

Appendix E

**Estimation of Contributions to
Deposition of Nitrogen in
Santa Clara County for the
Santa Clara Valley Habitat Plan**

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Prepared for:

County of Santa Clara
County Government Center
70 W. Hedding Street, 7th Floor, East Wing
San José, CA 95110
Contact: Ken Schreiber

Prepared by:

ICF International
630 K Street Suite 400
Sacramento, CA 95814
Contact: Tony Held, Ph.D.
916-737-3000

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Acronyms and Abbreviations

BAAQMD	Bay Area Air Quality Management District
Bay Area	San Francisco Bay Area
BCB	Bay checkerspot butterfly
CARB	California Air Resources Board
CMAQ	Community Multiscale Air Quality modeling system
CMB	chemical mass balance
CRPAQS	California Regional PM10/PM2.5 Air Quality Study
CVRP	Coyote Valley Research Park
EIR	environmental impact report
EPA	U.S. Environmental Protection Agency
Habitat Plan	Santa Clara Valley Habitat Plan
HNO ₃	nitric acid
HONO	nitrous acid
ISCST3	Industrial Source Complex—Short Term
kg-N/ha/y	kilograms of nitrogen per hectare per year
km	kilometer
km ²	square kilometers
N	nitrogen
NH ₄ -NO ₃	ammonium nitrate
NCDC	National Climatic Data Center
NH ₃	ammonia
NO	nitrogen oxide
NO ₂	nitrogen dioxide
NO _x	oxides of nitrogen
OPTM	Oxidant and Precursor Tagging Methodology
PAN	peroxyacetyl nitrate
PM10	particulate matter 10 microns in diameter or less
PM2.5	particulate matter 2.5 microns in diameter or less

ppb	parts per billion
PPTM	Particle and Precursor Tagging Methodology
SMOKE	Sparse Matrix Operator Kernel Emissions
SO ₂	sulphur dioxide
SR	State Route
TMDL	total maximum daily load
US 101	U.S. Highway 101
USFWS	U.S. Fish and Wildlife Service

Appendix E

Nitrogen Deposition Contribution Estimates in Santa Clara County for the Santa Clara Valley Habitat Plan

Executive Summary

Atmospheric nitrogen deposition is a complex process by which reactive chemical species of nitrogen (N)—nitrogen oxides (NO_x), ammonia (NH₃), and their reaction products—are deposited onto surfaces and enter ecosystems as N-fertilizer. N-deposition estimates (from varied studies) for the Santa Clara Valley range from 8–20 kilograms of nitrogen per hectare per year (kg-N/ha/y).¹ In Santa Clara County, N-deposition threatens serpentine grasslands that support numerous covered species, including the threatened Bay checkerspot butterfly (*Euphydryas editha bayensis*). The added N allows nutrient-poor serpentine soils to be invaded by non-native annual grasses that displace the native forbs that provide caterpillar food and adult nectar for the butterfly. N-deposition is the largest indirect impact of urban development on the serpentine grassland ecosystem.

The effects of N-deposition on non-serpentine annual grasslands and the grassland understory of oak woodlands are similar to those on serpentine grassland—increased annual grass growth displaces native forbs. Non-serpentine annual grasslands and oak woodlands in the study are extensive (310,875 acres, or 60% of the study area²), so these adverse effects could be widespread.

For this study, ICF International (ICF) analyzed nitrogen deposition using several modeling approaches in order to estimate the sources that contribute to deposition in the study area for the Santa Clara Valley Habitat Plan (Habitat Plan). In order to estimate contributions from individual roadways and to assess the increase in deposition due to increases in traffic, Gaussian models for a limited domain were applied to receptors centered on serpentine habitat that supports populations of the threatened Bay checkerspot butterfly (called *habitat areas* in this report). Serpentine habitat receptors were selected because of the sensitivity of these areas to N-deposition. The much more complex Community Multiscale Air Quality modeling system (CMAQ) was also used to simulate the area's more complex nitrogen transport processes, and, using the Particle and

¹ One hectare = 2.47 acres. 1 kg-N/ha/y = 0.93 lb-N/acre/y.

² The “study area” as referenced in this report includes State Parks lands.

Precursor Tagging Methodology (PPTM) source apportionment technique, to estimate contributors to deposition on a broader scale. The Gaussian models are relatively simple to apply but give results only within a few kilometers of the sources being modeled. The Gaussian models simulate the complex atmospheric chemistry that affects the deposition of nitrogen. The CMAQ model treats the complex transport, chemistry, and deposition processes required to simulate nitrogen deposition in detail. Because development of databases for CMAQ is a large undertaking, existing databases were acquired from the California Air Resources Board (CARB) and from the Bay Area Air Quality Management District (BAAQMD).

Estimates of overall deposition based on observations of nitrogen dioxide (NO₂) concentration and modeling using CMAQ both give estimates of total nitrogen deposition of about 6 kg-N/ha/y, which is consistent with other studies such as Weiss (2006). In general, modeling estimates may be biased high or low relative to estimates made on other bases. Given modeling estimates in reasonable agreement with other methods, however, modeling methods can be used in order to compare effects of different sources in a relative sense. Modeling with CMAQ also provides estimates of increases in deposition using emissions extrapolated to future years. Modeling with Gaussian models, while not providing an estimate of overall deposition, provides an estimate of deposition from individual roadways and the increases in deposition from those roadways with emissions extrapolated to the future.

Reliable future year emissions were not available when the CMAQ modeling was conducted. Future year emissions were extrapolated from the base year based on population growth which may overestimate emissions. Based on the CMAQ modeling, total nitrogen deposition in the Bay checkerspot butterfly habitat areas could increase to 8 kg-N/ha/y in 2035 and almost 10 kg-N/ha/y in 2060 using the extrapolated emissions. Using extrapolated emissions, Gaussian modeling indicates that contributions to nitrogen deposition from major roadways could increase by almost a factor of two by 2030 and by more than a factor of 4 by 2060.

The amount that various sources contribute to deposition was assessed with different modeling approaches. The most complete of these methods was the use of the PPTM tagging approach in CMAQ. In addition, however, Gaussian modeling provided estimates of the relative contributions of several major roadways to nitrogen deposition.

In the base year, the CMAQ PPTM simulation attributes 30% of the total nitrogen deposition to mobile sources within the study area. Another 16% of the nitrogen deposition comes from stationary sources in the study area. Therefore, 46% of nitrogen deposition on the habitat areas comes from existing development and vehicle traffic generated locally within the study area. The remainder of Santa Clara County contributes 17% of the nitrogen deposition while the remaining Bay Area counties account for about 11% of the deposition. The CMAQ simulation indicates that the remaining 26% of the N-deposition comes from anthropogenic emissions in the remainder of the modeling domain

(i.e., most of the remainder of California other than Bay Area counties and a portion of Nevada), initial and boundary concentrations (i.e., effects from outside of the modeling domain), and biogenic emissions within the Bay Area counties. Impacts of nitrogen deposition from Morgan Hill and Gilroy were not explicitly identified in our modeling, but are part of the contribution referred to as the remainder of Santa Clara County. In the emissions inventory used to prepare emissions for CMAQ, municipalities are not identified separately from the county in which they are located. Estimates of emissions for Morgan Hill and Gilroy were made based on the overlap of boundaries of these cities with grid cells in the modeling domain (see Table E-15). Because grid cells resolve emissions only to areas measuring 16 square kilometers (km²), this is necessarily an approximation. However, based on these estimates, Gilroy emissions make up 2% of the Santa Clara County NO_x emissions, Morgan Hill emissions make up 3% of the Santa Clara County NO_x emissions, San José emissions make up 79% of the Santa Clara County NO_x emissions, and the remainder of Santa Clara County emissions make up (16%) of the county NO_x emissions. (Note that these relative amounts of emissions in Santa Clara County should not be confused with the estimates of contributions to deposition that are derived from the CMAQ model results.) It is reasonable to assume that the contribution to nitrogen deposition from Gilroy and Morgan Hill would be roughly in proportion to their emissions. Of the 17% contribution to nitrogen deposition noted for the remainder of Santa Clara County, therefore, we could expect Gilroy to make up about 1.5% (9% of 17%) and Morgan Hill to make up about 2.7% (16% of 17%).

Increases in nitrogen deposition in future years were simulated for Bay Area counties. The emissions data files used in this study were available with only grid cell-by-grid cell emissions in the part of the domain outside of the Bay Area. Because county-by-county emissions projections are not readily made for files in this format, future-year emissions extrapolations were not made for the remainder of the domain. Within the Bay Area, future emissions were extrapolated from the base year based on population growth which does not taken into account expected improvements in emission control technology for motor vehicles. The extrapolations could therefore overestimate the emissions in the future years. Contribution of mobile source emissions in the habitat area are estimated to increase by about 0.6 kg-N/ha/y in 2035 over the base year and by another 0.5 kg-N/ha/y in 2060. The San José contribution to nitrogen deposition in the habitat areas is estimated to be 38% in 2035. Gaussian modeling of major roadways near the habitats indicates an increase in nitrogen deposition of about 0.25 kg-N/ha/y in 2030 over the base year (a 4% increase in total deposition). The increase in 2060 relative to 2030 could be from 0.4 kg-N/ha/y to more than 1 kg-N/ha/y (at the Hale Avenue site) depending on location (a 7% to 17% increase in total deposition).

Only growth in emissions in Bay Area counties was considered in the CMAQ PPTM simulations because future-year emissions were not available for the remainder of the modeling domain. Estimates of future-year nitrogen deposition could be even higher if growth in the rest of the state were included. Gaussian modeling was limited to an area in the immediate vicinity of the habitats due to the limitations in scale of this type of model.

The contribution of emissions outside of the study area but within Santa Clara County are estimated to grow from 1.1 kg-N/ha/y in the base year to 1.5 kg-N/ha/y using emissions extrapolated to 2035 and 1.7 kg-N/ha/y using emissions extrapolated to 2060. The contribution of emissions from all other Bay Area counties are estimated to grow from 0.7 kg-N/ha/y in the base year to 0.9 kg-N/ha/y using emissions extrapolated to 2035 and 1.0 kg-N/ha/y extrapolated to 2060.

Background

Urban development and rural development covered under the Habitat Plan are expected to increase air pollutant emissions due to an increase in passenger and commercial vehicle trips and other new industrial and nonindustrial sources. Emissions from these sources are known to increase airborne reactive nitrogen, of which a certain amount is converted into forms that can fall to the ground as depositional nitrogen.

It has been shown that increased nitrogen in serpentine soils can favor the growth of nonnative annual grasses over native serpentine species (Weiss 1999, 2006). These nonnative species, if left unmanaged, can overtake the native serpentine species, including dwarf plantain (*Plantago erecta*), the primary host plant for Bay checkerspot butterfly, a threatened species and a key covered species in the Habitat Plan. Nonnative plants may also compete with native plants for water, nutrients, light, and sites for germination, crowding out plants covered by the Habitat Plan (e.g., Metcalf Canyon jewelflower [*Streptanthus albidus* ssp. *albidus*], most beautiful jewelflower [*Streptanthus albidus* subsp. *peramoenus*], and fragrant fritillary [*Fritillaria liliacea*]).

The amount of available nitrogen in Santa Clara County serpentine grasslands is a function of biological uptake and generation, abiotic chemical transformation mechanisms, and transport of chemical nitrogen compounds (known as chemical “species”) into and out of the region. Nitrogen transport within the region is likely to be a function of farming and agricultural processes and atmospheric deposition from point and mobile sources. This report documents how nitrogen is transported into and within the region by atmospheric processes. A special emphasis is placed on characterizing the upwind sources of nitrogen that ultimately deposit on the serpentine grasslands in the Habitat Plan study area. Progressively more complex modeling techniques are used to estimate the amount of nitrogen deposition likely to affect serpentine grasslands in the study area.

Purpose

The primary purpose of this report is to quantify the expected increases in nitrogen deposition in Santa Clara County as a result of the urban and rural growth covered by the Habitat Plan to:

- 1) extrapolate changes in deposition rates over time; and
- 2) estimate the percentage of nitrogen deposition in the study area that results from air pollution emissions within the Habitat Plan study area, as opposed to air pollution that is transported from other regions to the study area.

The Habitat Plan addresses growth over a 50-year period in the cities of San José, Morgan Hill, Gilroy, and unincorporated Santa Clara County within the Habitat Plan study area (519,506 acres, approximately 62% of the county; see Figure 1-2 in the Habitat Plan).

A large fraction of the vehicle trips within the study area originate outside the study area. This report also quantifies expected increases in nitrogen deposition within the study area from projected growth outside the study area. Although this outside growth is not addressed by the Habitat Plan, it contributes to the cumulative impact of nitrogen deposition on habitats and covered species within the Habitat Plan study area. Knowing the expected increases in nitrogen deposition outside the study allows us to put the impacts of the Habitat Plan covered activities into the proper context of growth in the entire region.

Another purpose of this report is to link the deposition of nitrogen from mobile and point sources to impacts on natural communities and the covered species addressed by the Habitat Plan. This report therefore provides technical background for the impact analysis in Chapter 4 of the Habitat Plan. The report also provides technical justification for the approval of new local fees on public and private development to help fund the Habitat Plan.

Summary of Past Analyses

Three recent quantitative assessments of anticipated nitrogen deposition on serpentine grassland in Santa Clara County have been conducted for local projects (CH2M Hill 2000; U.S. Fish and Wildlife Service 2001; City of San José 2007). These assessments used relatively rudimentary techniques for estimating nitrogen deposition that were appropriate for each project. These methods could not be used in our study because of the complexity (e.g., many mobile sources) and large area over which the covered activities in the Habitat Plan occur. Because of the time scale involved (50 years), the Habitat Plan also needs to put the nitrogen deposition impacts of its covered activities into the context of impacts that will occur outside the study area, something these projects did not assess. These past analyses are briefly described below for context.

Metcalfe Energy Center

The Metcalfe Energy Center is a 600 MW natural gas-fired power plant built by the Calpine Corporation at the north end of Coyote Valley, adjacent to Tulare Hill, in the City of San José. The site is located on approximately 20 acres.

Construction of the plant and its associated transmission line, gas line, and water and wastewater lines began in 2002. The plant began operating in 2005.

Modeling of nitrogen deposition from the Metcalf Energy Center used the U.S. Environmental Protection Agency's (EPA) Industrial Source Complex—Short Term (ISCST3) model. The ISCST3 model was widely used at the time of the analysis. ISCST3 model does not account for the partitioning of nitrogen into gas phase versus aerosol species (Davis et al. 2003) which limits the applicability of the modeling results to determine relationships between nitrogen emissions and nitrogen deposition in Santa Clara County. Consequently, the Metcalf Energy Center model arrived at theoretically maximum nitrogen deposition levels by assuming complete and immediate conversion of nitrogen emissions to depositional nitrogen, overestimating the deposition of nitrogen from Metcalf Energy Center on adjacent serpentine grasslands, and underestimating the fraction of NO_x emissions that would be deposited in other locations, including nonserpentine areas in the Central Valley (CH2MHill 2000; Don Ballanti pers. comm.; Edith Allen pers. comm.). Because this facility was a stationary source of emissions, its model was not appropriate for the analysis used in this report.

Coyote Valley Research Park

The Coyote Valley Research Park is approximately 385 acres and is located in the North Coyote Valley, in the southern end of San José. The Coyote Valley Research Park is located immediately southwest of the Metcalf Energy Center. Development permits are currently in place to build out over six million square feet of office space.

The U.S. Fish and Wildlife Service (USFWS) quantitatively analyzed impacts of nitrogen deposition associated with the Coyote Valley Research Park (U.S. Fish and Wildlife Service 2001) based on the nitrogen deposition analysis conducted for the Metcalf Energy Center analysis described above. Based on this extrapolation, USFWS outlined a proposed quantitative regional impact analysis methodology (Nagano pers. comm.). As part of the analysis, USFWS made the following assumptions.

- **Extrapolation from power plant (Metcalf Energy Center) emissions to emissions from development is appropriate.** The USFWS method entails comparing NO_x emissions from the CVRP with NO_x emissions from the Metcalf Energy Center, and quantifying acreage affected on the basis of the comparison. Accordingly, if the CVRP were expected to emit twice as much NO_x as the Metcalf Energy Center, twice the area of serpentine grassland affected by Metcalf Energy Center would be affected by the CVRP.
- **The modeling approach used for Metcalf Energy Center emissions is appropriate for current analyses.** The USFWS model assumes that all of the assumptions applied for the Metcalf Energy Center are also appropriate for application to the Coyote Valley Research Park, except as noted below.

- **Ammonia emissions from the Metcalf Energy Center can be excluded from the calculation of overall Metcalf Energy Center emissions in considering the relative contribution of development to nitrogen deposition.** In comparing expected emissions from the CVRP and the Metcalf Energy Center, USFWS did not include expected NH_3 emissions.
- **A multiplier of two (2) applied to the expected CVRP emissions (as described in the first bullet above) can be used to account for local and regional contributions to nitrogen deposition.** Emissions from CVRP are expected to be relatively greater than emissions from the Metcalf Energy Center project due to contributions to nitrogen deposition from local development projects and regional use of U.S. Highway 101 (US 101). In making this comparison, the nitrogen emissions expected from the CVRP development were multiplied by 2 to account for regional use of US 101 and additional projects occurring in the region.
- **The same impact level should be applied to all critical habitat units in the county, regardless of location and habitat quality.** The USFWS analysis method assumed an equal distribution of impacts on some of the critical habitat in the county and did not account for likely differences in impacts based on location of critical habitat. For example, the Santa Teresa Hills are located west of US 101, and would therefore be expected to receive lower levels of nitrogen from increased traffic than Coyote Ridge (Kirby/Andersen critical habitat unit), as noted in the USFWS 2001 BCB critical habitat designation (66 FR 83, 21450).

In summary, the USFWS biological opinion quantifies the acreage of serpentine grassland expected to be affected by nitrogen deposition due to development of the CVRP by extrapolating from estimated impacts of the Metcalf Energy Center. The USFWS method compares extrapolated NO_x emissions from the CVRP (based on extrapolation of Metcalf Energy Center emissions) with NO_x emissions from the Metcalf Energy Center, and quantifying acreage affected on the basis of the comparison. In making this comparison, the nitrogen emissions expected from the CVRP development were multiplied by 2 to account for regional use of US 101 and additional projects occurring in the region.

USFWS quantified impacts from the CVRP on nearby Bay checkerspot butterfly (BCB) critical habitat units³ (Kirby/Anderson, Santa Teresa, Morgan Hill, Kalana, and Tulare) but did not discuss impacts on other Bay checkerspot butterfly critical habitat in Santa Clara County.

Coyote Valley Specific Plan

During development of the *Coyote Valley Specific Plan Draft Environmental Impact Report*, the City of San José was required to develop a quantitative assessment of nitrogen deposition impacts related to development of Coyote Valley. The methods and assumptions used in this analysis were based on the

³ Bay checkerspot butterfly critical habitat units are serpentine grassland areas.

Metcalf Energy Center and Coyote Valley Research Park analyses described above. In this analysis, the impacts of nitrogen emissions associated with the Coyote Valley Specific Plan were estimated by comparing extrapolated nitrogen emissions from the Coyote Valley Specific Plan Area with the nitrogen emissions from Coyote Valley Research Park and then scaling the Coyote Valley Specific Plan emissions accordingly. A similar analysis was prepared to analyze potential impacts to serpentine grasslands due to increased nitrogen emissions from the Coyote Valley Specific Plan Area (City of San José 2007).

Only the three analyses described above have attempted to quantify impacts of nitrogen deposition on serpentine land covers in Santa Clara County. Of these three, only the Metcalf Energy Center analysis was an original analysis (i.e., was not extrapolated from pre-existing analyses). As described above, the Metcalf Energy Center analysis likely overestimated impacts from that project. Furthermore, newer models have since been developed and are replacing the ISCST3 model used in the Metcalf Energy Center analysis. Finally, the type and extent of impacts associated with the covered activities proposed in the Santa Clara Valley Habitat Plan are very different than those activities for which the Metcalf Energy Center Analysis was conducted. Therefore, an entirely new approach and analysis is needed to assess the nitrogen deposition impacts associated with implementing the covered activities of the Santa Clara Valley Habitat Plan.

Background on Modeling Methods Considered for this Study

The goal of this study is to make quantitative estimates of nitrogen deposition to the Bay checkerspot butterfly habitat using established modeling techniques. There are several different techniques available to make such estimates. In the sections below we first give general descriptions of available techniques and then give a description of the techniques chosen for this study.

Review of Common Air Quality Modeling Techniques and Nomenclature

In air quality literature, *source apportionment* refers to the process of determining the upwind source of pollutants in an air sample. Typically, one categorizes the methodology of source apportionment as either “receptor based” or “source based.”

In a receptor-based analysis, one uses an air quality sample obtained at the location of interest and back-calculates the upwind source using a statistical model such as a chemical mass balance (CMB) model. The CMB model is relatively easy to apply because it has a low computation burden and does not require information about meteorological conditions or emissions inventories.

CMB calculations have been carried out in numerous studies around the world. Limitations of CMB include the need for a relatively high amount of detail in data used in the analysis (including, for instance, measurements of a broad spectrum of hydrocarbon species). In order to differentiate sources, CMB modeling also requires that the sources have identifiable differences in speciation profiles. It is difficult, for instance, to ascertain through CMB modeling if impacts come from a particular region.

Source-based models use spatially and temporally variable emission rate information—combined with modeling of atmospheric transport, chemical transformations, and deposition processes—to determine the concentration and deposition of pollutant in a study domain. Source-based approaches require significantly more input data and modeling resources in comparison to receptor-based models. Examples of source-based models are Gaussian models, such as the CALINE series of roadway transport models and the EPA’s ISCST3 and AERMOD models (AERMOD is being phased in to replace the ISCST3 model), and Eulerian grid models, such as EPA’s Community Multiscale Air Quality modeling system (CMAQ).

One goal of this study is to determine the amount of nitrogen deposition that comes from new and existing transportation sources within the study area as compared to sources further upwind, outside the study area. Because the pollution profile of nearby and distant roadway emissions will likely be indistinguishable from a CMB modeling perspective, it is unlikely that a receptor-based methodology can determine the exact source of nitrogen transport to serpentine grasslands. Consequently, a source-based model was used for nitrogen source apportionment to the serpentine grasslands in the study area.

When adequate input data are available, the CMAQ model is likely to provide the most accurate characterization of atmospheric transport in the region because it allows for non-uniform atmospheric conditions and multiphase chemical transformations. However, complex models such as the CMAQ model require extensive data that are sometimes difficult to prepare. Improper preparation of data can result in the simulation being overly sensitive to initial and boundary conditions or other modeling complications. For instance, if winds are not accurately represented in the CMAQ input fields, inaccurate transport and deposition fields could be simulated. Furthermore, depending on the location of the domain boundaries and the size of the modeling domain, boundary conditions can dominate study results, making it difficult to interpret the simulated nitrogen deposition patterns. For a study such as this one, it is desirable to have existing meteorological and emissions databases available in order to avoid having to invest in developing and evaluating these data.

Gaussian models such as the CALINE series of models and ISC and AERMOD are much simpler than the CMAQ model. However, these models do not account for the complex chemical transformations and transport processes in the atmosphere. Gaussian models perform best when the meteorological site used to supply input data for the model is in close proximity to the sources and receptors of interest. Unfortunately, routinely available meteorological data are not always

ideally located for all studies. In this study, the sites used to supply meteorological data were located up to 50 kilometers (km) from the sources and receptor areas considered. Although not ideal, this relative spacing between meteorological sites and study area is typical of most studies using Gaussian models.

The spatial scale appropriate for application of the Gaussian models versus that for the Eulerian models is quite different. The formulations of Gaussian models are valid up to a few km from the sources simulated. The formulation used in Eulerian models was developed for horizontal grid spacing ranging from a couple of kilometers up to much larger spacing. Practically speaking, developed databases for Eulerian models with resolution finer than about 4 km are rarely available.

The modeling techniques considered for this study share the following in their methodology. Air concentrations of nitrogen species are calculated by the models. Deposition is calculated using a deposition velocity expressed in units of meters per second (m/second), such that the deposited mass can be calculated using the following equation:

$$D = C * V_d * t$$

where D is the deposited mass in $\mu\text{g}/\text{m}^2$, C is concentration in $\mu\text{g}/\text{m}^3$, V_d is deposition velocity in m/second, t is the time interval considered in seconds. The units employed for the various quantities in this equation may vary among the models (and therefore could require the inclusion of conversion factors), but this basic calculation is made in the case of all the models considered here.

Air Quality Modeling Approaches Employed in this Study

For this study, ICF analyzed nitrogen deposition using several modeling approaches. One of the principal goals of the project is to estimate the sources that contribute to deposition in the habitat areas. In order to estimate contributions from individual roadways and to assess the increase in deposition due to increases in traffic, Gaussian models for a limited domain were applied around the habitats. The much more complex CMAQ model was also used to simulate the area's more complex nitrogen transport processes, and, using the PPTM source apportionment technique, to estimate contributors to deposition on a broader scale. Meteorological data for the Gaussian models are readily available. Gaussian models are commonly used to characterize overall air quality transport trends, but because they are very simplified, results from Gaussian models are best taken in context with more comprehensive modeling techniques such as the CMAQ model. For instance, a Gaussian model requires that the wind field is uniform speed at all elevations and across the entire area of interest.

In this application, meteorological data for several recent years were used in the Gaussian model simulations. On the other hand, treating all of the various area,

mobile, and point source emissions (regional and local), is difficult in the Gaussian models. Gaussian models were used to investigate the impacts of local roadways on the habitat areas, but characterizing the overall deposition was not attempted with these models given the simplicity of the models and their inability to capture certain transport and fate processes.

Due to the development time required to prepare the various meteorological and emissions inputs required for CMAQ modeling, we were constrained in this project to use existing modeling databases for CMAQ. Therefore existing CMAQ modeling databases from the California Air Resources Board (CARB) and the Bay Area Air Quality Management District (BAAQMD) were used as the starting point for modeling. The modeling databases available used a 4-km-square grid resolution for the modeling region and are populated with data from a winter episode period. Annual simulations available from CARB use 12-km resolution, which is not adequate to resolve the areas of interest around the target habitats. The areas of interest in this study are the serpentine bunchgrass grasslands shown in Figure E-8.

Background on Future Emissions Estimates

Emissions for the base year Gaussian modeling were based on traffic counts for highways and roads in 2005, as described below in more detail. For CMAQ modeling, base year emissions were acquired from BAAQMD. At the time the modeling was conducted, however, no future year emissions projections were available. In the sections below, we include extrapolations of emissions to future years based on projected growth in the Bay Area. Over the time period for which emissions projections are now (as of 2011) available, NO_x emissions are expected to decrease in the Bay Area. NO_x emissions in the Bay Area, dominated by on-road mobile emissions in 1990, are expected to be dominated by non-road mobile sources by 2025 (Bay Area Air Quality Management District 2011). Given the current trends, further reductions in NO_x emissions from turnover in the on-road mobile fleet will be smaller than in the past since NO_x emissions from this sector will already be small by 2025. Note that from 2022 to 2025, Bay Area NO_x emissions are projected to increase slightly over 2021 levels (Bay Area Air Quality Management District 2011).

Looking beyond the available projections to the years 2030 and 2060, emissions in the Bay Area would not be expected to continue to increase. Some additional benefit will be seen from fleet turnover, and additional regulation will likely curb growth in other areas. However, in order to assess the potential for impact on the habitat should emissions continue to grow, we have included deposition estimates in the sections below based on extrapolation of emissions. In all likelihood, these deposition estimates overestimate impacts, but show that increases in NO_x emissions lead to roughly proportional increases in deposition to habitat areas.

Gaussian Modeling

Gaussian modeling provides relatively high spatial resolution modeling that can estimate impacts from individual roadways or point sources. In contrast with Eulerian grid models such as CMAQ (see following section), which resolve spatial features down to about a 4-km scale, Gaussian models are applicable within a few km of the simulated sources and can differentiate receptors located only a few meters apart. For this study, Gaussian modeling was used to simulate the deposition from some major roadways that are located near the target habitat and to estimate future increases in deposition from these roadways.

Because of its limited spatial range, Gaussian modeling is not well suited to characterizing the effects of sources outside of the limited area considered in this study. Hence, observations of NO_x concentrations were used to estimate the overall amount of ambient NO_x and the overall contribution to deposition. Vehicular sources of NH₃ were not considered in the Gaussian modeling but will be discussed later.

In this section the sources of data used as input to the Gaussian modeling are described, chemical conversion processes affecting the deposition of nitrogen emissions are discussed, the specifics of the setup for the Gaussian modeling are described, and estimates of nitrogen deposition based on the Gaussian modeling are provided.

Meteorological Data

Gaussian modeling requires meteorological data to specify local temperature, wind speed, wind direction, and relative humidity. Upper air sounding data are also needed to characterize atmospheric mixing. For this application, surface meteorological data were acquired from the National Climatic Data Center (NCDC) for the surface site at the San José Airport. The upper air data were acquired from NCDC for the Oakland sounding. Both sets of data were acquired for the years 2005, 2006, and 2007.

Data were prepared for input to CAL3QHCR using the RAMMET preprocessor. For AERMOD simulations, the data were prepared using the AERMET processor.

Atmospheric Chemistry of Nitrogen

A complete treatment of nitrogen deposition must include all the various compounds in which nitrogen appears in the atmosphere. These compounds are treated in detail in models such as CMAQ, but Gaussian models treat only the directly emitted compound, perhaps including a single transformation or decay reaction. In order to support our discussion below of compounds to be considered in the Gaussian modeling, we present a highly abbreviated discussion of the

atmospheric chemistry of nitrogen. For further detail, the reader can refer to any of a number of available textbooks treating the atmospheric chemistry of smog formation.

Compounds of concern emitted from anthropogenic sources, either mobile or stationary, are primarily NO and NO₂, collectively referred to as NO_x. The composition of NO_x emissions is generally 90%–95% NO, with the remainder being NO₂. Chemical processes in the atmosphere, particularly the reaction of NO with ozone, rapidly convert the NO to NO₂. The effects of atmospheric chemistry do not end here, however, as the action of hydrocarbons and short-lived species called radicals continue to convert the NO₂ to a variety of additional compounds that have very different properties from the original NO_x emissions.

Among others, these compounds include nitrous acid (HONO), nitric acid (HNO₃), peroxyacetyl nitrate (PAN), and organic nitrates. Nitric acid will further react with NH₃ in the atmosphere to form ammonium nitrate (NH₄-NO₃). When examining the fate of emitted nitrogen (as we are in estimating nitrogen deposition), we must also consider the fate of these derivative compounds. After some hours or days of the action of atmospheric chemistry, what remains of the emitted NO_x will be primarily in the form of NO₂. A significant amount of nitrogen mass may also appear in the form of the derivative compounds above. The discussions below consider ways in which we might be able to augment the Gaussian modeling of NO₂ to include the effects of these other compounds on nitrogen deposition.

Background Levels of NO_x

In order to estimate the fraction of deposition due to a particular source, some estimate of the overall concentrations (and, hence, deposition) is necessary. Because the Gaussian modeling is not well suited to estimating the overall concentrations, we look to monitoring data to make this estimate. The EPA archives data from monitors around the country in order to assess trends in pollutant concentrations. Hence, we refer to these as “trends monitors.” Trends monitors in San José show ambient NO_x at around 20 parts per billion (ppb) over the past several years, so this value was used as the background NO_x concentration. Because this is an aged air mass, it was assumed this is primarily NO₂. In addition to NO₂, there will also be some other nitrogen compounds present in the atmosphere. Monitoring of the makeup of nitrogen compounds in the atmosphere has been undertaken for several sites in southern California (Buhr et al. 2005). At the more urban sites reported in the Buhr study (Fresno and Bakersfield), the nitrogen appears mostly as NO_x (nitrogen oxide [NO] and NO₂). Contribution from PAN is quite small. The contribution from nitrate is not insignificant, however. For the Fresno site, nitrate accounts for about 10% of the nitrogen. At Bakersfield, the nitrate is a little higher at about 20% of the total nitrogen.

In order to make estimates of overall nitrogen deposition (independent of the Gaussian modeling), a concentration of 20 ppb of NO₂ was used and a factor of

0.15 times the NO_2 was used as nitrate concentration. (See <http://www.arb.ca.gov/adam/> and <http://www.epa.gov/airtrends/nitrogen.html>), data for San José Jackson Street site, 2005.) These figures are based on a review of monitoring data in the South Bay. Nitrate derives from nitric acid, and for ambient air (an aged air mass), it was assumed the nitric acid would all appear as particulate nitrate.

Conversion of NO_x to Nitric Acid

The primary focus of this study is deposition of nitrogen. Although most emissions are initially introduced into the atmosphere as NO and NO_2 , chemical processes in the atmosphere rapidly convert these emissions to other forms. Nitric acid is of particular concern among these conversion products because it deposits much more rapidly than the emitted species. Gaussian models do not treat the products of atmospheric chemistry, so in this section we consider how much of the emitted NO_x might be converted to nitric acid and how that might affect the Gaussian model estimates of nitrogen deposition.

Treating the emissions as inert NO_2 would likely underestimate the near source deposition because the deposition velocity for the emitted species is low. Therefore, the amount of emitted NO_x converted to nitric acid was estimated using box model simulations. Box model simulations treat an individual parcel of air, calculating chemical transformations and diurnal variations in temperature and solar radiation. Mixing with surrounding air is not included, and, for our purposes, emissions are limited to the initiation of the simulations. These box model simulations made it possible to make an alternate calculation of nitrogen deposition assuming that some fraction of the emissions were converted to nitric acid.

Box model runs were made with the Ozone Isopleth Plotting Package (Revised) OZIPR model (Gery and Crouse), using the SAPRC97 chemical mechanism. The model was configured as a box model by maintaining a constant mixing height throughout the simulation. No deposition was simulated. The location, which allows the model to calculate the solar radiation intensity, was set to the latitude and longitude of San José.

Four different sets of meteorological conditions were used representing the four seasons: winter—January 15, 2005; spring—April 15, 2005; summer—July 15, 2005; fall—October 15, 2005. The meteorological differences include the ambient temperature, relative humidity, and amount of solar radiation (calculated by OZIPR based on the location and the date). (Since these OZIPR simulations are used only to obtain a rough estimate of the conversion rate to nitric acid, an exhaustive characterization of meteorology was not made for the OZIPR simulations. Although the data for temperature and humidity collected from these dates is not necessarily typical of the entire season in which they were collected, the solar radiation calculated for these mid-season dates is representative of the unattenuated seasonal values. This limitation on the detail in the meteorology does not apply to the Gaussian model simulations discussed later which used

hourly meteorology. More complete treatment of chemical effects is included in the CMAQ model simulations that are discussed later in this report.)

As expected, the rate at which NO_x is converted to nitric acid is strongly dependent on the amount of hydrocarbon and NO_x in the system. The choice of ambient levels of hydrocarbon and NO_x is therefore very important. The emissions from an individual source cannot be considered without regard to background because the rate of conversion is determined by the overall hydrocarbon and NO_x in the atmosphere near the source.

Based on annual average NMHC concentrations at the San José central monitor operated by BAAQMD (the only monitor available in the area) for the years available (2006 onward) and adjusted downward to account for non-reactive fraction, initial volatile organic compound levels for this study were set to 80 parts per billion of carbon. Trends monitors in San José show ambient NO_x at around 20 ppb over the past several years, so this was selected as the initial NO_x .

Figures E-1 through E-4 below show the fraction of the initial NO_x converted to HNO_3 as a function of distance from the starting point. Each of the lines on each chart represents a different hour of the day, and each line is identified by the time in 2400 hour military time (e.g., 800, 8 AM; 1400, 2 PM). (NO_x is also converted to other species such as PAN and HONO (nitrous acid), but these are relatively small contributors to total mass of nitrogen.) The percent HNO_3 is expressed as a function of distance from the source by using a wind speed of 3.7 km/hour. The lowest wind speed (other than calm) reported in each of the three years (2005, 2006, and 2007) of met data used in the Gaussian modeling is 3.6 km/hour. A wind speed of 3.7 km/hour is therefore a small but reasonable value of the wind speed. The choice of this wind speed in one sense make this a “worst case” analysis because the low wind speed allows more of the NO_x to be converted to nitric acid within the range of the habitat area. Lower wind speeds are, of course, possible though and are reported in our data files as calm. The choice of a wind speed for this calculation that is lower than the smallest value in the data would be difficult to justify, though, since it cannot be verified based on routinely available observations.

The figures extend to 8 km because the largest segment of Bay checkerspot butterfly habitat is roughly in the range of 0 to 8 km from US 101 and this range roughly matches the domain used in the Gaussian modeling. Using a higher wind speed would result in less conversion to nitric acid within this distance while a lower wind speed (e.g., calm conditions) would result in greater conversion in this range.

Simulations were started at several different times of day, as indicated on the legend for the charts. Midday start times in summer result in almost 25% of the initial NO_x being converted to nitric acid within 8 km of the source. There is a strong seasonal variation, the result of reduced solar radiation and lower temperatures in the winter.

In addition to the results in the displays, simulations were also run at several different initial NO_x levels. For comparable conditions, the percentage of NO_x that was converted to HNO_3 ranged from over 30% for an initial NO_x of 5 ppb to only about 7% for an initial NO_x of 60 ppb. Hence, there is a great deal of uncertainty regarding how much NO_x would be converted to nitric acid at any distance from a source.

Given the amount of NO_x that might be converted to nitric acid within a relatively short distance from the source, it is important to make some attempt to estimate how much deposition might be enhanced by considering the nitric acid concentrations. Considering the amount of uncertainty in these estimates and the need to keep the treatment simple for compatibility with the Gaussian model output, there will be uncertainties inherent in any treatment selected. Estimated nitric acid for daylight hours was based on a linear function of distance from the source. In each of the charts, the line for 1400 hours represents a roughly middle-of-the-road case, representing neither the highest percentage of nitric acid nor the lowest percentage of nitric acid. For each season, therefore, the linear function that was used to calculate the fraction of nitric acid was the percent conversion curve for 1400 hours.

Figure E-1. Conversion of NO_x to Nitric Acid as a Function of Distance from Source Using Meteorological Parameters Representative of Winter

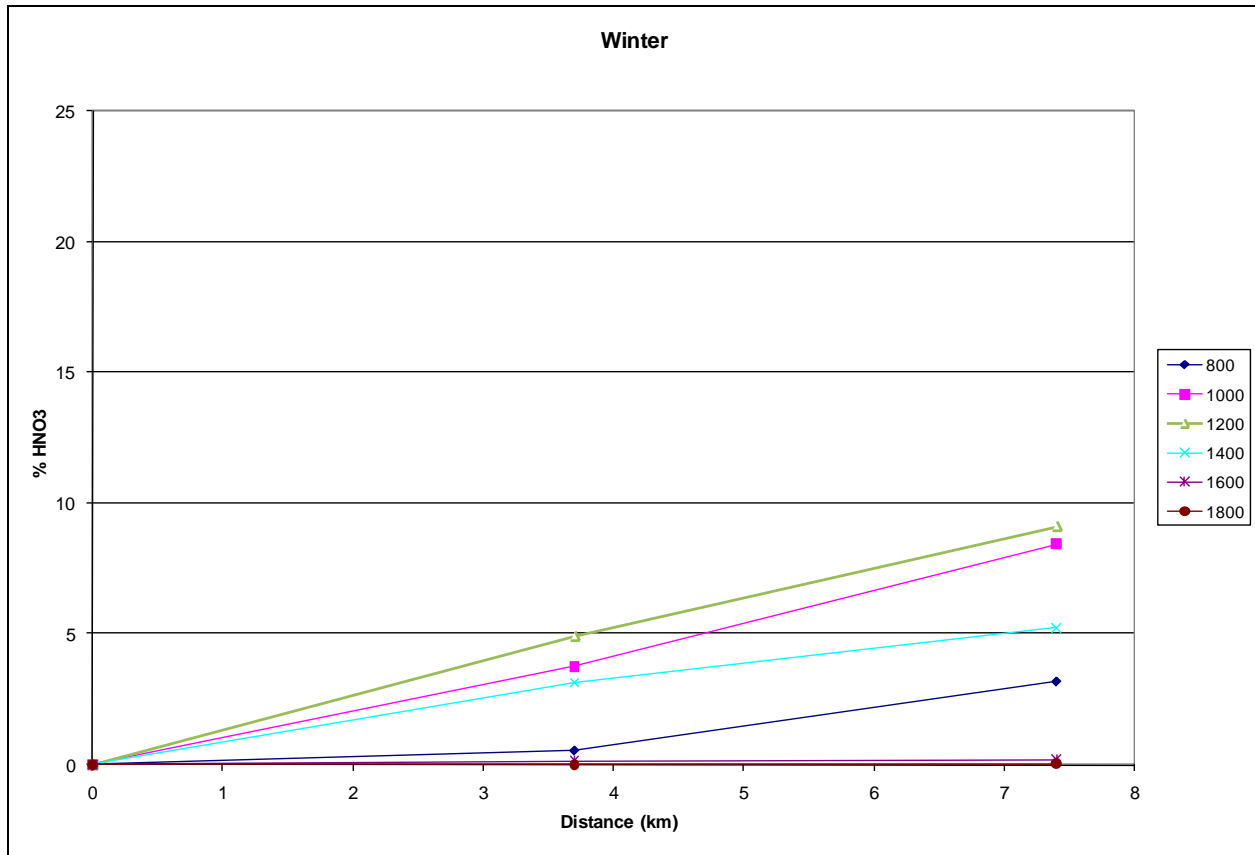


Figure E-2. Conversion of NO_x to Nitric Acid as a Function of Distance from Source Using Meteorological Parameters Representative of Spring

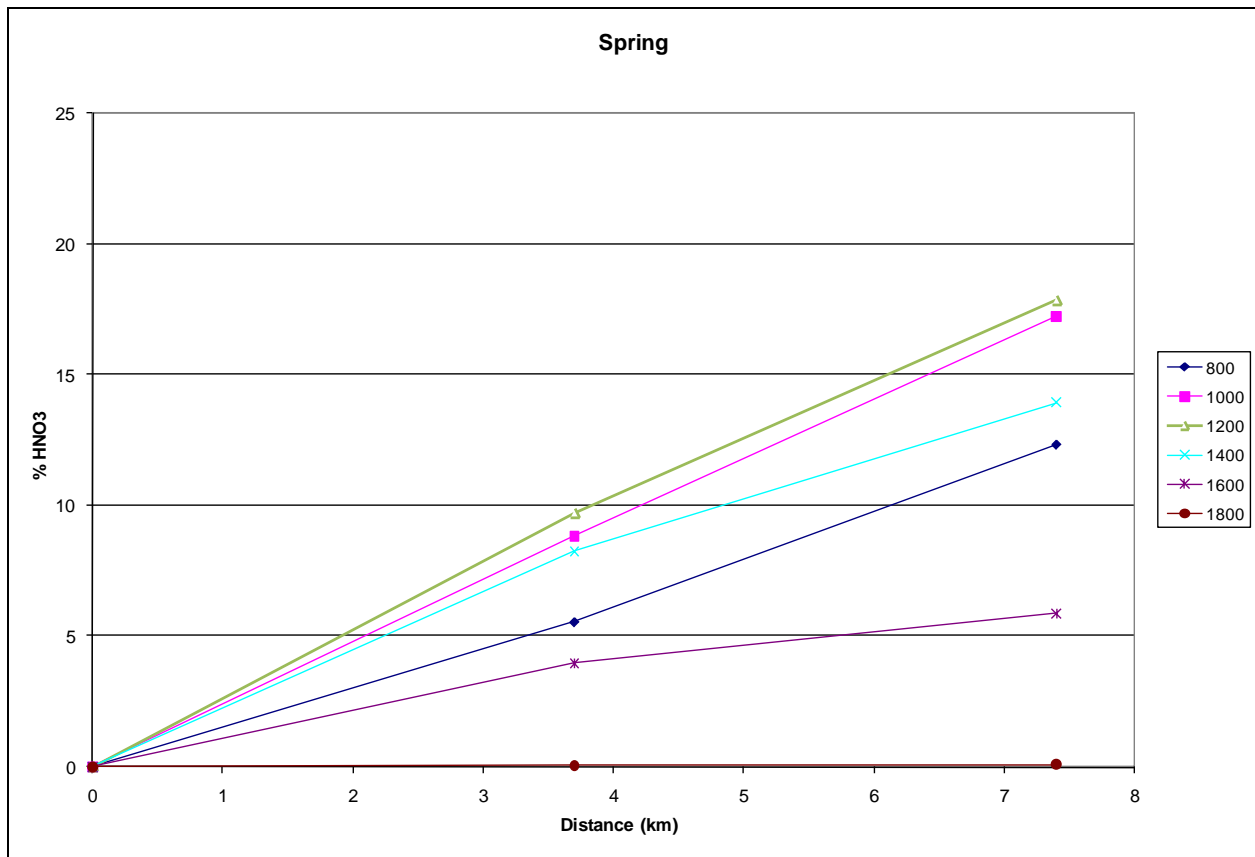


Figure E-3. Conversion of NO_x to Nitric Acid as a Function of Distance from Source Using Meteorological Parameters Representative of Summer

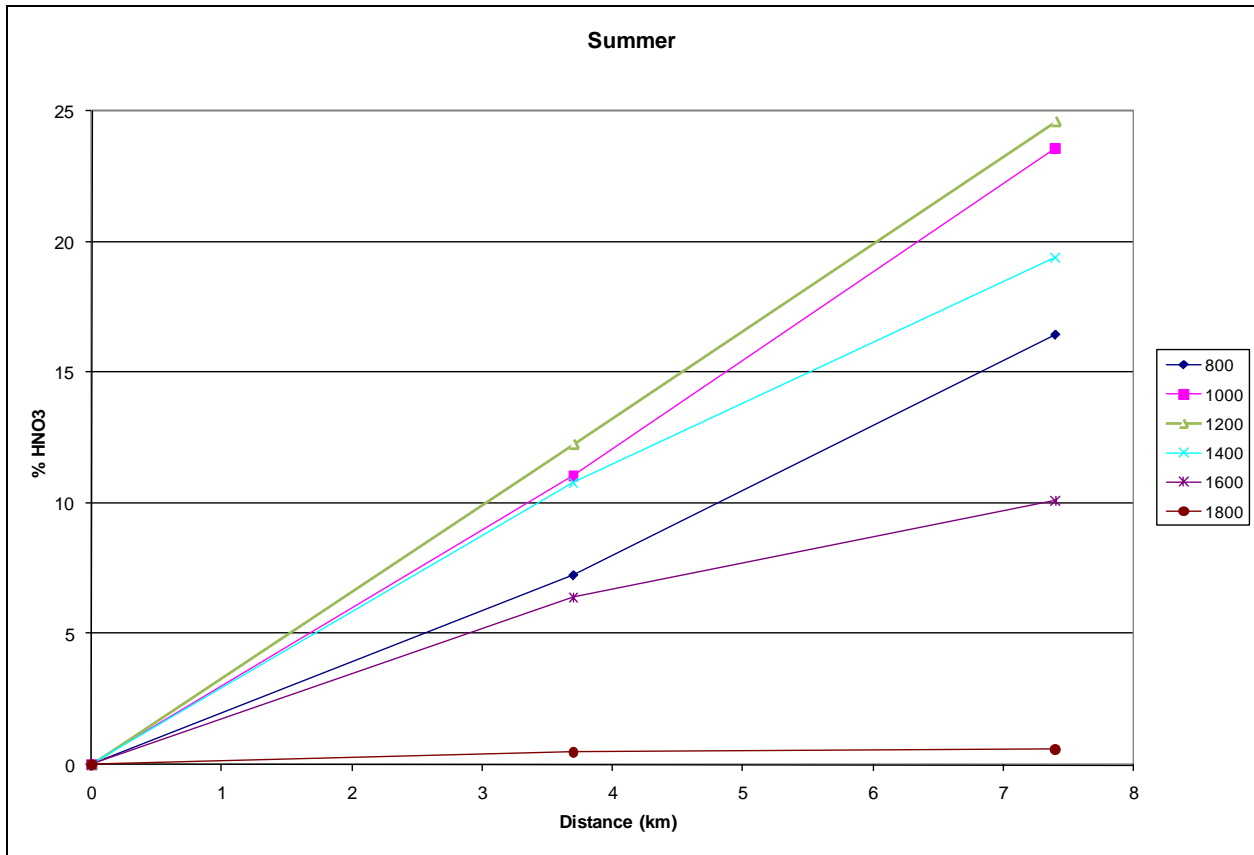
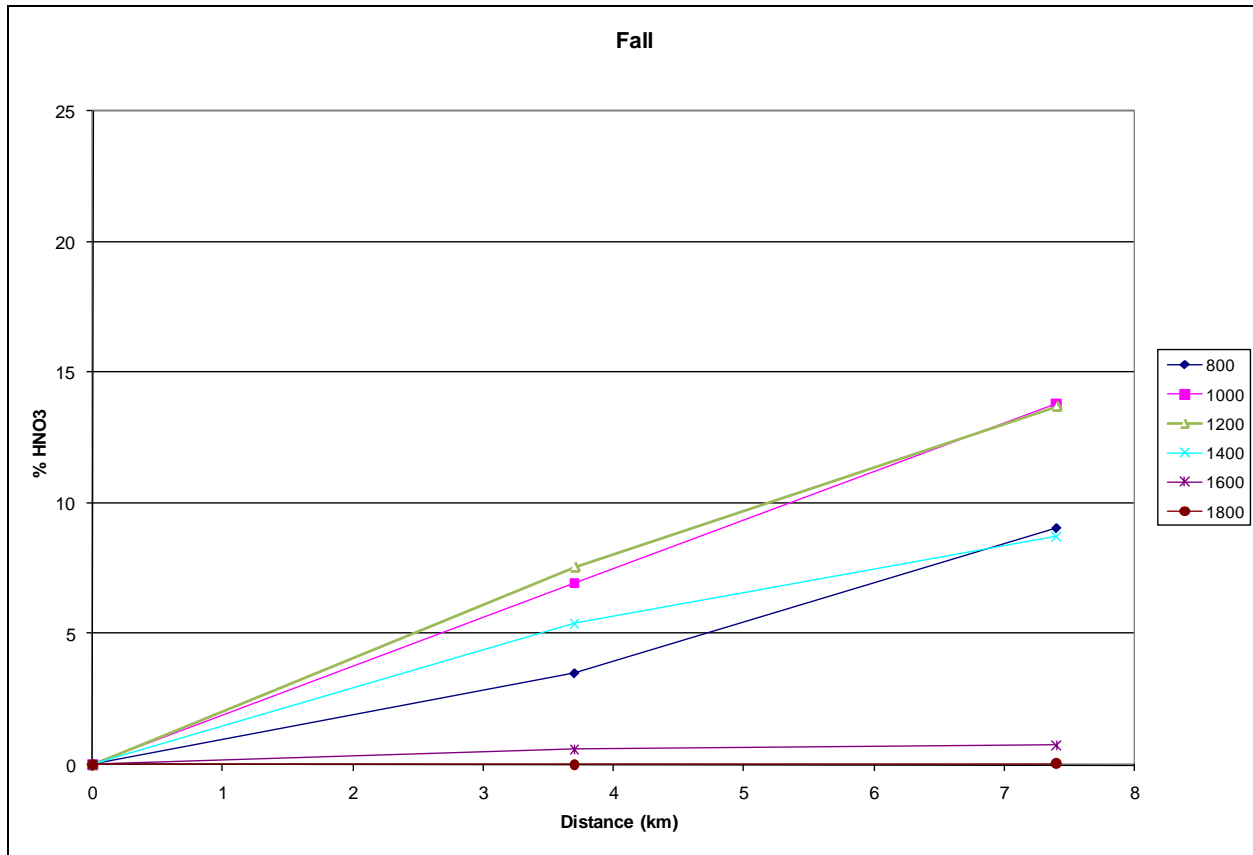


Figure E-4. Conversion of NO_x to Nitric Acid as a Function of Distance from Source Using Meteorological Parameters Representative of Fall



Modeling Using the CAL3QHCR Gaussian Model

The modeling domain used for the CAL3QHCR modeling was centered on 37.19N/121.69W and extended 15 km in each direction from that point. This domain extends from southern San José to northern Gilroy and includes several of the habitat areas (See Figure E-5 where habitat areas are shown as colored outlines on the map). Many roadways are located in proximity to the habitat units, the most important of these being US 101, State Route (SR) 85, Monterey Highway/Route 82, Santa Teresa Boulevard, and Hale Avenue. Simulations of Santa Teresa Blvd. and Hale Avenue were combined, so references to Santa Teresa Blvd. include the combined effects of Santa Teresa Blvd. in the north and Hale Avenue in the south. Simulations were run with CAL3QHCR for each of these roadways separately in order to assess their deposition impact separately, and deposition estimates for the base year (2005), 2035, and 2060 were made. Deposition estimates for an assumed overall average NO₂ air concentration of 20 ppb were also made based on a review of trends monitors in the San José area. (See <<http://www.epa.gov/airtrends/nitrogen.html>>.)

Figure E-5. Modeling Domain Included in the Gaussian Model Simulations

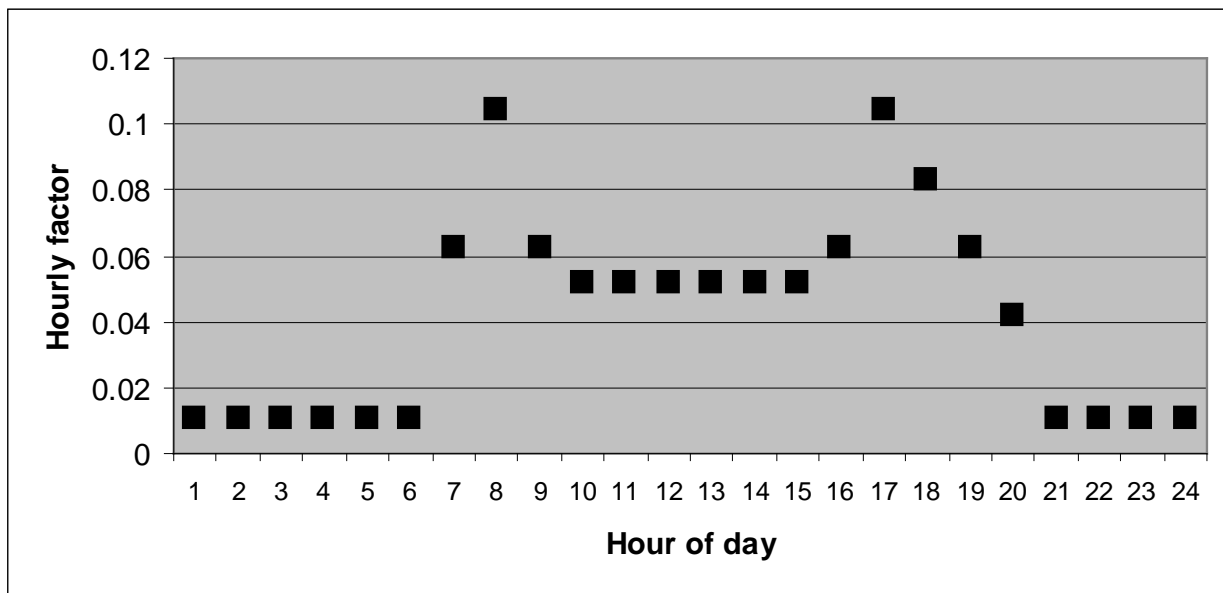


The highways listed above were broken up into segments for the purpose of modeling with CAL3QHCR. The intersections defining the intervals on the

highways are shown in Table E-1. Traffic volume between each of the intervals defined by these intersections were acquired from the San José Department of Transportation (Ma pers. comm.) and from summaries of traffic volumes from the California Department of Transportation (State of California 2006). Traffic counts for a base year (2005) and for a projected future year (2030) are provided. Recognizing this may be an overly simplistic methodology, projected traffic counts to 2060 based on the ratio of traffic counts in 2030 to traffic counts in 2005 are also provided. Average traffic counts for each roadway are presented in Table E-2. Note that the traffic counts in Table E-2 implicitly include contributions from projects that have or may have already taken action to accomplish N-deposition mitigation. Our analysis included these trips because we did not have access to data that excluded these projects, nor would it be feasible to exclude those projects consistently. The model results that use these traffic counts do not alter the assumptions used in the fee analysis, but rather provide justification for imposing the fee.

Variation of traffic counts (and hence emissions) during the day was imposed by applying a diurnal profile which varied by hour. The profile was derived from mobile emissions profiles used in the Sparse Matrix Operator Kernel Emissions (SMOKE) Modeling System⁴. The profile is presented in Figure E-6.

Figure E-6. Diurnal Variation in Traffic Counts (Normalized to Sum to 1)



Based on EMFAC2007 simulations, an average emissions rate of 0.915 g/veh-mile of NO_x emissions was used in order to estimate emissions for the major highway segments (US 101 and SR 85). This rate is based on the assumption of a

⁴ SMOKE is a standard processing package used for preparation of emissions for CMAQ and other Eulerian grid models. For more information, see www.cmascenter.org.

60 mph average speed, a temperature of 70 F and 50% humidity. An average speed of 60 mph is reasonable for this type of road. Note that emissions are not a strong function of speed (see Figure E-7). Temperature and humidity choices represent neither of the extremes of either range and give emissions estimates in roughly the middle of the range predicted by the EMFAC model. The most extreme choices for these parameters could result in only a 50% increase or decrease in emissions. For the Monterey Highway and Santa Teresa Blvd. segments, a lower average speed of 45 mph was used giving an emissions rate of 0.777 gram/vehicle-mile. For reference, the variation of emissions as a function of speed is shown in Figure E-7. Note that the available speed curve does not go above 65 mph. Travel speeds on US 101 and SR 85 could exceed this speed at times which might affect the emissions estimates.

Figure E-7. Emissions as a Function of Vehicle Speed

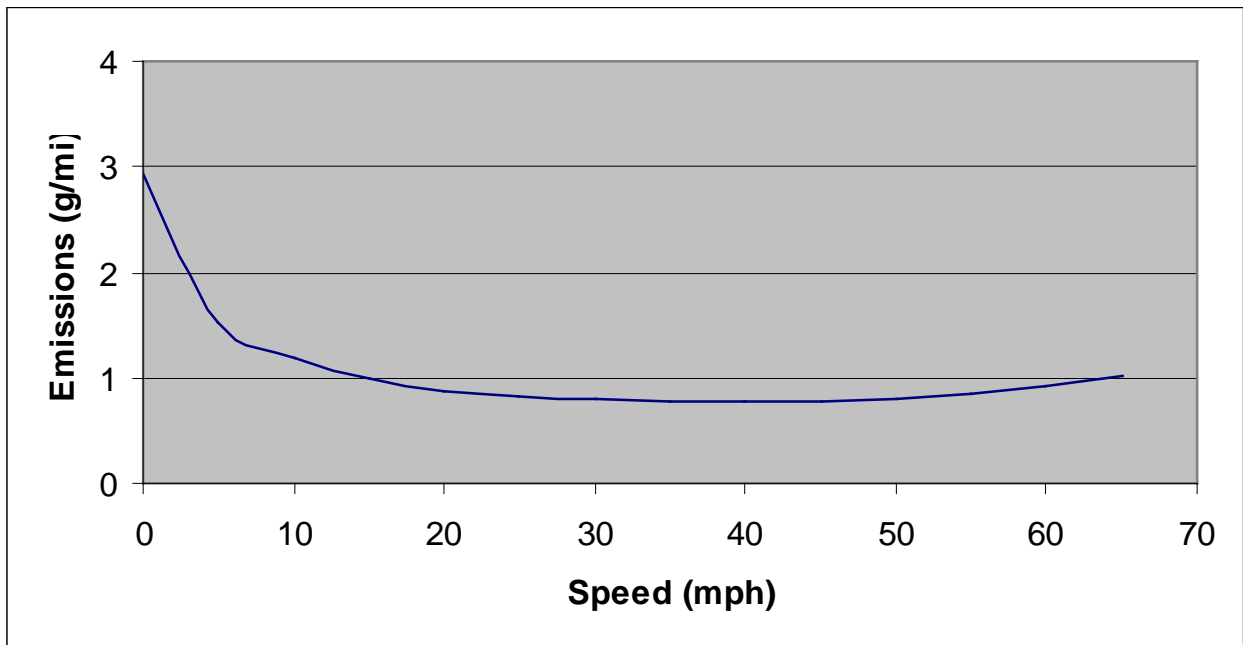


Table E-1. Highway Links for Gaussian Model Simulations

Roadway	Links
US 101	Gilroy, North Jct. Rte. 152 West, Leavesley Road Masten Avenue San Martin Tennant Avenue Interchange East Dunne Avenue Morgan Hill, Cochran Road San José, Jct SR 85, Bernal Road Interchange San José, Jct. Rte. 82 North Hellyer Avenue Interchange San José, Capitol Expressway Interchange San José, Tully Road Interchange
Monterey Highway (Route 82, Monterey St, Monterey Rd)	San José, Tully/Pettis Roads San José, Capitol Expressway Interchange San José, Blossom Hill Road San José, Jct. SR 85 San José, Bailey Avenue Morgan Hill, Cochran Road Morgan Hill, W. Dunne Avenue /E. Dunne Avenue Morgan Hill, Edmundson Avenue /Tennant Avenue San Martin, San Martin Avenue Gilroy, Masten Avenue
Santa Teresa Blvd/ Hale Ave	San José, Snell Avenue San José, Bernal Road San José, Bailey Avenue Morgan Hill, Liagas Road Morgan Hill, Watsonville Road San Martin, San Martin Avenue Gilroy, Fitzgerald Avenue
State Route 85	San José, Jct. Rte. 101 San José, Bernal Road San José, Great Oaks Boulevard Connection San José, Cottle Road Interchange San José, Blossom Hill Road

Table E-2. Average Daily Traffic Counts for Simulated Roadways

Roadway	Average Daily Traffic Count		
	2005	2030	2060
US 101	108,383	166,360	306,421
SR 85	87,580	139,393	266,229
Monterey Highway	16,078	40,469	122,235
Santa Teresa Blvd.	4,364	21,260	124,280

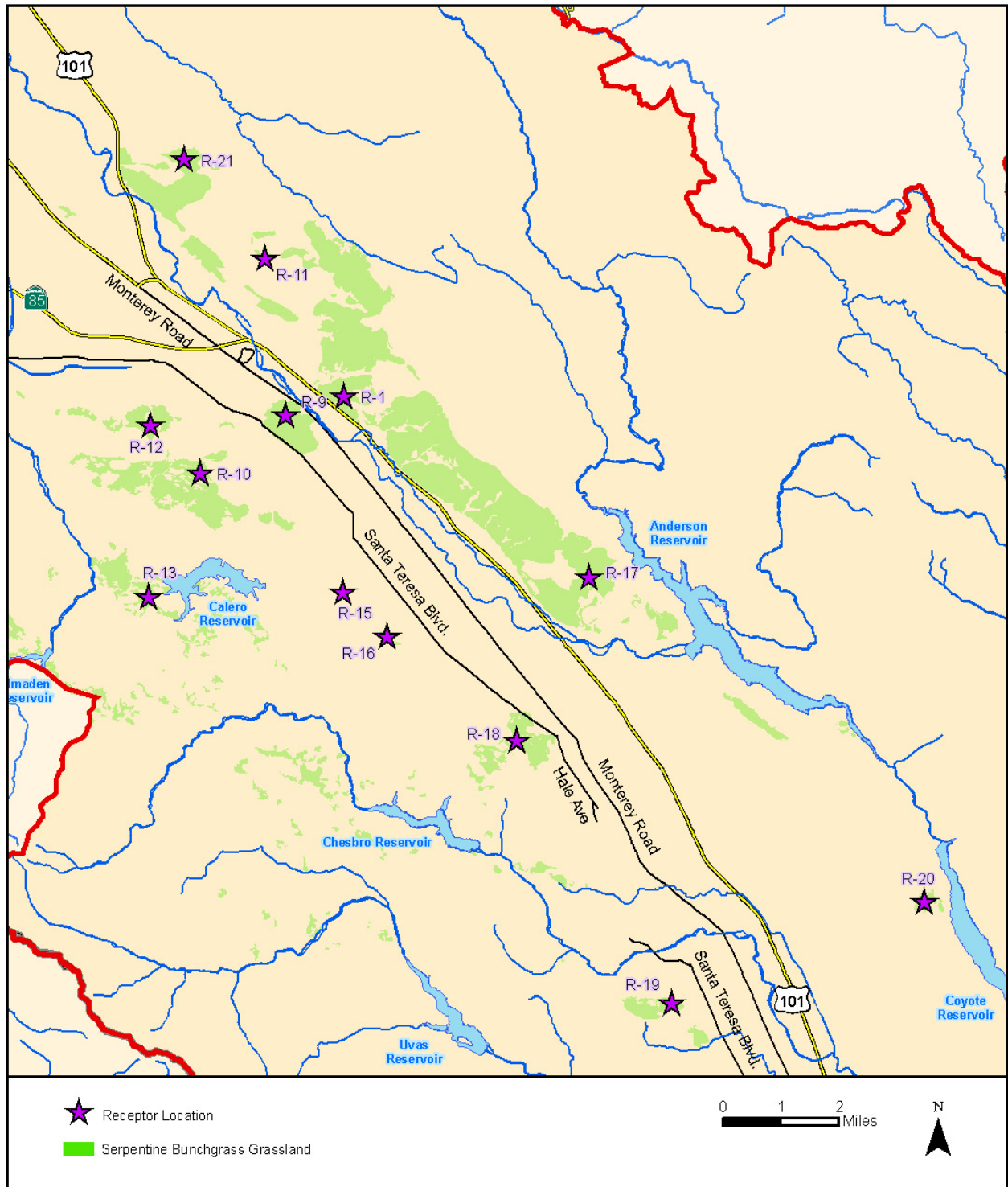
Twenty-one receptors were placed around the domain. Some of these were included to allow a general spatial distribution to be inferred. Others were specifically located in order to characterize effects on the habitat areas (habitat units) of the Bay checkerspot butterfly. Receptors were located in each of the disjoint habitat areas. Several of the receptors are located along the important Coyote Ridge, as noted in Table E-3. The receptors that are directly associated with a habitat area are shown in Table E-3 with the habitat unit that the receptor represents.

Table E-3. Receptors Associated with Bay Checkerspot Butterfly Habitat Areas as Defined in the Santa Clara Valley Habitat Plan

Receptor ID	Habitat Area ¹
Rcpt_1	Pound Site (Coyote Ridge)
Rcpt_9	Tulare Hill
Rcpt_10	Santa Teresa Main
Rcpt_11	Silver Creek Hills Central (Coyote Ridge)
Rcpt_12	Santa Teresa North
Rcpt_13	Calero Reservoir
Rcpt_15	Kalana Avenue 4
Rcpt_16	Kalana Avenue 2
Rcpt_17	Kirby Landfill Easement (Coyote Ridge)
Rcpt_18	Hale Avenue
Rcpt_19	San Martin/Hayes Valley
Rcpt_20	Coyote Lake
Rcpt_21	Silver Creek Hills North (Coyote Ridge)

¹ See Habitat Plan Table 5-9 and the Bay checkerspot butterfly species account in Appendix D for a description and map of these sites.

Figure E-8. Receptor Locations (Deposition estimates are presented in Figures E-10 through E-24)



The CAL3QHCR code was modified to write hourly concentration estimates and meteorological data to an output file. Deposition velocities were then applied to the simulated concentrations in order to calculate deposition mass at each hour for each of the simulated years. The deposition velocities were derived from the AERMOD deposition algorithm using a diagnostic option available in the model. The deposition velocities vary in time and range from about 0.02 cm/s to 0.4 cm/s, with an average of about 0.2 cm/s. Surface characteristics were developed by the AERSURFACE preprocessor using a center location consistent with the center of the domain used for the Gaussian modeling. The CAL3QHCR model does not calculate deposition. Deposition was calculated after the fact by applying a deposition velocity to the concentrations predicted by CAL3QHCR. Had the model included the deposition calculation internally, the predicted concentration would have been lower due to the effects of deposition. Therefore, the external calculation of the deposition velocities overestimates the amount of deposition. Note that we have not considered ammonia deposition in the Gaussian modeling. Ammonia deposition could add measurably to the total nitrogen deposition because it deposits more readily than NO₂.

On page 10, we used monitoring data to estimate total ambient NO₂ concentrations to be about 20 ppb. Nitrate concentrations were estimated to be about 0.15 times the NO₂ concentrations. We can make an estimate of the overall nitrogen deposition from all sources by applying the deposition velocities calculated by AERMOD to these ambient NO₂ and nitrate concentrations. The application of the deposition velocities to the 20 ppb estimate of ambient NO₂ results in the total annual deposition listed in Table E-4 for each of the three meteorological years considered. The second line assumes additional deposition due to contribution from nitrates containing 0.15 times the mass of nitrogen in the ambient NO₂. Appropriate particulate deposition velocities, again derived from AERMOD, were used for estimating the deposition of nitrates. The estimates for nitrates combined with NO₂ give overall deposition in the range of 5.9 to 6.4 kg-N/hectare [ha]/year. This overall estimate of deposition will be useful for comparison to the individual link estimates to be presented later. Based on figures presented by Tonnesen et al. (2007) (See Figure E-9) which showed total nitrogen deposition between 8 to 11 kg-N/ha/year, this overall estimate of deposition is consistent with their modeling based estimates.

Figure E-9. Nitrogen Deposition Simulated at 4-km Resolution using the CMAQ as Presented by Tonnesen et al. (2007)

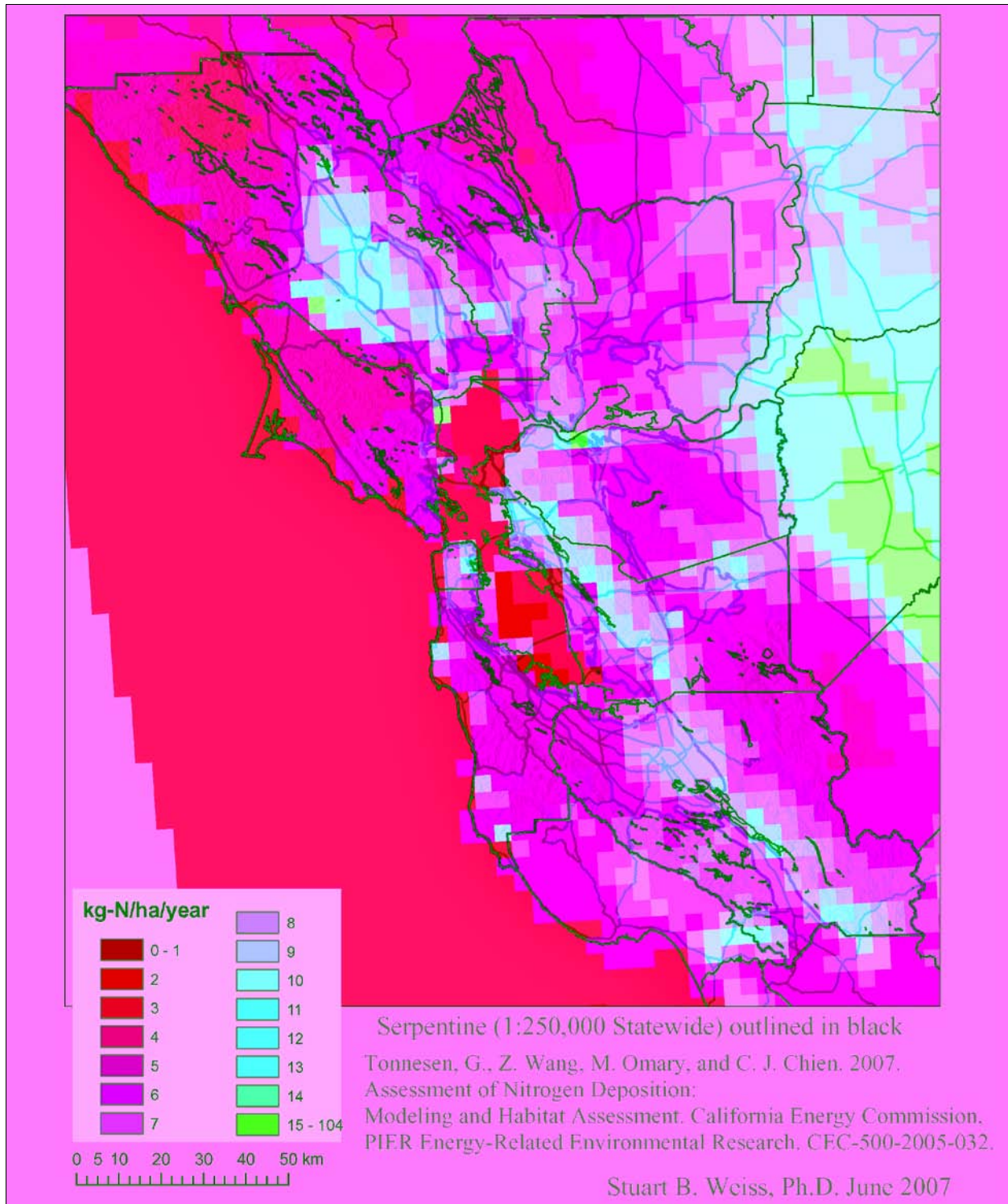


Table E-4. Estimated Deposition (kg-N/ha/yr) from Ambient NO₂

Year	2005	2006	2007
Deposition from NO ₂	4.5	4.8	4.9
Deposition from nitrate	1.4	1.5	1.5
Estimated total	5.9	6.3	6.4

Deposition estimates were made for each receptor (for each of the roadways noted above) and for each of the three meteorological years. The resulting annual total deposition estimates for each receptor for 2005 emissions averaged over the three meteorological years are shown in Figure E-10 and in Table E-5. These estimates use only deposition of NO₂ (i.e., no conversion to nitric acid is considered). At most sites, the simulated deposition from US 101 is higher than the simulated deposition from any other the other roadway links that were simulated. There are some comparable contributions from SR 85 for some of the more northerly receptor locations (e.g., Santa Teresa North). The magnitude of the simulated deposition is less than 0.1 kg-N/ha/y for any single roadway link at any of the receptors. This is only a small fraction of the approximately 6 kg-N/ha/y estimated above based on ambient NO₂ levels. The impact of roadways located some distance from US 101, even though comparable in traffic load such as SR 85, is low compared to US 101. This implies that the traffic on additional roadways not simulated here would not increase the simulated deposition to a level comparable to the ambient calculation. The lower deposition simulated in the CAL3QHCR runs warrants some discussion.

We have alluded to, but not explicitly stated, some potential reasons for lower deposition in the Gaussian model simulations. The Gaussian model simulations consider sources from only a limited area surrounding the habitats. That area includes only a small part of San José and part of Santa Clara County and does not include the remainder of the Bay Area or the rest of the state. We expect (and this expectation is corroborated by the CMAQ tagging simulations presented later) that sources outside of this limited area will also contribute to nitrogen deposition in the habitat area. Only selected, heavily traveled roadways are considered in our simulations. Other roadways not simulated here will contribute to nitrogen deposition, although we expect to a lesser extent than the roadways we are simulating. Chemical transformations may enhance nitrogen deposition. We attempt to account for the chemical effects by assuming some conversion to nitric acid, but it is possible that our necessarily simple approach may still underestimate the effects of these chemical transformations. (The effect of including nitric acid is presented next.)

We must therefore accept that the Gaussian model simulations cannot give an estimate of overall nitrogen deposition. Nevertheless, the comparison of the Gaussian model simulations for different sites and roadway links can give us an indication of which roadways could have the greatest impact on particular habitat areas.

Figure E-10. Simulated Annual Nitrogen Deposition using CAL3QHCR with 2005 Emissions Levels Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂

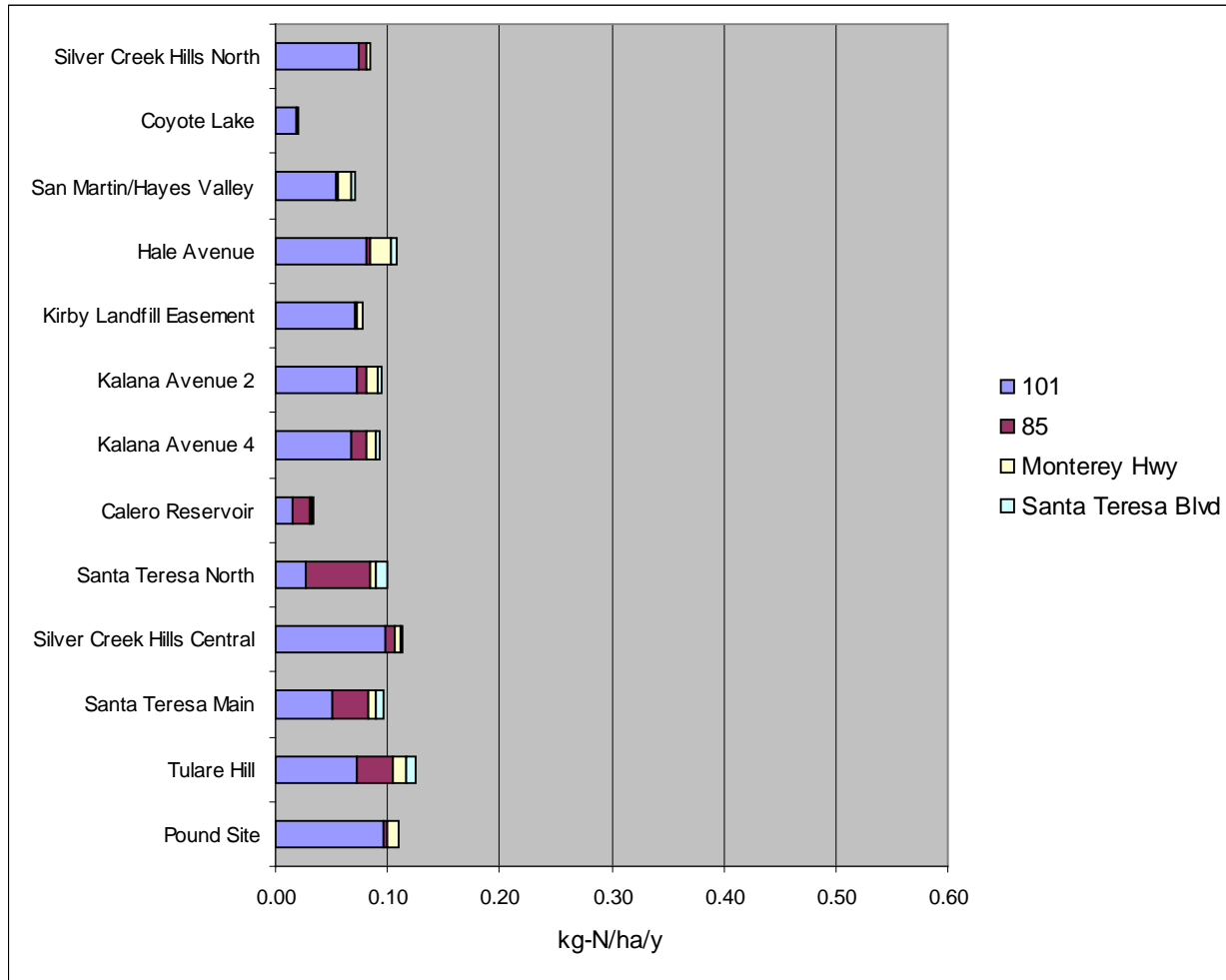


Table E-5. Simulated Annual Nitrogen Deposition using CAL3QHCR with 2005 Emissions Levels Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂

Site	From US 101	From SR 85	From Monterey Hwy	From Santa Teresa Blvd	Total
Silver Creek Hills North	0.075	0.006	0.004	0.001	0.085
Coyote Lake	0.019	0.001	0.001	0.000	0.021
San Martin/Hayes Valley	0.054	0.002	0.012	0.003	0.071
Hale Avenue	0.081	0.004	0.018	0.006	0.109
Kirby Landfill Easement	0.071	0.002	0.006	0.001	0.079
Kalana Avenue 2	0.073	0.009	0.010	0.004	0.095
Kalana Avenue 4	0.068	0.012	0.009	0.004	0.093
Calero Reservoir	0.016	0.014	0.003	0.002	0.034
Santa Teresa North	0.027	0.058	0.006	0.010	0.100
Silver Creek Hills Central	0.098	0.008	0.005	0.001	0.113
Santa Teresa Main	0.051	0.031	0.008	0.006	0.097
Tulare Hill	0.072	0.033	0.011	0.008	0.124
Pound Site	0.097	0.004	0.009	0.001	0.110

The total annual deposition differs somewhat depending on which of the three meteorological years is considered. The variation among the meteorological years can be expressed as the maximum percent difference among the results for all receptors. The variation in simulated deposition depending on the meteorological year is largest for the simulation of Santa Teresa Blvd and smallest for the US 101 simulation. The range of variation in deposition due to choice of meteorological year depending on receptor is summarized in Table E-6 for the 2005 emissions. The large variation for Santa Teresa Blvd. is most likely due to differences in prevailing wind direction resulting in very low impacts in some areas for some years but more significant impacts in others.

Table E-6. Minimum and Maximum Variation among Meteorological Years for the Roadways Simulated Using the CAL3QHCR Model

Roadway	Mean Deposition (Averaged over all receptors) (kg/ha/y)	Minimum Variation (%)	Maximum Variation (%)
US 101	0.070	3	28
SR 85	0.013	1	97
Monterey Highway	0.010	3	54
Santa Teresa Blvd.	0.004	2	1245

Earlier in this report, it was noted that chemical effects, in particular conversion of NO₂ to nitric acid, could enhance deposition of nitrogen. Using the methodology described in the earlier section, deposition was calculated assuming some conversion of NO₂ to nitric acid. Deposition velocities for nitric acid were

derived from AERMOD. The estimates of deposition of nitrogen, including the effects of conversion to nitric acid, are presented in Figure E-11 and Table E-7. The estimates of nitrogen deposition increase by more than a factor of 2 when the effects of nitric acid are included. The maximum simulated deposition from US 101 emissions is slightly more than 0.2 kg-N/ha/y.

Figure E-11. Simulated Annual Nitrogen Deposition using CAL3QHCR with 2005 Emissions Levels Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂ and Nitric Acid

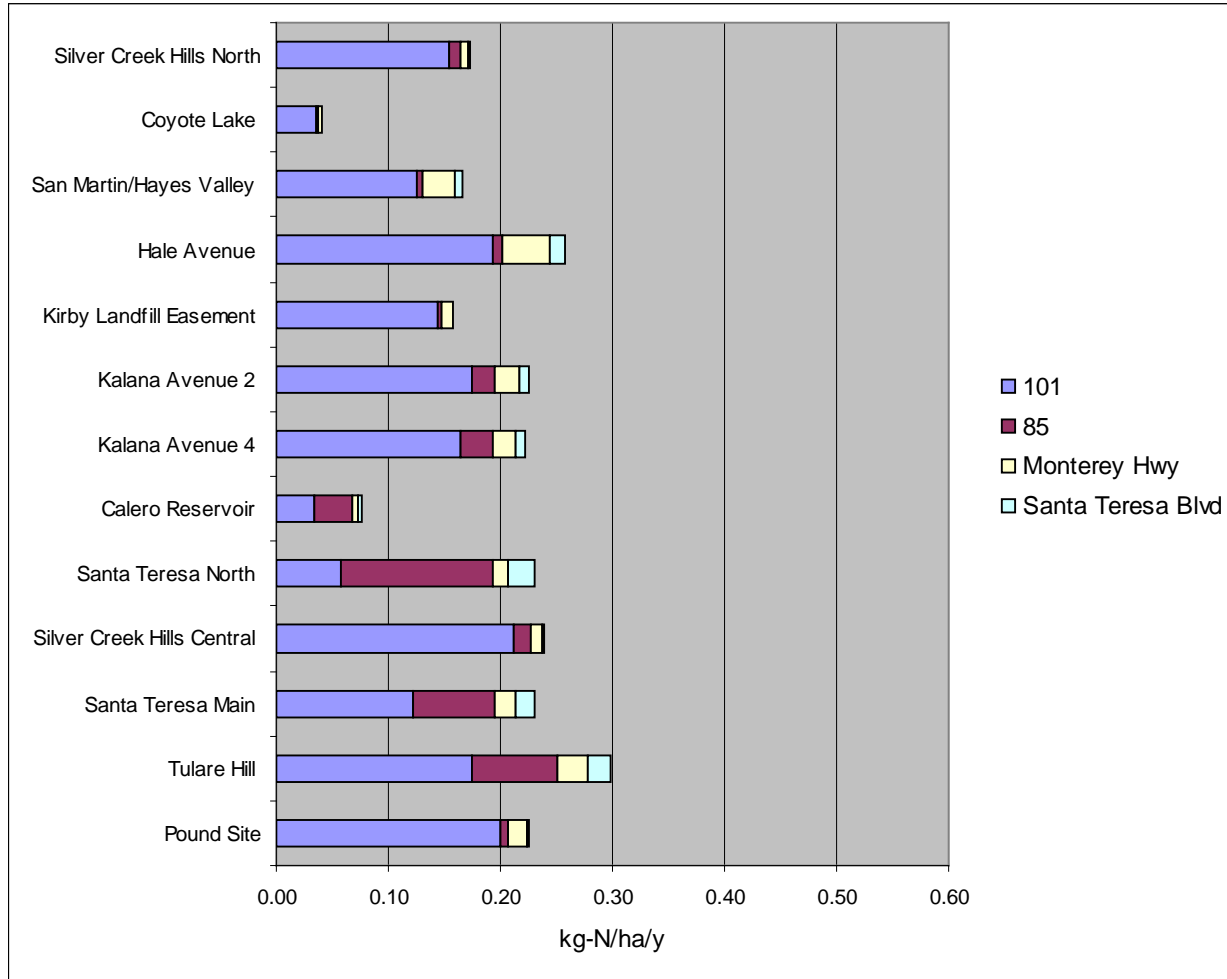


Table E-7. Simulated Annual Nitrogen Deposition using CAL3QHCR with 2005 Emissions Levels Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂ and Nitric Acid

Site	From US 101	From SR 85	From Monterey Hwy	From Santa Teresa Blvd	Total
Silver Creek Hills North	0.155	0.010	0.007	0.001	0.173
Coyote Lake	0.036	0.001	0.002	0.000	0.040
San Martin/Hayes Valley	0.126	0.004	0.029	0.006	0.165
Hale Avenue	0.193	0.009	0.043	0.013	0.258
Kirby Landfill Easement	0.144	0.003	0.011	0.001	0.158
Kalana Avenue 2	0.174	0.020	0.023	0.008	0.226
Kalana Avenue 4	0.164	0.029	0.020	0.009	0.222
Calero Reservoir	0.034	0.033	0.006	0.004	0.077
Santa Teresa North	0.057	0.136	0.014	0.024	0.231
Silver Creek Hills Central	0.212	0.014	0.011	0.002	0.239
Santa Teresa Main	0.122	0.074	0.019	0.016	0.230
Tulare Hill	0.174	0.078	0.025	0.020	0.298
Pound Site	0.200	0.007	0.017	0.002	0.226

When the emissions are extrapolated to 2030 reflecting projected increases in traffic volume, estimated deposition increases at all receptors (see Figure E-12 and Table E-8). Note that the relative increase is larger for the (currently) less-traveled roadways than for US 101. In particular, note that when nitric acid is included, the increase in deposition due to Santa Teresa Boulevard is considerable (see Figure E-13 and Table E-9). Traffic volumes are projected to increase several times between 2005 and 2030 on Santa Teresa Blvd. (a larger percent increase than any of the other simulated roadways), so the increase in deposition is consistent with the increased traffic.

Figure E-12. Simulated Annual Nitrogen Deposition using CAL3QHCR with 2030 Emissions Levels Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂

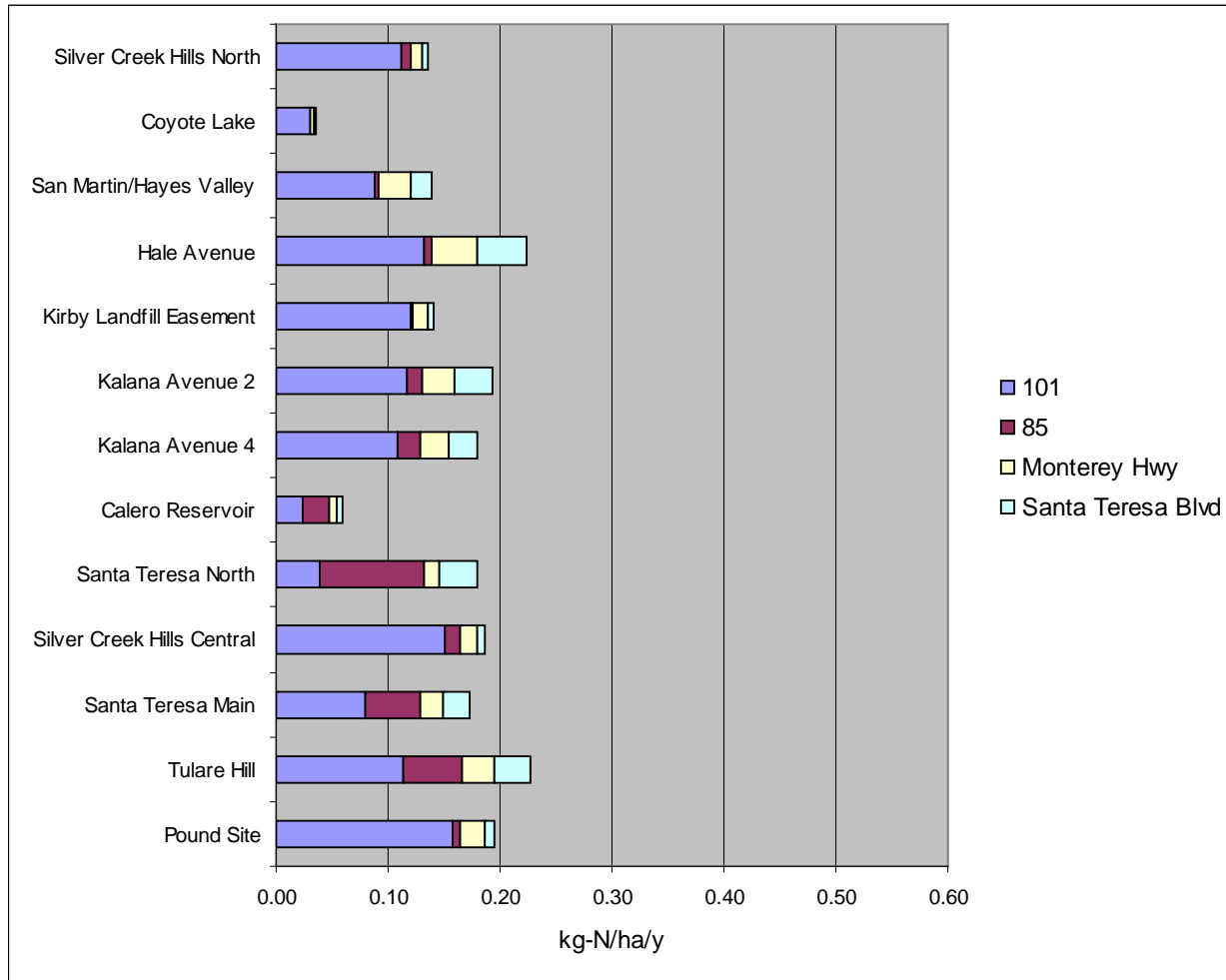


Table E-8. Simulated Annual Nitrogen Deposition using CAL3QHCR with Emissions Levels extrapolated to 2030 Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂

Site	From US 101	From SR 85	From Monterey Hwy	From Santa Teresa Blvd	Total
Silver Creek Hills North	0.112	0.009	0.009	0.004	0.135
Coyote Lake	0.030	0.001	0.004	0.001	0.036
San Martin/Hayes Valley	0.089	0.003	0.029	0.019	0.140
Hale Avenue	0.132	0.006	0.042	0.043	0.223
Kirby Landfill Easement	0.120	0.003	0.013	0.004	0.140
Kalana Avenue 2	0.117	0.014	0.028	0.033	0.193
Kalana Avenue 4	0.109	0.020	0.026	0.025	0.180
Calero Reservoir	0.024	0.023	0.006	0.006	0.060
Santa Teresa North	0.040	0.092	0.014	0.033	0.179
Silver Creek Hills Central	0.151	0.013	0.016	0.007	0.187
Santa Teresa Main	0.080	0.050	0.020	0.024	0.174
Tulare Hill	0.113	0.052	0.028	0.034	0.228
Pound Site	0.158	0.006	0.022	0.008	0.194

Figure E-13. Simulated Annual Nitrogen Deposition using CAL3QHCR with Emissions Levels extrapolated to 2030 Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂ and Nitric Acid

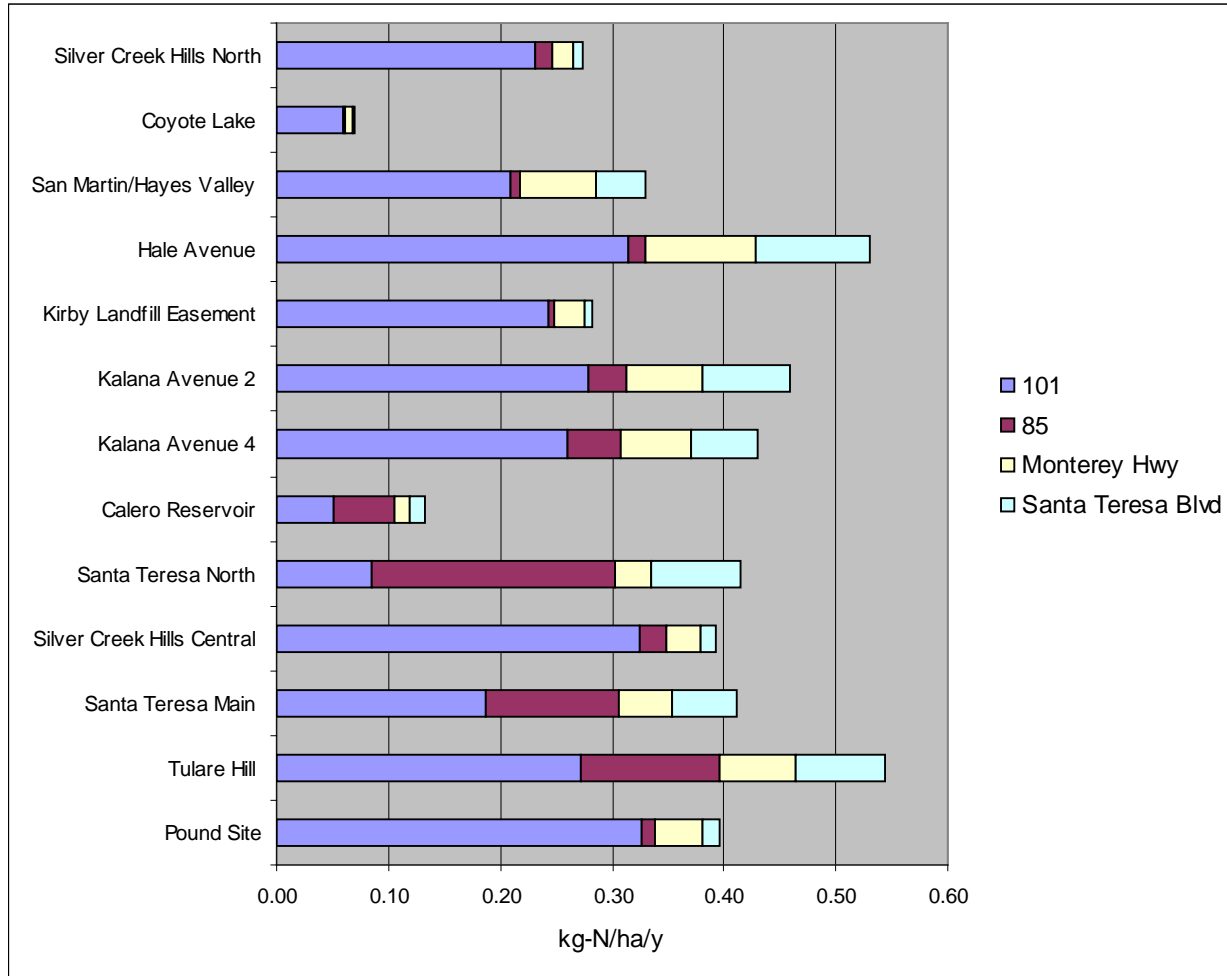


Table E-9. Simulated Annual Nitrogen Deposition using CAL3QHCR with Emissions Levels extrapolated to 2030 Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂ and Nitric Acid

Site	From US 101	From SR 85	From Monterey Hwy	From Santa Teresa Blvd	Total
Silver Creek Hills North	0.230	0.016	0.019	0.009	0.274
Coyote Lake	0.059	0.002	0.007	0.002	0.070
San Martin/Hayes Valley	0.210	0.007	0.069	0.044	0.330
Hale Avenue	0.315	0.015	0.099	0.103	0.531
Kirby Landfill Easement	0.244	0.005	0.026	0.008	0.283
Kalana Avenue 2	0.280	0.033	0.068	0.078	0.459
Kalana Avenue 4	0.261	0.047	0.062	0.060	0.430
Calero Reservoir	0.051	0.053	0.014	0.014	0.133
Santa Teresa North	0.085	0.217	0.033	0.079	0.414
Silver Creek Hills Central	0.325	0.023	0.031	0.014	0.393
Santa Teresa Main	0.188	0.118	0.049	0.058	0.412
Tulare Hill	0.271	0.125	0.068	0.081	0.544
Pound Site	0.327	0.011	0.043	0.016	0.396

Using the extrapolation of emissions to 2060 shows even greater increases in the deposition estimates. Impacts from US 101 alone reach levels greater than 0.2 kg-N/ha/y (see Figure E-14, and note change in scale for 2060, and see Table E-10). Including nitric acid further increases the estimated deposition (see Figure E-15 and Table E-11). Impacts from US 101 are for some receptors three times the 2005 levels. The extremely large increase in impact from Santa Teresa Boulevard may be an overestimate. Because these emissions were extrapolated, the rate of increase between 2005 and 2030 might not be maintained until 2060.

Figure E-14. Simulated Annual Nitrogen Deposition using CAL3QHCR with Emissions Levels extrapolated to 2060 Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂

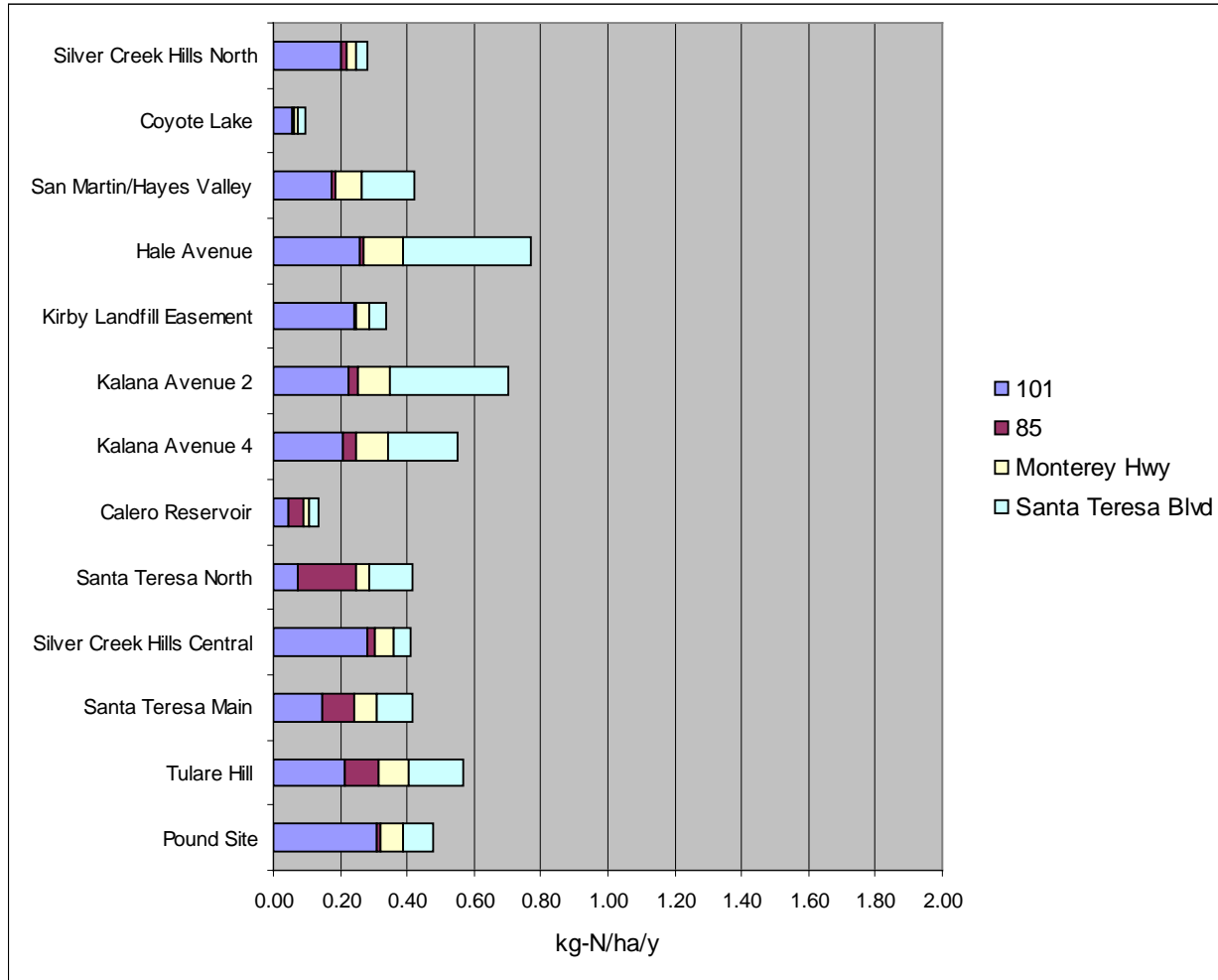


Table E-10. Simulated Annual Nitrogen Deposition using CAL3QHCR with Emissions Levels extrapolated to 2060 Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂

Site	From US 101	From SR 85	From Monterey Hwy	From Santa Teresa Blvd	Total
Silver Creek Hills North	0.200	0.018	0.030	0.031	0.279
Coyote Lake	0.057	0.002	0.012	0.021	0.093
San Martin/Hayes Valley	0.176	0.007	0.081	0.156	0.420
Hale Avenue	0.258	0.013	0.116	0.384	0.771
Kirby Landfill Easement	0.243	0.005	0.039	0.047	0.335
Kalana Avenue 2	0.226	0.028	0.097	0.354	0.705
Kalana Avenue 4	0.209	0.038	0.094	0.208	0.549
Calero Reservoir	0.044	0.044	0.020	0.028	0.136
Santa Teresa North	0.071	0.177	0.041	0.130	0.418
Silver Creek Hills Central	0.280	0.026	0.054	0.053	0.412
Santa Teresa Main	0.148	0.095	0.064	0.108	0.414
Tulare Hill	0.213	0.100	0.091	0.162	0.566
Pound Site	0.310	0.012	0.066	0.090	0.479

Figure E-15. Simulated Annual Nitrogen Deposition using CAL3QHCR with Emissions Levels extrapolated to 2060 Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂ and Nitric Acid

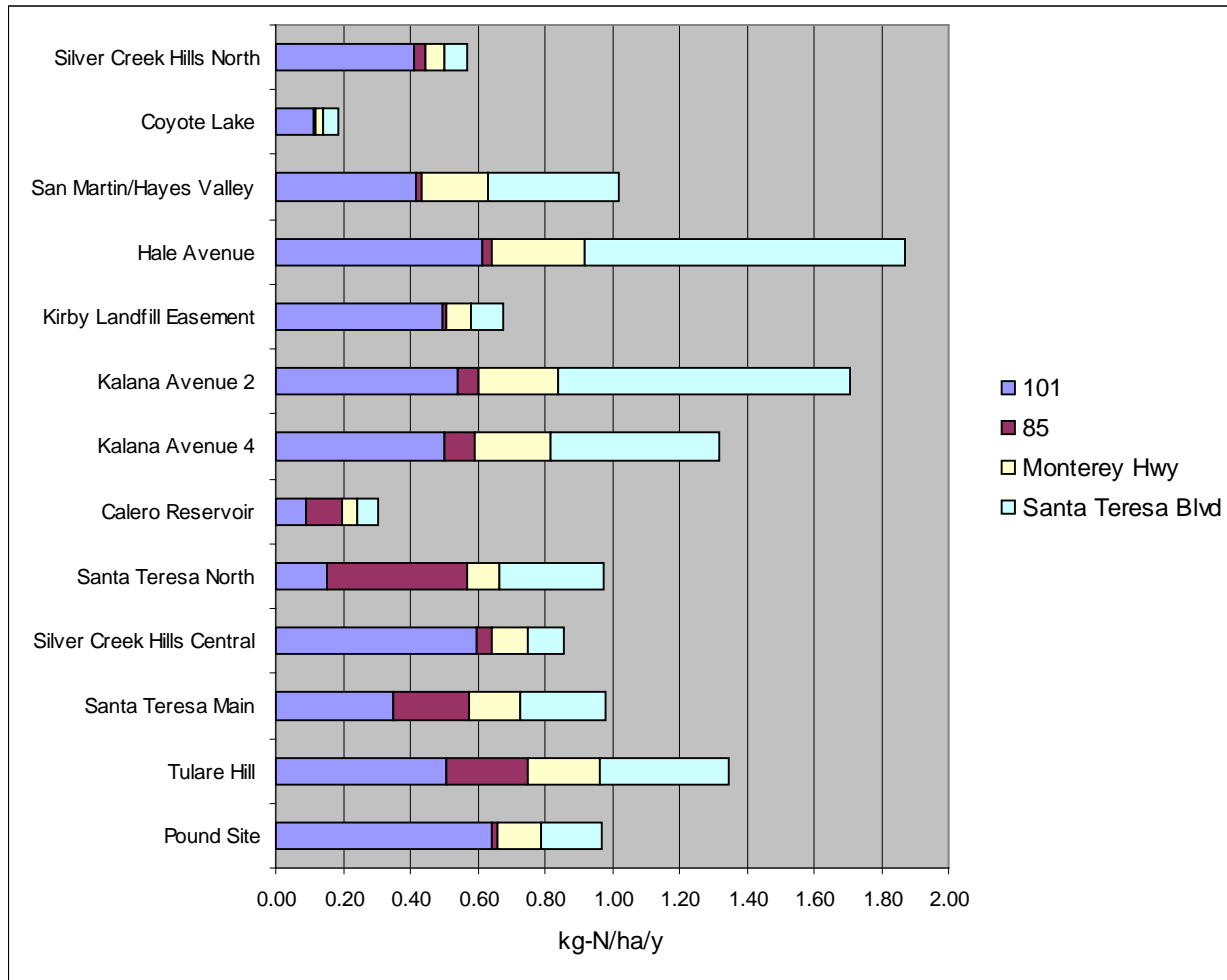


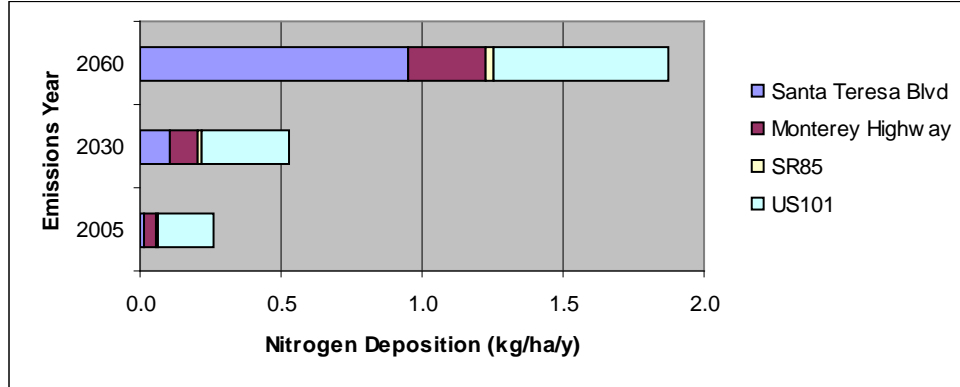
Table E-11. Simulated Annual Nitrogen Deposition using CAL3QHCR with Emissions Levels extrapolated to 2060 Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂ and Nitric Acid

Site	From US 101	From SR 85	From Monterey Hwy	From Santa Teresa Blvd	Total
Silver Creek Hills North	0.412	0.031	0.060	0.064	0.567
Coyote Lake	0.113	0.004	0.024	0.046	0.187
San Martin/Hayes Valley	0.418	0.016	0.195	0.389	1.017
Hale Avenue	0.616	0.029	0.273	0.953	1.871
Kirby Landfill Easement	0.495	0.010	0.077	0.095	0.676
Kalana Avenue 2	0.539	0.065	0.236	0.868	1.708
Kalana Avenue 4	0.499	0.091	0.229	0.497	1.316
Calero Reservoir	0.093	0.103	0.045	0.063	0.304
Santa Teresa North	0.150	0.417	0.095	0.311	0.973
Silver Creek Hills Central	0.597	0.044	0.107	0.110	0.858
Santa Teresa Main	0.347	0.227	0.151	0.255	0.980
Tulare Hill	0.508	0.239	0.217	0.383	1.346
Pound Site	0.640	0.021	0.128	0.182	0.971

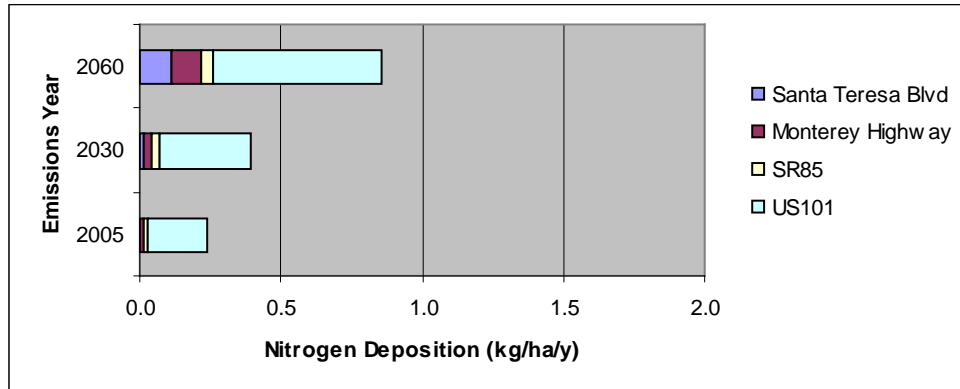
In order to provide a sense of the development of deposition over time, Figures E-16a–d presents stacked bar charts showing all three emissions years and the contributions from the simulated roadways for several habitat areas: Hale Avenue, Silver Creek Hills Central, Santa Teresa Main, and Pound Site. Pound Site and Silver Creek Hills Central, which are located along the Coyote Ridge area east of Highway 101, receive the largest increase in deposition from Highway 101. These sites also see increases in the contribution from other roadways in the area. Sites like Santa Teresa Main which originally saw contributions from several roadways, see increases in all these contributions. The Hale Avenue site sees a dramatic increase in deposition, coming primarily from the Santa Teresa Blvd. simulation. (Recall that the Santa Teresa Blvd. simulation included both Santa Teresa Blvd. and Hale Avenue.) This increase in deposition is due to the relatively larger projected percentage increase in traffic volume on roadways in the southern part of the modeling domain. On all roadways, increases in deposition using emissions extrapolated to 2060 are several times current deposition levels. Keep in mind, however, that the 2060 emissions are extrapolated from projected increases in 2030 and could be overestimated.

Figures E-16a–d. Deposition, Simulated Using CAL3QHCR, at Selected Habitat Sites for All Emissions Years, Including Deposition Due to NO₂ and Nitric Acid

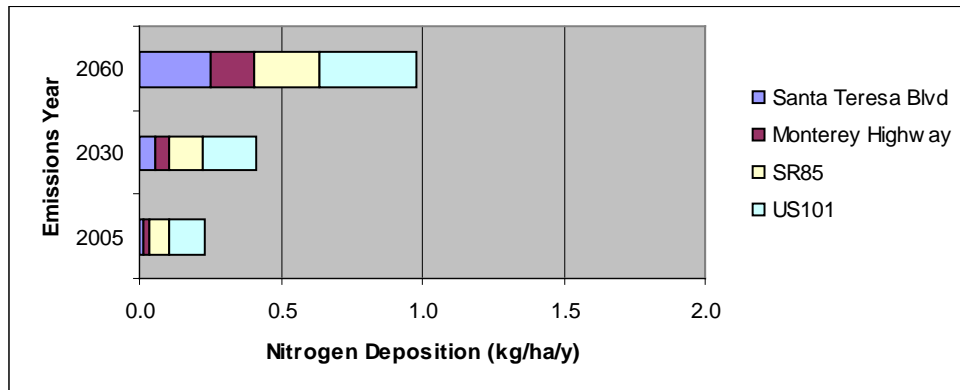
(16a) Hale Avenue



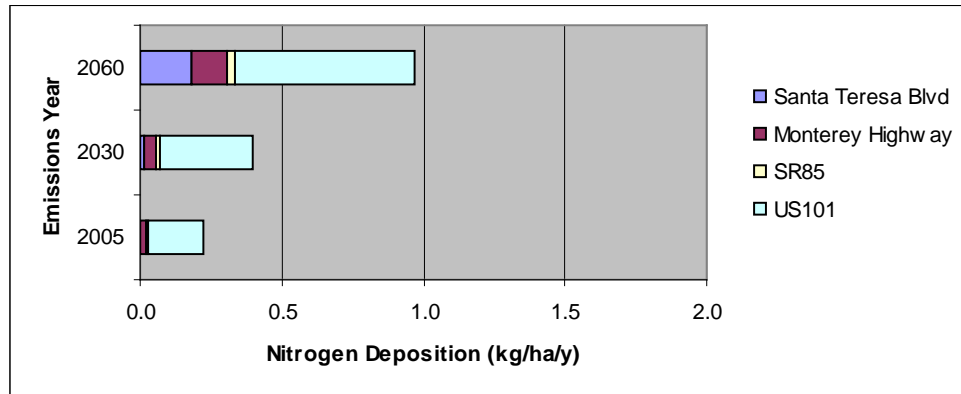
(16b) Silver Creek Hills Central



(16c) Santa Teresa Main



(16d) Pound Site



Modeling with the AERMOD Gaussian Model

AERMOD simulations were conducted over the same area and for the same meteorological and emissions years as the CAL3QHCR simulations. The emissions for AERMOD were prepared as area sources, using the length of each highway segment as one dimension of each area and an estimated width of the roadway for the width of each segment. Total emissions for each of the roadways within the simulated area is shown in Table E-12.

Table E-12. Total Emissions Simulated as Area Sources AERMOD for Each Roadway

Roadway	Total daily emissions (tpd)		
	2005	2030	2060
US 101	2.71	4.26	8.06
Route 85	0.43	0.69	1.32
Monterey Highway	0.31	0.77	2.27
Santa Teresa Blvd.	0.07	0.78	9.73

The AERMOD simulation included gaseous dry deposition of NO₂. In addition, as a post-processing step, we calculated the enhanced deposition due to inclusion of conversion to nitric acid. The same methodology was used to estimate the conversion as was used for the CAL3QHCR simulations.

The variation among meteorological years (see Table E-13) is similar for AERMOD to CAL3QHCR for Highway 101 and for Route 85. Maximum variation for Monterey Highway and Santa Teresa Blvd. is smaller using AERMOD than using CAL3QHCR.

Table E-13. Minimum and Maximum Variation of Simulated Nitrogen Deposition among Meteorological Years for the AERMOD Simulations

Roadway	Mean Deposition (Averaged over all receptors) (kg/ha/y)	Minimum Variation (%)	Maximum Variation (%)
Highway 101	0.088	4	26
Route 85	0.018	14	96
Monterey Highway	0.012	9	28
Santa Teresa Blvd.	0.004	6	75

The deposition simulated by AERMOD is presented in Figure E-17 and Table E-14 for the 2005 emissions and the average of the three meteorological years. In most cases, the AERMOD simulations produce higher deposition estimates than the CAL3QHCR simulations did. The differences between the two models range from a few percent to over 100% using base emissions and including only NO₂ deposition. The percent differences are smaller when deposition from nitric acid is included. The percent difference between the two models using 2005 emissions levels, with and without nitric acid deposition, is shown in Figure E-17. The maximum deposition estimates for 2005 using AERMOD are about 0.15 kg-N/ha/y.

Figure E-17. Simulated Annual Nitrogen Deposition Using AERMOD with 2005 Emissions Levels Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂

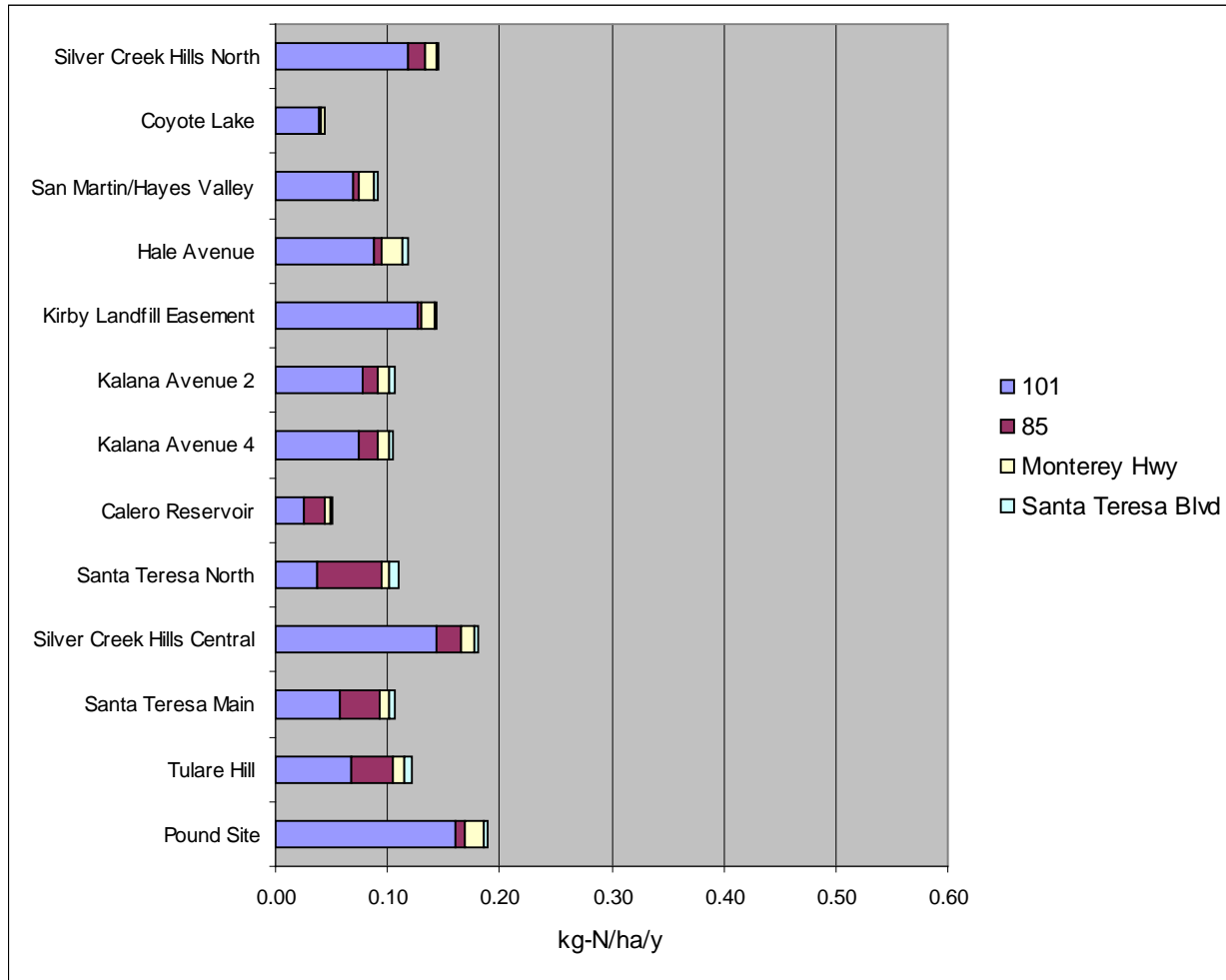
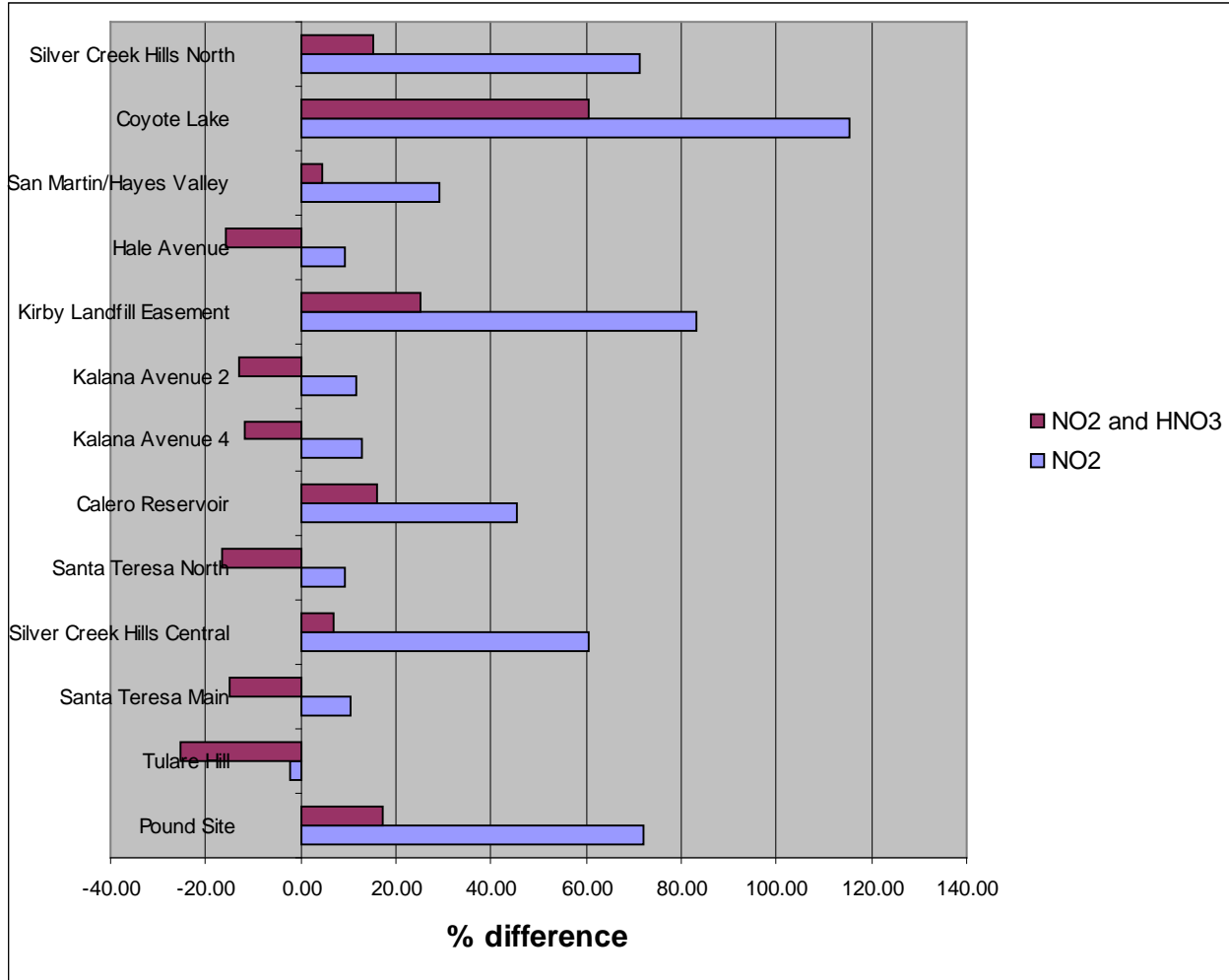


Table E-14. Simulated Annual Nitrogen Deposition Using AERMOD with 2005 Emissions Levels Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂

Site	From US 101	From SR 85	From Monterey Hwy	From Santa Teresa Blvd	Total
Silver Creek Hills North	0.119	0.016	0.009	0.002	0.146
Coyote Lake	0.038	0.002	0.003	0.001	0.045
San Martin/Hayes Valley	0.069	0.006	0.013	0.004	0.091
Hale Avenue	0.087	0.008	0.018	0.006	0.119
Kirby Landfill Easement	0.127	0.004	0.012	0.002	0.144
Kalana Avenue 2	0.078	0.013	0.011	0.004	0.106
Kalana Avenue 4	0.074	0.017	0.010	0.004	0.105
Calero Reservoir	0.026	0.019	0.004	0.002	0.050
Santa Teresa North	0.037	0.058	0.006	0.008	0.109
Silver Creek Hills Central	0.144	0.021	0.012	0.003	0.181
Santa Teresa Main	0.058	0.035	0.008	0.005	0.107
Tulare Hill	0.068	0.036	0.010	0.007	0.122
Pound Site	0.161	0.009	0.017	0.003	0.189

Figure E-18. Percent Differences in Simulated Annual Nitrogen Deposition between the AERMOD Simulation and the CAL3QHCR Simulation with 2005 Emissions Levels Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂ and due to Deposition of NO₂ and Nitric Acid



Including the effects of nitric acid conversion increases the estimated dry deposition of nitrogen in the AERMOD simulation results (See Figure E-19 and Table E-15). Estimated deposition is increased at each roadway and each receptor. Deposition estimates from AERMOD show somewhat more similarity to the CAL3QHCR than when only NO₂ deposition is considered. The maximum simulated deposition at any receptor is greater than 0.2 kg-N/ha/y.

Figure E-19. Simulated Annual Nitrogen Deposition Using AERMOD with 2005 Emissions Levels Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂ and Nitric Acid

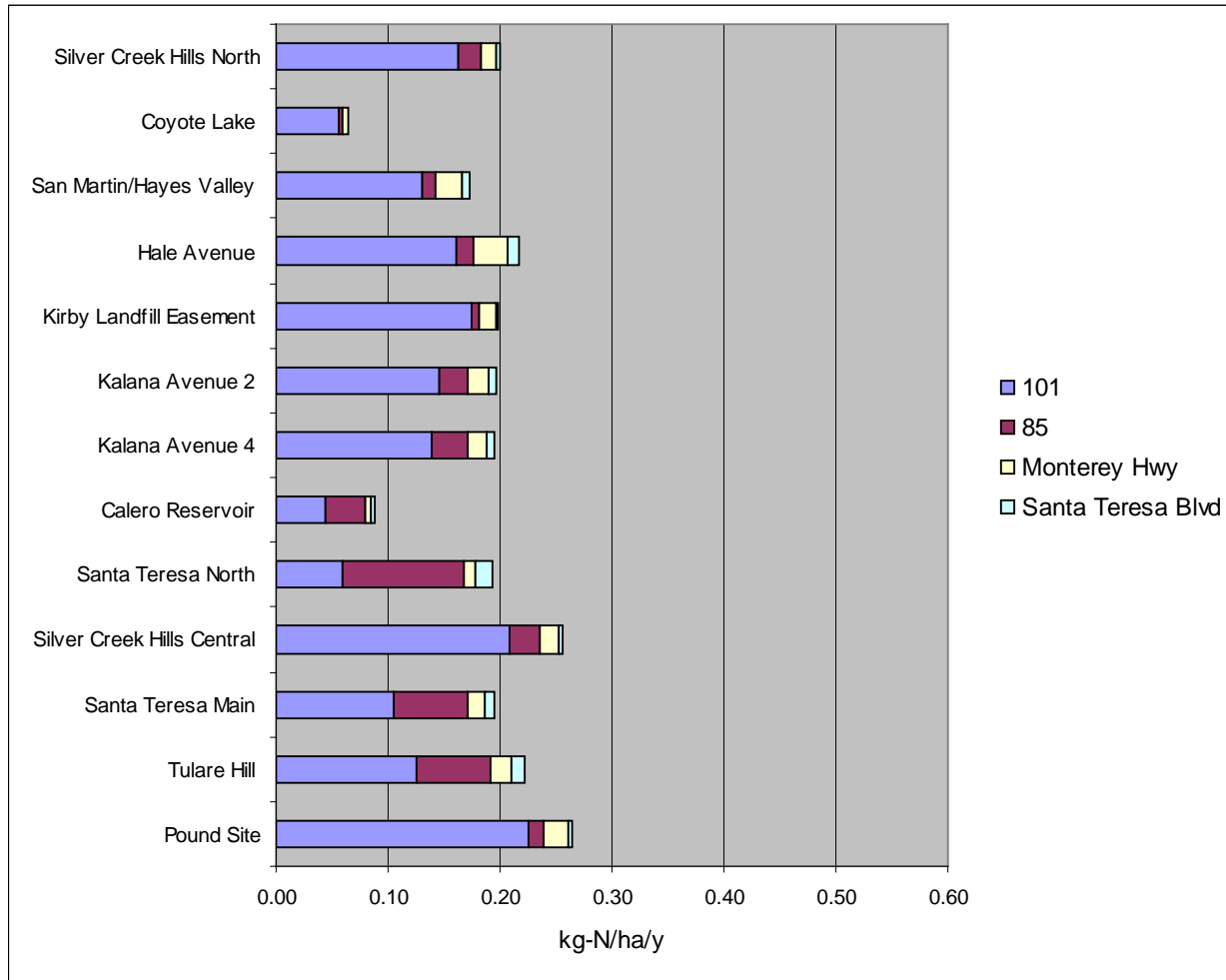


Table E-15. Simulated Annual Nitrogen Deposition Using AERMOD with 2005 Emissions Levels Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂ and Nitric Acid

Site	From US 101	From SR 85	From Monterey Hwy	From Santa Teresa Blvd	Total
Silver Creek Hills North	0.163	0.020	0.013	0.003	0.200
Coyote Lake	0.055	0.003	0.005	0.001	0.064
San Martin/Hayes Valley	0.130	0.012	0.024	0.007	0.173
Hale Avenue	0.161	0.015	0.031	0.010	0.217
Kirby Landfill Easement	0.175	0.006	0.016	0.002	0.198
Kalana Avenue 2	0.146	0.025	0.019	0.007	0.197
Kalana Avenue 4	0.139	0.032	0.017	0.007	0.195
Calero Reservoir	0.044	0.035	0.007	0.003	0.089
Santa Teresa North	0.060	0.108	0.011	0.014	0.193
Silver Creek Hills Central	0.209	0.026	0.017	0.004	0.256
Santa Teresa Main	0.106	0.065	0.015	0.010	0.195
Tulare Hill	0.126	0.065	0.019	0.012	0.222
Pound Site	0.226	0.012	0.023	0.003	0.264

The simulated deposition for 2030 using AERMOD are again higher at many sites than using CAL3QHCR for Highway 101 (see Figure E-20 and Table E-16). A few sites, however, have higher simulated values using CAL3QHCR than using AERMOD for the smaller roadways. Including nitric acid deposition increases the deposition estimates from AERMOD (see Figure E-21 and Table E-17). With only a few exceptions, the simulated values from the two models are more similar when nitric acid deposition is included. The maximum simulated deposition using AERMOD with 2030 emissions and including nitric acid is greater than 0.35 kg-N/ha/y.

Figure E-20. Simulated Annual Nitrogen Deposition using AERMOD with Emissions Levels extrapolated to 2030 Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂

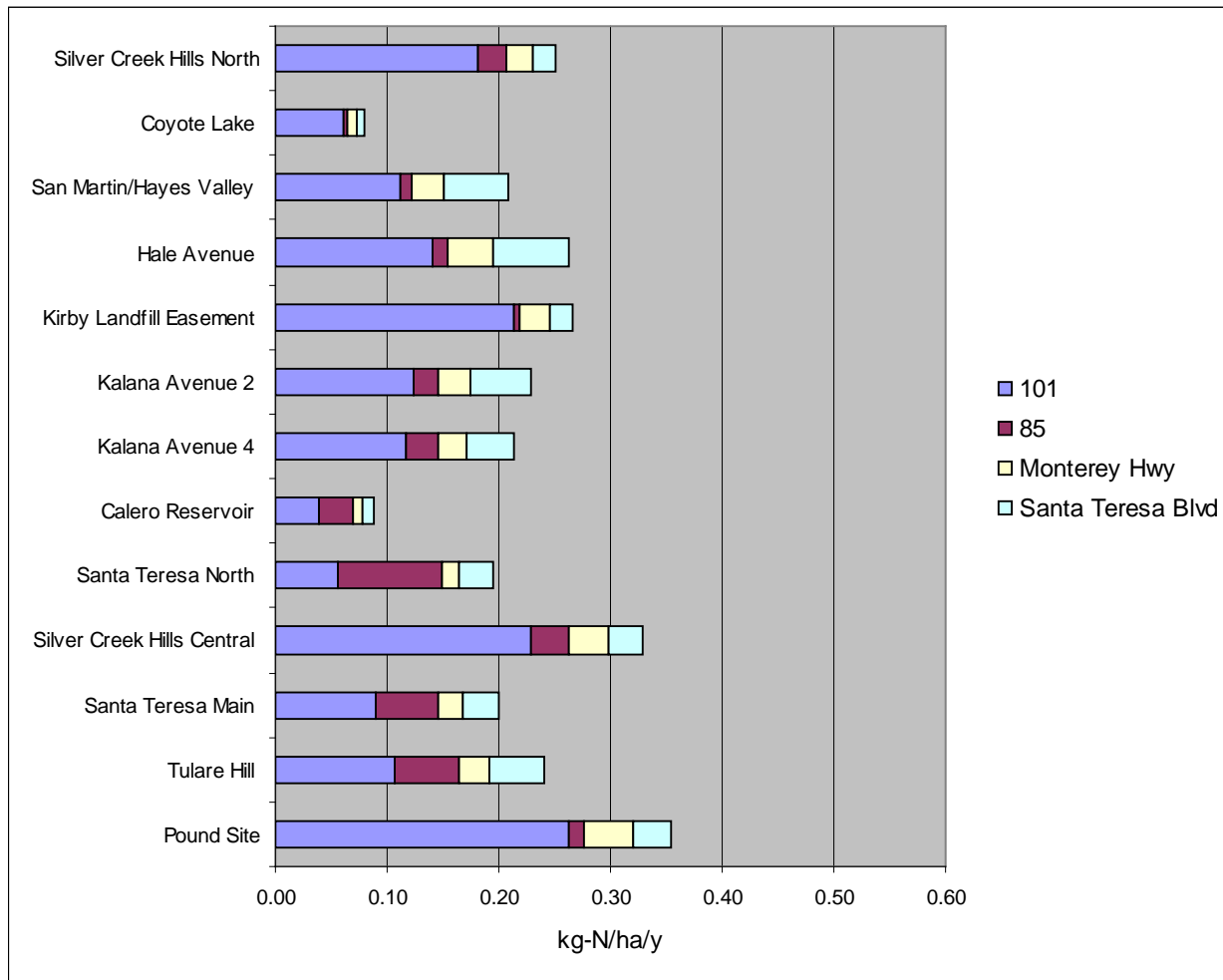


Table E-16. Simulated Annual Nitrogen Deposition using AERMOD with Emissions Levels extrapolated to 2030 Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂

Site	From US 101	From SR 85	From Monterey Hwy	From Santa Teresa Blvd	Total
Silver Creek Hills North	0.182	0.025	0.023	0.020	0.250
Coyote Lake	0.060	0.003	0.008	0.007	0.080
San Martin/Hayes Valley	0.112	0.010	0.029	0.058	0.209
Hale Avenue	0.141	0.013	0.041	0.069	0.263
Kirby Landfill Easement	0.213	0.006	0.027	0.021	0.266
Kalana Avenue 2	0.125	0.022	0.029	0.053	0.228
Kalana Avenue 4	0.118	0.028	0.027	0.042	0.214
Calero Reservoir	0.039	0.030	0.009	0.010	0.088
Santa Teresa North	0.056	0.093	0.015	0.031	0.195
Silver Creek Hills Central	0.229	0.034	0.034	0.031	0.329
Santa Teresa Main	0.090	0.056	0.021	0.033	0.200
Tulare Hill	0.107	0.058	0.027	0.050	0.241
Pound Site	0.263	0.014	0.043	0.035	0.355

Figure E-21. Simulated Annual Nitrogen Deposition Using AERMOD with 2030 Emissions Levels extrapolated to 2030 Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂ and Nitric Acid

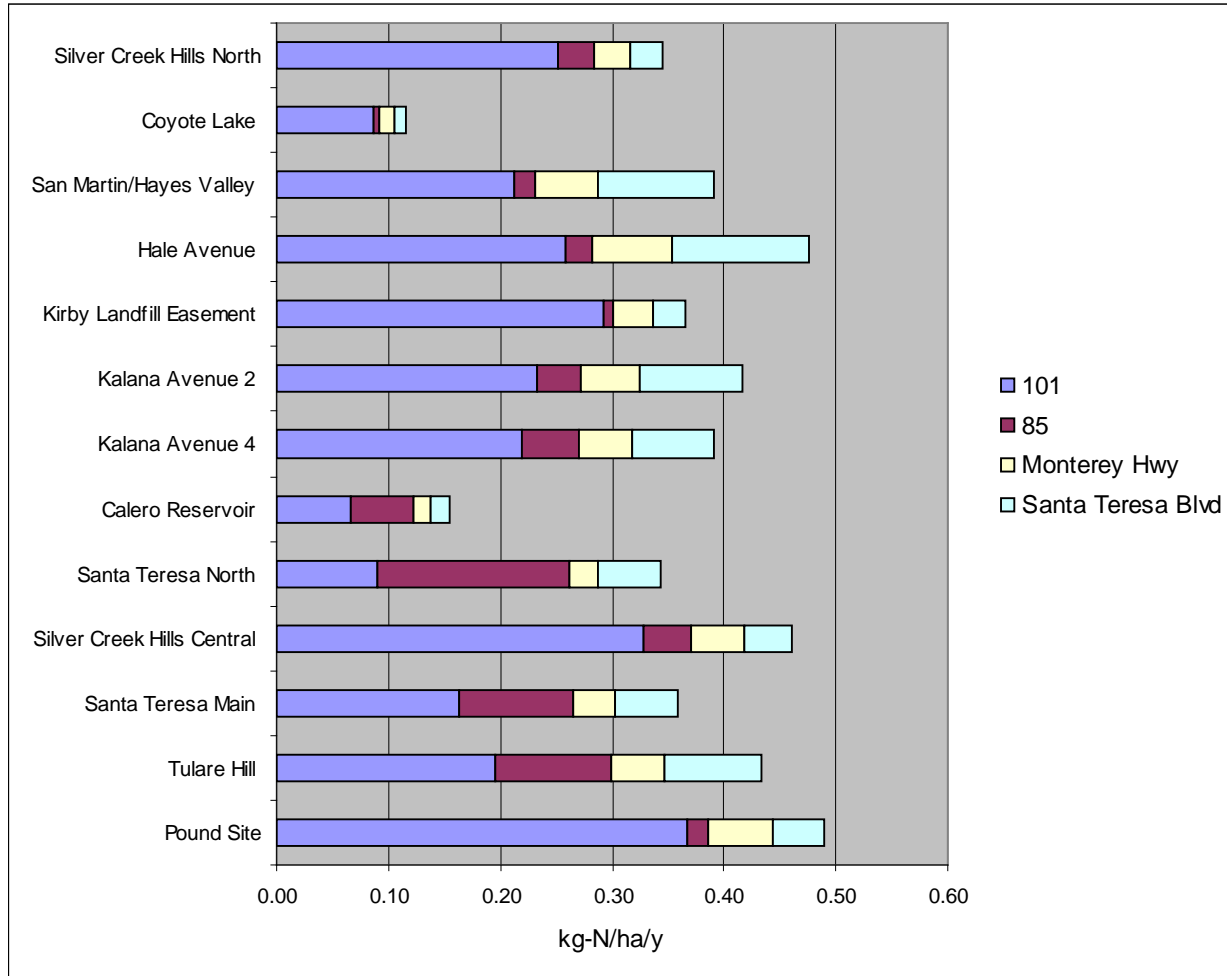


Table E-17. Simulated Annual Nitrogen Deposition Using AERMOD with Emissions Levels extrapolated to 2030 Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂ and Nitric Acid

Site	From US 101	From SR 85	From Monterey Hwy	From Santa Teresa Blvd	Total
Silver Creek Hills North	0.251	0.033	0.033	0.029	0.345
Coyote Lake	0.087	0.005	0.012	0.010	0.115
San Martin/Hayes Valley	0.212	0.019	0.055	0.104	0.391
Hale Avenue	0.259	0.024	0.071	0.122	0.476
Kirby Landfill Easement	0.293	0.009	0.036	0.027	0.365
Kalana Avenue 2	0.233	0.040	0.052	0.093	0.417
Kalana Avenue 4	0.220	0.051	0.048	0.073	0.391
Calero Reservoir	0.066	0.056	0.016	0.016	0.154
Santa Teresa North	0.089	0.172	0.026	0.056	0.343
Silver Creek Hills Central	0.329	0.042	0.047	0.042	0.460
Santa Teresa Main	0.163	0.103	0.037	0.056	0.359
Tulare Hill	0.195	0.104	0.048	0.086	0.434
Pound Site	0.367	0.019	0.058	0.046	0.490

The simulations using emissions extrapolated to 2060 result in the greatest increases for Santa Teresa Blvd. Maximum simulated deposition due to Santa Teresa Blvd. using AERMOD with these emissions is greater than 1.0 kg-N/ha/y (see Figure E-22 and Table E-18). (Please note the change in scale for the 2060 plots.) When deposition of nitric acid is included, the simulated deposition using AERMOD is considerably higher for Santa Teresa Blvd. than the CAL3QHCR simulations, reaching a maximum of more than 1.9 kg-N/ha/y (see Figure E-23 and Table E-19). The CAL3QHCR simulation results are higher for the next most important roadway in 2060, Highway 101. The reader is once again cautioned that the extrapolation of the emissions to 2060 may not be valid.

Figure E-22. Simulated Annual Nitrogen Deposition Using AERMOD with Emissions Levels extrapolated to 2060 Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂

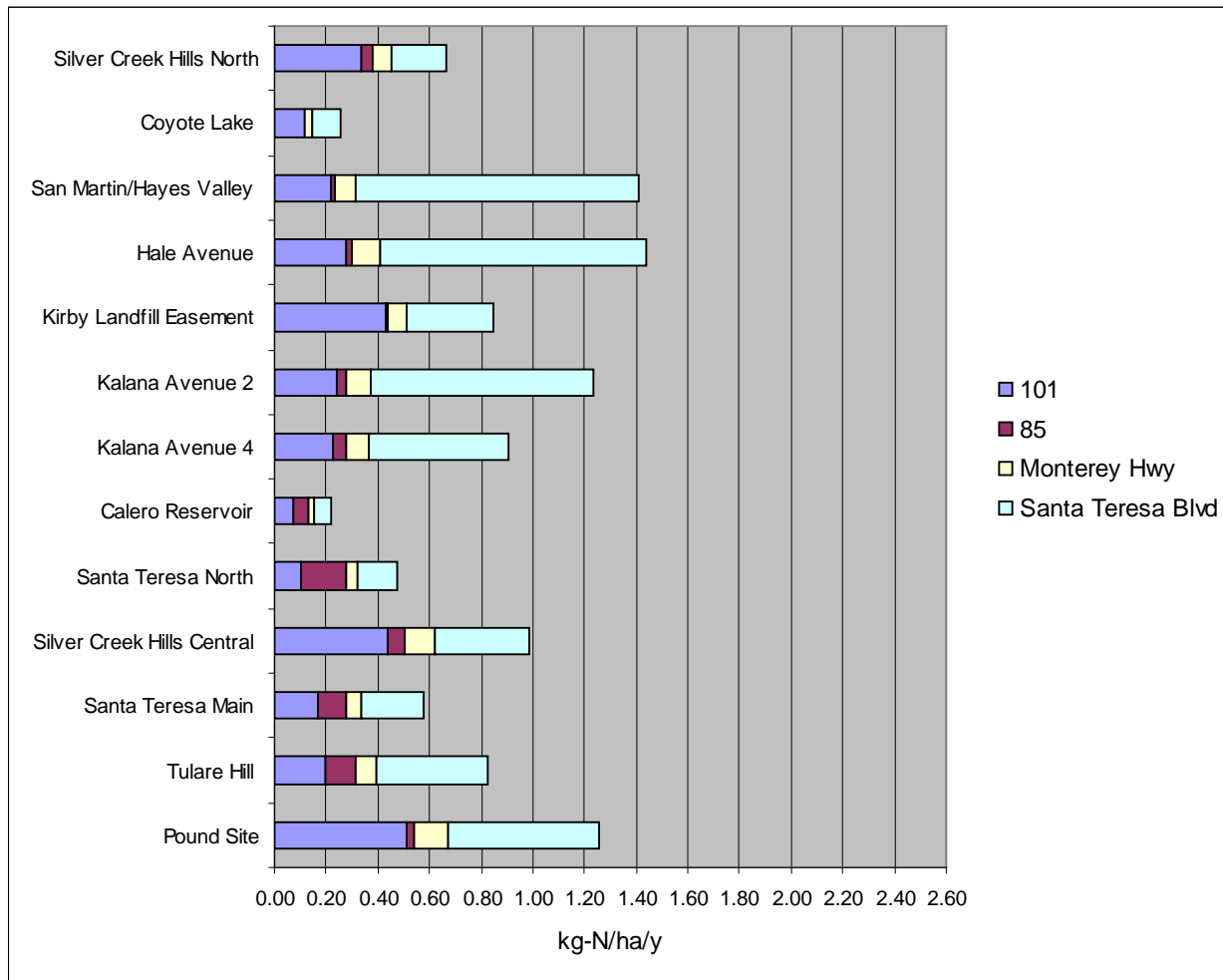


Table E-18. Simulated Annual Nitrogen Deposition Using AERMOD with 2060 Emissions Levels extrapolated to 2060 Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂

Site	From US 101	From SR 85	From Monterey Hwy	From Santa Teresa Blvd	Total
Silver Creek Hills North	0.335	0.048	0.072	0.210	0.665
Coyote Lake	0.114	0.006	0.025	0.112	0.258
San Martin/Hayes Valley	0.218	0.019	0.081	1.092	1.409
Hale Avenue	0.274	0.025	0.111	1.028	1.438
Kirby Landfill Easement	0.428	0.012	0.073	0.333	0.847
Kalana Avenue 2	0.240	0.041	0.092	0.864	1.237
Kalana Avenue 4	0.224	0.053	0.088	0.543	0.908
Calero Reservoir	0.072	0.057	0.026	0.063	0.218
Santa Teresa North	0.101	0.179	0.042	0.150	0.471
Silver Creek Hills Central	0.437	0.065	0.115	0.366	0.984
Santa Teresa Main	0.167	0.108	0.062	0.240	0.578
Tulare Hill	0.201	0.111	0.082	0.430	0.824
Pound Site	0.515	0.027	0.133	0.579	1.254

Figure E-23. Simulated Annual Nitrogen Deposition Using AERMOD with Emissions Levels extrapolated to 2060 Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂ and Nitric Acid

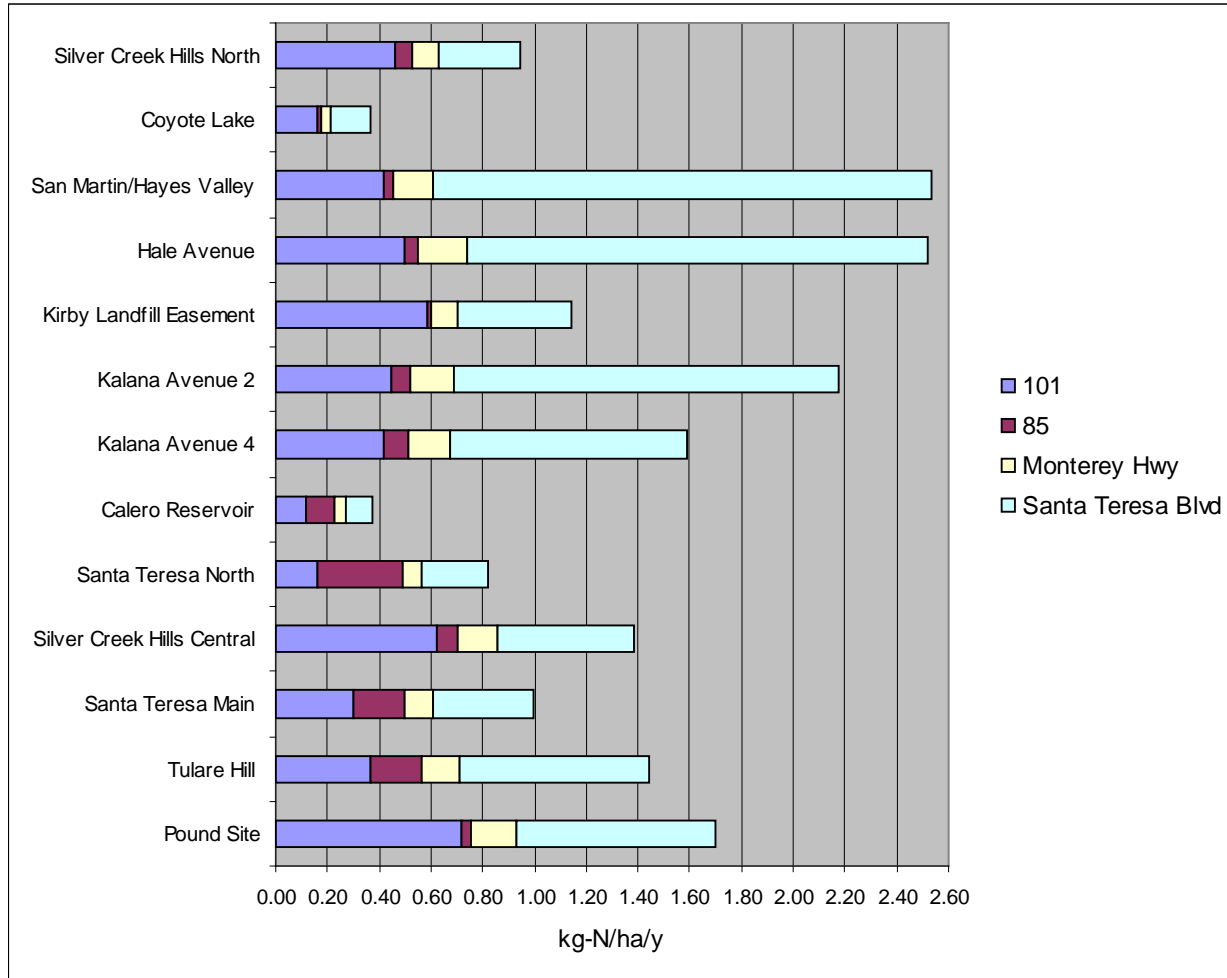


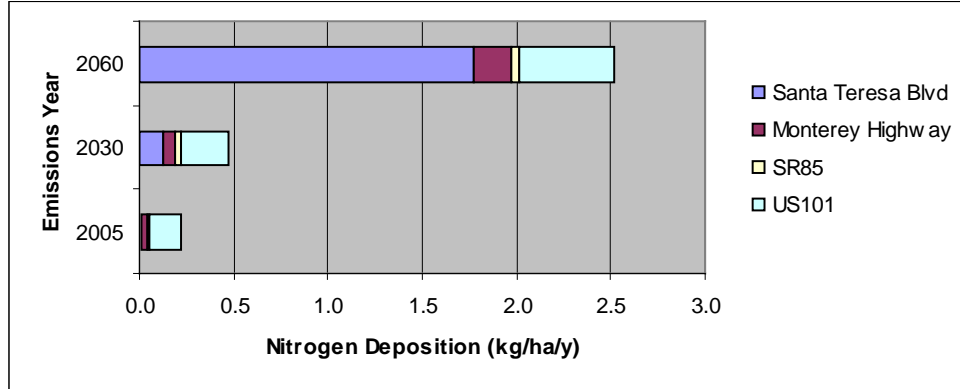
Table E-19. Simulated Annual Nitrogen Deposition Using AERMOD with Emissions Levels extrapolated to 2060 Averaged over Three Meteorological Years (2005, 2006, 2007) due to Deposition of NO₂ and Nitric Acid

Site	From US 101	From SR 85	From Monterey Hwy	From Santa Teresa Blvd	Total
Silver Creek Hills North	0.463	0.062	0.101	0.319	0.945
Coyote Lake	0.164	0.010	0.037	0.151	0.363
San Martin/Hayes Valley	0.415	0.037	0.153	1.932	2.537
Hale Avenue	0.501	0.045	0.196	1.775	2.517
Kirby Landfill Easement	0.586	0.017	0.100	0.441	1.144
Kalana Avenue 2	0.445	0.077	0.169	1.487	2.177
Kalana Avenue 4	0.416	0.098	0.160	0.917	1.591
Calero Reservoir	0.120	0.108	0.044	0.099	0.371
Santa Teresa North	0.161	0.330	0.071	0.256	0.818
Silver Creek Hills Central	0.621	0.081	0.156	0.526	1.384
Santa Teresa Main	0.300	0.198	0.109	0.390	0.997
Tulare Hill	0.364	0.200	0.145	0.733	1.442
Pound Site	0.715	0.037	0.176	0.772	1.699

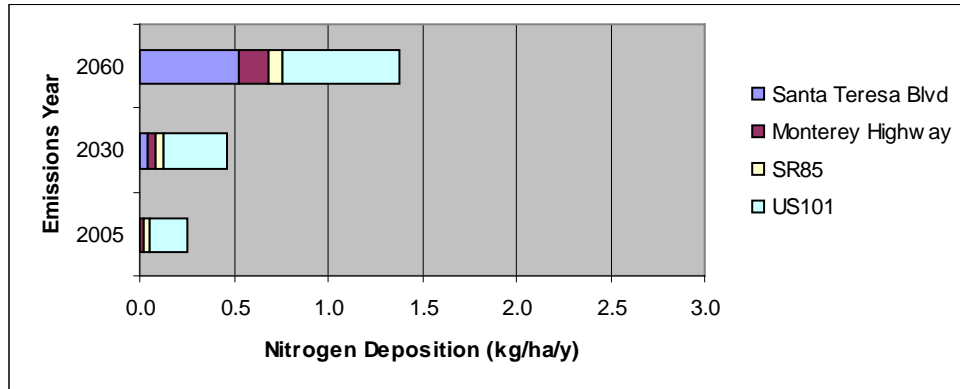
Summaries of the overall deposition simulated in the AERMOD simulations for the Hale Avenue, Silver Creek Hills Central, Santa Teresa Main, and Pound Site habitat areas are shown in Figures E-24a–d. Overall deposition is in general slightly higher than the simulated values from the CAL3QHCR simulations. There is, however, a larger increase in the AERMOD simulations due to the increase in traffic in the southern part of the domain than was predicted by the CAL3QHCR simulations. In the AERMOD simulations, the contributions to deposition at the Hale Avenue site from the simulated roadways are estimated to increase by a factor of more than 10 using the extrapolated 2060 emissions relative to the base year emissions.

Figures E-24a–d. Deposition Simulated Using AERMOD at Selected Habitat Sites for All Emissions Years, Including Deposition due to NO₂ and Nitric Acid

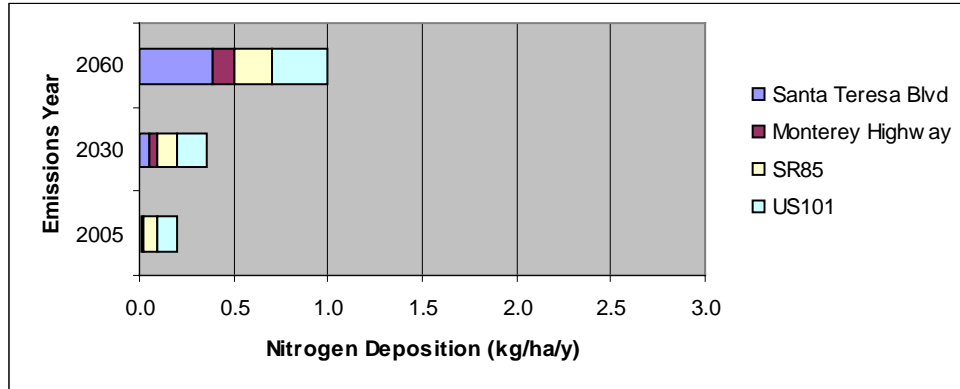
(24a) Hale Avenue



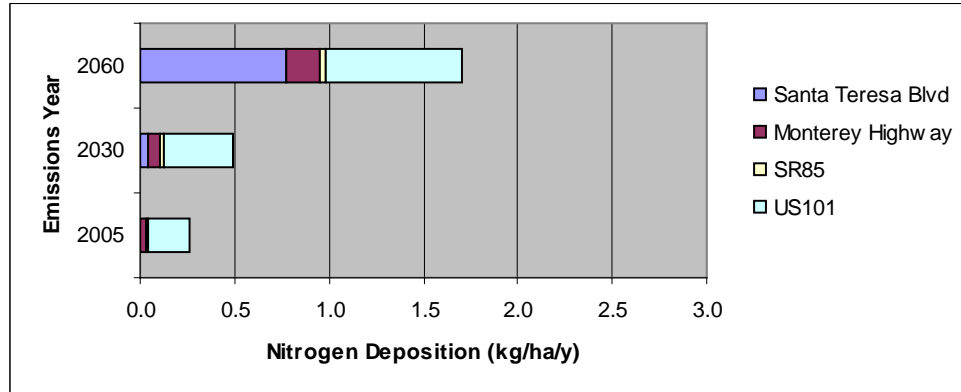
(24b) Silver Creek Hills Central



(24c) Santa Teresa Main



(24d) Pound Site



Summary of Gaussian Modeling Results

Two Gaussian models were applied: CAL3QHCR and AERMOD. Nitrogen deposition was calculated from the CAL3QHCR results using deposition velocities derived from AERMOD. AERMOD simulations included dry deposition. For both models, an additional calculation was made to estimate the effects of nitric acid formation on nitrogen deposition. The two Gaussian models produce deposition estimates that are of the same order of magnitude. Maximum deposition from Highway 101 is estimated to be on the order of 0.1 kg-N/ha/y to 0.2 kg-N/ha/y using 2005 emissions. Using emissions extrapolated to the future, estimated deposition is projected to increase considerably, particularly for the currently less traveled roadways. Nitrogen deposition estimates larger than 0.5 kg-N/ha/y were simulated for several roadway receptor combinations using future-year emissions. Ammonia deposition was not simulated using the Gaussian models. Given the nature of Gaussian models, the ammonia deposition will be (to the first order) a linear multiplier of the NO₂ results. However, the higher deposition velocity of NH₃ may lead to sharp roadside gradients. Areas close to US 101 in particular may be subject to larger deposition due to the effects of ammonia. NO_x deposition for the Coyote Ridge area may be inferred from the results for Pound Site and for Kirby Landfill. Note that these results include only the mobile source contribution from the highways modeled and do not represent overall deposition. Note also that these estimates include only deposition resulting from NO_x emissions and do not include ammonia deposition.

For particular roadways and emissions years, one or the other model may produce higher estimated deposition, but both models produce estimates substantially lower than the estimate from the ambient calculation and the CMAQ modeling estimates in the following section (on the order of 6 kg-N/ha/y).

CMAQ Modeling

This section describes the application of the CMAQ model to simulate nitrogen deposition in the study area. The CMAQ model is an EPA recommended model for regulatory air applications and includes state-of-the-science algorithms for transport, chemistry, deposition, particulate formation, and other atmospheric processes. CMAQ is a data intensive modeling system that requires vastly greater resources to run than the Gaussian models used in the previous sections. Application of CMAQ requires considerable specialized expertise.

Source Apportionment Methodology

ICF has recently enhanced the CMAQ model to include source attribution capabilities for ozone and particulate matter with the implementation of the Oxidant and Precursor Tagging Methodology (OPTM) and the PPTM. The tagging methods are designed to provide detailed, quantitative information about the *contribution* of selected sources, source categories, and/or source regions to simulated ozone and particulate matter 2.5 microns in diameter or less (PM_{2.5}) concentrations, respectively. Emissions of precursor pollutants from selected sources, source categories, or source regions are numerically tagged (i.e., labeled) and then independently tracked throughout a simulation. The contribution from each tag to the resulting simulated concentration of ozone, PM_{2.5}, or any of the PM_{2.5} component species for any given location within the CMAQ modeling domain can be quantified. By tracking the emissions from selected sources or source locations, the methodology also provides information on the fate of the emissions from these sources, including the contribution of each tagged source to deposition.

The tagging methodology differs from the use of air quality model sensitivity simulations in which the emissions are modified or eliminated (zeroed-out). Sensitivity simulations typically provide information about the effects of changes in the emissions on the simulation results. In contrast, tagging provides information about the contribution of the emissions from the tagged sources, relative to the unmodified simulated conditions. Identifying and quantifying source contributions from certain sources or source sectors can inform air quality planning and aid the identification of effective control strategies.

Applying CMAQ with PPTM provides the same estimate as a standard PPTM run for the overall concentration of each species, but in addition the amount of nitrogen originating from each tagged emissions source or category can be derived from the model outputs. For instance, the amount of nitrogen associated with motor vehicle emissions could be ascertained by setting up a tag of mobile source emissions.

PPTM is implemented in CMAQ with a level of detail consistent with the model. PPTM tracks individual species, taking into account different particle size modes and tracking changes at the process and subprocess level. For example, PPTM

has a separate tracer (or tag) for each nitrogen species (e.g., NO, NO₂, NO₃, N₂O₅) and each is advected as a separate species using the model algorithms. For sulfate, PPTM tracks each specific change in sulfate due to, for instance, the reaction sulfur dioxide (SO₂) with OH in the gas phase or the reaction with peroxide or ozone in the aqueous phase. PPTM tracks the changes separately for Aitken mode and accumulation mode aerosols. The level of detail is similar for all particulate matter components.

In this study, CMAQ/PPTM was used to quantify the contributions from selected source regions, which consist primarily of Santa Clara County and other neighboring San Francisco Bay Area (Bay Area) counties, to simulated deposition of nitrogen species to sensitive habitat areas in Santa Clara County.

Within the CMAQ model, PPTM requires the addition of duplicate model species variables for each source, source category, or source region that is to be tagged. The duplicated species may include PM-related sulfur, nitrogen, and secondary organic compounds, as well as primary organic carbon, elemental carbon, and other inorganic particulates. The tagged species have the same properties and are subjected to the same processes (e.g., advection, chemical transformation, deposition) as the actual (or base) species. For this study, the tagged species included all nitrogen species.

CMAQ numerically simulates the physical processes that determine the magnitude, temporal variation, and spatial distribution of the concentrations of each particulate species, including each tagged species. The simulation processes include advection, dispersion (or turbulent mixing), chemical transformation, cloud processes, and wet and dry deposition.

At each time step in the simulation, calculations are performed for the base species and the tagged species. Because the tagged species are separate from the base species, tagging does not alter or affect the base simulation results. The effects of linear processes, such as advection and dry deposition, are calculated directly for all tagged species. Potentially nonlinear processes, such as gas-phase chemistry, aqueous chemistry, and particle dynamics are calculated for the overall (or base) species and apportioned to the tagged species. The results for the tagged species are not normalized to ensure that the sum of the tagged species equals the total. Thus, the difference between the sum of all tags and the overall concentration gives an estimate of the numerical uncertainty in the contribution estimates. The tagged species are included as additional species in the model output files. A discussion of how PPTM is applied for each species and simulation process is provided in the user's guide (Douglas et al. 2007).

Modeling Databases

The habitat areas of interest in this study are located within an area of approximately 400 km². In order to distinguish the effects of sources local to the habitat areas from sources outside that area, a modeling database with a resolution on the order of 4 km is desirable. Databases with resolution more

resolved than 4 km are not available for this area. Resolution coarser than 4 km would make it difficult to resolve the area of interest and the emissions within that area. The identification of individual highways such as US 101 within the area surrounding the habitat is not attempted with the CMAQ modeling. The organization of emissions used in the CMAQ modeling does not allow the ready identification of individual roadways. Roadways are tagged collectively within Santa Clara County and within sub-areas of Santa Clara County. The effects of individual nearby roadways have been estimated using Gaussian models (see *Gaussian Modeling* section above).

CMAQ modeling databases for this study were acquired from CARB and from BAAQMD. The databases acquired from CARB included CMAQ-ready input files for an annual simulation of the year 2000 using a domain covering most of California. The results of this simulation were used solely to develop boundary conditions for a higher resolution simulation covering the Bay Area.

The BAAQMD provided a recently developed emissions inventory for the Bay Area counties. This inventory allowed preparation of CMAQ emissions files at 4-km resolution. For the portion of the modeling domain outside of Bay Area counties, emissions were derived from the model-ready files acquired from the CARB. Meteorological inputs for this domain were developed by CARB for a winter episode period covering December 17, 2000, through January 7, 2001, based on the California Regional PM10/PM2.5 Air Quality Study (CRPAQS) monitoring program. As a result of the limited availability of model-ready meteorological data, this was the only period modeled. A high-pressure system moved over central California late in the month of December. A front moved through during the period January 4–5, 2001. During the episode, therefore, the weather was dominated by high pressure. Winds were relatively light, and because it was winter, mixing heights were comparatively low. There was measurable rainfall in the San José area on only two days during the episode. The San José area is semi-arid and hence these conditions are fairly representative of average conditions in the area. Simulation of wet deposition is hindered by the lack of rainfall, but dry deposition is expected to dominate in this area due to the dry climate. Conversion of NO_x to nitric acid would likely be more rapid during summer months, but mixing heights would be higher which would dilute emissions more rapidly. These effects would apply to all source categories similarly, however, so estimates of relative contributions to deposition would not be greatly altered by the simulation of a longer time period. The modeling domain is shown in Figure E-25.

Figure E-25. Modeling Domain for the CMAQ Simulations



Emissions were prepared from the BAAQMD emissions inventory using standard emissions processing procedures and the SMOKE Modeling System⁵. This processing provided emissions for the portion of the modeling domain made up of the Bay Area counties. Bay Area biogenic emissions were prepared using the BEIS3 processor. An emissions inventory consistent with the SMOKE software was not available for the rest of the modeling domain. Therefore, the

⁵ SMOKE is a standard processing package used for preparation of emissions for CMAQ and other Eulerian grid models. For more information, see www.cmascenter.org.

CMAQ model ready emissions files acquired from the CARB were used to define emissions in any grid cell outside of the Bay Area.

Definition of Tags

Tags were defined to calculate the deposition from local sources in Santa Clara County, sources in the remainder of Santa Clara County, neighboring counties, and elsewhere in the modeling domain. The specific definitions of the tags are as follows.

Table E-20. Definition of Tags for Base-Year Modeling

Tag	Tag Description
Tag 1	Anthropogenic emissions originating in San Mateo County.
Tag 2	Anthropogenic emissions originating in Alameda County.
Tag 3	Anthropogenic emissions originating in Contra Costa County.
Tag 4	Anthropogenic emissions originating in San Francisco County.
Tag 5	Anthropogenic emissions originating in other Bay Area counties (Marin, Napa, Sonoma, and Solano).
Tag 6	Area source emissions for Santa Clara County originating in the Bay checkerspot butterfly habitat study area. (see Table E-9).
Tag 7	Mobile source emissions (road and nonroad) for Santa Clara County originating in the Bay checkerspot butterfly habitat study area.
Tag 8	Point source emissions for Santa Clara County originating in the Bay checkerspot butterfly habitat study area.
Tag 9	Anthropogenic emissions for Santa Clara County originating outside of the Bay checkerspot butterfly habitat study area (i.e., Santa Clara County emissions not included in Tags 6 through 8).
Tag 10	Initial and boundary concentrations for the 4-km modeling domain.
Tag 11	Biogenic emissions originating in the 8 Bay Area counties.
Tag 0	All emissions (anthropogenic and biogenic) for rest of the 4-km modeling domain not identified in tags 1–10.

The emissions for each tagged category are summarized in Table E-21. Although several different gaseous and particulate species are listed in the table, only the nitrogen containing species (NO_x, NH₃, and the particulate nitrate fraction of PM_{2.5}) were subject to the tagging treatment. For reference, the emissions originating in San José are presented in Table E-22. (These emissions can be compared to the emissions for 2030 which are presented in the future-year tagging section. See Table E-25 in that section.)

Table E-21. Emissions Summary for Base Year (Average Daily Emissions for the Episode Period)

Tag	Tag Description	CO (tpd ¹)	NO _x (tpd)	VOC (tpd)	NH ₃ (tpd)	SO ₂ (tpd)	PM2.5 (tpd)	PMC (tpd)
Tag 1	San Mateo County	244.7	71.4	45.8	6.4	11.9	9.0	10.2
Tag 2	Alameda County	483.6	149.3	101.0	10.7	4.2	18.1	21.9
Tag 3	Contra Costa County	397.5	93.8	95.9	10.7	23.4	22.1	16.5
Tag 4	San Francisco County	182.4	54.3	40.8	4.7	5.4	6.6	8.7
Tag 5	Other Bay Area Counties (Marin, Napa, Sonoma, and Solano)	482.6	96.3	117.6	22.4	21.2	26.0	26.1
Tag 6	Santa Clara County Area Source w/in study area	34.2	3.8	28.7	4.3	0.1	8.6	13.7
Tag 7	Santa Clara County Mobile Source w/in study area	205.3	39.8	22.7	1.4	0.4	1.3	0.4
Tag 8	Santa Clara County Point Source w/in study area	2.4	1.6	2.7	3.7	0.1	0.5	0.1
Tag 9	Santa Clara County, Non-Study Area	333.6	70.8	65.3	8.3	1.6	10.6	12.5
Tag 11	Bay Area 9 Counties Biogenic	28.6	8.9	127.9	0.0	0.0	0.0	0.0
Tag 0	Rest of Domain	8,693.1	1,971.1	1,724.6	569.9	123.5	665.9	1,626.8
Total		11,088.0	2,561.1	2,373.0	642.4	191.8	768.8	1,736.9

¹ tpd = Total daily emissions in tons per day.**Table E-22.** Emissions Summary for Base Year (Average Daily Emissions for the Episode Period) for San José Sources

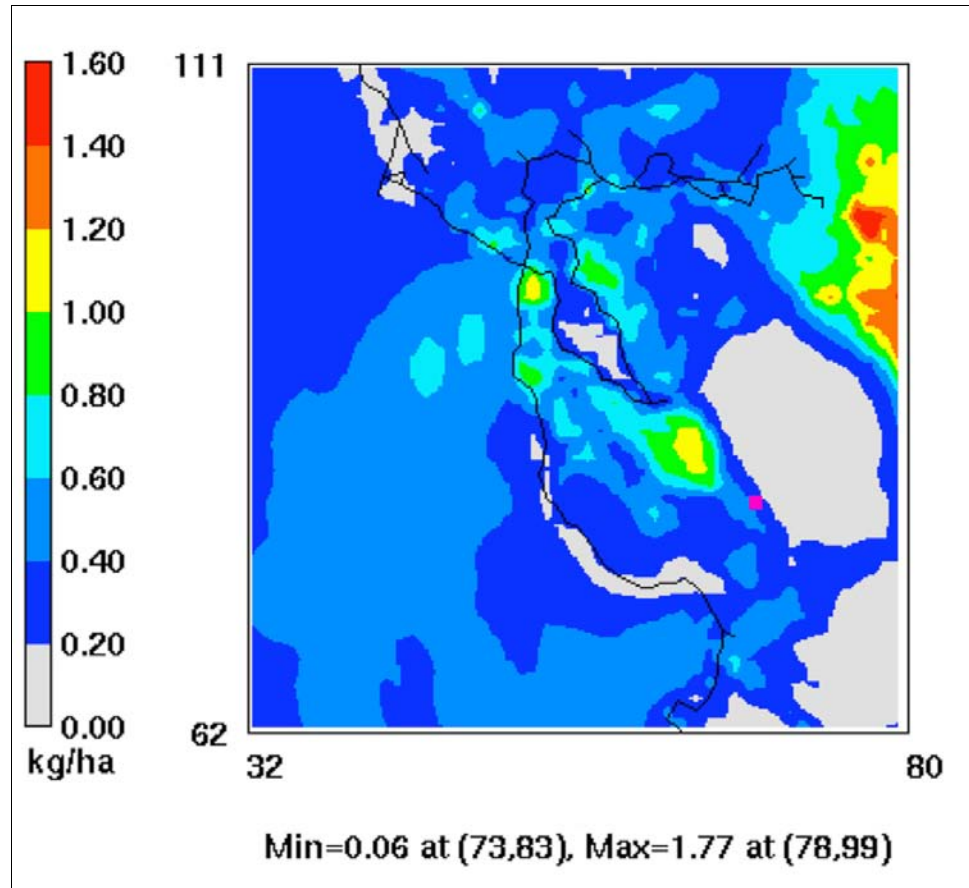
Description	CO (tpd ¹)	NO _x (tpd)	VOC (tpd)	NH ₃ (tpd)	SO ₂ (tpd)	PM2.5 (tpd)	PMC (tpd)
San José Area Source	19.4	3.0	14.9	2.5	0.1	4.8	7.7
San José Mobile Source	159.8	30.7	17.4	1.1	0.3	1.0	0.3
San José Point Source	2.2	1.3	2.0	1.5	0.1	0.4	0.1

¹ tpd = Total daily emissions in tons per day.

Simulation Results

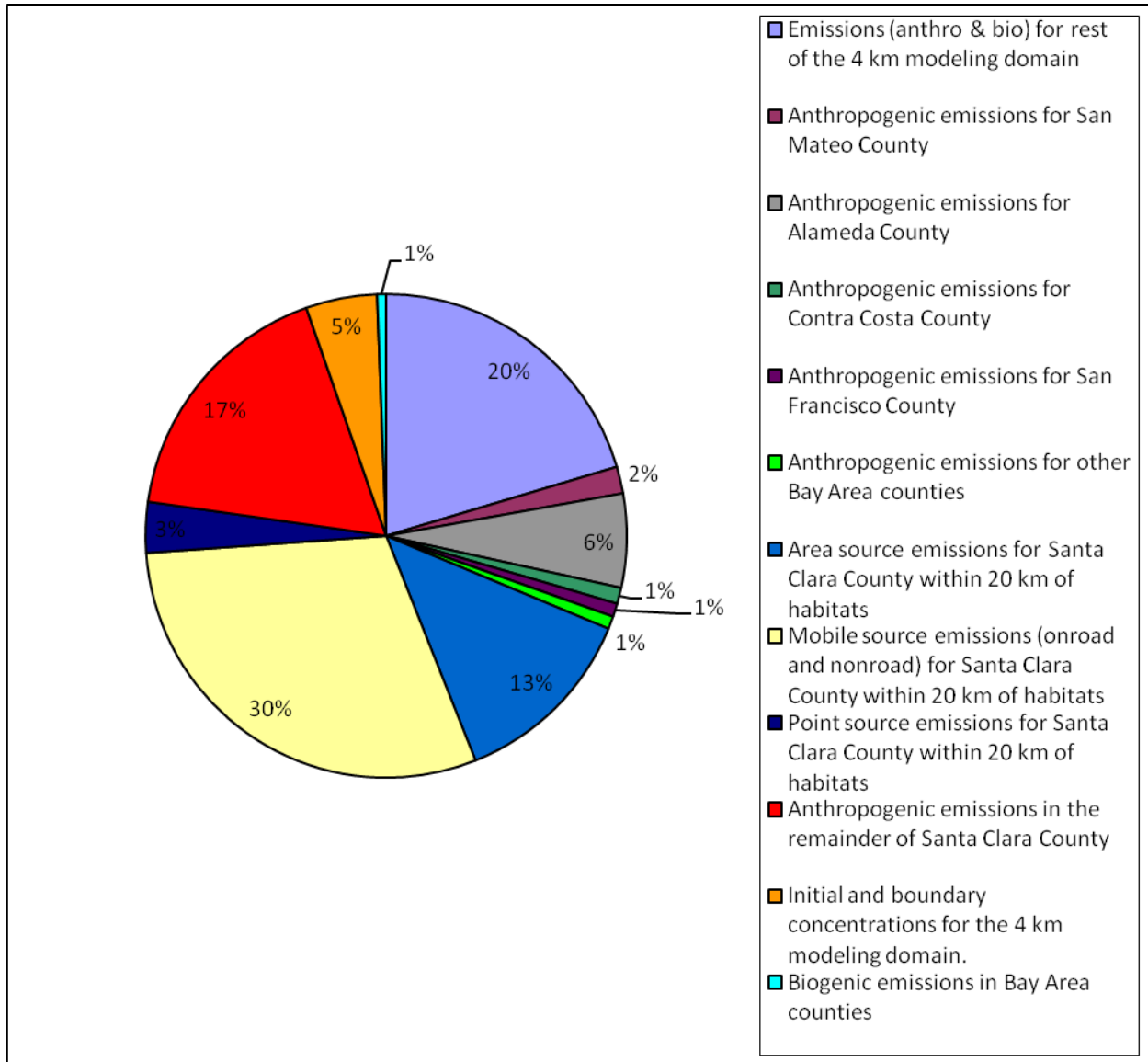
The simulated total nitrogen deposition (wet and dry combined) plot for the 22-day episode from December 17, 2000, through January 7, 2001, is presented in Figure E-26. This display presents a portion of the Bay Area which does not include the entire 185-by-185 grid cell modeling domain. The distribution shows peaks in deposition around the urban areas in the domain, including the San José area in the southern part of the Bay Area. These results are generally consistent with results from other studies such as Tonnesen and others (2007). It must be kept in mind, however, that these studies used different emission inventories and meteorological data files. The modeling also covered different time periods.

Figure E-26. Simulated Total Nitrogen Deposition (Wet and Dry) for the 22-Day Episode December 17, 2000 through January 7, 2001



The CMAQ simulation using PPTM provides estimates of the nitrogen deposition from each of the tagged sources of nitrogen listed in the previous section. Nitrogen deposition in all forms (ammonium, particulate nitrate, gaseous species such as NO, NO₂, etc.) is included in the simulation, but, in the summaries provided here, species have been combined into overall total nitrogen. For the episode period simulated, the sources contributing to nitrogen deposition in the vicinity of Bay checkerspot butterfly habitats are summarized in Figure E-27. It should be noted that because the resolution of the model run is 4 km, the summary does not provide a deposition estimate specifically for the habitat area but rather an average over a 16 km² area that includes both habitat area and surroundings. In this case, we refer to the specific grid cell centered at latitude 37.19 N and longitude 121.68 W, which is marked on the map by a pink square.

Figure E-27. Simulated Contributions from Tagged Sources of Nitrogen Deposition in the Vicinity of Bay Checkerspot Butterfly Habitat (grid cell at latitude 37.19 N and longitude 121.68 W)



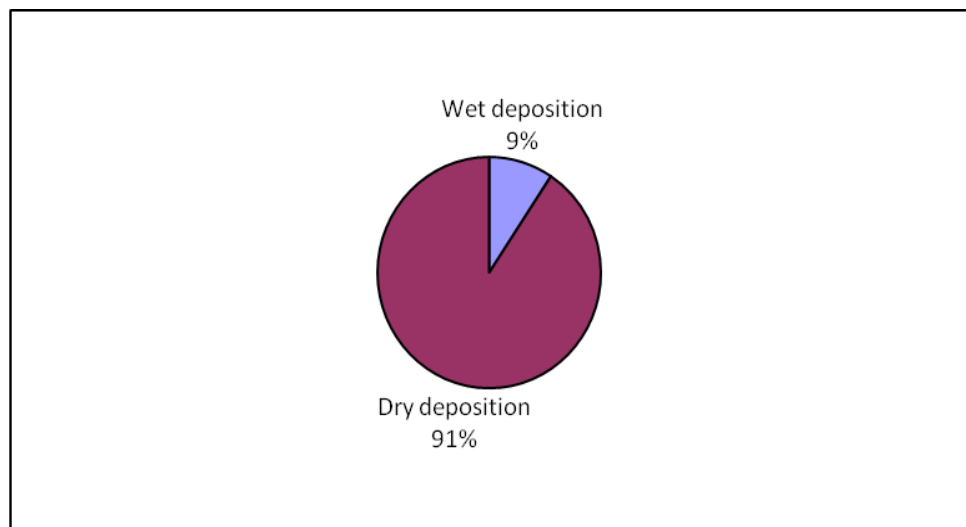
The simulated contributions to nitrogen deposition are spread across many different source categories, but the most important category is mobile source emissions in the vicinity of the habitat areas, contributing almost one-third of the total nitrogen deposition. Other source categories in the vicinity of the habitat also contribute to the total, with 13% coming from area sources within about 20 km of the habitat and 3% from point sources within about 20 km of the habitat. Sources in the remainder of Santa Clara County other than those near the habitat area contribute another 17% to the total nitrogen deposition. When all sources in Santa Clara County are considered, therefore, more than 60% of the total nitrogen deposition is accounted for.

Of the sources outside of Santa Clara County, the largest contributor at 20% is the tag representing sources in the modeling domain that are not in one of the Bay Area counties. This tag includes emissions from most of California (other than the Bay Area counties) except for a portion of southern California. This tag also includes a portion of Nevada.

Bay Area counties other than Santa Clara also contribute to nitrogen deposition in the habitat area. The contributions range from less than 1% (northern Bay Area counties are tagged collectively as other Bay Area counties) to 6% for Alameda County in this episodic simulation. Each of the other tagged counties (San Francisco, San Mateo, and Contra Costa) contributes 1–2% of the nitrogen deposition. The contributions simulated here for these individual counties could be dependent on the meteorological conditions during the episode that was simulated, and the relative contributions among these counties might vary for other time periods.

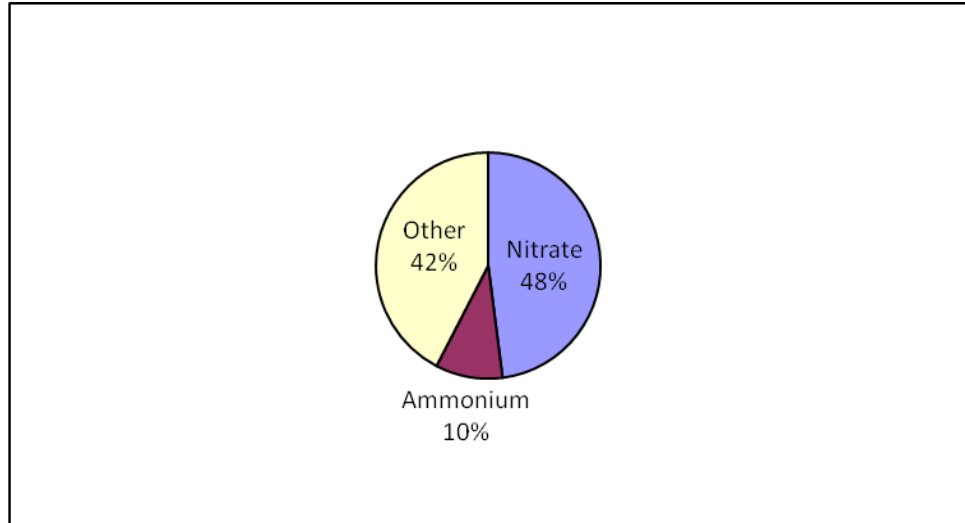
Figure E-28 shows the breakdown between simulated wet and dry deposition of nitrogen in the vicinity of the habitats. Deposition is dominated by dry deposition, which is consistent with the observed rainfall data during the episode period. Only two days during the episode had measurable rainfall. Annual deposition would likely be dominated by dry deposition, so the limited rainfall is not detrimental to our interpretation of the contributors to nitrogen deposition. Tonnesen et al. (2007) conducted annual CMAQ modeling that included the San José area. Tonnesen's simulations indicate annual dry deposition of between 47 and 811 kg-N/ha/y with less than 2 kg-N/ha/y of wet deposition. Monthly plots presented in their reports show a ratio of dry to wet deposition of at least 4:1 in January and at least 10:1 in July.

Figure E-28. Relative Contributions of Wet and Dry Deposition to the Total Nitrogen Deposition in the Vicinity of Bay Checkerspot Butterfly Habitat



The simulated contribution of various species to total nitrogen deposition in the vicinity of the habitats is summarized in Figure E-29. Nearly half of the deposition is from nitrate (including both particulate nitrate and nitric acid) with about 10% from ammonium. The remainder comes from other nitrogen species such as gaseous dry deposition of NO and NO₂.

Figure E-29. Simulated Contributions of Species to Total Nitrogen Deposition in the Vicinity of Bay Checkerspot Butterfly Habitat



Because this is an episodic simulation, it does not directly provide an estimate of annual total nitrogen deposition. For the episode period (22 days), the simulated nitrogen deposition in the vicinity of the habitats is 0.40 kg-N/ha. In order to compare to other studies, we can scale this to a per annum figure by multiplying by the ratio of the number of days in a year to the 22 days in our simulation. This scaling yields an estimate of 6.6 kg-N/ha/y for the 16 km² area around Coyote Ridge. Other modeling estimates of deposition in the area such as *Impacts of Nitrogen Deposition on California Ecosystems and Biodiversity* (Weiss 2006), which conducted CMAQ modeling at 36-km resolution, present annual deposition estimates of a similar magnitude (6 kg-N/ha/y in the South Bay). The annual estimate of 6.6 kg-N/ha/y is also consistent with the estimate made on page 25 (5.9–6.4 kg-N/ha/y) in the section on Gaussian modeling based on current ambient NO₂ concentrations in the San José area. As noted above, the 4-km resolution CMAQ modeling by Tonnesen et al. (2007) showed nitrogen deposition in the range of 7–11 kg-N/ha/y.

Future-Year Simulations

Projections were made for two future years for simulation with CMAQ: 2035 and 2060. The year 2035 was used because that is farthest out that the Association of Bay Area Governments projects population growth in the study area and the Bay Area. The year 2060 was used as the estimate of the end of the permit term for

the Santa Clara Valley Habitat Plan. The year 2060 thus represents the final “build out” in the study area of urban and rural development covered by the Habitat Plan.

Extrapolations of emissions were made for each of the Bay Area counties, for Santa Clara County minus the study area, for the San José area, and for the study area minus the San José area based on projected population growth. Projected population growth for 2035 for the each of the counties and for the San José area (includes the San José sphere of influence) was taken from the Association of Bay Area Governments *Projections 2007: Forecasts for the San Francisco Bay Area to the Year 2035* (Association of Bay Area Governments 2006). Projected population growth for the study area was derived from census tract-level data provided by the Association of Bay Area Governments *Projections 2007* data. Tracts that fell entirely within the study area were fully included, and tracts that fell partially inside the study area were divided proportional to the amount of tract falling within the study area. Population projections for Santa Clara County minus the study area and for the study area minus the San José area were derived by subtraction of the study area population from the total population of Santa Clara County and by subtraction of the San José area from the study area population, respectively. All 2060 populations were calculated by identifying the annual average rate of population change from 2010 to 2035 and extrapolating out to 2060. The assumed growth projections are shown in Table E-23.

Table E-23. Growth Factors for Bay Area Counties Used to Extrapolate Emissions to 2035 and 2060

County	2035 Growth Factor	2060 Growth Factor
Alameda	1.34	1.60
Contra Costa	1.37	1.62
Marin	1.14	1.24
Napa	1.25	1.38
San Francisco	1.23	1.42
San Mateo	1.22	1.39
Solano	1.48	1.82
Sonoma	1.24	1.37
Santa Clara County Minus Study Area	1.29	1.50
San José Projection	1.51	1.90
Study Area Minus San José	1.34	1.45

Source for 2035 projections: Association of Bay Area Governments 2006.

The area and mobile sources within each county were extrapolated. Point source growth was not projected because the supply of increased power demands due to factors such as population growth and increases in industrial activity would not necessarily be distributed proportionally to the increases in population. In addition, point sources were already estimated to be one of the smaller contributors to nitrogen deposition compared to mobile and area sources. Because a detailed emissions inventory outside of the Bay Area was not

available, projections were not made for other areas of the domain. The emissions outside of the Bay Area therefore remain at the base level in the future-year simulations. For this reason, and because the mobile source and area source projections do not take into account improvements in emissions control technologies or regulatory actions, the contributions estimated in this analysis may overestimate the role of local area and local mobile sources in the future. It is not clear whether overestimates of local increases in the total future nitrogen deposition might be offset by underestimates of increases due to sources outside of the Bay Area.

The tags for the future-year simulations were redefined in order to differentiate San José from the remainder of Santa Clara County. The tags used in the future-year simulations are shown below.

Table E-24. Tag Definitions for Future-Year (2035 and 2060) Simulations

Tag	Tag Description
Tag 1	Anthropogenic emissions originating in San Mateo County.
Tag 2	Anthropogenic emissions originating in Alameda County.
Tag 3	Anthropogenic emissions originating in Contra Costa County.
Tag 4	Anthropogenic emissions originating in San Francisco County.
Tag 5	Anthropogenic emissions originating in other Bay Area counties (Marin, Napa, Sonoma, and Solano).
Tag 6	Area source emissions originating in San José area.
Tag 7	Mobile source emissions (road and nonroad) originating in San José area.
Tag 8	Point source emissions originating in San José area.
Tag 9	Anthropogenic emissions originating in Santa Clara County minus study area.
Tag 10	Area source emissions originating in (non–San José) study area.
Tag 11	Biogenic emissions originating in Bay Area counties.
Tag 12	Mobile source emissions (road and nonroad) originating in (non–San José) study area.
Tag 13	Point source emissions originating in (non–San José) study area.
Tag 14	Initial and boundary concentrations for the 4-km modeling domain.
Tag 0	Emissions (anthropogenic and biogenic) for rest of the 4-km modeling domain.

The extrapolated future-year emissions are summarized in Tables E-25 and E-26 for 2035 and 2060, respectively.

Table E-25. Emissions Summary for 2035 (Average Daily Emissions for the Episode Period)

Tag	Tag Description	CO (tpd)	NO _x (tpd)	VOC (tpd)	NH ₃ (tpd)	SO ₂ (tpd)	PM2.5 (tpd)	PMC (tpd)
Tag 1	San Mateo County	298.0	86.8	55.2	7.7	14.5	10.9	12.5
Tag 2	Alameda County	648.3	199.0	132.6	14.2	5.3	23.8	29.2
Tag 3	Contra Costa County	541.4	121.9	126.9	13.9	24.1	29.0	22.4
Tag 4	San Francisco County	224.4	66.4	49.9	5.8	6.6	8.1	10.7
Tag 5	Other Bay Area Counties (Marin, Napa, Sonoma, and Solano)	614.1	123.0	169.1	27.4	22.0	32.7	34.0
Tag 6	San José Area Source	29.2	4.5	22.5	3.8	0.1	7.2	11.6
Tag 7	San José Mobile Source	241.4	46.3	26.3	1.6	0.4	1.5	0.5
Tag 8	San José Point Source	2.2	1.3	2.0	1.5	0.1	0.4	0.1
Tag 9	San Clara Non–Study Area	425.6	89.3	82.9	10.0	1.8	13.5	16.0
Tag 10	Non–San José Area Source	19.8	1.1	18.4	2.4	0.1	5.1	8.1
Tag 12	Non–San José Mobile Source	60.9	12.2	7.1	0.4	0.1	0.4	0.1
Tag 13	Non–San José Point Source	0.2	0.3	0.7	2.2	0.0	0.1	0.0
Tag11	Bay Area 9 Counties Biogenic	28.6	8.9	127.9	0.0	0.0	0.0	0.0
Tag 0	Rest of Domain	8,693.1	1,971.1	1,724.6	569.9	123.5	665.9	1,626.8
Total		11,827.2	2,732.0	2,546.1	660.7	198.6	798.7	1,771.9

Table E-26. Emissions Summary for 2060 (Average Daily Emissions for the Episode Period)

Tag	Tag Description	CO (tpd)	NO _x (tpd)	VOC (tpd)	NH ₃ (tpd)	SO ₂ (tpd)	PM2.5 (tpd)	PMC (tpd)
Tag 1	San Mateo County	339.5	98.8	62.5	8.7	16.5	12.3	14.2
Tag 2	Alameda County	770.5	235.9	156.1	16.7	6.1	28.1	34.6
Tag 3	Contra Costa County	638.9	140.9	147.9	16.1	24.5	33.7	26.4
Tag 4	San Francisco County	259.0	76.3	57.4	6.6	7.6	9.3	12.4
Tag 5	Other Bay Area Counties (Marin, Napa, Sonoma, and Solano)	694.4	139.7	190.3	30.5	22.6	36.8	38.9
Tag 6	San José Area Source	36.7	5.6	28.2	4.8	0.2	9.1	14.6
Tag 7	San José Mobile Source	303.1	58.2	33.0	2.0	0.5	1.9	0.6
Tag 8	San José Point Source	2.2	1.3	2.0	1.5	0.1	0.4	0.1
Tag 9	San Clara Non–Study Area	495.4	103.4	96.2	11.3	2.0	15.6	18.6
Tag 10	Non–San José Area Source	21.5	1.2	20.0	2.6	0.1	5.5	8.8
Tag 12	Non–San José Mobile Source	66.1	13.2	7.7	0.4	0.1	0.5	0.1
Tag 13	Non–San José Point Source	0.2	0.3	0.7	2.2	0.0	0.1	0.0
Tag11	Bay Area 9 Counties Biogenic	28.6	8.9	127.9	0.0	0.0	0.0	0.0
Tag 0	Rest of Domain	8,693.1	1,971.1	1,724.6	569.9	123.5	665.9	1,626.8
Total		12,349.3	2,854.8	2,654.7	673.2	203.7	819.2	1,796.1

The overall simulated nitrogen deposition for the future simulations is displayed in Figure E-30 for 2035 and Figure E-31 for 2060. Note the increases in deposition in the Bay Area counties relative to the base simulation in Figure E-32. Deposition in other portions of the domain is relatively unaffected by the changes in Bay Area emissions.

Figure E-30. Simulated Total Nitrogen Deposition (Wet and Dry) for the 22-Day Episode December 17, 2000 through January 7, 2001 Using Bay Area Emissions Extrapolated to 2035

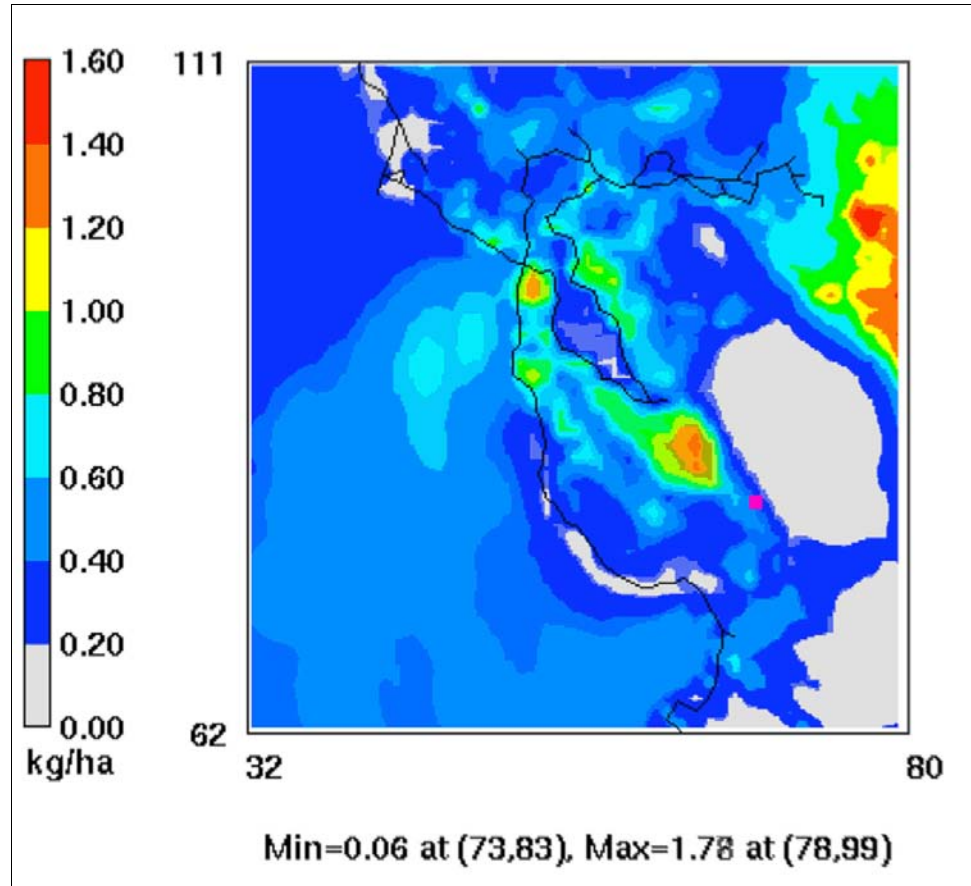
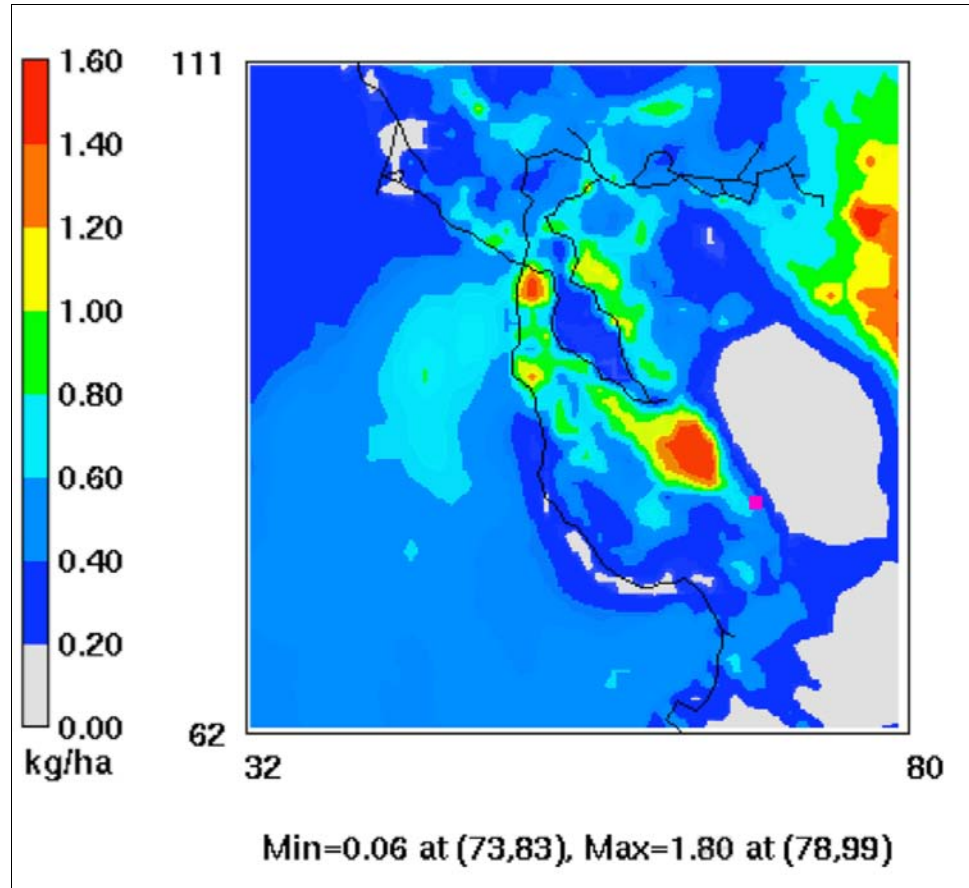


Figure E-31. Simulated Total Nitrogen Deposition (Wet and Dry) for the 22-Day Episode December 17, 2000 through January 7, 2001 Using Bay Area Emissions Extrapolated to 2060



For the episode period (22 days), the simulated nitrogen deposition in the vicinity of the habitats is 0.50 kg-N/ha in the 2035 simulation and 0.58 kg-N/ha in the 2060 simulation. These represent 25% and 45% increases relative to the base year. Scaled to per annum figures, these give 8.3 kg-N/ha/y in 2035 and 9.6 kg-N/ha/y in 2060.

Simulated contributions from the projected source categories in Santa Clara County to deposition are summarized in Figure E-32 for the base year (2005), 2035, and 2060. Deposition from each of the projected categories increases by about 30% in 2035 relative to the base and by about 50% in 2060 relative to the base. These increases are consistent with the extrapolated increases in emissions for these categories of sources. Similarly, the Bay Area counties other than Santa Clara (see Figure E-33) show increases in deposition in proportion to the increases in emissions.

In the base-year simulation, Santa Clara County sources within the study contributed 46% of the nitrogen deposition. This contribution increases to 49% in

2035 and 51% in 2060. The contributions from other Bay Area counties remain at about the same percentages as in the base year, while the percent contribution from sources outside of the Bay Area decreases to about 15% by 2060. Note that no growth was estimated for emissions outside of the Bay Area, so given the increase in Bay Area emissions, the relative contribution from sources outside the Bay Area would go down. It is therefore not known if these other sources would keep pace with the growth in Bay Area counties or not.

Figure E-32. Simulated Contributions from Tagged Sources to Nitrogen Deposition in the Vicinity of the Santa Clara County Bay Checkerspot Butterfly Habitat for the Santa Clara County Emission Categories (kg-N/ha/day)

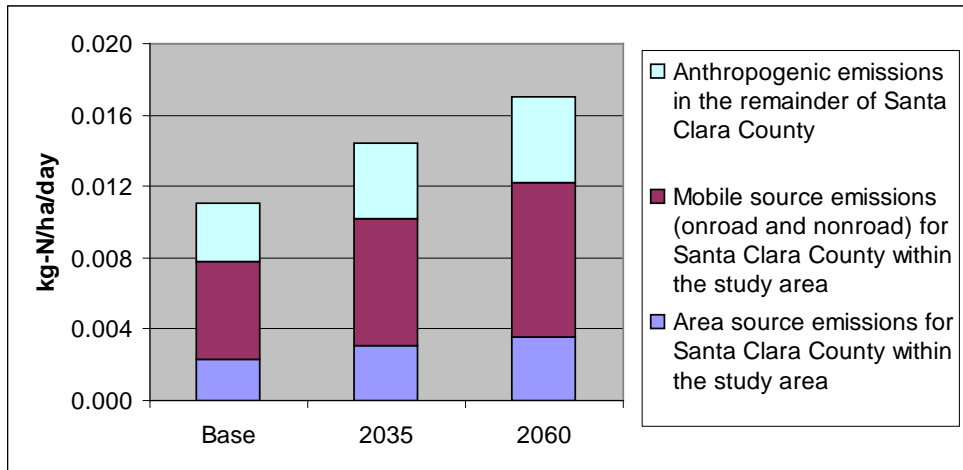
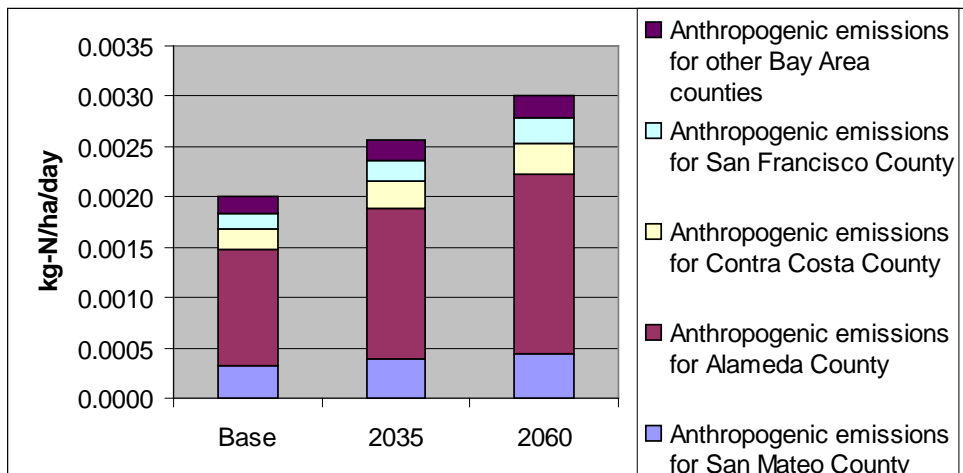
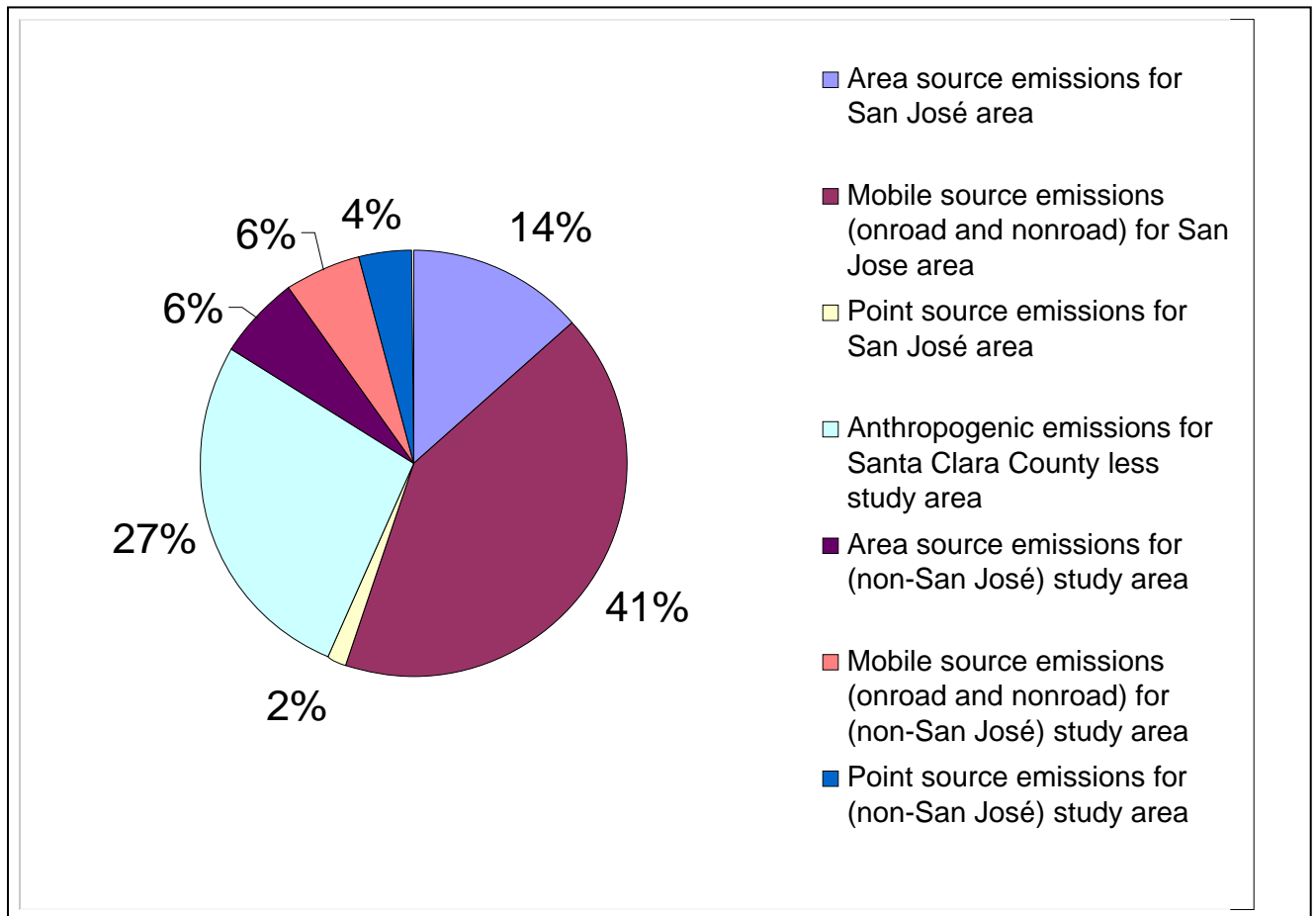


Figure E-33. Simulated Contributions from Tagged Sources to Nitrogen Deposition in the Vicinity of the Santa Clara County Bay Checkerspot Butterfly Habitat for the tagged Bay Area counties (kg-N/ha for the 22-Day Episode Period)



The tags included in the base year simulation did not treat San José sources separately from other sources. In the future-year simulations, tags were added to separate San José emissions from other Santa Clara County emissions within the study area. The simulated contributions of these separate categories of sources are presented in Figure E-34. San José area sources, point sources and mobile sources combined, account for 57% of the nitrogen deposition within the Santa Clara County share of deposition. Of all nitrogen deposition sources (inside and outside Santa Clara County), San José point and mobile sources account for 38% of nitrogen deposition in 2035. Other areas within the study area account for 16% of the nitrogen deposition while the portion of Santa Clara County outside of the study area accounts for 27% of the nitrogen deposition. These relative contributions remain essentially unchanged in the 2060 simulation.

Figure E-34. Simulated Relative Contributions from Separate Santa Clara Source Categories to the Santa Clara County Share of Nitrogen Deposition in 2035⁶



⁶ Impacts on nitrogen deposition from Morgan Hill and Gilroy were not explicitly identified in our modeling, but are part of the contribution referred to as the remainder of Santa Clara County. See discussion on p. 68 regarding impacts from these cities.

The relative contribution of wet versus dry deposition and from various species is similar in the future-year simulations relative to the base-year simulations (Figures E-35 through E-38). This is to be expected because the relative contributions of wet and dry deposition is driven by meteorological conditions during the period simulated. The distribution among species in the emissions files would be relatively unchanged in the future-year simulations because emissions of all species were extrapolated based on the same factors.

Figure E-35. Relative Contributions of Wet and Dry Deposition to the Total Nitrogen Deposition in the Vicinity of the Santa Clara County Bay Checkerspot Butterfly Habitat in the 2035 Simulation

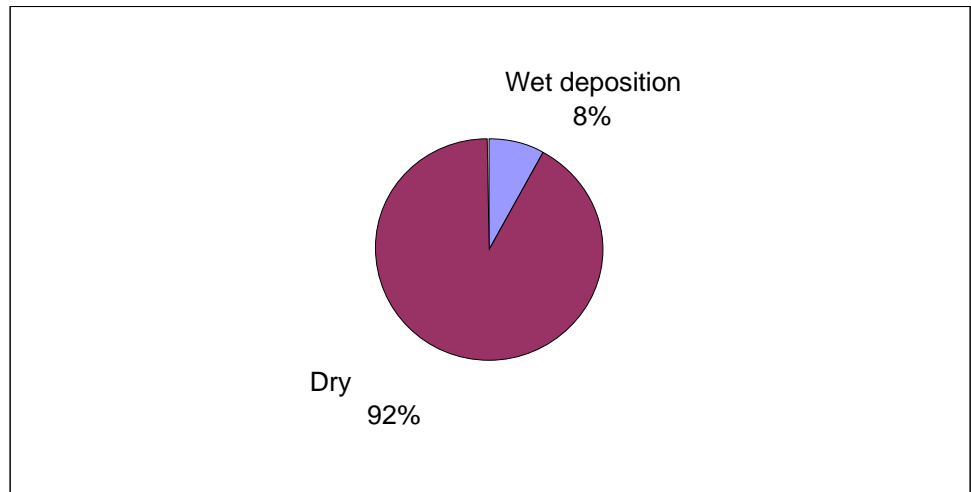


Figure E-36. Relative Contributions of Wet and Dry Deposition to the Total Nitrogen Deposition in the Vicinity of the Santa Clara County Bay Checkerspot Butterfly Habitat in the 2060 Simulation

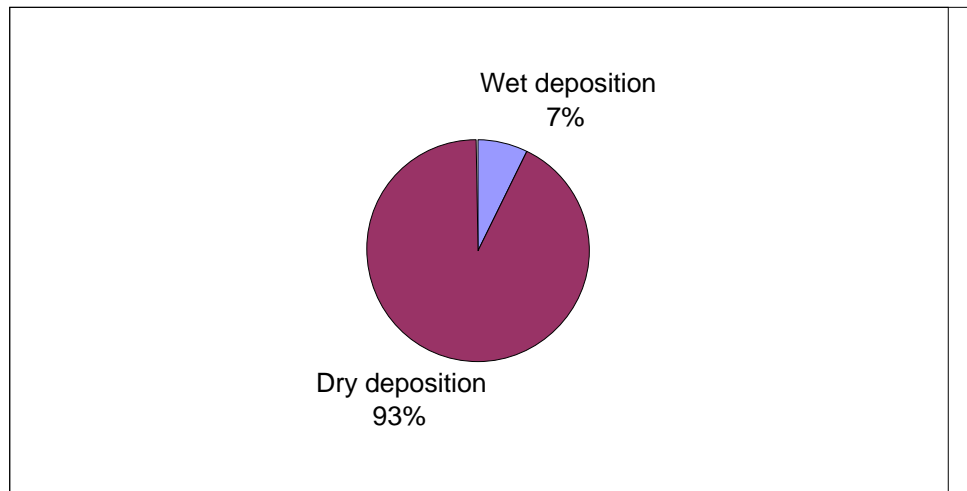


Figure E-37. Simulated Contributions of Species to Total Nitrogen Deposition in the Vicinity of the Santa Clara County Bay Checkerspot Butterfly Habitat in the 2035 Simulation

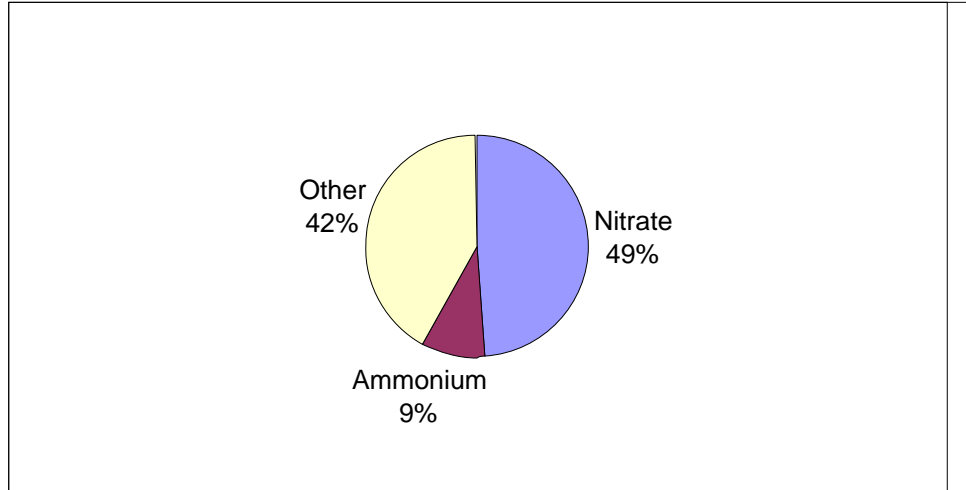
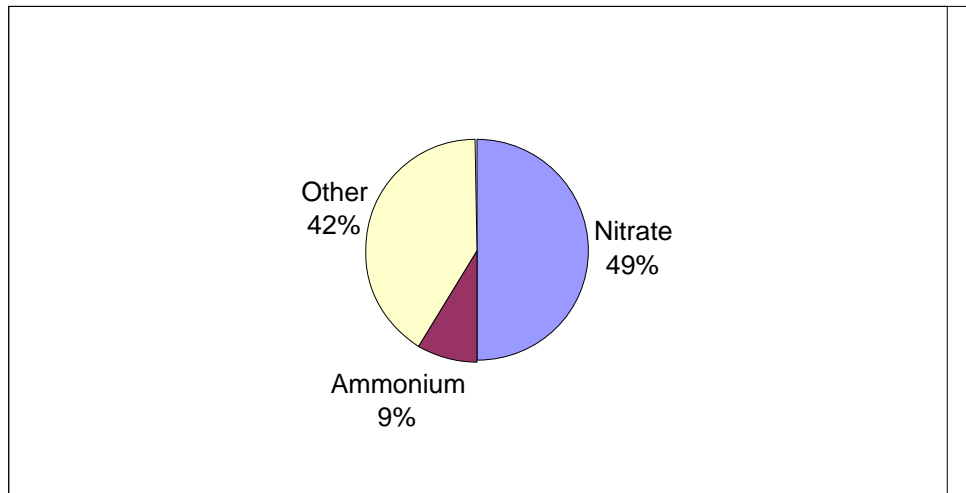


Figure E-38. Simulated Contributions of Species to Total Nitrogen Deposition in the Vicinity of the Santa Clara County Bay Checkerspot Butterfly Habitat in the 2060 Simulation



Limitations and Uncertainty

Before considering the analytical approaches available to determine the effects of nitrogen deposition, one must understand the uncertainties associated with these methods. The amount and location of nitrogen deposition depends on many factors, which can be difficult to characterize precisely. Rates of nitrogen deposition vary with the location of nitrogen sources and the amount and

chemical form of nitrogen they emit, as well as on meteorological conditions (e.g., prevailing wind direction, precipitation), topography, and vegetation structure. The location, amount, and type of nitrogen emissions in the study area in the future are difficult to predict and characterize because of the complex combination of additional point and mobile emission sources that will result from urban and rural development and road construction under the Habitat Plan. An important example is the uncertainty of additional automobile emissions, which would be the primary source of new nitrogen deposition in the study area as a result of covered activities.

Emissions per vehicle can be expected to decrease over time as technology and emissions standards improve. However, the amount of this reduction is difficult to estimate because technological improvements are uncertain and may have unexpected effects. For example, the introduction of three-way catalytic converters in automobiles has reduced overall emissions of NO_x , but has increased emissions of NH_3 , which has a higher deposition velocity and shorter transport range than NO_x (CH2M Hill 2004). The reader must bear in mind that the future year simulations reported here used emissions that were extrapolated from the base year without taking into account the expected improvements in motor vehicle emission control technologies, but also without the postulated, accompanying increase in ammonia emissions.

In addition to the uncertainties associated with the amount of nitrogen deposition that will occur as a result of covered activities, there is uncertainty associated with the degree of impact on covered species. Although it is clear that elevated rates of nitrogen deposition degrade serpentine communities, it is not clear to what extent the incremental addition of nitrogen over current levels will affect these communities and, ultimately, populations of covered species (Weiss 2006).

The CMAQ modeling reported here used a comparatively short time period. However, this time period is fairly representative of the average conditions in the area. In addition, use of a longer time period would not be likely to greatly alter the relative contributions of sources to nitrogen deposition.

The modeling analyses conducted here rely on established models that have been reviewed by the scientific community and evaluated in numerous applications in the past. Nevertheless, the representation of physical and chemical processes in the models can only be as good as current scientific understanding and may include unknown errors or shortcomings. In addition, the models rely on estimates of emissions, meteorological simulations, and limited sets of meteorological measurements as input data. As noted above, these meteorological and emissions estimates include some uncertainty. In this study, however, the model results were not used in an absolute sense to determine nitrogen deposition. Rather, we have used the models in a relative sense to assess the portion of the nitrogen deposition that is attributable to various categories of sources and the relative increase in nitrogen deposition that might be expected due to growth.

Conclusions

In this study we have used several modeling approaches in order to estimate nitrogen deposition to the Bay checkerspot butterfly habitat area. Deposition based on the line source modeling can only provide estimates of deposition from the highways that were modeled. Estimates based on observed data includes contributions from all sources, but, since the monitors considered are not at habitat locations, the estimates may not be representative for specific habitats. Estimates based on CMAQ include all sources but are averaged over an area that includes both habitat areas and non-habitat areas. Estimates of overall deposition based on observations of NO₂ concentration and modeling using CMAQ both give estimates of total nitrogen deposition of about 6 kg-N/ha/y, which is consistent with other studies such as Weiss (2006). Modeling with CMAQ also provides estimates of expected increases in deposition in future years. Modeling with Gaussian models, while not providing an estimate of overall deposition, provides an estimate of deposition from individual roadways and the expected increases in deposition from those roadways in the future.

Based on the CMAQ modeling, should increases in NO_x emissions occur in proportion to growth within the study area, within Santa Clara, and within the region, total average nitrogen deposition in the area around and including the habitat areas could increase to 8 kg-N/ha/y in 2035 (a 33% increase) and almost 10 kg-N/ha/y in 2060 (a 66% increase). Gaussian modeling indicates that, when emissions are extrapolated based on projected growth, contributions to nitrogen deposition from major roadways could increase by almost a factor of two by 2030 and by an even larger amount by 2060.

Contributors to Deposition

The amount that various sources contribute to deposition was assessed with different modeling approaches. The most complete of these methods was the use of the PPTM tagging approach in CMAQ. In addition, however, Gaussian modeling provided estimates of the relative contributions of several major roadways to nitrogen deposition.

Nitrogen Deposition from Santa Clara Valley Habitat Plan Covered Activities

In the base year, the CMAQ PPTM simulation attributes 30% of the total nitrogen deposition to mobile sources within the study area. Another 16% of the nitrogen deposition comes from stationary sources in the study area. Therefore, 46% of nitrogen deposition on the habitat areas comes from existing development and traffic generated locally within the study area. The remainder of Santa Clara County contributes 17% of the nitrogen deposition while the other eight Bay Area counties account for about 11% of the deposition.

The CMAQ simulation indicates that the remaining 26% of the N-deposition comes from anthropogenic emissions in the remainder of the modeling domain (i.e., most of the remainder of California other than Bay Area counties and a portion of Nevada), initial and boundary concentrations (i.e., effects from outside of the modeling domain), and biogenic emissions within the Bay Area counties.

Impacts on nitrogen deposition from Morgan Hill and Gilroy were not explicitly identified in our modeling, but are part of the contribution referred to as the remainder of Santa Clara County. In the emissions inventory used to prepare emissions for CMAQ, municipalities are not identified separately from the county in which they are located. Estimates of emissions for Morgan Hill and Gilroy were made based on the overlap of boundaries of these cities with grid cells in the modeling domain (see Table E-27). Since grid cells resolve emissions only to areas measuring 144 km², this is necessarily an approximation. However, based on these estimates, the values in Table E-27 indicate that Gilroy contributes 2% of the Santa Clara County NO_x emissions, Morgan Hill contributes 3%, San José contributes 79%, and the remainder of Santa Clara County contributes the remainder of the NO_x emissions (16%). It is reasonable to assume that the impacts from Gilroy and Morgan Hill would be roughly in proportion to their emissions. Of the 17% contribution to nitrogen deposition noted for the remainder of Santa Clara County, therefore, we could expect Gilroy to make up about 1.5% (9% of 17%) and Morgan Hill to make up about 2.7% (16% of 17%).

Table E-27. Estimated NO_x Emissions for Cities in Santa Clara County

City or Area	NO _x Emissions (tpd)	Santa Clara NO _x Emissions (%)	Non-San José NO _x Emissions (%)
San José	52.07	79	
Gilroy	1.20	2	9
Morgan Hill	2.20	3	16
Santa Clara County, other than above	10.20	16	75
Total	65.68		

Increases in nitrogen deposition based on extrapolation of emissions to future years were simulated for Bay Area counties. Future-year emissions projections were not available for the remainder of the domain. The simulated nitrogen deposition in the area around and including the Bay checkerspot butterfly habitats (once scaled to per annum values) is 8.3 kg-N/ha/y in 2035 and 9.6 kg-N/ha/y in 2060, a 25% and 45% increases relative to the base year, respectively.

Contribution of mobile source emissions in the Bay checkerspot butterfly habitat areas are estimated to increase by about 0.6 kg-N/ha/y in 2035 over the base year (a 10% increase) and by another 0.5 kg-N/ha/y in 2060 (an 18% increase). The

San José contribution to nitrogen deposition in the habitat areas is estimated to be 38% in 2035.

Gaussian modeling of major roadways near the habitats indicates an increase in nitrogen deposition of about 0.25 kg-N/ha/y using emissions extrapolated to 2030 over the base year (a 4% increase in total deposition). The increase using emissions extrapolated to 2060 relative to 2030 could be from 0.4 kg-N/ha/y to more than 1 kg-N/ha/y depending on location (a 7% to 17% increase in total deposition).

Nitrogen Deposition from Outside Growth

Only growth in emissions in Bay Area counties was considered in the CMAQ PPTM simulations because future-year emissions were not available for the remainder of the modeling domain. Gaussian modeling was limited to an area in the immediate vicinity of the habitats due to the limitations in scale of this type of model.

The contribution of emissions outside of the study area but within Santa Clara County are estimated to grow from 1.1 kg-N/ha/y in the base year to 1.5 kg-N/ha/y based on emissions extrapolated to 2035 (36% increase) and 1.7 kg-N/ha/y based on emissions extrapolated to 2060 (55% increase). The contribution of emissions from all other Bay Area counties are estimated to grow from 0.7 kg-N/ha/y in the base year to 0.9 kg-N/ha/y in 2035 (29% increase) and 1.0 kg-N/ha/y in 2060 (43% increase).

Effects of Nitrogen Deposition

Effects on Serpentine Grassland

The major effect of N-deposition on serpentine grassland is to promote invasion of nonnative annual grasses in the absence of grazing (Weiss 1999). Additional studies have been done since Weiss's study and are included in the Metcalf Energy Center Annual Monitoring reports (CH2M Hill 2002–2008), monitoring reports for the VTA mitigation lands (Harvey and Associates 2007), and USFWS funded research on Adaptive Management of Serpentine Grasslands in Santa Clara County (Weiss et al. 2007).

The effect is illustrated in the photo below (Figure E-39), taken in 1995 at the base of Coyote Ridge, just north of the Kirby Canyon Landfill. The right side of the fence was grazed, and the left side was ungrazed for 9 years (since 1986). Similar invasions have been noted and documented in the Silver Creek Hills, Tulare Hill, Santa Teresa County Park, and other sites (including small experimental plots).

The invasion occurs rapidly. Annual grasses build up over two to three years, eventually developing a thick layer of thatch that effectively smothers the native forbs. Native species cover and richness plummet across all but the thinnest soils. The major invasive grass species include Italian ryegrass (*Lolium multiflorum*) and soft brome (*Bromus hordeaceus*), with localized stands of common barley (*Hordeum*) spp. and compact brome (*Bromus madritensis*).

It is likely that invasions of barb goatgrass (*Aegilops triuncialis*) into serpentine soils are enhanced by N-deposition, but this species will invade serpentine soils in the absence of N-deposition.

Grazing management is essential. Grazing cattle select N-rich annual grasses and create bare soils that favor annual forbs. The existing grazing systems, documented elsewhere in the Habitat Plan and other management plans, have served well to maintain native diversity of serpentine grasslands. Typical stocking rates and seasonality include 1 cow-calf per 10–15 acres for winter-spring (rainy season) or summer-fall (dry season), with small modifications according to short-term seasonal variations. Cattle are moved from pastures that no longer supply enough grass to maintain cattle weight. Cattle can also keep barb goatgrass from completely dominating serpentine grassland if grazing occurs before the awns harden but after the other annual grasses have dried out.

Recovery with the reintroduction of grazing may take many years, as evidenced in the Silver Creek Hills (Wetlands Research Associates 2008). On Tulare Hill, Weiss and colleagues have noted that seedbanks from the final large cohort of native forbs in 2004 (3 years after the cessation of grazing) provided for dense native forb cover following a June 2004 fire on Tulare Hill (Metcalf Energy Center 2006). Once the native seedbank is depleted, restoration of high-quality serpentine grassland requires recolonization from forb-rich patches of thin soils, which is a much slower process.

The long-term effects of N-deposition are unknown, but the working hypothesis is that existing grazing regimes will be able to maintain diversity. However, recent research suggests that current levels of grazing may not be effective at maintaining native biological diversity or reducing invasive grass impacts under on-going nitrogen accumulation in serpentine grasslands (J. Pasari, pers. comm.).

It is estimated from roadside gradient studies at Edgewood that the critical load for intense grass invasions is on the order of 5 kg-N/ha/y (Weiss et al. in preparation). This level will likely be exceeded for several decades in Santa Clara County (where similar passive sampler methods estimate 10–20 kg-N/ha/y), with the higher levels in hotspots near freeways and urban fringe (Fenn et al. 2010).

Figure E-39. Invasion of Non-Native Annual Grasses due to Nitrogen Deposition at Coyote Ridge



Effects on Bay Checkerspot Butterfly

Dense stands of dotseed plantain (*Plantago erecta*) across many slopes and soil depths is an essential condition for Bay checkerspot butterfly populations. Loss of host plants and nectar sources due to grass invasions leads to rapid declines and eventual local extinction of populations. Numbers in the Silver Creek Hills rapidly declined from tens of thousands to near extinction over a 3-year period (Weiss 1999). A population of 1,000–2,000 butterflies on Tulare Hill in 2002 dropped following cessation of grazing in 2001 over two-thirds of the hill and reduced the number of checkerspot to a tiny remnant population (1 adult sighted in each of the three years from 2006 through 2008).

Effects on Serpentine Covered Plants

The main effect on covered plants to consider is their vulnerability to annual grass overgrowth. Brief assessments of these effects on covered plants are discussed below.

Santa Clara Valley dudleya (*Dudleya setchellii*) lives on rock outcrops and is relatively immune from grass invasions except when extremely tall grasses smother small rock outcrops. The species persists on medium to large rock outcrops in ungrazed areas (Weiss et al. 2008).

Metcalf Canyon jewelflower and most beautiful jewelflower (both subspecies of covered *Streptanthus albidus*) can be poor competitors against dense annual grasses (Green 2005), and some degree of grazing appears necessary to maintain populations. The two known populations of Tiburon paintbrush (*Castilleja affinis neglecta*) persist in grazed areas but likely would get overrun by dense grass growth if grazing were removed.

Mt. Hamilton thistle (*Cirsium fontinale* var. *campylon*) is a perennial that dominates serpentine seeps and persists in both grazed and ungrazed drainages. The annual grasses do not readily invade the active stream channels and the plant thrives in a variety of grazing regimes. Cattle avoid the sharp-spined leaves, but the physical disturbance in wet soils appears to encourage thistle recruitment.

Smooth lessingia (*Lessingia micradenia* var. *glabrata*) may be vulnerable to grass invasions but may have different dynamics because of its late-season (summer-fall) flowering.

Coyote ceanothus (*Ceanothus ferrisae*) is itself a nitrogen fixer and once established, is able to compete well with annual grasses. Fragrant fritillary (*Fritillaria liliacea*) is vulnerable to overgrowth by annual grasses but may persist as a bulb or vegetative state for many years before going locally extinct.

Effects on Other Natural Communities

The effects of N-deposition on non-serpentine annual grasslands and the grassland understory of oak woodlands are similar to those on serpentine grassland—increased annual grass growth displaces native forbs. Non-serpentine annual grasslands and oak woodlands in the study are extensive (310,875 acres, or 60% of the study area), so these adverse effects could be widespread. Vernal pools appear to be particularly susceptible to overgrowth by grasses (Marty 2005), although vernal pool habitats have largely disappeared from the study area. Increased grass growth also increases fuel loads and subsequent fire intensity. Other grassland weeds such as yellow star thistle likely react positively to increased N-availability, since weeds have high growth potential and can rapidly respond to increased nutrient availability. Growth and spread of weeds are major issues for biodiversity conservation.

Appropriate grazing management to control annual grass biomass is necessary in these habitats. Increased weed management costs are likely for those weeds that cannot be controlled by grazing.

Long-term effects on shrublands, denser woodlands, and forests have not been locally observed, but these habitats should be more resistant to effects of N-deposition than are grasslands. Increased grass growth in sparse shrublands can change fire frequency and lead to conversion to annual grassland following short-interval fires. However, all ecosystems can be subject to N-saturation given long-term deposition loads, with the results being increased rates of N-cycling leading

to leaching of nitrate, gaseous emissions of NO, nutrient imbalances, and changes in composition as more nitrophilous species gain competitive advantage.

The leaching of nitrate from N-saturated systems may have impacts on local aquatic systems, but have not been studied in depth. For example, the Llagas aquifer and Llagas Creek are under a set of nitrate Total Maximum Daily Load (TMDL) limits. Initial calculations by Weiss (2008) using the 4 km CMAQ run (Tonnesen et al. 2007) suggest that total atmospheric N-deposition directly on the Llagas Basin (the Santa Clara Valley floor from Cochrane Road south, not including tributary streams) is similar to agricultural N-fertilizer inputs (150 vs. 120 tons/year). However, no direct links have been made at present and further research is needed.

Effects on Water Quality

Water quality effects have not been studied in the region, but high nitrate has been observed in high deposition watersheds (20–50 kg-N/ha/y) in the Los Angeles basin (Fenn et al. 2003).

List of Preparers

ICF International

- David Zippin, Ph.D.—Project Manager
- Thomas C. Myers, M.A.—Senior Air Quality Specialist
- Yi Hua Wei—Senior Emissions Inventory Associate
- Tony Held, Ph.D., P.E.—Senior Air Quality Scientist

Creekside Center for Earth Observation, LLC

- Stuart Weiss, Ph.D.—Environmental Scientist

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