ENVIRONMENTAL JUSTICE ANALYSIS OF NITRATE CONTAMINATION IN SAN JOAQUIN VALLEY DRINKING WATER

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In partial fulfillment of
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Master of Arts

In

Geography: Resource Management and Environmental Planning

by

Katherine Ann Kilduff

San Francisco, California

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CERTIFICATION OF APPROVAL

I certify that I have read *Environmental Justice Analysis of Nitrate Contamination in San Joaquin Valley Drinking Water* by Katherine Ann Kilduff, and that in my opinion this work meets the criteria for approving a thesis submitted in partial fulfillment of the requirements for the degree: Master of Arts in Geography: Resource Management and Environmental Planning at San Francisco State University.

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ENVIRONMENTAL JUSTICE ANALYSIS OF NITRATE CONTAMINATION IN SAN JOAQUIN VALLEY DRINKING WATER

Katherine Ann Kilduff
San Francisco State University
2015

Community organizations, rural law groups, researchers, and residents have voiced concerns over drinking water in the San Joaquin Valley of California and the unequal burden of contamination borne by people of color and low-income populations. The abilities and needs of these groups should be considered in the efforts to realize the human right to water in California. This work reviews related literature and improves on previous studies of distributive justice of drinking water quality. The statistical analysis showed that an increase in the proportion of Latinos served by community water systems in the San Joaquin Valley was linked to an increase in nitrate concentrations in delivered drinking water. Median household income, in addition in to the proportion of Latinos served by community water systems, in Tulare County explain 15% of the variation in nitrate contamination.

I certify that the Abstract is a correct representation of the content of this Thesis.

Chair, Thesis Committee 5/12/2015 Date

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I. Introduction

a. Nitrates and Quality Monitoring

Insecticides, fungicides, herbicides, and fertilizers have been applied regularly throughout the industrial and intensive agricultural development of the San Joaquin Valley, which is now the richest agricultural region in the world. Agricultural inputs are not completely contained within fields, but instead travel in the air, overland and through soils to eventually reach the aquifers that serve as the main drinking water supply in the San Joaquin Valley. Even pesticides that have been banned for many years are still infiltrating through soil to contaminate groundwater. Pesticide presence in drinking water sources is highest where there is high pesticide use and California's Central Valley, composed of the San Joaquin and Sacramento valleys, has the worst pesticide contamination and the most Maximum Contamination Level (MCL) violations in the state (Heavner 1999). According to Helperin *et al.* (2001), the U.S. Geological Survey reported, "'the primary criterion for whether pesticides had been detected in the groundwater in a state appears to be whether or not [researchers] have looked [for them]'" (Helperin *et al.* 2001). Nitrates, most frequently from fertilizers and manure, are one of the most commonly detected contaminants of wells in California (CDPH WQM).

Nitrate presence in groundwater is influenced by a number of anthropogenic activities combined with physical geographic characteristics of a catchment. Animal feedlots and waste ponds, dairies, septic systems, sewage system pipes, wastewater treatment facilities, urban gardens and golf courses are sources of nitrates that can be important sources of contamination in groundwater in some areas, but nitrogen used for fertilizer on cropland is the primary source of groundwater nitrate in the San Joaquin Valley (Viers *et al.* 2012). Climate, depth to the water table, and soil type, permeability and organic matter influence rates of transport and attenuation, and thereby the percentage of nitrates that reach the aquifer. Irrigation generally increases the rate and likelihood of nitrate leaching when used on crops where fertilizer is also applied. In the San Joaquin Valley, nitrate fertilizer and irrigation are widely used; this region has one of the most contaminated aquifers (Dubrovsky *et al.* 2010). Cropland within two intensively farmed regions of California, the Tulare Lake Basin in the southern San Joaquin Valley and the Salinas Valley, was estimated to contribute to 96% of the nitrate loading in groundwater (Harter and Lund 2012). Nitrate presence in San Joaquin Valley groundwater has steadily increased over the past few decades and is likely to continue to increase (Harter and Lund 2012). Meanwhile, groundwater use in homes and on crops has been increasing. Most community water systems in the region are supplied by groundwater, including all samples analyzed in the present study. The health impacts of excessive nitrates in tap water are of particular concern for infants. When ingested, nitrates can limit blood absorption of oxygen and result in methemoglobinemia, which can cause shortness of breath, brain damage, or death ("blue baby syndrome").

All public water systems that use groundwater supplies are required by state and federal regulations to monitor for nitrates annually, though many systems using water with higher levels of nitrates or surface water must monitor every three months (Title 22, California Code of Regulations, Section 64432). The MCL for nitrate-ion (as NO_3) in drinking water is 45 mg/L. If a sample is shown to reach half this concentration (22.5 mg/L as NO_3), the system is required to repeat sampling every three months. When monitoring samples exceed the MCL, water systems are required to resample within 24 hours of receiving the results, and the average is then used to calculate a final nitrate level for reporting. If a water system cannot resample, the system is required to notify consumers of the risk and collect a new sample within 14 days. Despite this monitoring schedule, underreporting is widespread (Balazs and Ray 2014; Pannu 2012).

Many community organizations, rural law groups, and researchers working in the San Joaquin Valley have voiced concern over nitrates and other contaminants in drinking water and the unequal burden of contamination borne by people of color and low-income populations in the region. Such inequality can also be described as Environmental Discrimination - government or corporate action or inaction that results in “a disproportionate exposure of people of color and low-income people to environmental dangers that threaten their physical, social economic, or environmental health and well-being” (Deen *et al.* 2005). Environmental Injustice is a specific instance of this greater discrimination and an Environmental Justice framework is often explained using procedural or distributional perspectives. Procedural justice research points to linkages between policies and institutions, access to safe and affordable environmental services, and socio-economic status; distributive justice research can determine inequality in services across a study area. This paper will discuss prior research linking poor water quality to socioeconomic indicators in the San Joaquin Valley before presenting new research that models the relationship between nitrates in drinking water and minority populations.

b. Environmental Justice Analyses of Drinking Water Quality

i. Procedural and Qualitative Analyses

Procedural Justice is a branch of Environmental Justice concerned with the process by which environmental decisions are made. Environmental Law, Poverty Law, Environmental Poverty Law and Human Rights Law have contributed extensively to the literature on environmental injustice in the San Joaquin Valley and the potential for inequalities in drinking water quality. This section reviews the work in procedural justice analyses of drinking water in the San Joaquin Valley, in order to explain possible causes for systematic environmental discrimination in drinking water. This study aims to find evidence of these causes and their effects on certain populations through statistical analysis of contamination distribution.

Pannu (2012) argued that the governance of water resources in California has systematically limited participation and access to safe, affordable drinking water for some disadvantaged citizens. Pannu (2012) explains that because there are more than ten agencies that manage water resources in the Valley, and they often have overlapping responsibilities, communities find it difficult to ascertain which agency to contact to demand or enact change. The heads of many water governance agencies are appointed, so dissatisfied communities have no power to vote them out of office. Although this problem is at the regulatory level, at the local community water system level some have also reported difficulty in accessing representatives and information or have experienced accent and language-based discrimination (Balazs and Ray 2014). Language has been shown to be an important factor in understanding risks of nitrate contamination in drinking water. A study by the Pacific Institute found that Spanish-speaking residents were less likely to be aware of nitrate risk in their tap water and that when notifications are delivered, they are often not provided in Spanish, even in areas where there are high proportions of Spanish speakers (Moore and Matalon 2011).

At the local level, the political organization of water systems and municipal governments can also present challenges to accessing clean and affordable drinking water. Public water systems can be public, quasi-public, or private. Residents within public systems have direct electoral influence (one person, one vote). Public systems make up only half of all systems in California; most are in the northern part of the state and they are uncommon in rural, sparsely populated, or low-income regions, such as in many areas in the San Joaquin Valley. Quasi-public systems, often organized as water districts, have the same powers of eminent domain, taxation and bonding as public systems, but not everyone has a vote. Usually only landowners (including corporations) can vote and voting shares are often proportional to property size. Purely private systems operate like other companies: shareholders have votes, water is sold for a profit, and the higher costs are in turn passed on the residents (Pannu 2012). This lack of consumer power may explain some of the poorer drinking water quality and the higher costs experienced by consumers served by private, and especially smaller, systems (Pannu 2012, Bagi 2002a).

Residents of unincorporated communities may face exceptional difficulty in finding solutions through water governance regimes or local governments in the San Joaquin Valley. The Community Equity Initiative of California Rural Legal Assistance (CRLA) identified 220 disadvantaged unincorporated communities (DUCs) that lack basic infrastructure or services like potable drinking water, sewer systems, safe housing, public transportation, access to healthy food, sidewalks, streetlight or parks (CRLA, Community Equity Initiative). These unincorporated communities rely on county governments to initiate projects and manage these services at the local level, while other communities have elected city governments as well (Pannu 2012). Many of these DUCs are low-income communities of color that are composed of workers who settled on either the outskirts of cities, or alongside factory farms for rural job opportunities. DUCs have also been actively excluded historically through "intentional policy choice, reinforced by *de jure* and *de facto* race- and class-based segregation" and these demographic and exclusionary patterns persist today (Pannu 2012). For example, the Tulare County Planning Department General Plan from 1971 explicitly targeted some small rural communities for discontinuation of essential services:

> Public commitments to communities with little or no authentic future should be carefully examined before final action is initiated. These non-viable communities would, as a consequence of withholding major public facilities such as sewer and water systems, enter a process of long term,

> natural decline as residents depart for improved opportunities in nearby communities.
>
> Pannu 2012, 234

Thirteen of the fifteen "non-viable" unincorporated minority communities still exist despite reduced public funding (Pannu 2012). Their property values have depreciated because of planned "withholding" of public investments in basic infrastructure, so it has become even more costly for their residents to move away. Unequal quality of drinking water infrastructure has been shown to determine unequal access to safe drinking water (Balazs and Ray 2014). Other research has found that substantial economic development follows water and sewer projects in disadvantaged areas and that such projects “save and/or create jobs, spur private-sector investment, attract government funds, and enlarge the property tax base” (Bagi 2002b).

Systems with less funding have also been systematically excluded from receiving grants from the State of California for infrastructure improvements. For example, resource-poor and smaller communities may be served by resource-poor systems that lack technical, managerial and financial (TMF) capacity needed to write and obtain grants (Balazs and Ray 2014). The state revolving fund for small system capacity development requires that systems have TMF capacity. The American Recovery and Reinvestment Act (2009) stipulated that proposals for projects be “shovel-ready,” which means that a community must have the TMF capacity to develop water project development plans on its own (Balazs and Ray 2014). As a result of these political processes, “non-viable communities,” lower income communities of color, and smaller systems lacking TMF capacity have been excluded from drinking water infrastructure funding, exacerbating the inequalities in access to safe drinking water (Balazs and Ray 2014).

Smaller systems are inherently limited by "diseconomies of scale". Their per-customer costs to connect to sources and to operate, store, monitor and treat water for drinking are high. Thus, water deliveries are disproportionately expensive to their consumers in comparison to consumers served by metropolitan water systems. Bagi (2002a) found that smaller systems have the highest financial burdens (measured as operating ratio, debt service coverage ratio, and net takedown ratio) and greatest deficit or loss. Consequently, they charge residents higher rates and increase rates frequently. Their inefficiency and their operation by individuals who lack state certification may explain why, although smaller systems (classified as serving 25 – 500 residents) make up only 27% of all CWSs in the United States, they receive 65% of all MCL violations (Bagi 2002a). It is remarkable that this figure is so high, considering the low citation rate for MCL violations and small water systems’ frequent failure to monitor.

Many public systems (and smaller systems in particular) fail to test water as required by monitoring schedules and end up unregulated for quality (Pannu 2012, Balazs and Ray 2014). Balazs and Ray (2014) explain that MCL violations are prioritized over monitoring violations so, where the regulatory agencies are stretched thin, they do not always cite systems that fail to monitor. Given underreporting, there is no way to know whether water quality is exceeding MCLs and whether the consumers served by these systems are provided information on harmful contaminants.

ii. Statistical Analyses

Statistics can be used to assess the effects of policies such as those described above and to identify any consequent systematic differences in access to safe drinking water. Distributive Justice approaches using statistical analysis to determine equal or unequal distribution of environmental harms and benefits across socioeconomic groups support observations that certain groups are more likely to receive poorer quality and unsafe drinking water. Byrne (2003) made the first to attempt to show environmental injustice in drinking water quality in the San Joaquin Valley using Geographic Information Science, concluding that there was a positive, though weak, relationship between poverty and poor drinking water quality in San Joaquin County. Byrne also found a negative correlation between the percentage of Caucasian residents and poor drinking water quality. Balazs *et al.* (2011) studied the distribution of nitrate contamination in California's San Joaquin Valley community water systems (CWSs) and found that, within smaller water systems (<200 connections), higher proportions of Latinos correlated with higher levels of nitrates. Smaller water supply systems (more limited by diseconomies of scale) were more likely to serve contaminated water than larger systems, and also served higher proportions of Latinos and individuals of lower socioeconomic status. Balazs *et al.* (2012) performed a similar study and found a significant negative correlation between rates of homeownership and arsenic levels in drinking water of small systems in the San Joaquin Valley. This research also found that smaller systems, overall serving higher proportions of people of color and lower proportions of homeowners, were more likely to receive an MCL violation.

The Balazs *et al.* (2011) study was probably the first and only in the United States to try to model nitrate distribution in drinking water and socioeconomic indicators. That study used known locations of water sources (wells) to ascertain the population characteristics (from census block groups where these wells were located) of the affected population and compared these characteristics to nitrate monitoring data from 1999 to 2001. The present study makes use of newer data on water system boundaries - allowing for population estimates across community water system services areas - and nitrate monitoring and census data from 2008 to 2010. The present study also researches the CWSs found to have the highest levels of nitrates to explore possible relevant factors that are not accounted for in previous distributional and procedural analyses of drinking water quality in the San Joaquin Valley of California.

II. Methods

This study aims to investigate the relationship between levels of contamination and the demographic composition of consumers in the San Joaquin Valley by (a) determining distribution equality of nitrates in drinking water quality through statistical analysis and (b) performing document research on systems showing high nitrate concentrations. The statistical analysis in this study uses recent water system boundary, demographic, and contamination records to model their relationship using classical statistics, hypothesizing that higher percentages of Latinos and renters served and lower median household incomes are significant factors in higher nitrate concentrations in drinking water provided by community water systems in the San Joaquin Valley. The document analysis provided confirmation of the findings of high nitrate concentrations determined by these methods and insight into other relevant factors that are overlooked by a purely quantitative approach.

a. Statistical Analysis

i. Data

Three sources provided the environmental and population data used to perform a statistical analysis of nitrates in drinking water in the San Joaquin Valley, California. The California Department of Public Health (CDPH) provided findings and chemical and system codes from all sources tested between January 1, 2006 and December 31, 2010 in the Water Quality Monitoring (WQM) database. Drinking water system service area boundaries were provided by the Water Boundary Tool developed by CDPH California Environmental Health Tracking Program (CEHTP), and the United States Census Bureau produced the demographic information used in this study (5 year estimates, block group, 2006 - 2010).

ii. Sample

Nitrate samples obtained from the California Department of Public Health Water Quality Monitoring database were taken from 1 January 2008 to 31 December

2010 and comprise one complete monitoring period under the Safe Drinking Water Act. From 2008 through 2010, there were 1480 distinct public water systems tested in the region (CDPH WQM). The type of water system and source, the availability of geographic information for the public water systems, and the lack of testing for nitrate levels during this period reduced the number of systems included in the sample. Specifically, the present study only looked at systems classified as community water systems (CWSs) that served at least 25 people or 15 service connections year-round, so that this research could be compared to previous (Balazs *et al.* 2011) research. Very small systems and seasonal communities were excluded. This study of CWSs also used only water samples from active, end-of-line sampling points to avoid double counting of nitrate findings. Sampling locations classified as inactive, standby, and monitoring wells, as well as water from sampling locations that are sampled prior to treatment, were not included in this study. Only water samples from sources labelled "active treated," "active untreated," "purchased treated," and "distribution sample point treated" were used to estimate average system concentrations of nitrates. The water boundary tool provided geometric boundaries for 550 systems, which overlapped 3583 Block Groups (CDPH EHTP Boundary Tool). Given these parameters, the sample in the present study consists of 232 CWSs (6157 samples from 564 sampling point locations) in the San

Joaquin Valley, containing Fresno, Kern, Kings, Madera, Modesto, San Joaquin, Stanislaus and Tulare counties. All samples were sourced by groundwater. The CWS service areas locations in the San Joaquin Valley and their respective average nitrate levels are shown by gradient sized points in the map in Figure 1.

iii. Methods of Demographic and Contamination Estimates

ArcGIS 10.2 was used to relate CWS boundaries to U.S. Census block group geometries, as well as database management and summarization. The chemical identification information (STORET.dbf) and water system information (SITELOC.dbf and WATSYS.dbf) were first joined to the water system service area boundaries polygon shapefile. ArcGIS 10.2 was then used to join systems, based on their geographic boundaries, and the accompanying system information to the U.S. Census Bureau Block Group boundaries pre-joined with 2006 - 2010 demographic estimates. From the resultant database, demographic characteristics of each water system were estimated by summing the total population and the population with a particular demographic characteristic. The summation for the census estimates of Latinos (B03003e3 and B03003e1), renters (B25003e1 and B25003e3) and median household income were used to estimate the proportion Latino and proportion renter and average median household income for each water system. Latinos are the largest minority group in the region and renter population can be used as a proxy for low socioeconomic status, as it may reflect lower income and reduced political power (Balazs *et al.* 2011). Descriptive statistics of the sample are presented in Table 1.

Table 1. Community Water System (CWS) Study Sample Descriptive Statistics

Number of CWSs	232
Median % Latino	35.06 % [0,97.5]
Median % Renter	34.4 % [0, 94.4]
Median Income	$46,447 [17,438; 118,019]
Small Systems (≤ 200 connections)	69.8%

iv. Statistical Model

Analysis focused on nitrate concentrations from samples of treated and untreated sources that are last-in-line before distribution and actively used during the monitoring period from 1 January 2008 to 31 December 2010. Findings from each pollutant were averaged at each water source. These source findings were then averaged across systems to produce an average system concentration at the point of entry into distribution networks for the monitoring period, which served as a proxy for average water quality in the homes during the study period. This process assumed that all sources contributed the same amount of water to be distributed by a public water system because flow data were not available. The system averages of nitrates were used as the dependent variable in a linear regression model that tested the correlation with proportions of Latinos and renters served by CWSs.

A linear regression analysis of average system findings was used with the independent variables of the proportion of Latinos, proportion of renters, median household income, and system size. The square root of the minimum detection level for reporting was used (2μg NO_3 per liter) in cases of average nitrate concentration findings of zero, because of the low detection accuracy at that level (Balazs *et al.* 2011). A log-transformation was used on nitrate findings, as these were log normal. All linear models were run in R 3.0.3 for Windows (R Core Team 2013). These variables were compared at two scales: the distribution of nitrates in drinking water was analyzed at the scale of the San Joaquin Valley, to compare to the previous study, and in each county within this region, to illuminate site-specific relationships between the variables.

b. Document Analysis

This study included post-analysis document research to confirm that the methods used to derive average nitrate concentrations, as described above, were not invalid and to gather additional information on the most contaminated systems. This study used information found in the California Department of Public Health's "Drinking Water Source Assessment Program" from 2002 and the most recent "List of Small Systems Program Plan," updated in July 2014. This research confirmed that nitrate contamination was indeed a problem in all CWSs found to have "high" average nitrate concentrations (greater than 45 mg/L as NO_3), and noted the likely sources of nitrate contamination, whether the problem had been resolved, as well as the economic status of the water system as determined by CDPH.

III. Results

c. Statistical Analysis

The estimated average nitrate levels varied among community water systems, with a range from zero to 115.5 mg/L as NO_3. Nitrate concentrations across the study area are right skewed, reflecting the nitrate-free drinking water served to most customers. The varying average nitrate concentrations are presented in Figure 1. A log transformation was applied to the right-skewed nitrate concentration findings and a simple linear regression was used to model the relationship with rates of Latinos served by CWSs. The proportion of Latinos served by a CWS was found to be significantly and positively correlated with nitrate contamination in the San Joaquin Valley, though a race-based model cannot predict nitrate contamination with much precision. Homeownership and median household income were not significant factors at this scale and are thus excluded from the final model. The regression model is expressed by the following equation:

$$\log(y) = 1.9242 + 0.8158(x),$$
$$r^2 = 0.0437 \; and \; p = 0.0014$$

where y is nitrate concentration and x is proportion of Latinos within a system. This equation has a p-value less than 0.01 and a coefficient of determination of 0.0437. Though the low coefficient of determination indicates that race does not explain much of the variation in water quality and in fact, factors not explored in this study may better predict nitrate concentration, we can reject the null hypothesis that the proportion of Latinos served is not related to nitrate contamination. Race and income appear to explain more of the variation in the distribution of nitrate contamination in Tulare County.

The majority of highly contaminated community water systems were in Tulare County, which is located atop the more contaminated aquifers (Pannu 2012, Dubrovsky *et al.* 2010). This reflects the chemically intensive farming practices in the southeastern San Joaquin Valley and is a concern because the majority of drinking water is supplied by groundwater (Dubrovsky *et al.* 2010, Moore and Matalon 2011). Statistical analyses at the county scale revealed that only Tulare County had higher levels of nitrates in distributed water and both a significant and positive coefficient for proportions of Latinos served by CWSs sampled and a

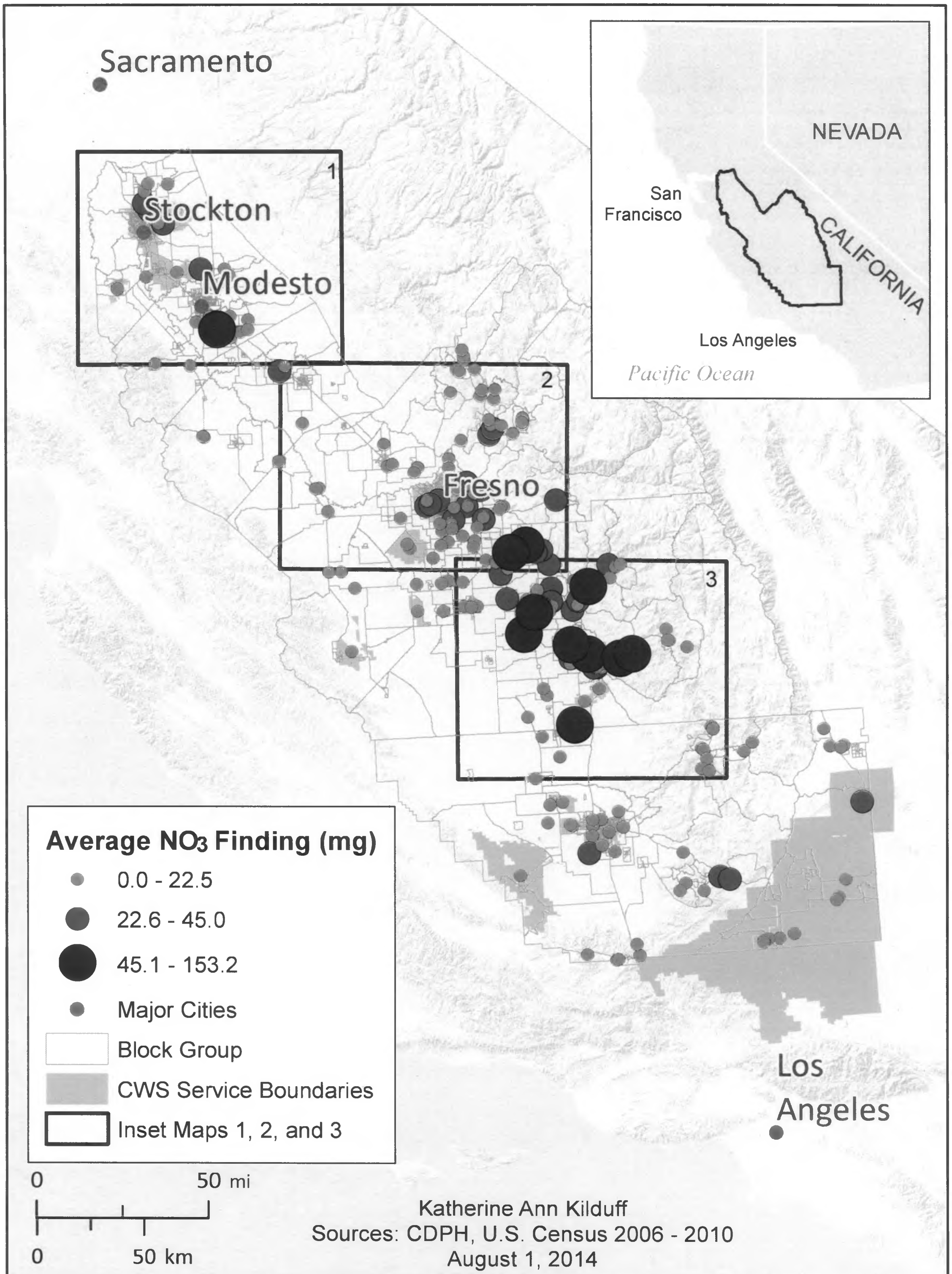
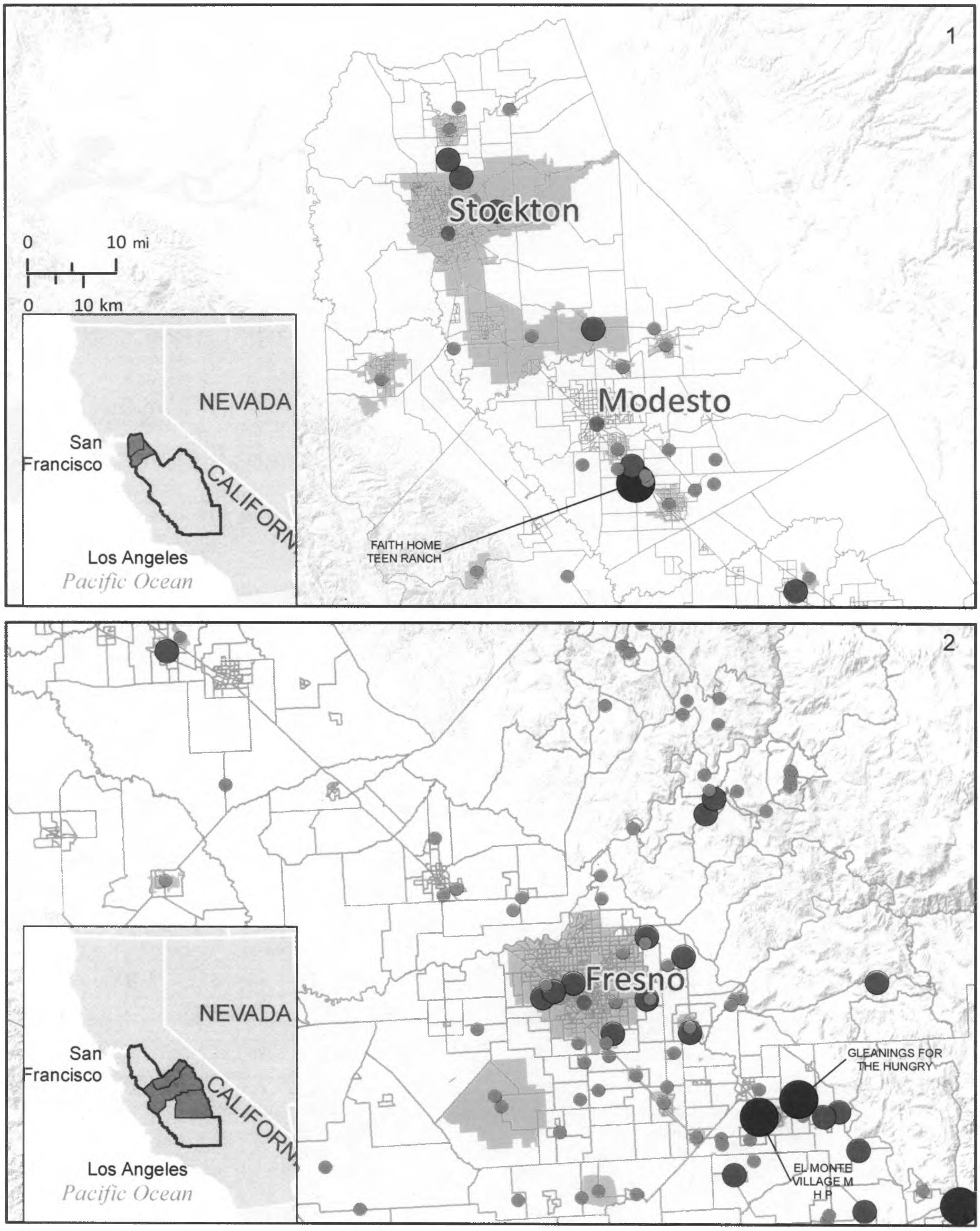


Figure 1. Study area depicting census block groups and water system service areas that were joined to estimate community water system customer demographics and relative average nitrate findings (low, medium and high)


1
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10 mi
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GLEANINGS FOR THE HUNGRY
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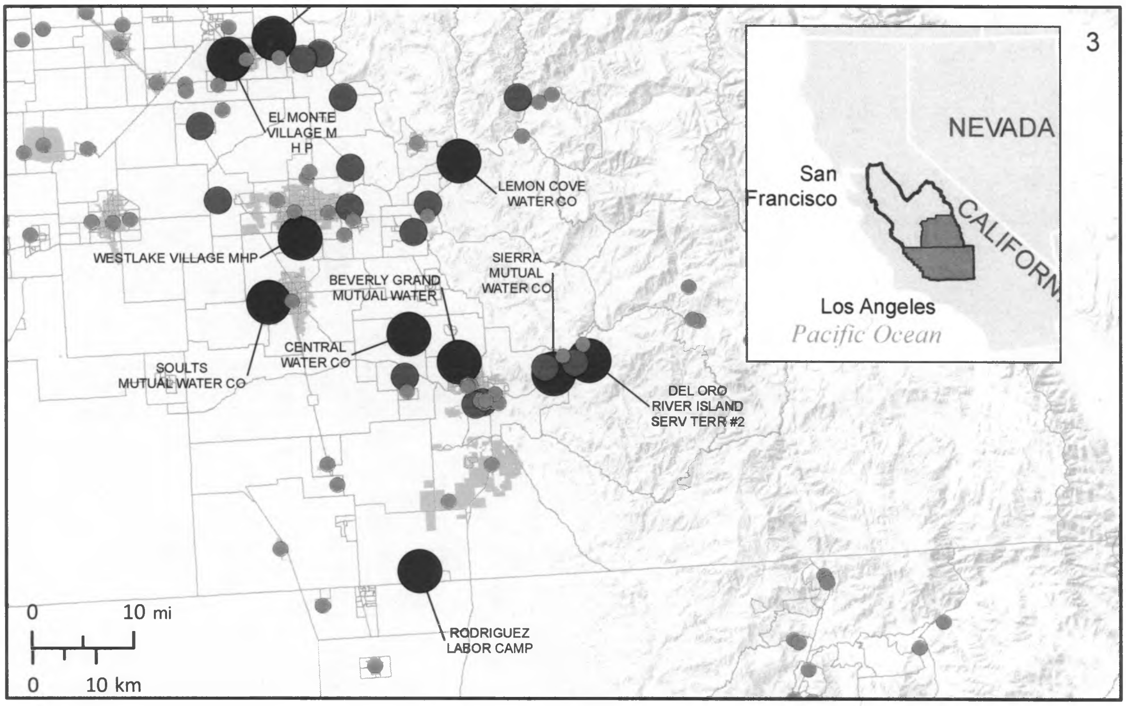

3
NEVADA
CALIFORN
San Francisco
Los Angeles
Pacific Ocean
EL MONTE VILLAGE M H P
LEMON COVE WATER CO
WESTLAKE VILLAGE MHP
SIERRA MUTUAL WATER CO
BEVERLY GRAND MUTUAL WATER
CENTRAL WATER CO
SOULTS MUTUAL WATER CO
DEL ORO RIVER ISLAND SERV TERR #2
RODRIGUEZ LABOR CAMP
0 10 mi
0 10 km

significant negative coefficient for median household income in modeling nitrate contamination. The linear regression equation for Tulare County follows and the scatterplots showing the relationship between proportions of Latinos served by CWSs and income with contamination can be seen in Figure 2.

$$\log(a) = 0.0329 + 0.0024(b) + 2.298e^{-5}(c),$$
$$r^2 = 0.1541 \; and \; p = 0.0056$$

In this model *a* is the predicted average nitrate contamination, *b* is the proportion of Latinos served by Tulare County CWS, and *c* is the average median household income of the CWS. Neither the proportion of renters in Tulare County CWSs nor the system size appeared to be related to nitrate contamination. This suggests that while race may explain some of the variability of drinking water quality in the San Joaquin Valley, the statistical evidence for environmental injustice via nitrate contaminated drinking water is most evident in Tulare County, though the model included only explains 15% of the variation.

Though community water system size was not a significant factor in predicting contamination in the regression model, smaller community water systems were more likely to have nitrates present in delivered water. Although 70% of all CWSs in the sample are small systems, characterized as having fewer than 200 connections, 85% (40 of 47) of CWSs designated in Figure 1 as having "medium" or "high" average nitrate concentrations (average estimated concentrations above

22.5 mg/L as NO_3) were small systems. All 11 CWS with "high" nitrate levels (above 22.5 mg/L as NO_3) were small systems. Descriptive statistics by nitrate concentration are presented in Table 2.

Table 2. Descriptive Statistics by Level of Nitrate Contamination

	All CWSs	**High** (≥ 45mg/L as NO_3)	**Medium** (22.5 – 45mg/L as NO_3)	**Low** (< 22.5mg/L as NO_3)
N	232	11	36	185
Small systems	70%	100%	85%	66%
Mean % Latino	40%	50%	42%	39%
Mean % Renter	35%	37%	36%	35%

* Wilcoxon rank-sum tests revealed a significant relationship (∝<0.1) between average concentrations of 22.5 mg/L as NO_3 or greater and system size (greater and less than 200 connections). While system size was not a significant factor in the linear regression model used in this study, these findings may support procedural justice accounts of the increased burden in small systems in managing contamination.

Within small systems, percent Latino was also positively correlated with nitrate concentrations. Wilcoxon rank-sum tests revealed a significant relationship (∝<0.1) between average concentrations of 22.5 mg/L as NO_3 or greater and the number of connections (system size) and between the percent Latino and nitrate findings in systems with 200 connections or less. These findings replicate findings from Balazs *et al.* (2011) discussed above. However, CWS size did not exhibit a strong correlation with nitrate contamination at the scale of the San Joaquin Valley and was not a significant factor in the regression model created in

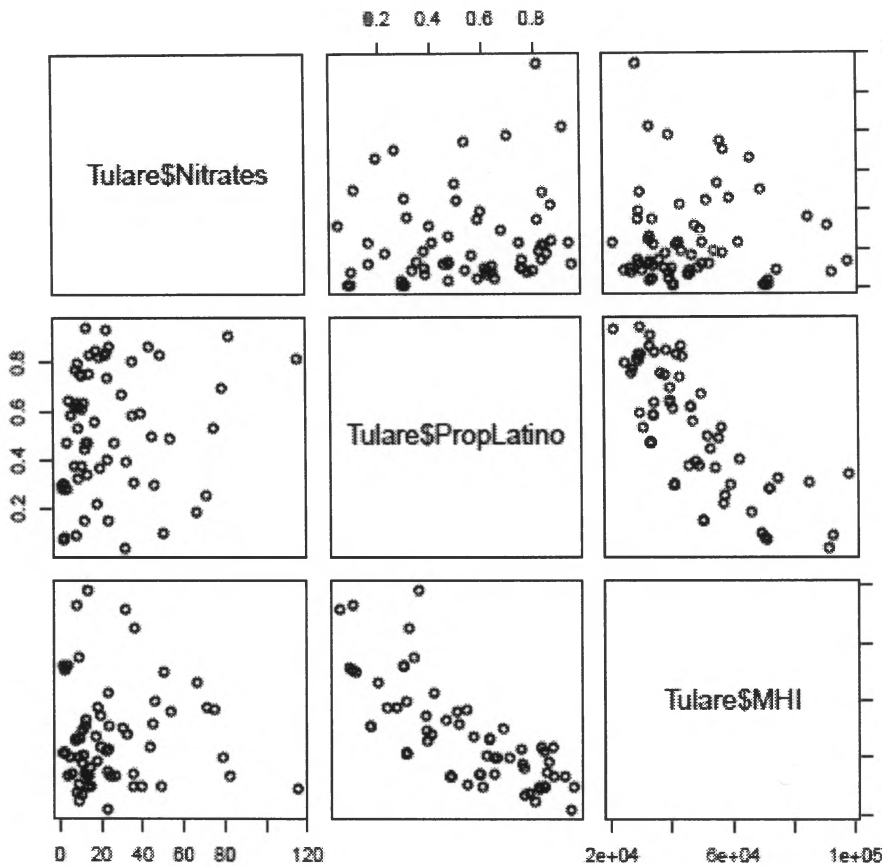

Figure 2. Scatterplot of Multiple Variables with Nitrate Contamination in Tulare County.

this study. A regression analysis of small systems alone did not show race to be a better predictor for contamination as in Balasz (2011).

a. Document Research Results of Most Contaminated Systems

This study also found supplemental information about the most nitrate-contaminated systems and their potential consumers to confirm that the methods used to determine concentrations and demographic characteristics were valid. A document analysis of the 11 systems with highest nitrate concentrations confirmed nitrate problems in all systems, as demonstrated in Table 3. All of these systems have been contacted by CDPH Small System Program Plan, which helps allocate funds for water system improvements. One system, Gleanings for the Hungry, now effectively filters for nitrates, having privately funded system improvements. Seven systems have begun the grants solicitation process, but have yet to receive funding or to begin construction. Two systems have not begun this process, and no information was found on whether these systems have solicited any other grant funding (Table 3).

The California Drinking Water Source Assessment and Protection (DWSAP) program identified the potential nitrate threats to well water quality for 10 of these 11 systems in 2002. Agricultural drainage, known contaminant plumes in the aquifer, and high concentrations of aging septic were common causes of nitrate vulnerability and contamination in these systems. The CDPH Small System Program Plan was also helpful for this research because they have designated disadvantaged statuses for small community water systems. Disadvantaged communities are generally defined as having a median household income below 80% of the statewide median household income; the median is below 60% in severely disadvantaged communities. As indicated in Table 3, the methods used to determine average "Median Household Income" of CWSs in this study did not always align with the "Disadvantaged Status" given by the CDPH. Whereas the Small Water Program Plan listed eight out of the eleven CWSs with high nitrate concentrations as disadvantaged or severely disadvantaged, the median household income estimates in this summary found only five of the eleven systems in these categories (calculated using the California 2010 Median Household Income of $61,655).

IV. Discussion

a. Statistical Evidence of Environmental Injustice

This study tested the statistical significance of factors that appear in the literature to affect drinking quality in the San Joaquin Valley by testing for number of connections, to reflect the population size; the median household income and rates

Table 3. Document Research Results of Most Contaminated Systems
* Mobile home parks, ** labor camp, + high levels of other contaminants

CWS Name	Avg. Nitrate (mg/L)	Disadvantaged Status according to CDPH	Median Household Income	Latino Estimate	Renter Estimate	# of Connection	Solicited Funding	Resolved as of July 2014
Rodriguez Labor Camp**	115.5	SD	$28,947 (SD)	81%	57%	35	Yes	No
Gleanings for the Hungry	82.4	SD	$30,087 (SD)	91%	65%	12	No	Yes
Soults Mutual Water Co	80	D	$44,609 (D)	70%	30%	36	Yes	No
Beverly Grand Mutual Water Co	75	SD	$54,000 (N)	53%	8%	28	Yes	No
Sierra Mutual Water Co	70.7	D	$55,497 (N)	26%	22%	15	No Info	No
Del Oro River Island Serv. Terr. #2	66.5	N	$55,938 (N)	19%	20%	30	Yes	No
El Monte Village MHP*+	53.7	N	$51,750 (N)	49%	46%	49	No Info	No
Faith Home Teen Ranch	50.8	N	$43,667 (D)	47%	50%	7	Yes	No
Lemon Cove Water Co	50	D	$68,728 (N)	10%	21.5%	50	Yes	No
Central Water Co +	49	SD	$26,250 (SD)	83%	48%	42	Yes	No
Westlake Village MHP*+	45.7	D	$63,556 (N)	30%	16.5%	139	Yes	No

of homeownership, which are related class; and the percentage of Latinos served by community water systems. The results indicate that the percentage of Latinos explains some of the variability in contamination, and thus supports the argument that the burden of drinking water contamination is unequally distributed. As the proportion of Latinos served increases, especially in Tulare County, incidence of nitrates in drinking water also increases. The coefficient of determination in this case was 0.15, so unavailable factors explain most of the variability. While statistical analysis of distributive justice may obscure individual cases of environmental discrimination when performed across a region, when race or class are significant within a large sample, this is indicative of a trend. Unlike previous findings (Balazs *et al.* 2011), this relationship was evident unrelatedly to community water system size. System size did not prove to be highly correlated with nitrate contamination (correlation test, regression analysis), but when CWSs were grouped by size and level of contamination, small systems were more likely to be contaminated than large systems (Wilcox test). While this may support previous research showing an increased burden on small systems, the relationship between system size at parameter of 200 connections and nitrate contamination is not apparent from available data.

a. Uncertainty

The document research findings in the CDPH Water Small System Program Plan suggest that different methods may be more effective in determining median household incomes of community water systems – and by extension, rates of homeownership and race. The uncertainty in the accuracy of these factors makes it difficult to capture their impact. It is unclear whether the differences between disadvantaged statuses predicted by the methods used in this study and those used by the California Department of Public Health resulted from different geographic methods or from more site-specific background information acquired by the Small Water System Program Plan team for the systems and the communities they serve. The use of census block group population estimates presents a modifiable areal unit problem that may inaccurately represent the population characteristics where block group and CWS boundaries are discrepant. It is possible that such errors may have also affected the results from the regression analysis, which found no correlation between median household income and nitrate contamination in the San Joaquin Valley. If the discrepancies in income are rooted in geographic methods, it is also possible that the trend, precision and significance of outcomes for race and homeownership can improve with more accurate or complete data.

Analysis of contamination was also affected by uncertainty because of the incomplete reporting of nitrate levels. Smaller systems were less likely to monitor for nitrates during the study period, so the relationship with nitrate contamination and system size is difficult to predict. Because smaller systems tend to serve higher proportions of Latinos and renters (Balazs *et al*. 2011), if they also have higher rates of contamination, the correlation and significance of race and income in this analysis is underestimated. This study defined small community water systems as ones with 200 connections or less in order to replicate a previous study. Small systems were shown to be more likely to be classified as having medium or high levels of nitrates, but size was not a significant factor in the regression model. Of the 11 CWSs classified as having high-levels of nitrates, all but one have 50 or fewer connections (Table 3). Very small systems may face more challenges than even small systems with 200 connections, but this would require further study.

In addition to low sampling rates, the time of year when the samples are taken can affect the results. In areas with a high water table and shallow wells, it is possible nitrate levels fluctuate with an increase in irrigation or precipitation. In fact, climate combined with land uses, farm management practices, and physical properties of the soil and aquifer influence the presence of nitrates in an aquifer.

Although this study focused on the estimated quality of water delivered to consumers, the increased rates of nitrate presence in the Tulare Lake Basin aquifer is what causes this problem for community water systems drawing from this groundwater. The relationship of nitrate presence in groundwater and nitrate presence in drinking water are geographically linked, but these factors were not used in model in this study.

b. Future Research

i. Compounding Factors

The variation in local results, as well as the document analysis, indicate a need for site-specific understanding. For example, although median household income was not an indicator for nitrate contamination in drinking water across the region, it may still be at play in specific cases, as discussed in procedural justice and rural economic research, demonstrated in the statistical analysis of Tulare County, and indicated by the systems with low median household income or disadvantaged status in Table 3. Where income and water quality are linked at a scale not captured by the available units of resolution, this relationship remains invisible.

This study did not determine whether CWSs were public or private, if they were located in unincorporated areas, the amount of money invested in maintenance, nor what types of governance oversight they received, so these characteristics, deemed relevant in some cases by procedural justice research, were not included in the statistical analysis. It is useful to understand the procedural justice research discussed previously in this paper to determine sources of structural discrimination, although a deeper analysis of the effects of labor and industry history and housing patterns in the San Joaquin Valley may also warrant consideration. A closer look at the water systems with the highest concentrations of nitrates revealed other potential explanatory characteristics that have not yet been discussed in the drinking water literature concerning the San Joaquin Valley. For example, three of the eleven systems with the most contaminated water - Beverly Grant Mutual Water Co., El Monte Village Mobile Home Park, and Soults Mutual Water Co., serve communities that have been identified as particularly vulnerable in a study by the Pacific Institute (Moore and Matalon 2011). Moore and Matalon (2011) reported that many residents are unaware of nitrate threats, and those who are, are economically burdened by actions to avoid nitrate contaminated water. Two of the eleven high-nitrate systems serve mobile home parks, one of which has problems with high arsenic concentration in addition to high nitrate contamination. A third system serves an agricultural labor camp. These communities may be more vulnerable to contamination because their populations are transient and socially marginalized, and/or because they are located in the heart of agricultural districts where chemical application and chemical spills most immediately pollute aquifers. The special vulnerability of transient labor communities to drinking water problems was noted in some of the earliest literature on the conditions of Central Valley farm labor but has not been discussed in recent literature examining drinking water quality in the San Joaquin Valley (McWilliams 1939, Kushner 1975, Mitchell 1996).

Further study can help explain the relationship between the locations of the observed disadvantaged communities, labor camps, and mobile home parks and the higher rates of nitrate contamination in drinking water served to these residents. The social contexts that sustain high levels of nitrate contamination in community water systems reflect an important critique of statistical analysis such as that performed in this study: that race (and income/homeownership) cannot be isolated from social, political, and economic structures, and that statistical analysis threatens to produce a simplified story of what is in fact a "multi-headed problem" (Pulido 1996, Kurtz 2003, Schweitzer and Stephenson 2007). A simplified story may encourage technical and site- or contaminant-specific fixes, or leave cases vulnerable to be "contained, grossly oversimplified, and refuted" (Kurtz 2003). Researchers have demonstrated links between zoning laws, unequal political power, city incorporation, and housing discrimination in the production of environmental inequality in California (Pulido 2000, Cole and Foster 2001, Anderson 2008), but little research has focused on the San Joaquin Valley or used these patterns to explain drinking water quality in the region.

ii. Compounding Impacts

Unequal exposure to environmental contamination, over time and from varying sources, is likely to produce a greater differential in health outcomes. The methods used in this study averaged source and system findings over just a three-year period. This may have obscured the magnitude of shorter-term high-nitrate events and has certainly limited a longitudinal understanding of longer-term nitrate contamination. In order to understand potential health effects, future research should aim to consider long-term exposure, as well as exposure to other contaminants that may occur in water or elsewhere in the home, neighborhood, school or workplace, as well as the ways in which these health risks are experienced by individuals, families and communities (Brulle and Pellow 2006, Evans and Kantrowitz 2002). In mapping "risk-scapes" in the San Joaquin Valley, one cumulative assessment of hazards found that socioeconomic status and exposure to contamination were highly correlated. For example, in areas that the study determined to be medium-high risk, 61% of the residents were people of color and 24% lived below the poverty line, whereas lower-hazard areas had only 47% people of color and 17% below the poverty line (London *et al.* 2011). Such a cumulative assessment could benefit from ascertaining potential exposure to toxics through water used for drinking, bathing, and washing (Huang and London 2012).

V. Conclusion

In continuing to explore the inequalities in access to safe drinking water in California, this study aimed to model the relationship between nitrate contamination, race, and socioeconomic status by replicating one of the only other studies of its kind. The results of the present study demonstrated a significant relationship between nitrate contamination and the proportion of Latinos served by San Joaquin Valley community water systems, as found in previous research (Balazs *et al.* 2011). Race and income appear to be more strongly correlated with nitrate contamination in Tulare County, though the greater range in nitrate contamination levels in this region may influence the difference in correlation coefficients.

Document research of the most contaminated systems identified by the present study indicates a need for research from other social science fields. Housing patterns, labor status and employment sector, and land-use patterns may provide important supplemental information to inform a more complete understanding of the distribution of and vulnerability to drinking water contaminants in the San Joaquin Valley of California. Though the causes may be unclear, the distribution of nitrates in drinking water of community water systems in the San Joaquin Valley appear to disproportionately affect systems serving higher proportions of Latino residents, and thus reflect environmental injustice. Site-specific analyses may help to explain the relationship between contamination levels and ethnicity and, for example, conditions of labor camps and rural trailer/mobile home parks. More importantly, site-specific understanding will support appropriate solutions to inequalities in access to safe and affordable drinking water.

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