Addressing Nitrate in California's Drinking Water

TECHNICAL REPORT 7:

Alternative Water Supply Options for Nitrate Contamination

With a Focus on Tulare Lake Basin and Salinas Valley Groundwater

Report for the State Water Resources Control Board Report to the Legislature

California Nitrate Project,
Implementation of Senate Bill X2 1

Center for Watershed Sciences
University of California, Davis
http://groundwaternitrate.ucdavis.edu

Prepared for the California State Water Resources Control Board

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Prepared for:

California State Water Resources Control Board

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[2] California Department of Water Resources, Land Use Classification: Irrigated acre totals.

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Acronyms and Abbreviations

ACR	Annual Compliance Report
Af	Acre-feet
af/year	Acre-feet per Year
ANSI	American National Standards Institute
BID	Background Information Document
CADWSAP	California Drinking Water Source Assessment and Protection Program
CCR	Consumer Confidence Report/California Code of Regulations
CDF	California Department of Finance
CDHS	California Department of Health Services
CDP	Census Designated Place
CDPH	California Department of Public Health
CFR	Calculated Fixed Radius
CPWS	Community Public Water System
CVP	Central Valley Project
CWC	California Water Code/Community Water Center
DAC	Disadvantaged Community
DBCP	Dibromochloropropane
DDWEM	Division of Drinking Water and Environmental Management (CDPH)
DUC	Disadvantaged Unincorporated Community
dus	Dwelling Units
DWP	Drinking Water Program
DWR	Department of Water Resources
DWSAP	Drinking Water Source Assessment Protection Program
EDB	Ethylene Dibromide
EDR	Electrodialysis Reversal
ELAP	Environmental Laboratory Accreditation Program (CDPH)
FDA	Food and Drug Administration
FDB	Food and Drug Branch (CDPH division)
FOB	Field Operations Branch
GAMA	Groundwater Ambient Monitoring and Assessment
gpd	Gallons Per Day
gpm	Gallons Per Minute
hhld	Household
ICE	Information Center for the Environment (UC Davis)
IX	Ion Exchange (Anion Exchange)
kgal	Kilogallon = 1,000 gallons
LPA	Local Primacy Agency
LSWS	Local Small Water System
MCL	Maximum Contaminant Level

MGD	Million Gallons per Day
MHI	Median Household Income
N	Nitrogen
NAWQA	National Water-Quality Assessment
NGWA	National Groundwater Association
NO_3^-	Nitrate
NSF	National Sanitation Foundation
NTNC	Non-Transient Non-Community
O&M	Operations & Maintenance
OEHHA	Office of Environmental Health Hazard Assessment
PCA	Possible Contaminating Activities
PCE	Perchloroethylene
PHG	Public Health Goal
PICME	Permitting Inspection Compliance Monitoring and Enforcement
PLC	Programmable Logic Controller
POE	Point-of-entry
POU	Point-of-use
ppm	Parts Per Million
PWS	Public Water System
RO	Reverse Osmosis
SB	Senate Bill
SCADA	Supervisory Control and Data Acquisition
SDAC	Severely Disadvantaged Community
SDWA	Safe Drinking Water Act
SSWS	State Small Water System
SV	Salinas Valley
SWB	State Water Resources Control Board (State Water Board)
SWP	State Water Project
SWS	Small Water System
TCE	Trichloroethylene
TCP	Trichloropropane
TLB	Tulare Lake Basin
TMF	Technical, Managerial and Financial
TNC	Transient Non-Community
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USGS	United States Geological Survey
U.S. EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WQM	Water Quality Management
ZOC	Zone of Contribution

Unit Conversions

Metric to US		**US to Metric**	
Mass		*Mass*	
1 gram (g)	0.04 ounces (oz)	1 ounce	28.35 grams
1 kilogram (kg)	2.2 pounds (lb)	1 pound	0.45 kilograms
1 megagram (Mg) (1 tonne)	1.1 short tons	1 short ton (2000 lb)	0.91 megagrams
1 gigagram (Gg) (1000 tonnes)	1102 short tons	1000 short tons	0.91 gigagrams
Distance		*Distance*	
1 centimeter (cm)	0.39 inches (in)	1 inch	2.54 centimeters
1 meter (m)	3.3 feet (ft)	1 foot	0.30 meters
1 meter (m)	1.09 yards (yd)	1 yard	0.91 meters
1 kilometer (km)	0.62 miles (mi)	1 mile	1.61 kilometers
Area		*Area*	
1 square meter (m^2)	10.8 square feet (ft^2)	1 square foot	0.093 square meters
1 square kilometer (km^2)	0.39 square miles (mi^2)	1 square mile	2.59 square kilometers
1 hectare (ha)	2.8 acres (ac)	1 acre	0.40 hectares
Volume		*Volume*	
1 liter (L)	0.26 gallons (gal)	1 gallon	3.79 liters
1 cubic meter (m^3) (1000 L)	35 cubic feet (ft^3)	1 cubic foot	0.03 cubic meters
1 cubic kilometer (km^3)	0.81 million acre-feet (MAF, million ac-ft)	1 million acre-feet	1.23 cubic kilometers
Farm Products		*Farm Products*	
1 kilogram per hectare (kg/ha)	0.89 pounds per acre (lb/ac)	1 pound per acre	1.12 kilograms per hectare
1 tonne per hectare	0.45 short tons per acre	1 short ton per acre	2.24 tonnes per hectare
Flow Rate		*Flow Rate*	
1 cubic meter per day (m^3/day)	0.296 acre-feet per year (ac-ft/yr)	1 acre-foot per year	3.38 cubic meters per day
1 million cubic meters per day (million m^3/day)	264 mega gallons per day (mgd)	1 mega gallon per day (694 gal/min)	0.0038 million cubic meters/day

Nitrate Units

*Unless otherwise noted, nitrate concentration is reported as milligrams/liter as nitrate (mg/L as NO_3^-).

To convert from:

Nitrate-N (NO_3-N)	→	Nitrate (NO_3^-)	multiply by 4.43
Nitrate (NO_3^-)	→	Nitrate-N (NO_3-N)	multiply by 0.226

Summary

The Tulare Lake Basin and Salinas Valley were chosen as pilot study areas because communities in these regions are faced with the need to manage high nitrate loads from agricultural lands and dairies, have a high risk of exposure to nitrate contamination in groundwater, and often cannot afford treatment or alternative water supply options. These factors combine to make the Tulare Lake Basin and Salinas Valley highly susceptible to health effects from nitrate in drinking water.

There are 371 active community public water systems (CPWS) and 30 state small water systems (SSWS) in the study area (281 and 120 in the Tulare Lake Basin and Salinas Valley, respectively). These systems supply water to about 2.4 million people. An estimated additional 245,490 people in these regions get their drinking water from an estimated 74,400 private domestic wells (self-supplied households or local small water systems with fewer than five connections) that are unregulated and largely unmonitored.

The 371 CPWSs are supplied by 3,829 sources and the 30 SSWSs by 31 sources. Of the 3,860 sources overall, 3,682 are wells pumping groundwater; the rest are surface water. According to the California Department of Public Health's (CDPH) Permitting Inspection Compliance Monitoring and Enforcement database (PICME), the Tulare Lake Basin has 8 SSWSs and 172 CPWSs serving very small systems (< 501 people) and 47 community public water systems serving small systems (501 to 3,300 people). About 81% of the Tulare Lake Basin water systems (five or more connections) are very small or small and in total serve 89,125 people (4% of the Tulare Lake Basin population). The Salinas Valley has 22 state small and 73 community public water systems serving very small systems and 11 community public water systems serving small systems. About 89% of the Salinas Valley water systems are very small or small and in total serve 23,215 people (6% of the Salinas Valley population). Thirteen water systems in the study area treat for nitrate. Of these, eight water systems treat by blending with lower nitrate sources, four water systems treat with ion exchange, and one system treats with reverse osmosis.

Approximately 254,000 people in California's Tulare Lake Basin and Salinas Valley have drinking water supplies susceptible or potentially susceptible to nitrate groundwater contamination. Water users that are served by a community public water system with water nitrate concentrations recorded in excess of 45 mg/L in the last five years, or lacking historical nitrate records, account for about 220,000 people. The remaining 34,000 people are estimated to be connected to a self-supplied household or local small water system located in areas with a high likelihood of groundwater in excess of 45 mg/L as nitrate. Assuming unchanging and unabated basin-wide trends in observed nitrate groundwater levels since 1970, the community public water system population facing financial impacts from excess nitrate in raw water supplies is estimated to increase from 57% currently, to 80% by 2050.

Each SSWS and CPWS with high susceptibility (50 and 35 systems in Tulare Lake Basin and Salinas Valley, respectively) will need individual engineering and financial analyses. No single solution will fit every community affected by nitrate in groundwater. In addition, the 34,000 people on approximately 10,000 household self-supplied systems at high risk of contamination remain unregulated and outside any currently existing regulatory framework to provide safe drinking water.

The most promising options (based on availability and economic considerations and in no particular order) for communities connected to highly susceptible water systems are to: i) consolidate with a nearby larger system; ii) consolidate with nearby smaller systems into a new larger regionalized system; iii) install groundwater community treatment; iv) drill a new well; v) blend sources; and as an interim solution, vi) provide and maintain point-of-use treatment for households. This analysis suggests significant potential for smaller water systems to consolidate with larger water systems. Promising solutions for self-supplied households or local small water systems within a highly susceptible sub-area are to install a point-of-use or point-of-entry treatment system or to drill a new, deeper well.

Consolidation of systems was examined based on system size and the distance from a smaller system to a larger system. In the Tulare Lake Basin and Salinas Valley, about 50% and 15% of smaller systems, respectively, are within five miles of a larger system (>10,000 people), and 88% and 97% of smaller systems, respectively, are within 12.5 miles of a larger system.

The overall cost of providing nitrate-compliant drinking water to the currently affected population in the Tulare Lake Basin and Salinas Valley is estimated to be about $20 million per year for the short-term and about $36 million per year for the long-term. Roughly $17 to $34 million per year of this estimate is for community public water system users for the short- to long-term, respectively, and about $2.5 million is for providing and maintaining point-of-use treatment for household self-supplied or local small water system users. To put this funding need in perspective, the overall costs correspond to $80 to $142 per year per susceptible person, $5 to $9 per study area irrigated acre per year, or $100 to $180 per ton of fertilizer nitrogen applied, for the short- to long-term, respectively.

1 Introduction

Nitrate is the most common chemical contaminant in the world's aquifers and has significant potential to harm human health (Spalding & Exner 1993). A 2002 report from Lawrence Livermore National Laboratory (Esser et al. 2002) concluded that of all regulated contaminants in drinking water, nitrate contamination poses the greatest threat to California's drinking water supply. High nitrate levels in groundwater in California are primarily from the use of fertilizers on agricultural land and land application of manure at dairies. On average, more than 80 pounds of nitrogen (N) per acre per year may leach into the groundwater from fertilizer application on California farms (Harter 2009 and Dzurella et al. 2012). Other locally important nitrate sources include animal feed lots, wastewater discharges, and septic systems. California's extensive agricultural lands and dairies have greatly increased nitrate loads to groundwater over time. Based on California Department of Public Health (CDPH) statewide data collected since 1980, of the approximately 13,150 public drinking water sources sampled, nitrate levels exceeded the primary drinking water standard (Maximum Contaminant Level or MCL) at least once in 1,077 wells (State Water Resources Control Board (SWB) 2010). A 1988 Report on nitrate in drinking water reported that 10 percent of the California samples in the U.S. EPA database exceeded the MCL, with the highest density of contaminated wells in the Central Valley located close to the Highway 99 corridor, in cities, and near dairies or feedlots (SWRCB 1988). In the San Joaquin Valley, between 2005 and 2008, 92 of the 671 drinking water systems had at least one groundwater well with nitrate levels exceeding the MCL. These 92 drinking water systems serve more than a million residents (Balazs 2011).

Groundwater nitrate concentrations exceeding 9 to 13 mg/L as nitrate (2 to 3 mg/L as N) generally indicate contamination from human-related nitrate sources (Mueller 1995). The drinking water MCL for nitrate was set by CDPH in 1994 at 45 mg/L as nitrate (NO_3^-). This is equivalent to the 1991 federally mandated MCL of 10 mg/L nitrate as nitrogen (N) (CaEPA 1997). In the regulatory literature, nitrate concentrations in water may be reported in milligrams of nitrate per liter (mg/L of NO_3^-) or in milligrams of nitrate-nitrogen per liter (mg/L of N). This report follows the convention of reporting in milligrams of nitrate per liter (as mg/L of NO_3^-).

The Salinas Valley and the Tulare Lake Basin were chosen as pilot study areas for examining solutions to groundwater nitrate contamination for reasons including the high dependence on groundwater for drinking, the high levels of nitrate observed in groundwater in community public water system and domestic wells, and the challenges faced by affected communities in securing safe drinking water in these regions. These factors combine to make the population in the Salinas Valley and the Tulare Lake Basin more at risk to health effects from nitrate in drinking water.

To address nitrate groundwater contamination in the Tulare Lake Basin and the Salinas Valley, the 2010 susceptible population is estimated and available alternative water supply options assessed for recent and long-term conditions. The susceptible population is the population that is currently at risk of drinking water from their tap with nitrate in excess of 45 mg/L, the safe drinking water limit, based on the most recent drinking water quality monitoring data available. First, background on each basin and a map of the study area is presented. The area and population are reviewed. To quantify susceptible water users, each water supply system type is first categorized in terms of vulnerability to deliver nitrate contaminated drinking water should excess nitrate in a groundwater source occur, and then the likelihood that groundwater sources or a system's actual delivered water with nitrate concentrations above 45 mg/L is examined. Each identified alternative water supply option is evaluated in terms of financial and economic costs, public health concerns, least cost management, and regulatory implications. Based on the estimate of susceptible water users and the costs and technical feasibility of alternative water supply options, promising alternatives are presented for differing water system types and sizes.

2 Study Area Background

2.1 Tulare Lake Basin (TLB)

The Tulare Lake Hydrologic region, as defined by DWR in the 2003 update of Bulletin 118, covers 8,000 square miles in the southern Central Valley of California (DWR 2003).

Here, the Tulare Lake Basin Study Area is defined as only the areas within the larger DWR-defined Tulare Lake Hydrologic Region that are a part of the San Joaquin Valley Groundwater Basin. The 8,045 square miles of underlying basin area (DWR 2003) can be defined by the following DWR Bulletin 118 Groundwater Sub-Basins: 5-22.08 (Kings), 5-22.09 (Westside), 5-22.10 (Pleasant Valley), 5-22.11 (Kaweah), 5-22.12 (Tulare Lake), 5-22.13 (Tule), 5-22.14 (Kern County), and the southern tail of 5-22.07 (Delta-Mendota) (Figure 1). The Tulare Lake Basin portion of the study area includes the Central Valley basin parts of Fresno, Kings, Kern, and Tulare counties (Figure 2).

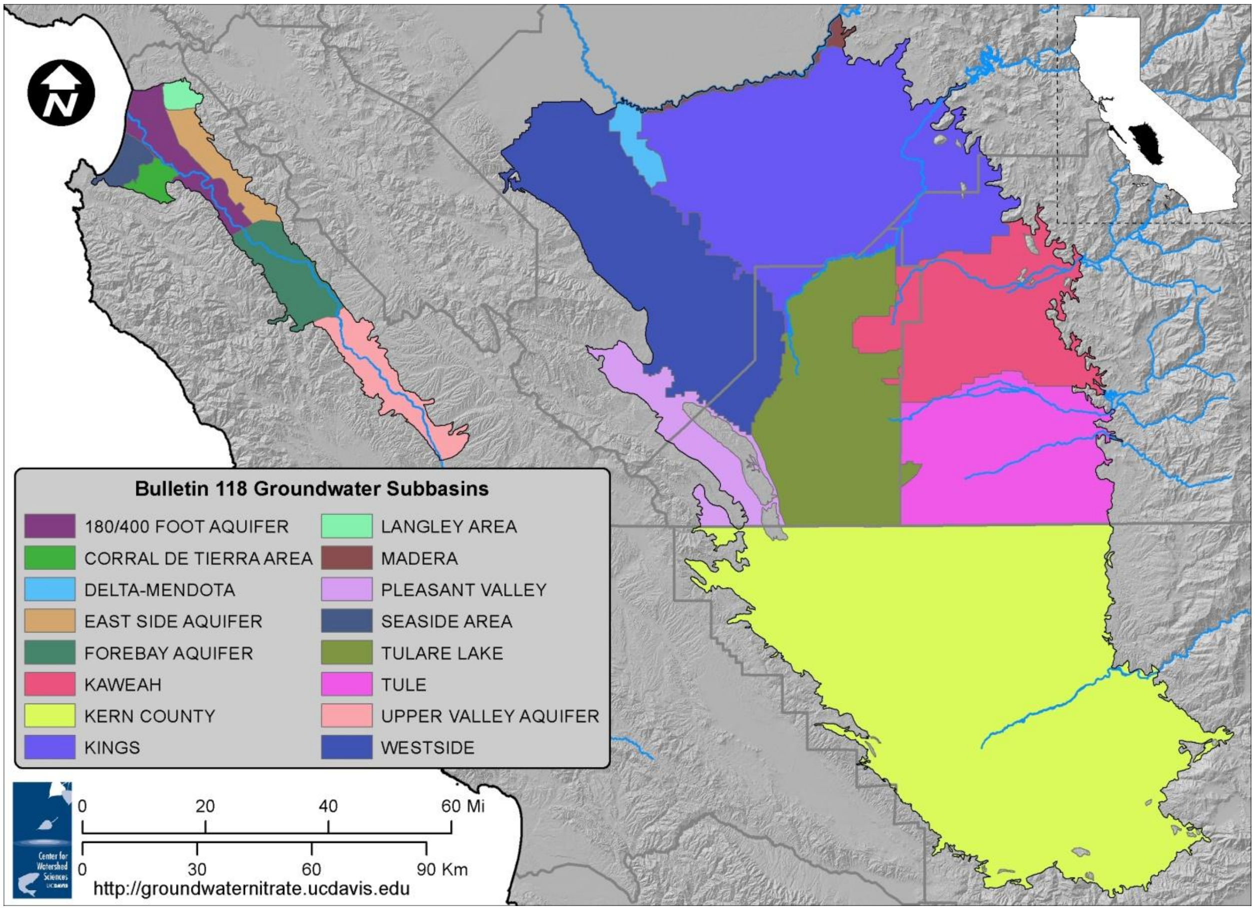

Figure 1. **Bulletin 118 groundwater basins in the study area. (Source: DWR 2003.)**

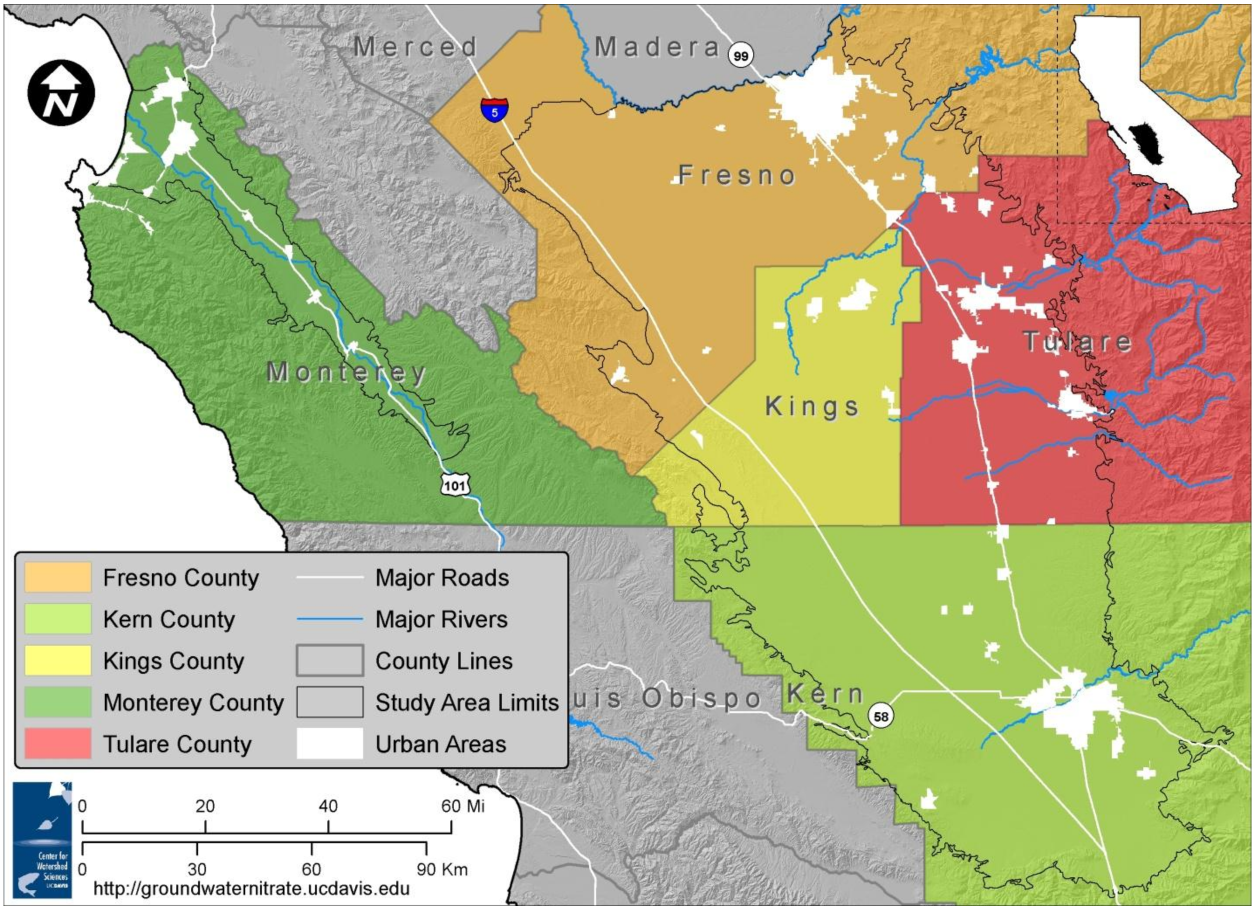

Figure 2. Salinas Valley and Tulare Lake Basin counties. (Source: 2000 Census.)

The Tulare Lake Basin has a Mediterranean climate with hot, dry summers and cool, moist winters. Average rainfall varies from seven inches in central and western parts of the Basin to thirteen inches in eastern parts of the Kaweah and Kern County Sub-Basins (DWR 2003). The Basin's largest city (Fresno) depends almost entirely on local groundwater (DWR 2003). Fresno, Tulare, Kern, and Kings Counties were first, second, third, and eighth among the nation's top agricultural producing counties with gross production values of $5.37 billion, $4.05 billion, $3.61 billion, and $1.76 billion for 2008 (USDA et al. 2008). There are approximately 3.4 million acres of irrigated land in the Tulare Lake Basin; production values are $1,579, $1,191, $1,062, and $518 per irrigated acre, for each county respectively.[2]

In 2000, 11% of the population, or over 200,000 people, lived in areas classified as rural. The other 1.6 million people lived in areas classified as urban.[3] Since 2000, the population of 1.8 million in the Tulare Lake Basin[4] grew to an estimated 2.25 million by 2010.

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[2] California Department of Water Resources, Land Use Classification: Irrigated acre totals.

[3] This designation used 2000 census blocks. It follows the 2000 US Census method of defining urban versus rural on the basis of population density: an urbanized area or an urban cluster consists of: 1) core census block groups or blocks that have a population density of at least 1,000 people per square mile and 2) surrounding census blocks that have an overall density of at least 500 people per square mile (US Census Bureau N.D.).

2.2 Salinas Valley (SV)

With a total drainage area of five thousand square miles, the Salinas Valley (SV) watershed is the largest southern California coastal basin (Kulongoski & Belitz 2005). It is bordered by the San Joaquin Valley and the Pacific Ocean. Boundaries for the SV for this report follow DWR Bulletin 118 Groundwater Sub-Basins: 3-4.01 (180/400 Foot Aquifer), 3-4.02 (East Side Aquifer), 3-4.04 (Forebay Aquifer), 3-4.05 (Upper Valley Aquifer), 3-4.08 (Seaside Area), 3-4.09 (Langley Area), and 3-4.10 (Corral de Tierra Area) (Figure 1) and cover a total drainage area of 650 square miles. The Paso Robles area of the SV watershed is not included in this study. The SV, as considered here, is entirely within Monterey County (Figure 2).

Its climate features warm, dry summers and cool, moist winters. In Monterey, the average annual temperature is 57˚F and average annual precipitation is 20 inches (mostly during the winter and early spring) (Kulongoski & Belitz 2005). Precipitation in the entire Salinas Valley increases with both latitude and altitude (Kulongoski & Belitz 2005). The Salinas Valley depends almost entirely on local groundwater for all water supplies, and the SV supports one of the most productive agricultural industries in California (Monterey County Water Resources Agency 1996). Monterey was fourth among the nation's top agricultural producing counties with a gross production value of $4.03 billion for 2008 (USDA et al. 2008). The Salinas Valley has approximately 200,000 acres of irrigated land with an average production value of $20,150 per irrigated acre.[5]

In 2000, 7% of the population, or approximately 22,600 people, were classified as living in rural areas. The other 300,000 people were classified as living in urban areas.[6]

2.3 Drinking Water Systems

The residential water systems examined in this report include self-supplied households (or domestic wells), local small water systems, SSWSs, and CPWSs (Table 1). A self-supplied water system is not shown in Table 1, but is a system served by a single domestic well and is considered a small water system. Water system definitions and regulations are further discussed in Section 3.1 Drinking Water Supply Systems.

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[4] The total population living in the Tulare Lake Basin is based on summarizing population values listed in the 2000 US Census blocks (www.census.gov). This is an overestimation of the total population within the study area because blocks extend beyond study area boundaries.

[5] California Department of Water Resources, Land Use Classification: Irrigated acre totals.

[6] This designation uses 2000 census blocks. It follows the 2000 US Census method of defining urban versus rural on the basis of population density: an urbanized area or an urban cluster consists of: 1) core census block groups or blocks that have a population density of at least 1,000 people per square mile; and 2) surrounding census blocks that have an overall density of at least 500 people per square mile (US Census Bureau N.D.).

Table 1. Drinking water system connections and service duration.

	Connections:		<5	5+	<15	15+	<200	200+
Duration of Service	Persons served:		<25			25+		
N/A	Small Water System (SWS)[1]	Classification defined by	connections					
<60 days/year	Local Small Water System (LSWS)		connections and (persons, duration)					
	State small Water System (SSWS)			connections and (persons, duration)				
year-round	Community Public Water System (CPWS)[2]					connections or (persons, duration)		

[1] Classification as a SWS does not preclude classification as any of the other types. SWSs may be regulated by CDPH or by LPA.

[2] A CPWS is a system for the provision of water for human consumption that has 15 or more service connections OR regularly serves 25 individuals at least 60 days a year (CDPH 2010 b,c).

3 Susceptible Water Users

This section examines the existing California drinking water supply systems within the study area and summarizes current threats to groundwater quality in the study area in the context of the established nitrate safe drinking water standard (45 mg/L). A discussion of nitrate susceptible drinking water users is provided, defining system vulnerability and the susceptible population. To identify susceptible water users within the Salinas Valley and the Tulare Lake Basin, all public data pertaining to drinking water systems and water quality were collected and analyzed. Self-supplied households and their domestic well locations were estimated on a land parcel level. The population that relies on domestic wells or local small water systems was deduced from the basin total population and the land parcel level estimates for domestic wells. An overview of the methods and data used for estimating susceptible water users is provided in Section 3.3 Susceptible Water Users Overview.

3.1 Drinking Water Supply Systems

Water system types are defined by the period of water service, the number of people served, and the number of connections. A public water system (PWS) pipes water for human consumption to 15 or more service connections or regularly serves at least 25 people daily for at least 60 days of the year (CDPH 2010b; CDPH 2010c). PWSs include a wide range of system types, both residential and non-residential. A CPWS is a PWS that serves at least 15 residential connections all year or regularly serves at least 25 residents all year (CDPH 2010b; CDPH 2010c). In addition to CPWSs, PWSs include non-transient non-community (NTNC) and transient non-community (TNC) systems. A NTNC PWS serves drinking water to a stable non-residential population of more than 25 people; these systems are often schools and places of business (CDPH 2010b; CDPH 2010c). A TNC PWS serves areas such as campgrounds or restaurants that serve a changing population of 25 or more people, 60 or more days per year (CDPH 2010b; CDPH 2010c). A SSWS is not a PWS and pipes water to five to fourteen connections, and does not regularly serve drinking water to more than an average of 25 people daily for at least 60 days of the year (CDPH 2010b; CDPH 2010c). Systems with two to four service connections are referred to as local small water systems in some counties or as self-supplied households on a domestic well in other counties. Systems with less than two connections and self-supplied households are often referred to together as domestic wells.

Water system regulations depend on water system type. PWSs and CPWSs are state-regulated, SSWSs are county-regulated, and local small and household self-supplied systems are largely unregulated, unless a County ordinance requires well monitoring when well property is sold. Monterey County regulates their local small water systems and requires them to comply with Title 22 of the California Code of Regulations and the Monterey County Code (Monterey County Environmental Health 2011). PWSs and CPWSs are regulated by the state pursuant to Title 22 of the California Code of Regulations and Health and Safety Code Section 131051, et seq. PWSs and CPWSs must also adhere to the National Primary Drinking Water Regulations under the Safe Drinking Water Act.

Most counties are designated Local Primacy Agencies (LPAs) and are responsible for regulating community public water systems with up to 199 connections. Tulare County, Kings County, and Monterey County are all LPAs (CDPH 2011b; CDPH 2011c). Fresno County relinquished LPA authority in 2007. LPAs are also responsible for regulation or oversight of SSWSs (five to fourteen connections). County-regulated systems serving five to fourteen connections are not explicitly covered by the Safe Drinking Water Act, but they may still be required to treat by a variety of other contractual or development permit terms, local/county ordinances, or anti-pollution laws. However, monitoring or procedures to implement these requirements may not be in place. County-regulated water systems are subject to tort law[7] if they fail to protect the water delivered to consumers. Public water systems are also subject to tort law if they fail to protect the water delivered to consumers.

3.2 Water Quality Threats

Once the water quality of an aquifer has been degraded, the aquifer may no longer be considered a safe drinking water source without treatment; however, all groundwater designated as having municipal or domestic supply (MUN) beneficial use still has that designated use even if the groundwater is contaminated. Threats to groundwater quality can be point or nonpoint source pollution (see Technical Report 2, Viers et al. 2012). Point sources are easier to identify than nonpoint sources because they originate from specific locations, are usually regulated, and are typically discharged from pipes. Nonpoint sources occur from pollutants over a wide area, such as irrigation runoff or infiltration from agriculture. Examples of point sources of nitrate contamination include leaking underground septic systems and discharge from wastewater treatment plants to percolation basins. Nonpoint contamination comes from agriculture, mining, dairies, feedlots, and urban stormwater. Contaminants also enter aquifers directly from surface water, improperly built groundwater wells, and surface water infiltrating through the soil. The primary constituents of concern within California's groundwater are pesticides, nitrate, perchlorate, arsenic, volatile organic compounds (VOCs), microbial agents, and salts (DWR 2003). Contaminated groundwater can also affect the quality of surrounding surface water.

To protect the public from harmful constituents in groundwater and surface water, Congress passed the Safe Drinking Water Act (SDWA) of 1974 to require regular testing of drinking water supplies, set standards for contaminant concentrations, and schedule for development of new standards (U.S. EPA 2011a). The SDWA also requires the Office of Environmental Health Hazard Assessment (OEHHA, within Cal EPA) to adopt Public Health Goals (PHGs), pursuant to California Health and Safety Code Section 116535, based solely on public health considerations (CaEPA 1997). PHGs represent the official level of a contaminant that can be consumed daily for a lifetime without imposing a health risk. The PHGs are based entirely on public health considerations and are used, along with consideration of health, economic cost, and technical feasibility (examined by CDPH), to establish state MCLs. PHGs are developed for chemical contaminants based on the best available toxicological data in the scientific literature.

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[7] Tort law is a body of rights, obligations, and remedies that is applied by courts in civil proceedings to provide relief for persons who have suffered harm from the wrongful acts of others (Farlex Inc. 2012).

The PHG for nitrate is 45 parts per million (ppm), which is equivalent to California's current MCL of 45 mg/L (as NO_3^-). A system becomes legally non-compliant with the nitrate MCL, or "in violation," when there are two successive reporting MCL exceedances or failure to report the results of a follow-up test on an initial reporting MCL exceedance. Water systems that are currently non-compliant with the state MCL must distribute public notifications to all consumers of potential health risks from consumption of their water. When half the MCL is exceeded for nitrate, systems must switch from annual monitoring and reporting to quarterly monitoring and reporting and they must include a health information notice in the consumer confidence report (CCR) discussing public health concerns from consumption of nitrate (CDPH 2008). If a water system exceeds half of the MCL the system must "notify the governing body of the local agency in which users of the drinking water reside" and it is recommended that the systems notify their customers about the occurrence and health concern of consumption of the contaminant (CDPH 2008).

A summary of the state and federal agencies involved in protecting and improving California's drinking water quality appears in Table 2.

Table 2. California's drinking water quality responsibilities.[1]

Department	Key Water Quality Responsibilities
California Department of Public Health (CDPH)	▪ Enforces federal SDWA and state drinking water statues and regulations ▪ Ensures the quality of the state's public drinking water
California Department of Toxic Substances Control	▪ Protects water quality through enforcement, regulation, and pollution prevention
California Office of Environmental Health Hazard Assessment	▪ Performs health-risk assessments related to establishing drinking water standards
California Public Utilities Commission	▪ Ensures reliable service to regulated water utility customers
California State Water Resources Control Board (State Water Board) and California Regional Water Quality Control Boards (Regional Water Board)	▪ Protects the quality of the state's surface water and groundwater for beneficial use

[1] Baass 2011.

3.3 Susceptible Water Users Overview

Susceptible water users are those that could be potentially harmed or affected by consuming drinking water containing contaminants, or by costs related to such contamination. Susceptibility can be classified or defined in a variety of ways. Here, susceptible population is defined in the context of residential consumption of drinking water and the potential or likelihood for that water to have nitrate levels above 45 mg/L as nitrate. The residential users examined in this report are connected to community public, state small, local small, and self-supplied water systems. Previous studies refer to nitrate susceptible population from a human health perspective, such as subpopulations with a history of immunostimulatory conditions or lacking nitrosation inhibitors in the colon (De Roos et al. 2003). In this study susceptible population is defined in terms of consuming nitrate contaminated drinking water and not in terms of specific human health-related conditions as that is outside the scope of our work.

Balazs (2011) suggested a susceptibility measure based on system water quality and the total number of raw water sources within a community water system. Balazs categorized community public water systems by considering three levels of source water quality: 1) low (< 22.5 mg NO_3^-/L), 2) medium (22.5 mg NO_3^-/L to 44.9 mg NO_3^-/L), or 3) high (≥ 45 mg NO_3^-/L). Balazs then estimated the total population potentially exposed based on the population served by these individual community public water systems (according to CDPH's Permitting Inspection Compliance Monitoring and Enforcement Database (PICME)). For this report, we use a similar approach for defining susceptible water users.

Here, the susceptible population is estimated by examining the water system vulnerability and the recent raw source water and delivered source water (method discussed in Section 10.1.2 Estimating "Delivering" Sources of a System) quality (if available). Specifically we define "susceptible population" as the number of individuals who:

1. are served by a CPWS with multiple drinking water sources that has reported at least one delivered water nitrate record in excess of 45 mg/L in the past five years in CDPH's Water Quality Management Database (WQM), or
2. are served by a CPWS or SSWS with only a single drinking water source that has reported at least one raw water nitrate record in excess of 45 mg/L in the past five years in WQM, or
3. are on domestic wells or local small water systems and located in an area (Thiessen polygon) where shallow groundwater (<300 feet) has exceeded 45 mg/L as nitrate in the past (1989-2010, data from the UC Davis California Spatio-Temporal Information on Nitrate in Groundwater (CASTING) database), or
4. are served by a CPWS or state-documented SSWS (reported in PICME) lacking nitrate water quality data.

Additionally, the Annual Compliance Reports (ACRs) from CDPH were used to find systems in violation of the nitrate MCL from 2004 to 2008, to provide a narrow regulatory violator based estimate of the susceptible population and for comparison with the estimated susceptible population as defined above in item 1, for multiple source CPWSs.

To estimate the population susceptible to nitrate groundwater contamination in the study area, we first categorize the vulnerability of water systems, or system vulnerability. Population susceptibility is then scored as "high", "low", or "unknown" by evaluating historical nitrate water quality data. In other words, the population susceptibility is derived by scoring water system vulnerability and by scoring its respective water quality record.

System vulnerability describes the intrinsic potential for a system to inadvertently deliver drinking water to users with high nitrate levels based on the type of system and based on the number of water sources within the system. System vulnerability is scored as follows:

- Lower system vulnerability is assigned to community public water systems (water systems with > 15 connections) that have more than one source of water (i.e., more than one well) irrespective of whether or not they treat their water to reduce or remove nitrate.
- Higher system vulnerability is assigned to all other water systems (community public water systems with one well, and state small, local small, and household self-supplied water systems).

- No system vulnerability (to groundwater contamination) is assigned to water systems that are solely supplied by surface water.

Next, the likelihood for a system to encounter adverse drinking water quality conditions (with or without addressing these in the treatment process) is estimated to determine the susceptible population. We examine the water quality history documented for each system, or, if that information is not available, the historical ambient groundwater quality in the vicinity of each source or system. Given the system vulnerability and its water quality history, the susceptible population served by the system is ranked as:

- Low susceptibility if there has been no recent nitrate record in excess of 45 mg/L documented delivered water for multiple source systems, in documented raw water for single source systems, or in ambient groundwater in the vicinity of the source for undocumented systems.
- High susceptibility if there has been at least one recent nitrate record in excess of 45 mg/L in documented delivered water for multiple source systems, in documented raw water for single source systems, or in ambient groundwater in the vicinity of a source for undocumented systems.
- Unknown susceptibility, if a community public water system has no nitrate water quality data available.

The highly susceptible population in this study is considered to be the estimated population served by systems ranked as being of high or unknown susceptibility. The rest of the population is considered to be of low susceptibility to nitrate contamination in groundwater.

The water system populations within the delineated Tulare Lake Basin and Salinas Valley pilot study areas were estimated combining a variety of information sources, including the 2010 Census, California Department of Finance 2010 population estimates, each county's Local Agency Formation Commission, and CDPH PICME data. Once the total pilot area study population was estimated, the PICME population numbers for community public and state small water systems located in each basin were recorded and summed, and the difference used to estimate the remaining population and number of households supplied by domestic wells and local small water systems. This estimation method is inherently imprecise as to absolute populations due to data limitations and inconsistencies, including data coverage (i.e., Census block groups versus county boundaries), population values listed in PICME that are rounded up and tend to exceed the actual population served, and systems within the study area boundaries that may serve households just outside.

Details and discussion of the approach, data and results for classifying system vulnerability and susceptible population, follow in Section 3.4 Water System Infrastructure and Section 3.5 Susceptible Drinking Water Users. These sections include assumptions and methods used to estimate the various categories of classified populations. The final results from the analysis of the population susceptible to nitrate contamination in the pilot study area and each basin are presented in Section 3.6 Major Findings on Susceptible Water Users.

3.4 Water System Infrastructure

Water system vulnerability is based on a system's ability to protect against nitrate contamination. The system vulnerability classification describes the potential for delivering high nitrate water to users and is a function of system type. All households in the study area are categorized into four types of residential drinking water supply systems: household self-supplied, local small, state small, or community public water system. A household self-supplied, local or state small water system (not already in PICME) has higher vulnerability since they lack multiple sources. A community public water system with multiple sources has less vulnerability and a system using only surface water has no vulnerability to nitrate in groundwater. The CDPH WQM and PICME database provided all community public water system data and some state small water system information to identify system type, locate sources, and determine nitrate levels in raw and distributed water for the vulnerability and susceptibility assessments. The domestic wells were located based on the method discussed in Section 3.4.2.1 Household Self-Supplied or Local Small Water Systems.

In most counties, state small water systems receive little monitoring or regulatory attention, and are typically considerably more vulnerable to ambient pollution than are CPWSs. CPWSs must adhere to the state MCLs for all drinking water contaminants, so households on these systems should have less vulnerability to nitrate contamination. However, community public water systems having only one well have the potential to be more vulnerable since blending cannot be used as a relatively inexpensive solution.

Lower vulnerability is assigned to regulated CPWSs that have more than one well and the opportunity to blend. Systems that rely completely on surface water have no vulnerability to delivering groundwater contaminated with nitrate, though they may be vulnerable to other pollutants.

This report only addresses system vulnerability from community public water systems or water systems that directly serve residences. It is assumed that the non-community systems adequately warn their users if nitrate contamination is a concern; since users are not permanent, we here assume that they are generally able to either avoid use or provide themselves with safe drinking water from another source. Approximately 382 non-transient, non-community public water systems serve about 190,000 people in the study area. These 382 systems are non-residential and serve the same people for at least 6 months, such as schools and businesses. Approximately 318 transient non-community public water systems in the study area serve about 150,000 people. These 318 systems are non-residential and serve a changing population for at least 60 days per year, such as restaurants, hotels, stores and campgrounds.

According to PICME, 401 active community public and state small water systems exist in the study area regions (281 in the Tulare Lake Basin and 120 in the Salinas Valley). These systems supply water to about 2.4 million people. The 371 CPWSs are supplied by 3,829 sources and the 30 state-documented (listed in PICME) SSWSs supplied by 31 sources. Of the 3,860 sources overall, 3,682 are groundwater; the remaining 178 are surface water. The state small water systems in PICME do not account for all state small water systems in the study area. The 30 state small systems were included in PICME as part of Assembly bill 1403 and are further referred to as state-documented state small water systems (CDPH 2011). The locations and information on any other state small water systems, not contained in PICME, could not be identified, and thus the population served by these systems was not considered further.

Figure 3 breaks down the number of state small and community public water systems by their U.S. EPA size categories,[8] in PICME and the study area. The Tulare Lake Basin has 8 state small and 172 community public water systems serving very small systems (< 501 people), and 47 community public water systems serving small systems (501 to 3,300 people). About 81% of Tulare Lake Basin water systems (CPWSs and state-documented SSWSs) are very small or small and serve 89,125 people (4% of the Tulare Lake Basin population). The Salinas Valley has 22 state small and 73 community public water systems serving very small systems, and 11 community public water systems serving small systems. About 89% of the Salinas Valley water systems are very small or small and serve 23,215 people (6% of the Salinas Valley population). Figure 4 and Figure 5 show the number of PICME state small and community public water systems treating or blending raw water within each U.S. EPA size category in the Tulare Lake Basin and Salinas Valley.

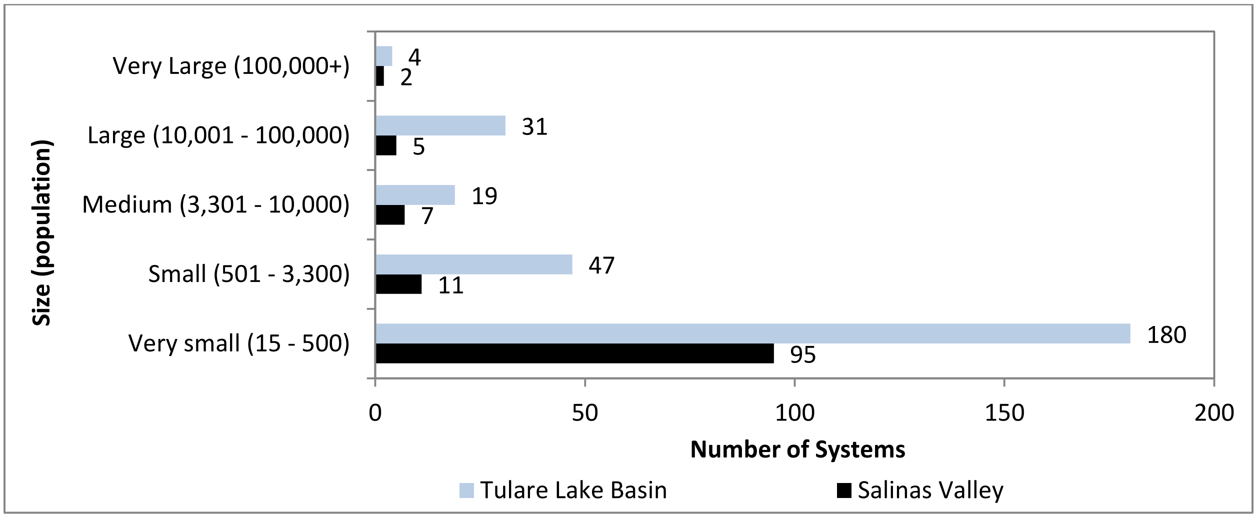

Figure 3. The size distribution (by population served) for state small (state-documented, listed in PICME) and community public water systems in the study area. (Source: CDPH PICME.)

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[8] USEPA system size definitions are: (1) very small serves 25-500 people; (2) small serves 501-3,300 people; (3) medium serves 3,301-10,000 people; (4) large serves 10,001-100,000 people; and very large serves greater than 100,000 people (U.S. EPA 2010). Available at: http://water.epa.gov/infrastructure/drinkingwater/pws/factoids.cfm.
Very small in this graph includes some of the SSWSs so the population ranges from 15-500.

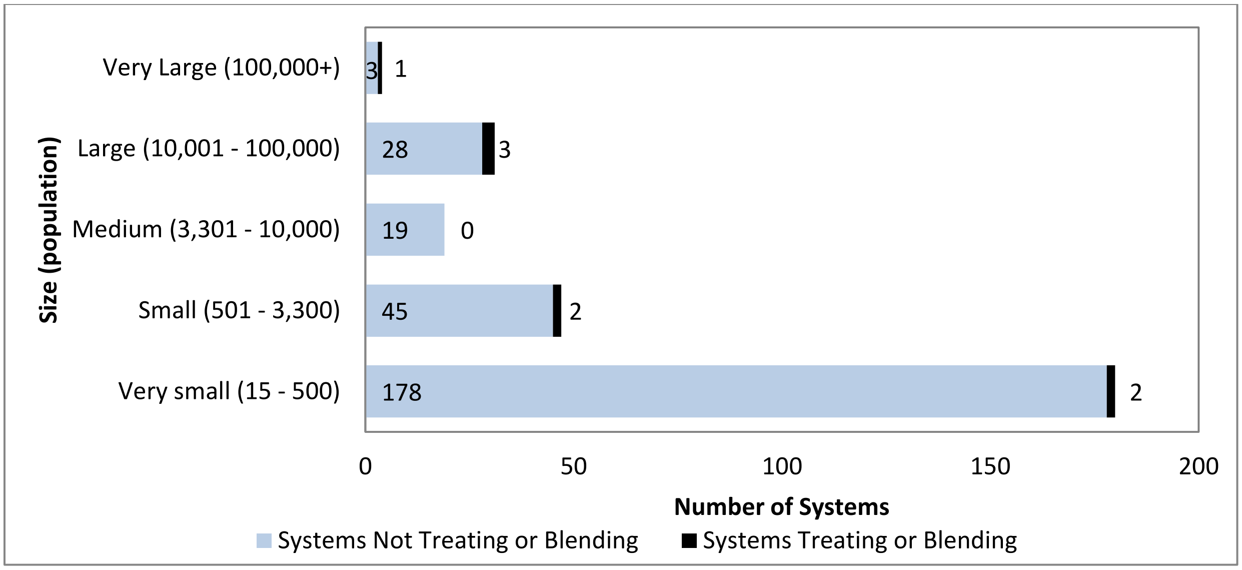

Figure 4. State small (state-documented) and community public water systems treating or not treating for nitrate in the Tulare Lake Basin. (Source: CDPH PICME and Technical Report 6, Section 5.2, Jensen et al. 2012.)

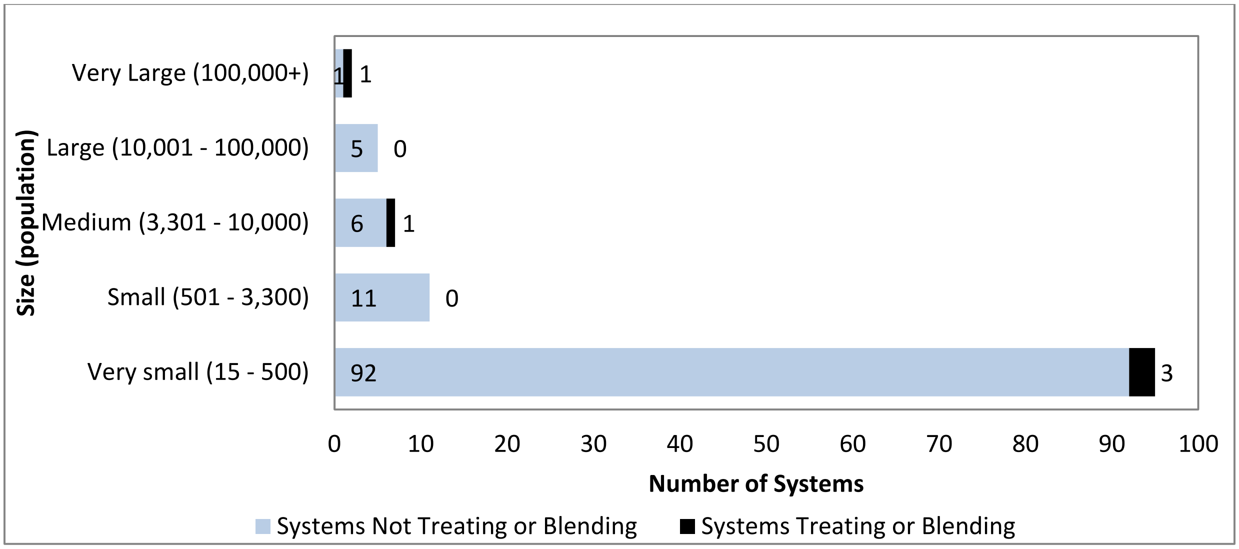

Figure 5. State small (state-documented) and community public water systems treating or not treating for nitrate in the Salinas Valley. (Source: CDPH PICME and Technical Report 6, Section 5.2, Jensen et al. 2012.)

3.4.1 Low System Vulnerability

Theoretically, a CPWS should not deliver water exceeding the nitrate MCL since they must adhere to the SDWA standards (see Section 3.5.1 Highly Susceptible). Where possible, high-nitrate sources can be blended with low-nitrate sources to reduce delivered nitrate levels to a compliant level (although daily monitoring and operations may not always identify an exceedance). Because of the strict regulations and guidelines and the availability of alternate sources, CPWSs with more than one well are considered to have lower system vulnerability.

The lower vulnerability CPWSs with more than one well include both systems treating for nitrate and not treating for nitrate. Thirteen water systems in the study area treat for nitrate (eight in TLB and five in SV) and eight of these systems treat[9] by blending with lower-nitrate sources (five in TLB and three in SV). Tables of these systems are presented below for the Tulare Lake Basin (Table 3) and the Salinas Valley (Table 4), and their size distributions are shown in Figure 4 and Figure 5, respectively. These systems were identified from inventories of counties in our study area, CDPH, and responses to *The Survey of Nitrate Treatment Systems* discussed in the Drinking Water Treatment Technical Report (See Technical Report 6, Section 5.2, Jensen et al. 2012).

Table 3. Community public water systems treating for nitrate in the Tulare Lake Basin.

UCD System Identifier	Treatment Type or Blending	Number of Sources	Connections	Population
1	Blending	4	81	230
2	Blending	29	7,406	25,500
3	Ion Exchange	15	2,220	12,138
4	Blending	36	7,035	26,860
5	Ion Exchange	2	44	139
6	Blending	8	471	1,904
7	Ion Exchange	190	40,530	133,749
8	Blending	10	89	2,567
TULARE LAKE BASIN TOTAL		**294**	**57,876**	**203,087**

Table 4. Community public water systems treating for nitrate in the Salinas Valley.

UCD System Identifier	Treatment Type or Blending	Number of Sources	Connections	Population
1	Blending	5	66	198
2	Blending	5	19	67
3	Blending	5	70	210
4	Ion Exchange	126	25,451	114,840
5	Reverse Osmosis	8	2,069	6,585
SALINAS VALLEY TOTAL		**151**	**27,680**	**121,945**

Of the total 401 active systems, 264 have more than one source (serving 2.3 million people) and have a lower vulnerability to nitrate contamination in groundwater. Of these, 193 systems are in the Tulare Lake Basin and serve 1.9 million people. The remaining 71 are in the Salinas Valley and serve 400,000 people. The susceptibility level of the population served by these lower vulnerability systems is discussed in Section 3.5 Susceptible Drinking Water Users.

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[9] Blending is an alternative that does not require a treatment technology; however blending is sometimes categorized as treatment because water systems are required to monitor and operate the blending process as a permitted treatment facility with a certified operator (CDPH 2008; Commandatore & Collins 2011).

3.4.2 High System Vulnerability

In addition to CPWSs with just one well source, households not served by a state-regulated CPWS, are considered highly vulnerable because county-regulated systems and individual household wells are usually neither monitored nor treated. If the groundwater source for these households experienced an increase in nitrate levels (above existing elevated anthropogenic levels), these households would not be protected from nitrate contamination. The systems with high system vulnerability are:

1) Household Self-Supplied or Local Small Water Systems (see Section 3.4.2.1)
2) Community Public or State small Water Systems with Only One Well (see Section 3.4.2.2).

3.4.2.1 Household Self-Supplied or Local Small Water Systems

The 1990 and 2010 Census spatial data, DWR land use class designation, and land parcel use code information were used to estimate the current 2010 population on household self-supplied or local small water systems and their approximate geographic locations.

Department of Water Resources (DWR) land use class designations and land parcel use codes were the key data sets used in this analysis. The number of dwelling units affiliated with each parcel was used to develop self-supplied household population estimates, while the parcel locations were used to estimate groundwater nitrate quality for residential susceptibility. It was assumed that 3.3 people reside at one dwelling unit, and parcels with four or fewer dwelling units (dus) were considered self-supplied (1-2 dus) or local small (3-4 dus) water systems. Residential parcels within city limits or water system boundaries were excluded from the count of self-supplied households.

Unlike more recent census data, the 1990 Census asked a sample population about their water systems. These data were collected at the household level and summarized in Attribute H23 of the 1990 Census.[10] Census block groups (for which data are reported) tend to be of small area in urban regions, but relatively large in rural regions so land use parcel code data was used in these areas for estimating self-supplied household and local small water system densities. We then compared the 2010 self-supplied household estimates to the 1990 Census block group numbers. The self-supplied and local small water system population found from parcel use codes and DWR land use designation is shown in Table 5.

The estimated location of these household self-supplied and local small water systems is shown in Figure 6, along with the area's community public and state-documented state small water systems from PICME. The total number of domestic wells in the study area portion of Kern County was difficult to accurately estimate as its parcel use code zoning differs from the other counties. In Kern County more parcels are zoned as having 100 plus dwelling units (i.e., apartment complexes and condominiums) than

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[10] Per the 1990 Census definitions, a source that supplies water to five or more housing units is considered a "Public system or private company." This includes any wells that supply water to five or more housing units. If the source serves four or fewer housing units, it is classified as: an "Individual drilled well," an "Individual dug well," or "Some other source." The last distinction, "Some other source," includes springs, creeks, rivers, lakes, cisterns, etc. (US Census Bureau 1999).

having single dwelling units. Approximately 235,125 people are on self-supplied household or local small water systems in the Tulare Lake Basin and 10,365 in the Salinas Valley (Table 5).

The US Census estimates that 7.6% of residents lived in rural areas in California between 2006 and 2008.[11] Using the counties' rural area definition,[12] an estimated 13% of California residents lived in rural areas in 2009. The self-supplied and local small water system population estimate based on the parcel code and DWR land use data falls within these rural population percentage estimates, accounting for 9.2% of the total study area population. The susceptible population served by these systems is examined in Sections 3.5.1.1 Household Self-Supplied or Local Small Water Systems with a High Likelihood of Nitrate Groundwater Contamination and 3.5.2.1 Household Self-Supplied or Local Small Water Systems with a Low Likelihood of Nitrate Groundwater Contamination.

Table 5. 2010 Estimated self-supplied and local small water system population within the study area based on the parcel use code and DWR land use designation.[1]

Basin	Domestic Wells	Population Served by Domestic Wells
Tulare Lake Basin	71,250	235,125
Salinas Valley	3,141	10,365
STUDY AREA TOTAL	**74,391**	**245,490**

[1] Domestic Wells = Household self-supplied and local small water systems. These are all well systems with fewer than four connections, based on the number of residential dwelling units on a parcel and its location outside of water system and city boundaries.

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[11] V. Manual Perez (Chair). Assembly Committee on Jobs, Economic Development and the Economy: *Fast Facts on California Rural Communities* (June 2010). Rural areas contain population densities of less than 500 people per square mile. US Census Bureau. "Census 2000 Urban and Rural Classification".

[12] Counties with 80% or greater rural land mass are generally considered rural.

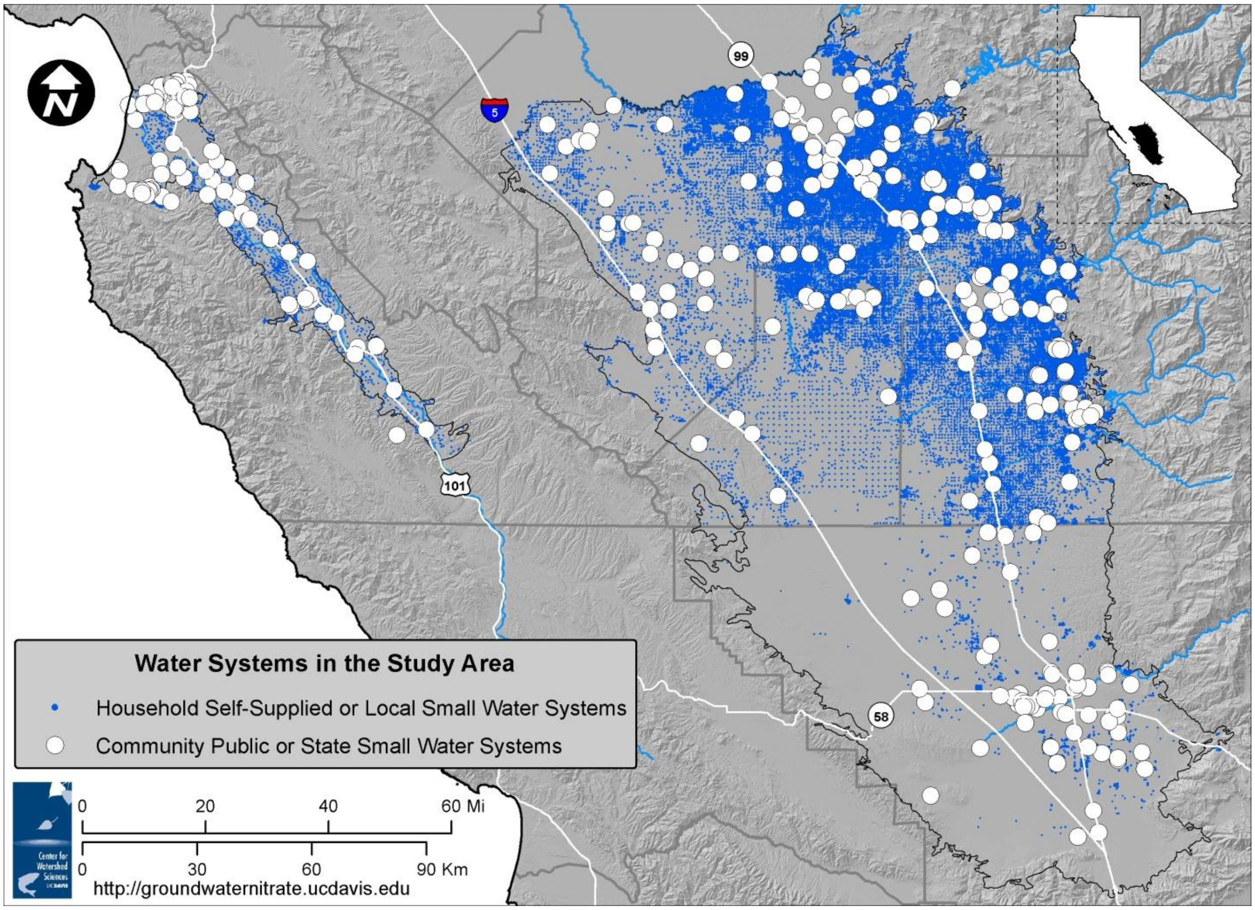

Figure 6. Estimated location of the area's 74,000 unregulated self-supplied water systems and the 402 regulated community public and state-documented state small water systems. (Source: DWR and County Assessor Parcel Land Use Codes and CDPH PICME 2010.)

Since the basin boundaries do not correspond with census or county delineations we have no existing data to effectively compare our domestic well analysis on a basin level, so a comparison on a county level is performed. Table 6 shows the results from applying this land parcel use code method on a county-level, but only regards domestic wells or parcels zoned as having one dwelling unit, located outside of city and water system boundaries. For Fresno, Kings, Monterey and Tulare Counties, the 2010 estimated population is at most one and a half times greater than the 1990 Census block group population. Kern County's 2010 estimate is a little over four times greater than the 1990 Census, which can be attributed to the inclusion of vacant parcels and the lack of water system boundaries outside of the study area and into the outer parts of the county, which would screen out parcels located within existing water systems. Since parcel use codes are from the county assessors they are not a true count of people actually living on the parcel, but are zoning values for distinguishing the number of people that can live there.

Table 6. 1990 Census v. 2010 Estimated domestic well (single dwelling unit) population by county.

County	1990 Census Block Group Population[1]	2010 Residential Code Population Estimate (Parcel Use Code)[2]
Fresno	110,022	126,968
Kern	40,742	167,274
Kings	15,975	23,354
Monterey	34,528	37,927
Tulare	68,511	91,219

[1] The sum of the 1990 Census Category H0230002 (an "individual drilled well") and H0230003 (an "individual dug well") is the domestic well block group population.

[2] Residential parcels with 1 dwelling unit estimated from County parcel land use codes.

3.4.2.2 Community Public or State Small Water Systems with Only One Well

There are 105 CPWSs or SSWSs in the study area with only one well as a source of drinking water (Figure 7). These systems are classified as having high system vulnerability because they cannot blend with other safe water sources if their source becomes contaminated. The 56 and 49 single source systems in the Tulare Lake Basin and Salinas Valley serve 6,600 and 2,000 people, respectively. Of the 56 one-well systems in the Tulare Lake Basin, 49 are CPWSs and 7 are SSWSs. Of the 49 one-well systems in the Salinas Valley, 27 are CPWSs and 22 are SSWSs.

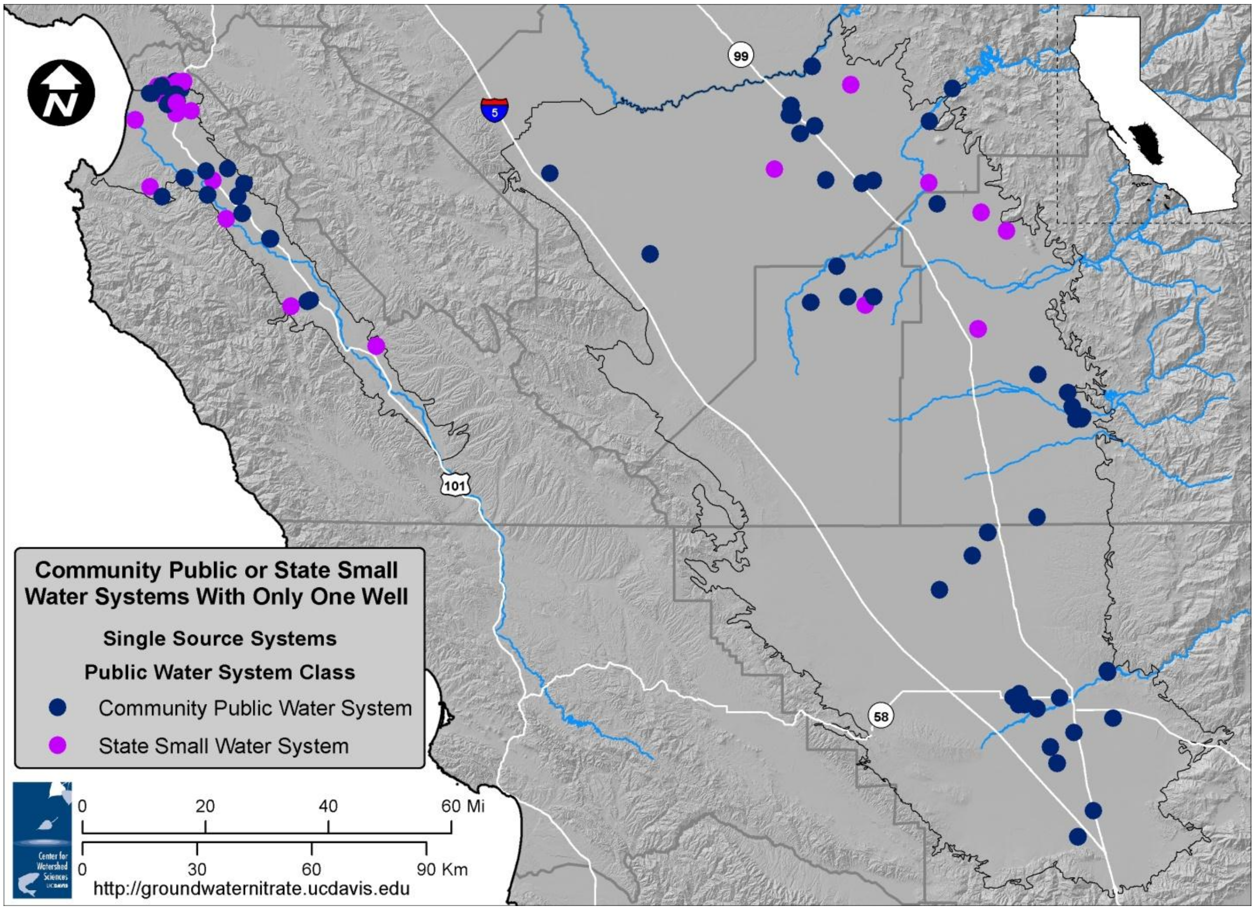

Figure 7. Community public or state small water systems with only one well. (Source: CDPH PICME 2010.)

3.4.3 No System Vulnerability

There are 32 CPWSs in the study area that are recorded in PICME as only having surface water sources (Figure 8). Surface water sources are inherently much less vulnerable to nitrate contamination overall and have essentially no system vulnerability to nitrate contamination in groundwater. The surface water source of most of these 32 systems is the Friant Kern Canal or the Coastal Branch of the California Aqueduct. All 32 surface water systems are in the Tulare Lake Basin.

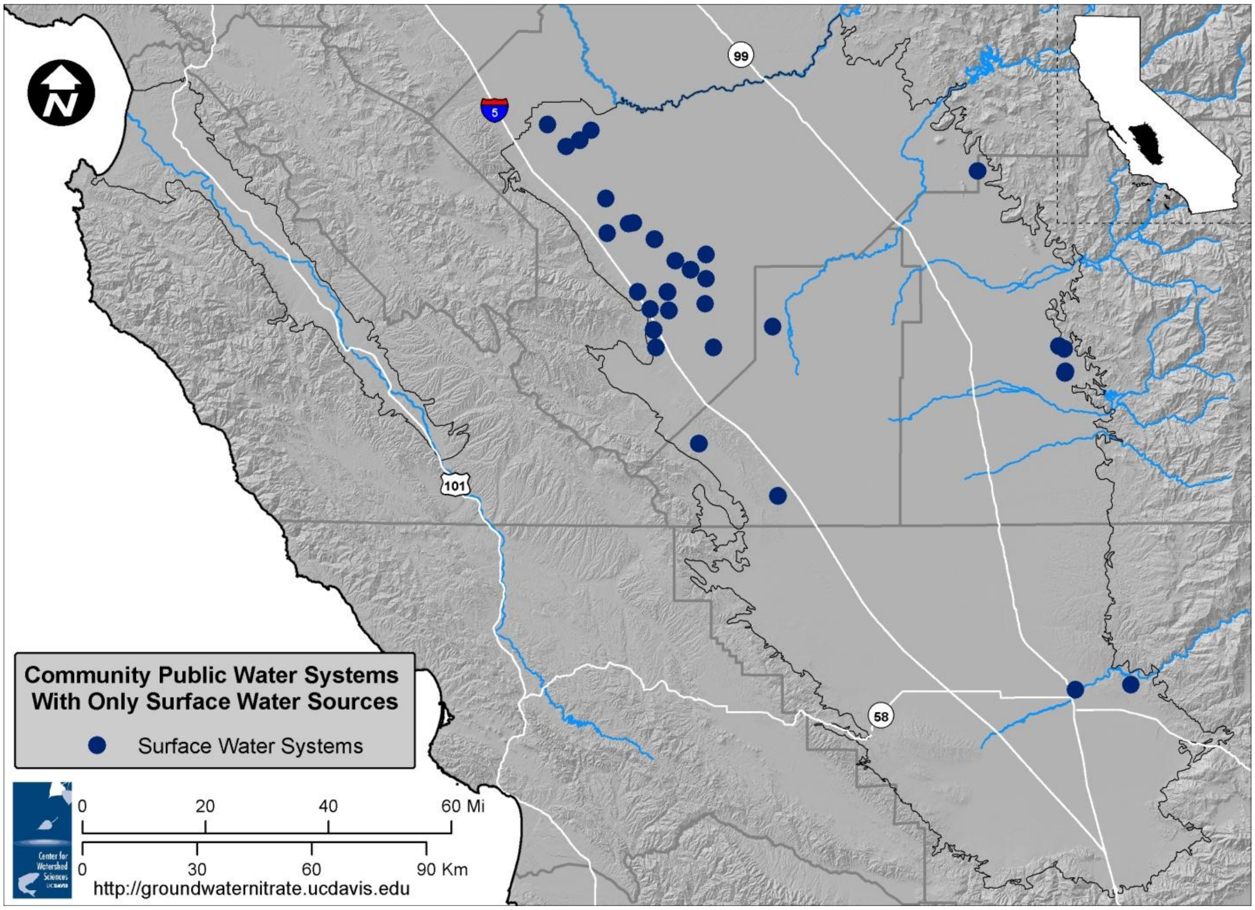

Figure 8. Community public water systems with only surface water sources. (Source: CDPH PICME 2010.)

3.5 Susceptible Drinking Water Users

The level of susceptibility of drinking water users is scored by considering the water system vulnerability and assessing their drinking water quality against a nitrate threshold based on the best historical available water quality information from the PICME WQM database or assembled for this study in the CASTING database (see Technical Report 4, Section 1 and Section 4, Boyle et al. 2012). For all water systems the chosen nitrate threshold for evaluating susceptibility is 45 mg/L. The population susceptibility was scored based on exceeding 45 mg/L as nitrate in delivered drinking water (method discussed in Section 10.1.2 Estimating "Delivering" Sources of Systems), raw source water, or in the case of self-supplied and local small water systems lacking delivered drinking water quality data, in ambient groundwater from historical measurements in the CASTING database from a well in the upper aquifer (depth of less than 300 feet) nearest to a system's estimated source well location.

For community public water systems with low system vulnerability (multiple source community public water systems), the distributed (or delivered) nitrate water quality levels in the PICME WQM database were used.[13] If the distributed water for a water system was in excess of 45 mg/L as nitrate at least once from 2006 to 2010, the population served by that water system was classified as having high susceptibility. The population served by systems recorded as distributing drinking water less than 45 mg/L was classified as having low susceptibility. The population served by community or state small water systems with no nitrate water quality data was determined as having an unknown susceptibility, but is included in the total highly susceptible population estimate. For the single source community public and state small water systems (higher vulnerability systems) the raw water quality data from WQM was used to estimate whether or not the system exceeded 45 mg/L as nitrate. For the local small and self-supplied household water systems without nitrate data (higher vulnerability systems), the highest nitrate level in the nearest well (from the CASTING database) was used to estimate whether or not the source exceeded 45 mg/L. The locations of state small water systems that are not accounted for in PICME could not be identified, and so their population of consumers is not considered in this analysis. An estimated 105 state small water systems are located in Tulare and Kern County alone, but there is uncertainty in the total number of state small water systems within the study area.

3.5.1 Highly Susceptible Population

Household self-supplied, local small, state small and community public water systems that have recently exceeded 45 mg/L as nitrate at least once using the relevant water quality data source, are defined as high susceptibility systems. Population considered to be highly susceptible is served by water systems with the following water quality records:

1) Household self-supplied or local small water systems in sub-areas characterized in the CASTING database as having a nitrate concentration in excess of 45 mg/L in shallow (<300 feet) groundwater (see Section 3.5.1.1 Household Self-Supplied or Local Small Water Systems with a High Likelihood of Nitrate Groundwater Contamination)
2) Community public and state small water systems with only one well and that have PICME WQM records of at least one raw source water in excess of 45 mg/L as nitrate since 2006 or lack water quality data (see Section 3.5.1.2 Community Public and State Small Water Systems with Only One Source and Reported Raw Water Nitrate Record in Excess of 45 mg/L or No Water Quality Data)
3) Community public water systems with more than one well and have PICME WQM records of at least one delivered water record in excess of 45 mg/L as nitrate since 2006 (see Section 3.5.1.3 Community Public Water Systems with Reported Delivered Water Nitrate)

For comparison with item 3, community public water systems that have violated the nitrate MCL at least once from 2004 to 2008 are discussed in Section 3.5.1.4 High Susceptibility Community Public Water Systems Evaluated as Violation (versus Exceedance). The difference between an exceedance and a violation is discussed in Section 3.5.1.4 High Susceptibility Community Public Water Systems Evaluated as Violation (versus Exceedance).

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[13] The method used for estimating the distributed (or delivered) nitrate water quality levels in the PICME WQM database is discussed further in Section 10.1.2.

3.5.1.1 Household Self-Supplied or Local Small Water Systems with a High Likelihood of Nitrate Groundwater Contamination

All groundwater wells with nitrate water quality data within the study area were compiled into a comprehensive wells database ("CASTING") that includes nitrate concentrations from 1989 to 2010.[14] Information from the CASTING database was used to evaluate the likelihood of a household self-supplied or local small water system being at risk of nitrate contamination. Each well within the database less than 300 feet[15] in depth was used to geographically seed the creation of a Thiessen polygon or proximal zone. Thiessen polygons represent areas where any location within the polygon is closer to its associated centroid well than any other well (ESRI 2010). Since the true raw source water quality in most of the domestic and local small wells is unknown, the nearest CASTING raw well water quality datum is used to determine whether a self-supplied or local small water system source was likely to be above or below 45 mg/L. The well of a self-supplied or local small system, based on the parcel location, is assumed to have a high likelihood of contamination if the centroid of the parcel is within a Thiessen polygon whose CASTING well nitrate water quality data includes a maximum nitrate concentration value greater than 45 mg/L. The population served by that system is given a high susceptibility rating. Alternatively, a self-supplied or local small water system well is assumed to have a low likelihood of contamination if it is within a Thiessen polygon with CASTING groundwater nitrate concentrations less than or equal to 45 mg/L. The population served by that system is given a low susceptibility rating. This method does not account for the direction of groundwater flow and the actual nitrate concentrations at the true well depth, but provides a reasonable approach to estimate the domestic well and local small water system users potentially at risk of drinking nitrate contaminated water on a geographic basis.

Figure 9 shows the maximum raw source water nitrate concentration from 1989 to 2010 in all wells in the CASTING database less than 300 feet deep. Household self-supplied or local small water systems with a high likelihood of current nitrate groundwater contamination and considered highly susceptible are systems within a Thiessen polygon with a raw water nitrate concentration in excess of 45 mg/L. Figure 10 shows all estimated household self-supplied and local small water systems within high susceptibility Thiessen polygons.

Table 7 provides the highly susceptible population estimated to be served by self-supplied or local small water systems with nitrate in excess of 45 mg/L. Approximately 34,000 people are highly susceptible.

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[14] UC Davis CASTING wells database, refer to Technical Report 4 (Boyle et al. 2012) for detailed information on compilation.
[15] Assumed as the average depth for household self-supplied wells.

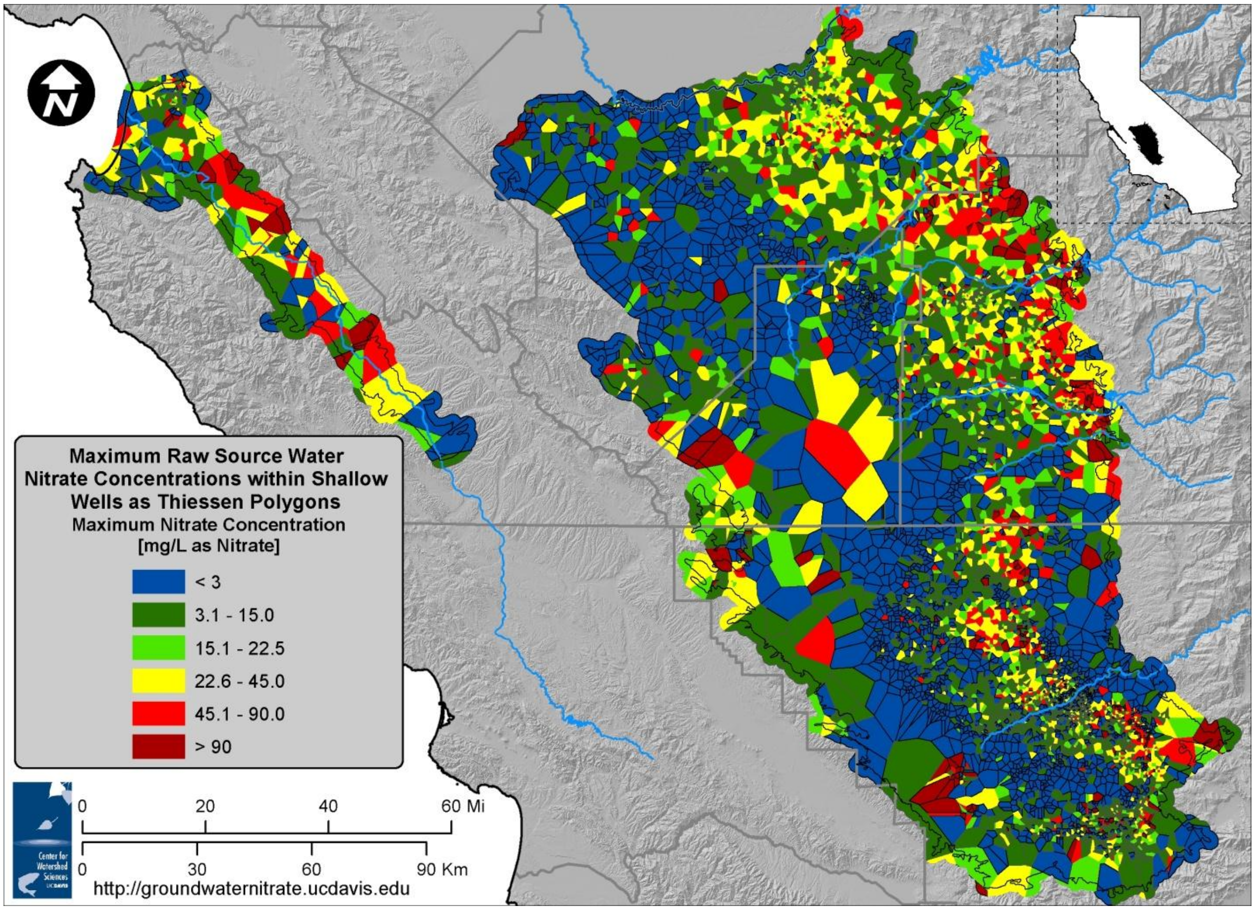

Figure 9. Maximum raw source water nitrate concentration within shallow wells (≤ 300’) as Thiessen polygons. (Source: 1989-2010 CASTING Database: GAMA, DWR, SWB, CDPH - CADWSAP, USGS, County Officials, Land Use Parcel Codes and DWR Land Use.)

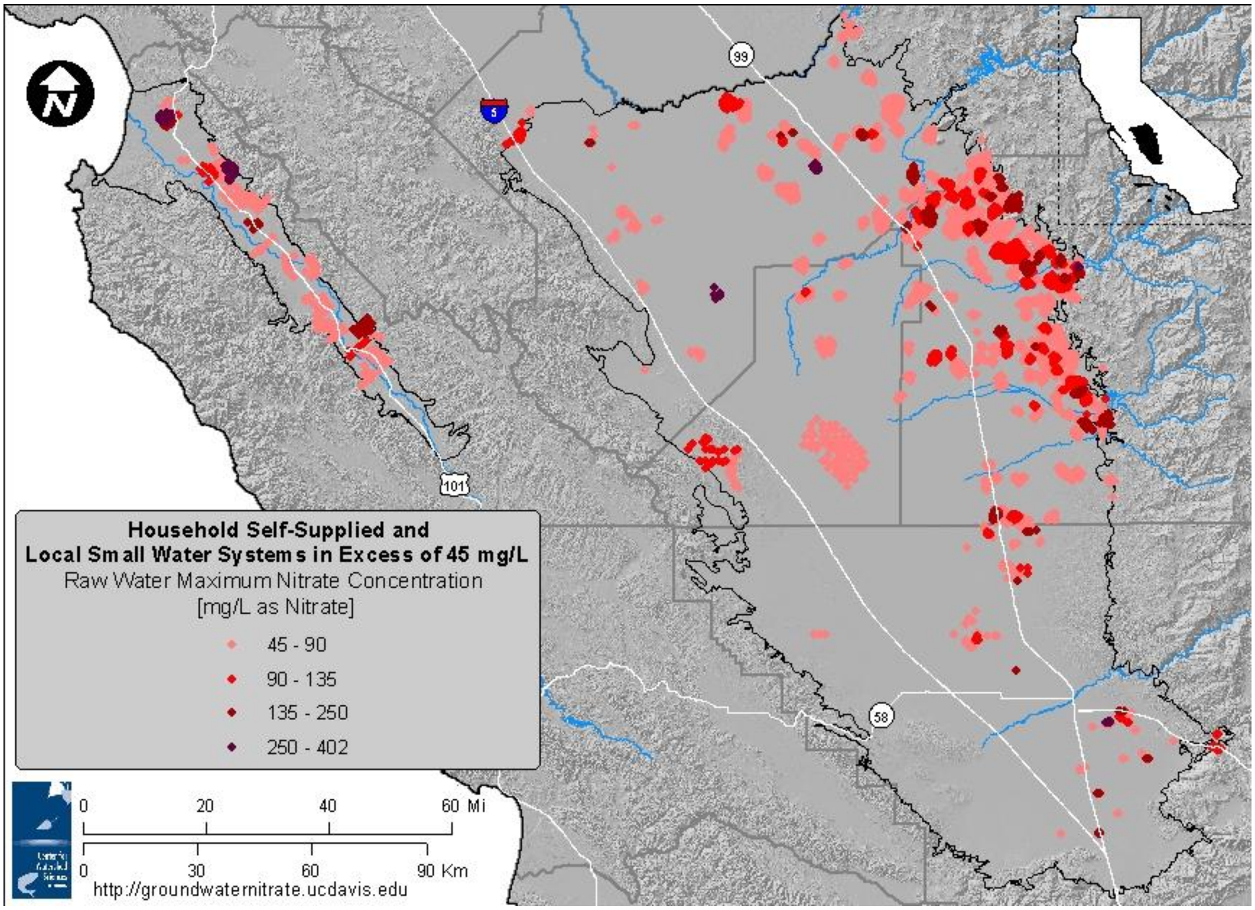

Figure 10. Household self-supplied and local small water systems within a Thiessen polygon having a maximum nitrate concentration value greater than 45 mg/L. (Source: 1989-2010 CASTING Database: GAMA, DWR, SWB, CDPH - CADWSAP, USGS, County Officials, Land Use Parcel Codes and DWR Land Use.)

Table 7. 2010 Estimated high susceptibility population served by self-supplied households and local small water systems (referred to as 'domestic well').

Basin	Population Served by Household Self-Supplied and Local Small Water Systems [1]	High Susceptibility Population Served[2]	% of Household Self-supplied and Local Small Water System Population
Tulare Lake Basin	235,125	32,795	14%
Salinas Valley	10,365	1,294	12%
STUDY AREA TOTAL	**245,490**	**34,089**	**--**

[1] Household self-supplied and local small water systems estimated from the DWR and parcel use code evaluation. These are all well systems with fewer than five connections, classified as residential dwelling units and located outside of water system and city boundaries.

[2] High susceptibility populations are served by systems with a high likelihood of nitrate contamination, these systems are within a Thiessen polygon that has a maximum raw water nitrate concentration greater than 45 mg/L (as NO_3^-).

3.5.1.2 Community Public and State Small Water Systems with Only One Source and Reported Raw Water Nitrate Record in Excess of 45 mg/L or No Water Quality Data

The highly susceptible population served by active community public and state small water systems listed in PICME that have only one source is defined as either:

1) have PICME WQM raw source water data in excess of 45 mg/L for nitrate since 2006, or
2) are lacking water quality data.

Of 105 single source systems in the study area, 34 have exceeded 45 mg/L (having a high likelihood of nitrate in groundwater) and are therefore classified as highly susceptible; the population served by these systems is listed in Table 8. If applicable, the highest recorded nitrate measurement per system was used to create conservative estimates. The 3,400 people served by these 34 systems are included in the high susceptibility estimate.

Table 8. Single source systems with a high likelihood of nitrate in groundwater.

Basin	**Highly Susceptible Population[1]**	**Single Source CPWSs or SSWSs that serve Highly Susceptible Population[2]**
Tulare Lake Basin	2,424	15
Salinas Valley	1,000	19
STUDY AREA TOTAL	**3,424**	**34**

[1] The highly susceptible population served by single source community public or state small water systems with no nitrate concentration data or systems with raw source water in excess of 45 mg/L (as nitrate) (WQM 2010).

[2] The single source systems that serve the highly susceptible population (PICME 2010).

3.5.1.3 Community Public Water Systems with Reported Delivered Water Nitrate in Excess of 45 mg/L

The maximum nitrate measurement in WQM for each community public and state small water system source in PICME within the study area was mapped. These measurements were taken between January 1st , 2006 and July 13th, 2010. Figure 11 shows a map of WQM raw nitrate data from all sources in the study area and provides an indication of raw nitrate levels in regulated drinking water systems.

To estimate the high susceptibility population served by low vulnerability systems, all active and pending CPWSs and SSWSs (with multiple sources) within CDPH's WQM database were evaluated to determine delivered water nitrate levels. Approximately 15% of the 264 Active/Pending and Community Public/State Small Water Systems (with multiple sources) in the study area delivered water that in excess of 45 mg/L at least once from January 1st, 2006 to July 13th, 2010 (see Figure 12). The method used for identifying the "delivering" source of a system is discussed in the Appendix (Section 10.1.2 Estimating "Delivering" Sources of a System). This includes 39 systems serving 670,000 people (35% of the entire population being served by CPWSs/SSWSs) and suggests potential consumption of water with nitrate levels exceeding the public health standards for an undetermined amount of time. Figure 12 shows the locations of these exceeding systems. For a system to exceed the 45 mg/L as nitrate, only one sample must be greater than 45 mg/L, versus two consecutive samples in a violation. The difference between exceeding 45 mg/L as nitrate and a CDPH code MCL violation is discussed in Section 3.5.1.4 High Susceptibility Community Public Water Systems Evaluated as Violation (versus Exceedance). This study looks at nitrate trends across the whole region.

Of these 39 systems, three currently blend and one treats with ion exchange (Technical Report 6, Jensen et al. 2012). According to PICME, four other systems are treating, but the type of treatment or reason for treating is not disclosed (i.e., they may be under LPA jurisdiction). Figure 13 shows the system size breakdown (based on established U.S. EPA size categories) for the same systems in Figure 12 that delivered water above 45 mg/L. About 77% of these systems (serving a total of 13,800 people) exceeding 45 mg/L are very small and small systems (serve less than 3,300 people). These smaller systems may find it difficult to comply with the drinking water standards because they lack economies of scale of larger treatment systems and they have a small rate payer base to fund capital expenses (discussed further in Section 4.2.4 Regionalization and Consolidation).

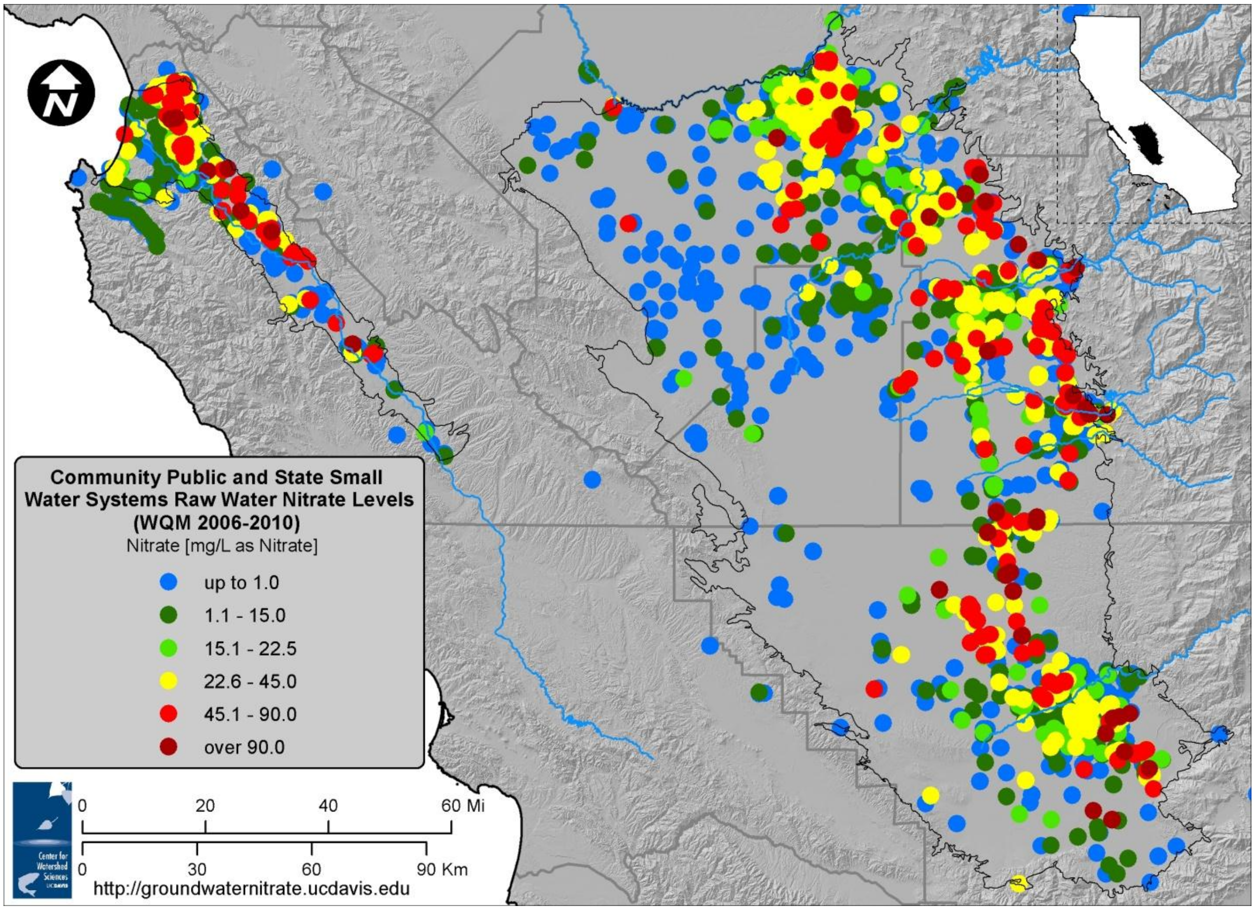

Figure 11. Maximum raw nitrate level records in community public and state small water systems. (Source: CDPH PICME WQM 2006-2010.)

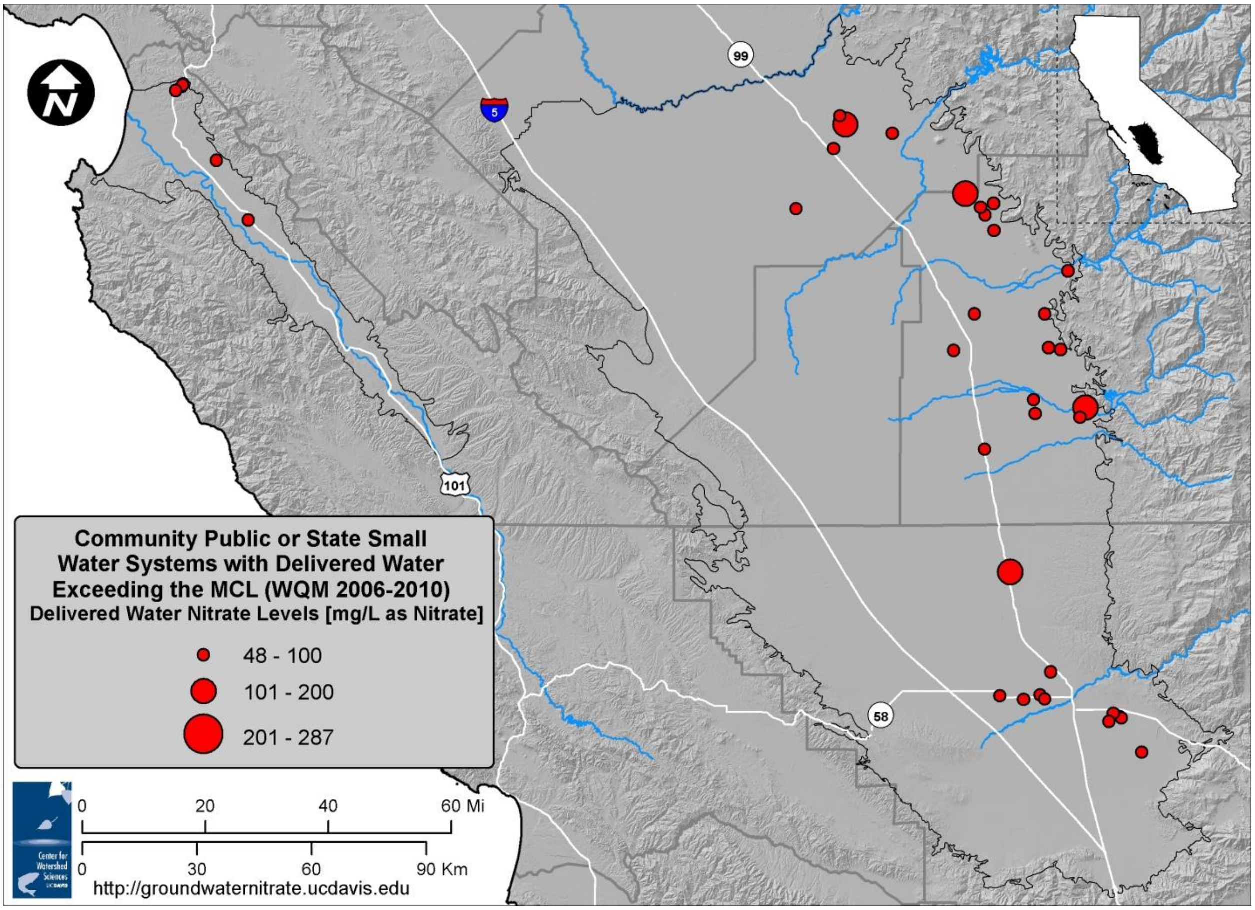

Figure 12. Community public water systems of low vulnerability with delivered water in excess of 45 mg/L as nitrate at least once. (Source: CDPH PICME WQM 2006-2010.) (The highest recorded NO3$^-$ measurement per system is shown.)

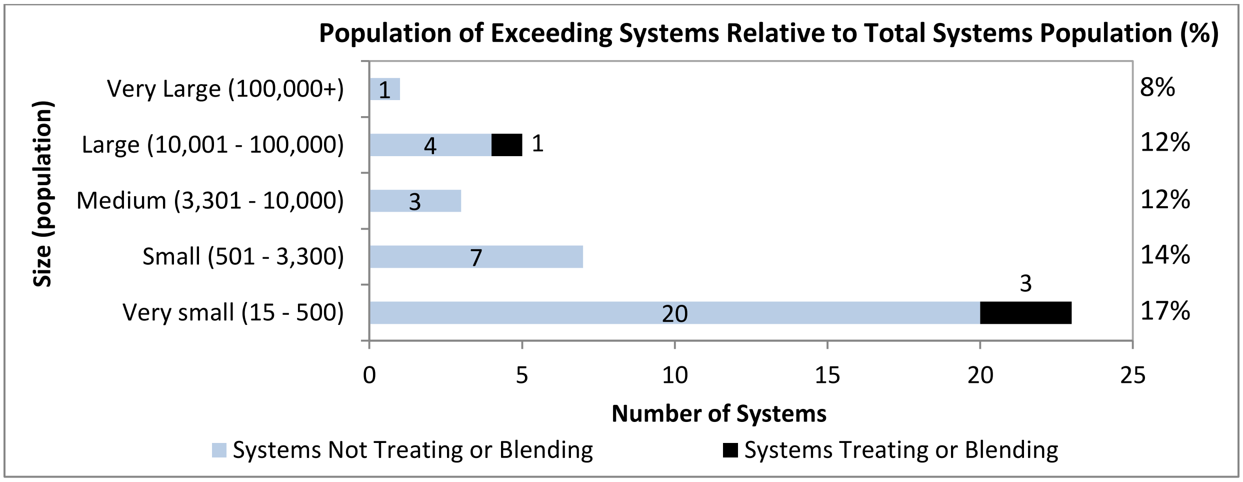

Figure 13. System size distribution (by population served) of the low vulnerability state-documented state small or community public water systems exceeding 45 mg/L as nitrate. (Source: CDPH PICME 2006-2010.)

Within these 39 systems, the City of Fresno's large system was found to exceed the 45 mg/L as nitrate between 2006 and 2010. The City serves approximately 457,000 people served by 250 municipal supply groundwater wells and 27.5 mgd (million gallons per day) of surface water. Given the system's large size, we assume that the system has the technical, managerial, and financial capacity and diversification to attend to nitrate contamination in some of their wells, so the population is removed from the multiple-source high susceptibility population total. The City's 2008 Urban Water Management Plan discusses the high nitrate levels found in supply wells (along with other contaminants, i.e., DBCP, EDB, TCP, TCE and PCE) and their plan to mitigate the increasingly poor groundwater quality. As of 2008, the City has constructed wellhead treatment systems and implemented blending plans for several wells as a result of several legal settlements (West Yost Associates 2008). To address the potential increases in groundwater contamination and further decrease their reliance on groundwater supplies, the City plans to expand their surface water treatment capacity by 90 mgd over the next ten years (West Yost Associates 2008). With the increased surface water supplies and treatment capacity the system will be able to decrease groundwater pumpage by 50,000 acre-feet per year (af/year) (West Yost Associates 2008). These factors combine to make the City of Fresno's water system capable of planning for and mitigating future groundwater pollution and the population served is in excess of 45 mg/L. Removing the City of Fresno results in 38 multiple-source systems estimated as high susceptibility systems, serving 213,000 people.

3.5.1.4 High Susceptibility Community Public Water Systems Evaluated as Violation (versus Exceedance)

An alternative to evaluating high susceptibility as the population served by community public water systems with an exceedance is to evaluate high susceptibility based on system violations (per CDPH regulatory language). Systems can sometimes err in reporting contaminant concentrations, and CDPH requires a second lab sample when an MCL is exceeded to verify the accuracy of the original sample. This comparison can only be performed for community public water systems that must submit annual compliance reports (ACRs) to CDPH. The CDPH ACRs were used to identify the CPWSs violating the nitrate MCL. A violation of the nitrate MCL occurs when the MCL is exceeded in two consecutive exceedance reports (CDPH 2008; Commandatore & Collins 2011). When the MCL for nitrate is exceeded once, a secondary, follow-up source sample is required and must be analyzed by an approved CDPH laboratory within 24-hours of notification of the first result. The two results are averaged and if the average exceeds the MCL or if the system fails to collect a confirmation sample, the system is in violation of the nitrate MCL and must contact their regulating agency (the CDPH field office or the local primacy agency) by phone or in writing within 24 hours (CDPH 2008; Commandatore & Collins 2011). The regulating agency then consults with the system to determine the best solution for protecting public health, and the long-term feasibility of complying with the MCL. The regulating agency also helps the system set up a monitoring and reporting schedule to proceed with until deemed necessary. Since the violation of nitrate is a Tier 1 violation, systems must notify customers of the violation within 24 hours and continue communication until the regulator says not to.

It was desired to obtain annual compliance reports for all systems in the Tulare Lake Basin and Salinas Valley from 2006 to 2010 for accurate comparison; however, 2008 is the last year these reports are publicly accessible. To be consistent with the length of record used for the exceedance assessments, a five year span evaluation based on ACRs from 2004 to 2008 was used to identify community public water systems violating the MCL. Twenty-six community public water systems (Table 9) violated the nitrate MCL within the Tulare Lake Basin and Salinas Valley, five in Kern, eight in Monterey, thirteen in Tulare, and zero in Kings and Fresno counties. The total population served by violating systems is about 130,000 (Table 9) and is about 83,000 people less than the total population estimated with high susceptibility based on multiple source MCL exceedance systems in Section 3.5.1.3 Community Public Water Systems with Reported Delivered Water Nitrate . This population difference stems from evaluating systems based on an exceedance versus violation. For a system to violate the nitrate MCL, the average of two consecutive samples must be greater than the MCL. For a system to exceed the nitrate MCL, only one sample must be greater than the MCL. CDPH has established the violation definition to avoid any discrepancy in monitoring or reporting at the system or lab level. A conservative approach is taken here in estimating the susceptibility based on an exceedance rather than a violation. The community public water systems in violation of the nitrate MCL are shown in Figure 14, highlighting the total years in violation between 2004 and 2008.

Table 9. Community public water systems in violation of the nitrate MCL (2004-2008).

County	System Number	System Name	Years in Violation	Population
Kern	1500373	SEVENTH STANDARD MUTUAL	1	110
	1500494	WILSON ROAD WATER COMMUNITY	1	72
	1500544	ENOS LANE PUBLIC UTILITY DISTRICT	1	250
	1500584	GOOSELAKE WATER COMPANY	1	80
	1510001	ARVIN COMMUNITY SERVICES DIST	1	14,500
KERN TOTAL POPULATION				**15,012**
Monterey	2700665	OAK HEIGHTS W & R CO INC	2	105
	2701036	APPLE AVE WS #03	1	60
	2701904	SAN JERARDO COOP WS	2	249
	2702409	EL CAMINO WC INC	1	90
	2702439	WOODLAND HEIGHTS MWC	1	57
	2702466	SAN VICENTE MWC	1	90
	2710010	CPWSC SALINAS	1	111,135
	2710851	SALINAS VALLEY STATE PRISON	1	5,400
MONTEREY TOTAL POPULATION				**117,186**
Tulare	5400523	EL MONTE VILLAGE M H P	1	100
	5400550	SEVILLE WATER CO	1	400
	5400567	TOOLEVILLE WATER COMPANY	3	300
	5400616	LEMON COVE WATER CO	4	200
	5400651	BEVERLY GRAND MUTUAL WATER	5	108
	5400663	FAIRWAYS TRACT MUTUAL	5	250
	5400666	WATERTEK - GRANDVIEW GARDENS	1	350
	5400735	RODRIGUEZ LABOR CAMP	3	110
	5400805	SOULTS MUTUAL WATER CO	3	100
	5401003	EAST OROSI CSD	2	106
	5401038	AKIN WATER CO	1	50
	5402047	GLEANINGS FOR THE HUNGRY	5	31
	5403043	YETTEM WATER SYSTEM	2	350
TULARE TOTAL POPULATION				**2,455**
STUDY AREA POPULATION VIOLATING THE NITRATE MCL (2004-2008)				**134,653**

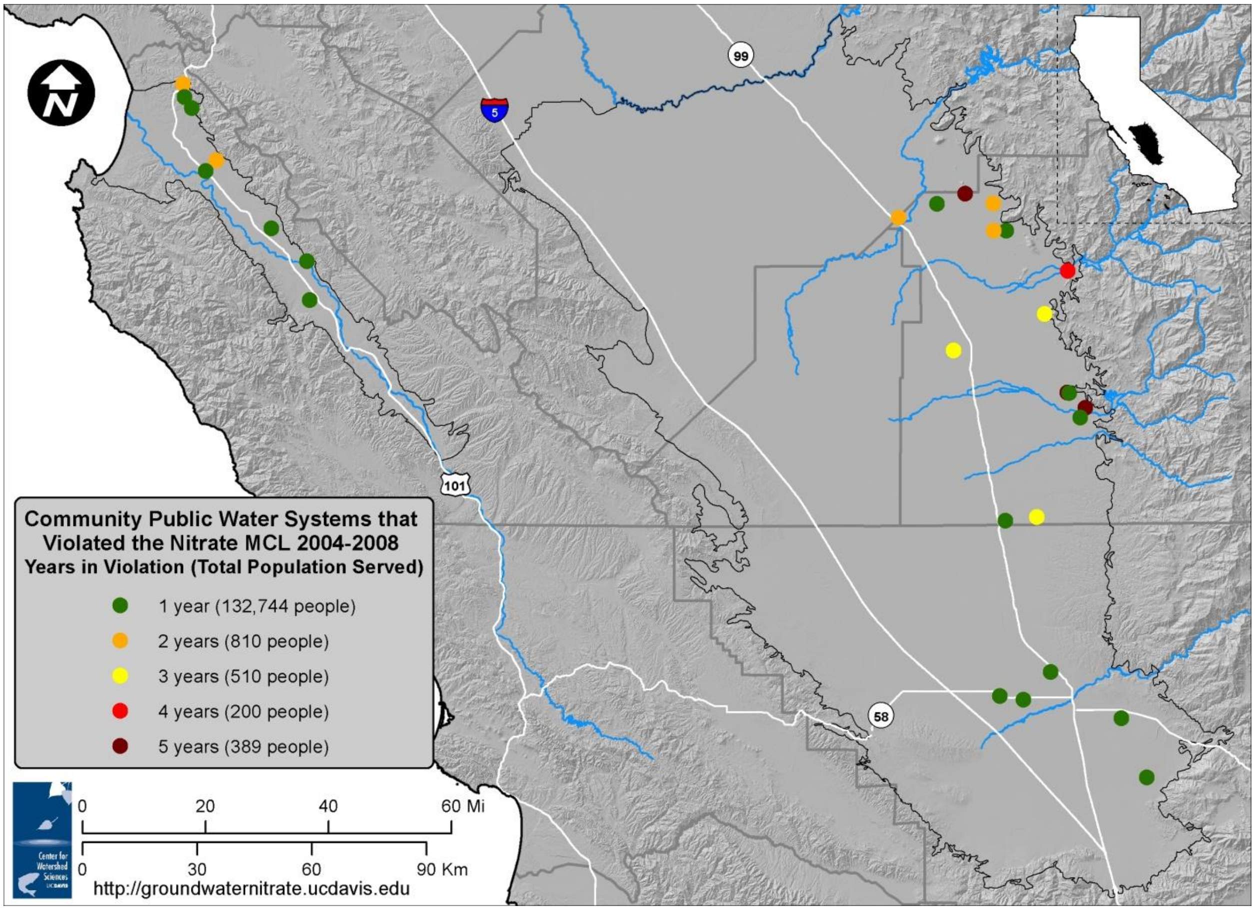

Figure 14. Community public water systems in the study area in violation of the nitrate MCL 2004 to 2008. (Source: CDPH 2010d.)

3.5.2 Low Susceptibility Population

Low susceptibility water users are on systems estimated to have a high vulnerability but with a low likelihood of nitrate contamination in the groundwater, or on systems estimated to have a low vulnerability (CPWSs with more than one well) with no record in excess of 45 mg/L since 2006. We estimate that 1.67 to 1.88 million people in the study area are not currently susceptible to consumption of nitrate-contaminated drinking water within their residences.

3.5.2.1 Household Self-Supplied or Local Small Water Systems with a Low Likelihood of Nitrate Groundwater Contamination

Household self-supplied or local small water systems are assumed to have a low likelihood of current nitrate groundwater contamination when they fall within a Thiessen polygon that has historical raw water nitrate concentrations less than or equal to 45 mg/L. Figure 15 shows all estimated household self-supplied and local small water systems within low-nitrate Thiessen polygons. Table 10 provides population estimates for persons supplied by low susceptibility systems relative to the total basin domestic well population. An estimated 212,000 people served by self-supplied household and local small water systems are included in the low susceptibility population estimate.

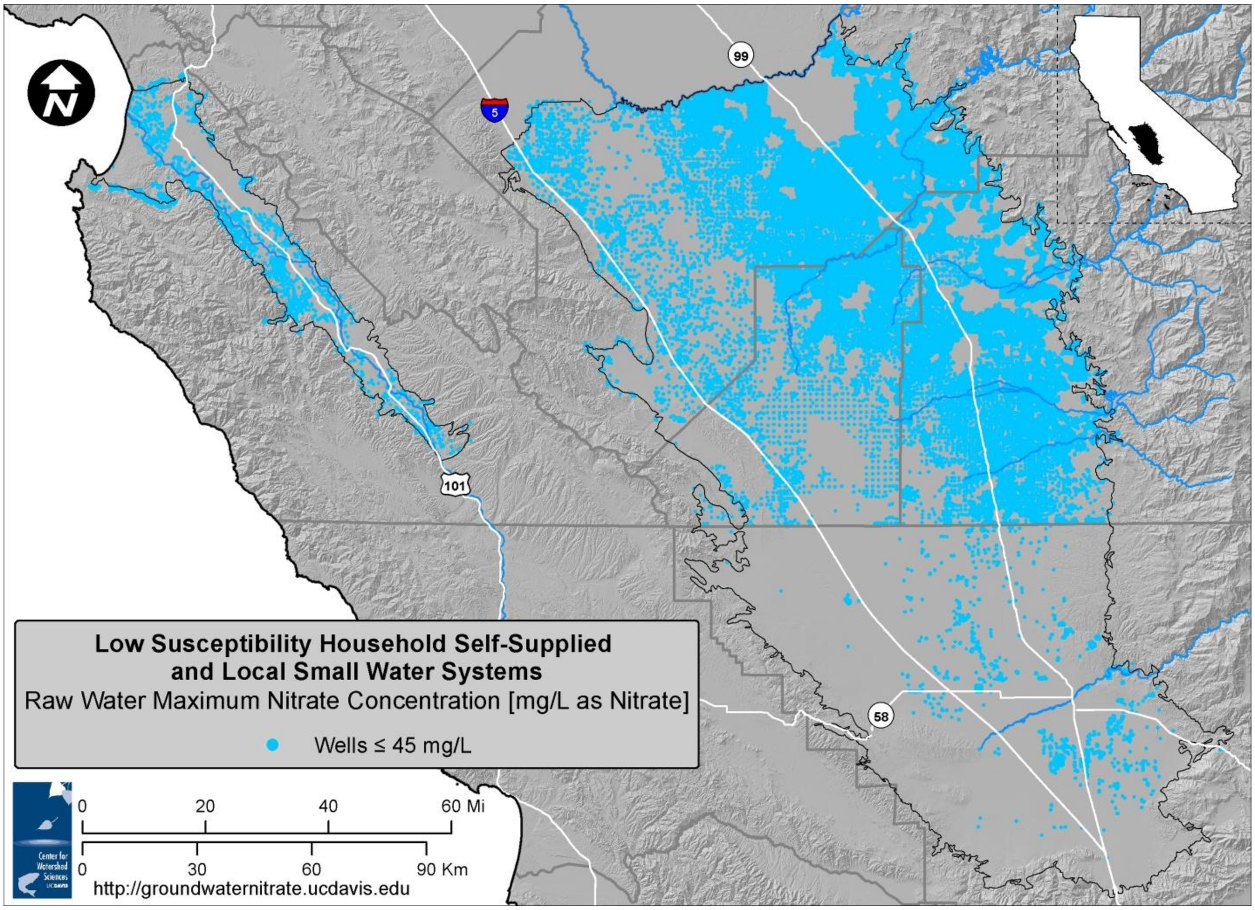

Figure 15. Household self-supplied and local small water system wells within a Thiessen polygon of a tested upper aquifer well (<300 ft) with maximum nitrate concentration less than 45 mg/L. (Source: 1989-2010 CASTING Database: GAMA, DWR, SWB, CDPH - CADWSAP, USGS, County Officials, Land Use Parcel Codes and DWR Land Use.)

Table 10. 2010 Estimated low susceptibility population served by self-supplied household and local small water systems.

Basin	Domestic Well Population[1]	Low Susceptibility Population[2]	% of Domestic Well Population
Tulare Lake Basin	235,125	202,676	86%
Salinas Valley	10,365	9,088	88%
STUDY AREA TOTAL	**245,490**	**211,764**	**--**

[1] Domestic Wells = Household self-supplied and local small water systems. These are all well systems with fewer than four connections, classified as residential dwelling units and located outside of water system and city boundaries.

[2] The low susceptibility population served by systems with a low likelihood of nitrate contamination. These systems are within a Thiessen polygon that has a maximum raw water nitrate concentration less than or equal to 45 mg/L.

3.5.2.2 Community Public or State Small Water Systems with Only One Source and No Reported Raw Water Nitrate Record in Excess of 45 mg/L

The active community public and state small water systems in PICME that have only one source (high vulnerability) and have not exceeded 45 mg/L for nitrate since 2006 in their raw source water are considered to have a low likelihood of nitrate in groundwater, and their users are considered to have low susceptibility to nitrate contamination. The raw nitrate levels of these systems are measured against the 45 mg/L as nitrate since the delivered water quality could not be estimated in PICME. Of the 105 single source systems, 71 have a low likelihood of nitrate in groundwater. The low susceptibility population served by these single source systems is given in Table 11 and is included in the low susceptibility estimate.

Table 11. Single source systems with a low likelihood of nitrate in groundwater.

Basin	Low Susceptibility Population[1]	Single Source CPWSs or SSWSs that serve the Low Susceptibility Population[2]
Tulare Lake Basin	4,234	41
Salinas Valley	1,176	30
STUDY AREA TOTAL	**5,410**	**71**

[1] The low susceptibility population served by single source systems with maximum source (raw water) nitrate concentrations less than 45 mg/L (WQM 2010).

[2] Single source community public or state small water systems that serve this low susceptibility population (PICME 2010).

3.5.2.3 Community Public Water Systems with Reported Nitrate Records less than 45 mg/L

There are 212 multiple source CPWSs in the study area with recorded PICME nitrate data having no delivered nitrate records in excess of 45 mg/L from 2006 to 2010. The population of these multiple-source systems is given in Table 12 and is included in the low susceptibility estimate.

Table 12. Community public water systems with a low likelihood of nitrate in groundwater.

Basin	Low Susceptibility Population[1]	Multiple Source CPWSs that serve the Low Susceptibility Population[2]
Tulare Lake Basin	1,259,724	157
Salinas Valley	405,783	55
STUDY AREA TOTAL	**1,665,507**	**212**

[1] The low susceptibility population served by systems with more than one source that has maximum delivered nitrate concentrations less than or equal to 45 mg/L (as nitrate) (WQM 2010).

[2] Community public water systems with more than one source that serve this low susceptibility population (as NO_3^-) (PICME 2010).

3.5.3 Unknown Susceptibility Population

The WQM dataset is incomplete for 13 multiple source CPWSs that are included in PICME (serving 3,900 people), and are lacking nitrate measurement data. These include three and ten systems in the Tulare Lake Basin and Salinas Valley, serving 2,450 and 1,450 people, respectively. These systems have an unknown water quality level, but are conservatively included in the higher susceptibility water users total for this analysis. This report assumes the lack of nitrate data is from the absence of monitoring and reporting, however, the data could be in the process of being incorporated into WQM. Figure 16 shows the distribution of system sizes for the multiple source water systems with no nitrate measurement data. Eleven of these CPWSs are county-regulated (<200 connections) and may have nitrate data within their respective County health departments.

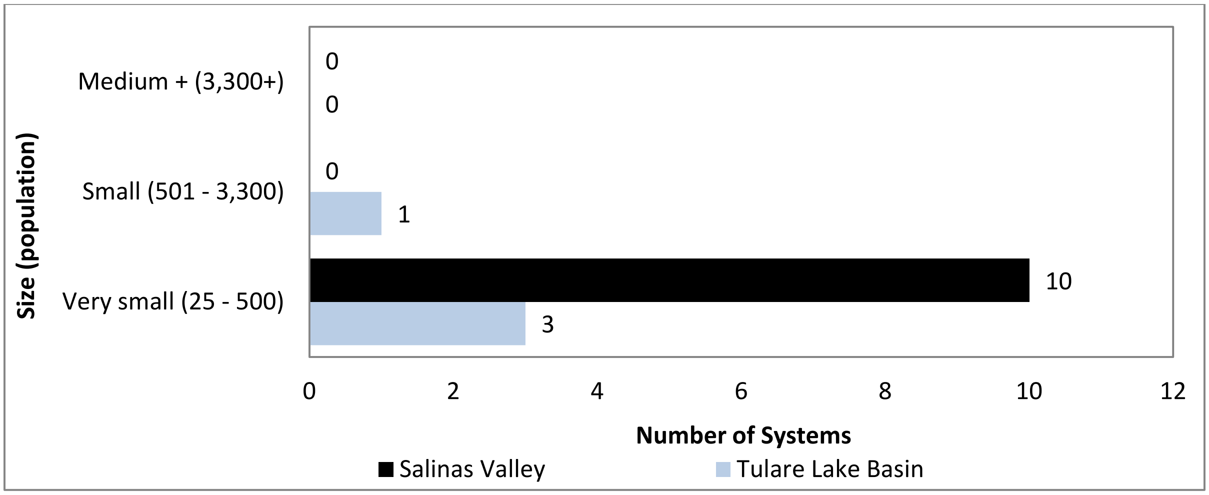

Figure 16. System size distribution (by population served) of the community public water systems without water quality information. (Source: CDPH PICME WQM 2006-2010.)

3.6 Major Findings on Susceptible Water Users

The population connected to each water system type, their system's vulnerability, and the population's susceptibility are summarized below.

- An estimated 246,000 people are served water by self-supplied and local small water systems (about 9% of the total study area population).
    - These systems are considered to have high vulnerability.
    - About 34,000 people, or 14% of the household self-supplied and local small water system population, are within Thiessen polygons with a maximum nitrate concentration in excess of 45 mg/L. This population is considered to have high susceptibility.
    - The remaining 212,000 people are considered to have low nitrate contamination susceptibility.
- Approximately 8,800 people are served by single source state small (listed in PICME) and community public water systems (less than 1% of the study area population).
    - These systems are considered to have high vulnerability.

    - Approximately, 1,100 people, or 13% of the single source state small and community public water system population, are served by a system with a maximum recorded (raw source water) nitrate level in excess of 45 mg/L; hence, this population is considered highly susceptible to nitrate contamination.
    - Approximately 2,350 people, or 27% of the single source state small and community public water system population, are served by a system having no recorded nitrate data, and so are considered to have high nitrate contamination susceptibility.
    - The remaining 5,400 people are considered to have low susceptibility.
- An estimated 2.3 million people are on multiple source community public water systems (about 88% of the study area population).
    - These systems are considered to be of low vulnerability.
    - Approximately 213,000 people, or 29% of the multiple source community public water system population, have a maximum recorded (delivered water) nitrate level in excess of 45 mg/L, and so have high nitrate contamination susceptibility.
    - Approximately 3,900 people (less than 1% of the multiple source community public water system population), have no recorded nitrate data, and so have high nitrate contamination susceptibility.
    - The remaining 1.7 million people are served by systems with no recorded nitrate levels in excess of 45 mg/L and considered to have low nitrate contamination susceptibility.

A summary of the existing susceptible water systems and the population served, overall and in each basin, is shown in Table 13 and presented visually in Figure 17, Figure 18, and Figure 19. Figure 17 illustrates how we assessed the degree of vulnerability and overall susceptibility for the study area population in year 2010. Figure 18 and Figure 19 show the 2010 population susceptibility assessment for the Tulare Lake Basin and Salinas Valley, respectively.

Approximately 254,000 people have higher susceptibility (about 10% of the study area population, which includes the unknown susceptibility population), 2.34 million have lower susceptibility (90% of the study area population), and 64,000 have no susceptibility (2% of the study area population) to nitrate groundwater contamination.

Finally, an important and cautionary note on the interpretation of the terms “vulnerable” water systems and “susceptible” population. Here, we have defined these terms to provide a tractable scoring system that allows us to estimate the potential for a water system to draw from a nitrate contaminated well and to estimate the magnitude of the population in the study area that may be exposed to nitrate in drinking water from that well. Our analysis does not consider whether the exposure actually occurs. Our analysis also does not consider whether exposure occurs once, occasionally, or regularly. The susceptibility score is merely a qualitative measure of the likelihood that a person is exposed to drinking nitrate contaminated water at the tap at least once, but potentially more than once. We do not know how many people in either the high susceptible population or in the low susceptible population actually drink water that is in excess of 45 mg/L, or how often they do so.

To improve upon our very general susceptibility measure, water quality data would need to be collected on a regular basis from all sources of drinking water, including all local and state small water systems, and all household self-supplied systems (domestic wells). Without these data, a scoring system such as the one presented here, provides the best possible practical representation of our current knowledge and available information on nitrate exposure in drinking water in the pilot study area.

Table 13. Assessment of susceptible water users in the study area.

		Population Served		
System Description	**Susc.[1]**	**Salinas Valley**	**Tulare Lake Basin**	**Total Study Area**
Total Basin Population[2]		**397,287**	**2,249,928**	**2,647,215**
Household Self-Supplied or Local Small Water Systems[3]		**10,365**	**235,125**	**245,490**
Max NO_3 45 mg/L Exceedance[3a]	H	1,294	32,795	34,089
Max NO_3 45 mg/L Non-Exceedance[3b]	L	9,088	202,676	211,764
Single Source State small or Community Public Water Systems[4]		**2,176**	**6,658**	**8,834**
Max NO_3 45 mg/L Exceedance or No WQM Data[4a]	H	1,000	2,424	3,424
Max NO_3 45 mg/L Non-Exceedance[4b]	L	1,176	4,234	5,410
Surface Water Community Public Water Systems [5]	No	0	64,501	64,501
Multiple Source Community Public Water Systems[6]		**408,123**	**1,931,267**	**2,339,390**
Treating or Blending for NO_3[7]		121,945	203,087	325,032
Not Treating or Blending for NO_3[8]		286,178	1,728,180	2,014,358
Max NO_3 Distributed Water 45 mg/L Exceedance[9]	H	894	669,101	669,995
Max NO_3 Distributed Water 45 mg/L Non-Exceedance[10]	L	405,783	1,259,724	1,665,507
No NO_3 Data[11]	H	1,446	2,442	3,888
TOTAL HIGHER SUSCEPTIBILITY POPULATION[12]		4,634	249,251	253,885
TOTAL LOWER SUSCEPTIBILITY POPULATION[13]		416,047	1,924,145	2,340,192
TOTAL NO SUSCEPTIBILITY POPULATION[14]		0	64,501	64,501

[1] Susceptibility – Levels: High (H), Low (L), and No.

[2] The total basin population. Estimated from US Census and California Department of Finance data, spatially verified in ArcGIS.

[3] Population on household self-supplied and local small water systems estimated using Parcel Use Codes from County Assessors and DWR land use classification. Household Self-Supplied Water Systems are any residential parcels zoned as having 1-2 dwelling units, located outside of city and water system boundaries. Local Small Water Systems are any residential parcels zoned as having 3-4 dwelling units, located outside of city and water system boundaries. Assumed 3.3 people per dwelling unit.

[3a] Population on household self-supplied and local small water systems located within Thiessen polygons that have a nitrate concentration greater than 45 mg/L (as NO_3). Nitrate concentrations are from DWR, CDPH, USGS, SWB, and all study area counties.

[3b] Population on household self-supplied and local small water systems that are located within Thiessen polygons that have a nitrate concentration less than 45 mg/L (as NO_3).

[4] Population on single source SSWS or CPWS from CDPH's PICME database.

[4a] Population on single source SSWS or CPWS with a maximum raw water nitrate concentration (PICME WQM, 2006-2010) greater than 45 mg/L (as NO_3) or without nitrate data in WQM.

[4b] Population on single source SSWS or CPWS with a maximum raw water nitrate concentration (PICME WQM, 2006-2010) less than 45 mg/L (as NO_3).

[5] Population on CPWSs serving only surface water sources (PICME 2006-2010).

[6] Population on CPWSs with more than one source (PICME 2006-2010).

[7] Population on CPWSs with more than one source treating or blending for nitrate (Technical Report 6, Jensen et al. 2012: Nitrate Treatment Systems Survey and systems approved for treatment by CDPH).

[8] Population on CPWSs with more than one source not treating or blending for nitrate, those systems that did not

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respond to the Nitrate Treatment Systems Survey and CDPH does not have treatment information on.

[9] Population on CPWSs with more than one source with delivered water in excess of 45 mg/L (as NO_3) (PICME WQM 2006-2010).

[10] Population on CPWSs with more than one source with delivered water less than the 45 mg/L (as NO_3) (PICME WQM 2006-2010).

[11] Population on community public water systems with more than one source with no nitrate water quality data (PICME WQM 2006-2010).

[12] Total Higher Susceptibility Population = 3a + 4a + 9 + 11 (Excluding the City of Fresno's water system that serves 457,511 people).

[13] Total Lower Susceptibility Population = 3a + 4a + 10 (Including the City of Fresno's water system that serves 457,511 people).

[14] Total No Susceptibility Population = 5.

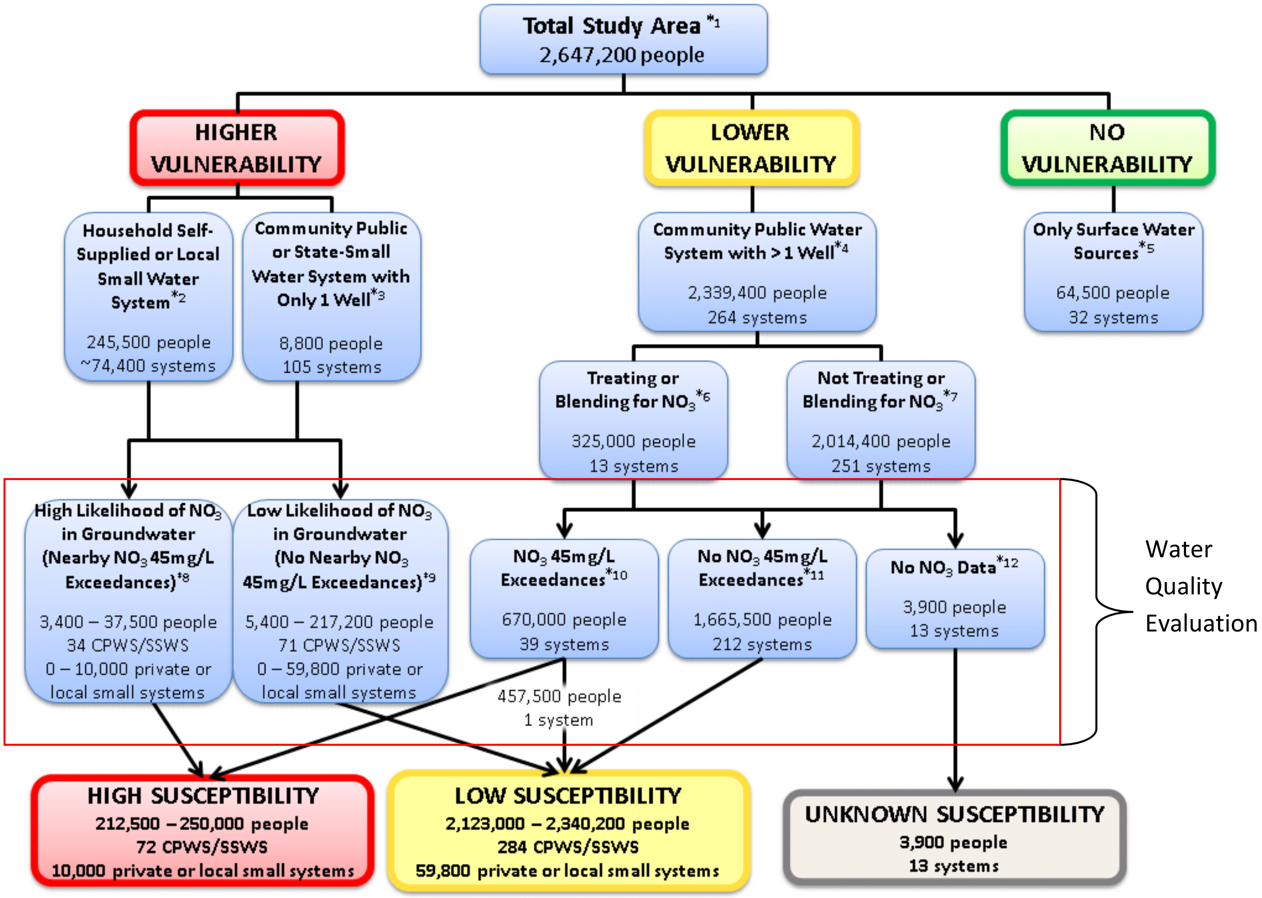

Figure 17. Classification of susceptible populations based on estimated vulnerability and water quality data for the study area.[16]

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[16] Due to different sources of data, the summation of the top row does not exactly equal the total study area population. All population and connection information is approximate. The methodology used for creating the susceptibility chart and chart footnotes are further discussed in the Appendix (Section 10.1.1 Susceptibility Charts). Table 13 includes the unknown susceptibility as the highly susceptible population.

As discussed in Section 3.5.1.3 Community Public Water Systems with Reported Delivered Water Nitrate even though the City of Fresno was detected as delivering drinking water in excess of 45 mg/L they are considered as having low susceptibility to nitrate contamination in groundwater. The methodology used for creating the susceptibility chart and chart footnotes are further discussed in the Appendix (Section 10.1.1 Susceptibility Charts).

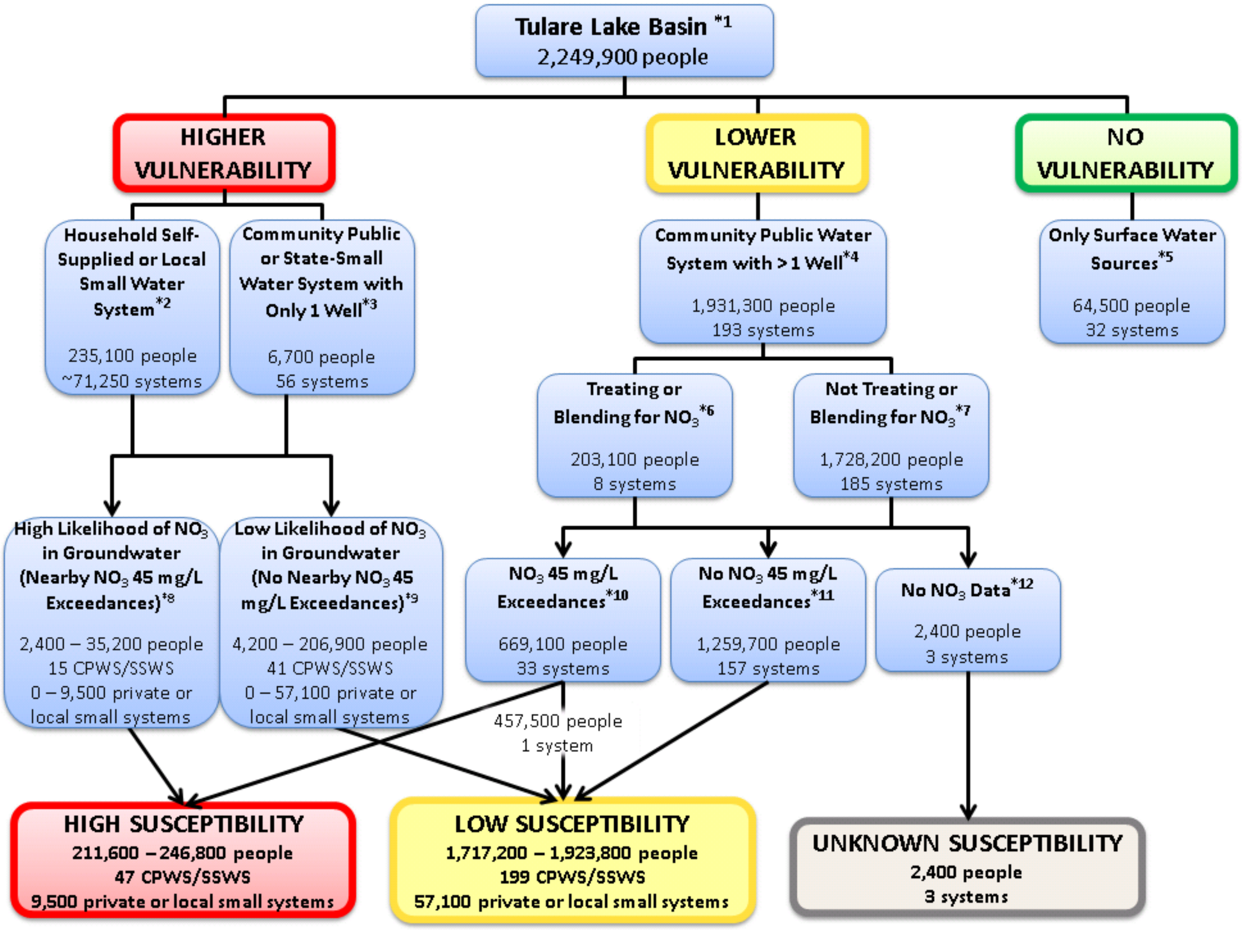

Figure 18. 2010 Population and susceptibility characterization for the Tulare Lake Basin based on estimated vulnerability and water quality data.[17]

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[17] See Methods section for detailed explanations. The methodology used for creating the susceptibility chart and chart footnotes are further discussed in the Appendix (Section 10.1.1 Susceptibility Charts). Table 13 includes the unknown susceptibility as the highly susceptible population.

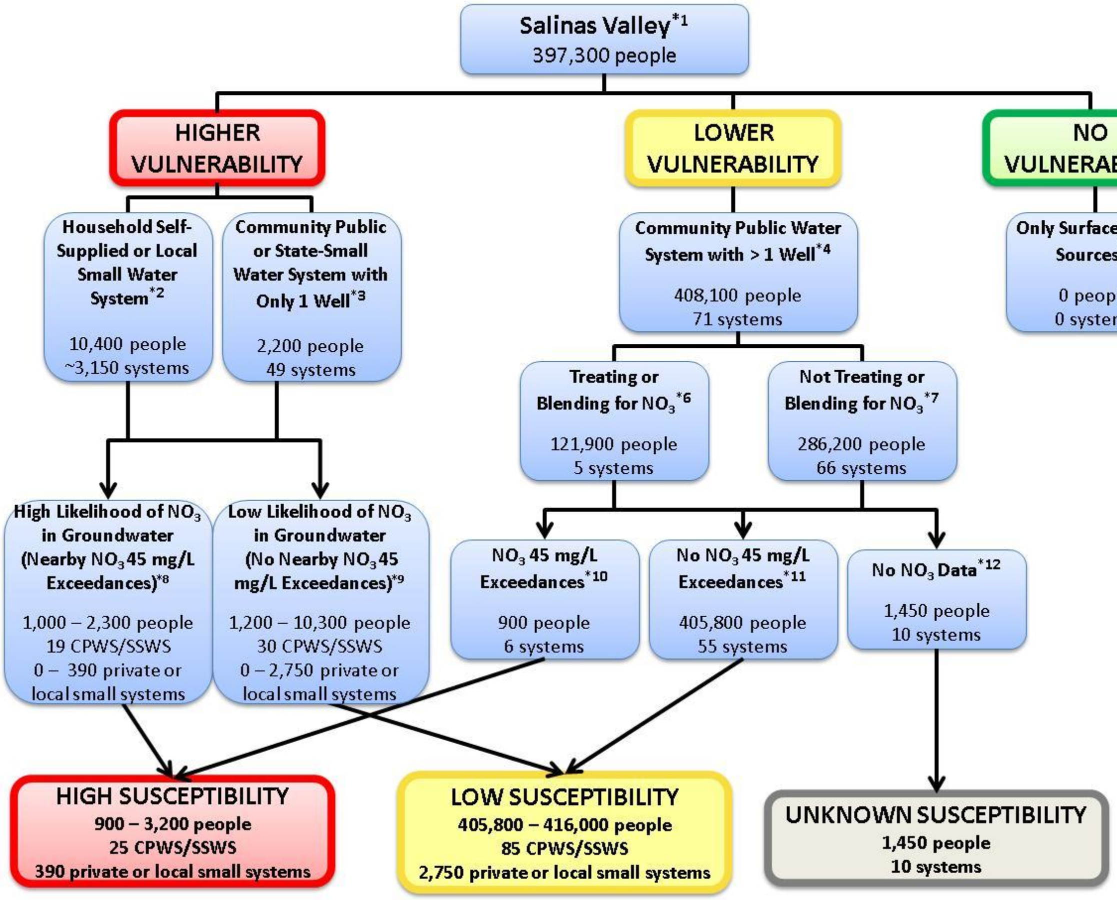

Figure 19. 2010 Population and susceptibility characterization for the Salinas Valley based on estimated vulnerability and water quality data.[18]

3.7 Health and Socioeconomic Disparities

This report estimates susceptibility as a qualitative likelihood of exposure; however, a more common definition of susceptibility to nitrate contamination is based on the health and socioeconomic status of an individual. Among those susceptible to the likelihood of consuming nitrate contaminated drinking water, there are sub-populations that are at financial risk and at a health risk from nitrate contamination of their water sources, but these are much more difficult to quantify. Those that are at a health and financial risk from nitrate contamination of their water sources are:

1) **Pregnant women or infants under six months** are more at risk to the health effects of higher levels of nitrate in drinking water. This is a direct public health concern.

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[18] Due to different sources of data, the summation of the top row does not exactly equal the total study area population. All population and connection information is approximate. See Methods section for detailed explanations. The methodology used for creating the susceptibility chart and chart footnotes are further discussed in the Appendix (Section 10.1.1 Susceptibility Charts). Table 13 includes the unknown susceptibility as the highly susceptible population.

2) **Residents of disadvantaged unincorporated communities** have a more difficult time paying for both the capital and on-going operations and maintenance (O&M) costs of point-of-use or community-wellhead treatment options, or replacement bottled water, if local nitrate contamination becomes a problem. This is primarily a financial impact and financial feasibility concern of higher levels of nitrate in drinking water.

3.7.1 Pregnant Women and Infants

The number of pregnant women and infants within each basin was estimated using the Department of Finance data on a county level. This overestimates the health at-risk population since the boundaries of each county are not fully within in the study area boundaries. Roughly 84,500 and 14,100 pregnant women and infants live in the Tulare Lake Basin counties and Monterey County, respectively (California Department of Finance 2010). However, the location of these pregnant women and infants is unknown, making it difficult to determine if they are currently drinking nitrate contaminated water for incorporation into the nitrate drinking water contamination at-risk analysis. Applying the estimated total at-risk percentages (11% and 1% for the Tulare Lake Basin and Salinas Valley - previous section), approximately 10,000 and 200 pregnant woman and infants within Tulare Lake Basin counties and Monterey may be at risk to health problems from consuming nitrate-contaminated drinking water, respectively. Again, the difference in basin boundaries and county boundaries makes this a conservative estimate (or an overestimation).

3.7.2 Disadvantaged Communities (Disadvantaged Unincorporated Communities)

Title 22 of the CA Code of Regulations defines a disadvantaged community (DAC) as a community whose median household income (MHI) is less than or equal to 80% of the statewide MHI. The MHI for CA was $47,493 in 2000, so for this report, any community with an MHI less than $37,994 is considered a DAC.

DACs that are unincorporated often lack central water and sewer services. These disadvantaged unincorporated communities (DUCs) are at risk of nitrate contamination because they may lack a safe water source and are less financially able to buy bottled water or treat with point-of-use systems if their water source becomes contaminated with nitrate. Since these areas have a large concentration of families with low incomes, community solutions to nitrate treatment or alternative water supply might also be difficult.

Disadvantaged communities within the Tulare Lake Basin and Salinas Valley are shown in Figure 20, along with the delivered water quality of multiple source CPWSs (WQM data from 2006 to 2010). Severely disadvantaged communities (SDACs) have a MHI of less than 60% of the statewide MHI (less than $28,496). Some DACs include areas known as Census Designated Places (CDPs), or unincorporated areas, and Figure 20 includes some disadvantaged unincorporated communities (along with disadvantaged incorporated communities). CPWSs with delivered water quality exceeding the nitrate MCL within severely disadvantaged or disadvantaged communities are shown in hollow blue circles. Those located outside of severely disadvantaged and disadvantaged communities are shown in blue points. About 45% of the multiple source systems that have delivered water exceeding the nitrate MCL are located within the severely disadvantaged and disadvantaged communities.

Figure 21 shows a scatter plot that relates the estimated 2000 MHI of the water system based on attributing the Census block group MHI to a water system located within it, with the maximum raw source water nitrate level of the water system (U.S. Census Bureau 2000). Systems are shown as being in an incorporated (non-CDP) or unincorporated (CDP) area. The systems above the red 45 mg/L (MCL) line and to the left of the blue 80% MHI line have a source where raw water has been in excess of 45 mg/L as nitrate at least once since 2006, and are located in a disadvantaged community. There are 51 community public water systems (serving about 714,000 people) in the study area with a raw source exceeding the nitrate MCL; 40 systems (serving about 379,000 people) are located in a disadvantaged community while eleven are located outside of a disadvantaged community. Thirteen of the 40 exceeding systems are CDPs (serving about 167,000 people) and 27 are non-CDPs (serving about 212,000 people). Of all 328 systems shown in Figure 21, 12% of the systems with raw water quality in excess of 45 mg/L as nitrate were located within a disadvantaged community while only 3% were located outside of a disadvantaged community. These numbers are different from Table 13, due to use of a system’s raw water sources rather than delivered water quality.

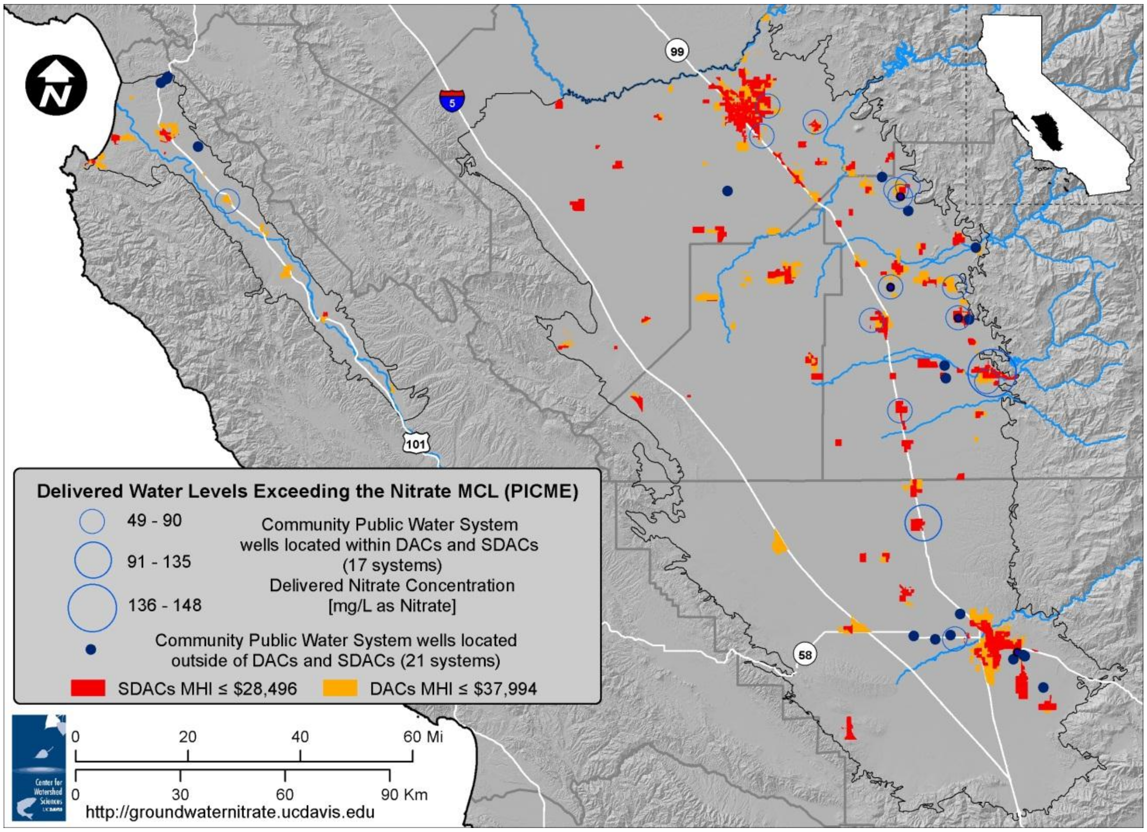

Figure 20. The relationship between DACs and SDACs and delivered water quality in multiple source CPWSs. (Source: CDPH PICME WQM 2006-2010; U.S. Census Bureau 2000; U.S. Census Bureau 2001.)

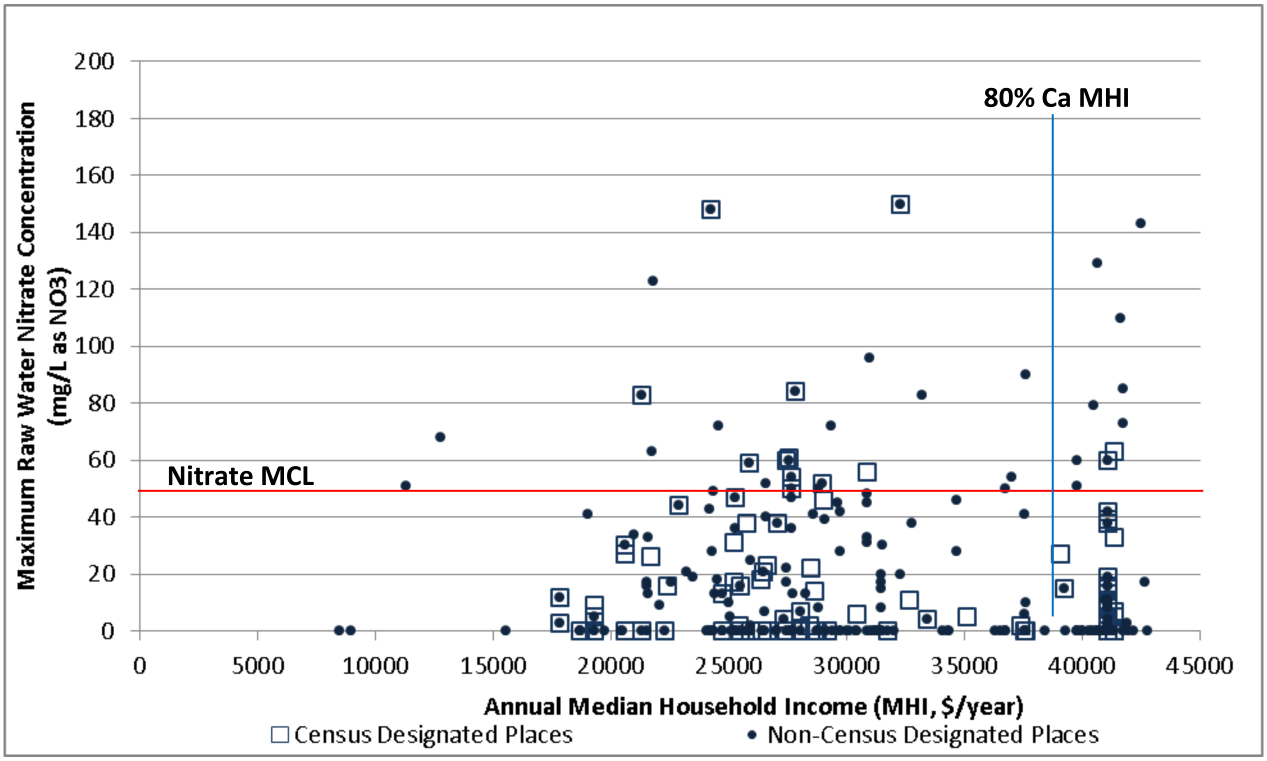

Figure 21. The maximum raw source water nitrate concentration for 328 state small and community public water systems in the Tulare Lake Basin and Salinas Valley with MHI data. (Source: CDPH WQM 2006 – 2010 and 2000 Census.) {Note: CDP = Unincorp. Place and non-CDP = Incorp. Place.}**

Disadvantaged unincorporated communities are smaller communities that are often either not connected to a public water system or are connected to very small systems. The smaller water systems lack technical, managerial and financial capacity to maintain an expensive water treatment facility or to provide alternative water supplies to their customers. Small water systems are typically responsible for more water quality violations and have persistent difficulties with successfully operating and maintaining their systems (Washington State Department of Health 2005).

3.8 Trends in Affected Populations over Time

Legacy nitrate contamination of groundwater will expand in spatial extent in the future and increase the at-risk population. By 2050, the total study area population is projected to grow to about 5.8 million people, with about 5.3 million people in the Tulare Lake Basin, and a little over 500,000 people in the Salinas Valley (California Department of Finance 2010).

3.8.1 Accumulating Nitrate and Population Changes

Current groundwater nitrate contamination is in part a legacy problem, as contamination percolates and spreads in groundwater decades after nitrogen is applied to the soil. In some places, source loading from decades ago is just now reaching the Tulare Lake Basin and Salinas Valley aquifers and nitrate applied to the surface today may not reach drinking water wells for decades. Nitrate accumulates in groundwater; given the extent of contamination there is little evidence to suggest that nitrate concentrations in deep groundwater will decrease without intervention (denitrification is very minor in the environments of this study). As the area's population increases, more people in small and household water systems will face health and financial consequences from nitrate contaminated groundwater. As the population increases and agricultural land is converted to residential property, risks from nitrate-laden groundwater will increase, requiring more aggressive and expensive treatment.

We determined the long-term trends (over the past 40 years) of nitrate concentrations in public supply wells in the pilot study area. The average annual change in nitrate concentration was calculated for all public supply wells with at least two nitrate records listed in WQM. Table 14 shows the mean change in nitrate concentration for public supply wells in the Tulare Lake Basin, Tulare County, and the Salinas Valley. Based on this annual trend for nitrate in public supply wells, the total number of community public water systems that will have raw source water exceeding the MCL by 2035 and 2050 is estimated in Table 15 (CDPH's WQM Database from 1970s to current), showing the predicted affected population if no remediation or abatement of source application occurs. This analysis only examines the increasing nitrate trend in existing community public water systems and is applied to the maximum raw source water data in WQM. The affected population is estimated to be approximately 1.9 million people by the year 2050. Approximately 79% of the existing community public water systems' sources could exceed the MCL for nitrate by 2050. This estimate does not consider any treatment implementation or distribution of alternative water supplies and ignores water system population increases.

Table 14. Long-term trends for nitrate concentrations in public supply wells.[1]

	Mean Change [mg/L-yr]	Confidence Interval -95%	Confidence Interval +95%
Tulare Lake Basin {Tulare County} Public Supply Wells, 1970s – current	0.27 {0.41}	0.17 {0.22}	0.36 {0.59}
Salinas Valley Public Supply Wells, 1970s – current	0.53	0.31	0.77

[1] The nitrate trend for all public supply wells listed in CDPH's CADWSAP (WQM) database from 1970s to current.

Table 15. Estimated time for CPWS sources to exceed the nitrate MCL and total affected population.

Time For Maximum Recorded Raw NO_3^- Level to Reach the MCL	Total Number of Affected CPWSs	Total Affected Population	Percent of Total CPWSs Population (Study Area)
0 Years (2010)	77	1,363,657	57%
25 Years (2035)	114	1,836,732	76%
40 Years (2050)	127	1,903,300	79%

3.8.2 Drinking Water System Regulatory Changes

Tightening drinking water regulations and increasing trends in nitrate concentrations will likely make it more difficult for small local suppliers to comply with regulations for nitrate, arsenic, and other contaminants. With drinking water regulations expected to become more stringent in the future with tighter drinking quality standards and increased contamination occurrences, more water systems will be forced to implement state-of-the-art treatment facilities and monitor more frequently with online monitoring tools. Systems must be prepared to comply with more complex regulations while simultaneously continuing to comply with existing regulations. Compliance will be increasingly difficult as nitrate levels increase over time. Small systems lacking the technical, managerial, and financial capacity for operating and maintaining a treatment facility will struggle with future regulations. The lack of resources and looming safe drinking water challenges should motivate smaller systems to regionalize and consolidate with bigger systems, where possible, to achieve the economies of scale and rate base to be able to assure safe drinking water in an increasingly challenging environment for small systems, or to consult assistance programs for financial, technical and institutional help.

4 Alternative Water Supply Options

Alternative water supplies and nitrate treatment for drinking water are presented and discussed in this section, including the latest technologies, limiting factors, and capital and O&M costs, with a goal of identifying promising options for providing safe water to high susceptibility populations. Guidelines are developed for selecting promising water supply options and evaluating solution costs as a function of source water quality, system size, and system location. The discussions are based on an inventory and analysis of nitrate drinking water management strategies and treatment options available to the study area population, identifying concerns for each option, including financial and economic aspects. The most promising alternative water supply options for the susceptible population are considered and costs are presented with estimated costs in Section 5 Evaluation of Options.

Alternative water supply and nitrate management options identified in this report are grouped into three categories: improving the existing water source, providing alternative supplies, and relocating households (Table 16). Several ancillary activities can improve the performance of some water supply alternatives. Although each system requires its own engineering design and analysis, generalized cost estimates are discussed in Section 5 Evaluation of Options.

Table 16. Alternative water supply options.

OPTION
IMPROVE EXISTING WATER SOURCE
Blending
Drill Deeper Well
Drill New Well
Community Supply Treatment
Household Supply Treatment
ALTERNATIVE SUPPLIES
Switch to Treated Surface Water
Piped Connection to an Existing System
Piped Connection to a New System
Regionalization and Consolidation
Trucked Water
Bottled Water
RELOCATE HOUSEHOLDS
ANCILLARY ACTIVITIES
Well Water Quality Testing
Dual System

4.1 Improve Existing Water Source

Several source improvement options, including both non-treatment and treatment alternatives, can be used to ensure the provision of water that is compliant with the nitrate MCL. In this report, non-treatment options include blending and drilling a deeper or new well. Both can be limited by well characteristics, quality of available sources, and financial resources. The most common treatment options for community public water systems are ion exchange (IX) and reverse osmosis (RO); additional options for drinking water nitrate treatment include electrodialysis/electrodialysis reversal (EDR), biological denitrification and chemical denitrification. Household treatment options include ion exchange at the point-of-entry or reverse osmosis at the point-of-use.

4.1.1 Blending

Blending dilutes a source with higher nitrate levels with a lower nitrate source to produce water that meets safe drinking water standards. Blending typically takes advantage of the differing nitrate concentrations typically found among wells of different locations, districts, and depths. Blending requires at least one nitrate compliant source and cannot occur in systems with only one well, unless additional water is brought from outside.

Blending is often considered a form of treatment because water systems are required to monitor and operate the blending process as a permitted treatment facility with a certified operator (CDPH 2008; Commandatore & Collins 2011). Requirements for blending include daily field monitoring, using continuous online nitrate analyzers to ensure complete mixing and compliant blended water quality; collection of monthly samples to certify a source is uncompromised; and consistent distribution of nitrate compliant water (CDPH 2008; Commandatore & Collins 2011). The compliance point for a blending system shifts from the source water in the well to the blended sampling point (or point-of-entry to the distribution system) (CDPH 2010). Water may be blended from several groundwater wells, or systems can blend groundwater with purchased treated surface water.

According to CDPH, blending is only acceptable as “a treatment process if one of the blended sources exceeds a primary MCL” (CDHS 2005). If a water system decides to blend their sources to comply with drinking water regulations, they must contact CDPH and coordinate with them to create a Blending Program and receive permission to blend. Blending requires two wells to continually operate, ensuring that one is always a low-nitrate source. A blending system must have an operator certified as Grade T2. If the low-nitrate blend water becomes compromised by high nitrate levels, a system automatically loses blending privileges. The maximum blend concentration allowed by CDPH is less than or equal to 40 mg/L (as NO_3^-).

Within the study area, eight CPWSs use blending alone to reduce nitrate in delivered water. Blending is typically the first choice and least expensive option when a nitrate compliant source is available. Estimated costs for blending are presented in Section 5.1.1 Blending.

4.1.2 Drilling a Deeper or New Well

Nitrate slowly follows general groundwater movement down from the surface to the saturated zone. Sometimes it is possible to avoid or defer nitrate contamination by drilling deeper wells. This is often considered a temporary solution because any nitrate contaminating the original shallower well can eventually infiltrate to the deeper well, unless any of the following conditions are met:

- a strongly chemically reducing aquitard zone, capable of denitrifying downward seeping groundwater, separates the current screen level from the target screen level;
- a rather impermeable layer separates the deeper well from the nitrate contamination; or
- the new well screen is much deeper (several hundred feet) below the current screen level *and* the well is properly sealed to the depth of the well screen.

A deeper aquifer protected by a clay layer could prevent upper aquifer nitrate-contaminated water from entering the new wells withdrawal zone. Depending on the local hydrogeology, source capacity may decrease with deeper wells – however, this is typically not an issue for small production domestic wells or wells with few connections. Other water contaminants (such as arsenic) may emerge at new depths. Jensen et al. (2012) found evidence of a possible increase in the incidence of arsenic MCL exceedance with well depth in areas of the Tulare Lake Basin (see Technical Report 6, Section 4.2, Jensen et al. 2012). New wells might be a feasible option for communities while they await long-term solutions, such as connection with larger systems, a new treatment system, or groundwater remediation. Drilling a deeper or new well takes less time than some construction and remediation projects. New well owners and systems employing new wells should test their well frequently.

Drilling a new or deeper well should employ an experienced well driller who is educated on the local hydrogeology. The driller should be familiar with the nitrate distribution and groundwater gradient at the desired well location. The main costs of drilling a new or deeper well will be drilling and pumping costs; both increase with the depth to uncontaminated water. Well modification of an existing well may limit the screened interval, to capture a region of groundwater with low nitrate concentrations. A packer/plug can be installed to restrict withdrawal from nitrated contaminated regions and installation can occur without removing pumps (BESST Inc. 2008).

A new well should be drilled more than about 30 meters (100 feet) from potential sources of pollution or contamination (such as septic fields). Drilling a well has many costs including:

- drilling a pilot test well and the larger diameter borehole for the production well;
- installing the well, filter pack, borehole seals, and surface completion;
- equipping the site;
- testing for sediment and water quality;
- well development;
- installation of storage and distribution systems; and
- planning, consulting, and engineering services.

Mettler Community Water District, in Kern County, drilled a 700 foot well at a capacity to serve 146 residents and it was estimated to cost $284,000. In 2009, a well comparable in size and depth was built by Plainview Mutual Water Company, in Tulare County, to serve 800 residents and it was estimated to cost $339,000. Ducor Community Service District, also in Tulare County, spent close to $725,000 on a 1,400 foot well for 850 residents. These cost estimates do not include the contingency, escalation, and design costs, that can add an additional 30% to the construction costs. (Self-Help Enterprises 2010)

Installing a new community water supply well can cost from about $300,000 to $1 million, depending on depth and capacity (Newkirk & Darby 2010). Kettleman City Community Services District estimated the costs for drilling a pilot test well to be about $320,000 (Summers Engineering 2011).

To estimate the costs for drilling a deeper well, a U.S. EPA BID document was used along with a quote from an experienced hydrogeologist. Costs for drilling a deeper or new well are presented in Sections 5.1.2 Drilling a Deeper Well and 5.1.3 Drilling a New Well.

4.1.3 Community Treatment

If an existing CPWS source exceeds the MCL for nitrate, centralized treatment may be implemented. Numerous factors are important in the consideration of community treatment, including the population served, the quantity of water distributed, and the technical and managerial capacity. The U.S. EPA has approved ion exchange, reverse osmosis, and electrodialysis as potable water treatment methods for nitrate removal (see Technical Report 6, Jensen et al. 2012). These three processes remove nitrate ions from the contaminated water and concentrate them into waste brines. The most common nitrate treatment method in the United States is ion exchange. Alternatively, denitrification methods do not transfer nitrate to a concentrated brine waste stream, but convert nitrate to a reduced nitrogen form, such as nitrogen gas. Full-scale application of denitrification treatment of potable water has been limited in the United States; however, two full-scale biological treatment plants, capable of denitrification, are being implemented in California and chemical denitrification has been used at the pilot-scale level. Europe has applied full-scale biological denitrification for potable water treatment (see Technical Report 6, Jensen et al. 2012).

The most appropriate treatment for nitrate contamination can be influenced by influent nitrate concentrations as discussed in Technical Report 6 (Jensen et al. 2012). Table 17 lists several scenarios for influent nitrate level and water system characteristics, with considerations listed for each option.

Table 17. Influence of nitrate concentration on treatment selection.[1]

Option	Practical Nitrate Range	Considerations
Blend	10 – 30% above MCL	Dependent on capacity and nitrate level of blending sources.
IX	Up to 2X MCL	Dependent on regeneration efficiency, costs of disposal and salt usage. Brine treatment, reuse, and recycle can improve feasibility at even higher nitrate levels.
RO	Up to many X the MCL	Dependent on availability of waste discharge options, energy use for pumping and number of stages. May be more cost-effective than IX for addressing very high nitrate levels.
BD	Up to many X the MCL	Dependent on the supply of electron donor and optimal conditions for denitrifiers. Ability to operate in a start-stop mode has not yet been demonstrated in full-scale application; difficult to implement for single well systems. May be more cost-effective than IX for addressing high nitrate levels.

[1] Based on contact with vendors and environmental engineering consultants. Excerpt from Technical Report 6 (Jensen et al. 2012).

The estimated costs for use of ion exchange and reverse osmosis are presented in Section 5.1.4 Community Treatment; additional information is provided in Technical Report 6 (Jensen et al. 2012). Since the most recent U.S. EPA Cost Estimating Manual is from 1979, collected cost information for arsenic treatment was used for a more up to date comparison of ion exchange treatment (U.S. EPA 2000). Refer to Technical Report 6 on Drinking Water Treatment for more nitrate treatment details (Jensen et al. 2012).

Communities with dual plumbing systems that separate drinking and cooking uses from other water uses, have the possibility to greatly reduce treatment quantities and costs, and reduce production of waste brines requiring disposal. However, dual plumbing systems increase capital and maintenance costs and may raise regulatory issues.

Any CPWS implementing treatment could consider using remote monitoring and management technology to lower operating and maintenance expenses. A remote telemetry or supervisory control and data acquisition (SCADA) system would be very beneficial to small systems lacking resources to support qualified operators on-site. Small water systems are more expensive and challenging to manage well and SCADA allows a skilled operator to supervise several systems remotely. A SCADA system allows real time control of system operation and maintenance of water quality by using a central computer to control mechanical processes and collect data from sensors. Emergency responses can be quick with instant notification of critical system events or episodes automatically sent to the operator. Additionally, the data acquisition component allows utilities to provide statistics on water quality and usage for budget planning, water quality compliance, system improvement, and targeted system expansions. A SCADA system can alert operators to changes in water quality requiring their assistance or automatically modify system operation through preprogrammed control functions not needing operator assistance. A SCADA and Programmable Logic Controller (PLC) control system for a 900 gallon per minute (gpm) surface water treatment plant costs about $75,000 (Summers Engineering 2011).

Based on the U.S. EPA 2007 Drinking Water Infrastructure Needs Survey and Assessment, approximate minimum costs for SCADA are represented for various system sizes in Section 5.1.4 Community Treatment.

4.1.4 Household Treatment

An alternative to community treatment is the use of a household water treatment device either at the point-of-entry (all water entering the home) or at the point-of-use (drinking and cooking water only). Point-of-entry (POE) solutions remove nitrate through reverse osmosis or ion exchange for the entire house (usually only indoor uses). Point-of-use (POU) solutions for nitrate commonly use reverse osmosis for kitchen taps (New Hampshire Department of Environmental Services 2008). Since nitrate is not a concern for non-drinking uses (showering), a POU system that treats drinking and cooking water is more economical than a POE system. POU systems have greater potential public health risks than POE systems, because residents may consume water from bathroom taps without a POU system. In general, reverse osmosis is the cheapest nitrate treatment at the household level (Mahler 2007).

Certification to the relevant ANSI/NSF standard by an ANSI accredited third party certifier ensures the safety and performance of the residential treatment systems (see Technical Report 6, Jensen et al. 2012). Currently there is only one ANSI/NSF household-level technology standard for nitrate reduction: NSF 58 - Reverse osmosis drinking water treatment systems (NSF 2010). POU devices that claim to reduce a drinking water contaminant must be certified by CDPH (CDPH 2008; CDPH 2010a). CDPH's Certified Residential Water Treatment Devices directory lists approved water treatment devices to reduce nitrate. "Under counter" approved systems reduce nitrate through reverse osmosis or reverse osmosis with carbon. "Counter top" approved systems reduce nitrate through reverse osmosis and granular activated carbon (CDPH 2011b).

POU treatment requires separation of drinking and cooking water supplies from other water uses and potentially increases public health risk, but is much less expensive than treating all household water to remove nitrate, and similarly generates much less waste brine. For a reverse osmosis system, piping from the device and faucet plumbing must be lead-free. This precaution is needed because reduction of the water's alkalinity can increase corrosiveness and leach lead (New Hampshire Department of Environmental Services 2008).

The average rated service flow for the certified residential nitrate treatment devices in the CDPH directory is about 20 gallons per day (gpd), with some devices as low as 7.6 gpd and some as high as 35.5 gpd (CDPH 2011a). The average human uses 0.8 gpd for cooking and drinking (NAS 2004), so these flow rates are appropriate for drinking and cooking needs of most family sizes.

While the residential water treatment devices in the CDPH directory are certified to remove nitrate from drinking water, there is a limit to their effectiveness. For example, many of the reverse osmosis with carbon treatment systems manufactured by Kinetico Incorporated are only acceptable for nitrate levels below 27 mg/L (measured as nitrogen) (CDPH 2011a). However, treatment with these devices can also remove other potential contaminants of concern, such as arsenic.

The estimated cost of a reverse osmosis POU device and an ion exchange POE device is discussed in Section 5.1.5 Household Treatment.

4.2 Connect to Alternative Water Supplies

Alternative water supplies include connection to a better quality water system, trucked potable water from a better source, and purchased bottled or vended water. A piped connection to a better quality water system can take three forms: connecting to an existing system, connecting to a newly created system, and consolidating several small systems into a larger new regional system. Trucking of water would most likely occur for remote, very small communities and businesses as an interim or emergency solution. The use of bottled or vended water is a simple and effective temporary solution for isolated households or small businesses, albeit at some cost and inconvenience.

4.2.1 Switch to Treated Surface Water

A piped connection to an existing surface water treatment system becomes promising if a community is reasonably near a well-functioning system with capacity. The costs for connecting to an existing surface water treatment system, currently supplied by a source such as the Central Valley Project (CVP) or State Water Project (SWP), would include the pipeline costs for the installed distribution pipe, trenching and excavation, embedment, backfill and compaction, valves, fittings and hydrants, dewatering, sheeting and shoring, horizontal boring, pavement removal and replacement, utility interference, and the fees for each connection to buy into capacity(varies within each system – the City of Davis charges about $9,000 for a residential ¾" meter connection to their system) (City of Davis Public Works Division 2011).

Kettleman City Community Services District is proposing switching from their contaminated groundwater (arsenic and benzene) to a surface water treatment plant. The County of Kings and Tulare Lake agricultural users are allocating some of their State Water Contract (900 acre-feet per year). The estimated cost for a surface water treatment plant is $6.6 million. The plant would supply 1.3 mgd of surface water to 1,500 people. An increase in residential rates is limited to $2.21 per month (1.94% of the MHI) (Summers Engineering 2011). The annual O&M will be subsidized by Kings County.

Although the quantities of water to serve a small community might not be large, legal and contracting issues will arise. When attempting to switch to surface water as a drinking source in the Tulare Lake Basin, operating characteristics of surface water supply systems designed for irrigation use, such as the Friant-Kern Canal, also may pose challenges to small rural communities when such systems are drained for maintenance during the off-season. To prepare for this type of surface water availability limitation, it may sometimes be appropriate to create a surface water treatment system with capacity to treat nitrate contaminated groundwater as well, so the residents have greater supply reliability.

Cutler and Orosi are two unincorporated communities in Tulare County located less than a mile from each other, and less than a mile from a smaller community, East Orosi. Cutler and Orosi each have their own water systems that are contaminated with DBCP and nitrate. The Alta Irrigation District has just completed the first stage of a feasibility study for treating Friant Kern Canal surface water to supplement Cutler and Orosi's contaminated groundwater sources. The project is estimated to cost approximately $17 million in capital costs and approximately $500,000 in annual operating costs (CWC 2011a).

4.2.2 Piped Connection to an Existing System

Costs for a piped connection to an existing water system with safe water would include infrastructure, base installed pipe, trenching and excavation, embedment, backfill and compaction, valves, fittings, and hydrants, dewatering, sheeting and shoring, horizontal boring, pavement removal and replacement, and connection fees to the existing safe water system. Most costs will be for distribution and connection.

Figure 22 shows the distribution of the minimum distances from a system serving less than 10,000 people (smaller systems) to a system serving more than 10,000 people (larger systems) for all CPWSs and SSWSs in the study area (distances are between sources, not service areas). Within the study area, 306 small systems and 38 large systems are analyzed in Figure 22 for possible interties, disregarding any institutional, political, technical, managerial, or financial barriers and costs. Of the 195 small systems in the Tulare Lake Basin, about 50% are within five miles of a larger system, and 88% are within 12.5 miles (Figure 22). Of the small systems in the Salinas Valley, about 15% are within five miles of a larger system, and 97% are within 12.5 miles (Figure 22). This analysis also assumes safe drinking water quality and available capacity for the systems with more than 10,000 connections. The connection potential for each basin is discussed further in Section 4.2.4 Regionalization and Consolidation.

East Niles Community Services District (ENCSD) charges $5,000 per connection to their system. Installing a 10" PVC pipe and valves was estimated by ENCSD to cost around $85 per foot (Self-Help Enterprises 2010), while U.S. EPA estimated $95 – 142 per foot (U.S. EPA 2007). Rehabilitating a pipeline is slightly less expensive at $73 per foot (U.S. EPA 2007). Any obstructions create additional expenses. For example, a railroad track crossing cost ENCSD $75,000 and crossing a canal cost $25,000 (Self-Help Enterprises 2010).

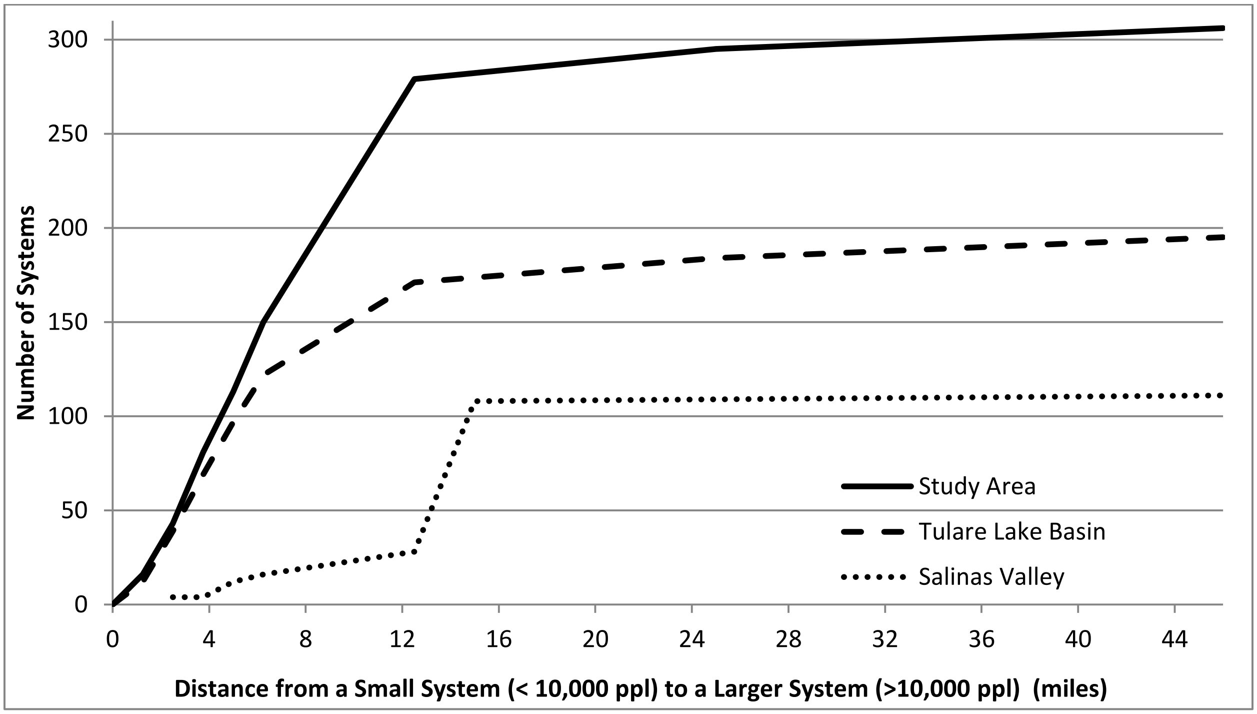

Figure 22. The minimum distance from a small system (≤ 10,000 people) to a larger system (> 10,000 people) for the entire study area. (Source: CDPH PICME 2010.)

4.2.3 Piped Connection to a Larger Newly Created System

Creating a new public water supply system is likely to involve costs for infrastructure, base installed pipe, trenching and excavation, embedment, backfill and compaction, valves, fittings, and hydrants, dewatering, sheeting and shoring, horizontal boring, pavement removal and replacement, utility interference, new sources, and treatment equipment. For a new groundwater system, a district or community may need to look outside for safe groundwater. If a new groundwater system is constructed within a district's boundaries there must be property available for a structure to house a nitrate treatment system. It is recommended to construct at least two wells since pumping units can fail within a well and it is prudent to have a backup source. Cost estimates would include costs for two wells, distribution, and treatment.

The San Jerardo Water System spent over $5 million installing two miles of water transmission pipelines, a 285,000 gallon water tank, a potable water well, and pumping station. They also created an intertie with a nearby potable water supply for emergency service (Monterey County Planning Commission 2009).

4.2.4 Regionalization and Consolidation

Regionalization and consolidation in the drinking water sector can take many forms. Inter-tying systems to create a new larger system combines several small water systems that suffer from diseconomies of scale into one larger water system that serves the desired population and provides treatment to comply with drinking water standards. Regionalization has more formally been defined as "…a creation of an appropriate management or contractual administrative organization or a coordinated physical system plan of two or more community water systems in a geographical area for the purpose of utilizing common resources and facilities to their optimum advantage" (Grigg 1989). Similarly, consolidation has been defined as "one community public water system being absorbed into, combined with, or served by other utilities to gain the resources they lack otherwise" (Raucher et al.2004). Consolidation often refers to giving up control and independence by one entity (or water system) as it is merged into another single entity. This transfer of control and loss of independence does not always occur with regionalization; multiple smaller systems can join together to create a larger system with management distributed evenly among all parties.

Kettleman City CSD identified potential safe water supplies about 8,000 feet away from their property. The CSD's Engineer estimated drilling two new groundwater wells, with an 8,000 foot distribution pipeline, to cost about $6.6 million (Summers Engineering 2011). The CSD also estimated treating two new groundwater wells (treatment for arsenic and odor) drilled on the existing property to cost about $7.7 million (Summers Engineering 2011).

Regionalization and consolidation combine neighboring water systems to improve service and efficiencies, and to lower costs through economies of scale (Eskaf 2009). Regionalization and consolidation can be considered for drinking water systems struggling to meet regulatory compliance, unable to sustain aging infrastructure, unable to operate the system, or concerned about future water availability. Regionalization and consolidation are especially attractive for small systems that lack population base and access to financial resources and technical expertise. Systems can achieve economies of scale through regionalization without being physically connected by sharing capital equipment and management staff, or by participating in joint business and logistic operations. The least to most collaborative regionalization options range from: 1) create a planning document together; 2) initiate communication to discuss water system issues or to call during an emergency; 3) share inventory or equipment; 4) share an operator; 5) join management or delegate bookkeeping or billing to one entity; 6) interconnect systems for emergency purposes only; 7) share water rights or water resources without an intertie; 8) intertie systems, but maintain separate operations; and 9) intertie systems, close current systems, or form a combined system (New Mexico Rural Water Association 2006).

The optimal economic water system size and least-cost service area are estimated by the cost trade-offs between the water source acquisition-treatment component and the transmission-distribution component (Clark & Stevie 1981). Smaller water systems may not have the economies of scale for the acquisition-treatment component, resulting in increased marginal costs for drilling and pumping. Ideally, in consolidation there is a balance between the increasing returns in acquiring and treating the water and the decreasing returns involved in distributing water further and further. Rural small community water systems are generally farther from large urban systems, resulting in high costs for the transmission-distribution component of consolidating that often are unaffordable by low income rural populations (Ottem et al. 2003).

There is significant potential based on size and distance analysis for systems to consolidate in the Tulare Lake Basin. There are 98 large systems and 195 small systems analyzed for connection. The number of smaller systems that are within 15 miles of larger systems is shown in Table 18. The Cities of Fresno, Dinuba and Porterville, as well as the CSU Fresno water systems, are available for ten or more small systems to connect based solely on their spatial proximity. Figure 23 shows the number of smaller systems that are within a specific distance range of a larger system (e.g., there are 12 smaller systems within 1.25 miles of a larger system in the Tulare Lake Basin). Considering only piping costs, about 97 smaller systems could consolidate and join a larger system less than five miles away at a cost of about \$1.6 million[19] per system. Spatial proximity is the only consideration in suggesting these interties; other territorial, institutional, infrastructure upgrading, legal, and political barriers are ignored.

Within the Salinas Valley, there are 19 large systems and 111 small systems analyzed for connection (Table 19). The California American Water Company in Monterey and the California Water Service Company in Salinas are close to ten or more small systems for possible connection consideration, based solely on spatial proximity. Figure 24 shows the number of smaller systems that are within a specific distance range of a larger system (e.g., there are 4 smaller systems within 1.25 miles of a larger system in the Salinas Valley). Again, considering only piping costs, about 28 smaller systems could consolidate and join a larger system less than thirteen miles away at a cost of about \$4 million per system (Monterey County Environmental Health 2010b).

Assuming sufficient capacity and adequate internal infrastructure of the small systems, there is significant potential for regionalization and consolidation if a system can afford the pipeline and connection costs. The costs considered in this report for connecting to a new or existing system are only those for installing the intertie pipeline and for connection fees. The operating costs for the intertie pipeline, the additional value of the safe water relative to the unsafe water, and the cost for land

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[19] This assumes a \$61/ft pipe cost from the Granite Ridge Regional Water Supply Project Feasibility Study (Monterey County Environmental Health 2010b).

easements for transmission are not considered in this report. Various cost scenarios for constructing pipeline to a new or existing system are presented in Section 5.1.6 Connect to an Alternative System.

Table 18. Large systems and the number of nearest small systems identified by distance proximity nearest-neighbor analysis in the Tulare Lake Basin.

System Number	System Name (> 10,000 System)	Connection	Population	Potential Number of Connecting Systems (< 10,000 ppl)[1]	Population of Potential Number of Connecting Systems
1010007	City of Fresno	130,176	457,511	11	11,731
1010019	City of Kingsburg	3,413	11,300	3	653
1010024	California Water Service Co. - Selma	6,078	24,307	8	8,377
1010025	City of Parlier	2,329	12,058	1	1,100
1010027	City of Reedley	5,445	25,584	2	60
1010029	City of Sanger	5,971	25,404	8	2,301
1010339	California State University, Fresno	550	22,000	15	12,094
1510001	Arvin Community Services District	3,446	11,847	1	400
1510005	City of Delano	8,829	53,855	9	14,500
1510006	East Niles Community Services District	7,406	25,500	7	2,560
1510012	Lamont Public Utility District	3,475	13,296	6	6,959
1510015	Oildale Mutual Water Company	7,708	26,000	7	11,307
1510019	City of Shafter	4,090	15,609	3	7,296
1510022	West Kern CWD	7,443	16,630	2	7,464
1510029	Vaughn WC INC F	9,246	28,100	11	1,930
1510031	City of Bakersfield	43,086	147,999	12	1,240
1610003	City of Hanford	15,509	53,320	9	7,157
1610005	City of Lemoore	6,117	24,500	5	3,386
5410002	City of Dinuba	6,025	21,087	13	17,909
5410003	City of Exeter	3,012	10,730	5	8,399
5410004	City of Farmersville	2,420	10,672	3	1,440
5410006	City of Lindsay	2,303	11,450	5	3,773
5410010	City of Porterville	14,896	51,467	17	9,957
5410015	City of Tulare	15,967	57,375	4	3,618
5410016	California Water Service Co. - Visalia	40,530	133,749	9	7,150

[1] Within 15 miles.

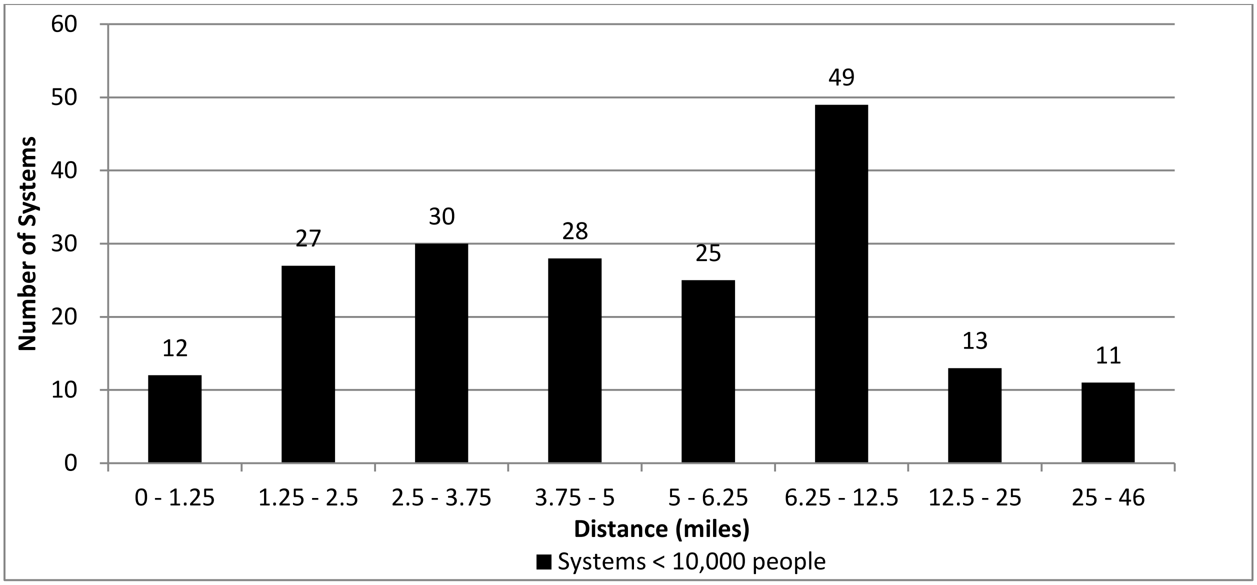

Figure 23. The minimum distance ranges between all existing small systems (≤ 10,000 people) and larger systems (> 10,000 people) in the Tulare Lake Basin. (Source: CDPH PICME 2010.)

Table 19. Large systems and the number of nearest small systems identified by distance proximity nearest-neighbor analysis in the Salinas Valley.

System Number	System Name (> 10,000 System)	Connection	Population	Potential Number of Connecting Systems (< 10,000 ppl)[1]	Population of Potential Number of Connecting Systems
2710004	California American Water Company Monterey	38,701	122,492	12	7,162
2710008	City of Greenfield	3,469	17,547	10	10,990
2710010	California Water Service Co. - Salinas	25,451	114,840	78	25,511
2710011	City of Soledad	4,082	16,146	9	9,411
2710017	Marina Coast Water District	8,357	34,600	2	1,050

[1] Within 15 miles.

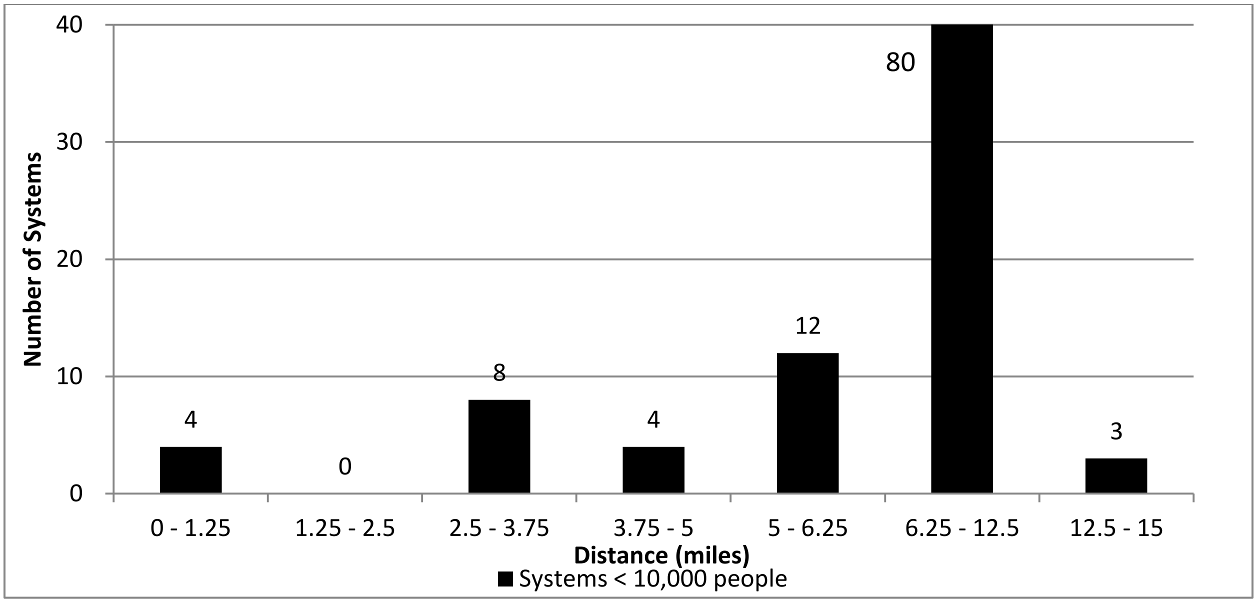

Figure 24. The minimum distance ranges between all existing small systems (≤ 10,000 people) and larger systems (> 10,000 people) in the Salinas Valley. (Source: CDPH PICME 2010.)

4.2.5 Trucked Water

Trucked water is a community or household water supply option that involves hiring a potable drinking water hauler, licensed with the California Department of Public Health, to deliver water to residential and commercial areas. Prior to use, the truck must be cleaned and inspected thoroughly, disinfecting all truck components with chlorine for 24 hours prior to delivery. Trucked water is often used for emergency supplies, but has permitting issues and is not acceptable for new public water systems (CDPH 2011c; CDPH 2011d). CDPH only recommends supplying trucked water for emergency or short-term situations (CDPH 2011c; CDPH 2011d). California water haulers are required to have a Water Hauler License from the Department of Public Health's Food and Drug Branch (FDB) (CDPH 2008). FDB periodically inspects water hauler trucks to ensure compliance with laws and regulations. Historical sanitary and financial concerns have made trucked water problematic.

Trucked water also could be used with a dual system, where only potable water for drinking and cooking is trucked in while the contaminated supply is used for other household needs. A trucked water dual system is infeasible as a long-term solution due to costs and CDPH regulations.

The estimated cost for providing a community or household in Tulare County with trucked water is shown in Section 5.1.7 Trucked Water.

4.2.6 Bottled Water

Bottled or vended water is often a temporary solution for communities or households with a nitrate problem. While other long-term solutions are being developed, funded, and implemented, bottled water is the quickest solution for low-nitrate drinking water. However, bottled water is considerably more expensive than publicly supplied systems or well water, and is regulated less stringently by the FDA than tap water is by the U.S. EPA (NRDC 2010).

As with any dual system, accidentally drinking water from a faucet served with water exceeding the nitrate MCL is a risk. Bottled water must be either delivered or picked up from the store or distributor, so households might occasionally run out of bottled water and use tap water. Households need to ensure that they order the appropriate amount, inventory their usage, and remember to place new orders. The reoccurring monthly cost is particularly unattractive to low income areas. While long-term purchase of bottled water is expensive, the monthly cost is less than a lump sum of capital-intensive solutions like drilling a new well. Households recently informed of their connection to a contaminated source purchase bottled water as an immediate solution, while still paying for non-potable piped water.

The estimated cost for delivering bottled water to a household in Tulare County is discussed in Section 5.1.8 Bottled Water.

Matheny Tract is a 45-acre disadvantaged unincorporated community outside of Tulare City limits that has been purchasing bottled drinking water since 2007. As of 08/2010 Tulare LAFCO is requiring the City of Tulare to extend water and sewer service to Matheny Tract (Pacific Institute 2011).

Beverly Grand Mutual Water Company (BGMWC), in Porterville, serves 108 people and has been in violation of the nitrate MCL since 2000, with the most recent violation in April 2010 (65 mg/L as NO_3^-). About 50 people are below or near the poverty level. The Pacific Institute surveyed households served by BGMWC and found that, on average, households spend $31.63 on non-tap replacement water per month, while still paying $25.00 per month on contaminated tap water (Pacific Institute 2011).

4.3 Relocate to Area with Better Water Supply

Relocating residents to a place with safe, reliable water supply is a socially and politically difficult extreme option. Susceptible populations would face costs of selling property (often at a loss) or completely abandoning property, moving, loss of jobs, increased travel distance to work, and potential social dislocation. Nearby employers would face higher labor costs and landlords would face reduced rental prospects. The area would also suffer a decrease in economic activity. Some residents currently living in nitrate-contaminated areas are there because rent is inexpensive and employment is nearby. Residents of many small rural communities might also be unable to afford to live in areas with safe water supplies. Nevertheless, under some circumstances relocation may be the most attractive option, particularly when a community faces other economic challenges. The estimated costs for relocating households in the study area to a place with a better water supply are discussed in Section 5.1.9 Relocate to Area with Better Water Supply.

4.4 Ancillary Activities

Some options can be improved by simultaneously installing a dual water distribution system or by a well water quality testing program. A dual water system for a self-supplied household can allow for more economical use of POU RO unit or bottled water. A dual water distribution system for community public water system customers will include constructing new plumbing and installing groundwater treatment for the potable portion of the supply, and maintaining the existing distribution of contaminated water for the non-potable supply. Well water quality testing can improve blending efficiency and increase the likelihood of providing low-nitrate water when drilling a new or deeper well.

4.4.1 Dual Water Distribution System

A dual water distribution system has two separate distribution networks, one for the distribution of potable water and another for the distribution of non-potable water. According to Title 22, Section 60301.250 a dual plumbed potable water system has separate piping for potable water (CDPH 2008). A dual water distribution system would rely on water from the current nitrate contaminated supply for non-potable uses while consuming potable water from a POU treatment system (reverse osmosis), bottled water, water trucked from an outside source, or safe drinking water from the existing water system that has been separated, treated, and piped through a secondary distribution network to the household. Total costs would be the current monthly cost for the contaminated supply plus the cost for a potable POU treatment system, bottled water, or trucked water. If the entire water system decided to create a dual plumbed system the costs would include the cost for the contaminated supply, new treatment, installation of a new pipeline to existing service connections, and the re-plumbing of households served. A system could continue to distribute the nitrate-contaminated supply for non-potable uses and install a smaller treatment system for the potable supply with delivery through a new second parallel distribution network. Any water used for irrigation, or other non-drinking water uses, could be delivered through the existing pipeline, with a new plumbing system installed for the delivery of the treated, potable water. This would greatly reduce the water treatment costs for a system since a smaller volume would need to be treated. Costs for dual water distribution systems also include proper maintenance on existing infrastructure, water quality, and water pressure. Costs for dual water distribution options are discussed in Section 5.1.10 Dual Water Distribution System.

4.4.2 Well Water Quality Testing

Well water quality testing is important for all households on non-public water systems to detect high nitrate levels within their water supply, and especially in nitrate affected risk areas. Well water quality testing is recommended for households or state small systems that have not yet tested their water supply for harmful contaminants to determine if they are at risk and need an alternative water supply. The National Ground Water Association (NGWA) recommends domestic well owners test the water quality annually for bacteria, nitrite/nitrate, and other constituents of concern. The local health or environmental health department may also provide water quality testing and well cleaning advice. Before blending wells, well water quality testing is required to discover and manage the appropriate blend of sources to produce water below the MCLs for nitrate and other contaminants. Similarly, when considering drilling a deeper well, the well water quality should be tested for other contaminants such as arsenic or manganese, as those contaminants may exceed regulatory levels in deeper wells. When testing the well water quality it is recommended to have a California State-certified drinking water testing laboratory conduct the analyses (a list of drinking water laboratories certified by the CDPH is available at : http://www.cdph.ca.gov/certlic/labs/Documents/ELAPLablist.xls). The costs for residential well water quality testing are discussed in Section 5.1.11 Well Water Quality Testing.

4.4.3 Rainwater Cisterns

Another option considered is implementing rainwater cisterns. However, cisterns are not commonly feasible for the scale of the problem in this arid area. A short description of this option is included in Appendix Section 10.2 Rainwater Cisterns.

5 Evaluation of Options

Each option is evaluated on a system scale, identifying economic and financial feasibility and addressing any public health concerns. While each water system requires its own engineering analysis to reflect local conditions, here we present a broad general comparison of the costs of various options for policy purposes. The advantages and disadvantages of each alternative are discussed for public water systems in Table 20 and for household self-supplied and local small water systems in Table 21.

Table 20. Advantages and disadvantages of options for public water systems.

	ADVANTAGES	DISADVANTAGES
Blending	▪ Simple non-treatment alternative ▪ Cost-effective, given suitable wells	▪ Capital investment for accessing an alternative source ▪ Relies on availability and consistency of low-nitrate source ▪ Monitoring requirements ▪ Rising nitrate levels may preclude ability to blend
Drilling a Deeper or New Well	▪ Potentially more reliable water supply ▪ Cheaper than bottled water for households using more than 8 gpd	▪ Potential decrease in source capacity ▪ Capital and operational costs increase with depth ▪ Potentially only a temporary "quick-fix"; longevity depends on local hydrogeologic conditions and landuse ▪ Risk of encountering other water quality concerns at greater depths (i.e., arsenic, manganese) ▪ Pipeline costs if source area is far from original source
Community Treatment (IX, RO & EDR)	▪ Multiple contaminant removal ▪ Feasible, safe supply	▪ Disposal of waste residuals (i.e., brine waste) ▪ High maintenance and/or energy demands ▪ Resin or membrane susceptibility
Piped Connection to an Existing System	▪ Safe, reliable water supply	▪ Capital cost of pipe installation ▪ Connection fee ▪ Water rights purchase (surface water)
Piped Connection to a New System	▪ Safe, reliable water supply	▪ Capital cost of pipe installation ▪ High treatment system capital and O&M costs ▪ Water rights purchase (surface water)
Regionalization & Consolidation	▪ Often lower costs	▪ High capital and O&M costs
Trucked Water	▪ Community-wide distribution ▪ No start-up capital cost	▪ Temporary "emergency" solution ▪ Not approved for new water systems
Relocate Households	▪ Safe, reliable water supply	▪ Socially and politically difficult, extreme option ▪ Loss of property value and jobs ▪ Social, familial dislocation
Well Water Quality Testing (Already in place)	▪ Water quality awareness ▪ Beneficial to blending	
Dual System	▪ Hybrid of options ▪ Treating only potable	▪ Possible consumption of water from contaminated source ▪ Cost of contaminated supply plus cost for POU system or trucked/bottled water, or capital dual plumbing costs

Table 21. Advantages and disadvantages of options for self-supplied households or local small water systems.

	ADVANTAGES	DISADVANTAGES
Drilling a Deeper or New Well	▪ Potentially more reliable water supply ▪ Cheaper than bottled water for households using more than 8 gpd	▪ Potential decrease in source capacity ▪ Capital and operational costs increase with depth ▪ Potentially only a temporary "quick-fix"; the nitrate plume follows groundwater movement ▪ Risk of encountering other water quality concerns at greater depths (i.e., arsenic, manganese) ▪ Pipeline costs if source area is far from original source
Household Treatment (RO)	▪ Multiple contaminant removal ▪ Low-nitrate supply	▪ Unless instructed, risk of improper handling or maintenance of equipment
Regionalization & Consolidation	▪ Cheaper treatment costs on a customer basis	▪ High capital and O&M costs
Trucked Water	▪ Community-wide distribution ▪ No start-up capital cost	▪ Temporary "emergency" solution ▪ Extra potable water storage required if a small community
Bottled Water	▪ Nitrate-free supply ▪ No start-up cost	▪ Inconvenience, monthly expenditure ▪ Temporary solution
Relocate Households	▪ Safe, reliable water supply	▪ Unpleasant, extreme option ▪ Loss of property value and jobs ▪ Social, familial dislocation
Well Water Quality Testing	▪ Water quality awareness ▪ Beneficial to blending	
Dual System	▪ Hybrid of options ▪ Treating only potable	▪ Possible consumption of water from contaminated source ▪ Cost of contaminated supply plus cost for community treatment of potable supply and capital dual plumbing costs.

5.1 Economic and Financial Costs

Affordability and sustainability are key issues for deciding if a solution is appropriate for an area. Small water systems with nitrate contamination will often be unable to support new development with limited safe water sources and unable to increase the number of connections (contributing to local economic decline). Consolidation of small water systems can increase economies of scale, and reduce technical and financial burdens by reducing total cost and distributing costs over a larger population. A community must have the technical, managerial and financial capacity to successfully implement a solution.

The Pacific Institute (2011) and others discuss the cost of avoiding or treating nitrate-contaminated water, suggesting that financing "is typically borne by water users and by local government and water providers, and is indirectly incurred by local and state tax payers, through tax revenues that pay for drinking water improvement projects." Individuals currently connected to an impacted water system must pay for their own bottled water, health care services, or point-of-use treatment device. The same costs may be incurred by individuals connected to systems at risk of future contamination. These economic and financial results will be considered when discussing future funding sources and policy options (see Technical Report 8, Canada et al. 2012) for the Tulare Lake Basin and Salinas Valley.

Compared to larger cities, small, disadvantaged, unincorporated communities and self-supplied households often have different economical solutions. Based on the analysis herein, the least expensive option for self-supplied households and local small water systems is often to install point-of-use reverse osmosis devices for all potable uses within their households. If a household can afford drilling a new well and if that well can tap an uncontaminated supply, then a new well can be an attractive alternative; the new well option has fewer potential health concerns from improper handling and accidental consumption of untreated water. The least expensive option for very small community public water systems (serving less than 500 people) is often to install ion exchange treatment within the system configuration. For small community public water systems (serving 500 to 3,300 people) the least expensive option is often to install reverse osmosis treatment. Another economical option for small water systems (serving less than 3,300 people) is often to connect to another system; however, the costs for connection here include pipeline costs and a rough estimation of connection costs. Constructing a new well also may be economical. For medium community public water systems (serving 3,300 to 10,000 people) the least expensive option often is to install groundwater treatment, either ion exchange or reverse osmosis, since the estimated costs overlap. Another economical option for medium systems is to construct a new well or to construct a new well some distance from the existing system location. The economies of scale for pipeline start to prevail for the medium system sizes, and they can pipe their way out of the problem. For larger community public water systems, all options are relatively equal and local conditions become more important. A larger community public water system also has more opportunity to connect to surface water; with the larger population base the costs of connecting, maintaining, and treating the system can be equitably distributed without imposing too much of a financial burden.

For the final basin-wide cost analysis presented in Section 6 Basin-wide Costs of Nitrate Contamination, the following alternative water supply options were excluded from community water supply options: bottled water, trucked water, blending, and a dual water distribution system. The U.S. EPA does not allow a community public water system to distribute bottled water to their consumers as a means of complying with drinking water standards.[20] In addition, new community public water systems are not allowed to have trucked water delivered to their consumers and older water systems are only permitted to use this option in an emergency (CDPH 2005; CDPH 2011c; CDPH 2011d). Lastly, blending was not considered in the basin-wide cost analysis, but is recommended as the first step for a community public water system towards complying with the nitrate MCL. If a water system has an additional, low-nitrate source (at least less than 40 mg/L as nitrate) a blending program should be set-up and permitted by CDPH, as the annual O&M costs are less than a groundwater treatment system. For a small water

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[20] National Primary Drinking Water Regulations, Code of Federal Regulations Title 40 §141.101.

system (less than 3,300 people), the annualized cost of blending and drilling a new well are almost equivalent, however, they both rely on the future fate of the sources available.

The costs of alternative water supply and treatment options vary with numerous factors and the numbers presented here are estimates based on averages of widely variable costs. Costs will be unique to each individual system. For proper cost estimation, a feasibility analysis is necessary to assess the potential solution for each unique system. The following overall assumptions were made to estimate costs for the alternative water supply options in Table 22:

- Twenty year life of product/equipment/materials (except for household treatment – 10 years and bottled/trucked water – no capital)
- 2.15 gallons per household per day of potable water consumption (NAS 2004)
- 3.3 persons per household
- 2010 dollars

Table 22. Summary of approximate alternative water supply option costs.

OPTION	**ESTIMATED ANNUAL COST RANGE ($/year)[1]**	
	Self-Supplied Household	**Small CPWS(1,000 households)**
IMPROVE EXISTING WATER SOURCE		
Blending[2]	N/A	$85,000 - $150,000
Drill Deeper Well[3]	$860 - $3,300	$80,000 $100,000
Drill a New Well[4]	$2,100 - $3,100	$40,000 - $290,000
Community Supply Treatment[5]	N/A	$135,000 - $1.09 M
Household Supply Treatment[6]	$250 - $360	$223,000
ALTERNATIVE SUPPLIES		
Piped Connection to an Existing System[7]	$52,400 - $185,500	$59,700 - $192,800
Trucked Water[8]	$950	$350,000
Bottled Water[9]	$1,339	$1.34 M
RELOCATE HOUSEHOLDS[10]	$15,090	$15.1 M
ANCILLARY ACTIVITIES		
Well Water Quality Testing[11]	$15 - $50	N/A
Dual System[12]	$575 - $1,580	$260,000 - $900,000

[1-12] See Table 36 and 37 for references.

The capital and operations and maintenance (O&M) costs were researched for each alternative water supply option. The capital costs for household and community treatment include process, construction, engineering and indirect costs, but do not include planning and preliminary alternative analysis costs (U.S. EPA 2000; U.S. EPA 2005). Alternative supply cost estimates were estimated in accordance with U.S. EPA cost estimation procedures (U.S. EPA 2000) and from historical project estimates.

Capital costs were converted to annualized capital costs ($/1,000 gallons or $/1 kgal) based on the following equation:

$$\text{Annualized Capital Cost (\$/kgal)} = \frac{\{\,Capital\ Cost\ (\$) * Amortization\ Factor\,\}}{\{\,Flow\ (mgd) * \frac{1000\ gal}{Mgal} * \frac{365\ days}{year}\,\}}$$

An amortization value of 0.0802 was used which corresponds with an interest rate (i) of 5% over 20 years (N), represented by the following equation:

$$\text{Amortization Factor} = \frac{i * (1+i)^N}{((1+i)^N - 1)}$$

Annual O&M costs were converted to annualize O&M costs based on the following equation:

$$\text{Annualized O\&M Cost (\$/kgal)} = \frac{O\&MCost\ (\$)}{\{\,Flow\ (mgd) * \frac{1000\ gal}{Mgal} * \frac{365\ days}{year}\,\}}$$

The total annualized cost of each alternative water supply option equals the sum of the annualized capital and O&M costs.

5.1.1 Blending

To estimate blending costs for nitrate compliance, a report written by Kennedy/Jenks was used that based “bid” cost estimates primarily for nitrate problems (Kennedy/Jenks 2004). They used a blending design case for a 14 inch casing well with a flow rate range of 300-1,200 gpm and a well depth of 700. This report uses the costs corresponding with flow rates of 300 and 600 gpm as the low and high estimate for blending costs for a 1,000 household community. The cost for obtaining a new low-nitrate source is not included in this cost estimate. The original capital and O&M costs are in 2003 dollars and are projected to 2010 dollars using the 2010 ENR CCI. The capital cost incorporates the cost for the basic blending facility and is estimated to cost about $131,000 for each flow rate. Indirect construction costs such as engineering, contingency, and permitting costs were estimated to be about 25 percent of the estimated bid costs (Kennedy/Jenks 2004). The O&M cost for blending water was estimated at $250 per acre-foot (af), costing approximately $50,000 and $100,000 (2003 dollars) annually for each flow rate, respectively. Table 23 shows the resulting blending costs, with annual costs estimated as $83,000 and $148,000, for each flow rate, or $0.52 and $0.47 per kilogallon, respectively. These blending estimates are for a 3,300 person (or 1,000 household) community, as blending is only recommended for public water systems with more than one well and the ability to obtain a low-nitrate source.

Table 23. Estimated costs for blending.

Itemized Cost	Low Estimate[1]	High Estimate[2]
2003 Capital Cost[3]	$131,000	$131,000
Indirect Construction Cost[4]	$32,750	$32,750
2010 Capital Cost[5]	$216,000	$216,000
2010 O&M Cost[6]	$$65,000	$130,000
Annualized Cost ($/kgal)[7]	$0.52	$0.47
Annualized Cost ($/year)[8]	**$83,000**	**$148,000**

[1] 14" casing well at 700' deep, 300 gpm. A single blending station is assumed for each source. These costs are based on similar projects implemented by Kennedy/Jenks, primarily for nitrate.

[2] 14" casing well at 700' deep, 600 gpm. A single blending station is assumed for each source. These costs are based on similar projects implemented by Kennedy/Jenks, primarily for nitrate.

[3] Capital costs include the construction "bid" costs for constructing the blending facilities.

[4] 25% indirect construction costs.

[5] The 2003 Capital Costs plus 25% Indirect Construction Cost and projected to 2010 costs using the 2010 ENR CCI.

[6] A major O&M cost is the cost of obtaining low-nitrate blending water. These O&M costs assume that there is already an uncontaminated source available for blending. The O&M costs were developed for electrical power, labor, maintenance materials, resin replacement, and monitoring. Labor rates were estimated at an average of $40 per hour, electricity rates were estimate at $0.12/kWh and an annual allowance for maintenance materials was estimated at 1 percent of total capital costs. The average O&M cost within the well range was chosen and projected to 2010 costs using the 2010 ENR CCI.

[7] The cost is annualized over a 20 year period with a 5% annual interest rate and expressed as dollar per kilogallon produced.

[8] The cost is annualized over a 20 year period with a 5% annual interest rate.

5.1.2 Drilling a Deeper Well

The lower bound cost estimates for drilling a deeper well are from a Background Information Document (BID) from U.S. EPA that provides well drilling cost estimates (U.S. EPA 2001). For a domestic well (assumed 10 gpm, 8 inch casing well), the drilling costs are about $50 per foot; and for a public supply well (assumed 700 gpm, 14 inch casing well), the drilling costs are about $110 per foot. Chris Johnson, a principal hydrogeologist, advises that drilling a deeper well can cost almost as much as drilling a new well and provided the upper bound cost estimates of $200 per foot for a domestic well and $1,000 per foot for a public supply well (Johnson 2011). Table 24 shows the estimated costs for drilling a deeper well based on these two references.

Table 24. Estimated costs for drilling a deeper well.[1]

Itemized Cost	Self-Supplied Household	Public Water System (1,000 hhld)
Drilling Cost ($/foot)	$50 - $200	$110 - $1,000
O&M Cost	$62	$82,000
Annualized Cost ($/kgal)	$6.76 - $25.61	$0.65 - $0.77
Annualized Cost ($/yr)	**$860 - $3,300**	**$84,000 - $98,000**

[1] The lower bound estimates are from the U.S. EPA Yucca Mountain BID Document: *Well Drilling and Pumping Costs* (U.S. EPA N.D.). A domestic well is assumed to be a 10 gpm, 8 inch casing well, originally 300 feet deep and deepened to 500 feet. A public supply well is assumed to be a 700 gpm, 14 inch casing well, originally 500 feet deep and deepened to 700 feet.

5.1.3 Drilling a New Well

The annualized total cost for drilling a new domestic well is based on cost estimates provided by an experienced senior geologist, and is shown in Table 25. The U.S. EPA 2007 Survey and Assessment was used for estimating the costs for drilling a new public supply well, shown in Table 26. New public supply well costs include pump and appurtenances, but do not include well houses. The Survey and Assessment provides the following cost functions for new wells and for rehabilitating existing wells (U.S. EPA 2007):

$$New\ Well\ Cost = e^{13.6502} * D^{0.56445}$$

$$Well\ Rehabilitation\ Cost = e^{11.72961} * D^{1.59738}$$

D is the design capacity of the well in millions of gallons per day (mgd), and *e* represents the exponential function (approximately 2.72) (Goldstein et al. 2006).

The annual O&M cost is assumed to be included in the model. With these functions, rough cost estimates can be made for the lower bound of system categories and a multiplication factor of seven is applied to estimate the upper bound cost. Estimated costs for a new public supply well are listed in Table 26 and estimated costs for public supply well rehabilitation are listed in Table 27.

Table 25. Annualized total cost ranges for drilling a new domestic well.

Option	Drill a New Well[1]
Initial Capital Cost ($/hhld)	$25,000 - $40,000
Annual O&M Cost ($/hhld)	$60
Total Annualized Cost ($/kgal)	$16.17 - $25.59
Total Annualized Cost ($/hhld)	**$2,100 -$3,300**

[1] Initial Capital Cost Estimates from David W. Abbott, Senior Geologist at Todd Engineers (Abbott 2011). Annual O&M Estimate: Assumed 300 foot well depth, 0.6 pump efficiency, and $0.15/kWh. Annualized over 20 years.

Table 26. Annualized total cost ranges for drilling a new public supply well.

U.S. EPA System Size Classification	Low Cost Range for a New Well ($/kgal)[1]	High Cost Range for a New Well ($/kgal)[2]
Very Small (25 - 500 people)	$0.44 - $1.60	$3.11 - $11.17
Small (501 - 3,300 people)	$0.20 - $0.44	$1.38 - $3.11
Medium (3,301 - 10,000 people)	$0.12 - $0.20	$0.86 - $1.38
Large (10,001 - 100,000 people)	$0.05 - $0.12	$0.32 - $0.86

[1] U.S. EPA 2007 Drinking Water Infrastructure Needs Survey and Assessment.

[2] U.S. EPA 2007 Drinking Water Infrastructure Needs Survey and Assessment multiplied by a factor of 7 to estimate engineering fees, well demobilization, etc.

Table 27. Annualized total cost ranges for public supply well rehabilitation.

U.S. EPA System Size Classification	Low Cost Range for Well Rehabilitation ($/kgal)[1]	High Cost Range for Well Rehabilitation ($/kgal)[2]
Very Small (25 - 500 people)	$0.01	$0.01 - $0.07
Small (501 - 3,300 people)	$0.01 - $0.03	$0.07 - $0.22
Medium (3,301 - 10,000 people)	$0.03 - $0.06	$0.22 - $0.42
Large (10,001 - 100,000 people)	$0.06 - $0.22	$0.42 - $1.62

[1] U.S. EPA 2007 Drinking Water Infrastructure Needs Survey and Assessment.

[2] U.S. EPA 2007 Drinking Water Infrastructure Needs Survey and Assessment multiplied by a factor of 7 to estimate engineering fees and other contingencies.

5.1.4 Community Treatment

The estimated costs for system application of ion exchange and reverse osmosis are shown in Table 28. Cost ranges shown are compiled from detailed literature review and survey responses, as described in Technical Report 6 (Jensen et al. 2012), and represent the lowest and highest cost found for each system size. Any inconsistencies in cost ranges are attributed to the lack of cost information currently available. The economies of scale exist with ion exchange and reverse osmosis treatment systems as the cost per kilogallon decreases with increasing capacity. The cost per unit of produced water decreases as system size increases, however larger treatment systems incur higher total capital and O&M costs. Ion exchange is the cheaper option. Refer to Technical Report 6 (Jensen et al. 2012) for additional details on treatment costs.

Table 28. Annualized total cost ranges for groundwater treatment systems.[1]

U.S. EPA System Size Classification (population)	Annualized Total Cost Range for Ion Exchange [$/kgal][2]	Annualized Total Cost Range for Ion Exchange [$/yr][2]		Annualized Total Cost Range for Reverse Osmosis [$/kgal]	Annualized Total Cost Range for Reverse Osmosis [$/yr]
Very Small (< 501)	$0.62 - $4.60	$2,100 - $285,000		$0.69 - $19.16	$2,300 - $1.2 M
Small (501 - 3,300)	$0.30 - $2.73	$21,000 - $1.1 M		$0.58 - $1.34	$36,000 - $533,000
Medium (3,301 - 10,000)	$0.36 - $2.04	$143,000 - $2.4 M		$1.35 - $3.39	$537,000 - $4.0 M
Large (10,001 - 100,000)	$0.22 - $1.81	$258,000 - $20.1 M		$0.73 - $3.67	$855,000 - $40.8 M

[1] Cost information is an excerpt from Technical Report 6 (Jensen et al. 2012).

[2] Disposal costs were not included in the U.S. EPA cost estimates of IX for arsenic removal (used to estimate nitrate removal).

U.S. EPA's 2007 Drinking Water Infrastructure Needs Survey and Assessment estimate the cost for a SCADA system by the following equation:

$$Cost\ of\ SCADA = e^{7.7799} * population^{0.48453}$$

The *e* is the exponential function (approximately 2.72).[21] The lower bound annualized cost of SCADA infrastructure was estimated and is shown in Table 29. As the system size increases the cost for SCADA becomes more affordable.

Table 29. Lower bound annualized cost of SCADA infrastructure.[1]

U.S. EPA System Size Classification	Annualized Total Cost for SCADA Infrastructure [$/kgal]	Annualized Total Cost for SCADA Infrastructure [$/yr]
Very Small (25 - 500 people)	$4.99	$11,400
Small (501 - 3,300 people)	$1.06	$49,000
Medium (3,301 - 10,000 people)	$0.42	$116,000
Large (10,001 - 100,000 people)	$0.23	$633,000

[1] U.S. EPA Drinking Water Infrastructure Needs Survey and Assessment (2007).

5.1.5 Household Treatment

The 2010 U.S. EPA POU/POE cost model was used to estimate the costs for installing a reverse osmosis POU device. The cost model assumes an average per capita water consumption of 100 gallons per

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[21] Goldstein, Lay, Schneider, and Asmar, *Brief calculus and its applications,* 11th ed., Prentice-Hall, 2006.

person per day, 2.6 people per household, a discount rate of 7%, and a discount period of 10 years (the lifetime of the unit) (U.S. EPA 2010). The cost model includes equipment installation, laboratory analyses, indirect capital costs, equipment maintenance, and public education and outreach. Table 30 shows the estimated cost per household for installing a reverse osmosis POU unit for one household and for 1,000 households. The lower bound estimate does not incorporate the public education and outreach that is required for systems using a POU device for emergency purposes to comply with drinking water quality standards (discussed in Section 7 Regulatory and Implementation Implications). For a self-supplied household it is cost-effective to not incorporate public education and outreach; however, for a 1,000 household (or connection) public water system it would be beneficial to incorporate public outreach to educate the user and ensure proper procedures are followed.

Table 30. U.S. EPA reverse osmosis POU device cost estimates.

Options	RO POU Cost Estimate (Single Household)[1]	RO POU Cost Range (1,000 Household System)[1]
Initial Capital Cost ($/hhld)	$406 - 1,981	$493 - $494
Annual O&M Cost ($/hhld)	$197 - $1,781	$144 - $145
Total Annualized Cost ($/kgal/hhld)	$3.01 - $24.85	$2.52 - $2.53
Total Annual Cost ($/hhld)	**$250 - $2,038**	**$214 - $215**

[1] Uses the 2010 U.S. EPA Cost Estimate Tool for an NSF/ANSI Certified RO Unit for nitrate treatment. The lower bound estimate includes unit purchase, installation, scheduling time, indirect costs (permitting, pilot testing, legal, engineering, and contingency) and all associated operations and maintenance costs. The upper bound estimate includes all listed above and public education (technical and clerical labor and printed material for all public outreach/education efforts). The tool allows for economies of scale.

For comparison, a quote from Culligan estimates a typical nitrate filter to cost about $360 per year including maintenance for one household, cost details are shown in Table 31 (Culligan 2011). The total annualized cost ($/kgal) is greater than the U.S. EPA cost model estimates because of the difference in maximum potable water consumption. Culligan also rents RO POU devices for about $26 to $36 per month, plus filter replacement and service fees (Culligan 2011). An RO POU device is estimated to cost between$250 and $360 annually discounted over 10 years at a rate of 0.07. For households unable to pay the initial capital, the next best option would be to rent a NSF/ANSI certified RO POU device for at least $430 per year (plus filter replacement and service fees).

Table 31. Culligan reverse osmosis POU device cost estimates.

Options	RO POU Cost Range (1 hhld)[1]
Initial Capital Cost ($/hhld)	$1,200
Annual O&M Cost ($/hhld)	$191
Total Annualized Cost ($/kgal/hhld)	$39.67
Total Annual Cost ($/hhld)	**$362**

[1] Culligan offers a lifetime warranty on the membrane and pre-filters. It costs about $1,100 to $1,200 to purchase the unit and the pre-filter needs to be replaced every 18 months and the main filter needs to be replaced every 3 years (all factored into the costs listed). The maximum potable water consumption of 25 gallons and a discount rate of 0.07 and discount period of 10 years are assumed.

Currently, there is no POE unit certified for treating nitrate so the U.S. EPA Cost Estimate Tool for an NSF/ANSI Certified POE unit for treating Radium was used to estimate the annual cost of a POE device. The U.S. EPA Cost Estimate Tool provides an annualized cost of $397 for one household to install and maintain a POE device (U.S. EPA 2010). This includes the unit purchase, installation, scheduling time, indirect costs (permitting, pilot testing, legal, engineering, and contingency) and all associated operations and maintenance costs. Future research is necessary to evaluate the true cost of a POE device used for treating nitrate. The costs for POU and POE devices are further discussed in Section 5.2.1 Self-Supplied Households or Local Small Water Systems.

5.1.6 Connect to an Alternative System

Most costs for a system to connect to an alternative system are for installing the pipeline. An estimated pipeline cost of $61 per foot (Monterey County Environmental Health 2010b) and a connection fee on the order of $100,000 are assumed for estimating the costs of connecting to an alternative system. Table 32 represents the annualized cost range estimates for a system with 1,000 connections to connect to an alternative system. The low estimate (or lower bound) is solely pipeline costs and a connection fee and the high estimate (or upper bound) includes pipeline costs, a connection fee, and engineering and administration costs as 43% of the capital (Summers Engineering 2011). These costs are essentially the same if a single household connects to a public water system (estimates shown in Table 22 and Table 36 used a $9,000 connection fee for a self-supplied household); however, the party responsible for the costs would vary by system size and acquisition policies. More involved mergers with a larger system will often require significant additional upgrades to the smaller distribution system.

Table 32. Estimated annualized cost ranges for a system with 1,000 connections to connect to an alternative system.

Pipeline Distance (miles)	Capital Costs[1]	Engineering & Administration Costs[2]	Total Annualized Cost ($/year)[3]	Annualized Cost ($/kgal)[4]	Annualized Cost ($/hhld)[5]
0.5	$161,040	$69,200	$20,900 - $26,500	$164 - $207	$20.90 - $26.50
2	$644,160	$277,000	$59,700 - $81,900	$467 - $641	$59.70 - $81.90
5	$1,610,400	$692,500	$137,200 - $192,800	$1,074 - $1,509	$137.20 - $192.80
10	$3,220,800	$1,384,900	$266,500 - $377,600	$2,086 - $2,956	$266.50 -$377.60

[1] Pipeline costs at $61 per foot for 1,000 households.

[2] Excerpt from Kettleman City Proposed Surface Water Treatment Plant and Commercial Tank Facility (March, 2011) (Summers Engineering 2011). 43% of the Subtotal: 15% Construction Contingencies; 2% Construction Application, CDPH Information & Labor and Compliance Monitoring; 2% Environmental Documentation & Legal Review; 10% Design & Project Bidding; 7% Project Administration; 5% Project Inspection; and 2% Project Surveying & Geotechnical Testing.

[3] Lower bound includes pipeline and $100,000 connection fee. Upper bound includes pipeline, $100,000 connection fee, and engineering and administration costs. Costs are discounted over 20 years at a 5% discount rate.

[4] Assumes a consumption rate of 350 gallons per household per day.

[5] Total annualized cost divided by 1,000 households.

5.1.7 Trucked Water

An estimate from RMR Water Trucks for providing their water trucks for service is used for estimating the delivered trucked water costs (RMR Trucks 2010):

($100/hr truck driver)* (x hr travel time) + (truck size (gal))*($0.xx/gal of nearby water supply)

Estimates are provided for a small community public water system serving 1,000 households and for a single household located in Tulare County. The estimated cost for providing a community in Tulare County with a single RMR 7,000 gallon water truck (travel time is estimated as 4 hours roundtrip and a nearby water supply is assumed to cost $0.35 per gallon) is about $2,850, or $410/kgal. Assuming one household uses about 2.25 gallons per day,[22] 1,000 households (or a small community water system) would receive water for about three days ($2.85/household). It would cost approximately $350,000 to provide 1,000 households with trucked potable water for one year. To provide one household with water, a 500 gallon RMR truck would cost $575 ($1,150/kgal), and would provide the household with water for 222 days (assuming storage is available). It would cost approximately $950 to provide one household with trucked potable water for one year.

5.1.8 Bottled Water

To estimate the cost of bottled water, the National Academy of Sciences Hydration Study (2004) was used, assuming 3.3 people per household and predicting about 2.25 gallons per household-day needed

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[22] NAS Hydration Study Estimate – 3.3 people per household.

for potable uses. Vended or bottled water can cost $0.25 to $1.30 per gallon, not including transportation costs (Pacific Institute et al. 2010). A common low price for water delivered near the city of Visalia by Alhambra Water is a 5 gallon bottle at $1.63 per gallon (Alhambra Water 2010). The annual cost for a household receiving Alhambra Water is about $1,260. For accuracy and consistency, this cost estimate is used as the cost of bottled water in this report.

5.1.9 Relocate to Area with Better Water Supply

To estimate the costs of relocating a community to an area with a better water supply, the true market value of houses in each respective county is evaluated. The range of average listing prices for houses in each county is shown in Table 33 and the median value of average ranges is used to estimate the cost of relocating a single household (Trulia 2011). To better represent Salinas Valley, the City of Salinas' average listing prices will be used, instead of Monterey County. Cost scenarios for relocating households are shown in Table 34, and the average cost across the study area to relocate one household is $188,000. Using this average, it would cost about $2 billion to relocate the susceptible population on self-supplied and local small water systems (about 10,000 households). It is estimated to cost $37.6 million to relocate 200 households per county. The costs for relocating a household will differ slightly between a homeowner and a renter. Renters should be cheaper to move if the County condemns the property and there may also be less attachment or sentimental value to the home. However, the total loss involved in relocation is probably similar for both homeowners and renters.

Table 33. Average listing prices for homes in study area counties.

County	Range of Average Listing Prices for Houses ($1,000)[1]
Fresno	$158 - $193
Kern	$137 - $167
Kings	$136 - $166
Tulare	$153 - $188
Monterey (City of Salinas)	$525 - $642 ($261 - $319)

[1] Trulia, Inc. *Range of Average House Listing Prices* (August, 2011)

Table 34. The estimated cost for relocating households.

County	Single Household Relocation ($1,000)[1]	200 Household Relocation ($1,000)[1]
Fresno	$176	$35,100
Kern	$152	$30,400
Kings	$151	$30,200
Tulare	$171	$34,100
City of Salinas	$290	$116,700
Study Area Average	**$188**	**--**

[1] Trulia, Inc. The median of the average range of listing prices (August, 2011).

5.1.10 Dual Water Distribution System

A dual water distribution system would require a household to continue paying for their contaminated water, using it only for non-potable uses, and to purchase an alternative supply. The four alternatives available for a dual water distribution system are: 1) purchasing bottled or vended water; 2) installing a POU device; 3) trucking in potable water or; 4) installing water system treatment for the potable supply and delivering it through a secondary distribution network. Given the nature of trucked water and the need for storage, it is not a feasible alternative for a dual water distribution system. To estimate the costs of a dual water distribution system, an average monthly residential water rate of $27 is assumed for the non-potable supply cost.[23] A dual system including the purchase of 5 gallon bottles from Alhambra would cost approximately $1,582 annually per household. A dual system including the purchase of a POU device would cost about $574 to $686 annually per household, ranging from the lower bound U.S. EPA POU Cost Model value to the Culligan POU quote.

If a dual water distribution system was installed for an existing 1,000 household water system, the total costs would include the cost for the contaminated supply, treating the potable supply, installing a distribution system to each connection, and re-plumbing each household for the distribution of the new supply to the bathroom and kitchen. Table 35 shows rough estimates for the cost of installing a dual water distribution system for a 1,000 household system. The total annualized cost per household is estimated to cost between $550 and $900.

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[23] California Water Company – Visalia, $27 a month for using 6,000 square feet or less per month.

Table 35. Estimated annualized cost ranges for a dual water distribution system.

Annualized Costs[1]	Cost Range for Dual Water Distribution for 1,000 Household Water System[2]
Contaminated Supply Costs ($/year)[3]	$324,000
Treatment Costs ($/year)[4]	$644,904
Pipeline Costs ($/year)[5]	$130,000 - $260,000
Re-plumbing Costs ($/year)[6]	$200,000 - $320,000
Engineering & Administration Fees ($/year)[7]	$165,000 - $270,000
Total Annualized Cost ($/year)[8]	$550,000 - $900,000
Household Total Annualized Cost ($/hhld-year)[9]	$550 - $900

[1] Costs are discounted at a 5% discount rate, over a 20 year period.

[2] Assumes a water system serves 1,000 households, with 3.3 people per household, and uses 0.20 million gallons of potable water per day, including showering and toilet flushing (112 gallons per capita per day) (Gleick 2003).

[3] Monthly water supply cost for California Water Company in Visalia.

[4] Costs for treating 0.20 mgd of water using an ion exchange treatment system - includes O&M costs (Technical Report 6, Jensen et al. 2012).

[5] Assumes 6” pipe costs $61 per foot and does not include excavation costs. Lower bound estimate uses 5 miles of pipeline and upper bound estimate uses 10 miles of pipeline (Granite Ridge Regionalization Feasibility Study, 2010).

[6] Rough cost estimates provided by ZURN and an experienced plumber for PEX piping to be installed in a 1200 sq. ft. 3 bed, 2 bath house within the kitchen and both bathrooms. The lower bound estimate is for a tract type house with raised wood floors (ease of “popping” pipes through the floor cabinets), and the upper bound estimate is for a slab house (requiring the sheet rock to be cut, patched and painted after installation). This is a rough estimate and each house will vary based on the chosen plumber’s site estimate.

[7] Excerpt from Kettleman City Proposed Surface Water Treatment Plant and Commercial Tank Facility (March, 2011). 43% of the Subtotal (treatment, pipeline, and re-plumbing costs): 15% Construction Contingencies; 2% Construction Application, CDPH Information & Labor and Compliance Monitoring; 2% Environmental Documentation & Legal Review; 10% Design & Project Bidding; 7% Project Administration; 5% Project Inspection; and 2% Project Surveying & Geotechnical Testing.

[8] Total annualized cost for all items. Lower bound estimate provides costs for a 1,000 connection system with a service area having a 5 mile distance and consisting of only tract type houses (the economies of scale involved in community tract type housing is ignored here, but could be represented in a true situation where dual plumbing occurs for a whole development). Upper bound estimate provides costs for a 1,000 connection system with a service area having a 10 mile distance and consisting of only slab houses.

[9] Total annualized cost per household.

5.1.11 Well Water Quality Testing

PurTest sells a water test kit for bacteria and nitrate based on U.S. EPA methods for $13 with a basic knowledge booklet that could be used for domestic well users (Home Depot 2011). The Environmental Health Investigations Branch of CDPH estimates certified laboratory water quality tests to cost approximately $50 for testing a private well (CDHS 2000). It is recommended that private wells are sampled once a year, preferably between April and July when nitrate levels are generally the highest (CDHS 2000).

These two estimates are the lower and upper bound estimates for domestic well water quality testing. County-specific estimates for a State-certified laboratory can be found on the CDPH Environmental Laboratory Accreditation Program (ELAP) website.

5.1.12 Summary of Alternative Water Supply Costs

The economic feasibility of each option will vary based on the effectiveness, benefits, savings, and costs expected from a candidate system. This section only summarizes the expected costs for alternative water supply options, but a true engineering analysis will include economic feasibility studies examined over a project's lifetime. The alternative water supply options for providing a self-supplied household with low-nitrate water all year, ranked from least expensive to most expensive, typically are to:

1) install a POU RO unit;
2) drill a deeper well;
3) install a dual water system;
4) purchase bottled water;
5) drill a new well;
6) relocate the household; and
7) install pipeline and connect to an existing system.

The estimated costs for self-supplied household alternative water supply options are shown in Table 36.

The alternative water supply options for providing a small community public water system (serving 1,000 households) with low-nitrate water all year, ranked from least expensive to most expensive, typically are to 1) drill a new well; 2) install a pipeline and connect to an existing system; 3) drill a deeper well; 4) implement a community groundwater treatment system; 5) blend sources; 6) provide households with POU RO units; 7) construct a dual water distribution system; 8) purchase bottled water; and 9) relocate households. The estimated costs for alternative water supply options for a small community public water system are shown in Table 37. The analysis performed here is general and includes many necessary assumptions. The costs for each option need to be assessed on a system specific basis before selecting the most economical option.

The estimated annual O&M cost ranges for alternative water supply and treatment options that include O&M are shown in Table 38. The cost ranges are shown as percent of the total annualized cost to reflect the wide range of researched and surveyed cost data gathered. For the estimated basin-wide solutions (Section 6 Basin-wide Costs of Nitrate Contamination), the average percentage of O&M is applied to each solution to roughly estimate the basin-wide O&M cost.

The lifetime of each alternative will vary depending on the existing water quality, soil properties, water usage, and existing source supply. An alternative should be evaluated on the least cost and lifetime of the system before choosing the best option for implementation. If a system blends sources to provide nitrate compliant water, the duration of the solution will last only as long as the low-nitrate source remains low and proper source ratios are maintained. Nitrate contamination and the associated groundwater degradation are expected to worsen over the next few decades and it is reasonable to expect that, over time, a low-nitrate source will approach the MCL. If an existing well is drilled deeper into a different aquifer, the lifetime of the safe supply will depend on the time it takes for nitrate in shallow groundwater to reach the new depth. There is the risk of the existing shallow nitrate migrating down and there is the risk of increased nitrate found at the new depth. If a new well is properly designed, constructed, developed and completed, it can last for up to 50 years (Harter 2003); however, pumping from a new well can quickly draw down an aquifer and draw nitrate into the existing safe supply. Depending on the type of treatment chosen (IX or RO), a community treatment system can last for 20 years (with the proper maintenance and membrane and resin lifetime will vary with water quality and pretreatment measures). With proper maintenance and replacement of filters, a household treatment system can last up to 10 years. Connecting to an alternative system ensures that future problems of nitrate contamination (or other water quality contaminants) can be managed more easily due to economies of scale. Switching to surface water shifts the problem of nitrate contamination in groundwater to other contaminants (i.e., *giardia lamblia* and *cryptosporidium parvum*) which will need to be addressed with surface water treatment. Constructing a dual water distribution system on a community public water system scale treats less water, expends less energy, and conserves resources.

Table 36. Summary of the estimated alternative water supply costs for self-supplied households.

Option	Estimated Annual Cost Range For a Self-Supplied Household[1]
IMPROVE EXISTING WATER SOURCE	
Blending[2]	N/A
Drill Deeper Well[3]	\$860 - \$3,300
Drill a New Well[4]	\$2,100 - \$3,300
Community Supply Treatment[5]	N/A
Household Supply Treatment [6]	\$250 - \$360
ALTERNATIVE SUPPLIES	
Pipeline and Connection to an Existing System[7]	\$52,400 - \$185,500
Trucked Water [8]	\$950
Bottled Water[9]	\$1,339
RELOCATE HOUSEHOLDS[10]	\$15,090
ANCILLARY ACTIVITIES	
Well Water Quality Testing[11]	\$15 - \$50
Dual Water System[12]	\$574 - \$1,582

[1] All costs are discounted over a 20 year period at a 5% discount rate, except for the RO POU estimate and trucked and bottled water costs.

[2] Blending is only considered for public water systems with more than one source.

[3] The lower bound estimate is from the U.S. EPA Yucca Mountain BID (U.S. EPA N.D.) with estimated drilling costs of \$50 per foot. The upper bound estimate is a quote from an experienced hydrogeologist, Chris Johnson; estimated drillings costs of \$200 per foot. Annual O&M costs estimated using a pumping well energy equation and assuming \$0.15/kWh.

[4] Capital costs estimated from senior geologist David Abbott (Abbott 2011). Annual O&M costs estimated using a pumping well energy equation and assuming \$0.15/kWh.

[5] Community supply treatment only refers to community drinking water systems (≥15 connections).

[6] Uses the 2010 U.S. EPA Cost Estimate Tool for 1 NSF/ANSI Certified Reverse Osmosis Point-of-Use Unit. The lower bound estimate includes unit purchase, installation, scheduling time, indirect costs (permitting, pilot testing, legal, engineering, and contingency) and all associated operations and maintenance costs. The upper bound estimate includes all lower bound costs plus public education (technical and clerical labor and printed material for all public outreach/education efforts). Assumes a 10 year lifespan for the unit and is discounted for

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10 years at a 7% discount rate.

[7] Only considers the costs for installing pipeline and the connection fees for connecting to an existing system that has a safe drinking water supply. The lower bound estimate assumes pipeline costs of $61 per foot for a distance of 2 miles, and a $9,000 connection fee per household. The upper bound estimate assumes pipeline costs of $61 per foot for a distance of 5 miles, and a $9,000 connection fee plus engineering and administration costs (43% of the pipeline costs).

[8] Assumes a 500 gallon RMR Water Truck travels from Castaic to Tulare County for a 4 hour roundtrip at $100/hour and purchases 500 gallons of a local, safe drinking water supply at $0.35 per gallon. A one-time 500 gallons cost. Does not include the cost for storage.

[9] Assumes Alhambra in Visalia delivers 5 gallons of "Crystal Fresh" water to a location in Visalia with 3 people per household. Each person consumes about 0.7 gallons per day for 365 days.

[10] The median listing prices for houses in each county (City of Salinas was used instead of Monterey County) were examined and the average listing for a house in the study area is estimated to be $188,000 (trulia.com).

[11] Well water quality test for nitrate and bacteria from PurTest sold at Home Depot ($13) and CDPH estimate of $50 for a private well nitrate sample from a State-certified laboratory. All public water systems (≥ 15 connections) are already required to sample and monitor their water.

[12] Lower bound estimate is the U.S. EPA POU Cost Estimate tool plus the monthly cost of the contaminated supply and the upper bound estimate is the cost for bottled water (Culligan – 5 gallon bottle) plus the monthly cost of the contaminated supply (Visalia Community Water Center is used for the reference, however this is not meant to suggest that Visalia CWC's water is contaminated).

Table 37. Summary of the estimated alternative water supply costs for a small water system (1,000 households).

Option	Estimated Annual Cost Range For a Small Water System (1,000 hhlds)[1]
IMPROVE EXISTING WATER SOURCE	
Blending[2]	$200,000 - $365,000
Drill Deeper Well[3]	$80,000 - $100,000
Drill a New Well[4]	$40,000 - $290,000
Community Supply Treatment[5]	$95,000 - $105,000
Household Supply Treatment[6]	$223,000
ALTERNATIVE SUPPLIES	
Pipeline and Connection to an Existing System[7]	$59,700 - $192,800
Trucked Water[8]	$2,850
Bottled Water[9]	$1.34 M
RELOCATE HOUSEHOLDS[10]	$15.1 M
ANCILLARY ACTIVITIES	
Dual Water Distribution System[11]	$500,000 - $900,000

[1] All costs are discounted over a 20 year period at a 5% discount rate, except for the RO POU estimate and trucked and bottled water costs.

[2] A 14" casing well with flow rates of 300 gpm (lower bound estimate) and 600 gpm (upper bound estimate) and well depth of 700 feet. Does not include the cost of obtaining a low-nitrate source. O&M for blending estimated at $250 per acre-foot and indirect costs are estimated to be about 25% of the estimated bid costs. Kennedy/Jenks (2004) "bid" cost estimates primarily based on nitrate problems.

[3] The lower bound estimate is from the U.S. EPA Yucca Mountain BID (U.S. EPA N.D.) with estimated drilling costs of $110 per foot. The upper bound estimate is a quote from an experienced hydrogeologist, Chris Johnson; estimated drillings costs of $1,000 per foot. Annual O&M costs estimated using a pumping well energy equation and assuming $0.15/kWh.

[4] Costs estimated from the 2007 U.S. EPA Drinking Water Infrastructure Needs Survey & Assessment (O&M assumed to be included in the cost model); projected to 2010 dollars using the 2010 ENR CCI. The upper bound estimate is from applying a multiplication factor of 7 to estimate engineering fees, well demobilization, etc.

[5] Cost estimates from Technical Report 6 (Jensen et al. 2012). Disposal costs were not included in the U.S. EPA cost estimates of ion exchange for arsenic removal (that was used to estimate nitrate removal).

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[6] Uses the 2010 U.S. EPA Cost Estimate Tool for 1,000 NSF/ANSI Certified Reverse Osmosis Point-of-Use Unit. The lower bound estimate includes unit purchase, installation, scheduling time, indirect costs (permitting, pilot testing, legal, engineering, and contingency) and all associated operations and maintenance costs. The upper bound estimate includes all lower bound costs plus public education (technical and clerical labor and printed material for all public outreach/education efforts). Assumes a 10 year lifespan for the unit and is discounted for 10 years at a 7% discount rate.

[7] Only considers the costs for installing pipeline and connection fees for connecting to an existing system that has a safe drinking water supply. The lower bound estimate assumes pipeline costs of $61 per foot for a distance of 2 miles, and a $100,000 connection fee. The upper bound estimate assumes pipeline costs of $61 per foot for a distance of 5 miles, and a $100,000 connection fee plus engineering and administration costs (43% of the pipeline costs).

[8] Assumes a 7,000 gallon RMR Water Truck travels from Castaic to Tulare County for a 4 hour roundtrip at $100/hour and purchases 7,000 gallons of a local, safe drinking water supply at $0.35 per gallon.

[9] Assumes Alhambra in Visalia delivers 5 gallons of water to a location in Visalia with 3 people per household. Each person consumes about 0.7 gallons per day for 365 days.

[10] The median listing prices for houses in each county (City of Salinas was used instead of Monterey County) were examined and the average listing for a house in the study area is estimated to be $188,000 (trulia.com).

[11] Lower bound estimate is the cost of the contaminated supply, the cost for treating 0.20 mgd (Gleick 2003) for 1,000 households assuming 3.3 people per household, a system pipeline distribution distance of 5 miles, PEX plumbing through tract type houses with raised wood flooring (2 bathrooms and 1 kitchen is re-plumbed per house), and a 43% engineering and administration fee. Upper bound estimate is the cost of the contaminated supply, the cost for treating 0.20 mgd (Gleick 2003) for 1,000 households assuming 3.3 people per household, a system pipeline distribution distance of 10 miles, PEX plumbing through slab houses (2 bathrooms and 1 kitchen is re-plumbed per house), and a 43% engineering and administration fee.

Table 38. Estimated O&M and capital cost ranges for alternative water supply options as percentage of total annual costs.

	O&M % of Total Annual Costs[1]		**Capital % of Total Annual Costs[1]**	
	Range	Average	Range	Average
POU/POE	50% - 70%	60%	30% - 50%	40%
Blending	78% - 88%	83%	12% - 22%	17%
Drilling a New Well	35% - 75%	55%	25% - 65%	45%
Centralized Nitrate Groundwater Treatment	45% - 85%	65%	15% - 55%	35%
Conventional Surface Water Treatment	15% - 50%	33%	50% - 85%	67%

[1] Refer to references shown in Tables 23-37.

5.2 Least Cost Management

Most alternative water supply option costs largely depend on the size of the system. Even if a system receives assistance in financing the capital costs for an alternative solution, such as treatment, the solution's sustainability can be threatened by high annual O&M costs. To assess the lasting viability of each alternative, in this section the previously discussed cost estimates are compared broadly, and least cost management alternatives are highlighted. The least cost management discussion is divided into domestic well water systems (self-supplied households or local small water systems) and public water systems. This section compares costs for self-supplied households or local small water systems on a cost per household and cost per kilogallon scale. Similarly, the costs for community public water systems are given on a cost per kilogallon and cost per household, but are compared on a system size scale.

5.2.1 Self-Supplied Households or Local Small Water Systems

The estimated costs for alternative solutions for self-supplied households and local small water systems are shown in Table 39 with the total annualized costs displayed per household and per kilogallon of water. The primary feasible options available to a household or local small water system are to purchase bottled water, install a POU device, drill a new well, or deepen an existing well. The least to most expensive cost alternative for households is to:

- install a reverse osmosis POU treatment device, estimated to cost $250 per year (not including any public outreach or education);
- install a POE device; however, currently no POE devices are NSF/ANSI certified for removing nitrate from drinking water (the estimate given in Table 39 is for treating Radium);
- drill a deeper well; however, the user must continually test and monitor the well to make sure the nitrate contamination does not reach the new depth.

Figure 25 shows the annualized cost curves of each option and highlights the cost-effective option for expected water use or consumption. If a household only requires low-nitrate *potable* water, a POU device is the less expensive solution. However, if a household desires to treat more than 18 gallons of water per day, a POU device is no longer cost-effective, and installing a POE device is preferred. The cost curves do not represent the actual maximum potable water consumption per day for filter pumping capacity, which varies by manufacturer (i.e., Culligan has a maximum of 25 gallons per day).

Table 39. Estimated household costs for alternative solutions for self-supplied households or local small water systems.

Option	Bottled Water[1]	Drill a New Well[2]	Drill a Deeper Well[3]	POE[4]	POU[5]
Initial Capital Cost ($/hhld)	0	$40,000	$25,000	$2,222	$406
Annual O&M Cost ($/hhld)	0	$60	$232	$109	$197
Total Annualized Cost ($/kgal)	$1,630	$25.59	$17.52	$5.12	$3.01
Total Annualized Cost ($/hhld)	**$1,260**	**$3,300**	**$2,238**	**$397**	**$250**

[1] Quote from Alhambra, Visalia for drinking water delivered in 5 gallon bottles (Alhambra Water 2010). Assumed units of water consumption from NAS Hydration Study.

[2] Initial Capital Cost Estimate: Upper bound estimate of David W. Abbott, Senior Geologist at Todd Engineers (Abbott 2011). Annual O&M Estimate: Assumed 300 foot well depth, 0.6 pump efficiency, and $0.15/kWh. Annualized over 20 years.

[3] Initial Capital Cost Estimate: Average estimate of U.S. EPA Yucca Mountain BID (U.S. EPA N.D.) and Chris Johnson, hydrogeologist (Johnson 2011). Annual O&M Estimate: Assumed 500 foot well depth (originally 300 feet, drilled 200 feet deeper), 0.6 pump efficiency, and $0.15/kWh.

[4] Uses the U.S. EPA Cost Estimate Tool for an NSF/ANSI Certified POE Unit for treating Radium. Includes unit purchase, installation, scheduling time, indirect costs (permitting, pilot testing, legal, engineering, contingency) and all associated operations and maintenance costs.**A POE Unit has not been certified for water systems to distribute so the U.S. EPA Tool does not have a Unit capable of treating nitrate for estimating the cost. Future research is necessary to evaluate the true cost of a POE device.

[5] Uses the U.S. EPA Cost Estimate Tool for 1 NSF/ANSI Certified ROU Unit for treating Nitrate. Includes unit purchase, installation, scheduling time, indirect costs (permitting, pilot testing, legal, engineering, contingency) and all associated operations and maintenance costs. Does not include public education/outreach costs.

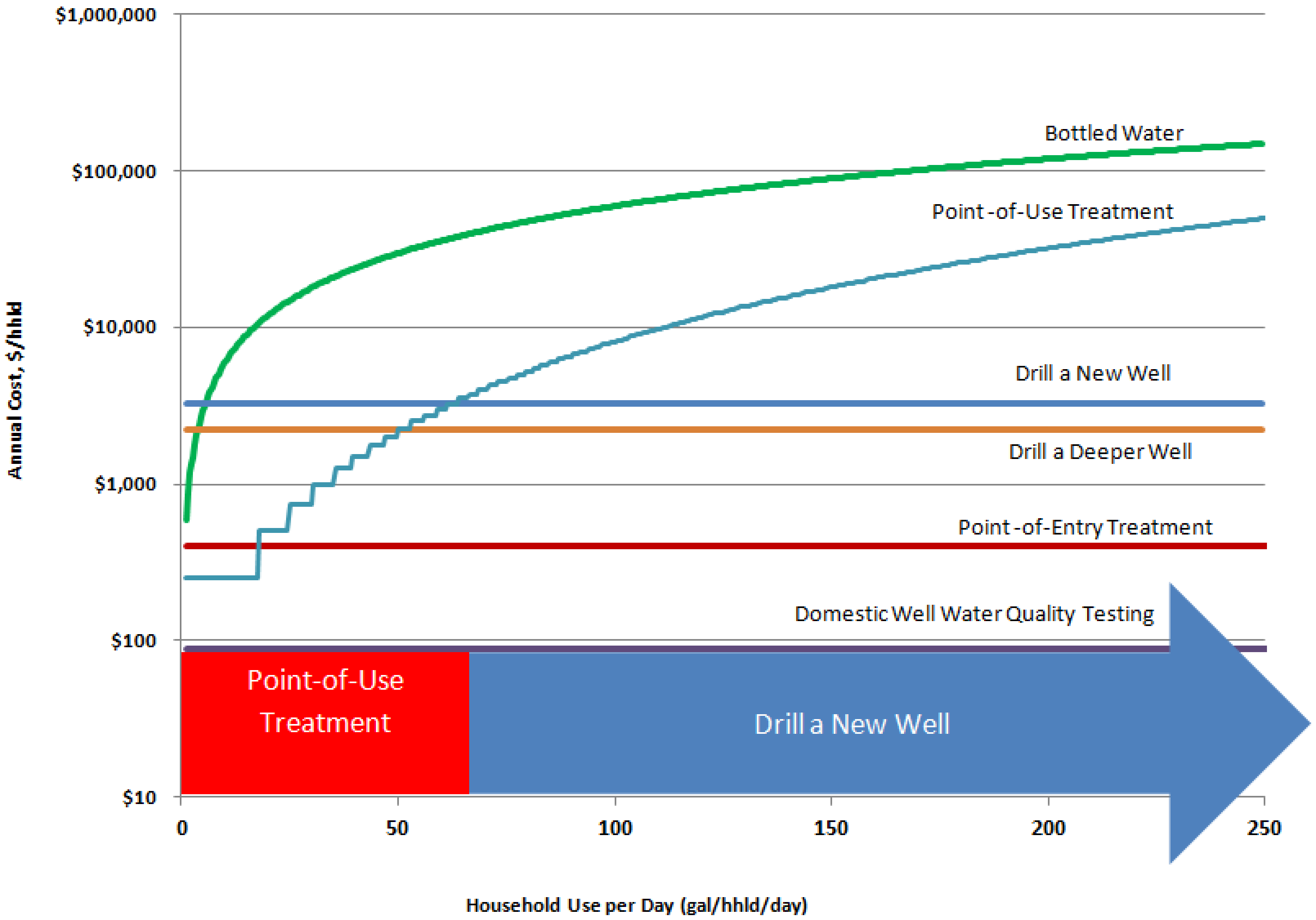

Figure 25. Annualized total household cost for household self-supplied and local small water system alternatives.

5.2.2 Community Public Water Systems

The minimum and maximum ranges of cost estimates for community public water system categories appear in Table 40 and Table 41, and the compiled cost ranges are shown in Table 42. The annualized low and high cost in dollar per kilogallon ($/kgal) for each alternative is evaluated by U.S. EPA–designated water system size (Table 40 and Table 41). The low cost case is the best case scenario for the least complex system, and the high cost case is more realistic for what the real world average costs would be when all external contingencies are included. For the low cost case, a groundwater treatment facility is the cheapest alternative per kilogallon for very small and small systems. For medium systems, the cost for installing a pipeline to a nearby system becomes very cost-effective, with groundwater treatment and drilling a new well as the next least cost options. POU RO devices are only cost-effective for systems with less than 3,300 people; this coincides well with the 3-year emergency regulations that only allow POU devices to be distributed to systems with less than 200 connections (discussed in Section 7 Regulatory and Implementation Implications). Bottled water costs more than all alternatives (per thousand gallons). Table 40 and Table 41 represent connecting to a better water system only as the pipeline costs and the connection costs are not included in the annualized cost.

For the high cost case, drilling a new well, installing a pipeline to a larger system, or installing a POU RO device are the cheaper options for very small systems. For small and medium systems, a pipeline to a larger system is the cheapest option per kilogallon, but depends on the distance to a nearby system as only two miles of pipeline are assumed. The next best options for small and medium systems are to implement a groundwater treatment facility or drill a new well. For large systems, the cost-effective solutions are to drill a new well or implement groundwater treatment. Bottled water costs more than all alternatives (per thousand gallons).

Figure 26 and Figure 27 graphically show the minimum annualized cost ($/kgal) of alternative options for public water systems; Figure 27 includes pipeline costs and excludes SCADA costs. Similar to the cost table results, Figure 26 shows that for small and medium systems groundwater treatment is the most cost-effective. For medium and large systems an ion exchange treatment facility or a new well are most cost-effective. SCADA costs are shown for treatment and system size comparison. Figure 27 includes the option to construct five miles of pipeline for connecting to another water system or drilling a new well in a low-nitrate location. The economies of scale for pipeline costs can be observed for systems serving more than 3,300 people as pipeline costs decline to less than reverse osmosis costs. A groundwater system with ion exchange remains the cheapest option; however, piping to another system allows a water system to share treatment with a larger entity (i.e., certified operators would already be hired) and the O&M costs would be distributed over a larger population base. Medium and large systems also can search for a low-nitrate source well near the existing system, instead of installing ion exchange treatment.

Figure 28 shows the annualized household cost ($/hhld) of alternative options for public water systems, including consolidation (a small system connecting to a larger system). Costs are shown for a system with 2,000 connections (households) and include pipeline costs ($61/foot)[24] and the estimated connection fees (on the order of $150,000), and are discounted over 20 years with an annual discount rate of 0.05. A 50% contingency was attributed to pipeline costs for external expenses, such as permitting activities and legal fees. For a 2,000 connection system, the best option is to drill a new well if the surrounding groundwater quality is acceptable for drinking water purposes. If drilling a new well is not an available option, the next least expensive option is to connect to a larger system that is less than eighteen miles away. If there are no larger systems less than eighteen miles away for a 2,000 connection system to connect to, then implementing an ion exchange system is the cost-effective solution. The maximum distance for connecting to an alternative system will vary with varying system sizes and connection cost estimates. The costs presented and discussed are rough estimates for alternative supply option comparison.

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[24] Granite Ridge Regionalization Feasibility Study (Monterey County Environmental Health 2010b).

Table 40. Low cost ranges for a basin-wide cost analysis.

LOW COST RANGES	Very Small	Small	Medium	Large	[Source]
System Population Range:	**(25 - 500 people)**	**(501 - 3,300 people)**	**(3,301 - 10,000 people)**	**(10,001 - 100,000 people)**	[1]
Assumed Design Rate (mgd):	**0.01 - 0.17**	**0.17 - 1.09**	**1.09 - 3.21**	**3.21 - 30.45**	[2]
Annualized Total Cost ($/kgal):					
Groundwater Treatment	$0.60	$0.30	$0.40	$0.20	[3]
Surface Water Treatment	-	-	-	$0.70 + pipeline	[4]
New Well	$0.44 - $1.60	$0.20 - $0.44	$0.10 - $0.20	$0.05 - $0.10	[5]
Pipeline (2 miles)	$0.80 - $15.70	$0.10 - $0.80	$0.04 - $0.10	$0.01 - $0.06	[6]
Annualized Total Cost for POTABLE USES only ($/kgal):					
POU System for Potable Uses	$2.67 - $3.52	$2.51 - $2.67	$2.51	$2.51	[7]
Bottled Water for Potable Uses	$1,630	$1,630	$1,630	$1,630	[8]

[1] U.S. EPA system size classification.

[2] (U.S. EPA 2005).

[3] (Jensen et al. 2012). These represent the best case scenario of the least complicated system including cheap waste residual disposal and potential blending. Based on the literature and survey data, the average costs for the small and medium system were approximately the same ($0.35/kgal).

[4] (Jensen et al. 2012) (8.25-10 mgd systems).

[5] (U.S. EPA 2007).

[6] (Monterey County Environmental Health 2010b). Does not include connection fee.

[7] (U.S. EPA 2010). Annualized Capital Costs at 7% discount rate over 10 years.

[8] (Alhambra Water 2010).

Table 41. High cost ranges for a basin-wide cost analysis.

HIGH COST RANGES	**Very Small**	**Small**	**Medium**	**Large**	**[Source]**
System Population Range:	**(25 - 500 people)**	**(501 - 3,300 people)**	**(3,301 - 10,000 people)**	**(10,001 - 100,000 people)**	[1]
Assumed Design Rate (mgd):	**0.01 - 0.17**	**0.17 - 1.09**	**1.09 - 3.21**	**3.21 - 30.45**	[2]
Annualized Total Cost ($/kgal):					
Groundwater Treatment	$4.60	$1.30	$2.00	$1.80	[3]
Surface Water Treatment	-	-	-	$1.20 + pipeline	[4]
New Well	$3.10 - $11.20	$1.40 - $3.10	$0.90 - $1.40	$0.30 - $0.90	[5]
Pipeline (2 miles)	$0.80 - $15.70	$0.10 - $0.80	$0.04 - $0.10	$0.01 - $0.06	[6]
Annualized Total Cost for POTABLE USES only ($/kgal):					
POU System for Potable Uses	$2.67 - $3.52	$2.51 - $2.67	$2.51	$2.51	[7]
Bottled Water for Potable Uses	$1,630	$1,630	$1,630	$1,630	[8]

[1] U.S. EPA system size classification.
[2] (U.S. EPA 2005).
[3] (Jensen et al. 2012).
[4] (Jensen et al. 2012). (8.25-10 mgd systems).
[5] (U.S. EPA 2007).
[6] (Monterey County Environmental Health 2010b). Does not include connection fee.
[7] (U.S. EPA 2010). Annualized Capital Costs at 7% discount rate over 10 years.
[8] (Alhambra Water 2010).

Table 42. Complete table of basin-wide alternative water supply options (minimum value of low range and maximum value of high range).

	Very Small	Small	Medium	Large	[Source]
System Population Range:	**(25 - 500 people)**	**(501 - 3,300 people)**	**(3,301 - 10,000 people)**	**(10,001 - 100,000 people)**	[1]
Assumed Design Rate (mgd):	**1 - 0.17**	**0.17 - 1.09**	**1.09 - 3.21**	**3.21 - 30.45**	[2]
Annualized Total Cost ($/kgal):					
Groundwater Treatment	$0.60 - $4.60	$0.30 - $1.30	$0.40 - $2.00	$0.20 - $1.80	[3]
Surface Water Treatment	-	-	-	$0.70 - $1.20 + pipeline	[4]
New Well	$0.44 - $10.20	$0.20 - $2.80	$0.10 - $1.30	$0.05 - $0.80	[5]
Pipeline (2 miles)	$0.80 - $15.70	$0.10 - $0.80	$0.04 - $0.10	$0.01 - $0.06	[6]
New Well + 2 Miles of Pipeline	$1.24 - $25.90	$0.30 - $3.70	$0.14 - $1.40	$0.06 - $0.80	[5,6]
Annualized Total Cost for POTABLE USES only ($/kgal):					
POU System for Potable Uses	$2.67 - $3.52	$2.51 - $2.67	$2.51	$2.51	[7]
Bottled Water for Potable Uses	$1,630	$1,630	$1,630	$1,630	[8]

[1] U.S. EPA system size classification.
[2] (U.S. EPA 2005).
[3] (Jensen et al. 2012).
[4] (Jensen et al. 2012). (8.25-10 mgd systems).
[5] (U.S. EPA 2007).
[6] (Monterey County Environmental Health 2010b). Does not include connection fee.
[7] (U.S. EPA 2010). Annualized Capital Costs at 7% discount rate over 10 years.
[8] (Alhambra Water 2010).

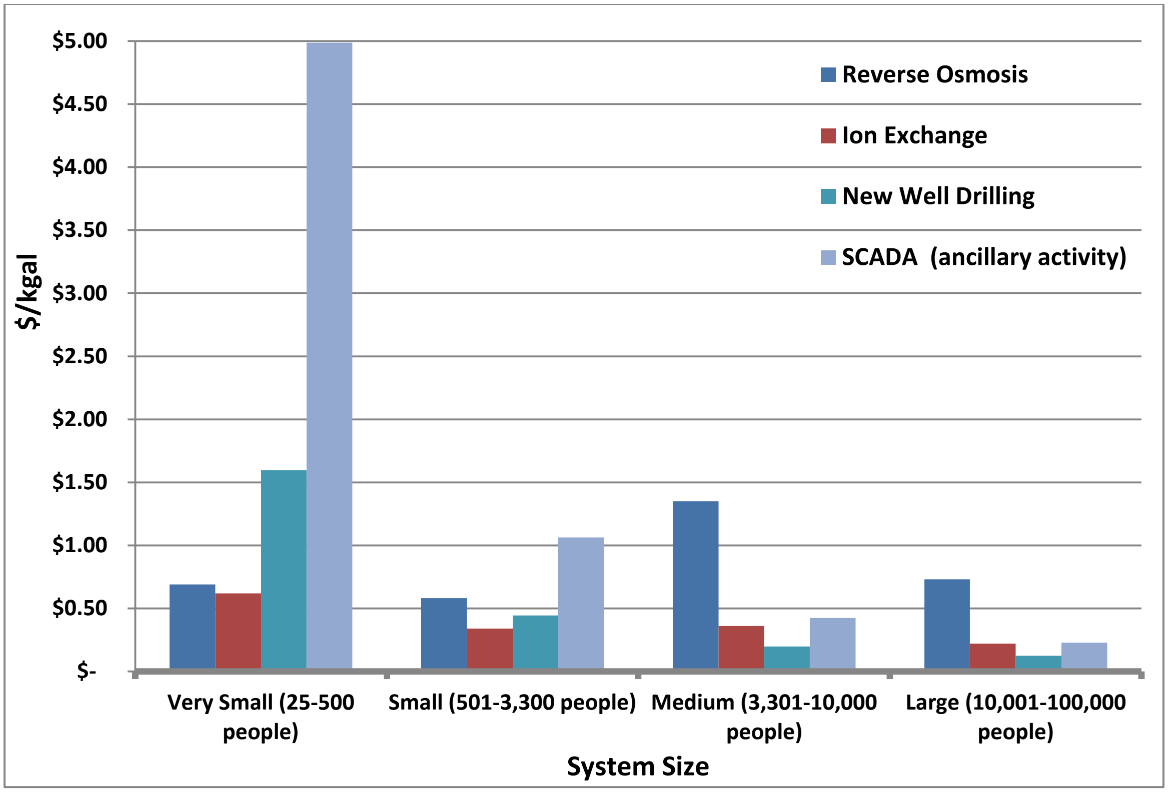

Figure 26. **Annualized cost ($/kgal) for community public water system alternatives (excluding pipeline costs).**

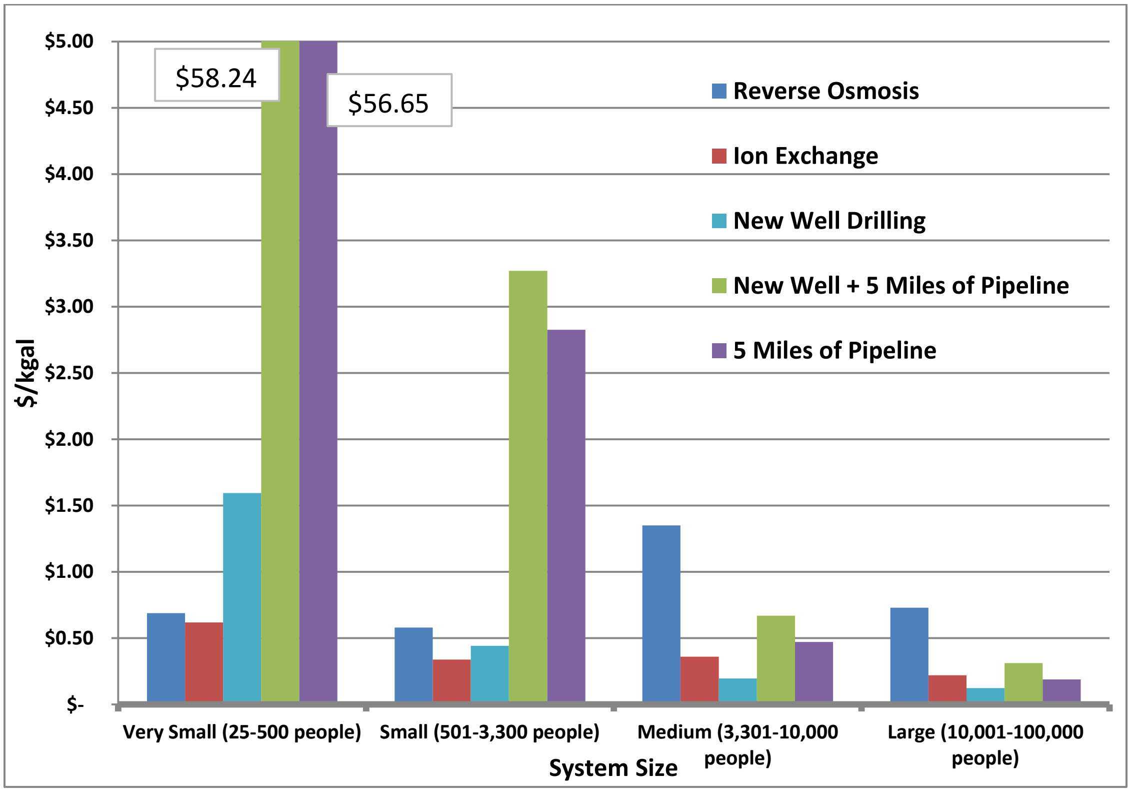

Figure 27. **Community public water system annualized cost comparison ($/kgal) for alternative water supply option (including pipeline for connecting to a nearby system and excluding SCADA costs).**

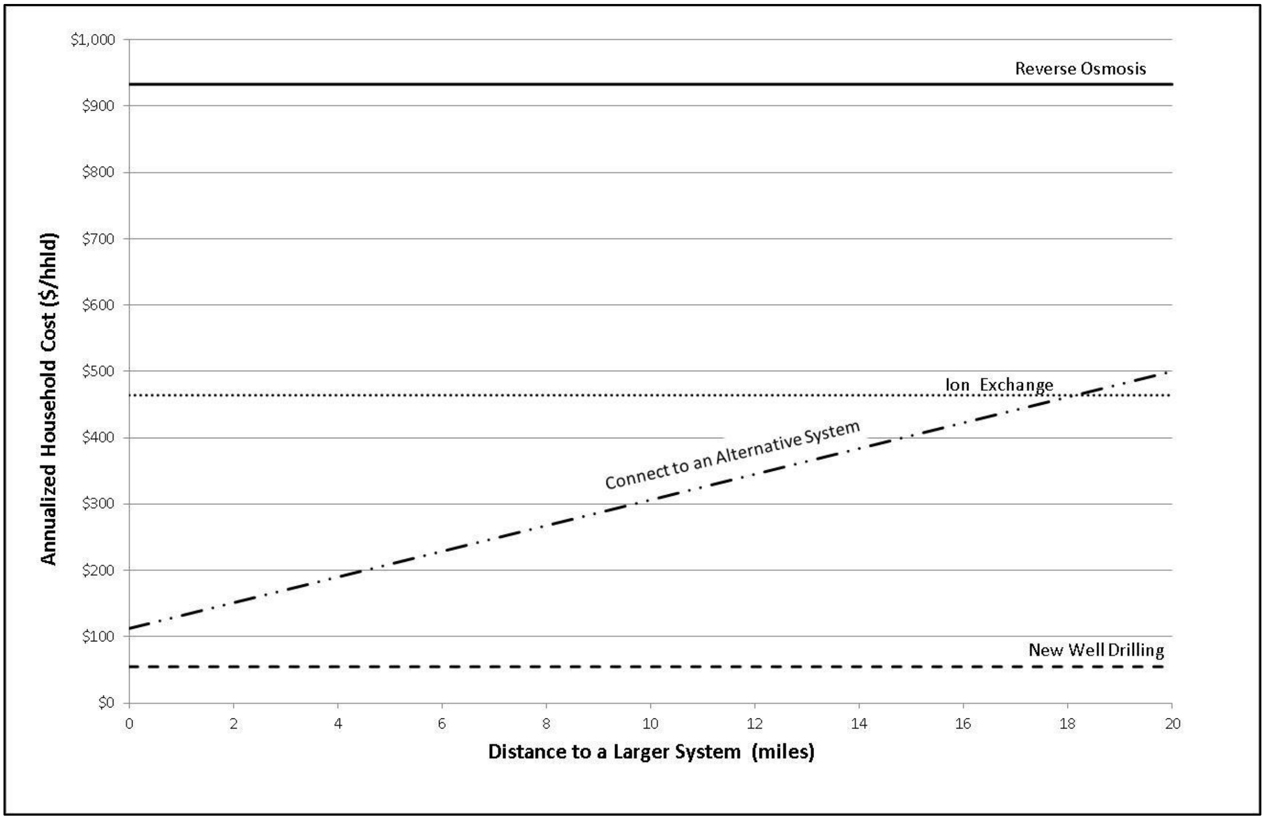

Figure 28. Annualized cost comparison ($/hhld) of alternative water supply options for a 2,000 connection community public water system.

These cost estimates (Table 39, Table 42, Figure 26, Figure 27, and Figure 28) are used to discuss the basin-wide cost estimates for providing alternative solutions to the population susceptible to nitrate contamination in the Salinas Valley and Tulare Lake Basin (discussed in Section 6 Basin-wide Costs of Nitrate Contamination).

5.3 Public Health and Other Considerations

The most recent twelve year survey of waterborne disease in the United States (1991-2002) documented 183 drinking water-related outbreaks, with 76% from groundwater sources (Reynolds et al. 2008). From 2001 to 2002, 92% of outbreaks related to drinking water were from groundwater, and 39% of the groundwater systems were household self-supplied systems not regulated by the U.S. EPA (Blackburn et al. 2004). Drinking water systems have an enormous effect on public health. Ford (1993, 1996, 1998) suggests that “there is reason to be concerned for the future microbiological safety of drinking water because a) source water continue to receive agricultural, industrial, and municipal waters; b) water treatment and distribution systems age and deteriorate; c) water supplies are overwhelmed by excessive demand; and d) there appears to be an increase in diseases, or at least an increased recognition of disease, caused by pathogens with varying degrees of resistance to treatment and disinfection” (Ford 1999).

A water system struggling with regulatory compliance must manage and plan for the future and prepare for potential tightening of regulations. Reverse osmosis (RO) and ion exchange (IX) are the most cost-effective treatment options to reduce nitrate and to provide the highest quality and reliability of safe water for all households connected to water systems. Furthermore, since nitrate is not the only contaminant of concern within the study area (see Technical Report 6, Jensen et al. 2012) RO treatment may be deemed the most promising option for certain systems because it is effective against many co-occurring contaminants. Until treatment can be afforded or completed, interim solutions include delivery of bottled or trucked water or distribution of POU treatment devices. Bottled water is regulated by the Food and Drug Administration (FDA) and is not required to follow as rigorous regulations as U.S. EPA-regulated tap water; however, bottled water will be better than the current supply of nitrate-contaminated groundwater, albeit at greater expense (particularly since most brands are bottled from U.S. EPA regulated municipal drinking water systems). Water delivered by a truck from a low-nitrate source should be of good quality if proper truck cleaning and transfer procedures are followed; however, CDPH does not allow water systems to serve trucked water to their community water supply customers (CDPH 2008; CDPH 2011c; CDPH 2011d). If POU treatment devices (usually RO) are distributed to households, they must be CDPH approved devices and require households to be properly educated on their use. RO devices require filter replacement. Often, a plumber must be employed to install the device and annual maintenance is advisable.

If a self-supplied household has tested their well for nitrate and found a problem, they can employ a POU or POE device and request assistance on installation and maintenance from a nearby vendor or water system. A POE system allows household members to have the convenience of using any sink in the house instead of only the sink with a POU treatment unit. A properly implemented and maintained POE device supplies a household with the highest quality and reliability of water, compared to a POU device. Drilling a deeper well is promising for households able to access an aquifer with low nitrate water. It would be best to drill to deeper, lower nitrate water, while also testing for arsenic levels.

6 Basin-wide Costs of Nitrate Contamination

Rough basin-wide costs for nitrate contamination in the pilot study area were estimated for communities, self-supplied households, and local small water systems, using a range of cost estimates from literature, surveys, and researching existing proposal estimates and final project costs as described in detail in Section 5 Evaluation of Options. The highly susceptible population (shown in Table 13) is estimated to be 254,000 people. Of this total, 220,000 people are connected to 85 community public or state small water systems and approximately 34,000 people are served by 10,000 self-supplied households or local small water systems. Overall, the estimated economic least cost for providing nitrate-compliant water to the total highly susceptible population in the study area is roughly $20 million per year ($80/susceptible person/year) for the short-term (excluding one very large system), and is roughly $36 million per year ($142/susceptible person/year) for the long-term (excluding one very large system). Short-term solutions are those that can be used in the interim or as temporary solutions, while a more sustainable, longer-term solution is being planned and implemented. Ideally, there would be a perfect long-term solution for each system; however, in some circumstances a short-term solution is the preferred long-term solution. Smaller water systems may not have the technical, managerial, or financial capacity to incorporate a centralized groundwater treatment system or they may be too far from a larger system to realistically consider a connection. In this case it may be better for small water systems to deliver and maintain POU devices to their customers or to drill a new well that is properly constructed and can avoid future contamination.

Again, the costs of alternative water supply and treatment options vary with numerous factors and the numbers presented here are estimates based on averages of widely variable costs. Costs will be unique to each individual system. For proper cost estimation, a feasibility analysis is necessary to assess the potential solution for each unique system.

6.1 Costs for Community Public and State Small Water System Alternative Solutions

A rough basin-wide lowest cost for solving nitrate contamination of drinking water in the study area was estimated for community public and state small water systems. Only multiple source systems having a recorded level of delivering water above the nitrate MCL, single source systems that have a raw source water level exceeding the nitrate MCL, and systems lacking water quality data within WQM were included in this analysis. The low and high ranges of the cost estimate for each alternative as a function of size of community public water system appear in Table 40 and Table 41, with the compiled cost ranges by size and option in Table 42. The maps in Figure 29 and Figure 30 show the estimated least-cost short-term option for each affected community system based solely on system size. The displayed options are not recommended solutions for specific systems since they only consider system size; individual solutions should be engineered and designed for the local situation of each system. This map merely shows which promising least cost solutions are found in the approximate short-term. The most promising least cost solutions for the approximate long-term are shown in Table 44. By short-term we mean temporary or interim solutions that do not address the legacy of worsening nitrate groundwater pollution. By long-term we mean sustainable solutions capable of addressing increasing nitrate levels in groundwater. The short-term least cost for providing nitrate-compliant water to those connected to susceptible community public and state small water systems is roughly $13 – 17 million per year (Table 43). The long-term least cost for providing nitrate-compliant water to those connected to susceptible community public and state small water systems is roughly $34 million per year (Table 44). The estimated annual O&M cost (already included in the aforementioned least cost scenarios) for short-term basin-wide solutions is approximately $6.4 – 8.3 million per year, and about $11.5 million per year for long-term solutions (Table 45).

Short-term Solutions

The alternatives considered for community public and state small water systems (discussed in Table 40 and Table 41) include drilling a new well, installing a pipeline to a nearby system (within 14 miles) that serves more than 10,000 people, delivering and maintaining a POU RO device for potable uses, installing groundwater treatment, or connecting to a nearby new surface water treatment facility. The final short-term cost estimates are based on selecting the high estimate of the least cost alternative (Table 40 and Table 41) as a function solely of system size and proximity to a larger system, and excluding the follow options: allowing systems to provide bottled water to their consumers as a means of compliance, allowing medium and large systems to deliver POU RO devices for compliance, and allowing large systems to install a pipeline to a larger system (only systems with less than 10,000 people are connecting to systems with greater than 10,000 people). The final short-term cost estimates are shown in Table 43, with the first column representing solutions including POU systems and the second column excluding POU systems. Note that the cost to connect to an alternative system does not include the estimated connection fee. Since the costs throughout this report are from literature, surveys and U.S. EPA cost models there is some uncertainty in the accuracy of values to the true system size and capability. To estimate any uncertainty in these costs, all high estimate values (Table 40 and Table 41) are used to estimate the overall basin-wide least cost solutions and a contingency factor is applied based on system size. This contingency factor is meant to account for external factors that may not be included in researched cost estimates.

The options chosen for the final least cost estimate for providing community public and state small water systems with short-term solutions are:

1. drilling a new well;
2. delivering and maintaining POU RO devices for potable uses (only for systems serving up to 200 connections over a three year regulatory time constraint);
3. installing a pipeline to a nearby system (10,000+ system);
4. building a groundwater treatment facility; and
5. connecting to a nearby surface water treatment facility.

Drilling a new well and installing a POU device are the only options considered short-term solutions; however, for cost comparison installing a pipeline, building a groundwater treatment facility and connecting a nearby surface water treatment facility are also included in the short-term cost estimates.

The susceptible systems included in the community public and state small water system least cost analysis cost model are:

1. all CPWS and SSWSs with multiple sources, delivering water that exceeded the nitrate MCL at least once from 2006 to 2010;
2. all single source CPWS and SSWSs with raw source water that exceeded the MCL for nitrate at least once from 2006 to 2010; and
3. all CPWS and SSWSs with no nitrate water quality data.

A total of 85 susceptible community public and state small water systems serve 220,000 people, shown in Table 43 and Table 44.

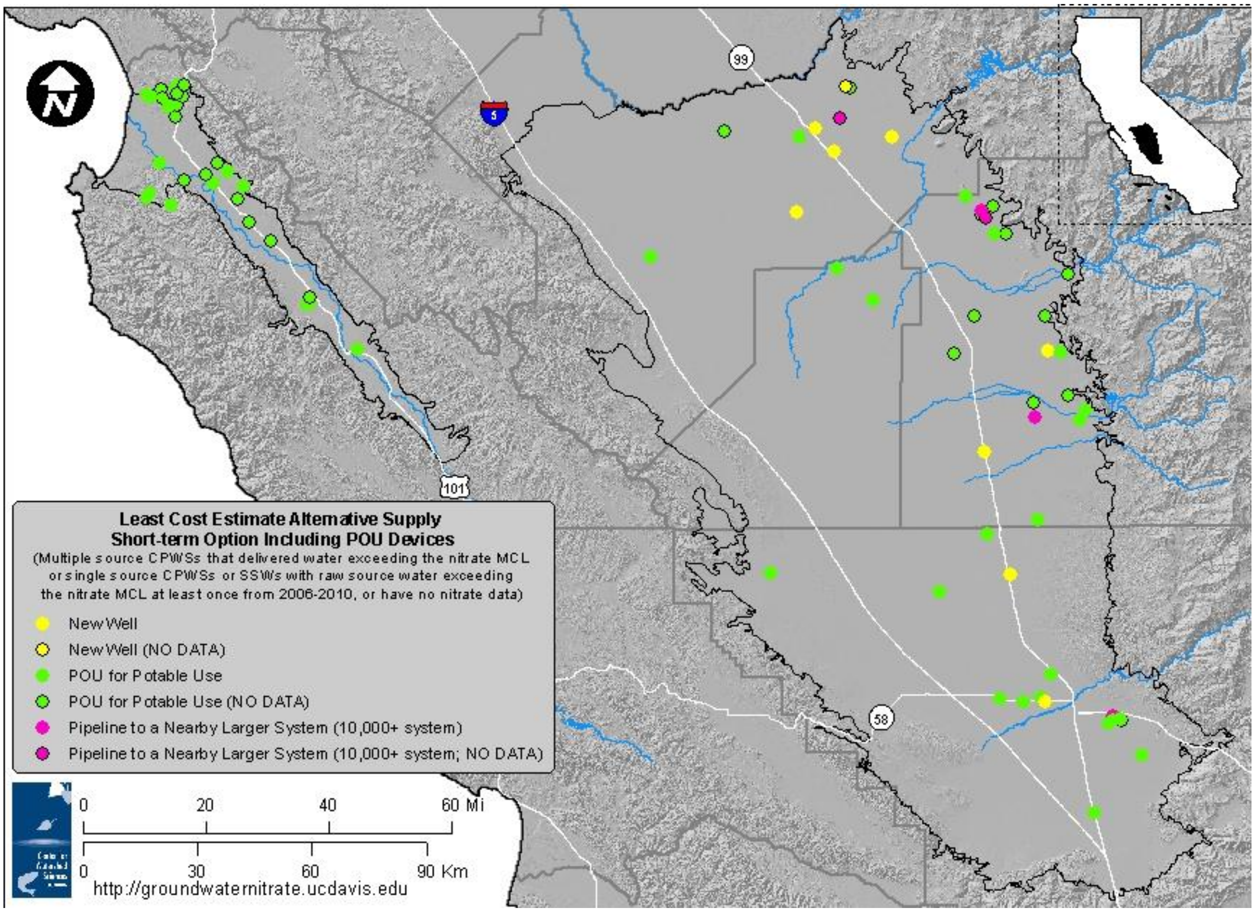

Figure 29. SHORT-TERM: Least cost alternative supply option (INCLUDING POU) based on high estimate of option costs for susceptible community public and state small water systems. (Source: CDPH PICME WQM 2006-2010 and cost estimate sources.)

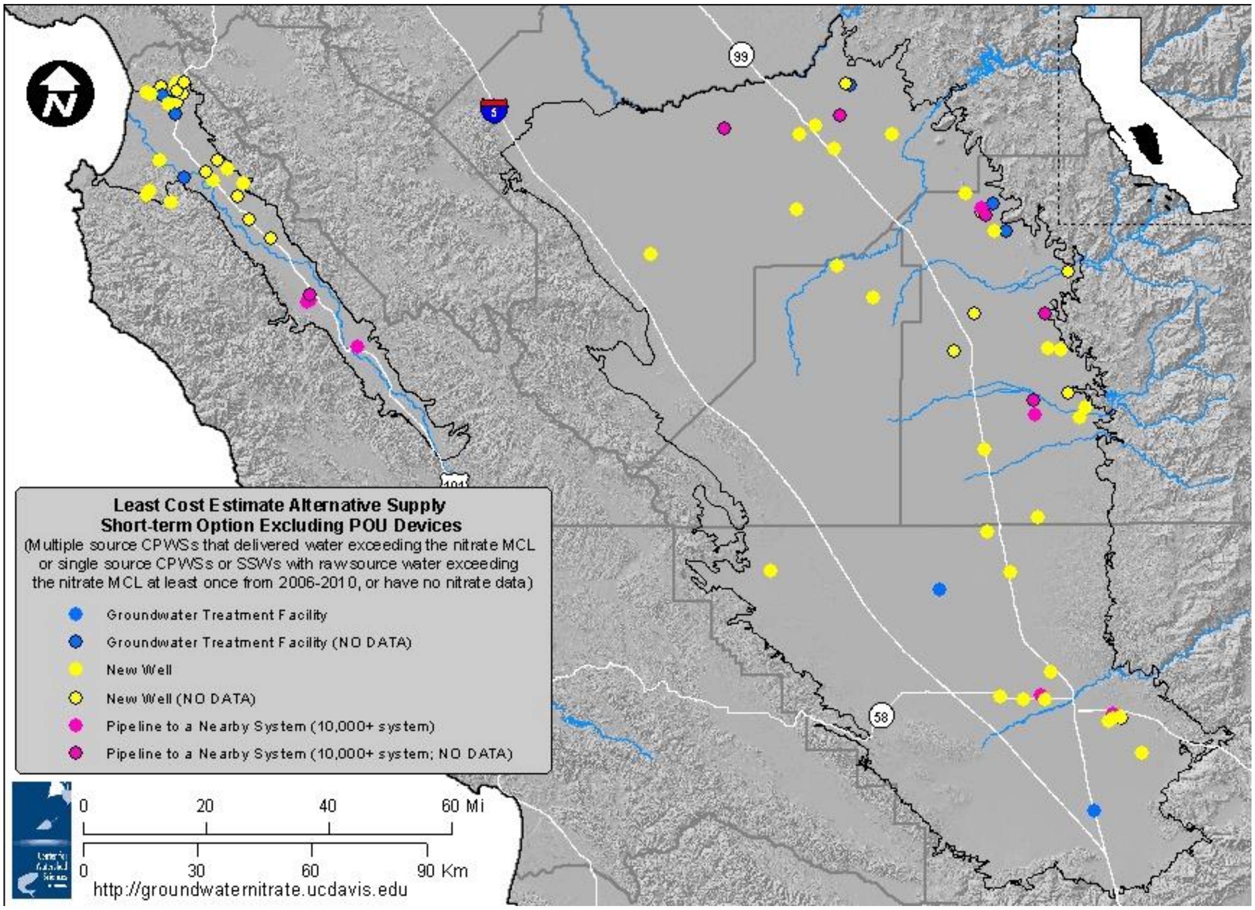

Figure 30. SHORT-TERM: Least cost alternative supply option (EXCLUDING POU) based on high estimate of option costs for susceptible community public and state small water systems. (Source: CDPH PICME WQM 2006-2010 and cost estimate sources.)

Table 43. Estimated cost range of the least cost short-term alternative water supply options for susceptible community public and state small water systems based on system size and proximity to a larger system.

	Number of Susceptible CPWSs/SSWSs		Population		Total Cost ($/year)	
Option	**Including POU**	**Excluding POU**	**Including POU**	**Excluding POU**	**Including POU**	**Excluding POU**
Drill New Well	10	63	184,123	191,715	$10,144,000	$14,500,000
POU Device for Potable Use	70	---	10,515	---	$1,320,000	---
Pipeline to a Nearby System (10,000+ system)	5	13	25,323	27,349	$865,000	$1,463,000
Groundwater Treatment Facility	0	9	0	897	$0	$450,000
Surface Water Treatment Facility	0	0	0	0	$0	$0
TOTAL	85	85	**219,961**	**219,961**	**$13 million**	**$17 million**

The least cost overall alternative water supply cost including POU devices is approximately $13 million per year (annualized), with ten systems drilling a new well, 70 systems delivering and maintaining a POU device for potable use, and five systems installing a pipeline to a nearby system. This is graphically displayed in Figure 29 and numerically shown in Table 43. Drilling a new well for ten systems provides a solution for 84% of the susceptible population at a cost of $10.1 million per year. Installing and maintaining a POU device for 70 systems (all serving up to 200 connections) provides a solution for about 5% of the susceptible population at a cost of $1.3 million per year. Installing a pipeline to a nearby larger system for five systems provides a solution for 12% of the susceptible population at a cost of $865,000 per year. Building a groundwater treatment facility was not a least cost option when POU devices were available.

The least cost overall alternative water supply cost excluding POU devices is approximately $17 million per year (annualized), with 63 systems drilling a new well, 13 systems installing a pipeline to a nearby system, and nine systems building a groundwater treatment facility. This is graphically displayed in Figure 30 and numerically shown in Table 43. Drilling a new well for 63 systems provides a solution for 87% of the susceptible population at a cost of $14.5 million per year. Building a groundwater treatment facility for nine systems provides a solution for less than 1% of the susceptible population at a cost of $450,000 per year. Installing a pipeline to a nearby larger system for 13 systems provides a solution for 12% of the susceptible population at a cost of $1.5 million per year. Connecting to a surface water treatment facility was not a least cost option under the short-term least cost analysis solution, for either estimated cost options for the currently susceptible system sizes and locations.

The total estimated range of costs for the least cost alternative option for community public and state small water system short-term solutions is $13 – 17 million per year. However, because there is uncertainty in the amount of time a well can produce nitrate-safe drinking water before it may become compromised by legacy and on-going nitrate leaching, an alternative “long-term” cost scenario is analyzed below and shown in Table 44, in which the option of drilling a new well and installing POU RO devices are excluded as a long-term option.

Long-term Solutions

As groundwater degradation continues over time, nitrate and other contaminants will be of concern (e.g., arsenic, chromium, DBCP, and salts). Drilling a new well does not reliably provide a long-term safe drinking water solution throughout the study area since it may take only a few years for a nitrate plume to contaminate the new well or for other groundwater contaminants to appear in the location chosen for drilling a new well. For this reason, a long-term analysis of alternative water supply costs was undertaken in which more vulnerable options were excluded as potentially unreliable solutions for the longer-term. Excluded solutions included: use of POU RO devices for compliance and drilling a new well. As with the short-term solution cost analysis, the cost of the option to connect to a larger system does not include the estimated connection fee. To estimate any uncertainty in these costs, all high estimate values (Table 40 and Table 41) are used to estimate the overall basin-wide least cost solutions and a contingency factor is applied based on system size. This contingency factor is meant to account for external factors that may not be included in researched cost estimates.

The options chosen for the low and high option cost estimates for the long-term least cost analysis of alternative water supplies for community public and state small water system solutions are shown in Table 44, and include:

1. installing a pipeline to a nearby system (10,000+ system);
2. building a groundwater treatment facility (RO or IX[25]); and
3. installing a pipeline and connecting to a nearby surface water treatment facility.

Table 44 shows the least cost long-term solutions for the 85 susceptible community public and state small water systems, based on excluding the above indicated options as having only short- to medium-term viability.

Table 44. Estimated cost range of the least cost long-term alternative water supply options for susceptible community public and state small water systems based on system size and proximity to a larger system.

Option	Number of Susceptible CPWSs/SSWSs	Population	Total Cost ($/year)
Pipeline to a Nearby System (10,000+ system)	29	36,577	$5,592,000
Groundwater Treatment Facility	51	8,057	$6,344,000
Surface Water Treatment Facility	5	175,327	$21,532,000
TOTAL	85	**219,961**	**$34 million**

Assuming the viable long-term options, the estimated overall least cost long-term alternative water supply cost is approximately $34 million per year (annualized), with 29 systems installing a pipeline to a nearby larger system, 51 systems building groundwater treatment facilities, and five systems connecting to a surface water treatment facility. Installing a pipeline to a nearby larger system for 29 systems provides a solution for 17% of the susceptible population at a cost of $5.6 million per year. Building a groundwater treatment facility for 51 systems provides a solution for about 4% of the susceptible population at a cost of $6.3 million per year. Connecting to a surface water treatment facility for five systems provides a solution for about 80% of the susceptible population at a cost of $21.5 million per year.

The total estimated least cost long-term alternative water supply solutions for the 85 affected community public and state small water systems is $34 million per year.

For a long-term scenario it should also be mentioned that the groundwater treatment options available each have limitations and environmental considerations. An ion exchange groundwater treatment facility may not be the best long-term solution because of the environmental sustainability and management concerns associated with the disposal of concentrated brine. Additionally, ion exchange can address several co-contaminants, but not all potential contaminants. Reverse osmosis groundwater treatment has similar environmental sustainability and waste brine management concerns, as well as problems with wasting water, but is more capable of treating multiple co-contaminants (see Technical

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[25] Reverse osmosis and ion exchange are the most commonly employed nitrate treatment options, but are not the only options for treatment. Other options may become more prevalent in the future (see Jensen et al. 2012).

Report 6, Jensen et al. 2012, for additional treatment information). The best long-term groundwater treatment will depend on the local characteristics of each system and the technology available at the time of interest.

Estimated O&M Costs for Basin Wide Alternative Water Supply Options

Using the average O&M percentage shown in Table 38, the annual estimated O&M cost associated with each least cost short- and long-term alternative is evaluated (Table 45). The estimated O&M cost related to short-term alternative solutions is approximately $6.4 – 8.3 million per year (including POU and excluding POU). The estimated annual O&M cost related to long-term alternative solutions is approximately $11.5 million. These costs are based on averages of widely variable costs and the true O&M cost for a unique system will require a proper cost estimate performed by a certified professional engineer or a professional cost estimator.

Table 45. Estimated O&M cost of the least cost short- and long-term alternative water supply options for susceptible community public and state small water systems.

	Short-term System Solutions[1]		Long-term System Solutions[1]	Estimated Annual O&M Cost ($/year)[2]		
Option	**Including POU**	**Excluding POU**		**Short-term with POU**	**Short-term without POU**	**Long-term**
Drill New Well	10	63	---	$5,580,000	$8,000,000	---
POU Device for Potable Use	70	---	---	$792,000	---	---
Pipeline to a Nearby System (10,000+ system)	5	13	29	$0	$0	$0
Groundwater Treatment Facility	0	9	51	$0	$295,000	$4,441,000
Surface Water Treatment Facility	0	0	5	$0	$0	$7,106,000
TOTAL	85	85	85	**$6.4 million**	**$8.3 million**	**$11.5 million**

[1] The number of CPWS and SSWSs that were shown in Tables 43 and 44.

[2] The estimated annual O&M cost uses the average O&M percentage from Table 38.

6.2 Costs for Household Self-Supplied and Local Small Water System Alternative Solutions

A rough basin-wide estimate of the least cost water supply solutions for the self-supplied households and local small water systems was developed using researched cost estimates for applicable options and is shown in Table 39. Susceptible self-supplied households and local small water systems are estimated within each Thiessen polygon that exceeds the MCL for nitrate (as discussed in Section 3.5.1.1 Household Self-Supplied or Local Small Water Systems with a High Likelihood of Nitrate Groundwater Contamination) and are estimated to amount to approximately 34,000 people in the study area. The least cost alternative for individual households is to install and operate a reverse osmosis POU device, estimated to cost $250 per year (not including any public outreach or education). The second least expensive alternative for households is to install a POE device; however, currently no POE devices are

NSF/ANSI certified for removing nitrate from drinking water. Figure 25 (in Section 5 Evaluation of Options) showed the annualized cost curves of each considered option, highlighting the least cost option based on expected water use or consumption per household. If a household only desires to have low-nitrate *potable* water, a POU device is the least expensive solution; however, treating more than 18 gallons of water per day with a POU device is not cost-effective and installing a POE device would be preferred. If installation of a POU or POE device is not preferred by the household user, drilling a new well is the next available option. However, without concurrent reduction in source loading, new wells will risk nitrate contamination over time as pumping and nitrate migration continue.

The expected total annualized costs for 10,000 households (34,000 people) to install a POU RO device is $2.5 million or $4 million for a POE IX device; however, installing a POE device provides the whole house with low-nitrate water and accidental consumption of nitrate-laden water is not of concern. The lifetime of the alternatives are different as well; a POU RO device or POE IX device have a ten year expected lifetime, while drilling a new well has a fifty year expected lifetime. However, if degradation and contamination of the study area continue, the lifetime of a well may be shortened if a nitrate plume spreads and eventually reaches the new well. The POU RO device is annualized over ten years; the cost for drilling a new well is annualized over 20 years.

The range in estimated nitrate costs for self-supplied households is $2.5 to $4 million per year. Using the average O&M percentage shown in Table 38, the estimated annual O&M cost associated with the POU and POE solutions is approximately $1.5 to $2.4 million.

6.3 Interim Solutions

The interim solutions discussed here are specific to domestic well users and small water systems serving less than 200 connections. Small water systems (serving less than 200 connections) may use an interim solution for compliance, such as a POU device, for up to three years under the emergency regulations established by CDPH (further discussed in Section 7 Regulatory and Implementation Implications). Providing POU devices to water system customers is only meant for systems that are in the process of creating or implementing a long-term solution. A small water system may not provide bottled water to consumers as an interim compliance option. Domestic well users may use alternative supplies, such as a POU or POE device or bottled water, at their own discretion and for the length of time they choose, without regulation. However, bottled water for an individual household's potable water needs is more costly over the long-term than installing and operating a POU device. Table 46 shows the estimated costs for interim water supplies for domestic wells and small water systems. The POU costs include capital, O&M, public education, and indirect costs. Cost estimates shown in parentheses exclude the costs of public outreach. For small public water systems serving 15 to 199 households, it is important to provide public education to users to increase proper use and handling. The economies of scale for the POU interim solution occur only in the added costs of public education; for each additional person the per capita price for education decreases. For domestic well users, the cost for U.S. EPA-suggested public education is not cost-effective, and self-education (by researching the POU device chosen) or a low budget, county prescribed public education program is suggested.

Table 46. Estimated cost ranges per household served for interim POU water supplies for households and small water systems serving fewer than 200 connections.

Options	Bottled Water[1]	POU 15 households[2]	POU 199 households[3]	POU 1 household[4]
Initial Capital Cost ($/hhld)	0	$443 ($406)	$411 ($406)	$1,981 ($406)
Annual O&M Cost ($/hhld)	0	$272 ($166)	$173 ($165)	$1,781 ($197)
Total Annualized Cost ($/kgal)	$1,630	$5.24 ($3.80)	$3.90 ($3.78)	$24.85 ($3.01)
Total Annualized Cost ($/hhld)	**$1,260**	**$435 ($315)**	**$324 ($314)**	**$2,038 ($250)**

[1] Quote from Alhambra, Visalia for drinking water delivered in 5 gallon bottles (Alhambra Water 2010). Assumed units of water consumption from NAS Hydration Study.

[2] Uses the 2010 U.S. EPA Cost Estimate Tool for an NSF/ANSI Certified RO Unit for treating nitrate. Includes unit purchase, installation, scheduling time, public education (technical and clerical labor and printed material for all public outreach/education efforts), indirect costs (permitting, pilot testing, legal, engineering, contingency) and all associated operations and maintenance costs. The tool allows for economies of scale representation assuming 15 households will be receiving units and management will be centralized. Costs in parentheses do not include public education.

[3] Uses the 2010 U.S. EPA Cost Estimate Tool for an NSF/ANSI Certified RO Unit for treating nitrate. Includes unit purchase, installation, scheduling time, public education (technical and clerical labor and printed material for all public outreach/education efforts), indirect costs (permitting, pilot testing, legal, engineering, contingency) and all associated operations and maintenance costs. The tool allows for economies of scale representation assuming 199 households will be receiving units and management will be centralized. Costs in parentheses do not include public education.

[4] Uses the 2010 U.S. EPA Cost Estimate Tool for 1 NSF/ANSI Certified RO Unit for treating nitrate. Includes unit purchase, installation, scheduling time, public education (technical and clerical labor and printed material for all public outreach/education efforts), indirect costs (permitting, pilot testing, legal, engineering, contingency) and all associated operations and maintenance costs. Costs in parentheses do not include public education.

7 Regulatory and Implementation Implications

Each alternative water supply option has its own regulatory and implementation implications. Since domestic well users are excluded from the statewide drinking water protections, and have no regulatory standards for testing their wells (except for a few local county ordinances), the implications of their water supply options will differ slightly from those for community public water systems.

7.1 Implications of Household Self-Supplied System Alternatives

The large numbers of self-supplied households pose several regulatory challenges. Their small size and unique and varying circumstances result in these small systems bearing significant financial costs and public health risks.

Drilling a New or Deeper Well: Some counties have existing regulations for drilling new domestic wells. In areas with nitrate contamination potential, counties and the state should consider additional monitoring and well construction regulations.

Household Treatment: Since there is little regulatory oversight for domestic well users, there are no specific requirements for POU or POE devices, but purchasing a certified unit is recommended. Households with self-supplied wells that choose to install a POU RO or POE IX device should consider hiring a certified POU/POE distributor to manage and operate the device or should seek training in proper maintenance. Given the often lesser and declining expense of POU/POE systems, the state should continue to examine its regulations to take advantage of these improving technologies.

Connect to Alternative System: If a household wishes to connect to a nearby safe community public water system they must contact the water system or county official and determine if they are within the water system boundary. If a household is outside of water system boundaries they will need to speak with local officials about annexation, an extension of the urban growth boundary, or a separate contractual relationship. Households outside of water system boundaries may find it more difficult to be incorporated into an existing water system.

Bottled Water: There are no regulatory implications for households to start purchasing bottled or vended water; however, the quality of bottled water is an under-regulated industrial activity, and can sometimes be of lower quality than other sources.

7.2 Implications of Community Public Water System Alternatives

Since CPWSs are larger in size and capacity and fewer in number they have many more options, but higher individual consequences. Community public water systems are always in direct contact with the regulators to determine the most effective solution for complying with drinking water standards.

Blending: CDPH has already established a Blending Program; however, the regulatory implications will differ slightly depending on whether the blending source is groundwater or surface water. A groundwater source used for blending will not be suitable for use if the groundwater quality eventually exceeds the MCL for nitrate. Once blending is implemented the water system must continually monitor the low-nitrate source to ensure the blending ratio is achieved.

Drilling a New or Deeper Well: California already has a Well Standards Ordinance established for community public water systems for drilling a new or deeper well. Local county ordinances also establish rules for each community water system. Also, CPDH regulates well construction and evaluates the location, source water quality and quantity for drilling a new or deeper well in a community public water system supply.

Community Treatment: CDPH has a Division of Drinking Water and Environmental Management (DDWEM) that provides permitting information for community public water systems and has established a Drinking Water Treatment and California Operation Certification Program that provides the minimum qualifications for a potable water treatment system operator. Furthermore, the respective regulatory agency for each community public water system must verify that the drinking water treatment device employed is consistent with Title 22 California Code of Regulations (CDPH 2008; CDPH 2011a).

Household Treatment: California regulations currently allow small public water systems to provide POU devices to customers as a means of complying with the nitrate standards under the following restrictions (CDPH 2008):
"…a public water system may be permitted to use point-of-use treatment devices (POUs) in lieu of centralized treatment for compliance with one or more maximum contaminant levels… if;

(1) the water system serves fewer than 200 service connections,

(2) the water system meets the requirements of this Article (Title 22 Division 4 Chapter 15 Article 2.5),

(3) the water system has demonstrated to the CDPH that centralized treatment, for the contaminants of concern, is not economically feasible within three years of the water system's submittal of its application for a permit amendment to use POUs,

… no longer than three years or until funding for the total cost of constructing a project for centralized treatment or access to an alternative source of water is available, whichever occurs first…."

According to the emergency legislation (Health and Safety Code 11680(a)(1)) for temporary compliance a POE device may also be employed in lieu of centralized treatment. As of September 22, 2011 a POE system must be considered as a system solution before a POU device. If the POE device is found to be "not economically feasible or not as protective of public health as POUs" then a POU device may be used (CDPH 2011e). . The most significant costs of a POU RO device are in the management and monitoring of the unit. Since the law states that POU units must be centrally-managed by the public water system or by a company hired by the public water system, a fair regulatory policy should be developed. For example, a public water system could work with a private company to create a reasonable contract that allows the company to manage, maintain and monitor all devices within a specific public water system service area. To use a POU device for complying with the SDWA amendments there must be 100% participation within a public water system. If any of the connections deny access to their house it automatically prohibits POU as an alternative for compliance. This is a substantial impediment to POU treatment. Other communities have addressed this by passing a local ordinance requiring installation, and employing the authority to disconnect the water supply if installation is refused (U.S. EPA 2006a). A local ordinance was passed in San Ysidro, New Mexico, making water use contingent on POU installation (U.S. EPA 2006a). It is important to provide public education to customers before, during and after implementation of a POU device to ensure success.

Connect to Alternative Supplies: All public water systems must submit an amended permit application to the local CDPH drinking water field office prior to changing their source or method(s) of treatment (CDPH 2011c; CDPH 2011d). If a water system switches from groundwater to surface water, the water treatment requirements change as specified in the State and Federal Surface Water Treatment Rule. Also, surface water treatment is almost always more expensive than groundwater treatment. However, all water served to the public for drinking water purposes is subject to the same nitrate drinking water standard. A switch to surface water could require purchasing existing surface water rights, contracting with another entity, petitioning for new surface water rights, or getting an existing surface water right owner, such as an irrigation district, to amend their use permit and expand activities to provide treated drinking water services.

Regionalization and Consolidation: Regionalization and consolidation allow systems to increase the levels of service by taking advantage of economy of scale benefits and complying with stringent regulations. Service duplications across management and operational functions can be eliminated, while achieving regulatory compliance and improving financial accountability. Rourke and Smith (1997) estimated that approximately 40 – 45% of community public water systems will experience financial instability from rising operational and future regulatory compliance costs; the larger population base found in regionalization can support increases in operational costs and future regulations. Legislation or CDPH should consider providing larger systems with financial and ratemaking incentives to encourage the acquisition of smaller systems. Regulatory incentives for regionalization have been considered in many policy areas, and "some states have enacted legislation authorizing the use of mandatory 'takeovers'…but, many water utilities would prefer positive incentives to mandatory takeovers" (Beecher 1996). Furthermore, if there was an incentive for larger systems to acquire smaller systems there would be fewer systems for regulating agencies to monitor, reducing administration costs.

Several studies have examined the advantages and disadvantages of regionalization, but the physical implementation depends on the unique needs and barriers in each region. Successful implementation of regionalization and consolidation requires planning in a regional context, along with strong public and political participation. Comprehensive planning that establishes public policy and resource planning on a regional scale will help meet the objective goals involved in consolidation (Beecher et al. 1996). Some implementation issues must be considered before consolidating systems, including: "(1) system income and expenses, (2) level of contributions in aid of construction, (3) rate base, (4) condition of facilities, (5) reasonableness of price and terms, (6) impact on customers, (7) required additional investments, (8) alternatives to sale and impacts of no sale, (9) ability to operate facilities, and (10) public interest assessment (Cloud 1994)" (Beecher 1996). Public participation is essential for regionalization, to properly educate the public and assure their involvement in the project, and for the future fate of the system. CDPH supports consolidation efforts through funding programs and low interest loans to construct facilities for the physical consolidation of water systems, but does not have an explicit program to support the planning needed for moving towards regionalization.

To be considered for Safe Drinking Water State Revolving Funds, a water system must prove its technical, managerial and financial (TMF) capability.[26] A water system must also submit an assessment that identifies all public water systems located within a five mile radius and determines the feasibility of consolidation (Newkirk & Darby 2010).

<u>Trucked Water</u>: Hauled or trucked potable water is often allowed by CDPH and used for public water systems in emergency situations when a water source is interrupted for an extended period of time and if there are no other alternatives. A water system that needs to provide trucked potable water to customers must contact CDPH and ensure that a CDPH Food and Drug Branch licensed water hauler is hired for service delivery. The water must be obtained from another regulated public water system and a "boil water advisory" may be given to each consumer as a precautionary measure to account for possible contamination during the delivery.[27]

<u>Dual Water Distribution System</u>: The permitting agency for dual water distribution systems or recycled water systems is the local Regional Water Board (Central Valley and Central Coast). A water system that wants to install two distribution systems, one for potable and one for non-potable or recycled water, must file a report with the appropriate Regional Water Board (CWC section 13522.5). CDPH reviews and evaluates recycled water proposals to verify the protection of public health and ensures that a system has the correct backflow protection established to prevent non-potable water from entering the drinking water system. CDPH encourages the use of recycled water in urban areas where recycled water or irrigation water is available (CDPH 2011d). To mitigate the concerns of inter-connection of the two sources or improper plumbing, water system personnel must be trained and a cross-connection control program must be implemented (CDPH 2011d). This program must also include annual testing of the backflow prevention devices and periodic shut-down tests (CDPH 2011d).

If a dual water distribution system is implemented on a community public water system level there must be full public acceptance among consumers. Along with customer acceptance and approval, there must be a consensus within the City or County about the quantity and quality of water expected for delivery, and communication with the state about existing regulations. If a system desires to install a dual water distribution system there must be consideration of the health effects, treatment, storage and distribution demands (American Water Works Association 1994).

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[26] California Health and Safety Code Section 116540.

[27] Boiling water is not an option to address nitrate contaminated water.

8 Conclusions

8.1 Major Findings

1) **A total of 254,000 people in California's Tulare Lake Basin and Salinas Valley have drinking water supplies susceptible or potentially susceptible to nitrate groundwater contamination.**
    a) Highly susceptible water users fall into one of three identified situations. These comprise: i) being served by a community public water system with multiple sources and at least one reported nitrate record in excess of 45 mg/L since 2006, ii) being a single source community public water system with at least one reported raw source water nitrate record in excess of 45 mg/L since 2006, or iii) being a self-supplied household or served by a local small water system located in the vicinity a shallow nitrate groundwater concentration in excess of 45 mg/L. Approximately 213,000 people in 38 multiple-source systems have at least one reported delivered nitrate record in excess of 45 mg/L. Approximately 3,400 people in 34 single-source systems have at least one, reported raw water nitrate record in excess of 45 mg/L or no nitrate water quality data in WQM. In addition, approximately 10,000 rural households (serving approximately 34,000 people) using domestic wells or on local small water systems of four or less connections are in the vicinity of shallow groundwater where the nitrate concentration exceeds 45 mg/L.
    b) Other water users considered highly susceptible include approximately 3,900 people in 13 multiple source water systems in the study area that have no recorded nitrate concentration data in the statewide water quality database (WQM).
2) **Nitrate contamination problems will grow.** According to recorded *raw* groundwater data in WQM, **57% of the current population of these regions uses a community public water system with recorded raw nitrate levels above 45 mg/L**. Assuming unchanging continued basin-wide trends observed since 1970 in nitrate groundwater levels, this number is expected to increase to almost 80% by 2050. Nitrate groundwater contamination problems will increase, treatment costs will rise, and there is growing potential for public health impacts.
3) **Each community public and state small water system with high susceptibility (50 and 35 systems in Tulare Lake Basin and Salinas Valley, respectively) will need individual engineering and financial analyses. No single solution will fit every community affected by nitrate in groundwater.**
4) **From a physical and engineering cost perspective, there is significant potential to consolidate systems.** The potential for consolidation is based on system size and the distance from a smaller system to a larger system. About 81% and 89% of the Tulare Lake Basin and Salinas Valley water systems are very small or small (defined as serving < 3,300 people) and serve 89,125 and 23,215 people (4% and 6% of the Tulare Lake Basin and Salinas Valley population), respectively. In the Tulare Lake Basin and Salinas Valley, respectively, about 50% and 15% of smaller systems (<10,000 people) are within five miles of a larger system (>10,000 people), and 88% and 97% of smaller systems are within 12.5 miles of a larger system. Consolidation permanently addresses nitrate problems, as well as many other small system safe drinking water problems typically encountered by these systems now and in the future.

5) **Options for communities connected to highly susceptible systems** are:
    a) consolidation with a larger system that can provide safe drinking water to more customers;
    b) consolidation of nearby small systems into a single larger system, with a larger rate payer base and economies of scale;
    c) ion exchange community water treatment;
    d) interim point-of-use treatment systems until a more long-term and sustainable solution can be implemented;
    e) drilling a new well, at least in the short-to-medium term;
    f) blending of contaminated wells, at least temporarily; and
    g) switching to surface water.

    Some of these options are less viable solutions for the long-term because they may fail to sustainably deliver nitrate-safe water. Those considered less viable in the long-term include POU, drilling a new well, and blending.
6) **Solutions for self-supplied household or local small water systems within a highly susceptible area** are bottled water (as an interim solution), reverse osmosis point-of-use treatment systems, point-of-entry ion exchange systems, and drilling a new or deeper well.
7) **Better data collection and management will improve knowledge of the extent of nitrate contamination.** Improvements in state and local management of data regarding state small wells, water system boundaries, domestic wells, and systems with unknown risk can facilitate understanding and more effective management of nitrate contamination.
8) **The overall estimated least cost, including capital and operating costs, for providing <u>short-term</u> nitrate-compliant drinking water to the Tulare Lake Basin and Salinas Valley is $15 – 20 million per year for the currently susceptible population. The overall estimated least cost, including capital and operating costs, for providing <u>long-term</u> nitrate-compliant drinking water to the Tulare Lake Basin and Salinas Valley is $36 million per year for the currently susceptible population.**

Roughly $13 – 17 million per year will be needed to provide safe drinking water for short-term solutions for multiple source community public water systems exceeding the nitrate MCL, single source community public water systems (and the small fraction of state small systems included in CDPH's database) with nitrate records in excess of 45 mg/L, and community public water systems (and the state small water systems included in CDPH's PICME database) lacking nitrate records in WQM, that together currently serve an estimated 220,000 people (85 systems). Of this cost, approximately $6.4 to 8.3 million is estimated as annual O&M costs. The provision of safe drinking water with long-term solutions for these 85 systems will cost roughly $34 million per year. Of this cost, approximately $11.5 million is estimated as annual O&M costs.

The annualized cost of providing nitrate-compliant drinking water to the estimated 34,000 people (10,000 rural households) using domestic wells or local small water systems (< 5 connections) highly susceptible to current or future nitrate contamination ranges from $2.5 million per year for point-of-use (POU) treatment for drinking purposes only, to $4 million per year for point-of entry (POE) treatment for each household for all water needs. Costs for both could be lower if a manufacturing discount for bulk purchase of POU/POE systems were available. Approximately $1.5 to $2.4 million is estimated as annual

O&M costs associated with providing POU/POE systems to the susceptible population served by domestic well or local small water systems. The least cost POU option is included in the total project study area estimated least cost of alternative water supply solutions in both the short- and long-term.

The cost to fund alternative water supplies for highly susceptible, nitrate-affected water systems amounts to $60 – 80 per susceptible person per year, $4 – 5 per irrigated acre per year for the four million acres of agriculture in these regions, or $75 – 100 per ton of fertilizer nitrogen (assuming about 200,000 tons of fertilizer is applied in these regions) in the short-term. Allowing for only long-term more viable and sustainable alternative drinking water solutions for affected communities, the total cost would amount to $142 per susceptible person per year, $9 per irrigated acre per year for the four million acres of agriculture in these regions, or $180 per ton of fertilizer nitrogen (assuming about 200,000 tons of fertilizer is applied in these regions) in the long-term.

8.2 Promising Actions

1) **A feasibility analysis should occur for individual systems to determine the most suitable alternative water supply option, in which consolidation and regionalization are actively explored and investigated as the best longer-term options for small systems.**
2) **For any solution, there are long-term considerations, such as:**
    a) **The need to remove additional contaminants.** Alternative water supplies or treatment options selected should be capable of addressing multiple contaminants if these currently exist or there is good evidence that additional contaminants are likely to emerge in the near-to-medium term.
    b) **The drawdown involved in pumping a new or deeper well.** Over time, as pumping continues, a new well could draw nitrate into the well.
    c) **Brine waste from treatment systems.** The low brine technologies in groundwater treatment offer a minimal waste approach, and future research and development of brine treatment alternatives seem promising for greatly reducing brine waste from treatment systems. Systems should consider the sustainable management and disposal of the brine in the selection of the groundwater treatment.
    d) **Environmental impacts of reliance on bottled water.** Manufacturing and transporting bottles uses a lot of energy and causes negative environmental impacts, and the disposal of these bottles stresses solid waste systems.
3) **Advance household treatment for community public water system compliance.**
    a) Create NSF certifiable POE devices for community public water systems to provide to customers.
    b) Allow community public water systems to provide POU devices to customers for more than three years under reasonable conditions.
4) **Regionalize and Consolidate.**
    a) **Fund non-structural regionalization/consolidation of drinking water systems.** Programs in California fund physical consolidation activities like the construction of new pipelines, the installation of water meters, or the expansion of treatment systems. Regionalization efforts

should be expanded to convene pilot projects that bring together communities of water systems to encourage informational, managerial, institutional, and future planning collaboration to lay the groundwork and foundations for future consolidation with respect to institutional, political, and shared needs. This could be done without necessarily having to start with historically, politically sensitive, and difficult consolidation, since appropriate regionalization projects can help communities begin to collaborate on information and other types of exchanges to address shared nitrate problems, as well as many of the other shared problems of small water systems.

   b) **Provide incentives to large safe drinking water systems to consolidate with or initiate regionalization projects with surrounding smaller systems.** To encourage larger systems to take on the risks of a smaller system, incentives should be offered. For example, it may be beneficial to increase the points given to large systems on State Revolving Funds' Project Priority Lists who help bring small systems up to the same technical standards as larger systems, often a prerequisite for consolidation.

5) **Construct, populate, and maintain a statewide publicly accessible comprehensive water quality database for groundwater and public water supply systems.** To facilitate accessibility of groundwater quality data throughout the state, one agency should manage a comprehensive database and create a simple graphical user interface for easy extraction of groundwater quality data.
6) **Create a Small System Water and Wastewater Task Force for integrating water and wastewater treatment projects and efforts.** Small water and wastewater systems have many chronic and common problems, and tend to have more frequent contamination problems and higher costs than larger systems. A Task Force should examine the state's effectiveness of overseeing and aiding such systems, with particular attention to possibilities for better integrating water and wastewater utility functions. This would require an inventory of existing and future system concerns with a special focus on very small and small systems' current infrastructure conditions, problems, and future needs.
7) **Require domestic wells water quality monitoring.** Collection of shallow domestic well water quality data is a promising management practice for identifying and protecting groundwater quality especially for domestic self-supplied households' drinking water needs in areas identified as being at risk for nitrate contamination.

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10 Appendix

10.1 Methods

10.1.1 Susceptibility Charts

Explanations are given below for the population/connections estimates given in the susceptibility breakdown charts (Figure 17, Figure 18, and Figure 19). The number below corresponds to the labeled boxes in the susceptibility breakdown charts.

[1] Total Population: California Department of Finance (CDF) estimates for city-wide populations were combined with US Census population estimates for Census Designated Places (CDP). Average annual county growth rates from the CDF 2007 report were applied to project the CDP population to 2010.

[2] Household Self-Supplied or Local Small Water Systems: All parcels with a parcel use code designated as residential and having one to four residential dwelling units outside of city and water system boundaries and 3.3 people were assumed to be inhabiting each dwelling unit.

[3] Community Public Water System with Only One Well: Public water system information is from the California Department of Public Health's PICME water system database. Data were pulled for all active community and state small systems in the study area with only one well.

[4] Community Public Water System with More than One Well: Public water system information is from the PICME database. Data were pulled for all active community and state small systems in the study area with more than one well delivering water directly to individuals. A system's source was assumed to be a "delivering" source following the method described below. Systems with one well and a treatment plant were also included.

[5] Only Surface Water Sources: Public water system information is from the PICME database. Data were pulled for all active community and state small systems in the study area where all "delivering" sources were surface water. A system's source was assumed to be a "delivering" source following the method described below.

[6] Treating or Blending for Nitrate: A list of systems that treat or blend specifically for nitrate was compiled through personal communication with County Environmental Health departments, individual water systems, and the California Department of Public Health.

[7] Not Treating or Blending for Nitrate: Population and connections from Box #6 was subtracted from Box #4.

[8] High Likelihood of Nitrate in Groundwater: A population range is presented based on the water quality analysis for populations listed in Box #2 and #3. The population estimated to reside in areas where there was exceedance of the nitrate threshold chosen (22.5 mg/L as NO_3^-). The UC Davis Wells Database (CASTING) was used to examine raw nitrate groundwater levels from 1989 to 2010 in all self-supplied

household and local small water systems. The CDPH Water Quality Management (WQM) database was used to examine all raw nitrate groundwater levels from 2006 to 2010 in all community public and state small water systems.

[9] Low Likelihood of Nitrate in Groundwater: A population range is presented based on the water quality analysis for populations listed in Box #2 and #3. The population estimated to reside in areas where there was not exceedance of the nitrate threshold chosen. The UC Davis Wells Database (CASTING) was used to examine raw nitrate groundwater levels from 1989 to 2010 in all self-supplied household and local small water systems. The CDPH WQM database was used to examine all raw nitrate groundwater levels from 2006 to 2010 in all community public and state small water systems.

[10] Nitrate MCL Exceedances: Public water system water quality information is from the CDPH WQM database. A system was assumed to exceed the nitrate MCL (i.e., deliver water to customers that exceeded the nitrate MCL) if the maximum recorded nitrate level from 2006-2010 for any "delivering" source in a system was greater than 45 mg/L as NO_3^-. A system's source was assumed to be a "delivering" source following the method described below.

[11] No Nitrate MCL Exceedances: Public water system water quality information is from the CDPH WQM database. A system was assumed to not exceed the nitrate MCL (i.e., no deliveries of water to customers that exceeded the nitrate MCL) if the maximum recorded nitrate level from 2006-2010 for all "delivering" sources in a system were less than or equal 45 mg/L as NO_3^-. A system's source was assumed to be a "delivering" source following the method described below.

[12] No Nitrate Data: This box contains the community water systems with more than one well (Box #4) that did not contain any water quality data on nitrate levels in PICME's CDPH database from 2006-2010.

10.1.2 Estimating "Delivering" Sources of a System

Often, the "sources" field listed in CDPH's PICME database simply refers to a water quality sample point along the treatment/distribution line, and not necessarily a well. Samples can be taken at the beginning, end or middle of the distribution line. A source can even refer to a treatment plant. There are various methods to determine which sources are actually delivering the recorded water quality to customers and which are merely intermediary points along the treatment/distribution line. The method used in this report is by no means infallible, but it uses a column in PICME that is present and consistent for most systems, and can therefore be used as a rough way to understand the bigger picture. CDPH's PICME database contains a column labeled "ENTITY_INFO" that describes the source. All sources (with the exception of inactive sources) that are labeled as "Treated" were considered to be delivering sources because this designation refers to a point along the distribution system after treatment has occurred. Similarly, all sources (with the exception of inactive sources) that are labeled as "Untreated" were also considered to be delivering because these sources refer to points along the distribution system where treatment has not occurred, but will NOT occur in the future. The sources labeled as "Raw" were not included because these sources will be treated in the future, and are therefore not the final entry point into the distribution line before the water reaches customers. Sources with the following specific codes in the “ENTITY_INFO” column were considered to be delivering sources and their water quality data was assumed to reach customers as listed in PICME:

- AT = Active Treated. Active source after treatment.
- AU = Active Untreated. Active Source that is not treated and will not be treated.
- CM = Combination/Blend Mixed. Blended sources included in this station are both treated and raw or untreated.
- CT = Combination/Blend Treated. Blended sources all treated prior to sample point.
- CU = Combination/Blend Untreated. Blended sources are all untreated and will not be treated using any method prior to delivery.
- DT = Distribution Treated. Sample point within the distribution system, after treatment.
- PT = Purchased Treated. Purchased source water that was treated by the seller.
- PU = Purchased Untreated. Purchased source water that has not and will not be treated.
- ST = Standby Treated. Emergency source that is used less than 15 calendar days per year, with periods not to exceed five consecutive days, and that receives treatment when in use.
- SU = Standby Untreated. Emergency source that is used less than 15 calendar days per year, with periods not to exceed five consecutive days, untreated (CDPH’s PICME Documentation).

A few active community or state small water systems in the study area did not have any sources labeled with the above designations. In these cases, all sources were maintained for the system and were considered to be delivering sources, even if they were labeled as “Raw”.

10.2 Rainwater Cisterns

A rainwater cistern is an underground basin or an above ground barrel or tank that collects and stores rainwater from rooftops or other catchments. Rainwater harvesting has been used for centuries to supply water for household, landscape, and agricultural uses and is currently being applied in locations including Hawaii, Africa, Asia and Australia. Rainwater harvesting relies on dependable rainfall and runoff and is suitable for locations where the average rainfall exceeds 400 mm/year (Lye 2002). A rainwater harvesting system has the following six components: a catchment area or roof, gutters and downspouts, leaf screens and roofwashers, cisterns or storage tanks, conveyance, and water treatment. Within the study area the rainwater will be applied to potable uses that will require proper filtration and disinfection prior to distribution. A rainwater cistern used for potable uses should have durable, watertight exterior and a clean, smooth interior sealed with a non-toxic joint sealant with all materials labeled as FDA-approved. Cisterns may be constructed of plastic, metal, concrete and masonry, or wood. Cistern design depends on the rainfall within the region, the catchment area, and the household’s daily water use. The cistern needs to be properly located to avoid sunlight penetration, maintain a minimum distance of 50 feet from septic fields, and have the proper foundation and support.

The average construction cost is estimated to be $1.48 per gallon of collection capacity; a potable water case study of a 5,000 gallon above ground fiberglass cistern with a 5 micron sediment filter, a carbon cartridge filter and UV light costs about $6,200 (Texas Water Development Board 2005).

Air pollution due to crop dusting and agricultural practices would create water quality problems, as the chemicals and debris left on rooftops would wash off into the cistern with the first rainfall. Another concern would be in the reliability, timing, and volume of the rainfall. As previously mentioned, the Salinas Valley annually receives about 20 inches of rain, and the Tulare Lake Basin annually receives between 7 and 13 inches of rain. The Texas Rainwater Harvesting Manual estimates a production of 600 gallons of water for every inch of rain over a 1,000 square foot catchment area, that would yield an annual amount of 12,000 gallons of water per household (32 gallons per day) within the Salinas Valley and an annual amount between 4,200 and 7,800 gallons of water per household (11 to 21 gallons per day) within the Tulare Lake Basin, assuming the average catchment area of 1,000 square feet. The inconsistency and unreliability of the distribution pattern of this source would not be a sufficient supply for a household to depend on for potable water.

Overall, public health and water quality seem likely to be the greatest impediment to the use of cisterns as a replacement water supply. Costs can be high, even though water yields are likely to be adequate for drinking and cooking water.

10.3 Glossary

Census Block	The smallest geographic unit used by the US Census for tabulating data collected from all households within a region. They are formed by streets, roads, railroads, streams and other bodies of water, other visible physical and cultural features, and the legal boundaries shown on Census Bureau maps. (US Census)
Census Block Group	A cluster of census blocks and a subdivision of a census tract. Census block groups generally have between 600 and 3,000 people. On average there are 39 blocks in a block group. (US Census)
Census Tract	Small, relatively permanent statistical subdivisions of a county delineated for most metropolitan areas and other densely populated counties by local census statistical areas committees. Census tracts usually have between 2,500 and 8,000 persons and, when first delineated, are designed to be homogeneous with respect to population characteristics, economic status, and living conditions. (US Census)
Census Designated Place (CDP)	Areas delineated for each decennial census as the statistical counterparts of incorporated places. CDPs are created to provide data for settled concentrations of population that are identifiable by name but are not legally incorporated under the laws of the state they are located. (US Census)
Community Public Water System (CPWS)	A public water system that serves at least 15 service connections used by yearlong residents or that regularly serves at least 25 yearlong residents of the area. (CDPH)
Disadvantaged Community (DAC) – Block Group	A block group that has a Median Household Income (MHI) of less than 80% of the State of California's Median Household Income.
Household Self-Supplied Water System	A water system that is not connected to a public water system, is assumed to be 1 to 2 dwelling units (or connections), and is considered a domestic well.
Local Small Water System	A water system with 2 to 4 connections.
Local Primacy Agency (LPA)	County environmental health jurisdiction that has applied for and was granted regulatory authority over small community and non-community public water systems in their county. (CDPH)
Maximum Contaminant Level (MCL)	Enforceable drinking water regulations established to protect the public against consumption of drinking water contaminants that present a risk to human health. (U.S. EPA)
Median Household Income (MHI)	The amount that divides the income distribution into two equal groups, half having income above that amount, and half having income below that amount. It is the sum of money received in the calendar year by all household members 15 years of age or older,

	including unrelated household members. (US Census)
Non-Transient Non-Community public water system (NTNC)	A public water system that is not a community public water system and that regularly serves at least 25 of the same persons over 6 months per year. (CDPH)
Permits, Inspection, Compliance, Monitoring, and Enforcement (PICME)	The PICME database maintained by the Drinking Water Program of the California Department of Public Health and containing information related to the regulation of public drinking water systems subject to the federal and California Safe Drinking Water Acts. (CDPH)
Public Water System (PWS)	A system for the provision of water for human consumption through pipes or other constructed conveyances that has 15 or more service connections or regularly serves at least 25 individuals daily at least 60 days out of the year. PWSs are regulated under the Safe Drinking Water Act. (CDPH)
State Small Water System (SSWS)	A system for the provision of piped water to the public for human consumption that serves at least five, but no more than 14, service connections and does not regularly serve drinking water to more than an average of 25 individuals daily for more than 60 days out of the year. SSWSs are not regulated under the Safe Drinking Water Act.
Susceptibility	The potential for the residential population to consume drinking water above the nitrate MCL.
Transient Non-Community public water system (TNC)	A non-community public water system that does not regularly serve at least 25 of the same persons over 6 months per year. (CDPH)
Vulnerability	The potential for a system to deliver water with high nitrate levels if nitrate contamination occurs at a source. A function of the type of system. Classified as higher, lower, or no vulnerability depending on the source of water and the number of system water sources.
Water Quality Management (WQM)	The WQM database contains one record for each CPWS per quarter and year with average concentrations of nitrate as well as the frequency of sampling, the number of sampling stations, and the date of the last sample.

11 Case Studies

CITY OF LINDSAY

Phone Conversation with Public Works Director, Mike Camarena (5/19/11)

The City of Lindsay's main water supply today is treated surface water from the Friant Kern Canal. They have some groundwater wells, but they prefer to use the surface water due to groundwater quality issues (groundwater sources contain nitrate, but do not exceed the MCL). The City has a long-term contract with the United States Bureau of Reclamation (USBR) for a set amount of water to be delivered costing $225/af (the contract was signed in 2006). The City is currently helping Paige-Moore Tract by supplying them with water, but the current water treatment plant was built at a specific capacity and the City is starting to have issues with maxing out capacity. They have to chlorinate the raw water from the canal prior to filtration and this initial and final chlorination process is causing disinfection byproducts (DBPs) to contaminate the supply. The facility needs to be expanded to allow the water to sit for a long enough detention time and allow the chlorine to properly disinfect the water. The City of Lindsay is applying for SRF funding for either a new, bigger contact tank or an alternative disinfectant, the total cost is estimated at $300,000 to $400,000. The City will not be funding the distribution or pipeline costs for El Rancho or Tonyville, but they have to apply for SRF funding to connect to the system. The Tonyville application had just been rejected. It is hard for the City to incorporate neighboring communities, even though they want to help because they need to do what is best for their future growth and they must preserve their best interest. Currently within the City of Lindsay, it is policy to charge double the cost of water to anyone served outside of the city limits. This double charge allows for the City to help fund their system and prepare for future growth. **13.04.300 (City Code) – Service Outside City: All water services outside the city limits are subject to council approval, and shall pay twice the applicable monthly rates. (Ord. 329 § 5-5.1974)

Since some of these smaller communities outside of city limits cannot afford to pay double rates, they may have to obtain council approval to try to lower that value. The City is a metered water system and anyone who is connecting must be metered as well. They do not have block water rates. Also, for the City to include Tonyville and El Rancho they must alter their contract with USBR and increase the allotment of Friant Kern Canal water they receive.

LEMON COVE WATER COMPANY

Phone Conversation with Bill Pensar (5/23/11)

They received Prop 84 Safe Drinking Water funding back in 1991 for a new well at Mateas Point; they have been experiencing nitrate fluxes over the past 20 years. The nitrate concentrations have gone up to 100 mg/L as nitrate and then down to below the MCL and then back up to 100 mg/L. In late October of 2008, they applied for funding for a Feasibility Study to drill a new well. They were accepted for loans, but want grant money. Their application was just recently re-submitted. The feasibility study will cost about $200,000 and drilling a new well will cost about $100,000. They are hoping that the study will also cover expenses for a new tank that can be built up on a hill and can pump at night utilizing the cheap energy costs and gravity driven distribution. The new well will be in a location that is closer to them than the existing well so they will not have to install pipeline or increase the distribution mains. They believe drilling a new well is the best option, avoiding the need for brine disposal associated with treatment, purchasing or filing a new license, hiring an operator or participating in a lot of O&M activities. They are under the impression that RO is outrageously expensive and they are worried about disposing the brine back into the TLB. The cost of trucking the brine to a remote location is too expensive as well.

PLAINVIEW MUTUAL WATER COMPANY: Leaky Distribution Lines and Contaminated Back-Up Well

Plainview Mutual Water Company provides drinking water to around 800 people in the unincorporated area of Plainview, Tulare County (CWC 2011b). When one of their wells was shut down because nitrate levels started to exceed the MCL, Plainview was forced to rely on their only other well. This second well had recorded concentrations of DBCP (CWC 2011b). The distribution mains for this area were installed in 1941 and severe rusting and leakage issues caused bacterial contamination of the drinking water being supplied to the homes (Doan 1995). A flat rate of $25 per month was charged to these households (Doan 1995) whose median income in 1997 was only $12,000. Funds raised by the water company were not enough to adequately maintain the water system or to protect the water; many households were left to struggle to finance their own in home chlorine treatment for the bacteria (Doan 1995). Plainview Mutual Water Company was able to secure $2.3 million from federal and state sources to replace their distribution system and build a new well. This tremendous sum could have never been financed by such a small disadvantaged community.

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CITY OF TUCSON: “Brown Water” Produced After Switching from Groundwater to Surface Water

With the enactment of Arizona’s Groundwater Management Act in 1980, the City of Tucson was required to achieve a safe yield by appropriately balancing groundwater withdrawals with recharge (University of Arizona 1998). This mandate led to the city’s adoption of a 110-year water plan that mapped out a strategy to serve 95% of the population with surface water from the Central Arizona Project (CAP) by 1995 (ADWR 1999). By 1992, the surface water treatment plant was constructed and the city began delivering treated CAP water to 60% of its municipal customers (ADWR 1999). The salts, which had built up inside of the pipes over the years that groundwater was distributed, were released due to the sudden change in pH (attributable to the surface water). Suddenly, households were receiving brown water. Municipal delivery of the surface water was halted in 1994 due to the poor water quality and concerned residents. Later, it was revealed that the utility was only replacing pipes at a rate of 0.5 percent per year (typical rates are 3 – 5%) (ADWR 1999).

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