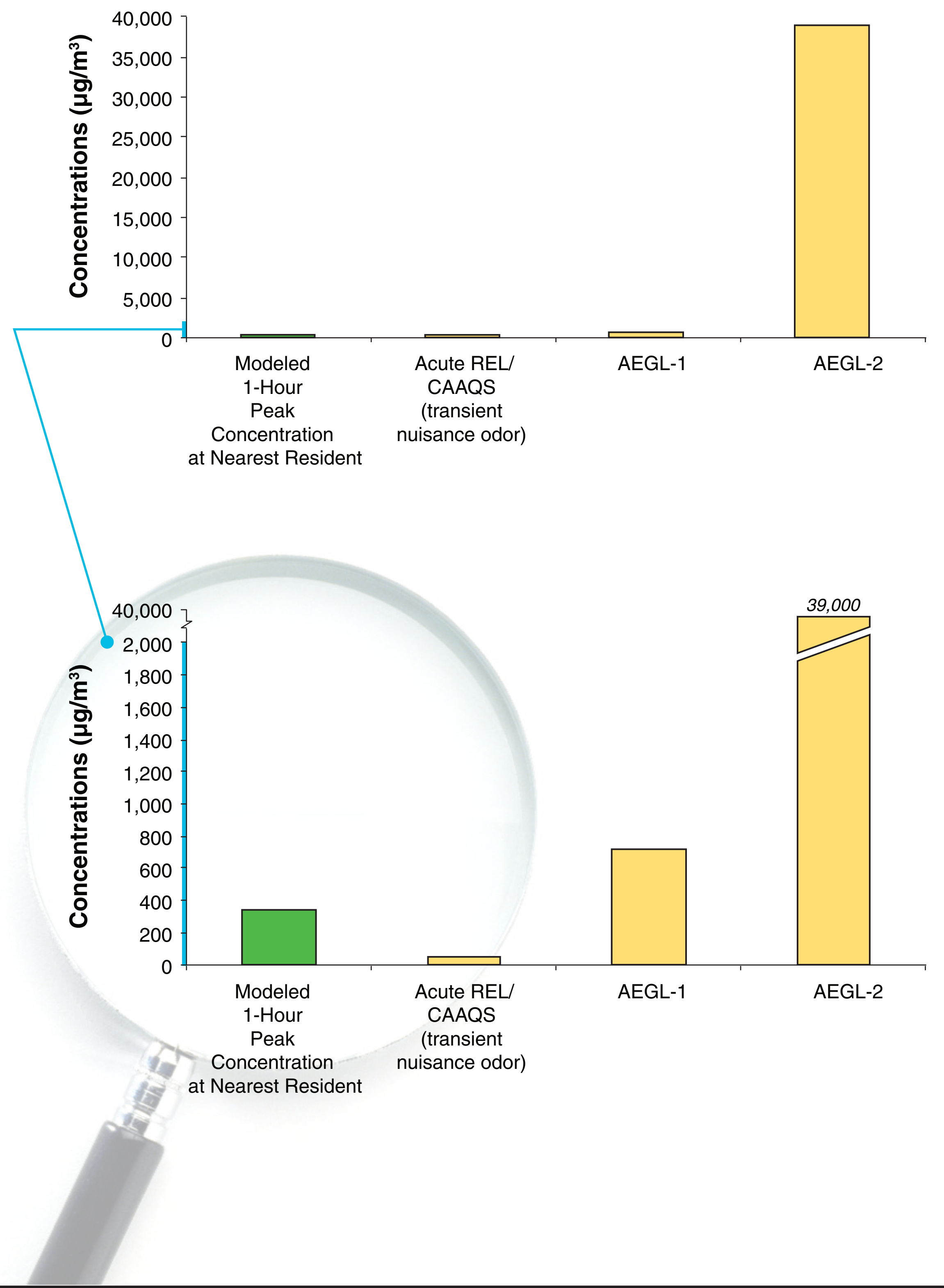

Figure 4. Comparison of maximum modeled (1-hour) H_2S concentrations and exposure levels

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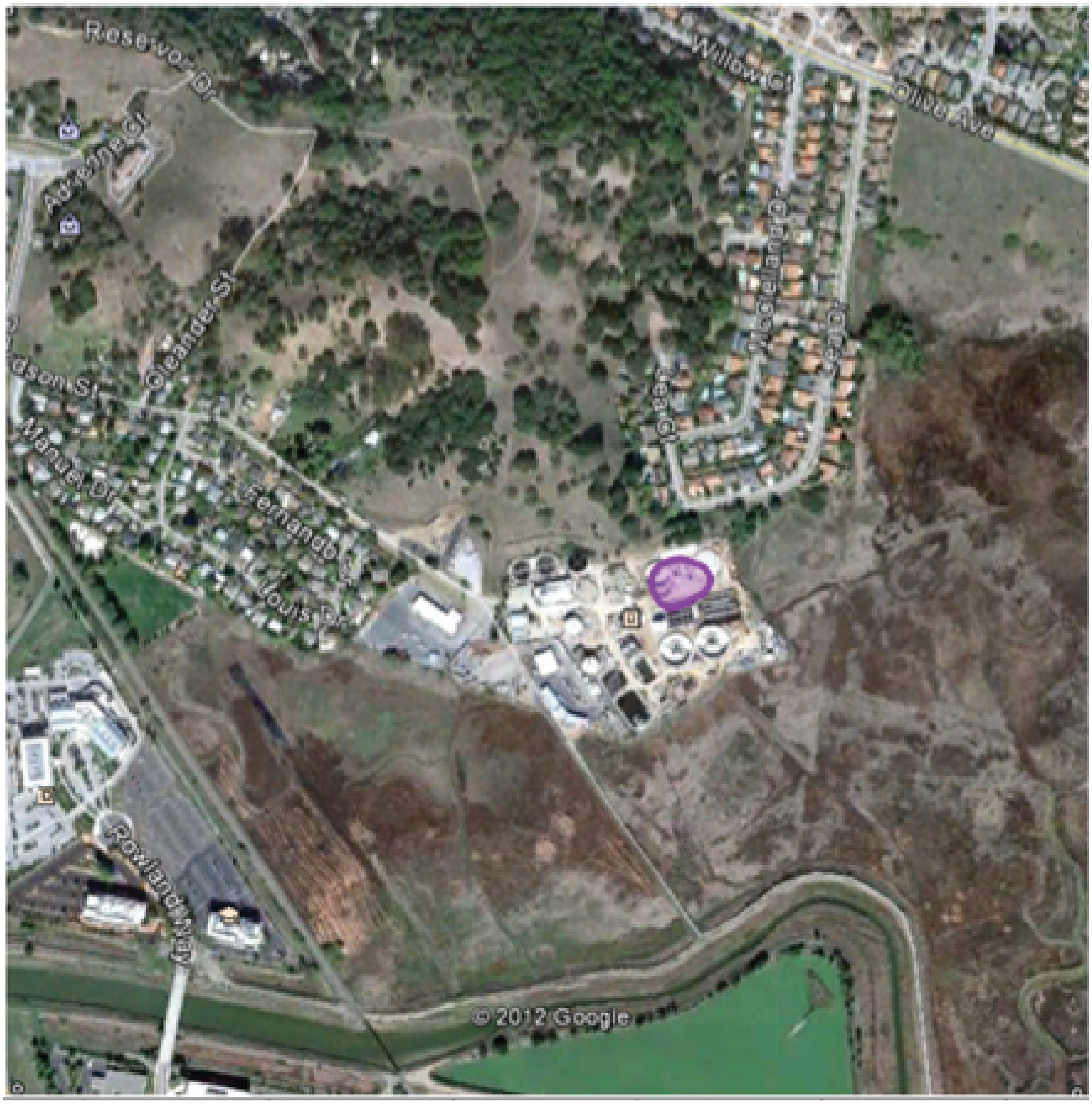

Figure 5. Isopleth for 1-hour H_2S concentrations of ≥710 µg/m^3

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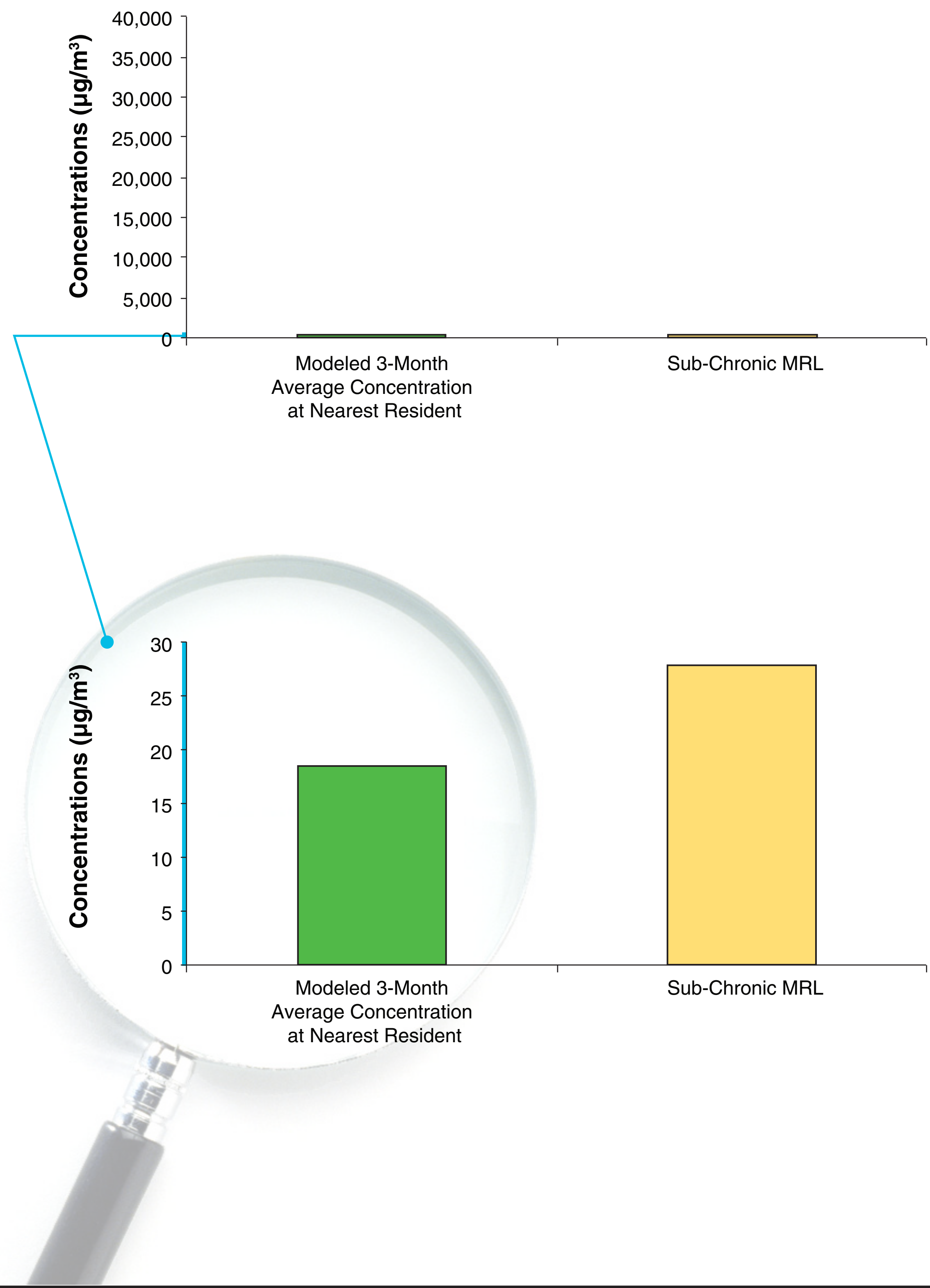

Figure 6. Comparison of maximum modeled (3-month) H_2S concentrations to exposure levels

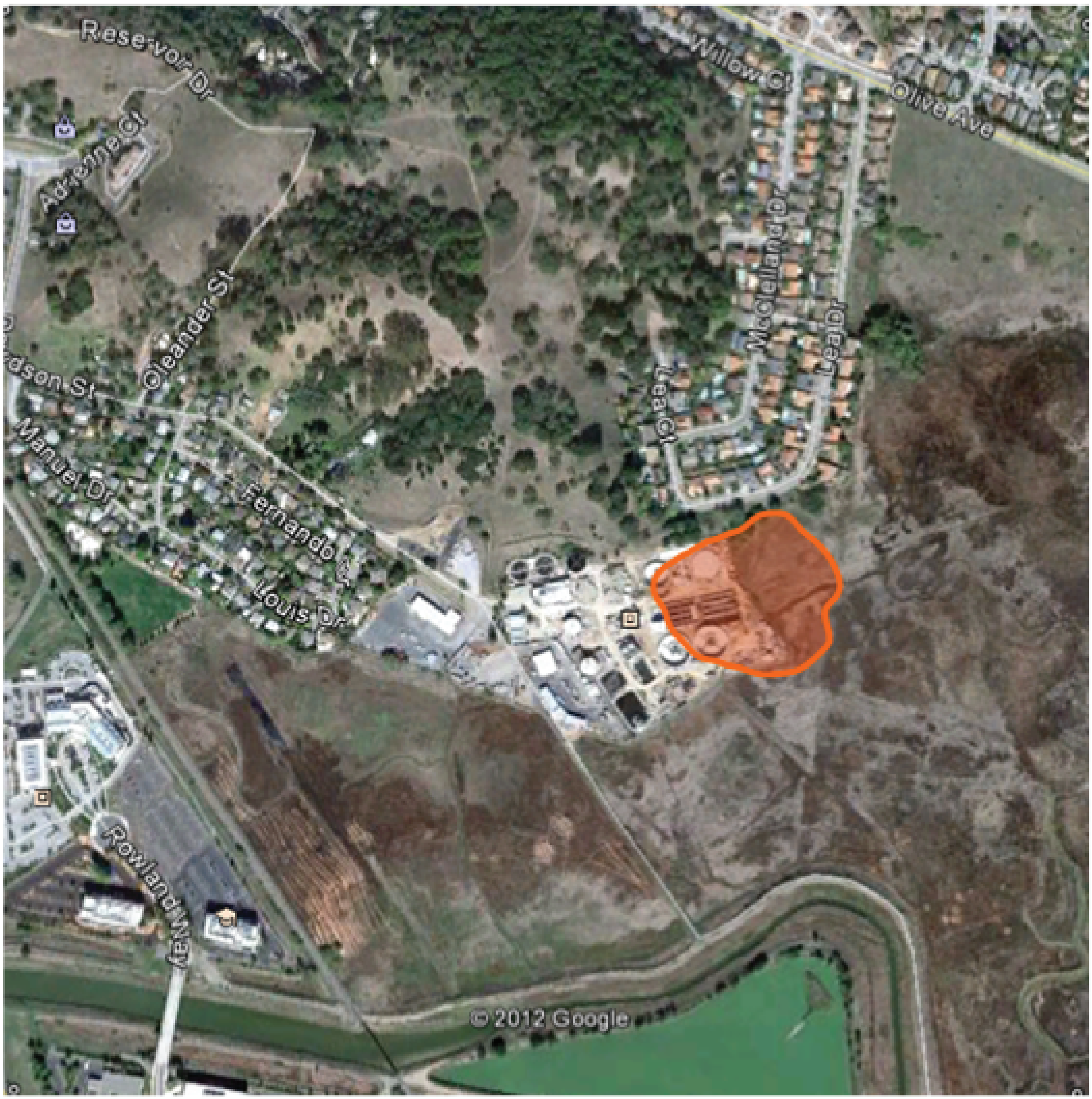

Figure 7. Isopleth for 3-month (sub-chronic) H_2S concentrations of ≥28 μg/m³