The Otter Project
www.otterproject.org

475 Washington Street, Suite A
Monterey, CA 93940
831/646-8837

August 30, 2012

Jeanine Townsend, Clerk to the Board
State Water Resources Control Board
1001 I Street, 24th Floor
Sacramento, CA 95814

Via E-mail: jbashaw@waterboards.ca.gov; commentletters@waterboards.ca.gov

Re: Requests for Stay, SWRCB/OCC FILES A-2209(a)-(e)

Dear Mr. Lauffer, Ms. Bashaw, Ms Townsend, Water Board Staff and Board Members:

This document and attachments are submitted on behalf of designated parties Monterey Coastkeeper (a program of The Otter Project), San Luis Obispo Coastkeeper, and Santa Barbara Channelkeeper.

Pursuant to the State Water Resources Control Board's August 21, 2012 Revised Notice, Petitioners Monterey Coastkeeper, San Luis Obispo Coastkeeper, and Santa Barbara Channelkeeper (collectively "Environmental Petitioners") submit this additional written response opposing the requests by various agricultural interests to stay implementation of Order No. R3-2012-0011, R3-2012-0011-01, R3-2012-0011-02, and R3-2012-0011-03. In Environmental Petitioners view, more environmentally protective conditions on growers in the Central Coast are long overdue and there is no basis in law or fact to delay implementation of the new waiver order.

INTRODUCTION

The requests by Petitioners Grower-Shipper Association of Central California, et al, Petitioners California Farm Bureau Federation, et al., Petitioners Ocean Mist Farms and RC Farms, and Petitioners Jensen Family Farms, Inc. and William Elliott (collectively "Agricultural Petitioners") for an immediate stay of Order No. R3-2012-0011 ("Order"), adopted by the Central Coast Regional Water Quality Control Board ("Regional Board") on March 15, 2012, after nearly four years of extensive – indeed, unprecedented – public process, should be denied because these requests do not satisfy any of the three criteria set forth in title 23, section 2053 of the California Code of Regulations. First, Agricultural Petitioners have not demonstrated that they will suffer substantial harm in the absence of a stay; the fact that some growers may incur modest costs to comply with the Order's first incremental steps over the course of the next year or two does not justify a stay of the Regional Board's long-overdue effort to begin bringing agricultural dischargers into compliance with the Porter-Cologne Act. Second, the record is unambiguous that the discharges subject to the Order are currently causing substantial harm to water quality, public health, and the ecosystem and that the Regional Board's ongoing measures to encourage voluntary pollution reduction have been largely unsuccessful. Although the Order certainly will not stop all harm posed by agricultural discharges, timely implementation of its initial requirements is critical to laying the groundwork for future reductions in the most egregious pollution and will inform viable management practices and solutions in the following years. The Order's provisions build upon the initial monitoring and reporting requirements. Finally, the petitions for review filed by agricultural interests do not raise substantial questions of law or fact regarding the Order.

Agricultural Petitioners obviously disagree with the Regional Board's ultimate policy choice, but the various constitutional and procedural arguments raised in their petitions have no legal merit. Accordingly, a stay of the Order or any provision within the order is entirely inappropriate.

QUESTIONS ASKED IN THE REVISED NOTICE

Environmental Petitioners submit this additional response to the issues raised in the "Revised Notice." This response is in addition to responses filed separately on July 13, 2012 by Monterey Coastkeeper/The Otter Project (Attachment 1) and the Environmental Law Clinic at Stanford University (Attachment 2).

You seek information regarding cost estimates, and explanation of the benefits to the environment of the irrigated lands regulatory program. We address these in turn.

Cost of compliance through the end of 2013.

As explained more thoroughly in our initial submission regarding the request for a stay, the cost of coming into compliance with the Porter Cologne Act does not impose an unreasonable burden or support a stay request. As explained in our earlier submission, annual food crop production in the four major Central Coast agricultural counties is valued at well over *six billion dollars*. Yet the impacts from the lack of sufficient regulation are severe, continuing, and getting worse.

The petitions filed by the agricultural interests claimed that implementation of the 2012 Agricultural Order would have high costs, but both the Environmental Petitioners and the Central Coast Regional Water Quality Control Board debunked those claims, both as to amount and immediacy. We attach our earlier submission hereto for your convenience, and refer you specifically to pages two to three of Attachment 1 and nine through sixteen of Attachment 2 for the analysis of the bloated and immaterial cost information put forward by the agricultural interests. In summary our review of the Agricultural Petitioners' stay request and declarations suggest:

- In arguing for a stay, Agricultural Petitioners both fail to provide credible quantitative analysis or other evidence to support their expense estimates and ignore the critically important context for their self-serving estimation of compliance costs (Environmental Petitioners' Opposition to Request for Stay (Attachment 2) at Pg 10 ¶ 2);

- Using the Agricultural Declarants' own inflated cost estimates, the cost of compliance for the top three ranked crops in Monterey County are:
  - i. Leaf lettuce: 1.3-2.5% of gross crop revenues per acre
  - ii. Strawberries: **.**13 - **.**30% (note decimal)
  - iii. Head lettuce: .8 – 1.5%

  (The Otter Project/Monterey Coastkeeper Opposition to Request for Stay (Attachment 1) at Pg 2 ¶ 6);
- The Barbeau Report submitted by the Agricultural Petitioners methodological biases, questions, errors, and uncertainties are reflective of the study's serious limitations as scientific analysis and render its conclusions – though nicely packaged in precise-looking charts and graphs – virtually meaningless for purposes of the Agricultural Petitioners' stay request. In fact, the report actually demonstrates how grower self reporting – of the same kind contained in the declarations submitted by Agricultural Petitioners – is inherently inaccurate and unreliable (Environmental Petitioners Opposition to Request for Stay (Attachment 2) at Pg 15 ¶ 3).
- Agricultural Petitioner declarations by Mr. Johnson and Mr. Suverkrupp offer estimates for development of a data quality assurance plan or QAPP. They offer estimates of $28,800 and $17,000 per ranch respectively, while the CCRWQCB staff estimates a cost of $750 using a QAPP template. Adaptable QAPP templates are readily available online for free (The Otter Project/Monterey Coastkeeper Opposition to Request for Stay (Attachment 1) at Pg 2 ¶ 7).

Should the agricultural interests submit new information regarding costs, we respectfully request the opportunity to provide a response at the hearing on August 30, 2012.

Benefit to the Environment or the Irrigated Lands Regulatory Program

Annual compliance form reporting

As stated in the Order, "The purpose of the electronic Annual Compliance Form is to provide up-to-date information to the Central Coast Water Board to assist in the evaluation of affect on water quality from agricultural waste discharges and evaluate progress towards compliance with this Order, including implementation of management practices, treatment or control measures, or changes in farming practices." Clearly, beginning to report compliance marks the beginning of the entire program and delaying reporting is delaying compliance.

The annual compliance form will track implemented management practices such as nutrient management, vegetated buffers, engineered wetlands, changes in irrigation practices, and partnerships within watersheds or with agencies. Knowing what management practices are implemented together with monitoring results will not only provide immediate feedback but will serve to guide the program for years to come. The immediate feedback can be used to help fine tune practices for both near- and long-term environmental and water quality benefit.

The information gained can be used to assess and compare the benefit of various implemented practices to help growers select less costly alternatives and lessen the costs of the program. Partnerships – with neighbors and/or agencies – to implement regional solutions such as vegetated buffers and engineered wetlands can also be evaluated.

The 2004 Agricultural Order, which would presumably be in place during a stay, has not resulted in cleanup of pollution. It has instead resulting in the worsening of conditions. As stated in Finding 5 of the Order:

> "Since the issuance of the 2004 Agricultural Order, the Central Coast Water Board has compiled additional and substantial empirical data demonstrating that water quality conditions in agricultural areas of the region continue to be severely impaired or polluted by waste discharges from irrigated agricultural operations and activities that impair beneficial uses, including drinking water, and impact aquatic habitat on or near irrigated agricultural operations. The most serious water quality degradation is caused by fertilizer and pesticide use, which results in runoff of chemicals from agricultural fields into surface waters and percolation into groundwater. Runoff and percolation include both irrigation water and stormwater."

Clearly, the 2004 Agricultural Order does not adequately address the serious agricultural pollution issues facing the Central Coast. As examples, the 2004 does not address or prioritize nutrient loading or groundwater pollution. And because the pollution is ongoing, delay in the implementation of even the incremental increases in monitoring and compliance form reporting would threaten both public health and the environment.

Throughout the nearly four-year debate over the renewal of the Irrigated Lands Regulatory Program, transparency was the most contentious issue. Agricultural representatives consistently argued that individual monitoring and compliance information be shielded and only reported in aggregate. The Regional Board concluded that individual reporting is both required by state law and good policy: Individual reporting, in the form of compliance forms, begets accountability and accountability is the most fundamental principal of any regulatory program.

Delaying reporting is delaying compliance and any meaningful steps to address the impacts to the environment from agricultural pollution.

Determination of nitrate loading risk factors, determination of total nitrogen applied

As stated in Finding 6 of the Order:

> "Nitrate pollution of drinking water supplies is a critical problem throughout the Central Coast Region. Studies indicate that fertilizer from irrigated agriculture is the largest primary source of nitrate pollution in drinking water wells and that significant loading of nitrate continues as a result of agricultural fertilizer practices. Researchers estimate that

tens of millions of pounds of nitrate leach into groundwater in the Salinas Valley alone each year. Studies indicate that irrigated agriculture contributes approximately 78 percent of the nitrate loading to groundwater in agricultural areas. Hundreds of drinking water wells serving thousands of people throughout the region have nitrate levels exceeding the drinking water standard. This presents a significant threat to human health as pollution gets substantially worse each year, and the actual numbers of polluted wells and people affected are unknown. Protecting public health and ensuring safe drinking water is among the highest priorities of this Order. This Order prioritizes conditions to control nitrate loading to groundwater and impacts to public water systems. In the case where further documentation indicates nitrate impacts to small water systems and/or private domestic wells, the Central Coast Water Board will consider proximity to impacted small water systems and private domestic wells for inclusion in tiering criteria."

This finding is based upon the Central Coast Regional Board, *Water Quality Conditions in the Central Coast Region Related to Agricultural Discharges* at 4 (March 2011), available at http://www.waterboards.ca.gov/rwqcb3/ board_info/agendas/2011/march/ Item_14/ 14_att7.pdf.

Since the publication of the Conditions Report, we have learned that the contribution of irrigated agriculture to nitrate pollution and the threats to public health are even greater than stated by the Regional Board. The "Main" U.C. Davis report is included here as Attachment 3 and the full report can be found at http://groundwaternitrate.ucdavis.edu/. The report states:

"Nitrate in groundwater poses two major problems and risks:

- Public health concerns for those exposed to nitrate contamination in drinking water; in California's Tulare Lake Basin and Salinas Valley, roughly 254,000 people are currently at risk for nitrate contamination of their drinking water.
- Financial costs of nitrate contamination include additional drinking water treatment, new wells, monitoring, or other safe drinking water actions; over 1.3 million people are financially susceptible because nitrate in raw source water exceeds the MCL, requiring actions by drinking water systems."

In addition to the public health risk posed by nitrates in groundwater are the environmental consequences. On the Central Coast there is little difference between ground and surface water: Ground water is pumped for irrigation and the tailwater becomes surface water. In "A review of nitrate toxicity to freshwater aquatic species" (Attachment 4) the New Zealand National Institute of Water & Atmospheric Research recommended nitrate (as N) concentrations ranging from 1.0 to 3.6 mg NO3-N/L for chronic exposures. Species such as rainbow trout, endemic to the Central Coast, were included in the review. Numerous studies back up these findings.

As detailed in the Conditions Report, monitoring results, and 303(d) list, nitrate and nutrients are a predominant impairment to Central Coast surface waters. Nutrient pollution is ongoing and any delay in curbing nitrogen and nitrate loading constitutes harm to the environment. Determining risk factors and total nitrogen applied are fundamental to bringing fertilizer applications in balance with crop requirements.

Understanding nitrate loading risk factors and total nitrogen applied, together with water quality monitoring (individual and group), and implemented management practices such as nutrient management, vegetated buffers, engineered wetlands, changes in irrigation practices, and partnerships within watersheds or with agencies will provide a more complete picture of how agriculture dominated watersheds function and respond. Knowing nitrogen applications together with what management practices are implemented and monitoring results will not only provide immediate feedback but will serve to guide the program for years to come. The immediate feedback can be used to help fine tune practices for both near- and long-term environmental and water quality benefit. Partnerships – with neighbors and/or agencies – to implement regional nutrient solutions such as vegetated buffers and engineered wetlands can also be evaluated.

The determination of nitrate loading risk factors and the determination of total nitrogen applied will be instrumental in determining how best to protect groundwater from excess nitrates, and what steps can be taken to address the risks that already harmful groundwater is not used for drinking or applied to crops in places and in a manner that can contribute to downstream nitrate impacts. Any delay in these determinations, particularly for a full growing season, will only allow the problem to worsen, resulting in increased risks to public health and the environment, and increased costs later.

An unnecessarily large proportion of the people in the Central Coast region are forced to purchase bottled water at great expense as a result of nitrate contamination in groundwater. Better assessment of risks and determination of where nitrates are being applied, can result in clear steps toward cleaning up the problem and allowing people to resume use of groundwater for drinking. This avoided cost must be considered in the calculus regarding whether to delay implementation of the order.

Individual surface water discharge monitoring and reporting:

Individual surface water discharge monitoring and reporting is intended to provide necessary information about those few dischargers that pose the greatest and most significant threat to water quality. This information will enable the Regional Board to target future analyses and work toward developing best management practices narrowly tailored to address the actual discharges rather than the assumed. The collection of this data is key to the near term steps the Regional Board will take to address water quality concerns, and essential to the long-term success of irrigated lands program.

Specifically, individual monitoring is required of Tier 3 growers (Condition 17):

"Tier 3 – Applies to all Dischargers whose individual farm/ranch meets one of the following sets of criteria (3a) or (3b):

3a.Discharger grows crop types with high potential to discharge nitrogen to groundwater (as defined in Attachment A) at the farm/ranch, and farm/ranch total irrigated acreage is greater than or equal to 500 acres;

3b.Discharger applies chlorpyrifos or diazinon at the farm/ranch, and the farm/ranch discharges irrigation or stormwater runoff to a waterbody listed for toxicity or pesticides on the 2010 List of Impaired Waterbodies (Table 1)."

In other words, individual monitoring is required of growers who apply the largest amounts of nutrients or specific pesticides and discharge into a waterbody impaired by these specific constituents. The reasonable requirement of individual monitoring and reporting applies only to those growers potentially discharging impairment causing constituents into impaired waters. Nothing could be more appropriate.

The monitoring will provide benefits to the environment by allowing the assessment of various on-farm practices sufficient to ensure scientifically rigorous development of best management practices. Further, it will provide the necessary information to focus attention on "hot spots" or areas with the greatest potential environmental degradation or risk to human health.

The monitoring will also provide necessary information about the effectiveness of the program, the level of compliance, the success of management practices, and build the data set necessary to implement the irrigated lands regulatory program more effectively.

Toxicity is a huge problem in the Central Coast region: The SWRCB report "Summary of Toxicity in California Waters: 2001 – 2009" (Attachment 5) shows that 22-percent of Central Coast surface waters are "highly toxic" (the highest percentage in the state) and that a total of 56-percent test "toxic" (second only to the Central Valley). But toxicity is an area where the Order will have immediate and measurable results.

The most common constituents of toxicity in Central Coast waters are Diazinon and chlorpyrifos, (agricultural pesticides) as detailed by the Toxicity Report and Central Coast monitoring results. But the good news is that both of these chemicals degrade quickly. According to the CDC the half-life of Diazinon "ranges from approximately 70 hours to 12 weeks in surface water and 10 to 200 days in soil." (www.atsdr.cdc.gov/toxguides/toxguide-86.pdf). The half-life of chlorpyrifos is reported as 11-141 days in aerobic soils and 80-100 days in water (http://pmep.cce.cornell.edu/profiles/extoxnet/carbaryl-dicrotophos/chlorpyrifos-ext.html).

Clearly, with such short half-lives of Diazinon and chlorpyrifos, improvement in water quality can come quickly and any delay of the monitoring and reporting requirement will lead to environmental harm.

Consistently throughout the nearly four year public process, the Environmental Petitioners advocated for a shorter timeline than what is expressed in the adopted order for the reduction of toxicity in surface waters. The Environmental Petitioners believe all surface waters should no longer be toxic within the five year term of this Order. This is a feasible and worthy goal, but it will only become more elusive if the monitoring and reporting in the Order is delayed or implementation fragmented.

It is important to note that not all dischargers initially in Tier 3 will remain in Tier 3 or will be required to conduct and report individual monitoring. Provisions are in place for growers to organize into watershed groups and/or form partnerships with neighbors and agencies. Partnerships may be particularly warranted in situations where a regional solution could be effective such as engineered wetlands, in-channel wetlands, or vegetated buffers. Watershed group and partnership solutions may be able to forego individual monitoring and conduct project efficacy monitoring instead.

IN CONCLUSION

Although the Order certainly will not stop all harm posed by agricultural discharges, timely implementation of its initial requirements is critical to laying the groundwork for future reductions in the most egregious pollution. The Order's provisions build upon the initial monitoring and reporting requirements highlighted in the Revised Notice and discussed in this letter. Granting any stay to all or part of the Agricultural Order will result in continued immediate harms to public health and the environment.

Sincerely,

Steve Shimek
Monterey Coastkeeper

Cc:
Deborah Sivas, Leah Russin, Alicia Thesing
Stanford Environmental Law Clinic

Ben Pitterle, Kira Redmond
Santa Barbara Channelkeeper

Gordon Hensley
San Luis Obispo Coastkeeper

Attachment 1

The Otter Project
www.otterproject.org

475 Washington Street, Suite A
Monterey, CA 93940
831/646-8837

July 13, 2012

Jeannette L. Bashaw, Legal Analyst
Office of Chief Counsel
State Water Resources Control Board
1001 I Street, 22nd Floor [95814]
P.O. Box 100
Sacramento, CA 95812-0100

Via E-mail: jbashaw@waterboards.ca.gov

Re: Requests for Stay, SWRCB/OCC FILES A-2209(a)-(e)

Dear Mr. Lauffer and Water Board staff,

Thank you for the opportunity to address the "Stay Request" and "Request for Hearing" presented by various growers and grower affiliated associations in regards to the Central Coast Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands, Order Numbers R3-2012-0011, R3-2012- 0011 -01, R3-2012-0011-02, R3-2012-0011-03, and resolution R3 -2012-0012 (collectively referred to here as the "Ag Waiver"). This letter represents a "policy statement" offered by Monterey Coastkeeper (Monterey Coastkeeper is the water quality program of The Otter Project); a more comprehensive legal response will be submitted on our behalf by the Stanford Environmental Law Clinic.

The Monterey Coastkeeper does not believe a stay is appropriate or warranted in any way and we request that a hearing not be granted and the request for stay be summarily dismissed.

The Monterey Coastkeeper has been a very active participant in the Central Coast Ag Waiver process. We followed and spoke in favor of the first 2004 Ag Waiver. In 2008, we were asked by the Central Coast Regional Water Quality Control Board (CCRWQCB) to participate in the Agricultural Stakeholders Group and we attended each monthly meeting, except for one, for nearly two years. We also attend nearly every CCRWQCB meeting and we have attended every hearing related to the Ag Waiver. We have offered comment and presentations on many occasions. When the growers walked out of the SWRCB facilitated CCRWQCB stakeholder process, The Monterey Coastkeeper advocated for a renewed process, supported by the Packard Foundation and facilitated by Judge Richard Silver (ret.).
The Ag Waiver process was lengthy and deliberate. The CCRWQCB convened a stakeholder panel in November of 2008, over six months before expiration of the 2004 Ag Waiver in July of 2009. In July 2009 the Ag Waiver was extended for a year in order to give the stakeholder group more time to work. After the stakeholder group disintegrated in November 2009, the CCRWQCB staff released a draft order on February 1, 2010. In April 2010 three whole-cloth alternatives were offered, including an alternative from the environmental caucus group Monterey Coastkeeper was part of and an alternative championed by the California Farm Bureau Federation. Immediately, rumors spread that another alternative, again championed by the Farm Bureau Federation, had been drafted by growers. That alternative was not formally offered until December 2010; and then it was offered as a work in progress. At nearly every subsequent meeting CCRWQCB Board meeting and Ag Waiver hearing the Ag Alternative morphed into something new; the Ag Alternative was a moving target impossible to comment on

because it kept changing. The CCRWQCB staff proposal responded to the Alternative's gyrations by incorporating some of agriculture's language and ideas; the result being that each CCRWQB staff proposal becoming less protective of public health and the environment, requiring less of the agricultural community, and applying to fewer and fewer growers. Two years and eight months after the expiration of the original 2004 Ag Waiver, a new Ag Waiver, staff iteration five, was finally adopted.

With the exception of ground water monitoring, Tier 1 growers will have fewer requirements than in the 2004 Ag Waiver. With the exception of ground water monitoring, Tier 2 growers will have about the same requirements. And Tier 3 growers, estimated to be just a few more than 100 farms, will have slightly greater requirements.

The various growers and affiliated associations base their stay request on three points:

1. They will be financially harmed
2. The public or the environment will not be harmed
3. There were various errors in the process that warrant delay.

We disagree, and will address each of these points in order.

1. <u>The growers will not be harmed</u>

    a. <u>Cost per acre</u>. The growers claim they will somehow be harmed by the costs of complying with the Ag Waiver. It must be noted that the declarations in support of the stay are from the major growers in the Salinas and Santa Maria Valleys and are far from representative of all growers. Except for one, they all have tier 3 lands; tier 3 lands and crops have a disproportionate impact on water quality and consequently are asked to do more to reduce or mitigate their impacts. The growers offering declarations provide absolutely no support for their annual cost-per-acre estimates of compliance through December of 2013 and the estimates vary widely:

        i. Grower estimate for Tier 2: $46/acre - $212/acre. m= $105
        ii. Grower estimate for Tier 3: $110/acre - $310/acre. m=$197

    The cost of compliance for the top three ranked crops in Monterey County[1] are:

        i. Leaf lettuce: 1.3-2.5% of gross crop revenues per acre
        ii. Strawberries: .13 - .30% (note decimal)
        iii. Head lettuce: .8 – 1.5%

    The growers maintain in their request that these costs cannot be passed on to buyers and consumers. We simply disagree with this unsupported assertion. These unsupported and wildly disparate cost estimates, from those with the most to lose, are insufficient justification to invalidate over three years of unprecedented regional effort.

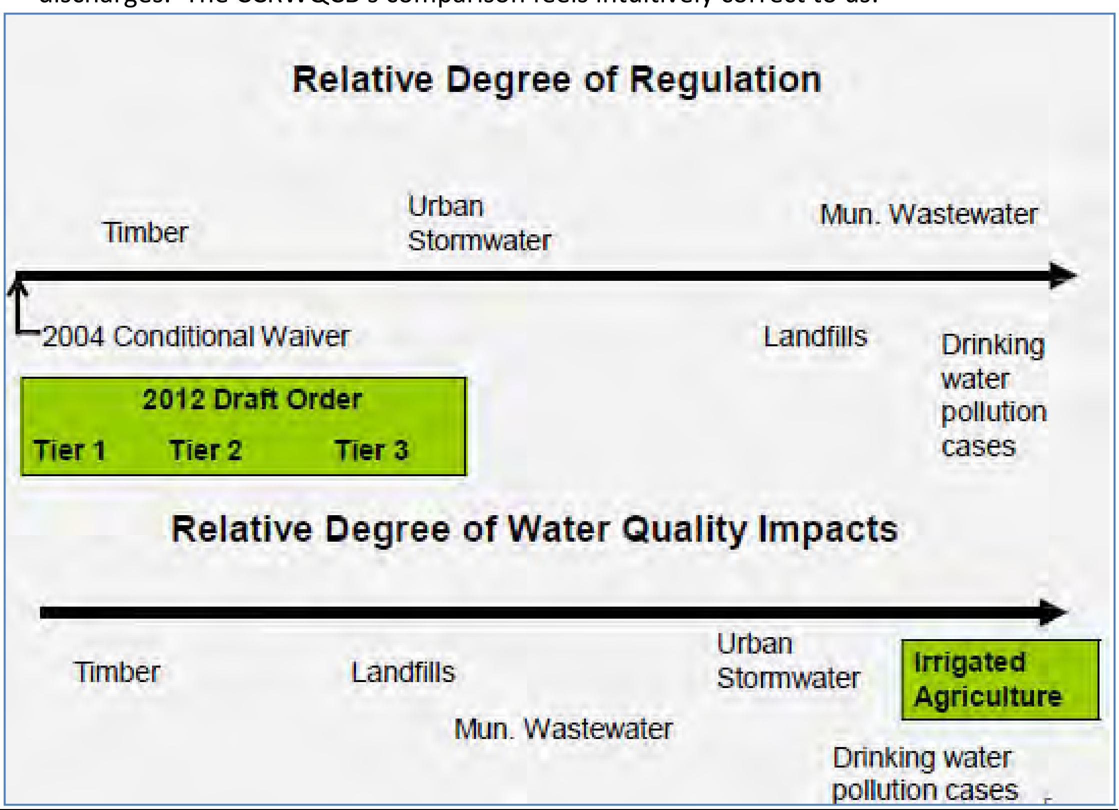
    b. <u>Data Quality assurance costs</u>. Declarations by Mr. Johnson and Mr. Suverkrupp offer estimates for development of a data quality assurance plan or QAPP. They offer estimates of $28,800 and $17,000 per ranch respectively, while the CCRWQCB staff estimates a cost of $750 using a QAPP template. The SWRCB website offers a template

[1] Cost of compliance was calculated by using the mean cost per acre divided by the gross revenue per acre. Gross revenue per acre was calculated using data found on pg 6 of the Monterey County Agricultural Commissioner's 2011 Crop Report found at http://ag.co.monterey.ca.us/assets/resources/assets/252/cropreport_2011.pdf.

and video tutorial at http://swamp.waterboards.ca.gov/swamp/qapp_advisor/ . The USEPA offers another free template at http://www.epa.gov/glnpo/quality/training/handouts/HO_QAPP_template_062310.pdf. The Otter Project has used these templates and was able to create a useful QAPP in less than two days.

c. Sampling costs. Mr. Suverkrupp offers in his declaration that any grower using Diazinon or chlorpyrifos will have monitoring costs of $7000 to $11,000. No basis is given for this calculation as to number of monitoring sites, acreage, or whether there is even any tailwater to monitor. If Mr. Suverkrupp is referring to the cost of the lab test, it should be noted that the CCRWQCB staff requested lab costs from a variety of labs throughout the region and found that the additional cost to test for Diazinon and chlorpyrifos (both organophosphates) to be $250. Tier 3 growers are required to sample four times per year for a cost of $1000.

We do not believe that unsubstantiated and wildly varying costs estimated by a small slice of the growers representing the greatest threat to water quality constitute real harm. Further, we feel that the cost of compliance must be measured against the burden experienced by other dischargers asked to step up and protect water quality. The Otter Project/Monterey Coastkeeper has a range of experience working with Phase 1 and Phase 2 municipal stormwater, Combined Animal Feed Operation ("CAFO"), aquaculture and aquarium, timber, and Areas of Special Biological Significance ("ASBS") dischargers. Throughout the CCRWQCB Ag Waiver process, CCRWQCB staff offered a comparison of the relative degree of regulation and relative degree of water quality impacts of various discharges. The CCRWQCB's comparison feels intuitively correct to us:



Specifically in our discussions with stormwater and ASBS dischargers we have repeatedly heard "Why are we being required to do so much while agriculture is allowed to pollute our water?" Monterey City Manager Fred Meurer requests the CCRWQCB Board: "keep in mind striking a reasonable balance between what you are requiring the urban areas to do under their storm water NPDES permits and the pollutant loads resulting from urban areas and the pollutant loads that are received from agricultural lands." Meurer further states: "Both the agricultural interests and the municipal permittees should be held to the same Maximum Extent Practicable (MEP) standard." (see attachment from City of Monterey). Burden must be shared and it is past time agriculture be regulated commensurate with its impact on water quality.

2. The public will not be harmed

   a. Public health. After over three years of shared experience, the grower declarants inexplicably claim: "I have not received any information that suggests interested persons or the public interest will be substantially harmed if a stay is granted, and on that basis, I believe that a stay will not cause substantial harm to interested persons or to the public interest." (Huss and Sites declarations). Growers, environmentalists, and environmental justice advocates all heard the repeated statements of farm workers and rural residents suffering rashes, hair loss, gastro-intestinal upset, and sickness from drinking from groundwater sources. The California Department of Public Health (CDPH) is supportive of the CCRWQCB Ag Waiver because it addresses public health threats (see attachment). The CDPH states: "Protection against continued nitrate contamination of the groundwater in the Central Coast region will minimize the need for additional treatment of public water supply sources from this contaminant which poses a significant public health threat." And although it was distributed the day before the March 14 hearing, we simply cannot ignore the UC Davis groundwater report.[2] That report states:
      i. "Public health concerns for those exposed to nitrate contamination in drinking water; in California's Tulare Lake Basin and Salinas Valley, roughly 254,000 people are currently at risk for nitrate contamination of their drinking water."
      ii. "Financial costs of nitrate contamination include additional drinking water treatment, new wells, monitoring, or other safe drinking water actions; over 1.3 million people are financially susceptible because nitrate in raw source water exceeds the MCL, requiring actions by drinking water systems."

   Public health and welfare are being harmed and future generations will be harmed if agricultural discharges are not abated and water quality not improved.

   b. Environment. Many regularly sampled monitoring sites test toxic to *Ceriodaphnia dubia* (invertebrate toxicity of water) and *Hyalella azteca* (invertebrate survival in sediment) every single test.[3] *Hyalella azteca* is native to Central Coast waters leaving little doubt that Central Coast aquatic habitats are impacted. The pesticides currently in use and impacting Central Coast waters are Diazinon and chlorpyrifos, both restricted use

[2] UC Davis Report for the SWRCB SBX2 1 Report to the Legislature found at http://groundwaternitrate.ucdavis.edu/

[3] Central Coast Ambient monitoring data and Cooperative Monitoring Program data can be found at www.ccamp.org. Referenced data can be viewed by selecting data browser and then selecting from the dropdowns: either Salinas (309) or Santa Maria (312), toxicity, and then the referenced analyte.

pesticides only available for commercial application. Both pesticides degrade in a matter of weeks or a few months and if discharge of these toxic chemicals is abated, harm will decrease immediately. Continued failure to regulate will result in continued harm.

c. Sea Otters. A core concern for our organization is health of the sea otter population. In 2010 a paper was published directly linking microcystis poisoning to the death of otters.[4] Further, the paper linked the sea otter deaths spatially to three nutrient impaired rivers in the Monterey Bay area. Continued discharge of nutrients will harm endangered sea otters.

Public health and the environment will be harmed by a stay.

3. Errors in process

a. Shimek. The requests for a stay suggest that there was inappropriate ex-parte communication between Steve Shimek and board members of the CCRWQCB – this is simply not the case. On February 24, 2012 Mr. Dirk Giannini and Mr. Norm Groot made presentations to a hearing of the Senate Agriculture Committee held in Salinas. In their presentations they made the following points:

   i. There was a deep distrust of CCRWQCB staff;
   ii. There was no language in the draft Ag Waiver that made it possible for a grower to move down in tier;
   iii. There was no provision for group efforts (such as the Los Huertos and Ross Clark concepts);
   iv. There was no incentive for longer-term water quality investments such as tailwater ponds or engineered wetlands, nor was there a provision for allowing extra compliance time to install such investments;
   v. There was a fear that individual farm reporting would make growers vulnerable to a third-party lawsuit.

Soon after the Committee Hearing, Shimek began working on a compromise proposal addressing the grower's concerns including:

   i. Creation of an independent but balanced committee to review group proposals;
   ii. Specifically stating that it was possible to move down in tier;
   iii. Specifically encouraging group proposals and specifically calling out the Los Huertos and Clark concepts;
   iv. Specifically saying that a group proposal could be given a project-specific timeline for compliance;
   v. Specifically stating that group projects could monitor project efficacy instead of discharge at the edge of individual fields.

On March 7, 2012 the proposal was passed on to Mr. Roger Briggs, Executive Officer at the CCRWQCB. Present at the meeting were Shimek, Roger Briggs, Lisa McCann, and Angela Schroeter. It is important to note that the meeting was just like three previous meetings when staff and environmental stakeholders met to discuss ideas and

[4] Evidence for a Novel Marine Harmful Algal Bloom: Cyanotoxin (Microcystin) Transfer from Land to Sea Otters. Abstract found at http://www.plosone.org/article/info:doi/10.1371/journal.pone.0012576.

competing language for inclusion in the Ag Waiver. The CCRWQCB staff also had 21 meetings with agricultural stakeholders as detailed in the "List of Stakeholder Meeting and Events" found on the CCRWQCB at: http://www.waterboards.ca.gov/centralcoast/water_issues/programs/ag_waivers/docs/ag_order/outreach_021412.pdf .

b. Plenty of deference and consideration were given to Ag Alternative. The requests for stay state that not enough deference and consideration was given to the Ag Alternative Proposal. We believe too much deference was given to the Ag Alternative. This is a case of agriculture not hearing what they wanted to hear; as opposed to not being heard at all. The Ag Alternative was first day-lighted in December of 2010. In March 2011 the Ag Alternative proposal was amended and the changes were allowed into the process. In May 2011 the proposal was amended yet again and the changes were again allowed into the process. And finally, at the March 14 2012 adoption meeting, extensive changes were suggested yet again by the Ag Alternative proponents.

With each new proposal offered by agricultural interests, CCRWQCB staff responded by weakening their proposal. Four iterations of the staff proposal along with a few key attributes can be summarized as follows:

Iteration	**Individual monitoring**	**Pesticide List**	**Nitrate discharges to groundwater**	**Buffer from impaired waters of the state.**
February 2010	All	Comprehensive list of 50+ pesticides that can cause toxicity	Reduce to DWS in 6 year	50, 75, and 100 feet.
November 2010	Tier 3 only	Diazinon and chlorpyrifos only	Tier 3: Achieve nitrate balance ratio within 3 years. DWS compliance in discharge within 4 years.	30 feet.
March 2011	Tier 3 Only	Diazinon and chlorpyrifos only	Tier 3: Nitrate balance ratio within 3 years; annual reduction in loading to groundwater	Protect existing habitat.
March 2012	Tier 3 only	Diazinon and chlorpyrifos only	Nitrate balance ratio reported but no compliance standard	Protect existing habitat.

In addition to these substantive changes, timelines before reporting and compliance were lengthened for nearly every measure.

And finally, in response to the Ag Alternative presentation made at the adoption hearing of March 14, 2012, dozens of word-for-word language changes were made to the staff proposal adopting the Ag Alternative's language.

The Ag Waiver process, while not ideal, could serve as a good model for public debate, deliberation, and decision.

i. The CCRWQCB Ag Waiver process lasted for three years five months.
ii. The process began with an exhaustive stakeholder process lasting over one year.
iii. When stakeholders could not agree, the staff offered their proposal.
iv. Stakeholders offered competing visions and language.
v. The staff proposal was iteratively modified and evolved throughout the process.
vi. Throughout the process there were numerous opportunities for public debate.
vii. Throughout the process there were numerous opportunities to meet with staff.
viii. Finally, comment was closed and the Board mixed and matched visions, options, and language to the best of their abilities and made a final decision.

The Monterey Coastkeeper does not believe a stay is appropriate or warranted in any way. We request that a hearing not be granted and the request for stay be denied. We do not believe that unsubstantiated and wildly varying costs estimated by a small slice of the growers representing the greatest threat to water quality are credible evidence of sufficient harm. Public health and the environment will be demonstrably harmed by a stay. The Ag Waiver process was lengthy and deliberative, and resulted in a thoroughly considered decision. That decision should not now be set aside, nor its implementation delayed.

Sincerely,

Steve Shimek
Chief Executive

CITY OF MONTEREY

Colton Hall, California Constitution Hall 1849

Mayor:
CHUCK DELLA SALA

Councilmembers:
LIBBY DOWNEY
JEFF HAFERMAN
NANCY SELFRIDGE
FRANK SOLLECITO

City Manager:
FRED MEURER

March 16, 2011

Jeffrey S. Young, Chair
Central Coast Regional Water Quality Control Board
895 Aerovista Place, Suite 101
San Luis Obispo, CA. 93401-7906

Subject: Conditional Waiver of Waste Discharge Requirements from Irrigated Lands (Ag Waiver) and Urban Storm Water Regulations

Dear Chair Young:

I am writing to ask, as you and your fellow Board members consider this item during your meeting on March 14, 2011, that you also keep in mind striking a reasonable balance between what you are requiring the urban areas to do under their storm water NPDES permits and the pollutant loads resulting from urban areas and the pollutant loads that are received from agricultural lands. Urban areas such as Monterey are being required to comply with ever-stringent requirements including the extreme requirements of the Areas of Special Biological Significance. Yet recent research conducted by the State Water Resources Control Board and the Southern California Coastal Water Research Program has disclosed that in most cases the ocean waters off of our coast are being polluted from sources outside of our urban control. Agricultural is one of those sources. Both the agricultural interests and the municipal permittees should be held to the same Maximum Extent Practicable (MEP) standard.

Sincerely,

Fred Meurer
City Manager

CITY HALL • MONTEREY • CALIFORNIA • 93940 • 831.646.3760 • FAX 831.646.3793
Web Site • http://www.monterey.org

JAN 2 9 2011

January 26, 2011

Angela Schroeter, P.G.
Program Manager, Agricultural Regulatory Program
Central Coast Regional Water Quality Control Board
895 Aerovista Place, Suite 101
San Luis Obispo, CA 93401-7906

RE: DRAFT AGRICULTURE ORDER NO. R3-2011-0006

Dear Ms. Schroeter,

The California Department of Public Health's Division of Drinking Water and Environmental Management has reviewed the Central Coast Regional Water Quality Control Board's proposed draft Agriculture Order. Implementation of the outlined Best Management Practices will enhance the protection of both surface water and groundwater in the Central Coast Region from fertilizer, pesticides and nitrate contamination.

The Department of Public Health supports the requirements outlined in the draft Agriculture Order and encourages the adoption of the Order by your Board. Protection against continued nitrate contamination of the groundwater in the Central Coast region will minimize the need for additional treatment of public water supply sources from this contaminant which poses a significant public health threat.

Thanks for allowing the Department to participate in the preparation of the Order and provide comments. Please contact me at (559)447-3130 if you have any questions.

Sincerely,

Cindy A. Forbes, P.E., Chief
Southern California Field Operations Branch
DIVISION OF DRINKING WATER & ENVIRONMENTAL MANAGEMENT

Attachment 2

Deborah A. Sivas, State Bar No. 135446
Leah Russin, State Bar No. 225336
Alicia Thesing, State Bar No. 238896
ENVIRONMENTAL LAW CLINIC
Mills Legal Clinic at Stanford Law School
Crown Quadrangle
559 Nathan Abbott Way
Stanford, California 94305-8610
Telephone: (650) 723-0325
Facsimile: (650) 723-4426
E-mail: dsivas@law.stanford.edu

Attorneys for Petitioners
MONTEREY COASTKEEPER,
SANTA BARBARA CHANNELKEEPER,
SAN LUIS OBISPO COASTKEEPER

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

In the Matter of Adoption of Order No. R3-2012-0011, by the Central Coast Regional Water Quality Control Board for the Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands	**SWRCB/OCC FILES A-2209(a)-(e)** **OPPOSITION OF MONTEREY COASTKEEPER, SAN LUIS OBISPO COASTKEEPER, AND SANTA BARBARA CHANNEL-KEEPER TO REQUESTS FOR STAY OF CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD ORDER NO. R3-2012-0011**

Pursuant to the State Water Resources Control Board's June 26, 2012 notice, Petitioners Monterey Coastkeeper, San Luis Obispo Coastkeeper, and Santa Barbara Channelkeeper (collectively "Environmental Petitioners") submit this preliminary written response opposing the requests by various agricultural interests to stay implementation of Order No. R3-2012-0011. In Environmental Petitioners view, more environmentally protective conditions on growers in the

Central Coast are long overdue and there is no basis in law or fact to delay implementation of the new waiver order.

INTRODUCTION

The requests by Petitioners Grower-Shipper Association of Central California, et al, Petitioners California Farm Bureau Federation, et al., Petitioners Ocean Mist Farms and RC Farms, and Petitioners Jensen Family Farms, Inc. and William Elliott (collectively "Agricultural Petitioners") for an immediate stay of Order No. R3-2012-0011 ("Order"), adopted by the Central Coast Regional Water Quality Control Board ("Regional Board") on March 15, 2012, after nearly four years of extensive – indeed, unprecedented – public process, should be denied because these requests do not satisfy any of the three criteria set forth in title 23, section 2053 of the California Code of Regulations. First, Agricultural Petitioners have not demonstrated that they will suffer substantial harm in the absence of a stay; the fact that some growers may incur modest costs to comply with the Order's first incremental steps over the course of the next year or two does not justify a stay of the Regional Board's long-overdue effort to begin bringing agricultural dischargers into compliance with the Porter-Cologne Act. Second, the record is unambiguous that the discharges subject to the Order are currently causing substantial harm to water quality, public health, and the ecosystem and that the Regional Board's ongoing measures to encourage voluntary pollution reduction have been largely unsuccessful. Although the Order certainly will not stop all harm posed by agricultural discharges, timely implementation of its initial requirements is critical to laying the groundwork for future reductions in the most egregious pollution. Finally, the petitions for review filed by agricultural interests do not raise substantial questions of law or fact regarding the Order. Agricultural Petitioners obviously disagree with the Regional Board's ultimate policy choice, but the various constitutional and procedural arguments raised in their petitions have no legal merit. Accordingly, a stay of the Order is entirely inappropriate.

FACTUAL BACKGROUND

The California Water Code authorizes State and Regional Water Boards to conditionally waive waste discharge requirements ("WDRs") if doing so both complies with applicable water quality plans and standards and is determined to be in the public interest. Cal. Water Code § 13269. Over the years, the Regional Boards have issued waivers for over 40 categories of discharges. Although waivers must be conditional, historically they contained few meaningful conditions. For example, waivers enacted before 2000 typically did not require any water quality monitoring, a feature of WDRs that allows Regional Boards to understand whether discharges are meeting water quality standards. Senate Bill 390, signed into law on October 6, 1999, was intended to strengthen the waiver process and bring dischargers utilizing a waiver into better compliance with the water quality provisions of the Porter-Cologne Act. It amended section 13269 of the Water Code to require, among other things, (i) a Regional Board determination that waivers are consistent with applicable water quality plans and in the public interest, (ii) the inclusion of water quality monitoring requirements, and (iii) an expiration date within five year. SB 390 required that Regional Boards review their existing waivers and renew them under the new statutory requirements or replace them with WDRs. Under SB 390, waivers not reissued automatically expired on January 1, 2003.

The Central Coast Regional Board adopted its first Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands under revised section 13269 on

July 9, 2004, expiring July 9, 2009. In late 2008, the Regional Board took steps to develop a new conditional waiver. That process included the formation of an Advisory Panel with stakeholders, iterative drafts of a new order prepared and proposed by Regional Board staff, multiple hearings and workshops by the Board, extensive comments from the public, scoping sessions, and multiple proposals from various groups, some of which submitted several different proposals over time.

During this lengthy and extensive public process, the 2004 waiver, which was slated to expire by its own term on July 9, 2009, was kept in place despite the Regional Board's unambiguous conclusion that it was not adequate to protect water quality. By a vote of the Regional Board, the 2004 waiver was extended, first, until July 10, 2010 and then again until March 31, 2011. It was administratively extended for a third time on March 29, 2011, this time by Regional Board staff instead of the Board and for a fourth time on September 30, 2011, again by the Regional Board staff. During each of these extension periods, outreach by staff and input from stakeholders, particularly agricultural interests, continued. The language of the proposed new waiver, which was first put forward by the Regional Board in February 2010, has been repeatedly revised over the last two years to accommodate concerns and objections expressed by growers.

<u>The Advisory Panel</u>: In a letter dated December 12, 2008, Central Coast Regional Board Executive Officer Roger Briggs invited various stakeholders to participate on a panel to assist in development of a new waiver. The goals of the new waiver were stated as:

- Eliminate toxic discharges of agricultural pesticides to surface waters and groundwater;
- Reduce nutrient discharges to surface waters to meet nutrient standards;
- Reduce nutrient discharges to groundwater to meet groundwater standards;

- Minimize sediment discharges from agriculture lands; and
- Protect aquatic habitat (riparian areas and wetlands) and their buffer zones.

The composition of the panel was heavily weighted towards agricultural interests: 12 members representing the agricultural industry and growers, 4 member representing environmental organizations, 2 Regional Board staff, 2 agricultural academics, and 2 agencies. The Advisory Panel first met on December 18, 2008 and, thereafter, met monthly through September 2009. Gita Kapahi from the State Board moderated the sessions, but the group was unable to reach any consensus.

Staff Drafts: Following dissolution of the Advisory Panel, the Regional Board directed staff to distribute a preliminary report and preliminary draft order for the regulation of discharges from irrigated lands, and staff did so on February 1, 2010. The preliminary report demonstrated in painstaking detail that the 2004 waiver was not consistent with water quality objectives for the region and did not comply with Water Code section 13269. Despite the existence of that waiver, staff found that impairment of beneficial uses by agricultural pollutants was widespread and severe and that the situation generally was not improving. Specifically, staff summarized the situation as follows:

> Agricultural discharges (primarily due to contaminated irrigation runoff and percolation to groundwater) are a major cause of water quality impairment. The main problems are:
>
> 1. In the Central Coast Region, thousands of people are drinking water contaminated with unsafe levels of nitrate or are drinking replacement water to avoid drinking contaminated water. The cost to society for treating polluted drinking water is estimated to be in the hundreds of millions of dollars.
>
> 2. Aquatic organisms in large stretches of rivers in the entire region's major watersheds have been severely impaired or completely destroyed by severe toxicity from pesticides.

> These impairments are well documented, severe, and widespread. Nearly all beneficial uses of water are impacted, and the discharges causing the impairments continue. Immediate and effective action is necessary to improve water quality protection and resolve the widespread and serious impacts on people and aquatic life.

Preliminary Draft Staff Recommendations for An Agricultural Order at 4 (Feb. 1, 2010). Staff recognized that the 2004 waiver focused on enrollment, education, and outreach, but lacked clarity and a focus on water quality requirements and did not include adequate compliance and verification monitoring. *Id.* at 18-19. The draft new waiver proposed by staff was intended to address those issues and bring the waiver into compliance with section 13269 of the Porter-Cologne Act.

In response to the February 2010 draft waiver, the Regional Board received extensive public comment and invited alternative proposals. At least three alternative proposals were submitted, by the California Farm Bureau Federation, OSR Enterprises, Inc., and, as a group, the Environmental Defense Center, Monterey Coastkeeper, Ocean Conservancy, Santa Barbara Channelkeeper, and the Santa Barbara Chapter of Surfrider Foundation. The Regional Board analyzed these submissions in subsequent staff reports and held two follow-up public workshops, on May 12, 2010 and July 8, 2010, during which it accepted additional public comment and allowed key stakeholders, including various agricultural industry representatives, to make formal presentations.

In response to ongoing public comment, and specifically in response to the criticisms of the agricultural community, staff continued to revise the original draft waiver over the next two year, producing a total of five new versions for public review and consideration at Regional Board meetings on November 19, 2010, March 17, 2011, May 4, 2011, September 1, 2011, and

March 15, 2012. The Regional Board held at least one additional public workshop on February 3, 2011 and staff continued thereafter to meet individually with various stakeholders. In an attempt to appease growers, every iteration of staff's draft waiver was less protective of the environment, and required less of the farming community, than the previous version. The time for reporting and compliance was extended in each draft. Additional changes to the drafts included:

Iteration	**Individual monitoring**	**Pesticide List**	**Nitrate discharges to groundwater**	**Buffer from impaired waters of the state.**
February 2010	All	Comprehensive list of 50+ pesticides that can cause toxicity	Require Compliance with Drinking Water Standards ("DWS") in 6 years	50, 75, and 100 feet.
November 2010	Tier 3 only	Diazinon and chlorpyrifos only	Tier 3: Achieve nitrate balance ratio within 3 years. DWS compliance in discharge within 4 years	30 feet.
March 2011	Tier 3 Only	Diazinon and chlorpyrifos only	Tier 3: Nitrate balance ratio within 3 years; annual reduction in loading to groundwater	Protect existing habitat.
March 2012	Tier 3 only	Diazinon and chlorpyrifos only	Nitrate balance ratio reported but no compliance standard	Protect existing habitat.

CEQA Process: Concurrent with this administrative process, the Regional Board undertook actions to comply with the California Environmental Quality Act ("CEQA"). On August 10, 2010 the Regional Board held a CEQA scoping meeting, and on October 14, 2010, the Regional Board released a "Notice of Preparation of a Draft Subsequent Environmental Impact Report." On November 19, 2010, the Regional Board released a Draft Subsequent Environmental Impact Report and accepted public comments on the document. This document was intended to tier to the earlier CEQA review prepare in connection with the 2004 waiver and to update that analysis for the proposed new waiver. On March 2, 2011, the Regional Board issued a Final SEIR, making minor clarifications and responding to public comments. On August 10, 2011,the Board issued an Addendum to the Final SEIR to address intervening revisions to the draft waiver.

The Ag Alternative: The agricultural community availed itself fully of the public process. The California Farm Bureau Federation submitted at least five proposals over the course of the process, additional and subsequent to the original proposal it had submitted in April 2010. First, on December 3, 2010, it submitted a "Draft Central Coast Agriculture's Alternative Proposal for the Regulation of Discharges from Irrigated Agricultural Lands" (the "Ag Alternative"). The organization subsequently submitted revised alternative language on March 17, 2011, May 4, 2011, February 14, 2012, and March 14, 2012. Each of these submissions was intended as a less burdensome alternative to the staff proposal, which itself was being continually weakened with each iteration. And each time, the California Farm Bureau Federation only made its alternative available to the public during a presentation at the Regional Board meeting where it was to be considered, thus preventing the public from being able to meaningfully review and consider it in advance of the meeting or to effectively respond to it.

Outreach, Public Hearings, and Meetings with Staff: From May 2010 through March 2012, there were eight full days of public hearings and workshops. Hundreds of in-person comments and scores of stakeholder group presentations were made to the Regional Board during the public hearings and many hundreds of written comments were submitted. In addition, the Regional Board staff conducted extensive outreach to grower organizations, and repeatedly offered to meet with anyone. *See* Central Coast Water Board – Agricultural Order Renewal, Stakeholder Outreach Meetings and Events (updated Feb. 14, 2012), available at http://www.waterboards.ca.gov/rwqcb3/ water_ issues/programs/ag_waivers/docs/ag_order/ outreach_021412.pdf. Indeed, the Regional Board and staff have commented that the Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands was given the most extensive and thorough public process in the Board's history.

On March 15, 2012, with all members present, the Board unanimously adopted the Order No. R3-2012-0011 (along with specific monitoring criteria for each of the three tiers of enrolled dischargers in Orders Nos. R3-2012-0011-01, R3-2012-0011-02, and R3-2012-0011-03).

ARGUMENT

A. Agricultural Petitioners Will Not Suffer Substantial Harm in the Absence of a Stay.

1. The Declarations Submitted by Petitioners Do Not Demonstrate Substantial Harm or Hardship.

Agricultural Petitioners complain that they will incur "substantial" compliance costs if a stay is not granted. But the cost of complying with a Regional Board order cannot properly be the basis for a stay – or virtually every petition for review would justify a stay. Even assuming that Agricultural Petitioners' self-proclaimed expense estimates were properly documented as true and accurate – an assumption that is not supported by any credible evidence, as discussed below – the cost of coming into compliance with the Porter-Cologne Act does not impose an unreasonable burden or support a stay request. The Order's modest requirements appropriately target the most environmentally risky farm operations, leaving the vast majority of growers with few, if any, new obligations. These incremental requirements are appropriately intended to compel the most polluting growers to begin internalizing the enormous environmental costs associated with their activities, costs they have been effectively externalizing for decades, to the detriment of our natural resources and the public. Given the lucrative nature of the region's agricultural industry – with annual food crop production in the four major Central Coast agricultural counties valued at well over *six billion dollars*[1] – the industry's complaints of financial hardship are not compelling, particularly in the face of the pollution burden created by its activities.

In arguing for a stay, Agricultural Petitioners both fail to provide credible quantitative analysis or other evidence to support their expense estimates and ignore the critically important context for their self-serving estimation of compliance costs. For instance, petitioner RC Farms submits a declaration by Dennis Sites, described only as a "Consultant" without further description or supporting credentials, which summarily states that "[t]o comply with these regulations, RC Farms will incur substantial costs, estimated to be over $100 per acre" for its 500-plus acre farming operations. Declaration of Dennis Sites at ¶ 5. Mr. Sites provides no

---

[1] *See, e.g.*, Monterey Co. Department of the Agricultural Commissioner, *Monterey County Crop Report 2011*, available at http://ag.co.monterey.ca.us/assets/resources/assets/252/cropreport_ 2011.pdf (valuing Monterey County crops at $3,850,000,000 in 2011); Santa Barbara Co. Agricultural Comissioners Office, *Agricultural Production Report 2011 Santa Barbara County*, available at http://www.countyofsb.org/ uploadedFiles/agcomm/crops/ CR2011Final.pdf (valuing Santa Barbara County crops at $1,194,379,00 in 2011); San Luis Obispo Co. Department of Agriculture, *Protecting Our Resources*, *2011 Annual Report*, available at http://www.slocounty. ca.gov/Assets/ AG/croprep/ 2011CropReport.pdf (valuing San Luis Obispo County crops at $736,000,000 in 2011); Santa Cruz Co. Office of the Agricultural Commissioner, *Santa Cruz County 2010 Crop Report*, available at http://www.agdept.com/ content/cropreport_ 10.pdf (valuing Santa Cruz County crops at $532,526,000 in 2010).

analysis to support his conclusory statement. Dale Huss, Vice-President of Artichoke Production for Petitioner Ocean Mist Farms, submits an almost identical – and equally unsupported – declaration stating that Ocean Mist Farms will incur costs "estimated to be between $50.00 and $100.00 per acre." Declaration of Dale Huss at ¶ 5. Even taking these unsupported estimates at face value, the proffered costs of compliance must be considered in context for these Salinas area growers. In 2011, some 289,523 acres in Monterey County were planted in major vegetable and fruit crops, yielding a value of $3,148,989,000 – or roughly $10,876 per acre planted.[2] Thus, declarants' estimated compliance costs constitute, at most, less than one percent of the annual planted value of their crops – hardly an economic hardship. Neither of the declarants provides the kind of revenue or profit figures that would be necessary for the Board to grant these individual operations a stay of the Order.

Indeed, although Agricultural Petitioners collectively repeat the mantra throughout their papers that "excessive" compliance costs will cause "substantial harm" to growers, they have artfully crafted their arguments and declaration testimony to avoid any actual claim or showing of comparative economic hardship. For instance, Peter Aiello, the owner and operator of Uesugi Farms in Gilroy, provides unsupported cost estimates for compliance with the new requirements on the 2,300 acres under production by his firm, but no profit context in which to understand them. Declaration of Peter C. Aiello at ¶ 1. Assuming for the sake of argument that his unsupported estimates are accurate, he declares that his cost of compliance between now and December 2013 will be $40,000 – *or $17.39 per acre* ($40,000 / 2,300 acres), roughly 0.2

---

[2] Monterey Co. Department of the Agricultural Commissioner, *Monterey County Crop Report 2011* at 6, available at http://ag.co.monterey.ca.us/assets/resources/assets/252/cropreport_2011.pdf.

percent of the average planted value. *Id.* at ¶ 7. Bob Campbell, the Lompoc owner and operator of Bob Campbell Ranches, Inc., testifies that the 38 farms/ranches operated by his company will likely fall within Tier 2 and that the cost of compliance between now and December 2013 will range *between $60 and $80 per acre* – or no more than 0.7 percent of the averaged planted value. Declaration of Bob Campbell at ¶ 7. Similarly, although Salinas grower Dave Costa does not state how many acres he has under production, but does testify that he owns 34 ranches divided into 414 blocks/farms that include 1350 plantings per year and that he averages 2.1 crops per acre per year. Declaration of Dave Costa at ¶¶ 4-5. Like other declarants, Mr. Costa does not provide any calculations or analysis for his estimates, but he concludes that between now and December 2013, his total cost of compliance per acre for the 34 ranches that will likely fall within Tier 2 will range between *$46 to $66 per acre*. *Id.* at ¶ 7. For the two ranches that he believes will fall into Tier 3, Mr. Costa estimates costs of compliance between now and December 2013 to range between *$100 and $148 per acre* – a little over one percent of the average planted value for the most environmentally risky lands subject to the Order. *Id.* at ¶ 6. Gary L. McKinsey, owner of B&D Farms, Inc. in Arroyo Grande, estimates (again, without supporting documentation or calculation) that five of his six ranches will be subject to Tier 2 (and none will be subject to Tier 3) and that the cost of compliance for those Tier 2 lands between now and December 2013 will range *between $55.39 and $78.89 per acre planted*. Declaration of Gary L. McKinsey at ¶ 5. Because none of these declarations include particular revenue or profit numbers, the Board reasonably should assume that the value of declarants' fruit and vegetable crops is similar to the Monterey County average of nearly $11,000 per acre.[3] Put

[3] Cost estimates by the remaining declarants are in the same ballpark, as a percentage of average

in proper comparative context, then, Petitioners' claims of financial harm are not compelling.

In short, even taking all declarants as credible and representative of the larger farming community (despite the absence of supporting analysis or documentation to support these assumptions), the Board must conclude that the near-term financial burden on growers to comply with the Order's minimal and commonsense environmental protections (farm plans, backflow devices, etc.) represents only a fraction of planted crop value, even for the highest risk operations with facing the most stringent requirements, on what is some of the most profitable farmland in the nation. Growers need to stop complaining about the cost of complying with the Porter-Cologne Act and begin to take the same initial steps to reduce harmful pollution-loading that industrial facilities took decades ago. Had they chosen simply to comply with the Order, instead of employing an army of high-priced lawyers to file hundreds of pages of meritless legal arguments, Agricultural Petitioners could already be well on their way to satisfying the modest, incremental first steps of the Order.

2. The Barbeau Report Does Not Demonstrate Substantial Harm or Hardship.

Agricultural Petitioners' reliance on the economic analysis produced by J. Bradley Barbeau and Kay L. Mercer is equally misplaced. That report, *Economic and Cost Analysis of the Proposed Ag Waiver and Ag Alternative* (Aug. 1, 2011) (hereinafter "Barbeau Report"), is constrained in many significant respects and does not support the grant of a stay. For one thing,

---

value per planted acre. Declarant Robert Martin provides an unsupported cost estimate range of $134 to $221 per planted acre ($519,082 / 3866 acres to $853,924 / 3866 acres). Declaration of Robert Martin at ¶¶ 1, 7. Thus, even the declarant with the highest per acre cost estimates, and even taking as credible and accurate the highest end of his estimate range, near-term implementation costs would constitute at most 2 percent of his crop value. (Declarant Dirk Giannini does not provide information on total acreage under production and thus his estimate cost per acre cannot be computed from his testimony.)

the interviews on which the report is based were conducted before the Regional Board's July 2011 revisions, Barbeau Report at 7-8, and the report was prepared in August 2011, before the Board made final revisions to the Order that further reduced requirements on growers. The report's conclusions, therefore, are not applicable to the actual Order adopted on March 15, 2012.

More important, the Barbeau Report is methodologically flawed in fundamental ways. As a threshold matter, the report suffers from apparent selection bias. As the report itself explains, the authors did not use a "random" or representative sample, but rather selected for interview (in some unspecified way)[4] 12 growers with a total of 26,448 acres under production. Roughly 60 percent of this acreage would likely fall within the Tier 3 category, according to the report authors, even though the Regional Board estimates that less than 3 percent of the farmed acreage in the region will be subject to Tier 3 requirements. Thus, the study – like the declarations discussed above – is not representative of the financial burden imposed by the Order on the vast majority of affected growers, roughly half of whom will likely fall within Tier 1 and actually see their regulatory obligations reduced under the new Order. The data on which the report relies were obtained through voluntary (and self-selected) participation by growers with some of the largest operations. There is no reason to believe, based on what little information is disclosed about the study methodology, that these operations are representative in any way of the 97 percent of farms that fall outside the Tier 3 classification. Indeed, the authors concede that

[4] How the authors actually selected which 12 growers to interview is not revealed anywhere in the report. Given that the study was funded by farming interests who are now using the report to argue against regulatory requirements, the lack of selection transparency renders the results highly suspect.

every farm is somewhat different, and large operations are likely quite different from smaller farms, the vast majority of which will be subject to fewer, not greater, obligations under the new Order. And because compliance with the more stringent Tier 3 requirements for the highest risk operations is phased in over several years, the study's focus on Tier 3 obligations does not provide an appropriate basis for an immediate, short-term stay of the Order.

Equally significant is the Barbeau Report's reliance primarily on self-reported cost estimates from interviews with self-interested growers, rather than on objective cost calculations formulated by independent third-party experts. This flaw is compounded by the authors' explicit recognition that growers were required to "speculate on what it would take to comply," thereby injecting "some level of uncertainty" into their estimates. Barbeau Report at 8. Adding to this uncertainty, and rendering the report's quantitative conclusions even less reliable, is the highly speculative nature of many of the cost estimates used by the report's authors. For instance, the study states that "[l]ining water containment ponds presents a significant expense to some growers," potentially up to $240,000 for 1 of the 12 interviewed growers who farms 5,500 acres and has 16 such ponds. *Id.* at 13. The authors concede that "[o]ther growers who do not use containment ponds avoid this expense," but they make no attempt to determine what percentage of dischargers subject to the Order actually use containment ponds; depending on that number, the "average" costs for compliance could fall dramatically. Moreover, the authors acknowledge a subsequent Regional Board clarification that the containment provision is not a "stand-alone requirement," but they do not adjust their analysis in any way to address this clarification, stating only that "this information was received too late to be included in this analysis." *Id.*

These methodological biases, questions, errors, and uncertainties are reflective of the study's serious limitations as scientific analysis and render its conclusions – through nicely packaged in precise-looking charts and graphs – virtually meaningless for purposes of the Agricultural Petitioners' stay request. In fact, the report actually demonstrates how grower self-reporting – of the same kind contained in the declarations submitted by Agricultural Petitioners – is inherently inaccurate and unreliable. *See, e.g.*, Barbeau Report at 13 (explaining how 1 of the 12 interviewed growers, based on erroneous assumptions, included a $575,000 cost estimate for compliance with one item that other growers considered to require a small or no expense).

In sum, Agricultural Petitioners have not come close to meeting their burden of showing substantial harm in the absence of a stay. The fact that there will be some costs associated with compliance, especially for the largest polluters and the most environmentally risky farms, is neither surprising nor unreasonable. Despite the unequivocal mandate of the Porter-Cologne Act, the agricultural community has continued for decades to discharge harmful pollutants and degrade water quality throughout the Central Coast. With hundreds of water bodies in the region now impaired for agricultural pollutants, especially in the Salinas Valley, the Regional and State Boards must act expeditiously to begin the cleanup process. The Regional Board's efforts over the last decade to obtain voluntary pollution reductions have been largely unsuccessful because growers have not stepped up and made the necessary pollution reduction investments that virtually every other industrial sector has. Further delay is not warranted by the relatively insignificant costs – as compared to the market value of the polluting activity – to begin the long process of bringing harmful farming practices into compliance with the Porter-Cologne Act.

B. The Public Interest Will Be Substantially Harmed by Issuance of a Stay.

The Regional Board has thoroughly documented the ongoing harm to the public and the environment that is occurring every single day. Agricultural Petitioners offer nothing but conclusory statements to dispute these facts, nor could they. Petitioners Ocean Mist Farms et al. and Jensen Family Farms, Inc. et al. say nothing in their respective stay papers about the ongoing harm. Petitioners California Farm Bureau Federation et al. offer a single, incomprehensible sentence: "Interested persons and the public interest will not be substantially harmed if a stay is granted as water quality will still be regulated." Petition for Review at 69. Petitioners Grower-Shipper Association of Central California et al. provide more words, but no more substance. They argue that "most of the provisions for which a stay is requested are monitoring and reporting provisions" and that these informational requirements do not result in water quality improvements. Request for Stay at 16. This argument, of course, ignores the fact that monitoring is a necessary precursor to implementing water quality improvements; the longer it is delayed, the slower the cleanup process. With respect to those provisions or management prescriptions in the Order that Petitioners concede will directly affect water quality, they contend (i) that because compliance will "take decades," a short-term delay will not substantially harm the public, and even less comprehensible (ii) that "[s]taying the specific management practices as requested does not remove any requirements with respect to implementing management practices that must improve and protect water quality. Thus, the public will not be harmed." *Id.* at 17-18. None of these oddly circular and cryptic arguments in any way overcomes the Regional Board's meticulously documented analysis of the real, ongoing environmental harm that is occurring and will continue to occur if a stay is granted.

The extensive agency record supporting adoption of the Order is replete with evidence of ongoing harm from agricultural discharges. In its March 2011 staff report on the proposed

Order, the Regional Board explains that while not all nutrient and pesticide pollution in Central Coast waters originates from agricultural land, "research projects and monitoring programs have shown high levels of chemicals leaving agricultural areas and entering the waters of our Region." Central Coast Regional Board, *Water Quality Conditions in the Central Coast Region Related to Agricultural Discharges* at 4 (March 2011), available at http://www.waterboards.ca.gov/rwqcb3/board_info/agendas/2011/march/ Item_14/ 14_att7.pdf. This agricultural pollution problem was evident when the 2004 agricultural waiver was issued, and more recent data have confirmed agricultural areas as the source of significant pollution. *Id.* Data collected throughout the region between 1998 and 2009 indicate that the two areas with the most degraded water quality are the lower Salinas area and the lower Santa Maria area, both of which are intensely farmed. *Id.* at 5. Of the 51 (out of 250) sampled Central Coast sites with the worst water quality scores, 82 percent are in these two areas, and all of the sites with the worst toxicity scores are in these areas. *Id.* at 6. The Central Coast region has 704 water bodies listed as impaired under section 303(d) of the Clean Water Act, 77 of which are in the lower Santa Maria area and 119 of which are in the lower Salinas area. *Id.*

Nitrate contamination is the most widespread and serious water pollution problem on the Central Coast, with 30 percent of the 250 sampled surface water sites exceeding the 10 mg/L drinking water standard, some by five-fold or more. *Id.* at 6-8. For the 20 worst sites, where nitrate levels ranged from 33 to 94 mg/L, row crop acreage averaged 48.4 percent of the catchment area and 27.1 percent of the upstream watershed. *Id.* at 8. Nitrate contamination of groundwater, upon which many local communities rely, is also widespread and serious. *Id.* at 23-25. The source of this contamination is attributable primarily to irrigated agriculture and the over-application of commercial fertilizer. *Id.* at 31. A very recent U.C. Davis study confirms the significance of nitrate contamination from agriculture in the Salinas Valley Groundwater Basin. Center for Watershed Studies, *Addressing Nitrates in California's Drinking Water, With a Focus on Tulare Lake Basin and Salinas Valley Groundwater* (Jan. 2012), available at http://groundwaternitrate.ucdavis.edu/files/138956.pdf ("Cropland is by far the largest nitrate source, contributing an estimated 96% of all nitrate leached to groundwater (Table 1). The total nitrate leached to groundwater . . . is four times the benchmark amount, which suggests large and widespread degradation of groundwater quality.").

With respect to toxicity and pesticides, the Regional Board has summarized the situation as follows:

> The levels of toxicity found in ambient waters of the Central Coast far exceed anything allowed in permitted point sources discharges. The California Toxics Rule allows only one acute and one chronic toxic test every three years on average for permitted discharges to surface waters. We have drainages in agricultural areas of the Region that are toxic virtually every time they are measured.

Water Quality Conditions in the Central Coast Region Related to Agricultural Discharges at 9. Of the 80 streams monitored in the region for toxicity, "[s]ome measure of lethal effect (as opposed to growth or reproduction) has been observed at 65 percent" of them. *Id.* Fifteen water bodies on the section 303(d) list for the Central Coast are impaired for water column and soil toxicity and another 14 are listed for water toxicity alone. *Id.* at 10. Of these toxicity listings, 73 percent are located in either the lower Salinas area or the lower Santa Maria area. *Id.* Thirty-six percent of the sampled sites are "severely toxic" and 90 percent of these are in the same two intensive agricultural areas. *Id.* Follow-up studies and other research have "documented a strong relationship between concentrations of diazinon and chlorpyrifos pesticides and water column toxicity in the lower Salinas and Santa Maria areas." *Id.* The breakdown products of these pesticides are "ten to 100 times more toxic to amphibians than the products themselves." *Id.* Sediment toxicity was found in 64 percent of the sites sampled, with 20 of the 23 most toxic sites located in the lower Salinas and Santa Maria areas. *Id.* "[S]ediment toxicity appears to be highly related to pyrethroid pesticides and chlorpyrifos, at least in the lower Salinas and Santa Maria areas." *Id.*

A recent Cooperative Monitoring for Agriculture follow-up study found the "highest average pyrethroid and chlorpyrifos concentrations in the lower Santa Maria area, where they were detected at all sites," and the "second highest average chemical concentrations were found in the Salinas tributaries and Reclamation Canal." *Id.* at 11. In a statewide comparative study of four agricultural areas (Salinas, Sacramento, San Joaquin, and Imperial valleys), conducted by the Department of Pesticide Regulation, "the Salinas study area had the highest percent of sites with pyrethroid pesticides detected (85 percent), the highest percent of sites that exceeded levels expected to be toxic (42 percent), and the highest rate (by three-fold) of active ingredients applied (113lbs/acre)." *Id.* In another recent Surface Water Ambient Monitoring Program summary report issued in 2010, where toxicity data were collected for each region of the state, 22 percent of the 109 water toxicity sites on the Central Coast were "highly toxic," which "was the highest percentage of any region." *Id.* (comparing Central Coast to the Central Valley, where only 2.3 percent of the sample sites were highly toxic).

The Regional Board staff report also summarized ongoing turbidity, temperature, and ammonia concerns on the Central Coast, *id.* 13-14, and water quality trends. Although in some areas water quality is improving, in other areas it is actually degrading. For instance, in some areas with very poor nitrate contamination conditions, the situation is getting worse, with that worsening concentrated in the lower Salinas and lower Santa Maria areas. *Id.* at 15. Moreover, "[i]n the lower Salinas and lower Santa Maria areas common measures of benthic macro-invertebrate community health and habitat health score low, especially compared to upper watershed monitoring sites and other high quality sites in the Central Coast Region." *Id.* at 16. As the Regional Board summarized:

> These findings indicate that streams in areas of heavy agricultural use are typically in poor condition in terms of benthic community health and that habitat in these areas is often poorly shaded, lacking woody vegetation, and heavily dominated by fine sediment. Invertebrate community composition is sensitive to degradation in both habitat and water quality. In some cases, the fine sediment dominating stream substrate is likely the largest influence on benthic community composition, but in areas where sediment and water toxicity is common, chemical impacts to the native communities are also probable. Heavily sedimented stream bottoms can result from the immediate discharge of sediment from nearby fields, the loss of stable, vegetated stream bank habitat, the channelization of streams and consequent loss of floodplain, as well as from upstream sources.

Id. at 17.

With respect to surface water contamination, the situation is extremely problematic and necessitates immediate action:

> Staff has examined a large amount of data from both CCAMP and the CMP. We have found that many of the same areas that showed serious contamination from agricultural pollutants five years ago, particularly nitrate and toxic pesticides, are still seriously contaminated. We have seen evidence of improving trends in some parameters in some areas. Dry season flow volume appears to be declining in many areas of intensive agriculture. However, we are not seeing widespread improvements in nitrate concentrations in areas that are most heavily impacted, and in fact a number of sites in the lower Salinas and Santa Maria areas appear to be getting worse, at least in terms of concentration. Invertebrate toxicity remains common in both water and sediment. Statistical trends in toxicity are not yet typically apparent, in part because of smaller sample sizes, but a few sites show indications of improvement. Persistent summer turbidity in many agricultural areas implies that water is being discharged over bare soil and is moving that soil into creek systems. Dry season turbidity is getting worse along the main stem of

> the Salinas River. High turbidity limits the ability of fish to feed. Bioassessment data shows that creeks in areas of intensive agricultural activity have impaired benthic communities, with reduced diversity and few sensitive species. Associated habitat is often poorly shaded and has in-stream substrate dominated by fine sediment. In general, staff finds poor water quality, biological and physical conditions in many waterbodies located in, or affected by, agricultural areas in the Central Coast Region.

Id. at 21-22.

If anything, the situation is even more bleak with respect to groundwater, especially as it relates to nitrate contamination of drinking water and the attendant public health and economic impacts:

> At this time, the largest contributing source of nitrate loading to groundwater in the Central Coast Region, fertilizer application from irrigated agriculture, is virtually unregulated. Nitrate loading to groundwater from fertilizer application is significant and ongoing and the documented impacts are widespread and severe. The combination of historical and ongoing nitrate loading from fertilizer application continues to impact major portions of entire groundwater basins that act as a sole source of domestic and municipal water supply resulting in a growing and significant number of drinking water systems being impacted with nitrate above the public health drinking water standard. Of particular concern is the potentially significant number of domestic water supply wells impacted with nitrate and the people who are unknowingly drinking water that doesn't meet public health standard for nitrate.
>
> . . .
>
> . . . the ongoing and significant discharges of nitrate to groundwater from irrigated agriculture as documented in this report are contributing to an already alarming level of impacts to the beneficial uses of groundwater. Unfortunately, nitrate concentrations are likely to increase in many deeper aquifers over the next several years or even decades even if nitrate loading is completely stopped. This is because high levels of nitrate already in the vadose zone and shallow groundwater will continue to move downward into the aquifers with irrigation return flows and recharge from rainfall or flooding events. Consequently, reduced loading at the ground surface will likely take years to decades to result in lower nitrate concentrations in groundwater because of the typically slow rate of groundwater recharge within many groundwater basins. Nonetheless, significant measures need to be implemented now to reverse the current trend in nitrate loading with the ultimate goal of improved groundwater quality years or even decades in the future.

Id. at 59-60.

The report goes on to conclude that, despite extensive research, education and outreach efforts, "[i]t appears very little has been done in the last thirty years to seriously address the nitrate problem since it was definitively identified as the biggest water quality problem in the State as well as within portions of the Region." *Id.* at 61. Moreover:

> At this time available data indicate an ongoing and significant trend in nitrate loading to groundwater from irrigated agriculture and an increase in the extent and severity of nitrate impacts to the beneficial uses of groundwater. Nitrate loading to groundwater from irrigated agriculture constitutes a discharge of waste to waters of the State and is subject to waste discharge requirements and enforcement actions pursuant to the California Water Code. Whereas discharges of nitrate to groundwater from municipal, industrial, domestic and other point sources are regulated in the Region, agriculture as been selectively excluded from similar regulation to date. Until such time as this significant gap in regulatory oversight is addressed, beneficial uses of groundwater will not be adequately protected. Consequently, regulatory programs need to be developed requiring the implementation of nitrogen and irrigation management practices to reduce nitrate loading to groundwater and require monitoring to document whether progress is being made to reduce nitrate loading.

Id. Agricultural Petitioners' requests for stay will only delay the inevitable and allow the already alarming surface water and groundwater contamination problem to worsen day by day, further harming public health, fish and wildlife, the ecosystem, and the larger public interest.

C. Agricultural Petitioners Do Not Raise Substantial Issues of Law or Fact.

In hundreds of pages of briefing, Agricultural Petitioners advance a kitchen sinkful of legal arguments, citing everything from the writings of James Madison to the participation of Steve Shimek. None of these arguments raise substantial concerns, either legal or factual, concerning the thorough public process that led to adoption of the Order. It is clear that Agricultural Petitioners would prefer a watered-down version of the Order, or none at all. That policy preference, however, does not constitute a legitimate legal argument. The Regional Board conducted a protracted and inclusive public process, revising the draft conditional waiver order time and again to accommodate the comments and concerns of the agricultural industry. Staff meticulously responded to public input, explaining in writing why the industry proposal could not possibly satisfy the requirements of the Porter-Cologne Act. As their petitions for review make abundantly clear, nothing short of complete capitulation to their demands will satisfy the Agricultural Petitioners. Under the law, however, the Regional Board simply does not have the authority or ability to accept the industry's weak proposal, no matter how many frivolous procedural and constitutional issues its lawyers dream up.

The Porter-Cologne Act is clear: Waste discharge requirements may be waived *only* if the State or Regional Board "determines . . . that the waiver is consistent with any applicable state or regional water quality control plan and is in the public interest." Cal. Water Code § 13269(a)(1). Moreover, any waiver must be conditioned on verification and effectiveness monitoring, with monitoring results made available to the public. Id. § 13269(a)(2). As the Regional Board explained in painstaking detail, the industry proposal does not meet these requirements because, among other things, the third-party monitoring provisions are inadequate and the proposal does not require compliance with water quality standards. Central Coast Regional Board, *Staff Report for Regular Meeting of September 1, 2011* at 8 (Aug. 10, 2011). Especially given the highly degraded condition of surface and subsurface water quality throughout the region and the lack of progress in reducing agricultural pollution, the Regional Board's substantive judgment on necessary conditions is neither arbitrary nor unreasonable, and the State Board should affirm it.

On the question of the Order's legality, Agricultural Petitioners' laundry list of alleged procedural errors is meritless. Their lengthy arguments under the California Environmental Quality Act ("CEQA") are particularly ludicrous given Petitioners' desire to weaken the environmental protections contained in the Order. As a threshold matter, Agricultural Petitioners' interest in a less environmentally protective waiver is not within the zone of beneficial interests protected by CEQA and, therefore, does not confer CEQA standing on these parties.[5] In any event, the Regional Board followed appropriate CEQA procedures here. Building off the prior CEQA review and documentation for the 2004 waiver, the Regional Board provided an updated, supplemental CEQA analysis for the more environmentally protective new Order and circulated it for public review and comment. As part of that review, the Regional Board analyzed economic impacts and, to the extent possible under the Porter-Cologne Act, incorporated measures to mitigate those impacts. Nothing more is required by CEQA.

Agricultural Petitioners' regulatory takings arguments are even more specious. Use of and discharge into state waters is a privilege, not a right. If growers elect to irrigate their land, they have a number of options: They can choose not to discharge wastewater at all, they can seek individual WDRs for their operations, or they can enroll in the conditional waiver put in place by the Order. For growers who choose the third option, their participation is conditioned, as the Porter-Cologne Act requires, on compliance with runoff, erosion control, and other requirements necessary to protect water quality from the highly toxic and environmentally damaging pollutants they generate. There is nothing unconstitutional about the Regional Board's requirement that landowners take steps to mitigate their pollution loading to waters of the state,

---

[5] For instance, Petitioners Ocean Mist Farms et al. argue that the Regional Board should have assessed potential mitigation for biological impacts of the Order, even as they are pressing for a waiver that would have greater biological impacts, not fewer.

notwithstanding Petitioners' appeals to the works of James Madison, Arthur Lee, and John Steinbeck.

Nor does the Order violate section 13360 of the Water Code, as several Petitioners contend. The Regional Board has the authority to structure compliance requirements that minimize polluted runoff. In the Order, the Board exercises this authority by requiring dischargers to (1) "implement water quality protective practices (*e.g.*, source control or treatment) to prevent erosion, reduce stormwater runoff quantity and velocity, and hold fine particles in place"; (2) "minimize the presence of bare soil vulnerable to erosion and soil runoff to surface waters and implement erosion control, sediment, and stormwater management practices in non-cropped areas, such as unpaved roads and other heavy use areas"; (3) "maintain existing, naturally occurring, riparian vegetative cover (such as trees, shrubs, and grasses) in aquatic habitat areas as necessary to minimize the discharge of waste [and] maintain riparian areas for effective streambank stabilization and erosion control, stream shading and temperature control, sediment and chemical filtration, aquatic life support, and wildlife support to minimize the discharge of waste"; and (4) where it is necessary to disturb aquatic habitat, "implement appropriate and practicable measures to avoid, minimize, and mitigate erosion and discharges of waste, including impacts to aquatic habitat." Order at 20-21, ¶¶ 36, 37, 39, 40. The constraints of section 13360 do not apply to such general performance standards, which are akin to "the installation of surface and underground drainage facilities to prevent runoff from entering the disposal area or leakage to underground or surface waters, or other reasonable requirements to achieve the above or similar purposes" and thus permissible under the statute. Cal. Water Code § 13360(a)(1). The courts have been clear that performance provisions designed to reduce runoff do not violate section 13360. *See Tahoe Sierra Preservation Council v. State Water Resources Control Board*, 210 Cal. App. 3d 1421, 14 (1989) (upholding waste discharge requirement for erosion control plan).

Several of the Agricultural Petitioners argue that the monitoring requirements in the Order are unlawfully onerous. This argument is absurd, both legally and factually. As a threshold matter, in order for any discharger to obtain a "waiver" from the normal permitting requirements, the Regional Board must ensure that adequate verification and efficacy monitoring are performed. Industrial dischargers obtaining individual WDRs face rigorous monitoring and reporting requirements as conditions of their permits. The monitoring provisions in the Order are less stringent, allowing enrolled Tier 2 and Tier 3 dischargers to electronically submit a single Annual Compliance Form. Order at 27-28, ¶¶ 67-68. High nitrate loading growers who fall into Tier 3 must engage in somewhat more sophisticated nitrate planning and must report that activity on their annual forms, but these requirements are imminently reasonable in light of the enormous nitrate contamination problem created by agricultural dischargers. If Petitioners are unhappy with the monitoring conditions in the Order, they remain free to apply for individual WDRs.

Finally, Agricultural Petitioners attempt to gin up an argument that Regional Board members engaged in improper ex parte communications. This argument is fatuous. Petitioners' argument rests on the contention that there was an improper "indirect" ex parte communication between Steve Shimek and Board Member Michael Johnston because compromise ideas suggested by Mr. Shimek to Regional Board staff was later taken up by Mr. Johnson as a possible way to address the agricultural industry's publicly expressed concerns with the proposed waiver. That transmittal of policy ideas from the public to the staff to the decisionmakers was not in any way improper or "ex parte"; it was precisely the way that policy development should work and has worked throughout the waiver renewal process. As he testifies under oath in the declaration submitted with this opposition, Mr. Shimek did not have any communication with Mr. Johnston before the March 15, 2012 Board vote regarding his compromise ideas. Declaration of Steve Shimek ("Shimek Decl.") at ¶ 10.

The actual facts – rather than the fanciful storyline that Agricultural Petitioners weave – are straightforward and not in the least suspect. Having attended a February 24, 2012 Senate committee hearing where growers voiced a number of specific concerns about the proposed new waiver – even after it had been significantly weakened through two years of staff revisions – Mr. Shimek developed a handful of ideas that he believed might address those concerns and allow the waiver process to finally conclude. Shimek Decl. at ¶¶ 3-4. These ideas were not intended to make the proposed waiver more environmentally protective, but to address specific industry concerns with some of its provisions. *Id.* Pursuant to the Regional Board's policy of meeting with individual stakeholders concerning development of the waiver, Mr. Shimek met with staff on March 7, 2012 to convey his compromise ideas. *Id.* at ¶ 5. That same day, he spoke by telephone at length with Rick Tomlinson of the California Strawberry Commission about his ideas. *Id.* Mr. Tomlinson agreed to share these ideas with others in the agricultural community and get back to Mr. Shimek. *Id.* at ¶ 6. Mr. Tomlinson subsequently confirmed that he had spoken to many others in the agricultural community about Mr. Shimek's ideas. *Id.* at ¶ 7. Thus, Agricultural Petitioners' claim that they were somehow blind-sided by Mr. Shimek's ideas is patently false.

Moreover, Mr. Shimek and the Regional Board followed precisely the same public input process that had occurred throughout the development of the waiver, a process used repeatedly by the agricultural industry. Shortly after hearing the industry's latest concerns expressed in a public hearing, Mr. Shimek made an appointment to meet with staff and, in a short meeting, conveyed his compromise ideas. Shimek Decl. at ¶ 5. This meeting was consistent with established procedures, where staff has met dozens of times with agricultural industry representatives and others to obtain stakeholder input. Mr. Shimek did not attempt in any way to conceal his ideas from the agricultural industry; to the contrary, he willingly discussed them with industry representatives in the hope of finding a way to address their expressed concerns. Mr. Shimek did not include his ideas during his March 14, 2012 presentation to the Board because other organizations on whose behalf he was speaking did not entirely agree with them, but he was aware that the agricultural community was familiar with the proposed compromise ideas. Shimek Decl. at ¶¶ 7-8. These circumstances stand in sharp contrast to the approach of the industry, which presented dozens of proposed textual changes during the March 14, 2012 hearing that had not been shared with other stakeholders or the public. Shimek Decl. at ¶ 9. Many of these textual changes were incorporated into the final Order adopted by the Regional Board the next day, even though environmental stakeholders and the public did not have any meaningful opportunity to review or respond to them. *Id.*

In sum, there is no merit to the factual and legal issues raised by Agricultural Petitioners. Accordingly, they fail to satisfy the criteria for a stay.

CONCLUSION

There are no grounds for a stay of the Order. It is beyond dispute that agricultural pollution is causing tremendous harm to the environment and public health. Every day of delay prolongs this substantial injury. In contrast, Agricultural Petitioners' own submissions demonstrate that the cost of complying with the Order while the State Board considers their petitions for review is negligible as compared to the market value of their crops. Moreover, a stay or partial stay of the Order will call into legal question the status of each grower's compliance with the Porter-Cologne Act. The prior waiver has expired and no longer protects growers from liability for their daily discharges into waters of the state. The agency's failure to regulate these discharges under either an effective conditional waiver or individual WDRs would constitute an unprecedented breach of its statutory and public trust obligations to the people of California. There is no legitimate or defensible basis for throwing years of work by the Regional Board into such regulatory chaos. Accordingly, Petitioners Monterey Coastkeeper, San Luis Obispo Coastkeeper, and Santa Barbara Channelkeeper urge the State Board to deny all requests for a stay of the Order, without further briefing or hearing.

Dated: July 13, 2012

Respectfully submitted,

ENVIRONMENTAL LAW CLINIC
Mills Legal Clinic at Stanford Law School

By: Debbie Sivas ________________
Deborah A. Sivas

Counsel for Environmental Petitioners
MONTEREY COASTKEEPER, SAN LUIS OBISPO COASTKEEPER, and SANTA BARBARA CHANNELKEEPER

Deborah A. Sivas, State Bar No. 135446
Leah Russin, State Bar No. 225336
Alicia Thesing, State Bar No. 211751
ENVIRONMENTAL LAW CLINIC
Mills Legal Clinic at Stanford Law School
Crown Quadrangle
559 Nathan Abbott Way
Stanford, California 94305-8610
Telephone: (650) 723-0325
Facsimile: (650) 723-4426
E-mail: dsivas@law.stanford.edu

Attorneys for Petitioners
MONTEREY COASTKEEPER,
SANTA BARBARA CHANNELKEEPER,
SAN LUIS OBISPO COASTKEEPER

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

In the Matter of Adoption of Order No. R3-2012-0011, by the Central Coast Regional Water Quality Control Board for the Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands	**SWRCB/OCC FILES A-2209(a)-(e)** **DECLARATION OF STEVE SHIMEK IN OPPOSITION TO REQUESTS FOR STAY OF CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD ORDER NO. R3-2012-0011**

I, Steve Shimek, declare as follows:

1. I am the Monterey Coastkeeper and the Chief Executive of the Otter Project. In that capacity, and as a concerned resident of the Salinas Valley, I have participated for several years in public processes related to the development and ultimate adoption of the Central Coast Regional Water Quality Control Board ("Regional Board") Order No. R3-2012-0011 ("2012 Ag Waiver"). This declaration is offered in support of the opposition of Monterey Coastkeeper, San Luis Obispo Coastkeeper, and Santa Barbara Channelkeeper to the various requests to stay

implementation of the 2012 Ag Waiver adopted by the Regional Board on March 15, 2012. The matters set forth herein are stated on my personal knowledge and if called upon to testify, I could and would testify competently as to them.

2. Beginning in 2008 and continuing through final adoption of the 2012 Ag Waiver, the Regional Board invited broad input from a wide range of stakeholders through a variety of outreach processes and fora, including an advisory panel, individual meetings with various stakeholders, interested party workshops, public meetings and hearings, and official comment periods. After receiving substantial community input, Regional Board staff prepared a new draft waiver to replace the expiring conditional waiver and presented it at a public meeting of the Board on February 1, 2010. Throughout the next two years, staff continued to solicit input and continued to revise its draft waiver to accommodate and address concerns raised by the agricultural industry. Revised versions of the draft waiver were presented at Board meetings on November 19, 2010, March 17, 2011, May 4, 2011, and September 1, 2011. With each new version, the draft waiver became, in my judgment, less environmentally protective.

3. Despite these numerous revisions to reduce the requirements on growers, some members of the agricultural industry still remained unhappy with the draft waiver. On February 24, 2012, I attended a California Senate Agriculture Committee hearing in Salinas, California, with Senator Anthony Cannella presiding. The topic of the hearing was “Regulatory Impacts on Agriculture” and one of the agenda items was the 2012 Ag Waiver, which was scheduled for adoption by the Regional Board on March 15, 2012. At that Committee hearing, Mr. Dirk Giannini and Mr. Norm Groot gave extended presentations about their concerns with the proposed waiver and with water quality regulation. In their presentations, I understood them to make the following points:

- There was a deep distrust of Central Coast Regional Board staff;
- There was no language in the draft waiver that made it possible for a grower to move to a lower, less regulated tier;
- There was no provision for group efforts (such as the Los Huertos concept);
- There was no incentive for longer-term water quality investments such as tailwater ponds or engineered wetlands, nor was there a provision for allowing extra compliance time to install such investments; and
- There was a fear that individual farm water quality reporting would make growers vulnerable to a third-party lawsuit.

4. Soon thereafter, I began work on a set of new ideas intended to address the specific concerns expressed by growers at the February 24 committee hearing. To be clear, these ideas were not intended to provide more environmental protection or more stringent regulation, even though I believed that more environmentally protective conditions were appropriate and necessary. Rather, each was intended only to provide a potential solution to the problems or concerns raised by growers at the February 24 Committee hearing about then-current version of the draft waiver. Specifically, my ideas included:

- Creation of an independent but balanced committee to review group proposals, thereby taking the burden away from Regional Board staff;
- An express acknowledgement in the waiver that growers can move to a lower, less burdensome tier;
- An express provision in the waiver encouraging group proposals and specifically calling out the Los Huertos and Clark concepts;
- An extended project-specific compliance timeline for group proposals; and
- An express provision allowing for project efficacy monitoring for group projects instead of edge of the field monitoring for individual growers.

5. Consistent with the open-door process that Regional Board staff had established with both agricultural and environmental stakeholders over the last several years, on March 7, 2012, I met with Regional Board Executive Officer Roger Briggs and program staff Lisa McCann and Angela Schroeter in their San Luis Obispo office to present the ideas identified in paragraph 4 above. This meeting was conducted in similar fashion to my prior meetings with staff, including

an explanation of why I was there and a brief discussion of my ideas. To the best of my recollection, the meeting lasted less than an hour.

6. Later in the day on March 7, 2012, a full week before the next scheduled Regional Board hearing on the 2012 Ag Waiver, I participated in a telephone call with Mr. Rick Tomlinson of the California Strawberry Commission. It was clear to me that Mr. Tomlinson had reviewed my proposed ideas. We discussed the concepts and many specifics, and I answered many questions. Mr. Tomlinson said he would think about and discuss my ideas with others and get back to me.

7. On March 13, 2012, I received an email from Mr. Tomlinson stating that he had discussed my ideas with many other people. A true and correct copy of that email is attached hereto as Exhibit A.

8. On March 14, 2012, I gave a presentation at the Regional Board hearing on the 2012 Ag Waiver representing the collective views of Monterey Coastkeeper, San Luis Obispo Coastkeeper, Santa Barbara Channelkeeper, and the Environmental Defense Center. Our group position was in support of the original version of the waiver presented by staff on February 1, 2010. The coalition on whose behalf I was speaking did not entirely support the compromise ideas I communicated to Mr. Briggs and Mr. Tomlinson on March 7. For that reason, I did not present them at the public meeting.

9. In their presentation at the same hearing, representatives of the agricultural industry offered literally dozens of new and specific substantive textual changes to the language of the September 1, 2011 version of the waiver. There was no practical opportunity for me or anyone else to respond to these dozens of language changes during the March 14 hearing, and to the best of my knowledge, none of the environmental stakeholders had been given advance notice of

these proposed changes before the hearing, unlike the agricultural industry's advance notice of the ideas I presented to Mr. Briggs and discussed at length with Mr. Thomlinson on March 7. Nevertheless, after the close of public comment hearing, Regional Board staff incorporated many of the agricultural industry's proposed changes into the 2012 Ag Waiver that was ultimately adopted by the Board on March 15, 2012.

10. At no time before the Regional Board's March 15 vote to adopt the 2012 Ag Waiver did I communicate my March 7 ideas or any language to any member of the Regional Board.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Executed on July 13, 2012 at Monterey, California.

Steve Shimek

EXHIBIT A

From: Rick Tomlinson
To: Steve Shimek
Subject: Re: ag waiver
Date: Tuesday, March 13, 2012 11:47:37 PM

Hi Steve

I wanted to let you know that there was considerable discussion about your proposal. Several farm groups reached out to environmental stakeholders to try and resolve some of the language issues we discussed. While many of your colleagues expressed support for either the staff proposal or the new proposal, they also expressed interest in the Ag proposal.

The Ag group also felt that seven days was just not enough time to get input, especially since the Ag proposal had been publicly available for nearly four months, and Dr. Los Huertos report available for the past two months. We felt that after that extensive public comment and consensus efforts on the ag proposal, that it would be inappropriate to push forward the proposal you made available without the opportunity for any public input.

Thanks
Rick Tomlinson
California Strawberry Commission
(916) 445-3335

Attachment 3

Addressing Nitrate in California's Drinking Water

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

The health of our waters
is the principal measure
of how we live on the land.

—Luna Leopold

Addressing Nitrate in California's Drinking Water

With a Focus on Tulare Lake Basin and Salinas Valley Groundwater

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

This Report and its associated eight Technical Reports were prepared by

Thomas Harter and Jay R. Lund
(Principal Investigators)

Jeannie Darby, Graham E. Fogg, Richard Howitt, Katrina K. Jessoe, G. Stuart Pettygrove, James F. Quinn, and Joshua H. Viers
(Co-Investigators)

Dylan B. Boyle, Holly E. Canada, Nicole DeLaMora, Kristin N. Dzurella, Anna Fryjoff-Hung, Allan D. Hollander, Kristin L. Honeycutt, Marion W. Jenkins, Vivian B. Jensen, Aaron M. King, George Kourakos, Daniel Liptzin, Elena M. Lopez, Megan M. Mayzelle, Alison McNally, Josue Medellin-Azuara, and Todd S. Rosenstock

With project management support from
Cathryn Lawrence and Danielle V. Dolan

Center for Watershed Sciences • University of California, Davis

Groundwater Nitrate Project, Implementation of Senate Bill X2 1

Prepared for California State Water Resources Control Board • January 2012

http://groundwaternitrate.ucdavis.edu

Suggested citation: Harter, T., J. R. Lund, J. Darby, G. E. Fogg, R. Howitt, K. K. Jessoe, G. S. Pettygrove, J. F. Quinn, J. H. Viers, D. B. Boyle, H. E. Canada, N. DeLaMora, K. N. Dzurella, A. Fryjoff-Hung, A. D. Hollander, K. L. Honeycutt, M. W. Jenkins, V. B. Jensen, A. M. King, G. Kourakos, D. Liptzin, E. M. Lopez, M. M. Mayzelle, A. McNally, J. Medellin-Azuara, and T. S. Rosenstock. 2012. Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater. Report for the State Water Resources Control Board Report to the Legislature. Center for Watershed Sciences, University of California, Davis. 78 p. http://groundwaternitrate.ucdavis.edu.

Contents

Tables

Figures

Acknowledgments

Preparation of this Report would not have been possible without assistance from many people contributing in many different ways: Staff members from local, state, and federal agencies and from non-governmental organizations, consultants, and academic colleagues were involved in collecting, organizing, and providing data; exchanging information and ideas; providing technical support and assistance; and reviewing drafts of the Technical Reports. Many students and UC Davis staff other than the authors helped with data entry, literature research, informal surveys, and report preparation.

We particularly thank the following persons for their support of this project: Ben Aldridge, Charles Andrews, Adam Asquith, Denise Atkins, Amadou Ba, Lisa Babcock, Keith Backman, Carolina Balazs, Jennifer Baldwin, Tom Barcellos, Stephen Barnett, Robert H. Beede, Ken Belitz, Daniel Benas, Jamie Bledsoe, Tim Borel, Tony Boren, John Borkovich, Paul Boyer, Scott Bradford, Beverly Briano, Jess Brown, Susan Brownstein, Karen Burow, Jim Butler, Michael Cahn, Kristine Cai, Mary Madison Campbell, Maria de la Paz Carpio-Obeso, Eugene Cassady, Thomas Chamberlain, Antoine Champetier de Ribes, Paul Charpentier, Anthony Chavarria, Kathy Chung, Jennifer Clary, Dennis Clifford, Ron Cole, Tom Coleman, Carol Collar, Paul Collins, Rob Coman, Marc Commandatore, David Cory, Leslie Cotham, Vern Crawford, Pamela Creedon, David Crohn, Debbie Davis, Kevin Day, Michelle De Haan, Susana Deanda, Ria DeBiase, Jesse Dhaliwal, John Dickey, John Diener, Danielle V. Dolan, Paige Dulberg, Murray Einarson, Erik Ekdahl, Brad Esser, Joe Fabry, Bart Faris, Claudia Faunt, Bret Ferguson, Laurel Firestone, Chione Flegal, Robert Flynn, Lauren Fondahl, Wayne Fox, Ryan Fox, Carol Frate, Rob Gailey, James Giannopoulos, Craig Gorman, Lynn Gorman, Kelly Granger, Sarge Green, David Greenwood, Nick Groenenberg, Amrith Gunasekara, Ellen Hanak, Elise Harrington, Tim Hartz, Tom Haslebacher, Charles Hemans, Samantha Hendricks, Tarrah Henrie, Charles Hewitt, Mike Hickey, Cheryl Higgins, Glenn Holder, Gerald Horner, Clay Houchin, Ceil Howe III, Allen Ishida, Chris Johnson, Tim Johnson, Joel Jones, Gary Jorgensen, Stephen Kafka, Mary Kaneshiro, Matthew Keeling, Sally Keldgord, Dennis Keller, Parry Klassen, Ralf Kunkel, William LaBarge, Tess Lake, Matt Landon, Michael Larkin, Sarah Laybourne, Armando Leal, Lauren Ledesma, France Lemieux, Michelle LeStrange, John Letey, Harold Leverenz, Betsy Lichti, Carl Lischeske, Katherine Lockhart, Karl Longley, Michael Louie, Jerry Lowry, Mark Lubell, Patrick Maloney, Elizabeth Martinez, Marsha Campbell Mathews, Megan Mayzelle, Joe McGahan, Mike McGinnis, Chiara McKenney, Zachary Meyers, Gretchen Miller, Eli Moore, Jean Moran, Shannon Mueller, Erin Mustain, Rob Neenan, Dick Newton, Mart Noel, Ben Nydam, Gavin O'Leary, Tricia Orlando, David Orth, Eric Overeem, Doug Parker, Tim Parker, Doug Patterson, Sam Perry, Joe Prado, Kurt Quade, Jose Antonio Ramirez, Solana Rice, Clay Rodgers, Michael Rosberg, Jim Ross, Lisa Ross, Omid Rowhani, Yoram Rubin, Victor Rubin, Joseph Rust, Blake Sanden, Cheryl Sandoval, Sandra Schubert, Kurt Schwabe, Seth Scott, Alan Scroggs, Chad Seidel, Eric Senter, Ann Senuta, David Sholes, Richard Smith, Rosa Staggs, Scott Stoddard, Daniel Sumner, Michael Tharp, Sonja Thiede, Kathy Thomasberg, Larry Tokiwa, Thomas Tomich, Andrew Tran, Thomas Travagli, Kaomine Vang, Leah Walker, Jo Anna Walker, Emily Wallace, Robin Walton, Greg Wegis, Frank Wendland, Dennis Westcot, Jim White, Blake Wilbur, Joel Wiley, Jeff Witte, Craig Wolff, Steve Wright, Xiaoming Yang, and Janice Zinky.

This work was funded by the State Water Resources Control Board under agreement number 09-122-250.

Acronyms and Abbreviations

AB	Assembly Bill
ac	Acre (about 0.4 hectares)
AF	Acre-foot (about 1,233 cubic meters)
AMBAG	Association of Monterey Bay Area Governments
AQUA	Association of People United for Water
ARRA	American Recovery and Reinvestment Act
AWP	Agricultural Waiver Program
BD	Biological Denitrification
BMP	Best Management Practices
CAA	Cleanup and Abatement Account
CalEPA	California Environmental Protection Agency
CAL FAC	California Food and Agriculture Code
CalNRA	California Natural Resources Agency
CCR	California Code of Regulations
CCR	Consumer Confidence Report
CDBG	Community Development Block Grant
CDFA	California Department of Food and Agriculture
CDPH	California Department of Public Health
CoBank	Cooperative Bank
CPWS	Community Public Water System
CRWA	California Rural Water Association
CV-SALTS	Central Valley Salinity Alternative for Long-Term Sustainability
CVSC	Central Valley Salinity Coalition
CWA	Clean Water Act
CWC	Community Water Center
CWSRF	Clean Water State Revolving Fund
DAC	Disadvantaged Communities
DPEIR	Draft Program Environmental Impact Report (of the Central Valley ILRP)
DPR	California Department of Pesticide Regulation
DWR	California Department of Water Resources
DWSAP	Drinking Water Source Assessment and Protection
DWSRF	Drinking Water State Revolving Fund
EDA	U.S. Economic Development Administration

EDR	Electrodialysis Reversal
ERG	Expense Reimbursement Grant Program
ERP-ETT	Enforcement Response Policy and Enforcement Targeting Tool
FFLDERS	Feed, Fertilizer, Livestock, Drugs, and Egg Regulatory Services
FMIP	Fertilizing Materials Inspection Program
FP	Food Processors
FREP	Fertilizer Research and Education Program
GAMA	Groundwater Ambient Monitoring and Assessment
Gg	Gigagram (1 million kilograms, about 1,100 tons)
ha	Hectare (about 2.5 acres)
HAC	Housing Assistance Council
HSNC	Historical Significant Non-Compliers
HUD	U.S. Department of Housing and Urban Development
I-Bank	California Infrastructure and Economic Development Bank
ILRP	Irrigated Lands Regulatory Program
IRWM	Integrated Regional Water Management
ISRF	Infrastructure State Revolving Fund
IX	Ion Exchange
KCWA	Kern County Water Agency
kg	Kilogram (about 2.2 pounds)
L	Liter (about 1.06 liquid quarts)
lb	Pound (about 0.45 kilogram)
LLNL	Lawrence Livermore National Lab
MCL	Maximum Contaminant Level
MCWRA	Monterey County Water Resources Agency
mg	Milligram (about 0.00003 ounce)
MHI	Median Household Income
MUN	Municipal or domestic water supply (beneficial use)
NDWC	National Drinking Water Clearinghouse
NMP	Nutrient Management Plan
NPDES	National Pollutant Discharge Elimination System
NRWA	National Rural Water Association
NUE	Nitrogen Use Efficiency
NWG	Nitrate Working Group

O&M	Operations and Maintenance
OW	EPA's Office of Water
PES	Payment for Ecosystem Services
PHG	Public Health Goal
PNB	Partial Nutrient Balance
POE	Point-of-Entry (for household water treatment)
Porter-Cologne	Porter-Cologne Water Quality Control Act (California Water Code § 13000 et seq.)
POU	Point-of-Use (for household water treatment)
PPL	Project Priority List
PWS	Public Water System
RCAC	Rural Community Assistance Corporation
RCAP	Rural Community Assistance and Partnership
RO	Reverse Osmosis
RUS	Rural Utilities Service
SB	Senate Bill
SDAC	Severely Disadvantaged Communities
SDWA	Safe Drinking Water Act
SDWSRF	Safe Drinking Water State Revolving Fund
SEP	Supplement Environmental Program
SHE	Self-Help Enterprises
SRF	State Revolving Fund
SSWS	State Small Water System
SV	Salinas Valley
t	Ton (U.S. short ton, about 907 kilograms)
TLB	Tulare Lake Basin
U.S. EPA	United States Environmental Protection Agency
U.S.C.	United States Code
USDA	United States Department of Agriculture
USGS	U.S. Geological Survey
WARMF	Watershed Analysis Risk Management Framework
WDR	Waste Discharge Requirements
WEP	Water Environmental Program
WMP	Waste Management Plan
WWTP	Wastewater Treatment Plant

Executive Summary

Executive Summary

In 2008, Senate Bill SBX2 1 (Perata) was signed into law (Water Code Section 83002.5), requiring the State Water Resources Control Board (State Water Board), in consultation with other agencies, to prepare a Report to the Legislature to "improve understanding of the causes of [nitrate] groundwater contamination, identify potential remediation solutions and funding sources to recover costs expended by the State… to clean up or treat groundwater, and ensure the provision of safe drinking water to all communities." The University of California prepared this Report under contract with the State Water Board as it prepares its Report to the Legislature.

This executive summary focuses on major findings and promising actions. Details can be found in the Main Report and eight accompanying Technical Reports.

Key Issues

Groundwater is essential to California, and nitrate is one of the state's most widespread groundwater contaminants. Nitrate in groundwater is principally a by-product of nitrogen use, a key input to agricultural production. However, too much intake of nitrate through drinking water can harm human health.

California's governments, communities, and agricultural industry have struggled over nitrate contamination for decades. **The California Department of Public Health (CDPH) has set the maximum contaminant level (MCL)** for nitrate in drinking water at 45 milligrams per liter (as nitrate). Nitrate concentrations in public drinking water supplies exceeding the MCL require water system actions to provide safe drinking water.

For this study, the four-county **Tulare Lake Basin and the Monterey County portion of the Salinas Valley are examined**. About 2.6 million people in these regions rely on groundwater for drinking water. The study area includes four of the nation's five counties with the largest agricultural production. It represents about 40% of California's irrigated cropland (including 80 different crops) and over half of California's dairy herd. Many communities in the area are among the poorest in California and have limited economic means or technical capacity to maintain safe drinking water given threats from nitrate and other contaminants.

Summary of Key Findings

1. **Nitrate problems will likely worsen for several decades. For more than half a century, nitrate from fertilizer and animal waste have infiltrated into Tulare Lake Basin and Salinas Valley aquifers. Most nitrate in drinking water wells today was applied to the surface decades ago.**

2. **Agricultural fertilizers and animal wastes applied to cropland are by far the largest regional sources of nitrate in groundwater. Other sources can be locally relevant.**

3. **Nitrate loading reductions are possible, some at modest cost. Large reductions of nitrate loads to groundwater can have substantial economic cost.**

4. **Direct remediation to remove nitrate from large groundwater basins is extremely costly and not technically feasible. Instead, "pump-and-fertilize" and improved groundwater recharge management are less costly long-term alternatives.**

5. **Drinking water supply actions such as blending, treatment, and alternative water supplies are most cost-effective. Blending will become less available in many cases as nitrate pollution continues to spread.**

6. **Many small communities cannot afford safe drinking water treatment and supply actions. High fixed costs affect small systems disproportionately.**

7. **The most promising revenue source is a fee on nitrogen fertilizer use in these basins. A nitrogen fertilizer use fee could compensate affected small communities for mitigation expenses and effects of nitrate pollution.**

8. **Inconsistency and inaccessibility of data prevent effective and continuous assessment. A statewide effort is needed to integrate diverse water-related data collection activities by many state and local agencies.**

Nitrate in groundwater poses two major problems and risks:

- **Public health concerns** for those exposed to nitrate contamination in drinking water; in California's Tulare Lake Basin and Salinas Valley, roughly 254,000 people are currently at risk for nitrate contamination of their drinking water. Of these, 220,000 are connected to community public (>14 connections) or state small water systems (5–14 connections), and 34,000 are served by private domestic wells or other systems smaller than the threshold for state or county regulation and which are largely unmonitored.
- **Financial costs of nitrate contamination** include additional drinking water treatment, new wells, monitoring, or other safe drinking water actions; over 1.3 million people are financially susceptible because nitrate in raw source water exceeds the MCL, requiring actions by drinking water systems. Nitrate contamination of drinking water sources will continue to increase as nitrogen from fertilizer, manure, and other sources applied in the last half century continues to percolate downward and flow toward drinking water wells.

Findings: Sources of Nitrate Pollution

Within the study area, human-generated nitrate sources to groundwater include (Figure ES-1):

- cropland (96% of total), where nitrogen applied to crops, but not removed by harvest, air emission, or runoff, is leached from the root zone to groundwater. Nitrogen intentionally or incidentally applied to cropland includes synthetic fertilizer (54%), animal manure (33%), irrigation source water (8%), atmospheric deposition (3%), and wastewater treatment and food processing facility effluent and associated solids (2%) (Figure ES-2);
- percolation of wastewater treatment plant (WWTP) and food processing (FP) wastes (1.5% of total);
- leachate from septic system drainfields (1% of total);
- urban parks, lawns, golf courses, and leaky sewer systems (less than 1% of total); and
- recharge from animal corrals and manure storage lagoons (less than 1% of total);
- downward migration of nitrate-contaminated water via wells (less than 1% of total).

Findings: Reducing Nitrate Pollution

Options for reducing nitrate pollution were identified for all sources. For cropland, where less than 40% of applied nitrogen is removed by crop harvest, 10 management measures (and 50 practices and technologies to achieve these management objectives) were reviewed that can reduce—but not eliminate—nitrate leaching to groundwater. These fall into four categories:

1. Design and operate irrigation and drainage systems to reduce deep percolation.
2. Manage crop plants to capture more nitrogen and decrease deep percolation.
3. Manage nitrogen fertilizer and manure to increase crop nitrogen use efficiency.
4. Improve storage and handling of fertilizers and manure to decrease off-target discharge.

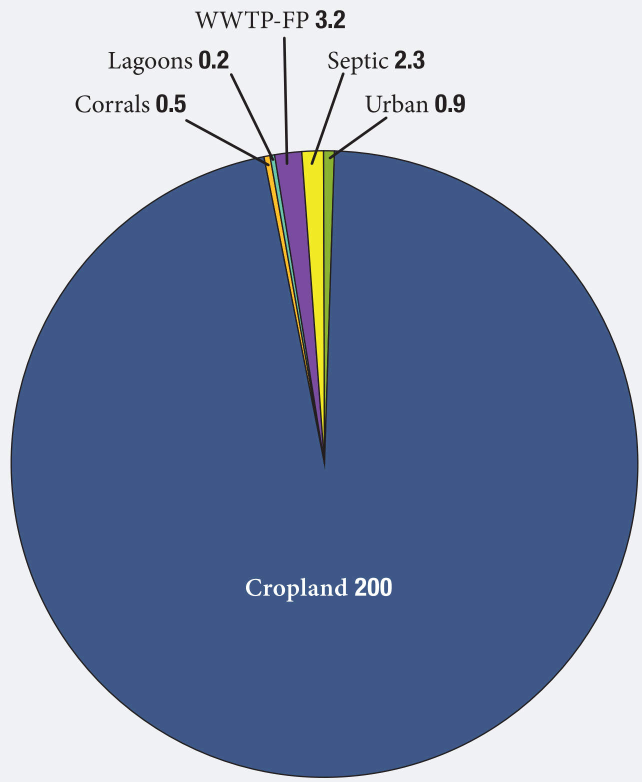
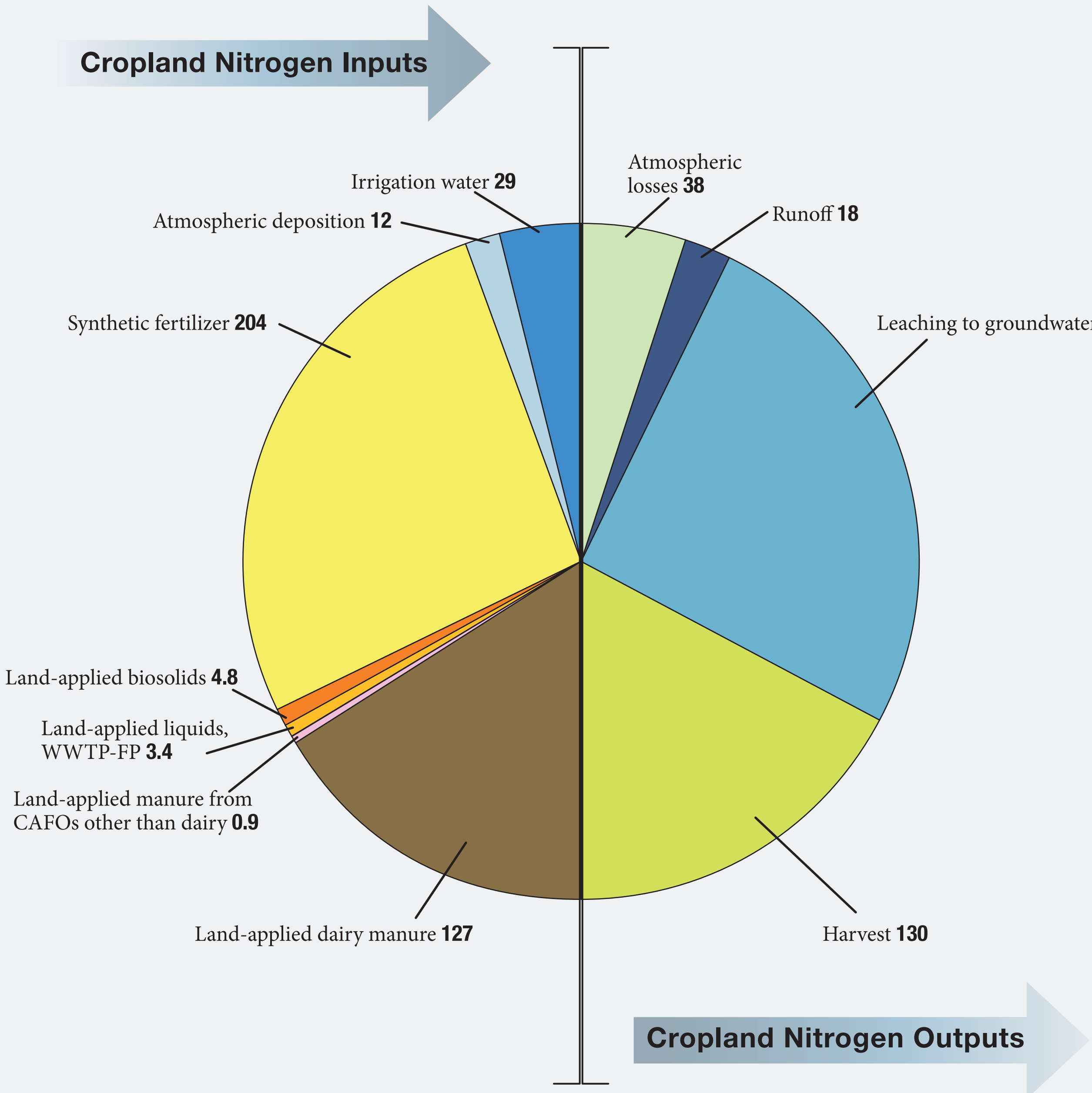


Figure ES-1. Estimated groundwater nitrate loading from major sources within the Tulare Lake Basin and Salinas Valley, in Gg nitrogen per year (1 Gg = 1,100 t).



Note: No mass balance was performed on 0.17 million ha (0.4 million ac) of nitrogen-fixing alfalfa, which is estimated to contribute an additional 5 Gg N/yr to groundwater. Groundwater nitrate loading from all non-cropland sources is about 8 Gg N/yr.

Figure ES-2. Overview of cropland input and output (Gg N/yr) in the study area (Tulare Lake Basin and Salinas Valley) in 2005. The left half of the pie chart represents total nitrogen inputs to 1.27 million ha (3.12 million ac) of cropland, not including alfalfa. The right half of the pie chart represents total nitrogen outputs with leaching to groundwater estimated by difference between the known inputs and the known outputs. Source: Viers et al. 2012.

Some of the needed improvements in nitrogen use efficiency by crops will require increased operating costs, capital improvements, and education. For some cropland, the high economic costs of nitrate source reduction sufficient to prevent groundwater degradation will likely hinder strict compliance with the state's current anti-degradation policy for groundwater (State Water Board Resolution 68-16).

Findings: Groundwater Nitrate Pollution

Groundwater nitrate data were assembled from nearly two dozen agencies and other sources (100,000 samples from nearly 20,000 wells). Of the 20,000 wells, 2,500 are frequently sampled public water supply wells (over 60,000 samples). In these public supply wells, about 1 in 10 raw water samples exceed the nitrate MCL. Apart from the recently established Central Valley dairy regulatory program in the Tulare Lake Basin, there are no existing regular well sampling programs for domestic and other private wells.

The largest percentages of groundwater nitrate MCL exceedances are in the eastern Tulare Lake Basin and in the northern, eastern, and central Salinas Valley, where about one-third of tested domestic and irrigation wells exceed the MCL. These same areas have seen a significant increase in nitrate concentrations over the past half century, although local conditions and short-term trends vary widely.

Travel times of nitrate from source to wells range from a few years to decades in domestic wells, and from years to many decades and even centuries in deeper production wells. This means that nitrate source reduction actions made today may not affect sources of drinking water for years to many decades.

Findings: Groundwater Remediation

Groundwater remediation is the cleanup of contaminated groundwater to within regulatory limits. Traditional pump-and-treat and in-place approaches to remediation, common for localized industrial contamination plumes, would cost billions of dollars over many decades to remove nitrate from groundwater in the Tulare Lake Basin and Salinas Valley. Timely cleanup of basin-scale nitrate contamination is not technically feasible.

Instead, long-term remediation by "pump-and-fertilize" would use existing agricultural wells to gradually remove nitrate-contaminated groundwater and treat the water by ensuring nitrate uptake by crops through appropriate nutrient and irrigation water management. Improved groundwater recharge management would provide clean groundwater recharge to mix with irrigation water recharge and partially mitigate nitrate levels in groundwater regionally.

Removal or reduction of contamination sources must accompany any successful remediation effort. Combining "pump-and-fertilize" with improved groundwater recharge management is more technically feasible and cost-effective.

Findings: Safe Drinking Water Supply

Nitrate contamination is widespread and increasing. Groundwater data show that 57% of the current population in the study area use a community public water system with recorded raw (untreated) nitrate concentrations that have exceeded the MCL at least once between 2006 and 2010. Continued basin-wide trends in nitrate groundwater concentration may raise the affected population to nearly 80% by 2050. Most of this population is protected by water system treatment, or alternative wells, at additional cost. But about 10% of the current population is at risk of nitrate contamination in their delivered drinking water, primarily in small systems and self-supplied households.

No single solution will fit every community affected by nitrate in groundwater. Each affected water system requires individual engineering and financial analyses.

Communities served by small systems vulnerable to nitrate contamination can (a) consolidate with a larger system that can provide safe drinking water to more customers; (b) consolidate with nearby small systems into a new single larger system that has a larger ratepayer base and economies of scale; (c) treat the contaminated water source; (d) switch to surface water; (e) use interim bottled water or point-of-use treatment until an approved long-term solution can be implemented; (f) drill a new well; or (g) blend contaminated wells with cleaner sources, at least temporarily.

There is significant engineering and economic potential for consolidating some systems. Consolidation can often permanently address nitrate problems, as well as many other problems faced by small water systems.

Solutions for self-supplied households (domestic well) or local small water systems (2–4 connections) affected by nitrate contamination are point-of-use (POU) or point-of-entry (POE) treatment and drilling a new or deeper well, albeit with no guarantee for safe drinking water.

Additional costs for safe drinking water solutions to nitrate contamination in the Tulare Lake Basin and Salinas Valley are roughly $20 and $36 million per year for the short- and long-term solutions, respectively. About $17 to $34 million per year will be needed to provide safe drinking water for 85 identified community public and state small water systems in the study area that exceed the nitrate drinking water MCL (serving an estimated 220,000 people). The annualized cost of providing nitrate-compliant drinking water to an estimated 10,000 affected rural households (34,000 people) using private domestic wells or local small water systems is estimated to be at least $2.5 million for point-of-use treatment for drinking use only. The total cost for alternative solutions translates to $80 to $142 per affected person per year, $5 to $9 per irrigated acre per year, or $100 to $180 per ton of fertilizer nitrogen applied in these groundwater basins.

Findings: Regulatory, Funding, and Policy Options

To date, regulatory actions have been insufficient to control nitrate contamination of groundwater. Many options exist to regulate nitrate loading to groundwater, with no ideal solution. Nitrate source reductions will improve drinking water quality only after years to decades. Fertilizer regulations have lower monitoring and enforcement costs and information requirements than do nitrate leachate regulations, but they achieve nitrate reduction targets less directly. Costs to farmers can be lower with fertilizer fees or market-based regulations than with technology mandates or prescriptive standards. Market-based approaches may also encourage the development and adoption of new technologies to reduce fertilizer use.

Current funding programs cannot ensure safe drinking water in the Salinas Valley and Tulare Lake Basin. Small water system costs are high, and some of these systems already face chronic financial problems. Most current state funding for nitrate contamination problems is short term. Little funding is provided for regionalization and consolidation of drinking water systems. Policy options exist for long-term funding of safe drinking water, but all existing and potential options will require someone to bear the costs.

Promising Actions

Addressing groundwater nitrate contamination requires actions in four areas: (a) safe drinking water actions for affected areas, (b) reducing sources of nitrate contamination to groundwater, (c) monitoring and assessment of groundwater and drinking water, and (d) revenues to help fund solutions. Promising actions for legislative and state agency consideration in these areas appear below (see also Table ES-1). Starred (*) actions do not appear to require legislative action, but might benefit from it.

Safe Drinking Water Actions (D)

Safe drinking water actions are the most effective and economical short- and long-term approach to address nitrate contamination problems in the Tulare Lake Basin and Salinas Valley. These actions apply especially to small and self-supplied household water systems, which face the greatest financial and public health problems from nitrate groundwater contamination.

D1: Point-of-Use (POU) Treatment Option. CDPH reports on how to make economical household and point-of-use treatment for nitrate contamination an available and permanent solution for small water systems.*

D2: Small Water System Task Force. CalEPA and CDPH convene an independently led Task Force on Small Water Systems that would report on problems and solutions of small water and wastewater systems statewide as well as the efficacy of various state, county, and federal programs to aid small water and wastewater systems. Many nitrate contamination problems are symptomatic of the broad problems of small water and wastewater systems.*

D3: Regional Consolidation. CDPH and counties provide more legal, technical, and funding support for preparing consolidation of small water systems with nearby larger systems and creating new, regional safe drinking water solutions for groups of small water systems, where cost-effective.*

D4: Domestic Well Testing. In areas identified as being at risk for nitrate contamination by the California Water Boards, as a public health requirement, CDPH (a) mandates periodic nitrate testing for private domestic wells and local and state small systems and (b) requires disclosure of recent well tests for nitrate contamination on sales of residential property. County health departments also might impose such requirements.

D5: Stable Small System Funds. CDPH receives more stable funding to help support capital and operation and maintenance costs for new, cost-effective and sustainable safe drinking water solutions, particularly for disadvantaged communities (DACs).

Source Reduction Actions (S)

Reducing nitrate loading to groundwater is possible, sometimes at a modest expense. But nitrate source reduction works slowly and cannot effectively restore all affected aquifers to drinking water quality. Within the framework of Porter-Cologne, unless groundwater were to be de-designated as a drinking water source, reduction of nitrate loading to groundwater is required to improve long-term water quality. The following options seem most promising to reduce nitrate loading.

S1: Education and Research. California Department of Food and Agriculture (CDFA), in cooperation with the University of California and other organizations, develops and delivers a comprehensive educational and technical program to help farmers improve efficiency in nitrogen use (including manure) and reduce nitrate loading to groundwater. This could include a groundwater nitrate–focused element for the existing CDFA Fertilizer Research and Education Program, including "pump-and-fertilize" remediation and improved recharge options for groundwater cleanup.*

S2: Nitrogen Mass Accounting Task Force. CalEPA establishes a Task Force, including CDFA, to explore nitrogen mass balance accounting methods for regulating agricultural land uses in areas at risk for nitrate contamination, and to compare three long-term nitrogen source control approaches: (a) a cap and trade system; (b) farm-level nutrient management plans, standards, and penalties; and (c) nitrogen fertilizer fees.*

S3: Fertilizer Excise Fee. Significantly raising the cost of commercial fertilizer through a fee or excise tax would fund safe drinking water actions and monitoring and give further incentive to farmers for reducing nitrate contamination. An equivalent fee or excise tax could be considered for organic fertilizer sources (manure, green waste, wastewater effluent, biosolids, etc.).

S4: Higher Fertilizer Fee in Areas at Risk. Areas declared to be at risk for nitrate contamination might be authorized to maintain a higher set of excise fees on nitrogen fertilizer applications (including synthetic fertilizer, manure, waste effluent, biosolids, and organic amendments), perhaps as part of a local safe drinking water compensation agreement.

Monitoring and Assessment (M)

Monitoring and assessment is needed to better assess the evolving nitrate pollution problem and the effectiveness of safe drinking water and nitrate source loading reduction actions. Such activities should be integrated with other state agricultural, environmental, and land use management; groundwater data; and assessment programs (source loading reduction actions)—along with other drinking water, treatment, and wastewater management programs (safe drinking water actions).

M1: Define Areas at Risk. Regional Water Boards designate areas where groundwater sources of drinking water are at risk of being contaminated by nitrate.*

M2: Monitor at-Risk Population. CDPH and the State Water Board, in coordination with DWR and CDFA, issue a report every 5 years to identify populations at risk of contaminated drinking water and to monitor long-term trends of the state's success in providing safe drinking water as a supplement to the California Water Plan Update.*

M3: Learn from Department of Pesticide Regulation Programs. CalEPA and CDFA examine successful DPR data collection, analysis, education, and enforcement programs for lessons in managing nitrogen and other agricultural contaminants, and consider expanding or building upon the existing DPR program to include comprehensive nitrogen use reporting to support nitrate discharge management.*

M4: Groundwater Data Task Force. CalEPA , in coordination with CalNRA and CDPH, convenes an independently led State Groundwater Data Task Force to examine the efficacy of current state and local efforts to collect, maintain, report, and use groundwater data for California's groundwater quality and quantity problems.

M5: Groundwater Task Force. CalEPA, CalNRA, and CDPH maintain a joint, permanent, and independently led State Groundwater Task Force to periodically assess and coordinate state technical and regulatory groundwater programs in terms of effectiveness at addressing California's groundwater quality and quantity problems. These reports would be incorporated into each California Water Plan Update.*

Funding (F)

Little effective action can occur without funding. Four funding options seem most promising, individually or in combination. State funding from fees on nitrogen or water use, which directly affect nitrate groundwater contamination, seem particularly promising and appropriate.

F1: Mill Fee. Increase the mill assessment rate on nitrogen fertilizer to the full authorized amount (CAL. FAC Code Section 14611). This would raise roughly $1 million/year statewide and is authorized for fertilizer use research and education.*

F2: Local Compensation Agreements. Regional Water Boards can require and arrange for local compensation of affected drinking water users under Porter-Cologne Act Water Code Section 13304. Strengthening existing authority, the Legislature could require that a Regional Water Board finding that an area is at risk of groundwater nitrate contamination for drinking water be accompanied by a cleanup and abatement order requiring overlying, current sources of nitrate to financially support safe drinking water actions acceptable to the local County Health Department. This might take the form of a local "liability district."*

F3: Fertilizer Excise Fee. Introduce a substantial fee on nitrogen fertilizer sales or use, statewide or regionally, to fund safe drinking water actions, nitrate source load reduction efforts, and nitrate monitoring and assessment programs.

F4: Water Use Fee. A more comprehensive statewide fee on water use could support many beneficial activities. Some of such revenues could fund management and safe drinking water actions in areas affected by nitrate contamination, including short-term emergency drinking water measures for disadvantaged communities.

Table ES-1. Likely performance of promising state and agency actions for nitrate groundwater contamination.

Action	Safe Drinking Water	Groundwater Degradation	Economic Cost
No Legislation Required			
Safe Drinking Water Actions			
D1: Point-of-Use Treatment Option for Small Systems +	♦♦		low
D2: Small Water Systems Task Force +	♦		low
D3: Regionalization and Consolidation of Small Systems +	♦♦		low
Source Reduction Actions			
S1: Nitrogen/Nitrate Education and Research +		♦♦♦	low–moderate
S2: Nitrogen Accounting Task Force +		♦♦	low
Monitoring and Assessment			
M1: Regional Boards Define Areas at Risk +	♦♦♦	♦♦♦	low
M2: CDPH Monitors At-Risk Population +	♦	♦	low
M3: Implement Nitrogen Use Reporting +		♦♦	low
M4: Groundwater Data Task Force +	♦	♦	low
M5: Groundwater Task Force +	♦	♦	low
Funding			
F1: Nitrogen Fertilizer Mill Fee		♦♦♦	low
F2: Local Compensation Agreements for Water +	♦♦	♦	moderate
New Legislation Required			
D4: Domestic Well Testing *	♦♦		low
D5: Stable Small System Funds	♦		moderate
Non-tax legislation could also strengthen and augment existing authority.			
Fiscal Legislation Required			
Source Reduction			
S3: Fertilizer Excise Fee	♦♦	♦	moderate
S4: Higher Fertilizer Fee in Areas at Risk	♦	♦	moderate
Funding Options			
F3: Fertilizer Excise Fee	♦♦	♦♦	moderate
F4: Water Use Fee	♦♦	♦♦	moderate

♦ Helpful

♦♦ Effective

♦♦♦ Essential

+ Legislation would strengthen.

* County health departments may have authority; CDPH requires legislation.

1 Introduction

The development of California's tremendous economy has not been without environmental costs. Since early in the twentieth century, nitrate from agricultural and urban activities has slowly infiltrated into groundwater. Nitrate has accumulated and spread and will continue to make its way into drinking water supplies. The time lag between the application of nitrogen to the landscape and its withdrawal at household and community public water supply wells, after percolating through soils and groundwater, commonly extends over decades.

This Report is an overview of groundwater contamination by nitrate in the Tulare Lake Basin and Salinas Valley. We examine the extent, causes, consequences, and costs of this contamination, as well as how it will likely develop over time. We also examine management and policy actions available for this problem, including possible nitrate source reduction, provisions for safe drinking water, monitoring and assessment, and aquifer remediation actions. The costs and institutional complexities of these options, and how they might be funded, also are addressed.

Addressing nitrate contamination problems in the Tulare Lake Basin and Salinas Valley will require decades to resolve, driven by the pace of groundwater flow and the response times of humans and institutions on the surface. Nitrate in drinking water today is a legacy contaminant, but years and decades from now the nitrate in drinking water will be from today's discharges. Assistance and management to improve drinking water supplies in response to nitrate contamination is a central and urgent policy issue for the State of California. Another major policy issue is the inevitability of widespread groundwater degradation for decades to come, despite even heroic (and ultimately expensive) efforts to reduce nitrate loading into aquifers. This introduction attempts to put the issue in a larger context.

Groundwater is essential to California. Groundwater is vital for California's agricultural, industrial, urban, and drinking water uses. Depending on drought conditions, groundwater provides between one-third and nearly one-half of the state's water supplies. As a source of drinking water, groundwater serves people from highly dispersed rural communities to densely populated cities. More than 85% of community public water systems in California (serving 30 million residents) rely on groundwater for at least part of their drinking water supply. In addition, approximately 2 million residents rely on groundwater from either a private domestic well or a smaller water system not regulated by the state (State Water Board 2011). Intensive agricultural production, population growth, and—indirectly—partial restoration of environmental instream flows have led to groundwater overdraft (Hanak et al. 2011). More protective health-based water quality standards for naturally occurring water quality constituents and groundwater contamination from urban and agricultural activities pose serious challenges to managing the state's drinking water supply.

Nitrate is one of California's most widespread groundwater contaminants. Nitrate is among the most frequently detected contaminants in groundwater systems around the world, including the extensively tapped aquifers in California's Central Valley and Salinas Valley (Figure 1) (Spalding and Exner 1993; Burow et al. 2010; Dubrovsky et al. 2010; MCWRA 2010; Sutton et al. 2011). Nitrate contamination poses an environmental health risk because many rural areas obtain drinking water from wells that are often shallow and vulnerable to contamination (Guillette and Edwards 2005; Fan and Steinberg 1996).

High levels of nitrate affect human health. Infants who drink water (often mixed with baby formula) containing nitrate in excess of the maximum contaminant level (MCL) for drinking water may quickly become seriously ill and, if untreated, may die because high nitrate levels can decrease the capacity of an infant's blood to carry oxygen (methemoglobinemia, or "blue baby syndrome"). High nitrate levels may also affect pregnant women and adults with hereditary cytochrome b5 reductase deficiency. In addition, nitrate and nitrite ingestion in humans has been linked to goitrogenic (anti-thyroid) actions on the thyroid gland (similar to perchlorate), fatigue and reduced cognitive functioning due to chronic hypoxia, maternal reproductive complications including spontaneous abortion, and a variety of carcinogenic outcomes deriving from N-nitrosamines formed via gastric nitrate conversion in the presence of amines (Ward et al. 2005).

Nitrate is part of the natural nitrogen cycle in the environment. Groundwater nitrate is part of the global nitrogen cycle. Like other key elements essential for life, nitrogen flows through the environment in a dynamic cycle that supports organisms ranging from microbes to plants to animals. Plants require nitrogen for growth, and scarcity of fixed soil nitrogen often limits plant growth. Specialized microorganisms can fix atmospheric elemental nitrogen and make it available for plants to use for photosynthesis and growth. The natural nitrogen cycle is a dynamic balance between elemental nitrogen in the atmosphere and reactive forms of nitrogen moving through the soil-plant-animal-water-atmosphere cycle of ecosystems globally. Production of synthetic nitrogen fertilizer has disrupted this balance.

Nitrogen is key to global food production. Modern agricultural practices, using synthetically produced nitrogen fertilizer, have supplied the nitrogen uses of plants to increase food, fiber, feed, and fuel production for consumption by humans and livestock. Agricultural production is driven by continued global growth in population and wealth, which increases demand for agricultural products, particularly high-value agricultural products such as those produced in California. Global food, feed, and fiber demands are anticipated to increase by over 70% over the next 40 years (Tilman et al. 2002; De Fraiture et al. 2010).

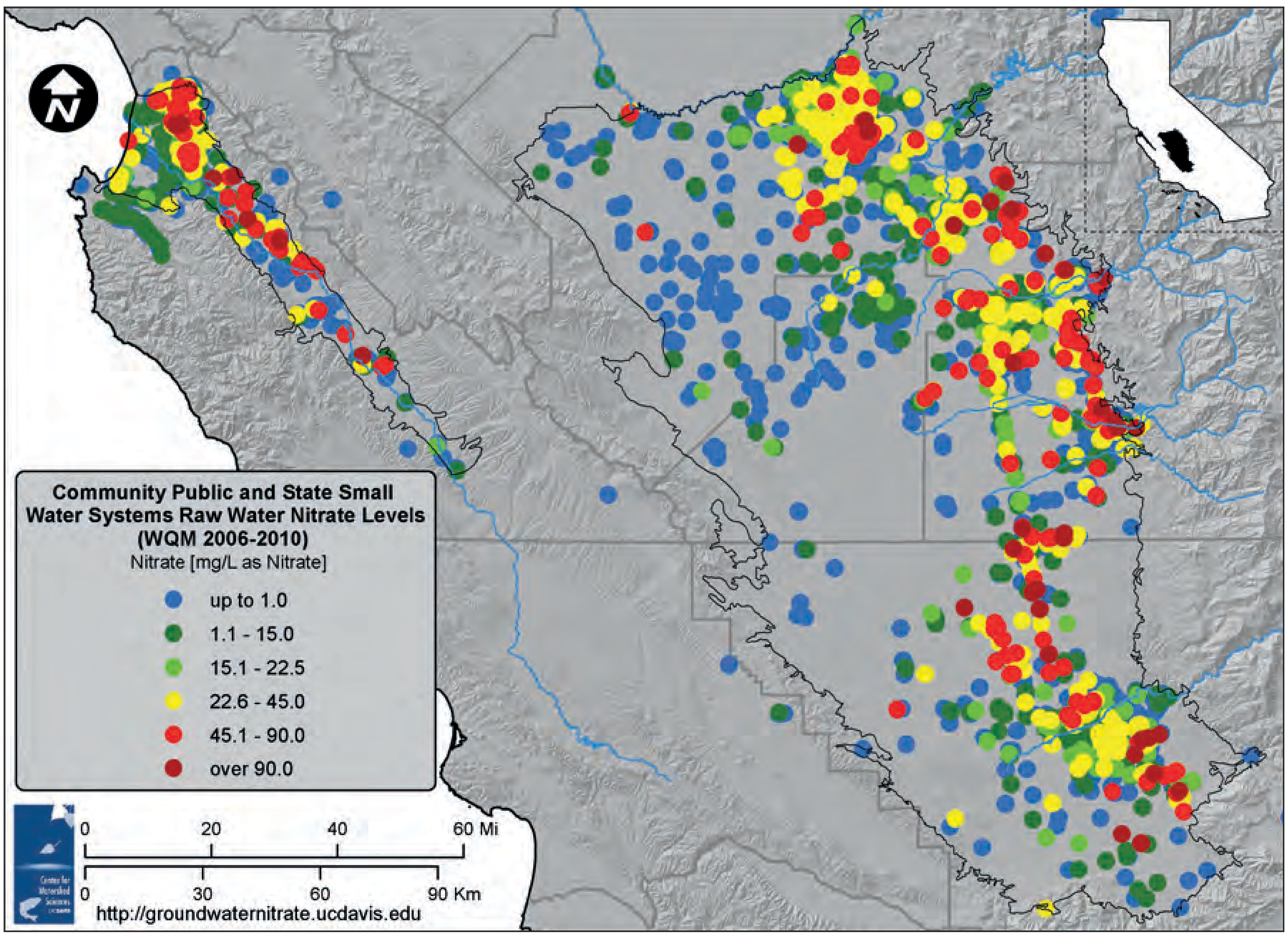


Figure 1. Maximum reported raw-level nitrate concentration in community public water systems and state-documented state small water systems, 2006–2010. Source: CDPH PICME WQM Database (see Honeycutt et al. 2011).

Intensive agriculture and human activities have increased nitrate concentrations in the environment. Greater use of nitrogen-based fertilizers, soil amendments such as manure, and nitrogen-fixing cover crops add nitrogen to deficient soils and dramatically raise crop yields. Technological advances in agriculture, manufacturing, and urban practices have increased levels of reactive forms of nitrogen, including nitrate, released into the atmosphere, into surface water, and into groundwater. The nearly 10-fold increase of reactive nitrogen creation related to human activities over the past 100 years (Galloway and Cowling 2002) has caused a wide range of adverse ecological and environmental impacts (Davidson et al. 2012).

The most remarkable impacts globally include the leaching of nitrate to groundwater; the eutrophication of surface waters and resultant marine "dead zones"; atmospheric deposition that acidifies ecosystems; and the emission of nitrogen oxides (NOx) that deplete stratospheric ozone (Keeney and Hatfield 2007; Beever et al. 2007; Foley et al. 2005). These widespread environmental changes also can threaten human health (Galloway et al. 2008; Guillette and Edwards 2005; Galloway et al. 2004; Townsend et al. 2003; Vitousek et al. 1997; Fan and Steinberg 1996; Jordan and Weller 1996).

California has decentralized regulatory responsibility for groundwater nitrate contamination. Nitrate contamination of groundwater affects two state agencies most directly. Sources of groundwater nitrate are regulated under California's Porter-Cologne Water Quality Control Act (Porter-Cologne) administered through the State Water Resources Control Board (State Water Board) and the Regional Water Quality Control Boards (Regional Water Boards). State Water Board Resolution 88-63 designates drinking water as a beneficial use in nearly all of California's major aquifers. Under the Porter-Cologne Act, dischargers to groundwater are responsible, first, for preventing adverse effects on groundwater as a source of drinking water, and second, for cleaning up groundwater when it becomes contaminated.

Drinking water in public water systems (systems with at least 15 connections or serving at least 25 people for 60 or more days per year) is regulated by CDPH under the federal Safe Drinking Water Act of 1972 (SWDA). CDPH has set the nitrate MCL in drinking water at 45 mg/L (10 mg/L as nitrate-N). If nitrate levels in public drinking water supplies exceed the MCL standard, mitigation measures must be employed by water purveyors to provide a safe supply of drinking water to the population at risk.

The California Department of Food and Agriculture (CDFA) and the Department of Water Resources (DWR) also have roles in nitrate management. The DWR is charged with statewide planning and funding efforts for water supply and water quality protection, including the funding of Integrated Regional Water Management Plans and DWR's management of urban and agricultural water use efficiency. CDFA collects data, funds research, and promotes education regarding the use of nitrogen fertilizers and other nutrients in agriculture.

SBX2 1 Nitrate in Groundwater Report to Legislature. In 2008, the California legislature enacted Senate Bill SBX2 1 (Perata), which created California Water Code Section 83002.5. The bill requires the State Water Board to prepare a Report to the Legislature (within 2 years of receiving funding) to "improve understanding of the causes of [nitrate] groundwater contamination, identify potential remediation solutions and funding sources to recover costs expended by the state for the purposes of this section to clean up or treat groundwater, and ensure the provision of safe drinking water to all communities." Specifically, the bill directs the State Water Board to

> identify sources, by category of discharger, of groundwater contamination due to nitrate in the pilot project basins; to estimate proportionate contributions to groundwater contamination by source and category of discharger; to identify and analyze options within the board's current authority to reduce current nitrate levels and prevent continuing nitrate contamination of these basins and estimate the costs associated with exercising existing authority; to identify methods and costs associated with the treatment of nitrate contaminated groundwater for use as drinking water; to identify methods and costs to provide an alternative water supply to groundwater reliant communities in each pilot project basin; to identify all potential funding sources to provide resources for the cleanup of nitrate, groundwater treatment for nitrate, and the provision of alternative drinking water supply, including, but not limited to, State bond funding, federal funds, water rates, and fees or fines on polluters; and to develop recommendations for developing a groundwater cleanup program for the Central Valley Water Quality Control Region and the Central Coast Water Quality Control Region based upon pilot project results.

The bill designates the groundwater basins of the Tulare Lake Basin region and the Monterey County portion of the Salinas Valley as the selected pilot project areas. In June 2010, the State Water Board contracted with the University of California, Davis, to prepare this Report for the Board as background for its Report to the Legislature.

Project area is relevant to all of California. The project area encompasses all DWR Bulletin 118 designated groundwater sub-basins of the Salinas River watershed that are fully contained within Monterey County, and the Pleasant Valley, Westside, Tulare Lake Bed, Kern, Tule River, Kaweah River, and Kings River groundwater sub-basins of the Tulare Lake Basin. The study area—2.3 million ha (5.7 million ac) in size—is home to approximately 2.65 million people, almost all of whom rely on groundwater as a source of drinking water. The study area includes four of the nation's five counties with the largest agricultural production; 1.5 million ha (3.7 million ac) of irrigated cropland, representing about 40% of California's irrigated cropland; and more than half of California's dairy herd. More than 80 different crops are grown in the study area (Figure 2). This is also one of California's poorest regions: many census blocks with significant population belong to the category of severely disadvantaged communities (less than 60% of the state's median household income), and many of the remaining populated areas are disadvantaged communities (less than 80% of the state's median household income). These communities have little economic means and technical capacity to maintain safe public drinking water systems given contamination from nitrate and other contaminants in their drinking water sources.

Report excludes assessment of public health standards for nitrate. Public health and appropriateness of the drinking water limits are prescribed by CDPH and by U.S. EPA under SDWA. The scope of SBX2 1 precluded a review of the public health aspects or a review of the appropriateness of the nitrate MCL, although this is recognized as an important and complex aspect of the nitrate contamination issue (Ward et al. 2005).

"Report for the State Water Resources Control Board Report to the Legislature" and supporting Technical Reports. This Report for the State Water Board Report to the Legislature ("Report") has been provided in fulfillment of the University of California, Davis, contract with the State Water Board. This Report provides an overview of the goals of the research, methods, and key findings of our work, and is supported by eight related Technical Reports (Harter et al. 2012; Viers et al. 2012; Dzurella et al. 2012; Boyle et al. 2012; King et al. 2012; Jensen et al. 2012; Honeycutt et al. 2012; and Canada et al. 2012). The Technical Reports provide detailed information on research methods, research results, data summaries, and accompanying research analyses that are important for evaluating our results and findings and for applying our approach and results to other groundwater basins.

The Report takes a broad yet quantitative view of the groundwater nitrate problem and solutions for this area and reflects collaboration among a diverse, interdisciplinary team of experts. In its assessment, the Report spans institutional and governmental boundaries. The Report quantifies the diverse range of sources of groundwater nitrate. It reviews the current groundwater quality status in the project area by compiling and analyzing all available data from a variety of institutions. It then identifies source reduction, groundwater remediation, drinking water treatment, and alternative drinking water supply alternatives, along with the costs of these options. Descriptions and summaries are also included of current and potential future funding options and regulatory measures to control source loading and provide safe drinking water, along with their advantages, disadvantages, and potential effectiveness.

This set of Reports is the latest in a series of reports on nitrate contamination in groundwater beginning in the 1970s (Schmidt 1972; Report to Legislature 1988; Dubrovsky et al. 2010; U.S. EPA 2011). This Report has some of the same conclusions as previous reports but takes a much broader perspective, contains more analysis, and perhaps provides a wider range of promising actions.

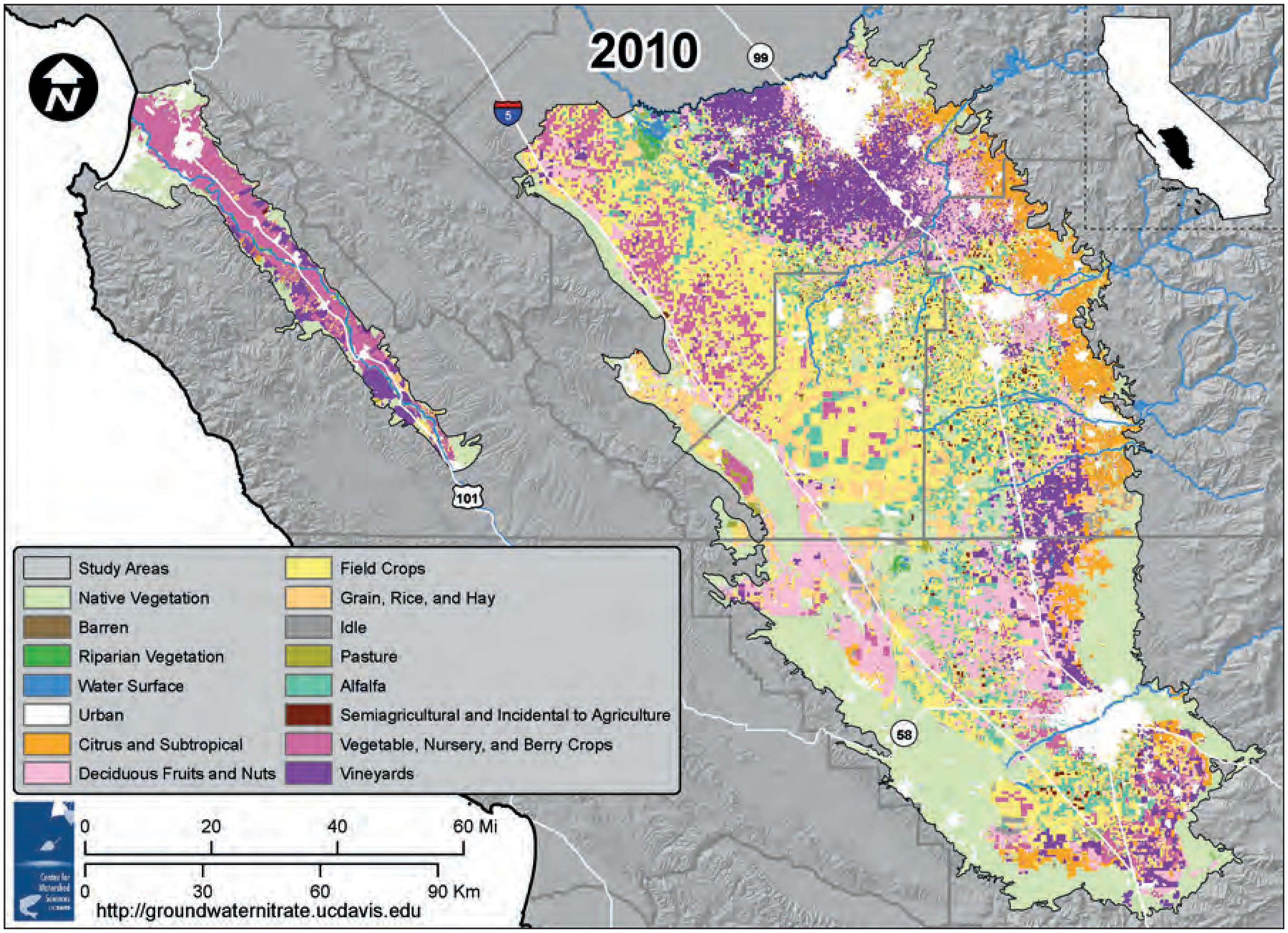
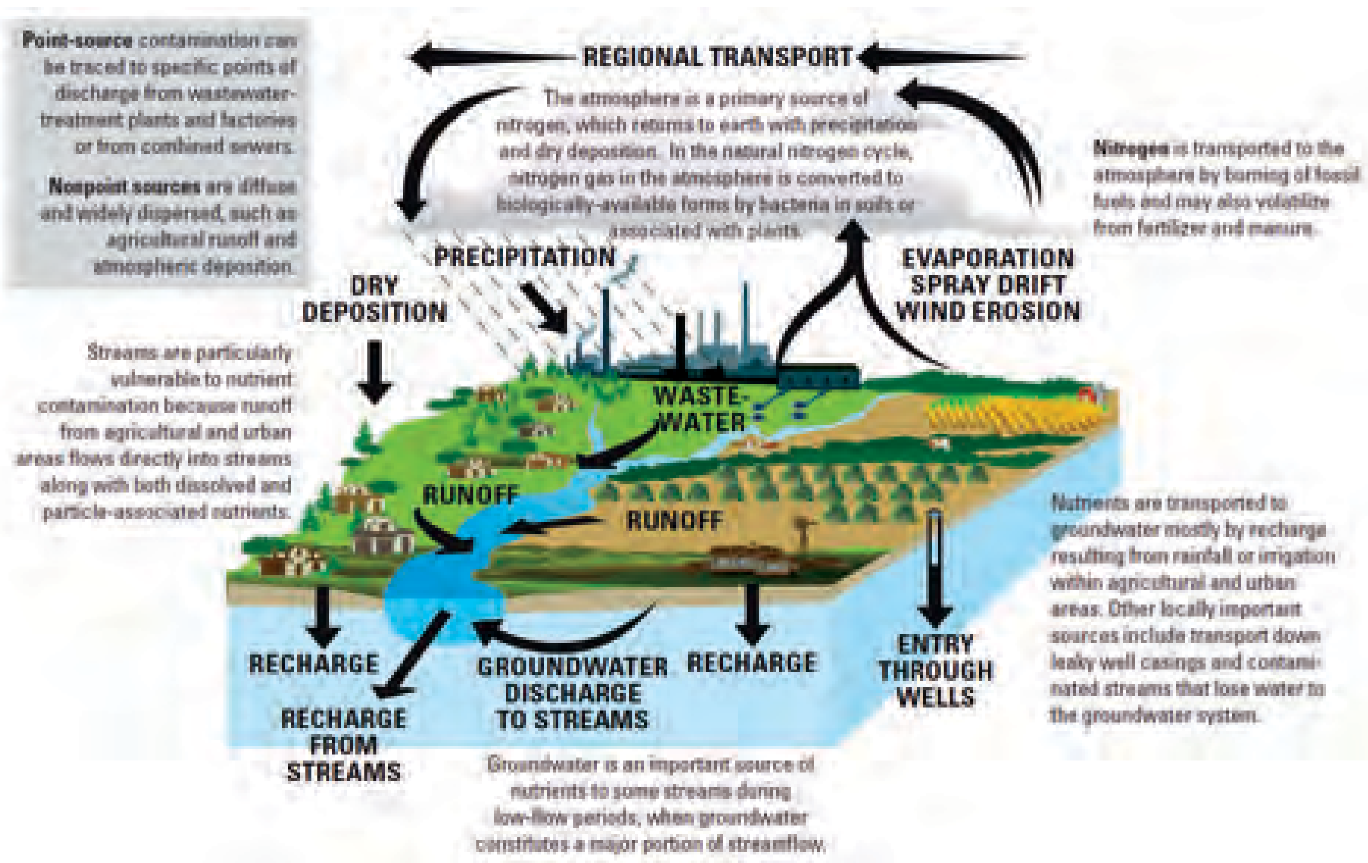


Figure 2. The Tulare Lake Basin (TLB) and Salinas Valley (SV) are the focus of this study. The study area represents 40% of California's diverse irrigated agriculture and more than half of its confined animal farming industry. It is home to 2.6 million people, with a significant rural population in economically disadvantaged communities. Source: Viers et al. 2012.



Source: Dubrovsky et al. 2010.

2 Sources of Groundwater Nitrate

2.1 Nitrogen Cycle: Basic Concepts

Nitrogen is an essential element for all living organisms. Nitrogen cycles through the atmosphere, hydrosphere, and biosphere. The dominant gas (78%) in the atmosphere is highly stable (inert) N_2 gas. Biological nitrogen fixation transforms N_2 gas into ammonia (NH_3), which is rapidly converted to the forms of nitrogen needed for plant growth. Nitrogen fixation is performed only by specialized soil and aquatic microbes. Other living organisms cannot use inert atmospheric N_2 directly but rely on accumulated soil organic matter, plants, animals, and microbial communities for nitrogen.

Soil nitrogen is most abundant in the organic form (N_{org}). Mineralization is a suite of processes performed by soil microbes that converts organic nitrogen to inorganic forms of nitrogen. The rates of mineralization depend on the environmental conditions such as temperature, moisture, pH, and oxygen content, as well as the type of organic matter available. The first product of mineralization is ammonium (NH_4^+), but under aerobic conditions, microbes can convert ammonium (NH_4^+) first to nitrite (NO_2^-) and then to nitrate (NO_3^-). Most plants use nitrate or ammonium as their preferred source of nitrogen (White 2006). Immobilization is the reverse of mineralization in that soil ammonium and nitrate are taken up by soil organisms and plants and converted into N_{org}.

The ultimate fate of "reactive" nitrogen (organic nitrogen, ammonium, nitrate, ammonia, nitrous oxide, etc.) is to return back to the atmosphere as N_2. For nitrate, this is a microbially mediated process ("denitrification") that requires an anoxic (i.e., oxygen-free) environment.

Groundwater is becoming a growing component of the global nitrogen cycle because of the increased nitrogen inflows and because of long groundwater residence times. Nitrate does not significantly adhere to or react with sediments or other geologic materials, and it moves with groundwater flow. Other forms of reactive nitrogen in groundwater are less significant and much less mobile: ammonia occurs under some groundwater conditions, but it is subject to sorption and rapidly converts to nitrate under oxidizing conditions. Dissolved organic nitrogen (DON) concentrations are generally much less than those of nitrate, except near wastewater sources, due to the high adsorption of DON to aquifer materials.

Groundwater nitrate inputs may come from natural, urban, industrial, and agricultural sources. Groundwater nitrate outputs occur through wells or via discharge to springs, streams, and wetlands. Discharge to surface water sometimes involves denitrification or reduction of nitrate to ammonium when oxygen-depleted conditions exist beneath wetlands and in the soils immediately below streams.

2.2 Sources of Nitrate Discharge to Groundwater

Nitrogen enters groundwater at varying concentrations and in varying forms (organic nitrogen, ammonium, nitrate) with practically all sources of recharge: diffuse recharge from precipitation and irrigation; focused recharge from streams, rivers, and lakes; focused recharge from recharge basins and storage lagoons; and focused recharge from septic system drainfields. Across major groundwater basins in California, diffuse recharge from irrigation, stream recharge, and intentional recharge are the major contributors to groundwater. Since groundwater is an important reservoir for long-term water storage, recharge is extremely important and desirable in many areas. Controlling nitrate in recharge and managing recharge are therefore key to nitrate source control.

Current groundwater nitrate, its spatial distribution, and its changes over time are the result of recent as well as historical nitrate loading. To understand current and future groundwater conditions requires knowledge of historical, current, and anticipated changes in land use patterns, recharge rates, and nitrate loading rates (Viers et al. 2012).

Natural Nitrate Sources

Nitrate occurs naturally in many groundwaters but at levels far below the MCL for drinking water (Mueller and Helsel 1996). The main potential sources of naturally occurring nitrate are bedrock nitrogen and nitrogen leached from natural soils. Surface water nitrate concentrations can be elevated in areas with significant bedrock nitrogen (Holloway et al. 1998), but they are not high enough to be a drinking water concern. During the early twentieth century, conversion of the study area's semiarid and arid natural landscape to irrigated agriculture may have mobilized two additional, naturally occurring sources of nitrate. First, nitrate was released from drained wetlands at the time of land conversion due to increased microbial activity in agricultural soils; stable organic forms of nitrogen that had accumulated in soils over millennia were converted to mobile nitrate. Second, nitrate salts that had accumulated over thousands of years in the unsaturated zone below the grassland and desert soil root zone due to lack of significant natural recharge were mobilized by irrigation (Dyer 1965; Stadler et al. 2008; Walvoord et al. 2003). However, the magnitude of these sources (Scanlon 2008) is considered to have negligible effects on regional groundwater nitrate given the magnitude of human sources.

Human Nitrate Sources

Anthropogenic groundwater nitrate sources in the study area include agricultural cropland, animal corrals, animal manure storage lagoons, wastewater percolation basins at municipal wastewater treatment plants (WWTPs) and food processors (FPs), septic system drainfields (onsite sewage systems), leaky urban sewer lines, lawns, parks, golf courses, and dry wells or percolation basins that collect and recharge stormwater runoff. Incidental leakage of nitrate may also occur directly via poorly constructed wells. Croplands receive nitrogen from multiple inputs: synthetic fertilizer, animal manure, WWTP and FP effluent, WWTP biosolids, atmospheric deposition, and nitrate in irrigation water sources.

Source categories. For this Report, we estimated the groundwater nitrate contributions for 58 individual agricultural cropland categories, for animal corrals, for manure lagoons, for each individual WWTP and FP within the study area, for dairies and other animal farming operations, for septic system drainfields, and for urban sources. Contributions from dry wells and incidental leakage through existing wells were estimated at the basin scale. Groundwater nitrate contributions were estimated for five time periods, each consisting of 5 years: 1943–1947 ("1945"), 1958–1962 ("1960"), 1973–1977 ("1975"), 1988–1992 ("1990"), and 2003–2007 ("2005"); the latter is considered to be current. Future year 2050 loading was estimated based on anticipated land use changes (primarily urbanization). These categorical or individual estimates of nitrate leaching lead to maps that show nitrate discharge at a resolution of 0.25 ha (less than 1 ac) for the entire study area and its changes over a period of 105 years (1945–2050) (Viers et al. 2012; Boyle et al. 2012).

Separately, we also aggregated nitrate loads to groundwater

- by crop categories (e.g., olives, persimmons, lettuce, strawberries) and crop groups (e.g., "subtropicals," "vegetables and berries") averaged or summed over the entire study area;
- by county, totaled across all cropland, all WWTPs and FPs, all dairies, all septic drains, and all municipal areas; and
- summed or averaged for the study area.

Higher levels of aggregation provide more accurate estimates but are less descriptive of actual conditions at any given location. Aggregated totals are most useful for policy and planning.

We report nitrate loading to groundwater in two ways:

- Total annual nitrate leached to groundwater, measured in gigagrams of nitrate-nitrogen per year (Gg N/yr).[1] As a practical measure, 1 gigagram is roughly equivalent to $1 million of nitrogen fertilizer at 2011 prices.
- Intensity of the nitrate leaching to groundwater, measured in kilograms of nitrate-nitrogen per ha of use per year (kg N/ha/yr) [lb per acre per year, lb/ac/yr], which represents the intensity of the source at its location (field, pond, corral, census block, city) and its potential for local groundwater pollution.

How much nitrate loading to groundwater is acceptable? To provide a broad reference point of what the source loading numbers mean with respect to potential groundwater pollution, it is useful to introduce an operational benchmark that indicates whether nitrate leached in recharge to groundwater exceeds the nitrate drinking water standard. This operational benchmark considers that nearly all relevant anthropogenic nitrate sources provide significant groundwater recharge and therefore remain essentially undiluted when

[1] One gigagram is equal to 1 million kilograms (kg), 1,000 metric tons, 2.2 million pounds (lb), or 1,100 tons (t). In this report, nitrogen application to land refers to total nitrogen (organic nitrogen, ammonium-nitrogen, and nitrate-nitrogen). For consistency and comparison, total nitrate loading and the intensity of nitrate loading from the root zone to groundwater are also provided in units of nitrogen, not as nitrate. However, concentrations of nitrate in groundwater or leachate are always stated as nitrate (MCL: 45 mg/L) unless noted otherwise.

reaching groundwater. Our benchmark for "low" intensity versus "high" intensity of nitrate leaching is 35 kg N/ha/yr (31 lb N/ac/yr).[2] Aggregated across the 1.5 million ha (3.7 million ac) of cropland, the benchmark for total annual nitrate loading in the study area is 50 Gg N/yr (55,000 t N/yr). Total nitrate loading to groundwater above this benchmark indicates a high potential for regional groundwater degradation.

Estimating nitrate loading by source category. We used two methods to assess nitrate loading:

- a mass balance approach was used to estimate nitrate loading from all categories of cropland except alfalfa;
- alfalfa cropland and nitrate sources other than cropland were assessed by reviewing permit records, literature sources, and by conducting surveys to estimate groundwater nitrate loading (Viers et al. 2012).

Groundwater Nitrate Contributions by Source Category

Cropland is by far the largest nitrate source, contributing an estimated 96% of all nitrate leached to groundwater (Table 1). The total nitrate leached to groundwater (200 Gg N/yr [220,000 t N/yr]) is four times the benchmark amount, which suggests large and widespread degradation of groundwater quality. Wastewater treatment plants and food processor waste percolation basins are also substantial, high-intensity sources.[3] Septic systems, manure storage lagoons, and corrals are relatively small sources basin-wide, but since their discharge intensity significantly exceeds the operational benchmark of 35 kg N/ha/yr (31 lb N/ac/yr), these source categories can be locally important. The magnitude and intensity of urban sources (other than septic systems) does not suggest widespread impact to groundwater (Viers et al. 2012). The following sections provide further detail on these sources.

Agricultural Sources

Cropland sources: Overview. The five counties in the study area include 1.5 million ha (3.7 million ac) of cropland, about 40% of California's irrigated cropland. Agricultural production involves many crops and significant year-to-year changes in crops grown and crop yields. The dominant crop groups in the project area include subtropical crops (citrus and olives), tree fruits and nuts, field crops including corn and cotton, grain crops, alfalfa, vegetables and strawberries, and grapes (see Figure 2). The study area also supports 1 million dairy cows. These produce one-tenth of the nation's milk supply as well as large amounts of manure.

Cropland sources: Alfalfa. The mass balance approach is not applied to alfalfa because it does not receive significant amounts of fertilizer, yet alfalfa fixes large amounts of nitrogen from the atmosphere. Little is known about nitrate leaching from alfalfa; we used a reported value of 30 kg N/ha/yr (27 lb N/ac/yr) (Viers et al. 2012). In total, 170,000 ha (420,000 ac) of alfalfa fields are estimated to contribute about 5 Gg N/yr (5,500 t N/yr) in the study area. Alfalfa harvest exceeds 400 kg N/ha/yr (360 lb N/ac/yr), or 74 Gg N/yr (82,000 t N/yr), in the study area.

Cropland sources other than alfalfa. Unlike other groundwater nitrate source categories, cropland has many sources of nitrogen application, all of which can contribute to nitrate leaching. Principally, crops are managed for optimal harvest. Synthetic nitrogen is the fertilizer of choice to achieve this goal, except in alfalfa. Other sources of nitrogen are also applied to cropland, providing additional fertilizer, serving as soil amendments, or providing a means of waste disposal. These additional nitrogen sources include animal manure and effluent and biosolids from WWTPs, FPs, and other urban sources. Often do they replace synthetic fertilizer as the main source of nitrogen for a crop. Atmospheric deposition of nitrogen and nitrate in irrigation water are mostly incidental but ubiquitous.

For the mass balance analysis, external nitrogen inputs to cropland are considered to be balanced over the long run (5 years and more) by nitrogen leaving the field in crop harvest, atmospheric losses (volatilization, denitrification), runoff to streams, or groundwater leaching. Hence, cropland nitrate leaching to groundwater is estimated by summing nitrogen inputs to a field (fertilizer, effluent, biosolids,

---

[2] A typical groundwater recharge rate in the study area is roughly 300 mm/yr (1 AF/ac/yr). If that recharge contains nitrate at the MCL, the annual nitrate loading rate is 30 kg N/ha/yr (27 lb N/ac/yr). We allow an additional 5 kg N/ha/yr (4.5 lb N/ac/yr) to account for potential denitrification in the deep vadose zone or in shallow groundwater.

[3] The benchmark of 35 kg N/ha (31 lb N/ac) is not adequate for percolation basins, as their recharge rate is much more than 1 AF/ac. Instead, we consider actual average concentration (by county) of nitrogen in FP and WWTP discharges to percolation basins, which range from 2 to 10 times the MCL and 1 to 2 times the MCL, respectively (Viers et al. 2012).

manure, atmospheric deposition, irrigation water) and then subtracting the three other nitrogen outputs (harvest, atmospheric losses, and runoff).

In total, the 1.27 million ha (3.1 million ac) of cropland, not including 0.17 million ha (0.4 million ac) of alfalfa, receive 380 Gg N/yr (419,000 t N/yr) from all sources. Synthetic fertilizer, at 204 Gg N/yr (225,000 t N/yr), is more than half of these inputs (Figure 3). Manure applied on dairy forages or exported for cropland applications off-dairy (but not leaving the study area) is one-third of all nitrogen inputs. Atmospheric deposition and nitrate-nitrogen in groundwater used as irrigation water are approximately one-tenth of all nitrogen input. Urban effluent and biosolids application are small portions of the overall nitrogen input in the study area, but they are locally significant.

Table 1. Major sources of groundwater nitrate, their estimated total contribution in the study area, their percent of total contribution, and their estimated average local intensity, which indicates local pollution potential (actual total nitrate loading from these source categories is very likely within the range provided in parentheses)

	Total Nitrate Loading to Groundwater Gg N/yr* (range) [1,000 t N/yr (range)]	Percent Contribution to Total Nitrate Leaching in the Study Area	Average Intensity of Nitrate Loading to Groundwater kg N/ha/yr [lb N/ac/yr]
Cropland	195 (135–255) [215 (150–280)]	93.7%	154 [137]
Alfalfa cropland	5 (<1–10) [5 (<1–10)]	2.4%	30 [27]
Animal corrals	1.5 (0.5–8) [1.7 (0.5–9)]	0.7%	183 [163]
Manure storage lagoons	0.23 (0.2–2) [0.25 (0.2–2)]	0.1%	183 [163]
WWTP and FP† percolation basins	3.2 (2–4) [3.5 (2–4)]	1.5%	1,200‡ [1,070]
Septic systems	2.3 (1–4) [2.5 (1–4)]	1.1%	<10 – >50 [<8.8 – >45]
Urban (leaky sewers, lawns, parks, golf courses)	0.88 (0.1–2) [0.97 (0.1–2)]	0.5%	10 [8.8]
Surface leakage to wells	<0.4 [<0.4]	—	§

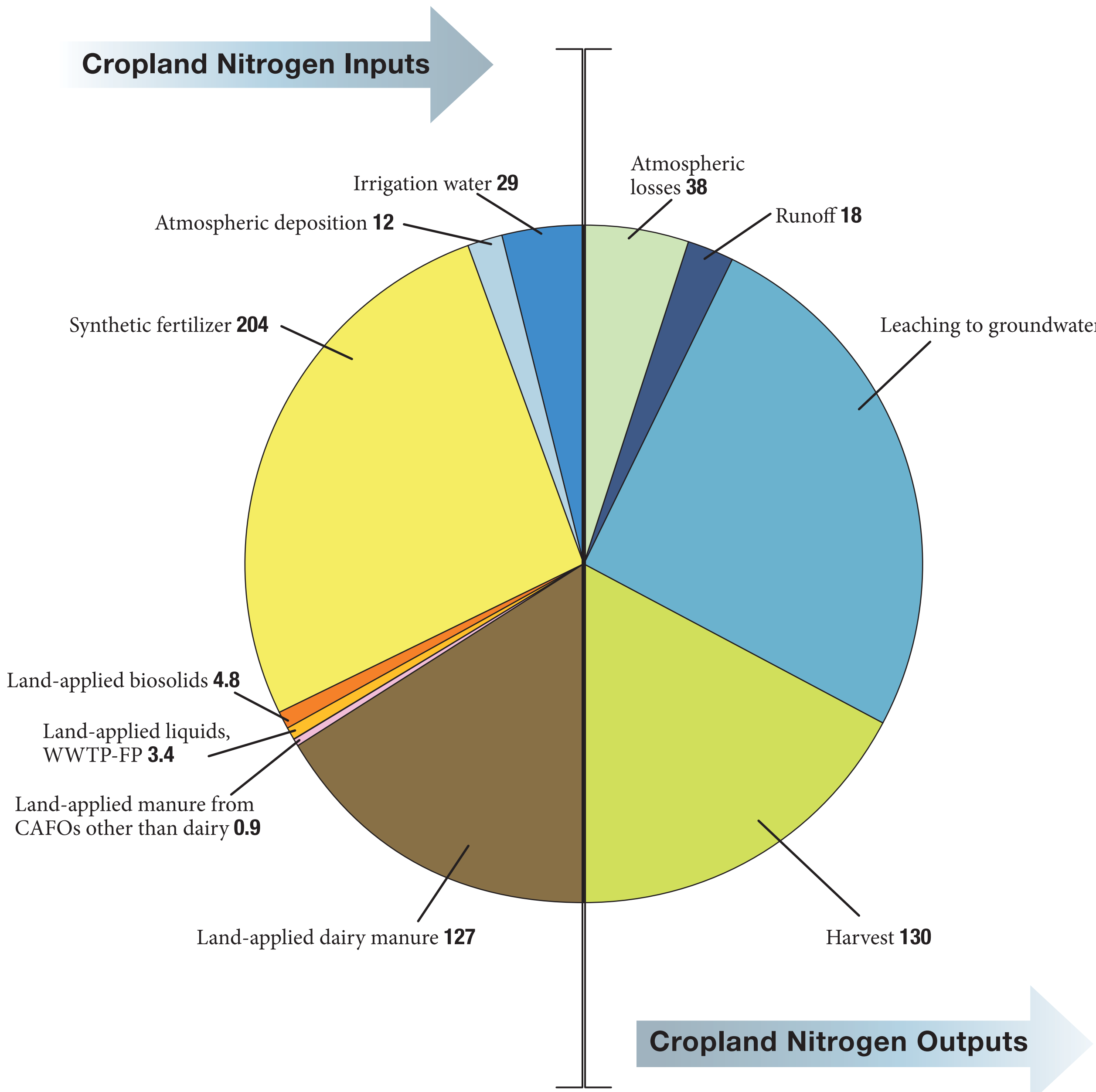
Source: Viers et al. 2012.

*At 2011 prices, 1 Gg N (1,100 t N) is roughly equivalent to $1 million in fertilizer nitrogen.

†WWTP = wastewater treatment plant; FP = food processor.

‡The benchmark of 35 kg N/ha/yr does not apply to WWTP and FP percolation basins, which may recharge significantly more water than other sources. Their nitrate loading may be high even if nitrate concentrations are below the MCL (Viers et al. 2012).

§Surface leakage through improperly constructed wells is based on hypothetical estimates and represents an upper limit.



Note: No mass balance was performed on 0.17 million ha (0.4 million ac) of nitrogen-fixing alfalfa, which is estimated to contribute an additional 5 Gg N/yr to groundwater. Groundwater nitrate loading from all non-cropland sources is about 8 Gg N/yr.

Figure 3. Overview of cropland input and output (Gg N/yr) in the study area (Tulare Lake Basin and Salinas Valley) in 2005. The left half of the pie chart represents total nitrogen inputs to 1.27 million ha (3.12 million ac) of cropland, not including alfalfa. The right half of the pie chart represents total nitrogen outputs with leaching to groundwater estimated by difference between the known inputs and the known outputs. Source: Viers et al. 2012.

On the output side, the total nitrate leaching to groundwater from cropland, not including alfalfa, comprises 195 Gg N/yr (215,000 t N/yr) and is by far the largest nitrogen flux from cropland, much larger than the harvested nitrogen at 130 Gg N/yr (143,000 t N/yr). The nitrogen leached to groundwater nearly matches the amount of synthetic fertilizer applied to the same cropland, suggesting large system surpluses of nitrogen use on cropland. Other outputs are small: atmospheric losses are assumed to be one-tenth of the inputs (Viers et al. 2012), and runoff is assumed to be 14 kg N/ha/yr (12.5 lb N/ac/yr) (Beaulac and Reckhow 1982).

Applying the benchmark of 50 Gg N/yr (55,000 t N/yr), groundwater leaching losses would need to be reduced by 150 Gg N/year (165,000 t N/yr) or more area-wide to avoid further large-scale groundwater degradation. Figure 3 suggests three major options to reduce nitrate loading to groundwater from cropland: develop techniques to make manure a useful and widely used fertilizer and reduce synthetic fertilizer application in the study area by as much as 75%; drastically reduce the use of manure in the study area; or significantly increase the agricultural output (harvest) without increasing the nitrogen input. Nitrate source reduction efforts will involve a combination of these options (see Section 2.3).

The following sections further discuss individual inputs and outputs that control agricultural cropland nitrate leaching.

Cropland inputs: Synthetic fertilizer (204 Gg N/yr [225,000 t N/yr]). Synthetic fertilizer application rates are estimated by first establishing a typical nitrogen application rate for each crop, derived from the literature, United States Department of Agriculture (USDA) Chemical Usage Reports,

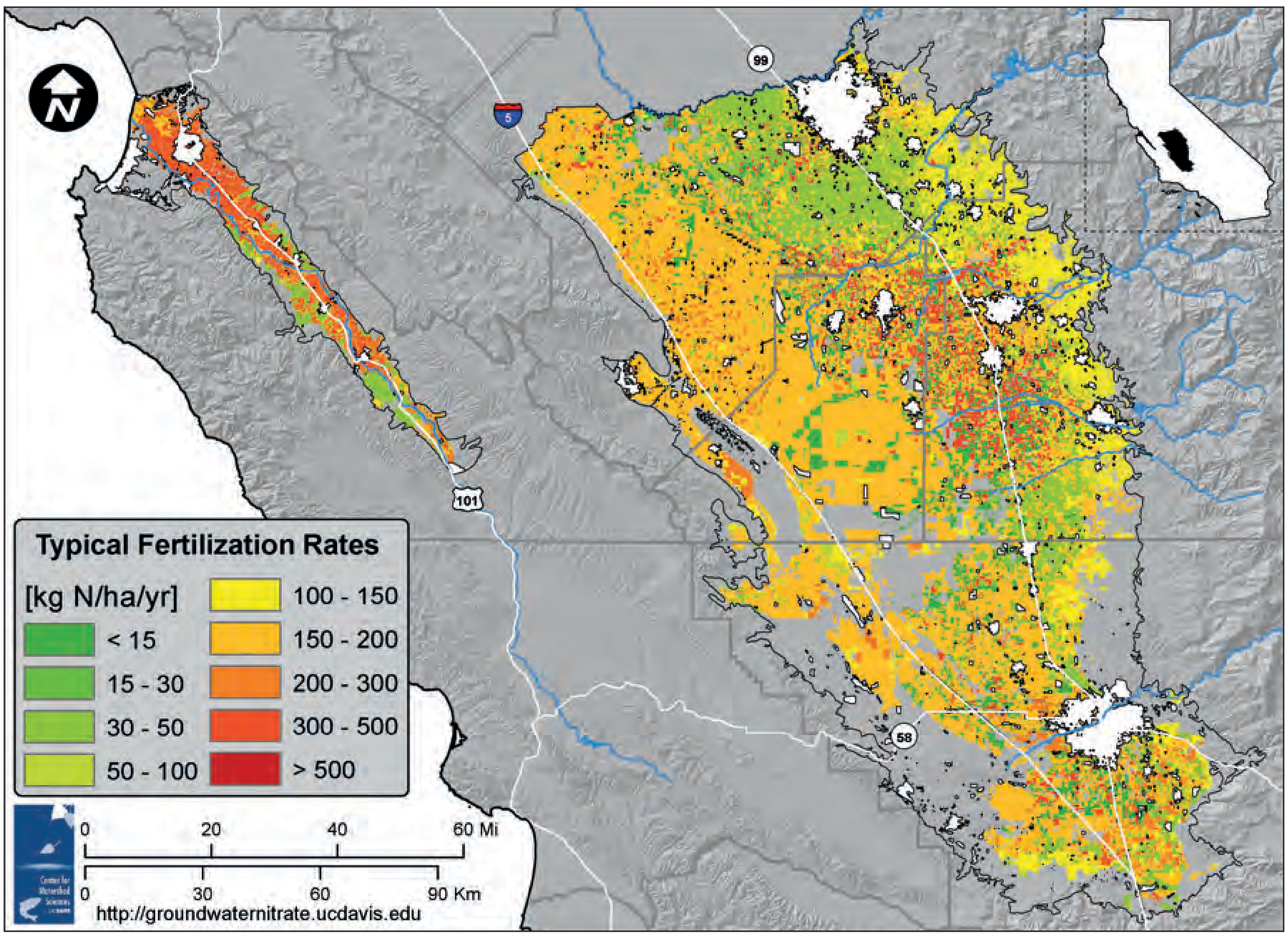


Figure 4. Current typical annual fertilization rates (1 kg/ha/yr = 1.1 lb/ac/yr) in irrigated agricultural cropland of the study area derived from the literature, USDA Chemical Usage Reports, and agricultural cost and return studies for each of 58 crop categories (does not include excess manure applications). Rates account for multi-cropping in some vegetable crops and double-cropping of corn and winter grain. Source: Viers et al. 2012.

and UC Davis ARE agricultural cost and return studies for each of 58 crop categories within 10 crop groups (Figure 4). In a second step, we assess whether some of the typical nitrogen application rate is met by other sources such as effluent, biosolids, and manure. The procedure varies with crop type, location, and aggregation level. Fertilizer needs not met by effluent, biosolids, or manure (see below) are assumed to be met by synthetic fertilizer, providing an estimate of synthetic fertilizer use at local (Figure 4), crop (see Figure 7), county (see Table 2), and study area (see Figure 3) levels. The magnitude of total estimated synthetic fertilizer use (204 Gg N/yr [225,000 t N/yr]) in the study area, on about 40% of California's irrigated land, is consistent with statewide average recorded sales of synthetic fertilizer used on cropland of 466 Gg N/yr (514,000 t N/yr) (D. Liptzin, pers. comm., 2012).

Cropland inputs: Animal manure (land-applied: 128 Gg N/yr [141,000 t N/yr]; corral and lagoon loading directly to groundwater: 1.7 Gg N/yr [1,900 t N/yr]). The Tulare Lake Basin houses 1 million adult dairy cows and their support stock (more than half of California's dairy herd), 10,000 hogs and pigs, and 15 million poultry animals. Dairy cattle are by far the largest source of land-applied manure nitrogen in the area (127 Gg N/yr [140,000 t N/yr]; see Figure 3). Manure is collected in dry and liquid forms, recycled within the animal housing area for bedding (dry manure) and as flushwater (freestall dairies), and ultimately applied to the land. Manure is applied in solid and liquid forms, typically on forage crops (e.g., summer corn, winter grain) managed by the dairy farm, or is exported to nearby farms (mostly as manure solids) and used as soil amendment. The amount of land-applied manure nitrogen is estimated based on: recently published studies of dairy cow, swine, and poultry excretion rates; animal numbers reported by the Regional Water Board and the USDA Agricultural Census; and an estimated 38% atmospheric nitrogen loss in dairy facilities before land application of the manure. Manure not exported from dairy farms is applied to portions of 130,000 ha (320,000 ac) of dairy cropland. Exported manure nitrogen is largely applied within the study area, mostly within the county of origin, on cropland nearby dairies.

Direct leaching to groundwater from animal corrals and manure lagoons is about 1.5 Gg N/yr (1,700 t N/yr) and 0.2 Gg N/yr (220 t N/yr), respectively (see Table 1).

Cropland inputs: Irrigation water (29 Gg N/yr [32,000 t N/yr]). Irrigation water is also a source of nitrogen applied to crops. Surface irrigation water is generally very low in nitrate. Nitrate in groundwater used as irrigation water is a significant source of nitrogen but varies widely with location and time. We used average nitrate concentrations measured in wells and basin-wide estimates of agricultural groundwater pumping (Faunt 2009) to estimate the total nitrogen application to agricultural lands from irrigation water, in the range of 20 Gg N/yr (22,000 t N/yr) to 33.4 Gg N/yr (36,800 t N/yr).

Cropland and general landscape inputs: Aerial deposition (12 Gg N/yr [13,000 t N/yr]). Nitrogen emissions to the atmosphere as NOx from fossil fuel combustion and ammonia from manure at confined animal feeding operations undergo transformations in the atmosphere before being redeposited, often far from the source of emissions. Nitrogen deposition estimates at broader spatial scales are typically based on modeled data. Nitrogen deposition in urban and natural areas was assumed to be retained with the ecosystem (Vitousek and Howarth 1991). In cropland, nitrogen deposition was included in the nitrogen mass balance. For the Salinas Valley, average aerial deposition is 5.6 kg N/ha/yr (0.6 Gg N/yr) (5.0 lb N/ac [660 t N/yr]). The Tulare Lake Basin receives among the highest levels in the state, averaging 9.8 kg N/ha/yr (11.3 Gg N/yr) (8.7 lb N/ac/yr [12,500 t N/yr]).

Cropland output: Harvested nitrogen (130 Gg N/yr [143,000 t N/yr]). The nitrogen harvested is the largest independently estimated nitrogen output flow from cropland. Historical and current annual County Agricultural Commissioner reports provide annual harvested acreage and yields for major crops. From the reported harvest, we estimate the nitrogen removed. For each of 58 crop categories, the study area total harvest nitrogen and total acreage used to estimate the rate of nitrogen harvested (Figure 5). All crops combined (not including alfalfa) contain a total of 130 Gg N/yr (143,000 t N/yr), with cotton (21 Gg N/yr [23,000 t N/yr]), field crops (28 Gg N/yr [31,000 t N/yr]), grain and hay crops (30 Gg N/yr [33,000 t N/yr]), and vegetable crops (30 Gg N/yr [30,000 t N/yr]) making up 85% of harvested nitrogen. Tree fruits, nuts, grapes, and subtropical crops constitute the remainder of the nitrogen export from cropland.

Historical Development of Fertilizer Use, Manure Production, Harvested Nitrogen, and Estimated Nitrate Leaching to Groundwater. Current and near-future groundwater nitrate conditions are mostly the result of past agricultural practices. So the historical development of nitrogen fluxes to and from cropland provides significant insight in the relationship between past agricultural practices, their estimated groundwater impacts, and current as well as anticipated groundwater quality. Two major inventions effectively doubled the farmland in production from the 1940s to the 1960s: the introduction of the turbine pump in the 1930s, allowing access to groundwater for irrigation in a region with very limited surface water supplies, and the invention and commercialization of the Haber-Bosch process, which made synthetic fertilizer widely and cheaply available by the 1940s.

The amount of cropland (not including alfalfa) in the study area nearly doubled in less than 20 years, from 0.6 million ha (1.5 million ac) in the mid-1940s to nearly 1.0 million ha (2.5 million ac) in 1960 (not including alfalfa) (Figure 6). Further increases occurred until the 1970s, to 1.3 million ha (3.2 million ac), but the extent of farmland has been relatively stable for the past 30 years.

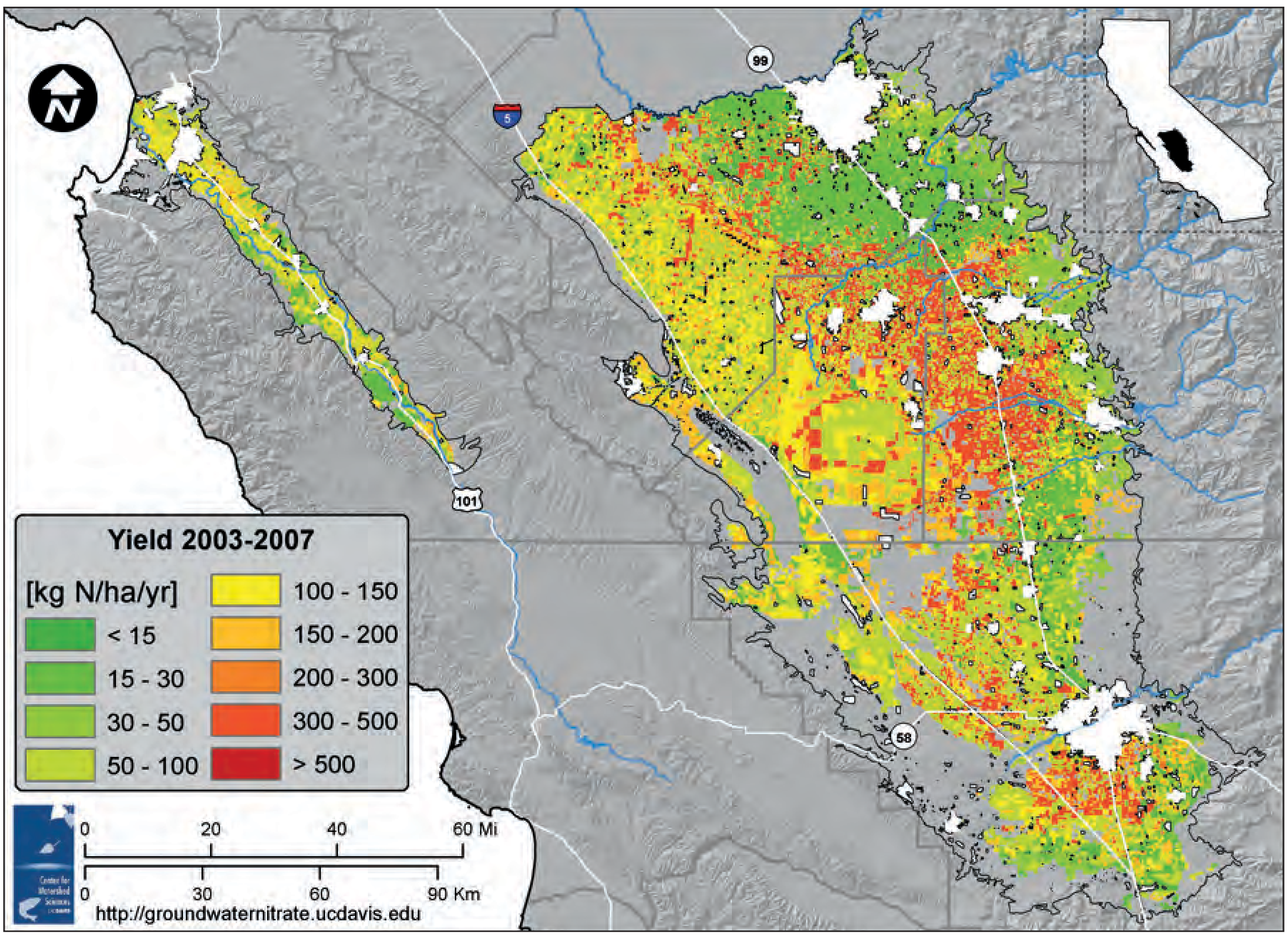


Figure 5. Current annual nitrogen removal rate in harvested materials (1 kg/ha/yr = 1.1 lb/ac/yr) derived from county reports of harvested area and harvested tonnage for each of 58 crop categories. Rates account for multi-cropping in some vegetable crops and double-cropping of corn and winter grain. Source: Viers et al. 2012.

In contrast, the harvested nitrogen has consistently increased throughout the past 60 years (see Figure 6). From 1945 to 1975, total harvested nitrogen increased twice as fast as farmland expansion, quadrupling from 20 Gg N/yr (22,000 t N/yr) to 80 Gg N/yr (88,000 t N/yr). Without further increases in farmland, harvests and harvested nitrogen increased by more than 60% in the second 30-year period, from the mid-1970s to the mid-2000s.

Synthetic fertilizer inputs also increased from the 1940s to the 1980s but have since leveled off. Between 1990 and 2005, the gap between synthetic nitrogen fertilizer applied and harvested nitrogen has significantly decreased.[4]

In contrast, dairy manure applied to land has increased exponentially, effectively doubling every 15 years (see Figure 6), from 8 Gg N/yr (9,000 t N/yr) in 1945 to 16 Gg N/yr (18,000 t N/yr) in 1960, 32 Gg N/yr (35,000 t N/yr) in 1975, 56 Gg N/yr (62,000 t N/yr) in 1990, and 127 Gg N/yr (140,000 t N/yr) in 2005, an overall 16-fold increase in manure nitrogen output. The increase in manure nitrogen is a result of increasing herd size (7-fold) and increasing milk production per cow (3-fold) and is slowed only by the increased nitrogen-use efficiency of milk production.

Until the 1960s, most dairy animals in the region were only partly confined, often grazing on irrigated pasture with

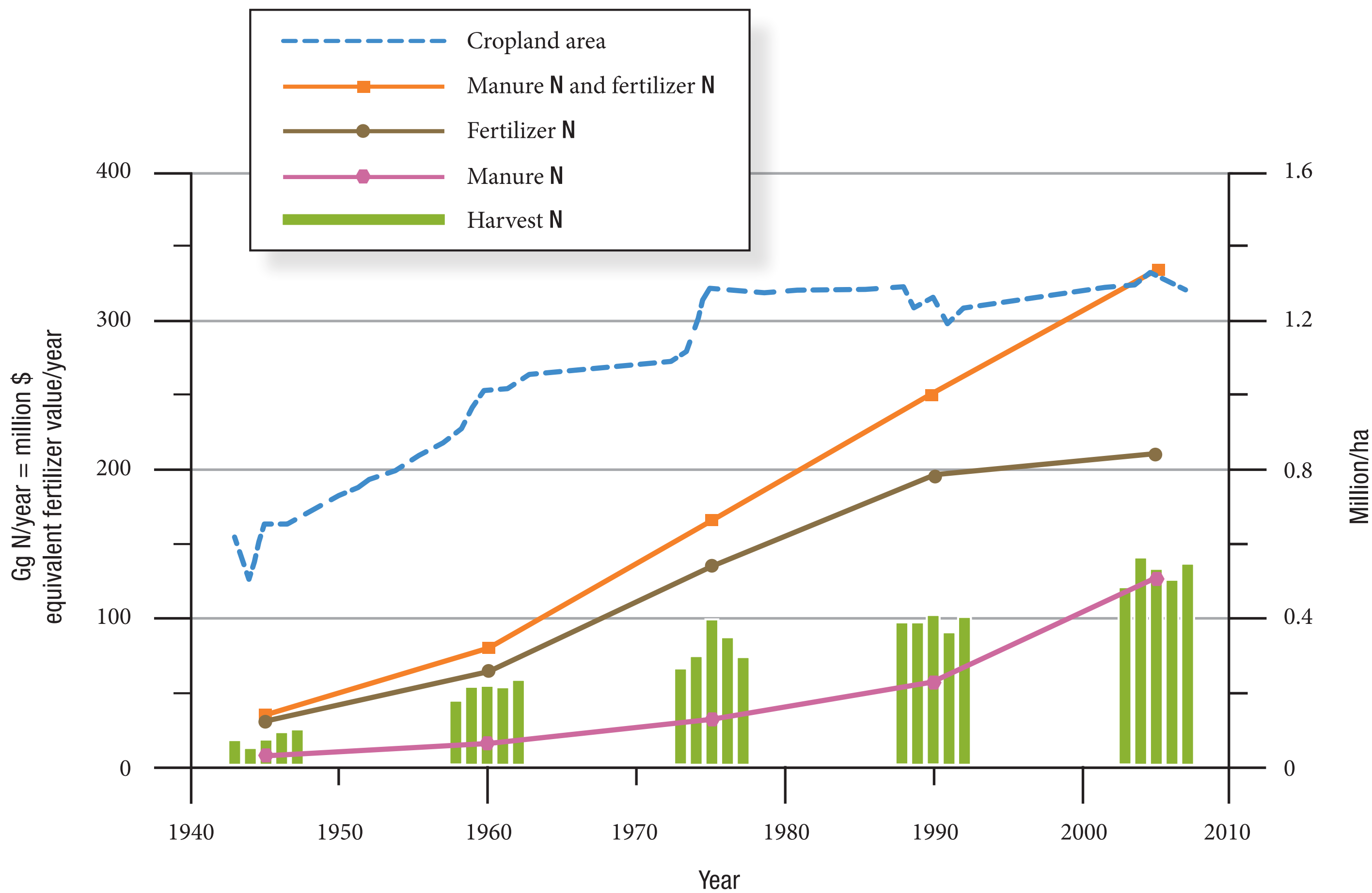


Figure 6. Estimated historical agricultural development in the study area (not including alfalfa): total harvested area, total harvested nitrogen in fertilized crops, fertilizer applied to cropland (5-year average), manure applied to cropland (5-year average), and sum of manure and fertilizer applied to cropland (5-year average). Not shown: In the study area, harvested alfalfa area grew from 0.12 million ha (0.3 million ac) in the 1940s to 0.2 million ha (0.5 million ac) around 1960, then leveled off to current levels of 0.17 million ha (0.42 million ac). Since the 1960s, nitrogen removal in alfalfa harvest has varied from 50 to 80 Gg N/yr. Note: 0.4 million ha = 1 million ac. Source: Viers et al. 2012.

[4] Fertilizer application rates and statewide fertilizer sales have grown little since the late 1980s.

limited feed imports. Manure from dairy livestock generally matched the nitrogen needs of dairy pastures. Since the 1970s, dairies in the Tulare Lake Basin have operated mostly as confined animal facilities, growing alfalfa, corn, and grain feed on-site, importing additional feed, and housing the animals in corrals and freestalls. The growth in the dairy industry has created a nitrogen excess pool that remains unabsorbed by crops (see Figure 6). Much of the nitrogen excess is a recent phenomenon (see Figure 6). With groundwater quality impacts delayed by decades in many production wells (see Section 3), the recent increase in land applied manure nitrogen is only now beginning to affect water quality in wells of the Tulare Lake Basin, with much of the impact yet to come.

Groundwater loading from irrigated agriculture, by crop group and by county. Significant differences exist in groundwater loading intensity between crop groups.[5] The intensity of groundwater loading is least in vineyards (less than 35 kg N/ha/yr [31 lb N/ac/yr]), followed by rice and subtropical tree crops (about 60 kg N/ha/yr [54 lb N/ac/yr]), tree fruits, nuts, and cotton (90–100 kg N/ha/yr [80–90 lb N/ac/yr]), vegetables and berry crops (over 150 kg N/ha/yr [130 lb N/ac/yr]), which includes some vegetables being cropped twice per year), field crops (about 480 kg N/ha/yr [430 lb N/ac/yr]), and grain and hay crops (about 200 kg N/ha/yr [180 lb N/ac/yr]). Manure applications constitute the source of nearly all of the nitrate leaching from these latter two crops. Without manure, field crops leach less than 35 kg N/ha/yr (31 lb N/ac/yr), and grain and hay crops leach 50 kg N/ha/yr (45 lb N/ac/yr). Figure 7 shows the rate of reduction (in kg N/ha/crop) that would be needed, on average across each crop group, to reduce groundwater nitrate leaching to benchmark levels.

At the county level, we aggregate cropland area, fertilizer applications (by crop category), manure output from individual dairies, effluent and biosolid land applications from individual facilities, and crop category–specific harvest. Differences in cropping patterns between counties and the absence or presence of dairy facilities within counties drive county-by-county differences in total groundwater loading and in the average intensity of groundwater loading (Table 2). Fresno County, which has fewer mature dairy cows (133,000) than Kings (180,000), Tulare (546,000), or Kern (164,000) Counties and also has large areas of vineyards (see Figure 2), has the lowest average groundwater loading intensity (103 kg N/ha/yr [103 lb N/ac/yr]). Monterey County is dominated by vegetable and berry crops (high intensity) and grape vineyards (low intensity).

Urban and Domestic Sources

Urban and domestic sources: Overview. Urban nitrate loading to groundwater is divided into four categories: nitrate leaching from turf, nitrate from leaky sewer systems, groundwater nitrate contributions from WWTPs and FPs, and groundwater nitrate from septic systems. For all these systems, groundwater nitrate loading is estimated based on either actual data or reported data of typical nitrate leaching.

Urban and domestic sources: Wastewater treatment plants and food processors (11.4 Gg N/yr [12,600 t/yr]: 3.2 Gg N/yr [3,500 t/yr] to percolation ponds, 3.4 Gg N/yr [3,800 t/yr] in effluent applications to cropland, and 4.8 Gg N/yr [5,300 t/yr] in WWTP biosolids applications to cropland). The study area has roughly 2 million people on sewer systems that collect and treat raw sewage in WWTPs. In addition, many of the 132 food processors within the study area generate organic waste that is rich in nitrogen (Table 3). Potential sources of groundwater nitrate contamination from these facilities include effluent that is land applied on cropland or recharged directly to groundwater via percolation basins, along with waste solids and biosolids that are land applied. Typically, WWTP influent contains from 20 mg N/L to 100 mg N/L total dissolved nitrogen (organic N, ammonium N, nitrate-N), of which little is removed in standard treatment (some WWTPs add treatment beyond

[5] Aggregated estimates were obtained from study area-wide totals for harvested area (by crop group), for typical nitrogen application, and for harvested nitrogen. The following averages were assumed: irrigation water nitrogen (24 kg N/ha/yr [21 lb N/ac/yr]), atmospheric nitrogen losses (10% of all N inputs), and runoff (14 kg N/ha/yr [12.5 lb N/ac/yr]). Most manure is likely land-applied to field crops, particularly corn, and to grain and hay crops. Little is known about the actual distribution prior to 2007 and the amount of synthetic fertilizer applied on fields receiving manure. As an illustrative scenario, we assume that two-thirds of dairy manure is applied to field crops and one-third of dairy manure is applied to grain and hay crops. In field crops, 50% of crop nitrogen requirements are assumed to be met with synthetic fertilizer, and in grain and hay crops 90% of their crop nitrogen requirements are assumed to be met by synthetic fertilizer. These are simplifying assumptions that neglect the nonuniform distribution of manure on field and grain crops between on-dairy, near-dairy, and away-from-dairy regions. However, corn constitutes most (106,000 ha [262,000 ac]) of the 130,000 ha (321,000 ac) in field crops, with at least 40,000 ha (99,000 ac) grown directly on dairies. Grain crops are harvested from 220,000 ha (544,000 ac). For further detail, see Viers et al. 2012.

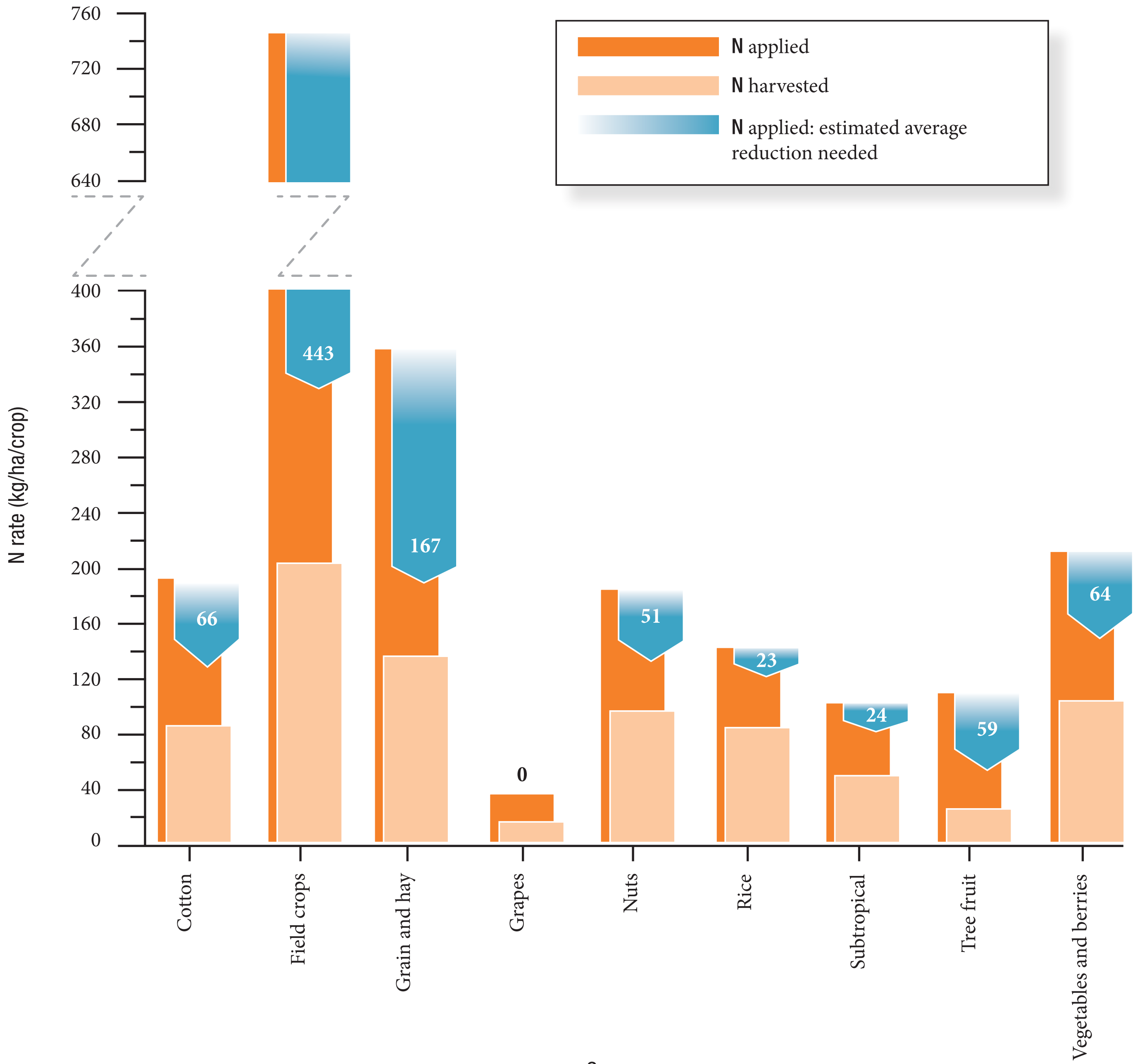


Figure 7. Nitrogen application reduction needed to reduce groundwater nitrate loading to less than 35 kg N/ha/crop, compared with average nitrogen applied (synthetic fertilizer and manure) and nitrogen harvested (all units in kg N/ha/crop). Rates are given per crop, and the required reduction does not account for double-cropping. Some vegetables and some field crops are harvested more than once per year. In that case, additional reductions in fertilizer applications would be necessary to reduce nitrate loading to less than 35 kg N/ha. Large reductions needed in field crops and grain and hay crops are due to the operational assumption that manure generated in the study area is applied to only these crop groups. Typical amounts of synthetic fertilizer applied ("N applied") to these crops, without excess manure, are 220 kg N/ha/crop for field crops and 190 kg N/ha/crop for grain and hay crops. Thus, without excess manure, average field crops and grain and hay crops may require relatively small reductions in nitrogen application. Source: Viers et al. 2012.

Table 2. Major nitrogen fluxes to and from cropland in the study area, by county (not including alfalfa)

	Synthetic Fertilizer Application Gg N/yr [1,000 t N/yr]	Manure Application Gg N/yr [1,000 t N/yr]	Land Applied Effluent and Biosolids, Gg N/yr [1,000 t N/yr]	Harvest Gg N/yr [1,000 t N/yr]	PNB* %	PNB_0† %	Groundwater Loading Gg N/yr [1,000 t N/yr]	Groundwater Loading Intensity kg N/ha/yr [lb N/ac/yr]
By County								
Fresno	62.1 [68.3]	16.6 [18.3]	0.8 [0.88]	35.5 [39.1]	44.7	54.4	42.4 [46.7]	103 [92]
Kern	50.3 [55.4]	20.4 [22.5]	4.6 [5.0]	29.6 [32.6]	39.3	56.4	42.8 [47.2]	141 [123]
Kings	27.5 [30.3]	22.0 [24.3]	1.9 [2.1]	19.6 [21.6]	38.1	62.7	29.2 [32.2]	179 [160]
Tulare	36.0 [39.7]	67.3 [74.2]	0.7 [0.77]	32.7 [36.0]	31.4	72.5	65.1 [71.8]	236 [210]
Monterey	28.1 [30.9]	1.4 [1.54]	0.1 [0.11]	12.4 [13.6]	41.9	43.5	15.6 [17.2]	138 [123]
By Basin								
TLB	176 [194]	127 [140]	8.1 [8.9]	118 [130]	37.8	60.5	179 [197]	155 [138]
SV	28 [30.8]	1 [1.1]	0.1 [0.11]	12 [13]	41.9	43.5	16 [18]	138 [123]
Overall	**204 [225]**	**128 [141]**	**8.2 [9]**	**130 [143]**	**38.2**	**58.3**	**195 [215]**	**154 [137]**

Source: Viers et al. 2012.

Manure applications include non-dairy manure nitrogen (0.9 Gg N/yr [(990 t N/yr)] for the entire study area). Groundwater loading accounts for atmospheric deposition (9.8 and 5.6 kg N/ha/yr [(8.7 and 5 t N/yr)] in TLB and SV, respectively), atmospheric losses (10% of all inputs), irrigation water quality (22.8 kg N/ha/yr [20 lb N/ac/yr]), and runoff (14 kg N/ha/yr [12.5 lb N/ac/yr]) to and from agricultural cropland, in addition to fertilizer and manure application, and harvested nitrogen. Synthetic fertilizer application on field crops is assumed to meet 50% of typical application rates; on grain and hay crops, 90% of typical applications, with the remainder met by manure.

* PNB = partial nutrient balance, here defined as Harvest N divided by (Synthetic + Manure + Effluent + Biosolids Fertilizer N).

† PNB_0 = hypothetical PNB, if no manure/effluent/biosolids overage was applied above typical fertilizer rates.

conventional processes to remove nutrients including nitrate and other forms of nitrogen). Across the study area, WWTP effluent nitrogen levels average 16 mg N/L. Within the study area, 40 WWTPs treat 90% of the urban sewage. FP effluent nitrogen levels to percolation basins and irrigated agriculture average 42 mg N/L and 69 mg N/L, respectively.

Urban and domestic sources: Septic systems (2.3 Gg N/yr [2,500 t N/yr]). Crites and Tchobanoglous (1998) estimated that the daily nitrogen excretion per adult is 13.3 g. Approximately 15% of that nitrogen is assumed to either stay in the septic tank, volatilize from the tank, or volatilize from the septic leachfield (Siegrist et al. 2000). Based on census data, the number of people on septic systems in the study areas is about 509,000 for the Tulare Lake Basin and 48,300 for Salinas Valley. Total nitrate loading from septic leaching is 2.1 Gg N/yr (2,300 t N/yr) in the Tulare Lake Basin and 0.2 Gg N/yr (220 t N/yr) in the Salinas Valley. The distribution of septic systems varies greatly. The highest density of septic systems is

Table 3. Total nitrogen discharge to land application and average total nitrogen concentration (as nitrate-N, MCL: 10 mg N/L) in discharge to percolation basins from WWTPs and FPs, based on our surveys of WWTPs and the FP survey of Rubin et al. (2007)

	Biosolids Gg N/yr [1,000 t N/yr]	WWTP Land Application Gg N/yr [1,000 t N/yr]	WWTP Percolation Concentration mg N/L	FP Land Application Gg N/yr [1,000 t N/yr]	FP Percolation Concentration mg N/L
By County					
Fresno	0.006 [0.006]	0.40 [0.40]	18.5	0.42 [0.46]	56.2
Kern	3.1 [3.4]	0.92 [0.92]	17.7	0.56 [0.62]	43.9
Kings	1.6 [1.7]	0.09 [0.09]	11.2	0.26 [0.29]	2.1
Tulare	0.038 [0.044]	0.50 [0.50]	14.9	0.13 [0.14]	34.2
Monterey	0 [0]	0.09 [0.09]	13.9	0.05 [0.05]	22.1
By Basin					
Tulare Lake Basin	4.8 [5.3]	1.9 [2.1]	16.3	1.37 [1.51]	43.3
Salinas Valley	0 [0]	0.09 [0.09]	13.9	0.05 [0.05]	22.1
Overall	**4.8 [5.3]**	**2.0 [2.2]**	**16**	**1.4 [1.5]**	**42**

in peri-urban (rural sub-urban) areas near cities but outside the service areas of the wastewater systems that serve those cities (Figure 8). In the Tulare Lake Basin and Salinas Valley, 7.9% and 12.6%, respectively, of the land area exceeds the EPA-recommended threshold of 40 septic systems per square mile (0.154 systems per ha). Nearly 1.5% of the study area has a septic system density of over 256 systems per square mile (1 system/ha, or 1 system/2.5 ac). In those areas, groundwater leaching can significantly exceed our operational benchmark rate of 35 kg N/ha/yr (31 lb N/ac/yr).

Urban and domestic sources: Fertilizer and leaky sewer lines (0.88 Gg N/yr [970 t N/yr]). Fertilizer is used in urban areas for lawns, parks, and recreational facilities such as sports fields and golf courses. These land uses differ in their recommended fertilizer use, and there is almost no evidence of actual fertilization rates. Based on the most comprehensive survey of turfgrass leaching, only about 2% of applied nitrogen fertilizer was found to leach below the rooting zone (Petrovic 1990). For our nitrogen flow calculations, we assume a net groundwater loss of 10 kg N/ha/yr (8.9 lb N/ac/yr) from lawns and golf courses in urban areas (0.35 Gg N/yr [380 t N/yr]).

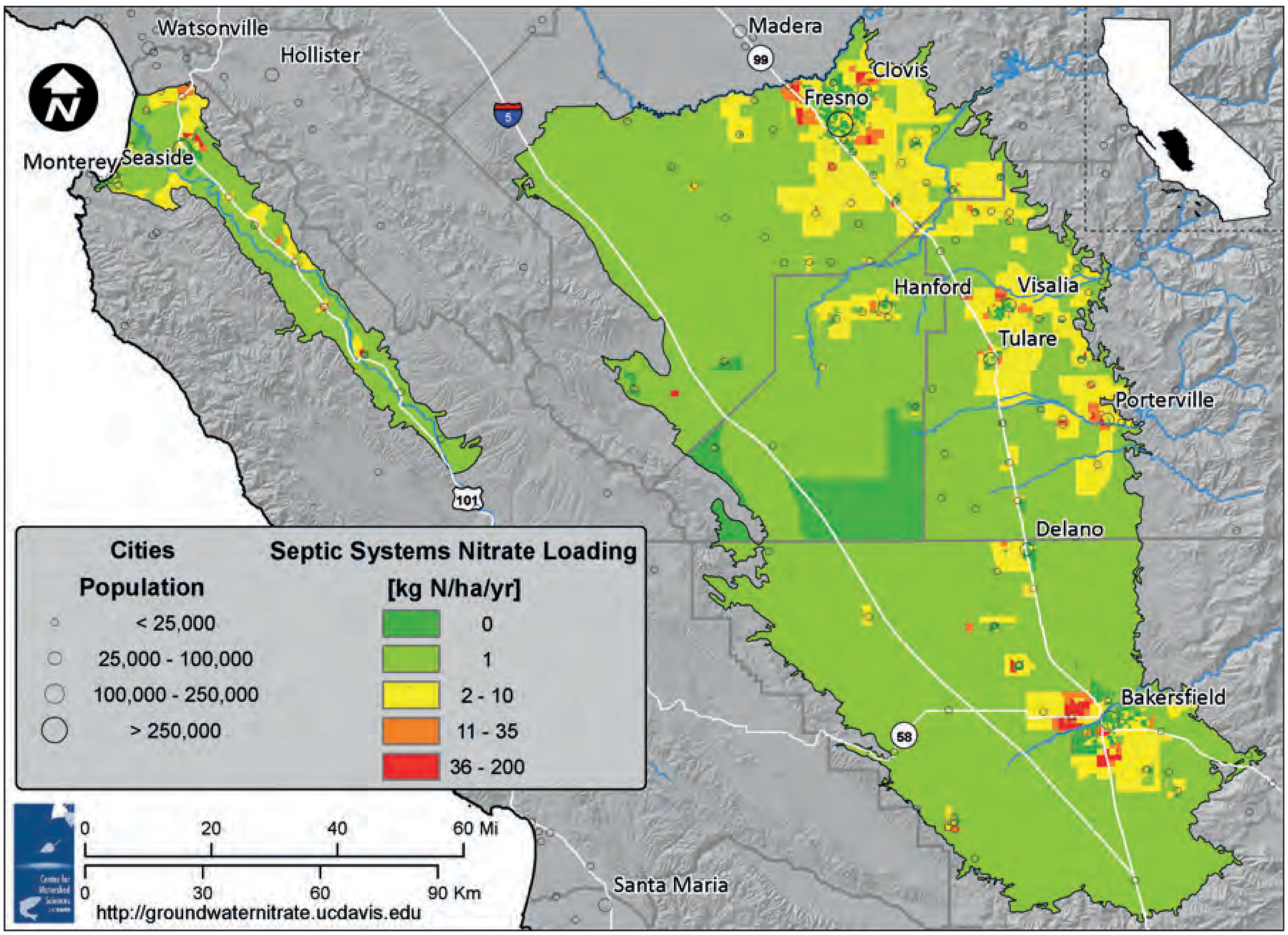


Figure 8. Septic-derived nitrate leaching rates within the study area. Source: Viers et al. 2012.

Sewer systems in urban areas can be a locally significant source of nitrogen. We use both reported sewer nitrogen flows and per capita nitrogen excretion rates to obtain total nitrogen losses via leaky sewer lines in urban areas. Nationally, estimated municipal sewer system leakage rates range from 1% to 25% of the total sewage generated. Given that much of the urban area within the study region is relatively young, we consider that the leakage rate is low, roughly 5% or less (0.53 Gg N/yr).

General Sources

General sources: Wells, dry wells, and abandoned wells (<0.4 Gg N/yr [<440 t N/yr]). Wells contribute to groundwater nitrate pollution through several potential pathways. Lack of or poor construction of the seal between the well casing and the borehole wall can lead to rapid transport of nitrate-laden irrigation water from the surface into the aquifer. In an inactive or abandoned production well, long well screens (several hundred feet) extending from relatively shallow depth to greater depth, traversing multiple aquifers, may cause water from nitrate-contaminated shallow aquifer layers to pollute deeper aquifer layers, at least in the vicinity of wells. Dry wells, which are large-diameter gravel-filled open wells, were historically designed to capture stormwater runoff or irrigation tailwater for rapid recharge to groundwater. Abandoned wells also allow surface water leakage to groundwater (spills) and cross-aquifer contamination. Lack of backflow prevention devices can lead to direct introduction of fertilizer chemicals into the aquifer via a supply well. Few data are available on these types of nitrate transfer in the Tulare Lake Basin or Salinas Valley. In a worst-case situation, as much as 0.4 Gg N/yr (440 t N/yr) may leak from the surface to groundwater via improperly constructed, abandoned, or dry wells, and as much as 6.7 Gg N/yr (7,400 t N/yr) are transferred within wells from shallow to deeper aquifers. Actual leakage rates are likely much lower than these worst-case estimates.

Groundwater Nitrate Loading: Uncertainty. The analyses above provide specific numbers for the average amount and intensity of nitrate loading from various categories of sources. However, discharges of nitrate to groundwater may vary widely between individual fields, farms, or facilities of the same category due to differences in operations, management practices, and environmental conditions. Also, average annual nitrate loading estimates for specific categories are based on many assumptions and are based on (limited) data with varying degrees of accuracy; the numbers given represent a best, albeit rough, approximation of the actual nitrate loading from specific sources. These estimates have inherent uncertainty. Very likely, though, the actual groundwater nitrate loading from source categories falls within the ranges shown in Table 1.

2.3 Reducing Nitrate Source Emissions to Groundwater

Although reduction of anthropogenic loading of nitrate to groundwater aquifers will not reduce well contamination in the short term (due to long travel times), reduction efforts are essential for any long-term improvement of drinking water sources. Technologies for reducing nitrate contributions to groundwater involve (a) reducing nitrogen quantity discharged or applied to the land and (b) controlling the quantity of water applied to land, which carries nitrate to groundwater (Dzurella et al. 2012).

Many source control methods require changes in land management practices and upgrading of infrastructure. Costs for mitigation or abatement vary widely and can be difficult to estimate. In particular, the quantity of nitrate leached from irrigated fields (the largest source) is determined by a complex interaction of nitrogen cycle processes, soil properties, and farm management decisions. Only broad estimates of the cost of mitigation per unit of decrease in the nitrate load are possible.

Reducing Nitrate Loading from Irrigated Cropland and Livestock Operations

Reduction of nitrate leaching from cropland, livestock, and poultry operations can come from changes in farm management that improve crop nitrogen use efficiency and proper storage and handling of manure and fertilizer. A common measure of cropland nitrogen use efficiency is the partial nitrogen balance (PNB), which is the ratio of harvested nitrogen to applied (synthetic, manure, or other organic) fertilizer nitrogen (Table 2).

We reviewed technical and scientific literature to compile a list of practices known or theorized to improve crop nitrogen use efficiency. Crop-specific expert panels reviewed and revised this list of practices. Input from these panel members also helped to estimate the current extent of use of each practice in the study area and to identify barriers to expanded adoption.

PNB can be increased by optimizing the timing and application rates of fertilizer nitrogen, animal manure, and irrigation water to better match crop needs, and to a lesser extent by modifying crop rotation. Improving the storage and handling of manure, livestock facility wastewater, and fertilizer also helps reduce nitrate leaching. A suite of improved management practices is generally required to reduce nitrate leachate most effectively, and these must be chosen locally for each unique field situation. No single set of management practices will be effective in protecting groundwater quality everywhere. The best approach depends on the crop grown, soil characteristics of the field, and other specific factors. As summarized in Table 4, ten key farm management measures for increasing crop nitrogen use efficiency (and PNB) are identified and reviewed (Dzurella et al. 2012).

Although PNBs as low as 33% have been reported, a recent EPA report estimated that with the adoption of best management practices, PNB could increase by up to 25% of current average values (U.S. EPA 2011). Improvements in PNB are possible, but a practical upper limit is about 80% crop recovery of applied nitrogen (U.S. EPA 2011; Raun and Schepers 2008). This limit is due to the unpredictability of rainfall, the difficulty in predicting the rate of mineralization of organic nitrogen in the soil, spatial variability and nonuniformity in soil properties, and the need to leach salts from the soil.

Table 4. Management measures for improving nitrogen use efficiency and decreasing nitrate leaching from agriculture (local conditions determine which specific practices will be most effective and appropriate)

Basic Principle	Management Measure	Number of Recommended Practices
Design and operate irrigation and drainage systems to decrease deep percolation.	MM 1. Perform irrigation system evaluation and monitoring.	3
	MM 2. Improve irrigation scheduling.	4
	MM 3. Improve surface gravity system design and operation.	6
	MM 4. Improve sprinkler system design and operation.	5
	MM 5. Improve microirrigation system design and operation.	2
	MM 6. Make other irrigation infrastructure improvements.	2
Manage crop plants to capture more N and decrease deep percolation.	MM 7. Modify crop rotation.	4
Manage N fertilizer and manure to increase crop N use efficiency.	MM 8. Improve rate, timing, placement of N fertilizers.	9
	MM 9. Improve rate, timing, placement of animal manure applications.	6
Improve storage and handling of fertilizer materials and manure to decrease off-target discharges.	MM 10. Avoid fertilizer material and manure spills during transport, storage, and application.	9
		Total: 50

Source: Dzurella et al. 2012.

Based on expert panel commentary, several farm management practices that reduce nitrate leaching have been widely adopted in recent years in the study area, representing a positive change from past practices that have contributed to current groundwater nitrate concentrations. High PNB can sometimes increase yields and decrease costs to the producer (by decreasing costs for fertilizer and water). Alas, field data that document improvements in nitrate leaching from these actions are largely unavailable.

Significant barriers to increased adoption of improved practices exist. These include higher operating or capital costs, risks to crop quality or yield, conflicting farm logistics, and constraints from land tenure. Lack of access to adequate education, extension, and outreach activities is another primary barrier, especially for the adoption of many of the currently underused practices, highlighting the importance of efforts such as those offered by the University of California Cooperative Extension. The future success of leaching reductions through improved crop and livestock facility management will require a significant investment in crop-specific research that links specific management practices with groundwater nitrate contamination. Additional investments in farmer (and farm labor) education and extension opportunities are needed, as well as increased support for farm infrastructure improvements. Monitoring and assessment programs need to be developed to evaluate management practices being implemented and their relative efficacy.

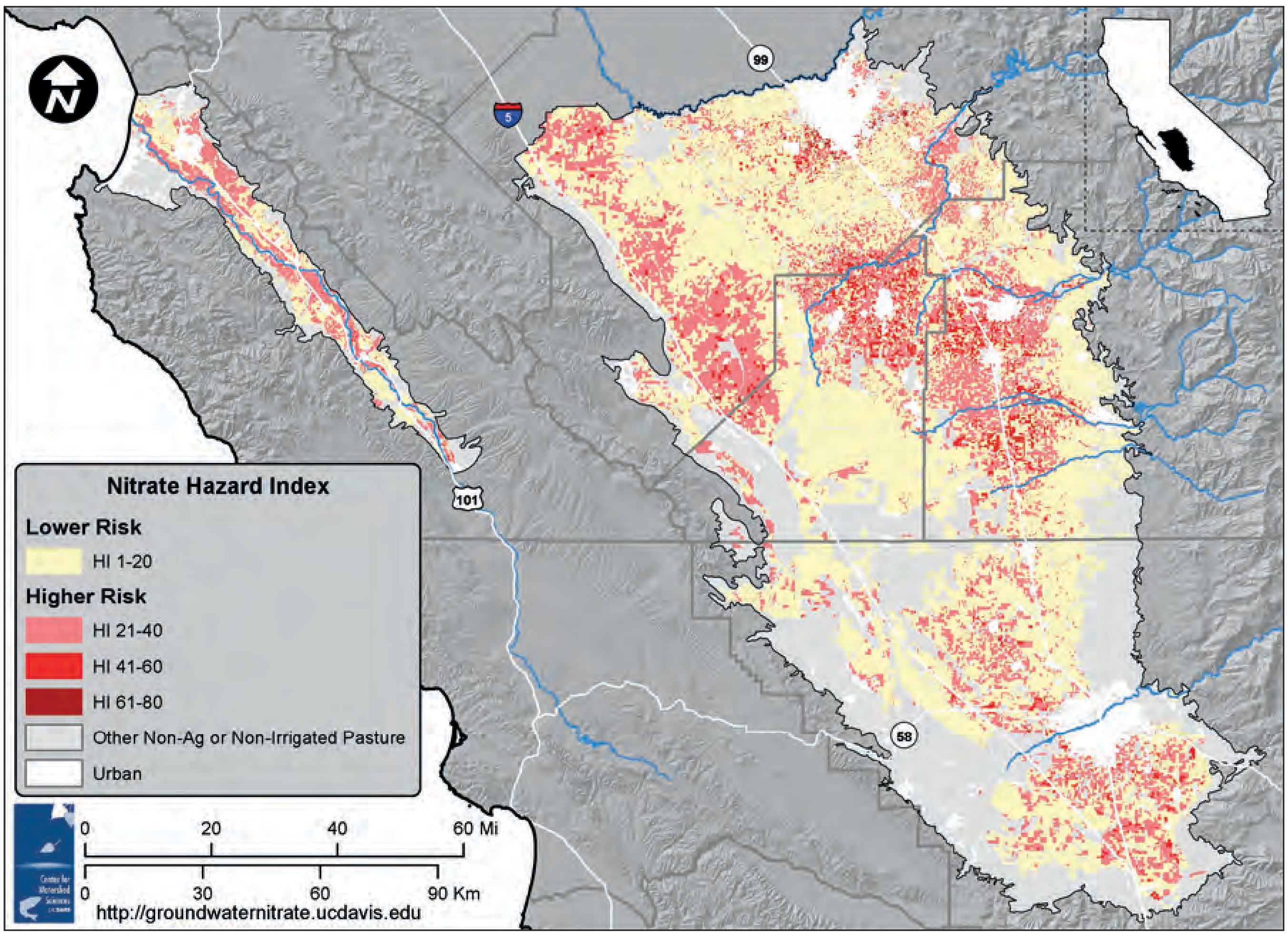


Figure 9. Overall nitrate hazard index calculated for the study area fields. Index values over 20 indicate increased potential for nitrate leaching from the crop root zone, benefiting most from implementation of improved management practices. Comparison between values in the higher-risk categories is not necessarily an indication of further risk differentiation, but it may indicate that multiple variables are involved in risk. Less-vulnerable areas still require vigilance in exercising good farm management practices. Source: Dzurella et al. 2012.

To establish the areas that would benefit most from improved management practices, we conducted a vulnerability assessment. Management-specific vulnerability was mapped using the UC Nitrate Hazard Index (Wu et al. 2005), which calculates the potential of nitrate leaching as a function of the crop grown, the irrigation system type in use, and the soil characteristics of each individual field. Based on this information, approximately 52% of irrigated cropland in the Salinas Valley and 35% of such land in the Tulare Lake Basin would most benefit from broad implementation of improved management practices (Figure 9).

A maximum net benefit modeling approach was developed to estimate relative costs of policies to improve PNB while maintaining constant crop yields for selected crop groups in the study area. Net revenue losses from limiting nitrate load to groundwater increase at an increasing rate (Table 5 and Figure 10). Our modeling results, although preliminary due to the lack of data on the cost of improving nitrogen use efficiency, suggest that reductions of 25% in total nitrate load to groundwater from crops will slightly increase production costs but are unlikely to affect total irrigated crop area, as summarized in Table 5. Smaller reductions (<10%) can be achieved at low costs, assuming adequate farmer education is in place (see Figure 10).

Greater reductions in total nitrate loading (>50%) are much more costly to implement, as capital and management investments in efficient use of nitrogen are required. Achieving such high load reductions may ultimately shift cropping toward more profitable and nitrogen-efficient crops or fallowing, as lower-value field crops and low-PNB crops lose

Table 5. Summary of how two groundwater nitrate load reduction scenarios may affect total applied water, annual net revenues, total crop area, and nitrogen applications, according to our estimative models for each basin*

Region	Scenario	Applied Water km^3/yr [million AF/yr]	Net Revenues $M/yr (2008)	Irrigated Land 1,000 ha [ac]	Applied Nitrogen Gg N/yr (%) [1,000 t/yr]
Tulare Lake Basin	base load	10.5 [8.5]	4,415 (0%)	1,293 [3,194]	200 (0%) [221]
	25% load reduction	10.0 [8.1]	4,259 (–3.5%)	1,240 [3,064]	181 (–9%) [199]
	50% load reduction	7.9 [6.4]	3,783 (–14%)	952 [2,352]	135 (–32%) [149]
Salinas Valley	base load	0.37 [0.30]	309 (0%)	92 [227]	18 (0%) [19]
	25% load reduction	0.33 [0.27]	285 (–7.5%)	83 [205]	15 (–16%) [16]
	50% load reduction	0.25 [0.20]	239 (–22%)	62 [153]	10 (–46%) [11]

Source: Dzurella et al. 2012.

* Irrigated land area and applied nitrogen in base load vary slightly from those reported in Section 2.2 due to land use data being based on Figure 2 (derived from DWR data) instead of County Agricultural Commissioner Reports (Figure 6).

favor economically. The average net revenue loss of reducing nitrate loading to groundwater is estimated to be $16 per kilogram of nitrogen at this 50% reduction level. Modeling a 7.5% sales fee on nitrogen fertilizer indicated an estimated reduction in total applied nitrogen by roughly 1.6%, with a 0.6% loss in net farm revenues.

Agricultural source reduction: Promising actions. Expanded efforts to promote nitrogen-efficient practices are needed. Educational and outreach activities could assist farmers in applying best management practices (BMPs) and nutrient management. Research should focus on demonstrating the value of practices on PNB and on adapting practices to local conditions for crop rotations and soils with the greatest risk of nitrate leaching. This especially includes row crops receiving high rates of nitrogen and/or manure that are surface- or sprinkler-irrigated. Research on the costs of increasing nitrogen use efficiency in crops would greatly benefit the capacity to estimate the economic costs of reductions in agricultural nitrate loading to groundwater. Research and education programs are needed to promote conversion of solid and liquid dairy manure into forms that meet food safety and production requirements for a wider range of crops.

We suggest that a working group develop crop-specific technical standards on nitrogen mass balance metrics for regulatory and assessment purposes. This nitrogen-driven metric would reduce the need for more expensive direct measurement of nitrate leaching to groundwater. Such

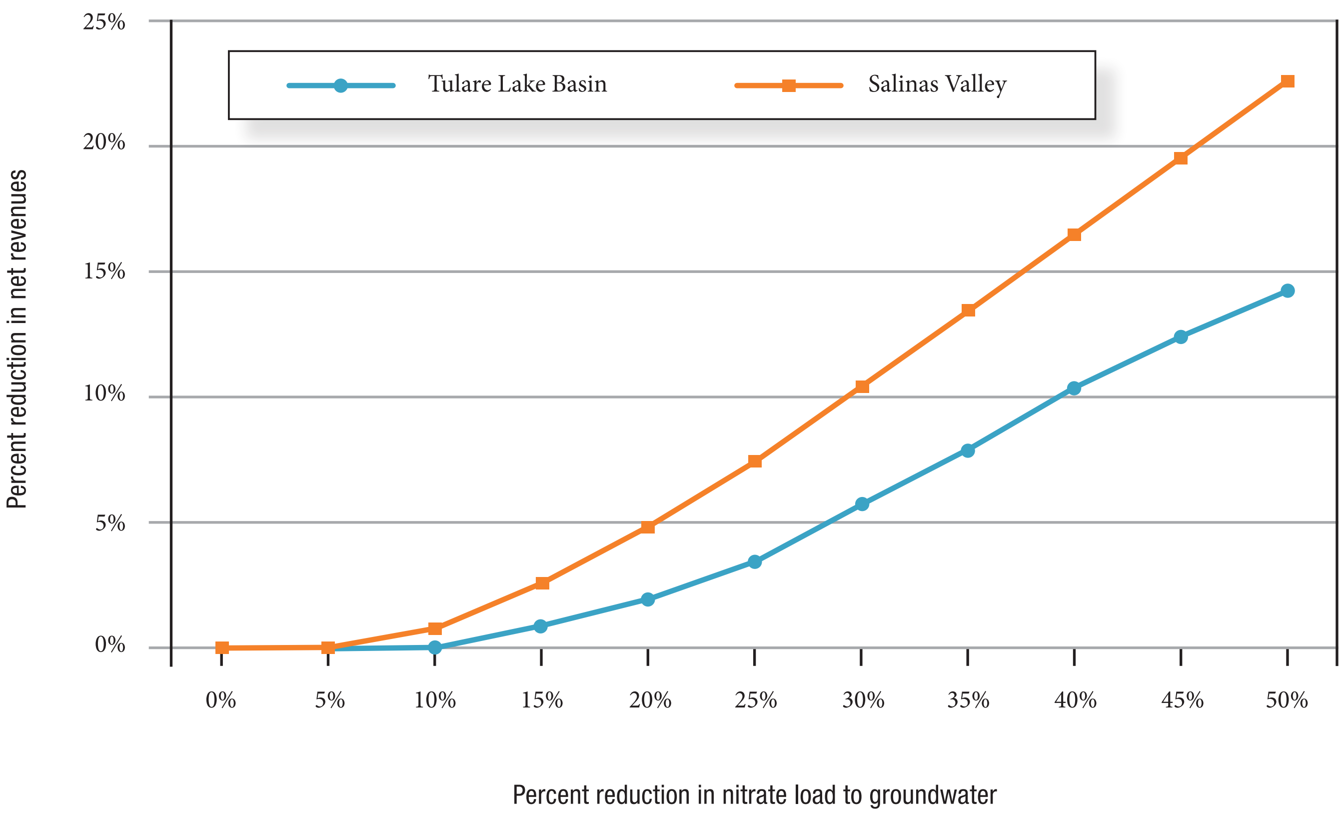


Figure 10. Percent reduction in net revenues estimated from different levels of reduction in nitrate loading to groundwater. Source: Dzurella et al. 2012.

metrics would also serve as a starting point to assist farmers in assessing their crop nitrogen use efficiency and be useful for nitrogen management. Finally, we recommend that a task force review and further develop methods to identify croplands most in need of improved management practices. Such a method should include consideration of soil characteristics (as in the UC Nitrate Hazard Index), as well as possible monitoring requirements.

Reducing Nitrate Leaching from Municipal Wastewater Treatment and Food Processing Plants

Implementation of nitrogen control options for WWTP and FP sources is feasible and useful. Nitrogen removal from wastewater can be accomplished using a variety of technologies and configurations; both biological and physical or chemical processes are effective. The selection of the most appropriate treatment option depends on many factors.

Estimated capital costs for nutrient removal from all wastewater (FPs and WWTPs) for facilities categorized as "at-risk" range from $70 to $266 million. Cropland application of wastewater treatment and food processing effluents can reduce direct groundwater contamination and total fertilizer application requirements of such fields, as the water and nutrients are effectively treated and recycled. These wastes should be managed in an agronomic manner rather than applied to land for disposal or land treatment purposes so that the nutrients are included in the overall nitrogen management plan for the receiving crops.

Optimizing wastewater treatment plant and food processing plant operations is another way to reduce nitrogen and total discharge volume. Facility process modifications may be sufficient in some cases. Groundwater monitoring is required for many facilities, but the data are largely unavailable since they are not in a digital format. To improve monitoring, enforcement, and abatement efforts related to these facilities, groundwater data need to be more centrally managed and organized digitally.

Reducing Nitrate Contributions from Leaking Sewer Pipes and Septic Systems

Retrofitting of septic system components and sewer pipes is the main way to diminish loading from these sources. Replacing aging sewer system infrastructure and ensuring proper maintenance are required to reduce risks to human health; such infrastructure upgrades also reduce nitrate leaching.

Loading from septic systems, significant locally, can be reduced significantly by two approaches where connection to a sewer system is not possible. Source separation technology can reduce nitrate loading to wastewater treatment systems by about 50%. Costs include separating toilets ($300–$1,100), dual plumbing systems ($2,000–$15,000), storage tank costs, and maintenance, pumping, heating, and transport costs (where applicable). Post-septic tank biological nitrification and denitrification treatment reduces nitrate concentrations below levels achieved via source separation technology but does not result in a reusable resource. Wood chip bioreactors have reduced influent nitrate by 74% to 91%, with costs ranging from $10,000 to $20,000 to retrofit existing septic systems.

Reducing Nitrate Leaching from Turfgrass in Urban Areas

Nitrate leaching from urban turfgrass, including golf courses, is often negligible due to the dense plant canopy and perennial growth habit of turf, which results in continuous plant nitrogen uptake over a large portion of the year. However, poor management can lead to a discontinuous canopy and weed presence, wherein nitrate leaching risk increases, especially if the turf is grown on permeable soils, is overirrigated, or is fertilized at high rates during dormant periods. The UCCE and UC IPM publish guidelines on proper fertilizer use in turfgrass. The knowledge and willingness of homeowners and groundskeepers to apply guidelines depend on funding for outreach efforts.

Reducing Nitrate Transfer and Loading from Wells

Backflow prevention devices should be required on agricultural and other wells used to mix fertilizer with water. Furthermore, local or state programs and associated funding to identify and properly destroy abandoned and dry wells are needed to prevent them from becoming nitrate transfer conduits. However, many well owners may not be able to afford the high costs of retrofitting long-screened wells to seal contaminated groundwater layers. As such, enforcement of proper well construction standards for future wells may be more feasible. Expenditures on retrofitting of existing dry and abandoned wells should be based on the contamination risks of individual wells. The nitrate contamination potential of wells needs to be identified as a basis for developing and enforcing improved, appropriate well construction standards that avoid the large-scale transfer of nitrate to deep groundwater in all newly constructed wells.

3 Impact: Groundwater Nitrate Occurrence

3.1 Current Groundwater Quality Status

We assembled groundwater quality data from nearly two dozen local, state, and federal agencies and other sources into a dataset, here referred to as the (Central) California Spatio-Temporal Information on Nitrate in Groundwater (CASTING) dataset (see Table 6 for information about data sources, Boyle et al. 2012). The dataset combines nitrate concentrations from 16,709 individual samples taken at 1,890 wells in the Salinas Valley and from 83,375 individual samples taken at 17,205 wells in the Tulare Lake Basin collected from the 1940s to 2011, a total of 100,084 samples from 19,095 wells. Almost 70% of these samples were collected from 2000 to 2010; only 15% of the samples were collected prior to 1990. Half of all wells sampled had no recorded samples prior to 2000 (Boyle et al. 2012).

Of the nearly 20,000 wells, 2,500 are frequently sampled public water supply wells (over 60,000 samples). Apart from the recently established Central Valley dairy regulatory program, which now monitors about 4,000 domestic and irrigation wells in the Tulare Lake Basin, there are no existing regular well sampling programs for domestic and other private wells.

From 2000 to 2011, the median nitrate concentration in the Tulare Lake Basin and Salinas Valley public water supply well samples was 23 mg/L and 21 mg/L,[6] respectively, and in all reported non-public well samples, 23 mg/L and 20 mg/L, respectively. In public supply wells, about one in ten raw water samples exceeds the nitrate MCL. Nitrate concentrations in wells vary widely with location and well depth. More domestic wells and unregulated small system wells have high nitrate concentrations due to their shallow depth (Table 6). Highest nitrate concentrations are found in wells of the alluvial fans in the eastern Tulare Lake Basin and in wells of unconfined to semi-confined aquifers in the northern, eastern, and central Salinas Valley (Figure 11). In the Kings, Kaweah, and Tule River groundwater sub-basins of Fresno and Kings County, and in the Eastside and Forebay sub-basins of Monterey County, one-third of domestic or irrigation wells exceed the nitrate MCL. Consistent with these findings, the maximum nitrate level, measured in any given land section (1 square mile) for which nitrate data exist between 2000 and 2009, exceeds the MCL across wide portions of these areas (Figure 12). Low nitrate concentrations tend to occur in the deeper, confined aquifer in the western and central Tulare Lake Basin (Boyle et al. 2012).

Nitrate levels have not always been this high. While no significant trend is observed in some areas with low nitrate (e.g., areas of the western TLB), USGS research indicates significant long-term increases in the higher-nitrate areas of the Tulare Lake Basin (Burow et al. 2008), which is consistent with the CASTING dataset. Average nitrate concentrations in public supply wells of the Tulare Lake Basin and Salinas Valley have increased by 2.5 mg/L (±0.9 mg/L) per decade over the past three decades. Average trends of similar magnitude are observed in private wells. As a result, the number of wells with nitrate above background levels (>9 mg/L) has steadily increased over the past half century from one-third of wells in the 1950s to nearly two-thirds of wells in the 2000s (Figure 13). Due to the large increase in the number of wells tested across agencies and programs, the overall fraction of sampled wells exceeding the MCL grew significantly in the 2000s (Boyle et al. 2012).

The increase in groundwater nitrate concentration measured in domestic wells, irrigation wells, and public supply wells lags significantly behind the actual time of nitrate discharge from the land surface. The lag is due, first, to travel time between the land surface or bottom of the root zone and the water table, which ranges from less than 1 year in areas with shallow water table (<3 m [10 ft]) to several years or even decades where the water table is deep (>20 m [70 ft]). High water recharge rates shorten travel time to a deep water table, but in irrigated areas with high irrigation efficiency and low recharge rates, the transfer to a deep water table may take many decades.

[6] Unless noted otherwise, nitrate concentration is given in mg/L as nitrate (MCL = 45 mg/L).

Once nitrate is recharged to groundwater, additional travel times to shallow domestic wells are from a few years to several decades and one to several decades and even centuries for deeper production wells.

3.2 Cleanup of Groundwater: Groundwater Remediation

Groundwater remediation is the cleanup of contaminated groundwater to levels that comply with regulatory limits. In the pump-and-treat (PAT) approach, groundwater is extracted from wells, treated on the surface, and returned to the aquifer by injection wells or surface spreading basins. In-situ treatment approaches create subsurface conditions that aid degradation of contaminants underground. In-situ remediation is not appropriate for contaminants spread over large regions or resistant to degradation. Both remediation methods typically also require removal or reduction of contamination sources and long-term groundwater monitoring.

Table 6. Data sources with the total number of samples recorded, total number of sampled wells, location of wells, type of wells, and for the last decade (2000–2010) in the Tulare Lake Basin and Salinas Valley: Number of wells measured, median nitrate concentration, and percentage of MCL exceedance for the Tulare Lake Basin and the Salinas Valley*

Data Source†	Total # of Wells	Total # of Samples	Location of Wells	Type of Wells	Years 2000–2010					
					# of Wells TLB	# of Wells SV	TLB Median mg/L nitrate	SV Median mg/L nitrate	TLB % > MCL	SV % > MCL
CDPH	2,421	62,153	throughout study area	public supply wells	1,769	327	12	8	6%	5%
CVRWB DAIRY	6,459	11,300	dairies in TLB	domestic, irrigation, and monitoring wells	6,459	—	22	—	31%	—
DPR	71	814	eastern Fresno and Tulare Counties	domestic wells	71	—	40	—	45%	—
DWR	26	44	Westlands Water District	irrigation wells	28	—	1	—	0%	—
DWR Bulletin 130	685	2,862	throughout study area	irrigation, domestic, and public supply wells	—	—	—	—	—	—
ENVMON	537	2,601	throughout study area	monitoring wells	357	180	—	27	52%	44%
EPA	2,860	4,946	throughout study area	—	—	—	—	—	—	—
Fresno County	368	369	Fresno County	domestic wells	349	—	18	—	15%	—
GAMA	141	141	Tulare County	domestic wells	141	—	38	—	43%	—
Kern County	2,893	3,825	Kern County	Irrigation, domestic wells	361	—	5	—	7%	—

Continued on next page

Groundwater remediation is difficult and expensive (NRC 1994, 2000). Groundwater remediation is done only very locally (less than 1 km^2 [<0.5 mi^2] to often less than 2 ha [<5 ac]). Cleanup of contaminants over a wide region is not feasible, and would require many decades and considerable expense. The success rate for cleanup of widespread groundwater contaminants is very disappointing (NRC 1994, 2000).

Because of the difficulty and poor success rates of plume remediation, an approach known as monitored natural attenuation (MNA) has become popular. MNA involves letting natural biochemical transformations and dispersion reduce and dilute contamination below cleanup goals, while monitoring to confirm whether MNA is adequately protecting groundwater quality. However, this approach is effective only for contaminants that transform to relatively harmless byproducts. The combination of circumstances that would favor denitrification of nitrate is generally lacking in California's alluvial aquifer systems (Fogg et al. 1998; Boyle et al. 2012), so MNA does not seem to be an effective way of remediating nitrate-contaminated groundwater in the study area.

The total estimated volume of groundwater exceeding the nitrate MCL in the Tulare Lake Basin and Salinas Valley is 39.7 km^3 (32.2 million acre-feet, AF) and 4.2 km^3 (3.4 million AF), respectively, more than the total groundwater

Table 6. *Continued*

Data Source†	Total # of Wells	Total # of Samples	Location of Wells	Type of Wells	Years 2000–2010					
					# of Wells TLB	# of Wells SV	TLB Median mg/L nitrate	SV Median mg/L nitrate	TLB % > MCL	SV % > MCL
Monterey County, Reports	239	1,018	Monterey County	monitoring, irrigation wells	—	98	—	14	—	36%
Monterey County, Geospatial	388	1,574	Monterey County	local small systems wells	—	431	—	18	—	15%
Monterey County, Scanned	452	5,674	Monterey County	local small systems wells	—	427	—	17	—	14%
NWIS	1,028	2,151	—	miscellaneous	76	4	35	0	36%	0%
Tulare County	444	444	Tulare County	domestic wells	438	—	22	—	27%	—
Westlands Water District	48	77	Westlands Water District	irrigation wells	31	—	4	—	0%	—

Source: Boyle et al. 2012.

* Median and percent MCL exceedance were computed based on the annual mean nitrate concentration at each well for which data were available.

† Data sources: CDPH: public supply well database; CVRWB Dairy: Central Valley RWB Dairy General Order; DWR Bulletin 130: data reports from the 1960–1970s, 1985; ENVMON: SWRCB Geotracker environmental monitoring wells with nitrate data (does not include data from the CVRWB dairy dataset); EPA: STORET dataset; Fresno County: Public Health Department; GAMA: SWRCB domestic well survey; Kern County: Water Agency; Monterey County, Reports: data published in reports by MCWRA; Monterey County, Geospatial: Health Department geospatial database; Monterey County, Scanned: Health Department scanned paper records; NWIS: USGS National Water Information System; Tulare County: Health and Human Services; Westlands Water District: district dataset. Some smaller datasets are not listed. Individual wells that are known to be monitored by multiple sources are here associated only with the data source reporting the first water quality record.

pumped from the project area aquifers between 2005 and 2010 (Table 7). This is a basin-scale groundwater cleanup problem. Annual costs of traditional remediation would be on the order of $13 to $30 billion (Dzurella et al. 2012; King et al. 2012). This explains why no attempt at remediation of a contaminated groundwater basin on the scale of the Tulare Lake Basin or Salinas Valley has ever been undertaken. Except for cleanup of hot-spot sites, traditional remediation for nitrate is not a promising option.

A more promising remediation approach is what we refer to as "pump-and-fertilize" (PAF) (Dzurella et al. 2012; King et al. 2012). This approach uses existing agricultural wells to remove nitrate-contaminated groundwater and "treat" the water by ensuring nitrate uptake into crops through proper nutrient management. A disadvantage of PAF is that many irrigation wells are drilled deep to maximize the pumping rate, but most high levels of nitrate contamination are seen at shallower depths. Shallower nitrate-contaminated groundwater is en route toward the deep intake screens of many of the irrigation wells (Viers et al. 2012). One option is to drill intermediate-depth irrigation wells to intercept contaminated groundwater before it penetrates farther into the deeper subsurface. The cost, energy, and management requirements of this approach would need to be carefully evaluated, as it requires the drilling and operation of many shallower wells with smaller capture zones and smaller pumping rates at each well. At a regional or sub-regional scale, it may be an innovative alternative, although decades of PAF operations would be needed together with large reductions in nitrate leachate from the surface.

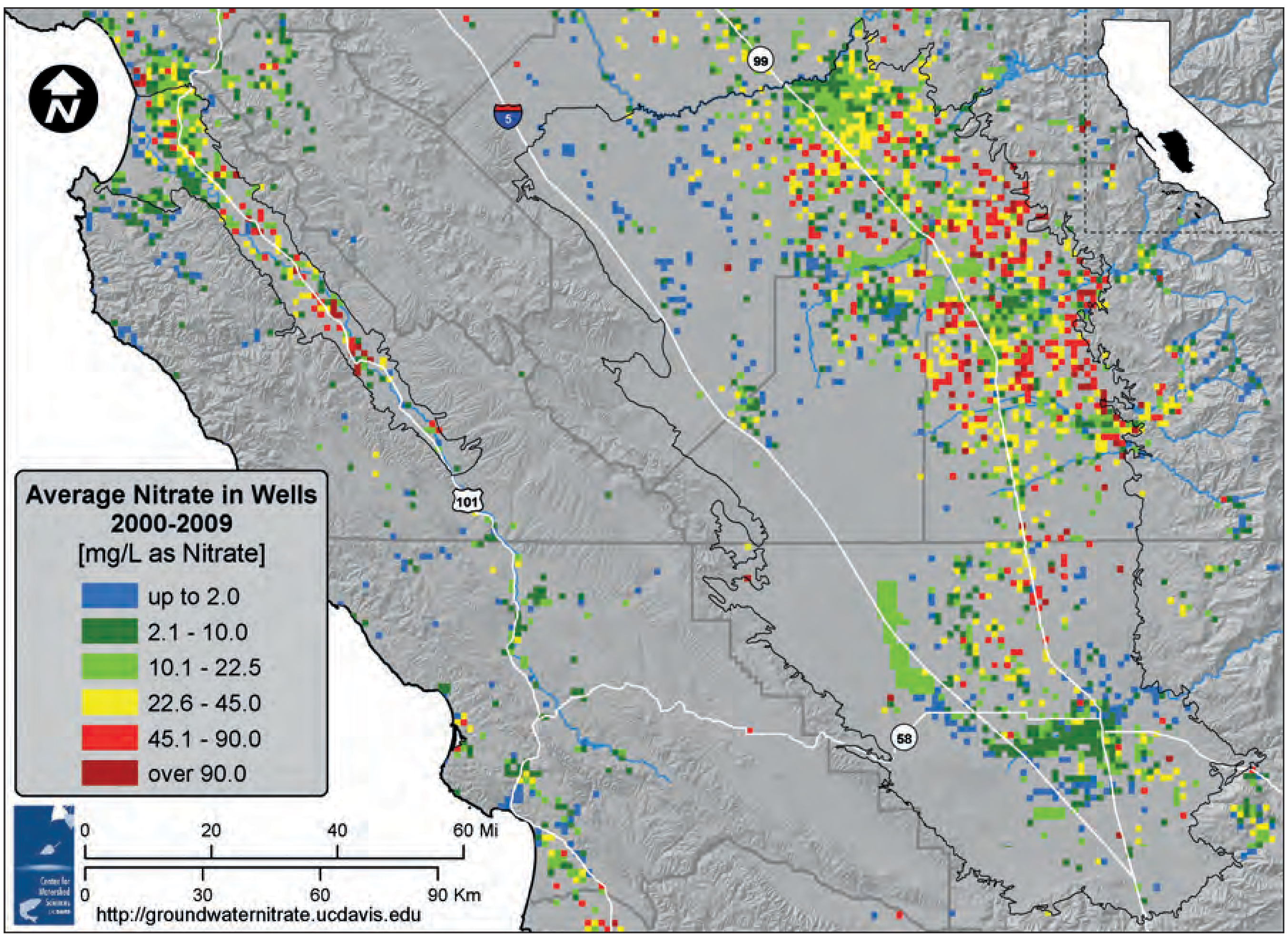


Figure 11. Mean of the time-average nitrate concentration (mg/L) in each well belonging within a square mile land section, 2000–2009. Some areas in the TLB are larger than 1 square mile. Source: Boyle et al. 2012.

Groundwater recharge operations could be managed to improve groundwater quality if the recharged water is of good quality and relatively low in nitrate (remediation by dilution). By introducing as much clean recharge water as possible, the long-term effects of contaminated agricultural recharge can be partially mitigated. But the large water volumes already affected would require decades of management.

Pump-and-fertilize along with improved groundwater recharge management are technically feasible, less costly alternatives than pump-and-treat and could help place regional groundwater quality on a more sustainable path. These alternatives should be accompanied by remediation of local nitrate contamination hot spots and long-term groundwater quality monitoring to track benefits of the strategy (for details, see King et al. 2012).

3.3 Existing Regulatory and Funding Programs for Nitrate Groundwater Contamination

Many regulatory and planning programs in the study area provide regulatory structure or technical and managerial support to water systems, communities, farmers, dairies, and others who deal with nitrate contamination in groundwater. Statutes also provide a regulatory framework for nitrate contamination of groundwater and drinking water. In the study area, there are several federal programs/statutes (Table 8a and Table 8b, blue), State programs/statutes (purple), and nongovernmental programs/agencies (orange) relevant to nitrate contamination and its effects on drinking water. Current regulatory/planning programs and statutes that have the ability to reduce groundwater nitrate contamination

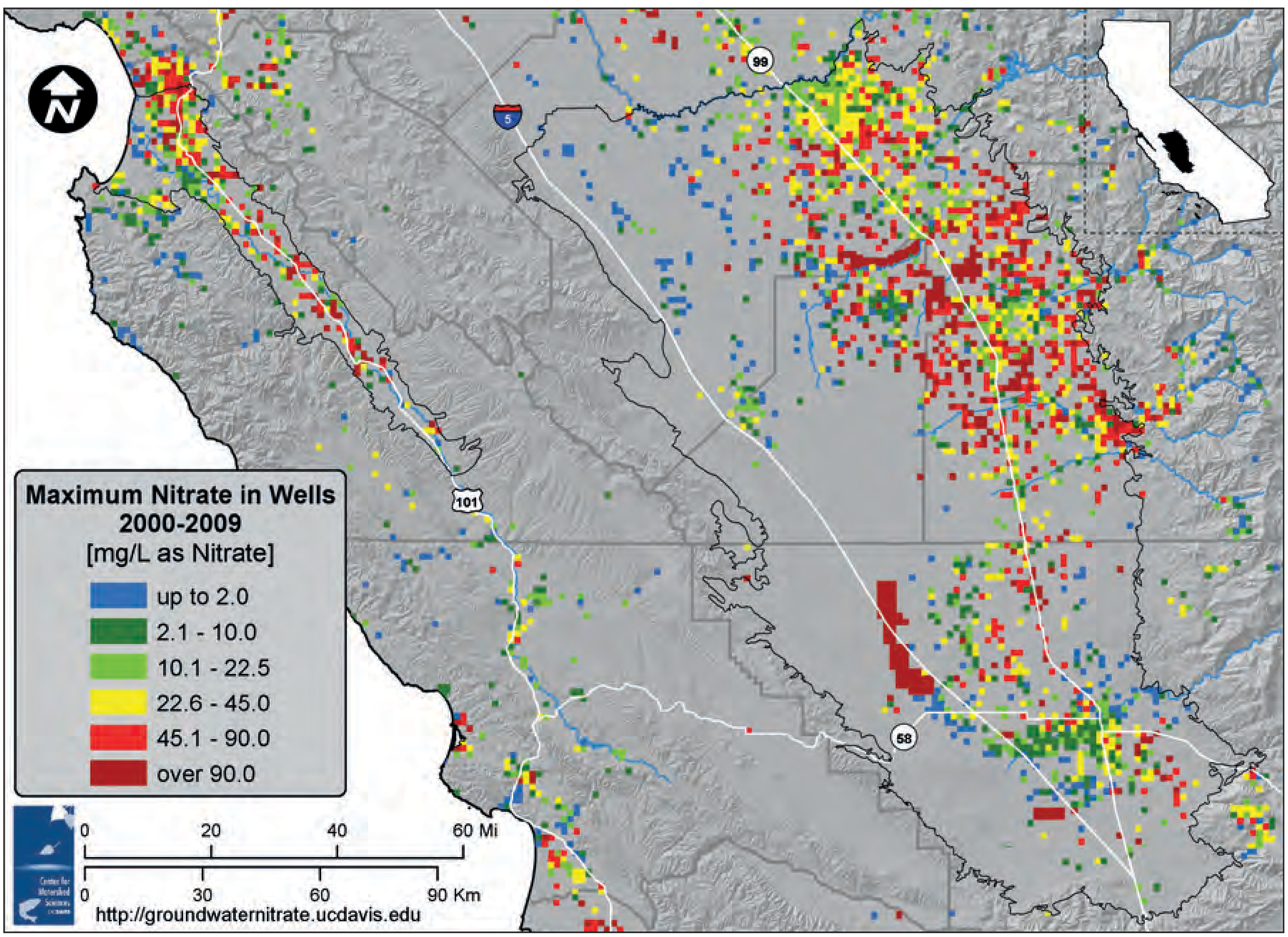


Figure 12. Maximum nitrate concentration (mg/L) measured at any time during 2000–2009 within a 1-square-mile land section. Some areas in the TLB are larger than 1 square mile. Source: Boyle et al. 2012.

are summarized in Table 8a. These programs/statutes have components that target nitrate source reduction or groundwater remediation. While providing a framework to address the groundwater nitrate issue, these programs have not been effective at preventing substantial nitrate contamination of groundwater used in drinking water supplies. Table 8b is a summary of current programs and statutes related to groundwater nitrate and drinking water. These provide for data collection, information, and education on nitrate sources and groundwater nitrate. Some of these programs regulate nitrate in drinking water.

In addition, several state, federal, and local agencies, as well as nongovernmental organizations, have established funding programs related to nitrate contamination in California's groundwater. A summary of existing funding sources to address problems related to nitrate in drinking water is shown in Table 9. In general, these programs are structured to provide assistance for activities related to alternative water supplies and nitrate load reduction. The State of California has eighteen relevant funding programs, administered by four agencies (Table 9, purple); the federal government manages an additional three funding programs (blue). Three large nongovernmental drinking water funding programs in the study area are highlighted in orange in Table 9. For a more detailed review, see Canada et al. (2012).

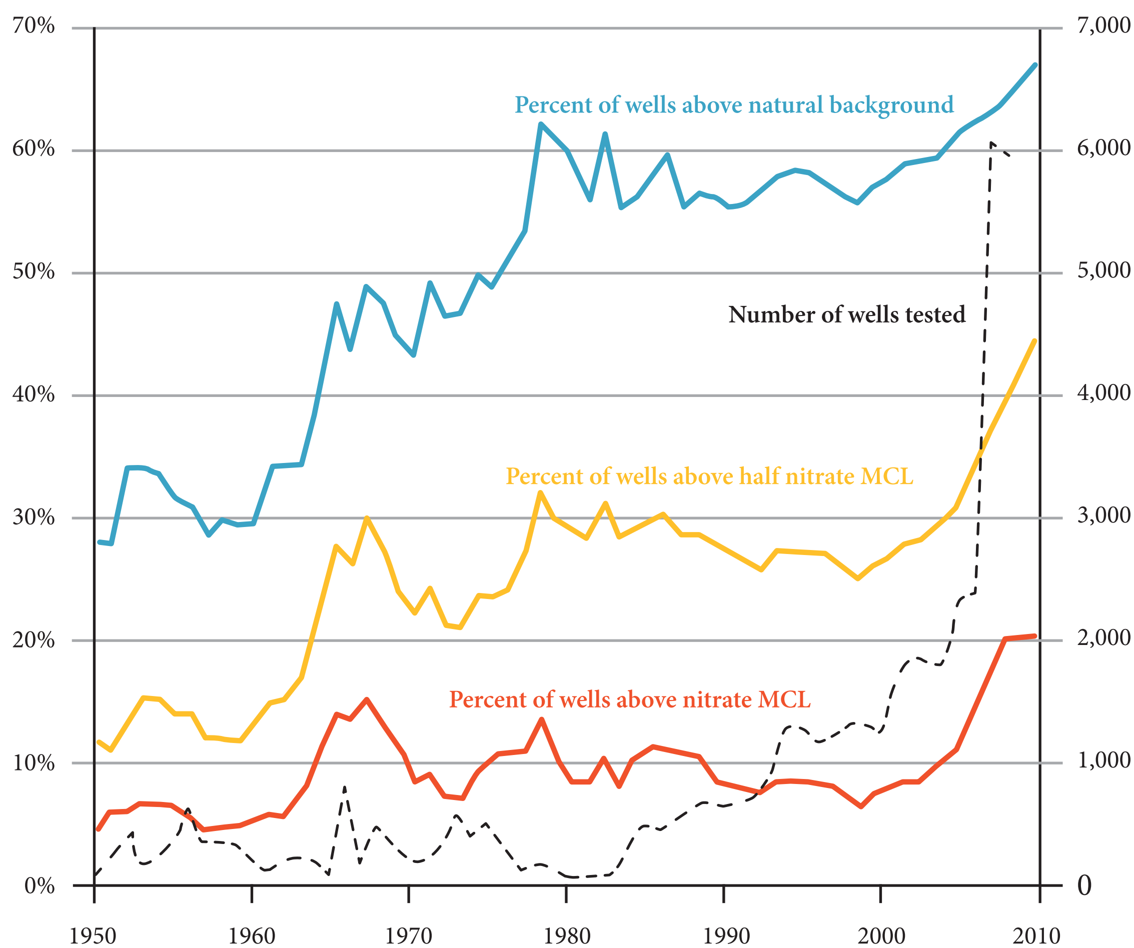


Figure 13. Five-year moving average of the percentage of wells for which the average annual measured concentration exceeded 9 mg/L (background), 22.5 mg/L (half of the MCL), and 45 mg/L (MCL) in any given year. Since the 1990s, an increasing number of wells other than public supply wells have been tested. In 2007, Central Valley dairies began testing their domestic and irrigation wells on an annual basis. Source: Boyle et al. 2012.

Table 7. Total groundwater volume* and estimated remediation volume by sub-basin

Sub-Basin	Total Groundwater Volume in Study Area km^3 [million AF]	Remediation Volume > MCL km^3 (% of total)	Remediation Volume > MCL million AF (% of total)
Tulare Lake Basin			
5-22.06–Madera	1.48 [1.2]	0.15 (10%)	0.12 (10%)
5-22.07–Delta-Mendota	3.21 [2.6]	0.16 (5%)	0.13 (5%)
5-22.08–Kings	115 [93]	12.75 (11%)	10.34 (11%)
5-22.09–Westside	64 [52]	1.67 (3%)	1.35 (3%)
5-22.10–Pleasant Valley	4.9 [4.0]	1.11 (23%)	0.90 (23%)
5-22.11–Kaweah	42 [34]	9.12 (21%)	7.39 (21%)
5-22.12–Tulare Lake	46 [37]	4.65 (10%)	3.77 (10%)
5-22.13–Tule	41 [33]	4.29 (11%)	3.48 (11%)
5-22.14–Kern	49 [40]	5.81 (12%)	4.71 (12%)
TLB TOTAL	366 [297]	39.7 (11%)	32.2 (11%)
Salinas Valley			
3-4.01–180/400 Foot Aquifer	8.46 [6.86]	0.91 (11%)	0.74 (11%)
3-4.02–Eastside	3.16 [2.56]	1.23 (39%)	1.00 (39%)
3-4.04–Forebay	5.59 [4.53]	1.37 (25%)	1.11 (25%)
3-4.05–Upper Valley	3.03 [2.46]	0.56 (19%)	0.45 (19%)
3-4.08–Seaside	0.78 [0.63]	0.07 (10%)	0.06 (10%)
3-4.09–Langley	0.44 [0.36†]	0.04 (9%)	0.03 (9%)
3-4.10–Corral de Tierra	0.60 [0.49‡]	0.002 (0.5%)	0.002 (0.5%)
SV TOTAL	22.1 [17.9]	4.19 (19%)	3.4 (19%)
Study Area Total	**315 [255]**	**43.9 (11%)**	**35.6 (11%)**

Source: King et al. 2012.

*Source: DWR 2010.

† Storage; actual groundwater volume not listed.

‡ Source: Montgomery Watson Americas 1997, not listed in DWR Bulletin 118.

Table 8a. Summary of programs and statutes for reducing nitrate contamination in groundwater

Agency	Program/Statute (year created/passed)	Goal/Purpose
U.S. Environmental Protection Agency (U.S. EPA)	Supplemental Environmental Programs (SEP) (1998)	Environmentally beneficial project that a violator of environmental laws may choose to perform (under an enforcement settlement) in addition to the actions required by law to correct the violation.
State Water Resources Control Board (State Water Board)	Porter-Cologne Water Quality Control Act (1969)	Grants the State Water Board authority over state water quality policy and aims to regulate activities in California to achieve the highest reasonable water quality.
	Recycled Water Policy (2009)	Resolution No. 2009-0011: Calls for development of salt and nutrient management plans and promotes recharge of clean storm water.
Regional Water Quality Control Boards	Cleanup and Abatement Order (CAO)	CA Water Code § 13304: Allows the Regional Water Board to issue a directive to a polluter to require clean up of waste discharged into waters of the state.
Central Coast Regional Water Quality Control Board	Irrigated Lands Regulatory Program (ILRP) (2004, draft in 2011)	*General Conditional Waiver of Waste Discharge Requirements, 3-Tiered Agricultural Regulatory Program (2004):* Groundwater quality monitoring required to different degrees based on discharger's tier. Draft (2001) requires Tier 3 dischargers with high nitrate loading to meet specified Nitrogen Mass Balance Ratios or implement a solution that leads to an equivalent nitrate load reduction.
Central Valley Regional Water Quality Control Board	Irrigated Lands Regulatory Program (ILRP) (2003, draft in 2011)	*Conditional Wavier of Waste Discharge Requirements of Discharges from Irrigated Lands:* Interim program to regulate irrigated lands. Does not address groundwater. *Recommended ILRP Framework (2011):* Development of new monitoring and regulatory requirements (includes groundwater).
	CV-SALTS (2006)	Planning effort to develop and implement a basin plan amendment for comprehensive salinity and nitrate management.
	Dairy Program (2007)	*Waste Discharge Requirements General Order for Existing Milk Cow Dairies:* Confined animal facilities must comply with set statewide water quality regulations, and existing milk cow dairies must conduct nutrient and groundwater monitoring plans.
California Department of Food and Agriculture (CDFA)	Feed, Fertilizer, Livestock, Drugs, Egg Quality Control Regulatory Services (FFLDERS)	Manages licenses, registration and inspection fees, and a mill fee levied on fertilizer sales, to fund research and educational projects that improve fertilizer practices and decrease environmental impacts from fertilizer use.

Table 8b. Summary of programs and statutes related to groundwater nitrate and drinking water (data collection, information, education, or regulation of drinking water)

Agency	Program/Statute (year created/passed)	Goal/Purpose
U.S. Environmental Protection Agency (U.S. EPA)	Safe Drinking Water Act (SDWA) (1974, 1986, 1996)	Mandates EPA to set the drinking water standards and to work with states, localities, and water systems to ensure that standards are met.
	Phase II Rule (1992)	Established federal maximum contaminant level (MCL) for nitrate in public water systems.
	Enforcement Response Policy—Enforcement Targeting Tool	Focuses on high-priority systems with health-based violations or with monitoring or reporting violations that can mask acute health-based violations.
U.S. Department of Agriculture (USDA)	Rural Utilities Service: National Drinking Water Clearinghouse (1977)	Provides technical assistance and educational materials to small and rural drinking water systems.
California Department of Public Health (CDPH)	22 CCR § 64431	Established state maximum contaminant level (MCL) for nitrate in public water systems.
	Drinking Water Source Assessment and Protection (DWSAP)	Evaluation of possible contaminating activities surrounding groundwater and surface water sources for drinking water.
	Expense Reimbursement Grant Program (EPG)	Education, training, and certification for small water system (serving < 3,301 people) operators.
	Groundwater Ambient Monitoring and Assessment (GAMA)	Improves statewide groundwater monitoring and increases availability of groundwater quality information. Funded by Prop 50 and special fund fees.
Assembly Bill 3030	(1993)	Permits local agencies to adopt programs to manage groundwater and requires all water suppliers overlying useable groundwater basins to develop groundwater management plans that include technical means for monitoring and improving groundwater quality.
Kern County Water Agency (KCWA)	(1961)	Collects, interprets, and distributes groundwater quality data in Kern County.
Monterey County Health Department		Implements a tiered, regular nitrate sampling program based on increasing nitrate concentration for local small water systems and for state small water systems.
Southern San Joaquin Valley Water Quality Coalition	(2002)	Protects and preserves water quality in the Tulare Lake Basin through surface water quality monitoring and dissemination of collected data. Particular focus is on agricultural discharge areas. Does not currently focus on groundwater.
Tulare County Water Commission	(2007)	Discusses water issues impacting Tulare County and advises the Tulare County Board of Supervisors. Special focus on nitrate in groundwater and improving drinking water in small communities.
Monterey County Water Resources Agency (MCWRA)	(1947)	Provides water quality management and protection through groundwater quality monitoring (including nitrate levels) and research and outreach efforts to growers to improve fertilizer management and reduce nitrate leaching.
The Waterkeeper Alliance	Monterey Coastkeeper (2007)	Collaborates with the State Water Board to ensure effective monitoring requirements for agricultural runoff and more stringent waste discharge requirements for other nitrate sources.
Rural Community Assistance Partnership (RCAP)	(1979)	Uses publications, training, conferences, and technical assistance to help communities of less than 10,000 people access safe drinking water, treat and dispose of wastewater, finance infrastructure projects, understand regulations, and manage water facilities.
National Rural Water Association (NRWA)	(1976)	Offers drinking water system technical advice (operation, management, finance, and governance) and advocates for small/rural systems to ensure regulations are appropriate.
California Rural Water Association	(1990)	Provides online classes, onsite training, low-cost educational publications, and other forms of technical advice for rural water and wastewater systems.
Self-Help Enterprises (SHE)	Community Development Program (1965)	Provides technical advice and some seed money to small/rural/poor communities for the planning studies and funding applications associated with drinking water system projects.
Community Water Center	Association of People United for Water (AGUA) (2006)	Advocates for regional solutions to chronic local water problems in the San Joaquin Valley. Focused on securing safe drinking water, particularly from nitrate-impacted sources.

Table 9. Summary of existing funding sources for water quality investigations and safe drinking water

Agency	Program (year passed or created)	Funding Provided (in millions of dollars)
California Department of Public Health (CDPH)	Safe Drinking Water State Revolving Fund (SDWSRF) (1996) (grants and loans)	**Generally $100–$150:** Low-interest loans and some grants to support water systems with technical, managerial, and financial development and infrastructure improvements.
	Proposition 84 (2006) (grants) **(fully allocated)**	**$180:** Small community improvements. **$60:** Protection and reduction of contamination of groundwater sources. **$10:** Emergency and urgent projects.
	Proposition 50 (2002) (grants) **(fully allocated)**	**$50:** Water security for drinking water systems. **$69:** Community treatment facilities and monitoring programs. **$105:** Matching funds for federal grants for public water system infrastructure improvements.
State Water Resources Control Board (State Water Board)	Clean Water State Revolving Fund (CWSRF) (1987) (loans)	**$200–$300 per year:** Water quality protection projects, wastewater treatment, nonpoint source contamination control, and watershed management.
	Small Community Wastewater Grants (2004, amended 2007) (grants)	**$86 (fees on the CWSRF):** Loan forgiveness to small disadvantaged communities and grants to nonprofits that provide technical assistance and training to these communities in wastewater management and preparation of project applications.
	Proposition 50 (2002) (grants) **(fully allocated)**	**$100:** Drinking water source protection, water contamination prevention, and water quality blending and exchange projects.
	Agricultural Drainage Program (1986) (loans) **(fully allocated)**	**$30:** Addressing treatment, storage, conveyance or disposal of agricultural drainage.
	Dairy Water Quality Grant Program (2005) (grants) **(fully allocated)**	**$5 (Prop 50):** Regional and on-farm dairy projects to address dairy water quality impacts.
	Nonpoint Source Implementation Program (2005) (grants)	**$5.5 per year:** Projects that reduce or prevent nonpoint source contamination to ground and surface waters.
	Cleanup and Abatement Account (2009)	**$9 in 2010:** Clean up or abate a condition of contamination affecting water quality.
	Integrated Regional Water Management (IRWM) (2002) (grants) **(fully allocated)**	**$380 (Prop 50):** Planning ($15) and implementation ($365) projects related to protecting and improving water quality, and other projects to ensure sustainable water use.

continued on next page

Table 9. *Continued*

Agency	Program (year passed or created)	Funding Provided (in millions of dollars)
California Department of Water Resources (DWR)	Integrated Regional Water Management (IRWM) (2002) (grants)	**$500 remaining (Prop 84):** Regional water planning and implementation.
	Local Groundwater Assistance Grant (2008) (grants)	**$4.7 anticipated for 2011–2012 (Prop 84):** Groundwater studies, monitoring and management activities.
	Proposition 82 (1988) (loans)	**$22:** New local water supply feasibility and construction loans.
	Water Use Efficiency Grant Program (2001) (grants)	**$15 in 2011 (Prop 50):** Water use efficiency projects for agriculture, such as: wellhead rehabilitation, water and wastewater treatment, conjunctive use, water storage tanks.
	Agricultural Water Conservation Loan Program (2003) (loans)	**$28 (Prop 13):** Agricultural water conservation projects, such as: lining ditches, tailwater or spill recovery systems, and water use measurement.
	Infrastructure Rehabilitation Construction Grants (2001) (grants) **(fully allocated)**	**$57 (Prop 13):** Drinking water infrastructure rehabilitation and construction projects in poor communities.
California Infrastructure and Economic Development Bank (I-Bank)	Infrastructure State Revolving Fund (ISRF) (1994) (loans)	**$0.25 to $10 per project:** Construction or repair of publicly owned water supply, treatment, and distribution systems.
U.S. Department of Agriculture (USDA)	Rural Utilities Service—Water and Environmental Programs (RUS WEPs) (loans and grants)	**$15.5:** Development and rehabilitation of community public water systems (less than 10,000 people), including: emergency community water assistance grants, predevelopment planning grants, technical assistance, guaranteed loans, and a household well water program.
U.S. Department of Housing and Development (HUD)	Community Development Block Grant (CDBG) (grants)	**$500 in 2010 for CA:** Community development projects: feasibility studies, final plans and specs, site acquisition and construction, and grant administration.
U.S. Department of Commerce	Economic Development Administration (EDA) (grants)	**Grants up to 50% of project costs:** supports economic development, planning, and technical assistance for public works projects.
Rural Community Assistance Corporation (RCAC)	Drinking Water Technical Assistance and Training Services Project (loans)	**$1.2 per year:** Administers funds from the US EPA Office of Groundwater & Drinking Water for infrastructure projects, including water.
The Housing Assistance Council (HAC)	Small Water/Wastewater Fund (loans)	**Up to $0.25 per project:** Loans for land acquisition, site development, and construction.
Cooperative Bank (CoBank)	Water and Wastewater Loan (loans)	**$1 per project:** Water and wastewater infrastructure, system improvements, water right purchases, and system acquisitions. **$0.05–$0.5 per project:** Construction costs.

Source: Canada et al. 2012.

The Dutch Experience

In response to increasingly intensive animal production and a growing awareness of its effects on nitrate concentrations in surface water and groundwater, the European Council Nitrate Directive (ND) (Council Directive 91/67/EEC) was established in 1991 as part of the European Union (EU) Water Framework. The ND imposes a performance standard of 50 mg/L nitrate on effluent, groundwater, and surface water quality levels within all EU countries. Furthermore, each country is required to establish nitrate contamination reduction plans, monitor program effectiveness, and regularly report their findings to the European Council (EC) (EU Publications Office). Compliance with the ND is costly in terms of time, expertise, and money; however, countries that do not meet ND standards face large fines from the EC. While the ND does very little in the way of explicitly specifying how countries should act in efforts to comply with these requirements, plans that do not propose to regulate manure application at ND standards (i.e., land application rates in the range of 170–210 kg N/ha) have been historically rejected.

As an agricultural hotspot, The Netherlands has struggled to meet the ND requisites. To fulfill the obligatory ND requirements (Ondersteijn 2002), the Dutch government first created the Mineral Accounting System (MINAS) in 1998 (Henkens and Van Keulen 2001). MINAS was a farm-gate policy created to ensure the balance of nitrogen and phosphorus inputs (fertilizer and feed) and outputs (products and manure) on individual farms via balance sheets (Oenema et al. 2005). MINAS resembled a farm-gate performance standard that was enforced by a penalty tax for excess nitrogen and phosphorus inputs: farms consuming more nitrogen or phosphorus than could be accounted for via harvest outputs would be fined per kilogram of nitrogen or phosphorus lost to the environment. As of 2003, fines of € 2.27/kg N ($1.40/lb N) were enforced, more than seven times the cost of nitrogen fertilizer at the time. MINAS was popular for its simplicity, and was well supported by government aid. RIVM (Netherland's National Institute for Public Health and the Environment), which monitors nitrogen and phosphorus soil and water concentrations nationally, reports that nitrogen surpluses in agricultural areas fell substantially beginning in 1998 as a result of its implementation. Nevertheless, the EU declared the Dutch MINAS policy noncompliant with ND requirements, stating that the policy did not directly regulate water nitrate concentrations (Henkens and Van Keulen 2001).

In response to the EU's rejection of MINAS, the Netherlands implemented an additional policy in 2002: the Mineral Transfer Agreement System (MTAS). MTAS was a cap-and-trade system that prescribed manure (not inorganic fertilizer) application rates (as per ND objectives) and allowed farmers to purchase surplus application rights from those farmers applying manure to their land below legal limits. Rather than repealing MINAS, however, the Dutch increased enforceable fines under MINAS to serve as a safety net under the newly implemented MTAS (Ondersteijn 2002). Following the enactment of MTAS, water nitrate levels continued to fall at pre-MTAS rates (Henkens and Van Keulen 2001; Ondersteijn 2002; Berentsen and Tiessink 2003; Helming and Reinhard 2009), suggesting that the implementation of MTAS in addition to MINAS had little or no additional effect.

Given the apparent futility of MTAS, and following the repeated rejection of MINAS by the European court of justice in 2003, both MTAS and MINAS were abandoned by the Dutch government by 2006. The two competing regulations were replaced by a composite policy that enforces nitrogen as well as phosphorus application standards for both manure and inorganic fertilizer, thereby satisfying both ND standards and the unique challenges encountered in Dutch territory, while minimizing administrative and economic costs. The composite policy remains in effect to date.

4 Impact: Drinking Water Contamination

About 2.6 million people in the Tulare Lake Basin and Salinas Valley rely on groundwater for drinking water. This section estimates the population susceptible to nitrate contamination of groundwater, identifies safe drinking water actions available and the most promising options to address nitrate groundwater contamination, and estimates the total cost of nitrate contamination to communities and households in these areas. This discussion summarizes more detailed examinations by Jensen et al. (2012) and Honeycutt et al. (2012).

4.1 Susceptible Populations

Groundwater nitrate contamination brings two forms of susceptibility: public health risks and the economic costs of avoiding such risks through treatment, source reduction, remediation, or alternative water supplies. California's Tulare Lake Basin and Salinas Valley are particularly susceptible to public health and financial risks from nitrate contamination for the following reasons (Honeycutt et al. 2012).

- Communities in this region are unusually dependent on groundwater. Less than 3% of the area's population is served by surface water alone.
- These areas have more and larger nitrate contamination sources than most other parts of California (Viers et al. 2012).
- Of the region's 402 community public and state-documented state small water systems, 275 are very small (15–500 connections) and 58 are small (501–3,300 connections) (Figure 14). Small and very small systems are about 81% of Tulare Lake Basin water systems (serving 89,125 people, 4% of the population) and about 89% of the Salinas Valley water systems (serving 23,215 people, 6% of the population).
- Many of these small systems rely on a single well, without emergency alternatives when contamination is detected. These small water systems are inherently less reliable and face higher per capita expenses to address nitrate contamination of groundwater.
- Roughly 10.5% and 2.6% of the populations of Tulare Lake Basin and Salinas Valley, respectively, use unregulated, unmonitored domestic wells, serving 245,000 people from 74,000 wells (Figure 15).
- The area has many poor communities that cannot afford drinking water treatment or capital-intensive alternative water supplies. Over 17% of the Tulare Lake Basin and 10% of the Monterey County population lives in poverty.

We estimated the population of these basins that is susceptible to significant financial cost and public health concerns from nitrate contamination in groundwater (Honeycutt et al. 2012). The drinking water source (groundwater well or surface water), history of nitrate contamination, size, and potential for contamination were considered for each water system and self-supplied rural household well location in this region. "Vulnerability" describes the intrinsic potential for a system to 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. Vulnerability is scored as follows:

- Lower vulnerability is assigned to community public water systems (water systems with >15 connections) having more than one water source (i.e., more than one well), regardless of whether they treat their water to remove nitrate.
- Higher vulnerability is assigned to all other water systems: community public water systems with a single source (one well) and state small (5–14 connections), local small (2–4 connections), and household self-supplied water systems (domestic well).
- No vulnerability to nitrate groundwater contamination is assigned to water systems solely supplied by surface water.

Susceptible water users could be harmed by consuming drinking water containing contaminants or by the costs for avoiding such contamination. We define "susceptible population" as those

- served by a water system with multiple sources (wells) that has reported at least one delivered water nitrate MCL exceedance in the past 5 years, or
- served by a water system with a single source (well) that has reported at least one raw water nitrate MCL exceedance in the past 5 years, or

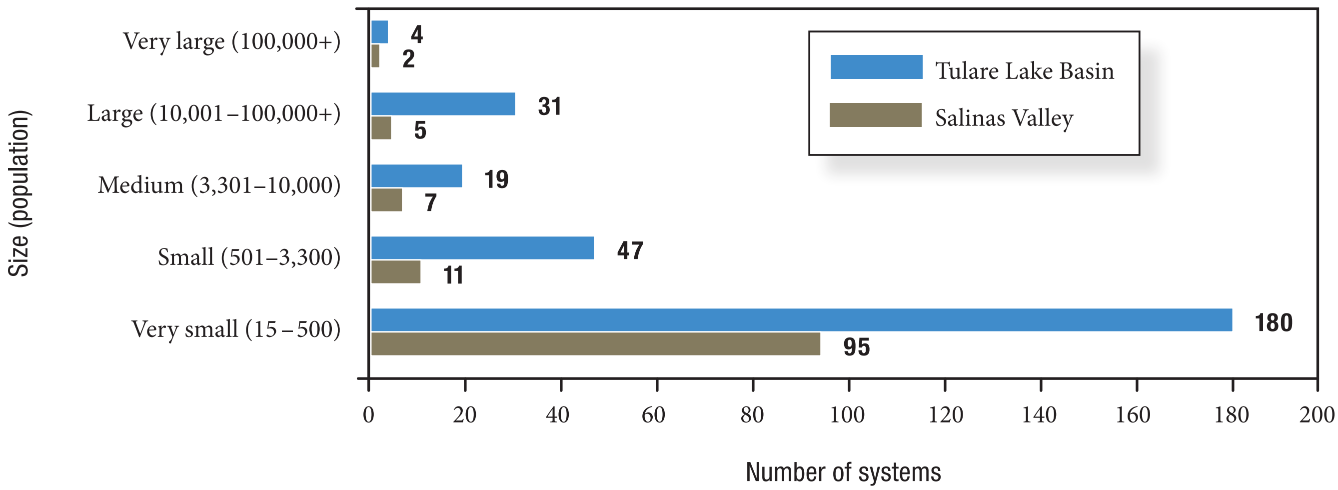


Figure 14. Community public and state-documented state small water systems of the Tulare Lake Basin and Salinas Valley. Source: CDPH 2010.

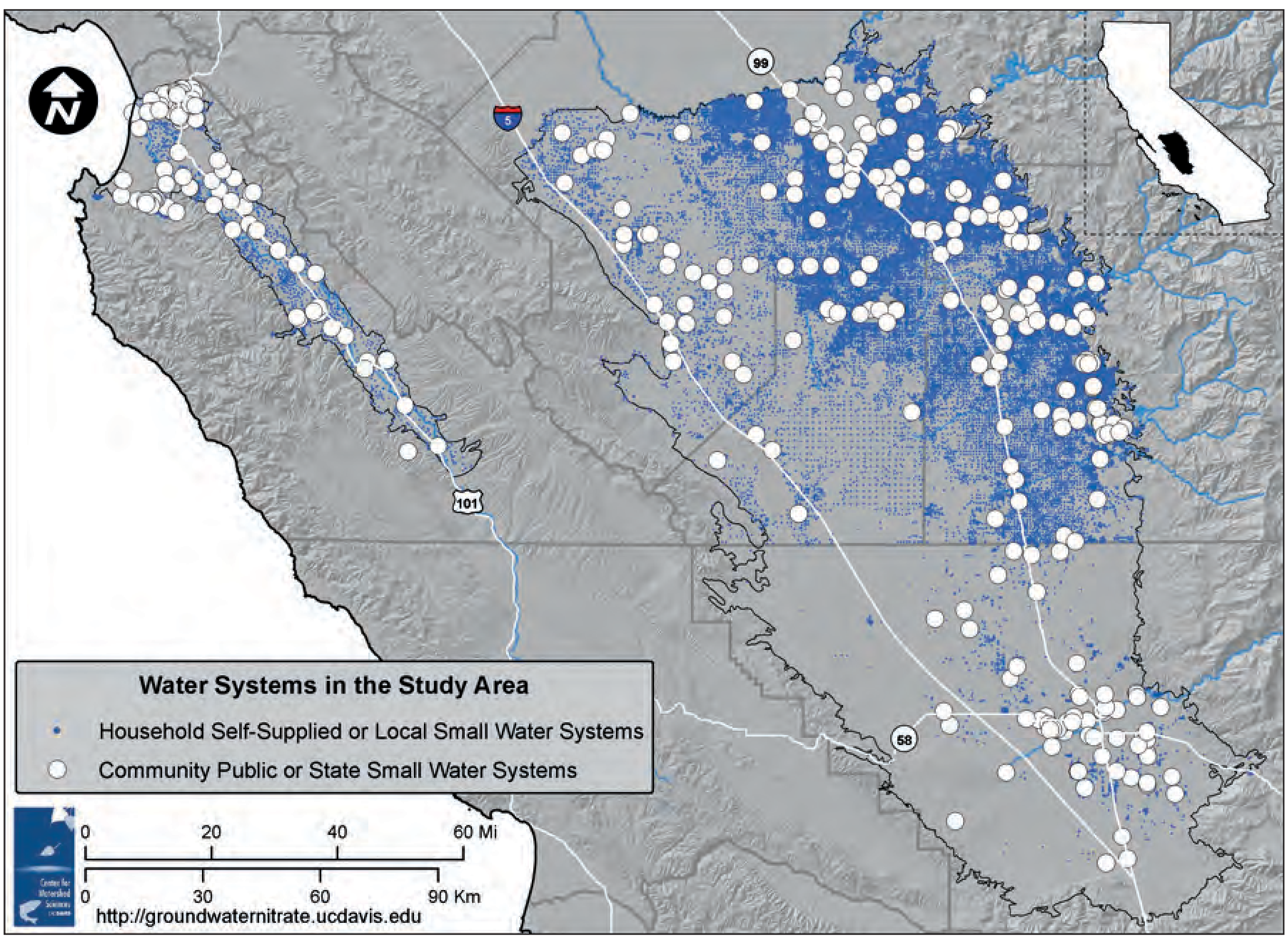


Figure 15. Estimated locations of the area's roughly 400 regulated community public and state-documented state small water systems and of 74,000 unregulated self-supplied water systems. Source: Honeycutt et al. 2012; CDPH PICME 2010.

- relying on domestic wells or local small water systems (fewer than 5 connections) in an area where shallow groundwater (<300 feet) has exceeded the nitrate MCL in the past (1989–2010), based on data from the UC Davis CASTING dataset (Boyle et al. 2012) or
- served by a water system lacking nitrate water quality data.

Figure 16 shows how these categorizations were used to classify populations and water systems. Of the 2.6 million people in the Tulare Lake Basin and Salinas Valley, 254,000 people have drinking water supplies susceptible to significant nitrate contamination. Of these, about 220,000 are connected to 85 community public or state small water systems with high or unknown susceptibility. For the majority of these systems, treatment will be expensive due to their small size (lack of economies of scale).

About 34,000 people are served by about 10,000 self-supplied household wells or local small water system wells at high risk for nitrate contamination given the known raw water quality exceedances in nearby wells (Figure 17). These systems are currently not regulated by the state or counties, and little public monitoring data exist for them.

Nine of 105 single-source small water systems in the study area exceeded the nitrate MCL at least once since 2006 and are not currently treating their water (CDPH 2010). Currently, 13 groundwater-supplied

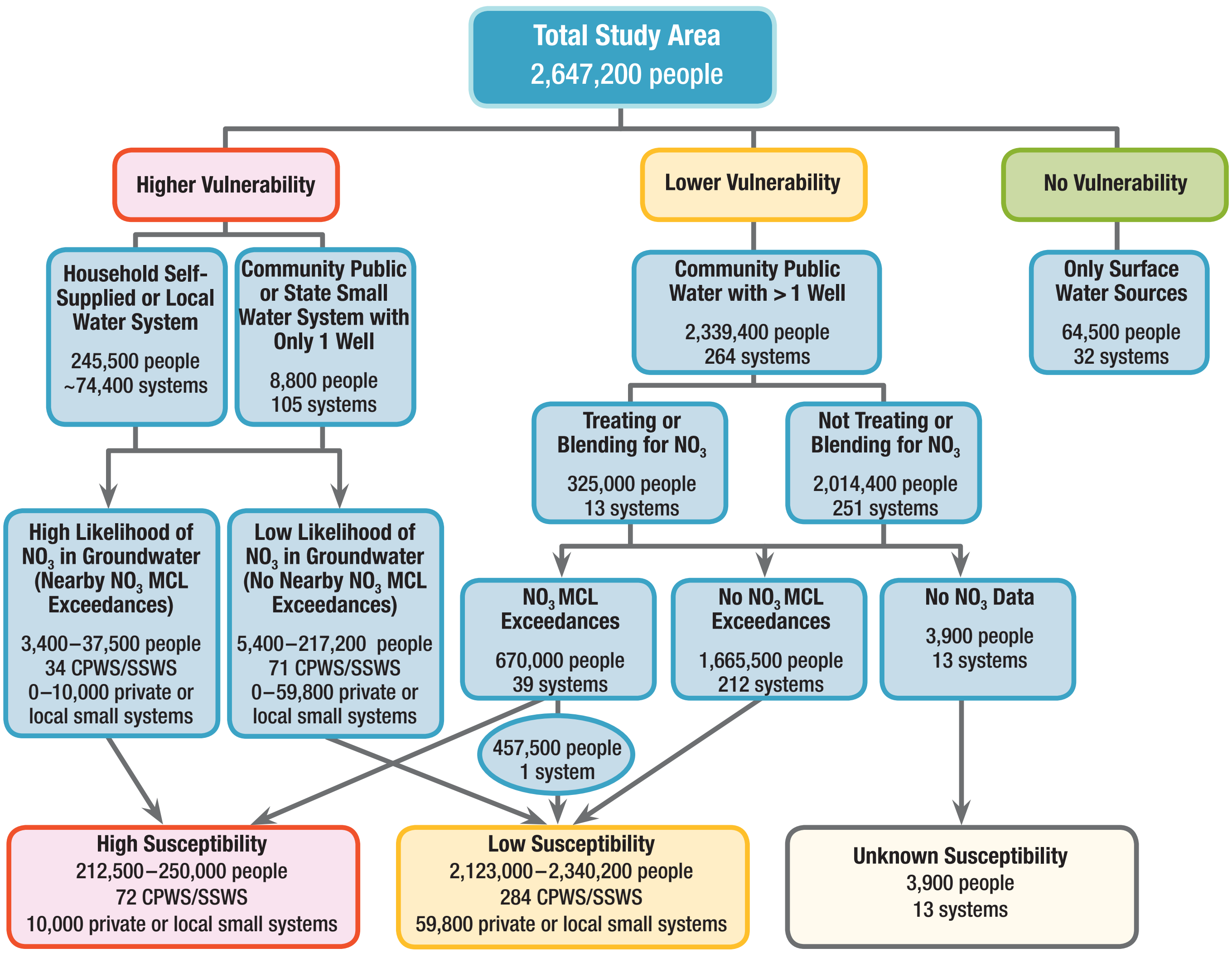


Figure 16. Classification of susceptible populations based on estimated vulnerability and water quality data for the study area. Due to different sources of data, the summation of the top row does not equal the total study area population. All population and connection information is approximate. CPWS: community public water system; SSWS: state small water system. Source: Honeycutt et al. 2012.

community public water systems and state small water systems treat for nitrate: 8 treat by blending and 5 by treatment processes (4 by ion exchange [IX] and 1 by reverse osmosis [RO]).

About 45% of the multiple-source systems that have delivered water exceeding the nitrate MCL serve severely disadvantaged and disadvantaged communities (SDACs and DACs) (Figure 18). DACs that are unincorporated, known as DUCs, often lack central water and sewer services. These DUCs are highly susceptible to nitrate contamination because they may lack a safe water source and are less financially able to resort to alternatives if their water source becomes contaminated. Since these areas have a large concentration of families with low incomes, community solutions to nitrate treatment or alternative water supply also might be difficult.

Over 2 million people in the study area are not classified as susceptible to a public health risk for nitrate contamination today. However, more than half of the study area population is considered to be at financial risk from nitrate contamination, having to potentially pay higher costs for treatment and monitoring because of regional groundwater contamination: A total of 1.3 million people (57%) in the area are served by community public water systems or state small water systems in which raw water sources have exceeded the nitrate MCL at least once between 2006 and 2010 (Figure 1 and Table 10). This includes over 457,000 people in the City of Fresno, which has nitrate exceedances in some wells but is taking measures to avoid this contamination, including significant expansion of surface water use.

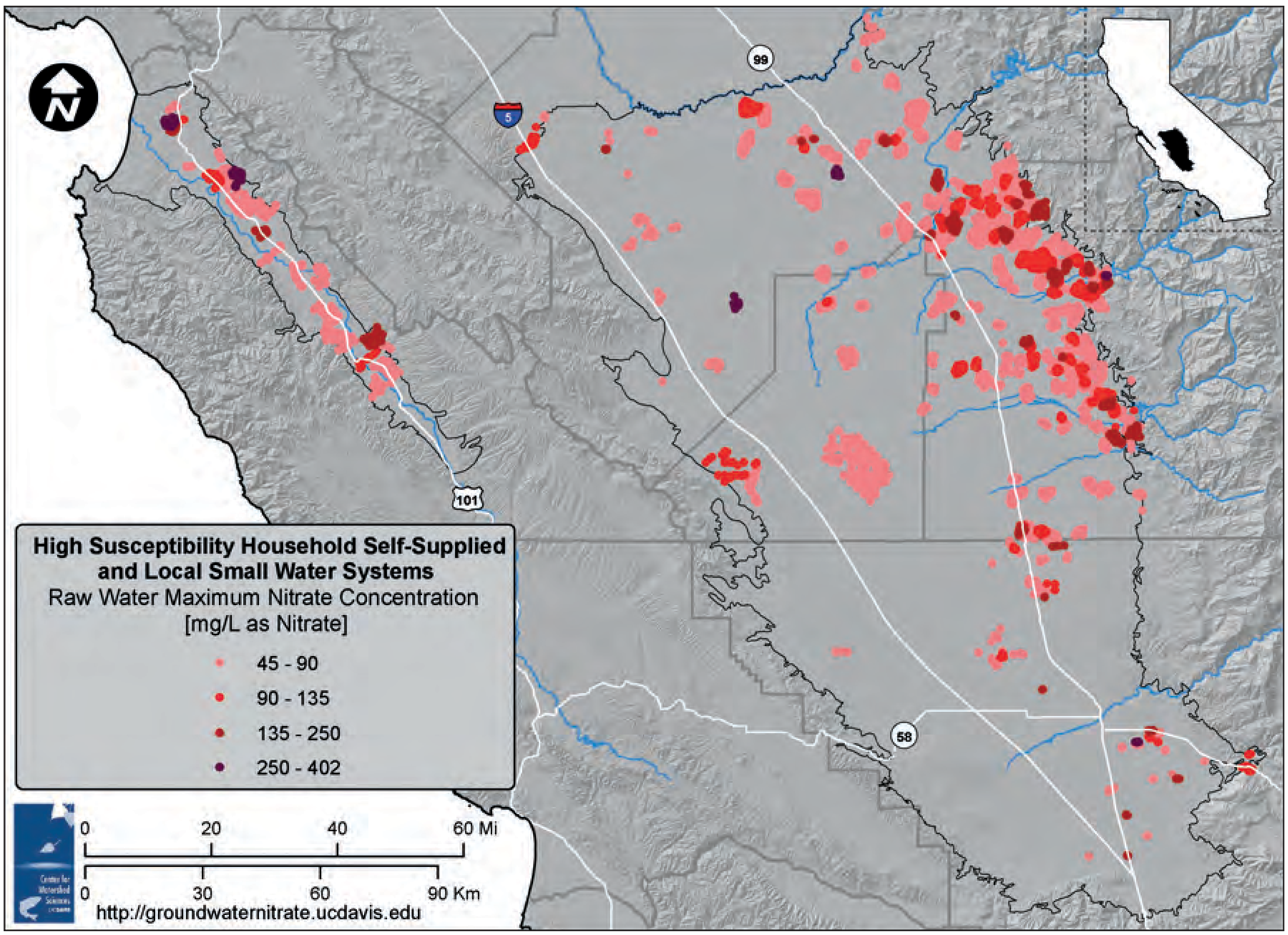


Figure 17. Household self-supplied and local small water systems located near wells having a maximum nitrate concentration value greater than the MCL. Source: 1989–2010 CASTING Database: GAMA, DWR, SWB, CDPH-CADWSAP, USGS, County Officials, Land Use Parcel Codes and DWR Land Use (see Honeycutt et al. 2012).

Severely disadvantaged communities (SDACs) are particularly vulnerable to financial costs. Of 51 community public water systems (serving about 714,000 people) in the study area with a raw source exceeding the nitrate MCL, most systems (40, serving about 379,000 people) are in a DAC. Thirteen of the 40 exceeding systems are in unincorporated areas (serving about 167,000 people), and 27 are in incorporated communities (serving about 212,000 people). They often cannot afford or organize and maintain capital-intensive solutions.

As past and current nitrogen applications migrate downward and through aquifers in the Tulare Lake Basin and Salinas Valley, populations susceptible to the costs and public health risks of nitrate contamination are likely to increase. Assuming unchanging and unabated basin-wide trends in CPWS raw nitrate groundwater levels since 1970, the financially susceptible population is estimated to increase from 57% currently to almost 80% or 1.9 million people by 2050 (not accounting for population growth, Table 10).

4.2 Alternative Water Supply and Treatment

Source reduction and aquifer remediation are insufficient to address drinking water nitrate contamination in the short- or near-term. In these cases, local water system authorities and users must select from a variety of treatment and alternative supply options. These options are summarized for community public water systems in Table 11 and for self-supplied

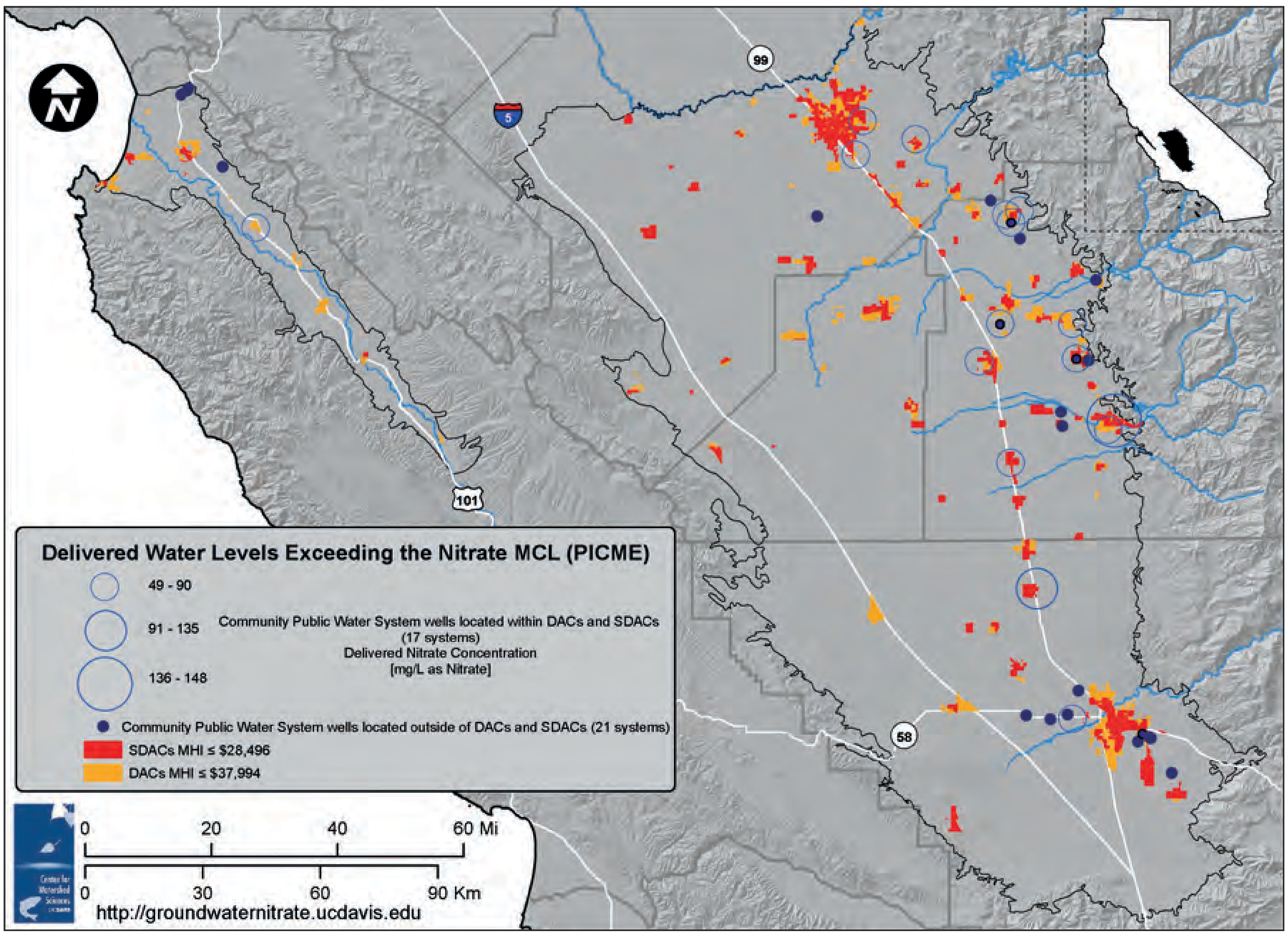


Figure 18. DACs, SDACs, and delivered water quality in multiple-source community public water systems. Source: CDPH PICME WQM 2006–2010; U.S. Census Bureau 2000, 2001 (see Honeycutt et al. 2012).

households and local small water systems in Table 12. This section further outlines these options (for details, see Honeycutt et al. 2012, and Jensen et al. 2012).

Community Public Water System Options

Each water system is unique, despite having many common problems and characteristics. No single solution will fit every community affected by nitrate in groundwater; each water system requires individual engineering and financial analysis.

The uniqueness of individual water systems is multiplied by the large number of small water systems in the Tulare Lake Basin and Salinas Valley. Small water systems have fewer and more expensive options per capita than do larger systems. They lack economies of scale and have fewer staff resources. Small water and wastewater systems also typically have disproportionately greater water quality and reliability problems and higher costs per capita (NRC 1997).

The options available for community public water systems faced with problems from nitrate contamination are summarized in Table 11. Blending is the most common approach to nitrate contamination for larger community public water systems with more than one water source. Water from the contaminated well is reduced, eliminated, or mixed with water from a safer water source. Eight community public water systems in the Tulare Lake Basin and Salinas Valley currently blend sources to comply with the nitrate MCL.[7]

Drilling a deeper or a new well is another common response to nitrate groundwater contamination. This approach can be cost-effective, but it is often only a temporary solution when nitrate contamination continues to spread locally and to deeper aquifers.

Treatment of community public water supplies is often explored and sometimes employed. A variety of treatment options are available (Jensen et al. 2012). Ion exchange and reverse osmosis are used for community public water system treatment in the basins. Additional treatment options, such as biological denitrification, may become economical and accepted in time (Jensen et al. 2012). However, treatment is expensive, especially for small systems. Under some circumstances, only a portion of extracted water is treated for nitrate because regulations can be met by blending treated water with water not treated for nitrate.

Management of waste concentrate or brine, by-products of ion exchange and reverse osmosis treatments, can also be costly. Options include discharge to a sewer or septic system, waste volume reduction using drying beds, trucking or piping for off-site disposal, deep well injection, and advanced treatment (Jensen et al. 2012).

Connecting to a larger system with reliable good-quality water can often solve many problems of small water systems, including nitrate contamination. This provides economies of scale in costs and greater access to expertise for resolving water system problems. However, connecting a small, often

Table 10. Estimated number of years until community public water supply (CPWS) sources exceed the nitrate MCL, and total affected population (not accounting for population growth)

Time for Maximum Recorded Raw Nitrate Level to Reach the MCL	Total Number of Affected CPWSs*	Total Affected Population*	Percent of Total CPWSs Population (study area)
0 years (2010)	77	1,363,700	57%
25 years (2035)	114	1,836,700	76%
40 years (2050)	127	1,903,300	79%

Source: Honeycutt et al. 2012.

* Based on raw water quality, not delivered quality susceptibility.

[7] Jensen et al. (2012) found a total of 23 water systems, including all types of water systems, in the study area that treat or blend to address the nitrate problem (10 blending systems, 10 IX systems, and 3 RO systems).

Table 11. Options for community public water systems

Option	Advantages	Disadvantages
Blending	• Simple nontreatment 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 gal/day.	• 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 land use. • 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 and 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 and 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 contaminated source. • Cost of contaminated supply plus cost for POU system or trucked/bottled water, or capital dual plumbing costs.

Source: Honeycutt et al. 2012.

substandard system to a larger system often involves substantial initial capital costs to make the connection and to upgrade the smaller distribution system. Establishing connections also can pose institutional challenges (such as water rights and governance) and financial risks to the larger system.

Connecting several smaller systems into a new larger water system has many of the same advantages and costs of connecting small systems to an existing larger system. Establishing a new system also requires additional start-up costs for infrastructure and institutional development.

Institutional consolidation of several small systems avoids the costs of hydraulically connecting small systems, and it can provide a higher level of staff expertise and administrative economies of scale. This is attractive when systems are too small to merit full-time, trained staff and too scattered to economically connect their distribution systems and sources.

Trucking uncontaminated water to supply small communities allows the servicing of small scattered water systems, usually at a high cost. Trucking in water is generally seen as a temporary or emergency solution while a more permanent high-quality drinking water source is being developed.

Relocating households to a different area with better-quality water is an extreme approach that might be suitable if a small community is unviable for a variety of reasons and can not attract additional customer investments. Relocating households is likely to be accompanied by a loss of property values and local jobs, as well as social dislocation.

Two ancillary options that can supplement some of the above options are well water quality testing and the development of dual plumbing systems. Well water testing programs provide better and more timely information for awareness of nitrate contamination and can also provide useful information for blending. Dual plumbing systems separate potable from nonpotable water distribution systems, allowing a smaller quantity of contaminated water to be treated or conveyed from a higher-quality source for potable water uses.

The least expensive option is usually to stop using a nitrate-contaminated well and switch to another existing well, if a safer well is available. Similarly, many systems with more than one well blend water from a low-nitrate source or well with more contaminated supplies.

Self-Supplied Households and Local Small Water System Options

There are approximately 74,000 self-supplied households and local small water systems in the Tulare Lake Basin and Salinas Valley. Their nitrate contamination response options are summarized in Table 12 and discussed below.

Water supply options for self-supplied households and local small water systems are are similar to the options available to community public water systems, but are are similar to the options available to community public water systems, but are applied at a much smaller scale.

Drilling a deeper or new well can provide a reliable supply where better water quality exists. This option is costly, deeper wells can be accompanied by additional forms of contamination (such as arsenic), and new wells might provide only temporary relief if the nitrate plume is spreading deeper into the aquifer.

Treatment of household water supplies for nitrate is typically by reverse osmosis (RO). RO has advantages including the ability to remove multiple contaminants (where nitrate is not the only concern). However, household treatment does require some costs as well as additional burdens for maintenance, inspection, and operation of equipment. Treatment can be either point-of-entry (treating all household water use) or point-of-use (treating only potable water at household taps, usually the kitchen). As with centralized nitrate treatment, RO units create a concentrate or brine waste that requires disposal. Dilute waste streams, characteristic of RO, can sometimes be used for irrigation.

Connection to a larger system with more reliable water quality is a promising solution where a larger system is nearby. Such a connection often has a high cost, but it may provide a net economic benefit from lower long-term costs and delegation of many water quality concerns to qualified entities.

Trucking in water to the household or local small water system can be convenient and requires little start-up cost, but it is often expensive and is commonly considered to be a temporary solution. Bottled water use is similar to trucking in water, but it often entails a greater cost.

Households or local small water systems can relocate to avoid water quality problems, but this typically would involve some loss of property value. If the household or business is prosperous, relocation is unlikely. Poorer households are likely to feel any resultant loss of jobs or social dislocation more acutely.

Well water testing can better inform self-supplied users of their risks from nitrate contamination. These tests are not expensive. Dual plumbing systems can help reduce the amount of water that is trucked in or treated, but it imposes additional costs and some risk of cross-connection of contaminated and safe water supplies.

Treatment to Remove Nitrate

Contaminated groundwater can be treated at a community treatment plant for all users, at the point-of entry-to residential or commercial buildings, or at the point of potable drinking water use (such as the kitchen sink). A variety of treatment options are available (Jensen et al. 2012). Ion exchange and reverse osmosis are used for community public water system treatment (Figures 19 and 20). RO is often used for point-of-use treatment in households and businesses. Additional treatment options, such as biological denitrification, may become economical and accepted (see Jensen et al. 2012). The effectiveness of treatment technologies across nitrate concentrations is summarized in Table 13.

Table 12. Options for self-supplied households and local small water systems

Option	Advantages	Disadvantages
Drilling a deeper or new well	• Potentially more reliable water supply. • Cheaper than bottled water for households using more than 8 gal/day.	• 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 required if source area is far from original source.
Household treatment (RO)	• Multiple contaminant removal. • Low-nitrate water supply.	• Unless instructed, risk of improper handling or maintenance of equipment.
Regionalization and 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 water 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 contaminated source. • Cost of contaminated supply plus cost for community treatment of potable supply and dual plumbing costs.

Source: Honeycutt et al. 2012.

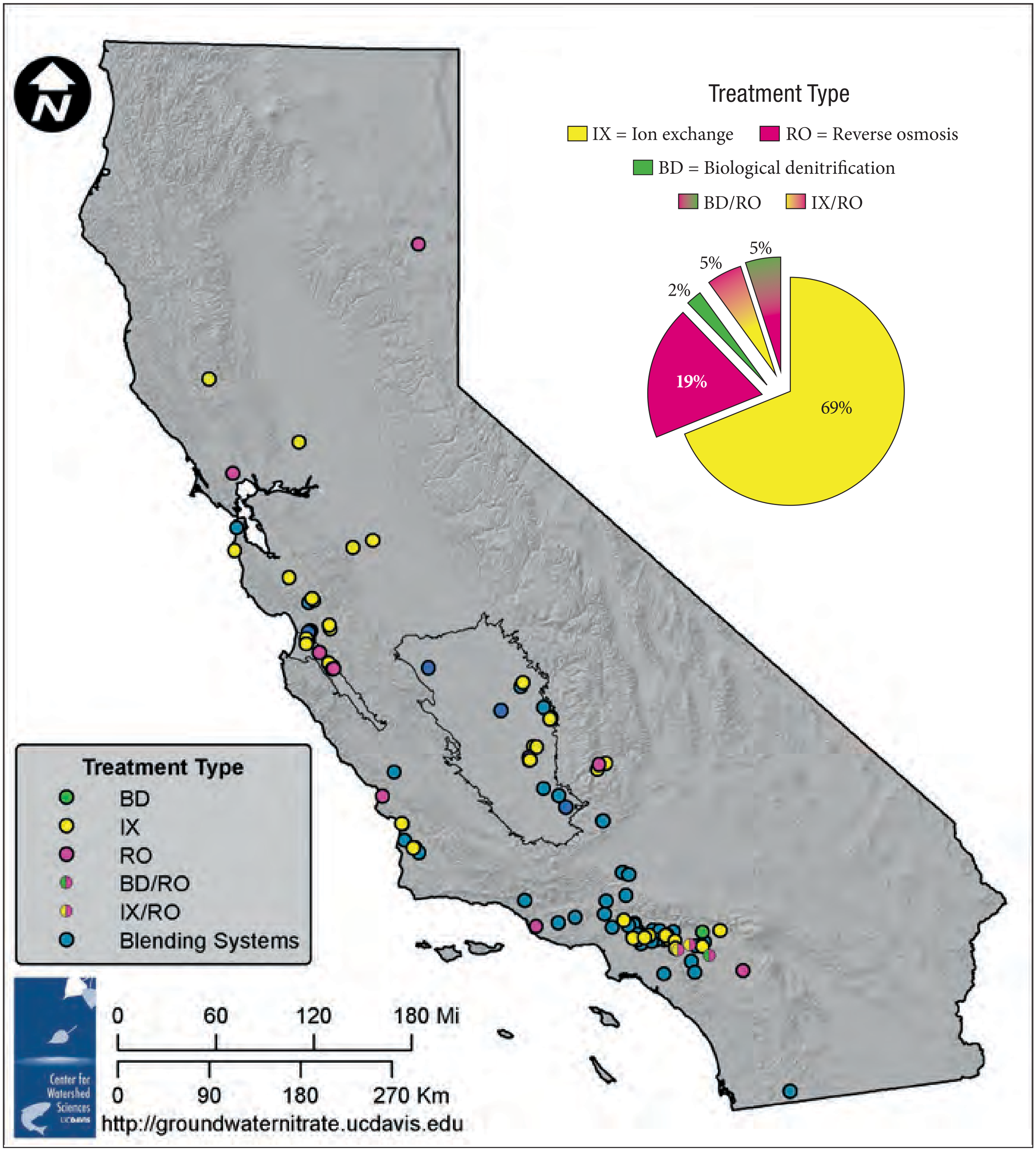


Figure 19. California drinking water systems treating or blending for nitrate, 2010. Source: Jensen et al. 2012.

However, treatment is expensive, especially for small systems. The development of treatment alternatives requires local engineering and development to accommodate local conditions. Nitrate contamination can be accompanied by other forms of groundwater contamination, including arsenic, magnesium, or pesticides, and treatment must accommodate the spectrum of water quality concerns as well as local water chemistry and distribution system conditions. Statewide, over 50% of nitrate treating systems utilize blending. Approximately 70% are using IX, and about 20% are using RO (Figure 19). In the Tulare Lake Basin and the Salinas Valley (Figure 20), 23 systems (of all types) were found to be treating and/or blending to address the nitrate problem (10 blending systems, 10 IX systems, and 3 RO systems).

Consolidation and Regionalization

Consolidation or regionalization of small systems is often suggested for addressing nitrate contamination and many other problems of small water systems. Although small systems are theoretically accountable and responsive to local customers, they often have diminished financial and technical resources that limit their ability to respond effectively or economically. Where a small system is near a larger system with superior water quality, connecting and consolidating these systems can provide a long-term remedy for the smaller system. Figure 21 shows the proximity of small systems (<10,000 people) in the Tulare Lake Basin and Salinas Valley to larger systems. Many small systems are reasonably close to potential long-term solutions.

However, the larger system may be concerned with financial and administrative burdens that may arise from upgrading the smaller system. Commonly, a smaller system must pay for the costs of connecting to a larger system as well as any distribution system upgrades needed to make the two systems compatible. This system upgrade burden on the financially weaker partner can require external financial assistance.

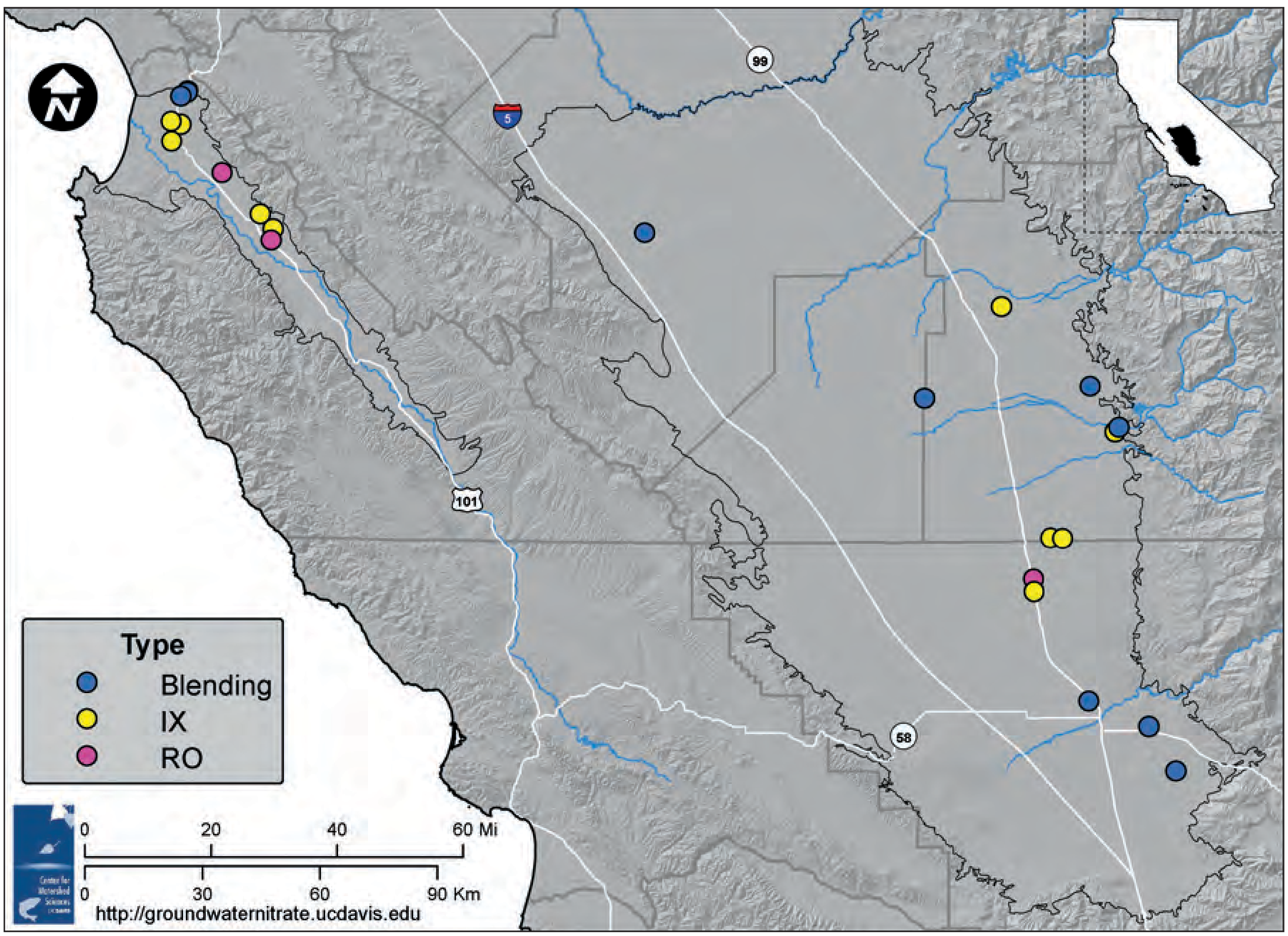


Figure 20. Utilities treating or blending for nitrate in the Salinas Valley and Tulare Lake Basin, 2010. Source: Jensen et al. 2012.

Many small systems are far from a larger system. For these cases, physical connection with a larger system is less financially attractive. However, even where systems remain hydraulically separated, consolidated operations, maintenance, and administration can sometimes have sufficient advantages to overcome financial barriers.

4.3 Comparison and Discussion

Economically promising and appropriate treatment and alternative water supply options have been identified (Honeycutt et al. 2012). These promising options give indications for state policy, and their costs are used to help estimate the overall cost of nitrate groundwater contamination in the Tulare Lake Basin and Salinas Valley.

Options for Small Community Public Water Systems

Estimated costs of options for community public water systems are compared in Table 14. Promising options for communities at risk of nitrate groundwater contamination are:

- **Consolidation to a larger system that can provide safe drinking water to more customers.** Although this option is viable for only a moderate number of systems, consolidation or regionalization of water systems can benefit a larger proportion of the vulnerable population and can help resolve many other long-term problems of small systems.
- **Consolidation of nearby small systems into a larger system** with a larger rate payer base and economies of scale. Even where small systems cannot economically connect to a large system, some opportunities exist to connect some small systems or to jointly manage several small systems to improve their overall financial condition.
- **Ion exchange treatment,** which is usually the most economical community treatment for groundwater contaminated by nitrate.
- **Interim point-of-use treatment or use of bottled water** until a more long-term and sustainable solution can be evaluated and implemented.
- **Blending of contaminated wells,** albeit temporarily if local nitrate contamination is expanding.

Table 13. Influence of nitrate concentration on treatment selection

Practical Nitrate Range	Option	Considerations
10–30% above MCL	blend	Depends on capacity and nitrate level of blending sources.
Up to 2× MCL	ion exchange	Depends on regeneration efficiency and costs of disposal and salt usage. Brine treatment, reuse, and recycling can improve feasibility at higher nitrate levels.
Up to many × MCL	reverse osmosis	Depends 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.
Up to many × MCL	biological denitrification	Depends 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.

Source: Contact with vendors and environmental engineering consultants; Jensen et al. 2012.

A preliminary analysis was conducted to identify the short-term lowest-cost option for susceptible water systems in the project area to respond to nitrate contamination (Honeycutt et al. 2012). Results from this preliminary analysis, with and without point-of-use treatment for state small water systems, are summarized in Table 15 and Figure 22 (excluding POU). Due to public health and reliability concerns, point-of-use treatment is currently only allowed by CDPH as an interim action for very small water systems (serving <200 connections) facing nitrate pollution. In either case, drilling a new well appears to be the most economical solution for larger systems serving most of the susceptible population. In the long term, expanding nitrate contamination might reduce the viability of this option. If permanently allowed, point-of-use treatment for individual households would be economically preferred for most very small systems. Regionalization by connecting to a nearby larger system is attractive for a substantial minority of systems and about 10% of the susceptible population. The expense of groundwater treatment makes it relatively rare, but it remains important when other options are unavailable. Connection to surface water facilities was generally not found to be economical due to the high cost of surface water treatment facilities.

If expanding nitrate contamination precludes sustainable use of new wells, costs increase greatly for community public water systems to respond to nitrate contamination (Table 16). In this most constrained case, connecting to nearby larger systems (regionalization) is more common,

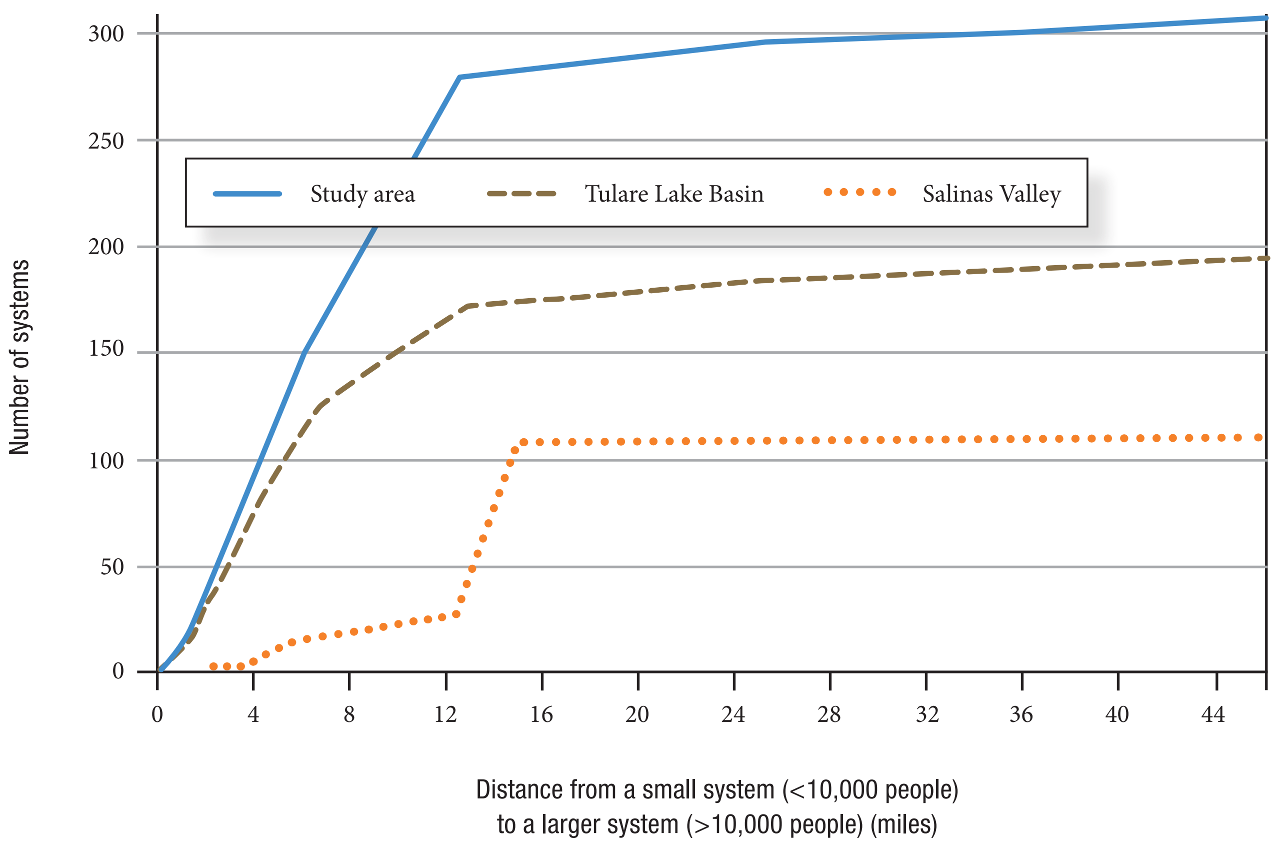


Figure 21. Cumulative distribution of the minimum distance from a small system (<10,000 people) to a larger system (>10,000 people) for the study area. Source: Honeycutt et al. 2012.

groundwater community treatment is common for small systems, and several of the largest systems (serving most of the susceptible population) switch to surface water treatment. The total estimated cost of alternative water supplies for susceptible community water systems more than doubles under this sustainable long-term scenario.

Options for Self-Supplied Households and Local Small Water Systems

Self-supplied and local small water systems have a smaller range of options (see Table 14). Point-of-use treatment is often the least-expensive option. Drilling a new well is sometimes more economical, where water use is greater and future nitrate contamination is less problematic.

Table 14. Safe drinking water option costs for self-supplied household and small community public water systems

Option	Estimated Annual Cost Range ($/year)	
	Self-Supplied Household	Small Water System (1,000 households)
Improve Existing Water Source		
Blending	N/A	$85,000–$150,000
Drill deeper well	$860–$3,300	$80,000–$100,000
Drill a new well	$2,100–$3,100	$40,000–$290,000
Community supply treatment	N/A	$135,000–$1,090,000
Household supply treatment	$250–$360	$223,000
Alternative Supplies		
Piped connection to an existing system	$52,400–$185,500	$59,700–$192,800
Trucked water	$950	$350,000
Bottled water	$1,339	$1.34 M
Relocate Households	$15,090	$15.1 M
Ancillary Activities		
Well water quality testing	$15–$50	N/A
Dual distribution system	$575–$1,580	$260,000–$900,000

Source: Honeycutt et al. 2012.

Table 15. Estimated cost of the lowest-cost short-term alternative water supply option for susceptible community public water systems and state small water systems based on system size and proximity to a larger system

Option	Number of Susceptible Water Systems		Population		Total Cost ($/year)	
	Including POU	Excluding POU	Including POU	Excluding POU	Including POU	Excluding POU
Drill new well	10	63	184,100	191,700	$10,144,000	$14,500,000
POU device for potable use	70	——	10,500	——	$1,320,000	——
Pipeline to a nearby large system (10,000+ system)	5	13	25,300	27,300	$865,000	$1,463,000
Groundwater treatment facility	0	9	0	900	$0	$450,000
Surface water treatment	0	0	0	0	$0	$0
Total	**85**	**85**	**219,900**	**219,900**	**$12,329,000**	**$16,413,000**

Source: Honeycutt et al. 2012.

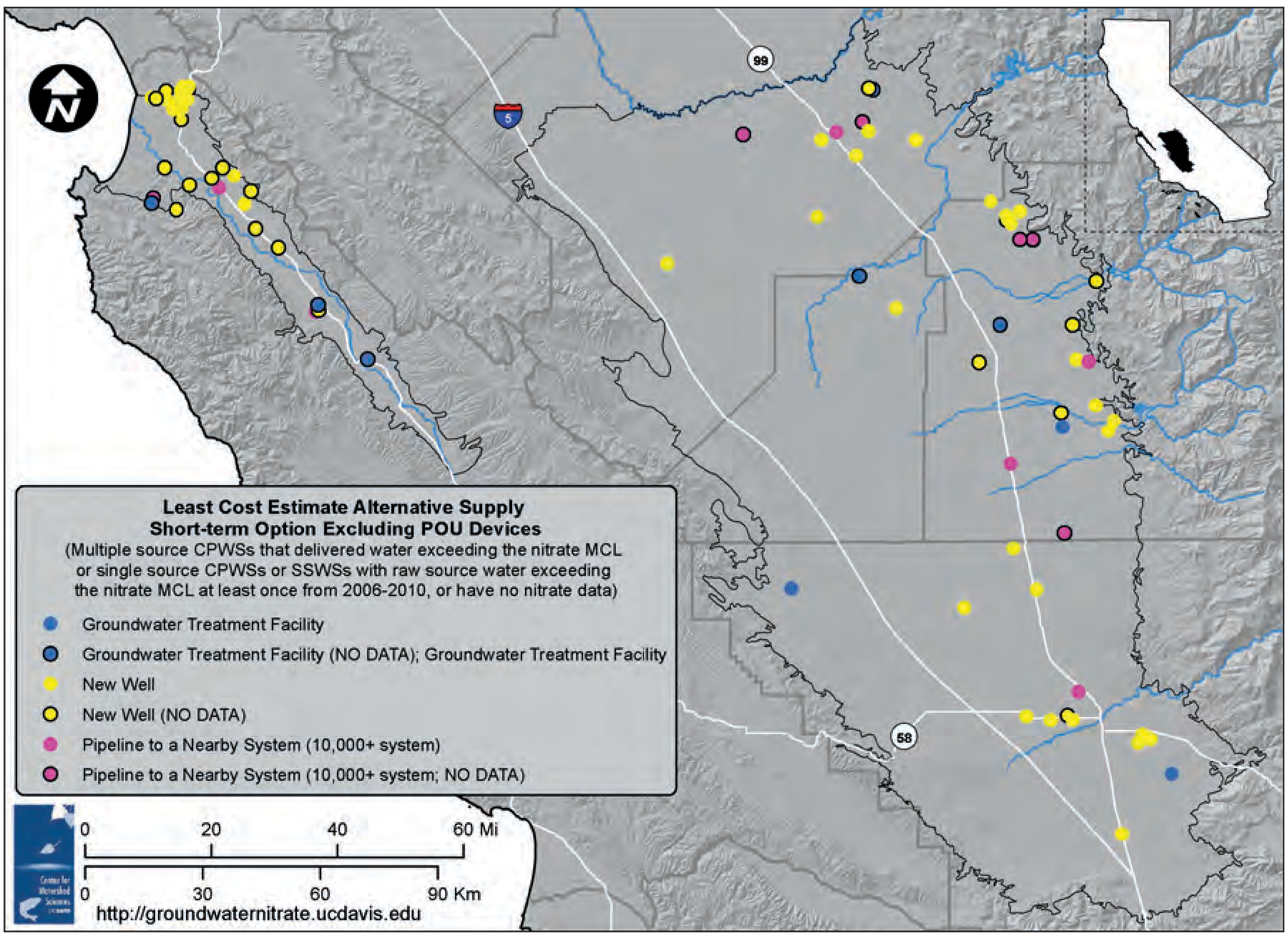


Figure 22. Lowest-cost alternative supply option (excluding POU systems) based on a high estimate of option costs for susceptible community public water systems and state small water systems (multiple source CPWS or SSWSs exceeding the nitrate MCL; or single-source CPWS or SSWSs exceeding the nitrate MCL at least once from 2006–2010; or those having no data). Source: Honeycutt et al. 2012.

4.4 Cost of Providing Safe Drinking Water

Roughly $12 to $17 million per year in additional costs in the near term will be needed to provide safe drinking water for people on community systems in the Tulare Lake Basin and Salinas Valley affected by nitrate contamination of groundwater (see Table 15). These costs are for 85 susceptible systems currently serving roughly 220,000 people. To provide safe drinking water for long-term solutions for these 85 systems will cost roughly $34 million per year if new wells are no longer sufficient. As additional systems become affected by nitrate contamination, these costs could increase.

The annualized additional 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 that are highly susceptible to current or future nitrate contamination is at least $2.5 million per year for point-of-use treatment for drinking purposes only. These costs could be lower if a manufacturing discount for bulk purchase of POU/POE systems were available. The lowest-cost POU option is used for all domestic well and local small water systems in the study area, estimated for both the short and long term. This does not include the cost of monitoring, public awareness, or regulatory programs to identify and reach out to this currently unregulated and unmonitored population.

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

Table 16. Estimated cost of the lowest-cost long-term alternative water supply options for susceptible community public water systems 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	36,600	$5,592,000
Groundwater treatment facility	51	8,000	$6,344,000
Surface water treatment facility	5	175,300	$21,532,000
Total	**85**	**219,900**	**$33,468,000**

Source: Honeycutt et al. 2012.

5 Policy Options for Nitrate Source Reduction and Funding

This section summarizes a range of policy options for reducing nitrate sources of contamination to groundwater and funding for resolving the problems of nitrate contamination. These options are drawn from the more detailed and extensive examination in Canada et al. (2012). Promising actions on future nitrate source reduction and funding options are discussed in Section 6.

5.1 Nitrate Source Reduction Policy Options

A wide range of policy options are available to reduce nitrate contamination to groundwater over time. We use four criteria for evaluating broad classes of regulatory options: the costs incurred by dischargers to reduce nitrate loading to achieve a nitrate standard (abatement costs), the costs of monitoring and enforcement, the information requirements, and the potential for raising revenues (for funding drinking water actions and other purposes related to nitrate contamination). These results are summarized in Table 17 and further described by Canada et al. (2012).

Specific technology mandates on farmers and agriculture will result in high per-unit costs for reducing nitrate contamination. Farming practices vary tremendously, even within these basins, so specific technology standards would be unlikely to be broadly effective or economical. Less-specific performance standards would provide more flexibility but still do not account for the variation in costs across farms. Nitrate or nitrogen fees or cap-and-trade approaches give farmers more flexibility to respond to required reductions in nitrate loading, thereby reducing the costs of nitrate abatement. If these actions are monitored and enforced based on nitrate leaching rates, much more costly and extensive on-site monitoring would be needed, whereas enforcement and accounting of fertilizer application requirements would be much less burdensome. Reducing nitrate leachate by imposing fees on nitrate or nitrogen has an added advantage of raising funds that may be used to compensate affected drinking water users. A cap-and-trade approach can also raise funds if nitrogen use permits are auctioned.

Hybrid options are also available to regulate nitrate. For nearly 15 years, the Netherlands has used a hybrid approach to manage nitrate (Kruitwagen et al. 2009; Ondersteijn et al. 2002). Under this system, agricultural sources are regulated using a performance standard combined with a fertilizer fee. (see "The Dutch Experience," p. 46). Hybrid regulations might be practical for managing nitrate leachate.

Information disclosure would have dischargers of nitrate or users of nitrogen make such information public. Water systems could also face more stringent water quality consumer reporting rules. Such disclosures should provide some motivation to reduce nitrate discharges.

Table 17. Summary of regulatory options to reduce nitrate contamination to groundwater

<table>
<tr><th>Regulatory Option</th><th>Abatement Costs</th><th>Monitoring and Enforcement Costs</th><th>Information Requirements</th><th>Revenue Raising</th></tr>
<tr><td>Technology mandate</td><td>high</td><td rowspan="4" colspan="2">Fertilizer application: low
Nitrate leachate: high</td><td>no (unless fines)</td></tr>
<tr><td>Performance standard</td><td>medium</td><td>no (unless fines)</td></tr>
<tr><td>Fee</td><td>low</td><td>yes</td></tr>
<tr><td>Cap and trade</td><td>low</td><td>yes (if permits auctioned)</td></tr>
<tr><td>Information disclosure</td><td>medium</td><td>low</td><td>low</td><td>no (unless fines)</td></tr>
<tr><td>Liability rules</td><td>—</td><td>high</td><td>high</td><td>yes</td></tr>
<tr><td>Payment for water quality</td><td>low</td><td>low (if payment made to farmers)
high (if payment made to state)</td><td>high</td><td>yes (if payment made to state)</td></tr>
<tr><td>De-designation of beneficial use</td><td>low</td><td>high</td><td>medium</td><td>no</td></tr>
</table>

Source: Canada et al. 2012.

Liability rules would make nitrate dischargers liable to users of drinking water and other groundwater users for the costs imposed by their discharges. If liability is established in courts, the costs could be quite high and may not necessarily result in much discharge reduction. Porter-Cologne Act Water Code Section 13304 might provide a useful framework.

Having water users or the state pay nitrate dischargers to reduce their dischargers ("payment for water quality") also has high transaction costs, without immediate effect to drinking water quality. But nitrate dischargers might find this an attractive long-term or preventive solution.

De-designating groundwater for drinking water use would shift all drinking water burdens to local water users. This would be administratively and politically awkward, acknowledging a permanent degradation to groundwater quality without compensating drinking water users.

Major Findings: Future Source Reduction Options

1. **Many options exist to regulate nitrate in groundwater, but there is no ideal solution.** The costs of regulatory options vary greatly, and while no option is perfect, some seem preferable to others.

2. **Regulating fertilizer application has lower monitoring and enforcement costs and information requirements than does regulating nitrate leachate, but it may be less effective in achieving nitrate reduction targets**. While the regulation of fertilizer application is easier to implement and enforce than the regulation of nitrate leachate, fertilizer regulation does not guarantee that water quality standards will be met. Due to nonuniform mixing, transport, and dispersion of nitrate in groundwater, it is difficult to quantify the impact of a unit of fertilizer on nitrate contamination of drinking water over time.

3. **Costs to farmers for reducing nitrate contamination can be lower with market-based regulations (fertilizer fees or cap-and-trade programs) than with technology mandates or prescriptive standards because of the additional flexibility farmers have in complying with market-based regulations.** Market-based instruments also encourage the development and adoption of new technologies to reduce fertilizer use, but they may lead to the formation of contamination hot spots.

4. **Well-defined and enforceable regulatory requirements are needed for liability rules to work.** In California, all groundwater is considered to be suitable, or potentially suitable, for municipal or domestic water supply and should be so designated by the Porter-Cologne Section 13304 which gives the California Water Boards authority to force polluters to pay for alternative water supplies for affected users of public water systems and private wells. Legislation might be useful to solidify Regional Board authority to apply this provision broadly.

5.2 Funding Options

Existing funding to address the costs of drinking water actions for communities and systems affected by nitrate contamination appears to be inadequate for many systems and largely requires drinking water users to bear the costs of groundwater contamination by others. The cost of nitrate contamination is felt disproportionately for small water systems (Honeycutt et al. 2012; Canada et al. 2012). Funding is also sparse for monitoring and for broad understanding of groundwater nitrate.

Many state, federal, and local programs exist to help fund local communities responding to nitrate contamination of their groundwater supplies, as discussed in Section 3 and Canada et al. (2012) and summarized in Table 9. Although current programs provide useful resources, they have been insufficient in addressing problems of nitrate groundwater contamination, particularly for smaller and poorer communities, who have less technical, managerial, and financial capacity for safe drinking water infrastructure and who are often ill-equipped for formal funding program applications.

A wide range of options is available to improve funding for drinking water supplies in areas affected by groundwater nitrate contamination, in addition to funding for nitrate source reduction and groundwater remediation activities. These options include state funding options summarized in Table 18 as well as traditional local water utility and tax options for funding water systems. These funding alternatives are addressed in greater depth by Canada et al. (2012). That examination and analysis led to the following findings for state funding and the promising options that are stated in Section 6.1(F).

Major Findings: Future Funding Options

1. **Many options exist to raise funds for safe drinking water and nitrate source reduction actions, but but all require that someone bear the cost, and many are awkward or insufficient.** Water use fees, groundwater pumping fees, bottled water fees, crop fees, and fertilizer fees are a few of the many potential sources for funding safe drinking water and source reduction actions.

2. **Some funding options give polluters a useful price signal.** Fertilizer (or nitrate leachate) fees and auctioned permits induce emitters to reduce fertilizer or nitrate use. Farmers do not pay sales tax on fertilizer in California.

Table 18. Summary of future state funding options

Option	Incentive to Reduce Nitrate	Who Pays	Example
Crop tax	no	producers and consumers of food	State Sales Tax Rate for Soft Drinks: The State of Maryland charges a 6% sales tax for soft drinks.
Fixed fee on drinking water agricultural water	 no no	 drinking water users agricultural users	Federal Communications Commission Universal Service Fee: A fixed fee placed on monthly phone bill to assure universal access to telecommunications for low-income and high-cost rural populations.
Volumetric fee on **drinking water** **agricultural water**	 no low	 drinking water users agricultural users	Gas Public Purpose Program Surcharge: A volumetric fee on gas bills in California to fund assistance programs for low-income gas customers, energy efficiency programs, and public-interest research.
Groundwater pumping fee	medium	agricultural groundwater users	Pajaro Valley Groundwater Pumping Fee: A per-acre-foot charge to secure financing for debt stabilization and to address groundwater overdraft.
Fee on bottled water	no	consumers of bottled water	California Redemption Value: A refundable fee placed on recyclable bottles at the point of sale.
Agricultural property tax	no	agricultural property owners	CA State Property Tax: A statewide ad valorem tax equal to a percentage of the purchase price is collected from all properties in the state, with some exceptions.
Fertilizer tax	high	consumers of fertilizer	Mill Assessment Program: The state imposes a fee of 2.1 cents per dollar on pesticide sales at the point of first sale into the state.
Nitrate leachate tax	highest	nitrate emitters	Duty on Wastewater: In the Netherlands, a tax of approximately $3.60 is imposed on each kilogram of nitrate in wastewater.
Cap and trade with auctioned permits	high/ highest	consumers of fertilizer and nitrate emitters	Title IV of the Clean Air Act Amendments: Established a tradable permit approach to control sulfur dioxide emissions. A small portion of permits sold in an auction.

Source: Canada et al. 2012.

Payment for Ecosystem Services in New York City

Currently, New York City participates in a payment for ecosystem services program for watershed protection. Under the U.S. Safe Drinking Water Act (SDWA), the city was required to meet the state water quality standards by either constructing a water filtration plant at an estimated cost of $6 billion in capital and $300 million in annual operating costs (Postel and Thompson 2005) or implementing a much less expensive watershed protection program. New York successfully requested a waiver from the SDWA filtration requirement and negotiated an agreement with upstream landowners and communities within the Catskill-Delaware watershed to establish a watershed protection plan. In 1997, a memorandum of agreement (MOA) was signed by state and federal officials, environmental organizations, and 70 watershed towns and villages to invest $1.5 billion over ten years to restore and protect the watershed (Postel and Thompson 2005). Program financing comes from bonds issued by the city and increases in residential water bills.

The program's fundamental activities include land acquisition; a program to manage and reduce agricultural runoff; a program for better forestry management; a program for enhanced stream management to reduce erosion and habitat degradation; improvements for wastewater infrastructure in the watershed; construction of an ultraviolet disinfection plant; and new regulation and enforcement of mechanisms to ensure continued water quality protection within the watershed (Postel and Thompson 2004). As of 2004, New York City has put $1 billion into the watershed protection program (Ward 2004). The negotiated partnership creates a watershed that provides high-quality drinking water, provides landowners with additional income, and improves recreational usage for nearby communities.

In this instance, negotiation or payment for ecosystem services led to the provision of safe drinking water at a lower cost than the default water filtration plant. By linking the ecosystem service providers with the beneficiaries, New York City successfully executed a comprehensive watershed protection program that delivers safe drinking water at a relatively low cost. New York City's watershed protection program is an example of a payment for ecosystem services program that guarantees the supply of high-quality drinking water and is financed via residential water bills and city bonds.

6 Promising Solutions

Many options are available to address the problems of drinking water quality, aquifer degradation, and economic costs from nitrate contamination of groundwater and its regulation. Of the many options available, some are more promising than others. But even among these promising options, major policy choices must be made.

6.1 Areas of Promising Action

Addressing groundwater nitrate contamination requires actions in four areas: (a) safe drinking water actions for affected areas, (b) reducing sources of nitrate contamination to groundwater, (c) monitoring and assessment of groundwater and drinking water, and (d) revenues to help fund solutions. Promising actions for legislative and state agency consideration in these areas appear below. Starred (*) actions do not appear to require legislative action, but might benefit from it. All actions are compared in Table 19.

Safe Drinking Water Actions (D)

Safe drinking water actions are the most effective and economical short- and long-term approach to address nitrate contamination problems in the Tulare Lake Basin and Salinas Valley. These actions apply especially to small and self-supplied household water systems, which face the greatest financial and public health problems from nitrate groundwater contamination.

D1: Point-of-Use (POU) Treatment. CDPH reports on how to make economical household and point-of-use treatment for nitrate contamination an available and permanent solution for small water systems.*

D2: Small Water System Task Force. CalEPA and CDPH convene an independently led Task Force on Small Water Systems that would report on problems and solutions of small water and wastewater systems statewide as well as the efficacy of various state, county, and federal programs to aid small water and wastewater systems. Many nitrate contamination problems are symptomatic of the broad problems of small water and wastewater systems.*

D3: Regional Consolidation. CDPH and counties provide more legal, technical, and funding support for preparing consolidation of small water systems with nearby larger systems and creating new, regional safe drinking water solutions for groups of small water systems, where cost-effective.*

D4: Domestic Well Testing. In areas identified as being at risk for nitrate contamination by the California Water Boards, as a public health requirement, CDPH (a) mandates periodic nitrate testing for private domestic wells and local and state small systems and (b) requires disclosure of recent well tests for nitrate contamination on sales of residential property. County health departments also might impose such requirements.

D5: Stable Small System Funds. CDPH receives more stable funding to help support capital and operation and maintenance costs for new, cost-effective, and sustainable safe drinking water solutions, particularly for disadvantaged communities.

Source Reduction Actions (S)

Reducing nitrate loading to groundwater is possible, sometimes at a modest expense. But nitrate source reduction works slowly and cannot effectively restore all affected aquifers to drinking water quality. Within the framework of Porter-Cologne, unless groundwater were to be de-designated as a drinking water source, reduction of nitrate loading to groundwater is required to improve long-term water quality. The following options seem most promising to reduce nitrate loading.

S1: Education and Research. California Department of Food and Agriculture (CDFA), in cooperation with the University of California and other organizations, develops and delivers a comprehensive educational and technical program to help farmers improve efficiency in nitrogen use (including manure) and reduce nitrate loading to groundwater. This could include a groundwater nitrate–focused element for the existing CDFA Fertilizer Research and Education Program (FREP), including "pump-and-fertilize" remediation and improved recharge options for groundwater cleanup.*

Table 19. Likely performance of promising state and agency actions for nitrate groundwater contamination

Action	Safe Drinking Water	Groundwater Degradation	Economic Cost
No Legislation Required			
Safe Drinking Water Actions			
D1: Point-of-Use Treatment Option for Small Systems +	♦♦		low
D2: Small Water Systems Task Force +	♦		low
D3: Regionalization and Consolidation of Small Systems +	♦♦		low
Source Reduction Actions			
S1: Nitrogen/Nitrate Education and Research +		♦♦♦	low–moderate
S2: Nitrogen Accounting Task Force +		♦♦	low
Monitoring and Assessment			
M1: Regional Boards Define Areas at Risk +	♦♦♦	♦♦♦	low
M2: CDPH Monitors At-Risk Population +	♦	♦	low
M3: Implement Nitrogen Use Reporting +		♦♦	low
M4: Groundwater Data Task Force +	♦	♦	low
M5: Groundwater Task Force +	♦	♦	low
Funding			
F1: Nitrogen Fertilizer Mill Fee		♦♦♦	low
F2: Local Compensation Agreements for Water +	♦♦	♦	moderate
New Legislation Required			
D4: Domestic Well Testing *	♦♦		low
D5: Stable Small System Funds	♦		moderate
Non-tax legislation could also strengthen and augment existing authority.			
Fiscal Legislation Required			
Source Reduction			
S3: Fertilizer Excise Fee	♦♦	♦	low
S4: Higher Fertilizer Fee in Areas at Risk	♦	♦	moderate
Funding Options			
F3: Fertilizer Excise Fee	♦♦	♦♦	moderate
F4: Water Use Fee	♦♦	♦♦	moderate

♦ Helpful

♦♦ Effective

♦♦♦ Essential

+ Legislation would strengthen.

* County health departments may have authority; CDPH requires legislation.

S2: Nitrogen Mass Accounting Task Force. CalEPA establishes a Task Force, including CDFA, to explore nitrogen mass balance accounting methods for regulating agricultural land uses in areas at risk for nitrate contamination, and to compare three long-term nitrogen source control approaches: (a) a cap-and-trade system; (b) farm-level nutrient management plans, standards, and penalties; and (c) nitrogen fertilizer fees.*

S3: Fertilizer Excise Fee. Significantly raising the cost of commercial fertilizer through a fee or excise tax would fund safe drinking water actions and monitoring and give further incentive to farmers for reducing nitrate contamination. An equivalent fee or excise tax could be considered for organic fertilizer sources (manure, green waste, wastewater effluent, biosolids, etc.).

S4: Higher Fertilizer Fee in Areas at Risk. Areas declared to be at risk for nitrate contamination might be authorized to maintain a higher set of excise fees on nitrogen fertilizer applications (including synthetic fertilizer, manure, waste effluent, biosolids, and organic amendments), perhaps as part of a local safe drinking water compensation agreement.

Monitoring and Assessment (M)

Monitoring and assessment is needed to better assess the evolving nitrate pollution problem and the effectiveness of safe drinking water and nitrate source loading reduction actions. Such activities should be integrated with other state agricultural, environmental, and land use management, groundwater data, and assessment programs (source loading reduction actions), along with other drinking water, treatment, and wastewater management programs (safe drinking water actions).

M1: Define Areas at Risk. Regional Water Boards designate areas where groundwater sources of drinking water are at risk of being contaminated by nitrate.*

M2: Monitor at-Risk Population. CDPH and the State Water Board, in coordination with DWR and CDFA, issue a report every 5 years to identify populations at risk of contaminated drinking water and to monitor long-term trends of the state's success in providing safe drinking water as a supplement to the California Water Plan Update.*

M3: Learn from Department of Pesticide Regulation Programs. CalEPA and CDFA examine successful DPR data collection, analysis, education, and enforcement programs for lessons in managing nitrogen and other agricultural contaminants, and consider expanding or building upon the existing DPR program to include comprehensive nitrogen use reporting to support nitrate discharge management.*

M4: Groundwater Data Task Force. CalEPA, in coordination with CalNRA and CDPH, convenes an independently led State Groundwater Data Task Force to examine the efficacy of current state and local efforts to collect, maintain, report, and use groundwater data for California's groundwater quality and quantity problems.*

M5: Groundwater Task Force. CalEPA, CalNRA, and CDPH maintain a joint, permanent, and independently led State Groundwater Task Force to periodically assess and coordinate state technical and regulatory groundwater programs in terms of effectiveness at addressing California's groundwater quality and quantity problems. These reports would be incorporated into each California Water Plan Update.*

Funding (F)

Little effective action can occur without funding. Four funding options seem most promising, individually or in combination. State funding from fees on nitrogen or water use, which directly affect nitrate groundwater contamination, seem particularly promising and appropriate.

F1: Mill Fee. Increase the mill assessment rate on nitrogen fertilizer to the full authorized amount (CAL. FAC Code Section 14611). This would raise about $1 million/year statewide and is authorized for fertilizer use research and education.*

F2: Local Compensation Agreements. Regional Water Boards can require and arrange for local compensation of affected drinking water users under Porter-Cologne Section 13304. Strengthening existing authority, the Legislature could require that a Regional Water Board finding that an area is at risk of groundwater nitrate contamination for drinking water be accompanied by a cleanup and abatement order requiring overlying, current sources of nitrate to financially support safe drinking water actions acceptable to the local County Health Department. This might take the form of a local "liability district."*

F3: Fertilizer Excise Fee. Introduce a substantial fee on nitrogen fertilizer sales or use, statewide or regionally, to fund safe drinking water actions, nitrate source load reduction efforts, and nitrate monitoring and assessment programs.

F4: Water Use Fee. A more comprehensive statewide fee on water use could support many beneficial activities. Some of such revenues could fund management and safe drinking water actions in areas affected by nitrate contamination, including short-term emergency drinking water measures for disadvantaged communities.

6.2 Developing an Effective Solution Strategy

Table 19 summarizes the required implementation levels and likely performance of promising actions identified above. Much can be done under existing authority and by existing agencies, although additional legislation could strengthen, augment, and further support these capabilities. While these actions include many helpful and effective solutions, none alone are sufficient to address the problems of groundwater nitrate contamination and the resulting drinking water problems. The most effective results will arise through a synergistic combination of major policy direction, legislation, and appropriate blends of of these identified actions.

Options without Fiscal Legislation

Without fiscal (tax, fee) legislation, there are several options to address drinking water or groundwater degradation, though each has a separate suite of choices. The most essential is having the Water Boards formally declare areas at risk for nitrate contamination. Such a declaration (M1) might entail a series of complementary actions, such as requiring domestic well testing in at-risk areas (D3), monitoring of at-risk populations (M2), and formation of a local compensation agreement or liability district for at-risk areas under Water Code Section 13304 (F2). Perhaps greater education and outreach to farmers in at-risk areas would also occur, along with discharger fees to fund safe drinking water actions to reduce nitrate discharges.

Porter-Cologne Act, Water Code Section 13304, states that "a cleanup and abatement order issued by the State Water Board or a regional Water Board may require the provision of, or payment for, uninterrupted replacement water service, which may include wellhead treatment, to each affected public water supplier or private well owner." This provides authority for the California Water Boards to require landowners contributing to nitrate in groundwater drinking water supplies to fund drinking water actions for affected public water supplies and private wells.

Using this authority, when a Regional Water Board establishes that an area is at risk for nitrate contamination of groundwater, it could simultaneously issue a cleanup and abatement order initiating a process for overlying landowners and contributors of nitrate to groundwater in that area to respond with an area drinking water compensation plan.

This process might involve requiring overlying landowners to support drinking water actions that comply with public health requirements established by the local County Health Department, including:

- an initial date by which groups of overlying landowners would submit a proposed area drinking water compensation plan for actions, implementation, and funding to the County Health Department;
- an intermediate date by which the appropriate Regional Water Board and County Health Department would approve such a plan, or one of their own, for overlying landowners to support drinking water actions; and
- a date by which any overlying landowner not complying with the area drinking water compensation plan would be required to cease and desist applications of nitrogen to overlying land exceeding a standard established by the Regional Water Board to protect drinking water users from nitrate pollution. This condition would apply to all overlying landowners if no alternative local compensation agreement drinking water action plan had been approved.

CDPH could issue suitable guidance to County Health Departments on establishing public health requirements.

County Health Departments would need to be empowered to collect fees from landowners pursuant to a drinking water action plan under a cleanup and abatement order. These fees would include the cost to the County Health Department of overseeing the drinking water action plan. Fees could be collected as part of annual county property tax assessments. This approach would provide a relatively organized and efficient means for landowners contributing nitrate to a contaminated aquifer to help decrease the additional costs incurred by drinking water users from nitrate contamination.

To protect public health, requiring testing of domestic wells in areas declared to be at risk of nitrate contamination seems prudent and in the public interest. Legislation seems needed to require such testing (perhaps periodically or on property sale), although perhaps this can be done by county ordinance or administratively as a requirement to receive compensation under Water Code Section 13304.

Options Requiring Fiscal Legislation

Raising additional revenue to address nitrate issues seems to likely require legislation. The only exception is raising the small mill fee on fertilizer to its full authorized limit, which is approved for funding nitrogen use education and research activities.

Among these funding options, perhaps the most promising is to establish a statewide fee on the sale of nitrogen fertilizers, or a more administratively awkward fee on nitrogen use only in designated drinking water contamination risk areas. Such fees would act as both funding sources for safe drinking water actions and as an incentive to reduce nitrogen use, thereby somewhat reducing nitrate loading to groundwater. Partial rebates on these fees could be arranged for farmers who are involved in local area drinking water compensation plans or who have agreed to enforceable reductions in nitrate loads to groundwater.

6.3 Getting Organized

Many promising options are organizational. The management of nitrate groundwater contamination and its drinking water consequences is currently divided among several state agencies, each with historically derived authorities, purposes, and funding, as summarized in Section 3. In particular, the State and Regional Water Boards have the greatest authority under California's Porter-Cologne Act for groundwater quality. The California Department of Public Health and County Health Departments have authority over drinking water quality and public health. The California Department of Food and Agriculture has the greatest authority over fertilizer management and agricultural activities. The Department of Pesticide Regulation has no authority or direct interest in nitrate problems, but it has a successful, modern, integrated program for pesticide management, which may serve as a model for other forms of contamination, including nitrate. California's Department of Water Resources has overall water planning responsibility for the state, including oversight and funding authority for Integrated Regional Water Management Plans, and the State Water Board regulates water rights. The nitrate issues of the Tulare Lake Basin and Salinas Valley overlap several agencies. As environmental problems evolve beyond the origins of these agencies, there is often a need to evolve and coordinate the actions of different state and local agencies.

Nitrate contamination of groundwater is just one example of groundwater quality (and quantity) issues that many state agencies have in common. Each of the above agencies has its own groundwater monitoring, data, management, and often funding programs for groundwater overall or for individual groundwater quality or quantity concerns. Each of these agencies is facing, or will soon face, a range of similar and related groundwater problems regarding nitrate, pesticides, salts, and groundwater recharge and overdraft quantities.

Informational Actions

To help prepare the state to better address these problems, we propose several informational actions. Many informational actions could be triggered by requiring each of the California Water Boards to declare areas at risk of drinking water contamination from nitrate in groundwater (promising action M1). This finding is purely technical and seems well within the means of the Regional Water Boards, perhaps with some coordination from the State Water Board. A declaration of an area being at risk for nitrate groundwater contamination could also trigger several other informational actions. To protect public health, households and other very small water systems would be required to test drinking water wells for nitrate concentration upon sale and periodically thereafter (D4). Populations depending on groundwater in at-risk areas would also be reported to DWR for inclusion in state water planning efforts (M2). The "area at risk" designation could also serve to prioritize or trigger other funding, fee, education, monitoring, or regulatory actions.

Task Forces

We also propose four independently led task forces consisting of a core of agencies with overlapping interests. Having independent leadership would provide some assurance that each task force views the subject problem from more than just a collection of pre-existing agency perspectives.

- A task force on small water systems would seek to develop a common state policy for the problems of small water and wastewater systems in California. Small systems have inherent problems with higher costs, more precarious finance, and fewer technical and managerial resources, as they lack economies of scale. CDPH has long recognized these problems on the water supply side, but there are likely to be benefits from addressing these local water and wastewater utility problems together.

- A task force on nitrogen mass accounting would explore the technical, economic, and institutional issues of having farms account for nitrogen and nitrate fluxes as a basis for regulation or fees. Currently, such detailed accounting is done for pesticides, air emissions, and dairy nitrogen, and it is being contemplated for salts and irrigation water. Having widespread and relatively detailed accounting for nitrogen would allow for some forms of economic management, such as cap and trade, and could also potentially support various educational and regulatory means of reducing nitrate loads to groundwater. This leads to a larger strategic question of whether the range of environmental emissions from agriculture should be accounted for separately by different agencies, gathered together in a single agency, or coordinated among separate agencies. Having a fragmented accounting system seems likely to increase costs and the regulatory burden, while reducing overall insight and understanding of environmental and agricultural problems. Accounting systems can be costly and time consuming for agencies and nitrogen users to administer.

- Two groundwater task forces are proposed. The first is in regard to groundwater data. A major difficulty in preparing this Report has been the fragmentation of groundwater data within and between agencies, as well as the lack of general access to groundwater data. Groundwater has become such an important issue that most agencies have their own groundwater activities. It is now critical that the state has a coherent and more forward-looking policy and technical capability for the collection and management of groundwater data. This issue seems sufficiently complex to call for a separate groundwater data task force.

- The many state interests and agencies involved with groundwater issues also seem to call for a periodic assessment of how effective these distributed programs are in practically addressing California's groundwater problems. This second independent groundwater task force would periodically review and report on the effectiveness of state groundwater activities to each California Water Plan.

6.4 Dilemmas for State Action

Groundwater nitrate contamination poses several overarching dilemmas and challenges for state policy, which will likely require broader discussions.

Local, statewide, or no compensation for pollution. In practice, the costs of pollution of drinking water sources are often borne by drinking water users. Some aspects of state policy (Water Code Section 13304) allow for fairly direct compensation for such costs. And general state support for water treatment also helps cover such costs. State general funds seem unlikely to be able to provide substantial support in the future, and many local communities, particularly small systems, are unlikely to have financial resources to cover such costs. Can the state establish a reasonable, relatively low-cost means to assess non-point source polluters for the drinking water (and perhaps other) costs entailed?

Degradation of groundwater. Current state law and policy does not allow degradation of groundwater quality to levels above water quality objectives defined in the applicable Basin Plan. However, no technological and institutional strategy has been found to economically reduce all nitrate discharges to levels that prevent further groundwater degradation. More modest approaches to reducing nitrate loads are likely to be economical. However, these more moderate reductions in nitrate loads would typically reduce the rate of groundwater degradation, but they would not always prevent degradation, particularly in the short term. If degradation is practically inevitable for some sources, how should state policy best oversee and regulate degradation?

Policy and policy implementation for environmental effects of land use. Both agriculture and urban land uses now face a host of environmental issues overseen by separate agencies and programs. The environmental causes and effects of nitrate contamination alone, for example, involve a diverse array of state agencies and programs. However, these same land uses also imply environmental impacts via pesticides, salinity, water use, air pollution, surface runoff, and endangered species. Many of these regulated (or potentially regulated) aspects interact environmentally, or their solutions have interactive effects and costs for land management. Is there a more effective and efficient policy approach to managing the environmental effects of land uses than mostly independent agencies and programs for each impact?

7 Conclusions

1. **Nitrate problems will likely worsen for decades.** For more than half a century, nitrate from fertilizer and animal waste have infiltrated into Tulare Lake Basin and Salinas Valley aquifers. Nitrate will spread and increase nitrate concentrations in many areas for decades to come, even if the amount of nitrate loading is significantly reduced. Most nitrate in drinking water wells today was applied to the surface decades ago.

2. **Agricultural fertilizers and animal waste applied to cropland are the two largest regional sources of nitrate in groundwater.** Although discharges from wastewater treatment plants, food processors, and septic tanks also contribute nitrate to groundwater and can be locally important, almost all of the regional groundwater nitrate contamination in the Tulare Lake Basin and Salinas Valley is from agricultural fertilizers and confined animal waste.

3. **Nitrate loading reductions are possible, some at modest cost. Large reductions of nitrate loads to groundwater can come at substantial economic cost.** Farm management is improving, but further improvements are necessary. While some are immediately achievable at modest cost, significant barriers exist, including logistical constraints and inadequate education. The cost of reducing nitrate loads to groundwater can be considerable for large reductions, especially on crops that require a substantial (much greater than 25%) decrease in nitrogen application from today's agronomically accepted, typical rates. Such dramatic reductions in fertilization rates without crop yield improvements can decrease net revenues by possibly several hundred million dollars per year within the study area.

4. **Direct remediation to remove nitrate from large groundwater basins is extremely costly and not technically feasible.** The volume of nitrate-contaminated groundwater is far larger than for urban contamination plumes. Standard pump-and-treat remediation to treat the groundwater underlying the Salinas Valley and Tulare Lake Basin would cost tens of billions of dollars. Instead, "pump-and-fertilize" and improved groundwater recharge management are less-costly long-term alternatives.

5. **Drinking water supply actions, such as blending, treatment, and alternative water supplies, are most cost-effective. Blending will become less available in many cases as nitrate pollution continues to spread.** Regardless of actions taken to reduce long-term nitrate loading to groundwater, many local communities in the Tulare Lake Basin and Salinas Valley will need to blend contaminated groundwater with cleaner water sources, treat contaminated well sources, or develop and employ safe alternative water supplies. Blending will become less available as an option in many cases as nitrate pollution continues to spread. The cost of alternative supplies and treatment for these basins is estimated at roughly \$20 million to \$36 million per year for the next 20 years or more.

6. **Many small communities cannot afford safe drinking water treatment and supply actions. High fixed costs affect small systems disproportionately.** Many small rural water systems and rural households affected by groundwater nitrate pollution are at or below the poverty level. Treatment and alternative supplies for small systems are more costly, as they lack economies of scale. Adherence to nitrate drinking water safety standards without substantial external funding or access to much less expensive treatment technology will potentially bankrupt many of these small systems and households.

7. **The most promising revenue source is a fee on nitrogen fertilizer use in these basins. A nitrogen fertilizer use fee could compensate affected small communities for mitigation expenses and effects of nitrate pollution. Under Water Code Section 13304, California Water Boards could also mandate that nitrate dischargers pay for alternative safe drinking water supplies.** Either mechanism would provide funds for small communities affected by nitrate pollution, allowing them to develop treatment or alternative water supplies that reduce the cost and effect of nitrate pollution over time.

8. **Inconsistency and inaccessibility of data from multiple sources prevent effective and continuous assessment. A statewide effort is needed to integrate diverse water-related data collection activities by various state and local agencies.** Throughout this study, we often faced insurmountable difficulties in gaining access to data already collected on groundwater and groundwater contamination by numerous local, state, and federal agencies. Inconsistencies in record keeping, labeling, and naming of well records make it difficult to combine information on the same well that exist in different databases or that were collected by different agencies. A statewide effort is needed to integrate diverse water-related data collection activities of various state and local agencies with a wide range of jurisdictions. Comprehensive integration, facilitation of data entry, and creation of clear protocols for providing confidentiality as needed are key characteristics of such an integrated database structure.

Literature Cited

Anton E. C., J. L. Barnickol, and D. R. Schnaible. 1988. Nitrate in Drinking Water: Report to the Legislature, Division of Water Quality Report No. 88-11WQ, California State Water Resources Control Board.

Assembly Bill 2222, Draft Report to the California Legislature. Sacramento: State Water Resources Control Board, April 5, 2005.

Beaulac, M. N., and K.H. Reckhow. 1982. An examination of land use–nutrient export relationships. Water Resources Bulletin 82077, 18:1013–1024.

Beever, D., F. Brentrup, P. Eveillard, P. Fixen, P. Heffer, B. Herz, R. Larson, and C. Palliere. 2007. IFA: Sustainable Management of the Nitrogen Cycle in Agriculture and Mitigation of Reactive Nitrogen Side Effects. Paris, France: International Fertilizer Industry Association.

Berentsen, P. B. M., and M. Tiessink. 2003. Potential effects of accumulating environmental policies on Dutch dairy farms. Journal of Dairy Science 86:1019–1028.

Boyle, D., A. King, G. Kourakos, and T. Harter. 2012. Groundwater Nitrate Occurrence. Technical Report 4 in Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater. Report for the State Water Resources Control Board Report to the Legislature. University of California, Davis, Center for Watershed Sciences.

Burow, K., et al. 2008. Regional nitrate and pesticide trends in ground water in the eastern San Joaquin Valley, California. Journal of Environmental Quality 37:S-249–S-263.

Burow, K., B. T. Nolan, M. G. Rupert, and N. M. Dubrovsky. 2010. Nitrate in groundwater of the United States, 1991–2003. Environmental Science and Technology 44:4988–4997.

Canada, H., K. Honeycutt, K. Jessoe, M. W. Jenkins, and J. R. Lund. 2012. Regulatory and Funding Options for Nitrate Groundwater Contamination. Technical Report 8 in Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater. Report for State Water Resources Control Board Report to the Legislature. University of California, Davis, Center for Watershed Sciences.

CDPH (California Department of Public Health). 2010. PICME (Permits Inspection Compliance Monitoring and Enforcement) and WQM (Water Quality Monitoring) databases.

Crites, R. and G. Tchobanoglous. 1998. Small and Decentralized Wastewater Management Systems. New York: McGraw-Hill.

Davidson, E. A., M. B. David, J. N. Galloway, C. L. Goodale, et al. 2012. Excess nitrogen in the U.S. environment: Trends, risks, and solutions. Issues in Ecology 15 (winter 2012). Ecological Society of America, http://www.esa.org/science_resources/issues/FileEnglish/issuesinecology15.pdf.

De Fraiture, C., D. Molden, and D. Wichelns. 2010. Investing in water for food, ecosystems, and livelihoods: An overview of the comprehensive assessment of water management in agriculture. Agricultural Water Management 97:495–501.

Dubrovsky, N. M., K. R. Burow, G. M. Clark, J. M. Gronberg, et al. 2010. The quality of our nation's waters: Nutrients in the nation's streams and groundwater, 1992–2004. U.S. Geological Survey Circular 1350. See http://water.usgs.gov/nawqa/nutrients/pubs/circ1350.

DWR (California Department of Water Resources). 2003. California's Groundwater Bulletin 118: California's Groundwater Update, 2003.

———. 2010. California's Groundwater: Bulletin 118. DWR website, http://www.water.ca.gov/groundwater/bulletin118/gwbasin_maps_descriptions.cfm.

Dyer, K. L. 1965. Interpretation of chloride and nitrate ion distribution patterns in adjacent irrigated and nonirrigated panoche soils. Soil Science Society of America Proceedings 29:170–176.

Dzurella, K. N., J. Darby, N. De La Mora, A. Fryjoff-Hung, T. Harter, A. D. Hollander, R. Howitt, V. B. Jensen, K. Jessoe, A. M. King, J. Lund, J. Medellín-Azuara, G. S. Pettygrove, and T. S. Rosenstock. 2012. Nitrogen Source Reduction to Protect Groundwater. Technical Report 3 in Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater. Report for the State Water Resources Control Board Report to the Legislature. University of California, Davis, Center for Watershed Sciences.

Fan, A.M., and V. E. Steinberg. 1996. Health implications of nitrate and nitrite in drinking water: An update on methemoglobinemia occurrence and reproductive and developmental toxicity. Regulatory Toxicology and Pharmacology 23:35–43.

Faunt, C. C., ed. 2009. Groundwater Availability of the Central Valley Aquifer, California. U.S. Geological Survey Professional Paper 1766.

Fogg, G. E., D. E. Rolston, D. L. Decker, D. T. Louie, and M. E. Grismer. 1998. Spatial variation in nitrogen isotope values beneath nitrate contamination sources. Ground Wate 6(3): 418–426.

Foley, J. A., R. DeFries, G. P. Asner, C. Barford, G. Bonan, S. R. Carpenter, F. S. Chapin, M. T. Coe, G. C. Daily, H. K. Gibbs, J. H. Helkowski, T. Holloway, E. A. Howard, C. J. Kucharik, C. Monfreda, J. A. Patz, I. C. Prentice, N. Ramankutty, and P. K. Snyder. 2005. Global consequences of land use. Science 309:570–574.

Galloway, J. N., and E. B. Cowling. 2002. Reactive nitrogen and the world: 200 Years of change. Ambio 31:64–71.

Galloway, J. N., J. D. Aber, J. W. Erisman, S. P. Seitzinger, R. W. Howarth, E. B. Cowling, and B. J. Cosby. 2003. The nitrogen cascade. BioScience 53:341.

Galloway, J. N., F. J. Dentener, D. G. Capone, E. W. Boyer, R. W. Howarth, S. P. Seitzinger, G. P. Asner, C. C. Cleveland, P. A. Green, E. A. Holland, D. M. Karl, A. F. Michaels, J. H. Porter, A. R. Townsend, and C. J. Vorosmarty. 2004. Nitrogen cycles: Past, present, and future. Biogeochemistry 70:153–226.

Galloway, J. N., A. R. Townsend, J. W. Erisman, M. Bekunda, Z. Cai, J. R. Freney, L. A. Martinelli, S. P. Seitzinger, and M. A. Sutton. 2008. Transformation of the nitrogen cycle: Recent trends, questions, and potential solutions. Science 320:889–892.

Guillette, L. J., and T. M. Edwards. 2005. Is nitrate an ecologically relevant endocrine disruptor in vertebrates? Integrative and Comparative Biology 45:19–27.

Hanak, E., J. Lund, A. Dinar, B. Gray, R. Howitt, J. Mount, P. Moyle, and B. Thompson. 2011. Managing California's Water: From Conflict to Reconciliation. San Francisco: Public Policy Institute of California.

Harter, T., J. Viers, and J. R. Lund. 2012. Project and Technical Report Outline. Technical Report 1 in Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater. Report for the State Water Resources Control Board Report to the Legislature. University of California, Davis, Center for Watershed Sciences.

Helming, J., and S. Reinhard. 2009. Modelling the economic consequences of the EU Water Framework Directive for Dutch agriculture. Journal of Environmental Management 91:114–123.

Henkens, P. L. C, and H. Van Keulen. 2001. Mineral policy in the Netherlands and nitrate policy within the European Community. NJAS Wageningen Journal of Life Sciences 49:117–134.

Holloway, J. M., R. A. Dahlgren, B. Hansen, and W. H. Casey. 1998. The contribution of bedrock nitrogen to high nitrate concentrations in steam water. Nature 395:785–788.

Honeycutt, K., H. Canada, M. W. Jenkins, and J .R. Lund. 2012. Alternative Water Supply Options for Nitrate Contamination. Technical Report 7 in Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater. Report for the State Water Resources Control Board Report to the Legislature. University of California, Davis, Center for Watershed Sciences.

Jensen, V. B., J. L. Darby, C. Seidel, and C. Gorman. 2012. Drinking Water Treatment for Nitrate. Technical Report 6 in Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater. Report for the State Water Resources Control Board Report to the Legislature. University of California, Davis, Center for Watershed Sciences.

Jordan, T. E., and D. E. Weller. 1996. Human contributions to terrestrial nitrogen flux. BioScience 46:655–664.

Keeney, D. R., and J. L. Hatfield. 2007. The nitrogen cycle, historical perspective, and current and potential future concerns. Nitrogen in the Environment: Sources, Problems and Management 3:16.

King, A., D. Boyle, V. Jensen, G. E. Fogg, and T. Harter. 2012. Groundwater Remediation and Management for Nitrate. Technical Report 5 in Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater. Report for the State Water Resources Control Board Report to the Legislature. University of California, Davis, Center for Watershed Sciences.

Kruitwagen, S., M. Reudink, and A. Faber. 2009. Pragmatics of policy: The compliance of Dutch environmental policy instruments to European Union standards. Environmental Management 43:673–681.

MCWRA (Monterey County Water Resources Agency). 2010. Technical Memorandum 1993-2007 Nitrate Tasks 2.01, 2.02, 2.04.2b EPA Grant XP-96995301: Ground Water Sampling, Reporting, and Storage, Ground Water Sampling, Data QA/QC, Data Reduction and Representation. Monterey County Water Resources Agency.

Montgomery Watson Americas, Inc. 1997. Salinas Valley Integrated Ground Water and Surface Model Update. Final Report Monterey County Water Resources Agency, Salinas Valley, California.

Mueller, D. K., and R. Helsel. 1996. Nutrients in the Nation's Waters: Too Much of a Good Thing. U.S. Geological Survey Circular 1136.

NRC (National Research Council). 1994. Alternatives for Ground Water Cleanup. Washington, DC: National Academy Press.

———. 1997. Safe Water from Every Tap: Improving Water Service to Small Communities. Washington, DC: National Research Council.

———. 2000. Natural Attenuation for Groundwater Remediation. Washington, DC: National Research Council.

Oenema, O., L. van Liere, and O. Schoumans. 2005. Effects of lowering nitrogen and phosphorus surpluses in agriculture on the quality of groundwater and surface water in the Netherlands. Journal of Hydrology 304:289-301.

Ondersteijn, C. J. 2002. The Dutch Mineral Accounting System and the European Nitrate Directive: implications for N and P management and farm performance. Agriculture, Ecosystems & Environment 92:283–296.

Ondersteijn, C. J. M., A. C. G. Beldman, C. H. G. Daatselaar, G. W. J. Giesen, and R. B. M. Huirne. 2002. The Dutch Mineral Accounting System and the European Nitrate Directive: Implications for N and P Management and Farm performance. Agriculture, Ecosystems, and Environment 92:283–296.

Petrovic, A. M. 1990. The fate of nitrogenous fertilizers applied to turfgrass. Journal of Environmental Quality 19:1–14.

Postel, S. L. and B. H. Thompson Jr. 2005. Watershed protection: Capturing the benefits of nature's water supply services. Natural Resources Forum 29:98–108.

Raun, W., and J. S. Schepers. 2008. Nitrogen management for improved use efficiency. In J. S. Schepers and W. Raun, eds., Nitrogen in Agricultural Systems. Madison, WI: ASA-CSSA-SSSA.

Rubin, Y., P. Benito, G. Miller, J. McLaughlin, Z. Hou, S. Hermanowicz, U. Mayer, and D. Silin. 2007. Hilmar Supplemental Environmental Project: Volume 2. Tucson: Hydrogeophysics, Inc.

Scanlon, B. R. 2008. Impacts of land use change on nitrogen cycling archived in semiarid unsaturated zone nitrate profiles, Southern High Plains, Texas. Environmental Science and Technolgy 42(20): 7566–7572.

Schmidt, K. D. 1972. Nitrate in ground water of the Fresno metropolitan area, California. Ground Water 10:50–64.

Siegrist, R. L., E. J. Tyler, and P. D. Jenssen. 2000. Design and performance of onsite wastewater soil absorption systems. St. Louis, MO: National Research Needs Conference.

Spalding, R., and M. Exner. 1993. Occurrence of nitrate in groundwater. Journal of Environmental Quality 22:392–402.

Stadler, S., K. Osenbruck, K. Knoller, A. Suckow, J. Sultenfuss, H. Oster, T. Himmelsbach, and H. Hotzl. 2008. Understanding the origin and fate of nitrate in groundwater of semi-arid environments. Journal of Arid Environments 72:1830–1842.

State Water Board (California State Water Resources Control Board). 2011. GAMA—Groundwater Ambient Monitoring and Assessment Program website, http://www.waterboards.ca.gov/water_issues/programs/gama/.

Sutton, M., C. Howard, J. Erisman, G. Bilen, A. Bleeker, P. Grennfelt, H. van Grinsven, and B. Grizzetti. 2011. The European Nitrogen Assessment. Cambridge, UK: Cambridge University Press.

Tchobanoglous, G., F. L. Burton, and H. D. Stensel. 2003. Wastewater Engineering: Treatment, Disposal, Reuse. 4th ed. New York: McGraw-Hill.

Tilman, D., G. G. Cassman, P. A. Matson, R. Naylor, and S. Polasky. 2002. Agricultural sustainability and intensive production practices. Nature 418:671–677.

Townsend, A. R., R. W. Howarth, F. A. Bazzaz, M. S. Booth, C. C. Cleveland, S. K. Collinge, A. P. Dobson, P. R. Epstein, E. A. Holland, D. R. Keeney, M. A. Mallin, C. A. Rogers, P. Wayne, and A. H. Wolfe. 2003. Human health effects of a changing global nitrogen cycle. Frontiers in Ecology and the Environment 1:240–246.

U.S. Census Bureau. 2000. The 2000 U.S. Census.

———. 2001. Places Cartographic Boundary Files Descriptions and Metadata, 2000. Incorporated Places/Census Designated Places. U.S. Census website, http://www.census.gov/geo/www/cob/pl_metadata.html.

U.S. EPA. Science Advisory Board. 2011. Reactive nitrogen in the United States: An analysis of inputs, flows, consequences, and management options. EPA-SAB-11-013.

Viers, J. H., D. Liptzin, T. S. Rosenstock, V. B. Jensen, A. D. Hollander, A. McNally, A. M. King, G. Kourakos, E. M. Lopez, N. De La Mora, A. Fryjoff-Hung, H. Canada, S. Laybourne, C. McKenney, J. Darby, J. F. Quinn, and T. Harter. 2012. Nitrogen Sources and Loading to Groundwater. Technical Report 2 in Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater. Report for the State Water Resources Control Board Report to the Legislature. University of California, Davis, Center for Watershed Sciences.

Vitousek, P. M., and R. W. Howarth. 1991. Nitrogen limitation on land and in the sea: How can it occur? Biogeochemistry 13:87–115.

Vitousek, P. M., J. D. Aber, R. W. Howarth, G. E. Likens, P. A. Matson, D. W. Schindler, W. H. Schlesinger, and D. G. Tilman. 1997. Human alteration of the global nitrogen cycle: Sources and consequences. Ecological Applications 7:737–750.

Walvoord, M. A., F. M. Phillips, D. A. Stonestrom, R. D. Evans, P. C. Hartsough, B. D. Newman, and R. G. Striegl. 2003. A reservoir of nitrate beneath desert soils. Science 302:1021–1024.

Ward, C. 2004. Around the Watershed. New York City Department of Environmental Protection.

Ward, M. H., T. M. deKok, P. Levallois, J. Brender, G. Gulis, B. T. Nolan, and J. VanDerslice. 2005. Drinking-water nitrate and health: Recent findings and research needs. Environmental Health Perspectives 113(11). USGS NAWQA website, http://water.usgs.gov/nawqa/nutrients/pubs/ehp_vol113_no11/.

White, R. E. 2006. Principles and Practice of Soil Science: The Soil as a Natural Resource. Oxford, UK: Wiley.

Wu, L., J. Letey, C. French, Y. Wood, and D. Birkle. 2005. Nitrate leaching hazard index developed for irrigated agriculture. Journal of Soil and Water Conservation 60:90A.

The Tulare Lake Basin and the Salinas Valley, with 2.6 million inhabitants and home to nearly half of California's agricultural production, are the focus of this report. Nearly one in ten people in these two regions are currently at risk for nitrate contamination of their drinking water. Water systems providing water for half of these regions' population have encountered excessive nitrate levels in production wells at least once over the last five years.

An independent team of scientists at The University of California, Davis, was contracted by the State Water Resources Control Board to examine this problem. Working in consultation with an Interagency Task Force representing many state and local agencies, the authors undertake a uniquely broad and comprehensive assessment of the wide spectrum of technical, scientific, management, economic, planning, policy, and regulatory issues related to addressing nitrate in groundwater and drinking water for the Tulare Lake Basin and Salinas Valley.

This report identifies, describes, and quantifies past and current sources of nitrate, details the extent of groundwater nitrate contamination, and provides a comprehensive, up-to-date guide to the many options available to address the problems of drinking water quality, aquifer degradation, and economic costs from nitrate contamination of groundwater and its regulation. The report concludes by outlining promising actions in four key areas: safe drinking water actions for affected areas; reducing sources of nitrate contamination to groundwater; monitoring and assessment of groundwater and drinking water; and revenues to help fund solutions. Even among these promising options, major policy choices must be made. The research compiled in this report provides a foundation for informed discussion among the many stakeholders and the public about these policy choices.

The Center for Watershed Sciences at the University of California, Davis, brings a wide range of experts together to examine California's major water issues and problems. Its activities range from scientific and analytical modeling studies to major works on urgent problems. More about the Center can be found at watershed.ucdavis.edu.

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

Attachment 4

Technical Report

Investigations and Monitoring Group

A review of nitrate toxicity to freshwater aquatic species

Report No. R09/57
ISBN 978-1-86937-997-1

Environment Canterbury
Your regional council

A review of nitrate toxicity to freshwater aquatic species

Report No. R09/57
ISBN 978-1-86937-997-1

Prepared for Environment Canterbury by

C.W. Hickey
M.L. Martin
NIWA

June 2009

Environment Canterbury
Your regional council

Report R09/57
ISBN 978-1-86937-997-1

58 Kilmore Street
PO Box 345
Christchurch 8140
Phone (03) 365 3828
Fax (03) 365 3194

75 Church Street
PO Box 550
Timaru 7940
Phone (03) 687 7800
Fax (03) 687 7808

Website: www.ecan.govt.nz
Customer Services Phone 0800 324 636

A review of nitrate toxicity to freshwater aquatic species

C. W. Hickey
M.L. Martin

NIWA contact/Corresponding author C.W. Hickey

Prepared for

Environment Canterbury

NIWA Client Report: HAM2009-099
June 2009

NIWA Project: ENC09201

National Institute of Water & Atmospheric Research Ltd
Gate 10, Silverdale Road, Hamilton
P O Box 11115, Hamilton, New Zealand
Phone +64-7-856 7026, Fax +64-7-856 0151
www.niwa.co.nz

Executive summary

Environment Canterbury (ECan) is preparing an amendment to the proposed Natural Resources Regional Plan (NRRP) to better manage the cumulative effects of non-point source discharges of nutrients, sediment and pathogens on rivers, lakes, wetlands and groundwater. As part of this work numerical limits are to be set for key contaminants to ensure that management objectives for the region's surface and ground water bodies will be achieved.

Environment Canterbury commissioned a review of the ANZECC (2000) and the 2002 revised guideline value freshwater quality guidelines for chronic nitrate (NO_3-N) concentrations in surface waters and groundwaters, together with advice on application of guidelines to seasonally varying concentrations (i.e., in groundwaters, rivers and lowland streams). Specific consideration was also requested regarding the availability of data for indigenous and representative species, together with introduced species resident in Canterbury's aquatic ecosystems.

A review of the international literature and toxicological databases, including the US EPA AQUIRE database and Environment Canada data was undertaken to compile a database of acute (short-term) and chronic (long-term) toxicity data. The ANZECC and Environment Canada decision-making criteria were applied to this database to select appropriate species for guideline derivation. Data were specifically excluded for potassium nitrate, as high potassium is not a normal component of contamination of surface waters, and its toxicity has been shown to be significantly higher than sodium nitrate to both fish and macroinvertebrates. Tropical species data was also excluded from the guideline derivation. Recently published data provided sufficient chronic data for use in guideline derivation, which had previously been based only on acute data for the ANZECC (2000) derivation.

Sufficient data was available for both acute and chronic guideline derivations. The acute guideline derivation followed the US EPA (2002) protocol and the chronic guideline the ANZECC (2000)/Environment Canada (2007) approach. A total of 20 species were used for the acute derivation. The acute data had only four species found in Canterbury's water bodies (rainbow trout, lake trout & Chinook salmon), including one indigenous species, the native snail, (*Potamopyrgus antipodarum*). However, there were also five representative species, including amphipods, caddisflies and a snail. The chronic dataset includes three species found in Canterbury's rivers and lakes (rainbow trout, lake trout and Chinook salmon). These three fish species are represented by tests which fell in the lower 30 percentile of the sensitivity distribution. While there were other invertebrate species in the chronic data that could be considered representative of lake habitats (i.e., *Daphnia* and *Ceriodaphnia*), their sensitivity is markedly less than the most sensitive fish species (i.e., >9.8x). Overall, the acute nitrate data showed macroinvertebrates were the more sensitive organisms, while the chronic data showed fish to be more sensitive to long-term exposures.

The datasets are particularly lacking in species which are known to be of high sensitivity to other common toxic contaminants, and that dominate the fauna in river environments. Studies have shown that amphipods, mayflies and some native fish species are more sensitive to some chemical contaminants than standard test species, such as cladocerans and rainbow trout. No information is available on the sensitivity of native fish species to nitrate.

The recommended freshwater guidelines suitable for application to freshwaters of Canterbury are:

Guideline type	**Application to:**	**Guideline value ($mg\ NO_3$-N/L)[a]**
Acute	Very localised point source discharge.	20 mg NO_3-N/L
Chronic – high conservation value systems (99% protection)	Pristine environments with high biodiversity and conservation values.	1.0 mg NO_3-N/L
Chronic – slightly to moderately disturbed systems (95% protection)	Environments which are subjected to a range of disturbances from human activity.	1.7 mg NO_3-N/L
Chronic – highly disturbed systems (80 to 90% protection)	Specific environments which: (i) either have measurable degradation; or (ii) which receive seasonally high elevated background concentrations for significant periods of the year (1-3 months).	2.4 – 3.6 mg NO_3-N/L
Chronic – site-specific (species-specific protection)	Collection of specific data for representative species and life-stages with calculation of site-specific guideline values.	No data

[a] Multiply by conversion factor of 4.43x to convert to NO_3

Contents

Figures

Tables

1 Background

Environment Canterbury (ECan) is preparing an amendment to the proposed Natural Resources Regional Plan (NRRP) to better manage the cumulative effects of point and non-point source discharges of nutrients, sediment and pathogens on rivers, lakes, wetlands and groundwater. As part of this work numerical limits are to be set for key contaminants to ensure that management objectives for the region's surface and ground water bodies will be achieved.

Environment Canterbury staff are reviewing the appropriateness of available standards and guideline values for a range of contaminants to achieve specific management objectives (e.g., protection of Canterbury's surface water ecosystems, drinking water). Questions have also been raised by consultants working for resource consent applicants over the appropriateness of the guideline values for nitrate (set out in ANZECC 2000) to protect New Zealand aquatic ecosystems. Environment Canterbury wants these values reviewed to establish confidence that they are relevant and applicable to New Zealand's freshwater ecology.

In addition to reviewing the guideline values for nitrate, Environment Canterbury is seeking advice on the following:

(i) the relative importance of the effects of short term exceedances of any toxicity threshold compared to longer-term exposure to concentrations below the guideline values. Many of Canterbury's lowland streams have very strong seasonal peaks in nitrate-N concentrations which may exceed current toxicity thresholds (of 7.2 mg N/L) for 1-3 months per year (usually late winter/spring) but concentrations may reduce considerably for the remainder of the year;

(ii) whether lower nitrate concentrations to provide protection for particularly sensitive species in specific areas are appropriate (as recommended by Carmago *et al.* 2005). In particular, is there justification for different thresholds in relatively undeveloped areas with very high natural water quality, such as the Mackenzie Basin.

Brief

A study brief (dated 17 October 2008) was supplied by ECan for this project.

The objective was: "To advise on the appropriateness of current nitrate guideline standards to protect New Zealand aquatic ecosystem values."

The specified tasks were:

1 Carry out a literature review to identify any new research (post 1998) on nitrate toxicity limits for surface water ecosystems. Review the relevance of nitrate toxicity literature and data to New Zealand aquatic fauna. The review will cover the published literature, water quality guidelines publications and international databases for toxicity testing (e.g., US EPA AQUIRE database).

2 Freshwater nitrate toxicity information will be summarised (Excel spreadsheet database) and reviewed and if appropriate used to calculate a revised water quality guideline for nitrate following the ANZECC (2000) guideline calculation procedures.

3 The relative sensitivity of species in the database will be compared with published data on the sensitivity of New Zealand aquatic species to nitrate contaminants (e.g., Hickey 2000) to provide a basis for addressing the specific issues below.

4 The adequacy of the species represented in the nitrate toxicity database will be assessed relative to known macroinvertebrate and fish distributions in Canterbury's rivers to provide a site-specific guideline assessment.

Comment on the following matters:

(i) Are there any reasons why international studies on nitrate toxicity will not be relevant to NZ aquatic fauna?

(ii) What is the importance of managing short term exceedances of any toxicity threshold as well as long-term exposure (i.e., 1 – 3 month period)?

(iii) Comment on the recommendations made by Carmago *et al*. (2005) regarding appropriate protection guideline values. Are there likely to be any sensitive aquatic communities in Canterbury that require a lower nitrate threshold?

(iv) Advise whether the ANZECC 2000 and the 2002 revised guideline value toxicity limits are appropriate for Canterbury water bodies, and if not provide, and justify the revised toxicity limits (see 2) and why these have been revised.

2 Methods

The original ANZECC (2000) guideline for nitrate was found to have an error in derivation, with a correction issued in 2002[1]. The 2002 revised guideline value is 7.2 mg NO_3-N/L for 95% species protection. The ANZECC (2000) guidelines are currently in an early stage of revision.

We undertook a search of the peer-reviewed scientific literature and toxicity databases to find nitrate information published since 1998. The primary sources were the US EPA AQUIRE (http://cfpub.epa.gov/ecotox/) database, the major published reviews of Camargo *et al*. (2005) and the Environment Canada (2003) nitrate ion guideline derivation. The Environment Canada (2003) procedure derived an "interim" water quality guideline of 13 mg NO_3/L (i.e., equivalent to 2.9 mg NO_3-N/L).

The AQUIRE database was searched for information on the nitrate ion (CAS 147-55-8), sodium nitrate (CAS 7631-99-4) and potassium nitrate (CAS 7757-79-1), with specific exclusion of ammonium nitrate (CAS 6484-52-2), because of the potential for ammoniacal-N toxicity with this compound. Data were loaded, or entered into, a summary Excel database and converted to a nitrogen (N) basis using the factors given in Table 2.1. Notably, a number of early publications were reported as the total salt weight (e.g., $NaNO_3$), with some of these data incorrectly reported in the ANZECC (2000) derivation.

Table 2.1 Conversion factors for various nitrate units to mg NO_3-N/L

Base unit	Multiply by:
mg NO_3/L	0.23
mg $NaNO_3$/L	0.16
mg KNO_3/L	0.14
mg NH_4NO_3/L	excluded
mg NO_3-N/L (ppm)	1
µg NO_3-N/L (ppb)	1000

We selected data suitable for acute and chronic endpoints following the ANZECC (2000) and Environment Canada (CCME 2007) selection criteria as detailed in Table 2.2. The selection procedures for categorising acute (short-term) and chronic (long-term) test durations, defining acceptable effects measures and endpoints generally follows documentation provided in ANZECC (2000), though we have adopted the more recent, and more specific, Environment Canada (CCME 2007) classification for durations and some of their document classifications. The generic derivation procedures were followed by selection of "site-specific" as required in the brief for this project. The selection criteria were:

1. **Effects:** The major effect classes included mortality (MOR), immobilisation (IMM), growth (GRO), reproduction (REP), population growth rate (PGR), and hatching (HAT) following the US EPA AQUIRE classifications as used in the ANZECC (2000) guidelines. A summary of effects codes is provided in Appendix 1. Biochemical effects (e.g., enzyme activity, serum protein concentrations) were not included as acceptable endpoints and while behavioural effects were included, special

[1] http://www.mfe.govt.nz/publications/water/anzecc-water-quality-guide-02/anzecc-nitrate-correction-sep02.html

consideration is made of these measured in the site-specific guideline derivation to assess whether the effects were relevant to survival.

2. **Duration:** The designation of acute and chronic durations generally followed the criteria used in the ANZECC (2000) guidelines, however because these are somewhat vague, the more specific Environment Canada (CCME 2007) criteria were used (Table 2.2). Generally, acute tests were up to 96 h exposure and with the predominant effect measured being survival, with an LC_{50} (lethal concentration causing a 50% effect) endpoint. The chronic tests had longer exposures, with the designation into "chronic" duration generally related to the life-span of the organism (shorter exposures are considered chronic for short-lived species), and favouring sub-lethal effects (e.g., growth, reproduction). Some best professional judgement was required for classification of some species/effects. Note that the ANZECC (2000) guidelines were only based on chronic guideline determinations.

3. **Endpoints:** Either an LC_{50} or EC_{50} (lethal or effective concentration causing a 50% effect, see Glossary (Section 6)) for the various effect measures were selected as suitable acute endpoints. According to the ANZECC (2000) procedures the "No Observed Effect Concentration" (NOEC) is the preferred endpoint for chronic exposures. Other reported chronic endpoints (e.g., "Lowest Observed Effect Concentration", LOEC; "Maximum Acceptable Toxicant Concentration", MATC) were converted to an estimated NOEC using the conversion factors used in ANZECC (2000) (Table 2.2).

In the updated Environment Canada procedures for guideline derivation (CCME 2007) the toxicity endpoint preference is for regression-based statistical evaluation (i.e., EC_x, values identifying no- or low-effects thresholds) over endpoints obtained through hypothesis-based statistical evaluation (i.e., NOEC and LOEC values). In hypothesis-based evaluations, the arbitrary nature of the selection of exposure concentrations, and dilution factors between consecutive dilutions, can result in a highly variable NOEC value relative to the onset of statistically significant effects detected at the LOEC concentration. While the use of the NOEC may provide a precautionary approach, it may also provide excessively conservative values depending on the design of the particular studies. Thus the Environment Canada preference ranking order is: EC_{10}>EC_{11-25}>MATC>NOEC>EC_{26-49}>non-lethal EC_{50}. In practice, threshold EC_{10} values are commonly not reported, especially in older literature, and hypothesis-based values must be used by default if data from those studies are to be included.

4. **Reference quality:** Publications with the ANZECC (2000) classification of "I" (insufficient data) or "Unacceptable data" from the Environment Canada (CCME 2007) classification system (see Appendix 2), were not included without specific justification. These classification scores are provided in the database where a publication has been previously considered. Note that the Environment Canada (2003) nitrate guideline derivation uses primary, secondary and "Ancillary source (A)" data classifications, and we have taken the latter as being equivalent to the "Unacceptable data" classification. We have used the ANZECC (2000) scoring procedure (Appendix 2) to classify any publication-derived data on highly sensitive species (in the lower 25%ile of the sensitivity distribution curve) which significantly affect the guideline derivation procedure.

5. **Calculation procedure:** The generic calculation procedure for guideline derivation involves selection of the longest duration exposure/effect/endpoint combination for each species/publication, and calculating a geometric mean for multiple independent studies where the same combination occurs (e.g., same species, same endpoint).

Notably, some of the ANZECC (2000) derivations calculate a geometric mean of a range of reported exposure durations (e.g., 24 h, 48, 96 h) from the same study, which does not follow their reported methodology. Providing there is adequate data (8 species for the ANZECC approach), the guideline derivation procedure involved modelling the cumulative species sensitivity distribution (SSD) estimating the 5%ile effect level (i.e., 95% protection level) of the SSD which provided the primary guideline derivation. This SSD approach is also the recommended primary calculation procedure for the recently revised Environment Canada procedure (CCME 2007).

For the acute guideline calculation, we have used the SSD approach to calculate a community 5%ile effect threshold based on LC_{50}/EC_{50} effects data. This acute 5%ile effects value then has an application factor (AF) of 2 applied to generate a final acute guideline following the US EPA standard procedure (Stephan *et al*. 1985; US EPA 2002). Though the recent Environment Canada protocol (CCME 2007) includes short-term exposure guidelines, which are: "meant to estimate severe effects and to protect most species against lethality during intermittent and transient events (e.g., spill events to aquatic-receiving environments, infrequent releases of short-lived/non-persistent substances)", their acceptance of a 50% effect for some species at the guideline level is probably inconsistent with the New Zealand Resource Management Act legislation (RMA 1991), as this would potentially constitute a significant adverse effect on aquatic life. Because of the large number of acute guideline derivations following the US EPA procedure, we consider that this is the preferred approach for use in this study to benchmark the acute nitrate toxicity relative to the available data.

The SSD model used for all guideline derivations was the BUR III model referred to in the ANZECC (2000) procedures.

6. **Key species:** Guideline derivation procedures generally include special consideration of data adequacy for rare and endangered species, and commercially or recreationally important species. This provision was explicitly included in the ANZECC (2000) guidelines and in the Environment Canada (CCME 2007) procedures, as defined by the "protection clause". This component of the derivation requires that effects and endpoint values for key species which fall below the 5%ile effect guideline be specifically considered on a case-by-case basis. If this endpoint is a moderate- or severe-effect level endpoint for a species at risk, then this value becomes the default guideline value (CCME 2007). Specific consideration of key species data was undertaken as a component of the procedure used here. An additional generic consideration in regard to key species, is the adequacy of the database in providing representative species/genus data for the diversity of species present in a given environment. Native and introduced species are also identified as part of this toxicity review.

7. **Site-specific selections:** A general site-specific selection was applied to exclude tropical species data. This was based on the contention that tropical species would not inhabit the temperate New Zealand freshwater aquatic environments. Tests for tropical species at ≥28ºC was the criteria for exclusion from the generic derivation.

Site-specific derivations were considered for species inhabiting particular environments (e.g., rivers, lakes, groundwaters) in the Canterbury region. This component of the study was assessed following the generic guideline derivation. The elimination of generic (i.e., non-local) species reduces the number of species and results in a dataset which is unsuitable for guideline calculation following the SSD model procedures.

Table 2.2 Decision criteria summary for data inclusion for site-specific nitrate guideline calculations

Number	Selection criteria	Comments	Reference
1	Database search	US EPA AQUIRE, Environment Canada, bibliographic references	
2	Effects: MOR, IMM, GRO, REP, PGR, PSR, HAT, DEV	Footnote a	ANZECC (2000)
3	Durations: acute (short-term): fish & amphibians, 96h; aquatic invertebrates, 48-96h; aquatic plants, case-by-case basis; algae, 24h; chronic (long-term): fish & amphibians, >21d, or >7d for eggs & larvae; aquatic invertebrates, >96h for short-lived, >7d for long-lived and non-lethal endpoints, >21d for long-lived and lethal endpoints; plants, case-by-case; algae, >72-96h	Classifications required for acute and chronic guideline derivations. Some best professional judgement required for classification of durations that fall outside these classes.	CCME (2007)
4	Selected endpoints: NOEC, LOEC, MATC & ECx for chosen EFFECTS	Footnote b & Glossary for terms	
5	Specific exclusions: toxicant	Only sodium nitrate (CAS: 7631994); exclusion of potassium nitrate, ammonium nitrate. Conversion of all data to standard measure: nitrate-nitrogen (NO_3-N)	
6	Specific exclusions: water quality	no marine or salt (>5 ppt) for freshwaters; or "NR" (not recorded)	
7	Specific exclusions: reference quality	Remove low reliability data. Based on "I" score for ANZECC & US EPA scoring system; "Unacceptable data" classification from Environment Canada. Specific justification for exclusion.	ANZECC (2000) & CCME (2007)
8	Effect selection	Multiple effects endpoints per species considered for species sensitivity distribution: most sensitive of traditional effects (e.g., growth, reproduction, survival) - with selection of most sensitive life-stage and effect; as well as endpoints for other effects (e.g., behavioural, physiological).	CCME (2007)
9	Duration selection	Longest duration within acute or chronic datasets for each author.	ANZECC (2000)
10	Endpoint selection and conversion	Conversion of chronic endpoints to NOEC values using following criteria: LOEC, MATC, LC/EC_{50} values divided by assessment factors of 2.5, 2 and 5 respectively. Toxicity data where insufficient concentration at the higher range (i.e., "toxicity greater than") included - on the basis that this will not result in an under-protective guideline. Note: NOEC is the preferred endpoint for ANZECC (2000); Environment Canada selection priority is for EC_{10} or LOEC.	ANZECC (2000)
11	Averaging	Geometric mean for each species having multiple authors/studies with common endpoints.	ANZECC (2000) & CCME (2007)
11	Key species selection	Specific consideration for inclusion of high economic, recereational or ecologically important species (i.e., exclusion from geometric mean averaging).	ANZECC (2000) & CCME (2007)
12	Site-specific: temperature	Tropical species and exposures at high temperatures (≥28°C) were excluded.	Site-specific criteria
13	Site-specific: environments	Separation of data into speciesinhabiting specific environments (e.g., rivers, lakes, groundwaters).	Site-specific criteria
14	Site-specific: species	Exclusion of exotic species not present in any local envionment. Best professional judgement with justification for exclusion.	Site-specific criteria

[a] Effects codes in Appendix 1

[b] NOEC, no observed effect concentration; LOEC, lowest observed effect concentration, MATC, geometric mean of NOEC + LOEC; LCx, lethal concentration causing x% effect; ECx, effective concentration causing x% effect

3 Results

3.1 Review of the ANZECC (2000) nitrate guideline derivation

A marked-up review of the ANZECC (2000) guidelines derivation for freshwater nitrate toxicity is provided in Appendix 3. The two chronic species and endpoints which were originally included in the ANZECC (2000) derivation have recently been identified as being potassium salts (R. van Dam, Environmental Research Institute of the Supervising Scientist (ERISS), Australia, pers. comm.) and should not have been included in the data set. The revision of the guideline undertaken in 2002[2] was based on a modification of the calculation approach to consider these two chronic data separately from the acute data in the guideline derivation process. Additional errors in original data and averaging have also been identified.

The publication of more recent chronic data since the ANZECC (2000) derivation means that these derivations are based on this new data rather than relying on the original acute database.

3.2 Update of nitrate guideline derivation

The data for all species are summarised in the accompanying Excel spreadsheet (NIWA_nitrate_2009.xls) [3]. This database includes annotations for analysis of nitrate in the tests, ranking of the source and the publication references. References are flagged to indicate those included in either the ANZECC (2000) or Environment Canada (2003) derivations. Details of the final acute and chronic datasets, together with the statistical model plots are provided in Appendix 4.

The derivation does not include potassium nitrate data, as both acute and chronic toxicity tests with the potassium salt have shown that it is markedly more toxic than the sodium salt for a range of fish and invertebrate species (Table 3.1). Notably, chronic data for two species which were included in the ANZECC (2000) derivation have recently been identified as being potassium salts. These data have not been included in this derivation and were identified in the marked-up review of the ANZECC (2000) derivation (Section 3.1).

[2] http://www.mfe.govt.nz/publications/water/anzecc-water-quality-guide-02/anzecc-nitrate-correction-sep02.html

[3] A copy of the data can be obtained upon request to Environment Canterbury

Table 3.1 Relative toxicity of sodium and potassium nitrate to freshwater organisms (from Environment Canada 2003)

Organism	Duration (h)	Endpoint	$[NO_3^-]$ (mg $NO_3^- \cdot L^{-1}$)		Reference
			K^+ Salt	Na^+ Salt	
Lepomis macrochirus (bluegill)	96	LC_{50}	1840	8753	Trama (1954)
	24	LC_{50}	3373	9338	Dowden and Bennett (1965)
Daphnia magna (water flea)	96	TL_m	552	3069	Dowden and Bennett (1965)
Polycelis nigra (planaria)	48	survival	555	2696	Jones (1940)
Gasterosteus aculeatus (stickleback)	240	lethal concen-tration limit	79	1348	Jones (1939)
Hydra attenuata (hydra)	288	NOEL	150 - 250	< 50	Tesh et al. (1990)

3.2.1 Acute data

A summary of the 20 acute results are provided in Table 3.2 and shown in Figure 3-1. These include: 9 fish; 9 invertebrate; and 2 amphibian species. The dataset spans a 37-fold range in sensitivity with the most sensitive species being an amphipod (*Echinogammarus echinosetosus*) with an LC_{50} of 56.2 mg NO_3-N/L. In general, the invertebrates appear to be more acutely sensitive to nitrate than fish (Figure 3-1), with rainbow trout 19x less sensitive than the most sensitive species, and the most sensitive fish (Siberian sturgeon) 7x less sensitive than the most sensitive species in the dataset.

Seven of the fourteen publications which contributed to the selected acute toxicity data were included in the ANZECC (2000) guideline derivation. All of the selected acute publications constituting the lower quartile of the sensitivity distribution were of reliable quality earning either a "primary" classification from Environment Canada or an "M" (moderate) classification from the ANZECC (2000) procedure (Appendix 2), with reference codes and classifications shown in Appendix 4.

Acute data for seven tropical species from six studies (Colt and Tchobanoglous 1976; Meade and Watts 1995; Tilak *et al*. 2002; Tilak *et al*. 2006a; Tilak *et al*. 2006b; Tilak *et al*. 2006c) were excluded from the guideline derivation procedure.

Table 3.2 Summary of acute toxicity data for sodium nitrate exposure selected for the 2009 derivation. Highlighted (white on black) indicate species which are resident in Canterbury's rivers and lakes bold indicates representative species with closely related families in rivers

Group	Common name	Latin Name	Life Stage	Duration (h, d)	End-point	Effect	Temp (ºC)	EC_{50}/LC_{50} (mg NO_3-N/L)[a]	Rank	Cumulative %	Author
Invertebrate	**Amphipod**	***Echinogammarus echinosetosus***	**Adults**	**120h**	**LC50**	**MOR**	**17.9**	**56.2**	**1**	**0**	**Camargo *et al*. (2005)**
Invertebrate	**Amphipod**	***Eulimnogammarus toletanus***	**Adults**	**120h**	**LC50**	**MOR**	**17.9**	**73.1**	**2**	**5.2**	**Camargo *et al*. (2005)**
Invertebrate	**Caddisfly**	***Hydropsyche accidentalis***	**Last instar larvae**	**120h**	**EC50**	**MOR**	**18**	**77.2**	**3**	**10.5**	**Camargo & Ward (1992)**
Invertebrate	Caddisfly	*Cheumatopsyche pettiti*	Early instar larvae	120h	LC50	MOR	18	107	4	15.7	Camargo & Ward (1992)
Invertebrate	**Caddisfly**	***Hydropsyche exocellata***	**Last instar larvae**	**120h**	**LC50**	**MOR**	**17.9**	**230**	**5**	**21**	**Camargo *et al*. (2005)**
Amphibian	Pacific Treefrog	*Pseudacris regilla*	tadpoles	10d	LC50	MOR	22	266	6	26.3	Schuytema & Nebeker (1999c)
Invertebrate	Water flea	*Ceriodaphnia dubia*	Neonates	48h	LC50	MOR	25	374	7	31.5	Scott & Crunkilton (2000)
Fish	Siberian sturgeon	*Acipenser baeri*	Adults	96h	LC50	MOR	22.5	397	8	36.8	Hamlin (2006)
Invertebrate	Water flea	*Daphnia magna*	Neonates	48h	EC50	MOR		479	9	42.1	**Geometric mean**
Invertebrate	**Snail**	***Lymnaea sp***	**eggs**	**96h**	**LC50**	**HAT**	**NR**	**535**	**10**	**47.3**	**Dowden & Bennett (1965)**
Invertebrate	**Snail**	***Potamopyrgus antipodarum***	**Adults**	**96h**	**LC50**	**MOR**	**20.4**	**1042**	**12**	**52.6**	**Alonso & Camargo (2003)**
Fish	**Rainbow trout**	***Oncorhynchus mykiss***	**fingerlings**	**7d**	**LC50**	**MOR**	**13-14**	**1061**	**13**	**57.8**	**Westin (1974)**
Fish	**Chinook salmon**	***Oncorhynchus tshawytscha***	**fingerlings**	**7d**	**LC50**	**MOR**	**13-14**	**1084**	**14**	**63.1**	**Westin (1974)**
Fish	Eastern mosquitofish	*Gambusia holbrooki*		96h	LC50	MOR		1095	11	68.4	Wallen *et al*. (1957)
Fish	**Lake Trout**	***Salvelinus namaycush***	**fry**	**96h**	**LC50**	**MOR**	**7.5**	**1121**	**15**	**73.6**	**McGurk *et al*. (2006)**
Amphibian	African clawed frog	*Xenopus laevis*	tadpoles	10d	LC50	MOR	22	1236	16	78.9	Schuytema & Nebeker (1999c)
Fish	Fathead minnows	*Pimephales promelas*	Larvae	96h	LC50	MOR		1317	17	84.2	**Geometric mean**
Fish	Catfish	*Ictalurus punctatus*	Fingerlings	96h	LC50	MOR	22	1355	18	89.4	Colt & Tchobanoglous (1976)
Fish	Lake Whitefish	*Coregonus clupeaformis*	fry	96h	LC50	MOR	7.5	1903	19	94.7	McGurk *et al*. (2006)
Fish	Bluegill	*Lepomis macrochirus*	fingerlings	96h	LC50	MOR		2094	20	100	**Geometric mean**

[a] Multiply by conversion factor of 4.43x to convert to NO_3

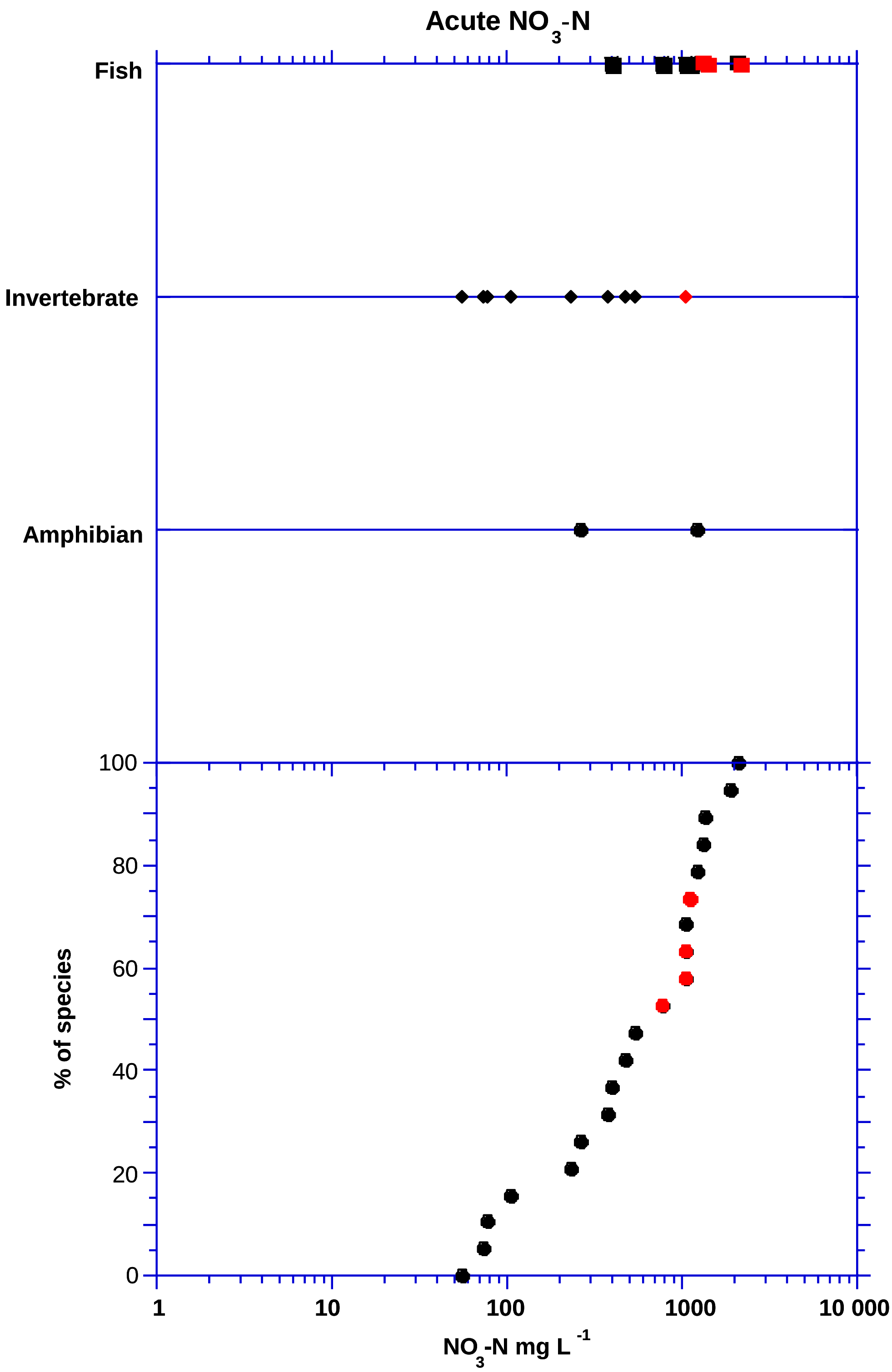


Figure 3-1 Cumulative species sensitivity distribution for <u>acute</u> toxicity dataset. Species resident in Canterbury indicated in red

3.2.2 Chronic data

A summary of the 16 chronic NOEC results are provided in Table 3.3 and shown in Figure 3-2. The details are contained in Appendix 4. These include: 7 fish, 4 invertebrate; and 3 amphibian species. The dataset spans a 224-fold range in sensitivity, with lake trout (*Salvelinus namaycush*) the most sensitive, with a NOEC of 1.6 mg NO_3-N/L for both growth and development endpoints measured after a 146 day exposure. In general, the chronic fish data indicates higher exposure sensitivity, though both fish and invertebrates show wide ranges in sensitivity (Figure 3-2). The most sensitive invertebrate NOEC (a freshwater crayfish) was 8.8x less sensitive than the most sensitive fish NOEC.

None of the eight publications included in the selected chronic studies were used in the ANZECC (2000) derivation. Most of these included studies scored a "C" classification ("complete") based on the ANZECC (2000) system, and either a "primary" or "secondary" under the Environment Canada classification (Appendix 2), with the exception of the "A" classification ("ancillary") for Kinchloe *et al*. (1979), which is addressed below. The reference codes and classifications are shown in Appendix 4.

The key primary data are the recent long-term (126-146 day) chronic studies of fish sensitivity by McGurk *et al*. (2006), who measured acute and chronic sensitivity of embryos, alevins, and swim-up fry of lake trout (*Salvelinus namaycush*) and lake whitefish (*Coregonus clupeaformis*) under laboratory conditions. The lake trout were the most sensitive species with a NOEC of 1.6 mg NO_3-N/L, and LOEC values of 6.25 mg NO_3-N/L for both growth (GRO) and development (DEV) endpoints (Table 3.3). Growth showed a progressive concentration-response with a 12% reduction in wet-weight at the LOEC value and a 22% reduction at 25 mg NO_3-N/L. The delayed development endpoint (>90% fry) is included for comparison but was not included in the guideline derivation calculation because growth was considered a more ecologically relevant measure.

The rainbow trout data was limited to two concurrent tests undertaken for fry of resident and anadromous ("Steelhead") rainbow trout by Kinchloe *et al*. (1979). This study measured mortality effects on eggs and fry after a 30 day exposure period. The egg sensitivity data in this study was compromised by the mortalities associated with *Saprolegnia* fungal infestations and the data was not included for consideration. There is no indication that the fry were adversely affected by fungal infestation, with good control survival (>95%) and a partial concentration-response for the "non-anadromous" rainbow trout. The NOEC values for the two trout types were 1.1 mg NO_3-N/L and >4.5 mg NO_3-N/L. We have included a geometric mean value for the reported nominal NOEC concentrations for use in the guideline derivation. Neither the stock solution nor the exposure solution concentrations were analytically confirmed in this study. Environment Canada (2003) did not include the results of this study in their nitrate guideline derivation because of fungal concerns about the fungal infestations.

The only tropical data excluded from the guideline derivation was for the freshwater prawn (*Macrobrachium rosenbergii*) (Wickins 1976) that is cultivated in New Zealand only in heated aquaculture facilities.

Environment Canada (2003) provide additional review comments on nitrate publications, together with reasons for exclusion of some studies from their derivation process.

Table 3.3: Summary of chronic toxicity data for sodium nitrate exposure selected for the 2009 derivation. Highlighted (white on black) indicate species that are resident in Canterbury's rivers and lakes.

Group	Common name	Scientific name	Life Stage	Duration (h/d)	End-point	Effect	Temp (ºC)	NOEC (mg/L NO_3-N)[a]	LOEC (mg/L NO_3-N)[a]	Author
Fish	**Lake Trout**	***Salvelinus namaycush***	**Fry**	**146d**	**NOEC**	**DVP**	**7.5**	**1.6**	**6.25**	**McGurk *et al*. (2006)**
Fish	**Lake Trout**	***Salvelinus namaycush***	**Fry**	**146d**	**NOEC**	**GRO**	**7.5**	**1.6**	**6.25**	**McGurk *et al*. (2006)**
Fish	**Rainbow trout**	***Oncorhynchus mykiss***	**Fry**	**30d**	**NOEC**	**MOR**	**10**	**2.2**	**2.3, >4.5**	**Kinchloe *et al*. (1979) (Geo mean)**
Fish	**Chinook salmon**	***Oncorhynchus tshawytscha***	**Fry**	**30d**	**NOEC**	**MOR**	**10**	**2.3**	**4.5**	**Kinchloe *et al*. (1979)**
Fish	Lahontan cutthroat trout	*Salmo clarki*	Fry	30d	NOEC	MOR	13	4.5	7.6	Kinchloe *et al*. (1979)
Fish	Coho salmon	*Oncorhynchus kisutch*	Fry	30d	NOEC	MOR	10	>4.5	>4.5	Kinchloe *et al*. (1979)
Fish	Lake Whitefish	*Coregonus clupeaformis*	Fry	126d	NOEC	DVP	7.5	6.25	25	McGurk *et al*. (2006)
Amphibian	American Toad	*Bufo americanus*	Egg	23d	NOEC	HAT	5-10	>9.26		Laposata & Dunson (1998)
Amphibian	Pacific Treefrog	*Pseudacris regilla*	tadpoles	10d	NOEC	GRO	22	12.0		Schuytema & Nebeker (1999c)
Invertebrate	Freshwater crayfish	*Astacus astacus*		7d	NOAEL	MOR	15	>14.0		Jensen (1996)
Invertebrate	Water flea	*Ceriodaphnia dubia*	neonates					15.6		Scott & Crunkilton (2000) (Geo mean)
Amphibian	African clawed frog	*Xenopus laevis*	Embryo	120h	NOEC	GRO	22	24.8		Schuytema & Nebeker (1999a)
Fish	Lake Whitefish	*Coregonus clupeaformis*	Fry	126d	NOEC	MOR	7.5	25.0	100	McGurk *et al*. (2006)
Invertebrate	Florida apple snail	*Pomacea paludosa*						25.3		Corrao *et al*. (2006) (Geo mean)
Fish	Fathead minnows	*Pimephales promelas*	Embryos and larvae	11d	NOEC	MOR	25	358		Scott & Crunkilton (2000)
Invertebrate	Water flea	*Daphnia magna*	neonates	7d	NOEC	REP	25	358		Scott & Crunkilton (2000)

[a] Multiply by conversion factor of 4.43x to convert to NO_3

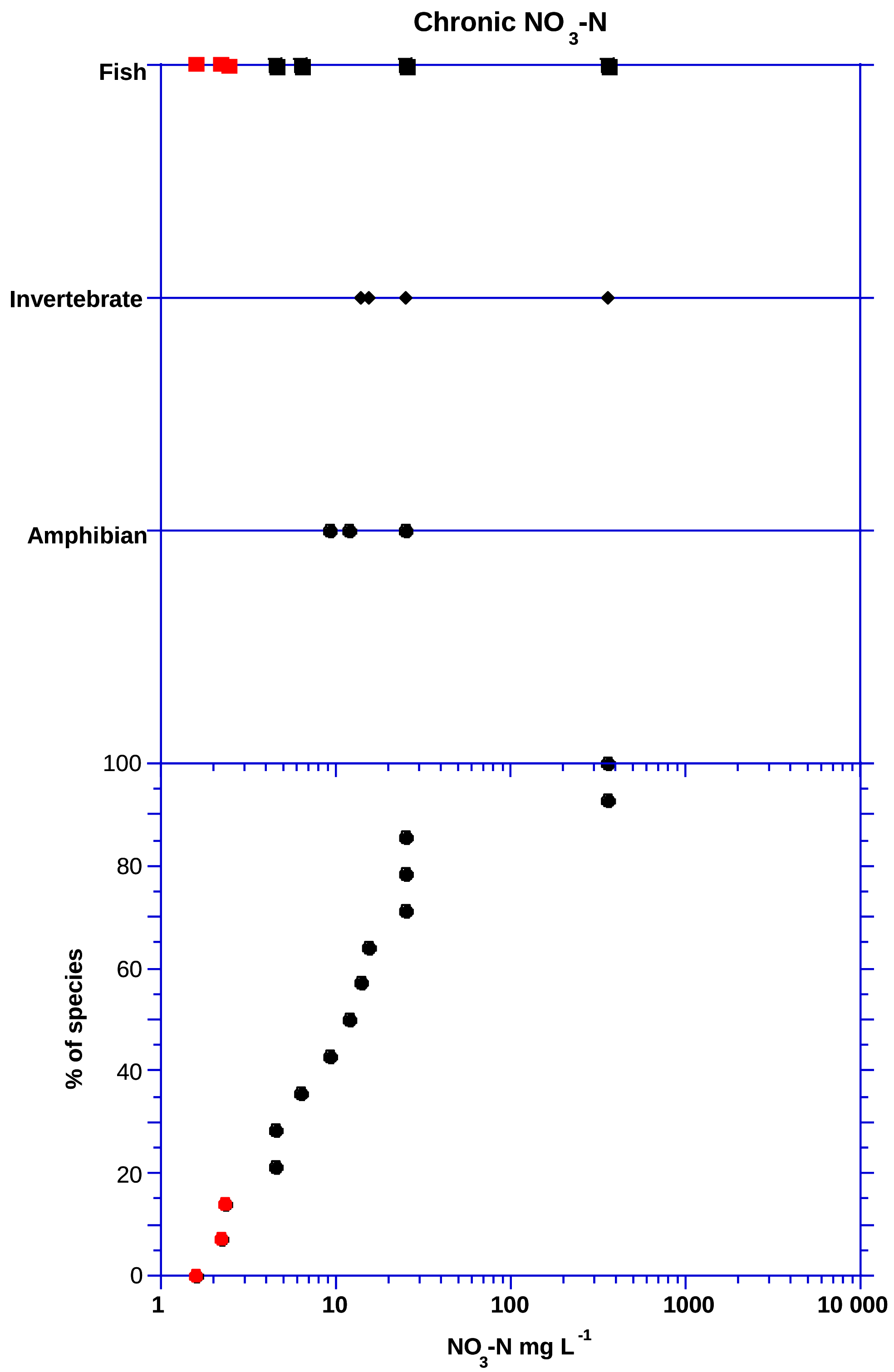


Figure 3-2 **Cumulative species sensitivity distribution for chronic toxicity dataset. Species resident in Canterbury indicated in red**

3.2.3 Generic acute and chronic guideline derivation

An **acute guideline** may be estimated from the species sensitivity distribution (Figure 3-1, Appendix 4 for model fit). The BurrIII model gave an acute 95%ile protection value of 39.7 mg NO_3-N/L. Following the US EPA procedure this value would be divided by a factor of 2 to provide an acute guideline of **20 mg NO_3-N/L**. This could be applicable to either short-term (<96 h) exposures or for application within mixing zones.

The **chronic guideline** trigger values were derived from the whole chronic dataset (Figure 3-3). Figure 3-3 shows a good fit of the BurrIII model to the dataset, with other alternative models (log-logistic, log-normal) shown. The trigger values were: 1.0 mg NO_3-N/L for 99% protection; **1.7 mg NO_3-N/L for 95% protection**; 2.4 mg NO_3-N/L for 90% protection; and 3.6 mg NO_3-N/L for 80% protection.

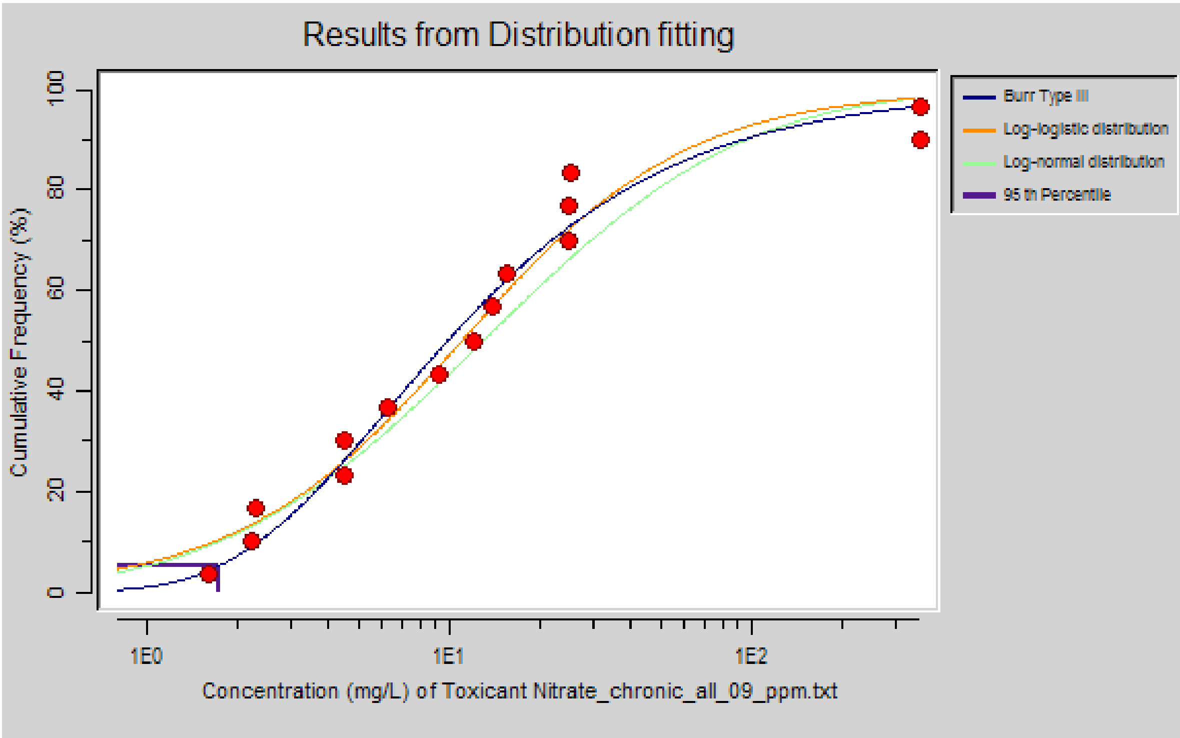


Figure 3-3 Cumulative frequency distribution plot with BurrIII model fit for chronic data. The 95th percentile guideline (1.7 mg NO_3-N/L) is shown

3.3 Site-specific guideline derivation

A site-specific guideline can be calculated by three alternative processes: (i) selection of local resident species from the acute or chronic datasets; (ii) recalculation using specific endpoints (e.g., recalculated from original data in publication); or (ii) selection of the most sensitive acute species and application of an acute-to-chronic ratio (ACR) to provide an estimated NOEC value.

The acute and chronic datasets have been highlighted for locally resident riverine and lake species and “representative” riverine species (Tables 3.2 & 3.3). The basis of this selection is discussed in the Section 4. Acute data is available for four resident species (a snail, rainbow trout, lake trout[4] & Chinook salmon), and eight representative/resident riverine species. However, the chronic dataset was more limited, with only three resident species (rainbow trout, lake trout & Chinook salmon), and no invertebrate species considered representative of riverine environments. These three fish species are represented by tests which fell in the lower 30 percentile of the sensitivity distribution. While there were other invertebrate species in the chronic data that could be considered representative of lake habitats (i.e., *Daphnia* and *Ceriodaphnia*), their sensitivity is markedly less than the most sensitive fish

[4] Lake trout or mackinaw (*Salvelinus namaycush*) are only present in Lake Pearson and are “often mistaken for poor-conditioned brown trout” McDowall (2000)

species (i.e., >9.8x). Notably, the rainbow trout data (Kincheloe *et al*. 1979) is among the most sensitive species (NOEC 2.2 mg NO_3-N/L), and may therefore be required to be retained as a "key" species. However, this publication is graded as "low-reliability" and therefore does not provide suitable assurance as the basis of a guideline. This very limited chronic dataset generally provides too few data to selectively modify to provide a site-specific, or species-specific derivation.

Some consideration can be given to recalculation of the guideline using alternative endpoints. The RMA (1991) is an effects-based legislation and thus consideration of the threshold for ecologically significant adverse effects should be considered. Examination of the nitrate chronic dataset shows the statistically significant effect threshold (LOEC) at 6.25 mg NO_3-N/L, with the threshold defined as the threshold effect concentration (TEC) (geometric mean of the NOEC + LOEC) of 3.2 mg NO_3-N/L.

An ACR of 9.9 was calculated for five species (3 fish, 2 invertebrate) based on acute (LC_{50}) and chronic (NOEC) data from two studies (Scott and Crunkilton 2000; McGurk *et al*. 2006) (Appendix 4, Table A4.3). The ACR values range widely (1.2 to 76), indicating the marked species-specific differences that may be expected for nitrate toxicity. Application of the average ACR to the most sensitive acute data (56.2 mg NO_3-N/L Table 3.2) gives an estimated NOEC of 5.7 mg NO_3-N/L, which is similar to the more sensitive chronic NOEC and LOEC values (Table 3.3). The ACR value could be applied to acute tests with site-specific native species to provide estimated NOECs for use in guideline derivation.

4 Discussion

Adequacy of the datasets

The derivation of water quality guidelines generally requires data of an international suite of species to be compiled in order to provide an adequately representative diversity of fish, invertebrates and other aquatic species. If there are substantive datasets, site-specific guidelines may be derived using a selection of species which are resident in the specific region or type of water-body (e.g., lakes or rivers). Additionally, tests with specific life-stages (e.g., eggs or embryo-larvae) may be omitted if they do not occur in the specific habitat.

We have identified the species known to be resident in Canterbury, together with representatives of those habitats from closely related families for the acute and chronic datasets (Tables 3.2 & 3.3). The acute data had only four species found in Canterbury's water bodies (rainbow trout, lake trout & Chinook salmon), including one indigenous species, the native snail, (*Potamopyrgus antipodarum*). However, there were also five representative species, including amphipods, caddisflies and a snail.

The two amphipods tested were the most sensitive acute species tested and would be expected to be representative of surface water and groundwater environments. Crustaceans have been found to be the predominant invertebrate group inhabiting Canterbury's and other New Zealand aquifers (Scarsbrook and Fenwick 2003; Gray *et al*. 2006). The most sensitive fish species was the rainbow trout, which was 19-fold less sensitive than the most sensitive species.

An acute exposure guideline of 20 mg NO_3-N/L has been calculated from this dataset. This could be applicable to either short-term (<96 h) exposures at specific sites or for application within mixing zones. An acute-to-chronic ratio (ACR) value may be used to estimate chronic exposure tolerance from measured acute values. New acute data for species representative of specific environments (e.g., groundwaters, lakes, trout spawning streams, lowland streams) could be used to provide the basis of site-specific "chronic" guidelines based on application of the ACR. Normally, five to eight species would be required to apply the SSD guideline derivation approach.

The chronic dataset has only three species that are found in Canterbury's rivers and lakes (rainbow trout, lake trout and Chinook salmon). These species are represented by three chronic fry exposures with endpoints in the lower 30 percentile of the sensitivity distribution (Table 3.3). While there are data on the sensitivity of invertebrate species to chronic nitrate exposure, the species are more commonly found in lentic (i.e., pond, lake) habitats (e.g., *Daphnia* & *Ceriodaphnia*), so riverine invertebrates are under-represented.

Are there any reasons why international studies will not be relevant to NZ aquatic fauna?

Some international aquatic studies contain species which are not present in the site-specific New Zealand environment. We have excluded tropical species data from the "generic" guideline derivations.

Amphibians and salamanders could be excluded from the dataset. The sensitivity of these species is generally poorly known compared to the more common fish and macroinvertebrate assemblages. As amphibians would be expected to be present in ponds and lakes, it would therefore be prudent to retain the existing amphibian data. These groups are not overly represented in the nitrate toxicity datasets, and excluding these groups would bias the guideline derivation.

The lack of chronic amphipod data raises concerns that this chronic guideline fails to protect species in groundwater environments. For example, the most sensitive invertebrates (freshwater crayfish, *Astacus astacus*; and the crustacean, *Ceriodaphnia dubia*) have chronic NOECs of >14.0 & 15.6 mg NO_3-N/L, which is 8.2-fold higher than the 95th percentile guideline value. An estimated chronic NOEC for the most sensitive acute amphipod species is 5.7 mg NO_3-N/L (using the ACR conversion), which would be adequately protected by the 95th percentile guideline value. Without benchmarking sensitivity data for relevant (preferably local) species the adequacy, or otherwise, cannot be determined.

What is the importance of managing short-term exceedences of any toxicity threshold as well as long-term exposure (i.e., 1 – 3 month period)?

Exposures of 1–3 months would be considered chronic exposure periods. Shorter duration exposures may occur in point source mixing zones or irrigation bywash flows where intermittent exposure could occur. We have calculated an acute guideline which could be used for such short-term exposures.

A chronic guideline with a lower protection threshold could be used for these seasonal periods of high background nitrate. An 80% percentile chronic guideline would be 3.6 mg NO_3-N/L. Use of this guideline for seasonal maxima would not be expected to result in marked ecological effects on broad ecological communities, given that the remainder of the year had lower concentrations of nitrate.

However, for communities making important seasonal use of these environments for critical life-stages at these times this might not hold true. For example, trout and salmon spawning in lowland spring creeks could be disproportionately affected by 1–3 month periods of high nitrate concentration exposure to eggs and fry in these high risk periods. Therefore, care should be exercised in applying the chronic guidelines that offer lower degrees of protection.

Generally, a conservative application of the 95%ile chronic guideline would be applied to discharge or managed inflow (e.g., groundwater intrusions) situations. Under the RMA, a chronic guideline would be applied after consideration of "reasonable mixing" with the receiving water.

Comment on the recommendations made by Carmago et al. (2005). Are there likely to be any sensitive aquatic communities in Canterbury that require a lower nitrate threshold?

Camargo *et al*. (2005) recommend (p1264) "… a maximum level of 2.0 mg NO_3-N/L would be appropriate for protection the most sensitive freshwater species". This value is similar to that which we have derived using the ANZECC (2000) and the Environment Canada (CCME 2007) methodology with the updated chronic dataset. Notably, the Environment Canada (2003) derives a "interim" water quality guideline of 2.9 mg NO_3-N/L [5].

Canterbury's groundwaters would be considered in many countries to be pristine and to contain potentially highly sensitive species, however, others are more modified and reflect the cumulative effects of the last 150 years of farming. The ANZECC (2000) guidelines would classify the pristine aquifers as (p3.1-10):

***High conservation/ecological value systems** — effectively unmodified or other highly-valued ecosystems, typically (but not always) occurring in national parks, conservation reserves or in remote and/or inaccessible locations. While there are no aquatic ecosystems in Australia and New Zealand that are entirely without some human influence, the ecological integrity of high conservation/ecological value systems is regarded as intact.*

Such environments would be afforded a 99th percentile protection level, which is 1.0 mg NO_3-N/L. However, based on consideration of the species sensitivity distribution in the chronic dataset, we would not recommend application of this data for use in sensitive groundwater environments without first benchmarking the sensitivity of representative key species (e.g., toxicity testing of native amphipods).

The majority of groundwaters (and surface waters) would be classified as:

***Slightly to moderately disturbed systems —** ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity. The biological communities remain in a healthy condition and ecosystem integrity is largely retained. Typically, freshwater systems would have slightly to moderately cleared catchments and/or reasonably intact riparian vegetation; marine systems would have largely intact habitats and associated biological communities. Slightly–moderately disturbed systems could include rural streams receiving runoff from land disturbed to varying degrees*

[5] Note: (i) that the Canadian guideline value is 13 mg NO_3/L, which is multiplied by 0.23 to convert to mg NO_3-N/L; (ii) The Canadian guideline is derived from the measured effect threshold on the most sensitive species with the application of a 0.1x "safety factor"

by grazing or pastoralism, or marine ecosystems lying immediately adjacent to metropolitan areas.

Such environments would be afforded a 95th percentile protection level, which is 1.7 mg NO_3-N/L.

The more modified groundwaters (or surface waters) could be classified as:

Highly disturbed systems. *These are measurably degraded ecosystems of lower ecological value. Examples of highly disturbed systems would be some shipping ports and sections of harbours serving coastal cities, urban streams receiving road and stormwater runoff, or rural streams receiving runoff from intensive agriculture or horticulture.*

Such environments would be afforded a 90th or 80th percentile protection level, which is 2.4 – 3.6 mg NO_3-N/L. Alternatively, a site-specific guideline could be calculated for these environments based on sensitivity measurements for representative local or valued species. Such measurements could be based on either chronic data or acute data with application of the ACR to estimate suitable chronic guidelines.

Advise whether the ANZECC 2000 toxicity limits are appropriate for Canterbury's water bodies, and if not comment on the revised toxicity limits (see 2) and why these have been revised.

As noted earlier, the ANZECC (2000) guidelines for nitrate contains errors in the derivation procedure, although Environment Canterbury has been using the corrected guideline value of 7.2 mg NO_3-N/L[2]. However, our present more detailed review has identified further transcription/calculation errors from the original papers which were not cited in the 2002 review, including the use of potassium nitrate data (see Appendix 3). We have corrected those errors in this review and incorporated the corrected data in this derivation. The original ANZECC (2000) derivation was based on 12 nominal "acute" results with the use of an ACR of 10 to derive the guideline. This review includes updated and expanded data with chronic results for 15 species.

We would recommend that this revised nitrate guideline value for 95% protection of 1.7 mg NO_3-N/L be used for Canterbury's rivers and lakes. Site-specific consideration for seasonally varying background levels (1–3 months duration), could use the lower protection threshold of 3.6 mg NO_3-N/L (80% protection value), if the seasonal period did not specifically serve sensitive species or life-stages, recognising that the remainder of the year would provide higher levels of protection.

Discontinuous point source discharges should not exceed the acute guideline, 20 mg NO_3-N/L, after "reasonable mixing". The acute guideline value could be applicable to either short-term (<96 h) exposures or for application within mixing zones.

5 Recommendations

Some information gaps were identified in undertaking this review. Normally, the requirements for guideline derivation would include representative photo-trophic species (i.e., planktonic algae and/or macrophytes). However, as nitrate is a beneficial nutrient for plant growth, the assessment of sensitivity to plants would not be required for normal environmental exposures.

The datasets are particularly lacking in species which are known to be of high sensitivity to contaminants and dominate the fauna in river environments. Studies have shown that amphipods, mayflies and some native fish species are more sensitive to some chemical contaminants than the standard international test species such as cladocerans and rainbow trout (Hickey 2000). No information is currently available on the sensitivity of native fish species to nitrate.

Validation of the nitrate guideline value could use a combination of laboratory testing with selected species and field assessment validation of effects on invertebrate communities. River sites with high nitrate groundwater inflows could provide suitable sites with gradients of mixed concentrations suitable for these studies. Environment Canada (CCME 2007) does not accept field studies for guideline derivation because the sites usually have a range of unmeasured variables (stressors) operating between sites, but they serve useful validation for laboratory-based tests.

However, for nitrate, we consider that a range of sites may be found which would provide a suitable basis for a field-based validation of guidelines. We have previously used this approach for investigating thresholds for effects on stream macroinvertebrates of: oxidation ponds (Quinn and Hickey 1993); inorganic suspended solids (Quinn *et al*. 1992); heavy metals (Hickey and Clements 1998); substrate particle size (Quinn and Hickey 1990b); and land-use development (Quinn and Hickey 1990a). We have also successfully used river mesocosms for establishing macroinvertebrate thresholds for ammoniacal-N (Hickey *et al*. 1999) and heavy metals (Hickey and Golding 2002).

A summary of the 2009 revision of the freshwater nitrate guidelines suitable for application to freshwaters of Canterbury is provided in Table 5.1.

Table 5.1 Summary of site-specific guidelines for nitrate (NO_3-N) for application to freshwater environments in Canterbury

Guideline type	Application to:	Guideline value (mg NO_3-N/L)[a]
Acute	Very localised point source discharges.	20 mg NO_3-N/L
Chronic – high conservation value systems (99% protection)	Pristine environments with high biodiversity and conservation values.	1.0 mg NO_3-N/L
Chronic – slightly to moderately disturbed systems (95% protection)	Environments which are subjected to a range of disturbances from human activity.	1.7 mg NO_3-N/L
Chronic – highly disturbed systems (80 to 90% protection)	Specific environments which: (i) either have measurable degradation; or (ii) which receive seasonally high elevated background concentrations for significant periods of the year (1-3 months).	2.4 – 3.6 mg NO_3-N/L
Chronic – site-specific (species-specific protection)	Collection of specific data for representative species and life-stages with calculation of site-specific guideline values.	No data

[a] Multiply by conversion factor of 4.43x to convert to NO_3

6 Acknowledgements

This work was supported by Environment Canterbury, with a contribution from the Ministry for the Environment. The authors wish to thank the Dr Rick van Dam and Dr Andrew Harford, Environmental Research Institute of the Supervising Scientist, Australia for undertaking a comprehensive review of an earlier version the report, and staff at Environment Canterbury for their comments.

7 Glossary

Acute toxicity	Is a discernible adverse effect (lethal or sublethal) induced in the test organisms within a short period (relative to the duration of the species life cycle) of exposure to a test material.
Chronic toxicity	Implies long-term effects that are related to changes in metabolism, development, growth, reproduction, or ability to survive. In this test, chronic toxicity is a discernible adverse effect (lethal or sublethal) induced in the test organism during a significant and sensitive part of the life-cycle.
EC_{50}	Is the median effective concentration (i.e., the concentration of material in water that is estimated to produce a specifically quantified effect to 50% of the test organisms) after a specified exposure time. The EC_{50} and its 95% confidence limits are usually derived by statistical analysis of a quantal, “all or nothing”, response (such as death, fertilization, germination, or development) in several test concentrations, after a fixed period of exposure.
Endpoint	The adverse biological response in question that is measured. May vary with the level of biological organisation examined, but may include biochemical markers, mortality or reproduction. End points are used in toxicity tests as criteria for effects.
IC_{50}	Is the median inhibition concentration, i.e., the concentration estimated to cause a 50% reduction in growth compared to a control. The exposure time must be specified, e.g., “IC_{50} (72 h)”, for a growth rate derived IC_{50} and a test duration of 72 h.
Indigenous	Species that have evolved in or spread naturally into this habitat. Sometimes termed **native** or **endemic** species.
Introduced	Species that have become able to survive and reproduce outside the habitats where they evolved or spread naturally. Sometimes termed **exotic** or **non-indigenous** species.
Lethal	Means causing death by direct action. Death of fish is defined as the cessation of all visible signs of movement or other activity.
LC_{50}, LC_{20}	The lethal toxicant concentration resulting in a 50% or 20% mortality (respectively) at a specific time of exposure, (e.g. 48 hr LC_{50}).
LOEC	Lowest observed effect concentration. The lowest concentration tested causing a statistically measurable effect to the test system. Derivation of this value is strongly influenced by the selected test concentrations.
MATC	Maximum Acceptable Toxicant Concentration = geometric mean of NOEC + LOEC.

NOEC	No observed effect concentration. The highest concentration tested causing no statistically measurable effect to the test system. Derivation of this value is strongly influenced by the selected test concentrations.
Representative	Species that have the same genus in this habitat.
TEC	Threshold Effect Concentration = geometric mean of NOEC + LOEC.
Toxicity test	Is a method to determine the effect of a material on a group of selected organisms under defined conditions. An aquatic toxicity test usually measures either (a) the proportions of organisms affected (quantal) (e.g., by measuring EC_{50}), or (b) the degree of effect shown (graded or quantitative) after exposure to specific concentrations of whole effluents or receiving water as measured by an IC_{50}.
Toxicity	Is the inherent potential or capacity of a material to cause adverse effects on living organisms.

8 List of Acronyms

ANZECC	Australian and New Zealand Environment and Conservation Council
CAS	Chemical Abstracts Service
CCME	Canadian Council of Ministers of the Environment
CCREM	Canadian Council of Resource and Environment Ministers
CV	coefficient of variation
[C]WQG	[Canadian] Water Quality Guidelines
DIN	dissolved inorganic nitrogen
DO	dissolved oxygen
DOC	dissolved organic carbon
DOM	dissolved organic matter
DON	dissolved organic nitrogen
EC	effects concentration
ECan	Environment Canterbury
EC_{50}	median effects concentration
KNO_3	potassium nitrate
LC_{50}	median lethal concentration
LO[A]EL	lowest observed [adverse] effects level
LOEC	lowest observed effects concentration
MATC	Maximum Acceptable Toxicant Concentration
N_2	molecular nitrogen
$NaNO_3$	sodium nitrate
NH_3	un-ionized ammonia
NH_4^+	ammonium ion
NH_4NO_3	ammonium nitrate
NO_2	nitrite
NO_3	nitrate
NO_3-N	nitrate-nitrogen
NO[A]EL	no observed [adverse] effects level
NOEC	no observed effect concentration
SSD	species sensitivity distribution

9 References

ANZECC (2000). Australian and New Zealand guidelines for fresh and marine water quality. National Water Quality Management Strategy Paper No. 4, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, Australia.

Camargo, J.A.; Alonso, A.; Salamanca, A. (2005). Nitrate toxicity to aquatic animals: a review with new data for freshwater invertebrates. *Chemosphere 58*: 1255-1267.

CCME (2007). A protocol for the derivation of water quality guidelines for the protection of aquatic life 2007. No. In Canadian environmental quality guidelines, 1999. Canadian Council of Ministers of the Environment, 1999, Winnipeg. pp. 37.

Colt, J.; Tchobanoglous, G. (1976). Evaluation of the short-term toxicity of nitrogenous compounds to channel catfish, *Ictalurus punctatus*. *Aquaculture 8*: 209-221.

Environment Canada (2003). Canadian Water Quality Guidelines for the Protection of Aquatic Life: Nitrate Ion. No. Ecosystem Health: Science-based Solutions Report 1-6. National Guidelines and Standards Office, Water Policy and Coordination Directorate, Environment Canada, Ottawa. pp. 115.

Gray, D.; Scarsbrook, M.R.; Harding, J.S. (2006). Spatial biodiversity patterns in a large New Zealand braided river. *New Zealand Journal of Marine and Freshwater Research 40*: 631-642.

Hickey, C.W. (2000). Ecotoxicology: laboratory and field approaches. In: *New Zealand stream invertebrates: Ecology and implications for management*. K. C. Collier; M. Winterbourn, ed. New Zealand Limnological Society, Christchurch, New Zealand. Vol. pp. 313-343.

Hickey, C.W.; Clements, W.H. (1998). Effects of heavy metals on benthic macroinvertebrate communities in New Zealand streams. *Environmental Toxicology and Chemistry 17*: 2338-2346.

Hickey, C.W.; Golding, L.A. (2002). Response of macroinvertebrates to copper and zinc in a stream mesocosm. *Environmental Toxicology and Chemistry 21*: 1854-1863.

Hickey, C.W.; Golding, L.A.; Martin, M.L.; Croker, G.C. (1999). Chronic toxicity of ammonia to New Zealand freshwater invertebrates: a mesocosm study. *Archives of Environmental Contamination and Toxicology 37*: 338-351.

Kincheloe, J.W.; Wedemeyer, G.A.; Koch, D.L. (1979). Tolerance of developing salmonid eggs and fry to nitrate exposure. *Bulletin of Environmental Contamination and Toxicology 23*: 575-578.

McGurk, M.D.; Landry, F.; Tang, A.; Hanks, C.C. (2006). Acute and chronic toxicity of nitrate to early life stages of lake trout (Salvelinus namaycush) and lake whitefish (Coregonus clupeaformis). *Environmental Toxicology and Chemistry 25*: 2187-2196.

Meade, M.E.; Watts, S.A. (1995). Toxicity of ammonia, nitrite, and nitrate to juvenile Australian crayfish, *Cherax quadricarinatus*. *Journal of Shellfish Research 14*: 341-346.

Quinn, J.M.; Davies-Colley, R.J.; Hickey, C.W.; Vickers, M.L.; Ryan, P.A. (1992). Effects of clay discharges on streams 2. Benthic invertebrates. *Hydrobiologia 248*: 235-247.

Quinn, J.M.; Hickey, C.W. (1990a). Characterisation and classification of benthic invertebrate communities in 88 New Zealand rivers in relation to environmental factors. *New Zealand Journal of Marine and Freshwater Research 24*: 387-409.

Quinn, J.M.; Hickey, C.W. (1990b). Magnitude of effects of substrate particle size, recent flooding, and catchment development on benthic invertebrates in 88 New Zealand rivers. *New Zealand Journal of Marine and Freshwater Research 24*: 411-427.

Quinn, J.M.; Hickey, C.W. (1993). Effects of sewage stabilization lagoon effluent on stream invertebrates. *Journal of Aquatic Ecosystem Health 2*: 205-219.

RMA (1991). Resource Management Act, 1991. Wellington, New Zealand, Ministry for the Environment, New Zealand Government.

Scarsbrook, M.R.; Fenwick, G.D. (2003). Preliminary assessment of crustacean distribution patterns in New Zealand groundwater aquifers. *New Zealand Journal of Marine and Freshwater Research 37*: 405-413.

Scott, G.; Crunkilton, R.L. (2000). Acute and chronic toxicity of nitrate to fathead minnows (*Pimephales promelas*), *Ceriodaphnia dubia*, and *Daphnia magna*. *Environmental Toxicology and Chemistry 19*: 2918-2922.

Stephan, C.E.; Mount, D.I.; Hansen, D.J.; Gentile, J.H.; Chapman, G.A.; Brungs, W.A. (1985). Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses. No. EPA 600/53-84-099. Office of Research and Development, U.S. Environmental Protection Agency, Washington D.C. pp. 98.

Tilak, K.S.; Lakshmi, S.J.; Susan, T.A. (2002). The toxicity of ammonia, nitrite and nitrate to the fish, *Catla catla* (Hamilton). *Journal of Experimental Biology 23*: 147-149.

Tilak, K.S.; Vardhan, K.S.; Kumar, B.S. (2006a). Comparitive toxicity levels of ammonia, nitrite and nitrate to the freshwater fish *Ctenopharyngodon idella*. *Journal of Ecotoxicology and Environmental Monitoring 16*: 273-278.

Tilak, K.S.; Veeraiah, K.; Lakshmi, S.J. (2006b). Effects of ammonia, nitrate and nitrite on toxicity and haematological changes in the carps. *Journal of Ecotoxicology and Environmental Monitoring 16*: 9-12.

Tilak, K.S.; Veeraiah, K.; Raju, J.M.P. (2006c). Toxicity and effects of ammonia, nitrite and nitrate and histopathological changes in the gill of freshwater fish *Cyprinus carpio*. *Journal of Ecotoxicology and Environmental Monitoring 16*: 527-532.

US EPA (2002). National recommended water quality criteria: 2002. No. EPA 822-R-02-047. United States Environmental Protection Agency, Office of Water, Washington D.C. pp.

Wickins, J.F. (1976). The Tolerance of Warm-Water Prawns to Recirculated Water. *Aquaculture 9*: 19-37.

Appendix 1 Effect codes

Table A1.1 Effects codes used (from ANZECC 2000)

Effect Code	Effect
ABD	Abundance
ABN	Abnormality
BIOLUM	Bioluminescent
BIOMASS	Biomass
DVP	Development
EMR	Emergence
FRT	Fertilisation
GRO	Growth (length or weight)
HAT	Hatchability
IMM	Immobilisation
LUM	Luminescent
MOR	Mortality
NR	Not Recorded
PGR	Population growth rate
POP	Population
PRP	Predator-prey dynamics
PSE	Photosynthesis
PSR	Photosynthetic rate
REP	Reproduction

Appendix 2 Data quality assessment

The ANZECC (2000) water quality guidelines used a data documentation system based on the US EPA AQUIRE classification system operating at that time. The fields and score allocations are summarised below (Table 8.3.1 from ANZECC 2000). The scores were categorised as: complete ("C" = 86-100); moderate ("M" = 51-85) or incomplete ("I" = <51). Data with an "I" classification were not included in the guideline derivation procedure without special consideration. ANECC (2000) also provides guidance on dealing with outlying data (section 8.3.4.2).

Table 8.3.1 AQUIRE (1994) fields and scores

AQUIRE Field	Score Points
Exposure duration	20
Control type	5
Organism characteristics	5
Chemical analysis method	5
Exposure type	5
Test location	4
Chemical grade	4
Test media	4
Hardness (freshwater exposures) Salinity (saltwater) 4 total	2
Alkalinity (freshwater exposures) Salinity (saltwater)	2
Dissolved oxygen	2
Temperature	2
pH	2
End-point	20
Trend of effect	5
Effect percent	5
Statistical significance	4
Significance level	4

Environment Canada (CCME 2007) provides specific recommendations for assessing data quality based on and a three level classification system. These are:

(i) "Primary data", with requirements including: toxicity tests must employ currently acceptable laboratory or field practices of exposure and environmental controls; as a minimum requirement for primary data, substance concentrations must be measured at the beginning and end of the exposure period; generally, static laboratory tests are not classified as primary data unless it can be shown that substance concentrations did not change during the test; preferred test endpoints from a partial or full life-cycle test include a determination of effects on embryonic development, hatching, or germination success, survival of juvenile stages, growth, reproduction, and survival of adults. Additional test endpoints, such as behavioural or endocrine-disrupting effects, can be included if it can be shown that these effects are a result of exposure to the parameter in question, lead to an ecologically relevant negative impact, and are scientifically sound; a clear dose-response relationship should be demonstrated in the study; controlled microcosm and mesocosm studies are acceptable and are ranked according to the applicable categorization criteria.

(ii) “Secondary data”, with requirements including: Secondary data are those that originate from studies where primary data cannot be generated, but are still of acceptable quality and documentation. Toxicity tests may employ a wider array of methodologies (e.g., measuring toxicity while test species are exposed to additional stresses such as low temperatures, lack of food, or high salinity). All relevant environmental variables that modify toxicity should be measured and reported. The survival of controls must be measured and reported; static tests, calculated substance concentrations, and measurements taken in stock solutions are generally acceptable; appropriate test replication is necessary; Preferred test endpoints include those listed for primary data as well as pathological, behavioural (if their ecological relevance can be shown, but not as clearly as for primary data), and physiological effects.

(iii) “Unacceptable data”, with requirements including: Toxicity data that do not meet the criteria of primary or secondary data are unacceptable for guideline derivation purposes. Unacceptable data cannot be used to fulfil minimum data set requirements for any derivation procedure; these data should be discussed and the reasons for their rejection clearly stated.

Appendix 3: June 2009 review of the ANZECC (2000) nitrate guideline derivation

Table A3.1 Original document from ANZECC (2000) document: "TOX-TVderivation.pdf" (p26), showing error in initial derivation. Note: this does not include new acute or chronic data.

Nitrate (NO_3)
Freshwater
Fails HR

MR Calculations

The data used to derive the TV were:

~~340406.4~~ 4854500 (a)	~~896847.9~~ (b)	~~7630126~~ 6391817 (c)	~~5582000~~ 5584429 (d)
~~14000~~ (e)	5998000	5799000	~~720085.7~~ 1252086 (f)
733058.5	576645.9	~~723490.7~~ 2198980 (g)	~~9000~~ (e)

HC1 50% = ~~167.4~~ 139330
HC5 50% = ~~6855~~ 482018
HC10 50% = ~~33909~~ 823270
HC20 50% = ~~167737~~ 1411644

NOTE: Because this TV was derived using acute toxicity data it is a MR TV and must be divided by either a default AF of 10 or an ACR. There was no ACR for this chemical.

~~MR TV = 6855/10 = 685.5 = 685 µg/L~~

MR TV = 482018/10 = 48201.8 = 48201 µg/L

The other levels of protection are:

99%	95%	90%	80%
~~16.74~~	~~685.5~~	~~3390.9~~	~~16773.7~~
13933	48201	82327	141164

These were rounded off to

~~17 700 3400 17 000 µg/L~~

2009 conversion to mg NO_3-N (x0.00023)

99%	**95%**	**90%**	**80%**
3.2	**11.1**	**18.9**	**32.5**

Footnotes for 2009 mark-up revision:

(a) corrected value based on highest time exposure only (Eastern mosquito fish)
(b) potassium salt (Guppy))
(c) 10x transcription error (Bluegills)
(d) 10x transcription error (Guadalupe bass)
(e) potassium salts and chronic tests (Purple Spotted Gudgeon & Hydra)
(f) errors in database (Daphnia)
(g) database errors (Pond snail – *Lymnaea*)

Table A3.2 Marked-up download from ANZECC (2000) database (downloaded 2/8/2002) showing corrected nitrate (NO_3) concentrations and identifying potassium nitrate values

Water Quality Search Results **Date:** **2/08/2002 download from ANZECC 2000 database**

Toxicant **nitrate (NO_3)**

Latin Name / **Common**	**Test Media**	**Test Type**	**Duration (h)**	**Endpoint**	**Effect**	**Concent-ration Used**	**Units**	**Ref ID**	**Ref**	**Notes/Comments**	**Corrected NO_3 Conc** ug/L NO_3	Use Y/N
Fish												
U												
Gambusia holbrooki Eastern mosquitofish	Freshwater	Acute	48	LC50	MORT	1.00E+07	ug/L	200508	Wallen et al. (1957)	NaNO3 value. Correct value from paper	7300000	N
U												
Gambusia holbrooki Eastern mosquitofish	Freshwater	Acute	48	LC50	MORT	137000	ug/L	200508	Wallen et al. (1957)	Potassium nitrate value	no value	N
U												
Gambusia holbrooki Eastern mosquitofish	Freshwater	Acute	96	LC50	MORT	99000	ug/L	200508	Wallen et al. (1957)	NaNO3 value. Correct value from paper	4854500	Y
U												
Gambusia holbrooki Eastern mosquitofish	Freshwater	Acute	96	LC50	MORT	99000	ug/L	200508	Wallen et al. (1957)	Potassium nitrate value	no value	N
Geometric	340406.42									all 4 above geomean	5952969.8	
U												
Lebistes reticulatus Guppy	Freshwater	Acute	48	LC50	MORT	969000	ug/L	207635	Rubin & Elmargahy (1997)	Potassium salt	no value	N
U												
Lebistes reticulatus Guppy	Freshwater	Acute	72	LC50	MORT	881000	ug/L	207635	Rubin & Elmargahy (1997)	Potassium salt	no value	N
U												
Lebistes reticulatus Guppy	Freshwater	Acute	96	LC50	MORT	845000	ug/L	207635	Rubin & Elmargahy (1997)	Potassium salt	no value	N
Geometric	896847.91											
U												
Lepomis macrochirus Bluegill	Freshwater	Acute	96	LC50	MORT	1.42E+07	ug/L	208037	Trama (1954)	Not sodium nitrate - could be calcium value (?).	no value	N
U												
Lepomis macrochirus Bluegill	Freshwater	Acute	96	LC50	MORT	885300	ug/L	208037	Trama (1954)	Wrong value, possibly incorrectly calculated, this value used in Camargo (2005)	1973000	

Friday, 2 August 2002 *Page 1 of 6*

Toxicant **nitrate**

Latin Name Common	Test Media	Test Type	Duration (h)	Endpoint	Effect	Concentration Used	Units	Ref ID	Ref	Notes	Corrected Conc	Use Y/N
U *Lepomis macrochirus* Bluegill	Freshwater	Acute	96	LC50	MORT	900000	ug/L	200930	Cairns & Scheier (1959)	10x error, value from Aquire	9000000	Y
U *Lepomis macrochirus* Bluegill	Freshwater	Acute	96	LC50	MORT	940000	ug/L	200930	Cairns & Scheier (1959)	10x error, value from Aquire	9400000	Y
U *Lepomis macrochirus* Bluegill	Freshwater	Acute	96	LC50	MORT	186000	ug/L	208037	Trama (1954)	Potassium nitrate value	no value	N
U *Lepomis macrochirus* Bluegill	Freshwater	Acute	96	LC50	MORT	1.00E+07	ug/L	200930	Cairns & Scheier (1959)	Wrongly transcribed	10000000	Y
Geometric	7630126.3											
U *Micropterus treculi* Guadalupe bass	Freshwater	Acute	96	LC50	MORT	558200	ug/L	211794	Tomasso & Carmichael (1986)	10x error, value confirmed from paper	5584428.6	Y
Geometric	5582000											
U *Oncorhynchus mykiss* Rainbow trout	Freshwater	Acute	96	LC50	MORT	599800	ug/L	205115	Westin (1974)	10x error, confirmed from paper	6000000	Y
Geometric	5998000									correct value		
U *Oncorhynchus* Chinook salmon	Freshwater	Acute	96	LC50	MORT	579900	ug/L	205115	Westin (1974)	10x error, confrimed from paper	5800000	Y
Geometric	5799000									correct value		
crustaceans												
U *Daphnia magna* Water flea	Freshwater	Acute	48	LC50	MORT	358100	ug/L	200915	Dowden & Bennett (1965)	10x error, NaNO3 value	2612330	N
U *Daphnia magna* Water flea	Freshwater	Acute	48	LC50	MORT	358100	ug/L	202465	Dowden (1961)	10x error, NaNO3 value	2610200	Y
U *Daphnia magna* Water flea	Freshwater	Acute	48	LC50	MORT	301000	ug/L	200915	Dowden & Bennett (1965)	Potassium nitrate value	no value	N

Friday, 2 August 2002 *Page 2 of 6*

nitrate

Latin Name Common	Test Media	Test Type	Duration (h)	Endpoint	Effect	Concent-ration Used	Units	Ref ID	Ref	Notes	Corrected Conc	Use Y/N
U *Daphnia magna* Water flea	Freshwater	Acute	72	LC50	MORT	212500	ug/L	200915	Dowden & Bennett (1965)	calculated from paper	1550182.4	Y
U *Daphnia magna* Water flea	Freshwater	Acute	72	LC50	MORT	137000	ug/L	200915	Dowden & Bennett (1965)	Potassium nitrate value	no value	N
U *Daphnia magna* Water flea	Freshwater	Acute	96	LC50	MORT	420600	ug/L	200915	Dowden & Bennett (1965)	calculated from paper	485115.9	Y
U *Daphnia magna* Water flea	Freshwater	Acute	96	LC50	MORT	665000	ug/L	200915	Dowden & Bennett (1965)	Potassium nitrate value	no value	N
U *Daphnia magna* Water flea	Freshwater	Acute	96	LC50	MORT	23000	ug/L	200915	Dowden & Bennett (1965)	Potassium nitrate value	no value	N
Geometric	720085.68											
Insects												
U *Cheumatopsyche pettiti* Caddisfly	Freshwater	Acute	72	EC50	MORT	845000	ug/L	203879	Camargo & Ward (1992)	Calculated from paper, rounded	845000	Y
U *Cheumatopsyche pettiti* Caddisfly	Freshwater	Acute	72	EC50	MORT	930000	ug/L	203879	Camargo & Ward (1992)	Calculated from paper, rounded	930000	Y
U *Cheumatopsyche pettiti* Caddisfly	Freshwater	Acute	96	EC50	MORT	732000	ug/L	203879	Camargo & Ward (1992)	Calculated from paper, rounded	732000	Y
U *Cheumatopsyche pettiti* Caddisfly	Freshwater	Acute	96	EC50	MORT	502000	ug/L	203879	Camargo & Ward (1992)	Calculated from paper, rounded	502000	Y
Geometric	733058.47											
U *Hydropsyche* Caddisfly	Freshwater	Acute	72	LC50	MORT	657000	ug/L	203879	Camargo & Ward (1992)	Calculated from paper, rounded	657000	Y
U *Hydropsyche* Caddisfly	Freshwater	Acute	72	LC50	MORT	812000	ug/L	203879	Camargo & Ward (1992)	Calculated from paper, rounded	812000	Y

nitrate

Latin Name Common	Test Media	Test Type	Duration (h)	Endpoint	Effect	Concent-ration Used	Units	Ref ID	Ref	Notes	Corrected Conc	Use Y/N
U *Hydropsyche* Caddisfly	Freshwater	Acute	96	LC50	MORT	430000	ug/L	203879	Camargo & Ward (1992)	Calculated from paper, rounded	430000	Y
U *Hydropsyche* Caddisfly	Freshwater	Acute	96	LC50	MORT	482000	ug/L	203879	Camargo & Ward (1992)	Calculated from paper, rounded	482000	Y
Geometric	576645.92											
Molluscs												
U *Lymnaea sp* Pond snail	Freshwater	Acute	48	EC50	HAT	914000	ug/L	200508	Wallen (1957)	Potassium nitrate value. Not in Wallen (1957) based on AQUIRE; may be from Dowden & Bennet (1965) (?) --> corrected conc.	4712554.4	Y
U *Lymnaea sp* Pond snail	Freshwater	Acute	72	EC50	HAT	624000	ug/L	200508	Wallen (1957)	See above comment.	4340510.6	Y
U *Lymnaea sp* Pond snail	Freshwater	Acute	96	EC50	HAT	664000	ug/L	200915	Dowden & Bennett (1965)	See above comment.	2371596.7	Y
Geometric	723490.7											
Fish												
U *Mogurnda mogurnda* Purple SpottedGudgeon	Freshwater	Chronic	216	NOEC	MORT	14000	ug/L	300119	Rippon & McBride	Potassium salt	no value	N
Geometric	14000											
Coelentrates												
U *Hydra viridissima* Hydra	Freshwater	Chronic	144	NOEC	PGR	9000	ug/L	300119	Rippon & McBride	Potassium salt	no value	N
Geometric	9000											
Fish												
U *Centropristis striata* Black sea bass	Marine	Acute	96	LC50	MORT	1.0624E	ug/L	209424		Marine	no value	N
Geometric	10624000											

nitrate

U												
Monacanthus hispidus Plane headFilefish	Marine	Acute	96	LC50	MORT	253600	ug/L	209424		Marine	no value	N
Geometric	2536000											
U												
Oncorhynchus mykiss Rainbow trout	Marine	Acute	96	LC50	MORT	465000	ug/L	205115	Westin (1974)	Marine 7d value	no value	N
Geometric	4650000											
U												
Oncorhynchus Chinook salmon	Marine	Acute	96	LC50	MORT	440200	ug/L	205115	Westin (1974)	Marine 7d value	no value	N
Geometric	4402000											
U												
Pomacentrus Beaugregory	Marine	Acute	96	LC50	MORT	1.328E+	ug/L	209424				
Geometric	13280000											
U												
Trachinotus carolinus Florida pompano	Marine	Acute	96	LC50	MORT	442600	ug/L	209424		Marine		N
Geometric	4426000											
Molluscs												
U												
Crassostrea virginica American or virginia	Marine	Acute	96	EC50	MORT	1.6821E	ug/L	205098		Marine		N
U												
Crassostrea virginica American or virginia	Marine	Acute	96	EC50	MORT	1.1509E	ug/L	205098		Marine		N
U												
Crassostrea virginica American or virginia	Marine	Acute	96	EC50	MORT	1.8946E	ug/L	205098		Marine		N
U												
Crassostrea virginica American or virginia	Marine	Acute	96	EC50	MORT	2.7578E	ug/L	205098		Marine		N
Geometric	17833740											

Friday, 2 August 2002 ***Page 5 of 6***

nitrate

U - Unmodified	HC - Hardness	T - Unmodified Total
C - Converted NOEC	UI - Unmodifie	Tp -Total at pH8.0
H - Hardness Corrected	UD - Unmodifi	TpC -Total at pH8.0, Converted NOEC

Friday, 2 August 2002 ***Page 6 of 6***

Appendix 4: Revised nitrate guideline derivation

Table A4.1 A,B Acute data from database showing reference codes and classifications

A

Group	Common	Latin Name	Life Stage	Duration(h	Endpoint	Effect	Temp	EC_{50}/LC_{50} (mg NO_3-N/L)	Analysis	Author
Invertebrate	Amphipod	*Echinogammarus echinosetosus*	Adults	120h	LC50	MOR	17.9	56.2	U	Camargo et al (2005)
Invertebrate	Amphipod	*Eulimnogammarus toletanus*	Adults	120h	LC50	MOR	17.9	73.1	U	Camargo et al (2005)
Invertebrate	Caddisfly	*Hydropsyche accidentalis*	Last instar larvae	120h	EC50	MOR	18	77.2	M	Camargo & Ward (1992)
Invertebrate	Caddisfly	*Cheumatopsyche pettiti*	Early instar larvae	120h	LC50	MOR	18	106.5	M	Camargo & Ward (1992)
Invertebrate	Caddisfly	*Hydropsyche exocellata*	Last instar larvae	120h	LC50	MOR	17.9	230.2	U	Camargo et al (2005)
Amphibian	Pacific Treefrog	*Pseudacris regilla*	tadpoles	10d	LC50	MOR	22	266.2	M	Schuytema & Nebeker (1999c)
Invertebrate	Water flea	*Ceriodaphnia dubia*	Neonates	48h	LC50	MOR	25	374.0	M	Scott & Crunkilton (2000)
Fish	Siberian sturgeon	*Acipenser baeri*	Adults	96h	LC50	MOR	22.5	397.0	M	Hamlin (2006)
Invertebrate	Water flea	*Daphnia magna*		48h	EC50	MOR		479.1		**Geometric mean**
Invertebrate	Snail	*Lymnaea sp*	eggs	96h	LC50	HAT	NR	535.5	NR	Dowden & Bennett (1965)
Invertebrate	Snail	*Potamopyrgus antipodarum*	Adults	96h	LC50	MOR	20.4	1042.0	U	Alonso & Camargo (2003)
Fish	Rainbow trout	*Oncorhynchus mykiss*	fingerlings	7d	LC50	MOR	13-14	1061.0	M	Westin (1974)
Fish	Chinook salmon	*Oncorhynchus tshawytscha*	fingerlings	7d	LC50	MOR	13-14	1083.9	M	Westin (1974)
Fish	Eastern mosquitofish	*Gambusia holbrooki*		96h	LC50	MOR		1095.4		Wallen et al.(1957)
Fish	Lake Trout	*Salvelinus namaycush*	fry	96h	LC50	MOR	7.5	1121.4	M	McGurk et al (2006)
Amphibian	African clawed frog	*Xenopus laevis*	tadpoles	10d	LC50	MOR	22	1236.2	M	Schuytema & Nebeker (1999c)
Fish	Fathead minnows	*Pimephales promelas*		96h	LC50	MOR		1316.6		**Geometric mean**
Fish	Catfish	*Ictalurus punctatus*	Fingerlings	96h	LC50	MOR	22	1355.0	unknown	Colt & Tchobanoglous (1976)
Fish	Lake Whitefish	*Coregonus clupeaformis*	fry	96h	LC50	MOR	7.5	1902.7	M	McGurk et al (2006)
Fish	Bluegill	*Lepomis macrochirus*	fingerlings	96h	LC50	MOR		2094.0		**Geometric mean**

B

Author	Env Canada classification	AQUIRE ref ID	ANZECC ref ID	NIWA ref ID	ANZECC ref classification	Group	Common	Latin Name
Camargo et al (2005)				500006	M	Invertebrate	Amphipod	*Echinogammarus echinosetosus*
Camargo et al (2005)				500006	M	Invertebrate	Amphipod	*Eulimnogammarus toletanus*
Camargo & Ward (1992)	1	3879	203879	203879	M	Invertebrate	Caddisfly	*Hydropsyche accidentalis*
Camargo & Ward (1992)	1	3879	203879	203879	M	Invertebrate	Caddisfly	*Cheumatopsyche pettiti*
Camargo et al (2005)				500006	M	Invertebrate	Caddisfly	*Hydropsyche exocellata*
Schuytema & Nebeker (1999c)	1	20488		6020488		Amphibian	Pacific Treefrog	*Pseudacris regilla*
Scott & Crunkilton (2000)	1			400001	C	Invertebrate	Water flea	*Ceriodaphnia dubia*
Hamlin (2006)				500005		Fish	Siberian sturgeon	*Acipenser baeri*
Geometric mean						Invertebrate	Water flea	*Daphnia magna*
Dowden & Bennett (1965)	A, b, c	915	200915	200915		Invertebrate	Snail	*Lymnaea sp*
Alonso & Camargo (2003)				500008	M	Invertebrate	Snail	*Potamopyrgus antipodarum*
Westin (1974)	2	5115	205115	205115	M	Fish	Rainbow trout	*Oncorhynchus mykiss*
Westin (1974)	2	5115	205115	205115	M	Fish	Chinook salmon	*Oncorhynchus tshawytscha*
Wallen et al.(1957)		508	200508	200508		Fish	Eastern mosquitofish	*Gambusia holbrooki*
McGurk et al (2006)		95870		6095870	C	Fish	Lake Trout	*Salvelinus namaycush*
Schuytema & Nebeker (1999c)	1	20488		6020488		Amphibian	African clawed frog	*Xenopus laevis*
Geometric mean						Fish	Fathead minnows	*Pimephales promelas*
Colt & Tchobanoglous (1976)	2			400002		Fish	Catfish	*Ictalurus punctatus*
McGurk et al (2006)		95870		6095870	C	Fish	Lake Whitefish	*Coregonus clupeaformis*
Geometric mean						Fish	Bluegill	*Lepomis macrochirus*

Note: see Environment Canada footnotes under Chronic data

Figure A4.1 Acute data for 2009 revision fitted to BurIII model (ANZECC 2000).

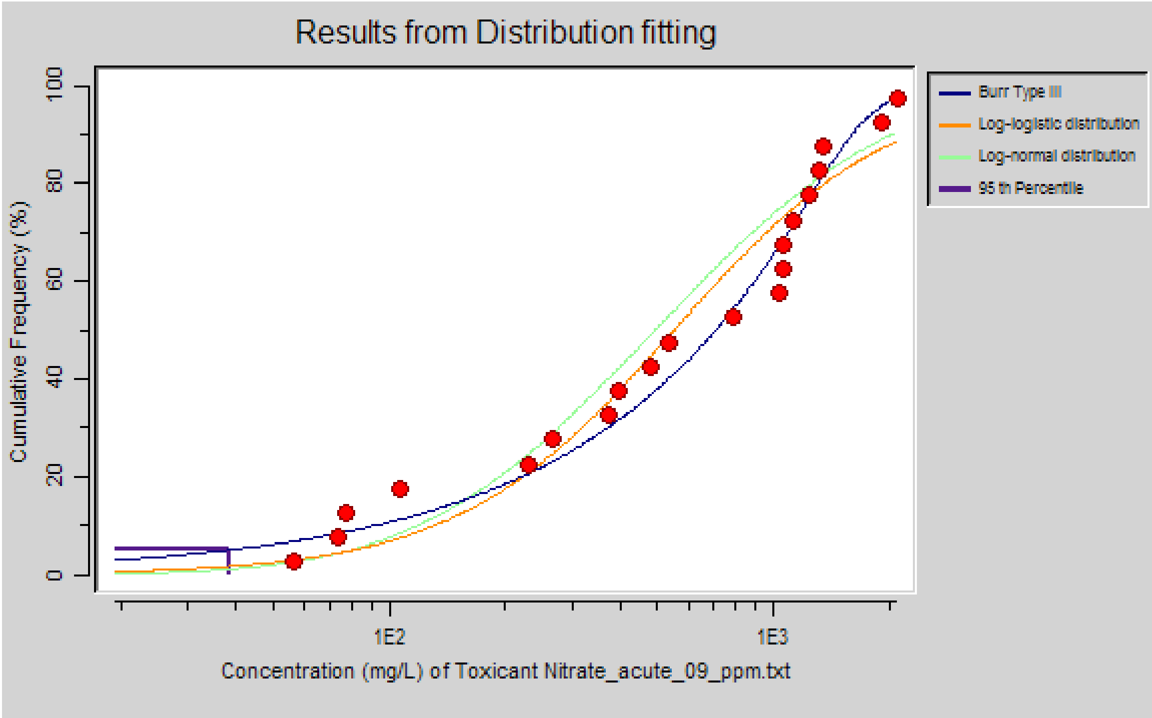


Table A4.2 A,B Chronic data from database showing reference codes and classifications

A

Group	Common name	Scientific name	Converted	Life Stage	Exposure conditions	Test Type	Duration (h/d)	Endpoint	Effect	Temp	NOEC (mg/L NO_3-N)	LOEC (mg/L NO_3-N)	Analysis	Author
Fish	Lake Trout	*Salvelinus namaycush*	U	Fry	R	Chronic	146d	NOEC	DVP	7.5	1.6	6.25	M	McGurk et al (2006)
Fish	Lake Trout	*Salvelinus namaycush*	U	Fry	R	Chronic	146d	NOEC	GRO	7.5	1.6	6.25	M	McGurk et al (2006)
Fish	Rainbow trout	*Oncorhynchus mykiss*	U	Fry	F	Chronic	30d	NOEC	MOR	10	2.2	2.3, >4.5	NR	Kinchloe et al (1979) (Geo mean)
Fish	Chinook salmon	*tshawytscha*	U	Fry	F	Chronic	30d	NOEC	MOR	10	2.3	4.5	NR	Kinchloe et al (1979)
Fish	Lahontan cutthroat trout	*Salmo clarki*	U	Fry	F	Chronic	30d	NOEC	MOR	13	4.5	7.6	NR	Kinchloe et al (1979)
Fish	Coho salmon	*Oncorhynchus kisutch*	U	Fry	F	Chronic	30d	NOEC	MOR	10	>4.5	>4.5	NR	Kinchloe et al (1979)
Fish	Lake Whitefish	*Coregonus clupeaformis*	U	Fry	R	Chronic	126d	NOEC	DVP	7.5	6.25	25	M	McGurk et al (2006)
Amphibian	American Toad	*Bufo americanus*	C	Egg	R	Chronic	23d	NOEC	HAT	5-10	>9.26		M	Laposata & Dunson (1998)
Amphibian	Pacific Treefrog	*Pseudacris regilla*	U	tadpoles	R	Chronic	10d	NOEC	GRO	22	12.0		M	Schuytema & Nebeker (1999c)
Invertebrate	Freshwater crayfish	*Astacus astacus*	U			Acute	7d	NOAEL	MOR	15	>14.0		U	Jensen (1996)
Invertebrate	Water flea	*Ceriodaphnia dubia*		neonates							15.6			Scott & Crunkilton (2000) (Geo mean)
Amphibian	African clawed frog	*Xenopus laevis*	C	Embryo	R	Chronic	120h	NOEC	GRO	22	24.8		M	Schuytema & Nebeker (1999a)
Fish	Lake Whitefish	*Coregonus clupeaformis*	U	Fry	R	Chronic	126d	NOEC	MOR	7.5	25.0	100	M	McGurk et al (2006)
Invertebrate	Florida apple snail	*Pomacea paludosa*									25.3			Corrao et al (2006) (Geo mean)
Fish	Fathead minnows	*Pimephales promelas*	U	Embryos and larvae	F	Chronic	11d	NOEC	MOR	25	358		U	Scott & Crunkilton (2000)
Invertebrate	Water flea	*Daphnia magna*	U	neonates	S, R	Chronic	7d	NOEC	REP	25	358		U	Scott & Crunkilton (2000)

B

Author	Env Canada classification	AQUIRE ref ID	ANZECC ref ID	NIWA ref iD	Classification	Selector	Group	Common name	Scientific name
McGurk et al (2006)		95870		6095870	C	N	Fish	Lake Trout	*Salvelinus namaycush*
McGurk et al (2006)		95870		6095870	C	Y	Fish	Lake Trout	*Salvelinus namaycush*
Kinchloe et al (1979) (Geo mean)	A	95870		6095870	C	Y	Fish	Rainbow trout	*Oncorhynchus mykiss*
Kinchloe et al (1979)	A			400003	C	Y	Fish	Chinook salmon	*Oncorhynchus tshawytscha*
Kinchloe et al (1979)	A			400003	C	Y	Fish	Lahontan cutthroat trout	*Salmo clarki*
Kinchloe et al (1979)	A			400003	C	Y	Fish	Coho salmon	*Oncorhynchus kisutch*
McGurk et al (2006)		95870		6095870	C	Y	Fish	Lake Whitefish	*Coregonus clupeaformis*
Laposata & Dunson (1998)	2, l	19803		6019803		Y	Amphibian	American Toad	*Bufo americanus*
Schuytema & Nebeker (1999c)	1	20488		6020488		Y	Amphibian	Pacific Treefrog	*Pseudacris regilla*
Jensen (1996)				500009		Y	Invertebrate	Freshwater crayfish	*Astacus astacus*
Scott & Crunkilton (2000) (Geo mean)				400001	C	Y	Invertebrate	Water flea	*Ceriodaphnia dubia*
Schuytema & Nebeker (1999a)	1			500010		Y	Amphibian	African clawed frog	*Xenopus laevis*
McGurk et al (2006)		95870		6095870	C	Y	Fish	Lake Whitefish	*Coregonus clupeaformis*
Corrao et al (2006) (Geo mean)				500007		Y	Invertebrate	Florida apple snail	*Pomacea paludosa*
Scott & Crunkilton (2000)	1			400001	C	Y	Fish	Fathead minnows	*Pimephales promelas*
Scott & Crunkilton (2000)	1			400001	C	Y	Invertebrate	Water flea	*Daphnia magna*

Notes: ND = no data provided; NR = not recorded
Test Types: R = renewal, S = static, F = flow-through
Environment Canada footnotes: Ranking Scheme: 1 = primary source, 2 = secondary source, A = ancillary source
a $LC_{0.01}$ extrapolated from Camargo and Ward (1992) LC_{50} data, therefore not used in guideline development
b tests run with filtered local lake water
c insufficient test details / water quality information provided
d lack of statistical support
e non-resident, or tropical species
f distilled water used as test medium
g lack of clear dose-response relationship
h potassium salts not suitable for guideline derivation
i inadequate test design or conditions
j control mortality > 10%
k organisms only exposed to one test concentration
l lowest observable effect level beyond nitrate concentration range tested
m >10% change in nitrate concentration in test containers
n the ecological significance of this endpoint is uncertain

Acute-to-chronic ratio (ACR)

Table A4.3: Acute and chronic toxicity data used for acute-to-chronic ratio (ACR) calculation. Highlight (white on black) indicates species which are present in Canterbury's rivers and lakes.

			Acute		**Chronic**		**ACR**	**Reference**
Group	**Common**	**Species**		**LC_{50}**		**NOEC**		
	Name			**mg/L NO_3-N** [a]		**mg/L NO_3-N** [a]		
Fish	**Lake Trout**	***Salvelinus namaycush***	**96 h swim up fry survival**	**1121**	**Embryo to swim up fry survival**	**100**	**11.2**	**McGurk *et al*. (2006)**
Fish	Lake Whitefish	*Coregonus clupeaformis*	96 h swim up fry survival	1903	Embryo to swim up fry survival	25	76.1	McGurk *et al*. (2006)
Fish	Fathead minnow	*Pimephales promelas*	96 h Survival	1317	Larvae 7 d post hatch growth	358	3.7	Scott & Crunkilton (2000)
Crustacea	Water flea	*Daphnia magna*	48h Survival	447	7d reproduction	358	1.2	Scott & Crunkilton (2000)
Crustacea	Water flea	*Ceriodaphnia dubia*	48h Survival	374	7d reproduction (geometric mean of 5)	15.6	24.0	Scott & Crunkilton (2000)
							9.9	**Geometric mean**

[a] Multiply by conversion factor of 4.43x to convert to NO_3

Table A4.4: Species list for all species in the nitrate database.

Species No.	Scientific name	Group	Commoni name
1	*Gambusia holbrooki (G. Affinis)*	Fish	Eastern mosquitofish
2	*Lebistes reticulatus*	Fish	Guppy
3	*Lepomis macrochirus*	Fish	Bluegill
4	*Micropterus treculi*	Fish	Guadalupe bass
5	*Oncorhynchus mykiss*	Fish	Rainbow trout (nonanadromous)
6	*Oncorhynchus tshawytscha*	Fish	Chinook salmon
7	*Coregonus clupeaformis*	Fish	Lake whitefish
8	*Salvelinus namaycush*	Fish	Lake trout
9	*Catla catla*	Fish	Indian major carp
10	*Labeo rohita*	Fish	Carp (Roha)
11	*Cirrhinus mrigala*	Fish	Mrigal Carp
12	*Cyprinus carpio*	Fish	Common carp
13	*Ctenopharyngodon idella*	Fish	Grass Carp
14	*Acipenser baeri*	Fish	Siberian sturgeon
15	*Pimephales promelas*	Fish	Fathead minnow
16	*Ictalurus punctatus*	Fish	Catfish
17	*Carassius carassius*	Fish	Crucian carp
18	*Oncorhynchus mykiss*	Fish	Rainbow trout (Steelhead anadromous)
19	*Salmo clarki*	Fish	Lahontan cutthrpoat trout
20	*Daphnia magna*	Invertebrate	Waterflea
21	*Mogurnda mogurnda*	Fish	Purple spotted gudgeon
22	*Salvelinus namaycush*	Fish	Lake trout
23	*Ceriodaphnia dubia*	Invertebrate	Waterflea
24	*Cheumatopsyche pettiti*	Invertebrate	Caddisfly
25	*Hydropsyche accidentalis*	Invertebrate	Caddisfly
26	*Eulimnogammarus toletanus*	Invertebrate	Amphipod
27	*Echinogammarus echinosetosus*	Invertebrate	Amphipod
28	*Hydropsyche exocellata*	Invertebrate	Caddisfly
29	*Oncorhynchus kisutch*	Fish	Coho salmon
30	*Bufi bufo*	Amphibian	Common toad
31	*Bufo boreas*	Amphibian	Western toad
32	*Acnthocyclops vernalis*	Invertebrate	Stygobite copepod
33	*Lymnaea sp*	Invertebrate	Snail
34	*Potamopyrgus antipodarum*	Invertebrate	Snail
35	*Macrobrachium rosenbergii*	Invertebrate	Freshwater prawn
36	*Pomacea paludosa*	Invertebrate	Florida apple snail
37	*Hydra viridissima*	Invertebrate	Hydra
38	*Cherax quadricarinatus*	Invertebrate	Australian crayfish
39	*Pseudacris regilla*	Amphibian	Pacific treefrog
40	*Xenopus laevis*	Amphibian	African clawed frog
41	*Hydra attenuatta*	Invertebrate	Hydra
42	*Rana catesbeiana*	Amphibian	Bullfrog
43	*Rana temporaria*	Amphibian	European common frog
44	*Polycelis niagra*	Invertebrate	Planaria
45	*Bufo americanus*	Amphibian	American toad
46	*Proasellus slavus vindobonensis*	Invertebrate	Stygobite isopod
47	*Paracyclops fimbriatus*	Invertebrate	Epigean copepod
48	*Diacyclops bicuspidatus*	Invertebrate	Stygobite copepod
49	*Rana clamitans*	Amphibian	Green frog
50	*Astacus astacus*	Invertebrate	Freshwater crayfish

Table A4.5: References used for acute and chronic guideline derivation.

	References - NIWA 2009 IDs			
	Envt Canada	**USEPA**	**ANZECC**	**NIWA2009**
Alonso & Camargo (2003)				500008
Baker & Waights (1993)	A, e, f			400006
Buhl & Hamilton (2000)		47875		6047875
Cairns & Scheier (1959)		930	200930	200930
Camargo & Ward (1992)	1	3879	203879	203879
Camargo *et al*. (2005)				500006
Colt & Tchobanoglous (1976)	2			400002
Corrao *et al*. (2006)				500007
Dowden & Bennett (1965)	A, b, c	915	200915	200915
Dowden (1961)		2465	202465	202465
Hamlin (2006)				500005
Jensen (1996)				500009
Johansson *et al*. (2001)	A, e,g			400005
Jones (1940)	A, c,f			400007
Jones (1941)	A, c,f			400008
Kinchloe *et al*. (1979)	A			400003
Laposata & Dunson (1998)	2, l	19803		6019803
McGurk *et al*. (2006)		95870		6095870
Meade & Watts (1995)		19529		6019529
Mosslacher (2000)		100653		60100653
Rippon & McBride (1994)			300119	300119
Rubin & Elmargahy (1997)	1, e, h	7635	207635	207635
Schuytema & Nebeker (1999a)	1			500010
Schuytema & Nebeker (1999b)	1			500011
Schuytema & Nebeker (1999c)	1	20488		6020488
Scott & Crunkilton (2000)	1			400001
Sullivan & Spence (2003)				500012
Tesh *et al*. (1990)	A, c,d			400004
Tilak, Lakshmi & Susan (2002)				500001
Tilak, Vardhan & Kumar (2006)				500004
Tilak, Veeraiah & Lakshmi (2006)				500002
Tilak, Veeraiah & Raju (2006)				500003
Tomasso & Carmichael (1986)	A, c	11794	211794	211794
Trama (1954)	2	8037	208037	208037
Wallen *et al*. (1957)		508	200508	200508
Westin (1974)	2	5115	205115	205115
Wickins (1976)	2	2320		602320

Envt Canada reference footnotes – see Table A4.2B

Appendix 5: References in nitrate dataset

Alonso, A.; Camargo, J.A. (2003). Short–term toxicity of ammonia, nitrite, and nitrate to the aquatic snail *Potamopyrgus antipodarum* (Hydrobiidae, Mollusca). *Bulletin of Environmental Contamination and Toxicology 70(5)*: 1006–1012.

Baker, J. & Waights, V. (1993). The effect of sodium nitrate on the growth and survival of toad tadpoles (*Bufo bufo*) in the laboratory. *Journal of Herpetology 3(4)*: 147-148.

Buhl, K.J.; Hamilton, S.J. (2000). Acute toxicity of fire–control chemicals, nitrogenous chemicals, and surfactants to rainbow trout. *Transactions of the American Fisheries Society 129*: 408–418.

Cairns, J.C.J.; Scheier, A. (1959). The relationship of bluegill sunfish body size to its tolerance for some common chemicals. Proceeding of the 13th Industrial Waste Conference, Purdue University, 243–252. 96.

Camargo, J.A.; Alonso, A.; Salamanca, A. (2005). Nitrate toxicity to aquatic animals: a review with new data for freshwater invertebrates. *Chemosphere 58(9)*: 1255–1267.

Camargo, J.A.; Ward, J.V. (1992). Short–term toxicity of sodium nitrate (NaNO3) to non–target freshwater invertebrates. *Chemosphere 24(1)*: 23–28.

Colt, J.; Tchobanoglous, G. (1976). Evaluation of the short–term toxicity of nitrogenous compounds to channel catfish, *Ictalurus punctatus*. *Aquaculture 8*: 209–221.

Corrao, N.; Darby, P.; Pomory, C. (2006). Nitrate impacts on the Florida apple snail, *Pomacea paludosa*. *Hydrobiologia 568(1)*: 135–143.

Dowden, B.F. (1961). Cumulative toxicities of some inorganic salts to *Daphnia magna* as determined by median tolerance limits. Proceedings of the Louisiana Academy of Sciences 23: 77–85.

Dowden, B.F.; Bennett, H.J. (1965). Toxicity of selected chemicals to certain animals. *Journal of the Water Pollution Control Federation 37(9)*: 1308–1316.

Hamlin, H.J. (2006). Nitrate toxicity in Siberian sturgeon (*Acipenser baeri*). *Aquaculture 253*: 688–693.

Jensen, F.B. (1996). Uptake, elimination and effects of nitrite and nitrate in freshwater crayfish (*Astacus astacus*). *Aquatic Toxicology 34*: 94–104.

Johansson, M.; Rasanen, K.; Merila, J. (2001). Comparison of nitrate tolerance between populations of the common frog, *Rana temporaria*. *Aquatic Toxicology 54*: 1–14.

Jones, J.R.E. (1939). The relation between the electrolytic solution pressures of the metals and their toxicity to the stickleback (*Gasterosteus aculeatus* L.). *J. Exp. Biol. 16(4)*: 425-437.

Jones, J.R.E. (1940). A further study of the relation between toxicity and solution pressure, with *Polycelis nigra* as test animal. *The Journal of Experimental Biology 17*: 408-415.

Jones, J.R.E. (1941). A study of the relative toxicity of anions, with *Polycelis nigra* as test animal. *The Journal of Experimental Biology 18*: 170-181.

Kincheloe, J.W.; Wedemeyer, G.A.; Koch, D.L. (1979). Tolerance of developing salmonid eggs and fry to nitrate exposure. *Bulletin of Environmental Contamination and Toxicology 23(1)*: 575–578.

Marco, A.; Quilchano, C. & Blaustein, A.R. (1999). Sensitivity to nitrate and nitrite in pond-breeding amphibians from the Pacific Northwest, USA. Environ. *Toxicol. Chem. 18(12)*: 2836-2839.

McDowall, R.M. (2000). The Reed Field Guide to New Zealand freshwater fishes. Reed, Auckland, New Zealand. 224 p.

McGurk, M.D.; Landry, F.; Tang, A.; Hanks, C.C. (2006). Acute and chronic toxicity of nitrate to early life stages of Lake Trout (*Salvelinus namaycush*) and Lake Whitefish (*Coregonus clupeaformis*). *Environmental Toxicology and Chemistry 25(8)*: 2187–2196.

Meade, M.E.; Watts, S.A. (1995). Toxicity of ammonia, nitrite, and nitrate to juvenile Australian crayfish, *Cherax quadricarinatus*. *Journal of Shellfish Research 14(2)*: 341–346.

Mosslacher, F. (2000). Sensitivity of groundwater and surface water crustaceans to chemical pollutants and hypoxia: implications for pollution management. *Archiv fur Hydrobiologie 149(1)*: 51–66.

Rippon, G.D.; McBride, P. (1994). Biological Toxicity Testing of Gadjarrigamarndah Creek Water at Nabarlek – Final Report for Project 2108.G. No. p.

Rubin, A.J.; Elmaraghy, G.A. (1977). Studies on the toxicity of ammonia, nitrate and their mixtures to guppy fry. *Water Research 11*: 927–935.

Schuytema, G.S.; Nebeker, A.V. (1999a). Comparative effects of ammonium and nitrate compounds on Pacific treefrog and African clawed frog embryos. *Archives of Environmental and Contamination Toxicology 36*: 200-206.

Schuytema, G.S.; Nebeker, A.V. (1999b). Effects of ammonium nitrate, sodium nitrate and urea on red-legged frogs, Pacific tree frog and African clawed frogs. *Bulletin of Environmental and Contamination Toxicology 63*: 357-364.

Schuytema, G.S.; Nebeker, A.V. (1999c). Comparative toxicity of ammonium and nitrate compounds to Pacific tree frog and African clawed frog tadpoles. *Environmental Toxicology and Chemistry 18(10)*: 2251–2257.

Scott, G.; Crunkilton, R.L. (2000). Acute and chronic toxicity of nitrate to fathead minnows (*Pimephales promelas*), *Ceriodaphnia dubia*, and *Daphnia magna*. *Environmental Toxicology and Chemistry 19(12)*: 2918–2922.

Sullivan, K.B.; Spence, K.M. (2003). Effects of sublethal concentrations of atrazine and nitrate on metamorphosis of the African clawed frog. *Environmental Toxicology and Chemistry 22*: 627–633.

Tesh, A.E.C.; Wilby, O.K.; Tesh, J.M. (1990). Effects of inorganic nitrates on growth and development of Hydra. *Toxicology in Vitro 4(4/5)*: 614–615.

Tilak, K.S.; Lakshmi, S.J.; Susan, T.A. (2002). The toxicity of ammonia, nitrite and nitrate to the fish, *Catla catla* (Hamilton). *Journal of Experimental Biology 23(2)*: 147–149.

Tilak, K.S.; Vardhan, K.S.; Kumar, B.S. (2006a). Comparative toxicity levels of ammonia, nitrite and nitrate to the freshwater fish *Ctenopharyngodon idella*. *Journal of Ecotoxicology and Environmental Monitoring 16(3)*: 273–278.

Tilak, K.S.; Veeraiah, K.; Lakshmi, S.J. (2006b). Effects of ammonia, nitrate and nitrite on toxicity and heamatological changes in the carps. *Journal of Ecotoxicology and Environmental Monitoring 16(1)*: 9–12.

Tilak, K.S.; Veeraiah, K.; Raju, J.M.P. (2006c). Toxicity and effects of ammonia, nitrite and nitrate and histopathological changes in the gill of freshwater fish *Cyprinus carpio*. *Journal of Ecotoxicology and Environmental Monitoring 16(6)*: 527–532.

Tomasso, J.R.; Carmichael, G.J. (1986). Acute toxicity of ammonia, nitrite and nitrate to the Guadalupe bass, *Micropterus treculi*. *Bulletin of Environmental Contamination and Toxicology 36(6)*: 866–870.

Trama, F.B. (1954). The acute toxicity of some common salts of sodium, potassium, and calcium to the common bluegill. Proceedings of the Academy of Natural Sciences of Philadelphia 106: 185–205.

Wallen, I.E.; Greer, W.C.; Lasater, R. (1957). Toxicity to *Gambusia affinis* of certain pure chemicals in turbid waters. *Sewage and Industrial Wastes 29(6)*: 695–711.

Westin, D.T. (1974). Nitrate and nitrite toxicity to salmonoid fishes. *The Progressive Fish Culturist 36(2)*: 86–89.

Wickins, J.F. (1976). The Tolerance of Warm–Water Prawns to Recirculated Water. *Aquaculture 9(1)*: 19–37.

Christchurch
58 Kilmore Street, PO Box 345, Christchurch

General enquiries: 03 365 3828
Fax: 03 365 3194

Customer services: 03 353 9007
or: 0800 EC INFO (0800 324 636)

Timaru
75 Church Street, PO Box 550, Timaru

General enquiries: 03 688 9069
Fax: 03 688 9067

www.ecan.govt.nz

Attachment 5

SWAMP

Surface Water Ambient Monitoring Program

Summary of Toxicity in California Waters: 2001 - 2009

J. Hunt

D. Markiewicz

M. Pranger

Prepared for the Surface Water Ambient Monitoring Program

November 2010

California Water Boards

www.waterboards.ca.gov/swamp

1 Assessment Questions

This document presents a summary assessment of toxicity in California watersheds and coastal waters using data from SWAMP and partner programs. The following questions are addressed:

1. Where has toxicity been observed in California waters?
2. What is the magnitude of observed toxicity?
3. How do the results of toxicity measurements compare among waters draining urban, agricultural, and other land cover areas?
4. What chemicals have been implicated as causing toxicity?
5. What are the ecological implications of aquatic toxicity?
6. How are test results affected by the statistical methods applied, particularly with respect to use of the Test of Significant Toxicity that US EPA recently released?

2 Background

The word "toxicity" is used here to indicate a statistically significant adverse impact on standard aquatic test organisms in laboratory exposures. A number of different species, including crustaceans, algae, fish, and mollusks, have been used, following widely accepted test protocols with strict quality assurance. Toxicity test organisms are surrogates for aquatic species found in the environment. Toxicity tests are especially useful in water quality monitoring because they can detect the effects of all chemicals (whether measured or not) and respond to pollutant mixtures. These results may or may not have any relationship to human health.

The test organisms have been chosen because they are relatively sensitive to toxic chemicals. Toxicity detected by these organisms might not acutely impact other types of organisms. Endpoints are the measured effects on test species (e.g., fish, crustaceans, etc.). All endpoints measured lethality (as % survival), except for cell counts for the algal population growth endpoint.

3 Findings

Information is presented here to answer the key assessment questions. Additional information, documentation, program information, data sources and literature cited are available from the authors and will be presented in a larger interpretive report available by early 2011.

Where has toxicity been observed in California waters?

The attached maps (Figures 1 – 8) show locations of sites sampled for toxicity by SWAMP and partner programs. All sites presented in this document are color coded using the categorization process described in Figure 11, which considers the available toxicity test endpoints in both water and sediment. Relative to the 303(d) impaired waterbody listing process, a site coded "green" would not be listed for toxicity. Sites coded "yellow" to "red" may be listed if the number of toxic samples met the criteria outlined in the State Water Board's Listing and Delisting Policy.

Toxicity has been observed in all Regions. Streams in upper watersheds and mountainous areas tend to produce fewer toxic samples, while samples from downstream sites in the valleys and along the coasts tend to be more toxic. These lower watershed sites drain larger areas with greater levels of human activity. Consistent sediment toxicity has been observed in many bay and harbor sites. In most years since 1991, for example, annual surveys of San Francisco Bay have shown at least moderate sediment toxicity at a majority of sites throughout the Bay.

Figures 1 – 8. See maps at the end of this document.

Table 1. Summary of information presented in attached maps (Figures 1 through 8)

Figure No.	Spatial Coverage	Results Presented (water, sediment, or both)
1	Statewide	Both
2	Statewide	Sediment
3	Statewide	Water
4	Northern CA	Both
5	Central CA	Both
6	Southern CA	Both
7	Statewide	Water (summary by Region)
8	Statewide	Sediment (summary by Region)

What is the magnitude of observed toxicity?

Of the 992 sites in this assessment, 473 (48%) had at least one sample in which toxicity was measured in either water or sediment with at least one endpoint (e.g., lethality in one of the test species). Of these, 129 (13% of the total) were classified as high toxicity sites, meaning that the average result for the most sensitive species in all samples from the site was more toxic than the high toxicity threshold for that species (see Figures 7 and 8).

Different Regional Boards use different monitoring designs based on water quality priorities. The North Coast (Region 1) and Lahontan (Region 6) Regions, for example, tend to focus on sedimentation and habitat degradation, so the number of sites in these Regions for which there were toxicity data for this assessment was relatively low (12 sites in each). The greatest number of sites (298) was in the Central Valley Region (Region 5), which has many lowland waterbodies where pollution from toxic chemicals is a concern. Many Regions have conducted non-SWAMP toxicity studies; however, those data are not yet available in CEDEN so they have not been included in this assessment. The percentage of sites with at least one toxic sample ranged from 17% in the Lahontan Region (Region 6) to over 50% in the San Francisco Bay (Region 2), Central Coast (Region 3), Central Valley (Region 5), and Santa Ana Regions (Region 8)(see Figures 7 and 8).

How do the results of toxicity measurements compare among waters draining urban, agricultural, and other land cover areas?

Samples from sites in agricultural and urban areas had significantly higher toxicity than sites in less developed areas (Figure 9), and had a greater magnitude of toxicity (Figure 10). The differences in toxicity between undeveloped and urban areas was highly statistically significant ($p < 0.0005$); and the same is true for the difference between undeveloped and agricultural areas. A subset of the sites assessed (536 out of 992) for this report were mapped and categorized for land cover using geographic information system (GIS) analysis. For each site, an area 1 km upstream (including tributaries) and 500 m on either side of the stream was mapped. If land cover within those areas was greater than 10% "developed" (National Land Cover Dataset classification), they were designated as urban. This is based on the widely supported impervious surface area model that shows decreased ecological condition in streams draining lands with greater than 10% impervious surface area. Sites with greater than 25% agricultural land cover were classified as agricultural sites. Sites were classified as "undeveloped" if they had both less than 10% urban and less than 25% agricultural land cover. Sites were classified as "ag-urban" if they had both greater than 10% urban and 25% agricultural land cover.

Figure 9. Toxicity distribution for samples collected from sites in urban, agricultural, and less developed areas. Lower values represent lower levels of survival, and indicate higher toxicity. Data are for the most sensitive test species at each site. Solid lines, from top to bottom, represent the 90th, 75th, 50th (median), 25th and 10th percentiles of the distribution. Dotted lines are the mean result.

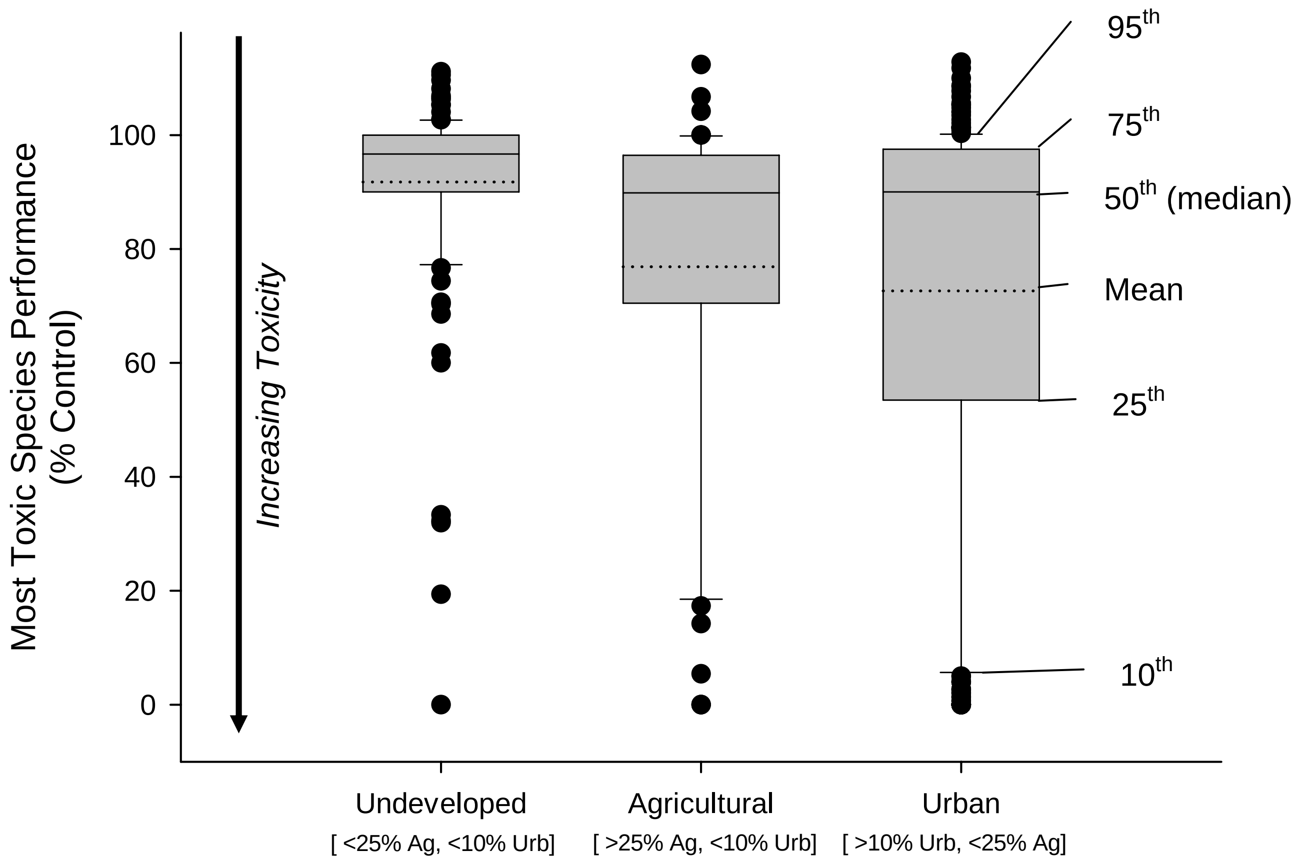
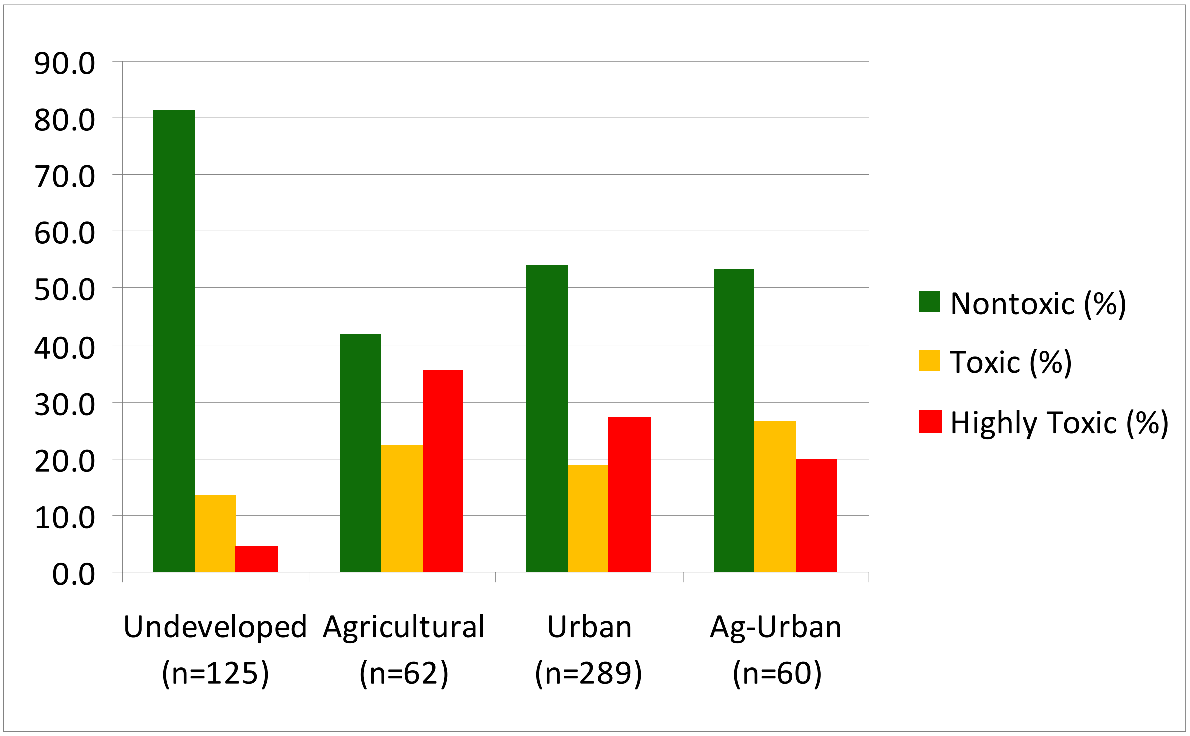


Figure 10. Numbers of sites (as a percentage of all sites in each land-cover category) classified as non-toxic, moderately toxic, or highly toxic, using the coding system shown in Figure 11. Some significant toxicity (yellow) and moderate toxicity (orange) categories are combined here.



What chemicals have been implicated as causing toxicity?

There are thousands of pollutants that can cause biological impacts in waterways, and only about 140 are routinely measured. Ambient water and sediment samples often contain complex mixtures of many pollutants, often with additive effects. Toxicity tests are especially useful in water quality monitoring because they can detect the effects of all chemicals (whether measured or not) and also respond to pollutant mixtures. To find out which chemicals in a sample are causing adverse impacts, toxicity identification evaluations (TIEs) can be used to provide direct experimental evidence.

Table 2 summarizes dozens of studies in which TIEs have identified the causes of toxicity in ambient water and sediment samples from California waterbodies, from 1991 to the present. With the exception of ammonia, all of these ambient TIEs implicated pesticides, primarily organophosphates and, more recently, pyrethroids. It is important to note that pesticides are implicated as causing toxicity in streams draining residential and urban areas as well as agricultural land.

Table 2. Classes of chemicals and specific compounds shown to have caused toxicity in California waterbodies. The third and fourth columns give the numbers of samples in which each of the chemicals listed was implicated in the TIEs conducted by the various studies.

Class	Compound	Water	Sediment
Ammonia	Ammonia	1	-
Carbamate Pesticide	Carbofuran	4	-
Organophosphate Pesticide	Chlorpyrifos	11	4
	Diazinon	13	-
	Ethyl Parathion	1	-
	Malathion	3	-
	Methyl Parathion	3	-
Pyrethroid Pesticide	Bifenthrin	4	8
	Cyfluthrin	3	3
	Cyhalothrin	2	7
	Cypermethrin	-	8
	Esfenvalerate	1	-
	Permethrin	-	1

What are the ecological implications of aquatic toxicity?

A small number of studies have measured chemistry, toxicity, and ecological indicators to investigate relationships between observed toxicity and observed impacts on stream and estuarine ecosystems. In most of these studies, the connection between observed toxicity and ecosystem impacts has been well established. In five journal articles, Anderson, Phillips, and colleagues measured declines in aquatic invertebrate population densities at sites where toxicity was observed in the Salinas and Santa Maria Rivers, downstream of the confluences with pesticide-laden streams draining intensive agriculture. These authors, along with Lao, also observed degradation of marine communities at sites exhibiting sediment toxicity in San Diego Bay, Newport Bay, and the Ballona Creek estuary. Weston observed population declines of the resident amphipod *Hyalella* in Delta and Central Valley waterways where sediment toxicity was observed, often in watersheds dominated by residential land use[1].

[1] Literature cited will be included in the larger interpretive report released in early 2011.

How are test results affected by the statistical methods applied, particularly with respect to use of the EPA Test of Significant Toxicity (TST)?

State Water Board staff is developing, for Board consideration, a Policy for Toxicity Assessment and Control to establish new numeric toxicity objectives. The proposed policy includes new numeric objectives for chronic and acute toxicity, a new statistical methodology for determining whether a sample is toxic that is based on the US EPA's Test of Significant Toxicity (TST), and monitoring requirements for wastewater, stormwater and some non-point source discharges. The TST also would be applicable to monitoring conducted by SWAMP so this assessment was conducted using the new methodology.

In toxicity testing of ambient or stormwater samples, a single site sample often is compared to a laboratory control sample. In these tests, the objective is to determine whether a given sample of site water is toxic, as indicated by a significantly different organism response in the site water compared to the control water using a traditional t-test or similar statistic. To demonstrate the TST approach for ambient toxicity programs, SWAMP data from 409 chronic tests for *Ceriodaphnia dubia* (crustacean) and 256 chronic tests for *Pimephales promelas* (fish) were used by the US EPA to compare results of the two statistical approaches. The following data are from the EPA TST Technical Document.

Table 3 summarizes results of *Ceriodaphnia* tests analyzed with the TST test method. The majority (92%) of these comparisons resulted in the same decision using either the TST or the traditional t-test approach. Of the other 8% of samples, approximately 6% (24 tests) would have been declared not toxic using the traditional t-test approach when the TST would declare them toxic. In 2% of the tests (7 tests), samples would have been declared toxic using the traditional t-test approach when the TST would not indicate toxicity.

Table 3. Comparison of results of chronic *Ceriodaphnia* ambient toxicity tests using the TST approach and the traditional (t-test) analysis.

		EPA Test of Significant Toxicity	
		Toxic	**Non-Toxic**
Traditional (t-test)	**Toxic**	20%	2%
	Non-Toxic	6%	72%

The two approaches agree 92% of the time (green).

This analysis indicates there is little difference in the assessment of ambient toxicity regardless of which statistical method is applied to the data.

4 Next Steps

The assessment questions addressed in this summary document will be more fully evaluated in a detailed report to be released in early 2011. The data set will be expanded to include additional information from SWAMP and partner programs to more fully address the details and implications of toxicity in California waters. Topics that will be more fully explored in the forthcoming report include: differences between sediment and water toxicity results, specific patterns related to land use and hydrology, additional information on the causes and ecological implications of toxicity, and temporal trends. In addition to the forthcoming statewide report, SWAMP will be producing separate reports for each Regional Board focusing on regional toxicity issues.

5 Caveats

The following points should be kept in mind when considering the information presented here:

1. Most of the data presented here were collected by monitoring studies designed to increase understanding of potential biological impacts from human activities. Site locations were generally targeted in low watershed areas, such as tributary confluences or upstream and downstream of potential pollutant sources. Only a minority of the sites were selected at random; therefore, these data characterize only the sites monitored, and cannot be used to make assumptions about unmonitored areas.
2. These results may underestimate ambient toxicity because most samples were collected as "grabs" by filling a sample bottle or collecting sediment at one point in time. Toxic chemicals often flow downstream in pulses. Studies in which test organisms were caged in-stream often have detected toxicity when grab sample tests have not.
3. This assessment integrates data sets from a number of programs. This integration was made possible by the SWAMP quality assurance conventions and the SWAMP and California Environmental Data Exchange Network (CEDEN) data management system. There are, however, data from a number of other Water Board monitoring programs that have not yet been submitted to CEDEN and were not used in this analysis. Information on data sources is given in Table 3.
4. The different programs often had different monitoring objectives, and there is large variation in the number of samples collected at each site and the number of sites surveyed in each Region.
5. For land use evaluations, only land cover within one kilometer upstream of a site was considered for categorizing the site. As a result, only local effects were assessed. There could be far field effects from other land use types that might cause toxicity at a site, which were not considered here.

6. All sites assessed were located in ambient waters, such as streams or estuaries. None of the data here represent effluent or other waste discharges.

6 Data Quality and Data Sources

Data Quality Objectives for this Assessment

Comparability and data sources for this analysis: This analysis was able to use data collected by SWAMP Regional and Statewide monitoring programs, as well as by partner programs, because SWAMP has a developed systematic structure to document and evaluate data comparability. This structure gives data users the ability to quickly combine data from multiple sources to perform integrated assessments. The SWAMP Quality Assurance Program has instituted standards for data quality and its verification while the SWAMP Data Management Program has developed data formats, transfer protocols, and the California Environmental Data Exchange Network that allow data to be brought together.

Statewide survey: Data were pooled from multiple sources to create the data set used in this statewide survey. The quality objective for data usability and comparability among data batches was defined as follows: data batches were usable for this analysis if toxicity test controls met test acceptability criteria as set by the test protocols. Other quality control and metadata information were not considered germane to the goals of this report. Data from multiple test protocols (indicator organisms) measured at multiple laboratories were integrated into a single data set for analysis.

Threshold development: Thresholds for distinguishing between moderate toxicity and high toxicity were developed using data from multiple laboratories for all toxicity endpoints presented in this analysis. For this purpose, the quality objective for data usability and comparability among data batches was defined as follows: data batches were used only if classified as “SWAMP-Compliant.” Data classified as “SWAMP-Compliant” have been verified as meeting all measurement quality objectives and requirements as defined in the 2002 SWAMP Quality Assurance Management Plan or the 2008 SWAMP Quality Assurance Program Plan.

Data Sources for this Assessment

The sources listed in Table 3 are for the data currently available in CEDEN. Many other studies by the State Board, the Regional Boards, regulated entities, and partner programs have been conducted but are not considered here. Many of those data sets will be entered into CEDEN as time and funding allow.

Table 4. Summary of data sources* and date ranges used for this assessment.

Region	Project	Date Range	No. of Sites	No. of Samples
1	SWAMP Monitoring	11/14/2006 - 11/15/2006	3	6
	SWAMP Stream Pollution Trends	10/14/2008 - 10/15/2008	9	9
	Region 1 Total Sampling	11/14/2006 - 10/15/2008	12	15
2	RMP - Status and Trends	7/27/2004 - 8/29/2007	72	220
	SWAMP Monitoring	9/18/2001 - 1/3/2007	58	366
	SWAMP Stream Pollution Trends	6/17/2008 - 8/13/2008	10	10
	Region 2 Total Sampling	9/18/2001 - 8/13/2008	137	596
3	Salinas River Watershed	7/8/2002 - 9/22/2004	45	268
	CCAMP	12/3/2001 - 9/22/2009	123	513
	SWAMP Monitoring	1/6/2007 - 2/5/2007	9	25
	SWAMP Stream Pollution Trends	5/22/2008 - 7/21/2008	11	11
	Region 3 Total Sampling	12/3/2001 - 9/22/2009	152	817
4	SWAMP Monitoring	10/29/2001 - 6/11/2008	169	342
	SWAMP Stream Pollution Trends	5/19/2008 - 5/22/2008	7	7
	Region 4 Total Sampling	10/29/2001 - 6/11/2009	176	349
5	Ag Waiver RWQCB5	3/26/2003 - 11/28/2007	155	1190
	East San Joaquin Water Quality Coalition	7/31/2004 - 9/25/2007	26	1246
	San Joaquin Water Quality Coalition	8/24/2004 - 9/25/2007	24	1074
	SWAMP Monitoring	10/19/2001 - 3/29/2007	76	951
	SWAMP Stream Pollution Trends	4/28/2008 - 8/20/2008	31	31
	Region 5 Total Sampling	10/9/2001 - 8/20/2008	298	4492
6	SWAMP Monitoring	10/30/2006	3	6
	SWAMP Stream Pollution Trends	9/17/2008 - 9/23/2008	9	9
	Region 6 Total Sampling	10/30/2006 - 9/23/2008	12	15
7	SWAMP Monitoring	5/6/2002 - 10/29/2008	25	235
	SWAMP Stream Pollution Trends	10/28/2008 - 10/29/2008	3	3
	Region 7 Total Sampling	5/6/2002 - 10/29/2008	25	238
8	SWAMP Monitoring	8/7/2001 - 1/7/2007	97	135
	SWAMP Stream Pollution Trends	5/20/2008 - 6/4/2008	5	5
	Region 8 Total Sampling	8/7/2001 - 6/4/2008	99	134
9	SWAMP Monitoring	3/12/2002 - 5/14/2009	85	344
	SWAMP Stream Pollution Trends	5/21/2008 - 5/22/2008	7	7
	Region 9 Total Sampling	3/12/2002 - 5/14/2009	85	351
Grand Total		***8/7/2001 - 9/22/2009***	***992***	***7007***

*There are data from a number of other Water Board monitoring programs (e.g., NPDES wastewater and stormwater receiving water monitoring) that have not yet been submitted to CEDEN and were not used in this analysis.

Authors

John W. Hunt, Ph.D., Department of Environmental Toxicology, University of California, Davis

Dan Markiewicz, Aquatic Toxicology Laboratory, University of California, Davis

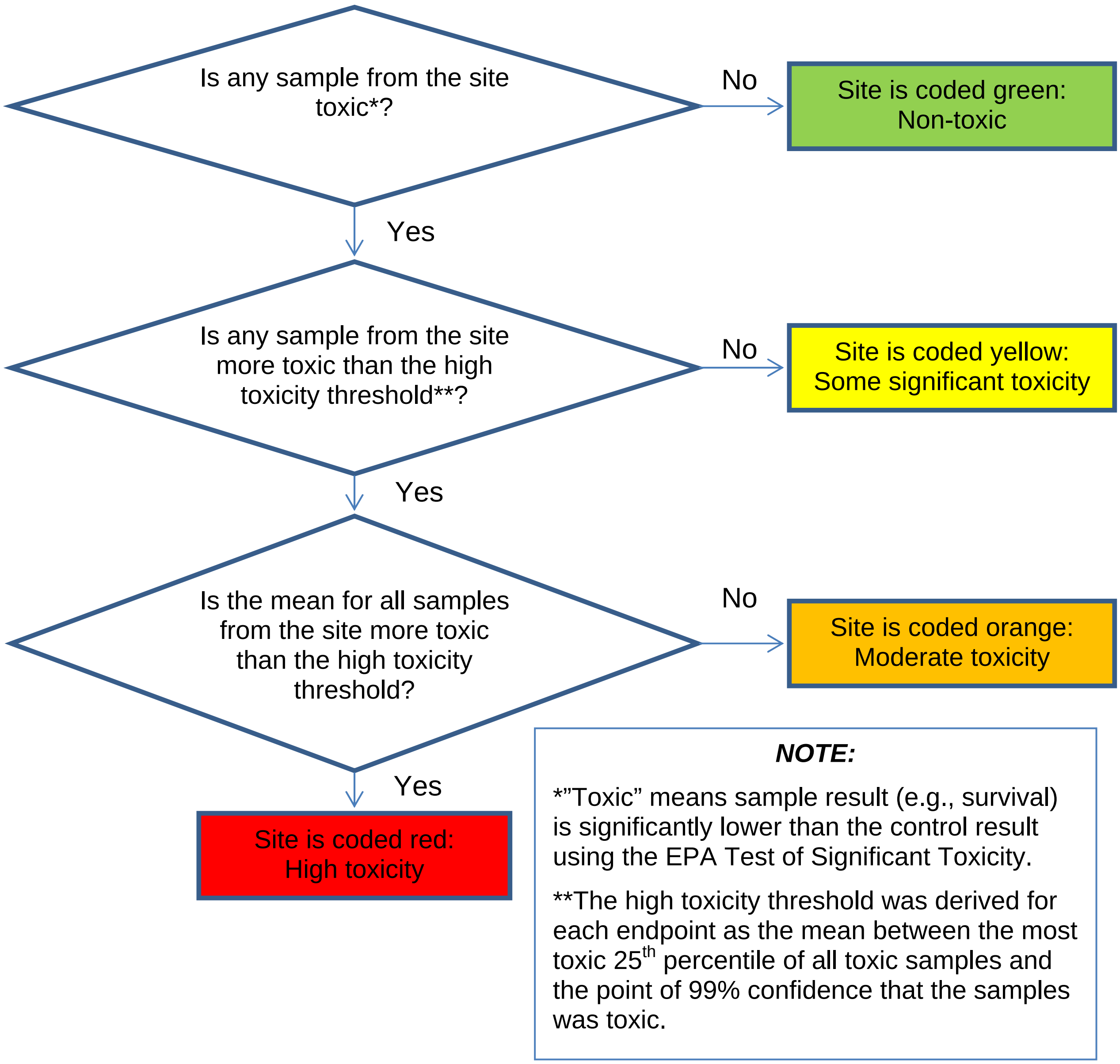
Mark Pranger, Moss Landing Marine Laboratories, SWAMP Data Management Team

Acknowledgements

We thank State Water Board staff Jeff Kapellas, Dana Nolan and Wynshum Luke for GIS analysis of site drainage areas and land cover, as well as for creating the maps of toxicity results in California.

Figure 11. Site categorization process

The process used to characterize the magnitude of toxicity at each site was designed to take into consideration the widely varying number of samples and test endpoints (such as fish or crustacean survival) among sites. If any toxic samples were measured for a site, the site was categorized based on the most sensitive endpoint. This process considers both individual sample results and the mean results for sites with multiple samples. Relative to the impaired waterbody listing process, a site coded "green" would not be listed for toxicity. Sites coded "yellow" to "red" would be listed if the number of toxic samples met the criteria outlined in the State Water Board's Listing and De-listing Policy.



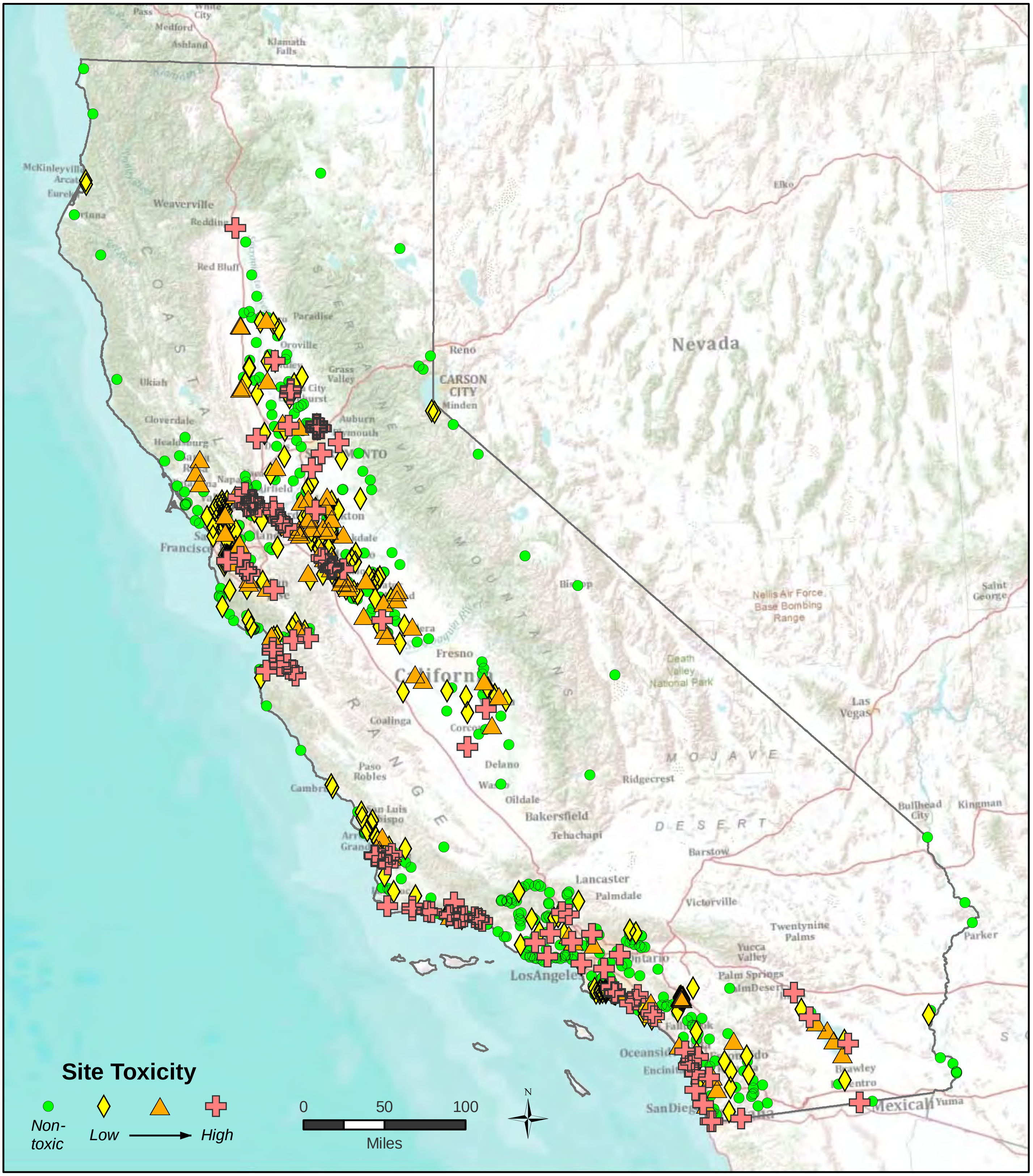


Figure 1. Magnitude of toxicity at all California sites assessed, based on the most sensitive species (test endpoint) in either water or sediment samples at each site.

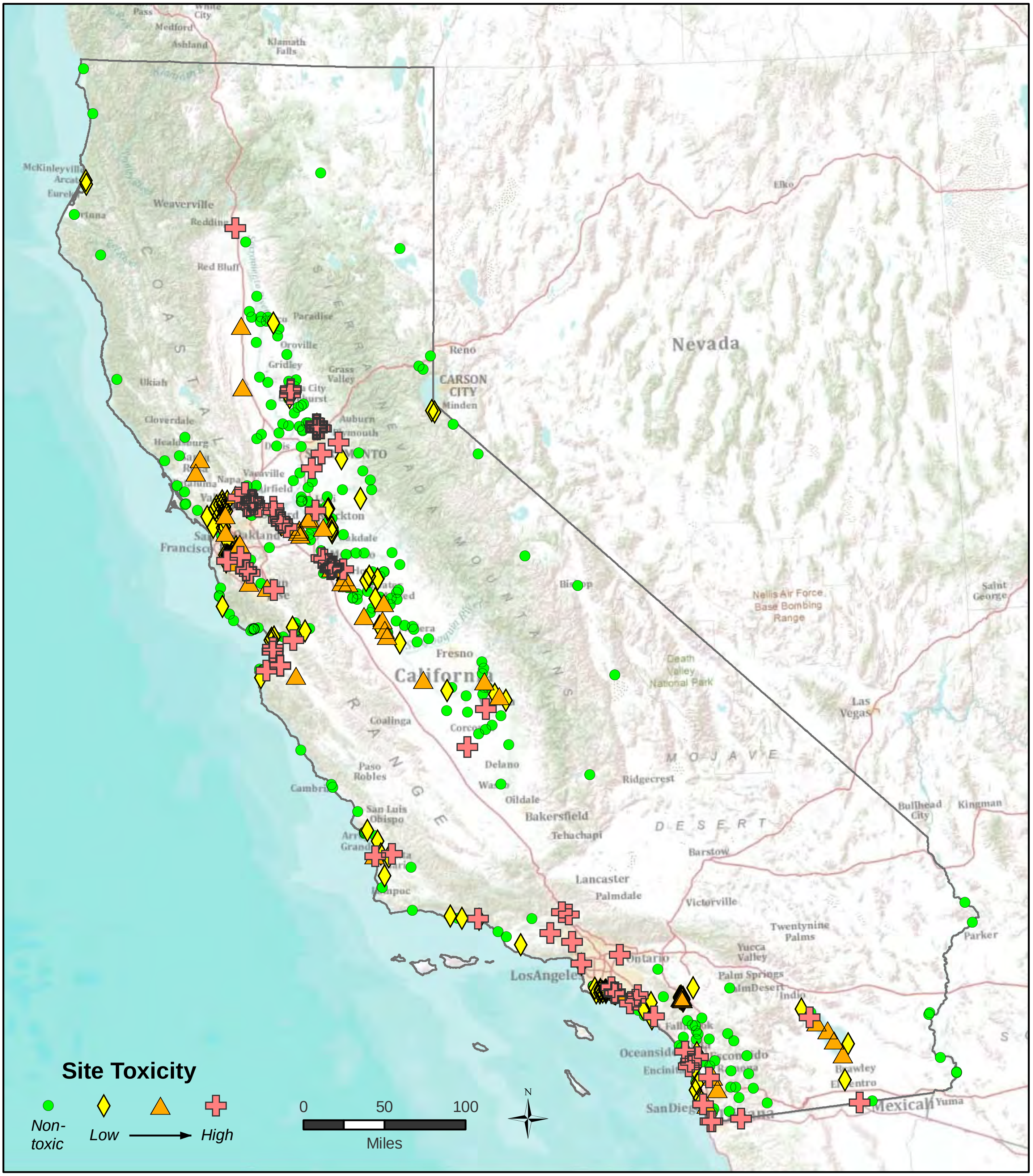
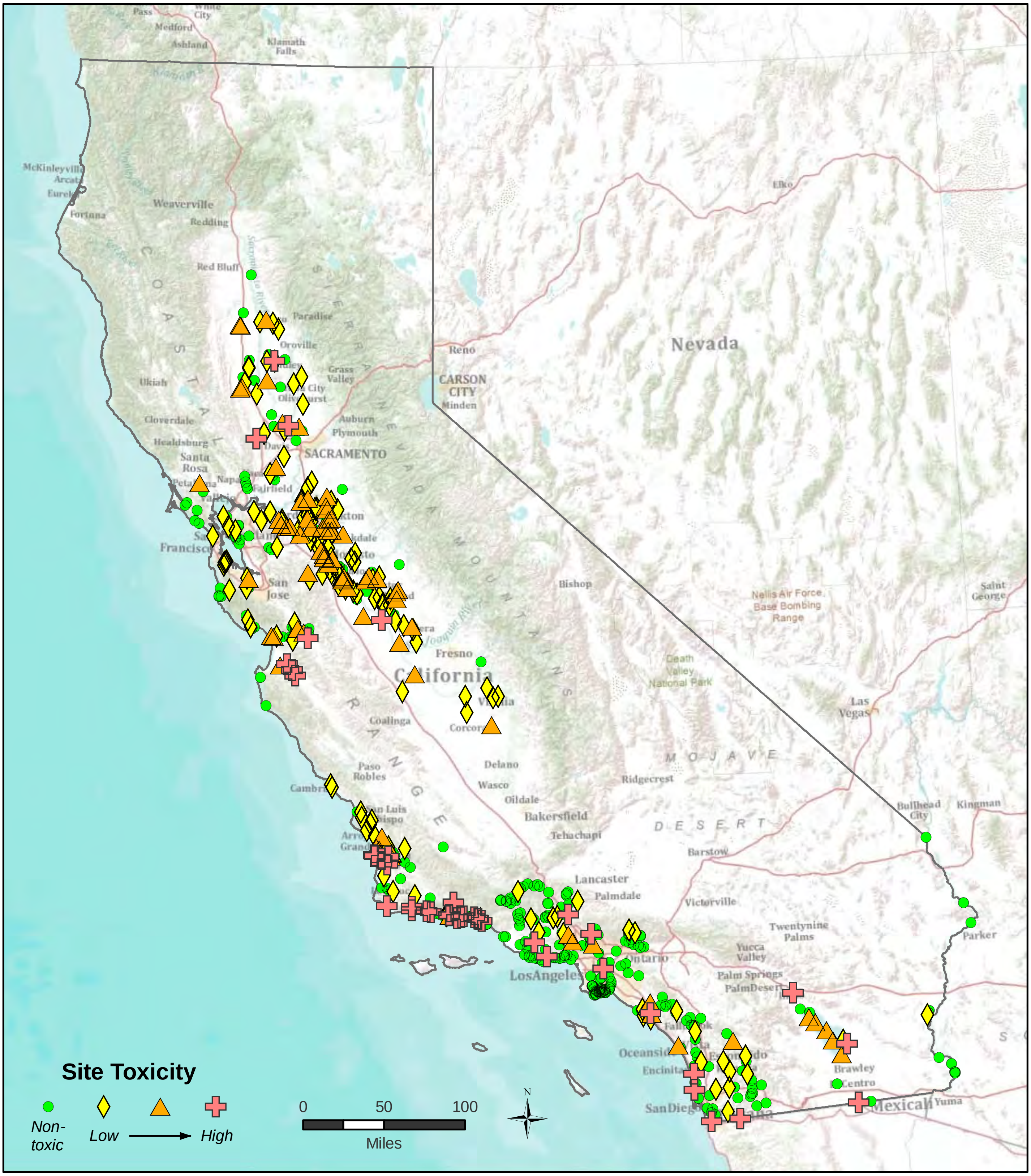


Figure 2. Magnitude of sediment toxicity at all California sites assessed, based on the most sensitive species (test endpoint) in sediment samples collected at each site.



S:\GIS\SWAMP\Toxicity Report\wattox map.mxd (11/5/10)

Figure 3. Magnitude of water column toxicity at all California sites assessed, based on the most sensitive species (test endpoint) in water samples collected at each site.

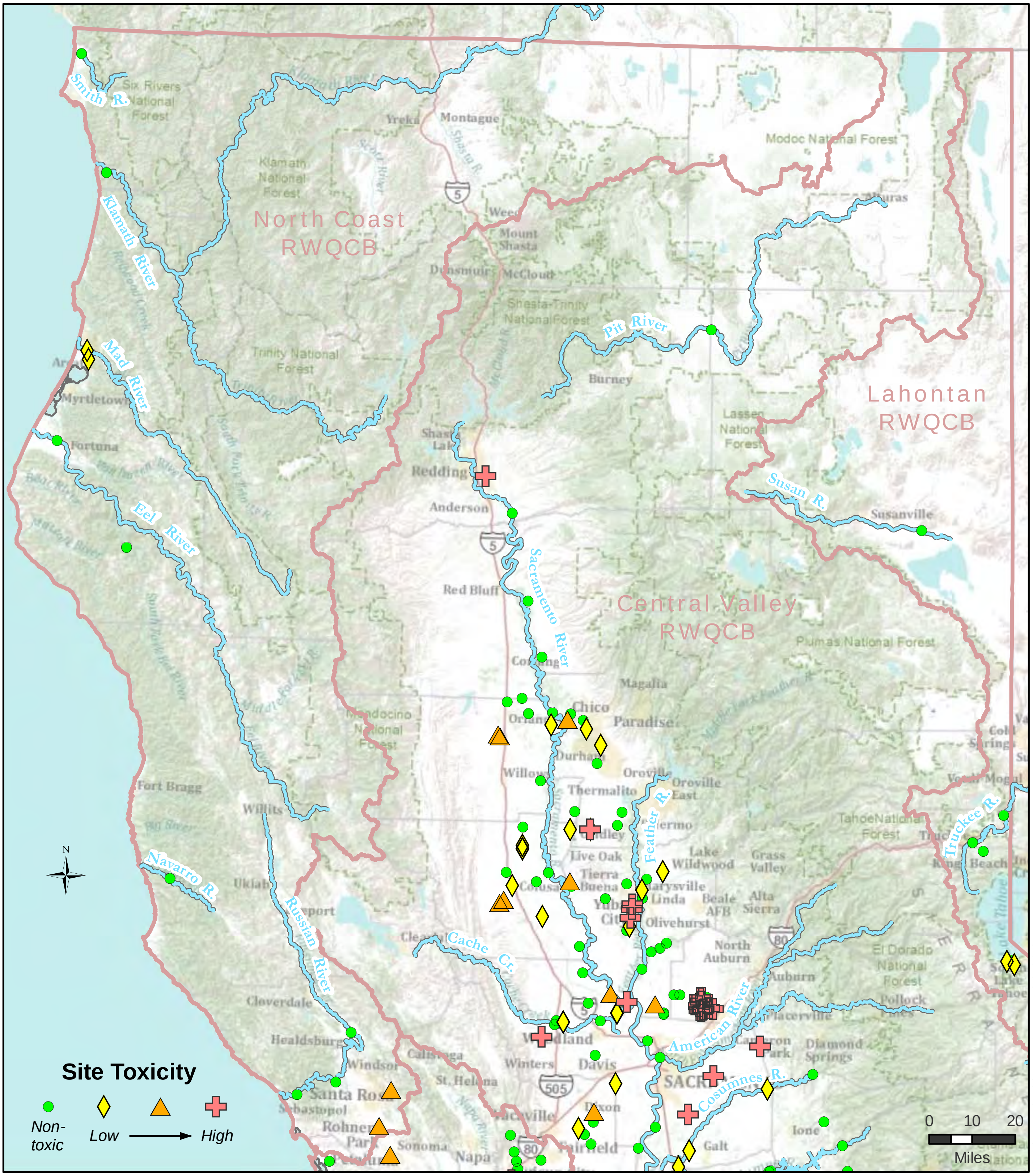
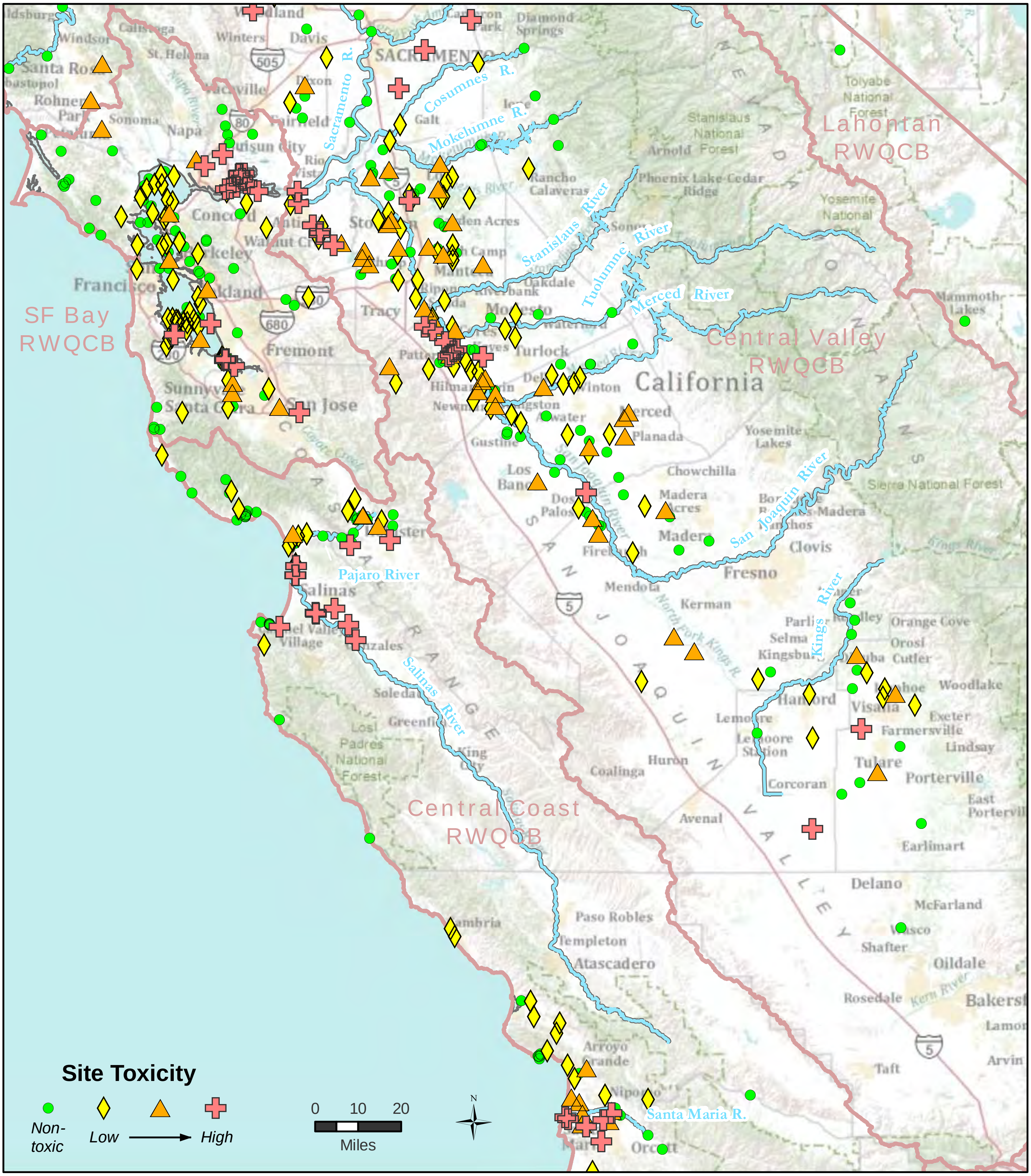
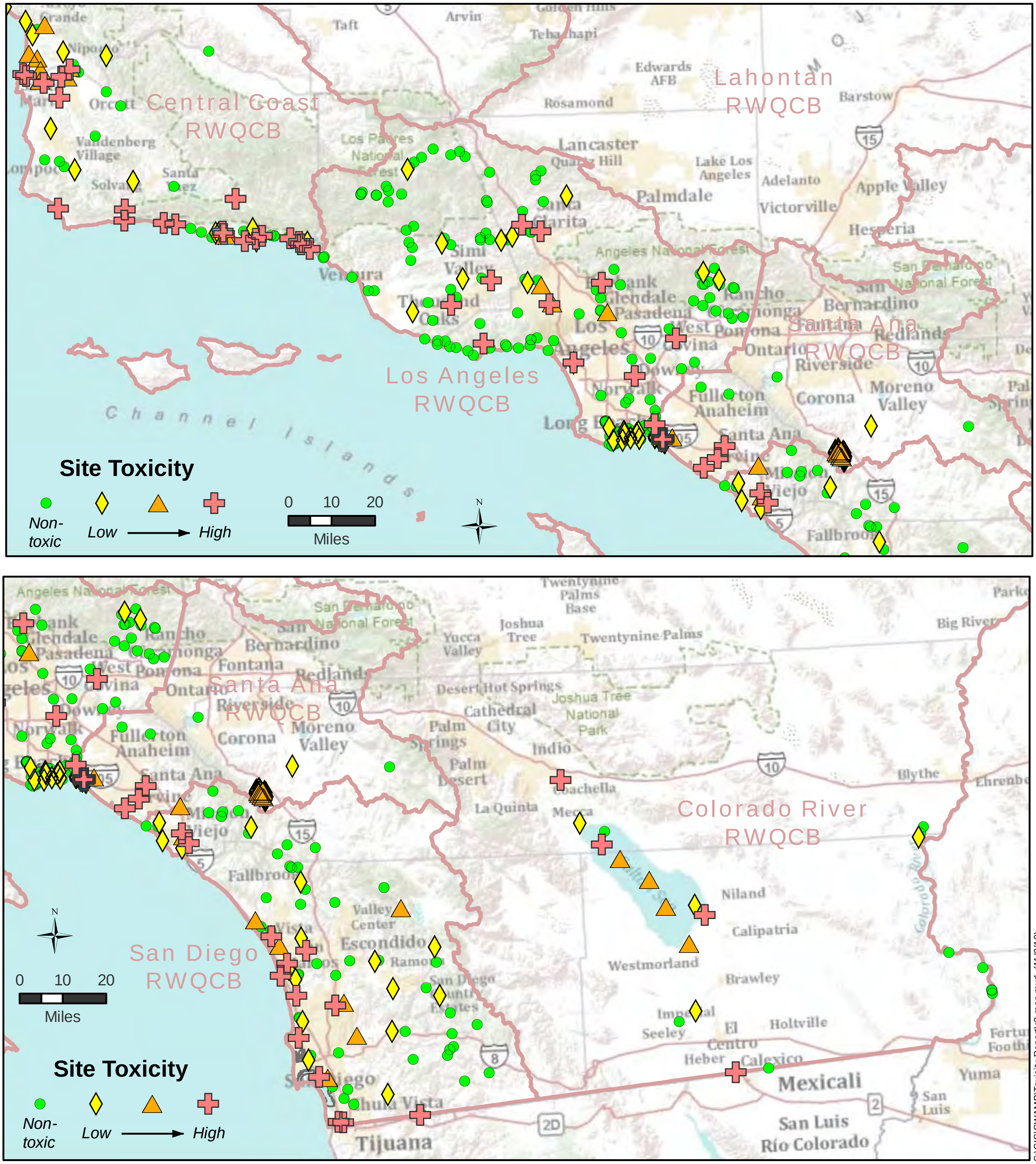


Figure 4. Magnitude of toxicity at sites in northern California, based on the most sensitive species (test endpoint) in either water or sediment samples at each site.



S:\GIS\SWAMP\Toxicity Report\r2 map.mxd (11/2/10)

Figure 5. Magnitude of toxicity at sites in central California, based on the most sensitive species (test endpoint) in either water or sediment samples at each site.



S:\GIS\SWAMP\Toxicity Report\r3 map.mxd (11/2/10)

Figure 6. Magnitude of toxicity at sites in southern California, based on the most sensitive species (test endpoint) in either water or sediment samples at each site.

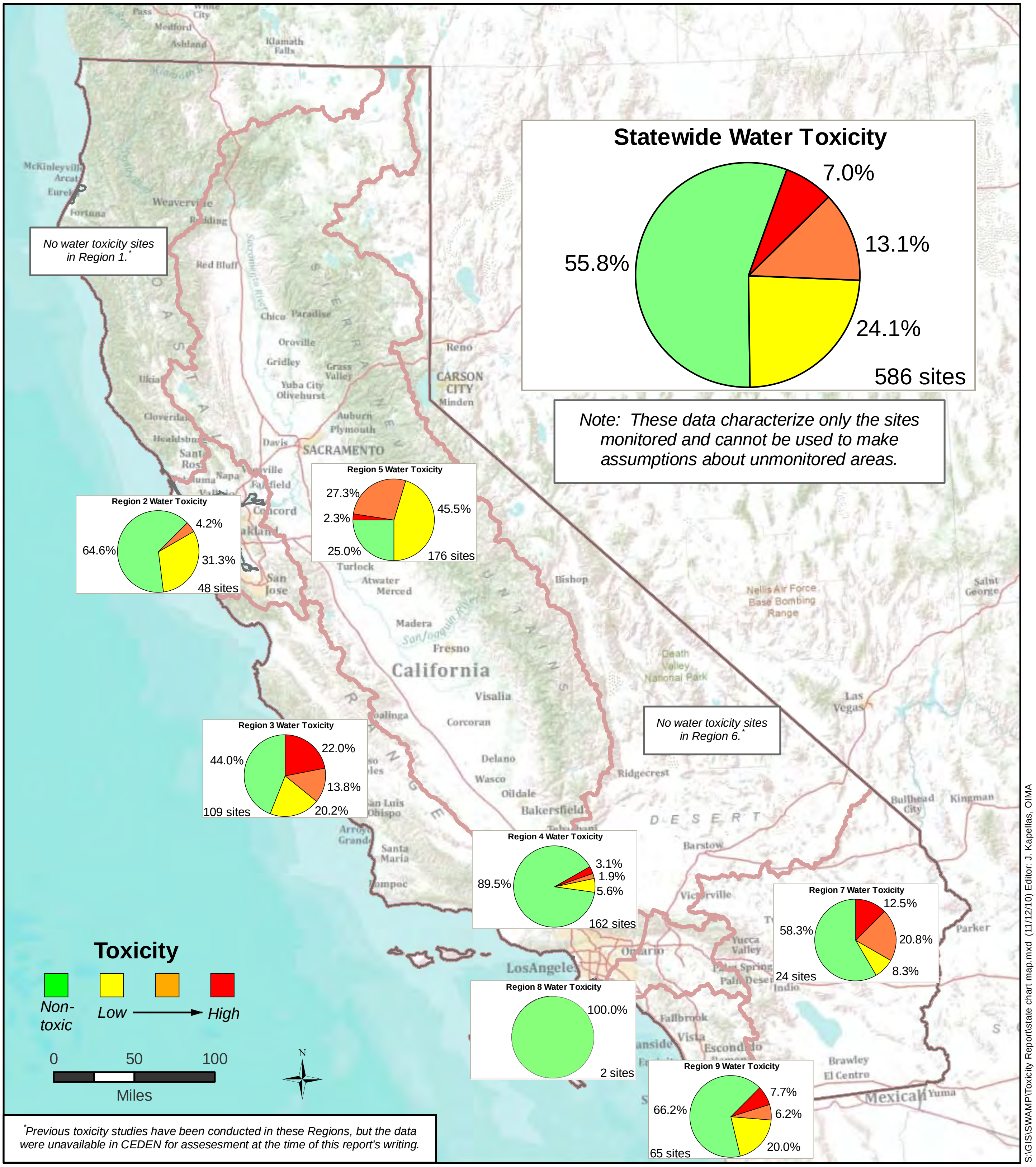


Figure 7. Magnitude of toxicity in water statewide and by Regional Water Board. Color coding is as shown in Figure 11.

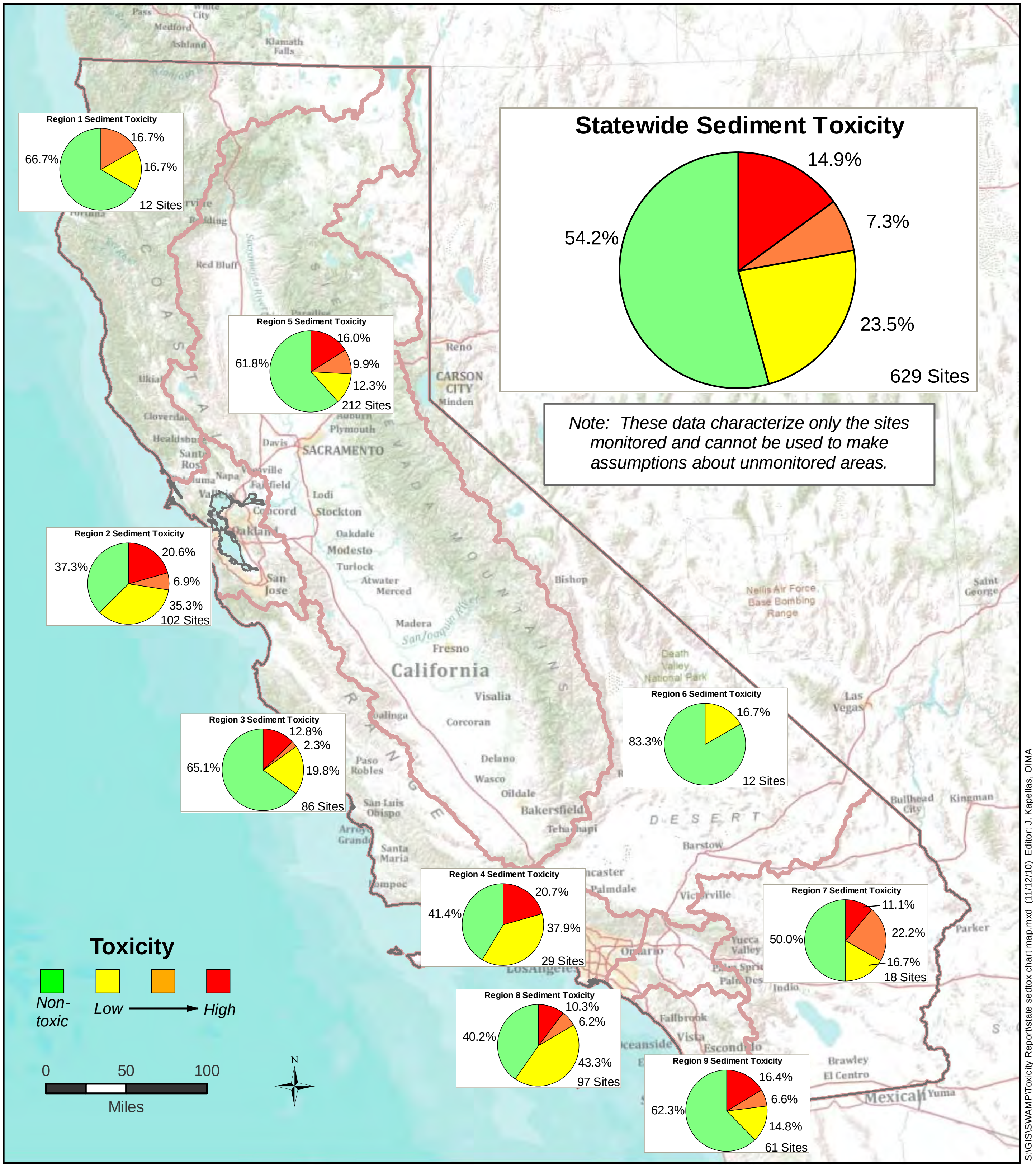


Figure 8. Magnitude of toxicity in sediment statewide and by Regional Water Board. Color coding is as shown in Figure 11.