CENTRAL VALLEY SALINITY ALTERNATIVES FOR LONG-TERM SUSTAINABILITY (CV–SALTS)

Nitrate Implementation Measures Study (NIMS)

Final Report

March 31, 2016

Prepared for
SAN JOAQUIN VALLEY DRAINAGE AUTHORITY

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Acronyms and Abbreviations

CAFOs	concentrated animal feeding operations
CASGEM	California Statewide Groundwater Elevation Monitoring
Central Valley Water Board	Central Valley Regional Water Quality Control Board
CV-SALTS	Central Valley Salinity Alternatives for Long-Term Sustainability
CVSC	Central Valley Salinity Coalition
CWA	Clean Water Act
DAC	disadvantaged community
DUC	disadvantaged unincorporated community
DWR	California Department of Water Resources
GAR	Groundwater Quality Assessment Report
IAZ	Initial Analysis Zone
ICM	Initial Conceptual Model
ILRP	Irrigated Lands Regulatory Program
IRWM	Integrated Regional Water Management
IX	Ion exchange
MCL	maximum contaminant level
mg/L	milligrams per liter
MPEP	Management Practices Evaluation Programs
NIMPS	Nitrate Implementation Measures Prioritization Score
NIMS	Nitrate Implementation Measures Study
POI	Plan of Implementation
RO	Reverse osmosis
ROWD	Report of Waste Discharge
SNMP	Salt and Nitrate Management Plan
SRWP	State Recycled Water Policy
SSALTS	Strategic Salts Accumulation Land and Transportation Study
State Water Board	State Water Resource Control Board
TAC	Technical Advisory Committee
TDS	total dissolved solids
TRC	Technical Review Committee
USEPA	US Environmental Protect Agency
WDRs	Waste Discharge Requirements

Section 1

Overview of the Nitrate Implementation Measures Study

"…[It is] the established 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." Assembly Bill No. 685[1].

1.1 Background

The Central Valley Salinity Alternatives for Long Term Sustainability (CV-SALTS) is in the process of developing a comprehensive regulatory and programmatic approach to the management of salt and nitrate as nitrogen[2] in the Central Valley that is not only consistent with the State Recycled Water Policy (SRWP) but meets the broader goals of CV-SALTS to develop a workable, comprehensive plan to address salinity, including nitrates, throughout the region in a comprehensive, consistent, and sustainable manner. In this regard, participants in CV-SALTS have established goals to (a) ensure that everyone in the Central Valley has access to a safe, reliable, and affordable drinking water supply; and (b) preserve the global competitiveness and sustain the long-term viability of the region's world class agricultural industry. The work of CV-SALTS 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.

The CV-SALTS Strategy and Framework document states that 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[3]. Fulfillment of this strategy will establish the basis for short- and long-term management of salt and nitrate across the Central Valley.

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[1] An Act to add Section 106.3 to the Water Code, relating to water. [Approved by Governor September 25, 2012. Filed with Secretary of State September 25, 2012. Effective January 1, 2013.] http://www.leginfo.ca.gov/pub/11-12/bill/asm/ab_0651-0700/ab_685_bill_20120925_chaptered.pdf. At its February 16, 2016 board meeting, the State Water Board will consider the adoption of a resolution that "would establish the human right to water as a core value and top board priority."

[2] By convention, nitrate is 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).

[3] CV-SALTS is developing a regional (Central Valley floor-wide) SNMP that meets the requirements of the SRWP. It is anticipated that local SNMPs will be developed at the management zone-scale by local stakeholders. A management zone is a portion of a groundwater basin – usually defined by hydrogeological boundaries and flow environment – that can be managed to achieve better ambient groundwater quality conditions.

The SRWP states the following:

> *"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.

Definition of Terms

Groundwater Basins and Subbasins. DWR's Bulletin 118 series "identified groundwater basins, subbasins, and what were referred to as "areas of potential ground water storage" in California as well as maps showing their location and extent…basin boundaries were based on geologic and hydrogeologic conditions except where basins were defined by a court decision." (DWR, 2003)

Groundwater Management Zones. "The Board could delineate 'management zones' which would be portions of existing waterbodies where alternate regulatory measures would apply. The Board would develop specific implementation plans to address salt and nitrate concerns within these zones." http://www.waterboards.ca.gov/centralvalley/water_issues/salinity/salt_management_efforts/cvsalts_2013aug28_ceqa_staffrpt.pdf

Initial Analysis Zones. IAZs are 22 hydrologically-based areas of analysis that were developed as part of the Initial Conceptual Model (ICM).

This report summarizes the Nitrate Implementation Measures Study (NIMS) which addresses nitrate contamination in the groundwater basins underlying the floor of the Central Valley and appropriate implementation measures to mitigate nitrate contamination for these areas using a phased approach that includes providing safe drinking water, reducing or eliminating impacts to drinking water sources and implementing managed restoration activities where needed to restore beneficial uses in groundwater. 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 NIMS Purpose and Objectives

The findings from the NIMS will provide input to policymakers regarding implementation measures to reduce current ambient nitrate concentrations in groundwater to protect and restore beneficial uses. The implementation measures will be phased and a prioritization methodology will be used to rank Initial Analysis Zones (IAZs) 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. (Sections 1.2, 4, and 5)

2. Summarize information about existing or planned nitrate mitigation programs and show how they will be integrated into the outcome of NIMS. (Section 2)

3. Develop a proposed phasing approach for implementation of various nitrate implementation measures to provide safe drinking water, reduce or eliminate impacts to drinking water sources, and where needed restore beneficial uses. (Section 3)

4. Define a prioritization methodology, wherein groundwater basins, subbasins or management zones are ranked based on existing nitrate impacts and potential for future impacts to users of groundwater as a water supply. Salinity and nitrate implementation measures must be coordinated to successfully remediate both constituents. Prioritization of IAZs for nitrate, TDS, and both were analyzed in the NIMS.(Section 4)

5. Estimate concept-level costs and establish milestones for implementation of specific nitrate implementation measures for a pilot study area. Nitrate implementation measures could include: providing alternate sources of drinking water, source control measures[4], managed aquifer restoration, pumping and fertilize (accounting for nitrate in the pumped irrigation water), blending, drilling deeper wells, *in situ* treatment, and treatment of pumped groundwater for beneficial uses including potable use. (Section 5)

6. Establish nitrate implementation measures in coordination with the interim and long-term salt management implementation measures proposed by SSALTS. The outcome of this effort will be the information needed to support development of a Management Plan for the SNMP that links both nitrate and salt priorities together. At the direction of CV-SALTS, joint implementation measures for nitrate and salt are considered where efficiencies can be realized because both constituents are co-located. Prioritization approach considers areas where both nitrate and TDS impact beneficial uses of groundwater. (Sections 4, 5, and 6)

7. Support SNMP development by providing a menu of acceptable or required nitrate and salt implementation measures consistent with SNMP implementation requirements. (Sections 5 and 6)

8. Provide input to Executive Committee policy discussions regarding acceptable salt and nitrate implementation measures.

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[4] For example, the Management Practices Evaluation Programs (MPEPs) that will be developed by the Irrigated Lands Regulatory Program (ILRP) coalition groups.

1.3 Setting

The Central Valley is a long valley in the center of California that extends from the north northwest to the south southeast. The valley includes 126 groundwater basins and subbasins; 41 groundwater basins underlie the valley floor. The valley floor covers about 85 percent of the area within the Region 5 jurisdictional boundaries. CV-SALTS is currently preparing a report called the *Region 5: Updated Groundwater Quality Analysis and High Resolution Mapping for Central Valley Salt and Nitrate Management Plan* (LWA and LSCE, 2015) which will characterize water quality in the out-of-valley floor groundwater basins/ subbasins. The NIMS focusses on the valley floor groundwater basins/ subbasins. The characterization of the water quality in the out-of-valley groundwater basins/ subbasins will be summarized in the SNMP.

The Central Valley floor is comprised of three hydrologic regions: the Sacramento River Hydrologic Region (27,200 square miles), the San Joaquin Hydrologic Region (15,200 square miles), and the Tulare Lake Hydrologic Region (17,000 square miles) (Figure 1-1).

"Geologically, the Sacramento Valley is a large trough filled with sediments having variable permeabilities. (California Department of Water Resources [DWR], 2003)." Well yields are generally good and the groundwater quality is excellent. There are areas of natural water quality impairment (salinity) in the northern end of the Sacramento Valley from marine sedimentary rocks.

The San Joaquin Valley is heavily groundwater dependent, and groundwater accounts for about 30 percent of the supply used for agriculture and urban needs. "Areas of high [total dissolved solids] TDS content are primarily along the west side of the San Joaquin Valley and in the trough of the valley. The high TDS content of west-side groundwater is due to recharge of streamflow originating from marine sediments in the Coast Range. High TDS content in the trough of the valley is the result of concentration of salts due to evaporation and poor drainage." (DWR, 2003)

In the Tulare Lake Hydrologic Region, "the areas of high TDS content are primarily along the west side of the San Joaquin Valley and in the trough of the valley. High TDS content of west-side groundwater is due to recharge of stream flow originating from marine sediments in the Coast Range. High TDS content in the trough of the valley is the result of concentration of salts because of evaporation and poor drainage – the Tulare Lake bed is a salt sink. In the central and west-side portions of the valley, where the Corcoran Clay confining layer exists, water quality is generally better beneath the clay than above it." DWR, 2003.

The DWR Bulletin 118-defined groundwater basins are shown in Figure 1-2 and IAZs are shown in Figure 1-3. By far, the predominant land use in the Central Valley is agriculture plus semi-agriculture, together which account for about 69 percent of the valley floor. Figure 1-4 shows general land use in the Valley; Table 1-1 defines the subclasses of the major land use types displayed in the figure.

In the Initial Conceptual Model (ICM), the shallow aquifer zone is defined (LWA *et al.*, 2013) as, "The vertical distance represents the distance that the water, at the water table, would travel downward or upward over a 20-year period. This defines the "shallow" portion of the subsurface where the ICM analysis is performed." The deep aquifer zone would represent a travel time greater than 20 years. The NIMS used the definition of wells as “deep,” “shallow,” or “unknown” as classified in the CV-SALTS database. CV-SALTS has on-going projects to potentially redefine aquifer zones as “upper,” “lower,” “unknown,” and “production;” because these studies were not completed when the NIMS was developed and published, the original classification system was used herein.

Figures 1-5 and 1-6 depict average nitrate concentrations in wells for the period 2003-2014. Nitrate is higher on the east side of San Joaquin River Valley and the Tulare Lake Basin (IAZs 13, 16, 17, 18) principally from agricultural practices. Prioritization of IAZs for nitrate and TDS is discussed in Section 4. The percentage of shallow and deep wells that exceed 5 mg/L and 10 mg/L in each IAZ for the same period are shown in Figures 1-7 and 1-8.

Table 1-1 Land Use Categories

Classes		Subclasses	
II	Agricultural	G	Grain and Hay Crops
		R	Rice
		F	Field Crops
		P	Pasture
		T	Truck, Nursery, and Berry Crops
		D	Deciduous Fruits and Nuts
		C	Citrus and Subtropical
		V	Vineyards
		I	Idle
III	Semiagricultural		Farmsteads
			Livestock Feed Lot Operations
			Dairies
			Poultry Farms
IV	Urban	U	Urban
		UR	Residential
		UC	Commercial
		UI	Industrial
		UL	Urban Landscape
		UV	Vacant
V	Native	NC	Native Classes Unsegregated
		NV	Native Vegetation
		NR	Riparian Vegetation
		NW	Water Surface
		NB	Barren and Wasteland

Source: DWR. 2009. Standard Land Use Legend. Land and Water Use Section, Statewide Planning Branch, Division of Planning. February 2009.

Figure 1-1 Hydrologic Regions in the Central Valley

Figure 1-2 DWR Bulletin 118 Groundwater Basins in the Central Valley

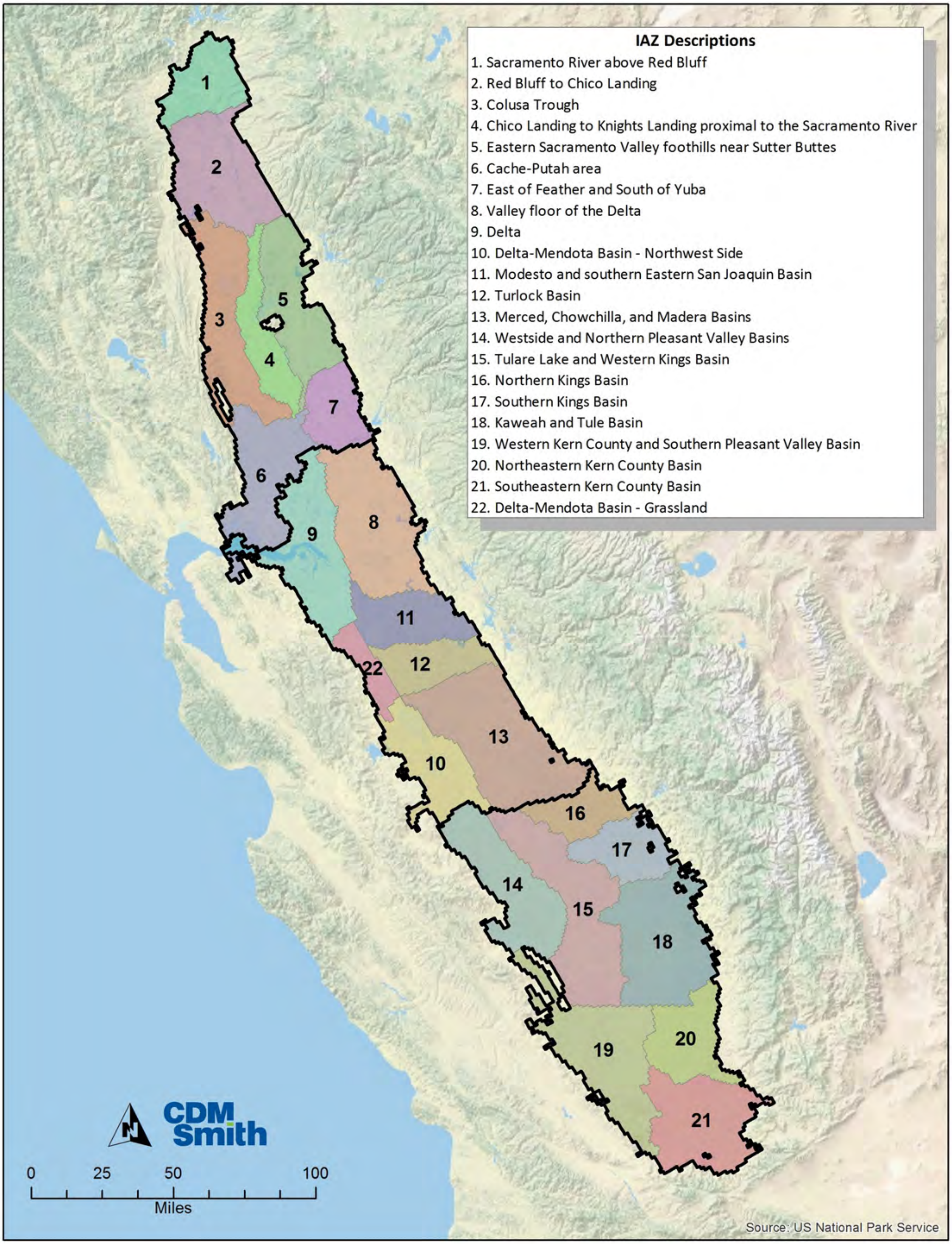

Figure 1-3 IAZs in the Central Valley

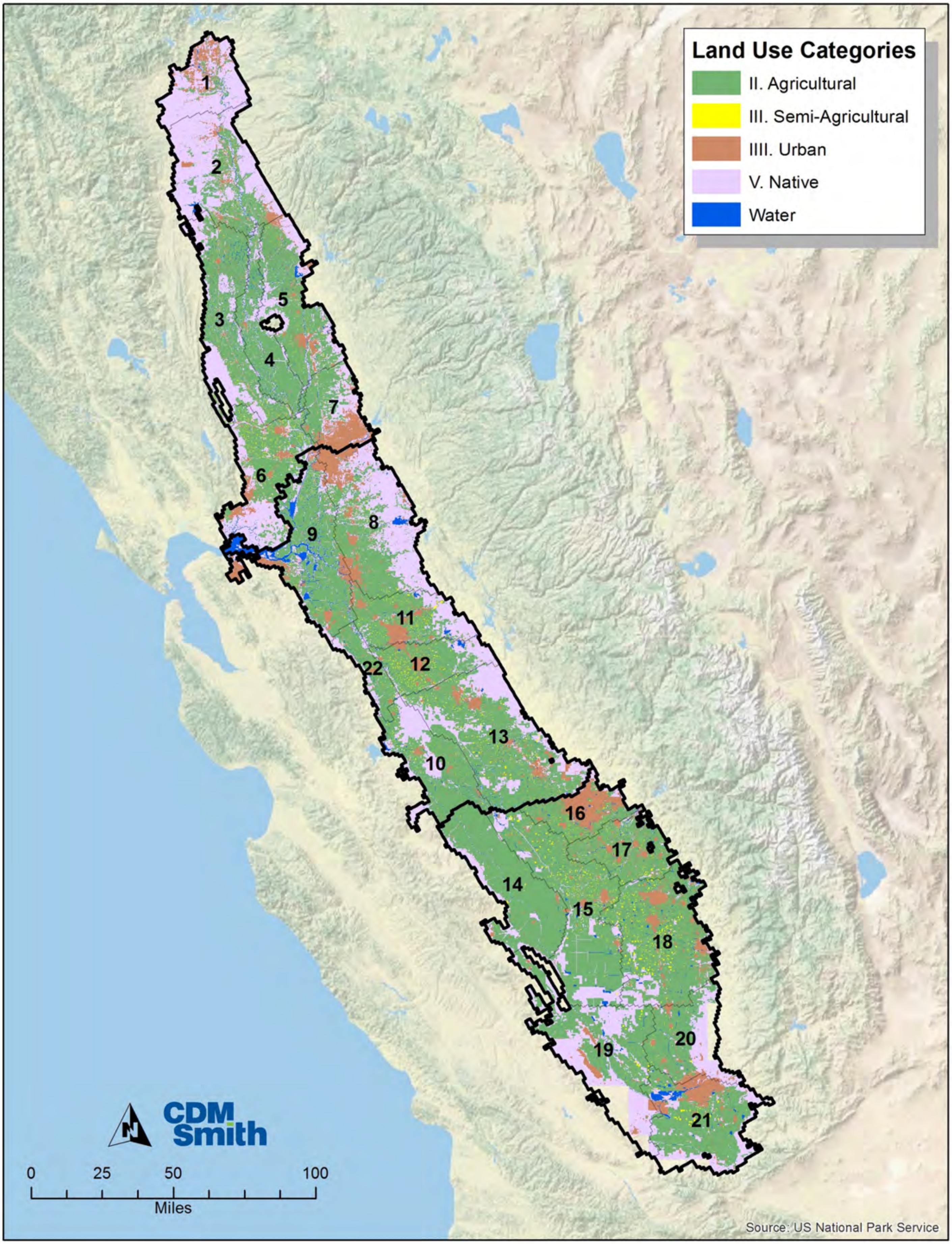

Figure 1-4 Land Use in the Central Valley Floor (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)

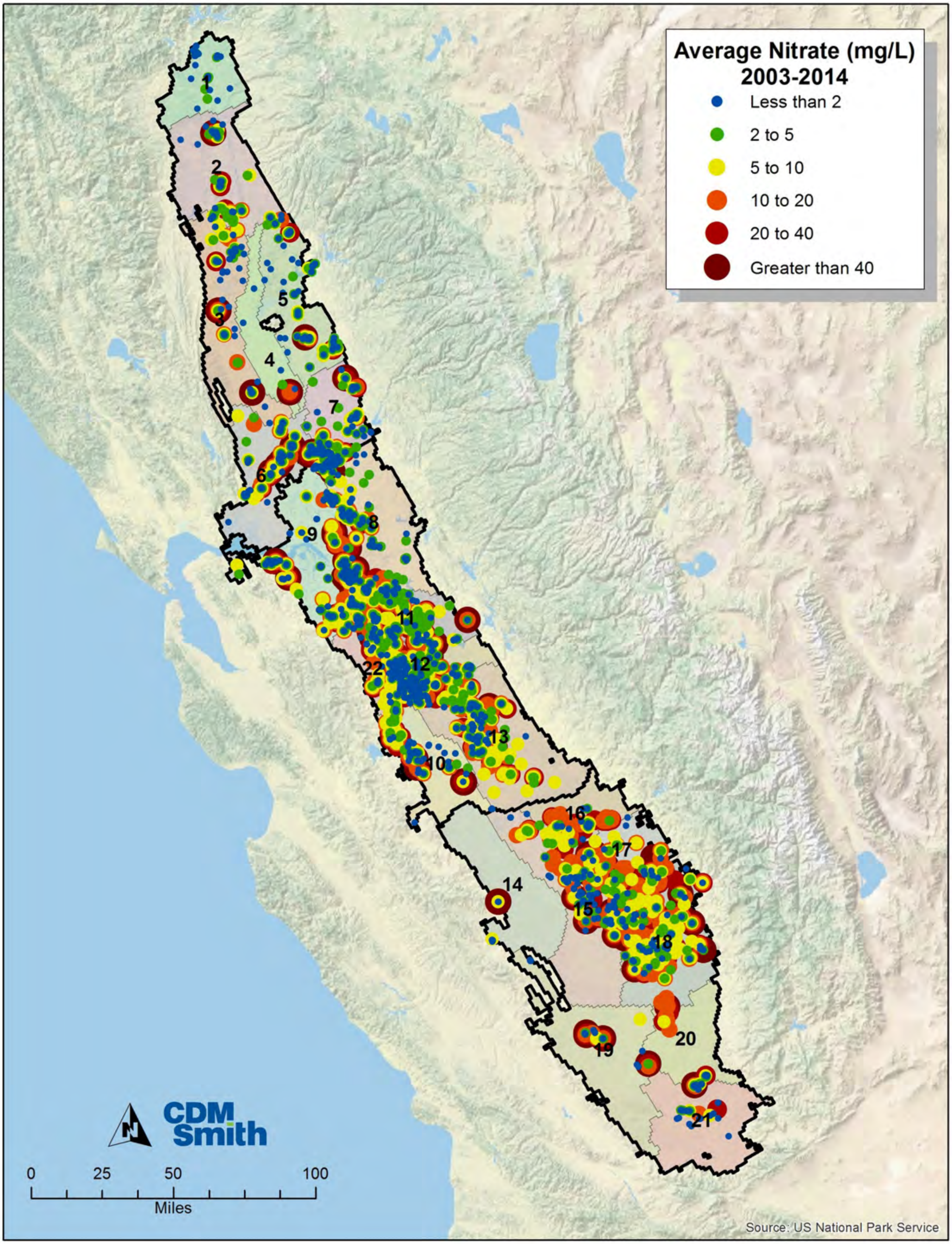

Figure 1-5 Nitrate Concentrations in the Shallow Zone ("Phase II Conceptual Model—Task 3: Groundwater Data Refinements and Updates, June 18, 2014)

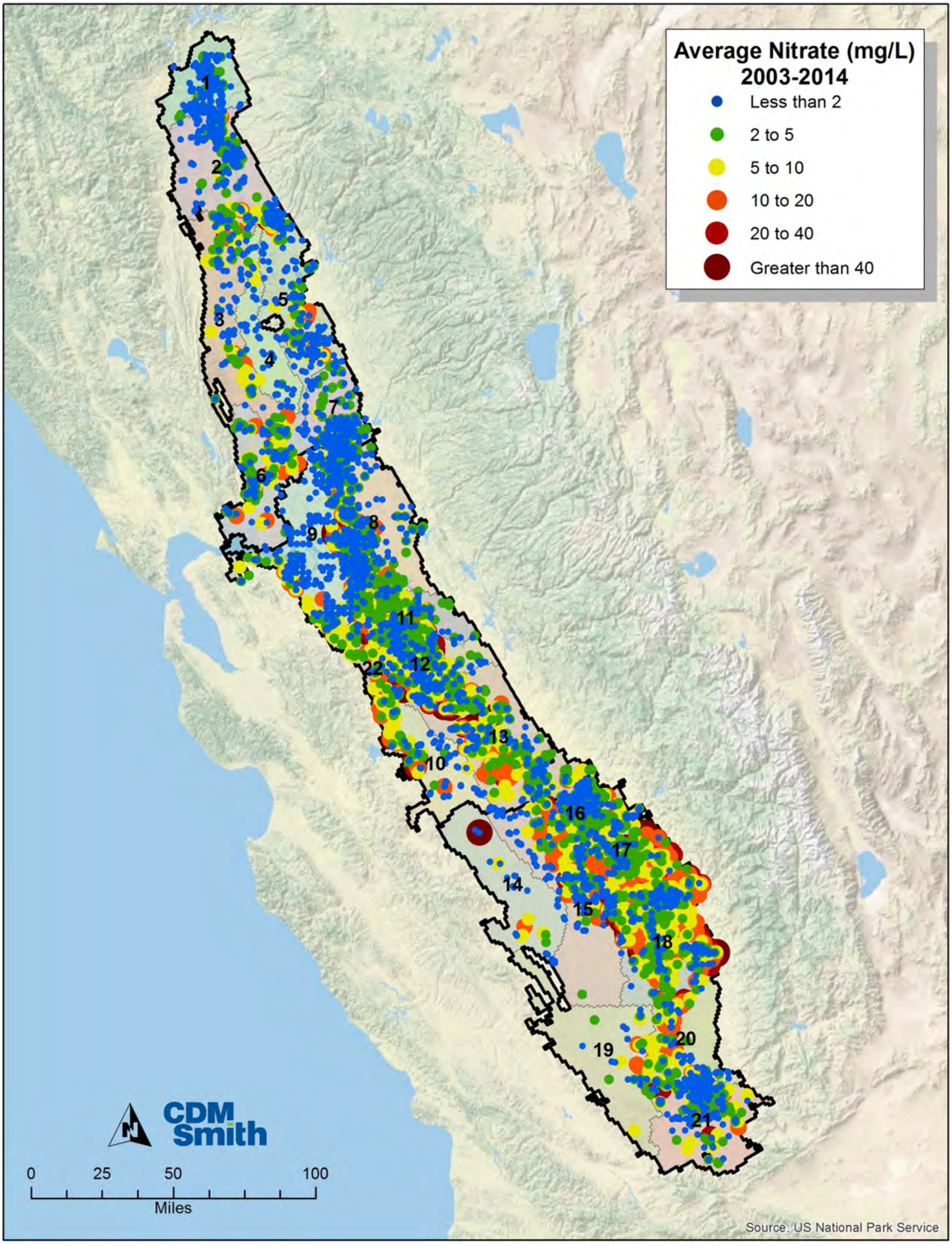

Figure 1-6 Nitrate Concentrations in the Deep Zone ("Phase II Conceptual Model—Task 3: Groundwater Data Refinements and Updates, June 18, 2014)

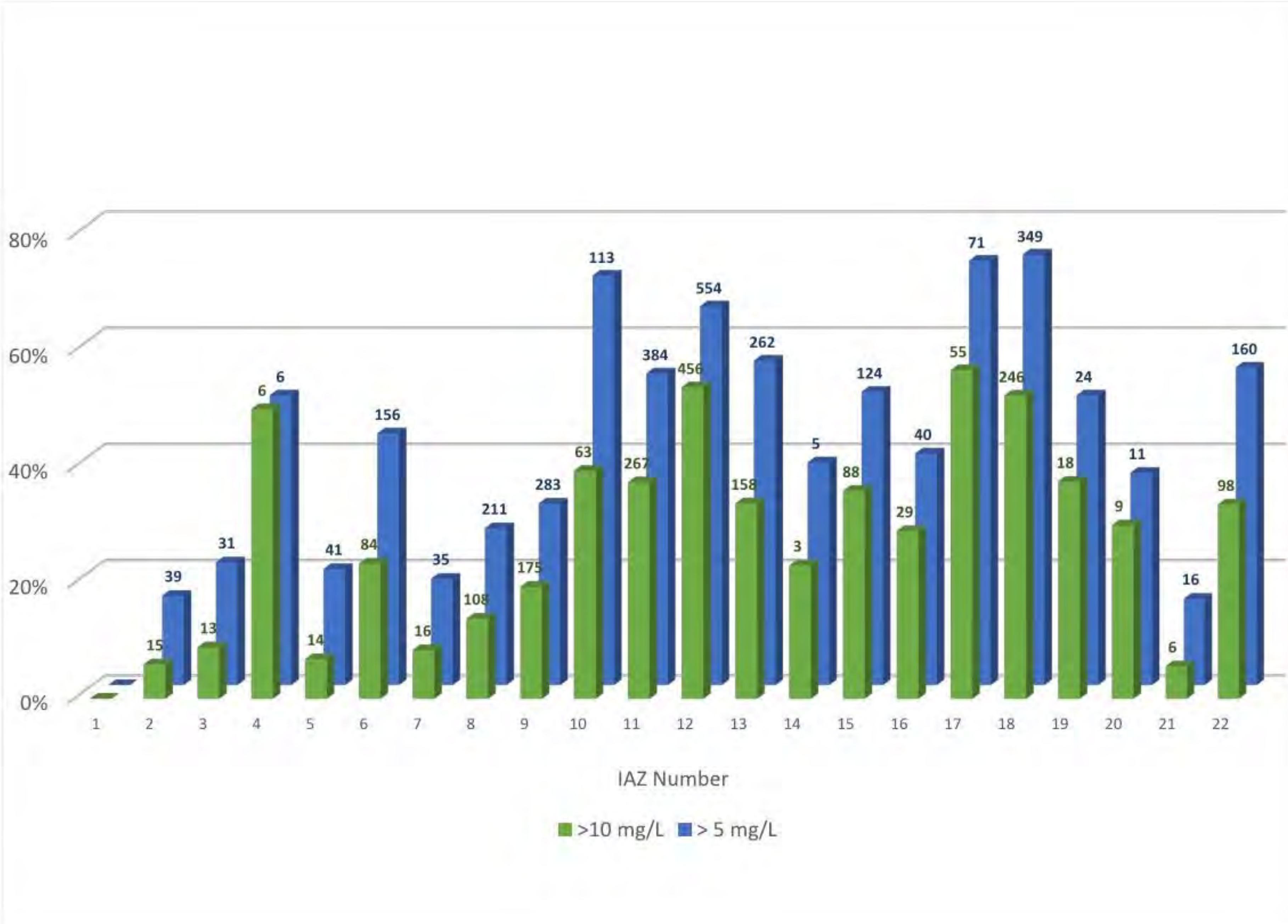

Figure 1-7 Percentage of Wells in Each IAZ where Nitrate Exceeds 5 and 10 mg/L in the Shallow Zone ("Phase II Conceptual Model—Task 3: Groundwater Data Refinements and Updates, June 18, 2014)

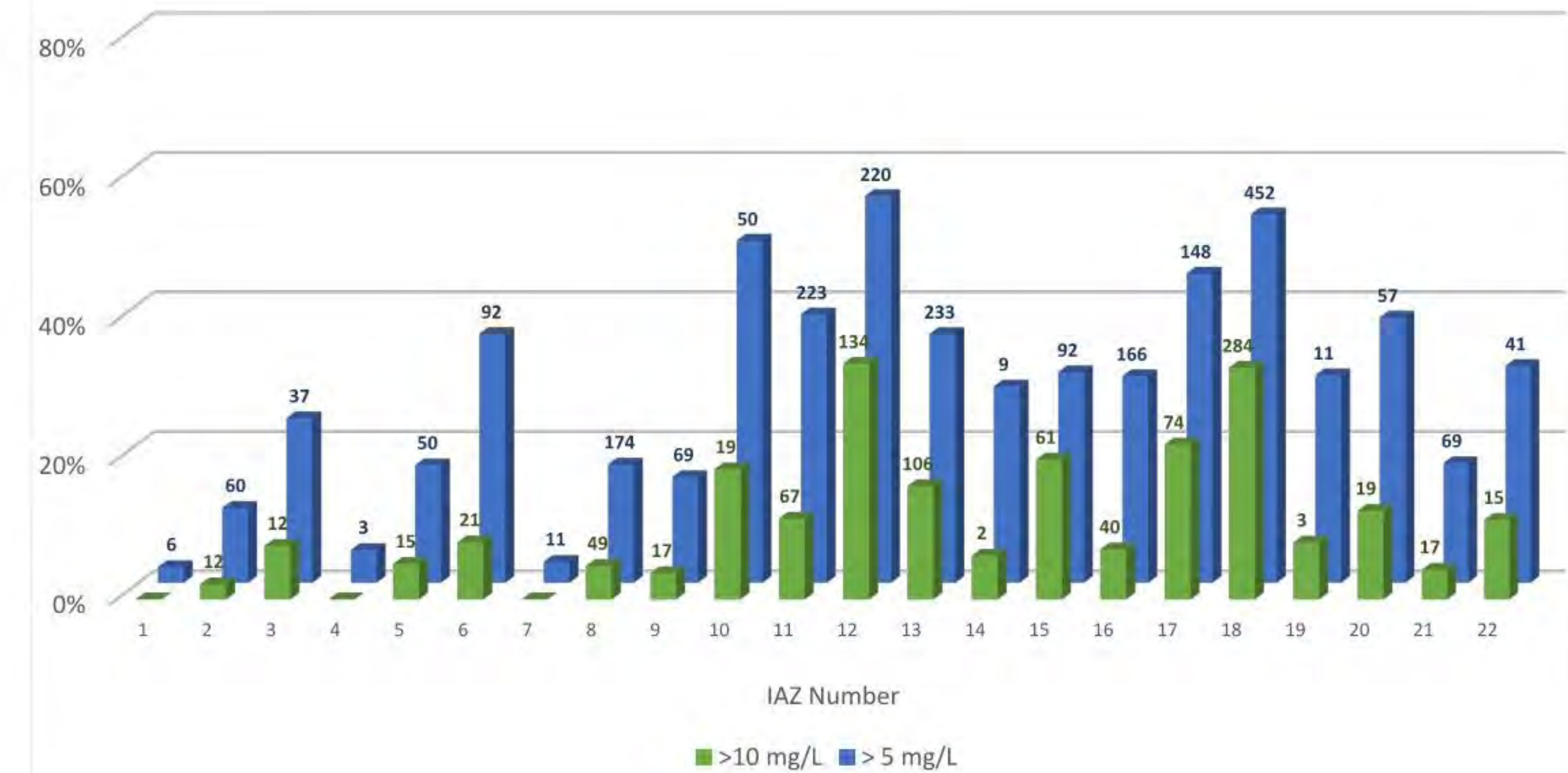

Figure 1-8 Percentage of Wells in Each IAZ where Nitrate Exceeds 5 and 10 mg/L in the Deep Zone ("Phase II Conceptual Model—Task 3: Groundwater Data Refinements and Updates, June 18, 2014)

Section 2

Existing or Planned Nitrate Mitigation Programs

Existing nitrate and salinity monitoring and mitigation programs were reviewed to identify current efforts to manage sources of salt and nitrate in the Central Valley. These programs include the Irrigated Lands Regulatory Program (ILRP), the Dairy Representative Monitoring Program, and Waste Discharge Requirements (WDRs) for Publically-Owned Treatment Works (POTWs) and other discharges. These programs will inform the NIMS process and provide the foundation upon which nitrate implementation measures identified through the NIMS can build upon existing management efforts to achieve the goals of nitrate management. In other words, the NIMS is focused on developing complementary/supplementary, rather than duplicative, nitrate implementation measures that support ILRP, Dairy Representative Monitoring Program, and other WDRs in minimizing future impacts to groundwater from nitrate, *e.g.*, through managed aquifer restoration to restore beneficial uses of groundwater. Regulatory and non-regulatory programs that are protective of groundwater quality are described in the Groundwater Quality Protection Strategy – A "Roadmap" for the Central Valley Region. (Central Valley Water Board, 2010).

As local SNMPs are developed there will be an implementation framework to ensure that the elements of the Management Plans for both the regional SNMP and local SNMPs are not duplicative or interfering, but rather that it complements the existing programs. Monitoring results from existing or planned mitigation programs are being used to the maximum extent practical to support development of CV-SALTS implementation measures for use in the implementation of regional or local SNMPs.

2.1 WDRs for Point Discharges

The Water Code requires that any entity discharging waste or proposing to discharge waste that has the potential affect the quality of the waters of the state file a Report of Waste Discharge (ROWD) in order to obtain coverage under the WDRs. The Central Valley Water Board has 1348 active orders; 486 of these are for POTWs. During the development of the local SNMPs, salt and nitrate implementation strategies undertaken by discharges, including POTWs, food processors, other industrial discharges, etc. will become an active component of the CV-SALTS implementation measures.

2.2 ILRP

The Central Valley Water Board issued WDRs in 2012 and 2013 that allow farmers to join coalitions of growers, which may be geographic or commodity-based. Permits are issued to the coalitions on behalf of the growers; the coalitions conduct monitoring and report to the Central Valley Water Board. Growers are not required to join coalitions, but they are responsible for monitoring, reporting and other activities specified in the permit. The ILRP Requirements for Coalition Groups include the following:

- Complete a Groundwater Quality Assessment Report (GAR) with 5-year updates. The GARs identify high and low vulnerability areas
- Complete and implement an individual or Comprehensive Groundwater Quality Management Plan for confirmed exceedances of groundwater quality
- Conduct a Management Practices Evaluation Program
- Develop a groundwater trend monitoring work plan
- Develop a groundwater QAPP
- Develop and implement Nitrogen Management Plans (Nitrogen Management Plans are discussed in Section 5.4.1.)
- Complete Nitrogen Management Plan Summary Report and submit to the Coalition (only applicable in High Vulnerable Areas)
- Conduct extensive education and outreach
- Complete the Farm Evaluation Template (every year in High, every 5 years in Low)

The current status of the ILRP deliverable is provided in Figures 2-1[5] and 2-2[6].

2.3 Dairy Program

The Central Valley Water Board regulates over 1300 dairies through the Reissued Waste Discharge Requirements General Order for Existing Milk Cow Dairies, Order No. R5-2013-0122. The General Order "serves as general waste discharge requirements for discharges of waste from existing milk cow dairies of all sizes[7]."

The Central Valley Dairy Representative Monitoring Program (CVDRMP) is a region-wide groundwater monitoring program that uses 42 representative dairies as surrogates in lieu of conducting individual monitoring program at all dairies in the Valley. The CVDRMP manages the installation of monitoring wells into the aquifer zone that represents first-encountered groundwater – groundwater that is at or just below the water table in an unconfined aquifer. Samples are collected through the program and annual reports of results are submitted. The diaries in the program are supposed to be representative of other dairies based on soil conditions, depth to water, agricultural management practices, number of cows, and waste lagoon construction and operations. The monitoring data from the CVDRMP will be used to inform local SNMP development.

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[5] http://www.waterboards.ca.gov/centralvalley/water_issues/irrigated_lands/water_quality_monitoring/groundwater/ilrp_gw_deliverables_sacsj.pdf
[6] http://www.waterboards.ca.gov/centralvalley/water_issues/irrigated_lands/water_quality_monitoring/groundwater/ilrp_gw_deliverables_tularelake.pdf
[7] http://www.waterboards.ca.gov/centralvalley/water_issues/dairies/index.shtml

ILRP Groundwater Deliverables & Due Dates - Sacramento San Joaquin Basin

Coalition Deliverables		East San Joaquin Water Quality Coalition	Westside San Joaquin River Watershed Coalition	California Rice Commission	Sacramento Valley Water Quality Coalition	San Joaquin County and Delta Water Quality Coalition
Groundwater Quality Assessment Report		Approved 12/24/2014	3/17/2015[1]	8/2/2013	6/4/2015[1]	4/25/2015[1]
Comprehensive Groundwater Quality Management Plan		2/23/2015	60 days[2]	N/A	6/4/2015	60 days[2]
Management Practices Evaluation Program Group Agreement		1/11/2014[1]	3/17/2015[1]	N/A	6/4/2015[1]	4/25/2015[1]
MPEP Group Option Workplan		6/4/2016	6/4/2016[3]	N/A	8/4/2016[3]	6/4/2016
Trend Monitoring Workplan		6/4/2015	5/15/2016[3]	10/1/2015	8/4/2016[3]	6/24/2016
Groundwater QAPP		6/4/2015	5/15/2016[3]	10/1/2015	8/4/2016	6/24/2016
Annual Groundwater Monitoring Results		Annually: May 1	Annually: June 15	Annually: December 31	Annually: May 1	Annually: May 1
NMP Summary Report Template		None	None	None	None	None
Grower Deliverables						
Nitrogen Management Plan	**High Vulnerability Areas**	N/A	N/A	N/A	3/1/2015[4]	6/15/2015[4]
	Large Farming Operations	3/1/2015	4/15/2015	N/A	N/A	N/A
	Small Farming Operations	3/1/2017	4/15/2017	N/A	N/A	N/A
	Certified Nitrogen Management Plan	3/1/2015 (3/1/2016)[5]	4/15/2016	N/A	3/1/2016	6/15/2015 (6/25/2016)[5]
	Low Vulnerability Areas	3/1/2017	4/15/2017	3/1/2016[4,6]	3/1/2015[4]	6/15/2017[4]
Nitrogen Management Plan Summary Report	**High Vulnerability Areas**	N/A	N/A	N/A	3/1/2016[4]	6/15/2016[4]
	Large Farming Operations	3/1/2016	3/1/2016	N/A	N/A	N/A
	Small Farming Operations	3/1/2018	3/1/2018	N/A	N/A	N/A
	Low Vulnerability Areas	N/A	N/A	N/A	N/A	N/A

1. Due one year following the NOA
2. Due 60 days following EO approval of GAR vulnerability design
3. Approximate - Due one year after GAR, 60-day review assumed
4. There is no distinction between large and small farming operations for these coalitions
5. Tentative for the April 2015 Board Meeting
6. Or 3/1/2017 upon Executive Officer Determination per WDR Section VII

Figure 2-1 ILRP Groundwater Deliverables & Due Dates—Sacramento San Joaquin Basin

ILRP Groundwater Deliverables & Due Dates - Tulare Lake Basin

Coalition Deliverables	Kings River Watershed Coalition Authority	Kaweah Basin Water Quality Association	Tule Basin Water Quality Coalition	Kern River Watershed Coalition Authority	Buena Vista Coalition	Cawelo Water District Coalition	Westside Water Quality Coalition	Westlands Water Quality Coalition
Groundwater Quality Assessment Report	Received 11/20/2014	Received 2/5/2015	Received 2/4/2015	Received 2/4/2015	Received 2/4/2015	Due 4/27/2015	Due 5/21/2015	Received 2/17/2015
Comprehensive Groundwater Quality Management Plan	Received 11/20/2014	Received 2/5/2015	Did not Elect Option	Received 2/4/2015	Did not Elect Option	N/A	N/A	Did not Elect Option
Management Practices Evaluation Program Group Agreement	Received 11/20/2014	Received 11/20/2014	Received 11/20/2014	Received 11/20/2014	Did not Elect Option	Received 11/20/2014	Did not Elect Option	Did not Elect Option
MPEP Workplan	2 Years After GAR Approval	2 Years After GAR Approval	2 Years After GAR Approval	2 Years After GAR Approval	1 Year After GAR Approval	2 Years After GAR Approval	1 Year After GAR Approval	1 Year After GAR Approval
Trend Monitoring Workplan	1 Year After GAR Approval	1 Year After GAR Approval	1 Year After GAR Approval	1 Year After GAR Approval	1 Year After GAR Approval	1 Year After GAR Approval	1 Year After GAR Approval	1 Year After GAR Approval
Groundwater QAPP	1 Year After GAR Approval	1 Year After GAR Approval	1 Year After GAR Approval	1 Year After GAR Approval	1 Year After GAR Approval	1 Year After GAR Approval	1 Year After GAR Approval	1 Year After GAR Approval
Annual Groundwater Monitoring Results[1]	Annually: May 1	Annually: May 1	Annually: May 1	Annually: May 1	Annually: May 1	Annually: May 1	Annually: May 1	Annually: May 1
NMP Summary Report Template	None	None	None	None	None	None	None	None

Grower Deliverables		Kings River Watershed Coalition Authority	Kaweah Basin Water Quality Association	Tule Basin Water Quality Coalition	Kern River Watershed Coalition Authority	Buena Vista Coalition	Cawelo Water District Coalition	Westside Water Quality Coalition	Westlands Water Quality Coalition
Nitrogen Management Plan	**High Vulnerability Areas**								
	Large Farming Operations	3/23/2015	3/23/2015	3/23/2015	3/23/2015	3/23/2015	3/23/2015	3/23/2015	3/23/2015
	Small Farming Operations	3/1/2017	3/1/2017	3/1/2017	3/1/2017	3/1/2017	3/1/2017	3/1/2017	3/1/2017
	Certified Nitrogen Management Plan								
	Large Farming Operations	3/1/2016	3/1/2016	3/1/2016	3/1/2016	3/1/2016	3/1/2016	3/1/2016	3/1/2016
	Small Farming Operations	3/1/2017	3/1/2017	3/1/2017	3/1/2017	3/1/2017	3/1/2017	3/1/2017	3/1/2017
	Low Vulnerability Areas	3/1/2017	3/1/2017	3/1/2017	3/1/2017	3/1/2017	3/1/2017	3/1/2017	3/1/2017
Nitrogen Management Plan Summary Report	**High Vulnerability Areas**								
	Large Farming Operations	3/1/2017	3/1/2017	3/1/2017	3/1/2017	3/1/2017	3/1/2017	3/1/2017	3/1/2017
	Small Farming Operations	3/1/2018	3/1/2018	3/1/2018	3/1/2018	3/1/2018	3/1/2018	3/1/2018	3/1/2018
	Low Vulnerability Areas	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

[1]Results will not be submitted until after the Trend Monitoring Workplan approval/implementation

Figure 2-2 ILRP Groundwater Deliverables & Due Dates—Tulare Lake Basin

Section 3

Salt and Nitrate Management Goals, Performance Targets, and Phasing

Preliminary development of the SNMP's Management Plan occurred iteratively with NIMS and other technical work products in order to establish management goals, performance targets, and the phasing of implementation[8].

3.1 Salt and Nitrate Management Goals

The SNMP proposed management goals based on information developed in the SSALTS and NIMS studies. These goals include a combination of an overarching water resource management strategy, statewide environmental policy directives, and water-quality-based goals established through the CV-SALTS process. Each of these goals is described below.

The Central Valley Region SNMP was developed collaboratively through the efforts of the CV-SALTS stakeholder-led process. The stakeholders have focused on developing a Central Valley Region SNMP that supports implementation of a water resource management strategy that ensures safe and reliable drinking water to all residents while preserving the Central Valley's world-class agriculture economy. In addition, the establishment of management goals must be consistent with statewide environmental policy goals that can affect how salt and nitrate are managed at the local or sub-regional level. These statewide policy goals include directives to increase water conservation, increase the use of recycled water, increase groundwater recharge and reduce greenhouse gas emissions.

Coupled with the above strategy and statewide policies, CV-SALTS has been committed to ensuring that safe drinking water is available to all communities already impacted by elevated salt and nitrate. To meet this commitment, the SNMP established three water-quality based management goals to guide the short- and-long term management of salt and nitrate in the Central Valley of California. In priority order these goals are:

Goal 1: Ensure User Protection for the Drinking Water Supply

The most immediate management goal for the Central Valley Region is to ensure that a safe drinking water supply is available to all residents of the region. This goal is consistent with Assembly Bill No. 685. Goal 1 explicitly targets groundwater where there are human health concerns, *i.e.*, where nitrate or other constituents exceed their primary maximum contaminant level (MCL).

Goal 2: Achieve Balanced Salt and Nitrate Loadings

[8] The concepts in Section 3 are based on the draft plan of implementation document that was presented at the Executive Committee Policy meeting on January 14, 2016. Language in this section may be modified based on comments from stakeholders on that document.

The second water quality-based management goal seeks to establish a balance of the mass of salt and nitrate in groundwater underlying each managed area. With regard to salt, balance is defined as achieving a state where inputs of salt (salt flux in) into a managed area are equal to outputs of salts (salt flux out) from the same area. Likewise, Goal 2 includes a balance of nitrate flux in and nitrate flux out of the managed area. The nitrate mass balance will need to account for nitrate taken up by crops and losses of nitrate from the nitrogen cycle in soil, including denitrification in the root zone by soil microbial activity and volatilization to the atmosphere. A periodic evaluation of ambient water quality (volume-weighted average concentration in groundwater in the managed area) will be used as the basis for assessing progress towards attaining this goal.

Goal 3: Implement Managed Aquifer Restoration Program for Impaired Waterbodies and Where Reasonable and Feasible

Goal 3 seeks to restore salt and nitrate levels within managed areas to concentrations that are below the water quality objective established for each constituent, where reasonable and feasible to do so. Specifically,

- For salinity, the initial goal is to meet a water quality objective of less than 1,000 mg/L TDS or 1,600 µS/cm EC, consistent with the acceptable Upper Level concentrations established in 22 CCR Table §64449-B. NIMS recognizes that there are portions of groundwater basins underlying the Central Valley floor with naturally-occurring salts that are derived from marine deposits – among other sources – and where TDS naturally exceeds the default objective.

- For nitrate, the goal is to meet a water quality objective of less than 10 mg/L nitrate as nitrogen[9].

Assessing compliance with Goal 3 will be based on a volume-weighted average of water quality data collected from the production zone[10] associated with the area being assessed, *e.g.*, the specific area targeted for salt and nitrate management.

The above water-quality based management goals are to be implemented in a manner that takes into account the overarching water resource management strategy and statewide policy initiatives described above. Establishing the appropriate balance among these potentially competing goals will be a key element in the development of salt and nitrate management plans required by the SNMP.

It is recognized that for salt the achievement of water quality management Goal 2 is a step along the way to achievement of Goal 3 and that the implementation activities for one goal may be the same as the other goal. Regardless, in many areas achieving Goal 2 in a groundwater basin or

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[9] While this performance target is being contemplated, the NIMS evaluated other performance targets – from an assumed background in groundwater of 2 mg/L to the MCL (see Section 3.2).

[10] CV-SALTS has on-going projects to potentially redefine aquifer zones as "upper," "lower," "unknown," and "production (Updated Groundwater Analysis Project);" however, these studies were not completed when the NIMS was developed and published. The definition of production zone for the purposes of this study is the depth interval where most of the groundwater production occurs.

subbasin will be a significant accomplishment requiring substantial resource commitments, and thus Goal 2 serves as an important milestone on the way to achieving Goal 3.

Ultimately, as demonstrated in the technical work used to support the SNMP, the challenge associated with simply achieving the salinity and nitrate objectives in all impacted waters is significant. In time it may certainly be possible to achieve a water quality concentration better than the objective (unless the elevated salinity in groundwater is a result of the natural hydrogeology). However, for the purposes of the SNMP it is most important to first meet the objective to ensure that beneficial uses are protected. Accordingly, development of local and sub-regional salt and nitrate management plans under the SNMP will focus first on these water-quality based goals. Achieving water quality better than the objective may be achievable in many areas in the future and the Central Valley Water Board may consider establishing additional, more stringent water quality-based management goals at a future date during the regular review and revision of the SNMP. The SNMP will be reviewed and updated periodically as part of an adaptive iterative process (AIP).

With regard to the protection of beneficial uses, the water-quality based management goal to ensure user protection for drinking water supplies (Goal 1) is the highest priority for the SNMP and shall be complied with as quickly as possible in all areas in the Central Valley Region. This goal may be achieved through a combination of the development of alternative water supplies, establishment of treatment systems, or implementation of education and outreach activities.

Technical analyses conducted to support the SNMP indicate that achievement of Goals 2 and 3 in the groundwater of the Central Valley will only be successful through a long-term commitment to salt and nitrate management activities at the local or sub-regional level, and will require commitment to regional solutions such as establishment of regional salt sinks or a Central Valley regulated brine line. The selection of specific projects or activities to make progress towards attainment of these goals will be implemented through local SNMPs tailored to the specific needs of each managed area. These specific projects and implementation measures are expected to be prioritized at the management zone level.

3.2 Salt and Nitrate Target Performance Targets

As discussed in Section 3.1, the performance target is to meet a water quality objective of less than 1,000 mg/L TDS or 1,600 µS/cm EC. TDS in concentrations above the acceptable Upper Level concentrations in drinking water has potential impacts on aesthetics and consumer acceptance, but is not generally a human health concern. However, nitrate may have health impacts on users, and therefore the NIMS analyzed conceptual level cleanup times for performance targets that ranged from “background” to the maximum contaminant level (MCL) of 10 mg/L.

The NIMS Project Committee[11] agreed that a range of performance targets would provide the information needed to inform CV-SALTS regarding costs and practicality of potential nitrate implementation measures. The USGS (1999)[12] has estimated nationwide background

[11] September 11, 2105 NIMS Project Committee Conference Call
[12] USGS, 1999; http://pubs.usgs.gov/circ/circ1225/pdf/nutrients.pdf

concentrations of nitrate in shallow wells to be 2 mg/L. Panno *et al.* (2006)[13], suggest a present day background in groundwater to range from 0.1 to 2.1 mg/L (Figure 3-1). Therefore, the NIMS will assume the background concentration of nitrate in groundwater to be 2 mg/L.

The MCL for nitrate (expressed as nitrogen) is 10 mg/L, which would correspond to the target concentration for the Irrigated Lands Regulatory Program. The NIMS evaluated the following performance targets in the analysis: 2, 4, 8, and 10 mg/L. These performance targets are for evaluating scenarios in the NIMS only.

3.3 Phased Approach

The purpose of this task is to develop a proposed phased approach for various nitrate implementation measures to achieve the nitrate performance targets discussed in Section 3.1. Each local SNMP shall include a detailed, management zone-scale phased implementation schedule to support the proposed SNMP Management Plan. A proposed schedule for a phased approach could include the following components (the assumed start date would after the adoption of the basin plan amendment and approval by the Central Valley Water Board, the US Environmental Protection Agency (USEPA), and the Office of Administrative Law):

- A Phase 1 (Years 1-15) short-term detailed schedule of implementation activities linked to the SNMP Management Goals, in particular a schedule to meet a first phase water quality-based Management Goal 1 within the first three to five years of implementation, even if the initial solutions are temporary. More permanent user protection measures would be introduced over a three- to fifteen-year period.
- A Phase 2 (Years 11-20) schedule of planned or projected implementation activities expected to be implemented in the future, but linked to water quality-based Management Goals 2 and 3. Less detail is necessary here given the time to implementation and the expected review of these planned implementation activities during the scheduled review of the local SNMP (see below).
- A long-term schedule for implementation of management activities for Phase 3 and beyond (> 20 years), to the extent known. For example, this schedule could include extended commitments to regional salt or nitrate water quality solutions, *e.g.*, participation in a regulated brine line. It should also show planning activities that may occur in Phases 1 or 2 intended to support a long term solution where a reasonably feasible and practicable means exists.
- An AIP that should begin by the beginning of Year 9 of Phase 1, Year 19 of Phase 2, etc. The purpose of the AIP is to determine how the local SNMP should be updated for the next phase (including providing detailed projects/activities for the next 10 year period). The schedule for implementing this activity should be included in the local SNMP.

13 https://www.researchgate.net/profile/Walton_Kelly/publication/5227088_Some_considerations_in_applying_background_concentrations_to_ground_water_studies/links/0fcfd510a8438c43a1000000.pdf

		Natural Background	Present-Day Background	Anthropogenic Contamination	Significant Animal/Human Waste
	Springs	< 0.4 mg/L	0.4 – 2.5 mg/L	> 2.5 mg/L	
	Wells	< 0.1 mg/L	0.1 – 2.1 mg/L	> 2.1 mg/L	> 15 mg/L
Atmospheric Sources		Natural combustion Lightning	Fossil fuel burning power plants, vehicle exhaust Volatile NH_3 and other windblown N compounds from livestock and synthetic fertilizers		
Soil/Plants/ Geology		Native flora N in rock and buried deposits	Disruption of soil vegetation due to changes in land use	Crop and lawn residue from legumes and fertilized vegetion	
Synthetic Fertilizer				Row crops Lawns	
Animal Waste		Native fauna		Diffuse or minor livestock and septic effluent	Concentrated livestock and septic effluent
	CUMULATIVE INCREASE IN MASS OF NITROGEN ▷▷▷				

Figure 3-1 Nitrogen Sources for Different Sample Populations (Panno *et al.,* 2006)

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Section 4

Prioritization at the IAZ Level

Given the substantial number of existing WDRs or Waivers already issued in the Central Valley Region, the NIMS establishes a priority-based schedule for submitting the required documents to demonstrate compliance with the salt and management requirements of the SNMP. Establishing a priority-based schedule allows resources to be focused on the most significant areas of water quality concern first. It also creates staggered schedule for submission of SNMP deliverables so that sufficient Central Valley Water Board staff resources are available to review the deliverables at an expedient pace. The prioritization approach was reviewed during the Executive Committee Policy meeting on January 14, 2016. The prioritization has been modified based on updated information and is now weighted. The stakeholders can define areas of local prioritization and create a salt and nitrate management plan that is internally phased to address the local priorities.

4.1 IAZ-Level Nitrate and TDS Prioritization

A prioritization methodology was developed as part of the NIMS, wherein the IAZs were ranked based on the potential for salinity and nitrate impacts to users. This programmatic prioritization ranked each IAZ into 5 categories:

- Low
- Low to Moderate
- Moderate
- Moderate to High
- High

The SAMP prioritization methodology was used to rank the 22 Central Valley Region IAZs and the score is called the Nitrate Implementation Measures Prioritization Score (NIMPS). The methodology proposed for prioritizing the groundwater basins in the NIMS work plan included the following criteria:

1. Ambient TDS and nitrate concentrations in groundwater[14].
2. Estimated nitrate and TDS loading to the upper groundwater aquifer[15].
3. California Statewide Groundwater Elevation Monitoring (CASGEM) Program Basin Prioritization Process and Ranking.

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[14] Criteria 1 and 2 were combined in the final analyses included in this final report.

4. Vulnerability assessment from the Groundwater Quality Assessment Reports (GARs) developed by ILRP Coalition groups[15].
5. The overlying population.
6. The percentage of the overlying population that would be considered a part of a DAC or a DUC[16].

4.1.1 Nitrate Existing Conditions, Estimated Loading, and Trends

Basin ranking based on current ambient concentrations, estimated loading, and trends were developed as part of the initial conceptual model. The rankings were assigned based on the following questions (LWA *et al.*, 2013):

1. Does one quarter or more of the Central Valley Hydrologic Model (CVHM) grid cells within each IAZ with water quality data contain a well at or above the MCL (10 mg/L NO_3-N) from 2003 to 2012?
2. Is the median shallow zone concentration for recent years (2003-2012) at or above half of the MCL (5 mg/L NO_3-N)?
3. Is the estimated 2003 deep zone concentrations at or above 2 mg/L NO_3-N?
4. Do more than three simulations result in shallow groundwater at or above half of the MCL (5 mg/L NO_3-N)?

A "yes" response to each of the four questions yielded a score of one point for a possible score of four points for this criteria. Basins with a zero ranking were given the lowest priority while basins with a four ranking were given the highest priority (Table 4-1).

Nitrate trends were estimated previously (LWA *et al.*, 2013) based upon median concentrations over time since 1910 (Table 4-2). Qualitative trend descriptions were given numeric values as follows: 0=Decreasing, 1=Slightly Decreasing, 2=No Trend, 3=Slightly Increasing, and 4=Increasing.

4.1.2 TDS Existing Conditions, Estimated Loading, and Trends

Basin ranking based on current ambient TDS concentrations[16], estimated loading, and trends were developed as part of the initial conceptual model. The rankings were assigned based on the following questions (LWA *et al.*, 2013):

1. Does one quarter or more of the CVHM grid cells within each IAZ with water quality data contain a well at or above 1000 mg/L TDS from 2003 to 2012?
2. Is the median shallow zone concentration for recent years (2003-2012) at or above 1000 mg/L TDS?

[15] Prioritization criteria 4 and 6, were not used in the NIMS, because the GARs were not yet approved during the development of the NIMS and DAC/DUC databases were found to be not complete and not reliable.

[16] Electrical conductivity (EC) in was converted to TDS in the CV-SALTS database.

3. Is the estimated 2003 deep zone concentrations at or above 250 mg/L TDS?

4. Do two or more simulations result in shallow groundwater with concentrations at or above 1000 mg/L TDS?

A "yes" response to each of the four questions yielded a score of one point for possible score of four points for this criteria. Basins with a zero ranking were given the lowest priority while basins with a four ranking were given the highest priority (Table 4-3).

TDS trends were estimated previously (LWA *et al.*, 2013) based upon median concentrations over time since 1910 (Table 4-2). Qualitative trend descriptions were given numeric values as follows: 0=Decreasing, 1=Slightly Decreasing, 2=No Trend, 3=Slightly Increasing, and 4=Increasing.

4.1.3 Ranking based on California Statewide Groundwater Elevation Monitoring (CASGEM)

As part of the CASGEM program, DWR is required[17] to prioritize groundwater basins in California to "help identify, evaluate, and determine the need for additional groundwater level monitoring.[18]" The CASGEM Basin Prioritization Process is based on the following eight criteria[1]:

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;

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.

For the SNMP priority ranking the overall CASGEM prioritization analysis was not directly included in the analysis. Instead, three of the eight CASGEM criteria (3, 4, and 5) were analyzed and implemented independently using the CV-SALTS database and DWR land use maps. Table 4-4 shows the rankings that were used to divide the IAZs evenly into 5 class intervals for the following three criteria.

1. **Public Supply Wells**. Public supply wells are herein defined as any CDPH well with a population served of 25 or more. The percentage of public supply wells from the total number of wells in an IAZ was used to determine the ranking. An IAZ with a greater percentage of drinking water production wells may be at a greater risk.

[17] The California Water Code (CWC) 10933 and 12924
[18] http://www.water.ca.gov/groundwater/casgem/basin_prioritization.cfm

2. **Total Number of Wells**. This criterion was normalized by the area of the IAZ and reported as the number of wells per 10 square mile. An IAZ with a greater number of wells may be more vulnerable from a beneficial use standpoint.

3. **Overlying Irrigated Acreage.** This criterion refers to the percent of overlying land defined as agricultural and semi-agricultural categories as described Table 1-1. An IAZ with a greater percentage of overlying irrigated acreage is potentially more vulnerable.

4.1.4 Population

Population data for each groundwater basin was determined from 2010 US Census Blocks[19]. To translate population data from census block to an IAZ basis, the population of the census blocks within an IAZ was added together (including clipped or fractions of census blocks) resulting in the total population for an IAZ. Table 4-4 shows the rankings that were used to divide the IAZs evenly into 5 class intervals.

4.1.5 Summary of IAZ Prioritization

Four categories for both nitrate and TDS, population ranking, CASGEM ranking, Priority Basin Based on Ambient and Mixing Model Simulations, and basin trends are used to determine IAZ prioritization by using a weighted average. The four categories are ranked as follows:

- 15% Population
- 5% Total wells
- 5% Public supply wells
- 5% Overlying irrigated acreage
- 45% Priority Basin Based on Ambient and Mixing Model Simulations
- 25% Trend

Table 4-5 shows the rankings that were used to define the TDS and nitrate priority ranking and the combined TDS and nitrate priority ranking. The input data for each of the four categories and their associated priority rankings for nitrate and TDS are summarized in Table 4-6 and Table 4-7. The four category ranking results for TDS and nitrate are depicted geographically in Appendix D. An average of the nitrate priority and TDS priority is used to determine the final Combined Nitrate and TDS IAZ prioritization and is summarized Table 4-8.

The IAZs with the highest nitrate priority ranking are generally located in the eastern and southern portions of the central valley with the exception of IAZ-6 which is in Northern Central Valley region (Figure 4-1). The High priority IAZs include: IAZ-12 and IAZ-13 in Middle Central Valley and IAZ-16, IAZ-17, and IAZ-18 in Southern Central Valley. IAZ-1 through IAZ-5 received the lowest nitrate priority ranking and are located in the North Central Valley region.

[19] https://www.census.gov/geo/maps-data/data/tiger-data.html

The IAZs with the highest TDS priority ranking are generally on the west side of the Middle Central Valley region and the Southern Central Valley region with an exception of IAZ-6 which is in the Northern Central Valley region (Figure 4-2). Based on the classification ranges established in Table 4-5 none of the IAZs had criteria ranking it as “High”. The highest ranking is “Moderate to High” and includes IAZ-6 in Northern Central Valley region, IAZ-11 and IAZ-12 in Middle Central Valley region, and IAZ-14, IAZ-15, and IAZ-19 in Southern Central Valley region. IAZ-1, IAZ-2, and IAZ-4 received the lowest TDS priority ranking and are located in the North Central Valley region.

The IAZs with the highest combined nitrate and TDS priority ranking are generally located in the Middle Central Valley region and the Southern Central Valley regions (Figure 4-3) with the exception of IAZ-6. The High priority IAZs include: IAZ-6 in the Northern Central Valley region, IAZ-11 and IAZ-12 in the Middle Central Valley region, and IAZ-16 and IAZ-18 in the Southern Central Valley. The IAZs with the lowest priority rankings include IAZ-1 through IAZ-5, all of which are in the North Central Valley region.

Table 4-1 Establishing Priority Ranking for Nitrate[1]

Region	IAZ	Does one quarter or more of the CVHM grid cells containing wells test data have a well at or above the MCL (10mg/L NO_3-N) in 2000s?	Is the median shallow concentration for recent years (2003-2012) at or above half of the MCL (5mg/L NO_3-N)?	Is the estimated 2003 deep concentration at or above 2 mg/L NO_3-N?	Priority Basin Based on Ambient Nitrate Data	Do more than three simulations result in shallow groundwater at or above half or the MCL (5 mg/L NO3-N)?	Priority Basin Based on Ambient Nitrate Data and Mixing Model Simulations
Northern Central Valle	1	NO	NO	NO	0	NO	0
	2	NO	NO	NO	0	NO	0
	3	NO	NO	NO	0	NO	0
	4	NO	NO	NO	0	NO	0
	5	NO	NO	NO	0	NO	0
	6	YES	NO	YES	2	YES	3
	7	NO	NO	NO	0	YES	1
Middle Central Valley	8	NO	NO	NO	0	NO	0
	9	NO	NO	NO	0	NO	0
	10	YES	NO	YES	2	NO	2
	11	YES	NO	YES	2	NO	2
	12	YES	YES	YES	3	NO	3
	13	YES	YES	YES	3	NO	3
	22	YES	YES	NO	0	YES	2
Southern Central Valley	14	NO	NO	NO	0	YES	1
	15	YES	NO	NO	1	YES	2
	16	YES	YES	YES	3	YES	4
	17	YES	YES	YES	3	YES	4
	18	YES	YES	YES	3	YES	4
	19	YES	NO	NO	1	YES	2
	20	YES	NO	NO	1	YES	3
	21	NO	NO	NO	0	YES	1

1. Adapted from CV-SALTS Initial Conceptual Model Tasks 7 and 8: Salt and Nitrate Analysis for the Central Valley Floor and a Focused Analysis of Modesto and Kings Subregions Report, December 2013.

Table 4-2 Nitrate and TDS Trends[1]

Region	IAZ	Shallow Median Nitrate Concentration Trends							Shallow Median TDS Concentration Trends						
		1910-1964	1965-1970	1971-1979	1980-1989	1990-2002	2003-2012	Trend	1910-1964	1965-1970	1971-1979	1980-1989	1990-2002	2003-2012	Trend
Northern Central Valley	1			0.1			0.1	No Apparent Trend			158	150		370	Slightly Increasing
	2	1.1	1.3	2.2	3	0.4	0.6	No Apparent Trend	179	145	270	230	195	201	No Apparent Trend
	3	2.3	1.2	1.3	1.3	0.7	0.9	No Apparent Trend	1023	572	347	398	588	583	Slightly Increasing
	4		0.2	0.2	0	0.1	2.8	No Apparent Trend		853	487	806	625	761	No Apparent Trend
	5	1.1	1.2	1.4	2.5	0.8	0.4	No Apparent Trend	164	183	216	219	435	329	Slightly Increasing
	6		1.8	3.6	3.4	0.2	0.6	Slightly Decreasing		381	408	423	528	1060	Increasing
	7	0.8	1.2	1.5	1.8	1.7	0.7	No Apparent Trend	168	177	186	221	506	398	Slightly Increasing
Middle Central Valley	8	1.1	2.5	1.9	2.4	1.5	1.2	No Apparent Trend	163	164	187	166	336	438	Increasing
	9	4.9	2.9	0.1	0.1	0.1	0.4	No Apparent Trend	954	995	736	703	714	961	No Apparent Trend
	10	3.4			2.7	2.2	2.7	No Apparent Trend	473	870	870	1960	838	842	No Apparent Trend
	11		3.2	7.5	12.6	8.1	4.9	Increasing to Decreasing?	315	173	257	227	640	565	Increasing
	12				0.1	3.4	10.4	Increasing	80	895		83	201	825	Increasing
	13		7.9		4.4	5.4	6.1	Slightly Increasing	235	423	180	204	258	648	Increasing
	22	3.4			13.1	17.5	7.4	Slightly Decreasing	962	5630		2575	2410	1160	No Apparent Trend
Southern Central Valley	14	3.4	2.5		23		0.4	No Apparent Trend	942	836		4310		3375	No Apparent Trend
	15				1.2	11.3	3	Increasing to Decreasing?	336	475	315	6490	783	1000	No Apparent Trend
	16	5.7			8.2	7.9	11.1	Slightly Increasing	419	124	303	378	497	575	Increasing
	17	6		8.1	8	10.1	8.5	Slightly Increasing	383		352	413	394	520	Increasing
	18				14.5	15	10.7	No Apparent Trend	160		356	1555	648	598	No Apparent Trend
	19	3.6			4.9		3.3	No Apparent Trend	1270			3370		11300	Increasing
	20	0.6			1.3		3.4	Slightly Increasing	518			290		870	No Apparent Trend
	21	0.7		8.6	8.6	0.3	0.2	Increasing to Decreasing?	359		353	3420	420	335	No Apparent Trend

1. Adapted from CV-SALTS Initial Conceptual Model Tasks 7 and 8: Salt and Nitrate Analysis for the Central Valley Floor and a Focused Analysis of Modesto and Kings Subregions Report, December 2013.

Table 4-3 Establishing Priority Ranking for TDS[1]

Region	IAZ	Does one quarter or more of the CVHM grid cells containing wells test data have a well at or above 1000 mg/L TDS in 2000s?	Is the median shallow concentration for recent years (2003-2012) at or above 1000 5mg/L TDS?	Is the estimated 2003 deep concentration at or above 250 mg/L TDS?	Priority Basin Based on Ambient TDS Data	Do two or more simulations result in shallow groundwater at or above 1000 mg/L TDS?	Priority Basin Based on Ambient TDS Data and Mixing Model Simulations
Northern Central Valle	1	NO	NO	NO	0	NO	0
	2	NO	NO	NO	0	NO	0
	3	NO	NO	YES	1	NO	1
	4	NO	NO	YES	1	NO	1
	5	NO	NO	YES	1	NO	1
	6	NO	YES	YES	2	NO	2
	7	NO	NO	NO	0	NO	0
Middle Central Valley	8	NO	NO	NO	0	NO	0
	9	YES	NO	YES	2	NO	2
	10	YES	NO	YES	2	YES	3
	11	NO	NO	YES	1	NO	2
	12	NO	NO	YES	1	NO	1
	13	NO	NO	NO	0	NO	0
	22	YES	YES	YES	3	YES	4
Southern Central Valley	14	NO	YES	YES	2	NO	3
	15	NO	YES	YES	2	NO	2
	16	NO	NO	NO	0	NO	0
	17	NO	NO	NO	0	NO	0
	18	YES	NO	NO	1	NO	1
	19	NO	YES	YES	2	YES	3
	20	NO	NO	YES	1	NO	1
	21	YES	NO	YES	2	NO	2

1. Adapted from CV-SALTS Initial Conceptual Model Tasks 7 and 8: Salt and Nitrate Analysis for the Central Valley Floor and a Focused Analysis of Modesto and Kings Subregions Report, December 2013.

Table 4-4 Summary of Ranking Scores

Rank	Population Range	Total Wells (per 10 Square mile)	Percent Production Wells	Percent Overlying Irrigated Acreage	Ambient Data & Mixing Model	Trends (Table 4-2)
0	Less than 100,000	0 to 5	0 to 20%	0 to 20%	See Tables 4-1 & 4-3	Decreasing
1	100,001 to 250,000	6 to 10	21 to 40%	21 to 40%	See Tables 4-1 & 4-3	Slightly Decreasing
2	250,001 to 500,000	11 to 15	41 to 60%	41 to 60%	See Tables 4-1 & 4-3	No Trend
3	500,001 to 750,000	16 to 20	61 to 80%	61 to 80%	See Tables 4-1 & 4-3	Slightly Increasing
4	Greater than 750,001	Greater than 20	81 to 100%	81 to 100%	See Tables 4-1 & 4-3	Increasing

Table 4-5 Priority Ranking

Rank	TDS and Nitrate Range	Combined TDS and Nitrate Range
Low	Less than 1.49	Less than 1.4
Low to Moderate	1.5 to 1.99	1.41 to 1.8
Moderate	2.0 to 2.49	1.81 to 2.2
Moderate to High	2.5 to 2.99	2.21 to 2.6
High	Greater than 3.0	Greater than 2.61

Table 4-6 Nitrate Priority Ranking

Region	IAZ	Overlying Population[1]	Population ranking	Total Number of Wells in CV-SALTS Database (2003-2014)	Wells per Square 10 Mile	Wells per Square 10 Mile Ranking	Percent Production Wells	Percent Production Wells Ranking	Percent Irrigated Agricultural Land Use[2]	Irrigated Agricultural Ranking	Shallow Ambient Nitrate in mg/L (2003-2012)[3]	Deep Ambient Nitrate in mg/L (1980-2012)[3]	Nitrate Priority Basins Based on Ambient Nitrate Data & Mixed Model[3]	Nitrate Concentration Trends[3]	Nitrate Concentration Trend (ICM) ranking	Nitrate Priority Ranking
Northern Central Valley	1	157,851	1	442	7	1	30%	1	7%	0	0.1	0.8	0	No trend	2	0.75
	2	151,039	1	961	8	1	24%	1	27%	1	0.6	1.4	0	No trend	2	0.80
	3	40,937	0	408	4	0	21%	1	60%	2	0.9	1.5	0	No trend	2	0.65
	4	29,369	0	144	3	0	22%	1	80%	3	2.8	0.2	0	No trend	2	0.70
	5	250,825	2	711	7	1	31%	1	61%	3	0.4	0.9	0	No trend	2	1.05
	6	690,942	3	807	8	1	27%	1	47%	2	0.6	2	3	Slightly decreasing	1	2.25
	7	923,411	4	633	12	2	49%	2	40%	1	0.7	1.1	1	No trend	2	1.80
Middle Central Valley	8	1,009,710	4	2,045	15	2	33%	1	36%	1	1.2	1.1	0	No trend	2	1.30
	9	768,875	4	1,598	14	2	24%	1	62%	3	0.4	0.5	0	No trend	2	1.40
	10	89,619	0	294	4	0	22%	1	63%	3	2.7	4.2	2	No trend	2	1.60
	11	516,297	3	1,389	21	4	30%	1	58%	2	4.9	3.2	2	Increasing to decreasing	2	2.20
	12	214,349	1	1,274	24	4	15%	0	70%	3	10.4	3	3	Increasing	4	2.85
	13	338,330	2	1,178	7	1	25%	1	63%	3	6.1	2.2	3	Slightly increasing	3	2.65
	22	64,023	0	433	15	2	12%	0	69%	3	7.4	1.9	2	Slightly decreasing	1	1.40
Southern Central Valley	14	44,954	0	124	1	0	12%	0	84%	4	0.4	1	1	No trend	2	1.15
	15	185,473	1	576	4	0	24%	1	81%	4	3	0.4	2	Increasing to decreasing	2	1.80
	16	720,411	3	689	14	2	71%	3	51%	2	11.1	3.1	4	Slightly increasing	3	3.35
	17	218,115	1	468	8	1	52%	2	82%	4	8.5	2.9	4	Slightly increasing	3	3.05
	18	433,913	2	1,392	10	1	31%	1	76%	3	10.7	3	4	No trend	2	2.85
	19	68,617	0	109	1	0	25%	1	46%	2	3.3	1.1	2	No trend	2	1.55
	20	223,504	1	198	3	0	65%	3	58%	2	3.4	2	3	Slightly decreasing	1	2.00
	21	530,258	3	545	5	0	63%	3	58%	2	0.2	1.5	1	Increasing to decreasing	2	1.65

References:

1 - US Census Population 2010 by IAZ: https://www.census.gov/geo/maps-data/data/tiger-data.html

2- DWR Land Use: http://www.water.ca.gov/landwateruse/lusrvymain.cfm

3 - CV-SALTS Initial Conceptual Model Tasks 7 and 8: Salt and Nitrate Analysis for the Central Valley Floor and a Focused Analysis of Modesto and Kings Subregions Report, December 2013

Table 4-7 TDS Priority Ranking

Region	IAZ	Overlying Population[1]	Population ranking	Total Number of Wells in CV-SALTS Database (2003-2014)	Wells per Square 10 Mile	Wells per Square 10 Mile Ranking	Percent Production Wells	Percent Production Wells Ranking	Percent Irrigated Agricultural Land Use[2]	Irrigated Agricultural Ranking	Shallow Ambient TDS in mg/L (2003-2012)[3]	Deep Ambient TDS in mg/L (1980-2012)[3]	TDS Priority Basins Based on Ambient TDS Data & Mixed Model[3]	TDS Concentration Trends[3]	TDS Concentration Trend	TDS Priority Ranking
Northern Central Valley	1	157,851	1	442	7	1	30%	1	7%	0	370	158	0	Slightly increasing	3	1.00
	2	151,039	1	961	8	1	24%	1	27%	1	201	228	0	No trend	2	0.80
	3	40,937	0	408	4	0	21%	1	60%	2	583	381	1	Slightly increasing	3	1.35
	4	29,369	0	144	3	0	22%	1	80%	3	761	363	1	No trend	2	1.15
	5	250,825	2	711	7	1	31%	1	61%	3	329	281	1	Slightly increasing	3	1.75
	6	690,942	3	807	8	1	27%	1	47%	2	1060	461	2	Increasing	4	2.55
	7	923,411	4	633	12	2	49%	2	40%	1	398	241	0	Slightly increasing	3	1.60
Middle Central Valley	8	1,009,710	4	2,045	15	2	33%	1	36%	1	438	226	0	Increasing	4	1.80
	9	768,875	4	1,598	14	2	24%	1	62%	3	961	560	2	No trend	2	2.30
	10	89,619	0	294	4	0	22%	1	63%	3	842	911	3	No trend	2	2.05
	11	516,297	3	1,389	21	4	30%	1	58%	2	565	278	2	Increasing	4	2.70
	12	214,349	1	1,274	24	4	15%	0	70%	3	825	267	1	Increasing	4	1.95
	13	338,330	2	1,178	7	1	25%	1	63%	3	648	236	0	Increasing	4	1.55
	22	64,023	0	433	15	2	12%	0	69%	3	1160	645	4	No trend	2	2.55
Southern Central Valley	14	44,954	0	124	1	0	12%	0	84%	4	3375	966	3	Increasing	4	2.55
	15	185,473	1	576	4	0	24%	1	81%	4	1000	337	2	Increasing	4	2.30
	16	720,411	3	689	14	2	71%	3	51%	2	575	218	0	Slightly increasing	3	1.55
	17	218,115	1	468	8	1	52%	2	82%	4	520	199	0	Slightly increasing	3	1.25
	18	433,913	2	1,392	10	1	31%	1	76%	3	598	213	1	No trend	2	1.50
	19	68,617	0	109	1	0	25%	1	46%	2	11300	397	3	Increasing	4	2.50
	20	223,504	1	198	3	0	65%	3	58%	2	870	309	1	No trend	2	1.35
	21	530,258	3	545	5	0	63%	3	58%	2	335	262	2	No trend	2	2.10

References:

1 - US Census Population 2010 by IAZ: https://www.census.gov/geo/maps-data/data/tiger-data.html

2- DWR Land Use: http://www.water.ca.gov/landwateruse/lusrvymain.cfm

3 - CV-SALTS Initial Conceptual Model Tasks 7 and 8: Salt and Nitrate Analysis for the Central Valley Floor and a Focused Analysis of Modesto and Kings Subregions Report, December 2013

Table 4-8 Basin Priority Ranking Summary

Region	IAZ	IAZ Description	TDS Priority Ranking	Nitrate Priority Ranking	Combined Nitrate and TDS Priority Ranking
Northern Central Valley	1	Sacramento River above Red Bluff	1.00	0.75	0.88
	2	Red Bluff to Chico Landing	0.80	0.80	0.80
	3	Colusa Trough	1.35	0.65	1.00
	4	Chico Landing to Knights Landing proximal to the Sacramento River	1.15	0.70	0.93
	5	Eastern Sacramento Valley foothills near Sutter Buttes	1.75	1.05	1.40
	6	Cache-Putah area	2.55	2.25	2.40
	7	East of Feather and South of Yuba	1.60	1.80	1.70
Middle Central Valley	8	Valley floor of the Delta	1.80	1.30	1.55
	9	Delta	2.30	1.40	1.85
	10	Delta-Mendota Basin - Northwest Side	2.05	1.60	1.83
	11	Modesto and southern Eastern San Joaquin Basin	2.70	2.20	2.45
	12	Turlock Basin	1.95	2.85	2.40
	13	Merced, Chowchilla, and Madera Basins	1.55	2.65	2.10
	22	Delta-Mendota Basin - Grassland	2.55	1.40	1.98
Southern Central Valley	14	Westside and Northern Pleasant Valley Basins	2.55	1.15	1.85
	15	Tulare Lake and Western Kings Basin	2.30	1.80	2.05
	16	Northern Kings Basin	1.55	3.35	2.45
	17	Southern Kings Basin	1.25	3.05	2.15
	18	Kaweah and Tule Basin	1.50	2.85	2.18
	19	Western Kern County and Southern Pleasant Valley Basin	2.50	1.55	2.03
	20	Northeastern Kern County Basin	1.35	2.00	1.68
	21	Southeastern Kern County Basin	2.10	1.65	1.88

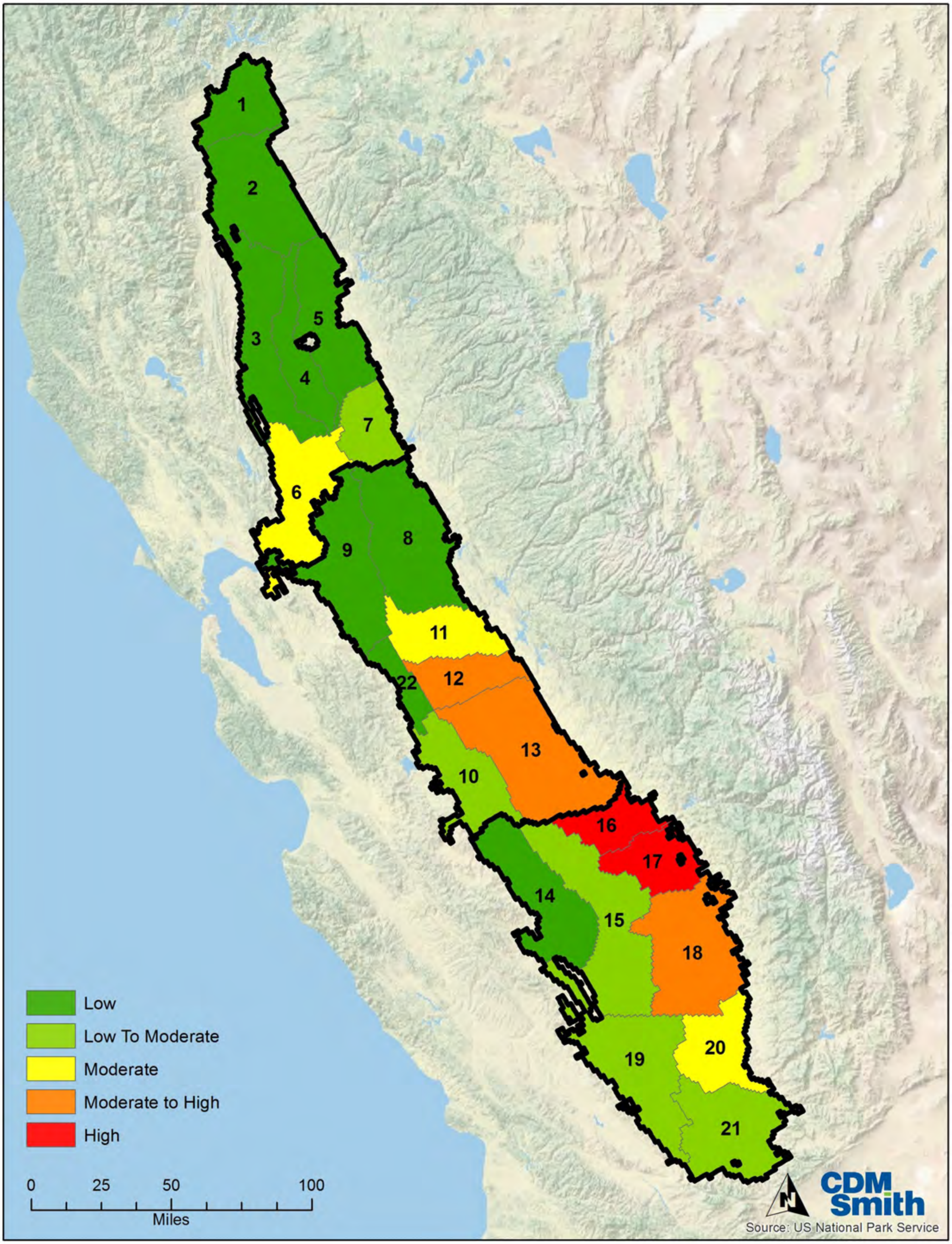

Figure 4-1 Map of Nitrate Prioritization by IAZ

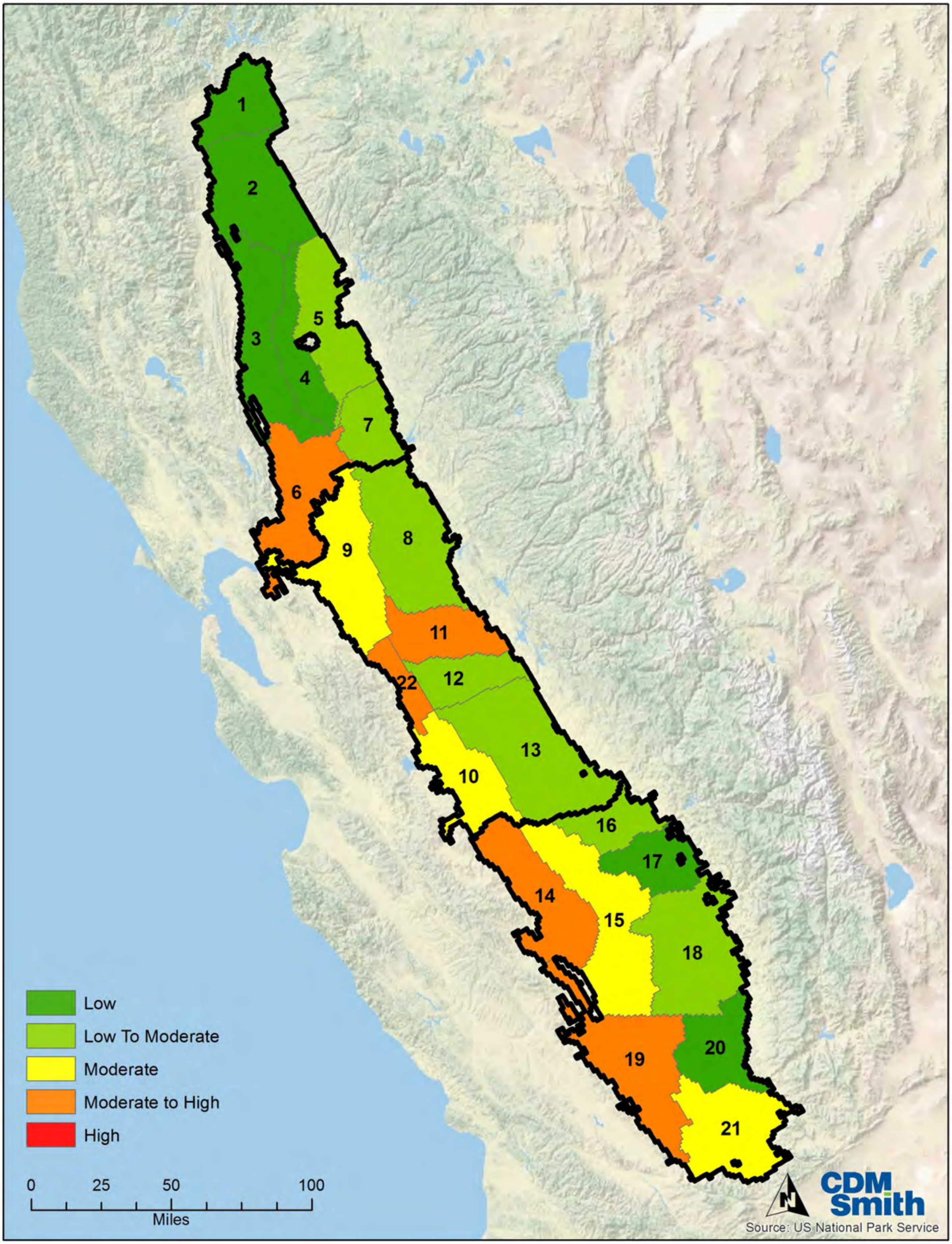

Figure 4-2 Map of TDS Prioritization by IAZ

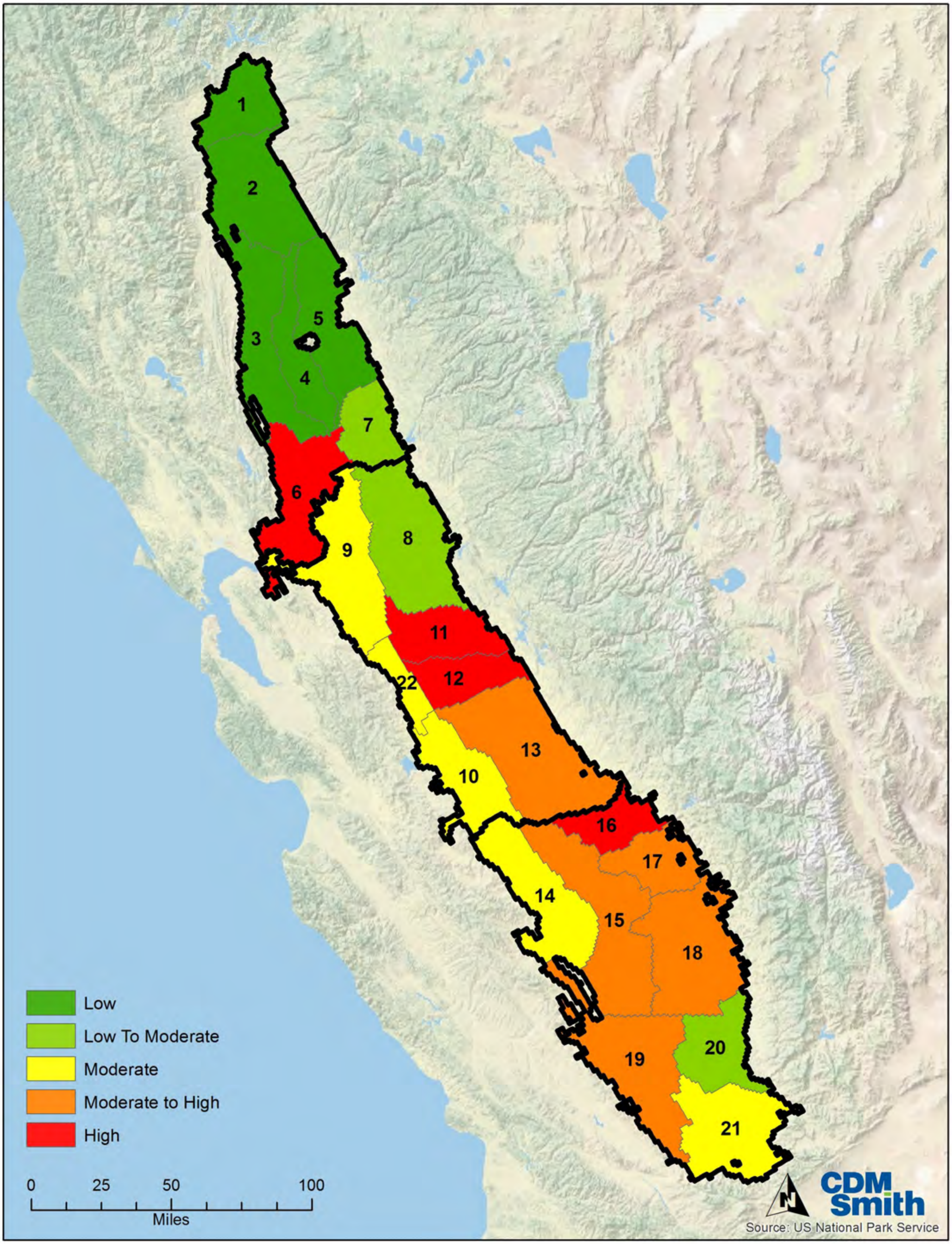

Figure 4-3 Map of Nitrate and TDS Prioritization by IAZ

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Section 5

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[20]
- Alternate water supplies

The goal of Task 5 is to consider the most critical measures and to determine the feasibility of implementing these and developing planning level costs and timeframes.

5.1 Current Nitrate Distribution and Mass Loading at the IAZ-Level

Section 1.2 provided an overview of the distribution of nitrate in groundwater underlying the Central Valley floor. Figures 1-5 and 1-6 depict average nitrate concentrations in wells for the period 2003-2014. Nitrate is higher on the east side of San Joaquin River Valley and the Tulare Lake Basin (IAZs 13, 16, 17, 18) principally from agricultural practices. The percentage of shallow and deep wells that exceed 5 mg/L and 10 mg/L in each IAZ for the same period are shown in Figures 1-7 and 1-8. Using data from the CV-SALTS database, the percentage of wells in the shallow and deep zones were calculated:

- 1927 of 6579 shallow wells have exceeded 10 mg/L – 29 percent
- 2915 of 6579 shallow wells have exceeded 5 mg/L – 44 percent
- 2951 of 15,252 deep wells have exceeded 10 mg/L – 19 percent
- 5310 of 15,252 deep wells have exceeded 5 mg/L – 35 percent

The NIMS Project Committee requested that the volume of groundwater that exceeds 10 and 5 mg/L also be estimated. An equal area, uniform grid approach was used for a range of grid cell sizes (square miles): 1, 2, 4, 6, 8, 9, 10, 12, 14, and 16. The median concentration of wells within the grid cells was chosen to represent the concentrations of groundwater in that grid cell for both shallow and deep zones. Smaller grid spacings will identify hot spots, but will also have a greater percentage of grid cells with no data. Larger grid spacings will estimate a higher volume of

[20] 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.

contaminated groundwater, but will not characterize hot spots with the same precision. Figures 5-1 and 5-2 show the distribution of nitrate in groundwater using the range of grid cells. The legend for each of the figures is as follows:

- Blue – Less than 2 mg/L
- Green – From 2 to 5 mg/L
- Yellow – 5 to 10 mg/L
- Light orange – 10 to 20 mg/L
- Orange – 20 to 40 mg/L
- Red – Greater than 40 mg/L

Using the grid cell analysis, the estimated volumes of groundwater that exceed 10 and 5 mg/L are:

- 54 MAF out of 235 MAF in the shallow zone have exceeded 10 mg/L – 23 percent
- 105 MAF out of 235 MAF in the shallow zone have exceeded 5 mg/L – 45 percent
- 40 out of 401 MAF in the deep zone has exceeded 10 mg/L – 10 percent
- 97 out of 401 MAF in the deep zone has exceeded 5 mg/L – 24 percent

King *et al.* (2012) estimated "the total annualized cost of remediation in the Tulare Lake Basin and Salinas Valley…based only on treatment costs and the calculated volume to be treated…" This estimate used unit costs of $1.18 per thousand gallons (kgal) of groundwater that would need to be treated for biological and $2.63/kgal for a combined reverse osmosis and ion exchange. In the King *et al.* (2012) study, "Pipeline and pumping costs for transport of water from remote locations to a large centralized facility are not included and would increase the total cost." Further, King *et al.* (2012) state, "We do not consider this basin-scale PAT [pump-and-treat] scenario to be either economical or feasible. This scenario is presented for context and to convey the scale of the problem." The range of annualized remediation costs to treat the volume of groundwater that exceeds 10 mg/L in the Tulare Lake Basin (King *et al.*, 2012) is $12.B to $27.6B.

The same analysis was performed in the NIMS for the groundwater underlying the Central Valley floor – Sacramento River Valley, San Joaquin River Valley, and the Tulare Lake Basin (Table 5-1). Again, this estimate does not include extraction wells, raw and treated water pipelines, *etc*. and serves to provide an estimate of the *minimum treatment costs* at a valley-wide scale. Using the same unit treatment costs and assumptions as King et al. (2012), the cost for treating groundwater that exceeds the MCL in the Central Valley would range from $36B to $81B.

Section 5.5.4 provides concept-level costs at the management-zone scale. These costs include costs for extraction wells, pipelines, treatment systems, and evaporation ponds.

In both cases, the volume of water that would be hypothetically treated is the volume of contaminated groundwater. The analyses do not account for either legacy nitrate contamination in the vadose zone or the continued flux of nitrate from on-going irrigated agricultural practices (and other sources of nitrate to groundwater).

As part of the NIMS, a mass-loading spreadsheet was developed similar to the TDS mass loading developed previously (CDM Smith, 2014). The mass balance model looks at projected concentrations of nitrate in groundwater for each of the IAZs based on the results from the ICM[21]. The information from ICM Tables 10-4 and 10-5 were used as the basis for nitrate loading in the NIMS (LWA *et.al*, 2013). The nitrate loading (kg/acre) and the area were used to determine the mass loading of nitrate for each IAZ on an annual basis (Table 5-2). 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. According to the ICM, the nitrate loading to the shallow groundwater zone Valley-wide ranges from 97,500 to 311,000 tons annually. Between 78 and 86 percent of the nitrate loading occurs in the Southern Central Valley.

5.2 Alternate Drinking Water Supplies

With regard to the protection of beneficial uses, the water-quality based management goal to ensure user protection for drinking water supplies (Goal 1) is the highest priority for the NIMS and the Central Valley SNMP and shall be complied with as quickly as possible in all areas in the Central Valley Region. This goal may be achieved through a combination of the development of alternative water supplies, establishment of treatment systems, or implementation of education and outreach activities. Goal 1 explicitly targets groundwater where there are human health concerns, *i.e.*, where nitrate or other constituents exceed their primary MCLs.

Making alternative drinking water supplies available places emphasis on disadvantaged communities (DACs), disadvantaged unincorporated communities (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 bottled water, connecting to an existing community water system or constructing a new community system, or providing well-head treatment will all be analyzed as each local SNMP is developed at the management zone-scale. An example of providing local treatment to serve multiple communities is provided in Section 5.4.4. Mitigating factors will need to be addressed: for example, drilling a deeper replacement well could encounter higher concentrations of arsenic or other trace constituents which may require additional treatment or blending.

The USEPA has developed guidelines for *Planning for an Emergency Drinking Water Supply* (AWWA and CDM Smith, 2011[22]). This document focusses on providing alternate drinking water sources in the event of the destruction, impairment, or contamination of the public water supply

[21] The ICM analyzed six loading scenarios for nitrate: high, medium and low nitrogen use efficiencies, where NUE = uptake/application mass of N. The remaining three scenarios were 90, 78, and 60 percent of the high NUEs.

[22] http://www.epa.gov/sites/production/files/2015-03/documents/planning_for_an_emergency_drinking_water_supply.pdf

from a disaster (man-made or natural), and looks at a very short timeframe for outages. However, many of the elements of the document are germane to meeting a longer-term alternate drinking water supply for nitrate-impaired groundwater sources. Table 5-3 provides alternate water supply options from the USEPA guidelines.

5.3 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 nitrate sources as illustrated in Figure 5-3:

- Irrigated agriculture (croplands),
- Wastewater treatment plant and food processing waste discharges,
- On-site waste disposal systems (septic systems),
- Urban land uses,
- Corrals, and
- Lagoons.

According to Harter *et al.*, (2012), the largest contributor of nitrate to groundwater in the study area was irrigated agriculture, accounting for 96 percent of the total nitrogen load to groundwater in these basins. While best management practices to reduce nitrate loading from all sources may be beneficial, at a macroscale the most significant gains for this particular area would be made by reducing nitrate loading from irrigated agriculture.

For example, groundwater protection from agriculture 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.”

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.

- Reduction of nitrogen fertilizer application to account for nitrate in irrigation water (pump and fertilize). This is discussed in more detail in Section 5.4.1.

There are a number of specific implementation measures that can be site- and crop-specific. The University of California Cooperative Extension can 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.

It is important to note that while the above example illustrates best management practices that may be considered to manage agricultural sources of nitrate loading, the SNMP will be implemented at varying scales, from a localized area (*e.g.*, a POTW) to a management zone, large agricultural area, or groundwater basin,. Accordingly, the local SNMPs will evaluate best management practices for reducing nitrate loading for all primary sources, including, but not limited to wastewater and waste dischargers, septic systems and urban land uses.

5.4 Recharge of High Quality Water

Recharge of low TDS, low nitrate water is a critical component of Sustainable Groundwater Plans (GSPs), as well as SSALTS and NIMS. Stormwater can be diverted to strategically located recharge basins or certain fields can be flooded during winter months when stormwater is available for diversion. Hydrologic modeling, water rights, and monitoring will need to be considered in order to balance stormwater recharge which benefits groundwater users with water requirements in streams.

5.5 Groundwater Mitigation

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*), and
- *In situ* treatment.

5.5.1 Pump and Fertilize

Pump and fertilize 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. Because of consumptive use, the concentration of TDS in water that becomes deep percolation from irrigated agriculture is considerably higher than the irrigation water.

In fulfillment of Senate Bill SBX 2 1, an Agricultural Expert Panel (Panel) was convened to address questions posed by the State Water Resources Control Board (State Water Board)[23] concerning

[23] http://www.swrcb.ca.gov/water_issues/programs/agriculture/docs/ILRP_expert_panel_final_report.pdf

the impacts of irrigated agriculture on groundwater quality. One of the Panel's conclusion is that "…any improvements in nitrogen management on the ground must require the development and implementation of simple and pragmatic nitrogen and water management plans by farmers."

The recommendations from the Panel pertain to the Irrigated Lands Regulatory Program (ILRP), which "was initiated in 2003 to prevent agricultural runoff from impairing surface waters. Waste discharge requirements, which protect both surface water and groundwater, address irrigated agricultural discharges throughout the Central Valley.[24]" The following is a narrative summary of the Panel's 11 recommendations:

> Nitrate contamination of groundwater is often a non-point pollution problem and requires different approaches by the Regional Water Board, as well as good nitrogen management by growers. Nitrate only moves below the root zone through deep percolation of irrigation water or stormwater; so irrigation practices are essential to limiting groundwater contamination. On the other hand, sustainable agriculture requires some leaching of water below the root zone in order to remove salt that has accumulated.
>
> The mechanism of nitrogen transformations, cycling, and transport in the root zone, vadose zone, and groundwater is extremely complicated, spatially and temporally variable, and not readily predictable with any precision. What is known is that if more nitrogen is applied to a field than is removed, most of the excess nitrogen will reach groundwater via deep percolation. Hence, the goal is to limit the excess applied nitrogen to the extent possible, without unduly impacting crop yield and farm economics. The Panel recommends a simple metric to help to manage nitrogen applications and minimize groundwater contamination. The ratio "A/R" is simply nitrogen applied (A) divided by nitrogen removed (R) or sequestered[25].

$$A/_R = \frac{Nitrogen\ Applied}{(Nitrogen\ Removed\ via\ Harvest) + (Nitrogen\ Sequestered\ in\ Perennial\ Crops)}$$

> Because of variability in crop yield, hydrology, and nitrogen transformation, an *annual* value of A/R has minimal value; multiple-year trend analyses will prove to be more useful in determining the effectiveness of the Nitrogen Management Plan.
>
> The effective implementation of nitrogen management programs will take many years, with outreach and education being a critical piece of the puzzle. Historically, university and consultant recommendations for nitrogen application focused on maximizing yield – new programs will need to maximize yield while working under a constraint to minimize the "A/R." Appropriate A/R values are not known at this time and will depend on climate, crop, and other conditions. The best method of determining the mass of nitrogen removed via harvest has not been determined.

The Panel further recommends the following for the development of Nitrogen Management Plans:

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[24] http://www.waterboards.ca.gov/centralvalley/water_issues/irrigated_lands/

[25] This AMP also assumes an additional loss nitrogen from microbial denitrification in the root zone and volatilization losses.

- Create and implement an irrigation and nitrogen management plan that is specific to each grower and management unit.
- These plans may take one to three years to fully develop and implement the data collection processes, data handling procedures, and the requisite tools.
- The components of the nitrogen management plan can be organized in a simple table (an electronic spreadsheet is preferred) and includes the following information:
    - Mass of nitrogen (range) required for the crop.
    - The mass of nitrogen (pounds per acre) planned to be applied from all sources, including synthetic fertilizers, organic fertilizers (compost and manure), and irrigation water. The Panel recommends that the timing and uniformity of nitrogen application be understood as well.
    - How much residual nitrogen is left in the soil[26]?
    - How much nitrogen is removed or sequestered by the crops?
    - How much irrigation water was applied?

An example of a Nitrogen Management Plan for the East San Joaquin Water Quality Coalition ILRP is provided at this link[27], along with the worksheet[28] where nitrogen management data will be stored and managed and the worksheet instructions[29],[30].

By following these nitrogen management plans, growers will reduce the mass of nitrate added at the surface, thus reducing the flux of nitrate to groundwater. Whether pump and fertilize will ultimately remove a greater mass of nitrate from groundwater than is added by the application of fertilizer and irrigation water depends on management zone- or site-specific conditions: nitrate concentrations in groundwater that is pumped for irrigation, fertilizer practices (amount, timing and form), irrigation practices, nitrogen loss in the root zone, harvesting and removal of plant biomass, etc.

Water, TDS, and nitrate fluxes were modeled in the CV-SALTS Management Zone Archetype Analysis: Alta Irrigation District (LWA *et al.*, 2016). Water and mass balance components in the analysis included recharge, streambed infiltration, and groundwater pumping. The recharge term includes recharge from artificial recharge basins, POTW discharge ponds, as well as recharge from irrigated agricultural practices. The study considered irrigation methods, applied water (generated by Soil and Water Assessment Tool [SWAT] model), soil parameters from the Soil

[26] The Nitrogen Tracking and Reporting System Task Force recommends reporting annual residual soil nitrogen credits, however, the Panel does not make that same recommendation because the quantification is difficult, there is the likelihood of short-term fluctuations and the multi-year A/R approach minimizes the value of soil residual nitrogen reporting.
[27] http://www.esjcoalition.org/nCalc.asp
[28] http://www.esjcoalition.org/NMPWorksheet.pdf
[29] http://www.esjcoalition.org/NMPWorksheetInstructions.pdf
[30] This template was approved on December 23, 2014 by the Executive Officer of Central Valley Regional Water Quality Control Board (Regional Board).

Survey Geographic Database (SSURGO), land use mapping from DWR, and estimates of fertilizer application rates based on crop types. The nitrate flux for baseline conditions and the three modeled scenarios[31] averaged over the AID MZ area are shown in the following table (LWA *et al.*, 2016: Appendix C-1):

Mass Balance Component	Nitrate-N							
	Baseline		Scenario 1		Scenario 2		Scenario 3	
	(tons/yr)	(lbs/ac/yr)	(tons/yr)	(lbs/ac/yr)	(tons/yr)	(lbs/ac/yr)	(tons/yr)	(lbs/ac/yr)
Recharge	9663	145	8685	130	7551	113	6755	101
Streambed Infiltration	1.21	0.02	1.22	0.02	1.20	0.02	1.22	0.02
Groundwater Pumping	-2332	-35	-2047	-31	-2331	-35	-2046	-31
Net Mass Flux	7332	110	6639	99	5221	78	4710	70

This analysis did not explicitly take into account legacy nitrate contamination in the vadose zone, but does take into account the reduction of nitrogen fertilizer applied in a pump and fertilize scenario[32]. Hence, even though nitrate in pumped groundwater was accounted for in Scenario 3, irrigated agriculture adds a net 70 pounds/acre/year for this archetype area. Future best management practices resulting from the MPEP studies, including increasing the use of drip irrigation, would reduce the net nitrate flux to groundwater – but it may not be possible to achieve Goal 2 through pump and fertilize.

5.5.2 Pump with Aboveground Treatment[33]

Pump with aboveground treatment of groundwater includes treatment using standard drinking water treatment technologies, 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. For the pilot study area, the NIMS identified 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

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31 Scenario 1 – Increased irrigation efficiency and greater recharge at selected project sites; Scenario 2 – Decreased nitrogen loading; Scenario 3 – Increased irrigation efficiency, greater recharge at selected project sites, and decreased nitrogen loading.

32 "However, N in applied water is assumed to be accounted for as part of the N rate, so the same crop gets the same N rate regardless of how that N is apportioned among irrigation water, mineral fertilizer, and organic fertilizer." Email from Karen Ashby/LWA. February 20, 2016.

33 The NIMS Project Committee provided direction to not include a comprehensive review of various current and emerging nitrate drinking water technologies, because technical reviews have been published recently, including Seidel *et al.* (2012) and Jensen *et al.* (2012). A matrix summarizing technologies is provided in Appendix E. Likewise recent reviews exist for phytoremediation, in situ denitrification, and pump and fertilize (King *et al.*, 2012).

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 scenario to be either economical or feasible." For the pilot study area, NIMS estimated conceptual-level cleanup times to meet the performance target levels.

5.5.2.1 Brine Mitigation

Technical analyses conducted during the NIMS and SSALTS studies indicate that achievement of Management Goals 2 and 3 will only be successful through a long-term commitment to salt and nitrate management activities at the local or sub-regional level, and will require commitment to regional solutions such as establishment of regional salt sinks or a Central Valley regulated brine line. The selection of specific projects or activities to make progress towards attainment of these goals will be implemented through salt and nitrate management plans tailored to the specific needs of each managed area. Salt accumulation areas are a critical interim solution until the Central Valley regulated brine line is operational.

5.5.2.2 Use of Product Water

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 draught, it is assumed that all of the water extracted and treated would be put to beneficial use. A percentage could possibly be used for potable supply as previously described, and 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.

In a pump, treat, and serve scenario, pumping of nitrate-contaminated groundwater would occur at a rate to meet potable demands, rather than pumping at a higher rate and then using the product water above that needed to meet potable demands for irrigation or for re-injection. Pump, treat, and serve would meet Management Goal 1 in that user protection would be assured, while progress is being made to meet Management Goals 2 and 3.

5.5.3 *In Situ* Treatment

Options for *in situ* nitrate treatment includes *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 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.

5.5.4 Alta Irrigation District Pilot Study Area

Alta Irrigation District (District) was chosen as the pilot study area because it is the CV-SALTS Management Zone Archetype and has areas where groundwater has nitrate concentrations in exceedance of the MCL.

The District is located in the eastern portion of the San Joaquin Valley within the Kings River Water Quality Coalition and Kings River Conservation District and comprises about 238 square miles (Figure 5-4). The boundaries of the District encompass parts of three counties (Tulare County, Kings County and Fresno County) and include two incorporated cities – Dinuba and Reedley – and several unincorporated communities. The District is in the eastern portion of IAZ 17.

5.5.4.1 Background

Except for nitrate, the District has high groundwater quality because its primary source is from the snowmelt from the Sierras which recharges the basin along the mountain front and from the Kings River and other streams. Nitrate contamination is primarily a result of agricultural practices, with the highest contamination in the southern portion of the District. All urban communities and many individual residences rely on the groundwater supply to meet the potable demands.

Groundwater elevations are depicted in Figure 5-5 and depth to first encountered groundwater is shown in Figure 5-6. Groundwater generally flows from areas of recharge along the mountain front to the west/southwest. Recharge also occurs from the deep percolation of applied irrigation water and from streambed recharge. Depth to water ranges from 20 to 120 feet below ground surface (bgs). Depth to first-encountered groundwater is greater in the southern portion of the basin. East Orosi may be a candidate for permeable reactive barriers, because the depth to water is relatively shallow (40 to 60 feet bgs) and the groundwater concentrations are relatively high (in some cases, greater than 40 mg/L).

Land use (Figure 5-7) is predominantly agriculture, with the following breakdown:

- Agriculture – 66.6%
  - Deciduous Fruits & Nuts – 25.1%
  - Grain and Hay – 11%
  - Field Crops – 9.1%
  - Vineyards – 8.6%
- Native – 23.3%
- Urban – 6.6%
- Semi Agricultural – 3.5%

Irrigated agriculture accounts for 82 percent of all agriculture for about 5,250,000 acres in the study area.

Well type and use are shown in Figure 5-8. “CDPH” wells are predominantly community water system wells, while “water supply” and “Agricultural” wells are typically irrigation wells.

Nitrate concentrations in the shallow and deep zones are shown in Figures 5-9 and 5-10. There are few wells designated as shallow in the CV-SALTS database. Groundwater nitrate concentrations are high along the southern portion of the study area where there are a number of CAFOs. The highest wells have concentrations greater than 80 mg/L. Figure 5-11 shows the areal distribution of nitrate in the deep zone using equal area, uniform grids. Figure 5-12 shows the computed, volume-weighted average nitrate concentration for each of the grid sizes. The NIMS used the four square mile grid, and estimated a volume-weighted average concentration of 12 mg/L was estimated for the study area for the period 2003 to 2012 for the remediation scenarios.

5.5.4.2 Remediation Scenarios

5.5.4.2.1 Pump, Treat, and Reinject at the MZ-Scale

The NIMS evaluated a scenario (Scenario 1a) for pump, treat, and reinject at the MZ-scale in order to demonstrate that mitigation timeframes are long and treatment costs are high. As noted by King *et al.* (2012). "Full, basin-scale application of pump-and-treat (PAT) methods is not practical, due to the prohibitively high costs associated with the required construction and operation of a vast network of contaminant capture wells for decades, possibly centuries. Moreover, vast amounts of groundwater would have to be treated and reinjected. The construction and energy costs alone would be enormous."

In this scenario, there is a hypothetical polyhedron that represents groundwater underlying the AID study area. The aquifer volume is defined by the area of the study area and a presumed depth of the production zone of 300 feet. The initial groundwater nitrate concentrations are assumed to be at ambient levels (12 mg/L average across the study area). The mass balance model estimates average nitrate on an annual time step assuming uniform mixing. Groundwater production was assumed to be equivalent to the current potable production rate. In this figure and subsequently in Figures 5-18 and 5-19, the nitrate mass balance is for groundwater only. The analyses do not account for neither legacy nitrate contamination in the vadose zone nor the continued flux of nitrate from on-going irrigated agricultural practices (and other sources of nitrate to groundwater). In this analysis, it was assumed that the pumped groundwater would be treated to 1 mg/L and reinjected. Figure 5-13 shows the predicted future concentrations of nitrate in groundwater over time. The mass balance model suggests that nitrate performance targets would be achieved in the following timeframes:

- Below 10 mg/L – 73 years
- Below 8 mg/L – 161 years
- Below 5 mg/L > 260 years
- Below 4 mg/L > 260 years

Figure 5-13 also shows the predicted concentrations of nitrate in groundwater where the extraction rate is twice the potable demand (Scenario 1b). For this subscenario, the mass balance model suggests that nitrate performance targets would be achieved in the following timeframes:

- Below 10 mg/L – 37 years

- Below 8 mg/L – 81 years
- Below 5 mg/L > 180 years
- Below 4 mg/L > 220 years

Pump, treat, and reinject at 27.16 MGD versus 13.58 MGD will achieve the target concentration in 37 years rather than 73 years, but at a higher cost. Using for example, the high end of the cost range for ion exchange the equivalent annual costs would be $17.1M versus $9.3M.

5.5.4.2.2 Pump, Treat, and Serve to Meet Potable Demands

There are 12 communities within the AID study area. Their areas, populations, and water demands[34] are shown in Table 5-5. The NIMS reviewed a number of pump, treat, and serve subscenarios. These subscenarios shared the following assumptions:

- Initial groundwater nitrate concentrations at ambient levels (12 mg/L).
- Pump and treat and serve to communities within the Alta Irrigation District
- Pump in areas of high nitrate concentrations, in lieu of current pumping from water supply wells.
  - Subscenario 2a. Three regional systems: West, Central, and East
  - Subscenario 2b. Two regional systems: Central and East
  - Subscenario 2c. Two regional systems. Wellhead treatment for small communities.
  - Subscenario 2d. Two regional systems.

For Subscenario 2a, the three regional systems would be (Figure 5-14):

- Traver, London, and Delft Colony – 668 AFY
- Monson, Yettum, Seville, and Dinuba – 4860 AFY
- East Orosi, Orosi, Sultana, Cutler – 2365 AFY

Each of the three regional systems would be independent from each other. Groundwater pumping would occur in portions of the study area that are relatively high nitrate in groundwater.

For Subscenario 2b, the two regional systems would be (Figure 5-15):

- Traver, London, Delft Colony, Monson, Yettum, Seville, and Dinuba – 5528 AFY
- East Orosi, Orosi, Sultana, Cutler – 2365 AFY

[34] Approximated from population data.

In Subscenario 2c, there would be two regional systems and well head ion exchange units for the other six communities (Figure 5-16):

- Dinuba – 4720 AFY
- East Orosi, Orosi, Sultana, Cutler – 2365 AFY
- IX Well head treatment for Traver, London, Delft Colony, Monson, Yettum, and Seville – 8089 AFY

For Subscenario 2d, the two regional systems would be (Figure 5-17):

- Traver, London, Delft Colony, and Dinuba – 5387 AFY
- East Orosi, Orosi, Sultana, Cutler, Monson, Yettum, Seville – 2506 AFY

The mass balance model suggests that the 10 mg/L nitrate performance target would be achieved in the following timeframe (Figure 1-18):

- Below 10 mg/L – 121 years

Lower targets would not be met during the period of the nitrate mass balance model.

The pump, treat, and serve subscenarios will take longer to reach a performance target of 10 mg/L (121 vs 37 to 73 years for pump, treat, and reinject). However, pump, treat, and serve achieves Management Goal 1 by providing treated water to meet potable demands and the cost for the pump, treat, and serve options are significantly lower than pump, treat and reinject. The equivalent annual cost for Scenarios 2a through 2d range from $2.2M to $8.7M, while Scenario 1 concept level equivalent annual costs range from $5.9M to $14.2M (Table 5-6).

5.5.4.2.3 Point Source-Scale, Pump, Treat, and Reinject

In this scenario, the polyhedron represents groundwater underlying a hypothetical point source plume of nitrate. The aquifer volume is defined by the area of the plume and a presumed depth of the production zone of 300 feet. The initial groundwater nitrate concentrations are assumed to be at background concentrations – in this scenario the starting point is 100 years ago, so the historical period occurs before year zero, which represents the current year. There is an assumed continuous point source of nitrate that contributes 2 MGD of effluent at 25 mg/L in the historical period. Figure 5-19 shows nitrate concentration (blue line) asymptotically approaching 25 mg/L over time. The increase of nitrate over time is offset somewhat by subsurface inflow from upgradient at an assumed nitrate concentration of 2 mg/L. At 100 years – current day – it was assumed that the concentration of nitrate in effluent discharged to the land surface was reduced from 25 to 10 mg/L. In Figure 5-19, the orange line represents pump, treat and serving the groundwater pumped from the nitrate plume, plus additional subsurface inflow to account for the additional water extracted. The red line in Figure 5-19 represents a situation where the additional pumped water is treated and reinjected. The mass balance model suggests that nitrate performance targets would be achieved in the following timeframes:

Performance Target (mg/L)	Reduce Nitrate in POTW Discharge	Pump, Treat, and Serve	Pump, Treat, Reinject

10	33 Years	18 Years	12 Years
8	–	54 Years	28 Years
5	–	–	–

Scenario 3in Table 5-6 shows the costs for pump, treat, and re-inject at the plume scale. Note that these costs include an additional three injection wells (approximately $4.2M in capital costs in order to reach a 10 mg/L performance target for nitrate in 12 years versus 18 years for the pump, treat, and serve option.

Table 5-1 Conceptual-Level Minimum Nitrate Drinking Water Costs

	Biological Denitrification		Combined RO/IX	
Scenario	> 10 mg/L	> 5 mg/L	> 10 mg/L	> 5 mg/L
Volume Treated	94 MAF	202 MAF	94 MAF	202 MAF
Annualized Cost per Unit	1.18 $/kgal	1.18 $/kgal	2.63 $kgal	2.63 $kgal
Total Annualized Cost	**$ 36B**	**$ 78B**	**$ 81B**	**$ 173B**

Table 5-2 Nitrate Loading by IAZs for Various ICM Scenarios

Central Valley Zone	IAZ	Acres (x1000)	Square Miles	Nitrate Loading (kg per acre)						Nitrate Loading for IAZ (tons)					
				High NUE	Mod. NUE	Low NUE	90% High NUE	75% High NUE	60% High NUE	High NUE	Mod. NUE	Low NUE	90% High NUE	75% High NUE	60% High NUE
Northern Central	1	391	611	0.4	1.0	2.0	2.4	3.2	6.5	172	431	862	1,034	1,379	2,802
	2	744	1,163	0.5	0.8	1.3	1.6	2.2	5.1	410	656	1,066	1,312	1,804	4,183
	3	712	1,112	1.1	1.5	2.2	3.0	4.7	13.3	863	1,177	1,727	2,355	3,689	10,438
	4	358	560	0.7	1.0	1.5	2.0	3.1	8.7	276	395	592	789	1,223	3,433
	5	612	957	0.3	0.5	0.9	1.2	1.9	4.9	202	337	607	810	1,282	3,306
	6	668	1,044	6.8	7.9	9.9	11.0	13.0	22.4	5,007	5,817	7,290	8,100	9,572	16,494
	7	342	534	3.3	4.5	6.2	7.2	9.3	18.8	1,244	1,696	2,337	2,714	3,506	7,087
Middle Central	8	872	1,362	1.8	2.1	2.6	3.0	3.7	7.2	1,730	2,019	2,499	2,884	3,556	6,921
	9	756	1,181	1.1	1.3	1.7	1.9	2.2	3.8	917	1,083	1,417	1,583	1,833	3,167
	10	180	282	2.7	3.1	3.7	4.2	5.1	10.0	536	615	734	833	1,012	1,984
	11	425	664	1.4	1.8	2.4	2.8	3.6	7.7	656	843	1,124	1,312	1,687	3,607
	12	346	540	1.4	1.7	2.2	2.6	3.3	7.0	534	648	839	992	1,259	2,670
	13	1,055	1,648	0.2	0.3	0.5	0.6	0.8	1.9	233	349	581	698	930	2,210
	22	513	801	0.7	0.8	1.0	1.1	1.4	3.0	396	452	565	622	792	1,696
Southern Central	14	685	1,071	1.1	1.1	1.2	1.3	1.5	2.9	831	831	906	982	1,133	2,190
	15	605	1,423	28.3	29.5	31.8	35.1	41.8	78.9	18,873	19,673	21,207	23,408	27,876	52,618
	16	306	478	6.3	6.9	7.8	8.2	9.1	12.9	2,125	2,327	2,631	2,766	3,069	4,351
	17	364	569	17.2	18.4	20.3	22.3	26.4	48.0	6,901	7,383	8,145	8,948	10,593	19,260
	18	869	1,358	12.8	13.8	15.6	17.2	20.4	37.4	12,261	13,219	14,943	16,476	19,541	35,826
	19	874	1,365	12.7	14.0	16.4	18.1	21.6	38.8	12,235	13,488	15,800	17,438	20,810	37,381
	20	451	705	14.2	15.0	16.4	18.0	21.3	39.0	7,059	7,457	8,153	8,949	10,589	19,389
	21	707	1,105	30.9	33.6	38.0	41.9	49.7	89.9	24,081	26,186	29,615	32,654	38,733	70,062
Total/Average		**12,835**	**20,533**							**97,544**	**107,084**	**123,642**	**137,657**	**165,869**	**311,073**

Table 5-3 Alternate Water Supply Options

Option*	***Description***	***Implementation Requirements***	***Capacity/Scalability***
Bottled Water	Distribute bottled water at distribution sites.	Vendor contract or contract agreement with other utilities for aid	Determined by vendor availability and local storage capacity (if storing bottles on-site)
Reverse osmosis	Treat saline water sources, such as saline ground water and ocean water.	• Water source • Power source • Mode of transport to distribution sites	0.5-1.0 MGD units
Filtration	Treat untreated local water sources by ultrafiltration, microfiltration, GAC, or other filtration methods.	• Water source • Pumps/intake • Chemicals • Power source • Operators • Distribution points (into system or to packaging)	0.5-1.0 MGD
Point-of-Use Treatment	Use boil water notices for contamination that can be treated by boiling. Other options include household bleach disinfection, purification tablets or manual filters.	• Power in customer homes • Functioning distribution system	Applicable over any scale demand
Bottle In-house	Bulk water can be bottled at the source prior to transport and/or distribution.	• Bulk supply of water • Power source • Packaging material • Operators	Up to 120 packages per minute (2.5 gal or less) (300 gpm ~ 0.4 mgd)
Bag In-house	Bulk water can be bagged at the source prior to transport and/or distribution.	• Bulk supply of water • Power source • Two operators	1-2.5 gal bags, 12-15 bags/min
Stationary bladders	Distribution can take place at the water source from large (not transportable) bladders.	• Water source near an appropriate distribution site • Pipe and spigot apparatus • Individuals must bring containers • Staffing and operators	10,000-100,000 gal
Bladder transport to distribution sites	Small bladders that can be transported on a truck bed can be brought to distribution sites.	• Local water source • Pipe and spigot apparatus • Individuals must bring containers • Truck beds appropriate for transporting full bladders and forklifts, etc. • Functioning roadways	Up to 6,000 gal
Transport in tanker-trucks	Utilities can make agreements with companies in the area that have access to potable tanker trucks (e.g., dairy trucks) – or may have some on hand.	• Contract with company to use trucks in an emergency • Potable water source • Distribution method (e.g., packaging on-site) • Functioning roadways	3,000-20,000 gal

* Costs will depend on multiple factors including size, duration, site conditions, equipment availability, security considerations, and degree of infrastructure required.

(Source: AWWA and CDM Smith, 2011)

Table 5-4 Treatment System Cost Sources

Component	Sources
General	
	Seidel, C., C. Gorman, J. L. Darby, and V. B. Jensen. 2011. AWWA Study: "An Assessment of the State of Nitrate Treatment Alternatives – Final Report http://www.awwa.org/Portals/0/files/resources/resource%20dev%20groups/tech%20and%20educ%20program/documents/TECNitrateReportFinalJan2012.pdf
Ion Exchange Cost Sources	
	Conlon, W.J., Blandon, F.A. and Moody, J. (1995). "Cost comparison of treatment alternatives for the removal of nitrates and DBCP from Southern California groundwater." Desalination, 103, 89-100
	Drewry, C. (2010). Representative from Calgon Carbon. Personal communication. Provided cost and IX waste volume estimates.
	Guter, G.A. (1995). Chapter: "Nitrate Removal from Contaminated Groundwater by Anion Exchange." In Ion Exchange Technology: Advances in Pollution Control. Sengupta, A.K., ed. Lancaster, PA: Technomic Publishing Company
	Meyer, K.J., Swaim, P.D., Bellamy, W.D., Rittmann, B.E., Tang, Y., and Scott, R., CH2M Hill (2010). "Biological and Ion Exchange Nitrate Removal: Performance and Sustainability Evaluation." Water Research Foundation
	Minnesota Department of Agriculture (N.D.). "Drinking Water Protection Series: Nitrate Contamination – What is the Cost?" Accessed June 11, 2010 via <http://www.mda.state.mn.us/protecting/waterprotection/~/media/Files/protecting/waterprotection/dwps2.ashx>
Reverse Osmosis Cost Sources	
	Cevaal, J.N., Suratt, W.B., and Burke, J.E. (1995). "Nitrate removal and water quality improvements with reverse osmosis for Brighton, Colorado." Desalination, 103, 101-111
	Conlon, W.J., Blandon, F.A. and Moody, J. (1995). "Cost comparison of treatment alternatives for the removal of nitrates and DBCP from Southern California groundwater." Desalination, 103, 89-100
	Walker, L.G., (N.D.). Presentation: "Nitrate Effects on Public Water System Wells." California Department of Public Health, Drinking Water Technical Programs Branch. Accessed August 12, 2010 via http://www.swrcb.ca.gov/rwqcb5/water_issues/irrigated_lands/long_term_program_development/15mar09_advisory_wrkgp_infosession/nitrate_effects_pws_wells.pdf
Biological Treatment Cost Sources	
	Carollo Engineers (2008). Final Report: "Direct Fixed-Bed Biological Perchlorate Destruction Demonstration." ESTCP Project ER-0544
	Meyer, K.J., Swaim, P.D., Bellamy, W.D., Rittmann, B.E., Tang, Y., and Scott, R., CH2M Hill (2010). "Biological and Ion Exchange Nitrate Removal: Performance and Sustainability Evaluation." Water Research Foundation
	Silverstein, J. (2010). Presentation: "Anaerobic biological treatment for removal of inorganic contaminants from drinking water." Workshop on Biological Drinking Water Treatment, IWA Leading Edge Technology Conference, June 1, 2010. Civil, Environmental, and Architectural Engineering, University of Colorado, Boulder.
	Webster, T.S. and Togna, P. (January, 2009). "Final Report: Demonstration of a Full-Scale Fluidized Bed Bioreactor for the Treatment of Perchlorate at Low Concentrations in Groundwater." ESTCP Project ER-0543.

Evaporation Pond Cost Sources	
	CDM Smith's Cambria AWTP (2014) CDM Smith's EMWD WTP (2014) CDM Smith's J.R. Simplot PWTRP (2011) WRF Project 4313: Biological and Ion Exchange Nitrate Removal Evaluation (2010)

Table 5-5 Communities within the AID Pilot Study Area

Community	County	Area (square miles)	Elevation feet MSL	Population	EPA System Classification	Density Persons/ Square Mile	Water Demand AF
Cutler	Tulare	0.807	361	5,000	Medium	6,196	1,013
Delft Colony	Tulare	0.066	312	454	V. Small	6,879	100
Dinuba	Tulare	6.47	335	21,453	Large	3,316	4,720
East Orosi	Tulare	0.248	394	495	V. Small	1,996	127
London	Tulare	0.629	299	1,869	Small	2,971	411
Monson	Tulare	0.492	325	188	V. Small	382	18
Orange Cove	Fresno	1.912	423	9,078	Medium	4,748	1,997
Orosi	Tulare	2.446	374	8,770	Medium	3,585	1,048
Reedley	Fresno	5.156	348	24,194	Large	4,692	5,323
Seville	Tulare	0.636	354	480	V. Small	755	66
Sultana	Tulare	0.444	364	775	Small	1,745	177
Traver	Tulare	0.843	289	713	Small	846	157
Yettem	Tulare	0.153	348	211	V. Small	1,379	57
Totals/Avg		**20.302**		**73,680**		**3,629**	**15,213**

Table 5-6 Concept Level Costs for Pump and Treat for Various Scenarios

Scenario	Treatment Type	Groundwater Treated (MGD)	Time to Reach Performance Target of 10 mg/L (years)[1]	Capital Low ($M)	Capital High ($M)	O&M Low ($M)	O&M High ($M)	Equivalent Annual Costs Low ($M)	Equivalent Annual Costs High ($M)
Scenario 1a	Reverse Osmosis	13.58	73	$106.9	$106.9	$8.0	$8.0	$14.2	$14.2
	Ion Exchange			$70.2	$87.4	$1.8	$4.3	$5.9	$9.3
	Biological Denitrification			$82.1	$87.8	$3.6	$4.6	$8.4	$9.7
Scenario 1b	Reverse Osmosis	27.16	37	$187.5	$187.5	$15.9	$15.9	$26.8	$26.8
	Ion Exchange			$114.1	$148.4	$3.6	$8.5	$10.2	$17.1
	Biological Denitrification			$137.8	$149.3	$7.2	$9.2	$15.2	$17.8
Scenario 2a	Reverse Osmosis	7.05	121	$53.0	$61.2	$3.1	$5.2	$6.2	$8.7
	Ion Exchange			$31.4	$49.5	$1.2	$3.2	$3.0	$6.1
	Biological Denitrification			$40.4	$45.6	$0.8	$1.2	$2.2	$2.7
Scenario 2b	Reverse Osmosis	7.05	121	$47.8	$56.1	$3.1	$5.2	$5.9	$8.4
	Ion Exchange			$26.3	$44.3	$1.2	$3.2	$2.7	$5.8
	Biological Denitrification			$35.3	$40.5	$0.8	$1.2	$2.9	$3.5
Scenario 2c	Reverse Osmosis	7.05	121	$39.0	$46.4	$2.8	$4.6	$5.1	$7.3
	Ion Exchange			$25.3	$41.5	$1.2	$3.2	$2.6	$5.6
	Biological Denitrification			$27.8	$32.4	$0.8	$1.1	$2.4	$2.9
			121						
Scenario 2d	Reverse Osmosis	7.05	121	$50.3	$58.5	$3.1	$5.2	$6.0	$8.6
	Ion Exchange			$28.8	$46.8	$1.2	$3.2	$2.8	$5.9
	Biological Denitrification			$37.8	$43.0	$0.8	$1.2	$3.0	$3.7
Scenario 3	Reverse Osmosis	2.16	12 - 33	$16.8	$19.3	$1.0	$1.6	$1.9	$2.7
	Ion Exchange			$10.7	$16.3	$0.4	$1.0	$1.0	$1.9
	Biological Denitrification			$13.5	$15.1	$0.3	$0.4	$1.0	$1.2

[1] *Does not include legacy nitrate contamination in groundwater or current and future practices that contribute to nitrate loading.*

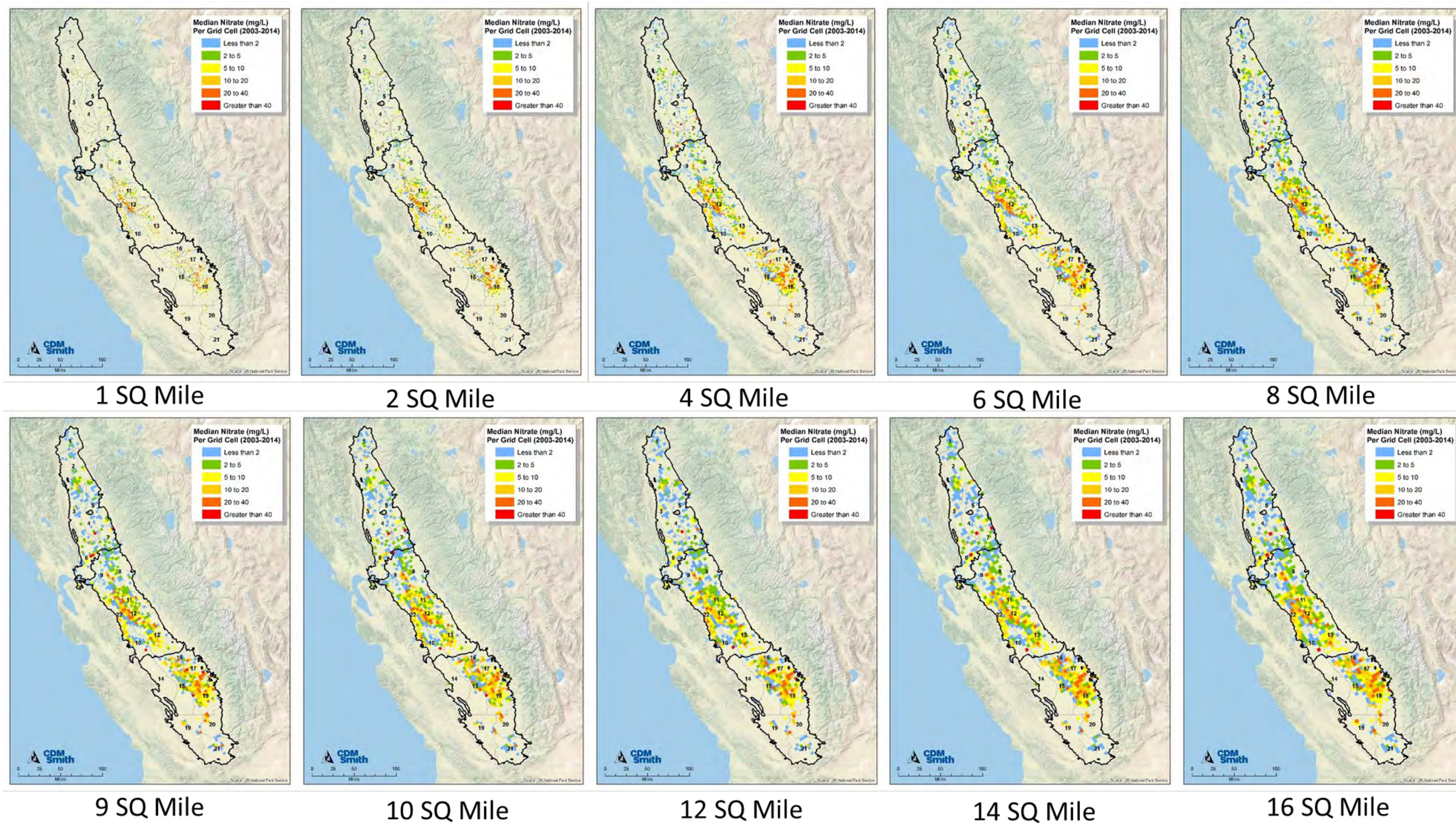

Figure 5-1 Comparison of Median Nitrate for a Range of Grid Cell Spacing for the Shallow Zone ("Phase II Conceptual Model— Task 3: Groundwater Data Refinements and Updates, June 18, 2014")

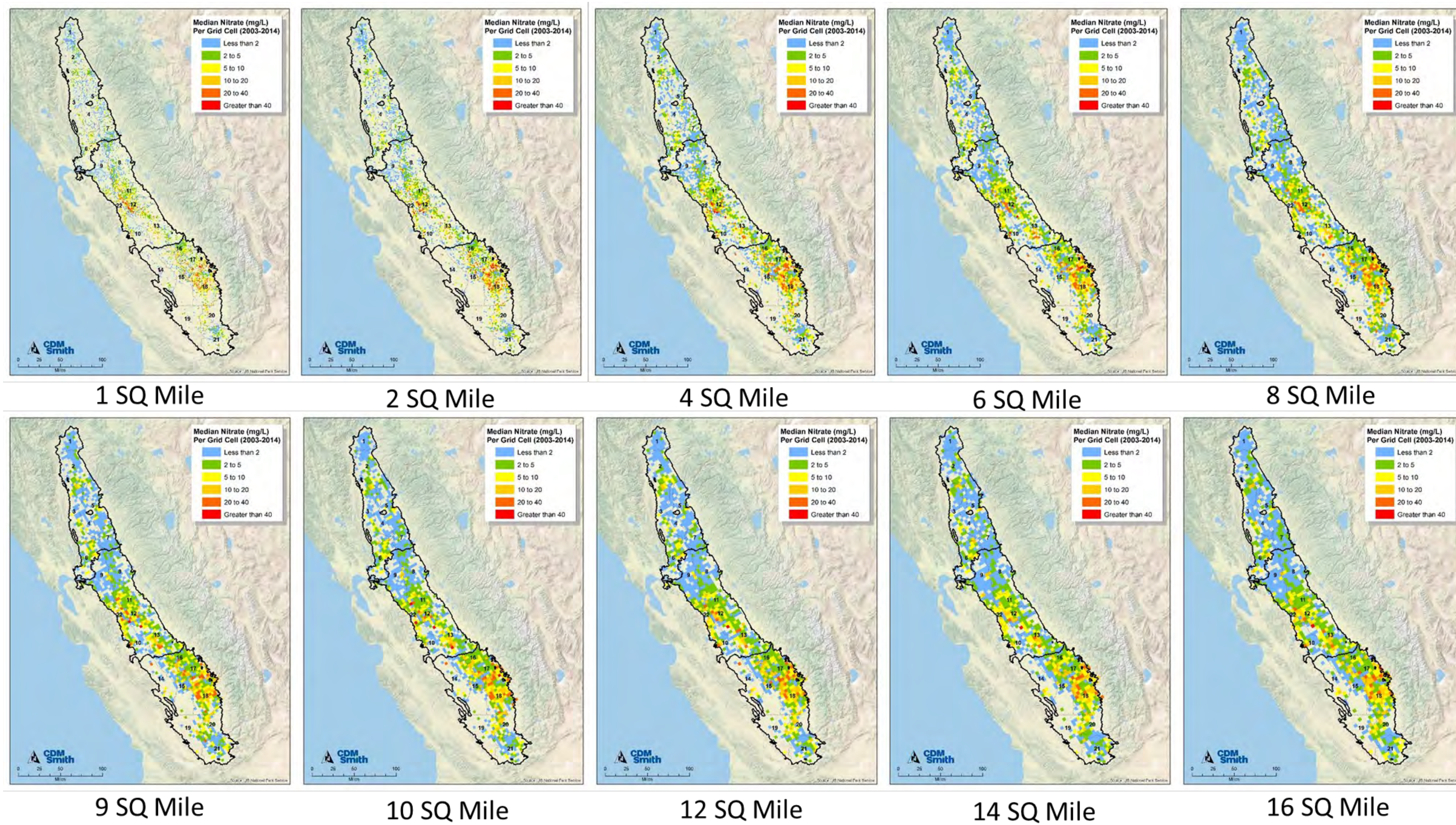

Figure 5-2 Comparison of Median Nitrate for a Range of Grid Cell Spacing for the Deep Zone ("Phase II Conceptual Model— Task 3: Groundwater Data Refinements and Updates, June 18, 2014")

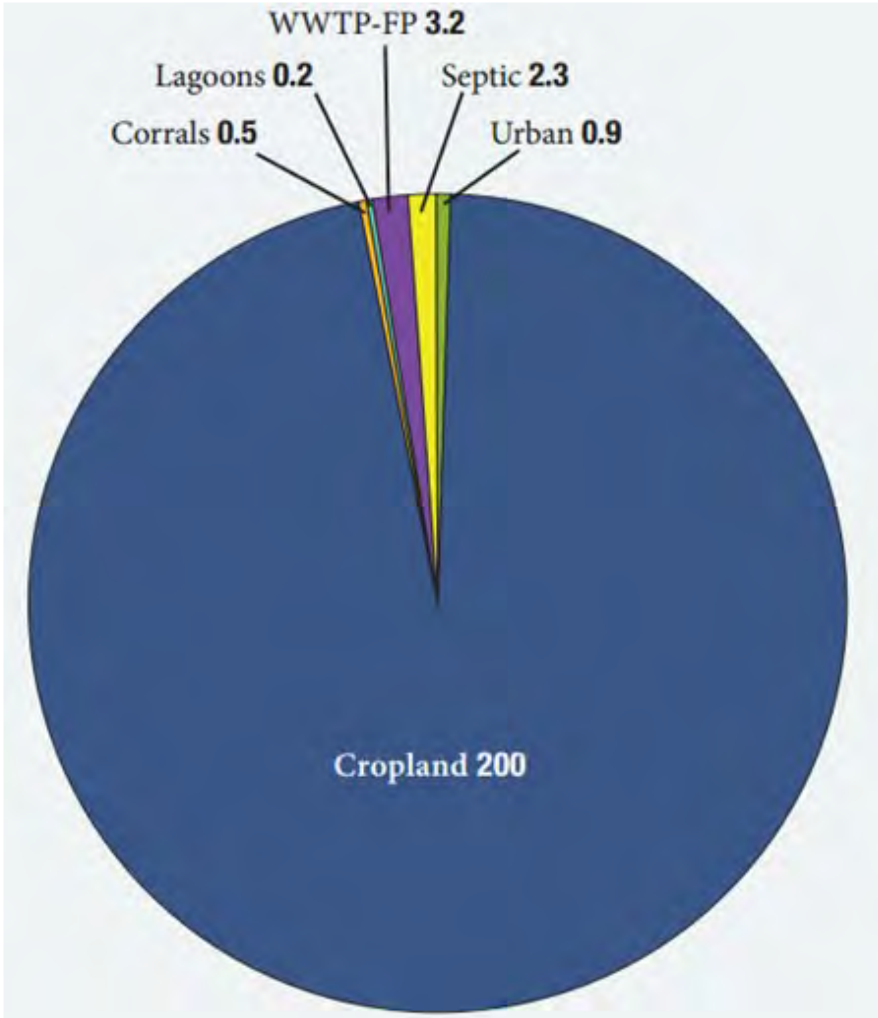

Figure 5-3 Estimated Nitrate Loading to Shallow Groundwater in the Tulare Lake Basin and Salinas Valley, in gigagrams (Gg) (Harter *et al.,* 2012)

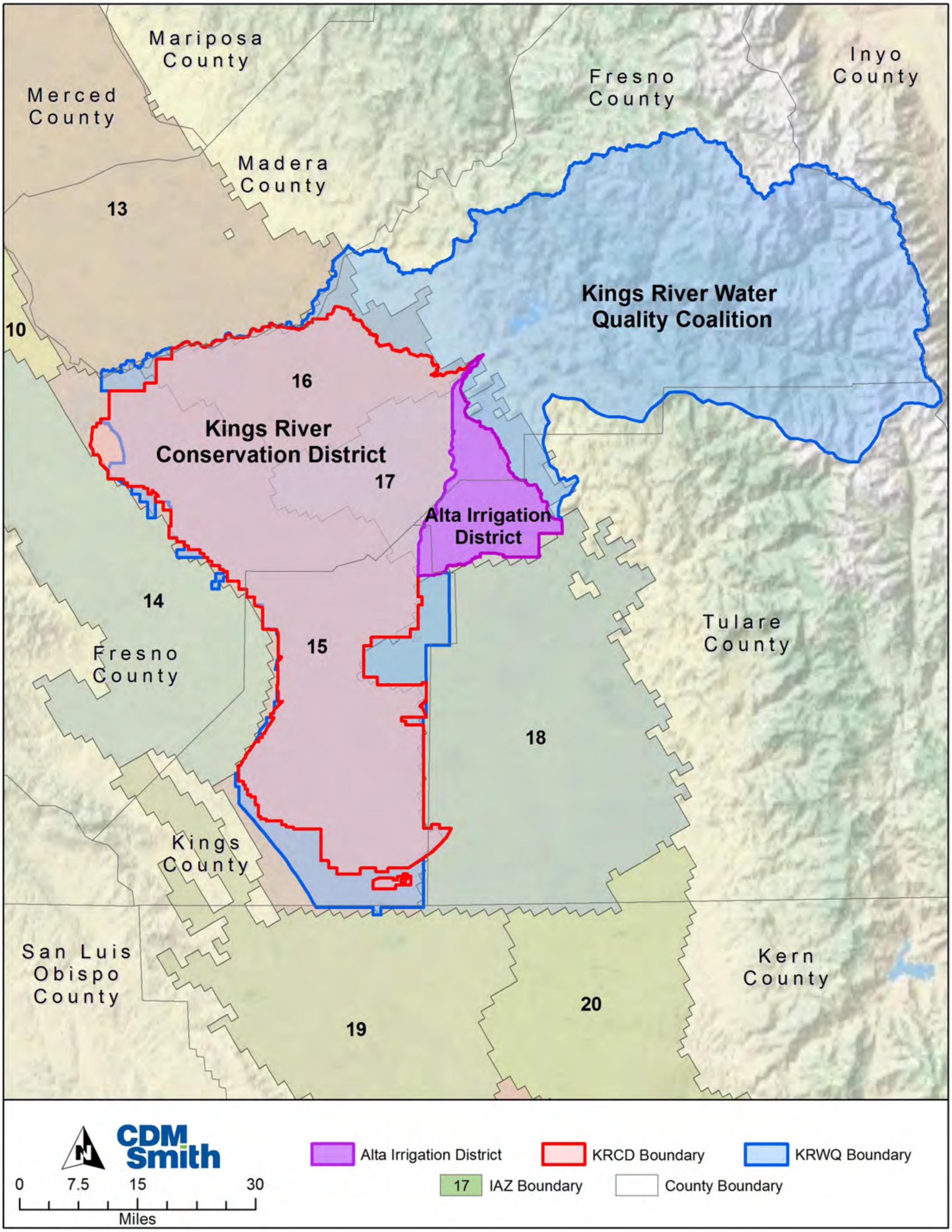

Figure 5-4 Alta Irrigation District Pilot Study Area (KRWCA, 2014)

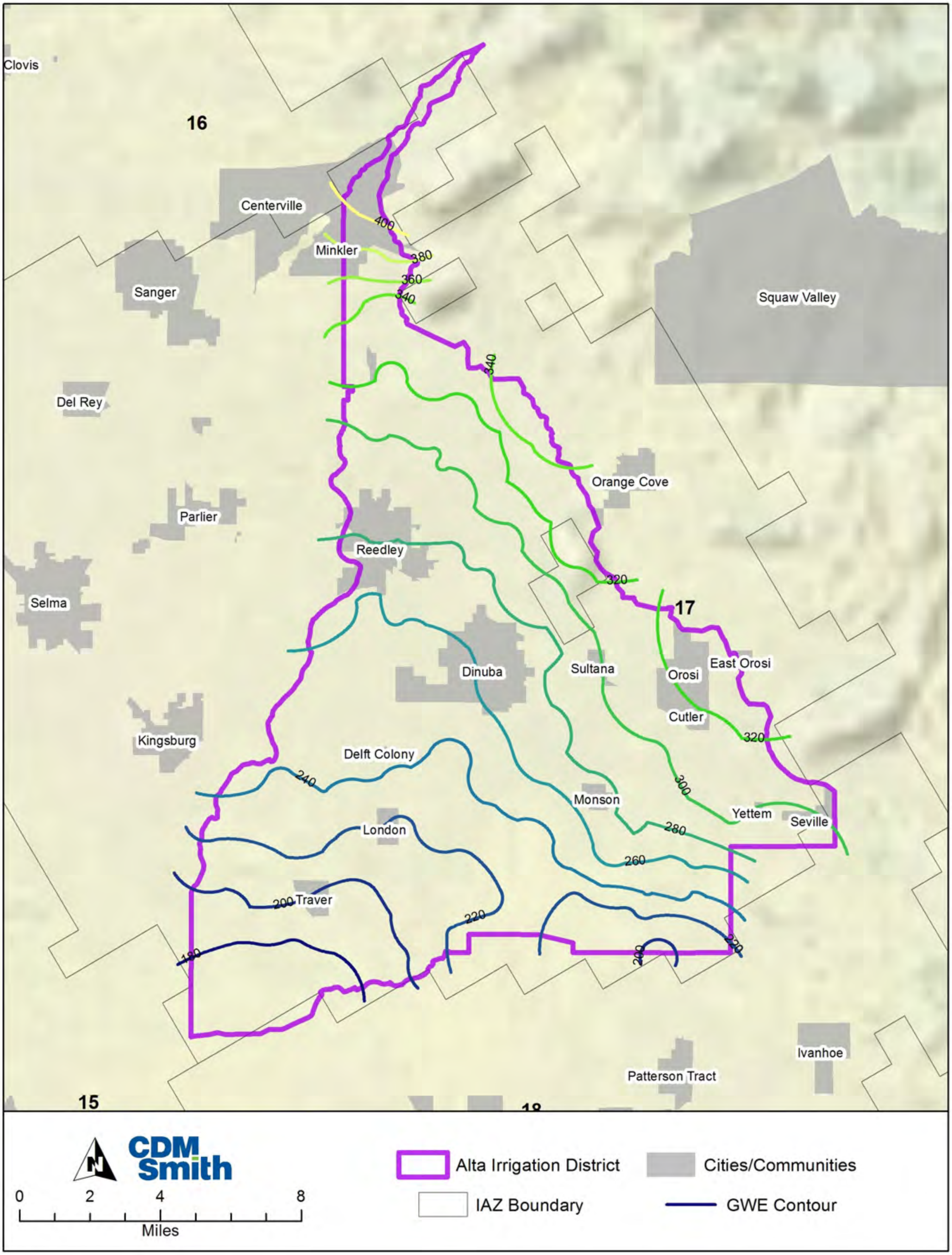

Figure 5-5 Alta Irrigation District Groundwater Elevations (Spring 2014) (KRWCA, 2014)

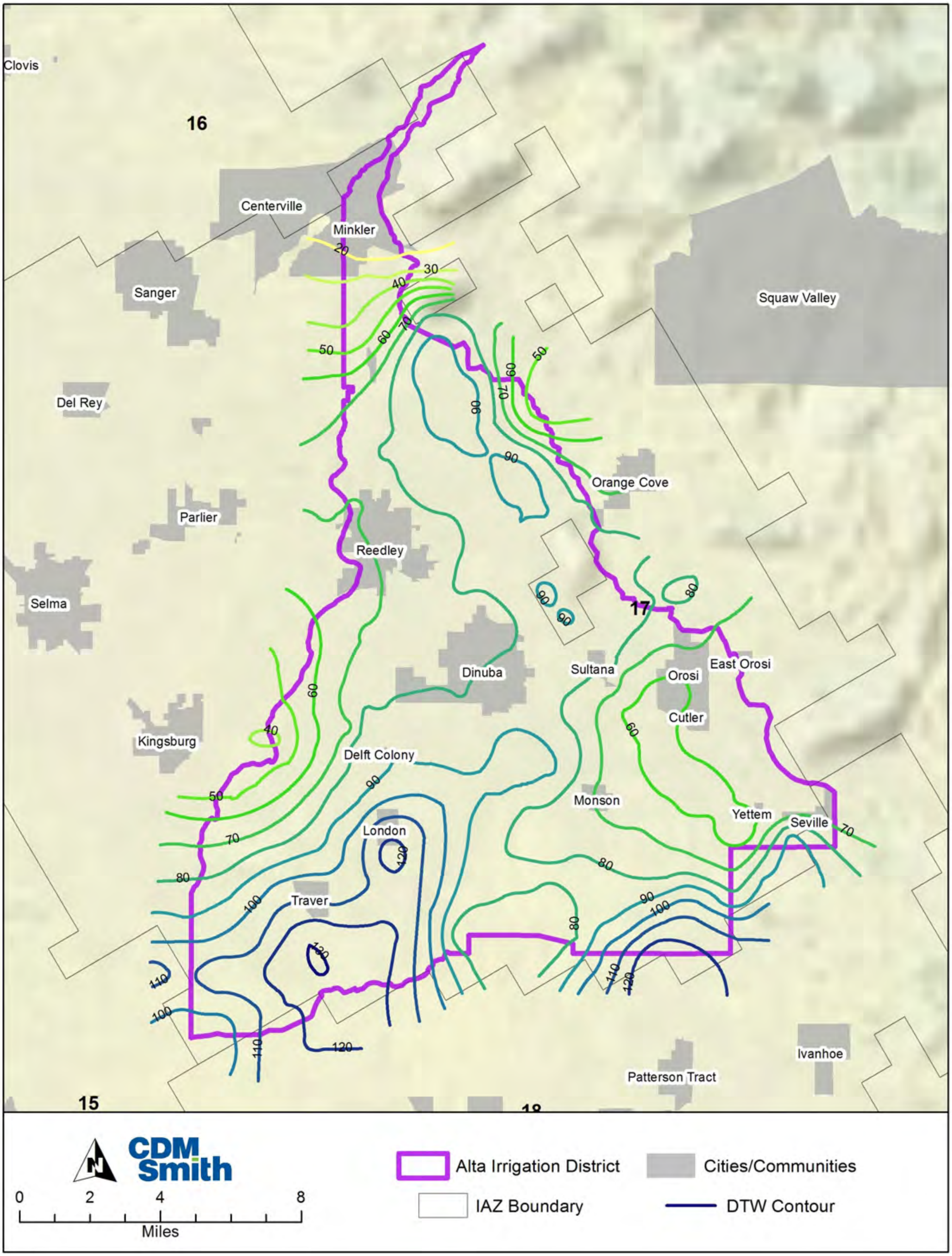

Figure 5-6 Alta Irrigation District Depth to Groundwater (Fall 2014) (KRWCA, 2014)

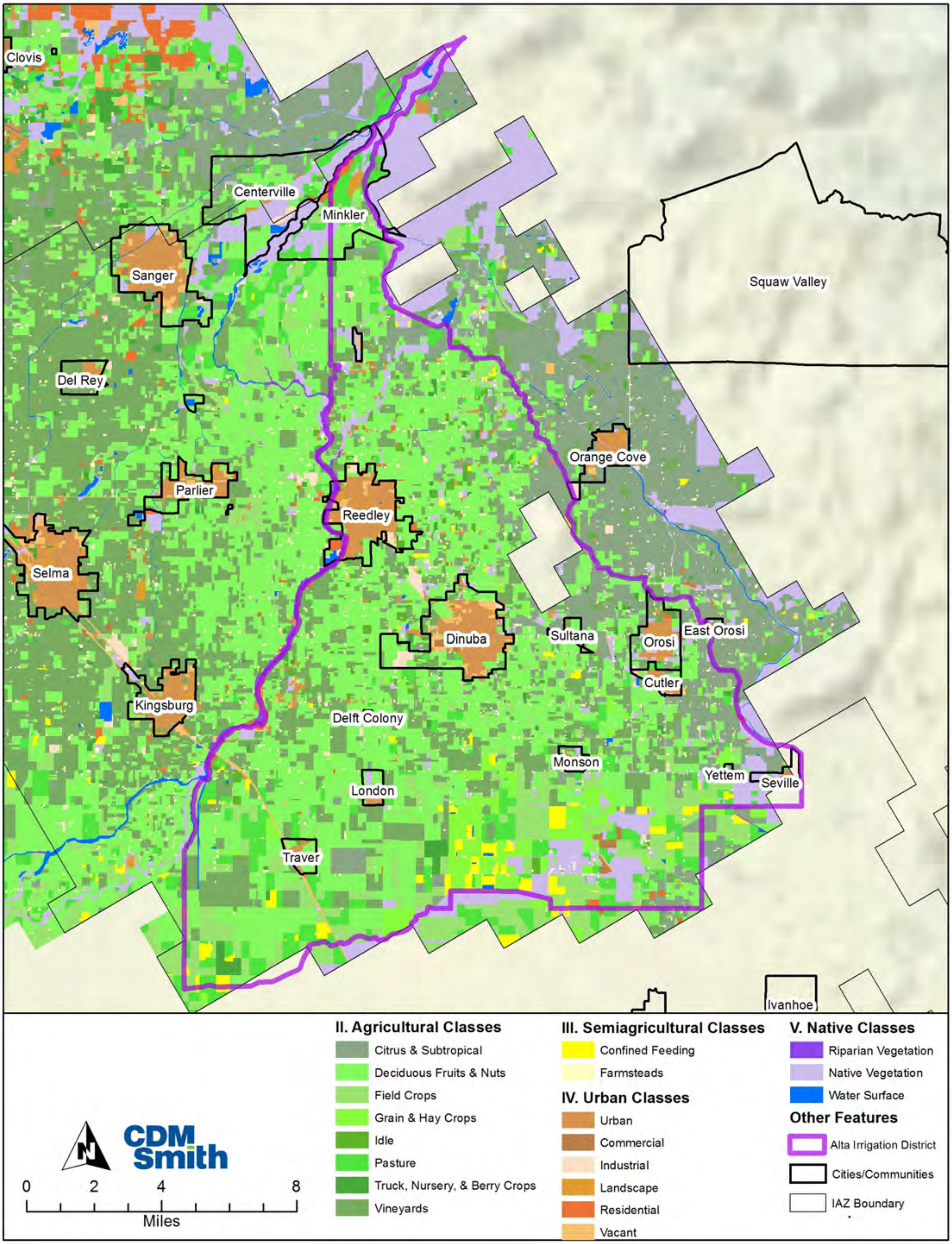

Figure 5-7 Alta Irrigation District Land Use Map (DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm)

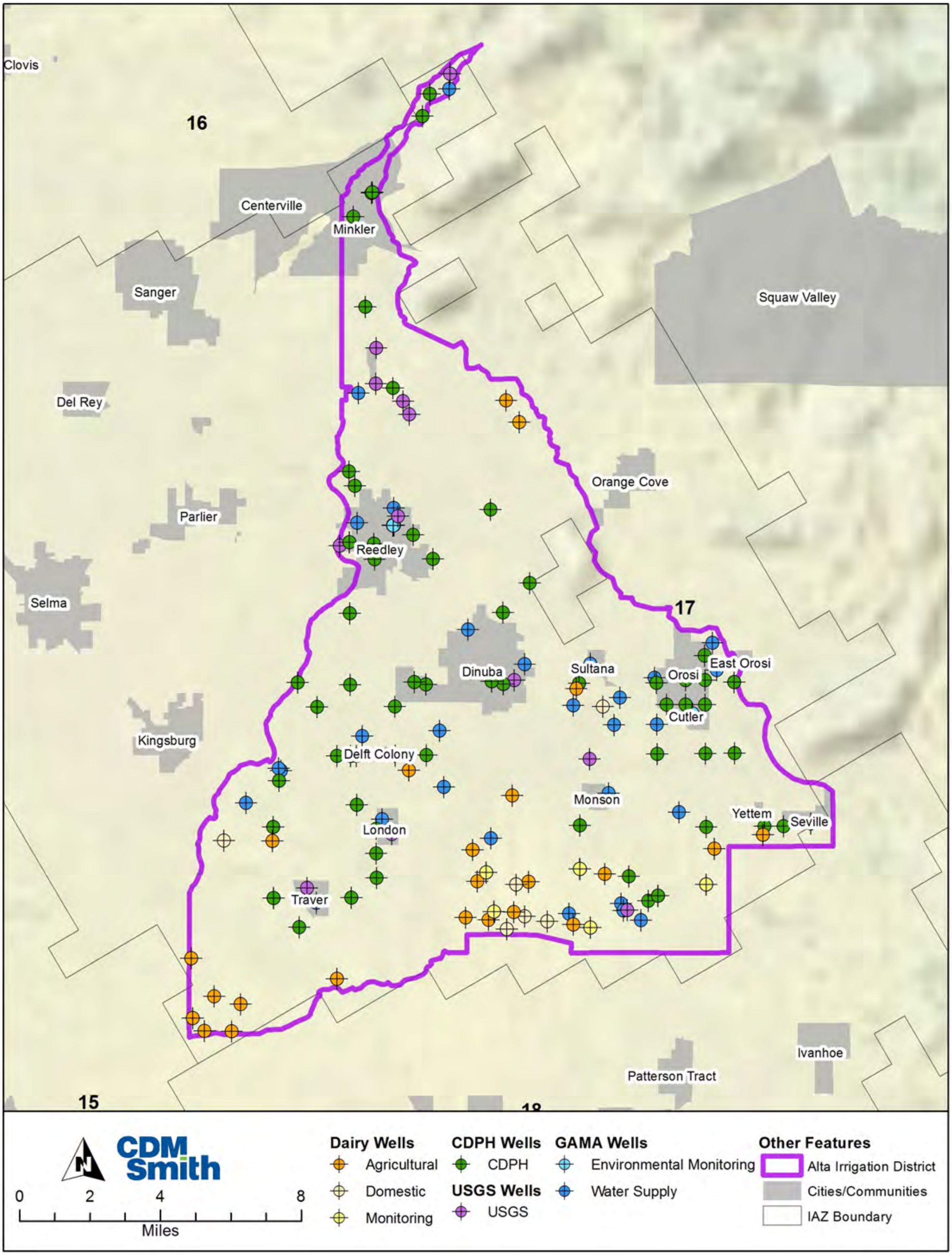

Figure 5-8 Alta Irrigation District Wells by Type and Use ("Phase II Conceptual Model—Task 3: Groundwater Data Refinements and Updates, June 18, 2014")

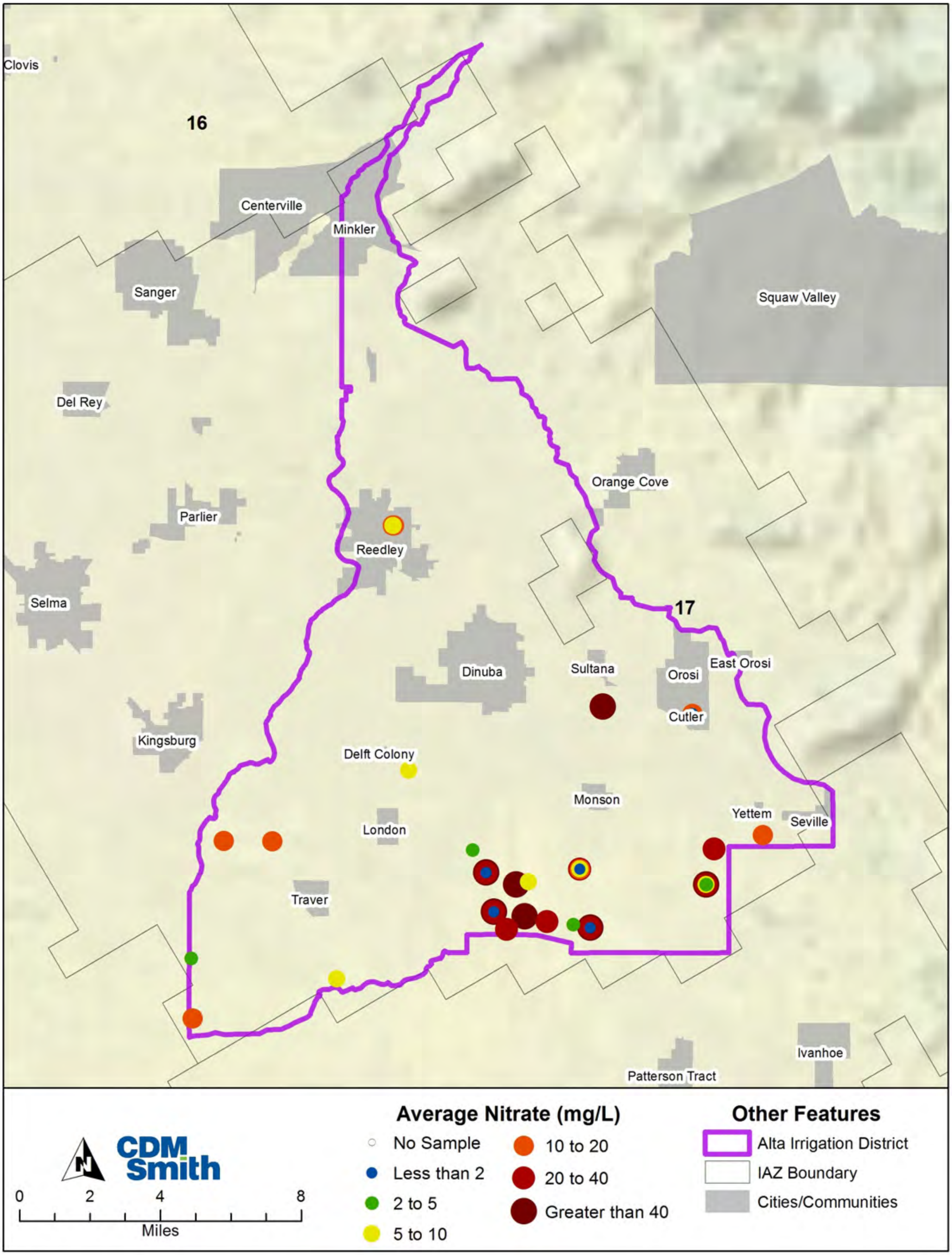

Figure 5-9 Alta Irrigation District Nitrate Concentrations in Shallow Wells ("Phase II Conceptual Model—Task 3: Groundwater Data Refinements and Updates, June 18, 2014")

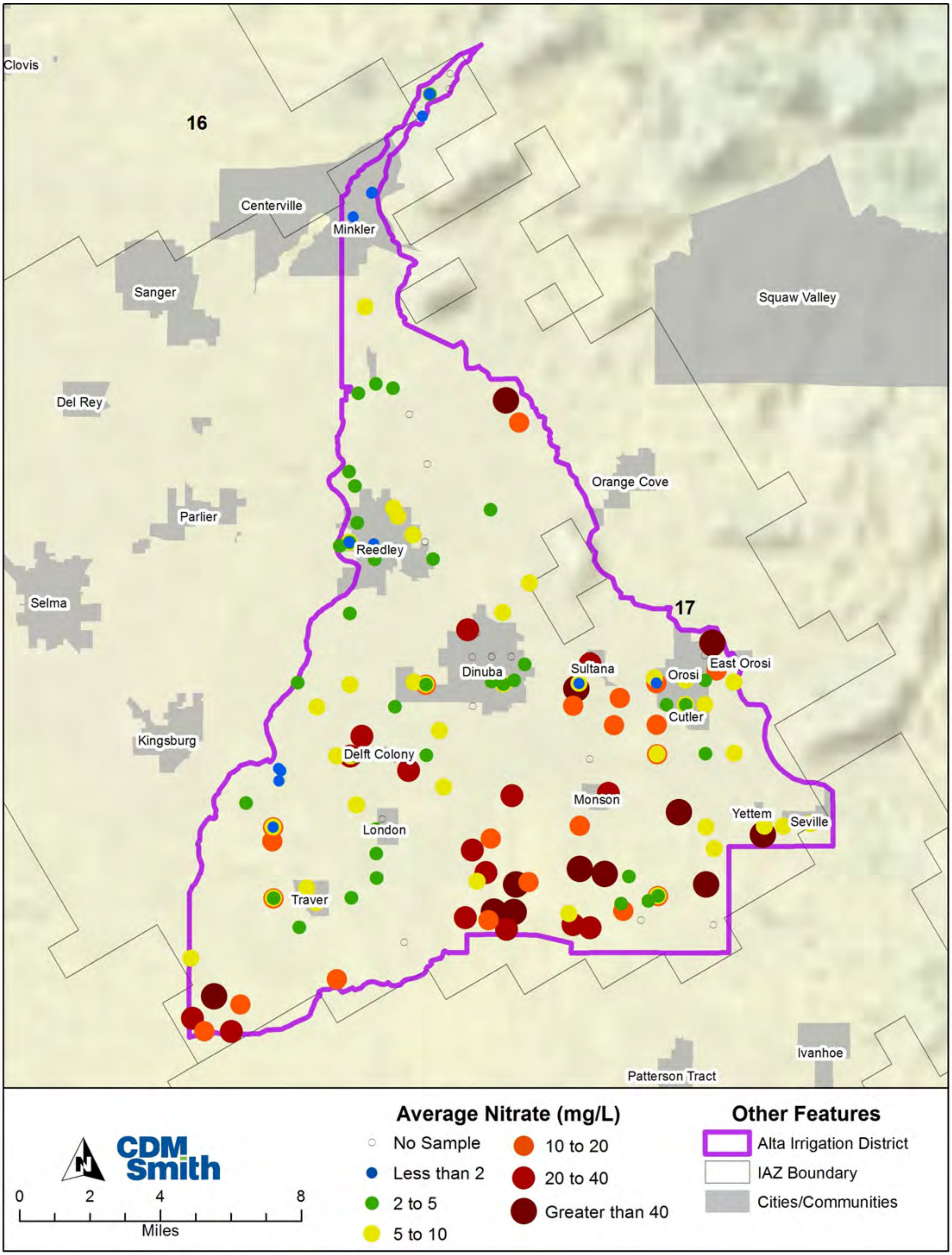

Figure 5-10 Alta Irrigation District Nitrate Concentrations in Deep Wells ("Phase II Conceptual Model—Task 3: Groundwater Data Refinements and Updates, June 18, 2014")

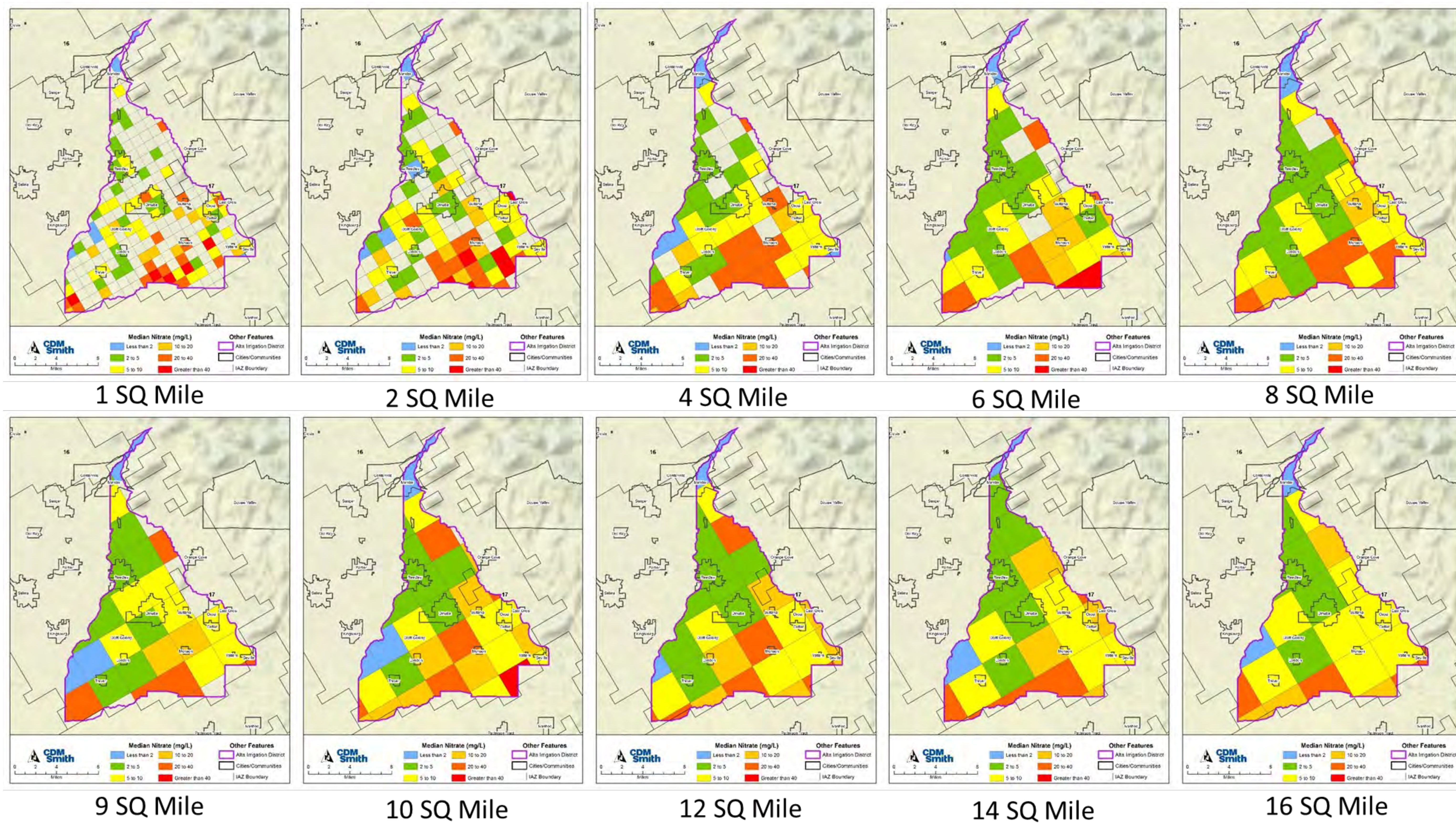

Figure 5-11 Alta Irrigation District Deep Zone Nitrate Concentrations by Grid Size (Nitrate data from "Phase II Conceptual Model—Task 3: Groundwater Data Refinements and Updates, June 18, 2014")

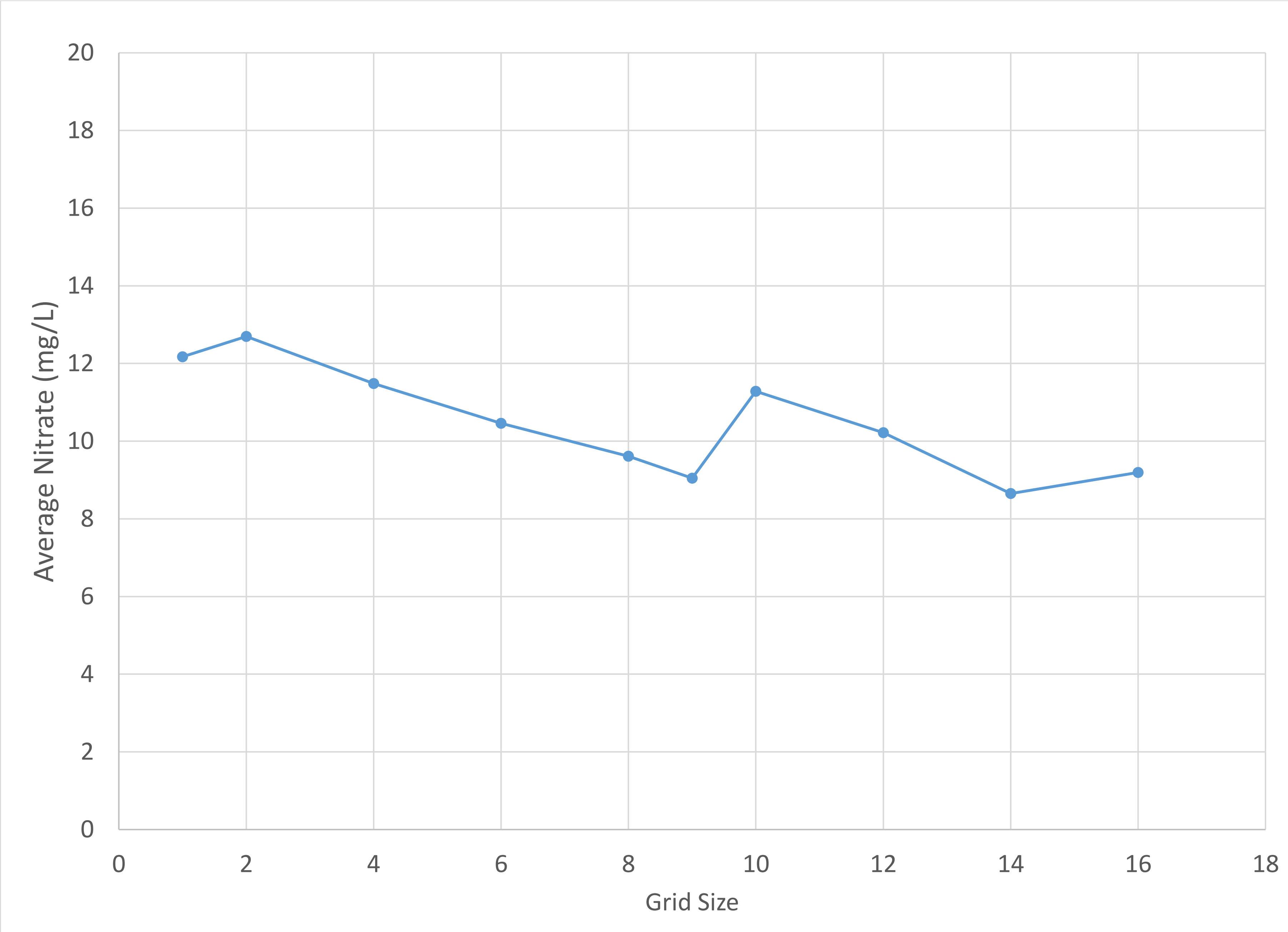

Figure 5-12 Alta Irrigation District Deep Zone Volume-Weighted Nitrate Concentrations as a Function of Grid Cell Spacing

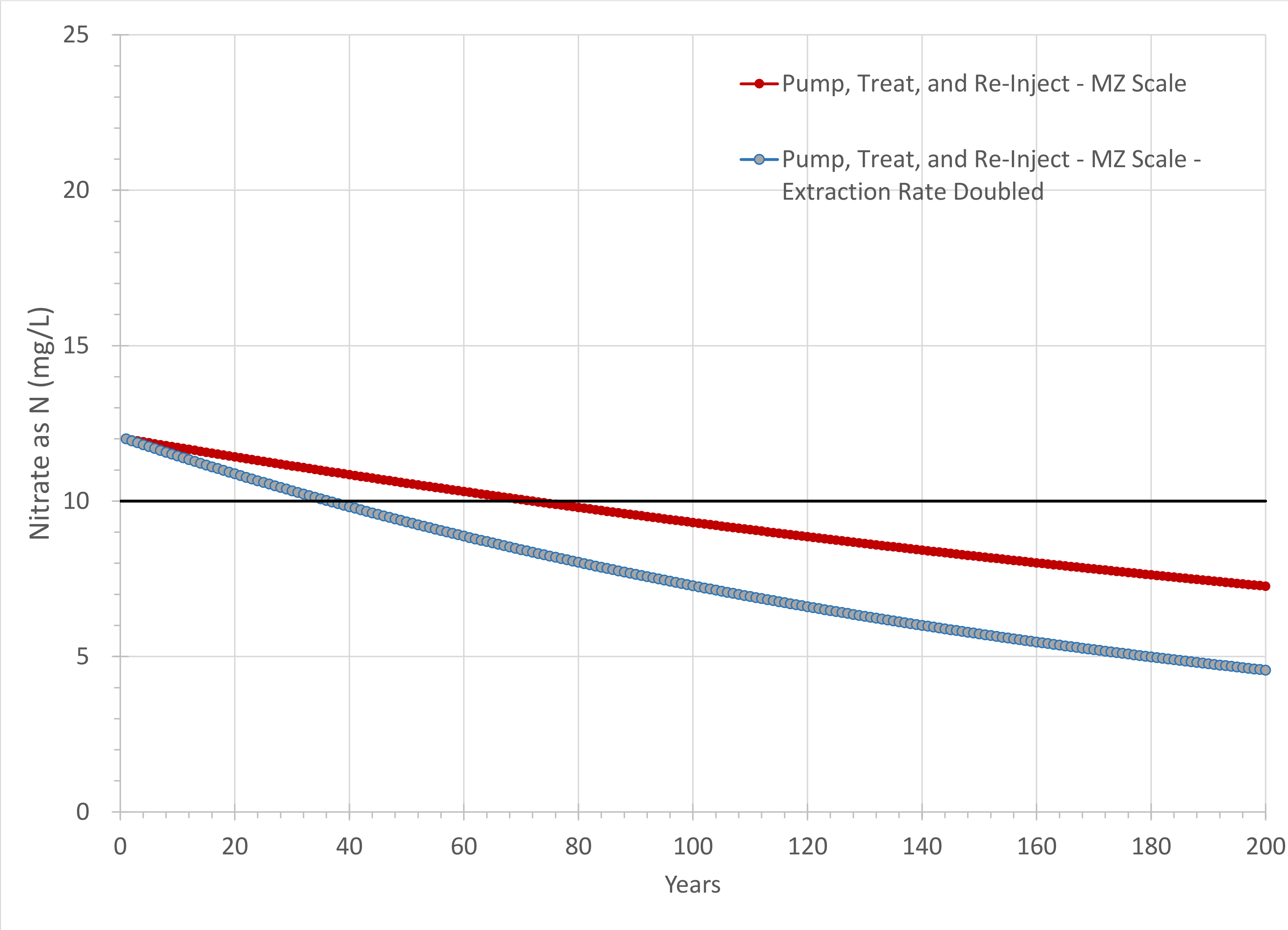

Figure 5-13 Predicted Future Concentration using a Nitrate Mass Balance Model: Pump, Treat, and Re-inject

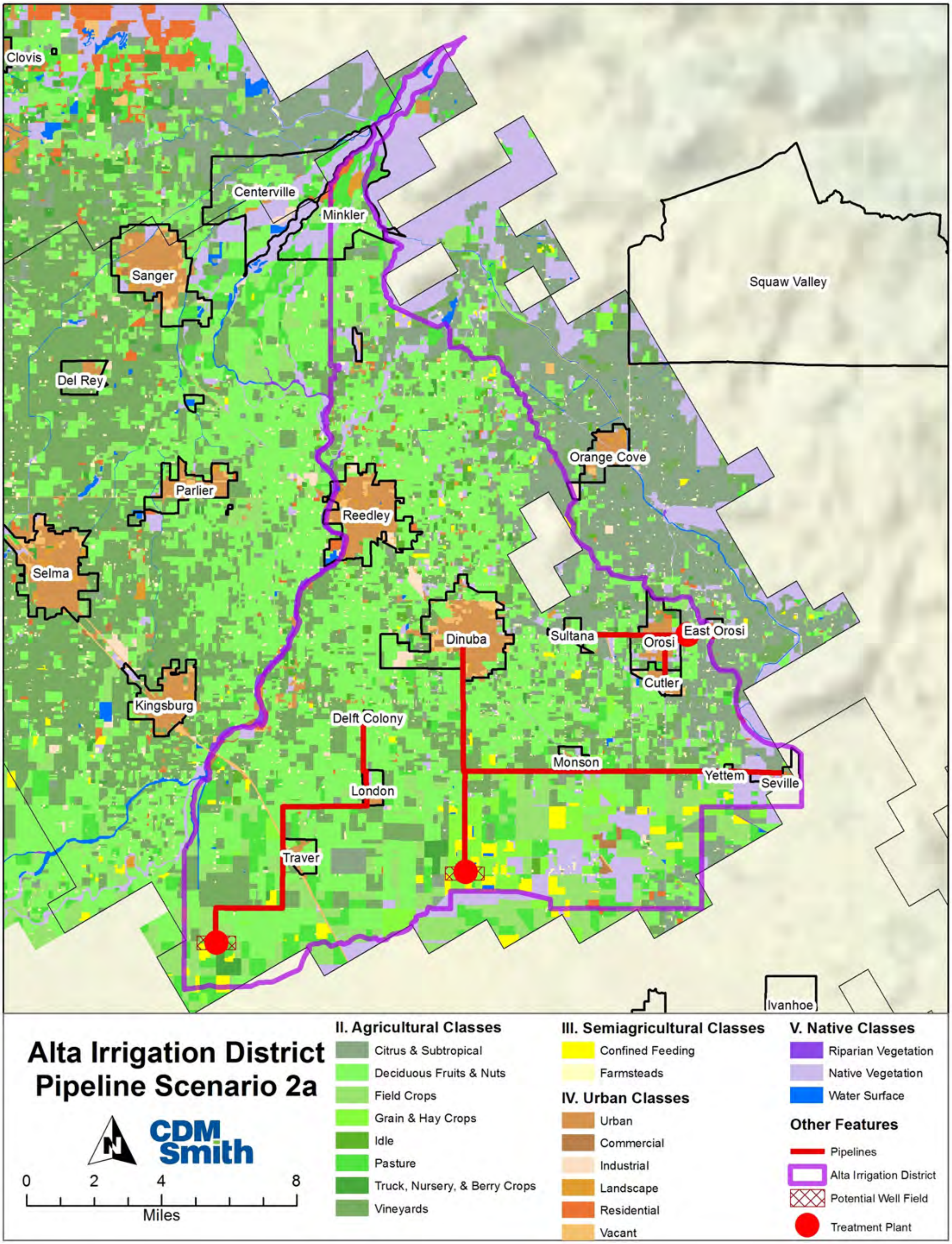

Figure 5-14 Alta Irrigation District Pump, Treat, and Serve Scenario 2a (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm)

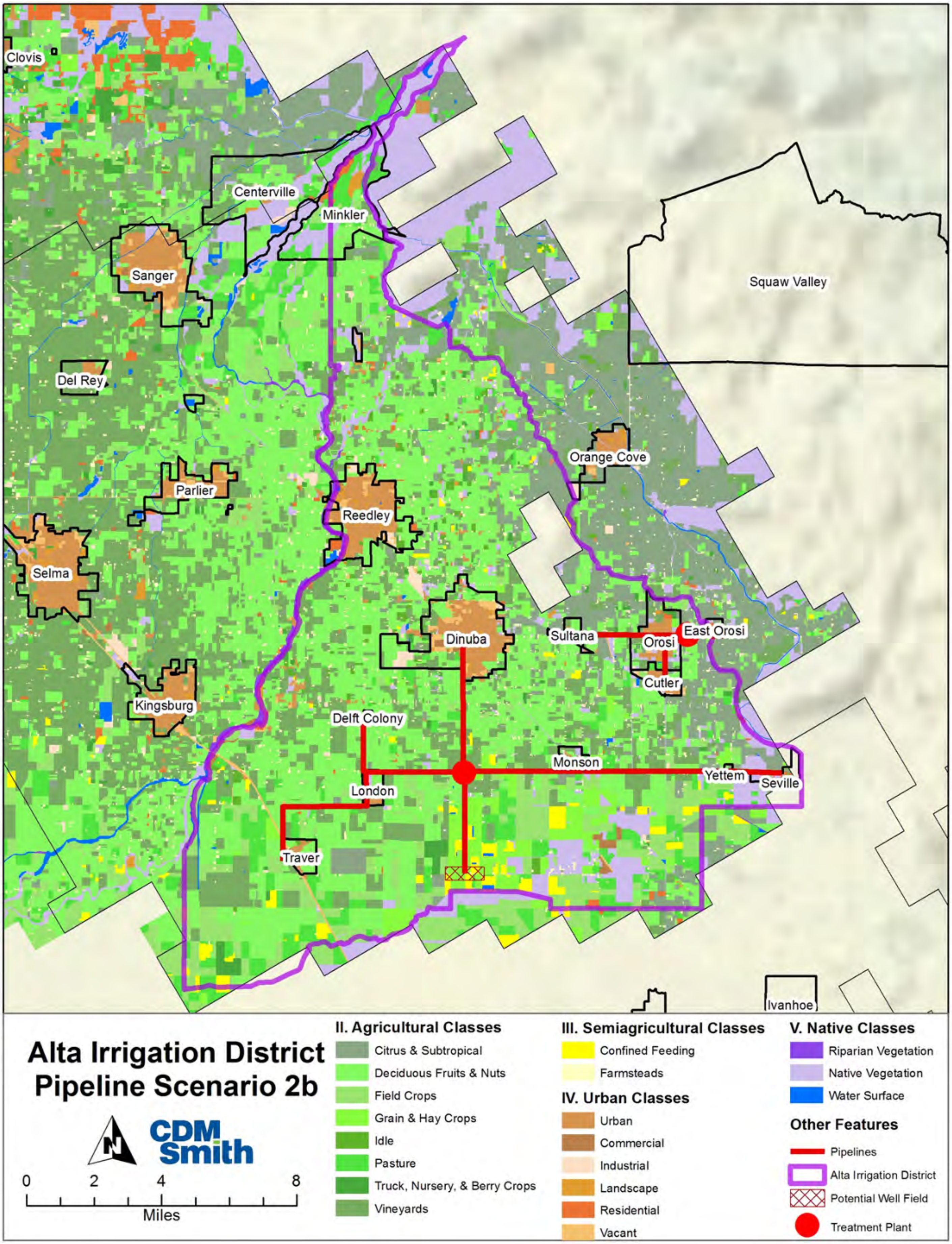

Figure 5-15 Alta Irrigation District Pump, Treat, and Serve Scenario (2b Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm)

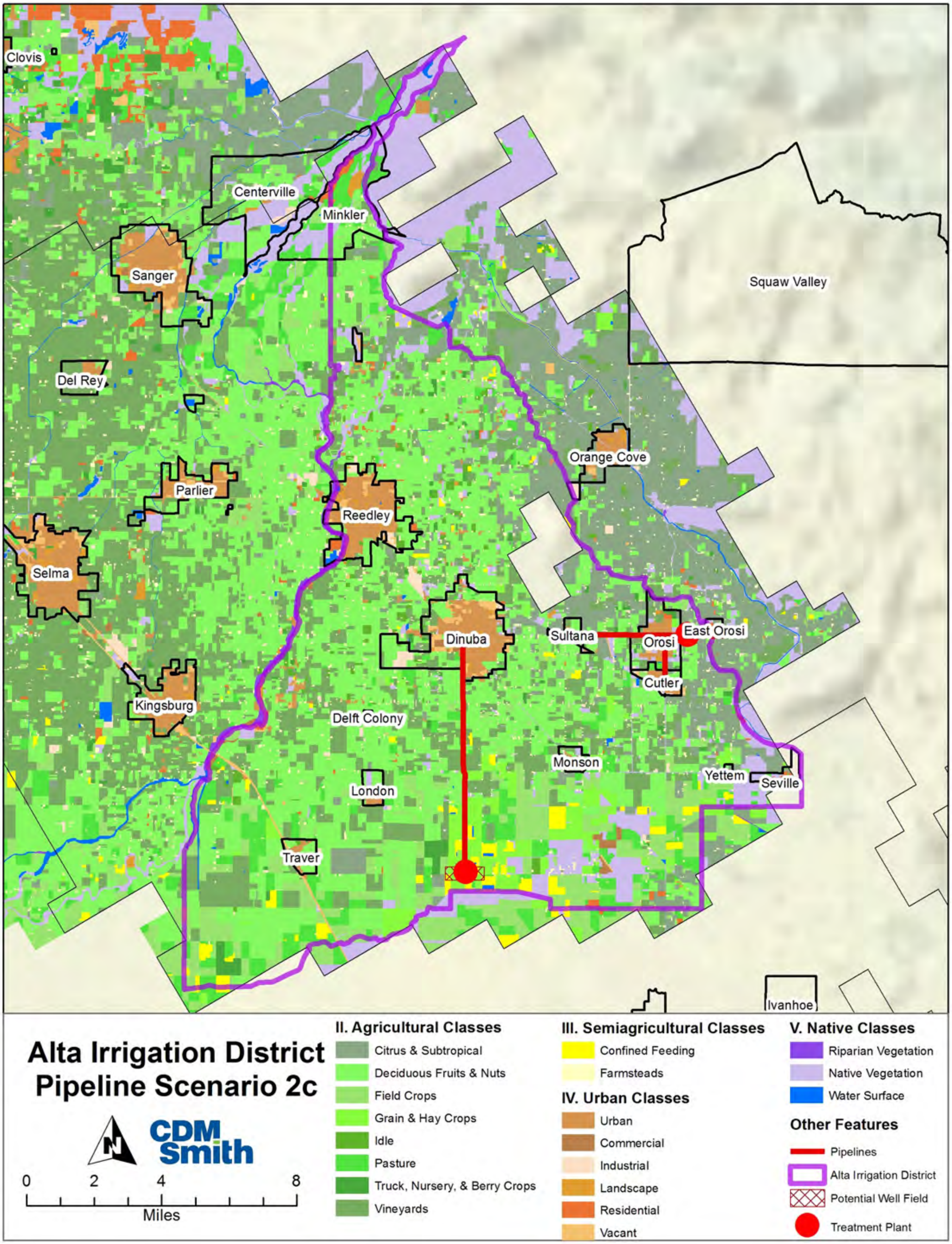

Figure 5-16 Alta Irrigation District Pump, Treat, and Serve Scenario 2c (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm)

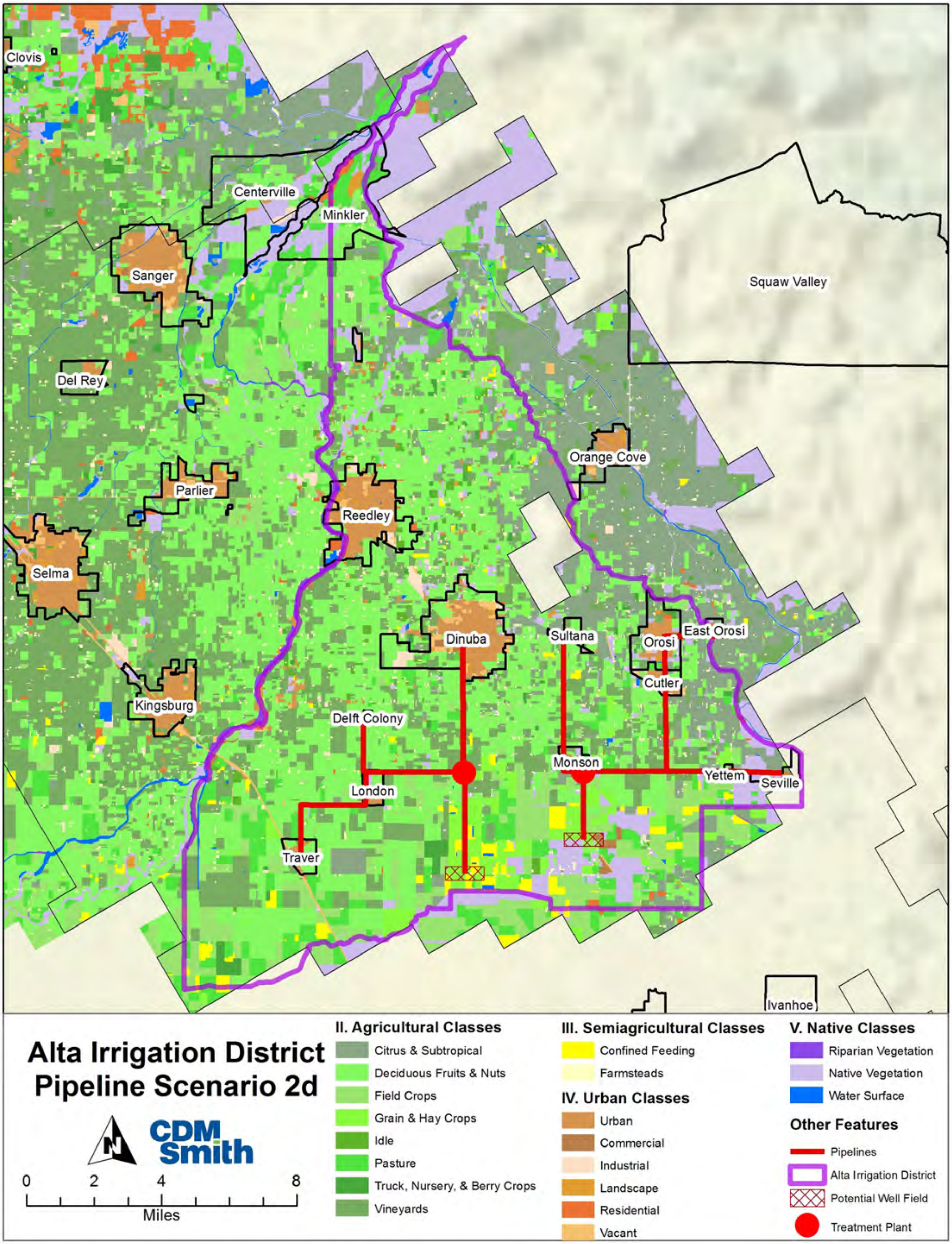

Figure 5-17 Alta Irrigation District Pump, Treat, and Serve Scenario 2d (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm)

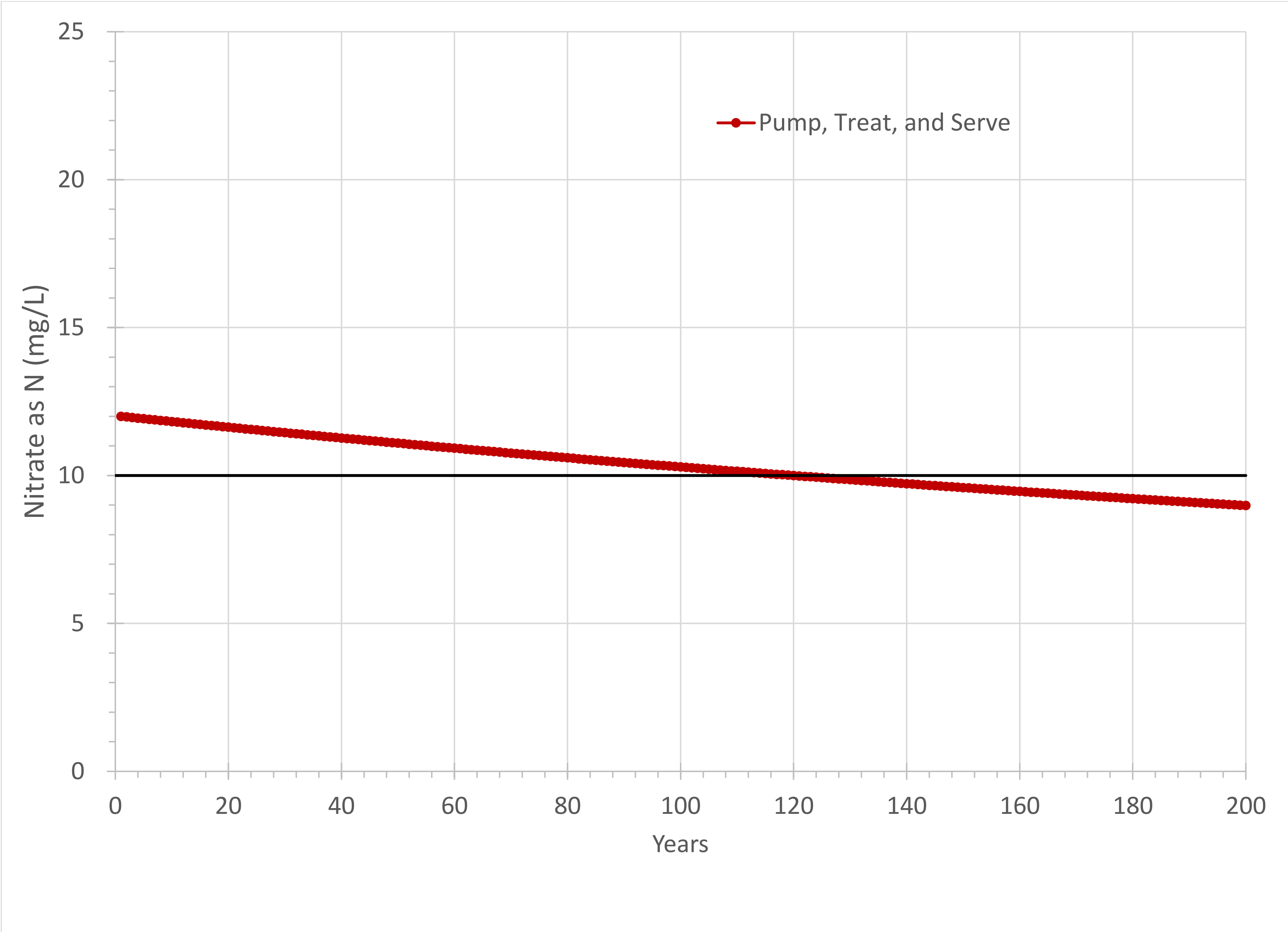

Figure 5-18 Predicted Future Concentration using a Nitrate Mass Balance Model: Pump, Treat, and Serve

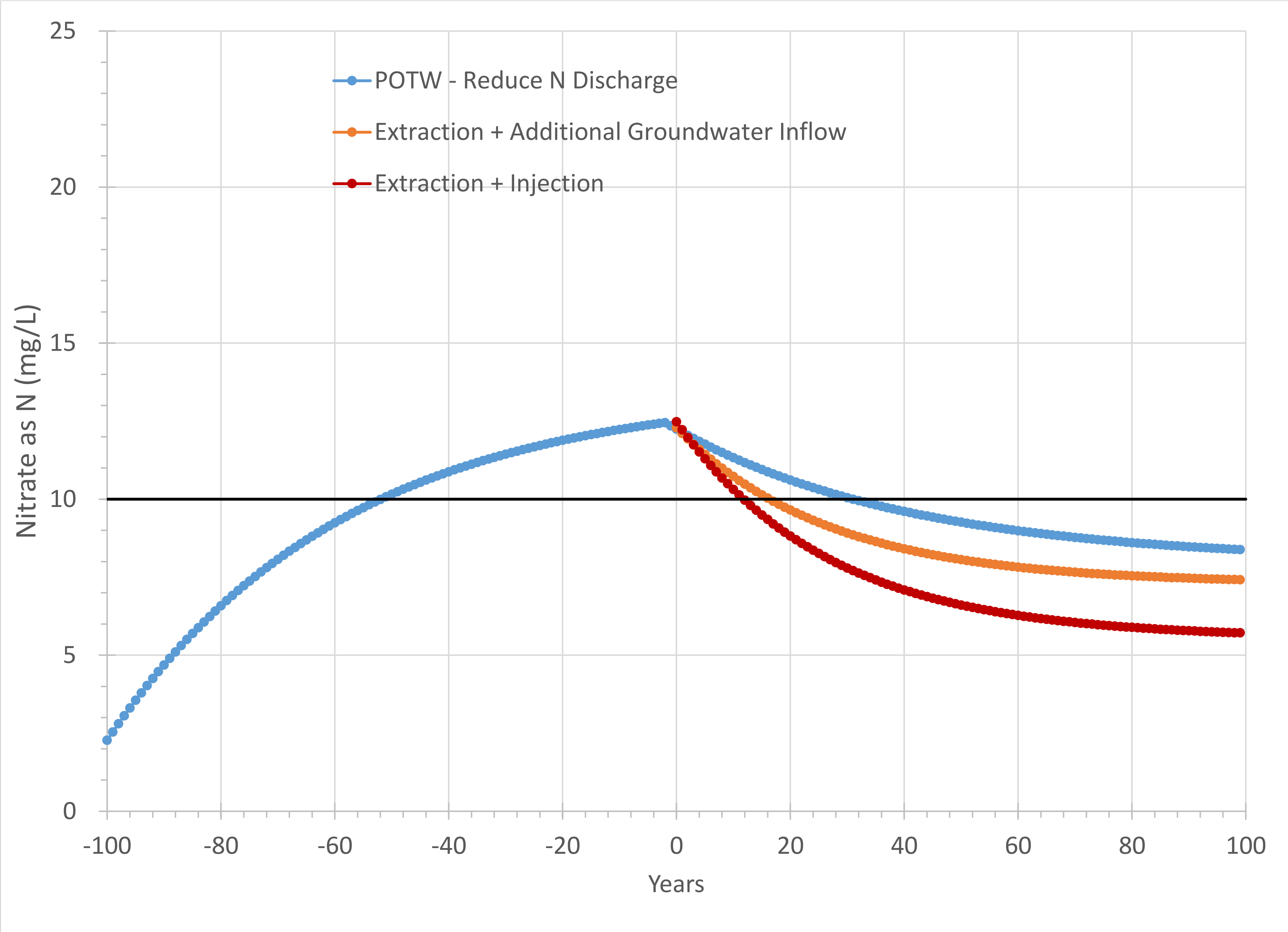

Figure 5-19 Predicted Future Concentration using a Nitrate Mass Balance Model: Pump, Treat, and Re-inject at a Point Source Scale

Section 6

Program of Implementation for Nitrate and TDS

CV-SALTS has established goals to (a) ensure that everyone in the Central Valley has access to a safe, reliable, and affordable drinking water supply; and (b) preserve the global competitiveness and sustain the long-term viability of the region's world class agricultural industry. To that end, CV-SALTS is developing a comprehensive regulatory and programmatic approach to the management of salt and nitrate as nitrogen in the Central Valley that is not only consistent with the State Recycled Water Policy (SRWP) but meets the broader goals of CV-SALTS to develop a workable, comprehensive plan to address salinity, including nitrates, throughout the region in a comprehensive, consistent, and sustainable manner.

Magnitude of the Problem

The estimated volumes of groundwater that exceed 10 and 5 mg/L are:

- 54 MAF out of 235 MAF in the shallow zone have exceeded 10 mg/L – 23 percent
- 105 MAF out of 235 MAF in the shallow zone have exceeded 5 mg/L – 45 percent
- 40 out of 401 MAF in the deep zone has exceeded 10 mg/L – 10 percent
- 97 out of 401 MAF in the deep zone has exceeded 5 mg/L – 24 percent

Where nitrate in groundwater exceeds 10 mg/L, there is a potential health concern, and conversely, groundwater at less than 5 mg/L represents areas where nitrate is not currently a potential health concern. It is expected that trend analyses would be done during development of a local SNMP-level to determine if there may be potential health concerns in wells with nitrate concentrations between 5 and 10 mg/L.

According to the ICM, the nitrate loading to the shallow groundwater zone Valley-wide ranges from 97,500 to 311,000 tons annually. Between 78 and 86 percent of the nitrate loading occurs in the Southern Central Valley. About 7 million tons of salt accumulate in the Central Valley annually (CDM Smith, 2014).

King *et al.* (2012) estimated "the total annualized cost of remediation in the Tulare Lake Basin and Salinas Valley…based only on treatment costs and the calculated volume to be treated…" The same analysis was performed in the NIMS for the groundwater underlying the Central Valley floor. This estimate does not include extraction wells, raw and treated water pipelines, *etc*. and serves to provide an estimate of the minimum treatment costs at a valley-wide scale. The cost for treating groundwater that exceeds the MCL would range from $36B to $81B.

Prioritization at the IAZ-scale

- The IAZs with the highest nitrate priority ranking are generally located in the eastern and southern portions of the central valley. The highest nitrate priority IAZs include:

IAZ-12 and IAZ-13 in the Middle Central Valley region and IAZ-16, IAZ-17, and IAZ-18 in Southern Central Valley. The lowest nitrate priority ranking and are generally located in the northern and western portions of the Central Valley.

- The IAZs with the highest TDS priority ranking are generally on the west side of the Middle Central Valley region and the Southern Central Valley region with an exception of IAZ-6 which is in the Northern Central Valley region.
- The IAZs with the highest combined nitrate and TDS priority ranking are generally located in the Middle Central Valley region and the Southern Central Valley regions (Figure 4-3) with the exception of IAZ-6. The High priority IAZs include: IAZ-6 in the Northern Central Valley region, IAZ-11 and IAZ-12 in the Middle Central Valley region, and IAZ-in the Southern Central Valley. The IAZs with the lowest priority rankings include IAZ-1 through IAZ-5, all of which are in the North Central Valley region.

A more refined prioritization scheme to identify critical areas within each management zone would be anticipated to be included as part of the local SNMPs.

Groundwater Management Goals

Coupled with the SNMP strategies and statewide policies, CV-SALTS has been committed to ensuring that safe drinking water is available to all communities already impacted by elevated salt and nitrate. To meet this commitment, the SNMP established three water-quality based management goals to guide the short- and-long term management of salt and nitrate in the Central Valley of California. In priority order these goals are:

- Goal 1: Ensure User Protection for the Drinking Water Supply
- Goal 2: Achieve Balanced Salt and Nitrate Loadings
- Goal 3: Implement Managed Aquifer Restoration Program for Impaired Waterbodies and Where Reasonable and Feasible

Performance Targets

The performance target for TDS is to meet a water quality objective of less than 1,000 mg/L or 1,600 µS/cm EC [35]. Because elevated concentrations of nitrate may have health impacts on users the NIMS analyzed conceptual level cleanup times for performance targets that ranged from “background” to the MCL of 10 mg/L. NIMS includes the following targets in the analysis: 2, 4, 8, and 10 mg/L. The NIMS analyzed cleanup timeframes to achieve the range of nitrate performance targets in groundwater.

[35] NIMS recognizes that there are portions of groundwater basins underlying the Central Valley floor with naturally-occurring salts that are derived from marine deposits – among other sources – and where TDS naturally exceeds the default objective.”

Existing and Planned Nitrate Mitigation Programs

As local SNMPs are developed there will be an implementation framework to ensure that the SNMP's Management Plan is not duplicative or interfering, but rather that it complements the existing programs. Monitoring results from existing or planned mitigation programs will be used in the development of CV-SALTS implementation measures. To the extent possible, CV-SALTS is using the management zone concept when considering implementation alternatives, because there are multiple potential sources and contribution from sources can vary across geographic areas.

Phasing of the SNMP Management Plan

Each local SNMP will include a detailed phased implementation schedule to support the proposed Management Plan. Implementation of nitrate and salt mitigation measures at the local SNMP-level can be executed without a basin plan amendment.

- A Phase 1 (Years 1-15) short-term detailed schedule of implementation activities linked to the SNMP Management Goals, in particular a schedule to meet water quality-based Management Goal 1 within the first three to five years of implementation, even if the initial solutions are temporary. More permanent user protection measures would be introduced over a three- to fifteen-year period.
- A Phase 2 (Years 11-20) schedule of planned or projected implementation activities expected to be implemented in the future, but linked to water quality-based Management Goals 2 and 3.
- A long-term schedule for implementation of management activities for Phase 3 and beyond (> 20 years), to the extent known.
- An AIP whose purpose is to determine how the local SNMP should be updated for the next phase (including providing detailed projects/activities for the next 10 year period).

Management Goal 1 and Alternative Sources of Drinking Water

With regard to the protection of beneficial uses, the water-quality based management goal to ensure user protection for drinking water supplies (Goal 1) is the highest priority for the NIMS and the Central Valley SNMP and shall be complied with as quickly as possible in all areas in the Central Valley Region. This goal may be achieved through a combination of the development of alternative water supplies, establishment of treatment systems, or implementation of education and outreach activities.

Making alternative drinking water supplies available places emphasis on DACs, DUCs, and individual families who do not have direct access to safe drinking water. Options for providing safe drinking water through blending, drilling deeper wells, packing off screen intervals with higher contamination, trucking in water, providing bottled water, connecting to an existing community water system or constructing a new community system, providing well-head treatment, or by other means will all be analyzed as each local SNMP is developed at the management zone-scale.

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*. The local SNMP will review source control measures that can be implemented in a cost-effective manner with water quality benefits at the management zone-scale. The regional Surveillance and Monitoring Program (SAMP), as well as management zone-scale groundwater monitoring programs should be designed to provide useful information to inform the AIP.

Recharge of High Quality Water

Recharge of low TDS, low nitrate water is a critical component of Sustainable Groundwater Plans (GSPs), as well as SSALTS and NIMS. Stormwater can be diverted to strategically located recharge basins or certain fields can be flooded during winter months when stormwater is available for diversion. Hydrologic modeling, water rights, and monitoring will need to be considered in order to balance stormwater recharge – which benefits groundwater users – with flow requirements in streams.

Pump and Fertilize

Pump and fertilize 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. Pump and fertilize may not result in a net reduction of mass of nitrate in given management zone, but it does reduce to the extent possible nitrate loading to groundwater from agricultural activities.

Pump with Aboveground Treatment

Pump with aboveground treatment of groundwater includes treatment using standard drinking water treatment technologies (a summary matrix is provided in Appendix E), 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.

Brine Management

Technical analyses conducted during the NIMS and SSALTS studies indicate that achievement of Management Goals 2 and 3 will only be successful through a long-term commitment to salt and nitrate management activities at the local or sub-regional level, and will require commitment to regional solutions such as establishment of regional salt sinks or a Central Valley regulated brine line. The selection of specific projects or activities to make progress towards attainment of these goals will be implemented through salt and nitrate management plans tailored to the specific needs of each managed area. Salt accumulation areas are a critical interim solution until the Central Valley regulated brine line is operational.

Product Water

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 percentage could possibly be used for potable supply as previously described, and the rest would presumably be re-applied for agricultural use (*i.e.*, putting treatment on agricultural wells). The alternative would be to re-inject, and or percolate the treated water back into the groundwater basin.

In a pump, treat, and serve scenario, pumping of nitrate-contaminated groundwater would occur at a rate to meet potable demands, rather than pumping at a higher rate and then using the product water above that needed to meet potable demands for irrigation or for re-injection. Pump, treat, and serve would meet Management Goal 1 in that user protection would be assured, while progress is being made to meet Management Goals 2 and 3. Each local SNMP will need to develop a Water Master Plan, in conjunction with Groundwater Sustainability Agencies.

In Situ *Treatment*

Options for *in situ* nitrate treatment includes *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 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. In situ treatment options can be quite cost effective and each local SNMP needs to consider these options where depth to water, nitrate concentrations, and hydrogeological conditions are favorable.

Pump and Treat – Scenarios

The NIMS evaluated three scenarios: (i) pump, treat, and reinject at the MZ-Scale; (ii) pump, treat and serve for communities in the AID study area, and (iii) pump, treat, and re-inject at a plume-scale.

A simple mass balance model approach to the pump, treat, and reinjection scenario suggests that nitrate performance targets would be achieved in the following timeframes:

- Below 10 mg/L – 37 to 73 years
- Below 8 mg/L – 81 to 161 years

- Below 5 mg/L > 180 to > 260 years
- Below 4 mg/L > 220 to 260 years

The pump, treat, and serve subscenarios will take longer to reach a performance target of 10 mg/L (121 vs 37 to 73 years for pump, treat, and reinject). However, pump, treat, and serve achieves Management Goal 1 by providing treated water to meet potable demands and the cost for the pump, treat, and serve options are significantly lower than pump, treat and reinject. The equivalent annual cost for Scenarios 2a through 2d range from $2.2M to $8.7M, while Scenario 1 concept-level equivalent annual costs range from $5.9 to $14.2M. This corroborates findings by King *et al.* (2012): "Full, basin-scale application of pump-and-treat (PAT) methods is not practical, due to the prohibitively high costs associated with the required construction and operation of a vast network of contaminant capture wells for decades, possibly centuries. Moreover, vast amounts of groundwater would have to be treated and reinjected. The construction and energy costs alone would be enormous."

During the development of a local SNMP, the stakeholders will evaluate implementation measures and evaluation factors that affect the implementation measures, to the extent that data and requisite information are available. These implementation measures are actions to be considered and not requirements and every local SNMP will consider site-specific conditions.

- Identify the governance structure – agency(ies), joint powers authority, or coalition(s) or other entities that will responsible for nitrate and salt implementation measures.
- Identify the primary sources of nitrate: Non-point sources? Point sources? Legacy nitrate contamination in the vadose zone.
- Identify salt sources: naturally-occurring, consumptive use/irrigated agriculture.
- Identify and review emerging treatment technologies for nitrate and TDS.
- Identify areas in the management zone where salt and nitrate are co-located and determine a suitable treatment option. For example, groundwater with nitrate performance targets may be treated most cost-effectively with ion exchange (IX) or biological denitrification. However, if TDS is also elevated, reverse osmosis (RO) may become the most efficient treatment technology. TDS concentrations in groundwater may increase in areas where pump and fertilize is employed as a mitigation strategy due to consumptive use by crops[36]. All of these factors will be analyzed at the local SNMP level.
- If the sources are predominantly non-point, work with the ILRP Coalition groups and contribute to or review and comment on the MPEP process.

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[36] "Irrigation concentrates salts through consumptive use of water by the crops. Since crops only consume the water molecules and leave behind the dissolved salts, salinity will increase in both the soil and water drainage and runoff." (Central Valley Water Board, 2006)

- Evaluate other source control measures (*e.g.*, other agriculture, municipal, food processing, domestic turf irrigation and fertilization, on-site waste disposal systems [septic systems]) and how effective they may be.

- If there is a point source of nitrate (*e.g.*, a wastewater treatment plant discharge pond), define what measures can be implemented to reduce nitrate at the source (*e.g.*, optimize municipal wastewater treatment plant 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, ion exchange, *etc.*) Consider brine management. Will the product water be used for potable supply or blended and used for irrigation?

- For pump and fertilize, 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. Increased 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. Consider pump, treat, and serve just to meet domestic water demands. Pump and treat 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. Pump, treat, and serve would be used in conjunction with pump and fertilize, and the highly treated water from pump, treat, and serve 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 pump and treat and pump, treat, and serve, need to consider brine disposal.

- Describe local, regional, state, and federal funding opportunities including, fertilizer use fees, water rate increases, grants, bonds, Proposition 1 project funds, *etc.*

An AIP will determine how the local SNMPs should be updated for the next phase (including providing detailed projects/activities for the approximately next 10-year period) and to make those changes.

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Section 7

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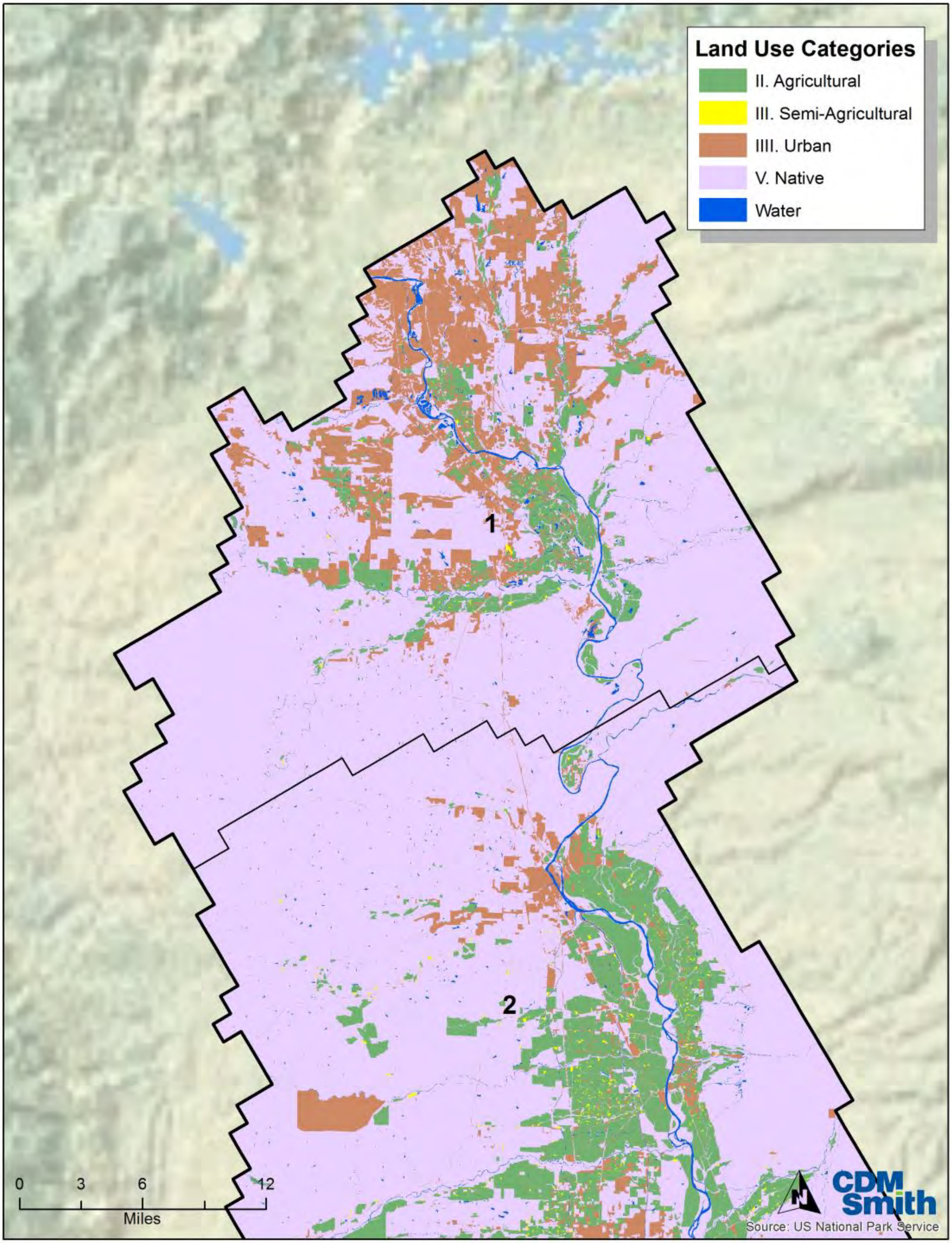
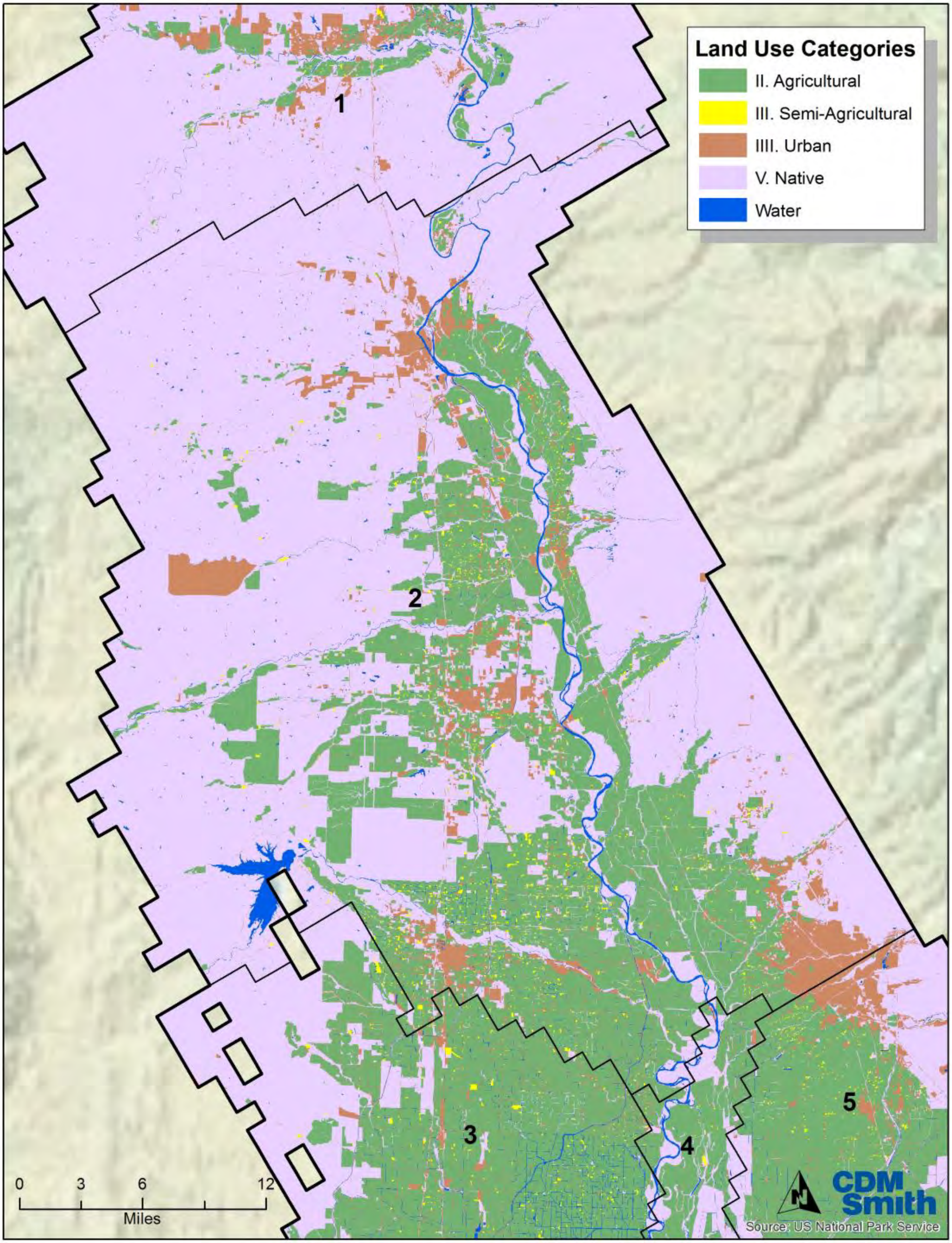
Appendix A

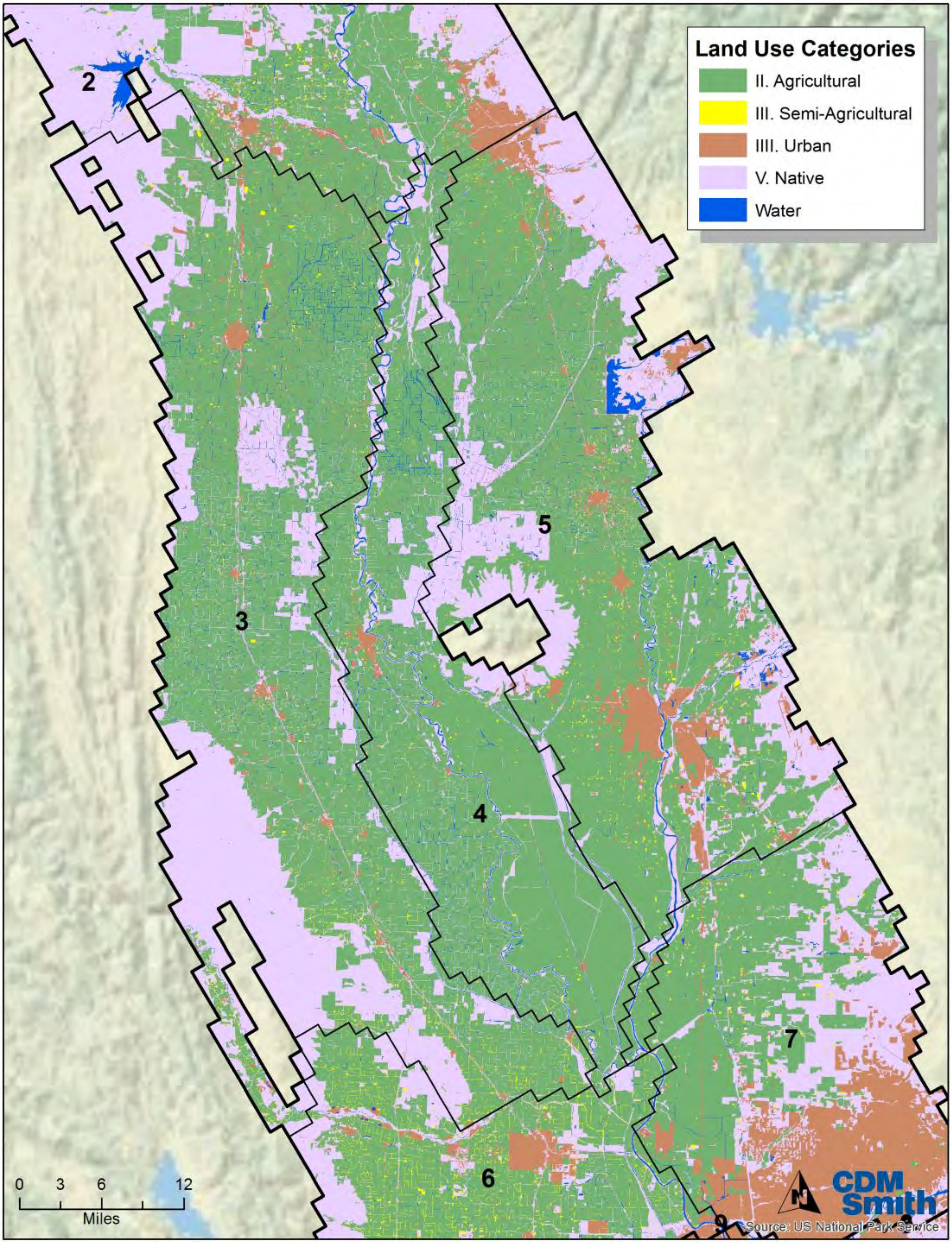
Land Use by IAZ



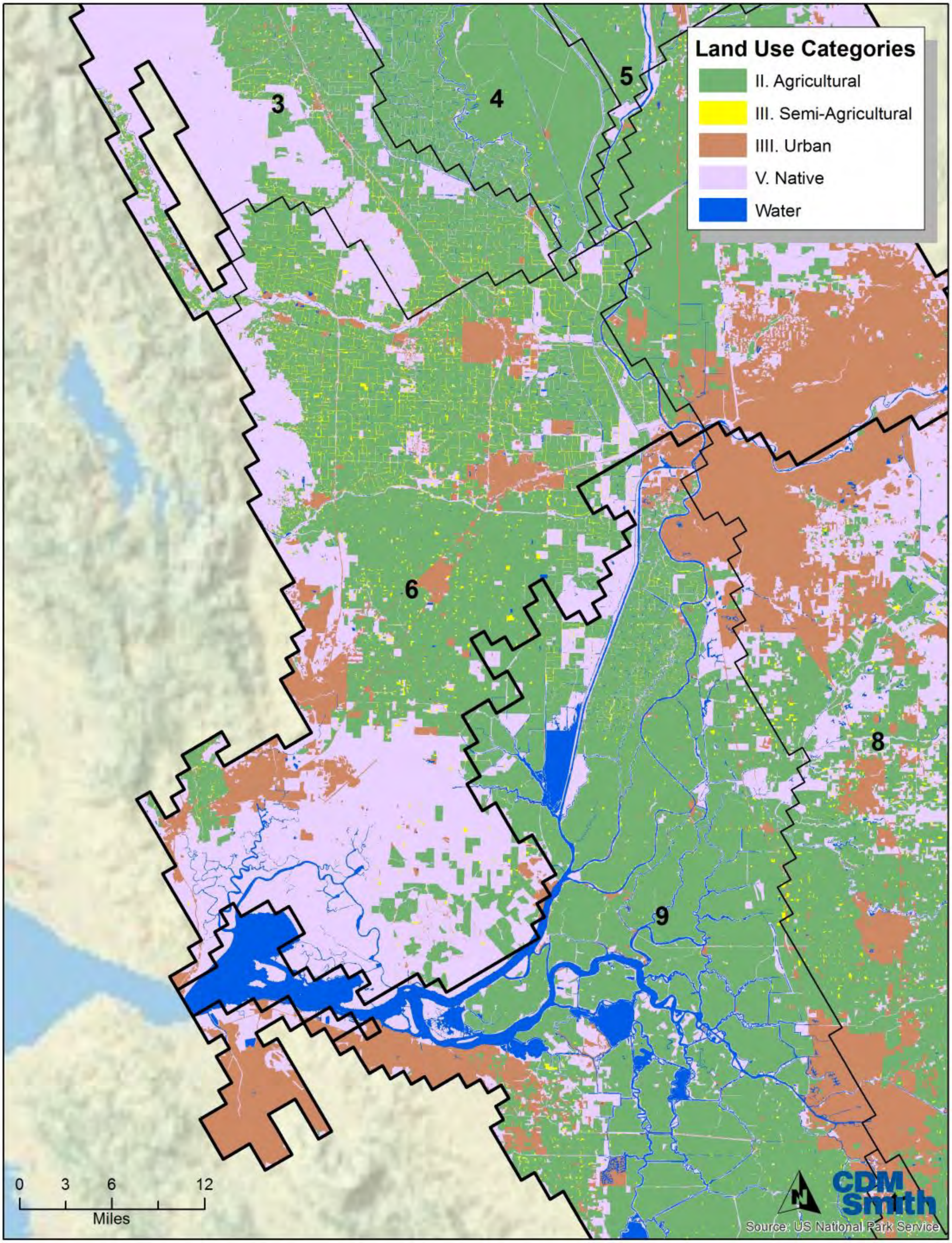
Appendix A.1 IAZ-1 Sacramento River above Red Bluff (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)



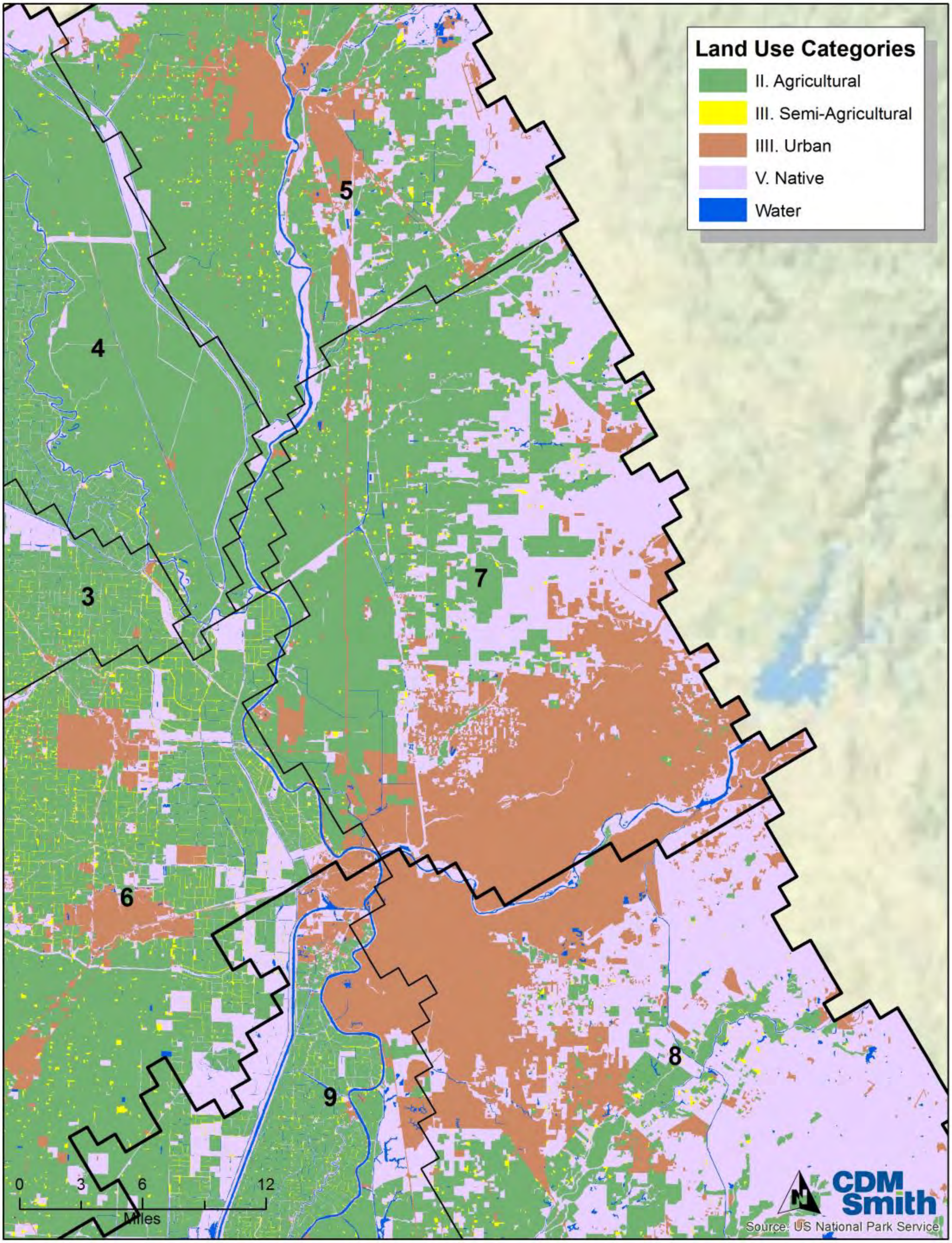
Appendix A.2 IAZ-2 Red Bluff to Chico Landing (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)



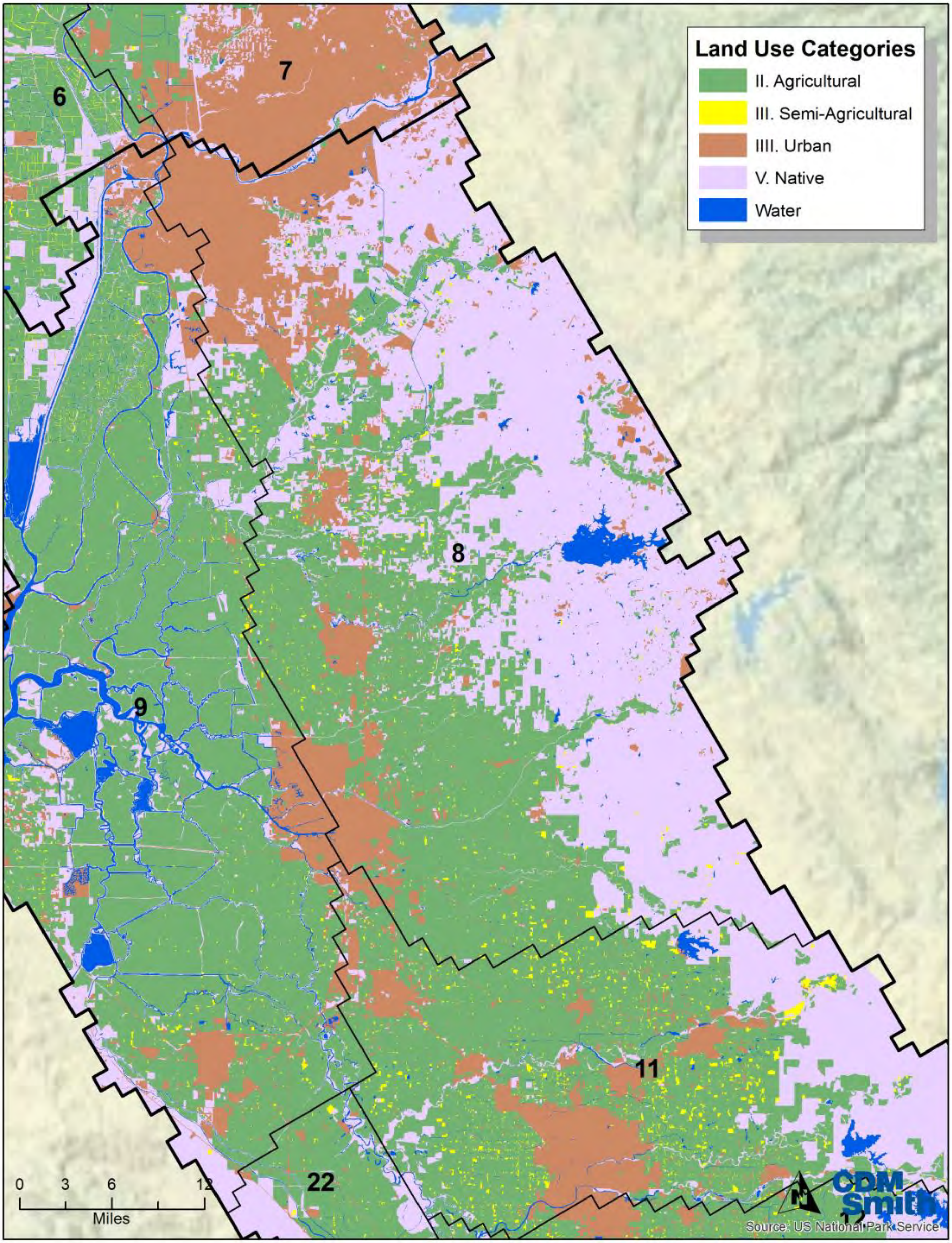
Appendix A.3 IAZ-3 Colusa Trough, IAZ-4 Chico Landing to Knights Landing proximal to the Sacramento River, and IAZ-5 Eastern Sacramento Valley foothills near Sutter Buttes (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)



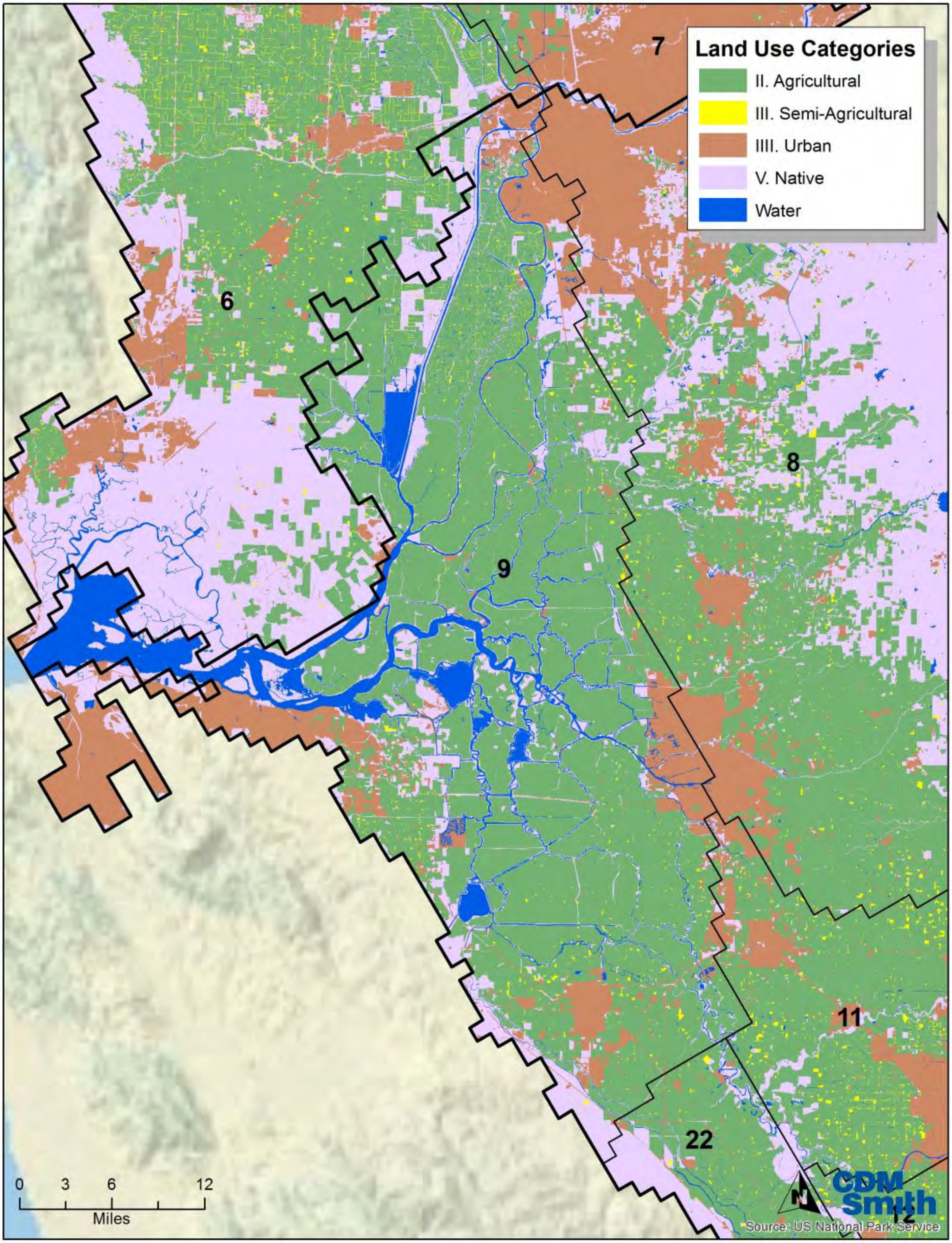
Appendix A.4 IAZ-6 Cache-Putah Area (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)



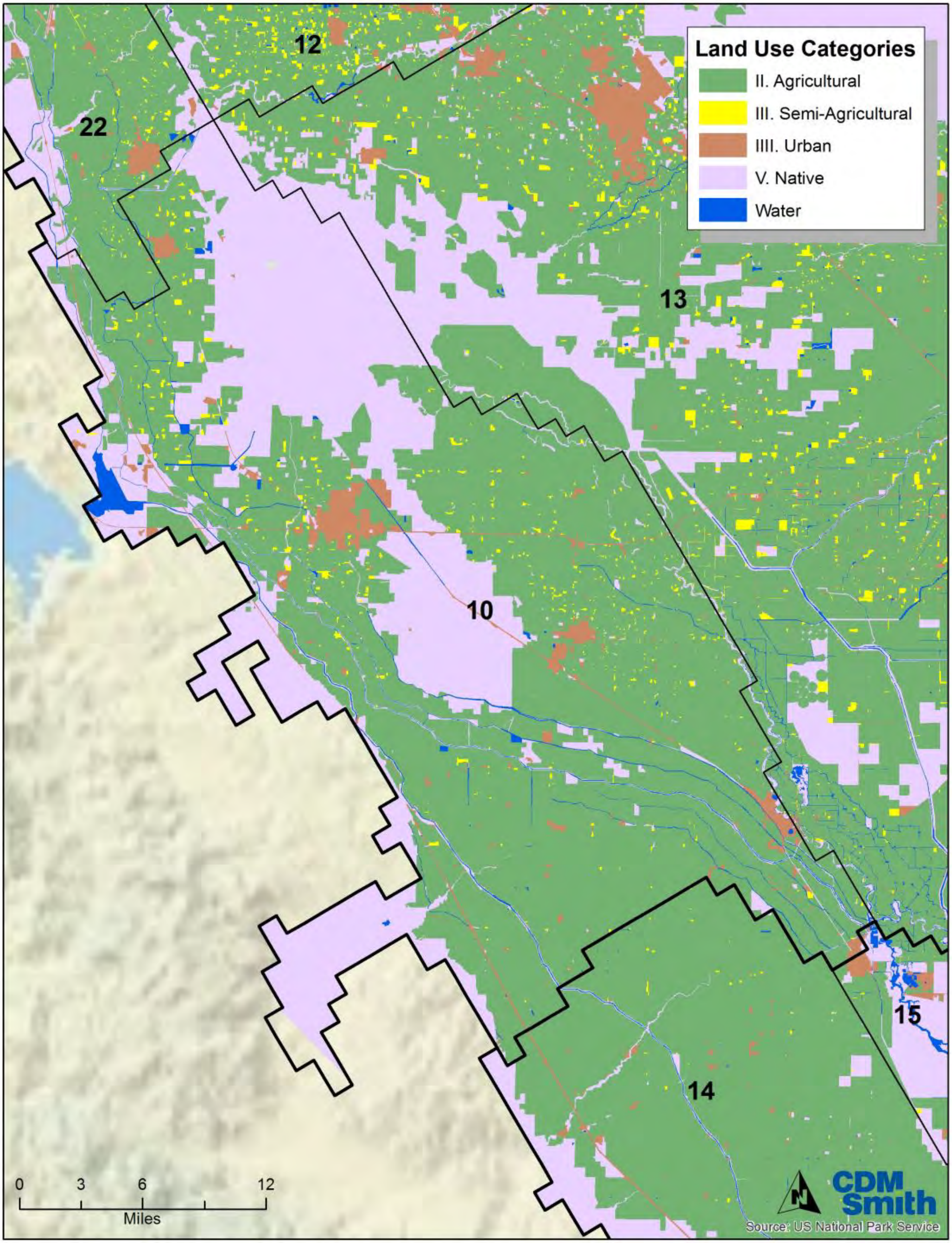
Appendix A.5 IAZ-7 East of Feather and South of Yuba (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)



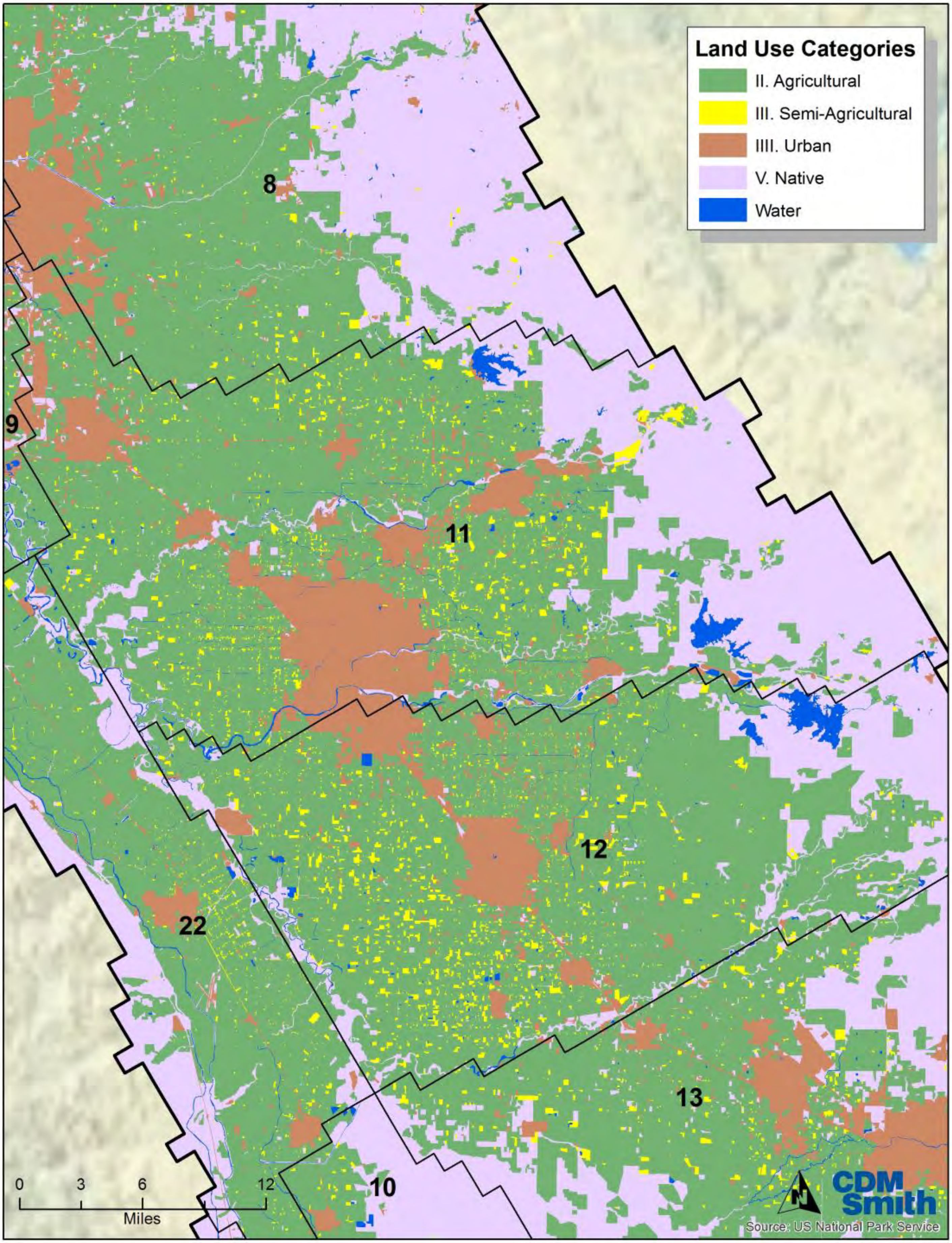
Appendix A.6 IAZ-8 Valley floor of the Delta (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)



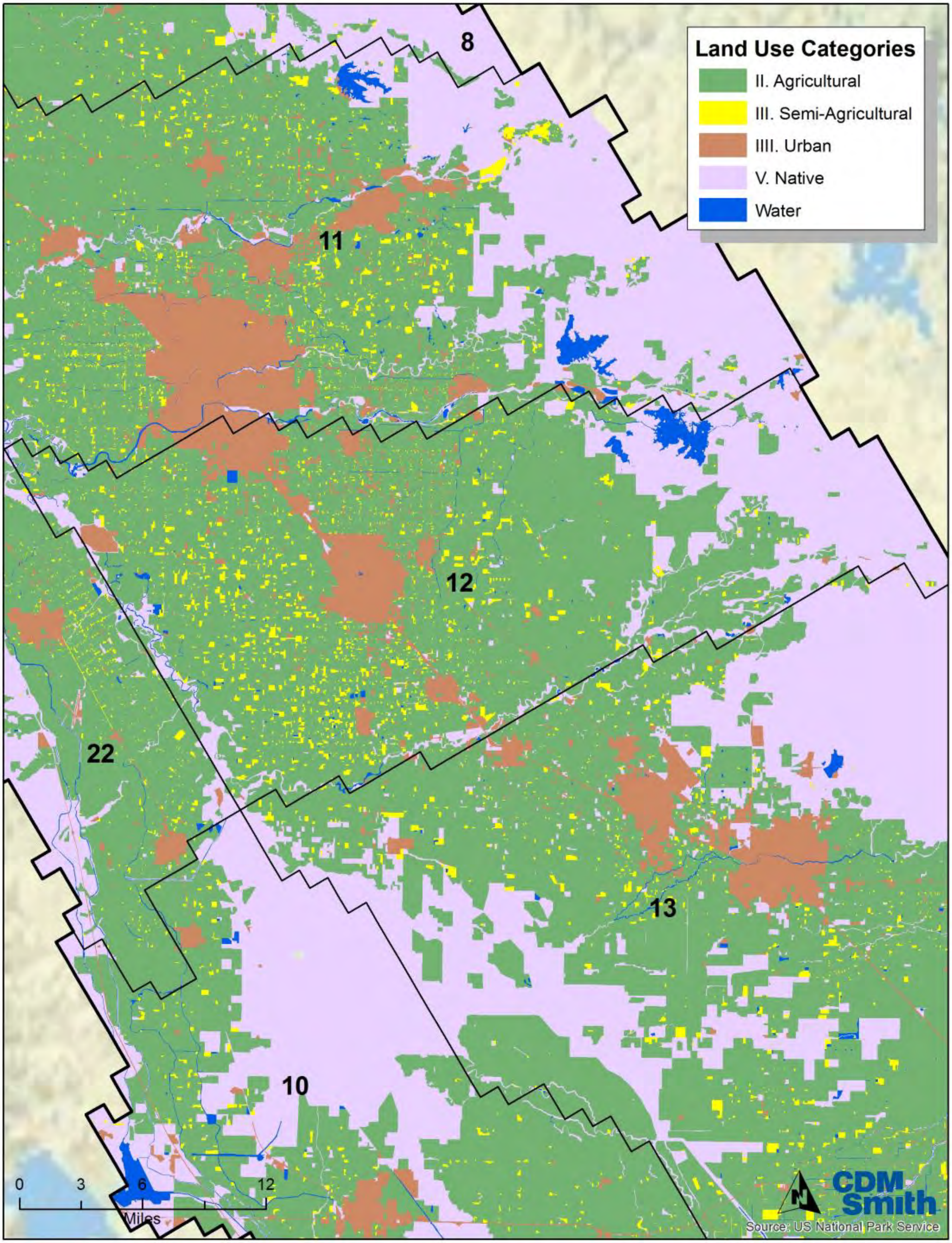
Appendix A.7 IAZ-9 Delta (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)



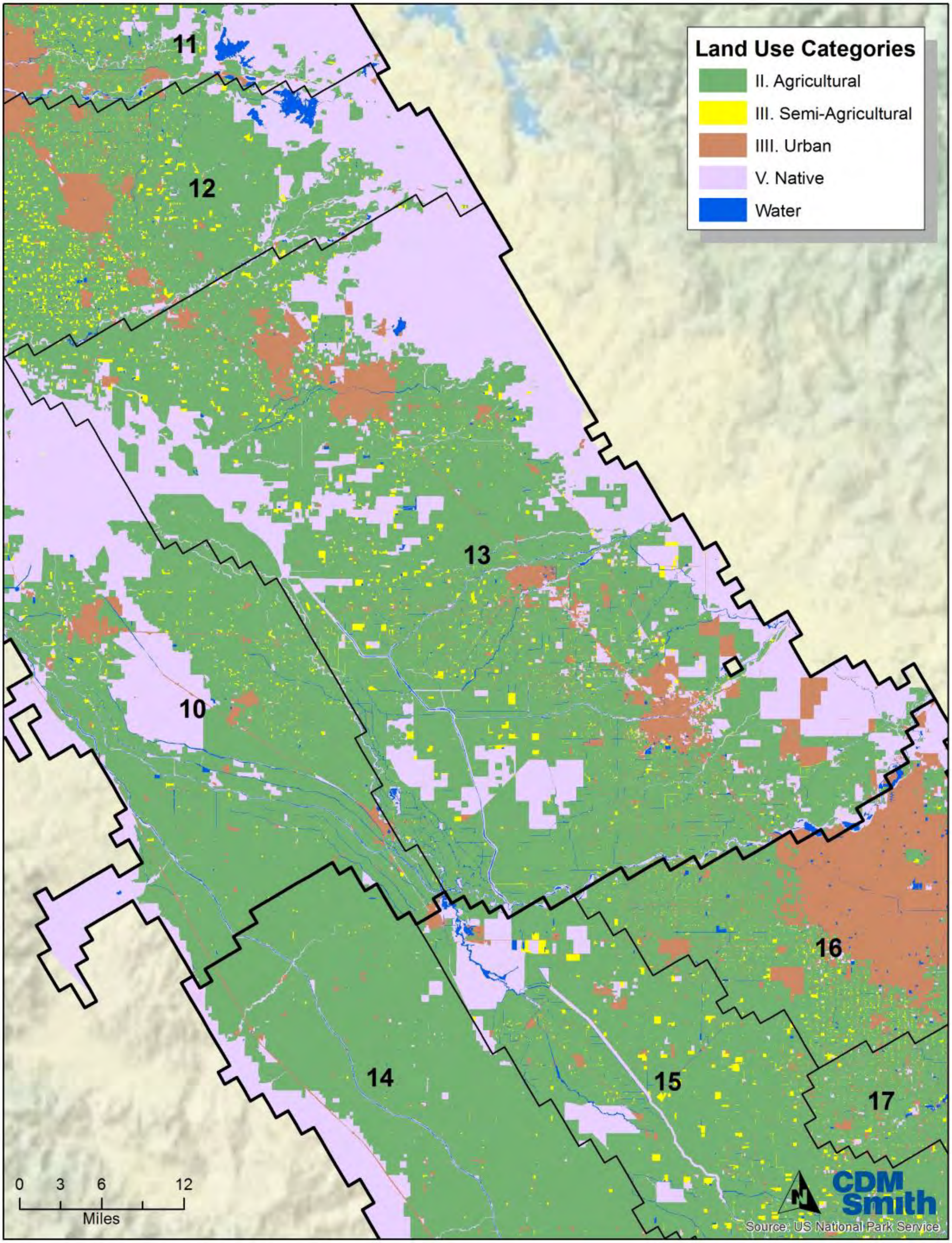
Appendix A.8 IAZ-10 Delta-Mendota Basin—Northwest Side (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)



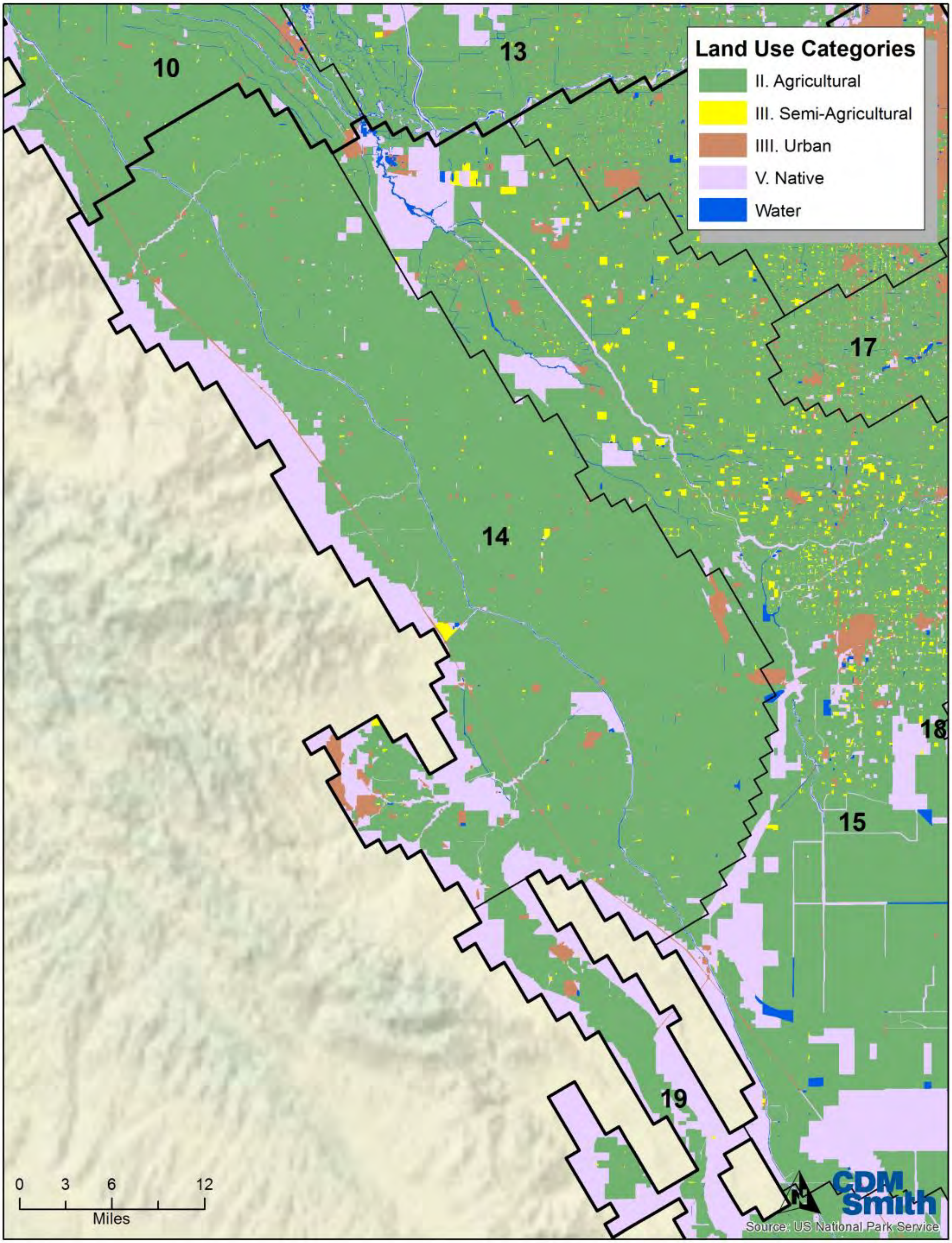
Appendix A.9 IAZ-11 Modesto and Southern Eastern San Joaquin Basin (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)



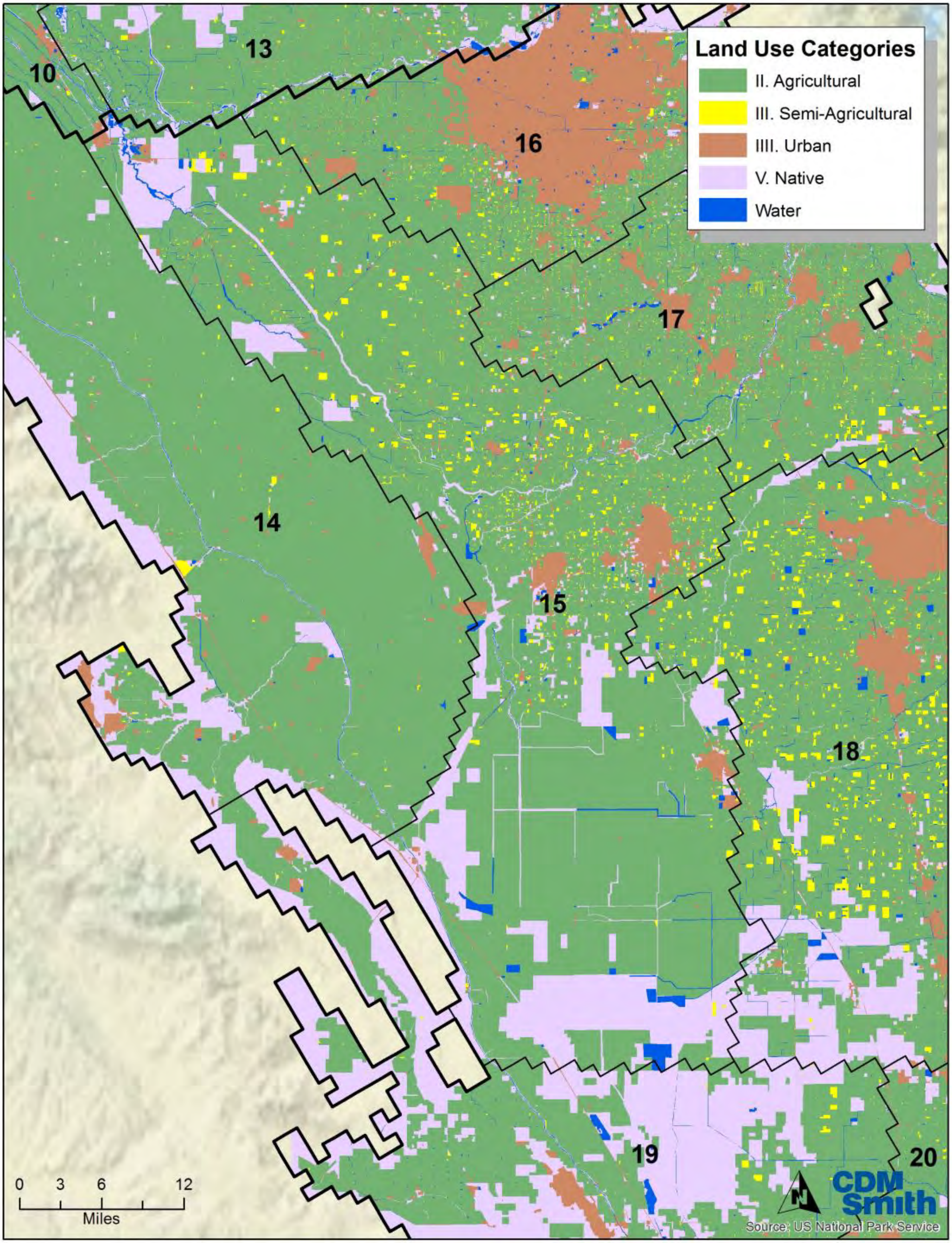
Appendix A.10 IAZ-12 Turlock Basin (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)



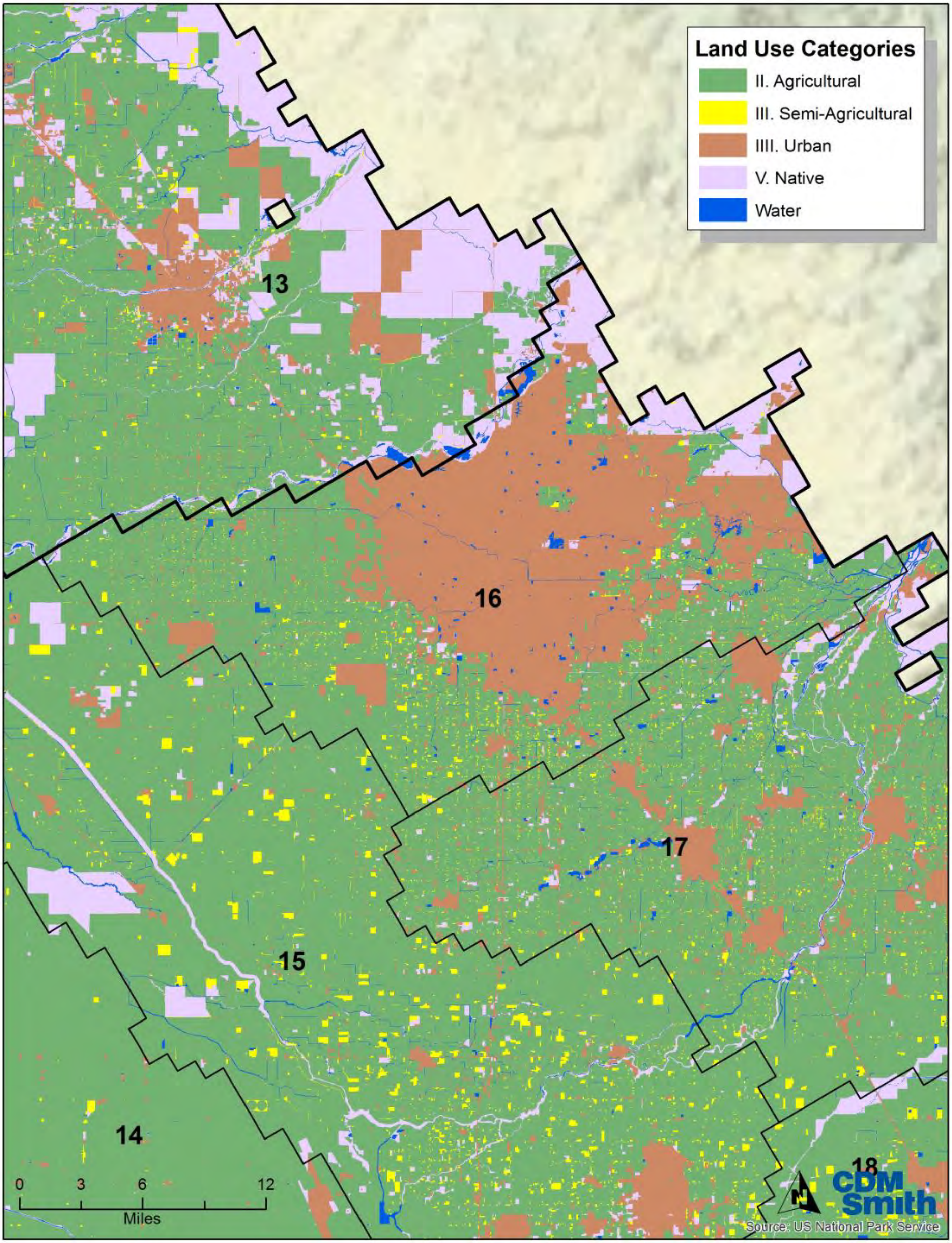
Appendix A.11 IAZ-13 Merced, Chowchilla, and Madera Basins (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)



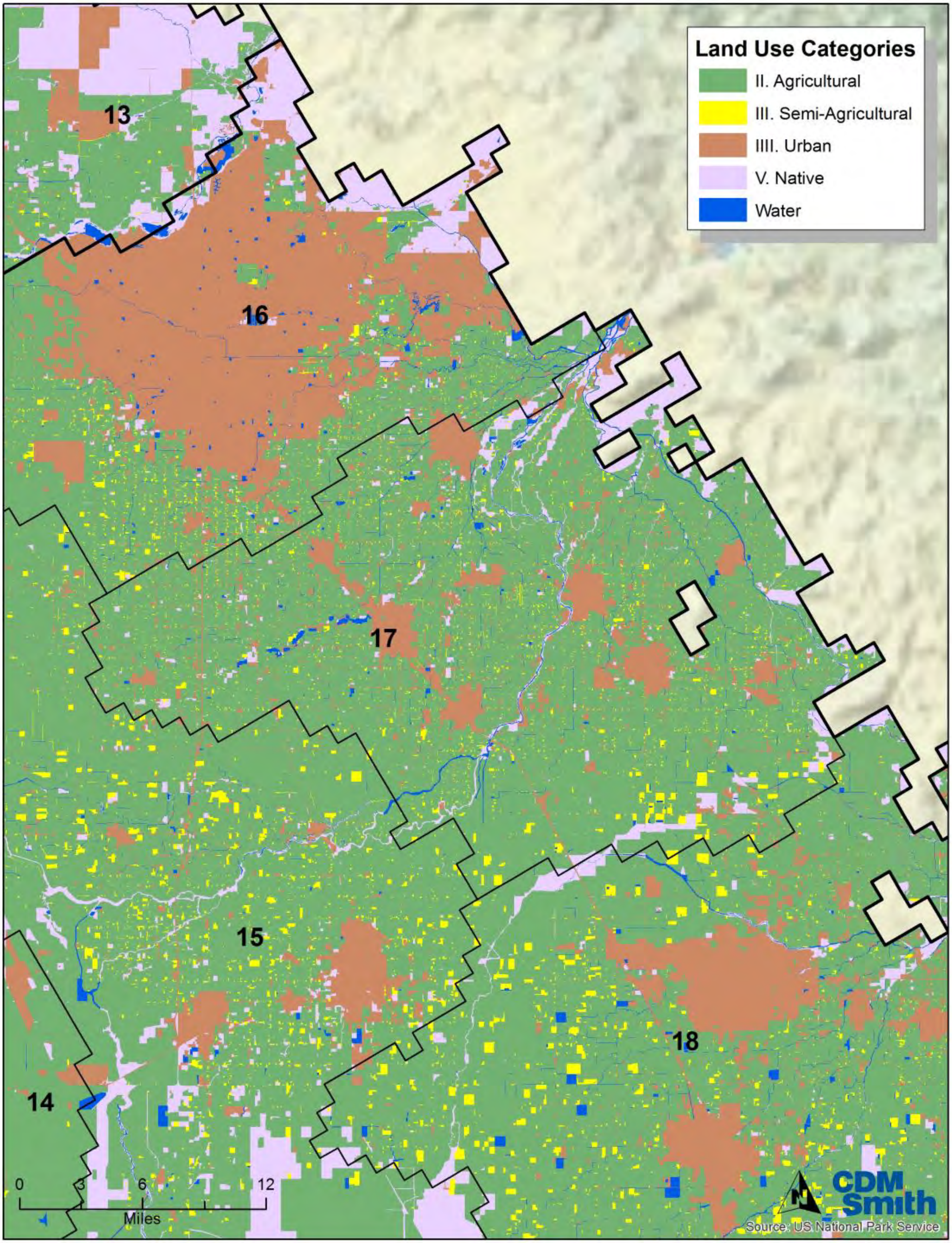
Appendix A.12 IAZ-14 Westside and Northern Pleasant Valley Basins (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)



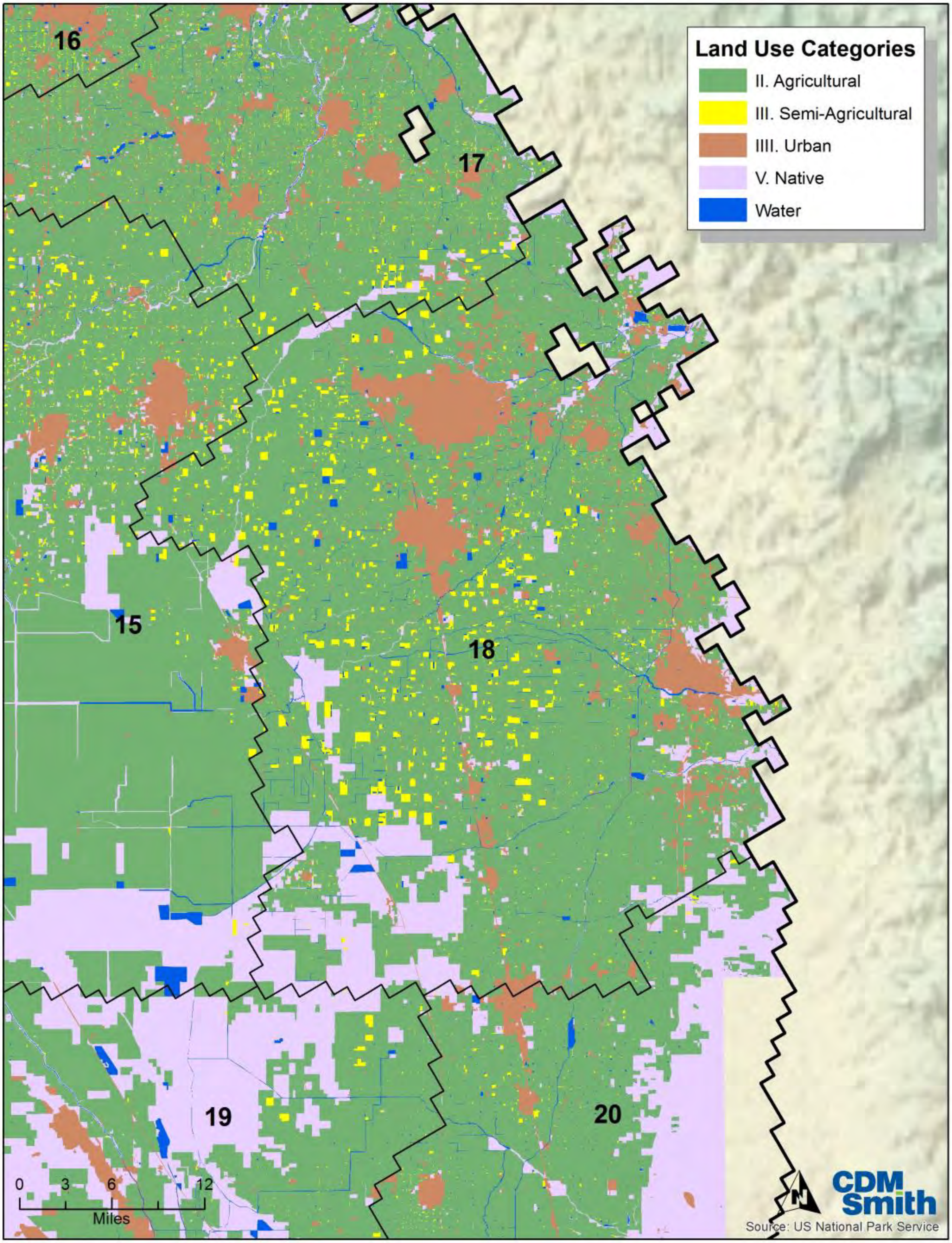
Appendix A.13 IAZ-15 Tulare Lake and Western Kings Basin (Land use from DWR http://www.water.ca.gov/ landwateruse/lusrvymain.cfm, year varies by county)



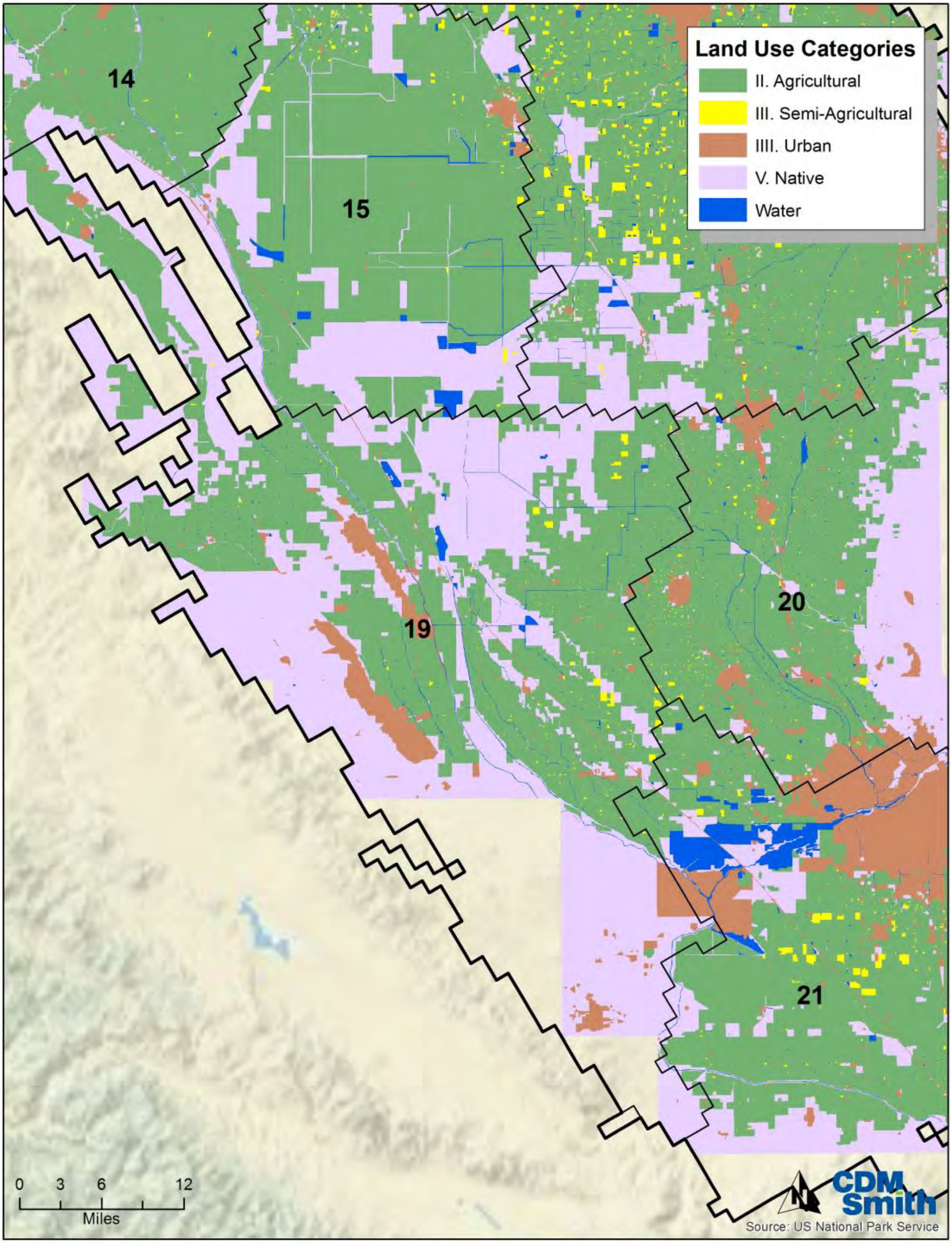
Appendix A.14 IAZ-16 Northern Kings Basin (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)



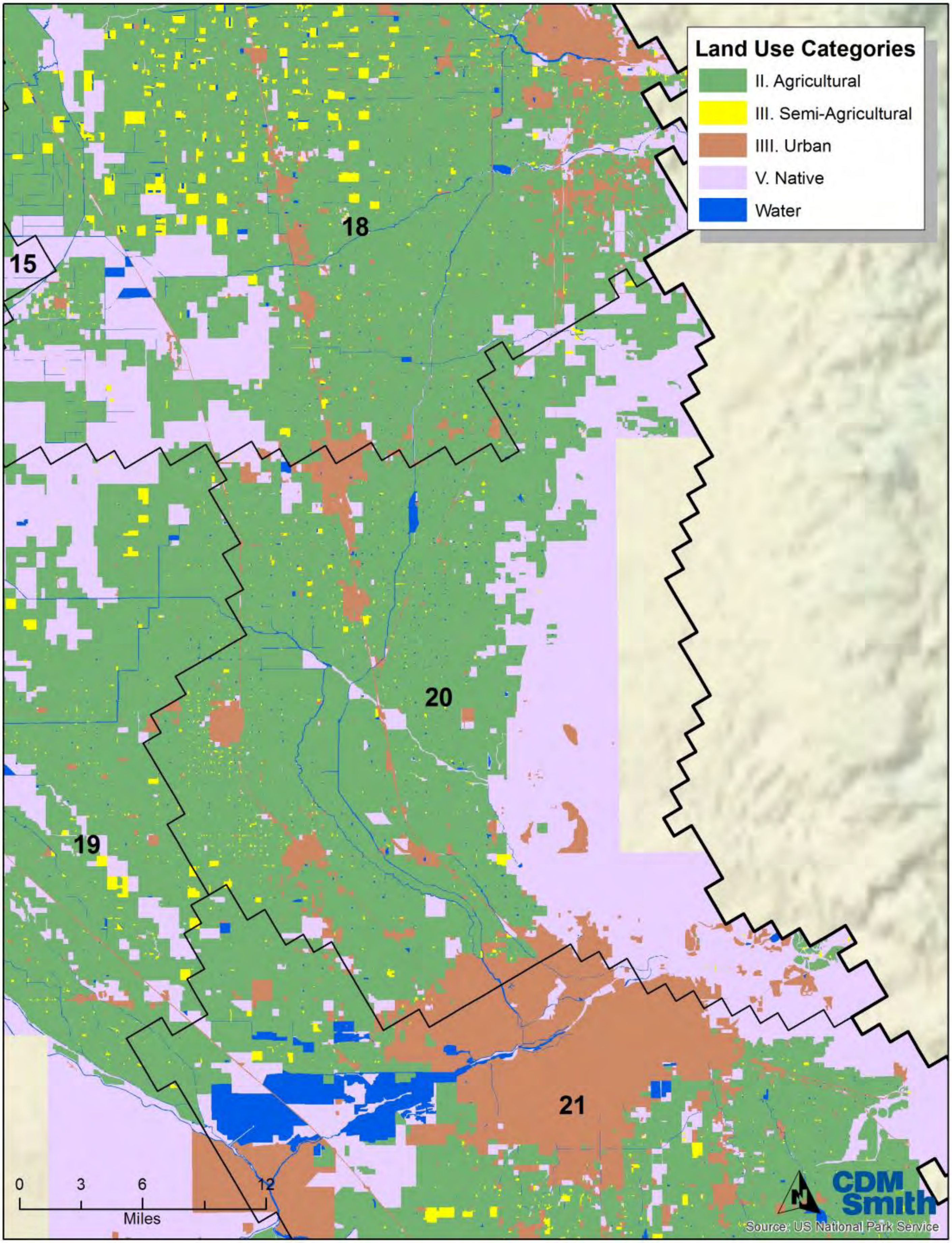
Appendix A.15 IAZ-17 Southern Kings Basin (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)



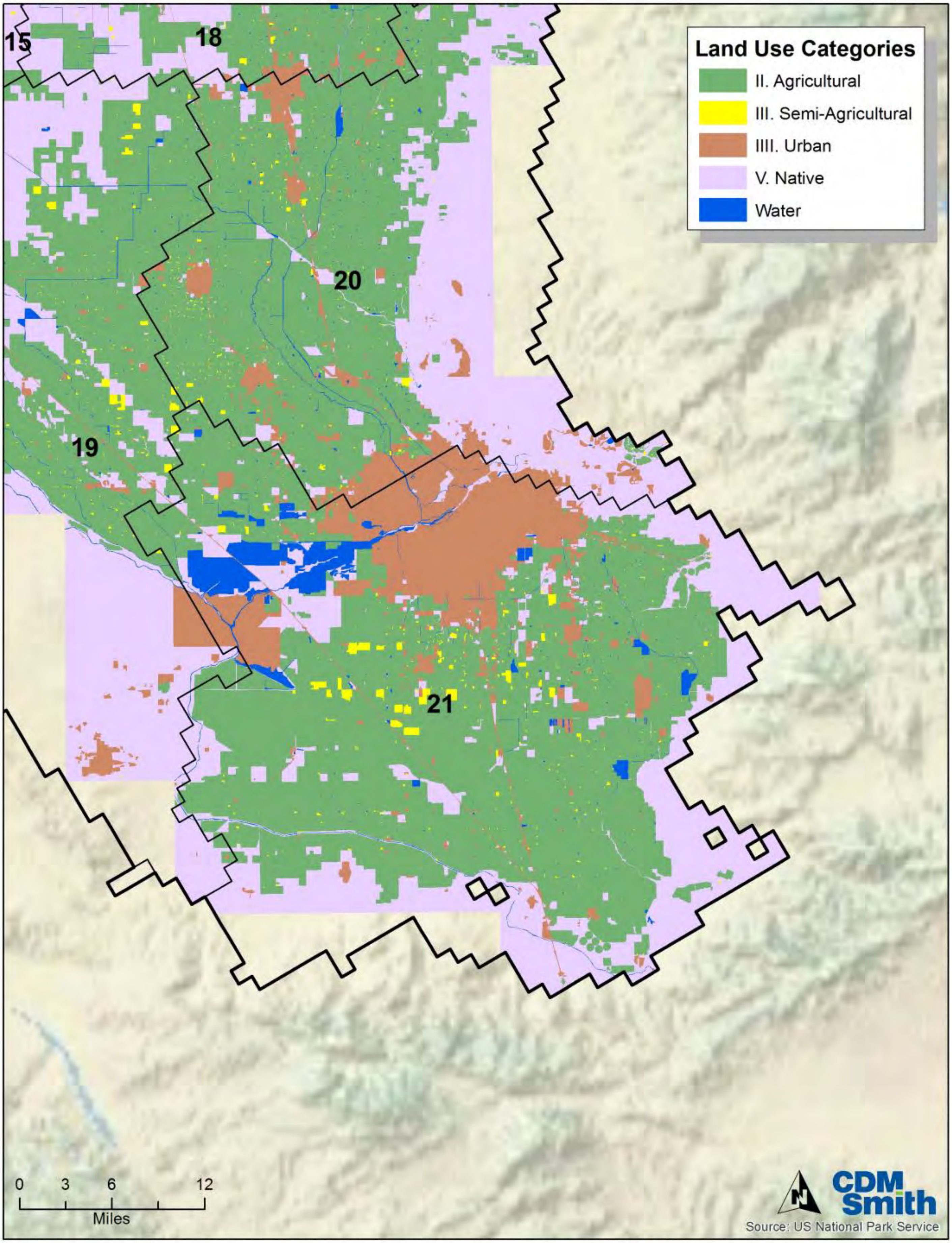
Appendix A.16 IAZ-18 Kaweah and Tule Basin (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)



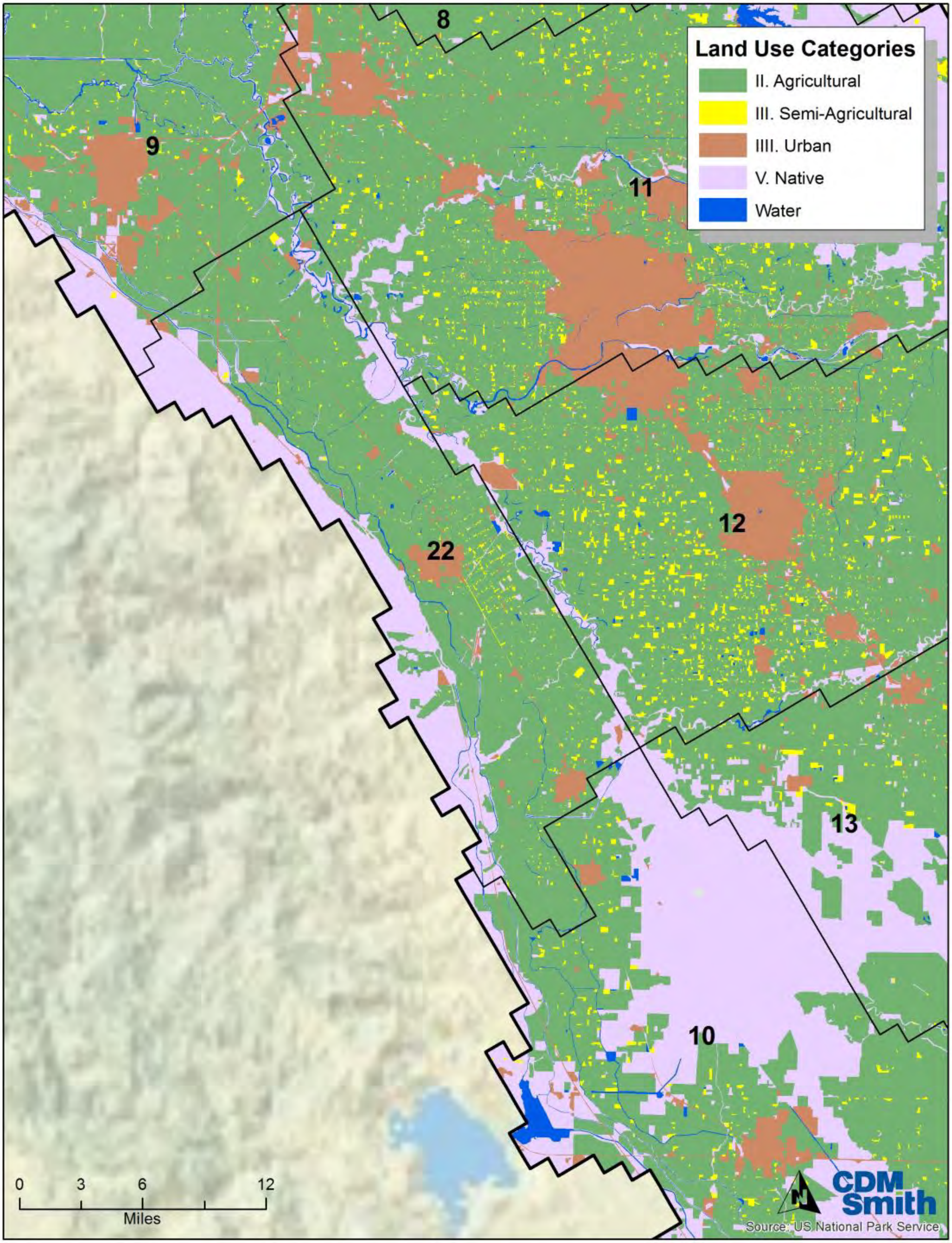
Appendix A.17 IAZ-19 Western Kern County and Southern Pleasant Valley Basin (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)



Appendix A.18 IAZ-20 Northeastern Kern County Basin (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)



Appendix A.19 IAZ-21 Southeastern Kern County Basin (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)

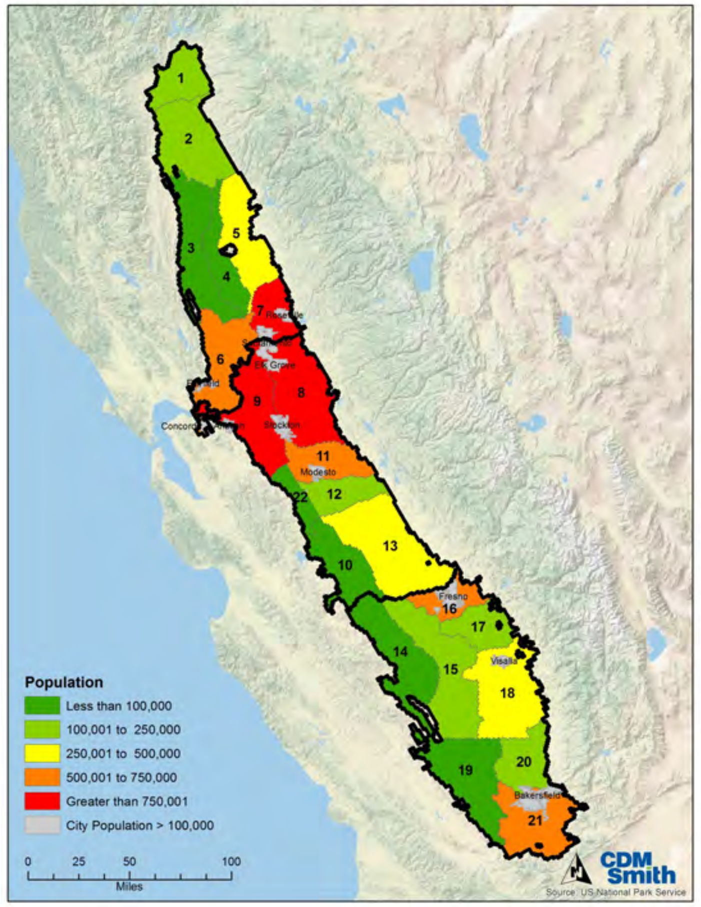


Appendix A.20 IAZ-22 Delta-Mendota Basin Grassland (Land use from DWR http://www.water.ca.gov/landwateruse/lusrvymain.cfm, year varies by county)

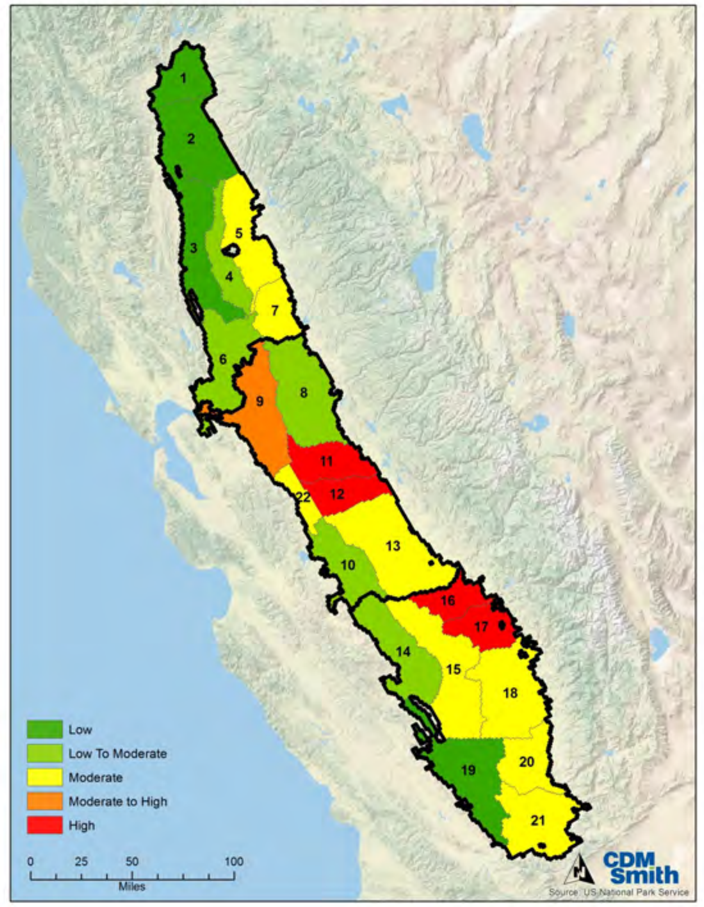
Appendix B

Nitrate & TDS Prioritization

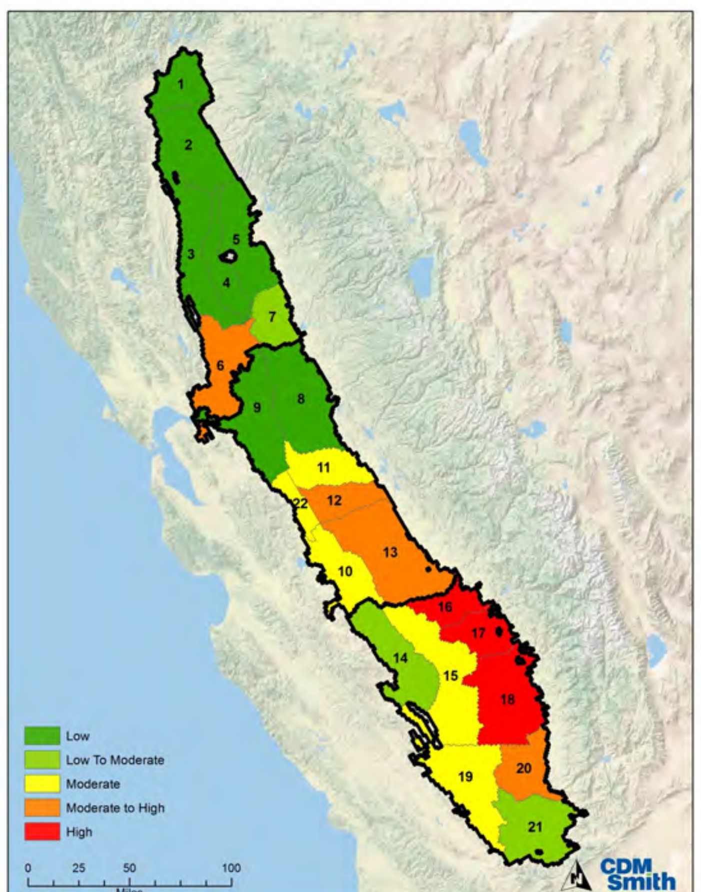
CDM Smith



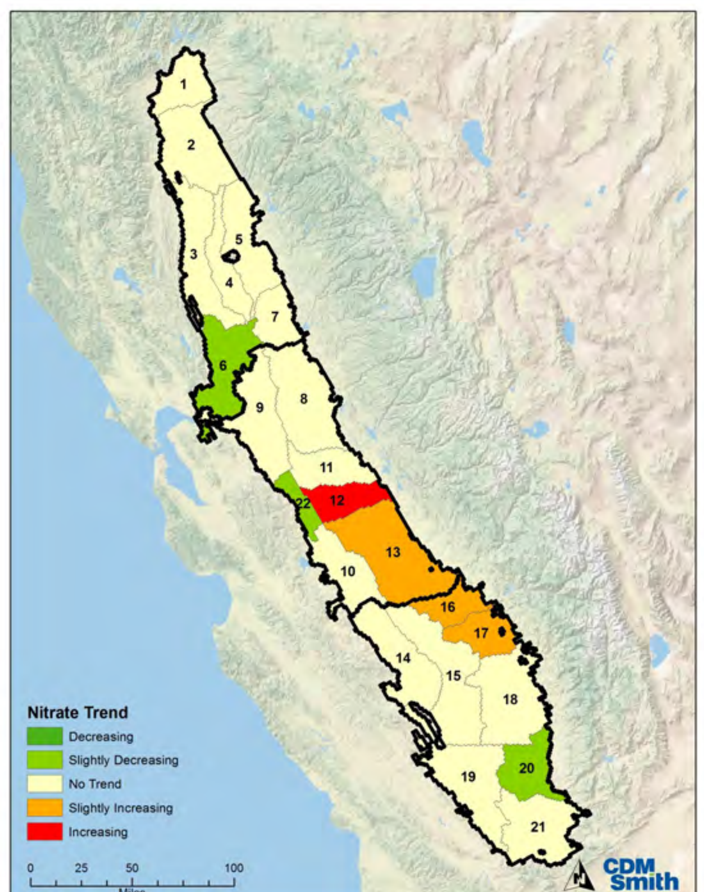
A. 2010 US Census Population by IAZ: https://www.census.gov/geo/maps-data/data/tiger-data.html



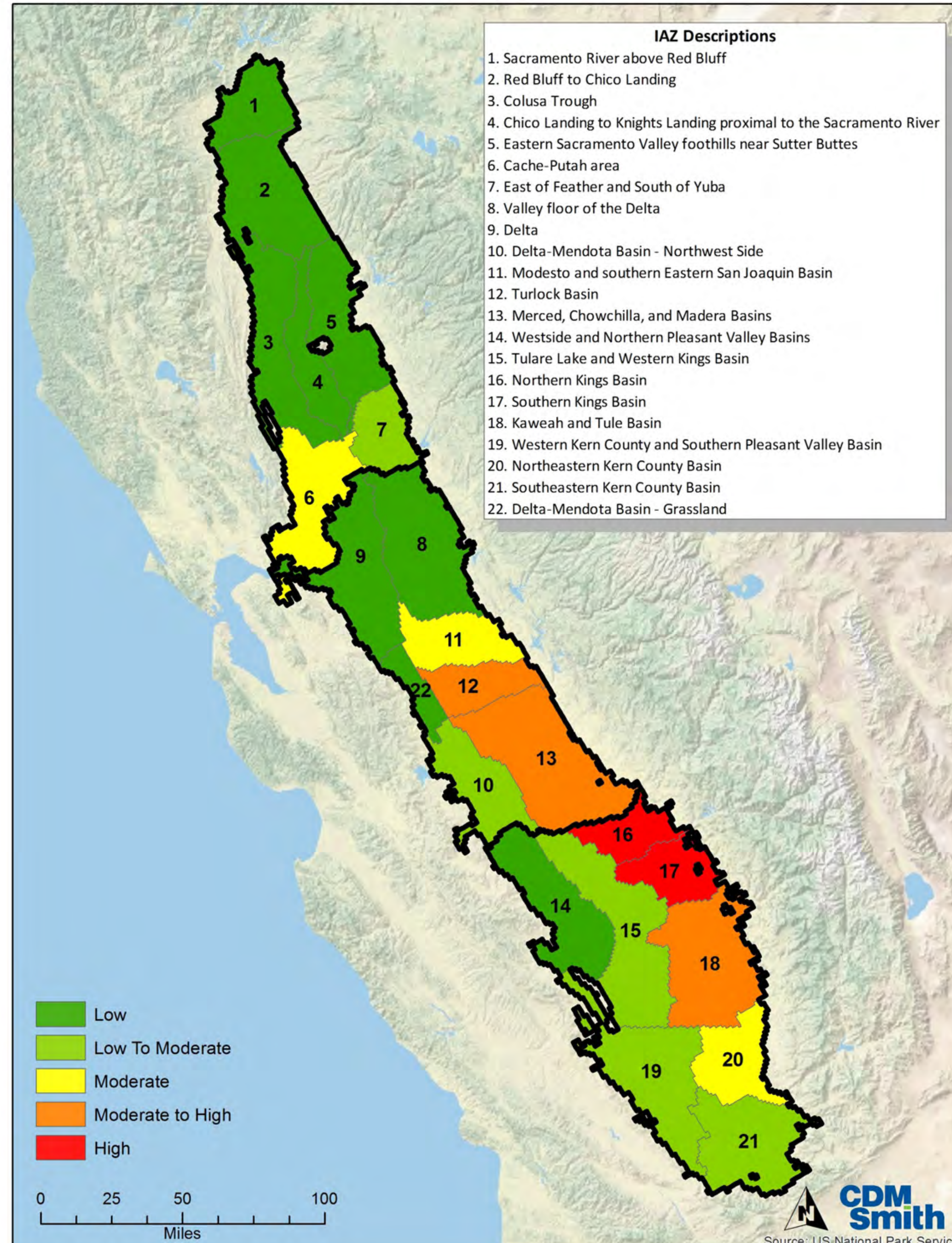
B. Ranking of Public Supply Wells, Total Wells, and Overlying irrigated acreage



C. Priority Basin Based on Ambient Nitrate Data and Mixing Model Simulations: CV-SALTS Initial Conceptual Model Tasks 7 and 8 - Salt and Nitrate Analysis for the Central Valley Floor and a Focused Analysis of Modesto and Kings Subregions Report, December 2013

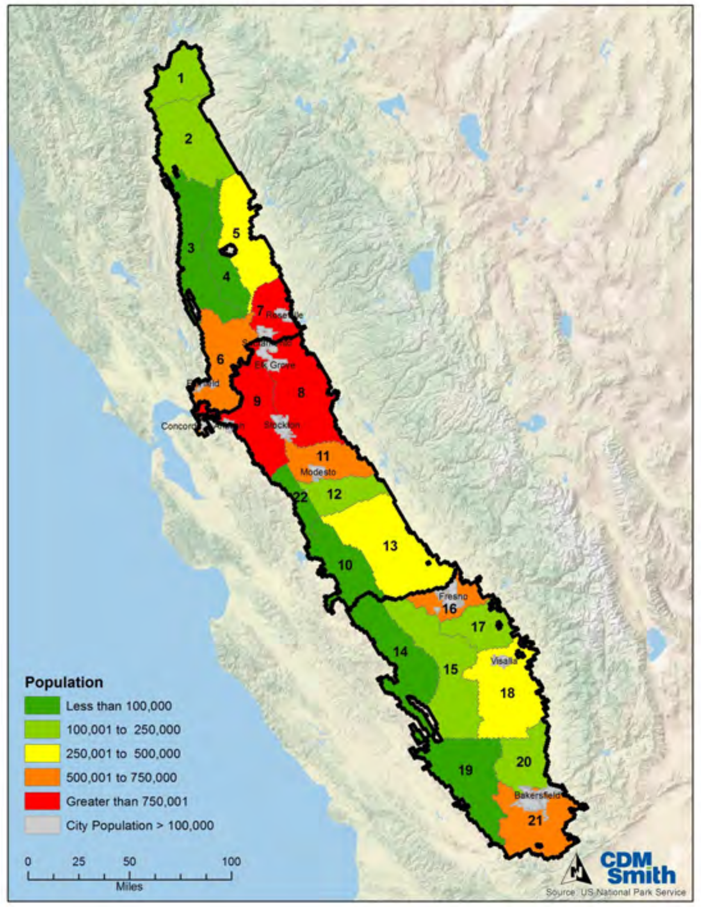


D. Shallow Median Concentration for Nitrate Through Time: CV-SALTS Initial Conceptual Model Tasks 7 and 8 - Salt and Nitrate Analysis for the Central Valley Floor and a Focused Analysis of Modesto and Kings Subregions Report, December 2013

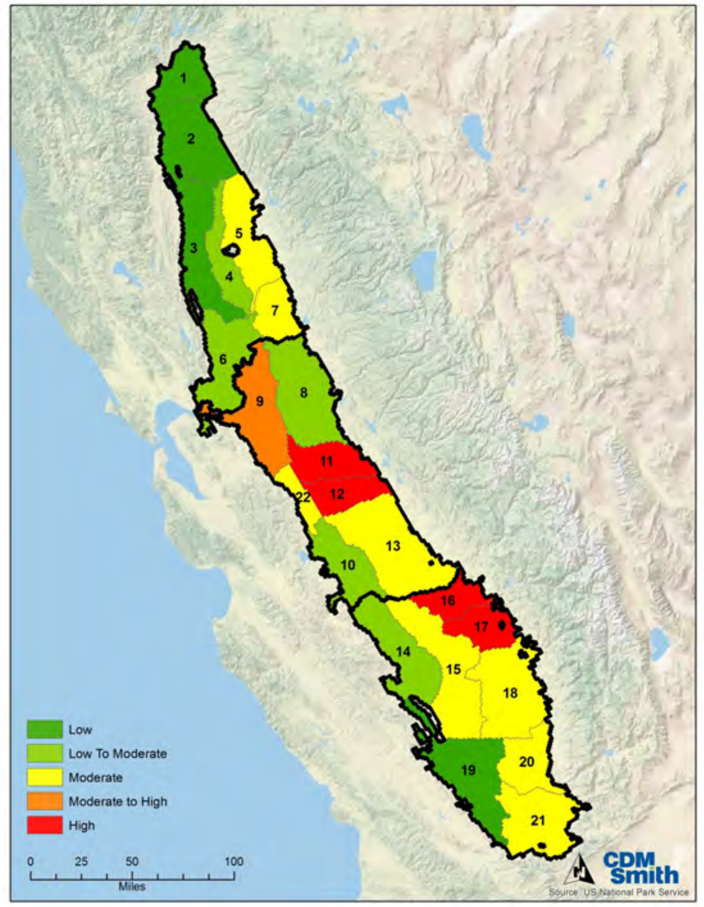


E. Nitrate Prioritization at the IAZ Level based on a weighted average of A-D. 15% Population (A), 15% CASGEM (B), 45% Ambient TDS data and Mixing Model Simulations (C), and 25% Shallow Median Concentration for TDS Through Time (D).

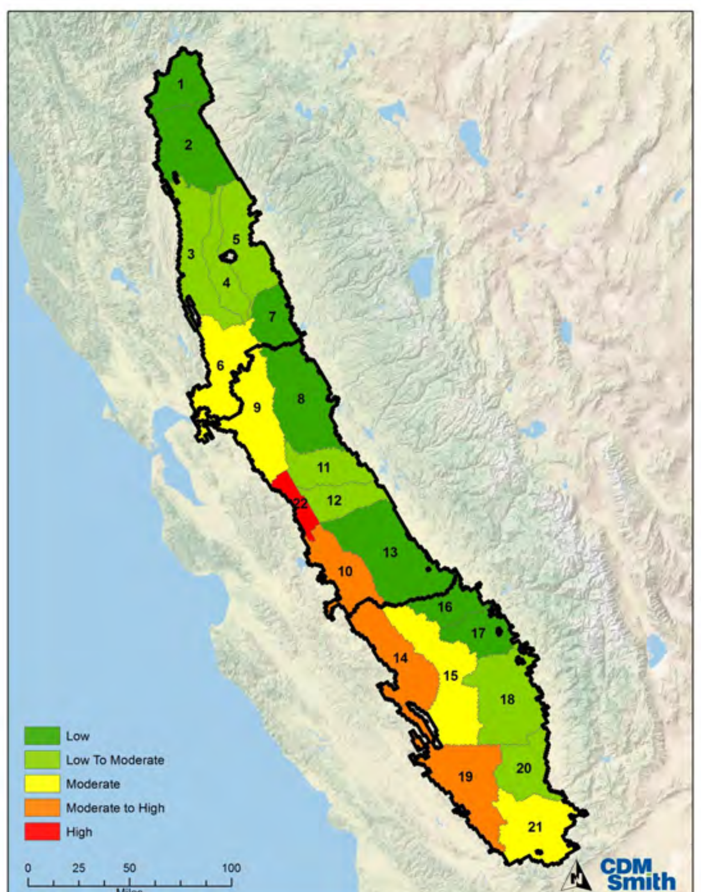
Appendix B.1 Nitrate Prioritization



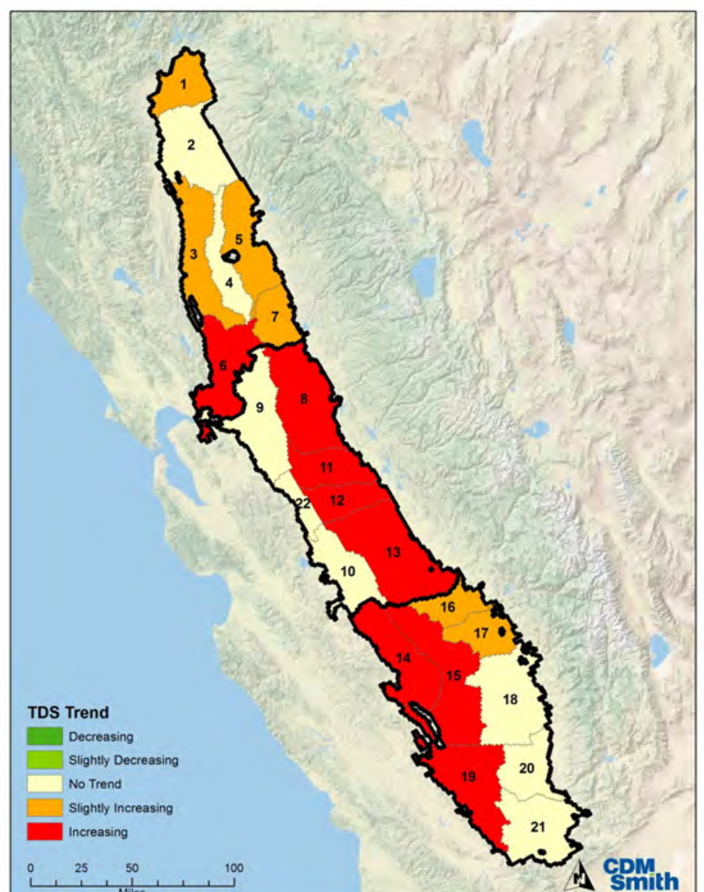
A. 2010 US Census Population by IAZ: https://www.census.gov/geo/maps-data/data/tiger-data.html



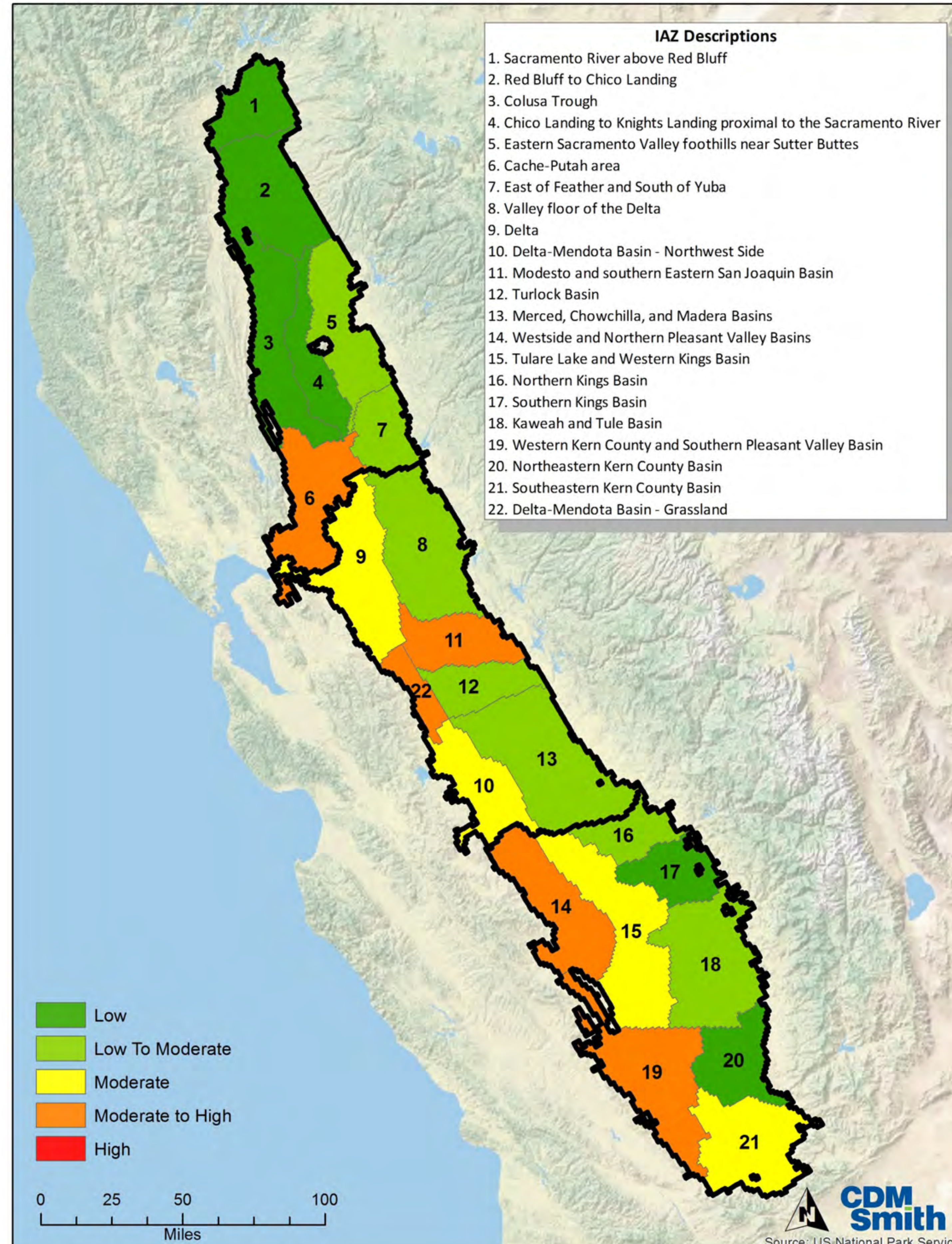
B. Ranking of Public Supply Wells, Total Wells, and Overlying irrigated acreage



C. Priority Basin Based on Ambient TDS Data and Mixing Model Simulations: CV-SALTS Initial Conceptual Model Tasks 7 and 8 - Salt and Nitrate Analysis for the Central Valley Floor and a Focused Analysis of Modesto and Kings Subregions Report, December 2013



D. Shallow Median Concentration for TDS Through Time: CV-SALTS Initial Conceptual Model Tasks 7 and 8 - Salt and Nitrate Analysis for the Central Valley Floor and a Focused Analysis of Modesto and Kings Subregions Report, December 2013



E. TDS Prioritization at the IAZ Level based on a weighted average of A-D. 15% Population (A), 15% CASGEM (B), 45% Ambient TDS data and Mixing Model Simulations (C), and 25% Shallow Median Concentration for TDS Through Time (D).

Appendix B.2 TDS Prioritization

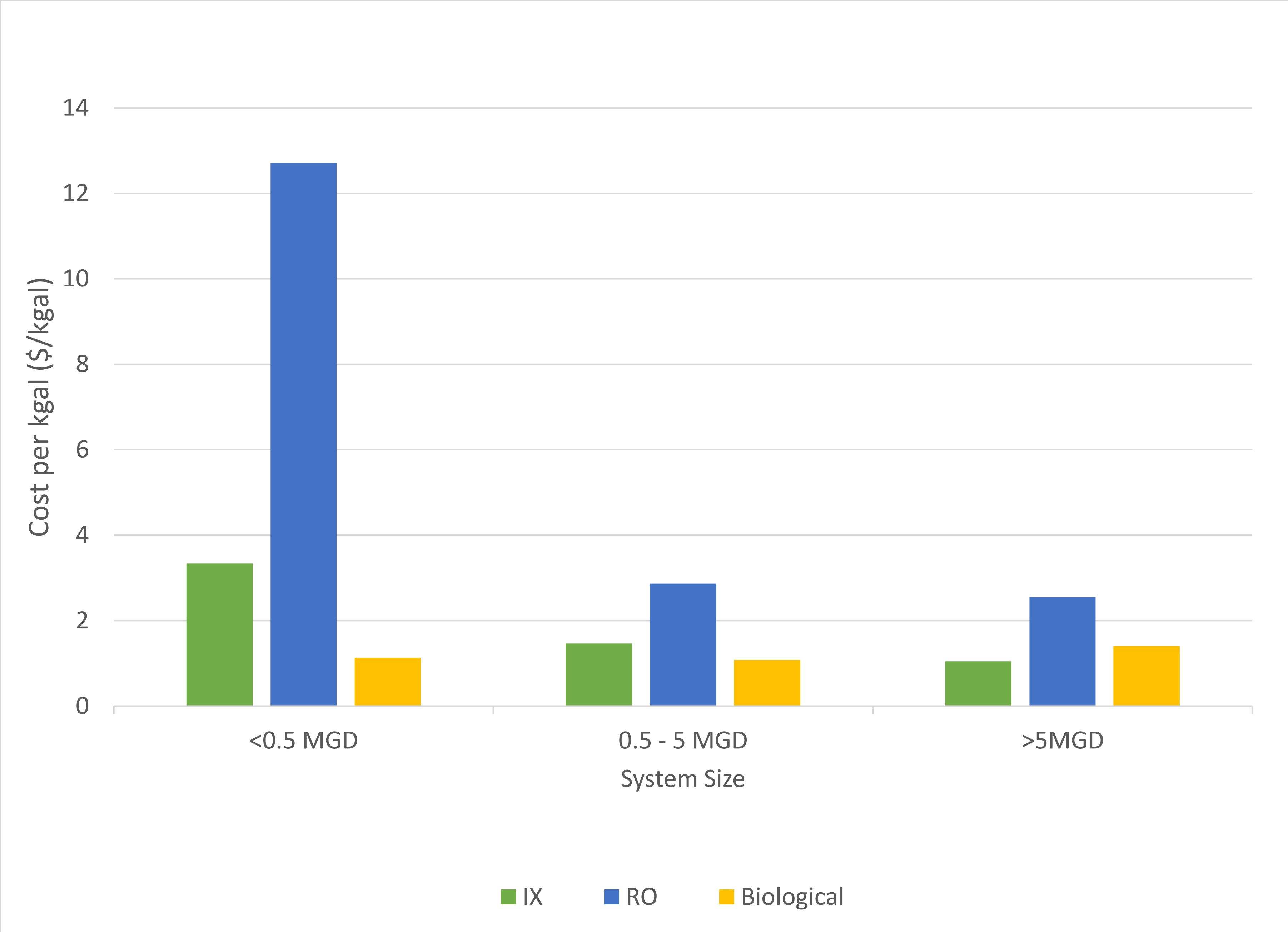
Appendix C

Nitrate Remediation Technologies

CDM Smith

Category	Technology	Technology Description	Technology Comparison (Unfavorable (-), Uncertain (+/-), Favorable (+) or Very Favorable (++))							Technology Applicability (Unfavorable (-), Uncertain (+/-), Favorable (+) or Very Favorable (++))												
			Costs			Time	Permitting	Waste	GW Impacts	Nitrate Concentration		System Size			Contaminant Depth			TDS	Aquifer Permeability	Reuse		
			Total Cost	Capital Cost	O&M Cost	Remediation Timeframe	Ease of Permitting	Amount Waste Generated	Potential for Secondary Impacts to Groundwater	Low (<10 mg-N/L)	High (>10 mg-N/L)	Very Small and Small Systems (< 0.25 MGD)	Medium Systems (0.25 to 1 MGD)	Large Systems (>1 MGD)	Shallow (<30 ft bgs)	Deep (> 30 ft bgs)	Very Deep (> 100 ft bgs)	High TDS Water	Low Permeability/ Heterogeneous Aquifers	Nutrient Reuse	Non-Potable Water Reuse	Potable Water Reuse
Ex-Situ (Groundwater Extraction and Treatment followed by Re-Injection, Discharge to Surface Water, or Potable Reuse)	Reverse Osmosis with Brine Disposal to Brine Line	Pump water to surface, through RO membranes; pipe brine to brine line	-	-	-	-	+	-	+	-	+	-	-	+	+	+	+	+	NA	-	+	+
	Reverse Osmosis with Brine Concentration and Evaporation	Pump water to surface, through RO membranes; pipe brine to evaporation pond	-	-	-	-	+	-	+	-	+	-	-	+	+	+	+	+	NA	-	+	+
	Disposable Ion Exchange	Pump water to surface, through IX resin; Landfill or incinerate resin when exhausted	+/-	+/-	+/-	-	++	-	+	+	-	+	+/-	-	+	+	+	-	NA	-	+	+
	Regenerable Ion Exchange with Brine Discharge to Brine Line	Pump water to surface, through IX resin; Regenerate resin, pipe waste to brine line	+/-	-	+/-	-	+	-	+	+	+	-	+	+	+	+	+	-	NA	-	+	+
	Regenerable Ion Exchange with Brine Concentration and Evaporation	Pump water to surface, through IX resin; Regenerate resin, pipe waste to evaporation pond	+/-	+/-	+/-	-	++	-	+	+	+	-	+	+/-	+	+	+	-	NA	-	+	+
	Anoxic Fluidized Bed Bioreactor	Pump water to surface and treat using an anoxic fluidized bed bioreactor that uses bacteria to reduce nitrate to nitrogen gas. Treated water can be re-injected to promote in situ biodegradation.	+	+	+	+	+/-	+	+	-	+	+	+	+/-	+	+	+	-	NA	-	+	+
	Anoxic Fixed Bed Bioreactor	Pump water to surface and treat using an anoxic fixed bed bioreactor that uses bacteria to reduce nitrate to nitrogen gas. Treated water can be re-injected to promote in situ biodegradation.	+	+	+	+	+/-	+	+	-	+	+	+	+/-	+	+	+	-	NA	-	+	+
	Extraction without Treatment Followed Crop Irrigation	Pump water to surface, surface spread onto crops	++	++	++	+/-	+/-	++	++	+	+	+	+/-	-	+	+	+	-	NA	+	+	-
	Electrodialysis Reversal with Brine Disposal to Brine Line	Pump water to surface, through EDR system, pipe concentrate to brine line	-	-	-	-	+	-	+	-	+	-	-	+	+	+	+	+	NA	-	+	-
	Electrodialysis Reversal with Brine Concentration and Evaporation	Pump water to surface, through EDR system, send brine to evap ponds	-	-	-	-	++	-	+	-	+	-	-	+	+	+	+	+	NA	-	+	-
In Situ	Phytoremediation	Install plants or trees (e.g., poplars) for nitrate uptake from soil and shallow groundwater	+	+	++	+/-	++	++	++	+	+	+	-	-	+	+/-	-	-	+	+	-	-
	Permeable Reactive Mulch Biobarrier	Dig a trench transverse to groundwater flow and fill with sand and mulch. Anoxic conditions develop resulting in reduction of nitrate to nitrogen gas.	+	+	++	+/-	+	++	-	+	+	+	+/-	-	+	-	-	-	+	-	-	-
	Permeable Reactive Biobarrier with Injected Slow-Release Electron Donor	Inject substrate into aquifer downgradient of nitrate, allow groundwater to flow across	+	+	++	+/-	+	++	-	+	+	+	+/-	-	+	+	-	-	+/-	-	-	-
	Permeable Reactive Biobarrier with Continuously Injected and Recirculated Electron Donor	Install groundwater extraction and injection wells to create capture zone, add substrate to water prior to injection	-	-	-	+/-	+	++	-	+	+	+	+/-	-	+	+	-	-	+/-	-	-	-
	Groundwater Diversion Using Impermeable Cut-Off Walls	Excavate and install impermeable barriers, directing groundwater flow around nitrate plume	+/-	-	+	+/-	+	++	+	+	+	+	+/-	-	+	+/-	-	+	+	-	-	-
	Groundwater Diversion Using French Drains	Excavate and install trenches with french drains thus directing clean water around nitrate-impacted groundwater zones	+/-	-	+	-	+	++	+	+	+	+	+/-	-	+	+/-	-	+	+	-	-	-
	Source Treatment and Monitored Natural Attenuation	Remove high concentration sources of nitrate contamination using in situ bioremediation and then allow residual nitrate to be biodegraded naturally.	+	-	++	+/-	+	++	-	+	+/-	+	+/-	-	+	+	+	-	+/-	-	-	-
	Groundwater Diversion and Monitored Natural Attenuation	Install impermeable barriers such as sheet pile or soldier piles thus directing clean groundwater flow around nitrate-contaminated groundwater zones. Allow nitrate within contained area to biodegrade naturally	+	-	+	+/-	+	++	+/-	+/-	+/-	+	+/-	-	+	+/-	-	-	+	-	-	-
	Source Bioremediation Using Slow-Release Electron Donor Injection	Periodically inject slowly biodegradable organic compound (such as emulsified vegetable oil) into aquifer at or up-gradient of contamination to stimulate denitrification of nitrate to nitrogen gas	+	+/-	++	++	+	++	-	+	+	+	+/-	-	+	+	+	-	-	-	-	-
	Source Bioremediation Using Fast-Release Electron Donor Injection and Recirculation	Continuously inject quickly biodegradable organic compound (such as molasses) into aquifer at or up-gradient of contamination to stimulate denitrification of nitrate to nitrogen gas	+	+/-	+	++	+	++	-	+	+	+	+/-	-	+	+	+	-	-	-	-	-

Appendix C.1 Nitrate Remediation Technologies



Appendix C.2 Treatment System Costs

Appendix D

Response to Comments on the Draft NIMS Report

CDM Smith

Appendix D – Comments and Responses on the NIMS Report (Draft Dated January 28, 2016)

No.	Commenter	Page	Reference	Comment	Response
A number of comments were made directly in the document itself, either as comments/redline in MS Word or as comments on the pdf version. Many of these comments were correcting grammar, seeking clarification, or were asking for more information. These comments were addressed within the text, tables, and figures of the Final NIMS report, as appropriate. The comments below were provided during the February 5, 2016 Project Committee Meeting or provided in written format via email. Comments made directly in the document that required further explanation are also included in this table.					
Comments and responses from the February 5, 2016 Project Committee Meeting.					
1	Glenn Meeks/ Regional Water Board	3-3	Salt and Nitrate Management Goals	Modify the following sentence, "This goal may be achieved through a combination of the development of alternative water supplies, establishment of treatment systems, or implementation of education and outreach activities." so that the "or" is replaced with "and."	The text has been revised. Note that the same comment applies to Section 5.2, page 5-3; and Section 6, page 6-3.
2	Casey Creamer/ Kings River Conservation District		Section 4. Prioritization at the IAZ Level	Why are the CASGEM rankings included as one of the criterion used in the NIMS prioritization?	The NIMS work plan specified the inclusion of the CASGEM rankings in the NIMS prioritization. However, as noted, CASGEM is more focused on water supply issues. There is some double-counting of population by including the CASGEM ranking. For the final report, the CASGEM ranking was removed, but the following criteria were added with a 5% weighting factor each: • Percentage of public supply wells • Total wells • Overlying irrigated acreage
3	Casey Creamer		Table 5-6	The cost summary table should incorporate the cleanup time.	The table has been revised to reflect cleanup times and volumes of water treated.
4	Laurel Firestone/ Community Water Center	5-5	Section 5.5.1. Pump and Fertilize	Expand the discussion so that there is an understanding of how much nitrate is reduced in the aquifer by pumping and applying water through irrigation.	The text of Section 5.5.1 has been modified. Also see response to Comment 8.

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5	Laurel Firestone		Table 5-6	Footnote the volumes of water treated for each of the scenarios/subscenarios.	The table has been revised to reflect cleanup times and volumes of water treated.
6	Casey Creamer	6-1	Section 6. Program of Implementation for Nitrate and TDS	The menu of implementation measures provides too much detail and therefore may be restrictive.	Glenn Meeks suggested that the menu of implementation measures be characterized as actions that may be considered. The text has been revised to reflect this.
7	Casey Creamer		Section 6	What about other constituents of concern, *e.g.*, arsenic, selenium, etc.	Trace constituents – both naturally-occurring and anthropogenic – may be included in the future versions of the Surveillance and Monitoring Program (SAMP). These constituents will likely also be addressed by local SNMPs.
Comments and responses from the Community Water Center (via email) February 12, 2016.					
8	Laurel Firestone			Volume seems to be a major driving factor for estimating both the time and cost involved. Yet pump and fertilize was not analyzed as part of a remediation strategy, which may be able to address a much higher volume and play a significant role in reducing the costs and time estimated for remediation. This study should look at where pump and fertilize can be part of the overall local remediation strategy and where it can't due to salinity concerns, as well as what the limitations of that strategy are for remediation purposes. Relatedly, it is not clear to me why the volume for pump treat and re inject was the same as the volume for pump treat and serve, except for easy comparison of costs and time. That seems a relatively random volume to choose for estimating time and costs for pump and treat.	Pump and fertilize is addressed in Section 5.5.1. By following nitrogen management plans, which include pump and fertilizer components, growers will reduce the mass of nitrate added at the surface, thus reducing the flux of nitrate to groundwater. Whether pump and fertilize will ultimately remove a greater mass of nitrate from groundwater than is added by the application of fertilizer and irrigation water depends on MZ- or site-specific conditions: nitrate concentrations in groundwater that is pumped for irrigation, fertilizer practices (amount, timing and form), irrigation practices, nitrogen loss in the root zone, harvesting and removal of plant biomass, etc.

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					The extraction rate for Section 5.5.4.2.2 Pump, Treat, and Serve to Meet Potable Demands now includes a volume equivalent to potable demands and twice the potable demands.
9	Laurel Firestone			I am concerned that the lack of any mass balance information or inclusion of vadose zone or at least on-going contributions from nitrate sources may render this estimate completely inaccurate. At a minimum, the data related to that from the Alta Archetype study should be integrated into this and I continue to not understand why that is not possible. Additionally, I am concerned that the overall volumetric averaging for the whole management zone significantly overestimates time and costs when there may be remediation focused on high concentration areas.	Quantifying legacy nitrate contamination in the vadose zone is beyond the scope of the NIMS. This analysis would need to include a model that takes into account historical land use (maps every 5 or 10 years, going back 50 to 100 years), historical irrigation practices, historical fertilizer loading, etc. The Agricultural Expert Panel concluded: • Lag times between deep percolation of nitrates and the nitrates reaching the top of the aquifer typically range from a year to up to extremes of several hundred years. • While there can always be exceptions, it cannot be assumed that groundwater quality even near the water table is reflective of management practices and the concentrations in deep percolating water, immediately above the groundwater monitoring point. Instead, many explanations and examples exist regarding the complex mixing of aquifer flows and the heterogeneous nature of the subsurface. • Groundwater simulation model results are only approximate even on very large scales. • California aquifer physical characteristics are very complex and even with large studies are poorly defined…Model results are only as good as the accuracy of the

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					data and boundary conditions that are used in the model… • …there is unsaturated flow through the vadose zone between the root zone and the aquifer. The long travel times and the varied mixing of water of different qualities and sources within the aquifer can both result in a considerable lag time between changes in irrigation/ nitrogen management practices and impacts in the aquifer.” In other words, the expert panel is cautioning that modeling or even correlation of current agricultural practices to the fate and transport of nitrate in the vadose zone and groundwater is difficult if not impossible. A similar estimate for historical periods would be even more daunting. One of the points of the analysis is that if it takes 100 years to reduce nitrate concentrations to the performance target without accounting for legacy contamination the vadose zone, the actual time frame will be even longer. Irrigated agriculture will continue to contribute nitrate to groundwater (see Section 5.5.1), lengthening cleanup times. The future contributions from irrigated agriculture are difficult to quantify prior to publication of the MPEP studies. *Burt, C., R. Hutmacher, T. Angermann, B. Brush, D. Munk, J. DuBois, M. McKean, L. Zelinski. 2014. Conclusions of the Agricultural Expert Panel. Recommendations to the State Water Resources Control Board pertaining to the Irrigated Lands Regulatory Program in fulfillment of SBX2 1 of the California Legislature. Editing and Organization:*

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					Irrigation Training & Research Center (ITRC). California Polytechnic University, San Luis Obispo.
10	Laurel Firestone			What I would have hoped could be done for the Alta area focused analysis, is an attempt at developing alternatives that optimize restoration in terms of time and cost by combining strategies. For example, if we used pump and fertilize, and pump treat and reinject in a few key hotspots, and pump treat and serve for community needs, how could we optimize both costs and time to achieve our goals in that area? I don't see this or any other study at CV Salts actually making an attempt at trying to figure out how to develop a realistic and optimized local restoration plan for nitrate, nor giving any real guidance for how to do this. Instead this analysis seems more designed to show that it isn't feasible to do one extreme for the whole region or whole basin or whole management zone.	Agree that an optimization study is warranted sometime in the future, but such a study is beyond the scope of the NIMS. NIMS provided nitrate implementation measures and estimated costs for some of the implementation measures for the AID archetype management zone. The optimization analyses should be done at the local SNMP level.
11	Laurel Firestone			On the Alternative 2 scenario, the range is so large that is isn't that useful. I provided Joe the attached nitrate treatment that has been approved and is being used in a small community in Tulare County, which is considered by the Drinking Water Program to be somewhat of a "game changer" in terms of the economics of ion exchange. I think it is important that these costs be used for the estimate to provide a more informative range for costs for pump treat and serve, in particular.	As noted, Ionex SG is a viable option for nitrate treatment and State Water Board has granted Ionex SG a Conditional Acceptance. Ionex SG was contacted directly to obtain current estimates of cost for treatment and performance data. The information provided by Ionex SG on a conference call held on March 29, 2016 suggests that their treatment costs and costs for brine management are within the range provided in the draft NIMS report, when considering treatment parameters for the alternatives in the NIMS. Ionex SG's systems are typically geared towards providing drinking water to consumers and most of the systems designed to date have a target nitrate concentration in the product water of about 8 mg/L. For the NIMS pump, treat and re-inject alternative, the target product

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					wwater nitrate concentration was 2 mg/L, which significantly increases salt requirements and the resultant volume of waste stream. wqAs with all emerging technologies for water treatment, an engineering evaluation and pilot testing would need to be conducted at the project scale. Pilot tests are conducted in order to understand the water chemistry of the groundwater basin and to determine if there are competing ions.
12	Laurel Firestone			I appreciate Joe's work to analyze multiple pump and treat and serve scenarios that are realistic on the ground, and I hope he can revise some of that based on the specific feedback we provided him, and provide that additional analysis on those to local stakeholders as part of this study.	See response to Comment 11.
Comments and responses from Debbie Webster (via email) March 6, 2016.					
13	Debbie Webster/ Central Valley Clean Water Association			There are two major concerns I have with moving forward. One is the attainability of the goals and how they are implemented The second is the evaluation on an IAZ level. I am not sure that really gets at where we need to prioritize. Note that other options should be described, including SSOs. These options will help to keep efforts focused on areas where improvements make sense.	Agree that the achievement of Management Goals 2 and 3 will be challenging, if not impossible. Section 5.5.1 shows that – at least for the pilot study area – irrigated agriculture contributes more nitrate to groundwater than is extracted using pump and fertilizer. The prioritization at the IAZ-level was a required element in the approved NIMS work plan. The goal of this effort was to provide a refined list of IAZs that are a priority based on the evaluation criteria for either nitrate, TDS, or both. Prioritization allows for the most efficient allocation of resources; however, how CV-SALTS decides to use this information is a policy issue. Local managed areas or management zones will be developed by overlying agencies. It is anticipated that priority of areas within each management zone

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					would be developed by the overlying agencies as part of the local SNMP. This local prioritization would be informed by site-specific conditions.
14	Debbie Webster			To the extent available, include Nitrate information for the whole Central Valley instead of just the IAZs.	CV-SALTS is currently preparing a report called the Central Valley Salt and Nitrate Management Plan - Region 5 Updated Groundwater Quality Analysis (LWA, 2015) which will characterize water quality in the out-of-valley floor groundwater basins/ subbasins. The NIMS focusses on the valley floor groundwater basins/ subbasins. Given the timing of the expected deliverables from the out-of-valley work, the characterization of the water quality in the out-of-valley groundwater basins/ subbasins would best be summarized in the SNMP rather than in the NIMS Report
15	Debbie Webster			Phase I may be two parts – first phase temp user protection 0-5 years; permanent user protection 2-15 years	Comment noted and the text has been modified appropriately.
16	Debbie Webster			In writing the report be clear what are goals, firm recommendations and timelines, etc. so that they are can be used appropriately when transferred to the SNMP and regulatory implementation measures.	Great comment. The NIMS team and SNMP team are collaborating closely so that the nitrate (and salt) implementation measures will be readily incorporated into the SNMP.
17	Debbie Webster			Discuss how these nitrate management measures could impact salt levels or how if a management alternative would have salt benefits too. For example, pump & fertilizer will concentrate salts – how significantly? Will we be solving one problem to create another? Stormwater recharge might provide duel benefits. Use this as a ranking tool.	These issues are discussed in Section 6.
18	Debbie Webster			Biosolids can provide a benefit as soil amendments.	The role of biosolids is discussed in the SSALTS Phase 3 report.

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19	Debbie Webster	3-1	Goal 2	We have concerns that these goals will be interpreted to overlay the antidegradation policy which is not a no-degradation policy (sorry for the number of negatives in this sentence). In areas where assimilative capacity exists, assimilative capacity should be available per the antidegradation policy.	The intent of Goal 2 is not to unduly restrict access to assimilative capacity. The second water quality-based management goal seeks to establish a balance of the mass of salt and nitrate in groundwater underlying each managed area. It is anticipated that a periodic evaluation of ambient water quality (volume-weighted average concentration in groundwater in the managed area) would be used as the basis for assessing progress towards attaining this goal. If assimilative capacity is created, than presumably it would be allocated to projects at the discretion of the Central Valley Water Board after evaluating the project proponent's antidegradation analysis.
20	Debbie Webster	3-2	Goal 3	Add "where reasonable and feasible to do so" to Goal 3.	Text has been revised.
21	Debbie Webster	3-2	Goal 3	This needs to recognize that there are areas in the valley that are above this level and historically have been.	The following text has been added, "NIMS recognizes that there are portions of groundwater basins underlying the Central Valley floor with naturally-occurring salts that are derived from marine deposits – among other sources – and where TDS naturally exceeds the default objective."
22	Debbie Webster	3-2		I also think this should state that it recognizes prioritization of areas.	The following text has been added, "These specific projects and implementation measures will be prioritized at the management zone level."
23	Debbie Webster	3-4	First bullet	If user protection means only bottled water, this may be reasonable. Otherwise, if construction/plant are required, this is may not be reasonable, especially for areas where there is no established community plan.	The short-term detailed schedule of implementation activities may include alternate drinking water sources, including, but not limited to, bottled water in the first three to five years of Phase 1. The planning, designing, and funding of longer-term solutions to meet management Goal 1 could be accomplished in Phase 1 (Years 1-10). These more permanent user protection measures would

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					be introduced over a three- to fifteen-year period. The text was edited to be clearer.
24	Debbie Webster	3-4	Second bullet.	Do you have anything to show that this is really possible, especially in impacted areas?	In Phase 2 (Years 11 – 20) – at a minimum – projected implementation activities that will help to achieve the water quality-based Management Goals 2 and 3 will at least be in the planning stages. Word “achievement” removed to clarify intent.
25	Debbie Webster			Stop tying [prioritization] to the IAZ. Just start sentence with Stakeholders or within each area of concern.	Text edited to remove reference to IAZ.
26	Debbie Webster			I think that this is completely the wrong way to go. The entities overlying an area that are impacted may or may not be the same as those groundwater boundaries, in fact those entities are more likely to be defined by surface watershed, growing patterns, county boundaries, etc. I also think this comment is consistent with the January Policy Meeting. I know that the RWB needs an assimilative capacity estimate for basin or subbasin, but that is really where these initial analysis zones should stop. This comment applies to the full section.	The prioritization at the IAZ-level was an element of the approved NIMS work plan (summer 2015); therefore, the work had to be executed to fulfill the requirements of the work plan. The goal was to provide a refined list of IAZs that are prioritized based on the evaluation criteria for either nitrate, TDS, or both. It is assumed that this prioritization will help guide the establishment of high level priorities for implementation in the Central Valley SNMP, but of course that will be a policy decision. .
27	Debbie Webster	4-1	Prioritization Criteria	Nitrate above MCL (the degree in which this is above the level) and the people relying on this drinking water may further be able to set priority. Another priority may be where there are entities able and willing to take on such a project, where the project is necessary.	Agree that these are important criteria and should be addressed at the local SNMP/management zone-level.
28	Debbie Webster	4-2	§4.1.1	Please note, you are seeing a lot of comments from me that basin wide approaches, although they be needed for the recycled water policy probably shouldn't be used for prioritizing actual work.	Completely agree. Note that in the response to Comment 26 we state that the prioritization issue is focused on meeting work plan requirements with the information to be used as determined by CV-SALTS. Prioritization with regard to managing

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					salt/nitrate would still occur at the local level, *e.g.*, within a management zone.
29	Debbie Webster	4-10	Table 4-8	Now, take these colors, graph the IAZ in this colors and add only impacted wells to the graph that are drinking water wells. Did you get it right?	Good comment, but this activity is beyond the NIMS scope. Nitrate distribution was reviewed at the management zone level (Section 5). The highest weighted criteria is current ambient quality and projected loading to shallow groundwater, so one would expect good correlation.
30	Debbie Webster	5-3	§5.2	Nitrate, and possibly other MCLs should be mentioned specifically in this section. Secondary MCLs are not a matter of safety, but of preference (i.e. consumer acceptance) and would have a lower priority. See the following link in the Water Quality section: http://www.waterboards.ca.gov/water_issues/programs/gama/docs/wellowner_guide.pdf	Goal 1 explicitly targets groundwater where there are human health concerns, *i.e.*, where nitrate or other constituents exceed their primary MCLs.
31	Debbie Webster	5-4		Reduction in any source does not equate to a benefit - you may see nothing. Need to focus on effective measures.	Comment noted. At the local-SNMP scale, stakeholders will ensure that effective source control measures are implemented.
32	Debbie Webster	5-4	§5.5.1	May also increase salt.	The following sentence was added: "Because of consumptive use, the concentration of TDS in water that becomes deep percolation from irrigated agriculture is considerably higher than the irrigation water."
33	Debbie Webster	5-4	"On the other hand, sustainable agriculture requires some leaching of water below the root zone in	And sustainable groundwater basins. In this case, the "some" should be removed.	Agree with the comment, however, this is a direct quote from the Agricultural Expert Panel.

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			order to remove salt that has accumulated."		
34	Debbie Webster	5-11	§5.5.4.2.3	Based on the table on the next pages, it looks as if you are looking at an ultra low level nitrogen system to achieve an effluent below 2 mg/L and the typical NDN system to reduce nitrate levels, typically from to levels between 8-10 but can vary up to 15 or down to 5 seasonally. This is not clear from the text.	Each of the treatment technologies is capable of producing product water with a nitrate concentration of 1 to 2 mg/L. There may be perception issues with biological NDN systems.
35	Debbie Webster	5-12		Not sure if the 1 was the best choice as air and other negative impacts of ultra low nitrate removal (carbon addition, etc.), including cost would not make this practicable for the community. 8-10 is realistic for an NDN system.	See response to Comment 34.
36	Debbie Webster	5-12		Should differentiate the system difference than typical biological nitrogen removal and the 1 mg/L you are proposing.	See response to Comment 34.
37	Debbie Webster	6-1	Magnitude of the Problem	I think the way this is verbalized is that over 5 is a problem. Anything less than 10 is considered safe drinking water meeting regs. Although 5 is probably appropriate in taking a closer look, we should not be assuming a problem at this level. Suggest only showing 10 in this scenario, then if you really want to show 5, do so in a separate paragraph and only include the areas where it is above 5 and increasing significantly.	The following text has been added, "Where nitrate in groundwater exceeds 10 mg/L, there is a potential health concern, and conversely, where nitrate in groundwater is less than 5 mg/L represents areas where nitrate is not currently a potential health concern. Trend analyses will be done at the local SNMP-level to determine if there may be health concerns in wells with nitrate concentrations between 5 and 10 mg/L."
38	Debbie Webster	6-2		Still not sure about these goals or their impacts, was hoping that this report would give more of an idea if these even could be met. Need to include discussion on the viability of these goals. See prior comments.	Yes, Goals 2 and 3 cannot be achieved in every portion of a given management zone or groundwater basin. The attainment of these goals ultimately depends on MZ- or site-specific conditions: naturally-occurring salinity and other

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					constituents, nitrate concentrations in groundwater that is pumped for irrigation, fertilizer practices (amount, timing and form), irrigation practices, nitrogen loss in the root zone, harvesting and removal of plant biomass, etc. On the policy side, a determination may need to be made as to whether resources should be invested in more aggressive implementation measures to achieve Goals 2 and 3, as long as Goal 1 is achieved.
39	Debbie Webster	6-2		There is so much uncertainty on what that means and permit implications. Much more thoughtful discussion needs to happen here in light of the findings in this and Alta [Irrigation District]. The IAZ is the wrong scale for this analysis, which doesn't help.	See response to Comment 38.
40	Debbie Webster	6-3		These need to have the ability to be implemented without BPAs, especially on small scale areas.	The following text has been added, "Implementation of nitrate and salt mitigation measures at the local SNMP-level can be executed without a basin plan amendment."
41	Debbie Webster	6-3		Will not happen unless the community is behind the solution. This phase may be phased too and three years in that type of program is not reasonable.	Agree that community support is crucial. The text concerning phasing has been modified.
42	Debbie Webster	6-3		This is where your three year timeframe is likely unrealistic, especially if it involves securing a new water source, determining future cost sharing (i.e. what portion is supported by others and what portion is the ratepayer) going through the environmental and funding work and actual construction. Where new surface water supplies have been needed, it has not been uncommon that the process has taken 20 +/- years.	The text concerning phasing has been modified.

Appendix D – Comments and Responses on the NIMS Report (Draft Dated January 28, 2016)

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43	Debbie Webster	6-3	Recharge of High Quality Water	Isn't this hypothesis being tested? Need to rephrase. I think we would all like this to work, but if we don't get water rights, are otherwise restricted from stormwater recharge or we don't get the recharge we expect/want, this may not work as contemplated. I think the catch-22 is so aptly described earlier. Nitrogen is put on fields at agronomic rates, nitrate will move quickly through the soil. By adding water on top, we move the nitrate down into the groundwater. Ideally, we can recharge at rates that reduce any nitrate concentrations to levels below the primary MCL.	Sentence was re-phrased. You are correct in that the flooding of fields during wet months will likely mobilize nitrate to move more quickly through the vadose zone.
44	Debbie Webster	6-4	Brine Management	I still don't know if it reasonable to say we will achieve either of these two goals everywhere. Certainly, we need to manage both salt and nitrate, but a zero sum net gain everywhere while maintaining groundwater levels with little supply in a way that the Central Valley can viably do has not been shown as a feasible solution.	See response to Comment 38.
45	Debbie Webster	6-5	Product Water	Still need to determine what to do with the brine.	Agree. The Water Master Plan will need to include a plan for brine management and disposal.
46	Debbie Webster	6-5	Pump and Treat	Is this going to become salt limited then?	It depends on the local area; if salinity is increasing in a given management zone from pump and fertilizer, than a strategy that includes salt mitigation may need to be considered.
47	Debbie Webster	6-6	Implementation Measures Checklist	Do not recommend checklist but rather give key questions. May have minimum considerations. Recommend that you include a matrix of possible issues/solutions recognizing that this is incomplete.	Comment noted.
48	Debbie Webster	6-7		This timeframe shouldn't be set in stone, otherwise effort better spent elsewhere would only be on planning and reporting level.	Agree. Text revised to reflect that the timeframe is suggested; it is necessary to have target timeframe.

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49	Debbie Webster	Appendix B.1		Here's a case where I question if IAZ six should really be a moderate to high level. According to the trend, the levels are decreasing. What does the well map look like on top of this? Again, CASGEM doesn't seem to do anything.	IAZ 6 has a relatively high population density, current ambient nitrate is relatively high, and the predicted nitrate flux to groundwater is relatively high. Past trends did not appear to be as reliable and they were given less weight.
50	Debbie Webster	Appendix C.1	Disposable Ion Exchange: Pump water to surface, through IX resin; Landfill or incinerate resin when exhausted.	Not sure if this would be very favorable if you needed to incinerate or landfill. What by-products are we talking about and in what quantity? Strict landfill and air requirements may not make this viable.	This technology scored a "plus" for permitting because these systems are widely used. The project proponent would not be landfilling or incinerating; the IX supplier typically will handle disposal or regeneration of their media.
51	Debbie Webster	Appendix C.1	Regenerable Ion Exchange with Brine Discharge to Brine Line: Pump water to surface, through IX resin; Regenerate resin, pipe waste to brine line	Have you considered the brine permitting?	Until subregional salt accumulation areas and/or the regional brineline are constructed, brine or near zero liquid discharge brine will need to be transported to an out of valley discharger or will need to be sequestered in local evaporation ponds. All brine management disposal options will require permitting.
52	Debbie Webster	Appendix C.1		The table and its options are dependent on groundwater quality and the desired effluent. Harter's appendix provides some useful information. Question some of the assessments.	The table in Appendix C.1 is a high level overview of treatment technologies. A much more detailed engineering analysis and cost estimate would be expected to be performed at the local SNMP-level.

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53	Debbie Webster	Appendix C.2		Should show the reduction. Where IX and RO can achieve lower NO3 levels, biological is limited typically to levels surrounding the Primary MCL.	See response to Comment 34.