Addressing Nitrate in California's Drinking Water

TECHNICAL REPORT 1:

Project and Technical Report Outline

With a Focus on Tulare Lake Basin and Salinas Valley Groundwater

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

California Nitrate Project,
Implementation of Senate Bill X2 1

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

Prepared for the California State Water Resources Control Board

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California Nitrate Project, Implementation of Senate Bill X2 1

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Contents

1 Significance and Scope of Work

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 micro-organisms 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).

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 (10mg/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.

2 Outline of Technical Reports

The reports are organized to address the specific questions posed by SBX2 1.

Technical Report 2 – Sources of Groundwater Nitrate (Viers et al., 2012) describes the sources of nitrate in groundwater, reviews literature data on groundwater nitrate leaching from these sources, and assembles a wide range of data from numerous sources to quantify groundwater nitrate loading from individual categories of dischargers.

Technical Report 3 – Nitrate Source Reduction to Protect Groundwater Quality (Dzurella et al., 2012) provides an extensive review of both literature information and expert opinion collected specifically for this project on options and costs for reducing nitrate loading to groundwater.

Technical Report 4 – Groundwater Nitrate Occurrence (Boyle et al., 2012) reviews the hydrogeology and groundwater quality in the study area with an emphasis on nitrate. It also documents the assembly of a large database of groundwater nitrate data from the study area, which are then analyzed for historic trends and spatial distribution of nitrate. To provide an assessment of future groundwater quality, a groundwater model was developed that links the source loading developed in Technical Report 2 (Viers et al., 2012) to a groundwater transport model and predict both, historic and future groundwater quality.

Technical Report 5 – Groundwater Remediation (King et al., 2012) explains options for groundwater remediation. Traditional and alternative remediation options are explored. To the degree possible, it also details potential costs of these options. The chapter outlines groundwater quality management practices.

Technical Report 6 – Drinking Water Treatment for Nitrate (Jensen et al., 2012) is a comprehensive guide on treatment options for potable water supplies. Ion exchange, reverse osmosis, electrodialysis, and biological and chemical denitrification processes are explained, their advantages and disadvantages are described, as well as costs. The chapter also provides a guidance for selecting mitigation strategies to address nitrate in drinking water.

Technical Report 7 – Alternative Water Supply Options for Nitrate Contamination (Honeycutt et al., 2012) defines and identifies the population susceptible to nitrate in drinking water, reviews alternative water supply options for water systems and private well owners, and reviews strategies and costs for the implementation of alternative water supply options.

Technical Report 8 – Regulatory and Funding Options for Nitrate Groundwater Contamination (Canada et al., 2012) provides a summary of current regulatory programs and outlines potential future regulatory options to manage nitrate. It reviews current and potential funding options to address safe drinking water issues in the study area.

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