Nitrate Implementation Measures Study (NIMS)

Draft Work Plan

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Prepared for
SAN JOAQUIN VALLEY DRAINAGE AUTHORITY

Submitted by
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<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>BPA</td>
<td>Basin Plan Amendment</td>
</tr>
<tr>
<td>CAFOs</td>
<td>concentrated animal feeding operations</td>
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<tr>
<td>CASGEM</td>
<td>California Statewide Groundwater Elevation Monitoring</td>
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<tr>
<td>Central Valley Water Board</td>
<td>Central Valley Regional Water Quality Control Board</td>
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<tr>
<td>CV-SALTS</td>
<td>Central Valley Salinity Alternatives for Long-Term Sustainability</td>
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<tr>
<td>CVSC</td>
<td>Central Valley Salinity Coalition</td>
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<tr>
<td>CWA</td>
<td>Clean Water Act</td>
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<tr>
<td>DAC</td>
<td>disadvantaged community</td>
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<tr>
<td>DUC</td>
<td>disadvantaged unincorporated community</td>
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<tr>
<td>DWR</td>
<td>California Department of Water Resources</td>
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<tr>
<td>GAR</td>
<td>Groundwater Quality Assessment Report</td>
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<tr>
<td>IAZ</td>
<td>Initial Analysis Zone</td>
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<tr>
<td>ICM</td>
<td>Initial Conceptual Model</td>
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<tr>
<td>ILRP</td>
<td>Irrigated Lands Regulatory Program</td>
</tr>
<tr>
<td>IRWM</td>
<td>Integrated Regional Water Management</td>
</tr>
<tr>
<td>IX</td>
<td>ion exchange</td>
</tr>
<tr>
<td>JPA</td>
<td>joint powers authority</td>
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<tr>
<td>MCL</td>
<td>maximum contaminant level</td>
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<tr>
<td>MHI</td>
<td>median household income</td>
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<td>MPEP</td>
<td>Management Practices Evaluation Programs</td>
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<td>NHI</td>
<td>nitrate hazard index</td>
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<tr>
<td>NIMPS</td>
<td>Nitrate Implementation Measures Prioritization Score</td>
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<tr>
<td>NIMS</td>
<td>Nitrate Implementation Measures Study</td>
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<tr>
<td>NTP</td>
<td>notice-to-proceed</td>
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<tr>
<td>PAF</td>
<td>pump and fertilize</td>
</tr>
<tr>
<td>PAT</td>
<td>pump and treat</td>
</tr>
<tr>
<td>PRBs</td>
<td>permeable reaction barriers</td>
</tr>
<tr>
<td>RO</td>
<td>reverse osmosis</td>
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<tr>
<td>SAMP</td>
<td>Surveillance and Monitoring Program</td>
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<tr>
<td>SNMP</td>
<td>Salt and Nitrate Management Plan</td>
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<tr>
<td>SRWP</td>
<td>State Recycled Water Policy</td>
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<tr>
<td>SSALTS</td>
<td>Strategic Salts Accumulation Land and Transportation Study</td>
</tr>
<tr>
<td>State Water Board</td>
<td>State Water Resource Control Board</td>
</tr>
<tr>
<td>TAC</td>
<td>Technical Advisory Committee</td>
</tr>
<tr>
<td>TDS</td>
<td>total dissolved solids</td>
</tr>
</tbody>
</table>
### Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>TRC</td>
<td>Technical Review Committee</td>
</tr>
<tr>
<td>USEPA</td>
<td>US Environmental Protect Agency</td>
</tr>
<tr>
<td>WWTP</td>
<td>wastewater treatment plant</td>
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</table>
Section 1

Project Overview

“...[It is] the policy of the state that every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes.” State Water Board, Report to the Legislature: Recommendations Addressing Nitrate in Groundwater.

1.1 Background

The Central Valley Salinity Alternatives for Long Term Sustainability (CV‐SALTS) is developing a comprehensive regulatory and programmatic approach to the management of salt and nitrate as nitrogen\(^1\) in the Central Valley that is consistent with the State Recycled Water Policy (SRWP). This work is being done with the Central Valley Regional Water Quality Control Board (Central Valley Water Board), the State Water Resources Control Board (State Water Board), the Central Valley Salinity Coalition (CVSC), and other stakeholders. As stated in the CV‐SALTS Strategy and Framework document, the strategy to fulfill the requirements of the SRWP is to adopt a Central Valley Salt and Nitrate Management Plan (SNMP) and revise the Basin Plans applicable to the Central Valley to facilitate implementation of the SNMP. Fulfillment of this strategy will establish the basis for short and long-term management of salt and nitrate across the Central Valley.

The SWRP states the following:

“\textit{It is the intent of this Policy that salts and nutrients from all sources be managed on a basin-wide or watershed-wide basis in a manner that ensures attainment of water quality objectives and protection of beneficial uses...the appropriate way to address salt and nutrient issues is through the development of regional or subregional salt and nutrient management plans rather than through imposing requirements solely on individual recycled water projects.}”

Among other things, the SRWP requires that development of the SNMP include the following element (SRWP Section 6.b.3 (e)): “Implementation measures to manage salt and nutrient loading in the basin on a sustainable basis.”

Salt disposal and implementation strategies were developed previously by CV‐SALTS in the three-phased Strategic Salt Accumulation Land and Transportation Study (SSALTS) (CDM Smith, 2013, 2014, and In Preparation). The purpose of SSALTS was to identify the range of viable Central Valley alternatives for salt disposal to provide input for consideration during development of the SNMP for the region under the jurisdiction of the Central Valley Water Board, and establish salt management implementation measures for inclusion in the SNMP.

This work plan for the Nitrate Implementation Measures Study (NIMS) addresses nitrate contamination in the groundwater basins of the Central Valley and appropriate implementation

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\(^1\) By convention, nitrate will be expressed in terms of nitrate as nitrogen in the NIMS. “Nitrate,” “nitrate,” and “NO\(_3\)-N” all refer to nitrate as nitrogen, with a maximum contaminant level (MCL) of 10 milligrams per liter (mg/L).
measures to mitigate nitrate contamination using a phased approach. These implementation measures will be incorporated into the SNMP. The findings from both the SSALTS and the NIMS will be used to guide discussions regarding the need for changes to the existing Basin Plan to facilitate salt disposal and mitigation measures for nitrate in a manner that is most beneficial to the region covered by the SNMP.

1.2 Work Plan Purpose and Objectives

The findings from the completion of the NIMS will provide input to policymakers regarding implementation measures to reduce current ambient nitrate concentrations in groundwater. The implementation measures will be phased and a prioritization methodology will be used to rank groundwater basins in order of priority – where risk reduction from nitrate in groundwater is optimized to facilitate use of the limited resources available. The specific objectives of this study include the following:

1. Summarize salient information about the occurrence, distribution, groundwater remediation, and drinking water treatment of nitrate from the literature. This information will be incorporated by reference. The NIMS will focus on the application of information in the literature to groundwater basins in the Central Valley.

2. Develop a proposed phasing approach for various nitrate implementation measures and establish the nitrate attainment goal in groundwater.

3. Define a prioritization methodology, wherein groundwater basins, subbasins or management zones are ranked based on the potential for nitrate impacts to users. The goal of NIMS is to reduce risk from nitrate in groundwater sources of water supply for the greatest number of users, given resource constraints.

4. Estimate concept-level costs and general timeframes for certain nitrate implementation measures. Nitrate implementation measures could include source control measures\(^2\), managed aquifer restoration, pumping and applying for fertilize value, blending, drilling deeper wells, *in situ* treatment, providing alternative sources of drinking water, and treatment of pumped groundwater for potable use.

5. Define the linkage between proposed nitrate implementation measures and interim and long-term SSALTS alternatives, and propose an

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\(^2\) For example, the Management Practices Evaluation Programs (MPEPs) that will be developed by the Irrigated Lands Regulatory Program (ILRP) coalition groups.
implementation program that considers both nitrate and salt priorities together.

6. Provide support for the development of the SNMP by providing information on acceptable nitrate and salt implementation measures that can be used as a menu for salt and nitrate management, which can help guide the development of specific implementation measures within groundwater basins and subbasins or management zones.

7. Provide input to Executive Committee policy discussions regarding acceptable salt and nitrate implementation measures.
Section 2

Tasks to Define Nitrate Implementation Measures

This introduction is a road map that describes how nitrate and salt implementation measures will be evaluated for inclusion into the SNMP. Task 1 will include project set-up and management tasks and meetings. Task 2 will develop a proposed phased approach and attainment goals for nitrate in groundwater. This will determine when certain implementation measures would be undertaken to achieve those attainment goals. In Task 3, various criteria will be evaluated to determine the priority ranking of groundwater basins for nitrate mitigation. Nitrate implementation measures for groundwater, including source control measures, groundwater remediation, and alternate water supplies will be reviewed in Task 4. Task 4 will also include the development of a nitrate balance model. The nitrate balance model will be used to determine how much mass of nitrate would need to be pumped and treated to achieve the Phase 2 and 3 goals discussed in Task 2. For a pilot study area, a similar estimate will be made to mitigate nitrate from only those portions of a groundwater basin that currently exceed the attainment target. The pilot study would be a groundwater basin or management zone, e.g., the Alta Irrigation District Management Zone. Task 5 will describe the nitrate implementation measures selection process for a pilot study area, developing the check-list of implementation measures that would be evaluated. Task 6 will develop joint nitrate and salinity implementation measures.

2.1 Task 1. Project Set-up and Management

CDM Smith will perform all project management services for NIMS, including resource allocation and scheduling, cost controls, monthly invoice preparation and review, and the preparation of monthly status reports. Richard Meyerhoff, PhD will serve as the project manager, while Joe LeClaire, PhD will be the technical lead. The establishment of a project committee to work on nitrate implementation measures and to assist with the linkage of NIMS and SSALTS is recommended. CDM Smith will lead and/or participate in the following meetings:

- **Project Kick-off Meeting.** This meeting will be conducted by conference call and will take place within two weeks of the notice-to-proceed (NTP).

- **CDM Smith Internal Technical Review Committee (TRC) Meeting.** An internal CDM Smith TRC meeting will be scheduled for the start of Task 5.

- **CV-SALTS NIMS Project Committee and Coordination with the CV-SALTS Technical Project Manager.** The NIMS Project Committee will meet at the start of Tasks 4 and 5, where input to proposed approaches will be solicited from the project committee members. CDM Smith will coordinate with and proceed under the direction of the CV-SALTS Technical Project Manager, Roger Reynolds

- **CV-SALTS Technical Advisory Committee (TAC) Meeting.** CDM Smith will present progress updates to the TAC and seek feedback; TAC meetings will be scheduled at the completion of Tasks 4 and 5. It is anticipated that the meetings would be conducted
through on-line conferencing. The specific timing and content of these meetings will be coordinated with the CV-SALTS Technical Project Manager, Roger Reynolds.

- **Executive Committee Meeting.** This Executive Committee meeting will be held after Task 5 and will incorporate input from the preceding TAC meeting.

### 2.2 Task 2. Develop a Proposed Phased Approach and Nitrate Attainment Goals

The purpose of this task is to develop a proposed phased approach for various nitrate implementation measures and to establish the nitrate attainment goals in groundwater. The phased approach for the mitigation of nitrate in groundwater includes the phases shown in Table 2-1. The implementation measures are described in Task 4; the purpose of Task 2 is to define and agree on the objectives of each phase.

**Table 2-1 Phases of Nitrate Implementation Measures**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Period (years)</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 – 5</td>
<td>User Protection</td>
</tr>
<tr>
<td>2</td>
<td>5 – 20</td>
<td>Balance input/outflow of nitrate</td>
</tr>
<tr>
<td>3</td>
<td>&gt; 20 to 50</td>
<td>Restore beneficial uses - managed aquifer restoration</td>
</tr>
</tbody>
</table>

The immediate concern in Phase 1 is user protection; reducing risk to individuals and communities from water supplies with nitrate concentrations greater than the MCL. The mapping subtasks in Task 3 will provide some information on communities most at risk of delivering and consuming pumped groundwater with nitrate concentrations exceeding the maximum contaminant level (MCL) of 10 milligrams per liter (mg/L). Larger water utilities that pump high nitrate groundwater currently are blending or treating water to meet the MCL. Smaller communities, especially disadvantaged communities (DACs) or disadvantaged unincorporated communities (DUCs), as well as individuals with shallow domestic supply wells, are at greater risk. Public outreach and education and alternative water supplies will be necessary at least in the near term to ensure user protection for those constituencies.

Phases 2 and 3 would implement measures to actively remove nitrate from groundwater and thereby lower ambient concentrations. These implementation measures are described in Task 4.

The default nitrate attainment goal in groundwater in general is the MCL. However, where current ambient groundwater nitrate is less than the MCL, the goal would be an antidegradation target that would be to preserve or maintain the current ambient nitrate concentrations and not allow a long term increase, absent a maximum benefit demonstration. If the current ambient groundwater nitrate is greater than the MCL, the target attainment goal would be to reduce average ambient groundwater concentrations to 10 mg/L. The determination of current ambient concentrations of TDS and nitrate in groundwater are the subject of other CV-SALTS initiatives.
2.3 Task 3. Define a Groundwater Prioritization Methodology

A prioritization methodology will be defined in the NIMS, wherein groundwater basins, subbasins or management zones are ranked based on the potential for nitrate impacts to users. The goal of NIMS is to reduce risk from nitrate in groundwater sources of water supply for the greatest number of users, given resource constraints. There are 118 groundwater basins and subbasins in the Central Valley, as defined by DWR Bulletin 118 (DWR, 2003). The NIMS prioritization methodology will be used to rank the groundwater basins and the score will be called the Nitrate Implementation Measures Prioritization Score (NIMPS). The proposed methodology for prioritizing the groundwater basins is based on the following criteria:

- Volume-weighted average nitrate concentration in groundwater.
- Modeled nitrate loading to the upper groundwater aquifer.
- Vulnerability assessment from the Groundwater Quality Assessment Reports (GARs) developed by ILRP Coalition groups.
- The overlying population.
- The percentage of the overlying population that would be considered a part of a DAC or a DUC.

Each of these criteria are proposed to be normalized to a common scale and weighted equally to determine the NIMPS. Brief descriptions of the ranking criteria are provided in the following subsections.

2.3.1 CASGEM Program Basin Prioritization Process and Ranking.

As part of the CASGEM program, DWR is required to prioritize groundwater basins in California to “help identify, evaluate, and determine the need for additional groundwater level monitoring.” The CASGEM Basin Prioritization Process is based on the following eight criteria:

1. Overlying population;
2. Projected growth of overlying population;
3. Public supply wells;
4. Total wells;
5. Overlying irrigated acreage;
6. Reliance on groundwater as the primary source of water;

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3 [http://www.water.ca.gov/groundwater/casgem/basin_prioritization.cfm](http://www.water.ca.gov/groundwater/casgem/basin_prioritization.cfm)
7. Impacts on the groundwater; including overdraft, subsidence, saline intrusion, and other water quality degradation; and

8. Any other information determined to be relevant by the Department.

The CASGEM rankings for groundwater basins in the Central Valley are shown in Table 2-2.

<table>
<thead>
<tr>
<th>Hydrologic Region</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
<th>Very Low</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sacramento River</td>
<td>5</td>
<td>18</td>
<td>4</td>
<td>61</td>
<td>88</td>
</tr>
<tr>
<td>San Joaquin River</td>
<td>7</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Tulare Lake</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>Totals</td>
<td>19</td>
<td>21</td>
<td>5</td>
<td>73</td>
<td>118</td>
</tr>
</tbody>
</table>

### 2.3.2 Volume-Weighted Nitrate Concentration

The volume weighted mass of nitrate in each groundwater basin will be estimated using a Thiessen polygon method. The Thiessen polygon method is a simple method for defining an area of influence around points and for distributing a property areally. An example would be nitrate concentration for a given well. ArcGIS will be used to construct the Thiessen polygon shapefile and polygons will be generated for each well in a groundwater basin such that any point within the polygon is closer to that well than any other well in the groundwater basin (Figure 2-1). The polygon would then be assigned the concentration of nitrate in the associated well. The data used in these analyses are from the CV-SALTS database (LWA, 2014). Figure 2-2 shows an example Thiessen polygon map for the Westside Basin.

The ten-year\(^5\) average nitrate concentration for a given well will be assigned to the entire polygon. The volume of groundwater associated with each polygon is calculated from the difference between groundwater elevation and the base of the aquifer or aquifer zone. Groundwater elevations for each polygon will be estimated from DWR’s California Groundwater Update 2013 or for the ILRP GARs. To the extent possible, average nitrate concentrations will be


\(^5\) 2004 through 2014
Figure 2-2  Thiessen Polygon Map of Nitrate Concentrations in the Westside Groundwater Basin: Maximum Concentrations from 1993 through 2015
estimated for the production zone for each polygon. Volume-weighted nitrate concentrations will be calculated based on the nitrate concentration assigned to each polygon, along with the estimated volume (with an assumed aquifer porosity).

2.3.3 Nitrate Loading to the Upper Groundwater Aquifer

The Initial Conceptual Model (LWA et al., 2013) provides an estimate of TDS and nitrate loading to the upper groundwater zone: “On a per acre basis, [Initial Analysis Zone] IAZs 14 through 21 in the southern Central Valley have relatively greater magnitudes of nitrate loading compared to the northern and middle portions of the Central Valley (Table 10-4). For the northern and middle portions of the Central Valley, IAZs 6 and 7 have relatively higher magnitudes of loading compared to other IAZs in these two regions.” The nitrate loading (kg/acre) will be assigned to each groundwater basin or subbasin within each IAZ. Each groundwater basin or subbasin will then be ranked in order of nitrate loading.

2.3.4 Nitrate Vulnerability Assessments

The GARs developed by the ILRP Coalition groups contain an assessment of the vulnerability of areas within the Coalition boundaries to nitrate leaching and impacts to groundwater. The GAR groundwater vulnerability analyses typically included factors for agricultural management systems: irrigation practices, soil characteristics and crop type and pattern. Combinations of these factors can be used to define a nitrate hazard index (NHI). Some of the GARs also accounted for current exceedances of water quality objectives in groundwater, trends in water quality, and proximity to DACs that rely on groundwater as a primary drinking water source.

2.3.5 Overlying Population

The 2010 Census Profile data from 2010 US Census of Population and Housing will be analyzed in ArcGIS to estimate the overlying population of each groundwater basin or subbasin.

2.3.6 DACs/DUCs

The population of DACs within a groundwater basin will be based on DWR’s Integrated Regional Water Management (IRWM) guidelines. For IRWMs, DWR defines DACs to be geographic areas where the annual median household income (MHI) is less than 80 percent of the statewide annual MHI. DWR used the US Census American Community Survey (ACS) 5-Year Data: 2009 - 2013 (MHI of $61,094 and a calculated DAC threshold of $48,875). Where defined, the NIMS will also take into account DUCs.

2.3.7 Nitrate Implementation Measures Prioritization Score

Each groundwater basin will be assigned a score for each of the six criteria and will be ranked according to their NIMPS. Groundwater basins with higher scores would be considered a higher ranked or prioritized basin. Nitrate implementation measures may be considered sooner in higher-ranked groundwater basins, subbasins, or a management zone within a groundwater basin. The goal of the prioritization analysis is to develop an implementation order that will

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6 As defined by CV-SALTS
7 http://www.policylink.org/sites/default/files/CA_UNINCORPORATED_2.PDF
reduce the risk from nitrate ingestion of drinking water for the largest at-risk population most efficiently.

### 2.4 Task 4. Nitrate Implementation Measures

There are a number of nitrate implementation measures that will reduce nitrate loading to groundwater and reduce ambient concentrations in impacted groundwater basins and subbasins as well as protect groundwater users. These implementation measures fall into three broad categories:

- Source control measures
- Groundwater remediation
- Alternate water supplies

The goal of Task 4 is to consider the most critical measures and to determine the feasibility of implementing these and developing planning level costs.

#### 2.4.1 Develop Nitrate Mass Balance Model

As part of the NIMS, a mass balance spreadsheet model will be developed similar to the TDS mass balance developed previously (CDM Smith, 2014). The mass balance model will look at projected concentrations of nitrate in groundwater for each of the IAZs based on the results from the Initial Conceptual Model (ICM). The information from ICM Tables 10-4 and 10-5 will be used as the basis for nitrate loading in the NIMS. The nitrate loading (kg/acre) and the area will be used to determine the mass loading of nitrate for each IAZ on an annual basis. The upper groundwater nitrate data will then be used in a mass balance analysis to determine the volume of groundwater that would need to be extracted to achieve various targets of nitrate in each groundwater basin. It should be noted that there is a large legacy nitrate load in the vadose zone and that the nitrate in groundwater is a result of anthropogenic activities that occurred decades ago. The NIMPS will make an assumption that loading from legacy nitrate in the vadose zone will not change for 50 years. In other words, changes in source control measures and other management practices made today to reduce nitrate leaching will not have an impact on groundwater concentrations until 2065.

#### 2.4.2 Source Control Measures

There are a number of source control measures that can be applied across all sectors of nitrate contributors to groundwater, including: agricultural (croplands, dairies, feedlots), industrial, urban (outdoor water use and fertilizer application, wastewater treatment plants), food processing wastewater disposal, etc. (Viers, 2012).

Harter et al., (2012) reviewed sources of nitrate to groundwater in the Tulare Lake Basin and the Salinas Valley (a similar distribution would be expected for the San Joaquin River Basin, as well) and identified the following as illustrated in Figure 2-3:

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8 Treatment technologies such as ion exchange, reverse osmosis, electrodialysis, weak-base anion exchange, chemical and biological denitrification are summarized in the literature (e.g., Jensen et al., 2012) and will be included herein by reference.
- Irrigated agriculture (croplands)
- Wastewater treatment plant and food processing waste discharges
- On-site waste disposal systems (Septic systems)
- Urban land uses
- Corrals
- Lagoons

By far the largest contributor of nitrate to groundwater is irrigated agriculture, accounting for 96 percent of the total nitrogen load to groundwater in these basins. Therefore, the focus of the NIMS will be on these sources. Other best management practices that may be applicable to other source categories will be briefly summarized. Excess nitrogen not used by the crop and subsequently removed by harvest is leached from the root zone to the vadose zone and subsequently to the underlying groundwater. While best management practices to reduce nitrate loading from all sources, the most significant gains will be made by reducing nitrate loading from irrigated agriculture.

Groundwater protection is best accomplished by reducing nitrate leaching below the root zone to the greatest extent possible. Dzurella et al. (2012) state “While the complete elimination of agricultural nitrate loading to groundwater is not possible, adoption of improved farming management practices can help to mitigate this concern.”

![Figure 2-3](image-url)

**Figure 2-3**
Estimated Nitrate Loading to Shallow Groundwater in the Tulare Lake Basin and Salinas Valley, in gigagrams (Gg). Source: Harter et al., 2012.
The general irrigated agriculture management practices to limit nitrate loading include:

- Design and operations & maintenance of irrigation systems to reduce deep percolation
- Optimize crop and field management (crop rotations, tillage) to reduce nitrate leaching.
- Manage nitrogen fertilizer and manure to increase crop nitrogen use efficiency and decrease deep percolation

There are a number of specific implementation measures that can be site and crop specific. The University of California Cooperative Extension will be contacted to provide expert opinions of ranges of nitrate leaching reductions that may result from the ILRP MPEP studies and subsequent implementation of enhanced management practices. A range of percent reduction of nitrate mass leached would be applied to the ICM nitrate loading values for IAZs in the mass balance model described in Section 2.4.1. The percent reduction would be adjusted based on an expected participation rate by growers, who may be reluctant to adopt new management practices for a variety of reasons (e.g., converting from furrow to drip systems can be expensive.)

### 2.4.2 Groundwater Remediation

As discussed in King et al. (2012) there are a number of general types of groundwater remediation strategies.

- Pump and fertilize
- Pump and treat (aboveground, or *ex situ*)
- In situ treatment

#### 2.4.2.1 Pump and Fertilize

Pump and fertilize (PAF) is an implementation measure that would use existing irrigation wells to pump groundwater that contains nitrate from legacy crop fertilization and irrigation practices. The applied irrigation water will have relatively high nitrate concentrations and the grower would reduce normal fertilizer application rates and/or formulations to account for the nitrate added through the irrigation water supply. This will require careful monitoring and adaptive management by the grower, as well as an outreach and education program.

#### 2.4.2.2 Pump with Aboveground Treatment

Pump with aboveground treatment of groundwater includes treatment using standard drinking water treatment technologies (Footnote 7), as well as other treatment systems (e.g., wood chip bioreactors). Relatively localized areas impacted by point sources of nitrate contamination can be treated more efficiently than much larger areas impacted by non-point sources (e.g., agricultural practices) where the nitrate is more dispersed and at typically lower concentrations. The NIMS will locate, to the extent possible, significant localized areas or sources of nitrate contamination in groundwater that would be suitable for pump and treat technologies at a plume-scale. Point sources of nitrate are typically associated with municipal and food processing waste discharge ponds, concentrated animal feeding operations (CAFOs), dairy lagoons, etc. The mass of nitrate
removed from plume-scale remediation will be accounted for in the nitrate mass balance model. It will also be assumed that the extracted and treated water from such projects will be put to beneficial use, if possible for municipal or industrial supply.

Managed aquifer restoration or basin-scale groundwater remediation will be costly and will take decades to achieve. King et al. (2012) states that they “…do not consider this basin-scale [pump and treat] PAT scenario to be either economical or feasible.” NIMS will perform a similar analysis to develop concept-level cost estimates for managed aquifer restoration with two attainment targets: (i) balance of nitrate inflows and outflows and (ii) restoration of beneficial uses (nitrate at or below the MCL of 10 mg/L). These correspond to Phases 2 and 3 discussed in Section 2.2 (Task 2). This will be accomplished using the same methodology as in SSALTS (CDM Smith 2014). Nitrate will be considered a conservative species (not transformed or degraded). The alluvial aquifers in the Central Valley are generally aerobic with little microbial activity and no carbon source to support denitrification.

For a pilot study area, a similar estimate will be made to mitigate nitrate from only those portions of a groundwater basin that currently exceed the attainment target. The pilot study would be a groundwater basin or management zone, e.g., the Alta Irrigation District Management Zone.

A key consideration in any large scale aquifer restoration program for remediation is what to do with the water that has been treated. Depending upon the time scale assumed, this could result in very large quantities of water to extract, treat and use/discharge. To avoid any sustained mining of the groundwater basins which are already under stress due to the prolonged drought, it is assumed that all of the water extracted and treated would be put to beneficial use. A small percentage could possibly be used for potable supply as previously described, but the rest would presumably be re-applied for agricultural use (i.e., putting treatment on agricultural wells) The alternative would be to re-inject the treated water.

### 2.4.2.3 In Situ Treatment

Options for in situ nitrate treatment will be reviewed in the NIMS, including in situ biological denitrification which involves injecting bacteria and a carbon source into the groundwater system. Distributing the bacteria and carbon throughout the nitrate contaminated area and controlling the oxidation-reduction potential is often difficult. Permeable reaction barriers (PRBs) can also be used to denitrify nitrates in groundwater under the right circumstances. If the nitrate plume is relatively shallow, a trench or series of borings can be advanced in the path of the nitrate plume and filled with reactive media.

### 2.4.3 Alternate Drinking Water Supplies

Section 2.4.3 will review options for supplying alternative water supplies to users, with emphasis on DACs, DUCs, and individual families who do not have direct access to safe drinking water. Options for blending, drilling deeper wells, packing off screen intervals with higher contamination, trucking in water, providing bottle water, connecting to an existing community water system or constructing a new community system, or providing well-head treatment will all be analyzed. Mitigating factors will be addressed for consideration in Task 5. An example could be potential increases in arsenic concentrations with depth for new well drilling requiring blending with the original shallow well.
2.5 Task 5. Select Nitrate Implementation Measures

For a pilot study area, this task will methodically complete a checklist of implementation measures and evaluation factors that affect the implementation measures, to the extent that data and requisite information are available. This pilot process can serve as the template or archetype for other groundwater basins or management zones. The checklist would include, but may not be limited to the following:

- Identify the agency, joint powers authority (JPA), or coalition that will responsible for nitrate (and possibly salt) implementation measures.

- Identify the primary sources of nitrate? Non-point sources? Point sources?

- If the sources are predominantly non-point, work with the ILRP Coalition groups and contribute to or review and comment on the MPEP process.

- Evaluate other source control measures (e.g., other agriculture, municipal, food processing, domestic turf irrigation and fertilization) and how effective they may be.

- If there is a point source of nitrate (e.g., a wastewater treatment plant [WWTP] discharge pond), define what measures can be implemented to reduce nitrate at the source (e.g., optimize municipal WWTP operations). Determine if in situ treatment is an option (i.e., review all of the factors, including depth to water that will determine if in situ nitrate remediation is possible). Is pump and treat an option for the point source plume of nitrate? Evaluate various pump and treat options (reverse osmosis [RO], ion exchange [IX], etc.) Consider brine management. Will the product water be used for potable supply or blended and used for irrigation?

- For PAF, how much nitrate mass will be removed annually? Work with UC Cooperative Extension and others in education and outreach programs to assist growers in monitoring irrigation water for nitrate concentration and reducing other nitrate applied (this is not straightforward).

- Evaluate stormwater capture and recharge programs. Increase stormwater recharge will dilute nitrate concentrations in groundwater (and increase available water supply).

- Identify DACs, DUCs and to the extent possible, individuals with access only to shallow groundwater. At a macro scale, estimate costs of supply alternate water supplies to those communities and individuals (see Section 2.4.3). Consider pump, treat, and serve (PTS) just to meet domestic water demands. PAT in a managed aquifer restoration program requires pumping large volumes of groundwater and the high quality product water is used for irrigation or re-injection back into the aquifer. PTS would be used in conjunction with PAF, and the highly treated water from PTS could be used to meet potable demands, especially of DACs, DUCs, and individuals without access to other safe drinking water. Education and outreach would be required so that users know not to drink from contaminated wells. For both PAT and PTS, consider brine disposal.
The objective of Task 5 is to develop a checklist and methodology for other groundwater basins and/or management zones for nitrate implementation measures.

2.6 Task 6. Joint Nitrate and Salt Implementation Measures

The purpose of Task 6 is to define the linkage between proposed nitrate implementation measures and interim and long-term SSALTS alternatives, and propose an implementation program that considers both nitrate and salt priorities together. The treatment technologies reviewed in SSALTS (CDM Smith, 2014) will remove nitrate together with all salts. On the other hand, there are lower cost technologies that focus only on nitrate that may be more appropriate if there are areas with elevated nitrates but acceptable levels of TDS. Future emerging technologies considered for mitigating both salt and nitrate in pumped groundwater in the Central Valley will need to evaluate if nitrate removals are acceptable. Opportunities for joint implementation measures exist where TDS and nitrate are above target attainment goals in a subregional area (i.e., a management zone).

A map, or series of maps, will be produced that show areas (using Thiessen polygons) where TDS exceeds 1000 mg/L, where nitrate exceeds 10 mg/L, and where both TDS and nitrate exceed their respective attainment targets. These would be areas where joint implementation measures would be cost effective. All of the other nitrate implementation measures would still be evaluated with the methodology described in Task 5.

2.7 Task 7. Prepare a Nitrate Implementation Measures Technical Memorandum

CDM Smith will prepare draft and final Technical Memoranda, including all requisite figures and tables. The Technical Memoranda will state the objectives of the NIMS, provide detailed results for each component of the NIMS, and summarize key findings. The Technical Memorandum will be written to be readily incorporated into the SNMP in order to facilitate its adoption. Comments are to be submitted in writing within 14 days of submission of the draft Technical Memorandum. The final Technical Memorandum will be revised based on comments received from the CV-SALTS stakeholders within 14 days. A detailed comment and response table will be completed and submitted as an appendix to the final NIMS Technical Memorandum.

2.8 Deliverables

The deliverables for the NIMS will include the following:

- Monthly status reports (included with the invoice).
- Electronic and hard copies of PowerPoint presentations prepared for the TAC meetings. TAC meetings are scheduled at the completion of Tasks 3 and 5.
- Meeting agenda and notes.
- Draft and final Technical Memoranda that include all of the work products from Tasks 1 through 6.
Section 3
Schedule and Cost

Figure 1 is a Gantt chart that shows the schedule for the completion of the SAMP. The objective is to have the work completed by late October or early November 2015, so that it can be incorporated into the SNMP which is due in May 2016. The schedule is contingent on direction from CV-SALTS and the availability and access to data in the CV-SALTS database.

![Gantt Chart](image)

Notice to proceed is anticipated to be in late July/early August 2015.

Schedule for the NIMS

Below is the work breakdown structure and cost estimate for the NIMS, which provides a breakdown of the level of effort by employee billing along with other direct charges (ODCs).

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<th>Oct-15</th>
<th>Nov-15</th>
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**Table 3-1**
Work Breakdown Structure and Cost Estimate for the NIMS
Section 4

References


